This is to certify that the

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USE OF ARTIFICIAL INSTREAM TROUT SHELTERS
BY TROUT IN THE AU SABLE RIVER, MICHIGAN

presented by

Andrew Joseph Nuhfer

has been accepted towards fulfillment
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Ray J. White
Major professor

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USE OF ARTIFICIAL INSTREAM TROUT SHELTERS BY TROUT IN THE AU SABLE RIVER, MICHIGAN

By

Andrew Joseph Nuhfer

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ABSTRACT

USE OF ARTIFICIAL INSTREAM TROUT SHELTERS BY TROUT IN THE AU SABLE RIVER, MICHIGAN

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Abundances of trout beneath 70 man-made coverts in a kilometer of stream were estimated by wetsuit diving and by electrofishing, and physical features of the coverts were measured to determine sources of variation in covert use by trout. Trout were more abundant in shelters having longer margins providing overhead cover parallel to flow, having deeper water adjacent to the device, and having ample interstices for concealment. Current velocity beneath or adjacent to coverts is likely to have influenced covert use, but my rough, indirect measures of velocity were insufficiently sensitive to detect a relationship.

There were no significant differences between the types of artificial structures tested: stream-edge log jams, log rafts submerged in open stream, and bundles of tree stumps partially submerged in open stream. More than 50% of the study area's trout that were 150mm or larger were associated with man-made shelters. The percentages of trout using man-made shelters increased as trout size increased. There was weak positive correlation between trout population density in 100m subsections of the study area and the amount of natural and man-made overhead cover per subsection.

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INTRODUCTION

This study was intended to examine cover used by trout in a 1-km section of the Mainstream of the Au Sable River which lies within several kilometers in which the Michigan Department of Natural Resources installed instream shelters in 1975 to enhance habitat for trout. It was not known how intensively these structures were used by trout. To my knowledge no study has been made which examines how many trout use individual shelters of the types constructed in the Au Sable River.

One of the primary purposes of these shelters was to increase the carrying capacity of the stream for trout, especially large trout, by increasing the amount of overhead hiding and resting cover. The shelters are readily characterized by size, type of construction, surrounding water depth and velocity, composition of streambed material beneath shelters, and position relative to the stream banks. A better understanding of the relationship of these parameters to the density of trout beneath shelters could lead to construction modifications that maximize the carrying capacity for large trout while minimizing construction costs.

It has been fairly well documented that trout abundance in streams is often positively correlated with the amount of hiding cover. Enk (1977) found that the length of overhead bank cover in Michigan's Pigeon River accounted for 88% of the variation in July number of trout $\geq$ 150mm long and 72% of the variation in July biomass of trout

150-399mm long. Lewis (1969) examined a number of physical parameters influencing trout populations in pools and found that current velocity and total cover were the most important factors. Both coho and cutthroat trout prefer sidepools offering overhanging bank cover as opposed to those without bank cover (Bustard and Narver 1975b). Bustard and Narver (1975a) found that the cover types used most frequently by coho and age I+ steelhead at low winter temperatures were logs and upturned tree roots. Knowledge of the association of trout with cover has led fishery managers to construct artificial cover in streams to increase carrying capacity and overwinter survival. The addition of bank-cover-deflectors in Lawrence and Big Roche-a-Cri Creeks in Wisconsin resulted in dramatic increases of both brook trout standing crops and anglers' catch (Hunt 1971; White 1975). The increases in abundance were greatest for the larger size classes. The addition of dams, deflectors and covers in a 450-yard section of Hayes Brook, Prince Edward Island, Canada resulted in a near doubling of the numbers of brook trout age I and older (Saunders and Smith 1962). Increases in trout standing crops following the installation of cover were reported for a mixed rainbow, brook, and brown trout population by Boussu (1954).

Stream salmonids are usually found in microhabitats associated with some type of shelter. Variables which have been examined in relation to microhabitat choice by salmonids include, water temperature, velocity, nearness to preferred velocity, turbulence, depth, turbidity, and direction of flow. Other factors are photoperiod, light intensity (incident and reflected), spatial limits, thigmotaxis, substrate type and color, visual reference points, lateral concealment, presence or or absence of competitors, overhead cover, distance to nearest overhead escape cover, size, amount, and periodicity of food items drifting past the salmonids position. The following section is a review of the literature dealing with the effect of some of the above factors on a salmonids choice of microhabitat.

Baldes and Vincent (1969) observed that brown trout (average length 21.3 cm) in an experimental flume occupied resting microhabitats within a velocity range of 12.2 to 21.3 cm/sec. Vincent (1969) states that modal water velocity in a resting microhabitat was 21.3 cm/sec for brown and rainbow trout and 15.2 cm/sec for brook trout. Areas with water turbulence, lack of cover, or water velocities less than 9.1 cm/sec or greater than 30.5 cm/sec were not used as resting microhabitat. When 25-39 cm brown trout were provided a choice of overhead coverts they preferred a range of sub-covert velocities somewhere between 12.5 and 17.5 cm/sec (Gruber 1978). Griffith (1972) found that the focal point velocities occupied by age 0-III+ brook trout ranged from 7.6-9.6 cm/sec in sympatric brook and cutthroat trout populations. Average focal point velocities ranged from 8.4-10.9 for allopatric brook trout. Griffith measured average maximum velocities within 0.6m of the centers of activity of trout ages I-III+ ranging from 12.7-24.1 and 15.7-25.7 cm/sec for sympatric brook and cutthroat trout and allopatric brook trout populations respectively. Trout minimize energy expenditures by positioning themselves in microhabitats of relatively low velocity adjacent to faster which carrying more drifting food items per unit of time thereby minimizing the amount of foraging time spent in swift water. Fausch (1978) found that in a sympatric brook and brown trout population, resting brook occupied resting microhabitats with mean focal point velocities near 20 cm/sec with mean maximum water velocities at 0.6m from the focal point near 36 cm/sec. For feeding brook trout, on the other hand, both focal point velocities and velocities at 0.6m were slightly higher, but the velocity difference between the focal point and maximum adjacent velocity was essentially the same as that for resting brook trout. The frictional force exerted on passing water by instream trout shelters can create areas of reduced current beneath the shelter, while faster current sweeps along the edge of the device.

Light is also an important activity regulating stimulus. Investigations of the activity of brook, brown, and rainbow trout show that all three species are photonegative (Baldes and Vincent 1969; Butler and Hawthorne 1968; Gibson and Keenleyside 1966; Gibson and Power 1975; Gruber 1978; Kwain and MacCrimmon 1969). Overhead cover provides hiding areas of low light intensity. Stewart (1970) reported that overhead cover use increased with increased structure size, decreased structure height and decreased percentages of holes in the overhead cover. The response was strongly related to the light intensity under the structures. DeVore (1975) reported that adult brown trout preferred overhead cover which was low (10cm) rather than high (15 or 20cm) in the water column. He concluded that the response was related to the close visual proximity of the cover to the stream bed but it may have been the result of decreased light intensity beneath low coverts. Gruber (1978) found that brown trout most often occupied coverts offering the greatest darkness within the range of 0.0100-5.0000 ft-c at current velocities ranging from 0-149mm/sec. At current velocities within the range of 150-199mm/sec, trout randomly selected coverts with different light intensities. Bassett (1978) demonstrated that brown trout also respond to reflected light, preferring overhead cover with a dark bed beneath it. Gibson and Power (1975) found that more brook trout were found in a shaded portion of a shallow tank (24-29cm) than in unshaded portions. Conversely, in a deep tank (43-50cm) more trout occupied unshaded areas than shaded ones. They suggested that a water depth of 50cm provided sufficient cover for trout 8-27cm. However, trout usually do not find shade as attractive as overhead cover in contact with the water (R. J. White pers. comm.).

More trout $\geq$ 152mm have been found in deep water than in shallower water beneath undercut banks and overhanging vegetation (Wesche 1976). Larger fish are typically found in deeper faster water than smaller individuals (Chapman and Bjornn 1969; Everest and Chapman 1972). To my knowledge no one has examined preference for overhead shelters in different water depths while controlling for light intensity, water velocity, and other behavior directive stimuli which may change with increased depth.

Tactile features of overhead cover also influence trout behavior. DeVore (1975) found that brown trout preferred overhead cover with clear plastic streamers beneath them over coverts without streamers.

Most stream-dwelling salmonids are strongly territorial. As fish grow larger the size of their territory increases and its physical characteristics change (Allen 1969). The size of each territory is also influenced by such factors as current velocity, bottom irregularities, or other forms of lateral concealment (Allen 1969; Keenleyside 1962; Basset 1978). Lateral concealment beneath overhead cover permits the establishment of smaller territories and reduces agonistic behavior by visually isolating trout from each other.

General objectives of this study are:

(1) To define the relationship of subshelter trout density in the Au Sable River to various physical and hydrological parameters

(2) To compare trout density beneath three types of artificial shelters.

(3) To determine what percentage of trout in 100-m stations are found beneath man-made shelters.

Specific objectives of this study were:

(1) To determine how much of the variation in subshelter trout density is accounted for by shelter size, maximum water depth adjacent to the shelter, and subshelter water velocity (as indicated by streambed material beneath shelters) and to define the relationship of these factors to trout density.

(2) To test for differences in subshelter trout density among three shelter types.

Secondary objectives of this study were:

(1) To obtain trout population estimates for a 1-km section of the Au Sable River.

(2) To determine if trout abundance/100-m station is correlated with the amount of permanent man-made, natural, or total overhead cover/100-m station.

DESCRIPTION OF THE STUDY AREA

The Main Branch of the Au Sable River lies in Otsego, Crawford, Oscoda, Alcona, and Iosco counties in Michigan's lower peninsula. The stream arises north of Frederic and flows south to Grayling, then generally eastward to its confluence with Lake Huron at Oscoda. The East Branch of the Au Sable River joins the Main Branch at Grayling. The study area (Figure 1) consisted of one kilometer of the Mainstream, lying about 21.5 km downstream from Grayling in the Knight Tract which is owned by Trout Unlimited and designated as a research area. The study area is also within a 14.5-km section of stream on which there are sportfishing regulations more restrictive than those on most other Michigan trout waters. The area of the drainage basin above the study area is 567.2 km^2 (Hendrickson and Doonan 1972). Riparian woody vegetation in the study area consist primarily of spruce, balsam fir, northern white cedar, speckled alder, paper birch, and pine, as well as some hardwood trees (Hendrickson and Doonan 1974; Schmidt and Rusz 1974).

The river basin in this area is characterized by sandy soils and glacial deposits. The permeability of these deposits causes a high percentage of precipitation to recharge the groundwater rather than to run off. The strong contribution of ground water to stream flow results in rather stable discharge and serves to stabilize and reduce

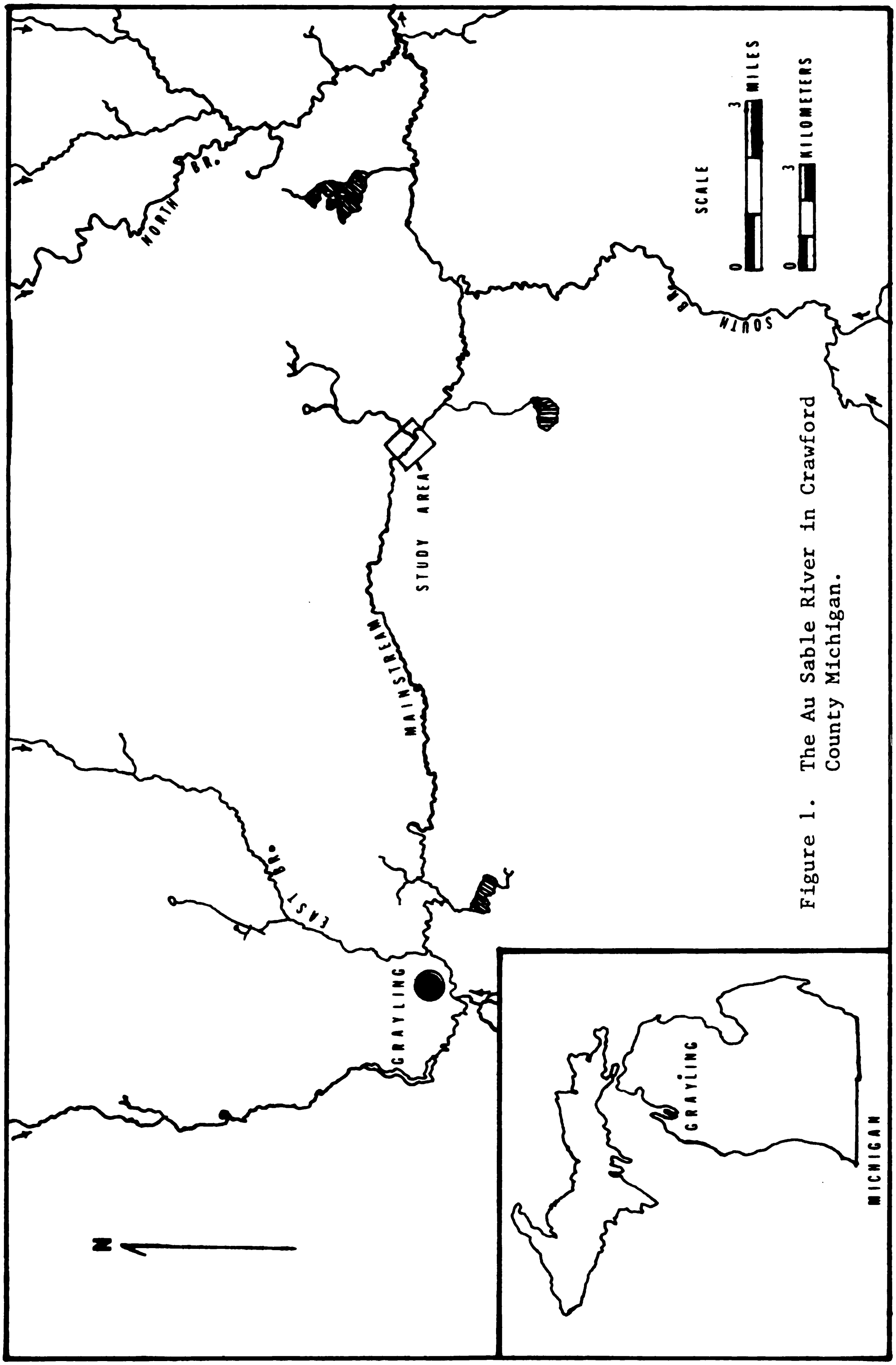

Figure 1. The Au Sable River in Crawford County Michigan.

summer temperatures in the upper reaches of the Au Sable, making these waters thermally suitable for trout.

Mean annual precipitation at Grayling is 76.2cm. The minimal infiltration rates is 30.48cm per hour (Bent 1970).

Specific Location and Dimensions of the Study Area

The study area lies in Crawford County, 14.5km east of the town of Grayling, Michigan. The study area is within Sections 3 and 11 of Township 26 North, Range 2 West, and consists of 100-m, as measured upstream from the south edge of the northeast quarter of Section 11 (Figure 2). The study area is 1.6km upstream kilometers above Wakeley Bridge and 21.5 stream kilometers below Grayling.

Two dirt roads leading south from Wakely Bridge Road provide access to the downstream end of the study section. Dirt roads leading to the Thunderbird Club provide access to the central and upper portions of the study area. The mean stream width and mean maximum depth in the study area are 29m and 78.7cm respectively (Schmidt and Rusz 1974).

The mean streambed slope in the study area is 1.39m/km. Barker Creek enters the study section from the northest about 300-m upstream from the lower edge of the study area.

Water Quality

Stephans Bridge and Wakely Bridge are 4.6km upstream and 1.6km downstream respectively from the study area. Hendrickson and Doonan conducted chemical analyses at a site above Stephans Bridge, NW 1/4 sec. 5 T. 26N., R. 2W (Figure 2) in 1972 (Table 1).

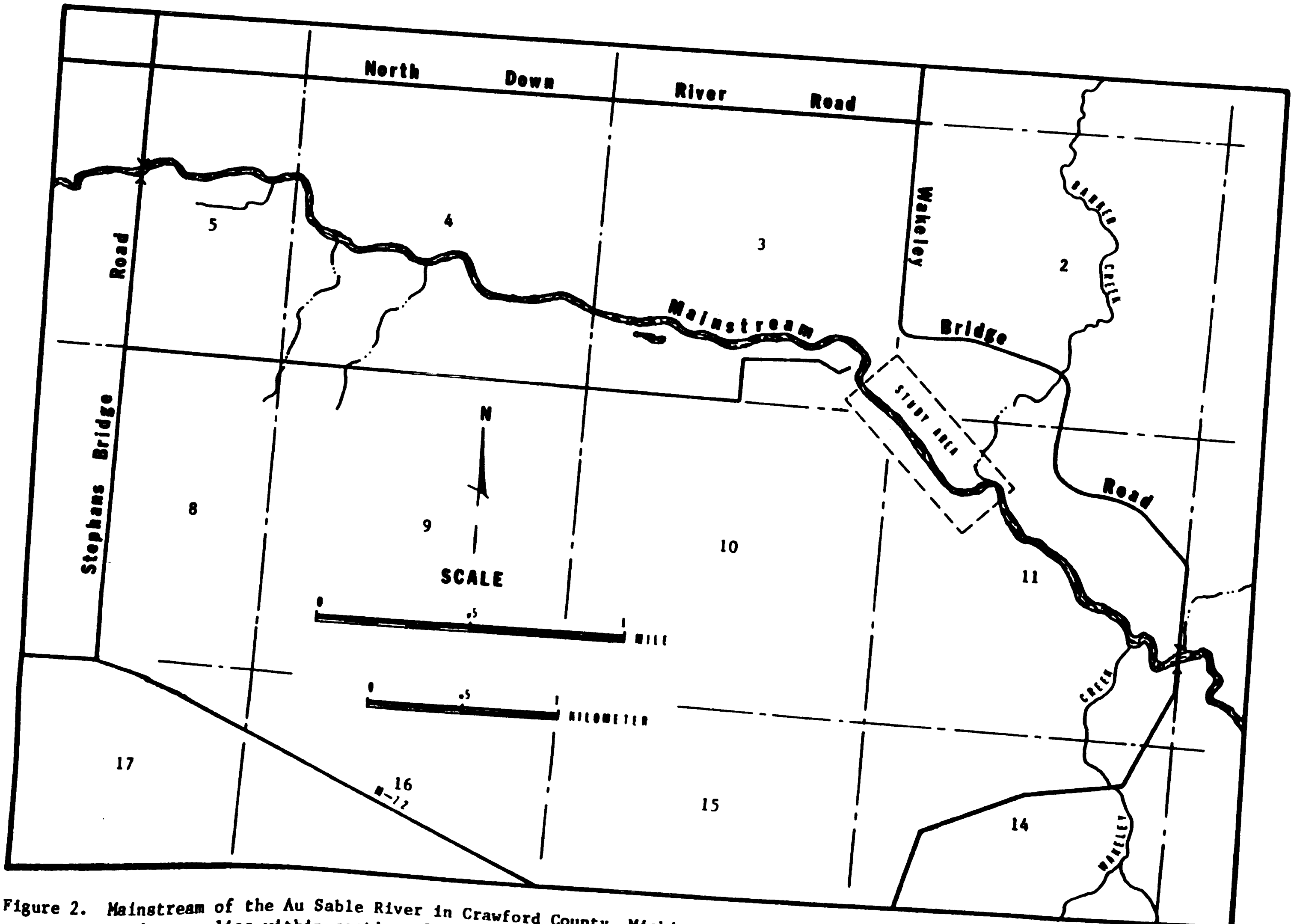

Figure 2. Mainstream of the Au Sable River in Crawford County, Michigan, showing the study area and Township sections. The study area lies within sections 3 and 11 of the Township 26 North, Range 2 West.

Table 1. Water chemistry above Stephans Bridge.*

Item Measured	mg/l
Calcium (Ca)	42.0
Magnesium (Mg)	7.6
Sodium (Na)	2.3
Potassium (K)	0.6
Bicarbonate (HCO_3)	158.0
Carbonate (CO_3)	0.0
Sulfate (SO_4)	7.6
Chloride (Cl)	4.0
Fluoride (f)	0.2
Nitrate (NO_3)	0.2
Dissolved solids:	
Residue on evaporation at 180°C	150.0
Hardness, as $CaCO_3$	140.0
Noncarbonate	6.0
Specific conductance	265.0 (micromhos at 25° C)
pH	7.4

* Hendrickson and Doonan (1972).

Dissolved oxygen in most of the river does not drop below 6 mg/l at any time (Hendrickson and Doonan 1974). (The Michigan Water Resources Commission water quality standards adopted in 1968, set the minimum dissolved oxygen standard at 6 mg/l for trout).

Discharge

Owing to the morphometry and soils of the Au Sable River basin, streamflow is very stable. The high permeability of the basin's glacial till causes most water to be absorbed into the ground and released slowly to the channel. At Stephans Bridge (about 4.6km upstream from the study area) mean annual discharge is $5.27m^3/s$ with 10-percent duration discharge of $6.80m^3/s$ and 90-percent duration discharge of $4.19m^3/s$. The ratio of 10-percent to 90-percent duration discharge is 1.62. Additional discharge data is shown in Table A1. Approximate daily streamflow discharges at Stephans Bridge for a period of time encompassing the period of data collection are plotted in Figure 3.

Bed Materials

The bed materials in most of the study are sand and gravel. Gravel predominates in riffle areas and provides excellent spawning habitat and substrate for aquatic invertebrates. Silt and muck predominate in shallow, low-velocity areas near the bank. Extensive silt beds are present beneath and downstream from many instream trout shelters. Most of the silt beds lying downstream from these shelters have been somewhat stabilized by rooted aquatic macrophytes. Some patches of clay are present in the upstream portion of the study area.

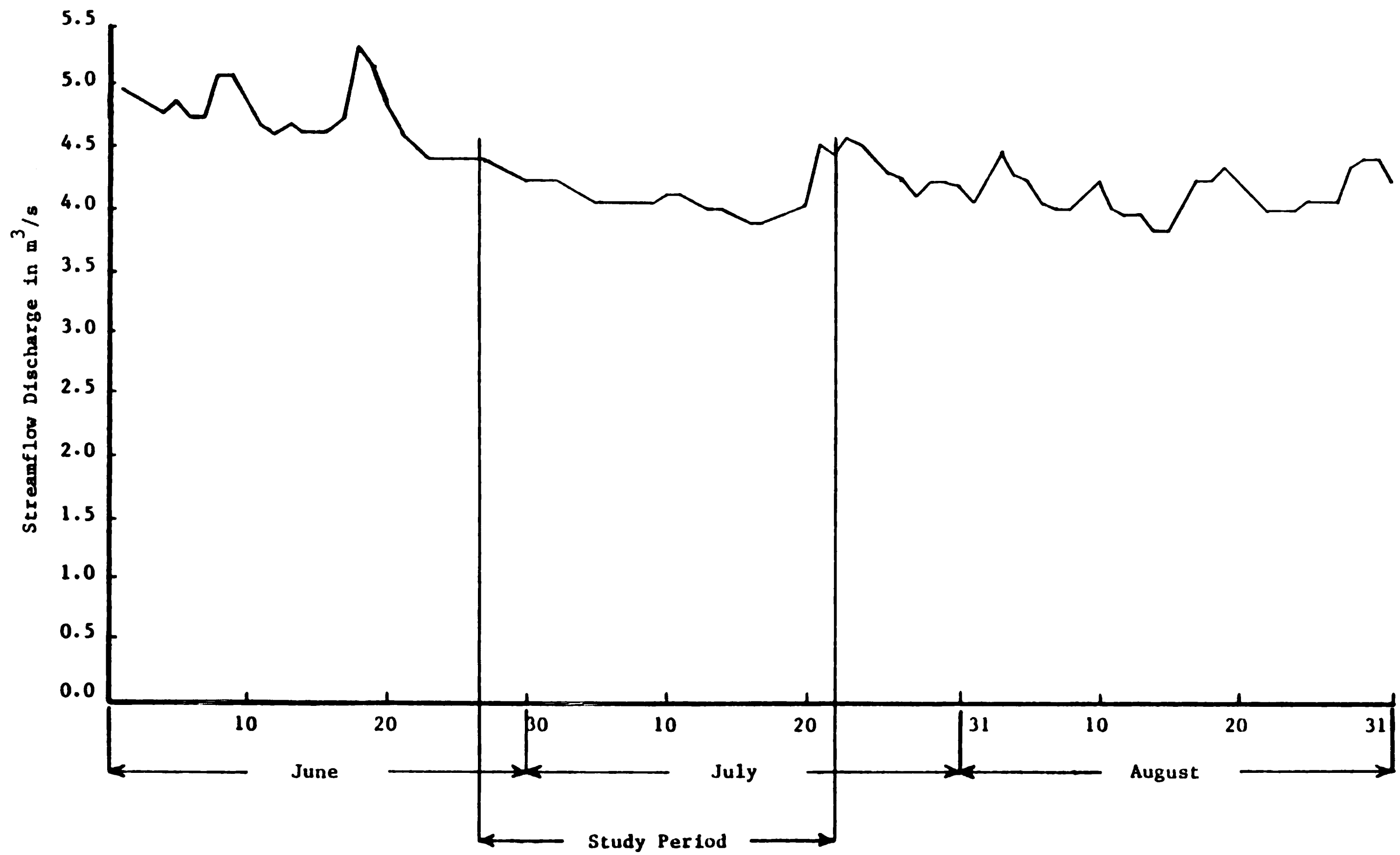

Figure 3. **Approximate daily streamflow discharge at Stephans Bridge in m^3/s, June through August 1978. (Data from Robert Larson USGS, Grayling, pers. comm.)**

Trout Cover

Cover for trout is provided by aquatic vegetation, water depth (pools), stream improvement structures, natural log jams and a few undercut banks. The most cover is provided by 70 man-made instream trout shelters.

Four major types of man-made shelters were found in the study section: (1) log jams (Figure 4), (2) sunken log rafts (Figure 5), (3) stump shelters (Figure 6), and (4) overhanging bank shelters (Figure 7).

Log jam shelters were built using both streamside and instream logs. In some cases natural log jams were anchored to the stream bottom to prevent them from washing away during high water. In other cases, natural log jams were widened and extended to form larger expanses of overhead cover. Streamside trees angling downstream across the current were used to deflect water against and beneath artificial log jams anchored at their downstream ends. The irregular shapes of the building materials prevented most of the log jams from presenting an artificial aspect when viewed from above and also created large amounts of lateral concealment in subshelter areas. The average amount of overhead cover available for use by trout was $8.28m^2$ for the 45 log jam shelters in the study section.

Sunken log raft shelters were usually solid rectangular structures constructed with natural logs and anchored beneath the water surface 4-10 inches off the stream bottom parallel to the current. Some logs were anchored on the bottom beneath the structures to provide areas of reduced current velocity and to create lateral concealment, as well

Figure 4. A large rectangular log jam shelter (foreground) and another log jam shelter constructed beside a tree angling downstream to form both a deflector and overhead cover (left center). View is downstream. Mainstream of the Au Sable River, June 1979.

Figure 5. Submerged log raft shelter positioned near midstream. Mainstream of the Au Sable River, June 1979.

Figure 4.

Figure 5.

Figure 6. Stump shelter positioned near midstream. View is downstream. Mainstream of the Au Sable River, June 1979.

Figure 7. Bank shelter in station 1. This device provides an overhang up to 4m wide adjacent to a deep pool and also serves to stabilize the bank. View is upstream. Mainstream of the Au Sable River, June 1979.

Figure 6.

Figure 7.

as visual and thigmotactic reference points. Most raft shelters were places in fairly deep water in midstream to allow canoes to pass over them unhindered. The mean amount of overhead cover beneath the 9 rafts in the study section usable by trout was $3.7m^2$.

Stump shelters were constructed by binding large stumps into a roughly circular shape and anchoring them off the bottom. The root structure of the stumps provided lateral concealment and caused the current to scour bowl-shaped depressions beneath the shelters. The mean amount of overhead cover beneath the 3 stump shelters in the study section potentially available to trout was $2.08m^2$.

Two large bank shelters, 61 and 79 meters in length, were within the study section. These shelters were constructed on the outside of meander bends in stations 1 and 3. Their solid surfaces were from 1.5-4m in width and provided large areas of overhead cover. These two structures prevent the stream from eroding the bank and have caused it to scour out long, deep pools which are 1.7m deep in some areas.

Fishes

The fish population in the study area consists primarily of brown, brook, and rainbow trout. These species are not native to the system but were introduced between 1884 and 1891 (Richards 1973). Richards collected fish with seines from most sections of the Au Sable watershed in 1972. Table 2 is a summary of the species of fish taken in 1972 by Richards at 3 stations near the study area.

Table 2. Species of fish captured in the 1970s in the Au Sable River, X's indicate fish presence.

Species		Location of Capture: 1.61 km above Stephans Bridge	1.61 km below Stephans Bridge	Wakeley Bridge	**In study area
Brook trout	*Salvelinus fontinalis* (Mitchill)	X	X	X	X
Rainbow trout	*Salmo gairdneri* Richardson		X		X
Brown trout	*Salmo trutta* Linnaeus	X	X	X	X
Round whitefish	*Prosopium cylindraceum* (Pallas)			X	X
Mottled sculpin	*Cottus bairdi* Girard	X	X	X	X
Slimy sculpin	*Cottus cognatus* Richardson			X	X
Common shiner	*Notropis cornutus* (Mitchill)		X	X	
Blackchin shiner	*Notropis heterodon* (Cope)			X	
Blacknose shiner	*Notropis heterolepis* Eigenmann and Eigenmann			X	

Table 2. (cont'd.)

Species		Location of Capture: 1.61 km above Stephans Bridge	1.61 km below Stephans Bridge	Wakeley Bridge	**In study area
Fathead minnow	*Pimephales promelas* Rafinesque			X	
Blacknose dace	*Rhinichthys atratulus* (Hermann)		X	X	
Creek chub	*Semotilus atromaculatus* (Mitchill)			X	
White sucker	*Catostomus commersoni* (Lacepede)	X	X	X	X
Brook stickleback	*Culaia inconstans* (Kirtland)			X	
Rock bass	*Ambloplites rupestris* (Rafinesque)		X		
Bluegill	*Lepomis macrochirus* Rafinesque			X	
Northern pike	*Esox lucius* Linnaeus				X

** Captured by electrofishing in the study section, July, 1978.

Benthic Invertebrates

Schmidt and Rusz's (1974) examinations of the benthos in the Stranahan tract (1.21km upstream from Stephans Bridge) and the Knight Tract revealed a diverse and abundant insect population. Table 3 lists the more common organisms they found.

Instream Vegetation

Abundant aquatic vegetation in the study area provides cover for trout as well as substrate and food for aquatic invertebrates. Vegetation proliferates in the shallow, silted areas found in slowly flowing water downstream from many trout shelters. Table 4 lists common types of aquatic vegetation found on the Knight Tract.

River Use

The Au Sable is used primarily for recreation. The section from Grayling to Wakeley Bridge is intensively used by both fishermen and canoers. Numerous cabins and homes are found along this stream reach. This wide, shallow section of river provides easy wading and fly casting. Fishing pressure is intense, especially during insect hatches.

There are special angling regulations on the 14.3km section between Burton's Landing and Wakeley Bridge. At the time of this study, fishing gear was restricted to artificial flies. Three trout could be taken a day. Minimum size limits were 8 inches for brook trout and 12 inches for all other trout. There was no closed season; trout could be caught but not kept from November 1 through April 28.

Table 3. Common benthic organisms found and identified on the Stranahan and Knight Tracts.[a]

Ephemeroptera (mayflies)

- *Trichorythodes sp*.
- *Baetis sp*.
- *Ephemerella invaria*
- *Ephemerella lata*
- *Pseudocloeon sp*.

Trichoptera (caddisflies)

- *Brachycentrus sp*.
- *Glossosoma sp*.
- *Heliocopsyche* sp.
- *Protoptila sp*.
- *Neophylax sp*.
- *Lepidostoma sp*.
- *Hydropsyche sp*.

Coleoptera (beetles)

- Elmidae

Odonata (dragonflies, damselflies)

- Agrionidae

Diptera (flies, midges)

- Simulidae (black flies)
- Chironomidae (midges)
  - Hydrobaeninae
  - Tendipedinae
- Tabanidae (deerflies)

Hemiptera (true bugs)

- *Gerris* sp. (water striders)

Megaloptera

- *Corydalis* sp. (Hellgramites)

Other

- *Physa* sp. (snail)
- *Sphaerium* sp. (fingernail clam)
- *Gammarus* sp. (scud)
- *Ascellus* sp. (sowbugs)

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[a] From Schmidt and Rusz (1974).

Table 4. Common aquatic vegetation found and identified on the Knight Tract.[a]

Common Name	Scientific Name
Submerged Forms	
Threadleaf Pondweed	*Potamogeton filiformis*
Whitestem Pondweed	*Potamogeton praelongus*
Crispedleaf Pondweed	*Potamogeton crispus*
Water Buttercup	*Ranunculus* sp.
Waterweed	*Elodea* sp.
Water Milfoil	*Myriophyllum* sp.
Attached Algae	
Stonewart	*Chara* sp.
Freshwater Red Algae	*Batrachospermum* sp.
Green Algae	*Cladophora* sp.
Emergent and Semi-aquatic forms	
Bulrush	*Scirpus* sp.
Spike Rush	*Eleocharis* sp.
Sedge	*Carex* sp.
Rush	*Juncus* sp.
Arrow Arum	*Peltandra virginica*

[a]From Schmidt and Rusz (1974).

METHODS

Population Measurements

Preparation of the Study Area

The study area was divided into ten 100-m stations which were marked by tying plastic tape to streamside trees at station boundaries. Stations were measured by trailing a 30m plastic clothesline marked in meters in the thalweg. Therefore, the stations are measures of thalweg distance rather than streambank distance. Station markers were numbered 1 (downstream) through 10 (upstream).

Small squares of plastic tape numbered 1 through 70 were nailed on the downstream end of each artificial instream trout shelter in the ten stations.

Snorkel Diving Observations

Wearing a black wetsuit consisting of hood, boots, face mask, snorkel tube and gloves, I slowly approached each shelter while submerged from downstream, looked beneath it and observed the number of visible trout. Trout were categorized as less than and greater than 150mm in total length. The number, size class, and species of trout observed under each shelter was told to a notetaker who waded about 30m downstream. An Ikelite C-Lite II underwater light was used to illuminate beneath objects so I could see trout not otherwise visible. Counts were made June 28, 29, and 30, 1978, from about 0830 h to 1200 h and from 1400h to 1630h. Counts were made 3 times for each of 39 shelters during this time. Only 39 of the 70 shelters were observed at this time because vandals had removed many of the identifying tags from the shelters.

Underwater visibility was measured at the beginning of each observation period and about every half hour afterward. Visibility was determined by holding the yellow tip of a black snorkel tube underwater in midstream and measuring the maximum distance away which it could be seen by a submerged diver. Sky conditions for each shelter observation were classified as overcast, clear, hazy, or with intermittent clouds. These broad categories were chosen because they were believed to influence fish behavior and possible cover-seeking activity.

Electrofishing Procedure

Trout populations were inventoried using mark-and-recapture electrofishing. The procedure was designed to make population estimates for individual trout shelters, natural cover, man-made cover, and for individual 100-m stream sections.

The electrofishing unit consisted of a 2.1m plastic boat carrying a 250-v, 1.75-kw generator. Three spring-loaded retracting reels mounted on the bow were connected to the generator's anode and to fiberglass handled capture electrodes. The reels permitted the crew members to be separated by as much as 16 meters. The cathode consisted of brass window screening under a styrofoam float trailed behind the boat.

A 3-man electrofishing crew moved upstream toward each trout shelter, one man towing the boat and each carrying an anode and hand net. The anodes were held out of the water until the crew had surrounded the shelter so that fish holding positions in midstream would not be driven into the shelter by the electrical field (but they could flee there when frightened by approaching crew). The crew then thrust their electrodes under the cover simultaneously, creating an electrical field around the shelter. Trout drawn to the electrodes were netted and transferred to a holding tank on the boat. The electrodes were probed into all accessible interstices of the shelters and withdrawn, pulling trout out where they could be netted. When no more fish could be found, the electrodes were removed from the water. A piece of plastic tape with a number corresponding to the number of the shelter was dropped into the boat's holding tank with that group of fish. A separatory net was then placed in the tank. The crew proceeded upstream to the next shelter with electrodes out of the water and repeated the above procedure. After about 5 shelters were inventoried, the holding tank was transferred to the stream for processing by a 2-man team following the electrofishing crew. This procedure was continued until all individual shelters in a 100-m station were sampled.

Because the stream was about 29m wide, we sampled shelters on one side until we reached the upstream station marker. The generator was shut off, and the crew moved to the downstream end of a station, walking on the side of the river already sampled. The crew then fished the shelters on the other side of the river until the upstream marker was reached. After all man-made shelters had been sampled individually, the crew once again moved to the downstream end of the station and began shocking all areas of the stream, holding their electrodes in the water at all times. Beds of aquatic plants, log jams, and riffle areas were all sampled. Man-made shelters were all reshocked to capture any fish driven into them from elsewhere. All fish captured on this sweep were kept separate in the notes.

A 2-man processing crew anesthetized captured trout with tricaine methane sulfonate (MS-222), weighed them to the nearest gram, and measured them to the nearest millimeter. Trout captured on the first run were marked by clipping the lower tip of the caudal fin. The length and weight data were recorded and cataloged according to species, shelter number, and station number. Captured trout were held in a live-box until at least one 100-m station was completely electrofished. Fish were then released at the downstream end of the station from which they had been captured so that the disoriented trout (which tend to swim upstream when released) could better assume their former distribution.

The second or recapture run was done by the same electrofishing procedure described above. During the process, fish were examined for caudal fin clips. The upper tip of the caudal fin was clipped on this run so that these fish would not be counted twice if they moved upstream overnight from the point where the crew stopped fishing. Unmarked fish were weighed and measured. Fish bearing fin clips from the first run were only measured, not weighed again. The shelter and station number where each fish was captured was recorded.

The first marking run was conducted July 17-18; the second or recapture run on July 20-21, 1978.

Population Estimates

Population estimates were calculated by the Schaefer modification of the Peterson Formula (Ricker 1975).

$$P = \left[\frac{m + 1\ (r + u + 1)}{(r + 1)}\right] - 1$$

Where P = estimated population

m = number of fish marked on first run

r = number of marked fish recaptured during the second run, and

u = number of unmarked fish captured on second run

The standard error of the estimate is calculated according to the following formula from Ricker (1975).

$$SE = \sqrt{\frac{P\ (u)}{(r + u + 1)\ (r + 2)}}$$

I calculated 95% confidence limits for all estimates. If the calculated lower limit was less than the sum of the marked and unmarked fish, the sum of marked and unmarked fish was recorded as the lower limit.

Separate population estimates and 95% confidence limits were calculated for fish of each 50-mm size class from 50mm to 350mm. Fish from 350-500mm were grouped for population estimates because both the total number and the number of recaptured fish in individual 50-mm size classes above 350mm were small. The number of fish in the three individual 50-mm size classes over 350mm were then calculated by prorating the total estimate for the 150-mm size class according to the procedure described below for species and station estimates.

Population estimates were made for the 1-km study section (all 10 stations). Estimates were also calculated for each size class for stations 2,4,5,6,7,8,9, and 10 combined and used as the basis for proration into individual trout shelters. Stations 1 and 3 were excluded from this section of the analysis as they were too deep and swift for effective electrofishing.

Estimates of the number of brown trout in each size class were obtained by multiplying the ratio of m + u brown trout to m + u brook and brown trout combined for a size class by the population estimate for that size class. This same ratio was multiplied by the upper and lower 95% confidence limits of each combined-species estimate of each size class to obtain confidence limits for brown trout size class estimates. These brown trout estimates were then partitioned into individual trout shelters according to the ratio of m + u fish for individual stations to m + u fish summed over all 8 stations. The same procedure was used to estimate the numbers of brown trout found in man-made shelters and in natural cover.

Brook trout estimates were obtained by partitioning the combined brook and brown trout estimates for 8 stations, into individual stations on the basis of m + u as described above. Individual station estimates were prorated from combined brook and brown trout estimates for 8 stations rather than brook trout estimates for 8 stations to minimize the rounding errors that would have occurred, owing to the small number of brook trout captured

I used the subdividing methods described above for a number of reasons. Cooper (1952) noted that, since large fish are captured more easily than small ones, it is necessary to make separate estimates for different sizes. He noted further that the total estimate can be subdivided into numbers of fish of each species if each species is represented in the total population in direct proportion to its representation in all of the sampling. A similar breakdown may be made for different portions of the stream if capture efficiencies for different parts of the stream are similar. Cooper states that subdividing the total estimate is believed to be more accurate than estimating the numbers of fish of each size and species in small portions of the stream separately and combining all the individual estimates for the total population.

Brown trout biomass estimates for stations and trout shelters were computed as the product of the number of fish and the average weight of brown trout in each size class for the entire study section. Brook trout biomass estimates were computed using the average weight of brook trout in each size class for all stations.

I obtained 95% confidence intervals for trout biomass by multiplying the upper and lower population limits for each species, size, and location category by the average weight of the corresponding species and size category.

Rainbow trout abundance estimates were caculated in the same manner described above for brook trout.

Habitat Measurements

Trout Shelter Classification Scheme

Shelter types were classified as treatments. These coverts were categorized as log jams, sunken log rafts, stump coverts, or overhanging bank coverts. After stations 1 and 3 were removed from data analysis only 1 overhanging bank cover remained. This bank cover was believed to be functionally equivalent to a log jam and was placed in this category, leaving only 3 shelter types or treatments for analysis.

Measurement of Overhead Cover

High rents and other expenses coupled with a paucity of funds at the time of data collection prevented me from making detailed maps and measurements of habitat. Therefore the kinds of habitat measurements I made were based on literature and on one week of snorkel diving observations. Based on preliminary observations of the minimum dimensions of cover used by trout in the Au Sable River, the area and length of overhead cover in contact with the water, 10cm or more above the substrate and 10cm or more in width was measured for each trout shelter. Similarly, permanent natural overhead coverts such as logs and undercut banks were measured and cataloged according to station and location relative to man-made trout shelters. A diver with wetsuit and meter stick looked under each cover and carefully measured the area of overhead cover meeting the minimal criteria described above. A notetaker recorded the measurements under the appropriate shelter code number. Lengthy overhead cover was measured with a steel tape. The diver made visual estimates of the percentages of subcovert rubble, gravel, sand and silt. Substrate size classifications were based on a table by Platts (1976), who defined substrate types according to particle diameter, where rubble is 76.1-304.7mm, gravel 4.7-76.0mm, and sand is less than 4.7mm in diameter. I defined silt as any fine organic matter. The maximum water depth found immediately adjacent to the trout shelters, the shelter type, and station was also recorded. Substrate type was recorded to obtain rough estimates of the subcovert water velocities. The large size and complexity of the trout shelters created a mosaic of current velocities, turbulence and direction beneath them and precluded measurement of any one representative or series of representative current velocities. The type of sediment present beneath the covert is an expression of the integrated effects of the mosaic of velocities. (Particles of 0-5mm diameter require a current velocity of around 20cm/sec to be eroded. Larger particles require progressively higher current velocities to be picked up and transported downstream (Morisawa 1968)). Light organic silts are much more readily eroded than inorganic particles of the same size and are found only in areas of very low current velocity.

Statistical Analyses

Multiple linear regression analysis was used to determine how much of the variation in trout numbers and biomass beneath individual trout shelters was accounted for by water depth, size of shelter, substrate type, and shelter type. All calculations were made with Michigan State University's CDC 6500 computer. I used the backward elimination procedure to reduce the number of independent variables in the equation to those which provided the best linear regression fit. Maximum water depth proximal to the shelter, length of overhead cover, area of overhead cover, percentage of subcovert gravel and rubble, percentage of subcovert sand and percentage of subcovert silt were initially entered into the regression equation. Electrofishing estimates of the numbers or biomass of trout in selected species size classes associated with individual trout shelters were used as the dependent variables.

Dummy variables to account for the effect of treatments (shelter type) were also created and made available for entry into the regression equations. Residuals were plotted and examined to determine if error components were independent with a mean of zero and if they had the same variance throughout the range of Y values.

To obtain better regression fits I elected to enter a number of interaction and polynonial terms in addition to the simple independent variables listed above. I used estimated numbers or biomass of trout in selected species size classes as the independent variables. These regression analyses were made using both the backward elimination method and the stepwise method. In the stepwise method independent variables were entered one-by-one in a series of regression steps if they had a F ratio greater than 3.0. Variables already in the equation were removed on subsequent steps if they had an F ratio of less than 2.8. Variables removed from the equation could be re-entered at later steps. Dummy variables were created and made available for entry into the regression equations to account for possible treatment effects. Residuals were plotted and examined for each regression equation.

Analysis of Effect of Cover Type

After examining the regression equations for various species/size classes, I chose 6 species size classes which seemed most likely to provide statistically valid comparisons between shelter types. Differences among shelter types in biomass (grams) of brown trout $\geq$ 100mm in total length per shelter, biomass of brook and brown trout $\geq$ 150mm per shelter, and biomass of brown trout greater than or equal to 150, 200, 250, and 300 mm per shelter were tested using analysis of covariance.

The three independent variables, maximum water depth proximal to the shelter x total length of overhead cover, maximum water depth proximal to each shelter and maximum water depth proximal to each shelter squared were chosen as covariates. Dummy variables were created to account for the effect of shelter type (treatments). Factors accounting for interactions between treatments and covariates were also created. Three separate regressions were calculated for each dependent variable. One regression equation contained only covariates, one contained covariates and dummy variables, and one contained covariates, dummy variables, and interaction factors. These regressions were first used to test for interaction or the lack of homogeneity of slopes. Since the F test for interaction was not significant ($\alpha = 0.05$) for any of the dependent variables I then tested the hypothesis that all treatment effects were equal to each other and zero. There were no significant treatment effects at $\alpha = 0.05$ so analysis ceased at this point.

Snorkel Diving Data Analysis

Multiple regression analysis was used to determine which physical parameters provided the best regression fit for the mean number of brook and brown trout (from 3 snorkel diving observation periods) sighted beneath individual trout shelters on various physical parameters. I used the backward elimination procedure and included interaction and polynomial factors among the independent variables. Dummy variables were available for entry into the regression equation to account for possible treatment effects (shelter types). Equations containing 2 and 3 predictor variables were derived. Residuals were plotted for the 2 variables "best fit" regression equations and examined for randomness.

Relationship of Trout Numbers and Biomass to Cover per Station

The relationship between trout abundance (numbers or biomass) per station and overhead cover per station was examined by both one way and multiple regression analysis. The relationship between trout abundance/100-m station and amount of overhead cover/100-m station was examined for natural and man-made overhead cover individually and in combination for stations 2, 4, 5, 6, 7, 8, 9, and 10.

RESULTS

Trout Abundance

The Au Sable was difficult to electrofish owing to its large size. However, the efficiency of recapture (60%) for trout 200mm or more in total length provided for precise population and biomass estimates. Recapture efficiency was 31% for trout 100-199mm and 8% for trout 50-99mm.

Brook, brown, and rainbow brout abundance and 95% confidence limits for all 10 stations combined are presented in terms of numbers (Table 5) and biomass (Table 6). Trout $\geq$ 150mm comprise 25% of total trout numbers and 82 percent of total trout biomass. Trout $\geq$ 300mm comprise 1.9% of total trout numbers and 22% of total biomass. These estimates for all 10 stations combined are undoubtedly low since two of the 100-m sections contained long deep pools which could not be electrofished effectively. Snorkel-diving observations of these deep pools showed that many large trout were present but very few were captured during electrofishing. Rainbow trout were observed frequently while diving but only 12 were captured in all 10 stations on the combined electrofishing runs. This indicated that rainbow trout were able to avoid the electrical field.

To compensate for this electrofishing inefficiency, estimates were calculated for brook and brown trout combined in the 8 stations which did not contain unwadable pools. These data are shown for individual 100-m stations and 50mm size classes in terms of numbers

Table 5. Population estimates for brook, brown, and rainbow trout combined in the 1-km study section (all 10 stations) of the Au Sable River, July 17 to 21, 1978.

Total length size class (mm)	Lower* Estimate	Point Estimate	Upper** Estimate
0-99	3482	4910	6338
100-149	331	530	729
150-199	997	1122	1247
200-249	278	315	352
250-299	208	237	266
300-349	98	112	130
350-399	20	22	28
400-449	2	2	3
450-499	2	2	3
500-549	1	1	1
Total	5419	7253	9097

* Lower limit of 95% confidence interval

** Upper limit of 95% confidence interval

Table 6. Biomass (kg) estimates for brook, brown, and rainbow trout combined in the 1-km study section (all 10 stations) of the Au Sable River, July 17 to 21, 1978.

Total length size class (mm)	Lower*	Point	Upper**
0-99	20.72	29.23	37.71
100-149	9.12	14.60	20.08
150-199	52.99	59.63	66.28
200-249	31.82	36.05	40.29
250-299	42.05	47.91	53.77
300-349	32.27	36.88	42.81
350-399	9.80	10.78	13.72
400-449	1.49	1.49	2.23
450-499	2.05	2.05	3.08
500-549	1.55	1.55	1.55
Total	203.86	240.17	281.52

* Lower limit of 95% confidence interval

** Upper limit of 95% confidence interval

(Table 11) and biomass (Table 12).

Station 2 which lay between the two stations with long deep pools had the greatest numbers and biomass of 300-349mm trout. Numbers and biomass of trout per station are presented graphically in Figure 8. The trend in numbers of trout did not closely parallel biomass trends, as trout were distributed differently among size classes in different stations.

Brown Trout

Brown trout abundance and 95% confidence limits for all ten stations are shown by 50-mm size class in terms of numbers (Table 7) and biomass (Table 8). These estimates were obtained by proration from the brook brown, and rainbow estimates for all 10 stations. Brown trout comprises 94% of the numbers and 95% of the biomass of all trout less than 300mm. Brown trout greater than 300mm made up 97.1% of the numbers and 98.5% of the biomass of all trout in this size group.

Brown trout abundance and 95% confidence limits for 8 individual stations by 50-mm size class have been calculated in terms of numbers (Table 14) and biomass (Table 16). These estimates were obtained by proration from combined brook and brown trout estimates for the 8 stations without deep, unshockable pools. Stations 4 and 10 held the least brown trout with 401 and 410 respectively. The greatest numbers of brown trout were found in station 2 with 1102 and station 7 with 1224. Biomass of brown trout decreased from 29.81kg-21.36kg from station 2-5. Biomass was greatest in station 6 with 31.23kg and lowest in station 10 with 18.89kg

Table 7. Brown trout population estimates in the 1-km study section (all 10 stations) of the Au Sable River, July 17 to 21, 1978. Estimate by proration from estimate for all species together.

Total length size class (mm)	Lower*	Point	Upper**
0-99	3273	4615	5957
100-149	312	499	687
150-199	937	1054	1172
200-249	265	301	336
250-299	201	229	257
300-349	97	111	129
350-399	19	21	27
400-449	2	2	3
450-499	2	2	3
500-549	1	1	1
Total	5109	6835	8572

* Lower limit of 95% confidence interval

** Upper limit of 95% confidence interval

Table 8. Brown trout biomass (kg) estimates in the 1-km study section (all 10 stations) of the Au Sable River, July 17 to 21, 1978.

Total length size class (mm)	Lower*	Point	Upper**
0-99	19.52	27.28	35.52
100-149	8.58	13.73	18.90
150-199	49.72	55.93	62.19
200-249	30.43	34.57	38.59
250-299	40.52	46.17	51.81
300-349	31.91	36.52	42.44
350-399	9.33	10.32	13.26
400-449	1.49	1.49	2.23
450-499	2.06	2.06	3.08
500-549	1.55	1.55	1.55
Total	195.11	229.62	269.57

* Lower limit of 95% confidence interval

** Upper limit of 95% confidence interval

Brook Trout

Brook trout abundance and 95% confidence limits for all 10 stations by 50-mm size class are presented by numbers (Table 9) and biomass (Table 10). These estimates were obtained by proration from combined brook, brown and rainbow estimates for all ten stations. Brook trout comprised 5.6% of total trout numbers and 3.2 percent of total biomass. There were 94 brook trout 100-199mm in total length. Only 14 brook trout 200-299mm in total length were present in all ten stations. No brook trout greater than 300mm were captured.

Brook trout abundance and 95% confidence limits for 8 individual stations by 50-mm size class were computed in terms of numbers (Table 15) and biomass (Table 17). Station 4 contained the greatest numbers (129) and biomass (2.16kg) of brook trout. No brook trout were captured in station 6 and only 1 was captured in station 10. The mean number of brook trout greater than 99mm for the 7 stations containing brook trout was 12.

Rainbow Trout

Rainbow trout abundance and 95% confidence limits for all 10 stations by 50-mm size class are shown in terms of number and biomass (Table 13). It was noted earlier that although rainbow trout were sighted frequently while snorkel diving, only 12 were captured on the combined electrofishing runs. None of the 9 rainbow trout marked on the first run were recaptured. Only 1 rainbow trout was captured in stations 1 and 3 although ten or more were often sighted in each of these stations during snorkel diving observations. Because rainbow

Table 9. Brook trout population estimates in the 1-km study section (all 10 sections) of the Au Sable River July 17 to 21, 1978. Estimates by proration from estimate for all species together.

Total length size class (mm)	Lower*	Point	Upper**
0-99	209	295	381
100-149	19	31	42
150-199	56	63	70
200-249	11	12	13
250-299	2	2	3
Total	297	403	509

* Lower limit of 95% confidence interval

** Upper limit of 95% confidence interval

Table 10. Brook trout biomass (kg) estimates in the 1-km study section (all 10 stations) of the Au Sable River, July 17 to 21, 1978.

Total length size class(mm)	Lower*	Point	Upper**
0-99	1.23	1.73	2.24
100-149	0.54	0.88	1.19
150-199	2.99	3.37	3.74
200-249	1.16	1.27	1.37
250-299	0.40	0.40	0.61
Total	6.32	7.65	9.15

* Lower limit of 95% confidence interval

** Upper limit of 95% confidence interval

trout were largely able to escape capture, the estimates presented in Table 13 are undoubtedly low.

Comparison of Brook and Brown Trout Abundance

The number of brown trout are compared graphically to brook trout numbers for 8 stations in Figure 9. Brook trout numbers/station were less than 8 percent of brown trout numbers/station for all stations except station 4 where brook trout comprised 32.0% of brown trout numbers.

Biomass of brook and brown trout per station are compared in Figure 10. Brook trout biomass was 5.1% and 8.9% of brown trout biomass in stations 2 and 4 respectively. Biomass of brook trout was less than 3 percent of brown trout biomass in the other 6 stations.

Brown trout were much more abundant than brook trout in terms of both numbers and biomass for all stations. Brook trout in the 50-99mm and 200-249mm size classes were slightly lighter than brown trout of this size. Thus, the ratios of brook trout biomass to brown trout biomass were less than the ratios of brook trout numbers to brown trout numbers. Conversely, brook trout in the 100-149mm and 150-199mm size classes were slightly heavier than brown trout in the same size class. Therefore, the ratios of brook trout to brown trout biomass were slightly greater than the ratios of brook trout numbers to brown trout numbers. This relationship holds for all stations since the mean weight for a species size class was computed from trout weights in all 8 stations to maximize sample size.

Table 11. Brown and brook trout population estimates by 100-m stations in the Au Sable River, July 17 to 21, 1978. (8-station estimate calculated from data with stations 1 and 3 omitted.)

Total length size class (mm)	Station 2	4	5	6	7	8	9	10*	Total (800m)	95% CI
50-99	878	259	218	531	987	476	497	279	4125	2561-5689
100-149	84	69	63	72	69	63	72	18	510	298-726
150-199	136	130	95	145	130	136	115	63	950	840-1058
200-249	47	31	31	44	34	33	32	15	267	236-298
250-299	18	23	25	33	22	23	19	16	179	163-198
300-349	16	12	8	15	8	11	8	10	88	80-101
350-399	2	4	4	2	6	4		10	32	27-36
400-449		2							2	2-3
450-499						2			2	2-3
Total	1181	530	444	842	1256	748	743	411	6155	4209-8112
95% CI	790-1573	380-682	316-573	585-1102	830-1682	518-980	505-981	285-539	4209-8112	

* The upstream station

Table 12. Brown and brook trout biomass (kg) estimates by 100-m station in the Au Sable River July 17 to 21, 1978.

Total length size class (mm)	Station 2	4	5	6	7	8	9	10*	Total (800m)	95% CI
50-99	6.53	1.93	1.62	3.95	7.34	3.54	3.70	2.08	30.69	19.05-42.33
100-149	2.29	1.88	1.72	1.96	1.88	1.72	1.96	0.49	13.90	8.11-19.76
150-199	7.21	6.89	5.04	7.69	6.89	7.21	6.10	3.34	50.37	44.52-56.07
200-249	5.39	3.55	3.55	5.04	3.90	3.78	3.67	1.72	30.60	27.05-34.16
250-299	3.66	4.68	5.08	6.71	4.47	4.68	3.86	3.25	36.39	33.15-40.26
300-349	5.22	3.92	2.61	4.90	2.61	3.59	2.61	3.26	28.72	26.11-32.96
350-399	0.99	1.98	1.98	0.99	2.97	1.98		4.94	15.83	13.34-17.80
400-449		1.72							1.72	1.72-2.58
450-499						2.23			2.23	2.23-3.35
Total	31.29	26.55	21.60	31.24	30.06	28.73	21.90	19.08	210.45	175.28-249.27
95% CI	25.83-35.92	22.54-31.73	18.00-25.39	26.51-36.98	24.01-36.11	24.14-34.74	17.80-25.99	16.45-22.41	175.28-249.27	

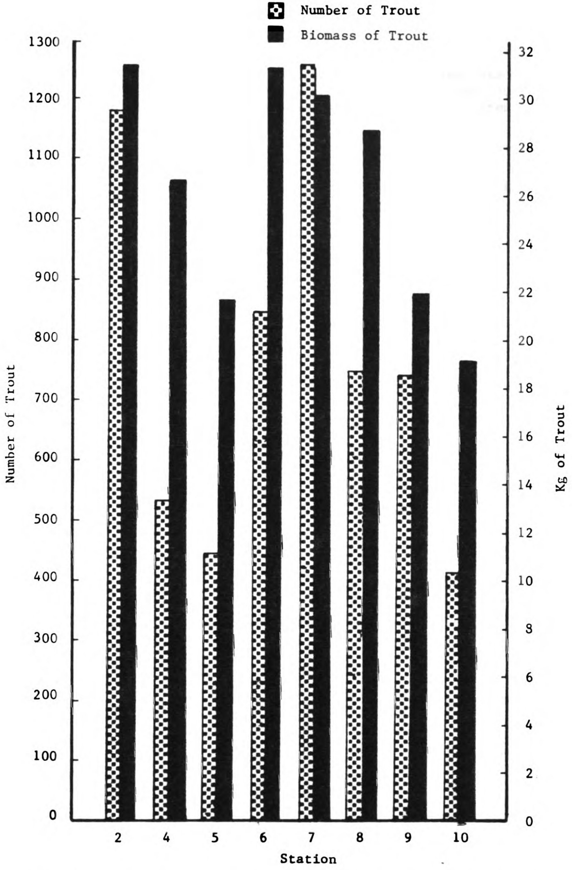

Figure 8. Comparison of number and biomass (kg) per 100-m station for brook and brown trout combined.

Table 13. Population estimates for rainbow trout in the 1-km study section (all 10 stations) of the Au Sable River, July 17 to 21, 1978. Biomass (kg) estimates shown in parenthesis.

Total length size class (mm)	Lower* Estimate	Point Estimate	Upper** Estimate
150-199	4 (.269)	5 (.386)	5 (.336)
200-249	2 (.222)	2 (.222)	3 (.333)
250-299	5 (1.122)	6 (1.346)	7 (1.571)
300-349	1 (.360)	1 (.360)	1 (.360)
350-399	1 (.470)	1 (.470)	1 (.470)
Total	13 (2.443)	15 (2.734)	17 (3.070)

* Lower limit of 85% confidence interval

** Upper limit of 95% confidence interval.

Table 14. Brown trout population estimates by 100-m stations in the Au Sable River, July 17 to 21, 1978. Estimates by proration from 8 stations combined brook and brown trout estimates.

Total length size class (mm)	Station 2	4	5	6	7	8	9	10*	Total (800m)	95% CI
50-99	824	157	197	531	967	463	477	279	3895	2418-5370
100-149	72	63	63	72	66	60	69	18	483	282-688
150-199	125	112	93	144	122	128	115	63	902	798-1006
200-249	45	28	31	44	33	31	32	15	259	229-289
250-299	18	23	25	33	22	23	19	15	178	162-197
300-349	16	12	8	15	8	11	8	10	88	80-101
350-399	2	4	4	2	6	4	-	10	32	27-36
400-449	-	2	-	-	-	-	-	-	2	2-3
450-499	-	-	-	-	-	2	-	-	2	2-3
Total	1102	401	421	841	1224	722	720	410	5841	4000-7693
95% CI	739-1467	296-509	301-541	585-1101	807-1640	499-946	490-950	283-539	4000-7693	

* The upstream station

Table 15. Brook trout population estimates by 100-m stations in the Au Sable River, July 17 to 21, 1978. Estimates by proration from 8 station combined brook and brown trout estimates.

Total length	Station								Total	
size class (mm)	2	4	5	6	7	8	9	10*	(800m)	95% CI
50-99	54	102	20	-	20	14	20	-	230	143-319
100-149	12	6	-	-	3	3	3	-	27	16-38
150-199	11	18	2	-	8	8	-	-	47	42-52
200-249	2	3	-	-	1	2	-	-	8	8-9
250-299	-	-	-	-	-	-	-	1	1	1-1
Total	79	129	22	-	32	27	23	1	313	210-419
95% CI	51-107	86-174	14-30	-	23-41	20-34	15-32	1-1	210-419	

* The upstream station

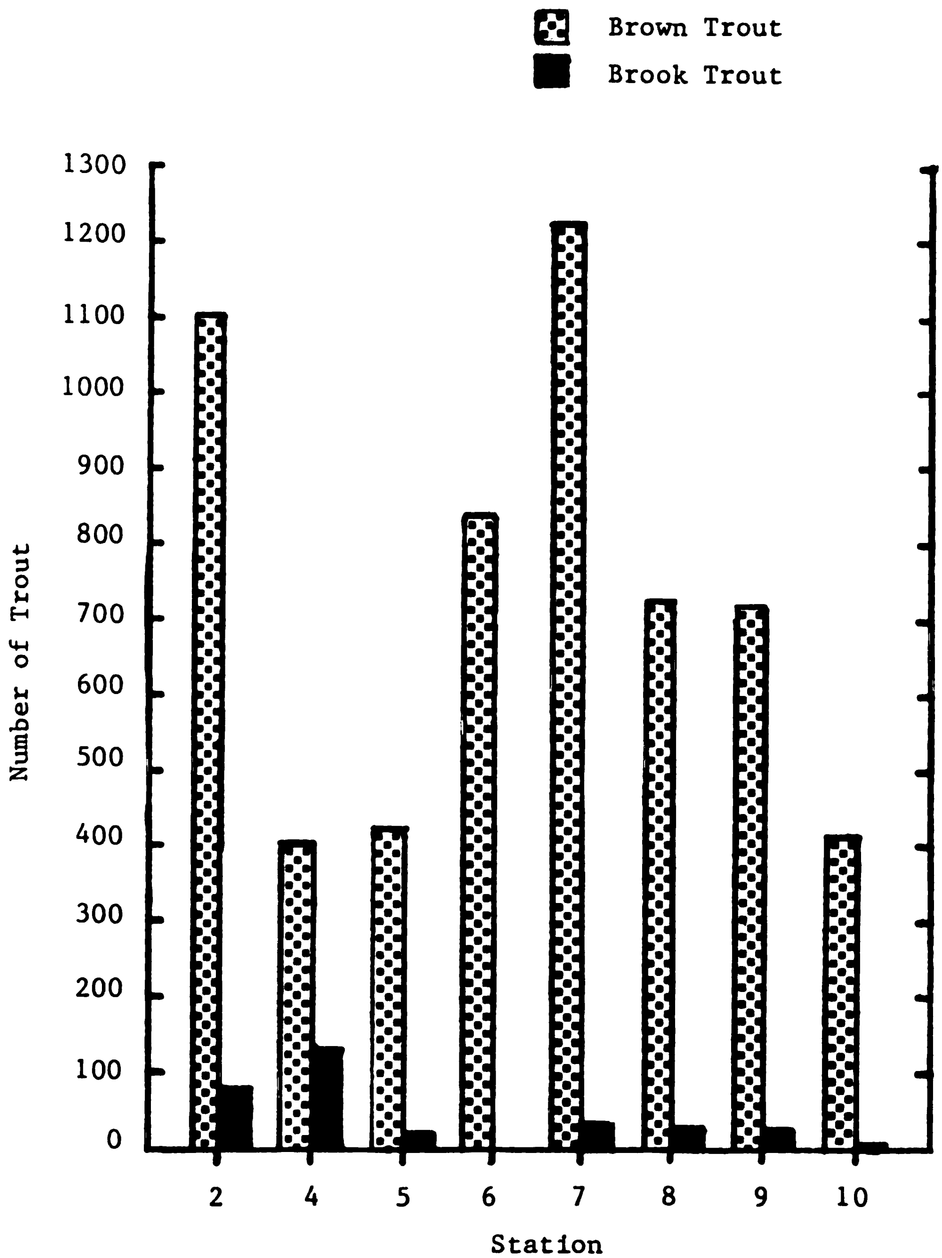

Figure 9. Comparison of the number of brook and brown trout by 100-m station.

Table 16. Brown trout biomass (kg) estimates by 100-m station in the Au Sable River, July 17 to 21, 1978.

Total length size class (mm)	Station								Total (800m)	95% CI
	2	4	5	6	7	8	9	10*		
50-99	6.19	1.18	1.48	3.99	7.26	3.48	3.58	2.09	29.25	18.16-40.33
100-149	1.95	1.71	1.71	1.95	1.79	1.63	1.87	0.49	13.10	7.65-18.66
150-199	6.63	5.94	4.93	7.64	6.47	6.79	6.10	3.34	47.84	42.31-53.34
200-249	5.17	3.22	3.56	5.05	3.79	3.56	3.68	1.72	29.75	26.30-33.20
250-299	3.66	4.68	5.09	6.71	4.47	4.68	3.86	3.05	36.20	32.95-40.07
300-349	5.22	3.92	2.61	4.90	2.61	3.59	2.61	3.26	28.72	26.11-32.96
350-399	0.99	1.98	1.98	0.99	2.97	1.98	-	4.94	15.83	13.35-17.80
400-449	-	1.72	-	-	-	-	-	-	1.72	1.72-2.58
450-499	-	-	-	-	-	2.23	-	-	2.23	2.23-3.34
Total	29.81	24.35	21.36	31.23	29.36	27.94	21.70	18.89	204.64	170.78-242.28
95% CI	24.71-34.07	20.93-28.94	17.91-25.00	26.71-37.00	23.52-35.29	23.55-33.52	17.67-25.73	15.78-22.73	170.78-242.28	

* The upstream station

Table 17. Brook trout biomass (kg) estimates by 100-m station in the Au Sable River, July 17 to 21, 1978.

Total length	Station								Total	
size class (mm)	2	4	5	6	7	8	9	10*	(800m)	95% CI
50-99	0.37	0.70	0.14	-	0.14	0.10	0.14	-	1.59	0.98-2.20
100-149	0.35	0.17	-	-	0.09	0.09	0.09	-	0.79	0.46-1.10
150-199	0.59	0.97	0.11	-	0.43	0.43	-	-	2.53	2.25-2.79
200-249	0.21	0.32	-	-	0.11	0.21	-	-	0.85	0.86-0.96
250-299	-	-	-	-	-	-	-	0.19	0.19	0.19-0.19
Total	1.52	2.16	0.25	0	0.77	0.83	0.23	0.19	5.95	4.74-7.24
95% CI	1.17- 1.97	1.68- 2.61	0.14- 0.30	- -	0.70- 0.85	0.71- 1.00	0.15- 0.32	0.19- 0.19	4.74- 7.24	

* The upstream station

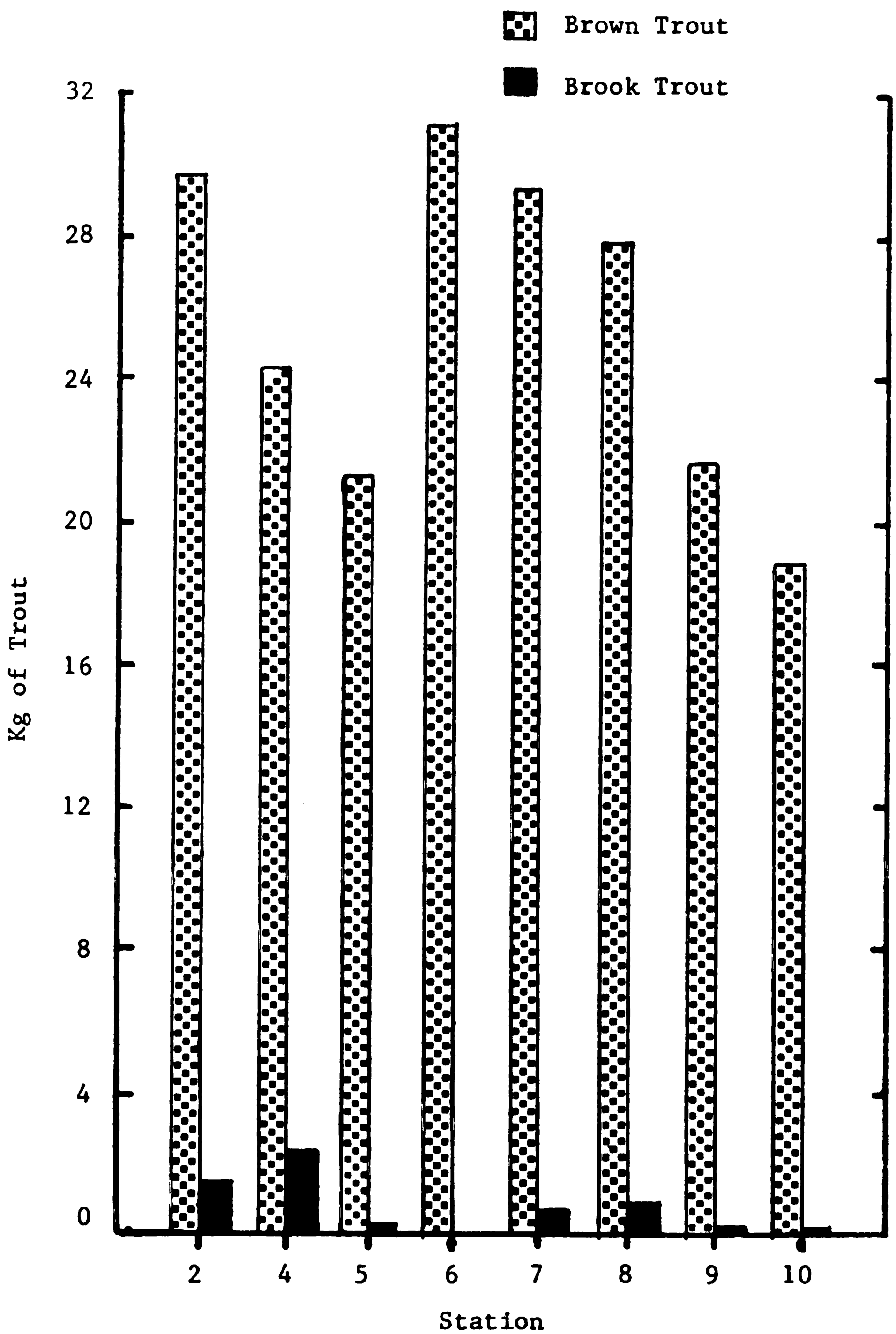

Figure 10. Comparison of the biomass (kg) of brook and brown trout by 100-m station.

Comparison of Standing Crop in Various Michigan Streams

The standing crop (kg/km and kg/hectare) of Mainstream Au Sable trout is compared to standing crops for other Michigan stream in Table 18. The study area had a greater standing crop of trout (kg/hectare) than all streams except the upper part of the Little South Branch of the Pere Marquette River, Poplar Creek, and a section of the Au Sable Main Branch from Burtons Landing to Wakeley Bridge which encompasses the study area. Coopes (1974) lists the standing crop of trout for this section at 166.4kg/hectare, which is slightly more than twice the 82.8kg of trout/hectare found in my study section in 1978.

Trout Population, Cover Relationships

The length and area of natural, man-made and total overhead cover per station are presented in Table 19. Stations 4 and 6 contained the greatest area of natural overhead cover, while stations 2 and 8 contained the greatest area of man-made cover. Station 2 had the greatest total area of cover ($118.27m^2$) and station 9 had the least ($24.7m^2$). Total area of overhead cover for the other 6 stations varied from 45.83-$62.60m^2$. There was $459.17m^2$ of overhead cover in the 8 stations. Thus, only about 2% of the surface area of the stream was beneath some form of overhead cover. The numbers of brook trout per station in each 50-mm size class were divided by proration into natural and man-made cover. These data along with the percentage of brook trout found in man-made cover are shown in Table 20. Less than 45 percent of the brook trout in stations 2-9 were found in man-made shelters. The one brook trout captured in station 10 was beneath a man-made trout shelter.

Table 18. Standing crops of trout in various Michigan streams.

Stream and locality	Trout Abundance Kg/km	Kg/hectare	Stream[3] width in meters	References
Au Sable - Main Branch	240.2	82.8	29.0	1
Au Sable - Main Branch Upper - Grayling to Burtons Landing	42.2	15.7	26.9	2
Lower - Burtons Landing to Wakeley Bridge	479.2	166.4	28.8	2
Au Sable - North Branch Upper - Dam 2 to Otsego County Line	114.8	53.9	21.3	2
Middle - County Line to Eamon's Landing	229.0	69.6	32.9	2
Lower - Eamon's Landing to Kelloggs Bridge	225.9	77.9	29.0	2
Pigeon River	40.2	31.9	12.6	2
Gamble River	47.7	82.3	5.8	2
Rifle River	36.9	29.3	12.6	2
Boardman River - Upper end of Brown Pond to Forks of the North and South Branch of the Boardman	71.9	55.7	12.9	2
Pere Marquette River - Little South Branch				
Upper	95.9	97.9	9.8	2
Lower	46.3	40.6	11.4	2
Poplar Creek	42.1	87.8	4.8	2

1 - This study, July biomass estimates.
2 - Coopes 1974, Fall biomass estimates
3 - Stream widths from Gaylord Alexander pers. comm.

Table 19. Length (m) and area (m^2) of overhead cover by station.

Station	Natural Cover Length	Area	Man-made Cover Length	Area	Total Length	Area
2	17.9	3.87	96.5	114.40	114.0	118.27
4	54.0	11.30	97.0	47.25	151.0	58.55
5	43.5	5.50	58.0	46.85	101.5	52.35
6	66.7	10.85	43.5	35.00	110.2	45.85
7	16.0	2.53	76.0	43.30	92.0	45.83
8	10.0	3.30	47.0	59.30	57.0	62.60
9	20.0	2.45	37.0	22.25	57.0	24.70
10	59.5	7.00	51.0	44.02	110.5	51.02
Total	287.20	46.80	506.0	412.37	793.2	459.17

Table 20. Abundance of brook trout per 100-m station associated with man-made cover and with other stream area.

Total length size class (mm)	Station 2	4	5	6	7	8	9	10*	Total
	Number of Brook Trout in Man-made Cover								
50-99	14	-	-	-	-	-	7	-	21
100-149	9	-	-	-	-	3	3	-	15
150-199	2	3	-	-	2	3	-	-	10
200-249	-	-	-	-	-	-	-	-	-
250-299	-	-	-	-	-	-	-	-	1
Total	25	3	-	-	2	6	10	1	47
	Number of Brook Trout Elsewhere								
50-99	41	102	20	0	20	14	14	-	211
100-149	3	6	-	-	3	-	-	-	12
150-199	9	15	2		6	5	-	-	37
200-249	2	3	-	-	1	2	-	-	8
250-299	-	-	-	-	-	-	-	-	-
Total	55	126	22	-	30	21	14	-	268
	% of Total Brook Trout in Man-made Cover								
50-99	25	-	-	-	-	-	33	-	9
100-149	75	-	-	-	-	100	100	-	56
150-199	18	17	-	-	25	37	-	-	21
200-249	-	-	-	-	-	-	-	-	0
250-299	-	-	-	-	-	-	-	100	100
Total	31	2	0	-	6	22	42	100	15

* The upstream section

Numbers of brown trout associated with man-made shelters and trout found elsewhere are displayed in Table 21 by station and 50-mm size class. The percentage of brown trout in a given station and 50-mm size class are shown in Table 22. Fifty percent or more of trout 150--449mm were associated with man-made shelters. Although man-made shelter covered only about 1.8 percent of the stream surface 71.5% of brown trout $\geq$ 350mm were in man-made trout shelters in the 8 stations. The percentage of brown trout in man-made shelters increased progressively by 50mm size class from 26% for 50-99mm trout to 100% for 400-449mm trout. The percentages of brook and brown trout in man-made shelters are compared graphically by 50-mm size class in Figure 11. The two trout in the 450-499mm class were not captured in man-made shelters. The percentages of brown trout per station in man-made shelters ranged from 16-58%. The lower values result from the large numbers of small trout which were not captured in man-made shelter.

When per-station trout abundance by number of biomass were regressed on per-station amounts of overhead cover--natural, man-made, and combined (Tables 23-25)--no correlation coefficients between trout abundance and <u>total</u> overhead cover or <u>man-made</u> overhead cover were significant ($p=0.05$), although the highest correlations were for numbers of brown trout $\geq$ 300mm.

For <u>natural</u> overhead cover considerd separately, however, the simple correlations between numbers and biomass of brown trout $\geq$ 250mm and area of overhead cover were both significant ($p = 0.05$). The multiple correlation of kg of brook and brown trout $\geq$ 150mm

Table 21. Number of brown trout per 100-m station associated with man-made cover and with other stream area.

Total length size class (mm)	Station 2	4	5	6	7	8	9	10*	Total
	Number of Brown Trout in Man-made Cover								
50-99	313	27	102	102	75	88	143	163	1013
100-149	36	18	33	42	9	24	39	9	210
150-199	75	38	43	98	63	64	38	35	454
200-249	32	13	19	29	26	20	13	11	163
250-299	15	14	19	20	16	14	12	9	119
300-349	14	5	3	11	6	9	8	4	60
350-399	2	2	2	2	6	2	-	10	26
400-449	-	2	-	-	-	-	-	-	2
450-499	-	-	-	-	-	-	-	-	-
Total	487	119	221	304	201	221	253	241	2047
	Number of Brown Trout Elsewhere								
50-99	511	129	95	429	892	374	334	116	2880
100-149	36	45	30	30	57	36	30	9	273
150-199	50	73	50	46	60	64	76	28	447
200-249	13	15	11	15	7	11	19	5	96
250-299	2	9	7	13	5	9	7	7	59
300-349	2	7	4	4	2	2	-	6	27
350-399	-	2	2	-	-	2	-	-	6
400-449	-	-	-	-	-	-	-	-	0
450-499	-	-	-	-	-	2	-	-	2
Total	614	280	199	537	1023	500	466	171	3790

* The upstream station

Table. 22. Percent of total brown trout in man-made cover by 100-m station.

Total length size class (mm)	Station 2	4	5	6	7	8	9	10*	Total
50-99	38	17	52	19	8	19	30	58	26
100-149	50	29	48	58	14	40	57	50	43
150-199	60	34	46	68	51	50	33	56	50
200-249	71	46	63	66	79	65	41	69	63
250-299	88	61	73	61	76	61	63	56	67
300-349	87	42	43	73	75	82	100	40	69
350-399	100	50	50	100	100	50	-	100	81
400-449	-	100	-	-	-	-	-	-	100
450-499	-	-	-	-	-	-	-	-	0
Total	44	30	53	36	16	31	35	58	35

* The upstream station

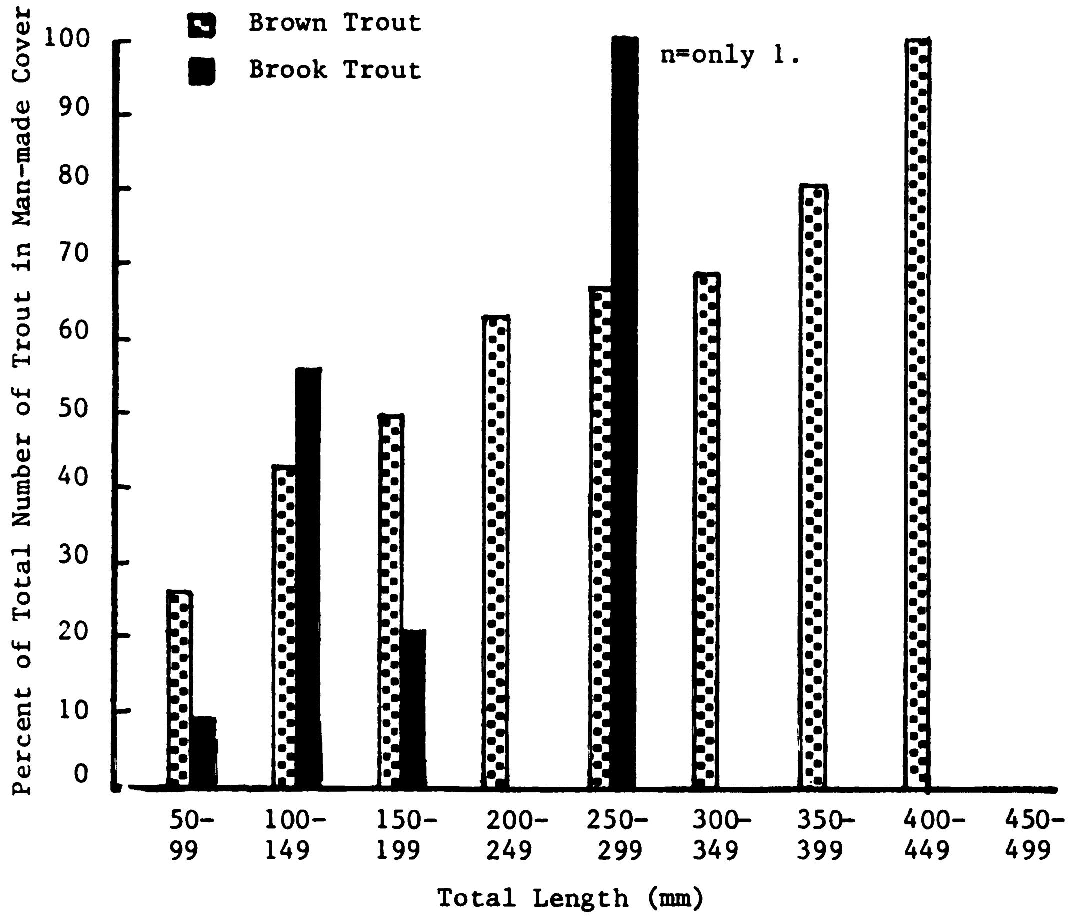

Figure 11. Comparison of percent of brook and brown trout in man-made cover by 50mm size class.

Table 23. Correlation coefficients (r) and coefficients of determination (r^2) for trout population variables (Y), total length, and total area of man-made and natural overhead cover per station in the Au Sable River.*

	Amount of Natural and Man-made Cover					
	Total length		Total area		Total length and total area	
Type of dependent variable (Y)	r	r^2	r	r^2	r	r^2
Numbers per station						
Brown trout ≥ 100mm	0.067	0.005	0.209	0.044	0.256	0.065
Brook and brown trout ≥ 150mm	0.055	0.003	0.317	0.100	0.322	0.104
Brown trout ≥ 200mm	0.199	0.040	0.349	0.122	0.360	0.130
Brown Trout ≥ 250mm	0.435	0.190	0.130	0.017	0.436	0.190
Brown trout ≥ 300mm	0.573	0.328	0.533	0.284	0.680	0.458
Biomass per station						
Brown trout ≥ 100mm	0.183	0.033	0.333	0.111	0.342	0.117
Brook and brown trout ≥ 150mm	0.273	0.074	0.397	0.158	0.424	0.180
Brown trout ≥ 200mm	0.331	0.110	0.380	0.144	0.437	0.191
Brown trout ≥ 250mm	0.454	0.206	0.221	0.049	0.460	0.211
Brown trout ≥ 300 mm	0.436	0.190	0.379	0.144	0.501	0.251

* No coefficients were significant at the 5% level.

Table 24. Correlation coefficients (r) and coefficients of determination (r^2) for trout population variables (Y), total length, and total area of man-made overhead cover only per station (n=8) in the Au Sable River.*

Type of dependent variable (Y)	Amount of Man-made Cover Only: Total length r	Total length r^2	Total area r	Total area r^2	Total length and total area r	Total length and total area r^2
Numbers per station						
Brown trout ≥ 100mm	0.143	0.021	0.199	0.040	0.200	0.040
Brook and brown trout ≥ 150mm	0.265	0.070	0.292	0.085	0.309	0.096
Brown trout ≥ 200mm	0.158	0.025	0.300	0.090	0.303	0.092
Brown trout ≥ 250mm	0.065	0.004	0.035	0.001	0.066	0.004
Brown trout ≥ 300mm	0.391	0.153	0.459	0.211	0.476	0.227
Biomass per station						
Brown trout ≥ 100mm	0.216	0.047	0.281	0.079	0.285	0.081
Brook and brown trout ≥ 150mm	0.311	0.097	0.338	0.114	0.360	0.129
Brown trout ≥ 200mm	0.273	0.075	0.310	0.096	0.325	0.106
Brown trout ≥ 250mm	0.179	0.032	0.134	0.018	0.181	0.033
Brown trout ≥ 300mm	0.318	0.101	0.319	0.102	0.352	0.124

* No coefficients were significant at the 5% level.

Table 25. Correlation coefficients (r) and coefficients of determination (r^2) for trout population variables (Y), total length, and total area of natural overhead cover only per station (n=8) in the Au Sable River

Type of dependent variable (Y)	Amount of Natural Cover: Total length r	Total length r^2	Total area r	Total area r^2	Total length and total area r	Total length and total area r^2
Numbers per station						
Brown trout ≥ 100mm	0.244	0.059	0.051	0.003	0.632	0.399
Brook and brown trout ≥ 150mm	0.203	0.041	0.152	0.023	0.751	0.564
Brown trout ≥ 200mm	0.109	0.012	0.337	0.114	0.536	0.287
Brown trout ≥ 250mm	0.532	0.283	0.716*	0.513	0.750	0.563
Brown trout ≥ 300mm	0.380	0.144	0.502	0.252	0.522	0.272
Biomass per station						
Brown trout ≥ 100mm	0.025	0.0006	0.359	0.129	0.734	0.539
Brook and brown trout ≥ 150mm	0.049	0.002	0.409	0.167	0.796	0.634
Brown trout ≥ 200mm	0.170	0.029	0.489	0.239	0.755	0.569
Brown trout ≥ 250mm	0.439	0.192	0.639*	0.408	0.699	0.488
Brown trout ≥ 300mm	0.268	0.072	0.411	0.169	0.462	0.214

* Indicates significance at the 5% level.

with length and area of natural cover yielded the highest correlation (r=0.796). Most correlation coefficients were less than 0.5.

Variables Influencing Density of Trout in Individual Trout Shelters

The numbers of brook and brown trout ≥ 150mm beneath individual shelters and the physical parameters used as independent variables for multiple regression analysis are presented in Table 26. Shelters 1-7 and 18-23 are not shown as they were in stations 1 and 3 which were excluded from analysis because they contained long unwadable pools. The best fit multiple regression models obtained for various trout population variables using the backward elimination procedure are displayed in Table 27.

Maximum water depth proximal to the shelter and total length of overhead cover were the most important of the features I measured in accounting for variation in the per-shelter biomass of brown trout in all cummulative size groups. The coefficients of multiple determination (R^2) for these 6 models ranged from 0.15 for the model for biomass of brown trout ≥ 350mm to 0.38 for biomass of brown trout ≥ 150mm and biomass of brown trout ≥ 200mm.

Trout biomass always was positively related to water depth and length of overhead cover per shelter. According to the model, per shelter biomass of brown trout ≥ 150mm should increase 17 grams for each 1cm increase in water depth and 44 grams for each 1m increase in shelter length.

Water depth and length of cover remained the most important variable influencing biomass of brook and brown trout combined. However, it should be observed that there were only 12 brook trout beneath the 57 shelters used to derive these models so one would not expect the models for brook and brown trout combined to differ significantly from the models derived from brown trout alone. For the same reason models derived for brook trout population variables are probably not useful. Water depth, length of overhead cover and percent subcovert sand were the most important independent variables when numbers of brown trout $\geq$ 150mm and $\geq$ 200mm were the dependent variables. Only water depth and length of cover were important in explaining variation in the numbers of brown trout $\geq$ 250, 300, and 350mm/shelter. The addition of brook trout numbers caused only a slight upward shift in the magnitude of the partial regression coefficient.

When considered within individual 50-mm size classes, water depth and length of cover were generally the most important independent variables, but the models were quite variable. Coefficients of multiple determination (R^2) for these models were generally much lower than those for models derived using cummulative numbers and biomass size classes as fewer fish were found in the smaller size intervals.

The regression equation for per shelter numbers of brown trout $\geq$ 250mm/shelter is as follows.

$$Y_4 = -0.558 + 0.0447x_1 + 0.00109x_2$$

Where Y_4 = Number of brown trout $\geq$ 250mm/shelter

x_1 = Maximum water depth (cm) proximal to the shelter

x_2 = Length (cm) of overhead cover/shelter

Thus, shelters with 4.5 meters of overhead cover positions such that water depth is 70cm would be expected to hold about 3 brown trout $\geq$ 250mm on the average. According to this model, if water depth was held

Table 26. Characteristics of 57 man-made trout shelters and the number of trout beneath them estimated by electrofishing. Shelters 1-7 and 18-23 not shown due to unwadable pools in stations 1 and 3.

Shelter		Number of trout ≥ 150mm		Subcovert substrate (%)				Maximum water depth	Per shelter amount of overhead cover	
No.	type	Brown	Brook	Silt	Sand	Gravel	Rubble	(cm)	Length (m)	Area (m^2)
8	log jam	5	-	15	-	85	-	55	3.5	2.7
9	log jam	16	-	-	10	90	-	50	14.0	7.6
10	log jam	33	-	-	90	10	-	75	8.0	16.0
11	raft	9	-	-	30	70	-	65	3.5	2.8
12	log jam	12	-	-	10	90	-	60	9.0	6.4
13	log jam	12		-	55	30	15	75	17.5	17.3
14	log jam	5	-	50	30	20	-	35	13.0	13.0
15	raft	23	-	-	55	45	-	90	11.0	5.2
16	log jam	20	2	40	50	10	-	90	13.0	40.9
17	log jam	3	-	-	100	-	-	25	4.0	2.4
24	log jam	10	-	30	30	40	-	60	6.0	1.8
25	log jam	23	3	30	23	47	-	75	59.0	17.0
26	raft	5	-	50	20	30	-	65	4.5	4.5
27	log jam	15	-	20	10	70	-	70	9.5	5.3
28	log jam	9	-	-	30	40	30	60	8.0	12.0
29	log jam	14	-	21	42	30	7	65	7.0	7.0
30	log jam	20	-	20	70	10	-	70	6.0	6.0
31	log jam	17	-	32	36	32	-	65	20.0	8.6
32	stump mass	7	-	-	30	10	60	70	1.5	2.2
33	log jam	12	-	35	25	40	-	55	10.0	7.0
34	log jam	15	-	25	45	30	-	70	13.5	16.0
35	log jam	3	-	100	-	-	-	40	4.0	3.2
36	log jam	7	-	100	-	-	-	40	4.0	3.2
37	log jam	19	-	30	40	30	-	65	7.0	10.0
38	log jam	21	-	20	50	30	-	80	6.0	4.4
39	log jam	21	2	30	40	30	-	60	7.0	7.0
40	log jam	16	-	50	50	-	-	80	2.5	1.8
41	raft	22	-	100	-	-	-	50	3.0	0.6
42	raft	27	-	100	-	-	-	80	1.0	0.3
43	log jam	7	-	20	40	40	-	28	3.0	3.0
44	log jam	19	-	20	40	40	-	70	8.0	7.7
45	raft	14	-	10	80	10	-	90	4.0	4.0
46	log jam	5	-	100	-	-	-	40	7.0	7.0
47	log jam	23	-	30	30	40	-	50	3.0	6.0
48	log jam	7	-	45	25	30	-	170	11.0	16.0
49	log jam	17	-	15	25	60	-	75	14.0	21.0
50	log jam	23	-	30	40	30	-	80	7.0	6.2
51	stump mass	5	-	50	40	10	-	60	2.0	3.0
52	log jam	16	-	40	40	20	-	85	4.0	4.0
53	raft	17	-	50	50	-	-	60	9.0	6.3
54	log jam	26	2	40	40	20	-	75	3.0	3.0
55	log jam	12	-	50	40	10	-	65	4.0	4.0

Table 26. (cont'd.)

Shelter		Number of trout ≥ 150mm		Subcover substrate (%)				Maximum water depth	Per shelter amount of overhead cover	
No.	type	Brown	Brook	Silt	Sand	Gravel	Rubble	(cm)	Length (m)	Area (m^2)
56	log jam	5	-	20	30	50	-	40	2.0	0.6
57	log jam	10	-	30	30	40	-	100	9.0	9.0
58	log jam	5	-	20	30	50	-	75	7.0	10.5
59	stump mass	9	-	40	40	20	-	75	1.0	1.0
60	log jam	9	-	100	-	-	-	45	4.0	4.0
61	log jam	11	-	90	-	10	-	70	3.0	3.0
62	log jam	18	-	90	10	-	-	80	6.0	6.0
63	log jam	12	-	90	-	10	-	40	12.0	1.4
64	raft	12	-	90	-	10	-	55	4.0	1.2
65	log jam	13	-	100	-	-	-	50	13.0	1.1
66	log jam	3	-	100	-	-	-	30	4.0	3.1
67	log jam	15	1	100	-	-	-	80	19.0	21.3
68	log jam	34	2	60	15	25	-	100	44.0	11.4
69	raft	16	-	19	50	40	-	40	13.0	8.5
70	log jam	11	-	40	30	30	-	60	10.0	6.0

Table 27. Multiple regression analyses (backward elimination procedure) of trout population variables (Y) on linear physical measurements of instream trout shelters (n=57). F for removal from regression = 2.0

X - variables entered on first regression step.

1 - Maximum water depth proximal to the shelter (cm).

2 - Total length (cm) of overhead cover/shelter more than 10cm wide and in water deeper than 10cm.

3 - Total area of overhead cover/shelter more than 10cm wide and in water deeper than 10cm.

4 - % of subshelter gravel + % subshelter rubble.

5 - % subshelter sand.

6 - % subshelter silt.

7 - Dummy variable = 1 if shelter type is a log jam.

8 - Dummy variable = 1 if shelter type is a sunken log raft.

Trout size class (mm)	Variables remaining in equation	Regression model	R^2	P
		Y_1 = Brown trout biomass (gm) per shelter		
Cumulative size groups				
≥ 100	1, 2	$Y_1 = 257 + 16.9X_1 + .453X_2$	.37	< .001
≥ 150	1, 2	$Y_1 = 16.47 + 17X_1 + .44X_2$	.38	< .001
≥ 200	1, 2	$Y_1 = -87.9 + 15.1X_1 + .39X_2$	.38	< .001
≥ 250	1, 2	$Y_1 = -249 + 13.4X_1 + .342X_2$	.34	< .001
≥ 300	1, 2	$Y_1 = -243 + 8.8X_1 + .23X_2$	.22	.001
≥ 350	1, 2	$Y_1 = -216.6 + 4.5X_1 + .159X_2$	.15	.012
50-mm interval groups				
100-149	4	$Y_1 = 20.94 + .553X_4$	.06	.066
150-199	2, 4	$Y_1 = 410.44 + .062X_2 - 1.78X_4$	.08	.098
200-249	2, 5	$Y_1 = 163.9 + .067X_2 + 3.28X_5$	.15	.013
250-299	1, 2	$Y_1 = -5.88 + 4.6X_1 + .112X_2$	.25	< .001
300-349	1	$Y_1 = -7.13 + 4.9X_1$	.09	.025
350-399	1, 2	$Y_1 = -228.5 + 4.3X_1 + .159X_2$	.17	.006
		Y_2 = Brook trout biomass (gm) per shelter		
Cumulative size groups				
0-300	2	$Y_2 = -1.22 + .269X_2$	.31	< .001
≥ 100	2, 3	$Y_2 = -9.68 + .0222X_2 + .00014X_3$	.34	< .001
≥ 150	2, 3, 4	$Y_2 = -8.5 + .0222X_2 + .00016X_3 - .316X_4$	.45	< .001
50-mm interval groups				
100-149	4	$Y_2 = -4.12 + .358X_4$	.16	.002
150-199	2	$Y_2 = -9.8 + .023X_2$	.40	< .001

Table 27. (cont'd.)

Trout size class (mm)	Variables remaining in equation	Regression model	R^2	P
		Y_3 = Brook and brown trout biomass (gm) per shelter		
Cumulative size groups				
≥ 100	1, 2	$Y_3 = 238 + 17.2X_1 + .478X_2$	.38	< .001
≥ 150	1, 2	$Y_3 = 145.7 + 17.2X_1 + .466X_2$	.38	< .001
≥ 200	1, 2	$Y_3 = -92 + 15.2X_1 + .398X_2$	.38	< .001
≥ 250	1, 2	$Y_3 = -253.34 + 13.5X_1 + .345X_2$	.34	< .001
		Y_4 = Number of brown trout per shelter		
Cumulative size groups				
≥ 100	1, 2, 4, 5	$Y_4 = 9.47 + .08X_1 + .0033X_2 - .082X_4 + .072X_5$	.26	.004
≥ 150	1, 2, 5	$Y_4 = 4.38 + .08X_1 + .0026X_2 + .064X_5$	.26	.001
≥ 200	1, 2, 5	$Y_4 = .189 + .05X_1 + .0016X_2 + .034X_5$	.39	< .001
≥ 250	1, 2	$Y_4 = -.558 + .0447X_1 + .00109X_2$	.38	< .001
≥ 300	1, 2	$Y_4 = -.53 + .02X_1 + .0005X_2$	.23	.001
≥ 350	1, 2	$Y_4 = -.448 + .009X_1 + .0003X_2$	.17	.007
50-mm interval groups				
100-149	4	$Y_4 = 4.72 - .0382X_4$	.06	.066
150-199	2, 4	$Y_4 = 7.74 + .0012X_2 - .034X_4$	.08	.098
200-249	2, 5	$Y_4 = 1.43 + .0006X_2 + .029X_5$	.15	.013
250-299	1, 2	$Y_4 = -.028 + .02X_1 + .0006X_2$	.25	< .001
300-349	1	$Y_4 = -.022 - .02X_1$	.09	.025
350-400	1, 2	$Y_4 = -.462 + .009X_1 + .0003X_2$	.17	.006
		Y_5 = Number of brook trout per shelter		
Cumulative size groups				
≥ 100	2, 4	$Y_5 = -.215 + .0004X_2 + .0092X_4$	.26	< .001
≥ 150	2, 3	$Y_5 = -.249 + .0004X_2 + .00001X_3$	.44	< .001
50-mm interval groups				
100-149	4	$Y_5 = -.142 + .0123X_4$	.16	.002
150-199	2	$Y_5 = -.182 + .0004X_2$	.38	> .001

Table 27. (cont'd.)

Trout size class (mm)	Variables entered	Regression model	R^2	P
		Y_6 = Number of brook and brown trout per shelter		
Cumulative size groups				
$\geq$ 100	1, 2, 4, 5	$Y_6 = 8.99 + .09X_1 + .0037X_2 - .0729X_4 + .0704X_5$	.27	.002
$\geq$ 150	1, 2, 5	$Y_6 = 4.06 + .08X_1 + .003X_2 + .0645X_5$	.29	< .001
$\geq$ 200	1, 2, 5	$Y_6 = .187 + .05X_1 + .0017X_2 + .0328X_5$	.39	< .001
$\geq$ 250	1, 2	$Y_6 = -.579 + .045X_1 + .0011X_2$	.38	< .001

to 70cm, length of overhead cover must be increased 8.6 meters if the cover is to hold 1 more brown trout 250mm or larger.

The mean water depth proximal to the 57 shelters was 65.4cm with a standard deviation of 22.6cm. Mean length of overhead cover per shelter was 8.88m with standard deviation of 9.49m. The per-shelter number of brown trout $\geq$ 250mm varied from 0-10 with mean 3.34 and standard deviation of 2.59.

Although there was no systematic deviation of the numbers of brown trout $\geq$ 250mm per shelter from the numbers predicted from the model, an examination of outlying observations is instructive. The above model predicts that shelter number 25 should hold 9.2 brown trout $\geq$ 250mm, whereas only 7 were present (in the ensuing examination of individual shelters I will refer to brown trout $\geq$ 250mm simply as trout). This log jam shelter consisted primarily of logs 2-5m long which were mostly less than 30cm wide. The logs were not close together and were not constructed to form a solid, light-attenuating surface.

Shelter number 27 held 6 trout versus the predicted 3.6. This log jam shelter extended about 7 meters perpendicular to the stream bank and had one solid block of overhead cover 3.5 by 1.0m. It was largely surrounded by silt and macrophytes, but water flow beneath the shelter had scoured away most fine sediments, as 70% of the subshelter bed was gravel. Although the deepest water proximal to the shelter was 70cm, most of the shelter was no more than 30cm above the stream bed.

Shelter number 29 held 6 trout versus the predicted 3.1 This shelter also consisted of solid blocks of overhead cover about 1m wide underlain by fairly swift waters as evidenced by the presence of 37% subshelter gravel and rubble. Most of this structure was less than

35cm above the stream bed with a proximal water depth of 65cm.

Shelter number 34 held almost 4 more trout than expected. This log jam shelter extended diagonally downstream from its point of attachment to the bank and acted as a wing deflector as well as overhead cover. The current was swift around the midstream side of the device and slower beneath some portions of the solid log jam which was 0.70-2.0m wide.

Shelter number 40 held 7 trout versus a predicted 4.3. This log jam shelter was triangular in shape with the apex directed upstream into the current. The water was shallow on the south side of the device but swift 75cm deep water swept along the north side where most of the trout were captured. The bulk of the device was solid and mostly less than 40cm above the stream bed.

In general, shelters with deep water sweeping past at least one side held the most fish. One notable exception was shelter 48. However, the water adjacent to this shelter was too deep and swift to electrofish effectively and was also frequented by a 596mm northern pike.

Regression Models with Polynomial and Interaction Factors

Upon examination of plots of trout population variables on polynomial and interaction variables, I determined that they might provide better fits of the data than the ones above. Maximum water depth proximal to each shelter, length and area of overhead cover/shelter, and subshelter substrate percentages were all squared for use as potential elements in the new models. In addition, maximum water depth proximal to each shelter was multiplied by length and area of cover/shelter to create variables to account for interaction factor effects on the dependent variables. The product of length and area of overhead cover/ shelter and the linear factors used in the models previously examined were also available for entry into the new models.

Trout population variables, independent variables, regression equations, coefficients of multiple determination, and significance levels for the new series of models are shown in Table 28. Both the backward elimination and forward stepwise regression methods result in identical models for almost all trout population variables. Best-fit regression equations derived for size classes of trout which contained large numbers of fish usually contained the independent variables of maximum water depth proximal to the shelter times length of overhead cover, maximum water depth and maximum water depth squared. The R^2's for the new models were higher for trout variables involving biomass of brown trout $\geq$ 250mm ($R^2 = 0.43$).

The highest R^2's ($R^2 = 0.65$) were obtained for the two models which described abundance of brook trout of 150-199mm as functions of length of overhead cover/shelter, squared, area of overhead cover/ shelter, squared, and the product of length and area of cover/shelter. These two models were based on only 11 brook trout distributed among 5 of the 57 shelters.

Usually, however, models for trout size classes with small numbers of fish containing polynomial and interaction factors did not provide better fits of the data than models with simple linear independent variables.

In summary, the most important independent variables were (1) the product of maximum water depth proximal to each shelter and length

Table 28. Multiple regression analysis (stepwise procedure) of trout population variables (Y) on linear, polynomial and interaction factor variables involving measurements of instream trout shelters (n=57). F for entry into regression = 3.0.

X - variables available for entry into regression equations

1 - Maximum water depth (cm) proximal to each shelter x total length (cm) of cover/shelter more than 10cm wide and in water deeper than 10cm.

2 - Maximum water depth proximal to each shelter (cm).

3 - Maximum water depth squared (cm^2).

4 - Total length of overhead cover (cm)/shelter more than 10cm wide and in water deeper than 10cm.

5 - Total area (cm^2) of overhead cover/shelter more than 10cm wide and in water deeper than 10cm.

6 - Total length of overhead cover squared (cm^2)/shelter.

7 - Total area of overhead cover squared (cm^4)/shelter.

8 - Maximum water depth proximal to the covert (cm) x total area of overhead cover (cm^2)/ shelter.

9 - Total length of overhead cover (cm)/shelter x total area (cm^2) of overhead cover/shelter.

10 - Percent subshelter silt.

11 - Percent subshelter sand

12 - Percent subshelter gravel + percent subshelter rubble.

13 - Percent subshelter gravel + percent subshelter rubble, squared.

14 - (Percent silt)^2 15 - (Percent sand)^2 16 - Percent subshelter gravel.

17 - Dummy variable = 1 if shelter type is a log jam.

18 - Dummy variable = 1 if shelter type is a sunken log raft.

Trout size class (mm)	Variables entered	Regression model	R^2	P
		Y_1 = Brown trout biomass (gm) per shelter		
Cumulative size groups				
≥ 100	1, 2, 3	$Y_1 = -1547 + .516 \times 10^{-2}X_1 + 71.77X_2 - .357X_3$	.53	< .001
≥ 150	1, 2, 3	$Y_1 = -1642 + .501 \times 10^{-2}X_1 + 71.76X_2 - .356X_3$	.53	< .001
≥ 200	1, 2, 3	$Y_1 = -1506 + .449 \times 10^{-2}X_1 + 58.73X_2 - .285X_3$	.50	< .001
≥ 250	1, 2, 3	$Y_1 = -1328 + .385 \times 10^{-2}X_1 + 47.09X_2 - .222X_3$	.43	< .001
≥ 300	1	$Y_1 = 324 + .338 \times 10^{-2}X_1$	.16	.002
≥ 350	1	$Y_1 = 76 + .232 \times 10^{-2}X_1$	.14	.005
50-mm interval groups				
100-149	13	$Y_1 = 120 - .015X_{13}$	.08	.034
150-199	1	$Y_1 = 369 + .727 \times 10^{-3}X_1$	.06	.061
200-249	11, 1	$Y_1 = 173 + 3.22X_{11} + .83 \times 10^{-3}X_1$	.16	.009
250-299	1, 6	$Y_1 = 225 + .354 \times 10^{-2}X_1 - .305 \times 10^{-4}X_6$	.25	< .001
300-349	2	$Y_1 = -7.14 + 4.92X_2$	.09	.025
350-399	1	$Y_1 = 47 + .23 \times 10^{-2}X_1$	.16	.002
150-349	1, 11, 2, 3	$Y_1 = -973 + .332 \times 10^{-2}X_1 + 6.19X_{11} + 48.67X_2 - .242X_3$	.45	< .001

Table 28. (cont'd.)

Trout size class (mm)	Variables entered	Regression model	R^2	P
		Y_1 = Brown trout biomass (gm) per shelter		
50-mm interval groups				
200-349	1, 2, 3	$Y_1 = -814 + .256 \times 10^{-2}X_1 + 39.29X_2 - .185X_3$	.41	< .001
250-349	2, 4, 3, 6	$Y_1 = -892 + 28.28X_2 + .479X_4 - .12X_3 - .603 \times 10^{-4}X_6$	.39	< .001
		Y_2 = Brook trout biomass (gm) per shelter		
Cumulative size groups				
≥ 100	9	$Y_2 = 4 + .168 \times 10^{-6}X_9$	.39	< .001
≥ 150	9, 10	$Y_2 = -13 + .179 \times 10^{-6}X_9 + .225X_{10}$	.53	< .001
50-mm interval groups				
100-149	13	$Y_2 = -1 + .502 \times 10^{-2}X_{13}$	.20	< .001
150-199	6, 7, 9	$Y_2 = 4 + .1097 \times 10^{-4}X_6 + .133 \times 10^{-8}X_7 - .262 \times 10^{-6}X_9$	.65	< .001
		Y_3 = Brook and brown trout biomass (gm) per shelter		
Cumulative size groups				
≥ 100	1, 2, 3	$Y_3 = -1585 + .548 \times 10^{-2}X_1 + 72.83X_2 - .363X_3$	.54	< .001
≥ 150	1, 2, 3	$Y_3 = -1673 + .534 \times 10^{-2}X_1 + 72.53X_2 - .361X_3$	.54	< .001
≥ 200	1, 2, 3	$Y_3 = -1518 + .453 \times 10^{-2}X_1 + 59.05X_2 - .287X_3$	.50	< .001
≥ 250	1, 2, 3	$Y_3 = -1340 + .39 \times 10^{-2}X_1 + 47.42X_2 - .224X_3$	.43	< .001
		Y_4 = Number of brown trout per shelter		
Cumulative size groups				
≥ 100	1, 13	$Y_4 = 16.5 + .428 \times 10^{-4}X_1 - .1096 \times 10^{-2}X_{13}$	.20	.002
≥ 150	11, 1	$Y_4 = 9.3 + .382 \times 10^{-4}X_1 + .0749X_{11}$	.23	.001
≥ 200	1, 11, 2, 3	$Y_4 = -5.6 + .189 \times 10^{-4}X_1 + .0275X_{11} + 236X_2 - .119 \times 10^{-2}X_3$	.53	< .001
≥ 250	1, 2, 3	$Y_4 = -3.9 + .124 \times 10^{-4}X_1 + .151X_2 - .0007X_3$	.47	< .001
≥ 300	1, 2, 3	$Y_4 = -2.2 + .563 \times 10^{-5}X_1 + .0743X_2 - .341 \times 10^{-3}X_3$	.27	.001
≥ 350	1	$Y_4 = .13 + .467 \times 10^{-5}X_1$	.15	.003

Table 28. (cont'd.)

Trout size class (mm)	Variables entered	Regression model	R^2	P
		Y_4 = Number of brown trout per shelter		
50-mm interval groups				
100-149	13	$Y_4 = 4.4 - .544 \times 10^{-3}X_{13}$	.08	.34
150-199	1	$Y_4 = 6.96 + .137 \times 10^{-4}X_1$	.06	.061
200-249	11, 1	$Y_4 = 1.5 + .028X_{11} + .723 \times 10^{-5}X_1$	.16	.009
250-299	1, 6	$Y_4 = 1.11 + .174 \times 10^{-4}X_1 - .15 \times 10^{-6}X_6$	.25	< .001
300-349	2	$Y_4 = -.022 + .015X_2$	.09	.025
350-400	1	$Y_4 = .095 - .465 \times 10^{-5}X_1$	.16	.002
		Y_5 = Number of brook trout per shelter		
Cumulative size groups				
≥ 100	1, 13	$Y_5 = -.11 + .53 \times 10^{-5}X_1 + .138 \times 10^{-3}X_{13}$	.30	< .001
≥ 150	9	$Y_5 = -.05 + .276 \times 10^{-8}X_9$	.53	< .001
50-mm interval groups				
100-149	13	$Y_5 = -.04 + .173 \times 10^{-3}X_{13}$	.20	< .001
150-199	6, 7, 9	$Y_5 = .07 + .205 \times 10^{-6}X_6 + .248 \times 10^{-10}X_7 - .49 \times 10^{-8}X_9$	.65	< .001
		Y_6 = Number of brook and brown trout per shelter		
Cumulative size groups				
≥ 100	1	$Y_6 = 15 + .474 \times 10^{-4}X_1$	.17	.001
≥ 150	1, 11	$Y_6 = 9.2 - .434 \times 10^{-4}X_1 + .0756X_{11}$	.26	< .001
≥ 200	1, 11, 2, 3	$Y_6 = -5.7 + .191 \times 10^{-4}X_1 + .026X_{11} + .238X_2 - .0012X_3$	.53	< .001
≥ 250	1, 2, 3	$Y_6 = -4 + .126 \times 10^{-4}X_1 + .152X_2 - .71 \times 10^{-3}X_3$	.47	< .001

of overhead cover/shelter, (2) maximum water depth proximal to each shelter, and (3) maximum water depth proximal to each shelter squared. These variables were present respectively in 30, 18, and 16 of the 43 regression equations presented in Table 28.

Regression Analysis of Snorkel-diving Counts and Physical Parameters of Shelters

The numbers (from three observation periods) of brook and brown trout $\geq$ 150mm sighted by snorkel divers beneath 39 trout shelters are shown along with a number of physical parameters in Table 29. Although all observations were made sometime between 0830h and 1630h there was considerable variation among the numbers of fish sighted/shelter on the 3 observation periods. The correlation between mean snorkel diving counts and electrofishing estimates for the 28 shelters where the data overlaps was only 0.365. The mean numbers of trout/shelter $\geq$ 150mm was 12.04 for electrofishing estimates and 2.65 for snorkel diving observations for these 28 shelters.

I used the snorkel diving observation trout counts to derive a fitted multiple regression equation. Numbers of brook and brown trout $\geq$ 150mm was used as the dependent variable. The independent variables available for inclusion in the regression equation, coefficients of multiple correlation, probability levels, and best 2 and 3 variable regression equations are presented in Table 30. The equation with 3 independent variables included the variables of percent subshelter gravel, area of overhead cover/shelter and the product of maximum water depth proximal to each shelter and area of overhead cover. These three variables

Table 29. Characteristics of 39 man-made trout shelters and the number of trout ≥ 150mm sighted beneath them while snorkel diving. Shelters whose identifying tags were removed by vandals are not shown.

Shelter No.	Shelter type	Number of brook and brown trout ≥ 150mm, Snorkel observation period 1	2	3	Subcovert substrate (%) Silt	Sand	Gravel	Rubble	Maximum water depth (cm)	Per shelter amount of overhead cover Length (m)	Area (m^2)
1	log jam	2	1	1	-	90	10	-	45	5.0	2.7
2	log jam	1	2	1	50	50	-	-	90	8.0	4.3
3	log jam	2	3	1	5	50	45	-	55	4.5	1.7
4	raft	1	2	1	-	100	-	-	90	4.0	1.6
6	log jam	-	-	-	30	70	-	-	40	6.0	2.1
7	log jam	3	2	2	5	80	15	-	55	17.6	9.9
8	log jam	-	1	1	15	-	85	-	55	3.5	2.7
9	log jam	5	1	6	-	10	90	-	50	14.0	7.6
10	log jam	2	5	-	-	90	10	-	75	8.0	16.0
11	raft	1	-	1	-	30	70	-	65	3.5	2.8
12	log jam	4	2	2	-	10	90	-	60	9.0	6.4
13	log jam	5	4	3	-	55	30	15	75	17.5	17.3
14	log jam	-	1	5	50	30	20	-	35	13.0	13.0
16	log jam	9	3	-	40	50	10	-	90	13.0	40.9
17	log jam	-	-	-	-	100	-	-	25	4.0	2.4
18	raft	-	-	-	100	-	-	-	60	1.0	0.1
19	raft	1	2	2	33	34	33	-	70	1.5	0.6
20	log jam	-	1	-	100	-	-	-	55	4.0	1.2
22	log jam	5	3	5	5	40	55	-	110	11.0	12.9
23	log jam	2	3	5	-	50	50	-	20	4.0	3.2
26	raft	-	-	-	50	20	30	-	65	4.5	4.5
27	log jam	4	3	2	20	10	70	-	70	9.5	5.3
28	log jam	3	6	2	-	30	40	30	60	8.0	12.0
32	stump mass	1	2	1	-	30	10	60	70	1.5	2.2
34	log jam	-	-	-	25	45	30	-	70	13.5	16.0
35	log jam	1	2	1	100	-	-	-	40	4.0	3.2
36	log jam	2	1	2	100	-	-	-	40	4.0	3.2
37	log jam	6	4	6	30	40	30	-	65	7.0	10.0
38	log jam	5	3	2	20	50	30	-	80	6.0	4.4
39	log jam	4	3	4	30	40	30	-	60	7.0	7.0
40	log jam	4	1	2	50	50	-	-	80	2.5	1.8
41	raft	-	2	1	100	-	-	-	50	3.0	0.6
43	log jam	3	-	-	20	40	40	-	28	3.0	3.0
44	log jam	5	7	9	20	40	40	-	70	8.0	7.7
45	raft	1	3	4	10	80	10	-	90	4.0	4.0
46	log jam	2	1	2	100	-	-	-	40	7.0	7.0
47	log jam	4	5	4	30	30	40	-	50	3.0	6.0
48	log jam	4	5	2	45	25	30	-	170	11.0	16.0
69	log jam	1	2	-	40	30	30	-	40	13.0	8.5

Table 30. Multiple regression analysis (backward elimination procedure) of the mean number (from three snorkel diving observation periods) of brook and brown trout $\geq$ 150mm (Y) beneath 39 man-made trout shelters on various physical parameters.

X - variables entered on first regression step

1 - Percent subcovert sand, gravel, and rubble.

2 - Percent gravel and rubble.

3 - Length squared $(cm)^2$ of overhead cover per shelter more than 10cm wide and in water deeper than 10cm.

4 - Area squared $(cm)^4$ of overhead cover per shelter more than 10cm wide and in water deeper than 10cm.

5 - Maximum water depth (cm) found proximal to each shelter x length (cm) of overhead cover/shelter.

6 - Maximum water depth (cm) found proximal to each shelter x area $(cm)^2$ of overhead cover.

7 - Length (cm) of overhead cover x area $(cm)^2$ of overhead cover/shelter.

8 - Maximum water depth squared $(cm)^2$ proximal to each shelter.

9 - Percent subshelter silt.

10 - Percent subshelter sand.

11 - Percent subshelter gravel.

12 - Percent subshelter rubble.

13 - Maximum water depth (cm) proximal to each shelter.

14 - Length (cm) of overhead cover per shelter.

15 - Area $(cm)^2$ of overhead cover per shelter.

16 - Dummy variable = 1 if shelter type is a log jam.

Number of trout $\geq$ 150mm (Y)	Variables remaining in equation	Regression Equation	R^2	P
Y	6, 11, 15	$Y = 0.73 - 0.132 \times 10^{-7} X_6 + 0.189 X_{11} + 0.271 \times 10^{-4} X_{15}$	0.32	0.003
Y	11, 15	$Y = 1.04 + 0.0194 X_{11} + 0.912 \times 10^{-5} X_{15}$	0.28	0.003

accounted for 32 percent of the variation in observed trout numbers/shelter. The best fit equation with 2 independent variables contained the variables of percent subshelter gravel and area of cover/shelter. These two variables accounted for 28 percent of the variation in observed trout numbers/shelter. Trout numbers/shelter increased when the magnitude of these two variables increased.

Comparison of Shelter Types

The abundance of trout/m^2 of overhead cover/shelter for 3 shelter types and 5 trout size classes is presented in terms of biomass (Table 31) and numbers (Table 32). Abundance of brown trout/m^2 of overhead cover per shelter is compared graphically for the 5 size classes in terms of biomass (Figure 12) and numbers (Figure 13). Sunken log raft shelters held more trout of all size classes/m^2 of overhead cover than the other 2 shelter types. Submerged log rafts held from 19-50% more trout/m^2 than stump shelters and 133-200% more trout/m^2 than log jam shelters for the 5 size classes. Rafts held 19% more brown trout $\geq$ 250mm/m^2 than stump shelters and 192% more trout of this size/m^2 than log jam shelters.

To test for differences in abundance (biomass) of trout beneath the 3 shelter types, treatment means were adjusted for three covariates, maximum water depth proximal to the shelter x total length of overhead cover, maximum water depth proximal to the shelter and maximum water depth squared. Interaction effects between covariates and treatments (shelter type) were not significant ($\alpha = 0.05$). There were no significant treatment effects ($\alpha = 0.05$).

Table 31. **Estimated biomass (kg) of trout beneath 1 square meter of overhead cover for 3 types of man-made trout shelters.**

	Shelter Type						
Species and total length size class (mm)	All shelter types (1)[a]	Log jam shelters (2)[b]	Stump shelters (3)[c]	Sunken log raft shelters (4)[d]	(3)-(2) as % of (2)	(4)-(2) as % of (2)	(4)-(3) as % of (3)
Brown trout ≥ 100	0.244	0.216	0.394	0.534	82	147	36
Brown trout ≥ 150	0.230	0.202	0.381	0.515	89	155	35
Brown trout ≥ 200	0.173	0.153	0.271	0.383	77	150	41
Brown trout ≥ 250	0.129	0.112	0.234	0.300	109	168	28
Brown trout ≥ 300	0.074	0.065	0.104	0.169	60	160	62
Brook and brown trout ≥ 150	0.232	0.205	0.381	0.515	86	151	35

a n = 57 mean size=7.235m^2

b n = 45 mean size=8.283m^2

c n = 3 mean size=2.084m^2

d n = 9 mean size=3.712m^2

Table 32. Estimated number of trout beneath 1 square meter of overhead cover for 3 types of man-made trout shelters.

Species and total length size class (mm)	Shelter Type: All shelter types (1)[a]	Shelter Type: Log jam shelters (2)[b]	Shelter Type: Stump shelters (3)[c]	Shelter Type: Sunken log raft shelters (4)[d]	(3)-(2) as % of (2)	(4)-(2) as % of (2)	(4)-(3) as % of (3)
Brown trout $\geq$ 100	2.43	2.17	3.84	5.06	77	133	32
Brown trout $\geq$ 150	1.93	1.69	3.36	4.34	99	157	29
Brown trout $\geq$ 200	0.85	0.75	1.28	1.86	71	148	45
Brown trout $\geq$ 250	0.46	0.39	0.96	1.14	146	192	19
Brown trout $\geq$ 300	0.19	0.16	0.32	0.48	100	200	50
Brook and brown trout $\geq$ 150	1.96	1.72	3.36	4.34	95	152	29

a n = 57 mean size 7.235m^2

b n = 45 mean size=8.283m^2

c n = 3 mean size=2.084m^2

d n = 9 mean size=3.712m^2

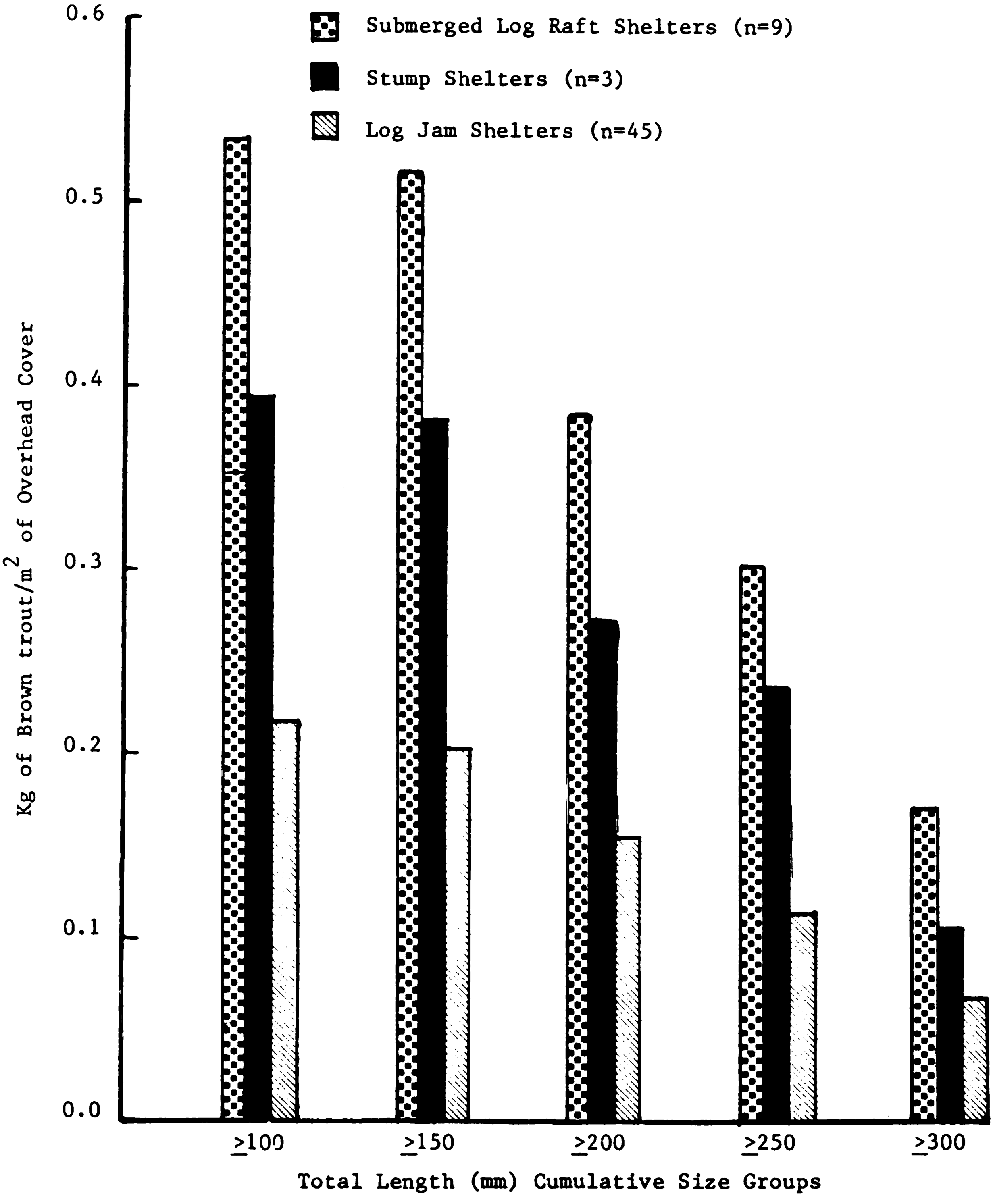

Figure 12. Comparison of biomass (kg) of brown trout beneath 1 square meter of overhead cover for 3 shelter types and 5 size classes of trout.

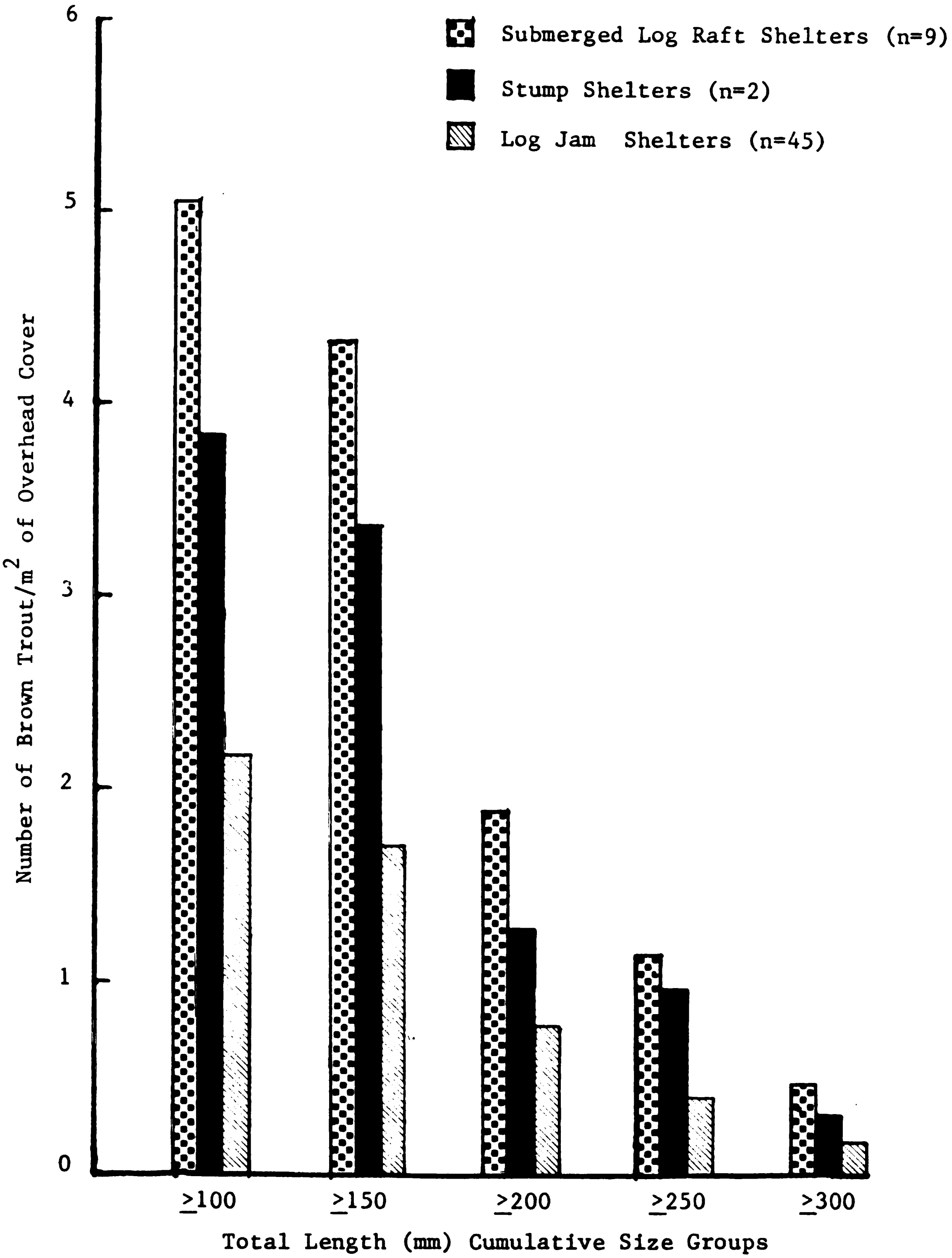

Figure 13. Comparison of the number of brown trout beneath 1 square meter of overhead cover for 3 shelter types and 5 size classes of trout.

DISCUSSION

Shelter Characteristics Correlated with Trout Abundance

Linear Regression Models

Two covert characteristics closely correlated with per-shelter trout abundance were length of overhead cover and depth of water in which the cover existed (Table 27). Length of overhead cover was more important than area of overhead perhaps because trout tend to position themselves near the edges of coverts rather than distributing themselves evenly throughout the subshelter area (Gibson and Keenleyside 1966). Deep water adjacent to cover might provide security for trout moving away from cover to feed.

Trout positioned in deep water near shelters may have moved into cover as the electrofishing crew approached. If deeper water held more fish than shallow areas, this might partially explain why more trout were captured under shelters near deep water. Few trout were captured in deep water when no overhead cover was nearby. This could be interpreted as meaning that trout did not find deep water as attractive when overhead cover was not nearby. One the other hand, it could mean that trout, even if preferring deep water, fled from the electrofishing crew until they reached cover whether it was near or distant.

Nonlinear Regression Models

Models for per-shelter trout abundance with interaction and polynomial terms (Table 28) provided better fits of the data than the models with simple terms (Table 27) because the relationship between trout abundance and water depth was quadratic rather than linear and because the product of length of cover per shelter and water depth was a better predictor of abundance than length alone. The importance of the product of length and maximum water depth in explaining variation in trout abundance is probably related to the association of trout with the edges of overhead cover adjacent to deep water as discussed above. Although water depth was only measured at the deepest point beside each shelter, coverts with deeper water at one place usually had deeper water at other points.

Most polynomial models for cummulative size groups were of the form $Y = a + b_1x_1 + b_2x_2 - b_3(x_2)^2$ where x_1 is the product of length of cover per shelter and maximum water depth, and x_2 is maximum water depth adjacent to each shelter. The magnitude of b_3 was always much smaller than that of b_2. Hence, for water depths such as those encountered in this study, which were mostly 25-100cm, the relationship between trout abundance and water depth remains strongly positive. According to these models, per-shelter trout abundance increases more slowly as water depth is increased. The models are probably not valid for very deep water since they imply that the net effect of water depth on trout abundance eventually becomes negative. It should be stressed that the models cannot be applied to data outside the range of values used to derive the models.

The negative y-intercepts in some of the equations in Tables 27 and 28 imply that greater water depths and shelter lengths are required for large fish than for small ones. Allen (1969) noted that as fish grow, the size of their territory increases and its physical characteristics change. Chapman and Bjornn (1969) reported that chinook salmon and steelhead trout shift to faster deeper water as they grow.

The relatively low R^2 values to the models in Tables 27 and 28 indicate that the predictor variables examined did not explain much of the variation in subshelter trout density. The lack of direct data on subshelter current velocities may partly explain the weakeness of the models. As stated in the methods section, substrate types beneath shelters were measured to give indication of current velocities. Coarser substrate usually indicates that current velocity is enough to remove finer sediments. Organic silts are light and easily washed away. I now realize, however, that the current which laid down or eroded the sediments may not have been the current which prevailed at the time of measurement.

One-way correlations between subshelter silt percentage and trout abundance were negative. Baldes and Vicent (1969) state that velocity in resting microhabitat must be sufficient for the fish to maintain orientation and must not be too high for fish to maintain position economically. Shelters with much silt beneath them may have had current velocities which were too slow for trout to maintain orientation or slower than the trout preferred in some other respect.

Data on one-way correlations was not presented in the results because I believe them to be misleading. Some variables in predictor equations often become meaningless when the effects of other variables are accounted for. The multiple regression used in this study avoids such errors by removing variables from the equation when they are highly correlated with other variables in the equation. Percent silt beneath coverts was not important in explaining variation in subshelter trout abundance after the effects of other variables had been accounted for in the models.

The high probability levels associated with the equations in Tables 27 and 29 (most P's were around 0.001) might seem to indicate that the alpha for entry into the regression equations was unrealistically small. On the contrary, it was around 0.1. Coefficients of multiple determination for equations containing all the independent variables were not appreciably higher than those obtained for the best fit equations. After the effects of water depth and length of cover had been accounted for, the addition of other predictor variables did not explain significant amounts of variation in trout abundance.

Regression Models Based on Snorkel Diving Counts

The 3-variable equation derived from snorkel diving counts (Table 30) contained the product of water depth and length of cover per shelter as did models derived using electrofishing data, but it also contained the variables of percent subshelter gravel and area of overhead cover per shelter. This contrasts with the models based on electrofishing data, derived by the backward elimination method, in which area of overhead cover was usually one of the first variables to be removed by the regression procedure. In the 2-variable equation derived from snorkel diving data, only the effects of gravel and area were accounted for.

The results are probably not as dependable as those derived from electrofishing data for a number of reasons. First, the snorkel diving may have disturbed many fish and chased them away from shelters before they were sighted. A major reason for this was low underwater visability. Visibility was usually only about 4.5 meters as measured by the maximum distance the yellow tip of a snorkel tube could be seen underwater. Camouflaged trout would have had to be considerably closer for a diver to see them. Trout this close to a diver were probably disturbed by the noise made while crawling upstream over gravel against the swift current. Furthermore, the water pouring around a diver's body sounded like water running over and around a large stone and would have sounded unusual to fish accustomed to the quiet waters of the Au Sable. Fish could have run into or out of shelters beyond the perimeter of visibility. Visibility beneath shelters was lower than in midstream where visibility measurements were taken so trout may have been frightened away before they could be seen and counted. The large amounts of lateral concealment beneath many shelters undoubtedly hid some fish from view. A number of investigators have found that salmonids are not unduly disturbed by divers approaching from downstream (Ellis 1961; Keenleyside 1962; Fausch 1978). In this study, low visibility and high current velocity reduced the effectiveness of diving techniques. The underwater light used to illuminate beneath large shelters probably also frightened some fish away. The small intershelter and relatively large intrashelter variability of trout density among the 3 observation periods (Table 29) suggests that the variance in numbers of trout counted beneath shelters is larger than desirable and thus snorkel diving counts are not a good basis for the derivation of models.

The criticism of snorkel diving results above do not necessarily make all conclusions invalid. The equations in Table 30 indicate that percent gravel was positively correlated with trout abundance. The presence of gravel beneath shelters usually indicated the presence of moderate current velocities. It was noted in the results that shelters with deep swift water on at least one side tended to hold more trout. Trout ≥ 250mm preferred shelters in deep swift water more than smaller trout, as evidenced by the high proportion of these trout to all trout under many wing-deflector type log jam shelters. Gruber (1978) reported that 250-300mm brown trout preferred a range of sub-cover water velocities between 12.5 and 17.5 cm/sec. More areas with water velocities in this range may have been present beneath deflector type shelters than beneath shelters which were largely silted or those in slow water.

Such velocities seemed to occur adjacent only to the downstream end of many log shelters of the deflector type, while current velocity adjacent to near-bank portions of the shelters was nearly zero. Deflectors of this type provided ample hiding space for frightened fish. Perhaps a combination of small interstices near the banks and more open area beneath cover adjacent to deeper and swifter water is preferred by trout. The preference for deflector-type log jam devices seems especially strong for trout ≥ 300mm. Perhaps this is because larger fish select microhabitats with faster current velocities (Everest and Chapman 1972; Chapman and Bjornn 1969). It may also be related to principle lines of drift and feeding behavior (Jenkins 1969). Swift current carries more food items per unit time than slower water.

Comparisons of Shelter Types

Log Jams, Rafts and Stump Shelters

Whether the shelter was a log jam, a log raft or a stump cover did not significantly influence per-shelter trout abundance. When such shelter types were entered into models (dummy variables), they had negligible effect, and were eliminated in the regression procedure. The comparisons of shelter types were not significant owing to great variability of trout abundance among shelters of the same type.

The finding that submerged rafts consistently held more trout per square meter of overhead cover than other shelter types (Tables 31 and 32) warrants a closer examination. Not all submerged rafts were in near-midstream positions. The 3 rafts holding the most fish were close to the banks near abundant natural cover. Many of the trout taken in these shelters were undoubtedly chased there from the natural cover. According to my electrofishing estimation procedure, submerged raft shelter number 41 and number 42 held 37 and 90 trout $\geq$ 150mm per square meter of overhead cover respectively. Clearly this is impossible. This result is based on what I arbitrarily measured as cover (see Methods). Actually shelter 41 was 1 by 3m and shelter 42 was 1.5m by 4m and owing to darkness beneath these devices I may not have measured all the cover that the trout were actually using. Even so, 23 trout $\geq$ 150mm were actually caught from beneath shelter 41 and 30 trout $\geq$ 150mm beneath shelter 42. The mean density of trout $\geq$ 150mm/m^2 for the other 55 shelters was 3.1 $\pm$ 2.7. There were no extreme outlying values for density among the remaining 55 shelters. I conclude that fish were drawn or herded from natural cover or other stream areas to be captured under rafts 41 and 42 to a greater extent than for other shelters. If these two shelters are omitted from analysis, the trout density beneath submerged rafts falls well within the density ranges found beneath log jam and stump shelters. The mean density of trout $\geq$ 150mm for the remaining log rafts is actually less than the mean density beneath the 3 stump shelters. Therefore, trout did not show preference between any of the shelter types examined. Type of shelter -- log jam, submerged log raft, or stump shelter -- did not influence trout abundance as much as other factors.

Trout Density in Bank Shelters

Snorkel diving observations indicated that trout were abundant in the deep pools (up to 1.7m deep) adjacent to the 2 large overhanging bank shelters in stations 1 and 3. However, it was not possible to accurately quantify these trout numbers. These deep pools may have an important influence on overwinter carrying capacity. Bjornn (1971) observed that fish in sections without rock were primarily beneath undercut banks in winter. Hunt (1971) reported dramatic increases in standing crops of wild brook trout following the installation of overhead bank cover, and attributed the increase to improved overwinter survival after habitat development. Bustard and Narver (1975a) found that when water temperature decreased to 2 C, coho and steelhead moved closer to cover, making use of logs and upturned tree roots. All four shelter types in the study area undoubtably enhance overwinter survival in the Au Sable.

Relationships Between Trout Population and Overhead Cover

All per-station correlations between trout abundance and amount of all overhead cover were positive and low (Tables 23-25). Most correlations were not significant at ($\alpha = 0.20$). Higher correlation coefficients and significance levels were obtained for trout abundance and natural overhead cover than for either man-made or total overhead cover.

The only correlations significant at $\alpha = 0.05$ were for natural overhead cover. There can be several interpretations of this result. One is that natural overhead cover is superior to man-made cover and has more influence on the abundance of trout in a stream section. In view of the small amount of natural overhead cover in the study section (Table 19) and the small numbers of trout captured by electrofishing or observed while snorkel diving beneath natural overhead cover, this interpretation does not appear valid.

A more likely interpretation is that natural cover was correlated with some other factors which influence trout abundance such as stream surface area, channel shape, the amount of water in a station deep enough to provide sufficient cover, or some other factors. Additional evidence that natural cover is not superior to man-made cover is that more brown trout (by far the most abundant species) $\geq$ 150mm were located beneath man-made cover than in all other parts of the stream including natural overhead cover (Table 21). It was also observed that most permanent natural overhead cover was in areas of shallow water close to the banks away from principle lines of current.

The amount of overhead cover (area) was more highly correlated with trout abundance than was length of cover per station (Tables 23-25). This suggests that in large streams, area of overhead cover is a slightly better index of habitat suitability than length. However, the small amount of variation in per-station trout abundance explained by overhead cover in this study indicates that overhead cover is not a good index of habitat suitability in large streams in summer.

Evidence of a strong positive correlation between the amount of overhead bank cover in stream sections and trout abundance has been presented by a number of investigators (White 1975, Enk 1977; Hunt 1971; Wesche 1976). These investigators examined relatively small streams with small surface areas. My study section in the Au Sable River had a mean stream width of 29m and mean maximum depth of 78.7cm. The stream was shallow along most of the banks and contained virtually no natural overhanging bank cover. Therefore, I measured the length and area of permanent overhead cover of all types in all parts of the stream which were in contact with the water, 10cm or more above the bottom and 10cm or more in width. These dimensions were chosen after making snorkel diving observations and after examining the work of Wesche (1976) who found few trout in overhead bank cover less than 9.1cm in width or in water depths less than 15.2cm. DeVore and White (1978) found that brown trout 25-30cm in length preferred overhead cover 10cm rather than 15 or 20cm above the streambed. Snorkel diving observations in the Au Sable showed that trout did utilize overhead cover which about 10cm above the stream bottom when deeper water was flowing over or around the cover. Basset (1978) states that distance between overhead cover and the stream bed should just exceed the body depth of the largest trout likely to use the cover.

Since stations 1 and 3 contained unwadable and unshockable pools they were excluded from the analysis of trout abundance and cover per station. There was little variation in the amount of overhead cover in the reamining 8 stations (Table 19). This contrasts with Enk (1977) and Hunt (1971) where the amount of overhead cover varied more between stream sections. Trout abundance varied little in the 8 stations used in the analysis (Tables 11, 12, 14-17). Most correlation coefficients were not significant, owing to low variability in trout abundance and overhead cover among stations and the small number of stations available for correlation analysis. Overhead shelter covered only about 2% of the surface area of the stream. This may be too small a fraction of the suitable living space to have greatly influenced per-station trout abundance.

In summary, the amount of per-station trout abundance was positively correlated with overhead cover, although the relationship was not nearly as strong in this large stream as the correlations usually obtained for permanent overhead bank cover and trout abundance in small streams. Trout abundance was slightly more correlated with area of overhead cover than with length of cover per station.

Percentage of Trout Beneath Man-Made Shelters

More than 50% of the total number of brown trout $\geq$ 150mm were beneath man-made cover (Table 21) which covered only about 1.8% of the stream surface area. The percentage of trout beneath man-made shelters increased progressively with trout size. Basset (1978) observed that brown trout in an experimental stream spent most of their time from sunrise to sunset under cover. Since electrofishing was done during the day it is not surprising that most fish were beneath cover.

Although special care was taken to approach man-made shelters (see Methods) with electrodes out of the water some trout could have been chased into shelter from other stream areas as the electrofishing crew approached. Even if many fish were driven into cover, the results demonstrate that man-made shelters provide areas of refuge for disturbed fish. After all man-made shelters in a section were electrofished individually the entire stream section was sampled. Most trout caught on this second sweep were also captured beneath man-made shelters. This indicates that these fish were not driven into man-made shelters until they were frightened there by electricity. I did not believe it was feasible to place a diver near shelters to count trout chased into them by the approaching crew because of poor underwater visibility and the potentially disruptive influence of the diver. Trout are probably not as frightened by waders in large stream as in small ones. The heavy recreational use of the Au Sable by fishermen and canoeists may serve to acclimate the trout to disturbances.

In summary, most larger trout ($\geq$ 150mm) were beneath man-made overhead cover during the day. This result is consistent with the findings of other investigators on the photonegative and cover seeking behavior of trout (Gruber 1978; Basset 1978; Butler and Hawthorne 1968; Baldes and Vincent 1969).

Population Estimates

Trout Abundance

Trout were more abundant in the study section (kg/hectare) than in most other Michigan streams (Table 18). This may be due to a combination of factors including greater mean water depth in the Au Sable River than in some other streams, restrictive angling regulations, or food abundance. Shetter and Alexander (1966) found that special regulations on the North Branch of the Au Sable caused a temporary stockpiling of trout during a given fishing season, but nonangling mortality between seasons lowered the gains to normal levels. Latta (1973) concluded that flies-only regulations alone, which reduce hooking mortality, do not lead to an increase in the standing crop of fish. The high population in this area of the Au Sable may be derived from high size limits and reduced creel limits.

An examination of Table 18 shows that the trout standing crop from Burtons Landing to Wakeley Bridge (an area encompassing the study section) given by Coopes (1974) is more than twice (kg/hectare) the standing crop in the study section in 1978. This may reflect lower habitat suitability in the study section than in other parts of the stream, a reduction in invertebrate production since the previous estimates were made, increased angler harvest, or other factors. The Grayling sewage disposal plant ceased discharging into the Au Sable in 1971 (Hendrickson and Doonan 1974). The nutrient rich discharge may have served to stimulate the production of invertebrates used by trout and forage fish. Warren et al (1964) reported that trout production and biomass increased 700 percent in sucrose enriched sections of Berry Creek.

Estimation Procedure

Population estimates made using Schaefer's modification of the Peterson method are biased less than 2% when the product of the marking and census runs is approximately equal to 4 times the size of the population (Robson and Regier 1964). This criterion was met and exceeded for the combined species population estimates made for this study. Another assumption on which mark and recapture estimates are based is that the capture method does not measurably affect the recapture of fish taken on the census run (Cooper 1952). Cooper believed that changes in catchability following an electrofishing marking run were minimal. Bouck and Ball (1966) observed fish following electroshocking and found that they fasted for about 2 weeks and were extremely excitable, swimming vigorously whenever their holding tank was approached whereas seined fish exhibited normal activity. This could lower capturability in a large stream such as the Au Sable where the large expanse of water presents many escape avenues.

Brook and rainbow trout abundance estimates were obtained by proration from combined brown, brook, and rainbow estimates. This method presumes that these three species were equally susceptible to capture by electrofishing which was shown by Cooper (1952). This assumption was probably valid for brook trout but not rainbow trout in this study. The relative numbers of brook and brown trout captured while electrofishing were consistent with the relative numbers observed while snorkel diving in the study area. Rainbown trout on the other hand were observed by diving to be abundant in several sections of the study area, but only 9 were captured on the marking run and 3 on the census run. Most rainbow trout sighted while snorkeling were in deep pools which could not be electrofished effectively. Capturability for all trout species is low in such areas. Therefore, the rainbow trout estimates in Table 13 are undoubtedly low. By the same token, all other species abundance estimates are low for stations 1 and 3 because of the long deep unwadable pools there. Snorkel diving observations indicated that large brown trout were also abundant in these pools but that small numbers of brook trout were present there. If the fish in deep pools of stations 1 and 3 had been adequately sampled, numbers and especially biomass estimates for the study section would be considerably higher.

Application to Stream Management and Implications for Further Research

This study indicated that trout preferred shelters with deep water flowing along at least one side. Shelters which serve as wing-deflector-overhead cover seem most likely to provide this kind of cover without silting in badly.

Future research into the physical factors affecting per-shelter trout abundance should use a more sensitive measure of water velocity than subshelter bed material composition as used in this study. Considerably better explanations of per-shelter trout abundance might be possible if shelters could be accurately characterized according to velocities beneath and around them.

Further study could also be undertaken to determine if trout abundance in large streams such as the Au Sable increases substantially following the addition of trout shelters. Such increases are common on small streams but may be less dramatic in large rivers where the water is deep throughout most of the channel. Population data on sections of large streams before and after the installation of trout cover would provide valuable insight into the effectiveness of habitat improvement in streams such as the Au Sable River.

Snorkel diving was not an effective method of determining trout abundance beneath complex log jams. However, diving observations can be used to some extent to determine the physical characteristics of cover used by trout. A diver can also measure the amount of overhead cover in a stream more accurately than someone above the surface.

Snorkel diving may be an effective way to count trout in pools which are too deep to electrofish. Diving counts in pools could be compared to the numbers of trout taken by explosives or some other capture method.

CONCLUSIONS

1. Water depth and length of overhead cover were the features of the study area's man-made trout shelters which were most important to trout. Trout preferred shelters with deep water flowing along at least one side with ample interstices for hiding cover.

2. More than 50% of trout $\geq$ 150mm were associated with man-made shelters. The percentages of trout associated with man-made shelters increased progressively as trout size increases.

3. There were no significant differences in the abundance of trout beneath log jam, submerged log raft, or stump type shelters.

4. Trout abundance in 100m stations was positively correlated with the amount of overhead cover per station, but the relationship was weak. The correlations of area of overhead cover per station and trout abundance usually were slightly higher than correlations of length of cover and abundance.

5. Brown trout were the most abundant trout species in the study section, comprising 95.6% of total trout biomass. Brook trout made up 3.2% of the biomass and rainbow trout accounted for 1.2%. Trout abundance estimates for the 1km section are low, especially for rainbow trout and large brown trout, because of unwadable pools in 2 of the 100m sections. Rainbow trout were concentrated in these pools and could not be captured effectively.

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APPENDIX

Table A1. Streamflow discharge and flow characteristics for the Mainstream of the Au Sable River at Stephans Bridge. (site shown in Figure 2).

Date	Discharge (m^3/sec)
1978 Monthly Means	
October	5.30
November	5.13
December	5.30
January	4.67
February	4.45
March	4.53
April	6.91
May	5.63
June	4.67
July	4.11
August	4.11
September	4.90
Mean Annual Discharges	
June	5.52
July	4.93
August	4.56
September	4.76
Peak Discharges	
2-year recurrence	10.76
5-year recurrence	12.74
10-year recurrence	13.88
25-year recurrence	14.44
50-year recurrence	15.00
100-year recurrence	16.42
7-day Low Flows	
10-year recurrence	3.54
20-year recurrence	3.40

* Data from Robert Larson, USGS, Grayling, Michigan, pers. comm.

Table A2. Estimated number of brook and brown trout by 50-mm size class beneath 57 trout shelters (estimates by proration from electrofishing population estimates) in the Au Sable River, July 17 to 21, 1978.

	Number of Brown Trout in 50mm Size Classes								Number of Brook Trout in 50mm Size Classes				
Shelter Number	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	50 99	100-149	150-199	200-249	250-299
8				4	1					3			
9	20		9	2	1	4				3			
10	34	9	21	8	2	2							
11	14		6	2	1								
12	7	3	8	2	1	1			7				
13	7	6	6	4	2								
14	75	9	5										
15	14		11	4	2	4	2			3			
16	68	6	8	6	4	2					2		
17	75	3	2	1					7				
24	7	3	6	2	2								
25		9	11	5	3	2	2				3		
26	14	3	2	1	2								
27	7		8	1	2	2		2					
28			5	2	1	1							
29	54	3	6	2	4		2						
30	14	6	12	6	2								
31	14	6	9	4	3	1							
32	14		5	1		1							
33	7	15	8	2	1	1							
34		3	3	4	8								
35		6	3										
36	14	6	6	1									
37			8	6	3	2							

Table A2. (cont'd.)

	Number of Brown Trout in 50mm Size Classes								Number of Brook Trout in 50mm Size Classes				
Shelter Number	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	50-99	100-150	150-199	200-249	250-299
38	14	3	12	6	0	1	2						
39	7	3	14	5	2						2		
40	14		12	1	3								
41	20	9	15	6	1								
42		9	18	2	5	2							
43	48	6	5	1		1							
44	41	6	12	7									
45			9	1	2	2							
46	20		3	1		1							
47	7	3	15	6	2								
48		3	3	1	2	1							
49	20		9	1	3	2	2						
50			12	7	2	2							
51			3		2								
52	7		5	4	3		4						
53	20	3	8	4	3	2							
54	7	12	15	6	3	2					2		
55	54	12	8	2	1	1							
56	20	3	3	1	1								
57	7	9	3	2	2	3				3			
58			3	1	1								
59	7	3	5	1	2	1							
60	27	6	5	4									
61	7	0	5	2	1	1	2						
62	14	12	11	1	3	3							
63	20	3	6	4	2				7				

Table A2. (cont'd.)

Shelter Number	Number of Brown Trout in 50mm Size Classes 50–99	100–149	150–199	200–249	250–299	300–349	350–399	400–449	Number of Brook Trout in 50mm Size Classes 50–99	100–149	150–199	200–249	250–299
64	27		8	2	2								
65	99		11	1	1								
66	7		2		1								
67	14		6	1	2	2	4						1
68	7	3	18	6	7	1	2				2		
69	7		6	2	4	4							
70		3	8		3								