TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE   WYOMING   SOIL CONSERVATION SERVICE

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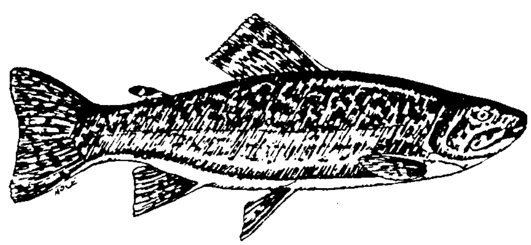
Subject: BROOK TROUT*

General

The native range of brook trout (Salvelinus fontinalis) originally covered the eastern two-fifths of Canada northward to the Arctic Circle, the New England States, and southward through Pennsylvania along the crest of the Appalachian Mountains to northeastern Georgia. Western limits included Manitoba southward through the Great Lake States. Reductions in the original range have resulted from environmental changes, such as pollution, siltation, and stream warming due to deforestation.

Brook trout can be separated into two basic ecological forms: a short-lived (3-4 years), small (200-250 mm) form, typical of small, cold stream and lake habitats and a long-lived (8-10 years), large (4-6 kg), predaceous form associated with large lakes, river, and estuaries. The smaller, short-lived form is typically found south of the Great Lakes region and south of northern New England, while the larger form is located in the northern portion of its native range. Although no subspecies designation has been recognized for these two forms, they respond as two different species to environmental interactions influencing life history.



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*Information taken from Ecoregion M3113 Handbook and Habitat Suitability Index Models, Wildlife Species Narratives (literature searches), U.S. Fish and Wildlife Service, various dates between 1978-1984.

Brook trout can be hybridized artificially with lake trout (to produce a fertile hybrid called splake trout) and with rainbow trout. In rare cases, natural hybrids occur between brook trout and brown trout (Salmo trutta); the hybrid is termed tiger trout. One researcher collected brook trout and bull trout (Salvelinus confluentis) hybrids in the upper Klamath Lake basin, Oregon. Brooktrout appear to be sensitive to introductions of brown and rainbow trout and are usually displaced by them. However, brook trout have displaced cutthroat trout and grayling in headwaters and tributaries of western streams.

Age, Growth, and Food

Brook trout appear to be opportunistic sight feeders, utilizing both bottom-dwelling and drifting aquatic macroinvertebrates and terrestrial insects. Such feeding habits make them particularly susceptible to even moderate turbidity levels, which can reduce their ability to locate food. Drifting forms may be selected over benthic forms when they are available. The choice of particular drift organisms is apparently either a function of seasonal availability and/or the overall availability of terrestrial forms in a particular situation. Between age groups, there may be a tendency for selection of food items based on size. In Idaho, age group 0 trout selected smaller drifting organisms (Diptera and Ephemeroptera) with less variation than did older trout, while age group I trout seemed to prefer larger Trichoptera larvae. Fish are an important food item in lake populations.

Reproductive Requirements

Age at sexual. maturity varies among populations, with males usually maturing before females. Male brook trout may mature as early as age 0+. In Wisconsin (Lawrence Creek), the smallest mature male was approximately 8.9 cm (3.5 inches) long.

Spawning typically occurs in the fall and has been described by several authors. Spawning may begin as early as late summer in the northern part of the range and early winter in the southern part of the range. The spawning behavior of brook trout is very similar to that of rainbow and Cutthroat trout. In streams and ponds, areas of ground water upwelling appear to be highly' preferred and to override substrate size as a site selection factor. Brook trout can be highly successful spawners in lentic environments in, upwelling areas of springs. Spawning occurs at temperatures ranging from 4.5°-10°C. The fertilized ova are deposited in redds excavated by the female in the stream gravels. Spawning success is reduced as the amount of fine sediments is increased and the intergravel oxygen concentration diminished.

Migration and Anadromy

With the exception of the sea-run New England populations, brook trout migrations are generally limited to movements into headwater streams or tributaries for spawning or relatively short seasonal migrations to avoid temperature extremes. Some brook trout may spend their entire lives, including spawning periods, within a restricted stream area as opposed to more migratory salmonids. However, some movement upstream or downstream may occur due to space-related aggressive behavior following emergence from the redd.

Special Habitat Requirements

Brook trout are the most generalized and adaptable of all Salvelinus species. They inhabit small headwater streams, large rivers, ponds, and large lakes in inland and coastal areas. Typical brook trout habitat conditions are those associated with a cold temperature climate, cool spring-fed ground water, and moderate precipitation. Warm water temperatures appear to be the single most important factor limiting brook trout distribution and production. In a comparative distribution study between brook and brown trout from headwater tributaries of the South Platte River, Colorado, researchers found that as the elevation increased and the streams became smaller and colder, brook trout became more abundant.

Optimal brook trout riverine habitat is characterized by clear, cold, spring-fed water, a silt-free rocky substrate in riffle-run areas; an approximate 1:1 pool-riffle ratio with areas of slow, deep water; well-vegetated streambanks; abundant instream cover; and relatively stable waterflow, temperature regimes, and streambanks. Brook trout south of Canada tend to occupy headwater stream areas, especially when rainbow and brown trout are present in the same river system. They tend to inhabit large rivers in the northern portion of their native range.

Optimal lacustrine habitat is characterized as clear, cold lakes and ponds that are typically oligotrophic. Brook trout are typically stream spawners, but spawning commonly occurs in gravels surrounding spring upwelling areas of lakes and ponds.

Cover is recognized as one of the basic and essential components of trout streams. One researcher was able to increase the number and weight of trout in stream sections by adding artificial brush cover and to decrease numbers and weight by removing brush cover and undercut banks. One study found that the amount of cover present was important in determining the number of trout in sections of a Montana stream. Cover for trout consists of areas of low stream bottom visibility, suitable water depths (>15 cm), and low current velocity (<15 cm/s). Cover can be provided by overhanging vegetation, submerged vegetation, undercut banks, instream objects (stumps, logs, roots, and large rocks), rocky substrate, depth, and water surface turbulence. In a study to determine the amount of shade utilized by brook, rainbow, and brown trout, researchers reported that rainbow trout showed the lowest preference for shade produced by artificial. surface cover. Brown trout showed the highest use of shade while brook trout were intermediate between brown and rainbow trout. Brook trout in two Michigan streams showed a strong preference for overhead cover along the stream margin. The major limiting factor for brook trout in these streams was bank cover.

Canopy cover is important in maintaining shade for stream temperature control and in providing allochtonous materials to the stream. Too much shade, however, can restrict primary productivity in a stream. Stream temperatures can be increased or decreased by controlling the amount of shade. About 50 to 75 percent midday shade appears optimal for most small trout streams. Shading becomes less important as stream gradient and size increases. In addition, a well-vegetated riparian area helps to control watershed erosion. In most cases, a buffer strip about 30 m deep, 80 percent of which is either well vegetated or has stable rocky streambanks, will provide adequate erosion control and maintain undercut streambanks characteristic of good trout habitat. The presence of fines in riffle-run areas can adversely affect embryo survival, food production, and cover for juveniles.

There is a definite relationship between the annual flow regime and the quality of trout habitat. The most critical period is typically the base flow (lowest flows of late summer to winter). A base flow ≥ 55 percent of the average annual daily flow is considered excellent, a base flow of 25 to 50 percent is considered fair, and a base flow of < 25 percent is considered poor for maintaining quality trout habitat.

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One study listed average depth, water volume, average depth of pools, amount of pool area, and amount of overhanging bank cover as the most important parameters relating to brook trout carrying capacity in Lawrence Creek, Wisconsin. The main use of summer cover is probably for predator avoidance and resting. Salmonids occupy different habitat areas in the winter than in the summer.

In some streams, the major factor limiting salmon densities may be the amount of adequate overwintering habitat rather than summer rearing habitat. One researcher suggested that some salmon population levels were regulated by the availability of suitable overwintering areas. Winter hiding behavior in salmonids is triggered by low temperatures. One study indicated that as water temperatures dropped to 4°-8°C, feeding was reduced in young salmonids and most were found within or near cover; few were more than 1 m from potential cover. Another study found juvenile rainbows 15-30 cm deep in the substrate, which was often covered by 5-10 cm of anchor ice. One researcher reported that the adult rainbow trout tended to move into deeper water during winter. The major advantages in seeking winter cover are prevention of physical damage from ice scouring and conservation of energy. A cover are ≥ 25 percent for adults and ≥ 15 percent for juveniles of the entire stream habitat appears adequate. for most brook trout populations.

Optimum turbidity values for brook trout growth are approximately 0-30

JT's with a range of 0-130 JT's. An accelerated rate of sediment deposition in streams may reduce local brook trout production because of the adverse effects on production of food organisms, smothering of eggs and embryos in the redd, and loss of escape and overwintering habitat.

Brook trout appear to be more tolerant than other trout species to low pH. Laboratory studies indicate that brook trout are tolerant of pH values of 3.5-9.8. Brook trout fingerlings in Pennsylvania inhabited a bog stream with a pH less than 4.75 and occasionally dropping to 4.0-4.2. One study reported brook trout inhabiting a stream in Missouri with a pH of 4.1-4.2. One researcher believed that brook trout tolerated pH ranges greater than the range of most natural waters (4.1-9.5). Another researcher demonstrated that continued exposure to a pH below 6.5 resulted in decreased hatching and growth in brook trout. The selection of spawning sites may be associated with the pH of upwelling water; neutral or alkaline waters (pH 6.7 and 8) were selected by brook trout held at pH levels of 4.0, 4.5, and 5.0. The optimal pH range for brook trout appears to be 6.5-8.0 with a tolerance range of 4.0-9.5.

Brook trout occur in waters with a wide range of alkalinity and specific conductance, although high alkalinity and high specific conductance usually increase brook trout production. Brook trout populations in the Smoky Mountains, North Carolina, are becoming increasingly restricted to low alkalinity headwater streams, apparently due to competition from introduced rainbow trout (Salmo gairdneri) , and are frequently in poor condition. The small size of the trout in the headwater areas has been attributed to the infertility of the water, which has been linked to low total alkalinities (10 ppm or less) and TDS values less than 20 ppm. TDS values in the Smoky Mountains are lower than values from similar streams in Shenandoah National Park, Virginia, and the White Mountains National Forest, New Hampshire, where trout populations appear to be more robust.

Headwater trout streams are relatively unproductive. Most energy inputs to the stream are in the form of allochthonous materials, such as terrestrial vegetation and terrestrial insects. Aquatic invertebrates are most abundant and diverse in riffle areas with rubble substrate and on submerged aquatic vegetation. However, optimal substrate for maintenance of a diverse invertebrate population consists of a mosaic of gravel, rubble, and boulders with rubble being dominant. The invertebrate fauna is much more abundant and diverse in riffles than in pools, but a ratio of about 1:1 of pool to riffle area (about 40-60 percent pool area) appears to provide an optimum mix of trout food-producing and rearing areas. In riffle areas, the presence of fines (>10 percent) reduces the production of invertebrate fauna.

Adult. The reported upper and lower temperature limits for adult brook trout vary; this may reflect local and regional population acclimation differences. One study reported that brook trout will not live and thrive in temperatures warmer than 20°C. Another study indicated that brook trout usually do poorly in streams where water temperature exceeds 20°C for extended periods. One researcher reported that brook trout exposed to temperatures of 25°C for more than a few hours did not survive. Another researcher observed brook trout living in temperatures of 24°-27°C for short durations and recommended 23.8°C as the maximum tolerable limit. One study found that 23.9°C represented the limit of even temporary endurance, but stated that the optimum temperature should not exceed 15.6°C. Another study stated that brook trout can withstand temperatures from O°-25.3°C, but acclimation is necessary. The upper tolerable limit is raised by approximately 1 degree for every 7-degree rise in temperature up to 18°C, where it levels off at the absolute limit of 25.3°C. Fish kept at 24°C and above cannot tolerate temperatures as low as 0°C. Seasonal temperature cycles from summer highs to winter lows provide the necessary acclimination period needed to tolerate annual temperature extremes. The overall temperature range of 0°-24°C has been observed.

The above upper and lower tolerance limits probably do not reflect the range of temperatures that is most conducive to good growth. One study cites an optimum growth rate at 14°C. He further contends that 11°-16°C is best suited for overall welfare, while trout exist at a relative disadvantage in terms of activity and growth at higher and lower, albeit tolerable, temperatures. Another study gave the optimum temperature range for activity and feeding for brook trout as between 12.8°C and 19°C. We assume that the temperature range for brook trout is 0°-24°C, with an optimal range for growth and survival of 11°-16°C.

Brook trout normally require high oxygen concentrations with optimum conditions at dissolved oxygen concentrations near saturation and temperatures above l5°C. Local or temporal variations should not decrease to less than S mg/l. Dissolved oxygen requirements vary with age of fish, water temperature, water velocity, activity level, and concentration of substances in the water. As temperatures :increase, the dissolved oxygen saturation level in the water decreases, while the dissolved oxygen requirements of the fish increases. As a result, an increase in temperature resulting in a decrease in dissolved oxygen can be detrimental to the fish. Optimum oxygen levels for brook trout are not well documented, but appear to be ≥7 mg/l at temperatures <l5°C and ≥9 mg/l at temperatures ≥ l5°C. Researchers have demonstrated that swimming speed and growth rates for salmonids declined with decreasing dissolved oxygen levels. In the (temperatures ≥10°C), cutthroat trout generally avoid water with dissolved oxygen levels of less than 5 mg/l. One study stated that the lowest dissolved oxygen concentrations where brook trout can exist is 0.9 ppm at 10°C and 1.6-1.8 ppm at 20°C. One researcher contends that the dissolved oxygen concentration should not be less than 3 cc per liter (4.3 ppm).

One study reported that brook trout prefer moderate flows. Another reported that focal point velocities for adult brook trout in Idaho ranged from 7-11 cm/sec with a maximum of 25 cm/sec. In a Wyoming study, 95 percent of all brook trout observed were associated with point velocities of less than 15 cm/sec.
The carrying capacity of adult brook trout in streams is dependent, at least in part, on cover provided by pools, undercut banks, submerged brush and logs, large rocks, and overhanging vegetation. One study

reported that the biomass and number of brook trout ≥150 mm in size were significantly correlated with bank cover in two Michigan streams. One researcher reported that cover for adult trout should be located in stream areas with water depths ≥15 cm and velocities of <15 cm/sec. We assume that an area ≥25 percent of the total stream area occupied by brook trout will provide adequate cover.

Embryo. Temperatures in the range of 4.5°-11.5°C have been reported as optimum for egg incubation. Length of egg incubation is about 45 days at 10°C, 165 days at 2.8°C, and 28 days at 14.8°C. Brook trout eggs develop slightly faster than brown trout eggs at 2°C or colder, but the reverse is true at 3°C or above. We assume that the range of acceptable temperatures for brook trout embryos is similar to that for cutthroat trout (Salmo clarki).

Dissolved oxygen concentrations should not fall below 50 percent saturation in the redd for embryo development. It is assumed that oxygen requirements for embryos are similar to those of adults. One researcher observed high mortality rates when water velocity in the redd was reduced. Water velocity is important in flushing out fines in the redds. Because brook trout can successfully spawn in spawning areas of lakes, velocity is not necessary for successful spawning as long as oxygen levels are high and the redd is free of silt. Spawning velocities for brook trout range from 1 cm/sec to 92 cm/sec. Spawning velocities measured for brook trout in Wyoming ranged from 3-34 cm/sec.

Two researchers stated that optimum substrate size for book trout embryos ranges from 0.34-5.05 cm. One study reported a range of suitable spawning gravel size of 3-8 cm in diameter for trout. Most workers agree that both water velocity and dissolved oxygen in the intergravel environment determine the adequacy of the substrate for the hatching and survival of salmonid embryos and fry. Increases in sediment that alter gravel permeability reduces velocities and intergravel dissolved oxygen availability to the embryo and results in smothering of eggs. In a California study, brook trout survival was lower as the volume of materials less than 2.5 mm in diameter increased. In a 30 percent sand and 70 percent gravel mixture, only 28 percent of implanted steelhead embryos hatched; of those that hatched, only 74 percent emerged. It is assumed that suitable spawning gravel conditions include gravels 3-8 cm in size (depending on size of spawners) with 5 percent fines.

Fry. One study cited temperature as an important limiting factor of growth and distribution of young brook trout. Fry emerge from gravel redds from January to April, depending on the local temperature regime. Temperatures from 9.8°-15.4°C were considered suitable, with 12.4°-15.4°C optimum; temperatures greater than 18°C were considered detrimental. The optimum temperature for brook trout fry, in a laboratory study, was between 8°-12°C. Upper lethal temperatures are Between 21° and 25.8°C, possibly a reflection of different acclimatization temperatures. One study reported that upwelling ground water was an important consideration for the well-being of fry in streams. Two researchers reported the same situation for fry in spring ponds. One study found that fry survival increased as pH increased from 5 to 6.5. Another study reported that focal point velocities for brook trout fry in Idaho ranged from 8-10 cm/sec, with a maximum of 16 cm/sec. Because brook trout fry occupy the same stream reaches as adults, we assume that temperature and dissolved oxygen requirements for brook trout fry are similar to those for adults,

Trout fry usually overwinter in shallow areas of low velocity with rubble being the principal cover. Optimum size of substrate used as winter cover by steelhead fry and small juveniles ranges from 10-40 cm in, diameter. A relatively silt-free area of substrate of this size class (10-40 cm), ≥10 percent of the total habitat, will probably provide adequate cover for brook trout fry and small juveniles. The use of smaller-diameter rocks for winter cover may result in increased mortality due to shifting of the substrate.

<u>Juvenile.</u> One study stated that temperatures of 11°-14°C are optimum for fingerling growth. Another study reported focal point velocities for juvenile brook trout that ranged from 8.0-9.0 cm/sec, with a maximum of 24 cm/sec. We assume that temperature and dissolved oxygen requirements for juvenile brook trout are similar to those for adults.

One study reported that brook trout fry and small juveniles <15 cm long were associated more with instream cover objects (rubble substrate) than overhead streambank cover. An area of cover ≥15 percent of the total stream area appears adequate for juvenile brook trout.