Molecular Ecology (1998) 7, 209–223

Microsatellite and mitochondrial DNA assessment of population structure and stocking effects in Arctic charr *Salvelinus alpinus* (Teleostei: Salmonidae) from central Alpine lakes

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Abstract

Despite geographical isolation and widespread phenotypic polymorphism, previous population genetic studies of Arctic charr, *Salvelinus alpinus*, have detected low levels of intra- and interpopulation variation. In this study, two approaches were used to test the generality of low genetic diversity among 15 Arctic charr populations from three major drainages of the central Alpine region of Europe. First, a representative subsample of each drainage was screened by PCR–RFLP analysis of mtDNA using 31 restriction enzymes. All individuals but one shared an identical haplotype. In contrast, microsatellite DNA variation revealed high levels of genetic diversity within and among populations. The number of alleles per locus ranged from six to 49, resulting in an overall expected heterozygosity from 0.72 ± 0.09 to 0.87 ± 0.04 depending on the locus. Despite evidence for fish transfers among Alpine charr populations over centuries, genetic diversity was substantially structured, as revealed by hierarchical Φ statistics. Eighteen per cent of total genetic variance was apportioned to substructuring among Rhône, Rhine, and Danube river systems, whereas 19% was due to partitioning among populations within each drainage. Cluster analyses corroborated these results by drainage-specific grouping of nonstocked populations, but also revealed damaging effects of stocking practices in others. However, these results suggest that long-term stocking practices did not generally alter natural genetic partitioning, and stress the importance of considering genetic diversity of Arctic charr in the Alpine region for sound management. The results also refute the general view of Arctic charr being a genetically depauperate species and show the potential usefulness of microsatellite DNAs in addressing evolutionary and conservation issues in this species.

Keywords: Arctic charr, conservation, microsatellite DNA, mtDNA, population genetics, *Salvelinus alpinus*

Received 2 May 1997; revision received 1 September 1997; accepted 16 October 1997

Introduction

The distribution, diversity, and genetic structure of northern biota have been considerably influenced by the repeated coverage of northern Europe and central mountain ranges (e.g. Alps, Pyrenees) by Pleistocene ice sheets (Hantke 1978). These dramatic climate oscillations undoubtedly resulted in habitat and range alterations by forcing species into suitable refugia during colder conditions and allowing recolonization and dispersal during warmer interglacials. Hewitt (1996) considered these processes instrumental to Quarternary population divergence in northern temperate regions.

The Arctic charr, *Salvelinus alpinus* L. (Teleostei; Salmonidae), has long intrigued biologists as a prime example for population differentiation in northern fishes. This freshwater and anadromous fish has a Holarctic

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distribution (Behnke 1972; Johnson 1980), and exhibits a complex mosaic of variability in morphology, colouration, ecology, and life-history traits (Hindar & Jonsson 1982; Skúlason *et al.* 1989; Malmquist *et al.* 1992). Paradoxically, most population genetic studies of Arctic charr have failed to detect significant genetic differentiation among morphs, distant populations, and even subspecies, using allozymes (Kornfield *et al.* 1981; Andersson *et al.* 1983), restriction fragment length polymorphism (RFLP) and sequence analysis of mitochondrial DNA (mtDNA) (Danzmann *et al.* 1991; Hartley *et al.* 1992; Volpe & Ferguson 1996), and even minisatellite fingerprinting (Volpe & Ferguson 1996). Although Wilson *et al.* (1996) documented the existence of three mtDNA phylogeographic assemblages among North American populations, they similarly observed extremely low levels of mtDNA polymorphism. Generalized low levels of genetic variation within species have often been associated with recent and rapid recolonization from bottlenecked refugial populations (e.g. Sage & Wolff 1986; Billington & Hebert 1991; Zink & Dittman 1993).

The central European Alps are of particular interest to the evolutionary history of Arctic charr for several reasons. Many Alpine lakes shelter sympatric and allopatric morphs that differ strikingly in morphological features, growth rate, feeding and water depth preferences (Brenner 1980, and references therein). This region was also completely covered by ice during the last glaciation. As a result, all lakes within this area have similar ages of about 10 000–20 000 years (Hantke 1978), which enables comparisons of rates of population differentiation both among and within lakes. Finally, all lakes containing native Arctic charr populations belong to one of three unconnected major river systems which drain into separate sea basins. This provides a situation in which contemporary drainage subdivision and historical isolation can be inferred.

Genetic studies of Arctic charr from the central Alpine region of Europe have been very limited, and involved allozyme analysis (Ruhlé 1977; Hecht 1984). Consequently, one objective of this study was to perform a PCR–RFLP analysis to test the hypothesis that central Alpine charr populations are similar to those from other regions, in possessing low levels of mtDNA variation. A second objective was to assess the potential of microsatellite DNA analysis to detect genetic variation in Arctic charr from the European Alps by comparison among drainage systems, among lakes within drainages, and among sympatric populations within lakes. Using microsatellite DNA has been effective in detecting variation in other species with low levels of either allozyme or mtDNA polymorphism (e.g. Hughes & Queller 1993; Taylor *et al.* 1994), and has also been used to address issues related to population structure in other *Salvelinus* species (Angers *et al.* 1995; Angers & Bernatchez 1996). Finally, by obtaining high-resolution genetic markers for these populations, it was possible to examine the genetic impacts of past stocking practices by comparing relationships of stocked populations with native ones.

Materials and methods

Sampling

A total of 440 Arctic charr was collected from 12 lakes of the central Alpine region of Europe, representing 15 populations from the Rhine, Danube, and Rhône river drainages (Fig. 1). All fish were caught over traditional spawning sites to take into account possible substructures within lakes due to reproductively isolated populations. An additional population from the Lake Saimaa system, Finland, was included in the clustering analyses as an outgroup. On the basis of classical morphology and zoogeography Behnke (1980, 1984) recognized Arctic charr from northern Europe as *Salvelinus a. alpinus*, distinct from the central Alpine *S. a. salvelinus*. Liver samples were recovered from freshly killed or deep-frozen specimens and preserved in 95% ethanol. Total DNA was isolated from liver tissue as described in Bernatchez *et al.* (1992).

Mitochondrial DNA

Mitochondrial DNA variation was analysed by RFLP performed on products amplified via PCR (Saiki *et al.* 1988). Two adjacent segments were amplified; one encompassing the complete NADH dehydrogenase subunits 5 and 6, the other, the cytochrome *b* gene and the control region. Primers and PCR conditions were described in Bernatchez & Danzmann (1993) and Bernatchez *et al.* (1995).

Ten individuals from each of five populations representing the three drainage systems were screened by digesting pooled PCR aliquots of the two amplified segments with 31 restriction enzymes (Table 1). The resulting fragments were separated by horizontal electrophoresis in 1% agarose gel and sized by using *Hin*dIII/*Eco*RI-digested λ phage DNA as a molecular-weight standard. Mitochondrial DNA fragments were visualized and photographed under UV light after ethidium bromide staining.

Microsatellite DNA

Eighty fish representing 10 Arctic charr populations were first screened at 16 loci to examine the potential of corresponding primers originally developed for other salmonids. Six primers producing microsatellite bands that could be unambiguously determined were then selected for final analysis. A summary of all loci tested, primer sources, and annealing temperatures is provided in Table 2.

Introgression and fixation of Arctic char (*Salvelinus alpinus*) mitochondrial genome in an allopatric population of brook trout (*Salvelinus fontinalis*)

Louis Bernatchez, Hélène Glémet, Chris C. Wilson, and Roy G. Danzmann

Abstract: Although mitochondrial introgression between taxa has been increasingly documented, interspecific replacement of mtDNA is rare, particularly when the donor species is absent. We document evidence for a population of brook trout (*Salvelinus fontinalis*) in which all individuals possess the mitochondrial genome of Arctic char (*S. alpinus*) despite the present-day absence of the latter species in the watershed where the population is located. The mitochondrial genotype of 48 brook trout from Lake Alain (Québec) was characterized by RFLP analysis performed over the entire mtDNA molecule and/or a 2.5-kb PCR-amplified segment of the ND-5/6 region. Although the fish examined were morphologically indistinguishable from typical brook trout and homozygous for the diagnostic alleles characteristic of brook trout, the mtDNA of all individuals was identical to the Québec Arctic char haplotype. Together, these results indicate that the mtDNA haplotype observed in Lake Alain brook trout has resulted from ancient introgression with Arctic char rather than ancestral polymorphism or convergent evolution. They also demonstrate that introgressive hybridization between those two species can have significant and long-term effects on their genetic composition.

Résumé : On rapporte de plus en plus l'introgression mitochondriale entre des taxons, mais l'échange d'ADNmt entre deux espèces est rare, notamment lorsque l'espèce donneuse est absente. Nous présentons une population d'Ombles de fontaine (*Salvelinus fontinalis*) dont tous les individus possèdent le génome mitochondrial de l'Omble chevalier (*S. alpinus*) sans que cette dernière espèce soit présente actuellement dans le bassin où la population d'Ombles de fontaine a été localisée. Le génome mitochondrial de 48 Ombles de fontaine provenant du lac Alain (Québec) a été caractérisé par une analyse des polymorphismes au niveau de toute la molécule d'ADNmt et/ou d'un segment de 2,5 kb de la région ND-5/6 amplifié par la PCR. Les poissons examinés étaient indifférenciables morphologiquement d'un omble de fontaine typique et étaient homozygotes pour les caractères allèles de diagnostic de l'Omble de fontaine, mais l'ADNmt de tous les individus était identique à l'haplotype d'ADNmt de l'Omble chevalier du Québec. Tous ces résultats indiquent que l'haplotype d'ADNmt observé chez l'Omble de fontaine du lac Alain provient d'une ancienne introgression avec l'Omble chevalier plutôt que d'un polymorphisme ancestral ou d'une convergence. Ces résultats montrent également qu'une hybridation introgressive entre ces deux espèces peut avoir des effets importants et à long terme sur leur composition génétique.

[Traduit par la Rédaction]

Introduction

There is little consensus regarding the evolutionary significance of hybridization and introgression, although there is increasing evidence for their occurrence. Traditionally, the transfer of genes across species boundaries has been thought to have little or no evolutionary importance (Mayr 1963; Heiser 1973). The main argument supporting this view is that introgressive hybridization among animal taxa is rare and that documented cases leading to persistent,

Received December 22, 1993. Accepted June 15, 1994.
J12214

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Review: Bartlett et al. Distribution of mitochondrial cytochrome b genotypes in Arctic char (*Salvelinue alpinus*) populations

Overall, this paper is somewhat of an improvement over most molecular genetic papers on salmonid fishes I have read to date. The authors are more aware of constraints and limitations, in relation to methods, for making sweeping conclusions.

There are now several critical review papers available that all authors of molecular genetic papers should be thoroughly familiar with, such as Myer (1994, DNA technology and phylogeny of fish, in Genetics and Evolution of Aquatic Organisms), Avise and Ball (1990 in Oxford Survey in Evolutionary Biology 7:45-67), Cronin (1993, Wildlife Society Bulletin 21:339-348), and Degnan (1993, Molecular Ecology 2:219-225). Journal editors should now expect the same standards for credibility, rigor, robustness, etc. for molecular genetic papers as they do for papers dealing with ecology.

First it must be recognized that the conclusions of the paper are based on a very small sample from a very conservative DNA region. Also, the first sentence claims the study includes S. alpinus "representing populations throughout its range." More than half the range of alpinus, the vast area of Siberia, is not represented in this study (important for tracing connections of northwestern North American charr with Siberia analogous to Osmerus mordax mordax and Coregonus lavaretus pidschian).

The direct sequencing method used does, in general, provide more information than restriction site analysis (why Grewe et al. Salvelinus and Salmonidae relationships are erroneous) but no firm conclusions should be made on such limited evidence without "testing," such as comparisons between cytochrome b evidence and other regions of the mitochondria, and all other evidence of divergence in S. alpinus and associated species likely sharing similar histories in the

Pleistocene (glacial refugia, pre- and postglacial movements, etc.). For example, smelt, Osmerus, show a preglacial separation into O. eperlanus, northern Europe, and O. mordax, which in turn has a Siberian, northwestern North American subspecies (mordax) and a northeastern North American subspecies (dentex). Bernatchez and Dodson (1990, Evolution 44:1263-71) presented mtDNA data on North American Coregonus, indicating preglacial divergence of Eurasian C. lavaretus-pidschian (Siberian form) and C. clupeaformis with a subsequent Beringia refuge for pidschian and two eastern refugia for clupeaformis. Postglacial distribution could be traced by DNA markers. Sympatric occurrence with reproductive isolation among the three lines is common (I have a more recent paper on this subject by these authors listed as "in press" 1994, Can. J. Fish. Aquat. Sci.). Obviously, an understanding of divergence, evolution and zoogeography in Osmerus and Coregonus can provide insightful associations to test hypotheses for Salvelinus.

It is important that the Dolly Varden used in the analysis (specimen from Ruth Phillips) be identified more precisely. The fact that the Dolly Varden DNA has a transversion rather than a transition appears to be a significant evolutionary event (but the validity of S. malma does not rest on one codon sequence of cytochrome b -- the Dolly Varden organismic phylogeny resulted in distinct differences in ecology and life history which allows malma to occur sympatrically with alpinus with reproductive isolation over a vast region of the North Pacific and Arctic oceans. This is what makes malma a valid species). S. malma, in turn, is clearly divided into a northern and southern subspecies. I assume Ruth Phillips' specimen is the southern subspecies, but its location must be identified. The obvious question is: do all malma have this cytochrome b transversion?

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divergence, don't keep time very well and this is now a widely recognized fact (see Thomas and Beckenbach [1989, J. Mol. Evol. 29] and many other papers). Such a statement is made in complete isolation from all that is known about the phylogenetic history of Salmonidae, especially the fossil record. Salvelinus is grouped with the genera Hucho and Brachymystax on one side of a dichotomy within the subfamily Salmoninae with Salmo and Oncorhynchus on the other side. The fossil record shows Salmo (Atlantic basin) and Oncorhynchus (Pacific basin) were separated by at least mid-Miocene. The separation leading to Salvelinus from the Salmo-Oncorhynchus progenitor may have occurred in the Oligocene (see Behnke 1992, Am. Fish. Soc. Monogr. 6, p. 15-16 for review and references).

Genotype 4, found only in Tree River alpinus is probably a localized population divergence. I know of no other solid evidence supporting significant differentiation of Tree River charr from other Northwest Territories alpinus, but it is a question which should be examined more thoroughly. In general, alpinus can be considered as an obligatory lacustrine species; it either lives its whole life in a lake or anadromous populations are dependent on lakes for most of their life. To my understanding the Tree River has an impassible falls about 20 miles from its mouth and no lake below the falls, but much of the river habitat has characteristics of a lacustrine environment. A few years ago an Alaskan fish and game magazine had a story about the giant Tree River charr. A color photograph depicted a charr with dense, small spots, elongated head and jaws with kype which undoubtedly was that of a northern Dolly Varden (the Tree River is far to the east of the known limit of distribution of malma -- the Mackenzie River). Subsequently, an angler who caught the world fly fishing record alpinus from the Tree River sent me a photograph of his fish. It is typical of Arctic alpinus (of the Northwest Territories) with large, rather sparse spots (I assume the magazine photo was a file photo of a Dolly Varden and not that of the Tree River charr). In any event, I would urge the authors to seek more information on Tree River charr.

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Genotype 4, found only in Tree River alpinus is probably a localized population divergence. I know of no other solid evidence supporting significant differentiation of Tree River charr from other Northwest Territories alpinus, but it is a question which should be examined more thoroughly. In general, alpinus can be considered as an obligatory lacustrine species; it either lives its whole life in a lake or anadromous populations are dependent on lakes for most of their life. To my understanding the Tree River has an impassible falls about 20 miles from its mouth and no lake below the falls, but much of the river habitat has characteristics of a lacustrine environment. A few years ago an Alaskan fish and game magazine had a story about the giant Tree River charr. A color photograph depicted a charr with dense, small spots, elongated head and jaws with kype which undoubtedly was that of a northern Dolly Varden (the Tree River is far to the east of the known limit of distribution of malma -- the Mackenzie River). Subsequently, an angler who caught the world fly fishing record alpinus from the Tree River sent me a photograph of his fish. It is typical of Arctic alpinus (of the Northwest Territories) with large, rather sparse spots (I assume the magazine photo was a file photo of a Dolly Varden and not that of the Tree River charr). In any event, I would urge the authors to seek more information on Tree River charr.

Overall, the authors conclusions explaining the relationships of relict New England, southern Quebec populations (oquassa), the Northwest Territories group (except for Tree River), and the Labrador group, are in agreement with morphological and zoogeographical interpretation despite limitations of their data. In preglacial times a common ancestor extended from northern Europe into northeastern North America. After glaciation, the North American populations persisted as isolated relicts (oquassa). The Northwest Territories and Arctic drainages of Siberia share the same form of charr (typically highly predaceous, large maximum size, 26-28 gillrakes, 67-68 vertebra). In postglacial times, the Arctic form expanded eastward and remnants of the original eastern North American alpinus, and probably charr from the Greenland area, expanded northward and westward. Contact and integration occurred in Labrador, where the charr show a transition in meristic traits from north to south.

Other comments are made on the manuscript. As will be noted, in my opinion, papers on genetics would have more credibility if authors used more restraint in invoking "bottlenecks" as an all-inclusive explanatory term. It is reminiscent of the literature of 50-60 years ago, after Sewall Wright created "genetic drift." Authors invoked genetic drift to explain all sorts of phenomena, real and imagined, until the term became an overly used cliché. Now it is "bottlenecking." Levels of genetic variation vary widely among different phylogenies, at least as recorded from the methods used (which are highly limited by sample size and what is sampled.) Some species, such as krill, have enormous abundance, but low genetic variation.

Dear Dr. Behnke:

I thought that you might like to know that we've found a lake on the lowlands of W. Nfld. that appears to have two distinct populations of char. One is dwarf and similar in appearance to those from Candlestick Pond while the other is much larger and may correspond to the Eastern Arctic form. Unfortunately we have not yet compared the morphometrics of the two groups but hope to get to it soon.

Peter Rombough

10 September 1979

Mr. John Reale
Vocational Rehabilitation Specialist
Veterans Administration REgional Office
Denver Federal Center
Denver, CO 80225

Dear Mr. Reale:

I am writing in support of the application of Mr. Ed Wick to continue his graduate education for the Ph.D. degree. I serve on Mr. Wick's graduate committee and I have been involved with studies of endangered and rare fishes for many years.

I see a particular need for continuity of research efforts on the endangered fishes of the Colorado River basin. Mr. Wick has conducted field research in the Colorado River basin with special emphasis on the endangered and rare fishes for four years as part of studies funded by the Bureau of Land Management and by the Colorado Division of Wildlife. He is now at the point where he knows more about the rare and endangered fishes and their habitats than anyone I know of. It would be regretable if his work terminated now.

I believe Mr. Wick will make an outstanding contribution to our understanding of endangered species and the factors that have caused their decline if he continues on for a Ph.D. degree.

Sincerely,

Robert Behnke
Associate Professor of
Fishery Biology

RJB:kle

Reprinted from

Journal of the Fisheries Research Board of Canada

Réimpression du

Journal de l'office des recherches sur les pêcheries du Canada

Life History and Taxonomic Status of an Isolated Population of Arctic Char, *Salvelinus alpinus*, from Gros Morne National Park, Newfoundland

P. J. Rombough, S. E. Barbour and J. J. Kerekes

Volume 35 ● Number 12 ● 1978

Pages 1537–1541

Fisheries and Environment Canada
Fisheries and Marine Service

Pêches et Environnement Canada
Service des peches et de la mer

The Systematics of Salmonid Fishes of Recently Glaciated Lakes[1]

ROBERT J. BEHNKE

Colorado Cooperative Fishery Unit
Colorado State University, Fort Collins, Colo. USA

BEHNKE, R. J. 1972. The systematics of salmonid fishes of recently glaciated lakes. J. Fish. Res. Bd. Canada 29: 639–671.

The systematics of the subfamilies Salmoninae and Coregoninae of recently glaciated regions are reviewed. Interrelation between systematics and fisheries biology are stressed, pointing out the abundance of intraspecific genetic diversity of some salmonid fishes manifested in ecological and behavioral specializations, but not necessarily by morphological divergence. Innate, reproductive homing behavior of salmonid fishes may allow closely related populations to exist in sympatry and maintain reproductive isolation. Examples are cited to support the contention that many sympatric "sibling species" have evolved from a common ancestor in postglacial times. Closely related, sympatric populations are a major taxonomic problem, but this phenomenon whi h allows a species to consist of genetically discrete units with reproductive isolation between the stocks is of great significance for fisheries management. Postglacial salmonid communities are typically fragile and highly susceptible to disruption or destruction by introductions, eutrophication, and exploitation. Every effort should be made to protect the genetic diversity of a species.

BEHNKE, R. J. 1972. The systematics of salmonid fishes of recently glaciated lakes. J. Fish. Res. Bd. Canada 29: 639–671.

L'auteur passe en revue la systématique des sous-familles Salmoninæ et Coregoninæ des régions récemment recouvertes de glaciers. Il appuie sur les relations entre la systématique et la biologie des pêches et souligne la grande diversité génétique intraspécifique de certains salmonoïdes qui se manifeste par des particularités écologiques et de comportement, non pas toujours par des différences morphologiques. Le retour instinctif des saumons à leur rivière natale pour la fraye peut permettre à des populations apparentées d'exister à l'état sympatrique et de maintenir une barrière à la reproduction. L'auteur donne des exemples à l'appui de la prétention que plusieurs espèces sympatriques apparentées ont évolué d'un ancêtre commun aux époques postglaciaires. Les populations sympatriques apparentées de près constituent un problème taxonomique majeur. Par contre, le phénomène en vertu duquel une espèce est constituée d'unités génétiquement discontinues, tout en maintenant des barrières à la reproduction entre les stocks, est de la plus grande importance pour l'aménagement des pêches. Les communautés postglaciaires de salmonoïdes sont typiquement fragiles et fort susceptibles au déséquilibre ou même à la destruction par les repeuplements, l'eutrophisation et l'exploitation. On devrait tout mettre en œuvre pour protéger la diversité génétique d'une espèce.

Received January 6, 1972

THE diverse array of ecological and behavioral adaptations found in the salmonid fishes of recently glaciated lakes, often resulting in sympatric, morphologically similar "sibling species," raises several profound questions on the speciation process and rates of evolutionary change; but, more important from a fisheries management viewpoint is the fact that an understanding of the biological diversity present in a salmonid community is necessary for proper management and basic for a correct interpretation of how exploitation, introductions, and eutrophication affect that community.

In most of the lakes of the Holarctic region, fishes have inhabited these waters for only 8000–40,000 years. How many of the evolutionary specializations apparent today were acquired during the postglacial period, and how many are the result of their phylogenetic heritage acquired prior to the last glaciation?

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[1]This paper forms part of the proceedings of the "SCOL Symposium" convened at Geneva Park, Ontario, in July 1971. The objective was to identify the separate and joint effects of cultural eutrophication, fisheries exploitation, and introductions of non-native fish species on the salmonid communities of recently glaciated oligotrophic lakes. Here "salmonid" includes salmonines and coregonines, and does not exclude consideration of other taxa commonly found in association with salmonids.

Printed in Canada (J2377)

Is the genetic differentiation allowing sympatry of "sibling species" attributable in all cases to preglacial allopatric speciation?

Two opposing points of view have been offered to explain the abundance of "sibling species," particularly in the genus *Coregonus* of recently glaciated lakes. The formerly widely accepted theory of sympatric speciation simply states that a population in any given lake can fraction into two or more discrete, reproductively isolated populations without the need for some kind of geographic isolation.

The more prevalent view among western biologists is guided by the biological species concept. Several publications of Dr G. Svärdson of the Drottningholm Institute states the case for allopatric speciation as the explanation of sibling species of *Coregonus* in recently glaciated regions. Svärdson believes that all present sympatric sibling species are the result of allopatric speciation in preglacial bodies of water with genetic differentiation proceeding to a degree that life history and ecological differences were incorporated into various genotypes but not to genetic incompatibility preventing hybridization when the various forms came in contact in postglacial times. Reproductive isolation, then, depended on ecological differences of the various forms and niche diversity in each body of water these forms invaded in the postglacial period. The systematic problems and implications of sibling species is well covered by Mayr (1963), and Mayr's views on the subject are similar to those applied by Svärdson to the classification of *Coregonus*.

The important consideration concerning fisheries management of some recently glaciated lakes is that closely related populations capable of hybridizing may occur under pristine conditions but the reproductive barriers are in delicate balance and susceptible to the effects of introductions, exploitation, and eutrophication, leading to the loss of unique genotypes.

Evidence is presented in this paper to support the contention that, in some instances, sympatric, reproductively isolated populations, behaving as good biological species, have differentiated from a common ancestor since the last glaciation, but in most cases this is not necessarily attributed to sympatric speciation, but rather is more likely associated with minor advances and retreats of glacial fronts and changes in the level of the seas resulting in relatively brief periods (perhaps 1000 years or more) of allopatry for neighboring populations. Although the overall genetic differentiation between populations separated for only a few thousand years would be expected to be slight, there could be rapid evolution of ecological specializations and of differences in time and place of spawning. The key factor in maintaining reproductive isolation between two closely related populations is the strong homing tendency exhibited by most salmonid fishes to return to their natal grounds for reproduction. Thus, two populations with different spawning preferences, such as lake spawning versus stream spawning, or differences in the timing of spawning peaks, or both, would segregate for reproduction. Once some degree of reproductive isolation was established, it would be reinforced by selection for further ecological differentiation to avoid direct competition and make more efficient use of the total environmental resources. Some of the common life history distinctions of salmonid sibling species such as growth rates (dwarf and normal), age at sexual maturity, maximum life span, habitat, and food preferences may be attributable to ecological specializations developed independently in numerous populations during postglacial times.

It is virtually impossible to arrange the biological diversity present in the salmonids of recently glaciated lakes in the binomial (or trinomial) system of nomenclature (based on the biological species concept) in a manner reflecting degrees of genetic divergence and evolutionary reality. Current taxonomy may encompass a multitude of populations with actual or potential reproductive isolation and diverse life histories under a single species such as *Salvelinus alpinus*, *Coregonus lavaretus*, and *C. artedi*. Such classifications have the inherent danger of promoting the typological approach among fisheries biologists, an approach that must be avoided if the tremendous diversity present in a polytypic species is to be recognized and utilized.

Many unique genotypes have been lost because of unwise and unimaginative fisheries management. In large river systems with several discrete stocks of an anadromous species, hatcheries may inadvertently break down the reproductive barriers between these stocks, established by thousands of years of natural selection, by forced mixing or favoring one or a few stocks over the others.

Although it is not possible to categorize all of the biological diversity in a polytypic species within the framework of zoological nomenclature, a shorthand technique might be devised by fisheries biologists to characterize the biological parameters of populations possessing ecological and behavioral attributes important for fisheries management. Such information might be compiled in a manner comparable to a "breeder's handbook." It is important that a start be made to document genetic diversity particularly as it is manifested in ecological adaptations of potential use in future fisheries management and breeding programs. This is an urgent matter because of the relatively brief evolutionary time span involved; postglacial salmonid communities typically are fragile and susceptible to disruption and de-

Comp. Biochem. Physiol., 1971, *Vol.* 38B, *pp.* 487 *to* 492. *Pergamon Press. Printed in Great Britain*

COMPARATIVE ELECTROPHORESIS OF ARCTIC CHAR

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(*Received* 26 *August* 1970)

Abstract—1. Electrophoretic patterns of five protein groups from seven geographically isolated populations of *Salvelinus alpinus* were compared.

2. Muscle protein patterns of *S. alpinus*, *S. aureolus* and *S. oquassa* revealed no interspecific variations.

3. Eye lens proteins, liver LDH and liver esterase demonstrated interpopulation variations which may be useful as population markers.

4. A liver esterase polymorphism was found within the population from Matamek Lake, Quebec.

INTRODUCTION

THE ARCTIC char, *Salvelinus alpinus* (Linnaeus), has been described as a polymorphic species in North America. The geographic isolation of relict populations in deep lakes from western Quebec to New England has resulted in the post-glacial evolution of several distinct races. Some authors refer to the various races as the *S. alpinus* complex (Backus, 1957; Bigelow, 1963; Leim & Scott, 1966); but some races have been described as separate species: *S. marstoni*, *S. aureolus* and *S. oquassa* (see Vladykov, 1954). Two separate species of char, *S. alpinus* and *S. malma*, are recognized from western North America; but there appears to be some disagreement concerning the presence of several species in eastern North America (McPhail, 1961). The confusion in char taxonomy may be attributed to overlapping ranges in meristic and morphometric characters among geographically isolated populations (Bigelow, 1963). Morphological characters are known to vary in response to different environmental conditions (Lindsey, 1961), and evidence of genetic divergence among char populations has not been demonstrated.

The need for a diagnostic tool to supplement conventional morphometric methods has led to the application of gel electrophoresis to systematics (Desauer & Fox, 1964). The use of this method in the biochemical systematics of fishes has been discussed in detail (Tsuyuki *et al.*, 1965), and several species of the family Salmonidae have been subjected to biochemical analysis. The electrophoretic patterns of muscle myogens of *Salvelinus namaycush*, *S. fontinalis*, *S. alpinus* and *S. malma* are species specific although the latter two demonstrate similarities which suggest subspecific designation (Tsuyuki *et al.*, 1966). The taxonomic validity of *S. marstoni*, *S. aureolus* and *S. oquassa* has not been tested electrophoretically and the status of these species, based on conventional morphometric techniques, is questionable.

Charrs, Salmonid Fishes of the Genus Salvelinus

Edited by Eugene Balon

1980

Taxonomic Status of the *Salvelinus alpinus* Complex

S. U. Qadri

Department of Biology
University of Ottawa, Ottawa, Ont.

Qadri, S. U. 1974. Taxonomic status of the *Salvelinus alpinus* complex. J. Fish. Res. Board Can. 31: 1355–1361.

Minor differences in osteology and morphology were observed in the eastern North American species of charrs *Salvelinus aureolus* (Sunapee), *S. marstoni* (Quebec red), and *S. oquassa* (blueback). The coefficient of difference values, which determine the degree of overlap were lower than 1.28 for the total numbers of vertebrae, ribs, epineurals, gill rakers, branchiostegals, pores on the lateral line scales, and also for many morphological characters suggesting that the three chars are conspecific and should by synonymized as *S. alpinus oquassa*.

Qadri, S. U. 1974. Taxonomic status of the *Salvelinus alpinus* complex. J. Fish. Res. Board Can. 31: 1355–1361.

L'auteur a observé des différences mineures dans l'ostéologie et la morphologie des espèces de truites de l'est de l'Amérique du Nord *Salvelinus aureolus* (Sunapee), *S. marstoni* (rouge du Québec) et *S. oquassa* (dos bleu). Les coefficients de différence, déterminant le degré de chevauchement, ont des valeurs inférieures à 1.28 pour le nombre total de vertèbres, côtes, épineuraux, branchicténies, rayons branchiostèges, pores sur les écailles de la ligne latérale, ainsi que pour plusieurs caractères morphologiques, ce qui donne à croire que les trois truites sont conspécifiques et devraient être synonymisées sous le nom de *S. alpinus oquassa*.

Received March 10, 1971
Accepted April 29, 1974

Reçu le 10 mars, 1971
Accepté le 29 avril, 1974

The present detailed osteological and morphological study was planned to clarify the status of the Quebec red (*Salvelinus marstoni*), blueback (*S. oquassa*), and Sunapee (*S. aureolus*) and also to establish their interrelationships.

In eastern North America, isolated populations of the Quebec red occur in the province of Quebec, the blueback in Maine, and the Sunapee in Maine and New Hampshire (Waters 1960)

From the earliest times, ichthyologists have recognized four species in the genus *Salvelinus:* the Arctic char (*S. alpinus* or its complex), the brook char (*S. fontinalis*), the Dolly Varden (*S. malma*), and the lake char (*S.(c). namaycush*). Henn and Rinkenbach (1925) included the aurora char (*S. timagamiensis*) in the genus; Qadri (1968) reduced it to a subspecies. The blueback and the Sunapee were considered distinct species by Kendall (1914) and Waters (1960). Vladykov (1954) suggested that *S. aureolus* and *S. marstoni* are distinct species and that the latter is conspecific with *S. oquassa*. Vladykov (1957) divided *S. marstoni* into three subspecies, *S. m. marstoni*, *S. m. intermedius*, and *S. m. cavanaghi*. Dymond (1947) and Legendre (1954) considered *S. marstoni* a subspecies of *S. alpinus*.

Printed in Canada (J2075)
Imprimé au Canada (J2075)

Methods and Materials

Number, size, and source of the fish studied are shown in Table 1. For osteological studies specimens were cleared in 1–2% KOH and stained with alizarin red S following the method of Evans (1948). All morphometric measurements and meristic counts were made on the left side of the fish.

The positions and shapes of all cartilages and chondral and dermal bones of the chondrocranium were studied. Only the following important bones, which showed promise in salmonid taxonomy (Qadri 1964), were considered: supraethmoid, frontal, premaxilla, maxilla, supramaxilla, dentary, vomer, lingual plate, and caudal skeleton.

The alveoles, representing missing teeth on the premaxilla, maxilla, dentary, vomer, and lingual plate were included in the count with the teeth. On the premaxilla and maxilla, up to seven replacement teeth were embedded in the connective tissue lateral to the first series but were not included in the count; on the dentary a maximum of eight such teeth were present.

Figure 1 shows the measurements taken on all the above bones except the caudal skeleton. The bone

Spode

~~U.S. Pratt~~

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Ted C. Bjornn

DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

A SURVEY OF THE WATERS OF THE CHALLIS NATIONAL FOREST, IDAHO

by

I. A. Rodeheffer,
Temporary Biologist

Washington
April, 1935

A Survey of the Waters of the Challis National Forest, Idaho

by

I. A. Rodeheffer,
Temporary Biologist

INTRODUCTION

The purpose of this survey was to collect certain basic information concerning the streams and lakes of this region in order to determine a suitable stocking program. The need for and the possibilities of stream and lake improvement and development of rearing ponds were also considered by the survey.

The streams and lakes surveyed in the Challis National Forest are all in the Salmon River Drainage. The country is mountainous and barren to wooded. The streams studied are typical mountain streams, high in velocity, low in temperature, and varying in volume with the melting of the snow.

The lakes and streams surveyed are listed below, with the approximate area of their drainages:

Stanley Lake Drainage.......	15 square miles
Hidden Lake Drainage........	3 square miles
Sawtooth Lake Drainage......	10 square miles
Yankee Fork Drainage........	400 square miles
Challis Creek Drainage......	150 square miles

Of the waters studied, Stanley Lake, Yankee Fork and Challis Creek are accessible by road. An excellent road has been built to Stanley Lake. The Custer Motor Highway, which is being improved at the present time with C.C.C. labor, follows the Yankee Fork. The lower section of Challis Creek flows along the Twin Peaks Road. The upper section and Mill Creek are accessible from the Custer Motor Highway.

One may drive within two miles of Hidden Lake on the road leading from Stanley to Cape Horn. A trail leads to the lake over hilly, wooded country.

Sawtooth Lake may be reached by trail, either from the town of Stanley or from Stanley Lake. Either way requires travelling about 7 miles on foot or on horseback. For the last 1½ miles, where it is necessary to leave the trail, a guide is needed.

The survey work was conducted in the Challis Forest from June 15 to July 17, 1934.

The personnel of the survey consisted of zoologists from Idaho, Utah and Michigan, as follows: I. A. Rodeheffer, Leader; Horace Telford, Ray Kelly, L. C. Glass, assistants; and J.J. Schreiber, cook.

Only those lakes and streams were covered that the Forestry Division asked to have surveyed. The Foresters gave wonderful cooperation. Mr. J.W. Farrell, the Forest Supervisor, and Mr. M.J. Markle, Ranger at the Valley Creek Station, cooperated wherever possible. The members of the sportsmen's club at Challis were very much interested in the survey and were at our service at any time.

The methods used are those described in a mimeographed bulletin of the U. S. Bureau of Fisheries entitled, "Instructions for Stream and Lake Survey Work." The significance of certain of the data collected is discussed in the following paragraphs:

SUMMARY OF IMPROVEMENT RECOMMENDATIONS

LAKES

The purpose of improvement work is to make a lake more habitable for fish life. It should, however, be remembered that the improvement of cold water lakes is still in the experimental stage.

Improvement work is recommended only for those lakes where it is practical and possible. Since each lake is a problem by itself, specific improvement recommendations are listed with each lake report.

Further lake improvement should await the results of this work which was done in 1934.

STREAMS

In the fast mountain streams of this forest, improvement work is highly desirable. Since many of these streams have a velocity that is normally too fast for trout, primary attention should be given to the development of pools and resting places for trout. Specific improvement recommendations are given with each stream report.

REPORTS ON LAKES

Stanley Lake

Location and Drainage. Stanley Lake lies on the east side of the Sawtooth Mountains about 8 miles northwest of Stanley. It is fed by drainage from an area of approximately 15 square miles in the Sawtooth Mountains. Stanley Lake Creek below the lake drains into Valley Creek which in turn empties into the Salmon River below the town of Stanley.

Accessibility. A good road running from the town of Stanley to Stanley Lake makes this lake popular as a tourist camping ground.

Stocking Recommendations. Rainbow will probably not repproduce in this lake. However, an occasional planting with a few hundred fingerlings should furnish a limited amount of good fishing. There is a possibility that brook trout would spawn on the gravel near the inlet. It would seem profitable to plant a few with the idea in mind to determine if they will use this gravel.

Improvement Recommendations. The installation of improvements in this lake is not recommended because of its inaccessibility and small size. Wave action will not hinder the growth of plants. Water lilies are started and should continue to grow and increase if conditions are proper for them.

When, and if, improvement is regarded as practical, it is recommended that square brush shelters with better soil placed in them be installed to get more plant life started. The gravel bed near the inlet should be extended if this runs on a normal year to increase the spawning area for the fish of the lake.

Sawtooth Lakes

Location and Drainage. The Sawtooth Lakes are located about eight miles southwest of Stanley. The larger Sawtooth Lake is one of the most peculiar lakes in this region. It will undoubtedly become popular with tourists from a scenic standpoint. It is not possible to walk around the lake as part of the shoreline is made up of high cliffs. Along the upper end, snow comes to the water's edge. The lake is fed by melting snow and two small ponds above the lake. Impassable falls keep fish from entering these ponds from Sawtooth Lake. The outlet drains into Lower Sawtooth Lake, a small shallow lake about one acre in size. There are impassable falls between these two lakes. Lower Sawtooth is the source of Iron Creek which drains into Valley Creek, which in turn empties into the Salmon River.

Accessibility. The sawtooth lakes may be reached by a trail that runs along Iron Creek. This trail takes one about 1½ miles from the lake. Another trail, starting along Stanley Lake and going over to the Payette side of the Sawtooth Mountains may be taken, but here again it is necessary to leave the trail to reach the lake. In either event it means hiking or riding horses for 7 miles and a guide is needed.

Time of Survey. Sawtooth Lakes were surveyed on the 13th, 14th, and 15th of July.

Temperature and Thermocline. Sawtooth Lake is a very cold lake. (Surface temperature 50° F., 3 P.M. Sky, clear; July 13). This probably is one of the factors limiting the food supply. Since the thermocline zone was formed at a depth of 40 to 50 feet a rather large volume of water for the development of microscopic organisms was indicated.

Turbidity. Visibility is recorded as 36 feet. (The reading may be too low since a perfectly quiet surface could not be found at the time the determination was made).

Area, Depth, and Bottom. The maximum depth of Sawtooth Lake is 254 feet. Practically the entire lake is over 50 feet deep. Its shoal area is limited to 3 per cent or less of the total area. The bottom of this shoal area is made up entirely of rocks. The lake has an approximate area of 300 acres.

Chemical Determinations. Dissolved oxygen tests were made at the surface and at a 108 foot depth. Oxygen was found sufficient to support fish life at both places. (Surface, 8.9 p.p.m., 108 foot depth 8.05 p.p.m.) Carbon dioxide determinations were low. (1.0 and 1.5 p.p.m. at surface and 108 feet, respectively.

Hydrogen ion concentration shows this lake to be acid. This possibly is one of the factors making the lake unproductive. Methyl orange and phenolphthalein alkalinity determinations indicated a low carbonate and bicarbonate content. (Bicarbonates 7.5 and 8 p.p.m; carbonates negative).

Food Supply and Vegetation. Examination of the few shallow areas did not reveal any fish foods. No vegetation was found anywhere in the lake. Stomach examinations of a few of the fish caught showed that they had been eating adult caddisflies, stoneflies, and bettles.

Fish and Previous Stocking. In 1925 a planting of 1,000 Sunapee golden trout was made in the larger lake. Total gill net settings of 20 hours caught 12 Sunapee trout, 8 to 9 inches long, very thin and slender. Several fish slightly smaller were seen among the logs near the outlet. – fish normally in deep water but in Sawtooth near surface.

Stocking Recommendations. It will be difficult to make this lake a satisfactory habitat for fish. Since Sunapee trout have not thrived here it is recommended that a planting of California golden trout be made as this species grows well in lakes of similar character.

Improvement Recommendations. The placing of improvement devices in this lake is not recommended, because of its inaccessibility and scarcity of materials. It has very little shoal area and damming of the outlet would reduce what shoal area there is.

Lower Sawtooth Lake

The location, drainage, and accessibility of Lower Sawtooth Lake have been described in the report for larger Sawtooth Lake.

Temperature, Thermocline, and Turbidity. Although this lake is too shallow to have a thermocline, (depth 15 feet) it is a cold lake. (Surface temperature 56° F. at 2 P.M. on a clear day with the air temperature at 70° F.) The bottom may be seen at all depths.

Area, Depth, and Bottom. Lower Sawtooth is a small lake having an area of a little over one acre. Its maximum depth is 15 feet over a rocky bottom.

Chemical Determinations. The chemical determinations are similar to those for Larger Sawtooth Lake. Dissolved oxygen runs 7.95 and 8.85 p.p.m. Carbon dioxide 2.5 and 2 p.p.m.

Hydrogen ion reaction shows an acid condition (pH 5.6). Methyl orange alkalinity (4.5 p.p.m.) is lower than for any other lakes surveyed in the Challis Forest.

Food Supply, Vegetation, and Fish. No fish food, vegetation, or fish were found or seen in this lake. As the bottom could be seen clearly at all depths it is not likely that any fish life exists here.

Stocking Recommendations. Stocking is not recommended for this lake. If, and when, Larger Sawtooth Lake becomes stocked with fish, this lake should become stocked from it if it is suitable.

Improvement Recommendations. Improvements are not recommended because of inaccessibility and scarcity of materials. This is a small shallow rock-bottomed lake and improvements would not justify the cost at the present time.

REPORTS ON STREAMS

Inlet and Outlet of Stanley Lake

Location and Drainage. Stanley Lake inlet has its source in the Sawtooth Mountains and drains into Stanley Lake from the West. The outlet flows into Valley Creek which in turn empties into the Salmon River.

Time of Survey and Temperature. Stanley Lake inlet and outlet were surveyed on July 9 and 10. The inlet is the cooler but the temperature of neither stream approaches the danger point for trout.

Flow and Bottom. The inlet of Stanley Lake has a volume flow of 15.7 cubic feet per second at the time of the survey. The outlet had a volume flow of 25 cubic feet per second. The bottom of the inlet is shifting gravel, which makes ideal spawning grounds. The outlet has a bottom composed of gravel and rocks up to a foot in diameter.

Chemical Determinations. The hydrogen ion concentration shows these streams to be neutral (pH 6.8 to 7.1). Methyl orange alkalinity reaction shows the inlet to have 23 p.p.m. of carbonates while the outlet has 21 p.p.m. Phenolphthalein reaction was negative for both streams.

Food Supply and Vegetation. Of the two streams the outlet has a better food supply. Caddisflies, mayflies, Diptera, stoneflies, Annelids, and Acarina are found in both streams. Very little aquatic vegetation is found in these streams. Algae, Diatoms, Sphagnum and Crowfoot are the kinds found.

Fish. In the inlet 12 trout and about 100 fingerlings were observed in the lower mile of stream. About 100 fingerlings, most of which were not trout, were observed in the outlet.

The inlet is closed to fishing because redfish use it for spawning. They were found spawning in this inlet in the second week of August and schools of 500 to 600 fish were observed travelling upstream. These redfish, approximately 8 or 9 inches long, are locally considered too small to be caught with hook and line.

Stocking Recommendations. If the stocking recommended for Stanley Lake is done in the inlet and outlet it will not be advisable to do additional stocking in the streams.

Improvement Recommendations. Stanley Lake Creek, above lake, should be improved from its mouth to within 200 yards of Lady Face Falls, a distance of 1 3/4 miles. Improvement is most desirable in the lower ½ mile of stream. One shelter for every 100 feet on the average is recommended. Obstacles to the spawning migration of redfish should be avoided.

Table 1. - Biological data on lakes

Number of Animals per Square Foot

	Stanley	Hidden	Sawtooth	L. Sawtooth
Caddisflies	-	2	6 (fish) stomachs)	
Mayflies	-	2	-	
Midges	36	5	-	No
Other Diptera	-	3	-	Animals
Amphipods	4	6	-	Found
Copepods	2	-	-	
Molluscs	-	1	-	
Worms	17	1	-	
Acarina	16	-	-	
Coleoptera	-	-	6 (fish stomachs)	

Aquatic Plants

	Stanley	Hidden	Sawtooth	L. Sawtooth
Equisetum	R	-	None	None
Sparganium	R	A (along shore)	None	None
Lilies	-	R	Found	Found
Potamogetum	C	-		

Fishes

	Stanley	Hidden	Sawtooth	L. Sawtooth
Gill net sets hrs.	72	5	20	-
Suckers	135	-	-	
Squawfish	51	-	-	No
Redfish	7	-	-	Fish
Dolly Varden	6	-	-	Life
Rainbow	-	1	-	Found
Whitefish	4	-	-	
Sunapee	-	-	12	
Silverside shiners	200	(in 5 seine hauls)		

Table 2.- Summary of previous stocking of waters surveyed in Challis National Forest

(No stocking record prior to 1923)

Year	Stanley Lake		Hidden Lake	Sawtooth Lake	Yankee Fork	Challis Creek
1923	E. Brook Landlocked Salmon 3" Rainbow	200 1,000 200	-	-	-	-
1924			-	-	-	Rainbow 14,850 Bayhorse Lake Challis Creek Chivers Slough
1925	Rainbow 3" E. Brook	4,500 3,000	-	Sunapee Golden Trout 1,000	-	-
1926	E. Brook	6,400	-	-	-	Native Cut-throat 9,900
1927	Some planting in 1927, 1928 and 1929 by the State Game Department.		-	-	-	-
1928			-	-	Rainbow 250 Slaughter-house Creek	-
1929	No Record		-	-	-	-
1930	Rainbow	340	-	-	-	-
1931	Rainbow	3,600	Rainbow about 200	-	-	-
1932	-		-	-	Rainbow 7,126	-
1933	Rainbow	11,934	-	-	Rainbow planted: Yankee Fork 2100 Eight Mile 1200 Five Mile 300	-

Bonneville County Sportsmen's Ass'n	Swan Valley	Cut-throat	17,400
Jefferson County Protective Ass'n	Swan Valley	Rainbow	96,000
Jefferson County Protective Ass'n	Swan Valley	Cut-throat	19,300
Fremon County Fish & Game Ass'n	Henry's Lake	Cut-throat	400,000
Isaac Walton League	Glenn's Ferry	Rainbow	33,750
Southern Idaho Fish & Game Ass'n	Twin Falls	Rainbow	148,400
Emmett Rod & Gun Club	Black Canyon	Rainbow	16,000
Coeur d'Alene F. & G. Protective Ass'n	Malkin's Bay	Cut-throat	350,500
Challis Rod & Gun Club	Challis	Cut-throat	10,000

The Department also operated the following rearing stations:

Payette Lakes	Sylvan Beach	Ouananiche	3,000
Payette Lakes	Sylvan Beach	Rainbow	72,000
Ruby Creek	Naples	Cut-throat	250,000
Game Farm Pond	Lapwai	Rainbow	50,000

Cooperation With Forest Service

Invaluable assistance has been rendered the Game Department by the United States Forest Service in the work of investigating lakes and streams, and in distributing suitable fishes to such waters. Owing to the closely related interests of these two agencies, far greater results may be accomplished by working hand in hand than would be possible by a division of efforts along simliar lines. Without exception, the supervisors and rangers in all the great national forests have manifested an increasing willingness to cooperate with the State officials whenever and wherever their regular duties would allow. Both the Forest Service and the Game Department realizing the importance of adopting some permanent policy in the development and maintenance of a fish supply in the high interior lakes and streams, have been conducting extensive stocking and research experiments in the Sawtooth Mountain section. This territory was selected, not only on account of the certainty that it will ultimately become one of the greatest outdoor playgrounds in Idaho, but because the results of such work will effect a larger area of angling waters, than would similar operations in any other part of the intermountain region. From these Alpine-like lakes of the Sawtooth's, spring the larger tributaries of the Payette, Boise, Salmon and Wood Rivers. The success of the past few seasons activity have been noteworthy, and in addition to the establishing of large stocks of salmon and trout into heretofore vacant waters, the knowledge gained of best methods of procedure, will be of incalculable value in developing the fish life under similar

See page 51

~~return to K. Ball~~

conditions elsewhere. Much
been accomplished, is due Mr.
Inspector of the Ogden, Utah,
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Progress of Fish Planti
Lake Section

GENERAL SITUATION, WORK

A program for building up the
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There have been planted in th
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salmon and 10,000 Montana graylin
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stocking and the entire amount co
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predatory fish are not sufficiently
Although the full effect of the pl
of years longer, it would seem th
are at present apparent. The main
stock in the lakes or their inlets a
possible that within two years add

Valley	Cut-throat	17,400
Valley	Rainbow	96,000
Valley	Cut-throat	19,300
's Lake	Cut-throat	400,000
s Ferry	Rainbow	33,750
'alls	Rainbow	148,400
Canyon	Rainbow	16,000
's Bay	Cut-throat	350,500
	Cut-throat	10,000

ıl the following rearing stations:

Beach	Ouananiche	3,000
Beach	Rainbow	72,000
	Cut-throat	250,000
	Rainbow	50,000

ith Forest Service

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conditions elsewhere. Much of the credit for what has been accomplished, is due Mr. S. B. Locke, District Forest Inspector of the Ogden, Utah, office. Largely through his efforts in investigating and planting the almost inaccessible headwaters, this wonderful country is rapidly being developed into an anglers' paradise. Mr. Locke's report upon the past two seasons inquiry and planting follows:

Progress of Fish Planting Work in the Redfish Lake Section, Idaho, 1925

GENERAL SITUATION, WORK UNDERTAKEN AND RESULTS

A program for building up the fishing in this region, which includes the principal headwaters of the Salmon River as well as the extreme headwaters of the South Fork of the Payette River on the Sawtooth, Challis and Boise National Forests, was undertaken in the fall of 1920. It has been continued cooperatively since that time each year by the Idaho State Game Department, the Bureau of Fisheries, interested individuals and associations, and the Forest Service. With at least 60 lakes having a total area of approximately 5,000 acres and 100 miles of connecting or tributary streams with excellent spawning and food conditions, it is potentially an area of great possibilities in fish production and its proper development will be of high value as a source of food supply as well as recreation. It is a very desirable and attractive summer play ground for the people living in the Snake River Valley in Idaho and in Northern Utah, but can never serve its highest value as such until good fishing is available.

There were two general problems in the stocking work, one to make productive of fish many alpine lakes and streams from which fish had been held by natural barriers, the other to improve fishing conditions in the several lakes easily accessible in the floor of the valley. These lower lakes had excellent spawning inlets and contained an abundant supply of minnows, suckers, squawfish and white fish but few trout.

The success in the vacant waters has been very encouraging and practically all species planted have thrived, these being rainbow, native blackspotted, Yellowstone blackspotted, eastern brook and landlocked salmon from Maine. A few native resident steelhead have been planted, the results not being known as also the results of planting silverside shiners in several lakes. Thirty such lakes previously vacant of all fish life have been stocked.

There have been planted in the inlets of the lower lakes and in the Salmon River from 1920 to 1925, inclusive, 146,000 rainbow, 51,200 eastern brook, 45,000 blackspotted, 48,000 little redfish, 40,500 landlocked salmon and 10,000 Montana grayling. Considering the amount of area and water involved and the period covered this is a relatively small stocking and the entire amount could be absorbed in one year. However, practically all of this planting has been very carefully done and predatory fish are not sufficiently abundant to be much of a factor. Although the full effect of the planting will not be felt for a couple of years longer, it would seem that better results should obtain than are at present apparent. The main object has been to build up a brood stock in the lakes or their inlets and this is not yet in evidence. It is possible that within two years additional results may develop. Possibly one reason for apparent lack of results is in the small amount of fishing done in the lakes due to a general unfamiliarity of the local fishermen with methods of fishing such waters. Rainbow and eastern brook trout have apparently spawned in some of the lake inlets and a hatch resulted, but such fish have rarely, if at all, been taken yet from the lakes.

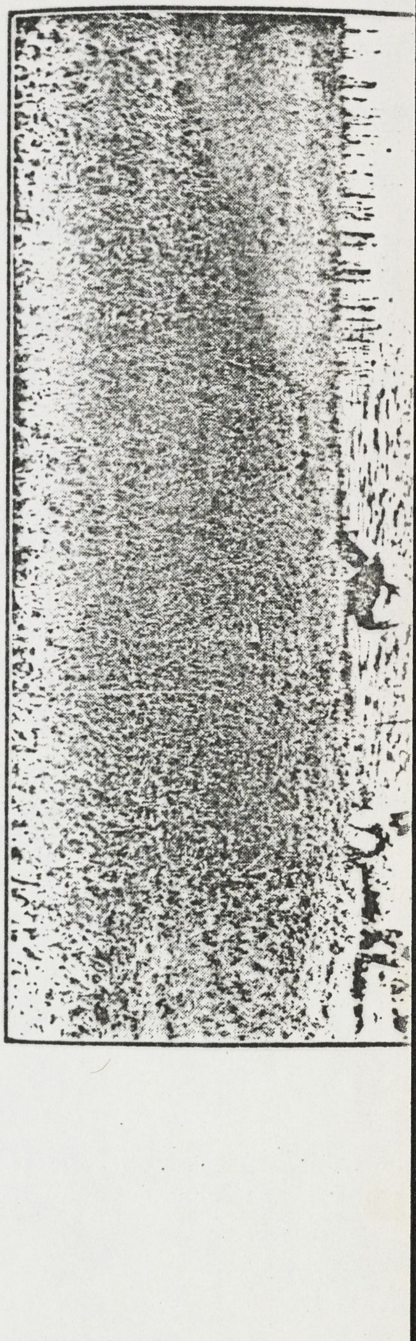
Observations in 1925

The Champion Lakes which were stocked in 1920 and 1922 were visited. The Yellowstone blackspotted trout planted in the lower lake in 1922 are doing well and have reached about two pounds in weight. The landlocked salmon planted there in 1922 are in fair condition and weigh from 2½ to 3 pounds. This lake is, however, too small and shallow to expect the salmon to thrive. The rainbow, eastern brook and Yellowstone cutthroat planted in the upper Champion Lake are in excellent condition, eastern brook having reached 4 pounds in weight and rainbow trout about 8 pounds. One dead male rainbow, about 7 pounds in weight, was observed which had become stranded in the outlet while spawning. A female rainbow of about 5 pounds weight was transferred from the pool where it was stranded to the lake. It was reported that in late October the eastern brook were spawning in rather deep water in the upper lake. At the same time a school of about 20 landlocked salmon was reported as gathered near the outlet of the lower lake. Rainbow trout planted in August, 1924 as 2-inch fingerlings, had made a growth up to 10 inches in length in the upper lake by the middle of July. A considerable number of fishermen visited these lakes during the summer and obtained excellent sport.

At Toxaway Lake several landlocked salmon from 2½ to 3½ pounds were taken. These fish were in excellent condition. Several rainbow trout from 3 to 4 pounds in weight were seen and one caught. No planting has been done at this lake except for silverside shiners since 1922 in an effort to see if a natural increase would take place. Apparently there has been only a slight natural increase of eastern brook but considerable schools of young rainbow were observed. Some of these were of fish 6 to 8 inches long, but the greatest number from 2 to 4 inches long, these latter being abundant wherever logs or other debris offered shelter. No doubt it will be unnecessary to stock it again with rainbow as the supply will build up naturally. The presence of a fall spawning species also would provide for the highest use of the limited spawning ground and it is hoped that there will be results from the natural spawning of the landlocked salmon which would have occurred in the fall of 1925. However, if these fish entered the outlet for any distance they would be unable to return to the lake, but no doubt would eventually reach some of the lakes below if they were not killed in passing over several high falls.

In 1921 about 500 landlocked salmon were planted in the upper Twin Lake at the head of the Pettit Creek drainage. This is a small lake and does not thaw out until in early July, but the salmon have grown fairly well and several were taken from 2 to 3 pounds in weight. Owing to the lack of a spawning inlet it is doubtful if a satisfactory natural increase will result by natural restocking but the lake is hardly suited to this fish anyway.

Rainbow trout planted in Alice Lake in 1923 and 1924 have made excellent growth. Several were observed in the lake although no fishing was done. Spawning grounds at this lake are extremely limited in the inlets, but fish can drop down the outlet for some distance without going over impassable falls.



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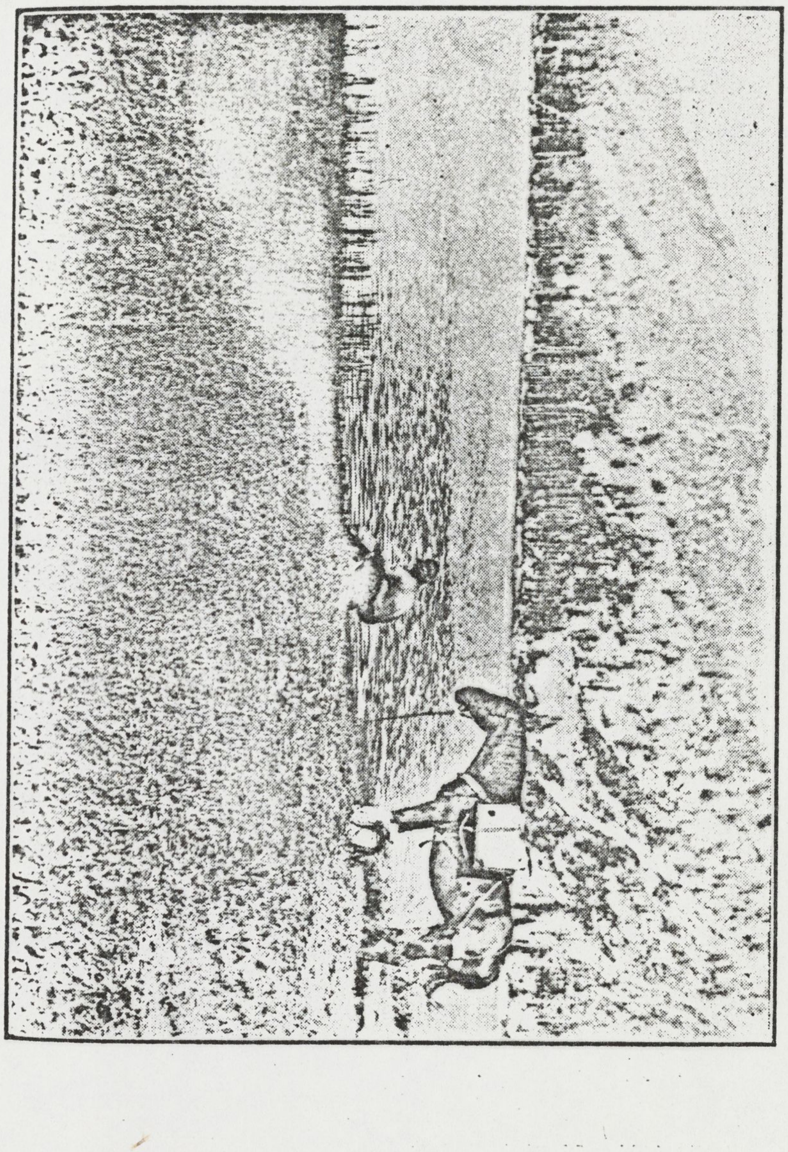

PLANTING LANDLOCKED SALMON IN IMOGENE LAKE, SAWTOOTH MOUNTAINS

Imogene Lake, near the head of Roaring Creek, has received plantings of landlocked salmon in 1923, 1924, and 1925, and of native resident steelhead in 1923. The salmon planted in August, 1924, were 10-inch fish this season and in excellent condition. The 1923 planting had grown to about 2½ pounds. None of the steelhead were observed but the observations were very limited and less than 100 were planted in the first place. Since this lake has the best opportunity for natural spawning as well as spawn taking operations of any of the high lakes, it will be interesting to watch the development.

Evidence of results at the lower lakes was generally lacking. Some fishing was done at Alturas Lake but no fish taken indicating results from the plantings. A few landlocked salmon were taken by fishermen and one caught about October 1 was reported as containing eggs practically in a condition to flow freely. An examination of the Alturas Lake inlet on November 1 gave no evidence of the presence of spawning fish. In an examination of a short stretch of the upper inlet to Redfish Lake two fish about 8 inches long were observed, which must have been young landlocked salmon, since this was above impassable falls and only landlocked salmon were planted there. Trolling at Redfish Lake was unproductive of results.

A visit to this section was made in late November, but a careful examination of the streams for spawning fish was impossible, owing to the short time available. The lake outlets were not frozen and one spawning bed recently used was observed a short distance below Redfish Lake. Fishhook Creek above Redfish Lake and below a series of cascades was heavily frozen and filled with anchor ice. It is probable that ice conditions in most of the inlets would make spawn taking operations impractical after November 15 unless spawning occurred in the outlets. The early cooling of these inlets and the low temperature in the lakes should have a tendency to produce early spawning in them.

The Salmon River in the valley above Stanley contained a great abundance of young trout from 3 to 7 inches in length this season. These are either rainbow or resident steelhead. If they are rainbow their presence can be credited to fish planting operations, but, although their presence in such numbers is unusual, I am inclined to think they are native fish. Bull trout are not nearly as abundant as formerly in these waters.

Additional observations at the lower lakes indicate no lack of fish foods and a scarcity of predatory fish. Bull trout are uncommon and squawfish are becoming less abundant. There are quantities of suckers in these lakes. Little redfish were not difficult to obtain at Alturas Lake by trolling with a small spoon after sundown over deep water. Although they are apparently present in numbers in Pettit, Big Redfish and Stanley Lakes, they average several inches smaller in size than at Alturas Lake and are difficult to take with a rod and line.

No boat has yet been used at Yellowbelly Lake and it is not known whether or not the planting work has been successful there.

Although a detailed examination was not made, no positive evidence of the success of the transplanting of weeds was found.

It was found necessary to lift the removable panels from the screen at the outlet of Pettit Lake during high water to prevent damage and they were not replaced. Gill netting of suckers and squawfish was not continued there this season.

Although two plantings of silverside shiners were made at Toxaway Lake and at Lower Champion Lake no results from these were observed. At Toxaway Lake, although there are grassy shallows where

they were planted and tangles of log
deep water, large trout were present w
and may account for the lack of succes
small lake offering no shelter for the
large trout, their disappearance was p

At Imogene Lake and Alice Lake
the original planting of fingerling trou
the second year. No careful examinati
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In some instances too many spec
or some lakes stocked with fish unsuit
tion in such cases seems to be adjusti

PLANTING WOR

Water	Rainbow Trout	Eastern Brook Trout	Landlock Salm
High Lakes			
Alice	2,000		2,0
Edna and below (So. Fork Payette river)			5
Vernon (So. Fork Payette river)			
Lake S. E. of Toxaway Lake			
Imogene			1,0
5 Bench Lakes above big Redfish	2,000	500	
5 Lakes on upper inlet to Big Redfish Lake			
Upper inlet Redfish Lake			
Sawtooth Lake			
Lower Waters			
Alturas Lake	4,500	2,400	4,
Pettit Lake	3,200	2,500	1,0
Yellowbelly Lake	2,000		
Redfish Lake	6,500	3,500	1,0
Stanley Lake	4,500	3,000	
Pole Creek and Salmon River		7,500	
	24,700	19,400	10,

*About 50% loss in planting. †A
planted in each lake. §About 50% los

As in the previous work, the pla
done with pack outfits while in the lo
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they were planted and tangles of logs in which they could hide in deep water, large trout were present when the first plants were made and may account for the lack of success. At Lower Champion Lake, a small lake offering no shelter for the shiners and well stocked with large trout, their disappearance was possibly expected.

(Silverside Shiners)

At Imogene Lake and Alice Lake some of them were placed with the original planting of fingerling trout and additional plantings made the second year. No careful examination was made here. It is quite probable that in view of their many natural enemies and lack of hardiness, it may take planting of several thousand to establish them, especially where large fish are already established.

It has taken a lot of difficult work to reach the high inaccessible waters but the results have been encouraging. Much of this was done where trails were entirely lacking and routes of possible access determined as the work progressed. Now that trails are making these lakes accessible, the fish have become well grown and established so that excellent sport is offered.

In some instances too many species have been planted together or some lakes stocked with fish unsuited to conditions, but the situation in such cases seems to be adjusting itself.

PLANTING WORK IN 1925

Water	Rainbow Trout	Eastern Brook Trout	Landlocked Salmon	Sunapee Trout	Steelhead Trout	Species Previously Planted
High Lakes						
Alice	2,000		2,000*	1,000		Rainbow
Edna and below (So. Fork Payette river)			500		1,500	Vacant
Vernon (So. Fork Payette river)				1,000		Vacant
Lake S. E. of Toxaway Lake					500	Vacant
Imogene			1,000			L. S., Native Steelhead
5 Bench Lakes above big Redfish	2,000	500				Vacant
5 Lakes on upper inlet to Big Red fish Lake				500†		Vacant
Upper inlet Redfish Lake				500§		L. S.
Sawtooth Lake				1,000		Vacant
Lower Waters						
Alturas Lake	4,500	2,400	4,500			Same as 1925
Pettit Lake	3,200	2,500	1,000			Same as 1925
Yellowbelly Lake	2,000					Same as 1925
Redfish Lake	6,500	3,500	1,000			Same as 1925
Stanley Lake	4,500	3,000				Same as 1925
Pole Creek and Salmon River		7,500				Rainbow, E. Brook, Native
	24,700	19,400	10,000	4,000	2,000	60,100

*About 50% loss in planting. †About 50% loss in planting, 50 planted in each lake. §About 50% loss, planted to avoid loss.

As in the previous work, the planting at the higher lakes was done with pack outfits while in the lower waters the fish were placed in the inlets or small feeders by scattering a few fish in a place from canvas buckets.

The rainbow fingerlings were about 1½ to 2½ inches, the eastern brook 2 to 4 inches, the landlocked salmon 2 to 3 inches, the Sunapee trout 2 to 4½ inches, and the steelhead 1 to 2 inches in length. The losses were all very nominal except for one small lot of landlocked salmon taken by pack horse up Yellowbelly Creek across to Alice Lake, and for one lot of the Sunapee trout taken up Redfish Lake and carried by man packs to several vacant lakes on that drainage. On account of the bad condition of the fish upon reaching the head of the lakes, they were sorted and those in poor condition turned loose in the inlet.

All of the fish used were brought by truck from the Hayspur State Hatchery about 75 miles away. The landlocked salmon were from eggs furnished by the Bureau of Fisheries from Maine and the Sunapee trout were from eggs furnished by New Hampshire Fish and Game Commissioner by exchange with the Idaho Fish Commissioner. The fish were delivered by the State men in charge of this work in excellent condition. Assistance in the planting work was given by a number of local people but more particularly by H. C. Beamer of Hailey, who supervised the planting at Sawtooth Lake, and to D. M. Williams, Tom Williams, and P. G. Snedecor who packed Sunapee trout to lakes accessible only by foot travel. The State Game Department supplied the stock, delivered the fish and paid for pack horses carrying the fish.

Early in September a shipment of aquatic vegetation with its accompanying life forms was gathered at Fish Lake, Utah, and shipped to the Sawtooth Forest where it was planted in the lakes by local Forest Officers.

Recommendations for Future

There are about twenty small lakes suitable for fish production yet to be stocked. In several of the best of these, two species may be planted, but to avoid conflict on the spawning grounds, which are generally limited in extent, one of these should be a spring spawner and the other a fall spawner. A sufficient number have been reached at present so that there is no pressing demand for completing this part of the program immediately. A few of these may be reached each season.

It is believed that in several of these as well as some of those already stocked, the native cutthroat should be used. Under such conditions it develops to ~~be~~ a very beautifully colored fish and should be placed in a greater proportion of these waters. One or two isolated basins could be stocked with Montana grayling, vacant waters being chosen. If carefully handled the planting in the high isolated basins can serve to perpetuate pure strains of trout which are rapidly becoming mixed in the lower waters. Such an example is the drainage into Roaring Lake in which no other spring spawning fish except the local resident steelhead from Roaring Lake should be planted. It is quite probable that some of the lakes lacking favorable spawning conditions will have to be re-stocked and in such cases care should be taken to duplicate if possible the original stock. An example of this is at Lower Champion Lake where the Yellowstone cutthroats are growing well and are prevented from possible mixing with the native cutthroat.

Since some of the higher series of lakes should be adapted to the California Golden trout it is believed that continued efforts should be made to acquire a small stocking.

The success of the landlocked salmon in several of the high lakes is encouraging but the final test will be as to whether or not they

will reproduce naturally. In such lakes
ing up to their reputation for gamenes
have had experience with them readil
game than any other species here. Co
and fly fishing lasts throughout the su

Now that the stocking program for
way, more attention needs to be given
general condition, there is a very co
plankton forms compared with the la
Such a condition often results in a rap
decided falling off of growth and co
slow recovery after spawning. In one
Toxaway or Imogene Lakes planting of
continued and if possible several thous
should be used. At Imogene Lake the p
small vacant lake a short distance
would be a natural drift which would
Planting in the lower Twin Lake above
der similar conditions. Experiments in
and its accompanying life are also desi
orate nor expensive. Some of the veg
from the Champion Lakes could be pl
the west side of the valley.

The situation in regard to the low
tory than with the higher waters. In
abundant food supply, but rather ins
work. Two factors which in my opinio
in the small size of the plants compare
the other that the principal inlets have
son and many of the fish planted the
men. This is particularly true with
Lake and the Fishhook Creek inlet to

It seems a very essential feature of
protected as nursery streams. Such pr
proclamation of the State Game Ward
tempt to build up a brood stock, to allo
the year after they are planted. An ab
as good or better is available in other
so that there is no particular necessi
lake inlets.

In view of the increasing tourist
area of water involved, large plantings
sential to adequate results in the lower
to fishermen and only benefit will resul
fish a season should be a fair test alth
could be well placed here.

There is comparatively slight dema
State in general and this field offers
vantage any number of these fish avai
ery. They would be less inclined to m
species and much will be accomplished
be developed here. If a drift-out doe
be determined where this species was

It is very desirable to establish the
lakes as well as the upper ones. Small
been made each year beginning with 19
the possibilities here without expecting
If a local spawn supply can be develope
greatly enlarged plantings, could be

were about 1½ to 2½ inches, the eastern
ndlocked salmon 2 to 3 inches, the Sunape
the steelhead 1 to 2 inches in length. The
al except for one small lot of landlocked
up Yellowbelly Creek across to Alice Lake,
pee trout taken up Redfish Lake and car-
ral vacant lakes on that drainage. On ac-
of the fish upon reaching the head of the
those in poor condition turned loose in the

ere brought by truck from the Hayspur
es away. The landlocked salmon were from
au of Fisheries from Maine and the Suna-
furnished by New Hampshire Fish and
hange with the Idaho Fish Commissioner.
the State men in charge of this work in
ce in the planting work was given by a
t more particularly by H. C. Beamer of
planting at Sawtooth Lake, and to D. M.
nd P. G. Snedecor who packed Sunapee
nly by foot travel. The State Game De-
k, delivered the fish and paid for pack

shipment of aquatic vegetation with its
gathered at Fish Lake, Utah, and shipped
ere it was planted in the lakes by local

ndations for Future

small lakes suitable for fish production yet
f the best of these, two species may be
ict on the spawning grounds, which are
one of these should be a spring spawner
r. A sufficient number have been reached
no pressing demand for completing this
ately. A few of these may be reached each

eral of these as well as some of those al-
tthroat should be used. Under such condi-
ry beautifully colored fish and should be
ion of these waters. One or two isolated
h Montana grayling, vacant waters being
the planting in the high isolated basins
e strains of trout which are rapidly be-
waters. Such an example is the drainage
no other spring spawning fish except the
Roaring Lake should be planted. It is
the lakes lacking favorable spawning con-
ocked and in such cases care should be
e the original stock. An example of this
e where the Yellowstone cutthroats are
ted from possible mixing with the native

series of lakes should be adapted to the
believed that continued efforts should be
king.
cked salmon in several of the high lakes
test will be as to whether or not they

will reproduce naturally. In such lakes the landlocked salmon are living up to their reputation for gameness, all the local fishermen who have had experience with them readily conceding them to be more game than any other species here. Conditions favor a bright coloring and fly fishing lasts throughout the summer.

Now that the stocking program for the higher lakes is well under way, more attention needs to be given to fish food conditions. As a general condition, there is a very considerable excess of minute or plankton forms compared with the larger insect or crustacean life. Such a condition often results in a rapid growth of young fish with a decided falling off of growth and condition in the larger fish and slow recovery after spawning. In one or two places, such as Alice, Toxaway or Imogene Lakes planting of the silverside shiner should be continued and if possible several thousand instead of several hundred should be used. At Imogene Lake the planting could well be done in a small vacant lake a short distance above, and if successful there would be a natural drift which would eventually stock Imogene Lake. Planting in the lower Twin Lake above Alice Lake could be done under similar conditions. Experiments in establishing aquatic vegetation and its accompanying life are also desirable, but need be neither elaborate nor expensive. Some of the vegetation and accompanying life from the Champion Lakes could be planted in some of the lakes on the west side of the valley.

The situation in regard to the lower lakes is much less satisfactory than with the higher waters. In this case there seems to be an abundant food supply, but rather insufficient results from stocking work. Two factors which in my opinion may influence the results, lie in the small size of the plants compared with the water involved, and the other that the principal inlets have been heavily fished each season and many of the fish planted the previous year taken by fishermen. This is particularly true with regard to the inlet to Alturas Lake and the Fishhook Creek inlet to Big Redfish Lake.

It seems a very essential feature of the program that the inlets be protected as nursery streams. Such protection may be given under a proclamation of the State Game Warden. It seems futile in an attempt to build up a brood stock, to allow the fish to end in a fry pan the year after they are planted. An abundance of stream fishing fully as good or better is available in other streams and the Salmon River so that there is no particular necessity for allowing fishing in the lake inlets.

In view of the increasing tourist use of the section and the large area of water involved, large plantings are recommended as being essential to adequate results in the lower waters; they are all accessible to fishermen and only benefit will result. A planting of at least 150,000 fish a season should be a fair test although several times this number could be well placed here.

There is comparatively slight demand for eastern brook over the State in general and this field offers an opportunity to place to advantage any number of these fish available from the Hayspur hatchery. They would be less inclined to migrate than some of the other species and much will be accomplished if any kind of trout fishing can be developed here. If a drift-out does take place, it could readily be determined where this species was used.

It is very desirable to establish the landlocked salmon in the lower lakes as well as the upper ones. Small plantings in these waters have been made each year beginning with 1921 and this should be a test of the possibilities here without expecting additional shipments of eggs. If a local spawn supply can be developed then additional, and probably greatly enlarged plantings, could be made. No matter how desirable the fish may be, continued importations of eggs cannot be expected in view of the inadequate supply of spawn. Spawning fish should appear within the next two or three seasons and this is believed to be of sufficient importance to justify the installation of a simple trap in the inlet to Alturas Lake about the middle of September. This could be placed not far above the lake and visited frequently through the fall. The presence of thickets of young lodgepole pine along the stream would make the construction of a trap a simple and inexpensive matter. The water at that season is low and floods infrequent. If sufficient fish appeared to justify it spawn takers could come from the Hayspur Hatchery 60 miles away. Present trail construction plans will make acccessible both Toxaway and Imogene Lakes. At Toxaway Lake landlocked salmon have already spawned and some should spawn this year at Imogene Lake. If the season permitted, spawn taking would be feasible at either place but transportation would be much more difficult than from the lower lakes. Even specific information on the spawning of these fish in the higher lakes would be well worth periodic trips there until snowfall made them impractical.

Mr. Tom Williams, who owns a ranch in the valley, is anxious to assist in the fish work in any way, and has offered to care for eggs placed in hatching troughs at a suitable spring near his house. This would provide for the establishment of an eyeing station and might provide means to make this section eventually self-supporting.

It is understood that Mr. Keil, the Idaho Fish Commissioner, has retained about 10,000 landlocked salmon over winter at the Hayspur hatchery. The bulk of these are intended for planting in Payette Lake where he hopes to develop a local spawn supply and which has received plantings of these fish during the years 1921 to 1924, inclusive. There is a small lake now vacant of fish on a branch of Prairie Creek about 2 hours drive from the Hayspur hatchery, which has no outlet, which could be stocked with a few hundred of these fish and held entirely for hatchery production.

Although there is a great abundance of minnows in the lower lakes as well as whitfish and little redfish in the deep waters, it is believed that the introduction of the fresh water smelt would increase the growth and production of trout there. The chief obstacle to such planting has been the short hatching period and consequent difficulty in shipping long distances. The development of airplane mail service might offer a possible means of transportation, since a package could be delivered between New York and Salt Lake City in 24 hours so that it could be carried from the spawn taking field to the planting waters in from 4 to 6 days. It might, therefore, be possible to make a shipment successfully from Massachusetts or New York points, but it would be preferable to have stock from some of the small fresh water races.

Biological Studies.

The most needed and most essential part of the entire program at this time would be the inauguration of systematic biologic studies of the waters of this locality. Such studies could not only be the basis of future plans but would place on record valuable scientific information. A large number of vacant waters have been stocked and although the results have already become apparent, sufficient time has not elapsed to affect the ecology of the life forms in these waters. The whole section presents a wide variety of problems, many of which will find their counterpart in various other parts of the district. In this place they are, however, of greater importance and variety and information gained here could be applied in many other places. The line of investigation would be a general survy and classification of the waters and

UPPER INLET TO REDFISH LAKE. PLA
WITH LANDLOCKED S

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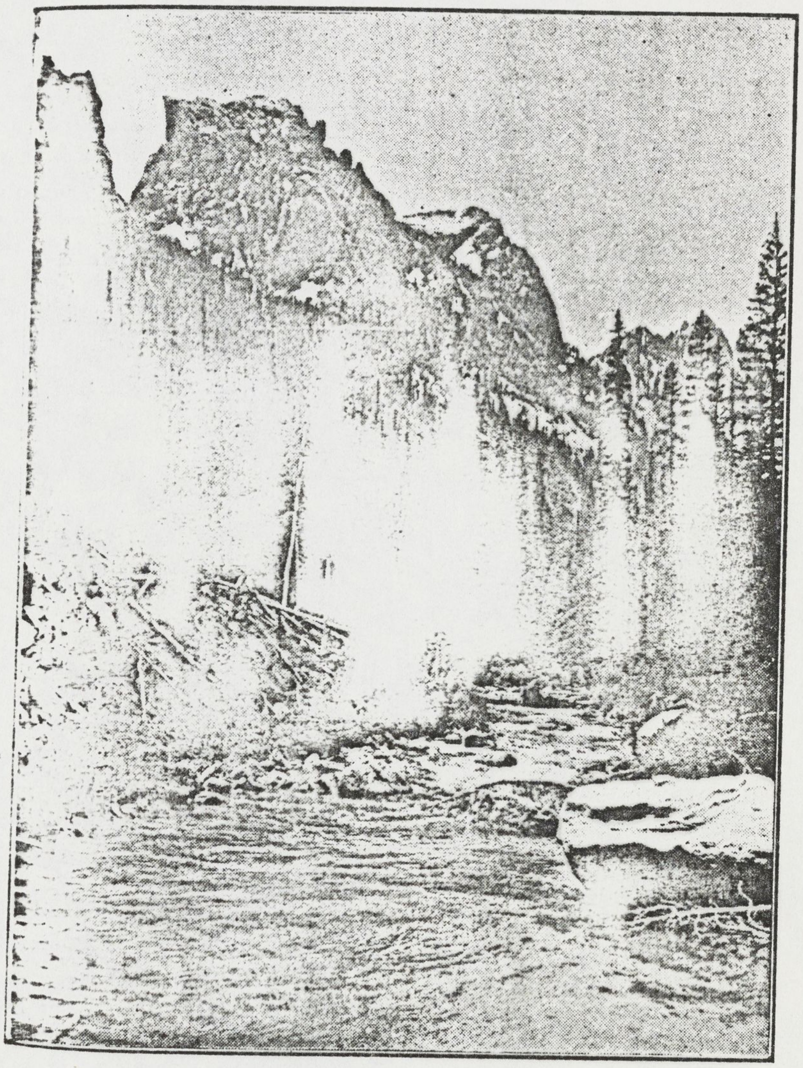

UPPER INLET TO REDFISH LAKE. PLANTED IN 1923 AND 1924 WITH LANDLOCKED SALMON problems followed by a detailed study of a sufficient number in each type to give the information upon which could be based a definite plan for the management of the water resources. We find such scientific studies essential for the preparation of adequate plans of management of our timber, grazing and game resources and I believe the conditions here justify the building of a plan of administering the water resources in this section on a detailed study and knowledge of the situation.

Such action might well be carried out cooperatively between the State, the Bureau of Fisheries and the Forest Service. If the Bureau of Fisheries could furnish a man capable of such a study as that made of the Rangeley Lakes and Sunapee Lake by Dr. Kendall or of Lake George by Dr. Needham and others, it is very probable that the State and Forest Service could cover the necessary expenses and offer other substantial assistance.

Summary of Recommendations.

Additional plantings of the remaining vacant lakes and streams to be accomplished gradually and provision made for Montana grayling, native cutthroat, steelhead and California golden trout. Silverside shiners should be planted in increased numbers in Alice, Toxaway, and Imogene Lakes.

Experimental planting of aquatic vegetation and fish foods should be done in both the higher and lower elevation lakes.

The lower waters should receive greatly increased plantings and a considerable proportion of these of eastern brook, to a total of at least 150,000 per year.

In order to take advantage of any spawning of the landlocked salmon, periodic patrol should be made during the fall and a trap installed in the Alturas Lake inlet.

That a few hundred of the landlocked salmon now on hand be planted in the landlocked lake on Prairie Creek and protected as a future spawn supply.

If any promise of a spawn take developes, a temporary eyeing station be established at the Tom Williams ranch.

That the feasibility of a shipment of eyed eggs of the freshwater smelt by ariplane mail to Salt Lake and from there by auto, a two days' trip to the planting waters, be considered.

Of greater importance than any other action, the undertaking of a biological study in connection with the possible fish production as a basis for a definite plan of management of the water resources of this section, through the cooperation of the Bureau of Fisheries, the State and Forest Service.

Work in 1926.

During this season a pack trip was made with the State Fish Commissioner, W. M. Keil, through the high lakes section, a short pack trip taken with fish for planting and several days spent in assistance in handling fish from the hatchery for the lower waters. Considerable valuable information was obtained while on other work.

Observations in 1926.

At Hell Roaring Lake there is a great abundance of the native steelhead or rainbow. These are apparently in sufficiently large numbers to cause slow growth and to retard development. A minnow which is quite abundant here was found to be a longnose dace, probably the same Rhinichthys reported by Dr. Evermann from Perkins

Lake. The presence of this little fish in
other minnows common in the general
esting.
At Imogene Lake the native steelh
ing Lake in 1923 have increased won
many small fish and the inlet was abu
present year's hatch and yearlings.
thrived, but may not have made as goo
Lake. One taken here which weighed a
planted in 1923 since it would appare
There are still several small lakes in t
stocked.
Vernon Lake, on the head of the So
was visited. This was planted last yea
evidence of their presence was seen.
Lake, stocked last year with landlocke
gave no positive evidence of favorable r
lakes yet to be stocked on a branch of
head of the river and east of Benedict (
A brief examination at Toxaway L
some eastern brook trout from natural
about two pounds each. Landlocked sal
no small ones from natural spawning w
No careful examination of the upp
evidence of attempted spawning by the
seen around the outlet. The clearing of
clogging it would improve the possibilit
This outlet flows a distance of about 75
Lake. The upper Twin Lake has furnish
ing this season.
At Alice Lake there is abundant ev
rainbow trout with which it has been
planted also some landlocked salmon an
direct evidence was obtained. It was r
might have been the Sunapee trout wer
Although no personal visit was ma
Redfish Lake, stocked in 1925, fish taken
both rainbow and eastern brook and s
inches long. During the latter part of th
taken were eastern brooks. Since these l
for planting and fishing, but lack natu
probably be desirable to continue stocki
waters. It was the intention to plant s
there during the fall of 1926.
Reports from the Champion Lakes i
of the trout there and at upper Cham
crease of both rainbow and eastern broo
ural increase at lower Champion and th
The outlet of the upper Champion and
into which it flows, was reported to co
probable that if these stay there over
snow slides customarily strike this sma
of the main lake flows.
At Washington Lake it was reported
rainbow trout. Since there are a numbe
below this lake now practically vacant c
bow trout should eventually stock this w
Nowhere were any results observed
side shiners. It is my belief that cond

study of a sufficient number in each
upon which could be based a definite
water resources. We find such scien-
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to retard development. A minnow
s found to be a longnose dace, prob-
rted by Dr. Evermann from Perkins

Lake. The presence of this little fish in a high elevation lake, where other minnows common in the general region do not occur, is interesting.

At Imogene Lake the native steelhead planted from Hell Roaring Lake in 1923 have increased wonderfully. The outlet contained many small fish and the inlet was abundantly stocked with both the present year's hatch and yearlings. The landlocked salmon have thrived, but may not have made as good growth as those in Toxaway Lake. One taken here which weighed about 2½ pounds was probably planted in 1923 since it would apparently have spawned this year. There are still several small lakes in this drainage which should be stocked.

Vernon Lake, on the head of the South Fork of the Payette River was visited. This was planted last year with Sunapee trout but no evidence of their presence was seen. Casual observations at Edna Lake, stocked last year with landlocked salmon and steelhead trout, gave no positive evidence of favorable results. There are two excellent lakes yet to be stocked on a branch of this stream west of the main head of the river and east of Benedict Creek.

A brief examination at Toxaway Lake indicated the presence of some eastern brook trout from natural spawning which now weigh about two pounds each. Landlocked salmon are still in evidence but no small ones from natural spawning were observed.

No careful examination of the upper Twin Lake was made but evidence of attempted spawning by the landlocked salmon there was seen around the outlet. The clearing of the outlet of heavy drift now clogging it would improve the possibilities of a successful spawning. This outlet flows a distance of about 75 feet to enter the lower Twin Lake. The upper Twin Lake has furnished some excellent salmon fishing this season.

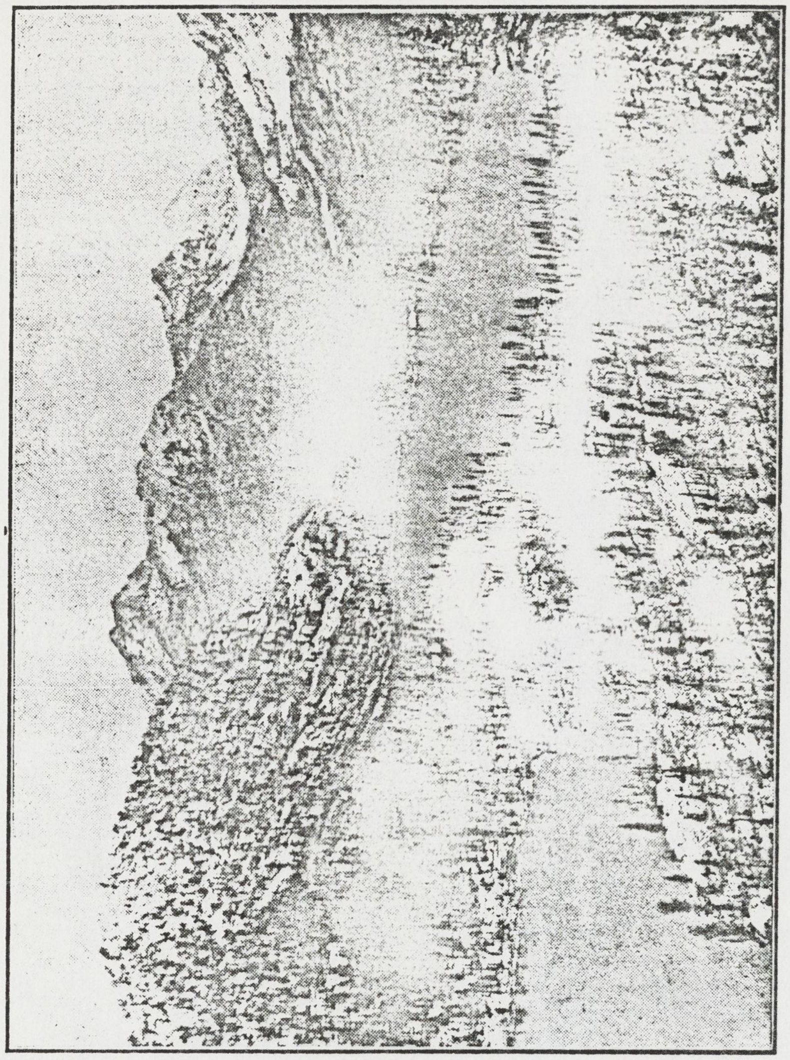
At Alice Lake there is abundant evidence of the survival of the rainbow trout with which it has been planted. In 1925 there were planted also some landlocked salmon and Sunapee trout of which no direct evidence was obtained. It was reported that some fish which might have been the Sunapee trout were taken here.

Although no personal visit was made to the Bench Lakes, near Redfish Lake, stocked in 1925, fish taken there were seen. These were both rainbow and eastern brook and some of them were nearly 14 inches long. During the latter part of the summer practically all those taken were eastern brooks. Since these lakes are quite accessible both for planting and fishing, but lack natural spawning facilities, it will probably be desirable to continue stocking and use them as growing waters. It was the intention to plant several thousand rainbow trout there during the fall of 1926.

Reports from the Champion Lakes indicated the continued growth of the trout there and at upper Champion an abundant natural increase of both rainbow and eastern brooks. There seems to be no natural increase at lower Champion and this may need periodic stocking. The outlet of the upper Champion and a small lake without outlet into which it flows, was reported to contain many small trout. It is probable that if these stay there over winter they will be lost, since snow slides customarily strike this small lake into which the outlet of the main lake flows.

At Washington Lake it was reported that there were many small rainbow trout. Since there are a number of miles of excellent stream below this lake now practically vacant owing to a high fall, the rainbow trout should eventually stock this water.

Nowhere were any results observed from the plantings of silverside shiners. It is my belief that conditions in these high elevation



VERNON AND EDNA LAKES. HEADWATERS OF SOUTH FORK OF PAYETTE RIVER. PLANTED WITH SUNAPEE TROUT AND LANDLOCKED SALMON IN 1925

lakes are unsuited to this fish. Confi
in their absence from Hell Roaring Lak
a small black sucker occur in addition

Results at Lower Lakes.

No particular evidence of results of
in lake fishing was obtained. Eastern
Fishhook Creek inlet to Redfish Lake.
abundant evidence of results from ra
these of several pounds weight being
weighing slightly over 6 pounds was t
short distance below its junction with

During the first week in August b
Fishhook Creek for spawning. It is be
in this inlet should be delayed until aft
the stream, or better yet, a rack placed

On September 25 whitefish were o
to Redfish Lake. This continued while
days. These fish enter the inlets in la
spawning principally in early evening a
the lake about 8 o'clock in the evening.
inlets at least up to midnight. Owing t
to ascend the upper inlet but a few hu
not prevented by rough water from asc
let for some distance, they do not go
the lake. During late September, consid
fish, bearing the conspicuous parr ma
the shores of the lake.

Food Conditions.

At most of the upper lakes the tr
forms of crustacean and insect life. An
observed in these high lakes, particularl
a large red diaptomus, probably diapto
were found in trout stomachs and they
in both shallows and over deep waters.

Continued observations confirm fo
there is in these high lakes a great
aquatic life, there is a lack of larger
under conditions there where the rock
water soft and without abundant aquat
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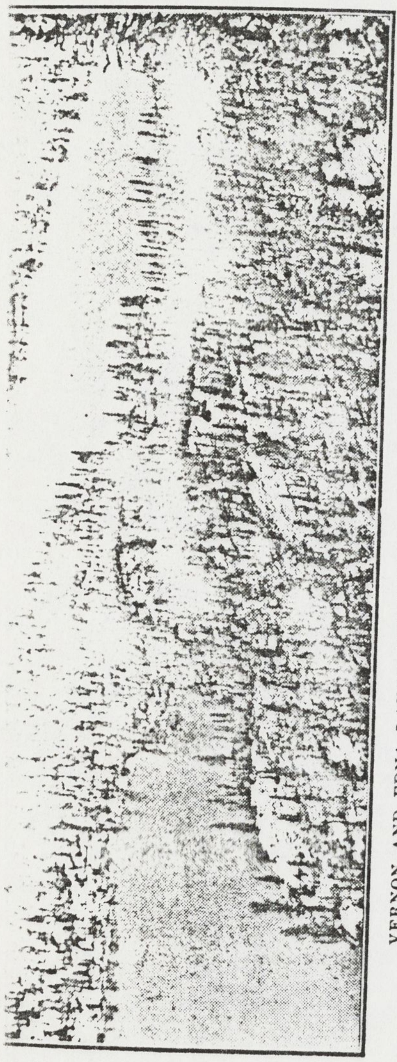
turn the plankton into a larger form sui
sible that the longnose dace would ans
it would thrive in these high waters, b
occurs principally in the shallows and
ently under logs, etc., so that it is not

SAWTOOTH PLANTIN

Waters Planted
Alturas Lake Inlet
Pettit Lake Inlet
Big Redfish Lake Inlets
Valley Creek
Frenchman, Smiley and Beaver Creeks
High Lakes



VERNON AND EDNA LAKES, HEADWATERS OF SOUTH FORK OF PAYETTE RIVER. PLANTED WITH SUNAPEE TROUT AND LANDLOCKED SALMON IN 19[illegible]

lakes are unsuited to this fish. Confirmation of this belief is found in their absence from Hell Roaring Lake, but where longnose dace and a small black sucker occur in addition to the trout.

Results at Lower Lakes.

No particular evidence of results of the stocking at the lower lakes in lake fishing was obtained. Eastern brook trout were seen in the Fishhook Creek inlet to Redfish Lake. In the Salmon River there is abundant evidence of results from rainbow trout planting, some of these of several pounds weight being taken. One landlocked salmon weighing slightly over 6 pounds was taken from the Salmon River a short distance below its junction with the outlet of Redfish Lake.

During the first week in August bull trout were observed entering Fishhook Creek for spawning. It is believed that planting operations in this inlet should be delayed until after these spawning fish had left the stream, or better yet, a rack placed to prevent their ascending it.

On September 25 whitefish were observed running in both inlets to Redfish Lake. This continued while I was there, a period of eight days. These fish enter the inlets in large numbers in late afternoon, spawning principally in early evening and beginning to drop back to the lake about 8 o'clock in the evening. Some few, however, enter the inlets at least up to midnight. Owing to rough water, they are unable to ascend the upper inlet but a few hundred yards. Although they are not prevented by rough water from ascending the Fishhook Creek inlet for some distance, they do not go over a quarter of a mile from the lake. During late September, considerable schools of young whitefish, bearing the conspicuous parr markings, were observed around the shores of the lake.

Food Conditions.

At most of the upper lakes the trout were living on very small forms of crustacean and insect life. Among the most abundant form observed in these high lakes, particularly in the granite formation, is a large red diaptomus, probably diaptomus shoshoni. Masses of these were found in trout stomachs and they were observed well distributed in both shallows and over deep waters.

Continued observations confirm former conclusions that, while there is in these high lakes a great abundance of small forms of aquatic life, there is a lack of larger forms. This is to be expected under conditions there where the rock formation is hard granite, the water soft and without abundant aquatic vegetation, and elevation so high that the mean temperature of the water is very low. Such a condition results in excellent growth of the young fish but a definite checking after the first year. Conditions of fish growth would be materially improved by the addition of some form of life which would turn the plankton into a larger form suitable for trout food. It is possible that the longnose dace would answer the purpose and probably it would thrive in these high waters, but it does not run in schools, occurs principally in the shallows and has a habit of hiding persistently under logs, etc., so that it is not easily accessible to trout.

SAWTOOTH PLANTINGS IN 1926

Waters Planted	Eastern Brook	Rainbow	L. L. Salmon
Alturas Lake Inlet	17,600		2,700
Pettit Lake Inlet	5,000	5,000	
Big Redfish Lake Inlets	7,200		
Valley Creek		3,600	
Frenchman, Smiley and Beaver Creeks	3,000		
High Lakes	2,400		2,000
	35,400	8,600	4,700

Planting at High Lakes.

An exceedingly difficult trip over the divide from the Hell Roaring drainage to some lakes at the extreme head of the upper inlet to Redfish Lake was made to plant these waters with landlocked salmon. No other trout should be planted in these waters and a brood stock here should result in stocking the main Redfish Lake through the ten miles of excellent connecting stream.

Waters now vacant of fish life on the inlet to Alturas Lake were planted to landlocked salmon. It was the intention to plant some of these in the upper inlet to Redfish Lake previously planted only to these fish.

Several high lakes, now vacant of fish, were to be planted by Ranger R. E. Allen from the Stanley Ranger Station.

Rearing Ponds.

Several sites for rearing ponds were examined and some very suitable ones seen at the T. H. Williams ranch. The development of a series of these ponds would permit the transportation of the fish from the hatchery when the fish were small and their holding for planting until better able to take care of themeslves. These ponds could be stocked to their normal carrying capacity, which would be considerable owing to a heavy growth of vegetation and abundant insect and crustacean life, or supplemental feed could be provided by using suckers and squawfish from nearby waters.

At the Stanley Ranger Station on the Challis National Forest, Ranger Allen constructed an excellent holding pond by installing screens in a spring slough supplemented by water from the river. He contemplates the addition of another such pond. Being in the station grounds, such ponds can be easily looked after and permit the receipt of fish from the hatchery at any time for distribution whenever most convenient.

Stocking at Lower Lakes.

Owing to the fact that the planting at the lower lakes was uncompleted at the time I left, figures of the total number planted are not available. These were in excess of any other previous year and would total about 75,000. The fish planted were largely rainbow trout but included also some landlocked salmon for vacant waters, some exceptionally large and well grown eastern brooks and some blackspotted trout. Plantings were made in all the lake inlets as well as in various streams and the Salmon River. Some of the eastern brooks from 4-6 inches long were planted along the lake shores wherever adequate protection was offered. There are several thousand landlocked salmon being held at the Hayspur hatchery to be planted as yearlings in the lower lakes.

In this planting work the State Game Department delivered the fish and did most of the planting at the lower lakes. Local residents and Forest officials assisted in the distribution and Mr. James McDonald furnished a truck for two trips to the hatchery.

Recommendations for Future Work.

It is certain that road development and contemplated building of hotels and resorts will increase the use of this section materially within the next few years. Its value as a recreation ground will largely depend upon the fishing obtainable and the responsibility to develop this to its utmost is a definite one. A sound plan for such development should have as a basis biological studies and such are badly

needed. However, until such can be
larger and more extensive plantings
available.

The problem for the high lakes
supply. Owing to the soft water it se
in establishing aquatic vegetation an
seem to be the introduction of some
microscopic life and in turn become
is the most desirable form available
them should be carefully investigated.

The same condition exists to a
lakes and it seems the smelt would
well as increasing the chances for the
salmon.

A few of the high lakes still vac
as well as those where a natural inc
these should be stocked with the nati
already mentioned are west of Edna
several in the head of the Middle For
Mt. These later could be reached on
Toxaway Lake. There are also several
Alpine Creek. The main range north
accurately mapped and there are pro
to fish life.

Until a biological study gives the
lower lakes about the only recourse
ter stock. To make such plantings m
are desirable where fish brought fro
small and easily transported may be
adequate size for release.

The presence here of the landlock
desirable to study carefully the resu
spawning fish being located will increa
dation for racking the Alturas Lake in

The importance of the introducti
justify careful consideration to determi
making a shipment of eggs either b
This matter will be considered furthe
Fish Commissioner and the Bureau of

Summary of Recommendations.

Continued study of conditions and
logical study.

Pending such a study, the developm
for a program of extensive plantings in

The gradual completing of the st
using in several cases the native blac

A close watch for the presence of
lakes, particularly of spawning fish.

A full investigation of the possibil
the eggs of the small form of freshwa

over the divide from the Hell Roar-
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ion on the Challis National Forest,
xcellent holding pond by installing
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planting at the lower lakes was un-
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salmon for vacant waters, some ex-
eastern brooks and some blackspotted
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pment and contemplated building of
use of this section materially with-
as a recreation ground will largely
le and the responsibility to develop
ne. A sound plan for such develop-
logical studies and such are badly

needed. However, until such can be undertaken, the only recourse is larger and more extensive plantings based on the best information available.

The problem for the high lakes is largely one of balancing food supply. Owing to the soft water it seems impractical to obtain results in establishing aquatic vegetation and the most feasible action would seem to be the introduction of some form which could live on the microscopic life and in turn become trout food. The freshwater smelt is the most desirable form available and the possibility of obtaining them should be carefully investigated.

The same condition exists to a considerable extent at the lower lakes and it seems the smelt would be a valuable addition there as well as increasing the chances for the establishment of the landlocked salmon.

A few of the high lakes still vacant may be stocked each season as well as those where a natural increase is not resulting. Several of these should be stocked with the native redsides if possible. Two lakes already mentioned are west of Edna and Vernon Lakes and there are several in the head of the Middle Fork of Boise River near Snowyside Mt. These later could be reached on foot and perhaps by horses from Toxaway Lake. There are also several fine small lakes on the head of Alpine Creek. The main range north of Redfish Lake has never been accurately mapped and there are probably several lakes here suitable to fish life.

Until a biological study gives the desired information regarding the lower lakes about the only recourse is in increased plantings of better stock. To make such plantings most economically, holding ponds are desirable where fish brought from the hatchery when they are small and easily transported may be retained until they have reached adequate size for release.

The presence here of the landlocked salmon makes it particularly desirable to study carefully the results obtained. The possibility of spawning fish being located will increase each year and the recommendation for racking the Alturas Lake inlet will be repeated.

The importance of the introduction of the smelt is sufficient to justify careful consideration to determine if there is any possibility of making a shipment of eggs either by air mail or through express. This matter will be considered further in cooperation with the State Fish Commissioner and the Bureau of Fisheries.

Summary of Recommendations.

Continued study of conditions and development of a detailed biological study.

Pending such a study, the development of holding ponds and plans for a program of extensive plantings in the lower waters.

The gradual completing of the stocking of high, vacant waters, using in several cases the native blackspotted stock.

A close watch for the presence of landlocked salmon in the lower lakes, particularly of spawning fish.

A full investigation of the possibility of obtaining a shipment of the eggs of the small form of freshwater smelt.

S. B. LOCKE,
District Forest Inspector.

S. B. LOCKE, 1929 U.S. Bureau F. Rpt.

SUNAPEE GOLDEN TROUT, WHITE TROUT, SAIBLING (*Salvelinus aureolus*)

Occuring only in a few waters in New Hampshire, Vermont, and one lake in Maine, this beautiful charr is not widely known. It is a lake fish and retires to deep water in summer. It can be identified by the lack of spotting or marking on back and fins, small head, golden sheen on scales, and under fins with white but lacking black. The maximum weights are from 6 to 8 pounds, but the average is much less. Spawning takes place in shoals in lakes in late fall. It has been planted in several high lakes in the Sawtooth Mountains and has been taken by trolling in Alice Lake. In these cold lakes it may

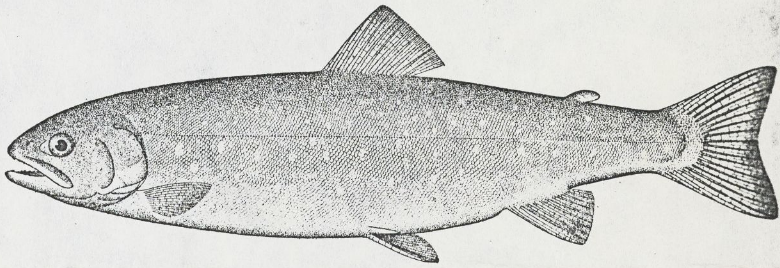

FIGURE 19.—Golden trout of Sunapee Lake, *Salvelinus aureolus*

probably be found away from deep water, but the usual method of taking it is with bait in from 40 to 100 feet of water. In such waters it may not grow to large size but probably will be brilliantly colored. Wherever found it is held in high esteem by anglers on account of its beauty of form and color, game qualities, and excellency for the table.

AFTERWORD

Forest fires destroy game birds and their nests, kill fish and wild animals, but of more serious consequences is the destruction of the opportunity for fish and game to survive and multiply. This loss is replenished only after the slow process of adequate replacement of food and shelter.

Fish and game survive no longer than their natural habitat. Every forest fire is dangerous to them. For your sport's sake—

BE CAREFUL WITH FIRE!

Green forests mean good fishing and good hunting. As many as 100 forest fires in a single year have been caused by recreation seekers on the national forests of the Intermountain District.

DON'T CAUSE ONE!

○

Taxonomic Characters of the Eastern North America Chars (*Salvelinus* and *Cristivomer*)[1,2]

By Vadim D. Vladykov
Department of Fisheries, Quebec, P.Q.

ABSTRACT

For the present study about 300 specimens have been examined. These specimens belong to the six species of chars: *C. namaycush*, *S. fontinalis*, *S. aureolus*, *S. oquassa*, *S. marstoni*, and *S. alpinus*. Among meristic characters, the number of pyloric caeca was found to be very important. Body proportions and meristic characters, such as fin rays and vertebrae, are inadequate to properly describe a species. On the other hand, the skull bones, different teeth, and skeleton of the tail are sufficient in themselves to define a species. The pearl organs were found only in *C. namaycush* of both sexes. The taxonomic relation between species is as follows: *C. namaycush* belongs to a distinct genus; *S. fontinalis* represents a subgenus *Baione*; while the remaining chars are grouped in a subgenus *Salvelinus*.

CONTENTS

INTRODUCTION

Apparently no paper dealing with critical reviews of taxonomic characters in chars as a group, has ever been published. Even such well-known works as that by Jordan and Evermann (1896, pp. 483–516) or Kendall (1914) do not contain sufficient information. The aim of the present paper is to close up to some extent the lacunae in our knowledge.

[1]Received for publication April 15, 1954.

[2]Contribution No. 42, Department of Fisheries, Quebec, P.Q. Presented at a meeting of the Canadian Committee for Freshwater Fisheries Research at Ottawa, January 3, 1954.

J. Fish. Res. Bd. Canada, 11(6), 1954.
Printed in Canada.

From Eastern North A
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data of these discoveries are
1. *Cristivomer namayc*
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Pennant (1792, p. 191). C
1953; etc.) include *C. na*
(Kendall, 1919; Stokell, 195
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trout, it has many features
present paper.
2. *Salvelinus fontinalis*
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different forms.
4. *Salvelinus oquassa.*
Moosemegantic Lake, one
5. *Salvelinus aureolus.*
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and Maine.
6. *Salvelinus marston*
known today as "red Q
Quebec.

Published data and
identification of Salmonid

Embryonic Stages

Although in taxonomi
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R. Behnke

R. J. B.

The Life History and Ecology of the Sunapee Trout, *Salvelinus aureolus* (Bean)

by

Arthur E. Newell

Management and Research Division

of the

New Hampshire Fish and Game Department

1958

Preface

This paper was origionally prepared for the Handbook of Biological Sciences of the National Academy of Sciences. Since efforts to publish the Handbook were recently abandoned, it was decided to have the paper mimeographed for distribution among those who might be interested in the Sunapee Trout, Salvelinus aureolus (Bean). This species is also known locally as the golden or white trout.

The material presented herein by no means represents active research on the part of the author, but is a compendium of all known information relative to the life history and ecology of this species.

Sunapee trout *Salvelinus aureolus*

Taxonomy

First described by Bean (1887). Later by Jordan and Evermann (1896), Kendall (1913), Vladykov and Corson (1953), and Vladykov (1954).

Geographical distribution

Originally described from Sunapee Lake, New Hampshire, it is also known to have occurred in Big Dan Hole Pond, New Hampshire; Averill Lake, Vermont; and Flood Pond, Maine; Warfel (1939). It has been unsuccessfully introduced into several other New Hampshire Waters. A population of this species was once established in the Third Connecticut Lake but a few years later, they disappeared when lake trout were introduced. There is an occasional Sunapee trout caught in Cornor Pond, Ossipee where it exists in competition with brook trout. It is not known whether or not the Sunapee trout ever reproduced naturally in either of these ponds. One reclaimed pond, Tewksbury Pond, shows some promise of sustaining golden trout populations.

Local distribution

Habitats: During the summer months in Sunapee Lake, this species resides in depths of from 60 to 90 or 100 feet, where the temperature is in the neighborhood of 50° F. or less. In the spring it occurs in shallow water along the shores. About mid-October it may be found on a reef near the entrance to Sunapee Harbor where it spawns. Kendall (1913) and Warfel (1939).

Associations: Smelt, lake trout, brook trout, rainbow trout, landlocked salmon, smallmouth black bass. Chinook salmon were also and associate when they inhabited Sunapee Lake.

Water temperature range: Unknown except that it apparently prefers temperatures of 50° F. or less.

Salinity range: Found only in fresh water.

Depth range (daily, seasonal, etc.): The summer range is known to be in water 50 to 100 feet deep. During the spring, fall, and winter months when the water is cool this species may be found in the shallow waters.

Factors influencing local distribution: Apparently the Sunapee trout cannot withstand competion of lake trout as it has in all cases virtually disappeared once lake trout have become established in any appreciable numbers.

It is interesting to note that there is some disagreement among authorities in regard to the description and coloration of this species. Chase (personal commuication in 1957*) feels that much of this disagreement could be due to considerable hybridization occurring before recent authorities examined the "Sunapee Trout". He feels that the specimens described by Vladykov and Corson (1953) and Vladykov (1954) were not true Sunapee trout but rather they were hybrids between Sunapee trout and lake trout and/or brook trout.

First Description

The following is taken from Vladykov and Corson (1953).

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*It is interesting to note that Chase who is a concrete engineer rather than a trained ichtyologist has for a number of years (27) gathered notes on the Sunapee trout as a hoby.

"By its deeply forked tail, the high number of vertebrae (more than 60 including the urostyle) and the presence of the well-developed hyoid teeth,* the Sunapee Trout is easily distinguished from the Speckled Trout (S. fontinalis). Moreover, our Char is lacking in the red spot encircled in blue, in the distinct vermiculations on the back and tail, and in the black strip on the lower fins, so typical of Speckled Trout.

"As Red Quebec Trout is closely related to Blueback (S. oquassa), the distinctive characters between the last mentioned species and Sunapee Trout is applicable also in the case of (S. marstoni). The adult Sunapee Trout can be separated from adults of Blueback Trout by its large size and wide mouth with the upper jaw (maxillary) extending well beyond the eye. In the young of Sunapee Trout there are several dark blotches, on the back, while in (S. oquassa), the back is uniform steel-blue. Moreover, the Blueback has a somewhat higher number (9-10) of branched rays in the anal fin, against the usual number of 8 in Sunapee. On the other hand, the number of branchiostegal rays is somewhat higher (usually 11 or 12) in Sunapee, than in either (S. marstoni), or (S. oquassa), both of which have typically 9 or 10 rays.

"As the area of distribution of the Artic Char,** several species of which have been described from the Canadian Arctic by Richardson (1836) and Gunther (1877), is farther North than that of the Sunapee, there is not a chance of meeting both of them in the same locality. Furthermore, the

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*"In the present author's experience, there never has been observed in American Waters a Speckled Trout with hyoid teeth. Kendall (1914, p 77) mentioned a few exceptional cases from Labrador and New England. However, Stokell (1940) observed very often the presence of hyoid teeth in (S. fontinalis) acclimatized in New Zealand.

**"For the distinction between anadromous and landlock forms found in the Hudson Bay area see Vladykov (1933, pp. 19-20)."

relationship between American Arctic Char and those described from northern Europe and Asia is not very clear and requires a thorough study. For instance, Berg (1948, pp. 269-295) for the Russian Arctic alone, in addition to (S. alpinus). recognizes ten other species of Chars, However, in the opinion of the present authors the characters, upon which many specific and subspecific names have been based, are obscure.

"It should be noted that the Sunapee Trout can be distinguished from any American species of Salvelinus by the skeleton of its tail. A detailed description of tail structures of different species of Chars will be given in a separate paper.

"By its general appearance, large size (up to 12 pounds), its habits and habitat the Sunapee Trout is closest to Lake Trout (Cristivomer namaycush). In addition to some differences in certain meristic characters, the principal separation of these two species lies in the number of pyloric caeca and skeleton. The Lake Trout has more than 100 caeca,* while the Sunapee has typically less than 50. The skeleton of the caudal fin is very characteristic for each species. Among the bones of the head, the most striking difference is in the pattern of teeth on the tongue (supralingual). In Sunapee Trout, two rows of teeth form a triangle with a wide base at the posterior end of the tongue. This disposition of the teeth is rather typical of Salmonidae in general. In Lake Trout, as has recently been established by the senior author, the teeth are in two parallel rows on the tongue.

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*According to Stokell (1951, p. 214) the Lake Trout, acclimatized in New Zealand retain the equally high number of caeca, the number of which varies there from 128 to 164.

"To understand better the Sunapee hybrids which can be found in nature, the junior author succeeded to obtain healthy hybrids crossing Sunapee Trout with either Lake Trout or Speckled Trout. The study of these hybrids will be a subject for a separate communication.

"In conclusion, the authors wish to stress that (S. aureolus), is a distinct species...."

Coloration: Vladykov (1954) describes the coloration of this species as follows:

"Small orange spots on sides; small whitish spots on sides and back; vermiculations on back. In the spawning males the sides are carmine or orange; lower fins carmine with a broad white margin; lower surface of head is blackish; tips of both jaws are carmine; roof of mouth is blackish."

"The brilliant red bellies of breeding males render this species among the most beautiful of the native fishes. The females during the spawning season are similarly but less brightly colored. In non-breeding adults the red is replaced by a golden yellow, and the yellow is hardly evident in immature fish." Warfel (1939).

Chase (unpublished) disagrees with other present authorities mainly on the following points:

Second Description

"...deeply forked tail..." Chase feels that the caudal fin should be described as moderately forked. The longest ray being 2 to 2 1/2 times the length of the shortest ray.

"By...the presence of the well developed hyoid teeth, the Sunapee trout is easily distinguished from the Speckled

Trout (S. fontinalis)."

Chase has made the following comments on this characteristic:

"There is much confusion in the use of the words 'hyoid' and 'hyoid bone' where basi-branchials is ment. Kendall (1914) 'The bones (basi-branchials) have been incorrectly called 'hyoids' or 'hyoid bones' in most fish literature. Comparative anatomists name no hyoid bones but describe a hyoid arch which is composed of a number of bones bearing different names. The teeth referred to are not on the bones composing this arch'. Kendall refers continually to 'teeth on basi-branchials' Owen, Stannius, Huxley and Parker do not use the term 'hyoid' or 'hyoid bone', according to Synonmic Table in Gunther (1880). Jordan and Evermann (1902) 'Hyoid, pertaining to the tongue'. If the above quotation is meant to imply that the Speckled Trout has no teeth on the tongue, the implication is contrary to my observations, having found that the largest teeth possessed by the Speckled Trout are on the tongue. However, if the word 'hyoid' is used where the word basi-branchial is meant, I can agree that the Speckled Trout has no teeth on the basi-branchials. I have found at times, that the Sunapee Trout has teeth on the basi-branchials, but they are not 'well-developed' Jordan and Evermann (1902) quote Quackenbos 'broad row of teeth on the hyoid' Kendall (1914) Addendum quote Regan (1914) Re: S. alpinus group 'Basi-branchial teeth uniserial' Foot note '...basi-branchial teeth not invariably uniserial, vary from elongate patches to few or no teeth at all. This seems to be individual variation rather than a group or specific character 'Raney (1948) Re: Teeth, Hyoid 'present but relatively few, patch smaller and many fewer developed teeth' (than in C. namaycush or hybrid). Chase (unpublished) 'teeth on basi-branchials may be present or lacking'".

"...lacking... black strip on the lower fins..." Chase describes the anal as "sometimes having a black band posterior to white margin". He also uses the following quotation from Kendall (1914) "pectoral having blackish line behind the white edge".

"...its large size..." Chase not only rejects size as a character for purposes of identification but also quotes Kendall (1914) as rejecting size as a means of distinguishing S. aureolus from S. oquassa".

"...and wide mouth..." Chase quotes Jordan and Evermann (1902) and Quackenbos as describing the species as follows "diminutive aristocratic mouth".

"...upper jaw (maxillary) extending well beyond eye". Chase reports the maxillary as "reaching to posterior margin of eye". He also makes the following quotations to support his belief: Bean (1887) "The maxilla reaches past the middle, but not to the end of the eye". Jordan and Evermann (1902) "maxillary usually not reaching beyond eye".

"...branched rays in anal fin...8..." Chase reports 7 to 10 branched rays, usually 8 or 9, Bean (1887) -8, Kendall (1914) -9 and Everhart (1950) -8.

"branchiostegal rays...(usually 11 or 12) in Sunapee..." Chase reports that the branchiostegals vary from 9 right and 8 left to 12 right and 11 left. He comments that the number of branchiostegal rays of S. aureolus vary within such wide limits as to appear to be of little value in separating S. aureolus from S. oquassa and S. marstoni.

"...large size (up to 12 pounds)..." Chase's comments regarding the size of Sunapee trout are as follows: "Kendall (1914) 'It is said to attain a weight of 10 pounds in Sunapee Lake, but a fish of 5 or 6 pounds in recent years is a monster' and Col. Elliot Hodge...wrote to Dr. Quackenbos: "I can show you an acre of these trout, hundreds of which will weigh from 3 to 8 pounds each". It has been stated many times and is probably true that size of a fish cannot be considered a specific character. However, any supposed Sunapee Trout weighing over 5 lbs. should be looked upon with suspision. From 1948 through 1950 I carefully examined 11 fish weighing from 6 lbs. to 10 lbs. 5 ozs. They were called by most of their captors, Sunapee Trout. Everyone had characters of both C. namaycush and S. aureolus. The largest undoubted Sunapee Trout, that I have ever seen was caught in Sunapee Lake in May, 1948 and weighed 4 1/2 lbs. and it is doubtful if more than a very few weigh more than 5 lbs."

Coloration: "small whitish spots on sides and back; vermiculations on back" Chase comments on this characteristic as follows: Bean (1887) "Sides, both above and below lateral line with numerous orange spots, fading out to whitish...No mottlings anywhere" Jordan and Evermann (1902) quote Quackenbos "the absence of mottling on the sea green back" and "the gaudy dyes of the milter are tempered in the spawner to a dead— lustre cadmium cream or olive chrome with opal spots" Kendall (1914) "Head, color of body, becoming lighter on side, with metallic lustre of yellow and light green and mottlings". Everhart (1950) "No wavy, olive worm-like lines on back". Chase (unpublished) "Body dark olive green dorsally, without spots or vermiculations, becoming purplish approaching the lateral line and extending nearly to level of pectoral changing to lighter and becoming orange which increases in brilliance ventrally" "pale orange spots... without aureola on sides above and below lateral line". Vladykov (1954) seems to contradict Vladykov and Corson (1953) in regard to vermiculations.

"In the spawning males the sides are carmine or orange"

Bean (1887) and Kendall (1914) do not use the words "carmine" or "red".

"lower fins carmine with a broad white margin" Chase comments on this as follows: "Bean (1887) 'Ventrals orange, with broad white margin' Kendall (1914) ' pectoral having blackish line behind the white edge' Chase (unpublished) 'pectoral ventral and anal fins and ventral appendage orange... pectorals and anal sometimes having a black band posterior to white margin".

"In non-breeding adults the red is replaced by a golden yellow" Chase comments on this characteristic as follows: "Bean (1887) 'Sides silvery white... There are about ten parr marks on the sides, and numerous small, roundish, white spots'. The length of specimen used by Bean was 6.4 inches to the caudal base. Chase (unpublished) 'Body dark olive green dorsally... As lateral line is approached side becomes silvery to below the lateral line, then gives way to pure white and continues ventrally. For a short distance above and below lateral line numerous nearly perfectly round very pale orange spots without aureola smaller than pupil'. It is this very conspicuous white belly that gives S. aureolus the local name of White Trout at Sunapee Lake. During the sport fishing (non-breeding) season it was noticeable that some Sunapee Trout did not show any spots until they had been out of the water two to four hours, when very small, very pale orange spots would appear.

"the yellow is hardly evident in immature fish" Warfel (1939) The same applies to immature fish as to non-breeding adults. See above paragraph.

Food and Feeding: Unknown except that smelt are believed to be an important item in diet of larger specimens.

Growth: Longevity (average and/or maximum observed)

Average life expectancy seems to be about 6+ years while the maximum observed age is 8+ years.

Length and weight at various ages:

Age	2+	3+	4+	5+	6+	7+	8+
Average total length (in.)	7.85	11.3	14.02	19.98	26.60	30	31.5
Sample	22	61	43	13	6	1	1
Average weight (oz.)	2.0	8.13	16.5	43.1	86.5	130	128
Sample	3	51	40	8	6	1	1

Factors influencing growth: Presence or absence of smelt are the only known factors. Although temperatures probably also influence growth as with other salmonoids little is known of the exact temperature requirements of this species.

Reproduction

Age of maturity: Some males in second year but most in third. Chase (unpublished) states that some males spawn in third year but most in fourth. Some females in third year but most in fourth.

Sex ratio: The true sex ratio of this species is unknown but Chase (unpublished) states "The ratio of males to females for a given season varied from 1.3 to 1.0 in 1927 to 3.27 to 1.0 in 1936. This includes the years beginning with 1926 through 1941 at spawning run only."

Sexual recognition: Males are much more vividly colored than females at spawning time. During the remainder of the year sexes are similar.

Courtship and breeding: These habits are very similar to those of the lake trout.

Spawning site: The only known spawning site in Sunapee Lake is an off-shore reef composed of rubble, boulders and some gravel. They have been known to spawn in water from a few inches to 20 feet deep. In Dan Hole Pond they have been known to spawn on a boulder and rubble strewn point known as Strawberry Point.

Spawning period: Usually between October 20 and November 20.

Water Temperature: Usually about 50° F.

Fecundity: Although there has been no study conducted concerning the fecundity of this species, records were maintained for the period 1951-1955 as to the number of female fish stripped and the number of eggs taken. These figures showed an average of 938 eggs/female for 237 fish. Unfortunately no length or weight measurements were taken but it is known that the size of these fish varied from about one pound to ten pounds.

Chase (unpublished) reports the average number of eggs per female for the following years: 1933, 689; 1935, 606; 1936, 533; 1937, 533; 1938, 722; 1939, 568; 1940, 684; 1941, 490. Total number of females stripped, 1,135.

Kendall (1913) reports that "A female is stated to average about 1,200 ova to the pound of fish".

Quackenbos (1896) also reports that "It is one of the most prolific of our salmonoids, the female averaging 1,200 eggs to the pound, and casting spawn when only two ounces in weight".

Post-spawning behavior, care of eggs and young: There is no parental care of either eggs or young as both parents leave the area soon after eggs are deposited.

Survival of young: Unknown.

Fate of breeders: No abnormal mortality after breeding. Adults live to reproduce several times.

Artificial propagation: Eggs may be stripped from female fish and artificially fertilized as with other members of the genus Salvelinus.

Embryonic development

Vladykov (1954) lists the following egg and sac fry sizes for S. aureolus:

Eyed eggs diameter (mm) 4.7; weight (g.) 0.050
Sac fry - total length (mm) 17.1; weight (g) 0.055

The approximate period of incubation in water temperature of 44° F. is 80 days.

Genetics

Hybridization: It is known that this species can be artificially hybridized with both the brook trout and lake trout. In Sunapee Lake, hybridization with the brook trout is not believed to be of any consequence as the two species spawn in widely separated locations. The lake trout, however, spawn on the same reef as do the Sunapee trout and at approximately the same time. (Hybridization with the latter species is believed by some to be quite common.) Reports indicate that in time past a shortage of mature males was common. It is reported that at such times male brook trout and lake trout, were occasionally used to fertilize the Sunapee trout eggs. On one occasion male Sunapee trout were used to fertilize landlocked salmon eggs. No further information concerning the fate of these hybrids is available.

Induced spawning: No information available.

Behavior

The only known information concerning the behavior of this species is the fact that it moves into shallow water on one reef (in Sunapee Lake) to spawn between October 20 and November 20. In the spring it may be found in the shallow water presumably feeding on the smelt and during the warmer months it is found in the deepest parts of the lake down to 90-100 feet. Little is known of the winter habitat except that an occasional specimen has been caught by pickerel fishermen indicating that they are to be found in shallow water at that time of year.

Populations

The population of this species has diminished to the point where it is nearly extinct in Sunapee Lake.

An attempt has been made to preserve this rare and beautiful species by reclaiming Tewksbury Pond, Grafton, New Hampshire and stocking it with Sunapee trout. It is hoped that through this experiment it will be possible to perpetuate the Sunapee trout. It remains to be seen, however, if this experiment will be successful.

Diseases

Unknown.

Predators and competitors

The lake trout and landlocked salmon are known to be competitors and probably even predators on the young. Lake trout, Sunapee trout, smallmouth black bass, brown bullhead, common sunfish, yellow perch, rainbow trout and suckers are all believed to feed upon loose eggs which have not settled in crevices between the rocks. Although no study has been conducted both loons and mergansers have been observed in the locality during the Sunapee trout spawning season. It is believed that these birds may feed on some of the smaller trout.

Relations to man

Values: In the past this species was an attraction to those anglers who were seeking to catch new and different species of trout. Today however, this value has for all practical purposes, ceased to exist.

Fisheries:

Methods: There are two methods of angling for this species. One consists of deep water trolling much as is done for lake trout while the other consists of hand lining with cut bait in deep water. Frequently while using this method the angler will have a second line baited with a live smelt. Usually still fishing sites are marked with a buoy and periodically chummed with cut bait.

Yields: The yield of Sunapee trout fishing is at the present time practically nil.

Conservation: For years the major conservation procedure has been to capture the trout at spawning time, strip them, and raise the offspring to fingerling or yearling size in a hatchery before returning them to Sunapee Lake. This procedure was believed to be more satisfactory than allowing the fish to reproduce naturally. They have also been protected with a twelve inch length limit and a two fish per day bag limit. In spite of these measures the Sunapee trout has virtually disappeared from its native habitat.

The following is taken from Vladykov (1954)

TABLE I Details of the Caudal Fin Skelton in Salmonidae

CHARACTER	S. fontinalis	C. namaycush	S. aureolus	S. marstoni	S. alpinus	Salmo salar
C.b.p.* shape	fan-like broad & short	crescent-like narrow & long	fan-like broad & long	crescent-like narrow & long	crescent-like narrow & long	fan-like broad & long
Number of centra covered by c.b.p.	3	4	3 1/2	3 1/2	3 1/2	3 3/4
Number of expanded haemal processes	6	5	7	6	5	4
Number of expanded neural processes	5	6	7	4	5	4
Shape of second uroneural	narrow & short	broad triangle	broad triangle	narrow & long	narrow & short	very narrow & long (sabre-like)
Second uroneural / First uroneural	1/2	3/4	1/2	4/5	1/2	3/4

*C.b.p.--caudal bony plate

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The decrease in numbers of bluebacks was synchronous with the increase in number of salmon, and coincidently the last blueback was taken in the year following the largest catch of salmon up to that date. There can be no doubt that the blueback entered largely into the food of the salmon, especially prior to the introduction of the smelt, living as it did in the deep waters to which salmon resorted during the summer months, and the introduction of smelt and later legislative action were both too late to save it. On the other hand, the large size of the few surviving bluebacks was very probably due to the smelt. Although the food of the blueback was formerly the smaller animal life of the lake, probably largely consisting of entomostracans, insect larvæ, and worms, the smelt afforded it an abundant additional supply of food, owing to the fact that while almost in a larval stage young smelts frequent deep water after leaving their birthplaces in the brooks. (See Tables VII, VIII, p. 593.)

WHITE TROUT (*Salvelinus aureolus*).

To the fish culturists this char is known as the golden trout or aureolus and sometimes as Sunapee trout or Sunapee Lake trout, these latter names due to its having been first discovered in Sunapee Lake, N. H. The name golden trout is derived from its

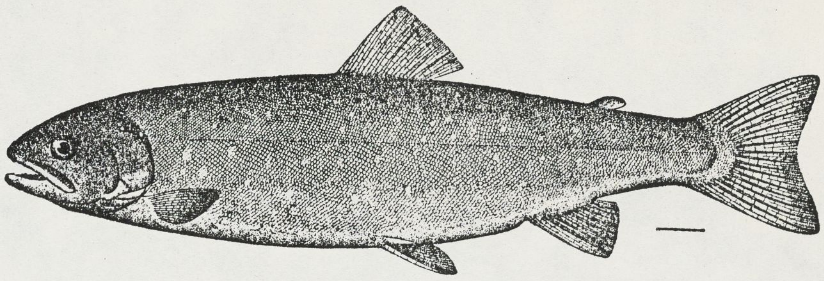

FIG. 18.—White trout (*Salvelinus aureolus*).

technical name, *aureolus*, which was given to it in reference to the golden sheen of the living fish in the water. The local name, white trout, is more appropriate to its summer coloration, when the brilliant orange of the males is absent. It is known as white trout at Sunapee Lake and is thus distinguished from the common trout (*Salvelinus fontinalis*) which at Sunapee Lake is called native trout, due to the popular impression, doubtless, that the white trout was introduced.

About the time the fish was discovered at Sunapee Lake there was an animated discussion regarding its identity, some claiming that it was the result of introduction of the saibling (*Salvelinus alpinus*) from Europe. But it was pretty conclusively shown that none of the lot brought from Europe was placed in Sunapee Lake or into any waters from which it could gain access to that lake. Others claimed, with more basis for their claim, that it was a blueback which there is no doubt was introduced about five years before the so-called discovery of this fish, which had attained a large size owing to favorable conditions in the lake. Some individuals were not wanting who averred that they had known the fish for many years prior to the introduction of bluebacks. The blueback advocates would have rejoiced had they foreseen that this fish in its native waters would reach the size of an average Sunapee white trout, as the main argument against the blueback theory was the small size attained by the blueback. As a matter of

In a letter to Fred Mather, published in Forest & Stream, May 5, 1887

Commissioner Stanley wrote that bluebacks were very hardy fish and nearly as tenacious of life as the eel or bullhead. He had frequently seen them alive in the morning after they had lain all night on shore.

J. P. Whitney (Forest & Stream, Oct 1896, and Report of Inland Fish & Game Commission of Maine for 1896)

- blue bk much more tenacious of life than brook - after lying out an hour resuscitated them by putting them in water again.
- a number would live in a barrel of water without change for weeks

Merrill found them juicy, tender, delicate but preferred brook

Whitney (Forest & Stream Nov. 24 1900) said that for food purp. it was inferior to brook & to his taste it was soft & muddy.

- Blueback char

1) smaller mouth than fontinalis
2) Differences in structure of opercular apparatus
3) fins more developed
4) smaller adipose
5) scales somewhat larger

"When first taken out of the water, it is impossible to imagine anything more beautiful and more delicate in the way of coloration in fishes of the temperate zone."

Girard

fact, the small size was the chief difference. Dr. Bean mentioned one additional character; that is, the difference in the gill rakers, which in the blueback were always straight and in the Sunapee fish usually more or less curled and distorted. But this character does not obtain in the small Sunapee fish, and in the large blueback they are frequently as distorted as in the Sunapee fish. Indeed, it is a difficult matter to distinguish a large blueback from a white trout after it has been preserved in alcohol for some time, or even when fresh. The writer, some years ago, suggested that the differences were ontogenetic. Such differences as exist as shown by the specimens examined are shown in the description of the blueback.

The white trout has been found also in Dan Hole Pond, N. H., Floods Pond, Me., and Averill Pond, Vt. Its discovery in these ponds precludes the necessity of going to Europe to account for its presence in Sunapee Lake. It seems unaccountable to many that the fish could have existed always in Sunapee, fished so much as it was, and not be detected before. As a matter of fact, this is not an unknown phenomenon. While the ponds subsequently found to contain white trout were perhaps not fished quite as generally as Sunapee, yet they were probably fished as much by the inhabitants about its shores, who, doubtless, did not distinguish the fish from the common trout, at least only to the extent of considering it a peculiar form of the latter.

The white trout is a rich and savory fish for the table, being fat in season, to which its flavor is apparently due. It is caught mainly by plug fishing with live bait and cut bait and very occasionally with worms. Not infrequently it is taken by trolling, but with a deep line as a rule. The best bait seems to be the smelt, which was introduced into Sunapee Lake and has always existed in Floods Pond. It is sought by still or plug fishing in about 80 or 90 feet of water in Sunapee Lake and about 30 to 40 feet in Floods Pond (in June). The fact that it is a deep-water species would in part account for its being seldom observed by the old inhabitants.

It is said to attain a weight of 10 pounds in Sunapee Lake, but a fish of 5 or 6 pounds in recent years is a monster.

In 1903[a] or 1904 white trout were planted in Mooselucmaguntic Lake, according to the report of the United States Bureau of Fisheries for that year. It is not known with what results; and probably should one or more be caught it would be considered another big blueback, to go on record as that species caught on a hook, which is a rare occurrence. It is unfortunate that the fish was planted in these waters, for it will confuse the history of the blueback, which, if not quite extinct, might increase in numbers again, and new reports of bluebacks will not be positive.

BROOK TROUT (*Salvelinus fontinalis*).

This char is everywhere in Maine the trout or brook trout par excellence. It is naturally peculiar to eastern North America. In Canada it occurs in many streams and tributary waters of the Great Lakes and St. Lawrence River and the Gulf of St. Lawrence as far north at least as Hamilton Inlet on the Labrador coast. Its northern limit is not definitely known, but it is restricted on the east by the Atlantic Ocean and it extends southward in the Alleghenies to headwaters of streams in the mountains of Georgia and Alabama.

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[a] There is an element of doubt attached to this record. The late State Commissioner Brackett wrote in reply to an inquiry regarding it, made about the time the record was first published, that he had no knowledge of any such plant. It is possible that it was an error in copying localities when the report was prepared.

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Discovery of the New England Sunapee Trout in Idaho

VI BODY

A Introduction

1. Purpose – summarize and organize info concerning the Sunapee of Sawtooth Lake
2. Qualities of Sunapee
3. Present Distribution

B. Methods +

1. Fish sampling
2. Procedure
3. mat'ls

C. Background

1. History of trout in New England
2. Blueback + Red.
3. Stocking history in Idaho

D. Life History

1. Feeding
2. Spawning
3. interaction with ~~brook trout + other sp.~~ other F. sp.
4. Hybrid evidence

E. RESULTS DATA COMPARISON

1. Comparison of experimental char. w/ Known characteristic
   a. Vertabrae Data
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2. ~~Comparison of Lakes in which Sunapee survived~~ Lake characteristics
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F. DISCUSSION

G Conclusion

A Intro

1. Purpose
2. Background
   a. Sunapee
   b. Blueback
   c. stocking history
3. Life History
   a. Feeding
   b. Spawning
   c. interaction w/ brook ~~trout~~ other F. sp.
   d. Hybrid evidence
4. Qualitres of Sunapee
5. mgt. characteristics
6. Present Distribution

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Vol. 94, No. 4, October 1965
pp. 393–397

Life History of the Blueback Trout (Arctic char, *Salvelinus alpinus* (Linnaeus)), in Maine

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Reproductive Biology and Early Life History of the Sunapee Trout of Floods Pond, Maine[1]

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ABSTRACT

The Sunapee trout (*Salvelinus alpinus* L.) of Floods Pond, Maine, spawned in October and November when surface water temperatures dropped below 15 C. There was little sexual dimorphism. Sexes were present on the spawning area in nearly equal numbers. Spawning occurred at night in shallow (30 to 100 cm) water near the lake shore. Eggs were scattered over a boulder-strewn bottom. There was neither redd construction nor site preparation. The eggs were relatively large (5.08 mm) and negatively buoyant. Females had approximately 2,500 eggs/kg of body weight. In hatchery tests eggs eyed in about 50 days and hatched in 79–122 days at mean water temperatures ranging from 11.0–3.0 C. The yolk sac was absorbed in about two weeks and the fry immediately moved to deep water. All males were mature at age III+ and all females were mature at age IV+. Many females spawned in alternate years while most males spawned every year.

The distribution of the Sunapee trout, *Salvelinus alpinus* L., is currently limited to only Floods Pond, Maine, and, as part of a project designed to increase its range, a study of its reproduction was undertaken.

Since the Sunapee trout is considered to be one of several varieties of landlocked arctic charr (*S. alpinus* L.) (McPhail 1961), it was assumed that its spawning habits would be similar to those of the arctic charr reported elsewhere. In Sweden and England the landlocked charr are reported to spawn in lakes and in streams (Frost 1963). Fabricius (1950) reported that a lake charr which spawned in 1 to 2 m of water in the littoral zone, continued to spawn on the same site but also spawned in flowing water in the inlets after damming submerged the original site to a depth of 10 m. Frost also reported three populations of charr in Lake Windermere separated only by spawning time and place. Sunapee trout in Sunapee Lake, New Hampshire, were reported to have spawned on Mile Rock, a rocky shoal area in the middle of the lake (Quackenbos 1887; Kendall 1913). Quackenbos (1893) also referred to a correspondence with Dr. Haines of Ellsworth, Maine, which stated that the Sunapee trout of Floods Pond spawned "in only one place—on a fine gravel beach in three feet of water."

[1] Contribution from Dingell-Johnson Project F-26-R, Maine.

The Sunapee trout of Sunapee Lake spawned in water ranging from 15 cm to 1.7 m deep (Newell 1958). The shoal was so situated that the wind, no matter from which direction, caused a current to flow over and through the gravel (Kendall 1914). These fish were reported to spawn similarly to lake trout (*Salvelinus namaycush*), with no redd preparation, several males attending each female, and no covering of the eggs or parental care of eggs or young. E. K. Balon, Guelph University (personal communication) reported that one female Sunapee trout placed in a stream tank with one male Sunapee trout attempted "to dig redds in the manner of a brook trout." These characteristics differ from those reported by Fabricius (1953) and Fabricius and Gustafson (1954) who described charr as spawning similarly to salmon with the female constructing a redd in walnut-sized gravel, spawning with one male, and then covering the eggs by digging an adjacent egg pit. However, the spawning characteristics for Sunapee trout reported by Kendall (1914) are similar to some situations found in Swedish charr as reported by Gonczi (1971). Gonczi (1972) also found that some landlocked charr "ploughed" the bottom in preparation for egg deposition while others in the same lake, hid their eggs in rock interspaces with no bottom preparation.

Spawning takes place in the fall of the year from September in the northern parts of the

TABLE 1.—*Fish species associated with the Sunapee trout in Floods Pond, Maine. Names are from Bailey et al. (1970).*

Common name	Scientific name
American eel	*Anguilla rostrata* (Lesueur)
Atlantic salmon	*Salmo salar* (Linnaeus)
Banded killifish	*Fundulus diaphanus* (Lesueur)
Brook trout	*Salvelinus fontinalis* (Mitchill)
Common shiner	*Notropis cornutus* (Mitchill)
Creek chub	*Semotilus atromaculatus* (Mitchill)
Fallfish	*Semotilus corporalis* (Mitchill)
Golden shiner	*Notemigonus crysoleucas* (Mitchill)
Pumpkinseed	*Lepomis gibbosus* (Linnaeus)
Rainbow smelt	*Osmerus mordax* (Mitchill)
Threespine stickleback	*Gasterosteus aculestus* Linnaeus
White sucker	*Catostomus commersoni* (Lacépède)

arctic charr range to November in the southern areas (Scott and Crossman 1973). In all reported cases concerning arctic charr, spawning takes place during the day at temperatures near 4 C. Kendall (1914) stated that Sunapee trout in Sunapee Lake spawned at night when temperatures at the beginning of the spawning season were from 4 C to 8 C and dropping to 0.5 C at the end of the season. The spawning season in Sunapee Lake usually began in early to mid-October and lasted about one month.

Saunders and Power (1969) reported that Matamek Lake charr had an average of 1,793 eggs for female fish averaging 398 mm and 720 gm (2,490 eggs/kg). Kendall (1914) reported that Sunapee Lake Sunapee trout had 2,640 eggs/kg of female body weight. Kendall (1912) stated that according to Hubbard "white" trout had 2,807 eggs/kg and that spawning took place on a reef in Sunapee Lake when water temperature was from 4–7 C. The eggs hatched in 102 days at water temperatures ranging from 0.5–7 C. Kendall (1911) reported that DeRocher stripped 290 "white" trout to obtain 370,000 eggs, or 1,276 eggs/fish. These may have been the same fish mentioned by Hubbard if the fish averaged half a kilogram in size.

STUDY AREA

Floods Pond is an oligotrophic lake on the Union River drainage in south-central Maine (lat. 44°45′N; long. 68°30′W). It is at an elevation of 91 m, is 265 hectares in area, with a maximum depth of 44.8 m and a mean depth of 12.5 m. Floods Pond is managed for Sunapee trout, but water levels are controlled by the Bangor Water District which utilizes the pond as the major water source for the city of Bangor and neighboring towns. There is one dwelling on the shore and the surrounding land area is wooded and hilly. Bedrock is primarily weathered granite. Associated fish species are listed in Table 1.

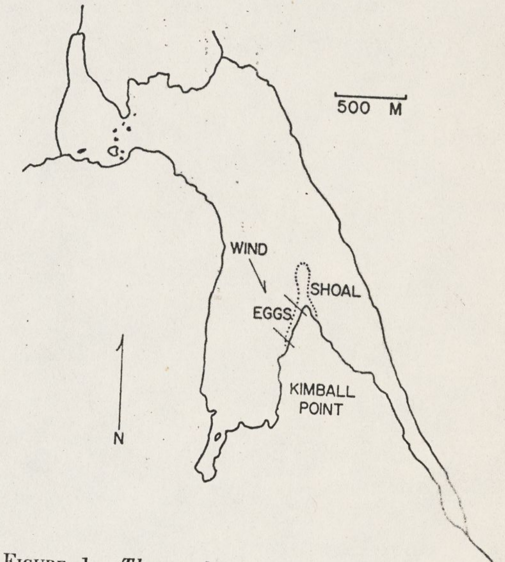

FIGURE 1.—*The study area: Floods Pond, Maine, including location of egg deposition, limits of shoal area, and prevailing wind direction.*

METHODS

Kimball Point, the suspected spawning area in Floods Pond (Fig. 1), was examined with the use of scuba gear during the spawning season for the presence of eggs and spawning fish. Diving was done during daylight hours and after dark with the use of clear and red underwater lights. Scuba gear was also used while examining other areas within Floods Pond for the presence of suitable spawning sites.

Spawning fish were trap-netted each fall for six years using Oneida Lake trap nets. Scale samples for age determination, lengths, weights, and sex information were taken for all fish. A portion of the spawning run was tagged each year. Mature fish were stripped

TABLE 2.—*Dates and temperatures for the spawning season at Floods Pond over a 6-year period.*

Year	Beginning date	Beginning temperature (C)	Ending date	Ending temperature (C)
1969	14 October	14	17 November	8
1970	21 October	13	17 November	7
1971	26 October	12.5	22 November	6.5
1972	23 October	10	2 November	9
1973	15 October	12.5	4 November	9
1974	16 October	12	30 October	9
1975	16 October	13	14 November	9

and released at Floods Pond, and the fertilized eggs were transported to the Cobb Fish-Culture Station for hatching and rearing. Small mesh (15 mm stretch) gill nets and a small otter trawl were used to locate 0+ and I+ Sunapee trout in Floods Pond. Fecundity studies were made by an actual count of eggs from mature fish. Egg size was calculated using the method reported by Von Bayer (1950). Egg development was monitored by hatchery personnel and a recording thermometer kept a record of hatchery water temperatures.

RESULTS AND DISCUSSION

Spawning

The spawning season in Floods Pond began when the water surface temperature dropped below 15 C. Over a 6-year period, the spawning season began between 14 October to 26 October and continued until 2 November to 22 November. The water temperature during this 6-year period ranged between 10 C and 14 C at the beginning of spawning and between 6.5 C and 9 C at the end, with a mean temperature for the whole period of 10.0 C. The length of the spawning season varied from 9 to 26 days with a mean of 19 days (Table 2), and seemed to be greatly influenced by water temperature and weather—the colder and more stormy the weather, the shorter the spawning season. Spawning activity was first noted in the evening about one hour after dark and continued for varying lengths of time depending on the number of fish present, the weather, and the degree of maturity of the fish. Sometimes the spawning activity lasted for only about one hour, while at other times there was some activity most of the night. Based on 1,170 fish taken over the 6-year

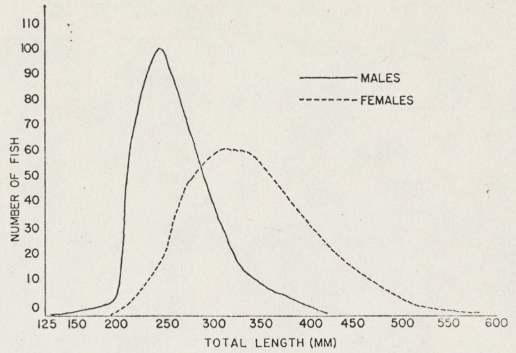

FIGURE 2.—*Total length distribution of 1,329 sexually mature Sunapee trout taken on the spawning run over a 6-year period at Floods Pond, Maine.*

period, males and females were represented on the spawning grounds in nearly equal numbers (M:F::1:1.05). Little sexual dimorphism was evident between male and female Sunapee trout. During the non-spawning season both sexes were quite similar: silvery-white with light colored spots. During the breeding season most of the larger fish of both sexes became highly colored with different degrees of yellow, red, and orange hues and cream-colored spots. Smaller fish, even though sexually mature, had rather dull coloration by comparison. Both sexes exhibited varying degrees of coloration, and the only dimorphism shown was in body shape; females were quite rounded when full of ova and males were slightly compressed laterally. Occasionally, a highly developed, larger male Sunapee showed a small kype, but this feature was uncommon. The mature female Sunapee trout was usually much larger than the mature male. Total length of spawning males averaged 250 mm and females 300 mm over a 6-year period. Only one male exceeded 400 mm in total length, while females commonly exceeded 400 mm and a few exceeded 500 mm (Fig. 2).

The spawning site was composed of broken rock scattered over the edge of the dropoff on the northwest side of Kimball Point (Fig. 1). The substrate consisted of granite rocks ranging in size from 10 cm up to boulders 1 m or more in diameter. This site is similar to many other bottom types in Floods Pond, but the combination of bottom type, exposure to the

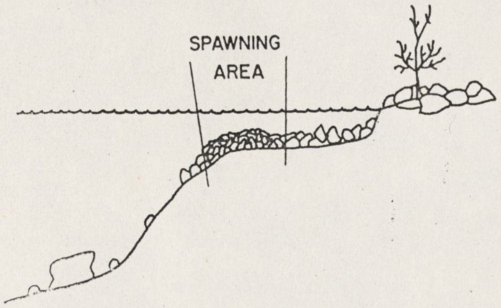

FIGURE 3.—*Schematic drawing of area on Kimball Point, Floods Pond, where Sunapee trout eggs were found.*

wind, and homing tendencies apparently made this the only suitable spawning location in the pond. During spawning, observations using scuba gear showed that there was no redd construction or other site preparation. The fish moved into very shallow water (30–100 cm) and swam close to the bottom. Two to four males accompanied each female, swimming just behind and off to the side as she moved over the spawning site. The fish moved to the spawning site in the early evening and deposited their eggs over the substrate where the stones were at least three layers deep (Fig. 3). The actual deposition of eggs was not observed because the fish spawned at night and were wary of underwater lights. Spawning did not take place on the nearby silt, gravel, clay, or other thinly covered areas.

Eggs and Fry

The eggs of the Sunapee trout were negatively buoyant and nonadhesive. This allowed them to settle into the crevasses in the rocky substrate. Sometimes the eggs were deposited so thickly that the ones on the bottom died from lack of aeration; large numbers of dead eggs were found in the spring after the live eggs had hatched. The eggs were pale yellow in color and varied little from 5.08 mm in diameter. Based on a three-fish sample, females contained approximately 2,600 eggs/kg of body weight (Table 3).

Five out of twenty (25%) of the fallfish (*Semotilus corporalis*) which were examined had preyed on Sunapee trout eggs. Although

TABLE 3.—*Fecundity data for three female Sunapee trout from Floods Pond, Maine.*

Fish length (mm)	Fish weight (gm)	Number of eggs per fish	Number of eggs/kg body weight
258	140	365	2,607
292	185	433	2,340
478	900	2,637	2,929

fallfish are common to abundant in the area during the spawning season, most of the eggs quickly sifted down into crevasses in the substrate out of reach of predators and it is doubtful that predation by this fish is significant. Atkinson (1931) and Green et al. (1932) have reported lake trout egg predation by the white sucker (*Catostomus commersoni* L.). Even though this fish is commonly captured along with spawning Sunapee trout none of 36 examined was found to have eaten Sunapee trout eggs. No other predator on Sunapee trout eggs was found.

Hatchery tests showed that eggs eyed-up in about 50 days at temperatures dropping from 11.0 C to 3.0 C. Total time for hatching at the same temperatures is from 79 to 122 days (Table 4 and Fig. 4). The fry absorbed the yolk sac and began feeding in about 30 days in water temperatures rising from 2.0 C to 3.5 C. At Floods Pond, the sac fry and some unhatched eggs were found at ice-out (mid-April) at water temperatures of 0.5 to 1.0 C.

TABLE 4.—*Development of Sunapee trout eggs at Cobb Hatchery, 1973–1974.*

Date eggs fertilized	Date eggs hatched[a]	Number of days for hatching	Mean temperature (C) for hatching period
16 October 1973	3 January 1974	79	6.1
17 October 1973	7 January 1974	82	5.8
18 October 1973	15 January 1974	89	5.3
25 October 1973	5 February 1974	103	4.1
28 October 1973	11 February 1974	106	3.8
29 October 1973	15 February 1974	109	3.7
2 November 1973	4 March 1974	122	3.2
4 November 1973	4 March 1974	120	3.0
7 November 1973	6 March 1974	119	3.0
Means		103	4.2

[a] These are the dates when all of the eggs in a particular lot were hatched. The eggs fertilized on 16 October 1973 began to hatch on 17 December 1973 but were not all hatched until 3 January 1974, 17 days later.

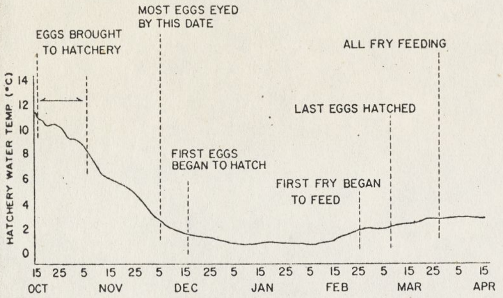

FIGURE 4.—*Sunapee trout egg and fry development at the Cobb Hatchery, West Enfield, Maine, 1973–1974.*

The sac fry remained in the gravel where they were hatched for about two weeks and then dispersed into deeper water. Fry were trawled from water depths up to 25 m within two weeks after the last fry left the spawning location.

Maturity

Male Sunapee trout in Floods Pond began to mature at age II+ and all were mature by age III+. A few precocious males may mature at I+. Females matured one year later at ages III+ and IV+. Tag and recapture data suggest that males spawned each year as did some females, but many females spawned every other year, as is common with other salmonid species (Grainger 1953). It is not known whether one male will spawn with more than one female nor whether a female spawns all of her eggs at one time. Mature males and females were captured on the spawning site and released up to 2.4 km away at the other end of Floods Pond. Many of these fish homed to Kimball Point after they were released. This homing tendency will be the subject of another paper.

ACKNOWLEDGMENTS

Numerous associates and assistants were involved with the fieldwork in this project. Among them I would especially like to thank P. S. Andrews, K. Warner, J. A. Easterbrooks, and E. E. Spear. Valuable criticism of the manuscript was offered by K. Warner, K. A. Havey, and D. A. Webster.

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SOME OBSERVATIONS, AGE, GROWTH, FOOD HABITS AND VULNERABILITY OF LARGE BROOK TROUT *(SALVELINUS FONTINALIS)* FROM FOUR CANADIAN LAKES

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Résumé

La plupart des ombles de fontaine *(Salvelinus fontinalis)* capturés de quatre lacs étaient d'une taille supérieure à 40 cm. Les individus de classes d'âge V et VI étaient abondants, et un spécimen atteignait la classe d'âge IX. Des analyses de contenus stomacaux révèlent qu'aucune nourriture spéciale ne fut capturée par ces individus de grande taille, dans les eaux du nord. Les grands brochets *(Esox lucius)* sont présents dans tous les lacs, tandis que le doré *(Stizostedion vitreum)* se rencontre dans les bassins d'eau du Québec. L'omble de fontaine est exposé à une capture facile dans les lacs où ont été faits les étiquetages ; ce fait, en plus de la taille des populations, doit être sérieusement considéré dans l'établissement d'un programme d'aménagement.

Abstract

Most specimens of brook trout *(Salvelinus fontinalis)* collected from the four lakes were over 40 cm in length. Brook trout of age V and VI were common with one fish reaching age IX. Stomach analysis did not disclose any particular food item that might account for the large size reached by brook trout in some northern waters. Northern pike *(Esox lucius)* were present in all lakes and walleye pike *(Stizostedion vitreum)* were present in the Québec waters. Large brook trout were vulnerable to angling in the lake where trout were tagged and this, plus population size, should be given careful consideration when setting management regulations.

Introduction

Few lakes consistently produce brook trout over five pounds. Sportsmen (Wulff, 1969) and biologists (LeJeune, 1964; Power, 1966) have pointed out the vulnerability to angling of populations of large brook trout but data are scanty on this point, as are explanations on why certain waters produce unusually large fish.

In 1959 Cornell University and the Department of Tourism, Province of Québec became interested in obtaining brook trout eggs from populations where specimens reached unusually large size. In connection with these operations data on species composition, growth and stomach contents were collected from three lakes in Québec and similar data, plus information on recapture of tagged trout from one lake in Labrador. Time and funds were insufficient to conduct detailed studies but the results obtained contribute to our meager knowledge of these unique populations about which almost nothing has been published.

Materials and methods

ASSINICA LAKE

Assinica Lake is located approximately 241 km east of the southern tip of James Bay (longitude 75°15′W, latitude 50°30′N) in the Province of Québec. The lake is approximately 10 000 ha in area but is very shallow, running mostly under 7 m in depth (LeJeune, 1962). Rocky islands and shoals are common. Brook trout commonly reach weights of 3 kg with some specimens running to nearly 5 kg. In the 1960 Field and Stream contest 14 of the 20 awards for brook trout came from Assinica Lake and its outlet, the Broadback River.

Trout from the lake are believed to move into the river in late summer. The river is precipitious with a rocky bottom. Impassable falls prevent fish from James Bay entering the upper portion of the Broadback River or Assinica Lake.

LAKE ALBANEL

Lake Albanel is approximately 96 km northeast of Assinica Lake (longitude 73°10′W, latitude 51°10′N) and drains into Lake Mistassini and then via the Rupert River into James Bay. A falls below Lake Albanel prevents fish from Lake Mistassini from reaching this water. The lake is approximately 26 000 ha in area and differs from Assinica Lake in that it has a much greater average depth. Depths of 12 m were common a short distance from shore.

The main inlet to Lake Albanel is the Temiscamie River. A brook trout spawning area is located approximately 128 km above the lake and it is presumed a portion of the trout from the lake spawn here. The brook trout from Lake Albanel and the Temiscamie River commonly reach 2 kg with some fish reaching 3,5 kg. The maximum size is believed less than Assinica Lake.

Large mayfly hatches (presumably Hexagenia) reportedly occur during mid-July but were not observed during the survey of July 17-22, 1965.

LAKE MISTASSINI

This is one of the largest lakes in Québec and part of the Lake Albanel system. It is located approximately four km west of Lake Albanel (longitude 73°40′W, latitude 51°10′N). Brook trout for stomach analysis were obtained from the Indians at Mistassini Post. The lake contains brook trout of 3-4 kg, although those collected ran only 0,6-2 kg.

LAKE ANNE MARIE

Lake Anne Marie (longitude 60°40′W, latitude 52°25′W) is part of the Minipi Lake system and is located approximately 95 km southwest of Goose Bay, Labrador. The lake is approximately 2 300 ha in area and is mostly shallow with rocky islands and shoals, similar to Assinica Lake. Brook trout of 2 kg are common with some occasionally reaching 3-4 kg; during late summer trout reportedly move into the outlet and inlet from the lake.

Fishing camp rules are designed to preserve fishing quality and each angler is allowed to kill one trophy brook trout. Angling is by flies only.

During July large hatches of mayflies *(Hexagenia)* occur and at this time large brook trout feed readily on the surface throughout the lake. Later in the season few trout are taken in the lake and fishing is carried on in the outlet or inlet.

DATA COLLECTION

Scales were used for age determination from all waters except Assinica Lake where otoliths were used. Annuli on scales were normally distinct through age 4 but beyond this point the possibility of error increases with age. It is doubtful, however, if misinterpretation was greater than plus or minus 1 year.

Assinica Lake and Lake Albanel were gill netted to obtain information on species composition, and gather data on brook trout populations. Lake Anne Marie was gill netted with small mesh nets to sample fish species that might be of a size suitable for brook trout forage. Seining was unsuccessful for collecting fish samples due to the rocky bottoms of all the lakes. Angling was a major method of collecting brook trout samples in Lake Anne Marie and Assinica Lake.

Trout were tagged in Lake Anne Marie. A minimum tagging size of approximately 1 kg was established to reduce possible predation by northern pike, because of the shiny hog ring jaw tag used. The tagging period extended through the angling season of June 21 to the middle of August.

Stomach samples were collected from trout taken by angling in Lake Anne Marie and from specimens collected by gill netting in Lake Mistassini and Lake Albanel.

Results

SPECIES ASSOCIATION

Northern pike are present in all four lakes and walleye pike in the three Québec waters. In Assinica Lake and Lake Albanel walleyes made up nearly 50 percent of the total catch (Table I). Brook trout made up less than 4 percent of the fish handled. Netting and angling indicated brook trout under 35 cm were scarce in all lakes and most specimens were over 40 cm. Nearly all of the small trout taken were captured in the outlets or inlets of the lakes.

Walleyes were not present in Lake Anne Marie and white suckers made up the major part of the catch in this water. Larger mesh size would undoubtedly

TABLE I

Species composition in gillnet samples from three Canadian lakes.

Species	*Québec*						*Labrador*		
	Lake Albanel [1]			*Assinica Lake* [2]			*Lake Anne Marie* [3]		
	Total no. caught	Percent total	Size range (cm)	Total no. caught	Percent total	Size range (cm)	Total no. caught	Percent total	Size range (cm)
Stizostedion vitreum	376	44	20-64	247	50	Not avail-	0	—	—
Catostomus commersoni	191	22	48-55	56	11	able	23	74	16-27
Catostomus catostomus	113	13	20-58	6	1		2	7	16-17
Coregonus clupeaformis	91	11	20-60	103	21		0	—	—
Salvelinus fontinalis	31	3	19-23	11	2		1	3	29
Prosopium cylindraceum	21	2	19-41	0	—		0	—	—
Salvelinus namaycush	14	2	45-69	0	—		0	—	—
Coregonus artedi	8	1	19-29	1	—		0	—	—
Esox lucius	8	1	55-77	73	15		2	7	16-42
Lota lota	7	1	20-80	0	—		1	3	10
Salvelinus alpinus	0	—	—	0	—		2	7	22-29

[1] 86 gillnet units,* 16-178 (mm) stretched mesh — July 1967.
[2] 153 gillnet units,* 51-102 (mm) stretched mesh — September-October 1962 (Le Jeune, 1962).
[3] 8 gillnet units,* 25-36 (mm) stretched mesh — August 1973.
* 1 gillnet unit represents 100 feet net set 24 hours.

TABLE II

Brook trout growth in four Canadian waters. Length in cm, weight in kg.

Water	*Item*	*Age in years*								
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*
Assinica Lake, PQ	Number fish	7[1]	4[1]	2	3	2	4	4		
(Aug-Sept 1962)	Length	19,8	31,0	30,7	42,7	62,7	61,2	66,0		
	Weight	,08	,26	—	—	—	—	3,80		
Lake Albanel, PQ	Number fish	2	2	6	4	12	8	2		
(Jul 1967)	Length	20,1	20,1	39,1	46,5	55,1	58,7	61,2		
	Weight	,08	,06	,65	1,02	1,55	1,80	2,08		
Lake Mistassini, PQ	Number fish	0	2	14	17	16	4			
(Jul 1967)	Length	—	36,6	44,5	49,5	53,3	57,9			
	Weight	—	,48	,91	1,24	1,45	1,74			
Lake Anne Marie, Lab.	Number fish	4	17	38	43	30	33	18	2	1
(Jul-Aug 1973-74)	Length	17,0	23,1	33,0	44,2	51,8	54,9	55,6	57,9	64,8
	Weight	—	—	,63[2]	1,27	1,78	2,10	2,46	2,50	2,61

[1] Stream habitat.
[2] Only 30 fish weighed.

have taken a larger number of fish in Lake Anne Marie and the catch is not considered representative of abundance of various species, except possibly for suckers.

Forage Species

The fine mesh gill net used in Lake Anne Marie and Lake Albanel failed to reveal any fish species in sufficient abundance to be considered important as brook trout forage. Suckers were common in both lakes but most specimens in the samples were of a size too large to be utilized by brook trout.

BROOK TROUT GROWTH

Growth rates were similar in all waters. The large size obtained by some individuals was the result of good growth at ages III to VI, rather than unusually fast growth during the early years (Table II). Trout of age VI were taken in all lakes and except for Lake Mistassini age VII was well represented. Assinica Lake produced the largest specimen with one fish at age VII reaching 71 cm in length. During two summers of observation in Lake Anne Marie no trout under age III were taken in the lake proper and it may be assumed that trout from the tributaries and outlet move into the lake as they reach a large size. Scale examination showed a wide range in size at age III and IV which would support this hypothesis.

TAG RECOVERIES

Fifty-seven trout were tagged in 1973 and the same number in 1974, in Lake Anne Marie. Fishing pressure in 1974 was light, less than 0,1 rod day per ha, yet 16 percent of the trout tagged the previous season were recaptured. In 1974 nearly all (93 percent) tagging took place during the last three weeks of the season. Although these tagged fish were available for only a short period, 14 percent were recaptured within the season.

Approximately one half of the twenty five recoveries made during the 1973-

74 season were taken in the same general area as tagged. There were 4 recoveries of fish that had traveled either to or from the inlet to outlet, a distance of approximately 10 km.

FOOD HABITS

Sixty percent of the brook trout stomachs containing food from Lake Albanel held fish remains, as did forty five percent of those from Lake Mistassini (Table III). Small ciscoes were the dominant species in the stomachs of specimens from both lakes. Insects were present in over one half of the stomachs containing food from the two Québec Lakes. Ephemeroptera was the major insect order utilized from Lake Albanel, with terrestrial Coleoptera dominant from Lake Mistassini (Table III).

None of the stomachs examined from Lake Anne Marie specimens contained fish. A variety of insects were eaten and Odonata, Diptera and Coleoptera (mainly terrestrial) dominated (Table III).

No benthic organism was abundant in the Ekman dredge (15 × 15 cm) samples taken from 18 locations in Lake Anne Marie in mid-August. Chironomid larvae were most common and were found in eleven of the samples with an average number of 6 per sample. Oligochaeta were found in 7 samples (average 4 per sample and second in occurrence). Mayflies, which hatched in large numbers in July, were taken in only 4 samples (average 1 per sample).

TABLE III

Frequency of occurrence of fish and invertebrate food in brook trout from three Canadian Lakes.

Water	*Lake Albanel*		*Lake Mistassini*		*Lake Anne Marie*	
Number fish examined	*20*		*35*		*35*	
Size range trout (cm)	*25-63*		*33-60*		*33-61*	
Food items	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
FISH						
Coregonus artedi	6	30	9	26	0	—
Percina caprodes	3	15	0	—	0	—
Stizostedion vitreum	1	5	0	—	0	—
Unidentified	4	20	7	20	0	—
Total containing fish	12	60	13	37	0	—
INVERTEBRATES						
Annelida	1	5	0	—	0	—
Coleoptera	2	10	23	66	20	57
Copepoda	0	—	0	—	1	3
Diptera	1	5	6	17	22	63
Ephemeroptera	10	50	2	6	16	46
Hemiptera	0	—	5	14	1	3
Hymenoptera	0	—	15	43	1	3
Neuroptera	0	—	0	—	14	40
Odonata	0	—	1	3	23	66
Trichoptera	3	15	2	6	2	6
Unidentified	2	10	27	77	8	23
Total containing invertebrates	12	60	26	74	35	100

Discussion

The coexistence of northern pike and brook trout is often encountered in northern waters and a departure from the species association encountered in the southern part of the brook trout range. Walleyes and brook trout are an even rarer species association in more southerly waters. The factors permitting this association of predator species and brook trout may require recruitment of trout of 12 to 14 inches from a relatively mitigated stream environment.

The trout in all waters investigated had greater longevity than is usual in the southern part of their range (Cooper, 1953; Hoover, 1939; Green, 1951). Although age determination was uncertain in some older individuals in natural populations it can be substantiated up to 9 years from known age Assinica strain brook trout naturalized in the Adirondack Mountains of northern New York State (Flick and Webster, 1971).

The food supply that produces rapid growth and large size in these northerly trout populations remains obscure. Movement from a stream to a lake environment is often reflected in improved growth but it would seem that a large forage organism (e.g. fish) would be necessary to produce the size fish involved. Obviously, data from more than 2 months of the year are required to satisfactorily investigate this aspect of life history. This information is of great importance if we are to successfully manage waters for large sized brook trout.

The tagging data from Lake Anne Marie indicates the vulnerability, of brook trout to angling and the possibility of over exploitation even with light fishing. Data on Assinica Lake strain brook trout in a New York lake also indicate high vulnerability with approximately 50 percent of the population recovered by flyfishing in 4 hours of angling on a ten ha pond (unpublished data of author). The vulnerability of brook trout to angling was also noted by Power (1966) in the Ungava area and LeJeune (1964) in Assinica Lake. The large trout in these areas apparently move out of the lake and concentrate in the fast water during the summer where they are readily taken by angling. The combination of high vulnerability and apparent low population densities of large brook trout in some northern waters are critical factors to be considered in setting angling regulations.

Acknowledgements

The Fisheries Service of the Department of Tourism, Fish and Game for the Province of Québec was extremely cooperative in working with Cornell University in arranging trips, collecting data and donating brook trout eggs for research programs. In particular, the efforts of Dr. H. E. Corbeil, Dr. Vianney Legendre and Mr. Magella Dufour are greatly appreciated. Mr. Russell Robertson of the Parks Service arranged for boats and guide on Lake Albanel and Mr. Gerard Emond of the Indian Affairs Department arranged for the collection of brook trout stomachs and scales from Mistassini Lake. Mr. Ray Cooper, manager of Norther Labrador Camps, was most helpful in allowing summer students to work out of his camp and aid in collecting of data. Cornell University students Brendon Hutchinson, Gary Martel, Dennis Pickard and Michael Carnevele assisted in collecting data as did University of Michigan student, Scott Quinn. The portion of the work carried out by Cornell University was made possible through the support of the late Mr. Donald P. Ross and Mrs. Ross of Montchanin, Delaware. Dr. Dwight A. Webster, Professor of Fishery Science at Cornell University and Dr. Geoff Power of Laval University, reviewed and made critical suggestions on the manuscript.

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