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ECOLOGY OF CATOSTOMIDS IN TWIN LAKES, COLORADO, IN RELATION TO A PUMPED STORAGE POWERPLANT

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ECOLOGY OF CATOSTOMIDS IN TWIN LAKES, COLORADO, IN RELATION TO A PUMPED-STORAGE POWERPLANT

by

Douglas A. Krieger Colorado Cooperative Fishery Research Unit Colorado State University, Fort Collins Lower Missouri Region

June 1980

Applied Sciences Branch Division of Research Engineering and Research Center Denver, Colorado



UNITED STATES DEPARTMENT OF THE INTERIOR

*

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

> In May of 1981, the Secretary of the Interior approved changing the Water and Power Resources Service back to its former name, the Bureau of Reclamation. All references in this publication to the Water and Power Resources Service should be considered synonymous with the Bureau of Reclamation.

FOREWORD

This report is one of a series presenting results of studies on the aquatic ecology of Twin Lakes, Colo. The purpose of these studies is to document the ecological effects of operating the recently constructed Mt. Elbert Pumped-Storage Powerplant. These studies are being done by researchers from the Water and Power Resources Service, Colorado Division of Wildlife. and the Colorado Cooperative Fishery Research Unit at Colorado State University. Funding for these studies is from the Water and Power Resources Service Lower Missouri Region, Fryingpan-Arkansas Project and the Water and Power Resources Service, Division of Research. Research, with the purpose of evaluating the effects of pumped-storage construction and operation, began in 1971. This project will continue until 3 years of postoperational data have

been collected and analyzed. The information obtained from this study has been used to design certain features of the Mt. Elbert Pumped-Storage Powerplant. In addition, based on results of research at Twin Lakes, the operation schedule will be modified to the extent practical to protect the aquatic environment. Results of the research completed during this study, along with those from studies like it, will be useful in planning future pumped-storage projects that will be as environmentally compatible as is practical.

> James F. LaBounty, Research Biologist Division of Research Water and Power Resources Service Denver, Colorado

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I would like to thank Dr. Eric Bergersen, my advisor at the Cooperative Fishery Unit, for his support of this project and me. His suggestions, review of the manuscript, and efforts in the field were greatly appreciated. Dr. William McConnell added insight and down-to-earth advice on this study. Mr. Ed Crispe, also of the Coop Unit, deserves recognition for his time and effort spent in preparing field equipment.

I would like to express my appreciation to the Water and Power Resources Service (formerly the Bureau of Reclamation) for funding of this investigation, and to Dr. James LaBounty for his contributions of time and equipment. His critical review of the thesis and suggestions during the study were also valuable.

Several Colorado Division of Wildlife biologists were instrumental in the completion of this study, and their efforts were invaluable. Mr. Tom Nessler provided equipment and manpower. Mr. Steve Putnam unselfishly furnished his electrofishing gear and necessary assistance. In addition, the suggestions and critical inspection of the manuscript by Dr. Wes Nelson were very helpful.

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PURPOSE

The data contained within this report are a significant part of the baseline information on the aquatic environment of Twin Lakes, Colo., to which findings during the postoperative period will be compared. By such comparison, the impacts of the Mt. Elbert Pumped-Storage Powerplant can be more accurately determined. The information in this report will be useful to those interested in cold-water fishery management and of particular use to those evaluating the impacts of powerplant operation on fisheries.

INTRODUCTION

Catostomid suckers inhabit a diverse spectrum of river and lake systems in North America, however, their role as a component of these ecosystems is frequently overlooked. Knowledge of the biology of the suckers can clarify their relationships to coexisting fish and invertebrate species. These fish have been the subject of many investigations in the U.S. and Canada [4, 6, 7, 8, 10, 19, 32, 36, 42, 45].¹ White suckers (*Catostomus commersoni*) and longnose suckers (*Catostomus catostomus*) have been found to occupy the same waters in Canada and in Colorado [2, 20].

Both white and longnose suckers are found in Twin Lakes along with lake trout (Salvelinus namavcush), a fish that provides a unique and valuable fishery for the area. Conflicting evidence on the interactions of suckers with lake trout is presented in the literature. Several authors concluded that suckers were not an important food source for small and intermediate size lake trout, but believed that they were frequently eaten by large lake trout [11, 27, 37]. In addition, suckers have been reported to feed on lake trout eggs [1, 11, 12, 37]. Past research on Twin Lakes has shown that suckers constitute 49 percent by volume of lake trout food [18] and that suckers may feed on lake trout eggs [30].

With operation of the Mt. Elbert Pumped-Storage Powerplant, white and longnose suckers may be subject to mortality from entrainment or indirect effects. Depending on the degree of association with the suckers, changes may also occur in the lake trout populations.

Pumped-storage powerplants have become an innovative means of hydroelectric generation in the past decade. This type of facility uses an elevated reservoir into which water is pumped during periods of low electrical power demand. When demand is high, this water is released and flows back to the lower reservoir, turning turbine generators as it descends. Studies to measure the environmental impact of pumpedstorage operation are being conducted in many areas to facilitate planning of future facilities with minimal adverse effects on aquatic resources.

Environmental conditions existing in an aquatic habitat affect the various life functions of fish living within it. Alterations to the ecosystem, such as those that might occur with operation of the Mt. Elbert Powerplant on Twin Lakes, might be evidenced by resulting changes in the life processes of the fish. Postoperational studies can be compared to the present study and any difference, if present, recognized. In this investigation, the age and growth process, food habits, reproductive biology, and the distribution of the two sucker populations prior to operation of the Mt. Elbert Powerplant are specifically examined. Food competition between lake trout and suckers and the degree of lake trout egg predation by suckers also are addressed.

Description of the Twin Lakes System

Twin Lakes is located approximately 24 km south of Leadville, Colo., on Lake Creek, a tributary to the Arkansas River. Originally two separate natural lakes, a man-made dam at the eastern end of the lower lake and a dredged channel between the two bodies have essentially created a single reservoir with two sections. At maximum water surface elevation (2802 m above sea level), maximum depth in the lower lake is about 27 m, and about 28 m in the upper lake. At that level, the surface areas for the lower and upper lakes are approximately 737 and 263 ha, respectively.

Shoreline habitat varies with location and water level, with slopes ranging from gentle to steep and covered with a substrate ranging from boulder-rubble to sand. At greater depths, the bottom consists of a fine, loosely compacted glacial

¹ Numbers in brackets identify reference material listed in the Bibliography.

flour. In littoral areas, organic detritus derived primarily from aquatic plants (*Potamogeton* sp., *Chara* sp., and *Nitella* sp.) is found. The bottom sediments of the upper lake contain large amounts of woody material probably derived from erosional processes occurring in a marsh on the west side of the lake. The lakes are considered as oligotrophic, second-class dimictic lakes, and are ice covered from mid-December to mid-May. Physical and chemical limnology of Twin Lakes have been examined extensively by Sartoris et al. [40].

Benthic organisms consist of at least two species of fingernail clams (*Pisidium casertanum* and *P. pauperculum*) and at least three species of midgefly larvae (*Chironomus* sp., *Phaenopsectra* sp., and *Dicrotendipes modestus*) with *Chironomus* being by far the most numerous [24]. Opposum shrimp (*Mysis relicta*) were stocked in Twin Lakes in 1957 and have become very abundant [17].

Four species of copepoda (Cyclops sp., Eucyclops sp., Diaptomus sp., and D. shoshone) and representatives of three rotifer genera (Keratella cochlearis, Kellicottia longispina, and Polyarthra sp.) have been reported in the lake (personal communication, James F. LaBounty, Water and Power Resources Service, Denver, Colo.). Two species of pelagic cladocerans have been found sporadically (Bosmina sp. and Daphnia pulex).

The white sucker, the only native species and the most numerous, and the longnose sucker are found along with lake trout, brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), and stocked rainbow trout (*Salmo gairdneri*). Cutthroat trout (*Salmo clarki*) and Kokanee salmon (*Oncorhynchus nerka*) are found occasionally. Twin Lakes is known for its lake trout fishery, which has been described by Nolting [30] and Griest [18].

METHODS

Fish Collection

Experimental multifilament gill nets, 38 m long and 1.8 m deep, were used to capture fish and

gather data on depth preference and distribution. Each net consisted of five, 7.6-m panels of bar mesh ranging in size from 19 to 45 mm in 6-mm intervals. Nets were set on the bottom and perpendicular to shore in 12 locations once each month from May to October 1978. In addition, nine nets were set under the ice in February and March. Stations were selected to ensure sampling within a variety of depths and habitat types in each lake. Because six nets were used. sampling took place during 2 to 6 consecutive days within each month. Nets were set before sunset and pulled shortly after sunrise. Effectiveness of davlight capture by the nets was negligible, as demonstrated by a number of davtime sets, therefore, only hours of darkness were counted in length of set.

From June to October, three vertical gill nets, 3 m wide and from 10 to 20 m deep, were fished for several 24-h periods in various locations to gain information on vertical distributions of the suckers. Bar mesh sizes ranged from 6 to 32 mm.

Shoreline areas were sampled during nighttime hours with an outboard powered electrofishing boat equipped with electrodes attached to a fore boom. The lower lake was sampled in June, August, and October, and the upper lake in the latter two months. This gear was used to capture smaller white suckers (less than 200 mm) and all sizes of longnose suckers.

Quantitative sampling of sucker larvae was considered impractical because of their habitat selection within shoreline areas. However, qualitative samples were taken weekly from mid-July to late September in the north bay area of the lower lake. Collections were made with a large-mesh plankton net towed by hand through water less than 1.3 m deep. To assess relative numbers of larvae appearing along shorelines of both lakes, a biweekly survey was conducted. Approximately 200 m of shoreline were examined in 10 areas of the lower lake and 6 areas of the upper lake, and an estimate made of numbers per square meter in each area. Later, an index number ranging from 1 to 5 was assigned to each area based on relative larval density compared to all other locations. This index was used to supplement investigations of areas used as spawning grounds within the lakes.

Data Analysis

All fish captured were scaled² to the nearest gram and measured to the nearest millimeter. Species, sex, condition of gonads, presence of fin clips, gear, and date and location of capture also were recorded. Only fish with mature gonads were sexed.

Pectoral fin-rays were removed from white suckers in a preliminary study in 1977 and were sectioned according to methods of Beamish and Harvey [4]. However, because of excessive preparation time, poorly defined annuli, and difficulties encountered with back-calculation, this method was abandoned. In 1978, both opercular bones were removed from about 450 white and 200 longnose suckers and cleaned by methods described by McConnell [28]. Operculars were then viewed under a magnifying glass using transmitted incandescent light and the center and annuli were marked on transparent tape laid along the opercular axis. The tape was removed, placed on a glass slide, and projected at a magnification of 6.57. Distance to annuli and outer edge were then measured directly. Opercular bones and scales were taken from 70 fish and used for age comparisons.

Total fish length was regressed against opercular radius, and first, second, and third degree equations fitted to the data by computer analysis. Linear equations gave correlation coefficients of 0.981 and 0.972 for white and longnose suckers, respectively; and were used to describe the relationship:

$$TL = b_o + b_I R \tag{Eq. 1}$$

where, TL = total length (mm), and R = opercular (annulus) radius (mm) × 6.57, b_o = constant describing the intercept, and b_l = constant describing the slope. Body lengths at annulus formation for each age class and grand averages were then computed, applying equation 1 to empirical lengths. Length-mass regressions were based on the form:

$$\log M = \log b_o + b_l \log L \qquad (Eq. 2)$$

where M = mass (g) L = length (mm) $b_l = constant$ describing the slope

 $b_o =$ constant describing the intercept

Coefficients b_o and b_l of equation 2 can vary with maturity and season, therefore, separate regressions were calculated according to species, season (spring, summer, and fall), and state of maturity (immature, mature). Statistical comparisons of length-mass relations were made using a computer program which tested for significantly different coefficients among various groups.

Gut contents from fish of the same species, captured in the same month and lake and within a given size group, were pooled into a single sample. This procedure eliminated the effort of examining individual stomachs while still allowing determination of the food habits of the population. Comparisons could then be made between species of a given size, in different lakes, and in different seasons. The number of stomachs used in each group ranged from 2 to 10. Size groups were 100 to 200 mm, 200 to 350 mm, and (for white suckers) greater than 350 mm. These size groups were based on feeding habits associated with various sized suckers, as presented by Stewart [45].

To obtain this information, the entire digestive tract was removed, wrapped in cheesecloth, and preserved in a 15-percent formalin solution. Guts of fish from similar groups were stored together. Contents from the anterior half of the digestive tracts of each group were removed and scaled (wet) to the nearest 0.01 g. All samples measuring more than 6 g were subsampled with a modified Waters [48] subsampler, after being agitated by hand to ensure homogeneity of the sample. Samples were then examined with a dissecting microscope, and all recognizable food items were counted. Food items which had been broken up were enumerated by counting only a recognizable part, such as a head. Remaining unidentified material, silt, and vegetation were scaled to the nearest 0.01 g. For subsamples, these data were multiplied by the division factor (approximately 8) to give numbers and mass for the total number of fish used in the group determination.

² "Scaled" as used in this report refers to a measurement of the mass (or the "weighing") of the fish.

Mass of food items and parts were reconstituted to obtain a better estimate of total mass eaten. Average live mass (wet) of organisms were determined from samples taken in Twin Lakes or from the stomach contents, if the item had not been crushed or digested. Reconstituted mass of the food item was then calculated by multiplying the number of individuals of species in a sample by its assigned mass.

Gut contents of fish less than 100 mm in length were analyzed qualitatively. Fish were examined individually and the percentage of volume and percentage of occurrence for each food item were recorded.

The biological index (TU) of Keefe and Bergersen [22] was used to compare the diversity of food items consumed by suckers of different species and sizes in both lakes at different seasons. This diversity index was based on the theory of runs method used for invertebrate habitat analysis. For the purposes of this study, the numbers of each food item eaten by a given group of fish were entered into the program. The index number obtained reflected the degree of diversity of food items taken and the evenness to which they were used. A high index number indicated that the fish were using a wide variety of food items and in nearly equal amounts.

Entire ovaries were wrapped in cheesecloth, identified by number, and placed in 10 percent formalin. Later, ovarian tissue was removed, and total mass of the loose eggs was determined. The eggs were divided into eight units with a modified Waters [48] subsampler and the eggs from one unit were scaled and counted. The number in that unit was then multiplied by the division factor to get the total number of eggs for each fish. Total numbers were regressed on length and mass for both species.

Mortality was estimated using the method of Ssentongo and Larkin [44]. This method enables calculation of a mortality coefficient from the mean length and the length at first capture. Only fish caught by similar gear (gill nets for white suckers, electrofishing for longnose suckers) were used in the computation. To test the validity of this method, a more traditional estimate using age class frequencies was calculated for white suckers by methods of Robson and Chapman [39]. Aged fish from the June and July gill net samples were used in the latter method. From August 15 to October 18, 1978, 203 white suckers were fin-clipped and released to be used for a population estimate. A unique combination of removed fins was used for different areas of both lakes. A Schnabel estimator [38] was used to calculate the population.

RESULTS AND DISCUSSION

Age and Growth

Growth in length

White suckers. – Opercular radius was plotted against fish length (*TL*) for 348 white suckers (fig. 1). A linear regression was fitted to the points by least squares (r = 0.981). The relationship was:

$$TL = 0.3830 R + 6.9531$$
 (Eq. 3)

where TL = total length in millimeters and R = opercular radius (mm) × 6.57.

Average lengths at annulus formation for each age group (AG) were computed by applying empirical opercular radius measurements to equation 3 (table 1). There was considerable variation in lengths at various ages between year classes which decreased with increasing age. It was assumed that this variation was due to unequal growth of young fish from the various year classes. Growth in later years of life seemed to tend towards long term averages.

Much overlap in length frequencies of consecutive age groups of white suckers was found (table 2). Length intervals for AG (age group) I and II are fairly well segregated, but for AG IV and older, length is not indicative of the age of the fish.

Females were longer than males at all years of life (table 3; fig. 2). Differences in their lengths were greatest between AG VII and IX, when male lengths averaged 93 percent of female lengths. Length differences were smaller during the earlier years. The apparent similarity of lengths at AG X is probably due to the small sample size of the male fish. Annual growth increments from AG II through IV were fairly constant, followed by a steady decline. The apparent large increases in growth for the males in the tenth year of life are again likely due to small sample size.





| Age | Year | Number | | | | Calc | ulated | length | at end | of yea | r of life | ; | | |
|-------------------------|--------|---------|----|-----|-----|------|--------|--------|--------|--------|-----------|-----|-----|-----|
| group | Class | of fish | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | 1977 | 27 | 85 | | | | | | | | <u>-</u> | | | |
| H | 1976 | 30 | 80 | 136 | | | | | | | | | | |
| 111 | 1975 | 34 | 73 | 120 | 175 | | | | | | | | | |
| IV | 1974 | 36 | 71 | 126 | 172 | 226 | | | | | | | | |
| V | 1973 | 27 | 71 | 120 | 165 | 203 | 252 | | | | | | | |
| VI | 1972 | 37 | 70 | 114 | 161 | 200 | 238 | 283 | | | | | | |
| VII | 1971 | 47 | 72 | 116 | 160 | 204 | 241 | 268 | 302 | | | | | |
| VIII | 1970 | 42 | 65 | 109 | 148 | 185 | 236 | 271 | 306 | 321 | | | | |
| IX | 1969 | 31 | 75 | 116 | 161 | 204 | 253 | 275 | 324 | 349 | 372 | | | ~ |
| . X | 1968 | 19 | 67 | 107 | 155 | 189 | 239 | 278 | 309 | 337 | 356 | 375 | | |
| XI | 1967 | 10 | 62 | 108 | 168 | 217 | 251 | 295 | 323 | 353 | 370 | 384 | 397 | |
| XII | 1966 | 8 | 72 | 125 | 172 | 218 | 265 | 308 | 332 | 355 | 372 | 385 | 397 | 405 |
| Grand a | verage | | 72 | 118 | 164 | 205 | 247 | 283 | 316 | 343 | 368 | 382 | 397 | 405 |
| Annual growth increment | | | | 46 | 46 | 41 | 42 | 36 | 33 | 27 | 25 | 14 | 15 | 8 |

Table 1.—Calculated lengths at annulus formation and annual growth increments for age groups of white suckers. Captured in 1978 from Twin Lakes, Colo.

Female white suckers lived longer than males, which were not found to live beyond 11 years. Many females attained AG XII and a few individuals (not reported here) were found to be in their seventeenth year of life.

Longnose suckers.—The opercular radius-fish length relationship determined for 140 longnose suckers was:

TL = 0.3265 R + 1.9561 (r = 0.972) (Eq. 4)

where TL = total length (mm) and R = opercular radius (mm) × 6.57

The data are plotted in figure 3.

Calculated lengths at annulus formation were computed using equation 4 (table 4). As was seen in the white sucker, variation in size at each age between the year classes decreased with increasing age. The maximum difference as percent of the smallest calculated length is at AG II and declines to 0.4 percent by AG VI.

Length frequencies for each age group clearly indicate substantial overlap between all ages, except AG I (table 5). Length intervals found for AG IV and VI are entirely included within the intervals of those age groups 1 year older and younger. Males were shorter than females at all ages except AG VI, but that age was represented by only one male fish (table 6; fig. 4). Growth of the sexes was nearly equal and parallel until the fourth year of life when growth of males declined rapidly. Because of the small sample size of AG VI males, the apparent growth increase for the males during the fifth year is probably not real.

Growth during the first year of life was rapid and was followed by a declining rate of growth in later years. There appeared to be a slight increase in growth during the fifth year for both sexes. Female growth declined steadily during the sixth and seventh years, whereas males showed an increase in the sixth year, which was thought not to be characteristic of the population. Females appeared to live 1 year longer (to AG VII) and obtained a length greater than males.

The validity of aging white and longnose suckers by their scales has been questioned by several authors. Geen et al. [16] and Coble [10] using recaptures of marked fish found ages to be underestimated when compared with the time elapsed since their original release, and concluded that annuli were not laid down each year. Ovchynnyk [33] compared ages of white suckers determined from scales and 19 other

| Total | | | - | | | | Age | group | | | | | |
|----------------|----|---|-----|----|--------|----|--------|-------|----|---|----|-----|----------------------|
| length (mm) | | H | 111 | IV | V | VI | VII | VIII | IX | x | XI | XII | Total No. of fish |
| 81-90 | 13 | | | | | | | | | | | | 13 |
| 91-100 | 12 | | | | | | | | | | | | 12 |
| 101-110 | 2 | | | | | | | | | | | | 2 |
| 111-120 | | ~ | | | | | | | | | | | 0 |
| 121-130 | | 5 | | | | | | | | | | | 5 |
| 131-140 | | 0 | | | | | | | | | | | / |
| 141-150 | | 3 | 1 | | | | | | | | | | 9 |
| 161-170 | | 5 | 3 | | | | | | | | | | 5 |
| 171-180 | | 5 | 11 | | | | | | | | | | 0 11 |
| 181-190 | | | 11 | | | | | | | | | | 11 |
| 191-200 | | | 5 | 2 | | | | | | | | | 7 |
| 201-210 | | | 1 | 1 | | | | | | | | | 2 |
| 211-220 | | | 1 | 9 | | | | | | | | | 10 |
| 221-230 | | | | 8 | 1 | | | | | | | | 9 |
| 231-240 | | | 1 | 7 | 2 | 1 | | | | | | | 11 |
| 241-250 | | | | 4 | 5 | 5 | | | | | | | 14 |
| 251-260 | | | | 2 | 3 | 2 | | | | | | | 7 |
| 261-270 | | | | 2 | 6 | 5 | e | | | | | | 13 |
| 2/1-280 | | | | 1 | 4 | 4 | 5 | 1 | | | | | 14 |
| 201-290 | | | | | ა ი | 4 | 5 5 | 2 | | | | | 12 |
| 301-310 | | | | | 1 | 3 | 6 | 1 | | | | | 13 |
| 311-320 | | | | | • | 6 | 10 | 4 | 1 | | | | 21 |
| 321-330 | | | | | | 3 | 6 | 5 | 3 | | | | 17 |
| 331-340 | | | | | | - | 4 | 5 | 3 | 2 | | | 14 |
| 341-350 | | | | | | 1 | 2 | 5 | 7 | | | | 15 |
| 351-360 | | | | | | | 2 | 7 | 1 | 3 | | 1 | 14 |
| 361-370 | | | | | | | 2 | 5 | 3 | 5 | 1 | | 16 |
| 371-380 | | | | | | | | 3 | 5 | 3 | | | 11 |
| 381-390 | | | | | | | | 2 | 2 | 2 | 1 | 2 | 9 |
| 391-400 | | | | | | | | | 5 | 2 | 6 | | 13 |
| 401-410 | | | | | | | | | 1 | 1 | 1 | 1 | 4 |
| 411-420 | | | | | | | | | | 1 | 1 | 2 | 2 |
| 421-430 | | | | | | | | | | 1 | I | 1 | 3 1 |
| 431-440 | | | | | | | | | | | | 1 | I |

Table 2. – Length frequency distribution of age groups of white suckers. Captured in 1978from Twin Lakes, Colo.

7



Figure 2. – Calculated total lengths at the end of each year of life (upper curve) and annual length increments (lower curve) for white suckers. Captured in 1978 from Twin Lakes, Colo.

| Age | Number Calculated length at end of year of life | | | | | | | | | | | | |
|---------------------------------------|---|----|-----|-----|-----|-----|-----|------|------|-------------|-----|-----|-----|
| group | of fish | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| · · · · · · · · · · · · · · · · · · · | | | | | | | M | ALES | | · · · · · · | | | |
| VI | 11 | 75 | 115 | 163 | 185 | 237 | 281 | | | | | | |
| VII | 13 | 68 | 111 | 158 | 201 | 241 | 277 | 303 | | | | | |
| VIII | 9 | 61 | 99 | 134 | 173 | 219 | 254 | 284 | 316 | | | | |
| IX | 2 | 69 | 104 | 149 | 192 | 231 | 260 | 283 | 307 | 325 | | | |
| х | 2 | 63 | 95 | 149 | 210 | 253 | 283 | 314 | 339 | 351 | 375 | | |
| Grand a | verage | 68 | 108 | 153 | 189 | 235 | 272 | 296 | 318 | 338 | 375 | | |
| Annual | increment | 68 | 40 | 45 | 36 | 46 | 37 | 24 | 22 | 20 | 37 | | |
| Percent | of | | | | | | | | | | | | |
| femal | e length | 99 | 95 | 97 | 94 | 96 | 97 | 94 | 91 | 93 | 99 | | |
| | | | | | | | FEN | ALES | | | | | |
| V | 3 | 79 | 130 | 181 | 226 | 263 | | | | | | | |
| VI | 7 | 74 | 119 | 172 | 210 | 250 | 297 | | | | | | |
| VII | 20 | 67 | 113 | 155 | 197 | 218 | 262 | 299 | | | | | |
| VIII | 29 | 66 | 113 | 154 | 196 | 253 | 279 | 315 | 362 | | | | |
| IX | 27 | 71 | 116 | 162 | 196 | 246 | 287 | 319 | 342· | 364 | | | |
| Х | 17 | 69 | 109 | 143 | 199 | 237 | 277 | 308 | 337 | 355 | 375 | | |
| XI | 10 | 62 | 108 | 168 | 217 | 251 | 295 | 324 | 353 | 370 | 384 | 397 | |
| XII | 8 | 72 | 125 | 172 | 217 | 270 | 308 | 332 | 355 | 372 | 385 | 397 | 405 |
| Grand a | verage | 69 | 114 | 158 | 202 | 244 | 281 | 314 | 350 | 364 | 380 | 397 | 405 |
| Annual i | increment | 69 | 45 | 44 | 44 | 42 | 37 | 33 | 36 | 14 | 16 | 17 | 8 |

Table 3. – Calculated total lengths at the end of each year of life, and annual growth increments for male and female white suckers. Captured in 1978 from Twin Lakes, Colo.

Table 4.—*Calculated lengths at annulus formation and annual growth increments for age groups of longnose suckers. Captured in 1978 from Twin Lakes, Colo.*

| Age | Year | Number | Calculated length at end of year of life | | | | | | | | | |
|-----------|---------------|---------|--|-----|-----|-----|-----|-----|-----|--|--|--|
| group | Class | of fish | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | |
| I | 1977 | 18 | .89 | | | | | | | | | |
| 11 | 1976 | 30 | 90 | 148 | | | | | | | | |
| m | 1975 | 45 | 85 | 133 | 181 | | | | | | | |
| IV | 1974 | 15 | 78 | 114 | 159 | 202 | | | | | | |
| V | 1973 | 21 | 77 | 124 | 168 | 205 | 239 | | | | | |
| VI | 1972 | 8 | 74 | 128 | 170 | 211 | 250 | 278 | | | | |
| VII | 1971 | 3 | 85 | 136 | 177 | 209 | 250 | 280 | 304 | | | |
| Grand av | erage | · · | 83 | 130 | 171 | 207 | 246 | 279 | 304 | | | |
| Annual gi | rowth increme | ent | 83 | 47 | 41 | 36 | 39 | 33 | 25 | | | |





| Total | | | | | | | | |
|----------------|---|-----|-----|----|---|----|-----|----------------------|
| length (mm) | I | II. | 111 | IV | V | VI | VII | Total No. of fish |
| 86-95 | 9 | | | | | | | 9 |
| 96-105 | 6 | | | | | | | 6 |
| 106-115 | 1 | | | | | | | 1 |
| 116-125 | 2 | 1 | | | | | | 3 |
| 126-135 | | 3 | | | | | | 3 |
| 136-145 | | 4 | | | | | | 4 |
| 146-155 | | 4 | | | | | | 4 |
| 156-165 | | 6 | 1 | | | | | 7 |
| 166-175 | | 3 | 6 | | | | | 9 |
| 176-185 | | 5 | 11 | | | | | 16 |
| 186-195 | | 3 | 11 | | | | | 14 |
| 196-205 | | 1 | 10 | 7 | 1 | | | 19 |
| 206-215 | | | 2 | 1 | 1 | | | 4 |
| 216-225 | | | 1 | 3 | 3 | | | 7 |
| 226-235 | | | | 2 | 4 | | | 6 |
| 236-245 | | | 1 | 2 | 1 | | | 4 |
| 246-255 | | | 2 | | 2 | | | 4 |
| 256-265 | | | | | 4 | | 1 | 5 |
| 266-275 | | | | | 2 | 2 | | 4 |
| 276-285 | | | | | 2 | 1 | | 3 |
| 286-295 | | | | | | 4 | | 4 |
| 296-305 | | | | | | | 1 | 1 - |
| 306-315 | | | | | 1 | 1 | | 2 |
| 316-325 | | | | | | | 1 | 1 |

Table 5.—Length frequency distribution of age groups of longnose suckers. Captured in 1978 from Twin Lakes, Colo.

bony parts and concluded the 1) annuli on scales may not be formed every year, 2) number of year marks on scales and on a number of bones were greatly different, and 3) bones, particularly the operculum and pectoral fin-rays, were more reliable than scales for determination of age. In the present study, opercular bone ages agreed well with scale ages up to AG VII (for white suckers). The difference in age determinations by the two methods increased with increasing ages. Usually the operculars revealed more annuli than did the scales.

Operculars were found to be a more suitable bony structure than scales for use in aging suckers, because they function as a ''key scale'', eliminating the variation caused by using various sized scales from the same fish. This effect increased the correlation coefficient for the body length-opercular radius regression. Lalancette [25] used scales in aging white suckers from Gamlin Lake, Quebec, and found a correlation coefficient of 0.924 for a linear regression. There did not appear to be differences in location of annuli between operculars of a pair, but often one bone had more distinct year marks.

Both species of suckers in Twin Lakes grew slower and white suckers lived longer than suckers from most other areas reported in the literature. Calculated lengths of fish from various locations are shown in tables 7 and 8.

Biomass estimates of benthic organisms in Upper Twin Lakes during 1974 and 1975 were the lowest reported for any lake in the literature [24]. Biomass in the lower lake was higher but moderate compared to other lakes. A scarce food source may be a limiting factor to the fish and perhaps may be keeping numbers in check, however, it is not believed to be responsible for the slow growth. Suckers in Twin Lakes almost always had abundant amounts of food in their guts and had plump shapes. It is thought that the cold temperatures and, therefore, short



Figure 4.—Calculated total lengths at the end of each year of life (upper curve) and annual length increments (lower curve) for longnose suckers. Captured in 1978 from Twin Lakes, Colo.

growing season are, perhaps, allowing only minimal growth to occur each year.

Haves [20] found that female longnose and white suckers from Shadow Mountain Reservoir. Colo., were larger than males at all ages. The life span of both sexes in that lake is equal. with white suckers living to AG VI and longnose suckers to AG V. Geen et al. [16] also determined that females grew faster than males in Sixteenmile Lake, British Columbia, Age was rearessed on length of white suckers by Lalancette [25] and indicated that male and female regression equations were significantly different. He found no difference in longevity of the sexes. No sexual difference in growth for longnose suckers was found by Harris [19] at Great Slave Lake or by Rawson and Elsey [37] at Pyramid Lake, Alberta, however, both studies showed that females were longer lived.

Growth in mass

White suckers.—Fish length-mass regressions were computed for six groups of fish, representing fish from three seasons (spring, summer, and fall) and two sizes (immature and mature). The equations are:

| Spring: | |
|----------------------------|---------|
| immature log | |
| M=3.126 log L-5.289 | (Eq.5) |
| mature log | |
| M=3.027 log L-5.049 | (Eq.6) |
| Summer: | |
| immature log | |
| $M = 3.018 \log L - 5.027$ | (Eq.7) |
| mature log | |
| $M = 2.887 \log L - 4.693$ | (Eq.8) |
| Fall: | |
| immature log | |
| $M = 3.046 \log L - 5.117$ | (Eq.9) |
| mature log | |
| $M = 3.047 \log L - 5.099$ | (Eq.10) |

Regression slope coefficient for the immature suckers captured in the spring (season 1-size 1) and the immature fish caught in the fall (season 3-size 1) were significantly higher than the slope coefficients for the mature, summer-captured suckers (season 2-size 2). Similarly, the intercept values for immature-spring and immature-summer fish were significantly lower than the intercept value for the mature-summer

regression. There were no significant differences in slope or intercept values for the equations within a given size at different seasons, however, variations did occur. Confidence intervals for the coefficients and length-mass regression curves are shown in appendix A.

Longnose suckers.—Fish length-mass relationships again were computed for each of six groups of fish:

| Spring: | |
|----------------------------|----------|
| immature log | |
| $M = 3.516 \log L - 6.124$ | (Eq.11) |
| mature log | |
| $M = 3.071 \log L - 5.183$ | (Eq.12) |
| Summer: | |
| immature log | |
| $M = 3.187 \log L - 5.183$ | (Eq.13) |
| mature log | |
| $M = 2.974 \log L - 4.930$ | (Eq.14) |
| Fall: | |
| immature log | |
| $M = 3.185 \log L - 5.428$ | (Eq.15) |
| immature log | |
| $M = 3.080 \log L - 5.184$ | (Eq. 16) |

Coefficients and 95-percent confidence intervals for each equation are shown in appendix B. As previously stated, significance was declared only for those equation coefficients which did not have overlapping confidence limits. Slope coefficient for the immature-spring fish equation (season 1-size1) was significantly higher than all others, as was the intercept value. In addition, the coefficients from the mature-summer regression (season 2-size 2) were significantly lower than the coefficient values of equation 15. As was found in the white suckers, the regression for a given size varied with different seasons, but not significantly so.

The slope and intercept values for immature fish were inversely related. Mature suckers, on the other hand, had equations which differed in a parallel fashion and, therefore, slope and intercept values changed in the same direction.

There was a general trend for immature fish of a given species to have higher slope coefficients than mature fish within a given season. These differences, however, were not usually significant. Apparently, immature fish tended to be slightly plumper than adults.

| Age | Number | | Calculate | ed length | at end of | year of life | (millimet | ers) |
|--------------------------|------------|----|-----------|-----------|-----------|--------------|-----------|------|
| group | of fish | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| · <u>·</u> ····· | u | | N | ALES | | | | |
| 11 | 3 | 87 | 144 | | | | | |
| III | 13 | 87 | 135 | 182 | | | | |
| IV | 6 | 81 | 114 | 161 | 194 | | | |
| V | 4 | 61 | 108 | 155 | 185 | 216 | | |
| VI | 1 | 77 | 117 | 169 | 224 | 260 | 285 | |
| Grand aver Annual gro | age wth | 78 | 127 | 172 | 193 | 225 | 285 | |
| incremen Percent of | t | 78 | 46 | 45 | 21 | 32 | 60 | |
| female le | ngth | 96 | 97 | 98 | 93 | 91 | 102 | |
| | | | FE | MALES | | | | |
| П | 3 | 92 | 156 | | | | | |
| iii | 28 | 90 | 135 | 184 | | | | |
| IV | - 9 | 76 | 114 | 157 | 207 | | | |
| V | 17 | 80 | 127 | 171 | 210 | 245 | | |
| VI. | 7 | 74 | 130 | 171 | 209 | 248 | 278 | |
| VII | 3 | 85 | 136 | 177 | 201 | 250 | 280 | 304 |
| Grand avera | age | 84 | 131 | 175 | 208 | 246 | 279 | 304 |
| incremen | t | 84 | 47 | 44 | 33 | 38 | 33 | 25 |

Table 6. – Calculated total lengths at the end of each year of life of male and female longnose suckers. Captured in 1978 from Twin Lakes, Colo.

Table 7. – Average total length at annulus formation for white suckers from various locations. (Carlander 1968)

| Lake | Number | ber Average total length at each annulus | | | | | | | | | | | |
|------------------------|---------|--|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|
| | of fish | 1 | 11 |)II | IV | V | VI | VII | VIII | IX | х | XI | XII |
| Pathfinder L., Wyo. | 70 | 71 | 157 | 251 | 330 | 376 | | | | | | | |
| L. Vermillion, Minn. | 94 | 142 | 234 | 312 | 366 | 411 | 465 | 478 | 472 | | | | |
| Muskellunge L., Wis. | 2990 | 71 | 117 | 163 | 203 | 231 | 262 | 290 | 310 | 345 | 335 | | |
| Many Points L., Minn. | 2655 | 109 | 206 | 295 | 351 | 401 | 424 | 437 | 490 | 495 | | | |
| Waskesiu L., Sask. | - | 52 | 81 | 142 | 216 | 254 | 358 | 445 | 498 | 543 | | | |
| Missouri R., Mont. | - | 66 | 135 | 208 | 257 | 310 | 348 | 358 | 386 | | | | |
| Shadow Mt. Res., Colo. | 56(m) | 69 | 135 | 196 | 249 | 267 | | | | | | | |
| | 66(f) | 76 | 155 | 229 | 295 | 328 | | | | | | | |
| Twin Lakes, Colo. | 37(m) | 68 | 108 | 153 | 189 | 235 | 272 | 296 | 318 | 338 | 375 | | |
| | 121(f) | 69 | 114 | 158 | 202 | 244 | 281 | 314 | 350 | 364 | 380 | 397 | 405 |

| Lake | Number | Average total length at each annulus | | | | | | | | | | | |
|-------------------------|---------|--------------------------------------|-----|-----|-----|-----|-----|-----|------|--|--|--|--|
| | of fish | I | | 111 | IV | V | VI | VII | VIII | | | | |
| Missouri R., Mont. | 87 | 76 | 140 | 206 | 264 | 312 | 348 | 373 | 394 | | | | |
| Yellowstone L., Wyo. | 253(m) | 48 | 119 | 213 | 292 | 340 | 381 | 417 | | | | | |
| | 222(f) | 51 | 124 | 221 | 302 | 366 | 409 | 445 | 460 | | | | |
| Montana Lakes, Mont. | 136 | 43 | 109 | 145 | 244 | 297 | 356 | 401 | 439 | | | | |
| Shadow Mtn. Res., Colo. | 42(m) | 76 | 130 | 185 | 231 | 264 | | | | | | | |
| | 79(f) | 84 | 152 | 211 | 251 | 264 | | | | | | | |
| Twin Lakes, Colo. | 43(m) | 79 | 124 | 167 | 201 | 238 | 285 | | | | | | |
| | 67(f) | 84 | 131 | 175 | 208 | 246 | 279 | 304 | | | | | |

Table 8. – Average total length at annulus formation for longnose suckers from various locations. (Carlander 1968)

Slope coefficients from the summer regressions appeared to be lower within a given species and size, but only in one case were these differences significant. This might be expected for mature fish which had no gonadal development at this time, but it does not explain the differences in the immature fish. It may be possible that the fish were increasing in length at a rapid rate during the summer, thus having less mass at a given length.

Slope coefficients for the white sucker equations were generally higher than those found by Lalancette [25]. His study was conducted at higher latitudes and he noted a lack of food for those white suckers. Slope coefficients for white suckers in the present study were lower than those determined for white suckers from Shadow Mountain Reservoir, Colo. [20]. Slope coefficients from the length-mass regressions for Twin Lakes longnose suckers were similar to those found by Hayes [20] but were higher than those determined by Coble [10].

Food Habits

Fish less than 100 mm in length

White suckers. – Cladocera were the most numerous food item taken but on a volumetric basis were much less important. Small chironomid larvae (less than 4 mm) were second in total numbers and were the dominant animal food by volume. Pupae were not eaten by fish of this size. Fingernail clams were used in very small numbers. Debris, which consisted of mucous and unidentifiable material, was the major constituent of the food by volume. Silt comprised at least 10 percent of total volume in all samples, and was found in greater amounts in fish eating large numbers of chironomids.

Cladocera were equally abundant in fish from both lakes in spring. Fish from the upper lake did not take cladocera in summer, and took fewer than fish from the lower lake in fall. Chironomid larvae reached maximum numbers in the diets of fish from both lakes during the summer, and were found less frequently in fall than in spring. Fingernail clams were used only by lower lake fish and only in the fall.

Longnose suckers.—Longnose suckers under 100 mm ate more cladocera than chironomid larvae but the latter, as with white suckers, were much more important on a volumetric basis and were the dominant animal food. The size of both cladocera and chironomid larvae were much smaller than those eaten by larger fish. Fingernail clams were taken only incidentally. Silt, sand, and debris constituted a large percentage of the volume (33 percent) and were again more prevalent in fish which had eaten predominantly chironomid larvae. Much mucous was present in all guts. There was a marked similarity in food habits between fish in the two lakes.

Cladocera were found more often and in greater volume in gut contents during the summer, with an average of 800 per fish. Chironomid larvae were excluded from some diets in the summer. In the fall, chironomid larvae were more abundant than cladocera. Silt and debris dominated gut contents on a volumetric basis in the fall.

White suckers less than 70 mm in length fed predominantly on cladocera, copepods, and chironomids in Many Points Lake, Minn. [32].

Longnose suckers under 50 mm relied on cladocera and to a lesser extent on chironomid larvae in Pyramid Lake, Alberta [37]. Haves [20] found 70 percent of total stomach volume of young white and longnose suckers composed of cladocera and some debris. He noted that many suckers had fed exclusively on cladocera, and believed this to be selective feeding by the fish. Stewart [45] determined that young suckers from 18 to 25 mm in length were beginning to feed on the bottom, but were limited by a small mouth that was intermediate between an inferior and a ventral position. These fish were also not adept at separating sand from benthic food organisms, and had much sand in their alimentary canal.

In Twin Lakes, small suckers contained either a variety of food items or all cladocera. Cladocerans found in the guts were thought to be *Alona* sp., a benthic species (personal communication, Dr. James V. Ward, Department of Zoology, Colorado State University). Guts containing only cladocera also contained little silt, and it is assumed that the cladocera were taken slightly above the sediments or among vegetation. Selection of cladocera by Twin Lakes suckers may be caused by the greater availability, location, and size of cladocerans in relation to muddwelling organisms. Siefert [41] concluded that white suckers under 27 mm were weak swim-

mers and had to take prey found in their immediate habitat. Those fish utilizing chironomid larvae in Twin Lakes had more silt in their guts as a result of their inability to expel it.

Both species of suckers at this size ate similar foods and in equivalent proportions. White suckers, however, ate more chironomid larvae and fewer cladocera in summer than did the longnose suckers. Rawson and Elsey [37] found no seasonal trends (May to September) in diets of small longnose suckers.

Fish 100 to 200 mm in length

White suckers.—Fish in this size group fed primarily on chironomid larvae, which made up 50.8 percent of total numbers and 59.1 percent of total mass (table 9). Large size of the chironomid pupae (greater than 16 mm) prevented predation by small fish, which is reflected in the low amounts taken. Cladocera ranked second in numbers (32.5 percent) but were not important on a mass basis. Fingernail clams were nearly equal in value for both numbers (4.6 percent) and mass (4.7 percent). Much silt was ingested and comprised 15.4 percent of the total mass. Debris and vegetation constituted 9.7 percent and 3.4 percent by mass, respectively.

| | | Lowe | r Lake | | | Uppe | r Lake | | | То | tal | |
|-------------------|-------|---------|--------|---------|-------|---------|--------|---------|--------|---------|-------|---------|
| Food Item | N | Numbers | | Mass | | nbers | M | ass | Nurr | bers | м | ass |
| | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent |
| Chironomid larvae | 10 52 | 5 43.7 | 23.47 | 55.6 | 6 478 | 69.1 | 14.45 | 65.9 | 17 003 | 50.8 | 37.92 | 59.1 |
| Chironomid pupae | 18 | 9 0.8 | 0.55 | 1.3 | 12 | 0.1 | 0.03 | 0.1 | 201 | 0.6 | 0.58 | 0.9 |
| Fingernail clams | 1 47 | 5 6.1 | 2.88 | 6.8 | 77 | 0.8 | 0.15 | 0.7 | 1 552 | 4.6 | 3.03 | 4.7 |
| Cladocera | 9 56 | 3 39.7 | 2.58 | 6.1 | 1 328 | 14.1 | 2.36 | 1.6 | 10 891 | 32.5 | 2.94 | 4.6 |
| Oligochaeta | | 2 tr | 0.01 | tr | 16 | 0.2 | 0.07 | 0.3 | 18 | 0.1 | 0.07 | 0.1 |
| Copepoda | 2 24 | 0 9.3 | 0.25 | 0.6 | 1 463 | 15.6 | 0.16 | 0.7 | 3 703 | 11.1 | 0.41 | 0.6 |
| Amphipoda | 7 | 8 0.3 | 0.91 | 2.1 | | | | | 78 | 0.2 | 0.91 | 1.4 |
| Gastropoda | | | | | | | | | | | | |
| Mysidacea | | | | | | | | | | | | |
| Trichoptera | | | | | | | | | | | | |
| Homoptera | | | | | | | | - | | | | |
| Ephemeroptera | | | | | | | | | | | | |
| Trout eggs | | | | | | | | | | | | |
| Silt / Sand | | | 5.60 | 13.3 | | | 4.29 | 19.6 | | | 9.89 | 15.4 |
| Plant material | | | 1.79 | 4.2 | | | 0.40 | 1.8 | | | 2.19 | 3.4 |
| Debris | | | 4.20 | 9.9 | | | 2.01 | 9.2 | | | 6.21 | 9.7 |
| Number of fish | | 5 | 2 | | | 2 | 9 | | | 8 | 1 | |

Table 9.—Food of white suckers (100 to 200 mm in length) from Lower and Upper Twin Lakes, Colo., in 1978, expressed as numbers, mass, percentage of total numbers and percentage of total mass. Tr = less than 0.1 percent.

White suckers in the upper lake utilized more chironomid larvae than fish from the lower lake, and ate less cladocera and copepoda. Cladocera made up 39.7 percent by numbers and 6.1 percent by mass of diets of suckers in the lower lake, compared to 14.1 percent by numbers and 1.6 percent of the total mass for upper lake fish. Fingernail clams comprised 0.8 percent by numbers and 0.7 percent by mass in guts of upper lake fish, but were 6.1 percent of total numbers and 6.8 percent of mass for suckers in the lower lake. More plant material and less silt was found in fish from the lower lake.

In spring, copepods were numerically dominant, chironomid larvae made up the largest part of the diets by mass, and silt and debris also were important (fig. 5). Plants were also utilized by fish in the lower lake. In summer, copepods declined, and chironomid larvae became more important by numbers and mass in both lakes. Cladocera were used to a greater extent in the lower lake but they also increased in the upper lake from that amount eaten in spring. In fall, small fingernail clams (1.5 mm) were abundant in diets of lower lake fish but were not found in upper lake suckers. Cladocera dominated the fall diets of fish from the lower lake by numbers but not mass. In the upper lake, animal food was almost exclusively chironomid larvae, and silt was the predominant non-animal portion.

The TU index for upper lake fish was highest in the summer (0.485) and much lower in spring (0.061) and fall (0.140). Lower lake values were higher and more stable than those for the fish from the upper lake.

Longnose suckers. – The primary constituent of animal food in the diets was chironomid larvae which made up 49.5 percent of total numbers and 69.0 percent of total mass in both lakes (table 10). Cladocera ranked second in numbers and were 7.9 percent of the total mass. Copepoda and fingernail clams were not consumed by this group. A number of trichoptera and homoptera were eaten, and a total of five species were used for food. Little plant material was eaten and the non-animal food was predominantly silt/sand and debris which made up 18.7 percent of total mass.

Chironomid larvae constituted 87.2 percent by numbers and 80.0 percent by mass of the upper lake sucker diets whereas cladocera were relatively unimportant. In contrast, the fish in the lower lake fed less on chironomid larvae and more on cladocera. Trichoptera were used only in the lower lake, while homoptera were used exclusively in the upper lake.

Chironomid larvae were eaten throughout summer and fall, but were more important in the fall

| l able | 10.—Food of longnose suckers (100 to 200 mm in length) from Lower and Upper 1 win Lakes, |
|--------|---|
| Colo. | , in 1978, expressed as numbers, mass, percentage of total numbers, and percentage of total |
| | mass. Tr = less than 0.1 percent. |
| | |

| | | Lowe | r Lake | | | | Upper | r Lake | | ļ | | То | tal | |
|--|-------------|-------------|----------------------|--------------------|----|------------|-------------|----------------------|--------------------|----|------------|-------------|----------------------|--------------------|
| Food Item | Num | Numbers | | Mass | | Nun | nbers | М | ass | | Num | bers | Ma | ass |
| | No. | Percent | Grams | Percent | 1 | No. | Percent | Grams | Percent | 1 | No. | Percent | Grams | Percent |
| Chironomid larvae Chironomid pupae Fingernail clams | 6 156 43 | 24.1 0.2 | 13.73 0.12 | 50.7 0.4 | 15 | 044 254 | 87.2 1.5 | 35.55 0.74 | 80.0 1.7 | 21 | 200 297 | 49.5 0.7 | 49.28 0.86 | 69.0 1.2 |
| Cladocera Oligochaeta Copepoda Amphipoda Gastropoda Mysidacea | 19 334 | 75.6 | 5.22 | 19.3 | 1 | 501 | 8.7 | 0.41 | 0.9 | 20 | 835 | 48.7 | 5.63 | 7.9 |
| Trichoptera Homoptera Ephemeroptera Trout eggs | 34 | 0.1 | 1.09 | 4.0 | | 449 | 2.6 | 0.10 | 0.2 | | 34 449 | tr 1.0 | 1.09 0.10 | 1.5 0.1 |
| Silt / Sand Plant material Debris | | | 4.10 0.50 2.30 | 15.2 1.8 8.5 | | | | 4.92 0.60 2.09 | 11.1 1.4 4.7 | | | | 9.02 1.10 4.39 | 12.6 1.5 6.1 |
| Number of fish | | 3 | 0 | | | | 1 | 7 | | | | 4 | 7 | |



Figure 5.—Seasonal food of white suckers (100 to 200 mm in length) from Twin lakes, Colo., in 1978, expressed as percentage of total numbers and percentage of total mass. Seasonal diversity indices with 95-percent confidence intervals are in parentheses.

Chironomid larvae = LR Chironomid pupae = PU Fingernail clams = FN Cladocera = CD Oligochaeta = OL Copepoda = CO Amphipoda = AM Silt/sand = ST Plant material = PM Debris = DB

(fig. 6). A few chironomid pupae were used in the summer. More cladocera were taken in the fall by upper lake suckers and in the summer by lower lake suckers. The TU index was higher in the fall in both lakes, and the lower lake sucker diets had larger values than those in the upper lake during both seasons.

Generally, diets of suckers of this size in Twin Lakes were composed predominantly of chironomid larvae. Cladocera were also eaten frequently and fingernail clams were important to the white suckers. From 10.8 to 25.7 percent of the total mass of the diet consisted of debris and silt/ sand. Olson [32] found chironomid larvae to occur in 79 percent of white sucker guts (96 to 250 mm in length). Fingernail clams were eaten by 41 percent of the fish. Similar findings were reported by Campbell [8] for white suckers (118 to 245 mm) where chironomid larvae and entomostraca (cladocera and copepoda) were used to a lesser extent.

The TU index values were significantly higher for the lower lake diets in all seasons for both species. This probably occurred because of the greater reliance on chironomid larvae by the upper lake fish, with a consequent reduction in quantities of other food items. Although complete information on abundance of all invertebrates in Twin Lakes is lacking, LaBounty and Sartoris [24] found a higher density of chironomid larvae in the lower lake. Diets of suckers in the lower lake were composed of a smaller percentage of chironomid larvae than fish from the upper lake even though chironomid larvae were more abundant in the lower lake. Apparently, they selected species other than chironomid larvae for prey. Fewer taxa were eaten by suckers in the upper lake with a corresponding increase in dependence on chironomid larvae This may be caused by the presence of fewer food items or by the suckers selecting chironomid larvae.

Fish 200 to 350 mm in length

White suckers. – Chironomid larvae dominated the diets in both lakes and made up 75.3 percent of total numbers and 63.8 percent by mass (table 11). Cladocera and fingernail clams were nearly equal in abundance, but clams were much more important in total mass. Chironomid pupae comprised 2.8 percent of numbers and 3.0 percent of total mass. Mysid shrimp were taken incidentally. A total of 10 animal-food species were utilized. Approximately 24 percent of the total diet mass was composed of silt and debris.

White suckers in the upper lake consumed more chironomid larvae than those in the lower lake. Fingernail clams were equally important in both lakes. Chironomid pupae and copepoda comprised a more substantial component of the diets of fish in the upper lakes compared to diets of fish from the lower lake. Gastropods, trichoptera

| | | Lowe | r Lake | | 1 | Uppe | r Lake | | | Τc | otal | |
|--------------------------|--------|---------|--------|---------|--------|---------|--------|---------|---------|---------|--------|---------|
| Food Item | Nun | bers | Ma | Mass | | bers | M | ass | Nur | nbers | Ma | ass |
| | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent |
| Chironomid larvae | 64 258 | 71.8 | 143.30 | 61.4 | 49 908 | 80.4 | 111.29 | 67.1 | 114 166 | 75.3 | 254.59 | 63.8 |
| Chironomid pupae | 2 056 | 2.3 | 5.96 | 2.6 | 2 138 | 3.4 | 6.20 | 3.7 | 4 194 | 2.8 | 12.16 | 3.0 |
| Fingernail clams | 9 210 | 10.3 | 17.96 | 7.7 | 3 890 | 6.3 | 7.59 | 4.6 | 13 100 | 8.6 | 25.55 | 6.4 |
| Cladocera | 13 349 | 14.9 | 3.60 | 1.5 | 2 911 | 4.7 | 0.79 | 0.5 | 16 260 | 10.7 | 4.39 | 1.1 |
| Oligochaeta | 97 | 0.1 | 0.44 | 0.2 | 270 | 0.4 | 1.22 | 0.7 | 367 | 0.2 | 1.66 | 0.4 |
| Copepoda | 307 | 0.3 | 0.03 | tr | 2 780 | 4.5 | 0.31 | 0.2 | 3 087 | 2.0 | 0.34 | 0.1 |
| Amphipoda | 91 | 0.1 | 1.06 | 0.5 | 197 | 0.3 | 2.30 | 1.4 | 288 | 0.2 | 3.36 | 0.8 |
| Gastropoda | 41 | tr | 0.38 | 0.2 | | | | | 41 | tr | 0.38 | 0.1 |
| Mysidacea | 17 | tr | 0.48 | 0.2 | | | | | 17 | tr | 0.48 | 0.1 |
| Trichoptera | 24 | tr | 0.77 | 0.3 | | | | | 24 | tr | 0.77 | 0.2 |
| Homoptera | | | | | | | | | | | | |
| Ephemeroptera | ļ | ļ | | | ļ | | ļ | | | | | |
| Trout eggs | | | | | 1 | | | | | | | |
| Silt / Sand | | | 24.21 | 10.4 | | | 22.00 | 13.3 | | | 46.21 | 11.6 |
| Plant material Debris | | | 35.13 | 15.1 | | | 14.21 | 8.6 | | | 49.34 | 12.4 |
| Number of fish | 58 | | 53 | | | 111 | | | | | | |

Table 11.—Food of white suckers (200 to 350 mm in length) from Lower and Upper Twin Lakes, Colo., in 1978, expressed as numbers, mass, percentage of total numbers, and percentage of total mass. Tr = less than 0.1 percent.



Figure 6. — Seasonal food of longnose suckers (100 to 200 mm in length) from Twin Lakes, Colo., in 1978, expressed as percentage of total numbers and percentage of total mass. Seasonal diversity indices with 95-percent confidence intervals are in parentheses.

 $\label{eq:chironomid} \begin{array}{l} \text{larvae} = LR & \text{Chironomid} & \text{pupae} = PU & \text{Cladocera} = CD & \text{Trichoptera} = TR & \text{Homoptera} = HM & \text{Silt/sand} = ST & \text{Plant material} = PM & \text{Debris} = DB \end{array}$

larvae, and mysid shrimp were eaten by fish in the lower lake only.

Primary food utilized during spring through fall was chironomid larvae (fig. 7). On a mass basis, chironomid larvae were used most during the summer. Chironomid pupae were relatively abundant in spring, but were absent from diets the rest of the year. Fingernail clams were most important in the fall, particularly to fish in the lower lake. A few clams were consumed in the spring. Cladocera were eaten throughout the year but constituted a larger percentage of total numbers in summer in both lakes Their contribution to total mass was minimal. Copepods were eaten only in the upper lake during spring and summer, and were relatively unimportant.

The diversity value was higher for the lower lake diets in summer and fall. Diets in the lower lake had significantly higher TU values in the fall, whereas a significantly higher value for diets from the upper lake was found in the spring.

Longnose suckers. – Gut contents of this group were dominated by chironomid larvae, which comprised 80.2 percent by total number and 55.8 percent by total mass (table 12). Cladocera ranked second in numbers but constituted only 0.8 percent by mass. Fingernail clams were a relatively important percentage of total numbers (total numbers were small) but they composed only 4.4 percent of the total mass. The non-animal component was made up of silt (21.3 percent by mass), debris (13.8 percent by mass) and plants (1.2 percent by mass.).

Longnose suckers from the upper lake fed almost exclusively on chironomid larvae, which composed 92.5 percent of total numbers and 61.5 percent of total mass. The other five forage species eaten made up only 7.5 percent of total numbers and 1.2 percent of total mass. Chironomid larvae were the predominant animal food item consumed by suckers from the lower lake; the lower lake suckers also consumed more fingernail clams and cladocera than the fish from the upper lake.

The contribution to the diets by chironomid larvae remained stable during the summer and fall, but was much higher for fish from the lower lake (fig. 8). Cladocera dominated the numerical component of the summer diets in the upper lake, but were far lower in the fall when fingernail clams predominated. Trichoptera larvae and homoptera were eaten only during the summer. In the fall, the silt and sand mass decreased slightly and debris increased.

The TU diversity index was significantly higher for diets from the lower lake during both seasons (0.514 to 0.166 in summer and 0.570 to 0.088 in fall). The index was also higher in the fall for fish from the lower lake and higher in the summer for longnose suckers from the upper

Table 12. – Food of longnose suckers (200 to 350 mm in length) from Lower and Upper Twin Lakes, Colo., in 1978, expressed as numbers, mass, percentage of total numbers, and percentage of total mass. Tr = less than 0.1 percent.

| | | Lowe | r Lake | | | Upper | r Lake | | | То | tal | |
|---|---------------------|---------------------|----------------------|---------------------|---------------|-------------|-----------------------|---------------------|------------------------|--------------------|------------------------|---------------------|
| Food Item | Num | bers | M | ass | Num | bers | M | ass | Num | bers | Ma | ass |
| | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent |
| Chironomid larvae Chironomid pupae Fingernail clams | 3 442 9 2 080 | 45.6 0.1 27.6 | 7,68 0.03 4.06 | 36.7 0.1 19.4 | 19 613 141 | 92.5 0.7 | 43.74 0.41 | 61.5 0.6 | 23 055 150 2 080 | 80.2 0.5 7.2 | 51.42 0.44 4.06 | 55.8 0.5 4.4 |
| Cladocera Oligochaeta | 1 966 | 26.1 | 0.53 | 2.5 | 728 | 3.4 | 0.20 | 0.3 | 2 694 | 9.4 | 0.73 | 0.8 |
| Copepoda Amphipoda Gastropoda Mysidacea | | | | | 232 | 1.1 | 0.03 | tr | 232 | 0.8 | 0.03 | tr |
| Trichoptera Homoptera Ephemeroptera Trout eggs | 47 | 0.6 | 1.51 | 7.2 | 24 471 | 0.1 2.2 | 0.07 0.11 | 0.1 0.2 | 69 • 471 | 0.2 1.6 | 2.28 0.11 | 2.5 0.1 |
| Silt / Sand Plant material Debris | | | 3.61 0.41 3.10 | 17.2 2.0 14.8 | | | 16.19 0.69 9.72 | 22.8 1.0 13.7 | | | 19.80 1.09 12.82 | 21.3 1.2 13.8 |
| Number of fish | | 1 | 8 | | | 3 | 3 | | | 5 | 1 | |



Figure 7. – Seasonal food of white suckers (200 to 350 mm in length) from Twin Lakes, Colo., in 1978, expressed as percentage of total numbers and percentage of total mass. Seasonal diversity indices with 95-percent confidence intervals are in parentheses.

 $\label{eq:chironomid} \begin{array}{ll} \mbox{larvae} = \mbox{LR} & \mbox{Chironomid} & \mbox{pupae} = \mbox{PU} & \mbox{Fingernail} & \mbox{clams} = \mbox{FN} & \mbox{Cladocera} = \mbox{CD} & \mbox{Oligochaeta} = \mbox{OL} & \mbox{OL} & \mbox{Oligochaeta} = \mbox{OL} & \mbox{Oligochaeta} = \mbox{OL} & \mbox{$



Figure 8.—Seasonal food of longnose suckers (200 to 350 mm in length) from Twin Lakes, Colo., in 1978, expressed as percentage of total numbers and percentage of total mass. Seasonal diversity indices with 95-percent confidence intervals are in parentheses:

 $\label{eq:chironomid} \begin{array}{l} \mbox{larvae} = \mbox{LR} & \mbox{Chironomid} & \mbox{pupae} = \mbox{PU} & \mbox{Fingernail} & \mbox{clams} = \mbox{FN} & \mbox{Cladocera} = \mbox{CD} & \mbox{Trichoptera} = \mbox{TR} & \mbox{Homoptera} = \mbox{HM} & \mbox{Silt/sand} = \mbox{ST} & \mbox{Plant} & \mbox{material} = \mbox{PM} & \mbox{Debris} = \mbox{DB} & \mbox{DB} & \mbox{Cladocera} = \mbox{Cladocera} & \mbox{Cladocera} = \mbox{Cladocera} & \mbox{Cladocera} = \mbox{Cladocera} & \mbox{Cladocera} = \mbox{Cladocera} & \mbox{Cladocera} = \mbox{TR} & \mbox{Cladocera} &$

lake. Chironomid larvae were the dominant animal food eaten by both species during all seasons studied. These larvae were found in 92.0 percent of adult white suckers in Many Points Lake, Minn. [32]. In spring, chironomid pupae ranked second in importance for Twin Lakes white suckers, but were seldom found other times because chironomids emerged during the second week of June and were less available after that time.

Cladocera were more numerous in summer gut samples of both species and were usually second in abundance after chironomid larvae. It is possible that cladocera were more prevalent during the warmer months. Pennak [34] stated that although their seasonal abundance is variable, some lakes show maximas in the warmer months.

Fingernail clams ranked second in importance in the fall. LaBounty and Sartoris [24] noted that the number of fingernail clams remained fairly stable throughout the year in the lower lake. Apparently clams were in some way more available to the suckers in the fall and were thus reflected in their diets.

Diets of longnose suckers, 200 to 350 mm total length, were similar to those of 100 to 200 mm total length, except that fingernail clams were included in the diets of the larger fish. White suckers, 200 to 350 mm total length, fed on a

number of prey items not eaten by smaller fish. These prey species (trichoptera and mysids) were larger sized organisms. More chironomid pupae were also used by the larger suckers.

The diversity index was generally significantly higher in the lower lake. Suckers of both species from the lower lake ate numerous chironomid pupae, fingernail clams, and cladocera during various seasons, thereby offsetting a dependence on chironomid larvae.

A similar trend of higher diversity index values for suckers from the lower lake in the fall was evident for both species. The importance of fingernail clams was the factor causing this occurrence.

Fish over 350 mm in length

White suckers.—The chief animal food of this size group was chironomid larvae, which composed 74.6 percent of total numbers and 61.3 percent of total mass (table 13). Cladocera ranked second in numbers but were only 2.2 percent of the total mass. Fingernail clams were third in importance by numbers and amphipods were ranked third by mass (2.4 percent). Traces (less than 1.5 percent) of mysids, trout eggs, and ephemeroptera larvae were found in the guts. This group ate 13 different food species. Silt and debris totaled 27.6 percent of the total mass of the diet.

Table 13.—Food of white suckers (over 350 mm in length) from Lower and Upper Twin Lakes, Colo., in 1978, expressed as numbers, mass, percentage of total numbers, and percentage of total mass. Tr=less than 0.1 percent.

| | | Lowe | r Lake | | | Uppe | r Lake | | Total | | | |
|-------------------------------|--------|---------|--------|---------|--------|---------|--------|---------|---------|---------|--------|---------|
| Food Item | Num | Numbers | | Mass | | bers | м | ass | Num | bers | Ma | ass |
| | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent | No. | Percent | Grams | Percent |
| Chironomid larvae | 73 304 | 76.9 | 163.47 | 56.5 | 83 475 | 72.7 | 186.15 | 66.2 | 156 779 | 74.6 | 349.62 | 61.3 |
| Chironomid pupae | 2 770 | 2.9 | 8.05 | 2.8 | 770 | 0.7 | 2.23 | 0.8 | 3 541 | 1.7 | 10.28 | 1.8 |
| Fingernail clams | 9 079 | 9.5 | 17.70 | 6.1 | 825 | 0.7 | 1.61 | 0.6 | 9 904 | 4.7 | 19.31 | 3.4 |
| Cladocera | 8 799 | 9.2 | 5.08 | 1.8 | 27 036 | 23.5 | 7.30 | 2.6 | 45 835 | 21.8 | 12.38 | 2.2 |
| Oligochaeta | | | | | 41 | tr | 0.19 | 0.1 | 41 | tr | 0.91 | 0.2 |
| Copepoda | 527 | 0.6 | 0.06 | ťr | 1 833 | 1.6 | 0.20 | 0.1 | 2 360 | 1.1 | 0.26 | tr |
| Amphipoda | 800 | 0.8 | 9.33 | 3.2 | 394 | 0.3 | 4.59 | 1.6 | 1 194 | 0.6 | 13.92 | 2.4 |
| Gastropoda | 16 | tr | 0.15 | tr | 17 | tr | 0.16 | 0.1 | 33 | tr | 0.31 | 0.1 |
| Mysidacea | 16 | tr | 0.45 | 0.2 | | | | | 16 | tr | 0.45 | 0.1 |
| Trichoptera | | | | | 250 | 0.2 | 8.03 | 2.9 | 250 | 0.1 | 8.03 | 1.4 |
| Homoptera | | | | | 121 | tr | 0.03 | 0.1 | 121 | tr | 0.03 | tr |
| Ephemeroptera | | | | | 40 | tr | 0.72 | 0.3 | 40 | tr | 0.72 | 0.1 |
| Trout eggs | | | | | 66 | tr | 6.76 | 2.4 | 66 | tr | 6.76 | 1.2 |
| Silt / Sand Plant material | - | | 30.53 | 10.6 | | | 22.92 | 8.1 | | | 53.45 | 9.4 |
| Debris | | | 63.44 | 21.9 | | | 40.48 | 14.4 | | | 103.92 | 18.2 |
| | | | | | | | | | | | | |
| Number of fish | 60 | | | | 3 | 2 | | 92 | | | | |

Suckers in the upper lake ate more chironomid larvae (by mass) than those fish in the lower lake, but lower lake diets were composed of more chironomid pupae. Fingernail clams were much more abundant in gut contents of fish from the lower lake (9.5 percent by numbers and 6.1 percent by mass). Fish from the upper lake used a larger variety of invertebrate species.

Chironomid larvae were the major animal-food constituent from spring to fall, being most abundance in the spring (fig. 9). Chironomid pupae were found only in the spring diets. Fish from the lower lake used clams extensively in the fall, only slightly in the summer and not at all in the spring. Cladocera became numerically important in summer in the upper and lower lakes. They were present in diets at all other times, but were of negligible value on a mass basis. Some copepoda and trichoptera larvae were found but only in summer. Trout eggs were impotant to fish from the upper lake in the fall. Significantly higher diversity index values were calculated for summer diets of suckers from both lakes.

Food of white suckers over 350 mm long was similar to that of white suckers 200 to 350 mm long, with chironomid larvae remaining the dominant animal food item. Campbell [8] found that large white suckers fed on slightly more chironomid larvae than medium sized fish (120 to 245 mm) but in both cases, the larvae were predominant. Nelson [29] noted that chironomid larvae and mollusca were used more by larger white suckers (over 356 mm) in Green Mountain Reservoir, Colo.

Larger food items were eaten by the large suckers in Twin Lakes. Lake trout eggs were eaten in the fall. Amphipods were eaten infrequently by small suckers, but were more important to those individuals over 350 mm long.

Large numbers of cladocera were consumed during the summer, which tended to reduce the relative importance of the chironomid larvae. A high TU value resulted because of the evenness in numbers within taxa.

General discussion

The major difference in food habits of suckers from the upper and lower lake is the greater importance of chiromonid larvae to the diets of suckers in the upper lake. In contrast, sucker diets in the lower lake were composed of larger percentages of less common food taxa. This trend is evident for both species in all seasons sampled. Eder and Carlson [14] concluded that carp (a more efficient bottom feeder in their view), in competition with suckers, took a larger percentage of less available food items in the South Platte River, Colorado. A similar situation seems to exist in Lower Twin Lake.

Based on catch data, the lower lake contained a higher density of suckers than the upper lake. In addition, the diversity of benthic organisms in Lower Twin Lakes is greater. The combination of these factors may intensify competition for the food available and result in increased consumption of less common food items. If this is true, suckers in the lower lake especially would be considered opportunistic feeders, taking whatever foods were available in attempts to reduce the competition. The possibility also exists, however, that food items found in the lower lake are not present in the upper. This would account for the greater reliance on chironomid larvae in the upper lake. A greater diversity of food source items has been found in the lower lake (personal communication, James LaBounty, Water and Power Resources Service, Denver, Colo.).

In view of this, seasonal differences in the diets could be explained by the increased availability of certain invertebrate taxa at various seasons. Chironomid pupae were eaten in the spring when they were most available. Cladocera, which may reach highest densities during the warmer months, were found more often in summer diets. In the fall, fingernail clams became much more important.

The diversity index (TU) was computed using the number of different food taxa consumed by a certain group of fish as well as the number of individuals consumed by the fish in each of those taxa. It, therefore, measured the breadth and depth of the diet. The evenness of individual numbers among the taxa used was equally as important as the variety of taxa consumed. Fish that ate a wide variety of food taxa did not necessarily have a high diversity index value if most of the individual food items eaten were of one species (taxa). Suckers in the lower lake usually had the highest TU value in the fall. During this time, the variety of taxa eaten was low, but the individual items were spread more evenly among those taxa.



Figure 9. – Seasonal food of white suckers (over 350 mm in length) from Twin Lakes, Colo., in 1978, expressed as percentage of total numbers and percentage of total mass. Seasonal diversity indices with 95-percent confidence intervals are in parentheses.

Reproductive Biology

Sex ratio and maturity

White suckers. – Of the mature fish captured, 346 (40 percent) were males and 525 (60 percent) were females. Chi-square testing revealed these proportions to be significantly different $(X^2 = 36.75, 1 \text{ df})$.

Females first reached maturity at AG V and males at AG VI. However, due to the low number of mature females at AG V and VI, it is believed they are not mature, as a group, until AG VII. More fish were sexed as males than females at AG VI. This occurred at no other age, and suggests that males reached maturity, on the average, at AG VI, one year earlier than females. At AG VII, 68 percent of the fish were mature and at AG VIII, 88 percent. Some fish were not mature at AG IX.

Longnose suckers. – Sexes were determined for 344 fish and, of these, 159 (46 percent) were males and 185 (54 percent) were females. A chi-square test indicated that there was no significiant difference in sex proportions $(X^2 = 1.96, 1 \text{ df})$.

Both sexes had mature members at AG II, however, only 20 percent of AG II fish were mature. By the fourth year, 91 percent of all fish were mature, and it was evident that both sexes had reached maturity at AG III. All fish AG IV and older were mature.

Hayes [20] reported that sexes of white and longnose suckers in Shadow Mountain Reservoir, Colo, were in a 1:1 ratio. This tendency was found for white suckers by Lalancette [25]. Female longnose suckers outnumbered males by 2.5:1 in Great Slave Lake [19]. The female white suckers in Twin Lakes were much longer lived than males, and the female longnose suckers slightly outlived males. Differential mortality for the white suckers is reflected in the large female to male ratio. The longnose sucker sex ratio was probably equal because of the nearly equal longevity of the sexes. Geen et al. [16] found the female:male ratio of a spawning group of longnose suckers to increase each year when they returned to the same area. He attributed this to differential mortality. The investigations of Hayes and Lalancette [20, 25], which reported the sex ratios of 1:1, also reported the sexes to have equal longevity.

A high reproductive potential is possible with a population that has a large percentage of females, as is the case with white suckers in Twin Lakes. This potential is curtailed for these fish, however, due in part to their delayed maturity. Mortality acts for a longer time on the population before they are able to reproduce, thus reducing the size of the spawning population.

A survey of the literature indicated an earlier age at maturity for white suckers and a later maturation for longnose suckers than was observed in the present study. Hayes [20] found that male white suckers matured at AG III and females at AG V, and male longnose matured at AG III and females at AG IV. Both sexes of white suckers in a Quebec lake matured during their third year [25]. Male longnose matured one year earlier (IV) than females (V) in Yellowstone Lake [6].

Fecundity

White suckers.—Estimates were made on 19 fish captured in June, ranging in size from a 316-mm (365-g) fish with 10 888 eggs to a 441-mm (844-g) female containing 21 970 eggs (table 14). Eggs per gram of body mass ranged from 33 to 24 and showed no trends with increasing mass of the fish. Ovary mass as percent of body mass (less ovary) was highest for mid-sized fish.

Total length in millimeters (L) was regressed on total egg numbers (Y) giving the logarithmic equation:

 $\log Y = 2.29 \log L - 1.70$ (r² = 0.95) (Eq. 17)

The relationship of female mass in grams (M) to total egg count (Y) was linear:

$$Y = 20.74 M + 2700 (r^2 = 0.93)$$
 (Eq. 18)

Longnose suckers. — Number of eggs ranged from 2361 to 6750 for females of 176-mm (49 g) and 264-mm (181 g) length, respectively (table 15). Eggs per gram of fish mass (less ovary) ranged from 41 to 76. Ovary mass as percent of body mass increased with increasing size of the fish, except for the largest individual.

The relationship of total length in millimeters (L) to total egg count (Y) was logarithmic:

$$\log Y = 1.71 \log L - 0.292$$
 (r² = 0.95) (Eq. 19)

| Length (mm) | Mass (g) | Ovary mass (g) | Number of eggs | Ovary mass as percentage of of body mass | Eggs per gram of body mass |
|----------------|-------------|-------------------|-------------------|--|----------------------------|
| 316 | 365 | 37.1 | 10 888 | 11.3 | 33 |
| 320 | 392 | 40.0 | 11 072 | 11.4 | 31 |
| 336 | 443 | 42.7 | 11 561 | 10.7 | 29 |
| 350 | 437 | 40.2 | 12 321 | 10.1 | 31 |
| 355 | 488 | 52.1 | 12 106 | 11.9 | 28 |
| 357 | 492 | 56.1 | 12 560 | 12.9 | 29 |
| 362 | 528 | 64.2 | 13 400 | 13.8 | 29 ⁺ |
| 370 | 538 | 62.9 | 14 431 | 13.2 | 30 |
| 372 | 569 | 59.9 | 14 796 | 11.8 | 29 |
| 378 | 585 | 69.3 | 15 321 | 13.4 | 30 |
| 385 | 630 | 63.3 | 15 128 | 11.2 | 27 |
| 393 | 634 | 65.8 | 15 630 | 11.6 | 28 |
| 394 | 703 | 68.8 | 16 822 | 10.2 | 27 |
| 396 | 730 | 67.6 | 15 943 | 10.2 | 24 |
| 411 | 750 | 71.7 | 17 722 | 10.6 | 26 |
| 421 | 797 | 87.0 | 19 847 | 12.3 | 28 |
| 426 | 923 | 97.1 | 20 134 | 11.8 | 24 |
| 430 | 884 | 96.0 | 22 976 | 12.2 | 29 |
| 441 | 844 | 88.4 | 21 970 | 11 7 | 29 |

Table 14.—Ovary mass, total number of eggs, ovary mass as percent of body mass, and eggs per gram of body mass for various sized white suckers. Captured in 1978 from Twin Lakes, Colo.

Table 15.—Ovary mass, total number of eggs, ovary mass as percent of body mass, and eggs per gram of body mass for various sized longnose suckers. Captured in 1978 from Twin Lakes, Colo.

| Length (mm) | Mass (g) | Ovary mass (g) | Number of eggs | Ovary mass as percentage of of body mass | Eggs per gram of body mass |
|----------------|-------------|-------------------|-------------------|--|-------------------------------|
| 168 | 53 | 6.4 | 3335 | 13.7 | 72 |
| 176 | 49 | 4.0 | 3261 | 8.8 | 72 |
| 177 | 63 | 8.6 | 3420 | 15.8 | 63 |
| 180 | 66 | 9.7 | 3904 | 17.3 | 69 |
| 182 | 61 | 9.2 | 3534 | 17.8 | 68 |
| 191 | 64 | 10.3 | 4062 | 19.1 | 76 |
| 204 | 82 | 14.5 | 4769 | 21.5 | 71 |
| 208 | 86 | 15.6 | 4989 | 22.2 | 71 |
| 264 | 181 | 17.2 | 6751 | 10.5 | 41 |

Mass of the fish (*M*) regressed on total egg count (*Y*) resulted in a linear equation:

Y = 26.80 M + 2126 (r² = 0.91) (Eq. 20)

Most researchers have reported longnose and white suckers to be quite fecund. Two suckers from Great Slave Lake, 475 and 555 mm long, contained 17 525 and 60 307 eggs, respectively [19]. White suckers from Waskesiu Lake, Saskatchewan had a range of 24 eggs per gram for a 405-mm female to 28 eggs per gram for a 496-mm fish [8]. Hayes [20] estimated fecundity for a number of white and longnose suckers and found that the number of eggs per gram of female ranged from 24 to 49 for white suckers, with no increase with increasing size of fish. Lalancette [25] investigated a population of white suckers that had very low fecundity. The largest recorded number of eggs was 787; this fish was only 66.2 g.

The high correlation for the relationships indicates that fecundity is directly related to fish size (both length and mass). All fish examined were in a similar state of maturity and little variation in size of the eggs was evident.

There appears to be a direct relationship between the length of female longnose suckers in Twin Lakes and their ovary mass:total body mass proportion. This proportion is highest for white suckers at intermediate size (355 to 393 mm in length).

Spawning

White suckers.—At the end of May, all mature white suckers were in a gravid condition (sex organs distended, testis white, ovaries with round nearly ripe eggs). Of 11 fish captures on June 5, 6 were ripe males (milt flowing with pressure) and 5 were gravid females. Monthly gill netting of both lakes from June 14 to 18 produced 82 mature females and 20 mature males. Of these, 80 percent of the females were ripe or spent and 100 percent of the males were spent. All mature fish captured after this time were found to be spent. There were no differences in percentage of spent fish between the two lakes.

The white suckers did not use the Lake Creek inlet for spawning. Gill nets placed near the mouth of Lake Creek produced few fish, as did electrofishing of the first 1600 meters of Lake Creek in early June. The inlet was examined for suckers during June and July with negative results. In addition, no sucker fry were found around the Lake Creek Inlet during the larval fish surveys.

Snorkeling at night was attempted to observe suckers in the act of spawning. Visibility was generally low and no suckers were seen. During electrofishing operations on the night of June 27, a congregation of large suckers was seen south of the powerplant in approximately 1 m of water. Groups of large suckers were usually not observed during electrofishing; it was thought that these fish were engaged in spawning activity.

Larval fish first appeared along shoreline areas on July 12. Location and relative abundance were noted during bi-weekly surveys of both lakes (fig. 10; table 16). Highest numbers were observed at stations A, F, and G. Only a small number of larvae were seen in the upper lake.



Figure 10. - Location of larval survey stations in Twin Lakes, Colo., in 1978.

| Station | Shoreline | Abundance | | | | | | | |
|---------|--------------|-----------|----------|-----------|-------------|--|--|--|--|
| | | July 27 | August 8 | August 24 | September 8 | | | | |
| Α | Sand | 4 | 3 | 1 | 1 | | | | |
| В | Rocks | 3 | 2 | 2 | 2 | | | | |
| С | Sand/rocks | 3 | 3 | 2 | 1 | | | | |
| D | Sand/2 | 0 | 0 | | | | | | |
| E | Boulders | 0 | 0 | 0 | 0 | | | | |
| F | Sand | 4 | 4 | 2 | 2 | | | | |
| G | Sand/gravel | 5 | 5 | 4 | 0 | | | | |
| н | Sand/rocks | 3 | 2 | 4 | 2 | | | | |
| l l | Rocks | 1 | 1 | 1 | 2 | | | | |
| J | Gravel/rocks | 0 | 0 | 2 | 1 | | | | |
| K | Sand/rocks | 1 | 0 | 0 | 0 | | | | |
| L | Gravel/rocks | 1 | 0 | 0 | 0 | | | | |
| Μ | Silty sand | 0 | 0 | 0 | Ō | | | | |
| Ν | Silty sand | 0 | 0 | 0 | 0 | | | | |
| 0 | Sand/gravel | 1 | Ō | Ō | ŏ | | | | |
| Р | Gravel/rocks | 0 | 0 | 1 | 0 | | | | |

Table 16. – Index of larval fish densities and description of stations in Twin Lakes, Colo.

Temperatures were recorded in the lower lake during the time of white sucker spawning (table 17). Depending on depth of spawning, temperatures probably ranged from 8.4 to10.0 °C at onset of spawning.

Longnose suckers. – Few longnose suckers were captured in May, but all mature fish that were captured were gravid. June gill net sampling revealed that 29 of 49 females (59 percent) were spent and 39 of 40 males (97 percent) had already spawned. Of 12 males caught in July, 10 (83 percent) were spent, as were 11 of 18 females (61 percent). In August, a larger sample of fish (73) yielded 86 percent spent females and 92 percent spent males. Eggs of the females retaining eggs at that time were opaque. Larval suckers could not be identified to species and all observations reported in the previous section for white suckers may be applied to the longnose suckers as well.

A correlation between initiation of spawning activity and water temperature was determined by Campbell [8] for white suckers and by Brown and Graham [6] for longnose suckers. Geen et al. [16] counted fewer numbers of spawning suckers when stream temperatures declined. They also found that longnose suckers spawned earlier than white suckers. Hayes [20] determined that white suckers used areas within Shadow Mountain Reservoir from July 1 to 14, when water temperatures were 14.7 to 18.6 $^{\circ}$ C.

Depth of spawning would have to be determined in Twin Lakes in order to reveal temperature preferences. Suckers may select for a specific depth, a specific temperature, or both. There did not appear to be any differences in time of spawning between fish in the two lakes, even though temperatures in the upper lake are usually from 2 to 4 °C colder at all depths because of the inflow from Lake Creek. It seems plausible that the suckers may respond to stimuli other than temperature. Spawning in response to photoperiod may account for the coinciding spawning periods of the suckers in the two lakes.

Longnose suckers in Twin Lakes appeared to have a longer spawning period than did the white suckers. Hayes [20] suggested that sporadic spawning occurred from late May until mid-August, based on occurrence of fry in the reservoir. In Twin Lakes, the longnose suckers may have developed eggs and yet not have spawned, thereby accounting for the gravid females found in August. Geen et al. [16] concluded that some longnose suckers did not spawn in consecutive years, and Harris [19] reported gravid females returning from spawning runs.

| Depth (m) | June 5 | June 16 | June 27 | July 7 | July 18 | July 30 |
|-----------|--------|---------|---------|--------|---------|---------|
| Surface | 10.0 | 11.5 | 12.7 | 15.2 | 15.5 | 17.1 |
| 3 | 9.4 | 11.0 | 12.5 | 13.5 | 15.0 | 16.4 |
| 6 | 9.0 | 10.0 | 12.1 | 11.7 | 12.7 | 14.6 |
| 9 | 8.9 | 9.5 | 10.2 | 10.6 | 11.5 | 13.1 |
| 12 | 8.5 | 9.5 | 10.0 | 10.4 | 10.7 | 10.7 |
| 15 | 8.4 | 9.0 | 9.7 | 9.8 | 10.0 | 10.1 |

Table 17. – Water temperatures (°C) at various depths and dates in Twin Lakes, Colo.

Hayes [20] concluded that fry were observed only at locations which he had found to be spawning grounds for adult suckers. If this relationship existed at Twin lakes, it could be inferred that the suckers were making use of areas near stations A, F, and G. Stations A and F had shallow shorelines with sand and gravel substrates. Station G had a sand substrate and a steep drop-off. Hayes described a typical white sucker spawning area as having water from 0.5 to 2.1 m deep and a gravel substrate. All areas in Twin Lakes which had high initial abundance of fry are considered sheltered. The possibility also exists that fry may have sought out these areas where wind and wave action are minimal.

Sucker fry appeared 33 days after the first suckers spawned in tributaries to Yellowstone Lake [6]. Geen et al. [16] noticed fry migrating 1978 data

back to Sixteenmile Lake 30 days after the onset of spawning activity. This included a 2-week hatching time at temperatures less than 10 °C followed by 1 to 2 weeks development in the gravel before moving. In Twin Lakes, larvae were seen on July 12; if development proceeds as noted, this would place first spawning at June 9 to 14.

Distribution

White suckers

Locations of gill netting stations are shown in figure 11. Monthly gill net catches were expressed as numbers of fish captured at each station (table 18), and were plotted as catch per hour per net for each season and station (fig. 12).



Figure 11.-Location of gill netting stations in Twin Lakes, Colo., in 1978.



= fall

Figure 12.-Seasonal catch rates [(fish/h)/net] of white suckers in gill nets at stations 1 through 12 in Twin Lakes, Colo., in 1978. NC = no catch.

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| Month | Length of | | Stations Lower Lake Upper Lake | | | | | | | | | | | |
|-----------|----------------|------------|-----------------------------------|-------------|-------------|-------------|--------------|--------------|------------|-------------|------------|-------------|----------|--------------|
| | Set (hours) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| Мау | 9.28 | 10 (8) | 5 (3) | 7 (3) | 11 (4) | 33 (10) | 8 (1) | 7 (6) | 2 (2) | 11 (2) | 8 (5) | 14 (7) | 1 (0) | 117 (51) |
| June | 9.00 | 14 (10) | 11 (6) | 14 (11) | 26 (13) | 16 (8) | 23 (13) | 36 (26) | 1 (1) | 3 (1) | 5 (2) | 4 (4) | 0 (0) | 153 (94) |
| July | 9.17 | 6 (5) | 15 (12) | 33 (21) | 56 (36) | 28 (8) | 8 (7) | 20 (9) | 2 (2) | 12 (8) | 7 (1) | 8 (6) | 0 (0) | 195 (115) |
| August | 10.23 | 14 (13) | 57 (45) | 18. (8) | 10 (1) | 82 (49) | 54 (39) | 46 (40) | 1 (1) | 40 (28) | 9 (5) | 48 (35) | 0 (0) | 379 (264) |
| September | 11.75 | 26 (17) | 22 (22) | 21 (12) | 6 (4) | 9 (1) | 50 (42) | 31 (30) | 9 (7) | 35 (24) | 22 (17) | 21 (18) | 0 (0) | 252 (194) |
| October | 12.95 | 26 (20) | 25 (20) | 13 (7) | 9 (5) | 12 (8) | 36 (20) | 41 (35) | 13 (12) | 21 (10) | 14 (6) | 15 (12) | 1 (0) | 228 (155) |
| Total | | 96 (73) | 135 (108) | 106 (72) | 118 (63) | 180 (84) | 179 (122) | 181 (146) | 28 (25) | 122 (74) | 65 (38) | 110 (78) | 2 (0) | |

 Table 18. – Total numbers of white suckers caught in gill nets from Lower and Upper Twin Lakes,

 Colo. Number of mature fish in parentheses.

1978 data

Spring. – Highest catches in the lower lake were made at stations 4, 5, and 7. The majority of the catch at stations 4 and 5 was immature suckers, but at station 7, they contributed only 24 percent of total catch. The lowest catch in the lower lake occurred at stations 8, 2, and 1. Most stations in the upper lake had similar catch rates except for 12, which was far lower.

Summer. — The catch rate increased at all stations except 1 and 8, which also had the lowest catches in the lower lake. The highest catches in the lower lake were at stations 5 and 2, with 48 percent of the suckers at station 5 being immature. In the upper lake, stations 9 and 11 had the highest catches. No fish were captured in deep water in the upper lake (station 12).

Fall. — The catch rate decreased at most stations in the lower lake but increased at stations 1, 6, and 8. Catch rate at stations 1, 6, and 7 was the highest for lower lake stations during the fall. Large decreases in catch were evident at stations 4 and 5. In the upper lake, the highest catches were made at station 9 and the lowest at station 12. Vertical distribution.—The percentage of total catch of white suckers at each depth is shown in figure 13. From June to October, a majority of fish were found within 2 m of the bottom. However, in July, 54 percent of the suckers were found 3 to 6 m from the bottom.

Longnose suckers

Total numbers of longnose suckers caught each month at each station are shown in table 19. Catch was also expressed as fish per hour per net for each season and station (fig. 14). Seasons were: spring (May and June), summer (July and August); and fall (September and October).

Spring. — The highest catch was recorded at stations 1 and 7 in the lower lake and station 11 in the upper. No fish were captured at stations 2, 3, 5, 8, 10, and 12.

Summer.—The catch increased greatly at stations 2 and 7 in the lower lake, and at 9 and 10 in the upper lake. The catch decreased at stations 1, 4, and 11.



Figure 13. - Vertical gill net catch of white suckers as a percentage of monthly catch, in relation to depth in Lower Twin Lakes, Colo., in 1978.

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Fall.—The catch was highest at station 1 (powerplant) in the lower lake. Station 9 had the highest catch of all upper lake stations.

Vertical distribution.—No longnose suckers were captured in vertical gill nets. Characteristics of gill netting stations are shown in table 20. In the spring, large catches of white suckers were evident at the shallow stations (4 and 5) but a majority of those fish were immature. The mature fish were more evenly distributed. A higher catch of adult fish was made at station 7 in the lower lake and this may correspond to spawning activities in this area.

During summer, catches of white suckers were higher than spring catches at most stations, and it is thought that increased activity associated with warmer water was the reason. Smaller fish in the shallow areas of the lower lake accounted for much of the catch at those stations, while large fish seemed to prefer areas of sharper

| Table 19. – Total numbers of longnose suckers cau | ught in gill nets from Lower and Upper Twin |
|---|---|
| Lakes, Colo. Number of mate | ure fish in parentheses. |

| Month | Length of | | | I | Lower | Lake | | Stat | tions | | Upper | Lake | | |
|-----------|----------------|-----------|----------|----------|----------|----------|----------|------------|----------|------------|----------|------------|----------|------------|
| | Set (hours) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| May | 9.28 | 0 (0) | 0 (0) | 0 (0) | 1 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 2 (2) | 0 (0) | 3 (2) | 0 (0) | 6 (4) |
| June | 9.00 | 3 (3) | 0 (0) | 0 (0) | 3 (2) | 0 (0) | 1 (1) | 8 (8) | 0 (0) | °0 (0) | 0 (0) | 7 (7) | 0 (0) | 22 (21) |
| July | 9.17 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 1 (1) | 11 (11) | 0 (0) | 3 (3) | 5 (5) | 4 (4) | 0 (0) | 24 (24) |
| August | 10.23 | 0 (0) | 8 (8) | 0 (0) | 2 (2) | 0 (0) | 0 (0) | 5 (5) | 0 (0) | 5 (5) | 0 (0) | 4 (4) | 0 (0) | 24 (24) |
| September | 11.75 | 3 (3) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 1 (1) | 0 (0) | 0 (0) | 16 (15) | 1 (1) | 0 (0) | 0 (0) | 21 (20) |
| October | 12.95 | 4 (4) | 1 (1) | 0 (0) | 1 (1) | 3 (2) | 3 (3) | 0 (0) | 0 (0) | 5 (4) | 2 (2) | 5 (4) | 0 (0) | 24 (21) |
| ſotal | | 10 (9) | 9 (8) | 0 (0) | 7 (5) | 3 (2) | 6 (6) | 24 (24) | 0 (0) | 31 (29) | 8 (8) | 23 (21) | 0 (0) | |
| | | | | | | | | | | | | | | 1978 |

Table 20. – Description of gill net stations in Lower and Upper Twin Lakes, Colo.

| Stati | on [| Depth (m) | Description |
|---------------|--|---|--|
| Lower Lake | 1 3 2 4 3 4 4 2 5 3 6 4 7 3 8 | .7-12.2 .6-13.7 6.1 .4-3.7 .0-4.6 .6-13.7 .7-13.7 21.0 | Rocks (shallow)- glacial flour (deep) Small rocks (shallow)-glacial flour (deep) Sand with some plants Sand with some plants Sand and large rocks with plants Boulders (shallow)-glacial flour (deep) Sand (shallow)-glacial flour (deep) Glacial flour |
| Upper Lake | 9 2 10 3 11 3 12 | .1-6.1 .0-9.8 .0-10.7 22.0 | Sand with some plants Small rocks (shallow)-sand (deep) Sand and rocks (shallow)-glacial flour (deep) Glacial flour |



Figure 14.—Seasonal catch rates [(fish/h)/net) of longnose suckers in gill nets at stations 1 through 12 in Twin Lakes, Colo., in 1978. NC = no catch.

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drop-offs (stations 2, 6, 7, and 11). Fish were occasionally captured in deep water (more than 21 m) but these also were large fish.

Catch rate of white suckers in shallow areas greatly decreased during fall. LaBounty and Sartoris [24] reported that chironomid larvae were reduced in numbers (from April to November 1975) due, in part, to predation by suckers, and that densities were higher at greater depths in all seasons. Suckers may have moved to deeper water after depleting chironomid larvae by predation in the shallows. This conjecture is supported by the increased catch of white suckers at the deep station (No. 8) in the lower lake. Dyer [13] found that longnose suckers moved offshore in the fall in Lake Superior. Walch [47] determined that lake trout in Twin Lakes used shallow areas near Hartmann Point (station 5) for spawning. Movement out of this area by white suckers may have been in response to the presence of lake trout, many of which were large fish.

Due to small numbers of longnose suckers captured, analysis of distribution is more difficult for this species. One condition which seems apparent from the gill net catch data is a higher density of longnose suckers in the upper lake. Electrofishing was used to capture most longnose suckers, although it was not used as a standard gear effort. This technique produced approximately equal numbers of longnose suckers from each lake. However, more shoreline area was covered in the lower lake, thus supporting the hypothesis that a higher density of longnose suckers exists in the upper lake. A qualitative analysis of electrofishing catch indicated that longnose suckers and white suckers less than 300 mm long share similar habitats. During electrofishing efforts in June, the highest numbers of both species were taken in the north bay (station 3). In October, more individuals of both species were found near stations 6 and 7, which are deeper drop-off areas.

Gill nets were effective only during hours of darkness in Twin Lakes and no information on daytime distribution was gathered. Lack of catch during the day may be a result of the fish avoiding the net by sight, or more probably, less movement during the day. Campbell [7] found aquarium-held fish to disperse more at night and show increased swimming rates. Spoor and Schloemer [42] concluded that the visibility of the gill net did not result in a differential catch rate between day and night sets.

From June to October, white suckers frequently were found at depths of less than 2 m in Twin Lakes. The reason for this depth selection is unknown. Gut contents of suckers caught in open water were compared to food of those captured on the bottom and no obvious differences were found. Emery [15] observed longnose and white suckers in Ontario lakes and determined that during the day, fish were near the bottom, but not on it. At night the fish were more active and were feeding directly on the bottom. In the present study, the vertical nets were set for 24 hours and it is not known whether the suckers were captured during the night or day. Horak and Tanner [21] used vertical nets in Horsetooth Reservoir, Colorado, and found that

| Table 21.—Age frequency of white suckers from 7 | Twin Lakes, | Colo. Ca | aptured with g | gill nets in | 1978. |
|---|-------------|----------|----------------|--------------|-------|
|---|-------------|----------|----------------|--------------|-------|

| Month | Age Groups | | | | | | | | | | |
|-------|------------|------|------|------|------|------|------|------|------|------|------|
| | י1975 | 1974 | 1973 | 1972 | 1971 | 1970 | 1969 | 1968 | 1967 | 1966 | 1965 |
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| June | 2 | 7 | 11 | 19 | 20 | 25 | 23 | 20 | 13 | 7 | 6 |
| July | 0 | 25 | 33 | 23 | 27 | 36 | 24 | 16 | 6 | 3 | 2 |

'The corresponding year of the hatch

68 percent of white suckers were caught within 1.5 m of the bottom and 85 percent within 3 m of the bottom in an area of the reservoir that ranged from 5.5 to 12.2 m in depth.

Mortality

White suckers

Ages of all white suckers in the June and July gill net samples were determined (table 21). Fish were first fully captured at AG VII. Mortality was calculated using these data and methods of Robson and Chapman [39]. The instantaneous mortality rate was determined to be 0.533 with a 95-percent confidence interval of 0.496 to 0.570.

The method of Ssentongo and Larkin [44] also was employed to allow more fish to be used in the computation of a mortality coefficient. A total of 409 white suckers was included. The average length in the catch was 373 mm. The instantaneous mortality rate with 95-percent confidence limits was then 0.597 ± 0.013 .

Longnose suckers

Complete aging of a total catch of longnose suckers was not performed, and the survival was estimated (using the lengths of 173 fish) by the method of Ssentongo and Larkin [44]. The average length at first capture was 170 mm and the average length in the catch was 237 mm. These numbers were used with the coefficients L and K, from the Von Bertalanffy equation, to calculate an instantaneous mortality rate of 0.532 with 95-percent confidence limits of 0.492 to 0.573.

Coble [10] analyzed tagging information to estimate survival of white suckers from Lake Huron. His estimates ranged from 0.600 to 0.758. He also used length frequency data to correlate numbers at successive lengths with survival rate. Estimates ranged from 0.885 for fish from 392 to 418 mm (fork length) to 0. 517 for fish 494 to 519 mm long. Olson [31] reported a survival rate of 0.869 for white suckers of all ages during 1957 and 1958 in Many Points Lake, Minn. Survival rate for white suckers in Gamelin Lake, Quebec, during 1970 and 1971 was found to be 0.550 for males and 0.560 for females [25].

Population Estimates

From August 15 to October 18, 203 white suckers were marked with a fin clip to identify area of capture and released. During the period August 16 to November 2, nine fish were recaptured. All were caught in the lower lake near the general area of first capture, except for one fish which had moved to the upper lake and one which had moved from the northwest corner of the lower lake to the northeast section. A Schnabel estimate [38] was calculated using those marked suckers captured in the lower lake. All suckers caught in the upper lake (all unmarked and the single marked) were not included in this estimate. The Schnabel equation [38] was used to calculate a population estimate of 8366 with a 95-percent confidence interval of 4942 to 27 248.

The wide confidence interval of the estimate is a result of the small numbers of fish marked and the low return of those fish. As an estimate of the lower lake population, it probably is an underestimate. A large number of the suckers marked were from the south side of the lower lake. It was in this same general area that the fish were recaptured. An assumption that all fish be randomly distributed was therefore violated, and the estimate was essentially for the south side of the lower lake.

Sucker-Lake Trout Relationships

Suckers as prey of lake trout

Of approximately 150 lake trout stomachs examined during the period of this study, 4 contained a total of 5 suckers (3 white, 2 unknown). The lake trout ranged in size from 411 to 543 mm in total length. Griest [18] examined 216 stomachs of Twin Lakes lake trout in 1974 and 1975 and determined that suckers were taken infrequently (6.2 percent by occurrence) but constituted 49.2 percent of total food volume. Suckers were found more frequently in lake trout than more 400 mm long.

Rawson and Elsey [37] noted that less than 7 percent of 50 lake trout examined in Pyramid Lake, Alberta, contained longnose suckers. They believed that the percentage might have increased had larger fish been examined. Martin [27] found that lake trout preferred yellow perch but occasionally took white suckers. DeRouche [11] found that white suckers were seldom eaten by adult lake trout, however, they became an important part of the diet of large lake trout (more than 2.7 kg).

Walch [47] used biotelemetry techniques to determine distribution of the lake trout in Twin Lakes. He found that they were equally distributed in all areas of the lake during spring and fall. In the summer, they were more abundant in deeper, cooler water (12 °C), however, large fish (over 550 mm) invaded warmer waters. Walch attributed movements into warmer water to feeding behavior. Suckers were prevalent in habitat similar to that of the lake trout during spring and fall. During summer, suckers and lake trout were more segregated but suckers were susceptible to predation due to the movements of the trout into warmer water. Martin [27] determined that during summer, white suckers were usually restricted to areas within or above the thermocline, while lake trout were typically below it. He thought that suckers eaten in the summer were taken by the lake trout which had entered warmer water to feed.

Lake trout egg predation by suckers

Gut contents of large (350 mm or more) white suckers captured in the fall from Upper Twin Lakes contained a total of 66 trout eggs which made up 13.9 percent of total food mass for that group. In gill nets intended to capture spawning lake trout in the lower lake, 13 white suckers were caught, of which 6 contained trout eggs. These suckers were all more than 350 mm in length.

The amount of egg predation by suckers in Twin Lakes was probably underestimated because the fish used for food analysis were captured in mid-October, just prior to the peak of lake trout spawning. If suckers captured in early November over spawning areas had been included, egg predation may have appeared to be greater.

Brown trout spawning occurred during the same period as did lake trout, and eggs eaten by suckers could not be identified by inspection. The eggs were tested against known lake trout and brown trout eggs using electrophoretic techniques by Dr. Donald Nash of Colorado State University. The "unknown" eggs were determined to be from lake trout. It appears that sucker predation on lake trout eggs was rather minimal in Twin Lakes. Numerous nets were set over spawning areas but few suckers were taken. Of those captured, only the large white suckers had eaten eggs. Atkinson [1] found 18 or 29 white suckers captured over lake trout spawning beds to contain 1477 eggs. These captured suckers were all of a large size. Rawson and Elsey [37] failed to find eggs in the stomachs of longnose suckers captured over lake trout spawning beds.

Because suckers have limited abilities to obtain eggs from rock crevices, most eggs eaten probably were in more accessible locations. The probability of these eggs hatching properly, had they not been eaten, was in all likelihood reduced. DeRouche and Boyd [12] made the observation that lake trout eggs that were eaten were probably not lodged deeply in crevices of spawning rubble. They also determined that lake trout were predators on their own eggs.

Competition for food

Griest [18] determined that *Mysis relicta* was the predominant food item of the lake trout in Twin Lakes. He also found that chironomid larvae and pupae were eaten by 48.8 percent of the lake trout examined, and constituted 6.1 percent of total volume of food eaten. This food source was more important to the younger fish. The suckers in Twin Lakes seldom ate mysids (see food habits) but used chironomids extensively.

Rawson and Elsey [37] concluded that lake trout competed with suckers for amphipods and some terrestrial insects. Martin [27] stated that both white suckers and lake trout took considerable numbers of chironomid pupae.

Food habits of suckers and lake trout overlap very little in Twin Lakes. The greatest similarity in food habits occurred between suckers and the young lake trout in the consumption of chironomid larvae and pupae. However, this may not have constituted competition for food between the two species. Food competition can occur only if the common food item is limiting to one or both of the fishes due to their combined predation. It is doubtful that the lake trout eat sufficient numbers of larvae to limit the suckers. Conversely, the lake trout could easily turn to mysid shrimp in the event that sucker predation substantially reduced the numbers of chironomids available.

Impact of Mt. Elbert Powerplant

Direct effects—Entrainment of adult suckers

The degree of susceptibility of fish to entrainment is dependent upon the amount of time spent in the area of the powerplant tailrace. This, in turn, depends on 1) distribution of the fish, 2) home range tendencies, and 3) movements into the powerplant tailrace area.

Distribution. —Gill net catches at various locations can be used to define the distribution of the suckers in Twin Lakes. Gill net catches of white suckers near the powerplant tailrace (station 1) were the lowest of all lower lake shoreline sets in 1978 (table 19). Few longnose suckers were captured by gill nets in the lower lake, however, of those captured, more were taken near the powerplant tailrace than at any other station except station 7 (table 20). Highest catches of both species near the powerplant tailrace occurred in the fall, and the lowest catch was made during summer. Possibility of entrainment thus appears to be higher in fall and less in summer.

Home range tendencies. - White suckers that were fin-clipped and released tended to remain within 800 m of the point of capture, with few exceptions. Coble [10] noted that white suckers seldom moved out of South Bay, Lake Huron, and generally remained in a limited area within the bay. A statistically significant homing tendency was found by Hayes [20] for longnose and white suckers. Suckers within the area of the Mt. Elbert Powerplant tailrace may have a greater chance of entrainment than fish in other parts of the lake. Conversely, if suckers establish home ranges in areas other than the powerplant and seldom make excursions out of them, they should suffer fewer mortalities du to entrainment.

Movements into the powerplant tailrace area. – Observations of shoreline habitat during daylight hours failed to reveal suckers. At night, however, numerous fish were captured with gill nets and electrofishing gear in the same areas. Although gill net sampling in this study was not designed to reveal onshore/offshore movements, their existence seems apparent. Lawler [26] captured more white suckers in shallow areas from sunset to sunrise and in deeper areas from sunrise to noon. Spoor and Schloemer [43] found inshore movements of suckers from noon to midnight and offshore movements from midnight to noon.

The Mt. Elbert Powerplant will pump water to the upper reservoir during times of low power demand, which occurs at night. Any inshore movements of the suckers at night will, therefore, greatly increase their chances of becoming entrained in the powerplant.

Suckers in Twin Lakes did not use Lake Creek for spawning and were not attracted to the currents during the spawning period. It is thought that the currents produced during the generating mode of the powerplant will not be an attractant to the suckers during that time.

Direct effects—Entrainment of larvae

Larval fish are particularly vulnerable to entrainment due to their fragile structure and weak swimming abilities. Currents moving into the tailrace area are likely to carry sucker larvae along. Snyder [46] concluded that the number of larvae entrained at the Muddy Run Pumped-Storage Powerplant (Pennsylvania) depended on utilization of areas near the plant as spawning grounds. In Twin Lakes, densities of larvae may be indicative of spawning areas used by the suckers. If this assumption is correct, little spawning occurs near the powerplant as evidenced by the low abundance of fry in that area (table 17). Tests conducted with a scale model of the Mt. Elbert Powerplant indicated that water will move along the north shore and enter the tailrace channel during the pumping modes [23]. Because very low densities of larvae were found along the north shore, few fish should be entrained

The duration of vulnerability to entrainment is of critical importance in assessing the impact on fish [5]. Sucker larvae were numerous within shoreline areas from mid-July to early November, and were observed in limited abundance into October. Depth selection by larvae after this period was not investigated. Campbell [8] noted that yearling white suckers moved from a shoreline habitat to a bottom-dwelling existence in 0.6 to 1.3 m of water, and that suckers up to 3 years of age occupied depths of 1.5 to 11.0 m.

Indirect effects – Food organisms

Operation of the Mt. Elbert Pumped-storage Powerplant may result in increased turbidity if cold water returning to the lakes during the generating mode were to sink rapidly and disturb the fine glacial flour. However, the food source of suckers in Twin Lakes might not be seriously affected by a rise in turbidity. Chironomid larvae, the primary food of the suckers, are found on a wide variety of substrates within different water bodies [34]. This demonstrates an adaptation to varying water conditions. Only severe siltation would limit the ability of chironomids to reach organic detritus and algae which comprise their main food. Most freshwater clams are not found in areas of high turbidity, but the family Sphaeriidae (of which fingernail clams are a member) are far more adaptable [34]. Clams have the ability to remove at least moderate amounts of inorganic material from their filter feeding mechanisms, thus reducing turbiditycaused interference with feeding. In areas of severe turbidity and siltation, however, the feeding of clams might be impaired and their numbers reduced accordingly.

The crustacean zooplankters (cladocera and copepods) are an important food of young suckers in Twin Lakes. These organisms are capable of only limited movement and may be swept into areas of increased susceptibility to entrainment by powerplant intake currents. Phytoplankton, which often are an important food for the zooplankton, must have sufficient light to carry on photosynthetic activities. If high turbidity were to shade the phytoplankton, their production would be reduced, and a reduction in zooplankton densities would probably result.

Indirect effects – Feeding

Suckers feed primarily by tactile rather than by visual senses. Feeding activity consists of taking in a portion of substrate, separating food material, and then expelling the remaining fraction. These fish are found in a variety of lotic and lentic environments and it is unlikely that moderate turbidity and turbulence would seriously limit their ability to feed. Small fish (less than 200 mm) experience more difficulty in that they are somewhat limited to feeding by visual means on organisms on or slightly above the bottom.

Populations of food organisms probably would remain fairly stable in areas experiencing minimum effect from powerplant operation. Should a reduction in abundance of food items occur in areas near the powerplant, the number of suckers using these areas might be reduced. The possibility exists, however, that the powerplant will have a "chumming" effect, with remains of entrained fish, mysids, and zooplankton being scattered with generating mode currents. This detrital food source could be an attractant to suckers.

Indirect effects – Reproduction

As previously stated, attraction of suckers to flowing water during spawning season was not observed in Twin Lakes. In addition, areas around the powerplant do not seem to be used extensively for spawning. The entrainment of eggs and larvae may by possible only if sufficient current velocities and intake volumes are present to move them into the tailrace area.

Indirect effects-General

This study was undertaken to provide baseline information on life history aspects of the suckers in Twin Lakes. The environmental conditions now existing in the lakes will be changed with operation of the Mt. Elbert Powerplant. Some of the possible impacts resulting from those changes have been considered, but there are numerous effects which are more difficult to predict. The trophic dynamics of the ecosystem may be altered by operation of the powerplant. For instance, if the mysid population were to be reduced by entrainment, the mid-sized trout may utilize more suckers in their diets.

Growth rate of the suckers could respond to powerplant effects discussed previously. Multiple factors influence growth (population, size, food availability, temperature, etc.), and the degree that those factors are impacted by the Mt. Elbert Powerplant will determine changes in growth rates.

Many potential impacts, some of which are unknown at this time, are difficult to predict and may not be recognized for some time after operation begins. If future studies reveal changes in the biology of the suckers in Twin Lakes, it will be necessary to compare pre- and postoperational biotic and abiotic conditions to identify the causative factors.

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APPENDIX A

Length-mass regression coefficients and equations for white suckers from Twin Lakes, Colo., in 1978.

Table A1.—Length-mass regression coefficients and 95-percent confidence intervals for white suckers captured in Twin Lakes, Colo., in 1978.

| Season | Size | Coefficient | Coefficient Value | Std. Error | Lower Limit | Upper Limit |
|--------|----------|----------------|----------------------|------------|-------------|-------------|
| Spring | immature | Bo | - 5.289 | 0.0517 | - 5.392 | - 5.186 |
| Spring | immature | B₁ | 3.126 | .0224 | 3.081 | 3.170 |
| Spring | mature | Bo | - 5.049 | .1667 | - 5.383 | -4.714 |
| Spring | mature | B1 | 3.027 | .0656 | 2.895 | 3.158 |
| Summer | immature | Bo | - 5.027 | .0828 | - 5.191 | -4.862 |
| Summer | immature | B₁ | 3.018 | .0361 | 2.946 | 3.090 |
| Summer | mature | Bo | -4.693 | .1348 | -4.960 | -4.425 |
| Summer | mature | B ₁ | 2.887 | .0535 | 2.781 | 2.993 |
| Fall | immature | Bo | - 5.117 | .0535 | - 5.223 | - 5.011 |
| Fall | immature | B1 | 3.046 | .0226 | 3.001 | 3.091 |
| Fall | mature | B₀ | - 5.099 | .1428 | - 5.382 | -4.815 |
| Fail | mature | В, | 3.047 | .0566 | 2.935 | 3.160 |





Figure A1.-Length-mass relationships of mature white suckers in Twin Lakes, Colo., during three seasons of 1978.

Figure A2.—Length-mass relationships of immature white suckers in Twin Lakes, Colo., during three seasons of 1978.

APPENDIX B

Length-mass regression coefficients and equations for longnose suckers from Twin Lakes, Colo., in 1978.

Table B1.—Length-mass regression coefficients and 95-percent confidence intervals for longnose suckers captured in Twin Lakes, Colo., in 1978.

| Season | Size | Coefficient | Coefficient Value | Std. Error | Lower Limit | Upper Limit |
|--------|----------|----------------|----------------------|------------|-------------|-------------|
| Spring | immature | Bo | -6.124 | 0.1774 | -6.479 | - 5,770 |
| Spring | immature | B1 | 3.516 | .0845 | 3.347 | 3.685 |
| Spring | mature | Bo | - 5.183 | .2224 | - 5.628 | -4.739 |
| Spring | mature | B1 | 3.071 | .0976 | 2.876 | 3.266 |
| Summer | immature | Bo | -5.414 | .1265 | - 5.669 | -5.160 |
| Summer | immature | B ₁ | 3.187 | .0592 | 3.068 | 3.306 |
| Summer | mature | Bo | -4.930 | .1313 | -5.192 | -4.668 |
| Summer | mature | B1 | 2.974 | .0568 | 2.861 | 3.087 |
| Fall | immature | Bo | - 5.428 | .0956 | -5.619 | - 5.237 |
| Fall | immature | B1 | 3.185 | .0457 | 3.094 | 3.276 |
| Fall | mature | Bo | - 5.184 | .1256 | - 5.435 | -4.933 |
| Fall | mature | B1 | 3.080 | .0537 | 2.973 | 3.188 |





Figure B1.-Length-mass relationships of mature longnose suckers in Twin Lakes, Colo., during three seasons in 1978.

