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Propagation of the creek chub in ponds with artificial raceways[1]

[1] Contribution from the Michigan Institute for Fisheries Research

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Abstract

Successful spawning of the creek chub (Semotilus a. atromaculatus) was achieved in a specially designed raceway. An artificial stream, having a graveled bottom with pools and riffles, was constructed within the basin of a pond in which brood stock were introduced. Spawning activity commenced in late April and terminated in early May. A heavy mortality occurred among the brood stock when the ratio of males was equal to, or greater than that of the females. A better survival was attained by increasing the number of females in the combination. The breeding fish had a tendency to concentrate in certain zones of the spawning raceway, and as a result many redds were destroyed in the overworked areas. To offset this condition, thus increasing the efficiency of the raceway, deposited eggs were removed from the beds and successfully cultured in a hatchery by the use of Meehean jars and egg trays. The complete incubation period, (fertilized egg to free swimming fry) required about 25 days at a mean temperature of 55° F. Several rearing ponds were stocked with 8-day-old fry; others with 20-day-old fry. Though the 8-day-old fry were found to tolerate long-distance transporting, they did not survive in any appreciable numbers

after introduction into rearing ponds. The stocking of ponds with 20-day-old fry was more successful, for better than 50 percent of the fry survived. Production in ponds where the fish had to rely on a natural food supply was light as compared to that achieved in a pond where artificial feeding was practiced.

Introduction

In recent years, various investigators have given considerable attention to the propagation of bait minnows and forage fishes. They have been prompted by several considerations, among them: (1) regional scarcity of bait minnows in natural waters so great as to induce or even require dealers to propagate their own bait; (2) recognition by fish-culturists of a need for propagating forage minnows to support game fish in hatchery ponds; and (3) realization that it may be desirable, occasionally, to introduce minnows into natural waters.

As a contribution to this problem, studies were initiated in 1940 on the propagation of the creek chub, Semotilus atromaculatus atromaculatus Mitchill. Although the experiments are still in progress, enough data have been obtained to warrent publication of results obtained during three seasons from 1944 to 1946.

Accounts of the successful culture of several species of minnows and other forage fishes have been published. Methods for the artificial propagation of the creek chub have been published by Hankinson (1910), Marcus (1934), and Clarke (1943). Clarke (loc. cit.) made the first large-scale demonstration of the culturing of this species, using artificial raceways and spawning grounds. There were, however,

important details lacking from his report. The creek chub's life history has been reported on by Reighard (1910); Hankinson (1910); Leonard (1927); and Greeley (1930).

Preparation of a spawning raceway

Observations on the natural spawning habits of the creek chub by the writer together with information in the above references, were of value in designing a spawning raceway. In the first place, it was concluded that the desired production and rate of return from spawning would be dependent upon adequate spawning space for the brood stock. In other words, the raceway had to be large enough to accomodate the brood stock without excessive competition for spawning space. Furthermore, the volume of water and stream gradient had to be sufficient to give a rapid flow, a gravel stream bed was needed for spawning, and some protection for the brood stock against predation by birds was desired.

As a preliminary step in the study a small spawning raceway was constructed in one of the ponds at the State Fish Hatchery at Drayton Plains, Michigan, during the spring of 1944. A graveled stream 110 feet long by 2 feet wide by 4 inches deep was prepared. The actual construction consisted of digging a trench from the intake pipe toward the outlet, within the basin of the pond, and partially filling this excavation with a 3-inch layer of one-fourth to one-half-inch screened gravel. At intervals of about 25 feet the stream was widened to form shallow pools which were covered with boards to act as shelters for the breeders. The gradient of the stream from the source to the

outlet amounted to 8 inches in the 110 feet, and the incoming flow was regulated at one-half cubic foot per second. Splash boards were installed at the outlet of the pond, raising its water level to a point even with the lower end of the raceway, thus providing a pool for the adults. Operation of this 1944 raceway indicated that various improvements could be made. In 1945 the length of the raceway was increased to 285 feet and the bed widened to 3 feet to provide a greater spawning area. The pools were enlarged somewhat and deepened to provide better cover. The deposition of gravel was increased to 4 inches and the screening size changed to include three-quarter-inch stones. The flow was increased to three-quarters of a cubic foot per second and the velocity controlled by installing a series of small check dams. In 1946, in further experimentation, the length of the raceway was extended to 300 feet and the width to 5 feet; the depth of the gravel was increased to 5 inches; and the flow of water regulated at one cubic foot per second.

As a result of these experiments in raceway construction and operation, certain features of a satisfactory spawning raceway have been evaluated. A spawning raceway for creek chubs should be constructed within the basin of a pond (Figure 1), or at a location where a small retaining pool can be formed at the lower end. The purpose of this pool is to provide a haven for the brood stock during inactive periods and to serve as a collecting basin for the newly hatched fry. A raceway capable of furnishing adequate spawning facilities for 500 to 700 fish should be at least 300 feet long and have a minimum width of 5 feet. The flow of water should be at least 1-1/4 cubic feet per second. Shelters should be provided at intervals

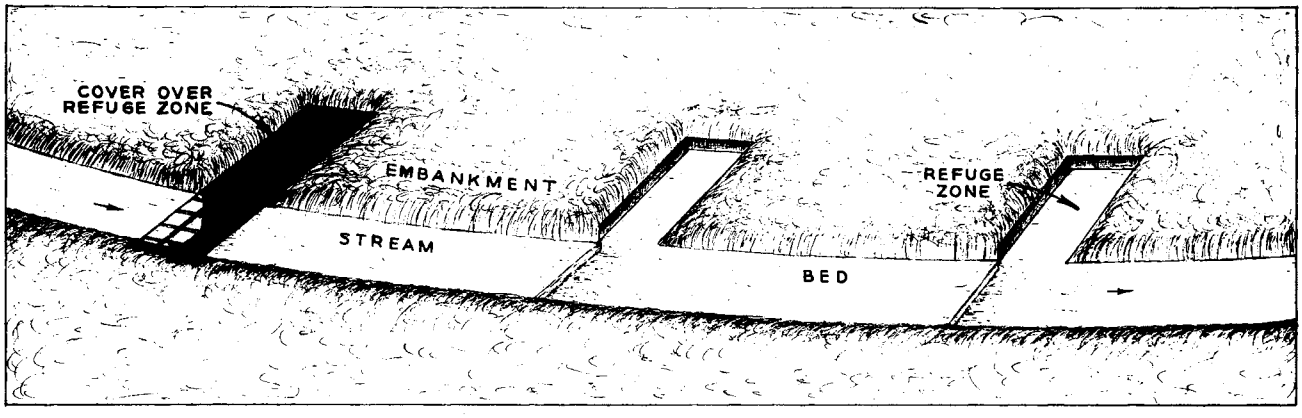
Figure 1. - Creek chub spawning raceway showing pools, riffles, refuge zones and lower impoundment. The netting supported by stakes driven in along the stream banks is used to protect the spawning fish from predaceous birds.

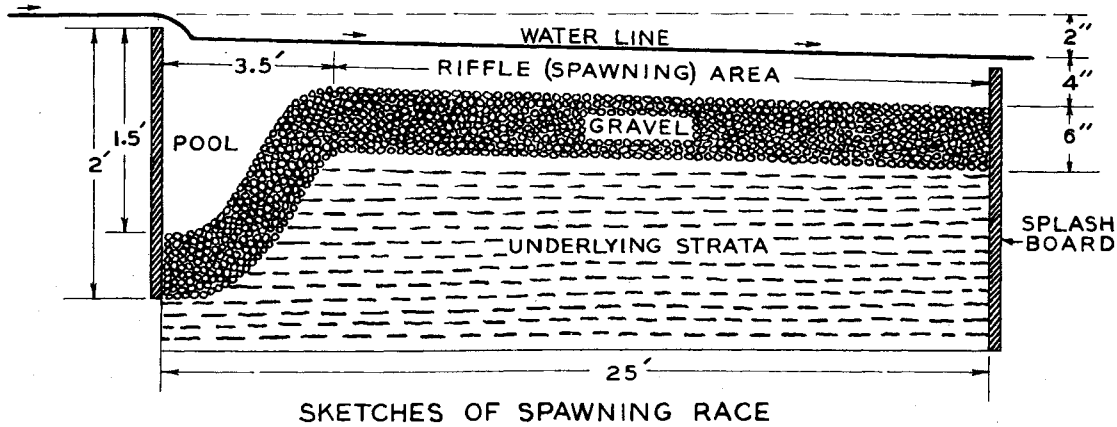
of approximately 25 feet along the raceway (upper part of Figure 2). A suitable type of shelter consists of an offset excavation, joined to the main channel at a point opposite each splash board and covered with any type of weatherproof construction material, such as tarred felt, plywood, or boards. To induce full utilization of the available spawning area by the creek chubs, it is necessary to install splash boards (lower part of Figure 2) creating pools of slowly moving water between the riffled areas. The height of the splash boards can be altered, thus allowing a control of the velocity and depth of water for any one section. It is desirable to have the stream bed covered with gravel to a depth of 6 inches as studies have shown that egg deposition sometimes occurs nearly to that depth. To allow a good circulation of water through the substratum the gravel should be of one-fourth to three-fourth-inch size, and be free from sand or other fine materials. To protect the breeding fish from predacious birds, the entire raceway should be covered with some type of netting, or else some sort of a control over these predators should be exercised. In these studies, fish netting supported by stakes (Figure 1) was used and proved to be satisfactory.

Selection of brood stock

In the selection of a brood stock of creek chubs suitable for use in an artificial spawning raceway it is desirable to secure a stock of fish in which all females mature at nearly the same time, thus restricting the spawning season to the shortest period possible. The disadvantages arising from an extended season (more than 20 days) are many. The eggs deposited at the onset of the season will have

Figure 2. - Sketch of creek chub spawning race. Upper: Surface view. Lower: Longitudinal section of a pool - riffle unit.





SKETCHES OF SPAWNING RACE
UPPER: SURFACE VIEW. LOWER: LONGITUDINAL SECTION OF A POOL-RIFFLE UNIT.

undergone complete incubation and many of the emerging fry will be eaten by the parent fish or will be lost by injury or escape during the operations incident to removing the adults. Furthermore, finished redds, unguarded, are often reworked by later spawners, thus destroying eggs and developing fry. A principle difficulty encountered in the selection of a brood stock which will meet the above requirements arise from the fact that there is a sex difference in both rate of growth and age of maturity, and also from the fact that age of maturity is dependent to some extent on rate of growth. Greeley (1930) found that the males grow faster and mature at a later age than females. This and the greater size of mature males has been observed by the writer. This sex difference in size at maturity makes it difficult to select a brood stock except immediately preceding the spawning season when maturing males can be selected by the presence of nuptial tubercles and females on the basis of size and extended abdomen. Age alone is not a dependable criterion for the selection of a brood stock, judging from the results of studies by Greeley (1930) and the results of present studies on pond-reared chubs. Greeley found that chubs in natural waters normally mature in their fourth and fifth summers. Presumably the fish studied by Greeley had slow growth. One stock of chubs used in the present experiment comprised pond-reared, fast-growing fish among which some individuals of both sexes were mature in the spring of their second growing season, 25 percent of the males and 50 percent of the females were mature among fish in their third season, and 75 percent of the males and 100 percent of the females were mature among fish in their fourth season. In another lot of

120 pond-reared chubs, averaging 5 inches long at one year of age (very fast growth), 75 percent of the individuals of each sex were found to be mature by June 1 of their second season. It would appear that the attainment of a certain minimum size is a more important criterion than age in the selection of mature fish. Selection of a brood stock on the basis of a minimum size of about 5 to 6 inches for females and 6 to 8 inches for males (or 6 to 7 inches for both sexes) among a population with at least moderately fast growth would insure mostly adult fish, and would aid in the restriction of the spawning season. However, in a slowly growing population in which the size at maturity might be somewhat less than among rapidly growing fish, the minimum size limit for the selection of a brood stock would of necessity be smaller, or otherwise a preponderance of males would be chosen.

An example of the results from an unselected brood stock may be cited. At the Drayton Plains Hatchery in 1946, the pond was stocked on April 22 with a mixed brood stock of 384 chubs from natural waters and 42 pond-reared chubs. Those of wild stock (4 - 9-1/2 inches) were larger than the pond-reared 2-year-olds (3 - 6 inches), and presumably were much older. In the spawning raceway, all of the larger females (mostly wild stock) had spawned by May 2, while most of the smaller females spawned during the period May 2 to 16 and later. The entire spawning season had extended over a period of 25 days, and the earlier fry were leaving the redds before spawning was completed. Also, there was considerable reworking of completed redds during spawning in the latter part of the season.

In order to utilize efficiently the facilities of a spawning raceway, a prescribed number of breeders per unit of area is needed. Varying the rate of stocking over the 3-year period and determinations on the fecundity of females and on the concentration of eggs in redds of known area, have given some indication of the desired number of breeders. On the average an individual male creek chub requires an area one foot in width and several feet in length for nesting space; upon completion the redd is about 8 inches wide and 2 to 6 feet long. An average of several counts on the number of eggs screened from completed redds gave approximately 2,500 eggs per running foot. Egg counts on female creek chubs averaged approximately 3,500 for females averaging 5 inches in length, and 5,000 for 6-inch chubs. On the basis of these findings, the potential egg production of the brood stocks used in 1944 to 1946 is compared with the capacity of the raceway for the different seasons, in Table 1. It is shown that theoretically the raceway was overstocked in 1944 and understocked in 1945 and 1946. Unfortunately the true capacity of a raceway cannot be determined on such simple grounds. Attention should be called especially to a difficulty that is commonly encountered and is accentuated by a protracted spawning season. The chubs do not disperse their redds efficiently over the area available, but the late spawners rework and destroy earlier redds. In 1944, though the raceway was potentially overstocked from the standpoint of egg capacity, the breeders used only a portion of the available spawning area. In 1945, only about 35 percent of available area was utilized, and a still smaller percentage in 1946 (Table 3). In that year through intensive

observations it was found that there was a tendency for male chubs to concentrate in certain zones of the spawning raceway and as a result many redds were reworked. From outward appearance the physical features of the entire raceway were more or less identical and as yet no apparent reason can be found to explain why this occurred. It is apparent that there still remains the problem of determining more exactly the spawning requirements of the creek chub. Once this has been accomplished and a satisfactory raceway designed in which the entire available spawning area is uniformly utilized by the brood stock it will then be possible to calculate on a theoretical basis satisfactory stocking rates. Pending the results of more critical studies, the stocking rates used during the three years at the Drayton Plains pond (Table 1) may be regarded as representing the minimum and maximum of a suitable rate of stocking for the size of raceway indicated. The average size of the females should be taken into consideration because of the difference in fecundity. A ratio of about two males to three females is recommended to minimize the conflict among males on the spawning grounds.

Observations on the spawning activity of creek chubs

In Michigan, the spawning season of the creek chub commences about mid-April in streams along the Michigan-Ohio border and extends to late June in waters of the Upper Peninsula. In a single locality the length of the season is about 25 days. At Drayton Plains the brood stock of chubs each year was introduced into the raceway pond shortly before the time of spawning in local streams. In Table 2 are the spawning dates for the raceway fish, covering a 3-year period, showing

Table 1.--Stocking rate of adult creek chubs for a 3-year period including estimated footage of spawning raceway needed in comparison with that available.

Year	Stocking rate		Average fecundity of females[1]	Estimated total egg production	Raceway dimensions	
	Males	Females			Square feet needed for egg deposition[2]	Square feet available[3]
1944	83	101	5,000	505,000	202	123
1945	60	90	5,000	450,000	180	506
1946	164	262	3,500	917,000	367	988

[1] The average fecundity for females (16 ovary counts) ranging between 3 and 7 inches was 3,500 and for 4- to 8-inch fish (12 ovary counts) 5,000.

[2] Calculated on a basis of an average of 2,500 eggs deposited per running foot.

[3] Pools, refuge zones, and stream-bank margins have been deducted from total area.

Table 2.--Extent of spawning season of creek chubs in a prepared raceway and prevailing water temperatures (°F.), for a 3-year period.

Stocking date	Water temperature	First spawning activity		Date of Termination of spawning [1]	Total length of season
		Date	Water temperature		
April 24, 1944	46	April 29, 1944	55	May 19, 1944	25
April 14, 1945	61	April 16, 1945	61	May 27, 1945	41
April 17, 1946	50	April 22, 1946	56	May 21, 1946	29

[1] The date recorded is approximate (accurate within 2 days).

the extent of the season and the prevailing water temperature at the onset of reproductive activity. The extended season in 1945, 12 days longer than either of the other two years, can be explained in part by the presence of abnormal weather. Unseasonably high water temperatures in early April caused a flurry of activity which soon subsided with lowering temperatures, and as a result a 2-week inactive period was encountered.

In the raceway, spawning activity was more concentrated in the lower sections during the first few days, and the activity was gradually extended upstream as the season progressed. Data on the distribution of redds in the raceway throughout the season are presented in Table 3. On the first observation date, April 22, 1946, about 63 percent of the redds were found in the lower one-third of the raceway, whereas by April 25 this figure was reduced to 45 percent, indicating that relatively more males were establishing redds in upper sections. By the end of the season 4 of the 13 sections (4, 7, 9 and 11), comprising about one-third of the total area, contained 56 redds or 60 percent of the total.

Both sexes took part in the first upstream movement of the breeders from the pond; the males were extremely active on the riffle zones and the females darted about in secluded areas. During the initial phase it was noted that spawning activity started about mid-morning and terminated an hour or so before dusk. At the height of the season, however, the fish were engaged in nesting operations day and night, stopping only when water temperatures fall below 51° F. The lower-of the water temperature not only curtailed reproductive activity, but

Table 3.--Addition of the new creek-chub redds in raceway sections over a 19-day period.

(The sections are numbered consecutively with No. 1 at the upstream end.)

Date of observation	Number of new redds in raceway sections													Total number redds to date
	1/ 1	2	3	4	5	6	7	8	9	10	11	12	2/ 13	
April 22, 1946	1	0	1	3	0	2	1	0	4	2	7	1	0	22
April 23, 1946	0	1	0	1	0	1	1	1	1	1	1	0	1	31
April 25, 1946	0	2	3	3	1	0	6	2	3	0	2	0	1	53
May 4, 1946	0	0	0	2	0	2	4	0	5	2	2	0	0	71
May 10, 1946	0	0	1	5	6	2	2	0	1	0	2	3	0	93
Total number of redds per section	1	3	5	14	7	7	14	3	14	5	14	4	2	...

1/ Inlet section, about one-half length of others.

2/ Partial section below number 12, junction of stream and pond.

also brought about a downstream movement of the brood stock to the pool below. Periodic observations of the adults over the entire spawning season revealed that some fish were present in the pool at all times. The presence of many spent females in the pool indicates that some, if not all, of them leave the race after spawning.

Within a few days after the end of each spawning season, all surviving adults were recovered from the pond and raceway. In each year there was a large loss of both sexes. In 1944, out of 184 fish introduced, only 65 survived--16 males and 49 females. The mortality rates were of 80 and 50 percent respectively. During the 1945 season the combined mortality was somewhat higher--78 percent of the males and 62 percent of the females. In 1946, the mortality was much lighter than for either of the two former years, amounting to 40 percent of the males and 15 percent of the females. It is believed that the exceptionally high mortality recorded for 1945 was in part due to the predations of the great blue heron, since the raceway was not screened that year and herons were common. However, for 1944 and 1946 it is definitely known that predacious birds were not a contributing factor because the raceways were well screened. The difference between the mortalities of 1944 and 1946 might have been due to the difference in growth history: - the 1944 breeders were large, fast-growing, pond-reared chubs, and the 1946 fish were smaller, presumably more slowly growing, wild chubs. It has been noted by numerous investigators that fast-growing fish tend to have a shorter life span.

Collecting of eggs and incubation period

During 1944 and 1945 studies of the mortality and incubation of chub eggs were limited to the examination of several redds. By screening the eggs from portions of redds, it was found that a higher mortality occurred in nests located in the quieter waters. Since it was observed that sediment had accumulated more over the nests in quieter water, it is possible that the mortality was due to suffocation. During the season of 1945 a protracted incubation period, due to low average water temperatures, a considerable deposit of silt accumulated over all the redds, even those in fast water. There was an excessive mortality among the newly hatched fry in all redds, again presumably as the result of suffocation.

In view of the observed loss of eggs in redds during 1944 and 1945, a variation in the procedure was instituted in 1946. Certain redds were opened, the eggs removed, taken to a fish hatchery, and incubated. The purpose was twofold: first, to seek a means of greater production of fry by the progressive removal of a portion of the eggs from over-crowded nesting areas (Table 3); and second, to secure pertinent data on the incubation period. As a means of collecting eggs a three-sided, 12-inch-square, screen box, was placed immediately below a nest. By sifting the gravel through the hands, the eggs were washed free and collected in the trap below. It required several successive washings to insure that all of the eggs were removed from a particular redd. The loss of eggs (by crushing or failure to be trapped) during removal in this manner was estimated at not more than 25 percent.

A total of 98 fluid ounces of eggs (115,000 to 130,000 per quart) was removed from redds in the above manner:--31 ounces on April 23, 35 ounces on the 25th, and 32 ounces on the 29th. These eggs were placed in hatchery jars on each occasion, and the incubation period studied. It was found that creek chub eggs could be incubated to the eyed staged in hatchery jars, but could not be hatched successfully because the heavy fry would not escape with the running water. If left in the jars the fry had a tendency to settle and accumulate near the bottom and die as a result of mechanical injury. At the eyed stage the eggs were transferred to screened trays in standard hatchery troughs for the remainder of their development. This jar-tray method proved to be successful (Table 4). The use of trays alone for the entire incubation was attempted but was found to be less satisfactory than employing jars for early development, because of the difficulty of picking dead eggs from trays. The greatest egg mortality was encountered within the first 6 days of development. In the jar method the dead eggs were found to accumulate at the surface of the egg mass and could be siphoned off. From the original 98 ounces of eggs (3,750 per ounce) approximately 46 ounces of fry (5,400 per ounce) were produced, representing a hatch of about 67 percent. The average incubation period at a mean temperature of 55°F. was 10 days, 6-1/2 hours.

The sac fry upon hatching pass through the 14- by 18-mesh screen to the bottom of the trough and undergo further development there for a period of 12 to 16 days. At hatching the fry are gold-colored and the eyes are without any marked pigmentation. Within 2 to 3 days, the

Table 4.--Percentage of hatch of creek chub eggs collected from nests and incubated in the hatchery.

Egg collection		Water temperature (°F.)	Incubation period (hours)			Ounces[2] of fry produced	Percentage of hatch
Date	Ounces[1]		Jar	Tray	Total		
April 23, 1946	31	55	147	94	241	14.5	67
April 25, 1946	35	54	178	81	259	17.4	71
April 29, 1946	32	56	154	86	240	14.0	63

[1] The average number of eggs per fluid ounce was 3,750.

[2] The average number of fry per fluid ounce was 5,400.

fry take on a darker orange, and the eyes become very conspicuous. Within another 3 days, dark lateral bands of melanophores appear on the sides of the body. Within 12 days after hatching the fry are able to maintain a normal position, can swim feebly, and support themselves in a weak current. By 16 days the yolk sac is absorbed and the fry are ready to take food. It was noted during these studies that the fry had a tendency to concentrate in shaded areas or about any dark object placed in the trough (negatively phototrophic). It was discovered further that they react positively to a current (positively rheotrophic) and will collect in large masses. One such large concentration of fry was followed by an abnormal mortality. Thereafter, excessive concentrations were dispersed by feathering, or prevented by control of water currents and reduction in the number of fry in the troughs.

For a comparison with incubation period of creek chub eggs by the jar-tray method, observations were made on eggs in the raceway redds. Certain redds were examined periodically throughout the spawning season. The water temperature in the spawning raceway averaged about 1 to 2 degrees higher than that in the jar, and the range of variation was found to be greater. In the hatchery, the lowest temperature recorded was 50° and the highest 59°, while in the stream the lowest was 49° and the highest 64°. The rate of development of the eggs up to hatching was about the same in redds and jars. However, development of fry must have been somewhat faster in the redds, for free-swimming fry were observed in the raceway within 20 days after the first spawning, whereas it required from 22 to 26 days to reach a comparable stage in jar-tray development.

In some redds dark pigmented fry were found still imbedded in the gravel at depths up to 3 inches. Upon liberation, these fry quickly swam away in a normal manner. Apparently the fry remain in the beds until they are well developed.

For a comparative study of the viability of naturally and artificially spawned eggs, 47 ounces of creek chub eggs were obtained from 14 redds in Paint Creek, Oakland County, Michigan on April 26, 1946, and taken to the hatchery for incubation. At the time of collection, some of these eggs showed no signs of development and others had progressed to the eyed stage. Many of the eggs were hatching 2 days later, while others required 6 to 8 days. From the 47 ounces of eggs only 13.8 ounces of fry were produced, representing a hatch of about 42 percent. The low rate of hatching of the Paint Creek eggs, as compared to the 67 percent hatch of eggs from raceway redds, can be attributed partly to the spread in time of hatching (discussed below). The spread in time of hatching among individual lots of eggs was found to be an objectionable feature in the jar-tray method, because of the need for transfering eggs to trays at the eyed stage. Many fry not removed are destroyed by mechanical action in the jars (see above). It is desirable therefore to have individual lots of eggs of uniform age. The experience with the eggs from Paint Creek indicated that it normally would be more difficult to obtain eggs of uniform age from wild streams where the history of individual redds is not observed. Other contributing factors might have been the sensitivity of the eggs at some specific stage in development to changes in water temperature, to handling or to jarring in transit. It is a well-known fact that eggs of salmonids can be handled safely either when "green" or at the eyed stage, but that there is a long intervening period when the eggs are highly sensitive to jarring. It is probably safe to assume that the same is true

of creek chub eggs, although it has not been demonstrated. It would therefore seem desirable to collect the eggs from nests shortly after deposition. In the present studies at the Drayton Plains raceway the eggs were removed within 24 hours, which proved to be satisfactory.

Transfer of fry

During the 1946 studies it was found that 4- to 8-day-old sac fry could be handled safely and transported for long distances. On May 7, 1946, 95,000 sac fry (volumetric measurement, 180 fry per cubic centimeter) were carried in a light truck in 10-gallon fish cans at the rate of 12,000 per can for a distance of 110 miles without significant loss. This successful operation was repeated again on May 13, at which time 115,000 fry were moved the same distance. Each of these trips required about 3-1/2 hours to complete, and the water was not changed enroute. The sac fry, not advanced enough for free swimming, settled to the bottom when placed in the can, and remained in that position during transit.

Some transfers of advanced fry (free-swimming for 8 to 12 days) were made from the raceway pond to other ponds at the Drayton Plains Hatchery. These fry were collected by bobbinet seine and transported in pails and fish cans. A total of 33,000 of these fry was handled without appreciable loss. In another transfer, 20,000 fry of this age were transported by truck in 10-gallon cans for a distance of 60 miles without significant loss. It is concluded from these results that advanced fry can survive handling and transportation over long distances.

Stocking of fry

Some information was obtained by studies during 1946 on the relationship between rate of stocking, age of stocked fry, rate of

survival and rate of growth (Table 5): Eight ponds at the Hastings State Fish Hatchery and two ponds at the Drayton Plains State Fish Hatchery were stocked with 8-day-old and 20-day-old creek chub fry, respectively. The 8-day-old fry (not free swimming) were placed on screen trays located in one foot of water. The 20-day-old fry (free swimming) were simply liberated into the ponds. During September all ponds were drained. The fish were removed, counted, weighed and individual lengths were obtained from representative samples.

The ponds stocked with 20-day-old fry gave much higher rates of survival (51 and 73 percent)than those stocked with 8-day-old fry (17 percent and less). In the series of experiments at Hastings where rates of stocking were varied from 10,000 to 44,000 per acre, the percentage rate of survival tended to be higher in those ponds stocked at the higher rates. This result is contrary to that ordinarily obtained from fry planting. The great variation among the three ponds which were stocked at 25,000 per acre indicates, however, that rate of survival was determined mostly by factors other than rate of stocking. Rapid growth was strikingly related to low concentrations of chubs in this series of experiments. In Ponds 5, 12, 7, and 11 where production was extremely low, the fish in a 135-day growing season attained an average length of more than 4 inches; in Ponds 2, 8, 10 and 6, where production was moderate, the fish in 128 days attained average lengths between 3 and 4 inches; while in Ponds 3 and 4 where relative high production occurred, the fish in a 115-day season grew to an average length of 2-1/2 inches. It is believed that the differences in growth among the three groups of fish can be attributed to the amount of food

Table 5.--Results from stocking ponds with creek chub fry at different ages and rates. (Ponds 3 and 4 were at the Drayton Plains Hatchery; the remaining ponds were at the Hastings Hatchery).

Pond No.	Area (acres)	Stocking rate		Maximum age of fry (days)	Date of introduction	Date of removal	Total number removed	Average length (inches)	Percentage survival
		Per acre	Per pond						
5	2.11	10,000	21,100	8	May 7, 1946	Sept 19, 1946	421	4.82	2.0
12	1.50	10,000	15,000	8	do.	do.	219	4.26	1.5
3	0.46	38,700	17,800	20	Jun 3, 1946	Sept 26, 1946	9,158	2.53	51.4
4	0.48	32,000	15,400	20	do.	do.	11,224	2.47	72.9
7	1.11	25,000	27,750	8	May 7, 1946	Sept 19, 1946	342	4.37	1.2
11	1.25	25,000	31,250	8	do.	do.	84	4.19	0.3
2	1.02	25,000	25,500	8	May 14, 1946	do.	4,500	3.10	17.6
8	0.98	35,000	34,300	8	do.	do.	1,312	3.70	3.8
10	1.0	35,000	35,000	8	do.	Sept 20, 1946	2,880	3.72	8.2
6	0.56	44,000	24,640	8	do.	do.	3,850	3.92	15.6

available per individual. Since the fish in all of the ponds had to rely upon food from natural sources it is assumed that the fish in those ponds experiencing a light survival and a rapid growth had an abundant supply of food. If the assumption is correct that food is a major limiting factor in growth of pond-reared chubs, then artificial feeding with the correct diet might be expected to give a greater production of larger fish. In a separate experiment at Drayton Plains, there was a marked indication of increased production by artificial feeding. A 1.8-acre pond produced 58,000 chubs of 2-3/4 inches average length in a 115-day growing season; 800 pounds of food was used and the 58,000 chubs, when recovered, weighed 328 pounds. The rate of feeding was relatively low as compared to that employed by Clark (1943) in the propagation of creek chubs. In a 1941 experiment a total of 952 pounds of food was used to produce 11,000 chubs weighing 137 pounds in a 1/12-acre pond, and in 1942, 776 pounds of food was used to produce 9,000 chubs in a 1/7-acre pond.

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