REGIONAL COPPER-NICKEL STUDY:
SPAWNING BEHAVIOR, FOOD HABITS AND MOVEMENTS OF FISHES
A LITERATURE REVIEW

Principal Authors: Steve Johnson
Steve Williams
Mark Johnson

Associate Authors: Tom Lager
Jeff McCulloch

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ABSTRACT

The physical and biological characteristics of lakes and streams may be altered by copper-nickel development in northeastern Minnesota. These alterations may affect the region's fishery resource by causing changes in the behavior of the fishes inhabiting the impacted areas. To determine the indirect affects of copper-nickel development on fishes, literature was reviewed concerning the spawning behavior, food habits, and movements of fishes collected in the Regional Copper-Nickel Study area. The characteristics of studv area fishes have been categorized with respect to each of the above subjects.

Fishes can be classified by their spawning behavior into groups depending on the type of substrates utlized and individual spawning habits. More than half of the fish species from the study area were found to spawn on clean rock or gravel substrates while most of the remaining species spawn on vegetation. Categories developed for the spawning habits of study area fishes are: nonguarding egg scatterers and guarding nest builders; both of which contain about 45% of the species collected; and nonguarding egg hiders which include the remaining 10%.

Food habits are well documented for fish species found in the study area. Although specific food items utilized bv a species may vary between areas, the basic food types remain the same. Adult fish have been categorized, by their feeding habits, into the following groups: aquatic insect feeders; fish feeders; algae feeders; zooplankton feeders; and opportunistic feeders. The majority of the fishes are aquatic insect and fish feeders while opportunistic, algae, and zooplankton feeders comprise respectivelv smaller categories. Over 75% of the fish species are known to utilize aquatic insects as a food source at some point in their life. Based on literature information, drifting aquatic insects serve as an important food source for those fishes that feed on aquatic insects.

Fishes move for reasons such as spawning, food availability, and changes in light and temperature. Movements of adult fishes collected in the study area have been categorized into three main groups; sedentary; semimobile; and mobile. The majority of fish species collected are classified as sedentary and can be expected to remain in the same general area for long periods of time.

INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are to characterize the region in its pre-copper-nickel development state: 1) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 2) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 3) to conceptualize alternative degrees of regional copper-nickel development; and 4) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

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1.0. INTRODUCTION

The following review summarizes the available information on spawning behavior, food habits, and movements of fish species found in the Regional Copper-Nickel Study Area (Study Area). Specific aspects of fish life histories were summarized to provide information necessary to predict the possible impact of copper-nickel development on lakes and streams in northeastern Minnesota. Behavioral changes in fish movements, spawning and food habits may result from physical and chemical changes in lakes and streams caused by copper-nickel development. These impacts will be reviewed in the following Regional Copper-Nickel Study reports: Biological Effects of Physical Impacts to Stream Ecosystems; Toxicity of Heavy Metals to Aquatic Organisms; Toxicity of Beneficiation Chemicals to Aquatic Organisms; Effect of pH changes on Lake and Stream Ecosystems.

Much of the information in this review is a summary of the work of Scott and Crossman (1973). Fisheries literature published after 1972 on the above topics as well as literature on topics not contained in Scott and Crossman (1973) were also reviewed during the preparation of this report.

2.0. SPAWNING HABITS

Reproductive habits are well known for most fishes in the Study Area. Spawning time, temperature, location, and substrates are reviewed for each species in Table 1. Balon (1973) classified spawning habits into several categories. Fishes from the following categories were collected during the Regional Study: nonguarding egg scatterers; nonguarding egg hiders; and guarding nest builders. Nonguarding egg scatterers randomly deposit or scatter eggs over gravel bottoms or vegetated shorelines abandoning the site when spawning is completed. Fishes which bury their eggs in nests excavated in gravel stream bottoms and lake shoals before leaving the site are considered nonguarding egg hiders. Guarding nest builders construct nests by digging burrows, cleaning bottom substrates, or utilizing vegetation. At least one adult remains at the nest to care for the eggs and young. Classification of fish species collected during the Regional Study can be found in Table 2.

3.0. FOOD HABITS

Food habits of fishes have been studied extensively with most data obtained by analysis of stomach contents. Availability, abundance, and vulnerability of food items determine the amount of their utilization by fish (Beyerlye and Williams 1968). Table 3 reviews the food habit information available for juvenile and adult fish species found in the Study Area. Few detailed food habit studies have been completed on the cyprinids primarily because of difficulties in analyzing their stomach contents. Fish can be classified into six general categories by the food items they prefer. The categories are: fish; fish and aquatic insects; aquatic insects; zooplankton; algae; and opportunists. Opportunists eat a variety of food items including fish, insects, molluscs, crustaceans, algae, and detritus. Table 4 classifies adult fish species collected during the Regional Study into these food habit categories.

4.0. UTILIZATION OF INVERTEBRATE DRIFT BY FISH

Study of the drifting component of the benthic community has been an area of major interest in recent years. Several investigators have suggested an energy flow between producers in riffles and consumers in pools, with drift acting as the transport mechanism (Ide 1942, Dendy 1944, Berner 1951, Muller 1954, Karr 1963, Hunt 1965, Bailey 1966, Elliott 1967, and Bishop and Hynes 1970, cited in Reisen 1972). Invertebrate drift is important to stream fishes because it provides a readily available supply of food. Hooper (1973) suggests drift as the primary source of food for stream fishes. Gard (1961, cited in Hooper 1973) found that drift organisms comprised one-half of the summer diet of trout in Sagehen Creek, California.

A review by Waters (1969) lists two direct effects of drift on food availability: 1) transport of invertebrates from an area of production (shallow riffle inaccessible to fish) to an area where they may be consumed (such as a pool where fish reside); and 2) a drifting invertebrate is moving making it more visible and therefore more available. Drift may have the effect of increasing the production of invertebrates and thus optimizing the food supply for fish.

Diel periodicity in drifting invertebrates is closely related to "feeding cycles" in stream fish. Jenkins et al. (1970) found that aerial invertebrates were more abundant in both the drift and fish stomachs during midday and afternoon than at night or in the morning. Mayfly and caddisfly larvae were mainly nocturnal and blackfly larvae diurnal. All three were eaten primarily in the afternoon and at night in September, but in the morning and at night in October. Elliott (1973) studied the diets of rainbow and brown trout and found a major feeding period occurring in the early evening. This peak corresponds with peak drifting of benthic invertebrates. A second feeding period occurred during the day when terrestrial invertebrates and emerging insects formed a large portion of the diet. Availability of food organisms in the drift determined the time of feeding but not the amount of food consumed.

Selection by fish of certain groups of organisms has been shown to be a major factor in drift utilization. Griffith (1974) found selectivity to be species specific when studying trout populations. Brook trout and cutthroat trout, when living together, occupied portions of streams with significantly different water velocities. Brook trout remained near the bottom where water velocities were reduced. This placed the fish in close proximity to the substrate where heavier Trichoptera larvae were found drifting. Cutthroat trout, on the other hand, lived in areas with higher current velocities and fed on immature and adult Diptera.

Elliott (1973) found that the diets of rainbow and brown trout were similar to each other and were related to the percentage composition of the drift. Stomach contents did not show strong correlation with the composition of the benthos, indicating a positive selection for drifting organisms. Reisen (1972) reported that drift organisms were consumed in quantities proportional by weight to their composition in the drift.

Mundie (1971) reported that coho salmon apparently do not make use of peak drift rates of larvae. "Forage ratios demonstrated greater consumption of chironomid pupae and adults than would be expected from proportions in the drift." Selection of an item was thought to be related to its visibility (e.g. an item is most visible when floating on the surface of the water).

Hooper (1973) states that the study of drift offers potential as an indicator of fish productivity. By relating flows with the amount of food available to fish, a more meaningful measurement of productivity can be gained.

A drift-feeding fish population may also affect the drift. Peterson (1966, cited in Waters 1969) found that a fish population heavily exploiting its supply of aquatic foods might be expected to reduce drift rates significantly. Brocksen, Davis, and Warren (1968, cited in Petrosky and Waters 1975) reported that sculpins influenced the food consumption and production of trout by cropping the benthic food organisms, thus reducing the numbers of drifting organisms. The trout, however, affected the production of sculpins very little through food competition, because their consumption of drifting organisms usually did not reduce the benthic populations.

Chapman (1966, cited in Waters 1969) points out that a feedback mechanism cannot occur against drift of an allochthonous(organic inputs from outside the stream) source, such as terrestrial insects. Since allochthonous materials are affected by and respond to a different set of conditions than those present in the stream, an internal force. such as fish, cannot affect a change in those materials.

5.0. FISH MOVEMENTS

Freshwater lake and stream fish move within their preferred habitats. The reasons for changing locations may vary depending on the life habits of individual species. The most common reasons for movements are spawning and changes in light and temperature. Food availability, overcrowding, and physical and chemical habitat alteration are also important reasons for fish relocation. Table 5 summarizes into three groups movements of fish collected during the Regional Study: sedentary; semimobile, and mobile (Funk 1957). Sedentary fish usually do not have large spawning migrations but do exhibit a tendency to remain in or near specific boundaries for long periods of time. Semimobile fish may have distant spawning migrations but tend to remain near particular areas for at least short time periods. Mobile fish have extensive spawning movements and are continually moving throughout the water body in which they live. The following literature review was completed so that the impacts of copper-nickel development on the movement patterns of fish in the Study Area might be determined.

5.1. Salmonidae

The movements of three of the four salmonids collected in the Study Area are very similar. Lake trout (Salvelinus namaycush), cisco (Coregonus artedii), and lake whitefish (Coregonus clupeaformis) are all fall spawners (Rahrer 1968, Scott and Crossman 1973). Rahrer (1968) observed adult lake trout moving off the spawning grounds by early winter and dispersing throughout the lake, sometimes moving up to 120 miles by spring. During the summer these three species moved into deeper, cooler waters and began migrating back to their spawning grounds (Martin 1952, Rahrer 1968, Daly et al. 1962, Engel and Magnuson 1976, Qadri 1961, Scott and Crossman 1973). Only Loftus (1958) noticed river spawning lake trout staying in relatively shallow water throughout the year.

The brook trout (Salvelinus fontinalis), generally a stream fish, usually lives in its preferred spawning habitat and therefore makes only limited movements. Some movement out of streams into larger rivers and lakes may occur during the summer when temperatures increase (Scott and Crossman 1973). Manion (1977) noted high numbers of brook trout moving downstream when flows increased in the spring and fall. No reason was given for the observed movements.

5.2. Osmeridae

Rainbow smelt (Osmerus mordax) adults are pelagic fish which vary their diel, and seasonal vertical distribution in relation to light and temperature (Scott and Crossman 1973). This species ascends streams at night during the spring to spawn.

5.3. Umbridae

Little information is available on the movements of the central mudminnow (Umbra limi). Scott and Crossman (1973) noted possible upstream and lateral spawning migrations from their preferred habitat in the center of rivers and streams. Other movements are thought to be limited.

5.4. Esocidae

Scott and Crossman (1973) call the northern pike (Esox lucius) a fairly sedentary fish developing vague territories in the top 15 feet of lake and river waters. They observed slight movement to deeper, cooler water in the heat of summer. The northern pike has been reported to migrate long distances for spring spawning. Threinen et al. (1966) noted a nocturnal spawning migration toward flooded marshes and stream banks. After hatching, young pike move off spawning grounds only when light intensity is high, usually during midday when the sky is clear (Franklin and Smith 1963).

5.5. Cyprinidae

Little information is available on the movements of minnows. Some evidence of spawning migrations does exist (Scott and Crossman 1973) but is not well documented. The seventeen species of cyprinids collected are thought to limit their movements to the small lakes and streams in which they live.

5.6. Catastomidae

Funk (1957) lists the redhorses as semimobile and found more downstream than upstream movements. Nocturnal upstream spawning runs were observed for both the shorthead redhorse (*Moxostoma macrolepidotum*) and the white sucker (*Catostomus commersoni*) Green et al. (1966), Schneberger (1972b), and Scott and Crossman (1973). Newly hatched white sucker fry move downstream at night in huge numbers (Clifford 1972). Most authors agree that white suckers move in response to light and temperature more than any other stimulus.

5.7. Ictaluridae

Little published information is available on the movements of black (*Ictalurus melas*), yellow (*Ictalurus natalis*), and brown bullheads (*Ictalurus nebulosis*). Considering that their life histories are similar and that Funk (1957) lists the yellow bullhead as very sedentary, it is expected that they move little outside their preferred habitat.

Funk (1957) and Scott and Crossman (1973) note movements of the channel catfish (*Ictalurus punctatus*) but disagree on their extent. Funk (1957) lists the catfish as mobile while Scott and Crossman (1973) found it to be largely sedentary.

Scott and Crossman (1973) was the only available publication on the tadpole madtom (*Noturus gyrinus*). They observed nightly feeding movements, and inactivity under some sort of protection during the day.

5.8. Gadidae

Burbot (Lota lota) are winter spawners and can be found migrating to their spawning grounds under the ice. After spawning they return to their specific habitats and move little until the next spawning season (Scott and Crossman 1973). Some movements out of small streams toward deeper water, during the summer months, were also noted by Scott and Crossman (1973), but by July all movements had stopped.

5.9. Gasterosteidae

Observations of brook stickleback (Culaea inconstans) movements are limited to stream spawning migrations. Winn (1960) found the stickleback migrating into shallow streams in spring followed by a gradual downstream movement through the summer. Lamsa (1963) and Manion (1977) noted large downstream movements in early summer.

5.10. Percopsidae

According to Scott and Crossman (1973), trout perch (Percopsis omiscomaycus) have lake to stream spawning migrations. Sensitivity to light keeps the trout perch in deeper water through the day with movement to the shallows for night feeding.

5.11. Centrarchidae

There have been several studies on movements of the sunfish family. Most studies have reported the same results. Gerking (1950, 1953), Funk (1957), and Brown (1961) all found rock bass (Ambloplites rupestris) to have definite home ranges and remain in or near them year round.

Snow et al. (1960) noted that the bluegill (Lepomis macrochirus) had a home range in shallow, warm water but exhibited some movement toward deeper, cooler water on hot, sunny days. Bluegills also aggregate together, but remain active in deeper water during the winter months (Scott and Crossman 1973). There is little available data for the pumpkinseed (Lepomis gibbosus), but its life habits are very similar to many of the other sunfishes, especially the bluegill.

Most reviews of centrarchid movements have included information on the smallmouth bass (Micropterus dolomeui). The smallmouth shows a high degree of stability in a particular habitat (Gerking 1953, Funk 1957, Brown 1961). This indicates a definite home range with only a small amount of movement. Schneberger (1972a) and Scott and Crossman (1973) observed a voluntary movement toward areas with preferred temperatures while Fajen (1962) simply found straying and homing over short periods of time. Fajen (1962) also studied the effects of sedimentation on movement of smallmouth. He noted that the bass will abandon any home area when the habitat becomes unsuitable because of sedimentation of chert gravel.

Kramer and Smith (1960), Mraz et al. (1961), and Heidinger (1975) studied the seasonal and diel movements of largemouth bass (Micropterus salmoides) and noted that temperature was the main reason for relocation. The largemouth moved toward deeper water during summer days and throughout the winter months. Funk (1957) listed this species as semimobile.

There is little information available on the movements of the black crappie (Pomoxis nigromaculatus) although it is thought to exhibit similar habits to the rest of the sunfish family (Scott and Crossman 1973).

5.12. Percidae

Herman et al. (1959) and Scott and Crossman (1973) noted yellow perch (Perca flavescens) to be active in open water during the day, and inactive resting on the bottom at night. Scott and Crossman (1973) suggest that most other perch movements are in response to temperature, food availability or spawning migration.

Yellow perch and walleye (Stizostedion vitreum) have both been observed moving either shoreward or into streams during spring spawning migrations (Rawson 1956, Olson and Scidmore 1962, Priegel 1970, Scott and Crossman 1973) but only the walleye has been described as homing to specific spawning grounds (Crowe 1962, Forney 1963, and Priegel 1970).

Seasonal movements of the walleye were seen by Rawson (1956) and include: nocturnal feeding habits; staying in cooler; deeper water throughout the summer; and activity in shallow bays during the winter. Forney (1963) noted that walleyes have specific areas in which they remain throughout the year.

Winn (1958) made observations on the log perch (Percina caprodes), Johnny darter (Etheostoma nigrum) and Iowa darter (Etheostoma exile). Their movements included spawning migrations in the spring and early summer from the lake body to the shoreline or occasionally up small streams.

5.13. Cottidae

Limited information has been published concerning movements of slimy sculpins (Cottus cognatus) and mottled sculpins (Cottus bairdi). They apparently migrate to lake shallows or streams for spawning (Scott and Crossman 1973). Manion (1977) observed downstream movements of the mottled sculpin peaking during spring floods but the significance of this move was not determined.

Table 1. Spawning habits of fishes collected in the Regional Cu-Ni Study Area

Species	Spawning Time & Temperature	Spawning Habits	References[1]	Comments
Brook trout *Salvelinus fontinalis*	Oct. to Nov. Day	Form redd in shallow gravel headwater streams or spring upwelling in lakes and streams.	Brasch et al. (1958) Webster and Eiriksdottir (1976)	Cover eggs after spawning
Lake trout *Salvelinus namaycush*	Oct. to Nov. 48° to 57° F Night	Usually in lakes over large boulders or rubble with a current. Egg scatterer.	Daly et al. (1962)	Cleaning of some spawning substrate observed
Lake herring *Coregonus artedii*	Nov. to Dec. 37° to 41° F	In 3-10 feet of water over almost all substrates, usually gravel. Egg scatterer.		Spawns one week after lake whitefish when ice is forming
Lake whitefish *Coregonus clupeaformis*	Nov. to Dec. < 46° F	In water 25 feet deep over hard or stony bottom, sometimes sand. Egg scatterer.		Sometimes spawn in deeper waters
Rainbow smelt *Osmerus mordax*	Mar. to May 46° F Night	Most commonly in streams of high current velocity. Scatter adhesive eggs over gravel bottom.		Easily caught by fishermen during spawning runs
Central mudminnow *Umbra limi*	Mar. to April 55° to 60° F	On lake shoreline or headwaters of streams and rivers. Adhesive eggs are laid singly on vegetation.		Eggs are abandoned after spawning

[1]Information from Scott and Crossman (1973) unless otherwise noted.

Table 1. Spawning habits of fishes collected in the Regional Cu-Ni Study Area contd.

Species	Spawning Time & Temperature	Spawning Habits	References	Comments
Northern pike *Esox lucius*	April to early May 40° to 52° F Day	Adhesive eggs are scattered among heavy vegetation of river flood plains and marshy lake shores.	Franklin & Smith (1963) Threinen et al. (1966)	Spawn early in spring after ice breakup
Northern redbelly dace *Chrosomus eos*	Spring to early summer	Nonadhesive eggs are deposited in masses of flamentous algae.		limited data available
Finescale dace *Chrosomus neogaeus*	Spring			limited data available
Lake chub *Couesius plumbeus*	April to May	Migrates up tributary streams; spawns among large rocks in shallows.		At the same time or just previous to smelt spawning runs
Brassy minnow *Hybognathus hankinsoni*	Probably May or June	Could resemble related species; eggs deposited over silt in quiet water.		Limited data available
Golden shiner *Notemigonus crysoleucas*	June to August 68° F	Adhesive eggs are scattered over aquatic vegetation in quiet water.	Bovee (1975)	Spawning occurs in still water
Pugnose shiner *Notropis anogenus*	Probably spring			Limited data available
Emerald shiner *Notropis atherinoides*	Late spring to early summer 75° F	Probably spawn in mid water of lake shore areas.		Prolonged spawning period indicated

Table 1. Spawning habits of fishes collected in the Regional Cu-Ni Study Area
contd.

Species	Spawning Time & Temperature	Spawning Habits	References	Comments
Common shiner *Notropis cornutus*	May to June 60° to 65° F	Shallow nests in gravel or sand of riffles.	Moyle (1973)	Exclusively a stream spawner
Blackchin shiner *Notropis heterodon*	May to June			No reported observations on spawning habits
Blacknose shiner *Notropis heterolepis*	Spring and summer	Over sandy bottoms; possibly in quiet streams or lake shallows.		No reported observations on spawning habits
Spottail shiner *Notropis hudsonius*	Spring and early summer	Probably in filamentous algae over sandy shoals.		Limited data available
Bluntnose minnow *Pimephales notatus*	Late May to June 68° F	Adhesive eggs are deposited on the underside of a rock, board, or log in shallow water 6 in. to 3 feet.		Male protects nest
Fathead minnow *Pimephales promelas*	June to August 60° to 64° F	Adhesive eggs are deposited on the underside of a log, branch, rock, or board in beaver ponds or small lakes.	Bovee (1975)	The male guards the nest
Blacknose dace *Rhinichthys atratulus*	May to June 70° F	Spawning occurs over gravel bottoms in fast shallows of riffles up to one foot deep. Eggs are deposited randomly.		There are differences in spawning between races of blacknose dace

Table 1. Spawning habits of fishes collected in the Regional Cu-Ni Study Area contd.

Species	Spawning Time & Temperature	Spawning Habits	References	Comments
Longnose dace *Rhinichthys cataractae*	May to early July 53° F	Gravel bottomed riffles are probably chosen for spawning. Adhesive eggs are laid randomly.	Bovee (1975)	No nest built
Creek chub *Semotilus atromaculatus*	May to June 55° F	Eggs are buried under the gravel at sites chosen in small streams above or below a riffle.	Bovee (1975)	
Pearl dace *Semotilus margarita*	Spring 63° to 65° F	Clear water less than 2 feet deep with weak or moderate current, usually on sand or gravel.		Small territories with no nests
White sucker *Catastomus commersoni*	Early May to early June 45° to 50° F Dusk and Dawn	Usually scatters adhesive egg on gravelly stream bottoms; occasionally spawns on lake margins in shallow water.	Bovee (1975) Schneberger (1972b)	
Shorthead redhorse *Moxostoma macrolepidotum*	May 52° F Night or early morning	Migrates to streams and small rivers and spawns in shallow (3 ft) gravel bottom riffles. Eggs are adhesive.	Meyer (1962)	Eggs are abandoned after spawning
Black bullhead *Ictalurus melas*	May to June 69° F	Nest is built in areas of vegetation and adhere to the gravel, sand, or silt substrate.	Bovee (1975) Dennison & Bulkley (1972)	Eggs and young are guarded

Table 1. Spawning habits of fishes collected in the Regional Cu-Ni Study Area contd.

Species	Spawning Time & Temperature	Spawning Habits	References	Comments
Yellow bullhead *Ictalurus natalis*	Late May to early June 75°	A nest is built under a stream bank or near some object that offers protection.	Bovee (1975)	Sometimes a deep burrow is dug instead of a shallow nest
Brown bullhead *Ictalurus nebulosis*	May to June 70° F Day	A shallow depression is made in mud, sand, or roots of aquatic vegetation, usually near some sort of protection. Water depth is from inches to several feet along lake or pond shores.		Occassionally nest in hollow stumps or even in automobile tires attached to docks
Channel catfish *Ictalurus punctatus*	Late spring to summer 75° to 85° F	Spawning occurs in semidark nests in holes, undercut banks, log jams, or rocks.	Bovee (1975)	Spawning habits similar to the brown bullheads
Tadpole madtom *Noturus gyrinus*	Late June to July	Usually spawns in rivers, occassionally on shallow lake shores. Adhesive eggs are deposited in nests built in dark cavities.		Similar to the Ictalurids
Burlot *Lota lota*	Jan. to March 33° to 35° F Night	Usually spawn in less than 10 feet of water over sand or gravel bottoms of lakes under the ice.	Bailey (1972)	Sometimes spawns in streams or rivers
Brook stickleback *Culaea inconstans*	Late April to July 46° to 66° F	Males build nests from grass and algae near the bottom in shallow water of pools, ponds, or small lakes.	Winn (1960)	Males are very territorial
Trout perch *Percopsis omiscomaycus*	May 50° F	Spawn over sand, gravel or rock substrates of shallow streams or lakeshores.		Temp. listed is average air temp.

Table 1. contd. Spawning habits of fishes collected in the Regional Cu-Ni Study Area

Species	Spawning Time & Temperature	Spawning Habits	References	Comments
Rock bass *Ambloplites rupestris*	Late spring to early summer 60° to 70° F	A shallow nest is dug in a diverse range of substrate types. Eggs are adhesive.		Male guards eggs
Pumpkinseed *Lepomis gibbosus*	Late spring to early summer 68° to 82° F	Site selection for nest is shallow ponds, lakes, or slow moving streams with clay, sand, gravel, or rock bottom types. Eggs are adhesive.		Nests near aquatic vegetation
Bluegill *Lepomis macrochirus*	Late spring to summer 67° to 76° F	The adhesive eggs are deposited in shallow nests with firm bottoms of gravel, sand, or mud.	Snow et al. (1960) Bovee (1975)	The male defends the nest
Smallmouth bass *Micropterus dolomeui*	Late May to early July 61° to 65° F	Sand, gravel, or rock bottoms of lakes and rivers are used for nest building. Water depth is from 2 to 20 ft. Adhesive eggs are laid in nests built near protection of rocks, logs, or rarely vegetation.	Bovee (1975) Schneberger (1972a)	Spawn shortly after largemouth bass
Largemouth bass *Micropterus salmoides*	Late spring to mid-summer 62° to 65° F	Nests are most commonly built on marl, soft mud, sand, or gravel around aquatic vegetation roots in 1 to 4 feet of water. Eggs are adhesive.	Allan & Romero (1975) Kramer & Smith (1960) Mraz et al. (1961)	Nests mostly in association with vegetation.

Table 1. Spawning habits of fishes collected in the Regional Cu-Ni Study Area contd.

Species	Spawning Time & Temperature	Spawning Habits	References	Comments
Black crappie *Pomoxis nigromaculatus*	Late May to mid-July 66° to 68° F	Nest builder in water 10 inches to 2 feet on sand, gravel, or mud substrates.	Bovee (1975)	Nest usually near some protection
Yellow perch *Perca flavescens*	Mid-April to early May 44° to 54° F Night and early morning	Spawning takes place along shallows of lakes and streams, near rooted vegetation or fallen trees usually over sand or gravel. No nest is built.	Bovee (1975) Herman et al. (1959)	Eggs are in long gelatinous ribbons, attached to the substrate at one end and usually moving with water currents.
Walleye *Stizostedion vitreum*	April to early May 45° to 50° F Night	Eggs are scattered over spawning sites chosen in rocky areas of streams or lake shoals. Spawning has been observed over matted vegetation of river flood plains. Walleye usually migrate upstream to spawn in water generally 2 to 4 feet deep.	Bovee (1975) Niemuth et al. (1959) Priegel (1970) Rawson (1956)	Spawning may occur right after ice breakup
Iowa darter *Etheostoma exile*	April to May	Spawns in lake shallows or river pools on bottom organic debris or on fibrous roots.	Winn (1958)	Seldom spawn on sand
Johnny darter *Etheostoma nigrum*	May	Adhesive eggs are laid in nesting sites on undersides of rocks in streams and shallows of lakes.	Winn (1958)	

Table 1. Spawning habits of fishes collected **in the Regional Cu-Ni Study Area**
contd.

Species	Spawning Time & Temperature	Spawning Habits	References	Comments
Log perch *Percina caprodes*	June	Eggs are deposited on sandy inshore shallows of lakes and streams in a few inches to severäl feet of water.	Winn (1958)	After deposition the eggs are abandoned
Mottled sculpin *Cottus bairdi*	May to June 50° F	Adhesive eggs are laid in a nest under a ledge or rock in streams or lakes.		Spawning is much like slimy sculpin
Slimy sculpin *Cottus cognatus*	Late April to May 41° to 50° F	Spawning takes place in streams or lakes in a nest under a rock or ledge. Eggs are adhesive.	Petrosky & Waters (1975)	Few studies have been published

Table 2. Spawning habits classification[1] summary of fishes in the Regional Copper-Nickel Study Area

NONGUARDING EGG SCATTERERS		NONGUARDING EGGHIDERS	GUARDING NEST BUILDERS	
Over Gravel Substrates	Over Vegetation	In Gravel Substrates	In Holes or Burrows	On or Near Bottom Substrates
Burbot	Northern pike	Brook trout	Bluntnose minnow	Common shiner
Lake whitefish	Central mudminnow	Lake trout	Fathead minnow	Smallmouth bass
Lake herring	Northern redbelly dace	Creek chub	Black bullhead	Largemouth bass
Rainbow smelt	Golden shiner	Pearl dace	Brown bullhead	Pumpkinseed
Blacknose dace	Blacknose shiner		Yellow bullhead	Bluegill
Longnose dace	Spottail shiner		Channel catfish	Black crappie
Lake chub	Brassy minnow		Tadpole madtom	Rock bass
Trout-perch	Iowa darter		Johnny darter	Brook stickleback
White sucker	Log perch		Mottled sculpin	
Shorthead redhorse			Slimy sculpin	
Yellow perch				
Walleye				

[1]Classification based on Balon (1973).

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area

Species	Foods of Young	Foods of Adult	References[1]	Comments
Brook trout *Salvelinus fontinalis*	Dipteran larvae *Chironomus* *Simulium* Ephemeroptera nymphs *Baetis*	Variety of aquatic organisms: insect larvae to fish, even small mammals.	Brasch et al. (1958) Dineen (1951) Leonard (1942) Miller (1974)	Opportunist, will eat most types of food
Lake trout *Salvelinus namaycush*	Zooplankton Mysidacea Some fish, midge larvae and *Chaoborus*.	Mainly fish, ciscoes most important.	Daly et al. (1962) Dryer et al. (1965)	Organisms eaten depend on availability
Lake herring *Coregonus artedii*	Plankton, algae, copepods, cladocerans.	Primarily plankton, aquatic insects & larvae. Some fish & fish eggs.	Siefert (1972)	A common forage fish, pelagic
Lake whitefish *Coregonus clupeaformis*	Copepods, *Diaptomus* Cladocerans, *Bosmina*	Aquatic insect larvae molluscs, amphipods and small fish.	Forbes (1883) Qadri (1961)	Bottom feeder
Rainbow smelt *Osmerus mordax*	*Cyclops*, copepod nauplii, diatoms and green algae	Amphipods, ostracods, aquatic insect larvae.	Siefert (1972)	Carnivorous

[1]Information from Scott and Crossman (1973) unless otherwise noted.

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area contd.

Species	Foods of Young	Foods of Adult	References	Comments
Central mudminnow *Umbra limi*	Ostracods, newly hatched snails.	Aquatic insects and larvae, molluscs, amphipods, isopods, and arachnids.		Carnivorous seldom feed on fishes
Northern pike *Esox lucius*	Zooplankton, *Daphnia* *Cyclops* *Ceriodaphnia* aquatic insects.	Primarily fish; some frogs and crayfish. Prefer *Etheostoma*, perch, minnows and suckers.	Beyerle & Williams (1968) Franklin & Smith (1963) Threinen et al. (1966)	Opportunist, will eat anything cannabalistic
Northern redbelly dace *Chrosomus eos*		Diatoms, filamentous algae, zooplankton, aquatic insects.		Important in food chain
Finescale dace *Chrosomus neogaeus*		Mainly insects. Crustaceans and plankton also important.		Little available data
Lake chub *Couesius plumbeus*		Chironomid larvae and other aquatic insect larvae, some cladocerans and algae.		Little available data
Brassy minnow *Hybognathus hankinsoni*		Plankton, algae, and small aquatic insects.		Little available data
Golden shiner *Notemigonus crysoleucas*	similar to adult.	Cladocerans, chironomid larvae, and filamentous algae; some aquatic insects and molluscs.		Important forage species

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area
contd.

Species	Foods of Young	Foods of Adult	References	Comments
Pugnose shiner *Notropis anogenus*		Minute organisms and organic detritus.		Very small mouth
Emerald shiner *Notropis atherinoides*	Rotifer, *Trichocera* Bluegreen algae and protozoa.	Mainly microcrustaceans. Algae, pupae of tricopterans and chironomids, and a variety of other miscellaneous food items.	Siefert (1972) Whitaker (1977)	Important forage fish
Common shiner *Notropis cornutus*		Chironomid pupae and larvae, aquatic insects and algae.	Moyle (1973)	Versatile feeder
Blackchin shiner *Notropis heterodon*		Small crustaceans and insects, *Chydorus* and *Bosmina*.		Specialized feeder
Blacknose shiner *Notropis heterolepis*		Cladocerans, insects and green algae.		Food studies are not detailed
Spottail shiner *Notropis hudsonius*	*Bosmina* and *Alona* Some copepod nauplii	Aquatic insect larvae, chironomids and ephemeropterans. Algae, and cladocerans.	Bulkley et al. (1976)	Very important forage fish, flexible food habits
Bluntnose minnow *Pimephales notatus*		Organic detritus. chironomid larvae, algae, and clodocerans.		bottom feeder

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area
contd.

Species	Foods of Young	Foods of Adult	References	Comments
Fathead minnow *Pimephales promelas*		Primarily algae, some detritus, aquatic insects and zooplankton.		Important experiment organism and forage fish
Blacknose dace *Rhinichthys atratulus*		Aquatic insect larvae esp. chironomids, also diatoms and desmids.		Very common forage fish
Longnose dace *Rhinichthys cataractae*		Benthic aquatic insects, primarily chironomids, simulids, and mayflies.		Food items depend on abundance
Creek chub *Semotilus atromaculatus*	Planktonic organisms.	Mainly aquatic insect larvae, pupae and adults, some algae and cladocerans.		Omnivorous
Pearl dace *Semotilus margarita*		Copepods, cladocerans, and chironomids.		In association with acidic headwaters
White sucker *Catastomus commersoni*	Plankton and small invertebrates.	Benthic invertebrates; chironomids, trichopterans.	Dobie (1966) Siefert (1972)	Bottom feeders, important forage species

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area contd.

Species	Foods of Young	Foods of Adult	References	Comments
Shorthead redhorse *Moxostoma macrolepidotum*		A wide variety of benthic food organisms, aquatic invertebrates, molluscs, oligochaeta , crustaceans, and diatoms.	Meyer (1962)	Bottom feeders
Black bullhead *Ictalurus melas*	Zooplankton, immature insects, crustaceans and leeches.	Immature insects and molluscs most important. Some plant material, leeches, and fishes, *Chironomus* pupae *Caenis* nymphs.	Repsys et al. (1976)	Nocturnal bottom feeder
Yellow bullhead *Ictalurus natalis*		Offal crustaceans, imature aquatic insects, molluscs, and some fish.		Nocturnal scavenger
Brown bullhead *Ictalurus nebulosis*	Chironomid larvae, cladocerans, some ostracods amphipods and immature aquatic insects.	Feed on nearly all types of foods, from waste to plant material and from plankton to fish.	Raney & Webster (1940)	Omnivorous bottom feeder
Channnel catfish *Ictalurus punctatus*	Plankton and chironomid larvae most important. Also some cladocerans, copepods, ostracods and aquatic insects.	Wide variety of larger food from aquatic insects and plants to large crustaceans and fish.	Bonneau et al. (1972)	Bottom feeder

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area
contd.

Species	Foods of Young	Foods of Adult	References	Comments
Tadpole madtom *Noturus gyrinus*		Cladocerans, ostracods chironomids, and immature aquatic insects.		Nocturnal bottom feeder, little available data
Burbot *Lota lota*	*Gammarus*, mayfly nymphs, crayfish, aquatic insects, *Mysis relicta*.	Feed almost entirely on fishes although invertebrates are taken seasonally.	Bailey (1972) Dobie (1966)	Nocturnal voracious predators, fish eaten depend on availability
Brook stickleback *Culea inconstans*		Aquatic insect larvae, crustaceans, eggs and larvae of other fishes, sometimes snails, oligochaetes and algae.		Carnivorous
Trout perch *Percopsis omiscomaycus*		Insect larvae, primarily chironomid and ephemeroptera, some small fishes.		Little available data, important forage fish
Rock bass *Ambloplites rupestris*	Mainly chironomids, ephemeropterans, odonates, cladocerans and amphipods.	Aquatic insects, crayfish small fishes, esp. minnows and yellow perch.	Dobie (1966)	Found in aggregation with other centrarchids
Pumpkinseed *Lepomis gibbosus*	Amiphipods, cladocerans and chironomid larvae, some small odonate nymphs.	Mainly a variety of insects, secondarily other invertebrates and vertebrates.	Sadzikowski Wallace (1976)	A lesser forage fish

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area contd.

Species	Foods of Young	Foods of Adult	References	Comments
Bluegill *Lepomis macrochirus*	Chironomid larvae, *Chironomus* *Crictopus* odonate nymphs, some cladocerans, ostracods and copepod nauplii.	Chironomid larvae, cladocerans, some aquatic insects, molluscs, small fishes and plant material.	Laarman & Schneider (1972) Sadzikowski & Wallace (1976) Siefert (1972) Snow et al. (1960)	Eat most types of food organisms, a lesser forage fish
Smallmouth bass *Micropterus dolomieui*	Copepods and cladocerans, some insects.	Mainly crayfish, although fishes and aquatic and terrestrial insects are important also.	Schneberger (1972a)	Food items depend on availability
Largemouth bass *Micropterus salmoides*	Copepods, cladocerans, mayfly nymphs, amphipods and chironomid larvae.	Primarily small fish, also crayfish, frogs, worms, and molluscs.	Allan & Romero (1975) Kramer & Smith (1960) Lewis et al. (1961) Mraz et al. (1961)	Fish species eaten depends on availability, although Golden shiners are preferred
Black Crappie *Pomoxis nigromaculatus*	Planktonic crustacea, *Chaoborus* *Procladius*.	Some aquatic insects, fishes become more important with growth.	Bulkley et al. (1976) Dobie (1966)	Long planktivorous feeding period
Yellow perch *Perca flavescens*	Copepods nauplii, cladocerans *Daphnia* amphipods.	Microcrustacea, chironomids and other aquatic insects, *Hyallela*, and small fish.	Bulkley et al. (1976) Herman et al. (1959) Laarman & Schneider (1972) Ney & Smith (1975) Noble (1975) Siefert (1972)	Very important forage fish

Table 3. Food habits of fishes collected in the Regional Copper-Nickel Study Area
contd.

Species	Foods of Young	Foods of Adult	References	Comments
Walleye Stizostedion vitreum	Copepods, cladocerans Daphnia small fish.	Some larger aquatic insects, mayfly nymphs and chironomid larvae, mainly fishes.	Bulkley et al. (1976) Dobie (1966) Niemuth et al. (1959) Priegel (1970) Rawson (1956) Swenson (in press)	Will take any fish readily available, sometimes cannabalistic
Iowa darter Etheostoma exile	Copepods and cladocerans.	Midge and mayfly larvae, amphipods, snails, and Corixidae.		Inhabit still, clear water with vegetation
Johnny darter Etheostoma nigrum	Copepods, midge larvae and cladocerans.	Midge and mayfly larvae most important.		Important fish in food chain
Log perch Percina caprodes	Cladocerans and copepods.	Midge larvae, amphipods, isopods; dragonfly and mayfly immatures.		Possibly an important forage fish
Mottled sculpins Cottus bairdi	Chironomid larvae and mayfly nymphs.	Mayfly and stonefly immatures, caddisfly larvae, fish and fish eggs annelids and chironomids.	Dineen (1951)	Associated with brook trout
Slimy sculpin Cottus cognatus	Chironomid larvae.	Primarily aquatic insect immatures, some crustaceans, small fishes and plant material also.	Petrosky and Waters (1975)	Greatly varied habitat requirements

Table 4. Classification of fish species collected in the Regional Copper-Nickel Study Area according to their primary food source as adults.

FISH	FISH AND AQUATIC INSECTS	AQUATIC INSECTS	ZOOPLANKTON	ALGAE	OPPORTUNISTS
Lake trout	Brook trout	Rainbow smelt	Pugnose shiner	Northern redbelly dace	Golden shiner
Northern pike	Lake herring	Central mudminnow	Blackchin shiner	Brassy minnow	Emerald shiner
Burbot	Lake whitefish	Finescale dace	Pearl dace	Fathead minnow	Shorthead redhorse
Largemouth bass	Trout-perch	Blacknose dace			Blacknose shiner
Walleye	Rock bass	Longnose dace			Bluntnose minnow
	Smallmouth bass	Creek chub			Brook stickleback
	Black crappie	Lake chub			Bluegill
	Yellow perch	Common shiner			Black bullhead
	Mottled sculpin	Spottail shiner			Yellow bullhead
	Slimy sculpin	Pumpkinseed			Brown bullhead
		White sucker			Channel catfish
		Tadpole madtom			
		Iowa darter			
		Johnny darter			
		Logperch			

Table 5. Summary of the movements of fishes from the Regional Copper-Nickel Study Area.

SEDENTARY	SEMIMOBILE	MOBILE
Brook trout	Lake chub	Lake trout
Central mudminnow	Emerald shiner	Rainbow smelt
Northern pike	Golden shiner	Lake whitefish
Most cyprinids	White sucker	Lake herring
Yellow bullhead	Shorthead redhorse	
Brown bullhead	Channel catfish	
Black bullhead	Trout-perch	
Tadpole madtom	Yellow perch	
Burbot	Walleye	
Brook stickleback		
Smallmouth bass		
Bluegill		
Pumpkinseed		
Rock bass		
Largemouth bass		
Black crappie		
Johnny darter		
Iowa darter		
Log perch		
Mottled sculpin		
Slimy sculpin		

Table 6. Family, scientific, and common names of all fishes collected in the Regional Copper-Nickel Study Area

FAMILY NAME	SCIENTIFIC NAME	COMMON NAME
Salmonidae	Salvelinus fontinalis	Brook trout
	Salvelinus namaycush	Lake trout
	Coregonus clupeaformis	Lake whitefish
	Coregonus artedi	Cisco, Tullibee
Osmeridae	Osmerus mordax	Rainbow smelt
Umbridae	Umbra limi	Central mudminnow
Esocidae	Esox lucius	Northern pike
Cyprinidae	Rhinichthys atratulus	Blacknose dace
	Rhinichthys cataractae	Longnose dace
	Couestius plumbeus	Lake chub
	Semotilus atromaculatus	Creek chub
	Semotilus margarita	Pearl dace
	Chrosomus eos	Northern redbelly dace
	Chrosomus neogaeus	Finescale dace
	Notemigonus crysoleucas	Golden shiner
	Pimephales notatus	Bluntnose minnow
	Pimephales promelas	Fathead minnow
	Notropis anogenus	Pugnose shiner
	Notropis atherinoides	Emerald shiner
	Notropis cornutus	Common shiner
	Notropis hudsonius	Spottail shiner
	Notropis heterolepis	Blacknose shiner
	Notropis volucellus	Mimic shiner
	Notropis heterodon	Blackchin shiner
	Hybognathus hankinsoni	Brassy minnow
Catostomidae	Moxostoma macrolepidotum	Northern redhorse
	Catostomus commersoni	White sucker

Table 6. contd. Family, scientific, and common names of all fishes collected in the Regional Copper-Nickel Study Area

FAMILY NAME	SCIENTIFIC NAME	COMMON NAME
Ictaluridae	Ictalurus punctatus	Channel catfish
	Ictalurus nebulosus	Brown bullhead
	Ictalurus melas	Black bullhead
	Ictalurus natalis	Yellow bullhead
	Noturus gyrinus	Tadpole madtom
Percopsidae	Percopsis omiscomaycus	Trout-perch
Gadidae	Lota lota	Burbot
Gasterosteidae	Culaea inconstans	Brook stickleback
Centrarchidae	Micropterus salmoides	Largemouth bass
	Micropterus dolomieui	Smallmouth bass
	Ambloplites rupestris	Rock bass
	Lepomis macrochirus	Bluegill
	Lepomis gibbosus	Pumpkinseed
	Pomoxis nigromaculatus	Black crappie
Percidae	Perca flavascens	Yellow perch
	Stizostedion v. vitreum	Walleye
	Percina caprodes	Log perch
	Etheostoma nigrum	Johnny darter
	Etheostoma exile	Iowa darter
Cottidae	Cottus bairdi	Mottled sculpin
	Cottus cognatus	Slimy sculpin

Table 7. Summary of life history information of fishes collected in the Regional Copper-Nickel Study Area

NEH:	Nonguarding egg hider
NES-G:	Nonguarding egg scatterer-over gravel
NES-V:	Nonguarding egg scatterer-over vegetation
GNB-B:	Guarding nest builder-on or near bottom substrates
GNB-H:	Guarding nest builder-in holes or burrows
F.-Aq.in.:	Fish and aquatic insects
Sed.:	sedentary

Table 7. Summary of life history information of fishes collected in the Regional Copper-Nickel Study Area.

Species	Spawning Time Sp	S	F	W	Spawning Substrate	Spawning Current Velocity cm/sec	Spawning Temp °F.	Spawning Type	Food Habit Type	Movement Type
Brook trout			—		gravel	15-91	38° - 45°	NEH	F - Aq. in.	sed.
Lake trout			—		boulder, rubble	weak to moderate	48° - 57°	NEH	Fish	mobile
Lake herring			—	—	gravel, most others	still to moderate	37° - 41°	NES-G	F. - Ag.in.	mobile
Lake white fish			—	—	gravel, rubble, sand	still to moderate	<46°	NES-G	F. - Ag.in.	mobile
Rainbow smelt	—				gravel	fast	46°	NES-G	Aquatic insects	mobile
Central mudminnow	—				vegetation	weak	55° - 60°	NES-V	Aquatic insects	sed.
Northern pike	—				vegetation	still	40° - 52°	NES-V	Fish	sed.
Northern redbelly dace	—	—			filamentous algae	still		NES-V	Algae	sed.
Lake chub	—				rubble, boulders	weak to moderate		NES-G	Aquatic insects	semimobile
Brassy minnow	—	—			silt	still		NES-V	Algae	sed.
Golden shiner		—			vegetation	still	68°	NES-V	Opportunist	semimobile
Pugnose shiner	—								Zooplankton	sed.
Emerald shiner	—	—			midwater				Opportunist	semimobile

Table 7. Summary of life history information of fishes collected in the Regional Copper-Nickel Study Area. contd.

Species	Spawning Time Sp	S	F	W	Spawning Substrate	Spawning Current Velocity cm/sec	Spawning Temp. °F	Spawning Type	Food Habit Type	Movement Type
Common shiner	—	—			gravel, sand	moderate	60° - 65°	GNB-B	Aquatic insects	sed.
Blackchin shiner	—	—				still			Zooplankon	sed.
Blacknose shiner	—	—			sand	still		NES-v	Opportunist	sed.
Spottail shiner	—	—			filamentous algae	still to weak		NES-V	Aquatic insects	sed.
Finescale dace	—								Aquatic insects	sed.
Bluntnose minnow	—	—			underside of rock or other object	still	68°	GNB-H	Opportunist	sed.
Fathead minnow		—			underside of rock or other object	still	60° - 64°	GNB-H	Algae	sed.
Blacknose dace	—	—			gravel	fast	70°	NES-G	Aquatic insects	sed.
Longnose dace	—	—			gravel	15-45	53°	NES-G	Aquatic insects	sed.
Creek chub	—	—			gravel	49 - 91	55°	NEH	Aquatic insects	sed.
Pearl dace	—				gravel, sand	weak to moderate	63° - 65°	NEH	Zooplankton	sed.

Table 7. Summary of life history information of fishes collected in the Regional Copper-Nickel Study Area. contd.

Species	Spawning Time Sp	S	F	W	Spawning Substrate	Spawning Current Velocity cm/sec	Spawning Temp °F	Spawning Type	Food Habit Type	Movement Type
White sucker	—	—			gravel	31 - 45	45°-50°	NES-G	Aquatic insects	semimobile
Shorthead redhorse	—				gravel	31 - 61	52°	NES-G	Opportunist	semimobile
Black bullhead	—	—			gravel, sand silt	still	69°	GNB-H	Opportunist	sed.
Yellow bullhead	—	—				still	75°	GNB-H	Opportunist	sed.
Brown Bullhead	—	—			mud, sand vegetation	still	70°	GNB-H	Opportunist	sed.
Channel catfish	—	—			mud, sand vegetation	still	75° 85^5	GNB-H	Opportunist	semimobile
Tadpole madtom		—				still		GNB-H	Aquatic insects	sed.
Burbot	—			—	gravel, sand	still to moderate	33° - 35°	NES-G	Fish	sed.
Brook stickleback	—	—			vegetation	still	46° - 66°	GNB-B	Opportunist	sed.
Trout perch	—				gravel, sand rubble	moderate		NES-G	F.-Aq.in.	semimobile
Rock bass	—	—			variety of types	still-weak	60° - 70°	GNB-B	F.-Aq.in.	sed.

Table 7. Summary of life history information of fishes collected in the Regional Copper-Nickel Study Area.
contd.

Species	Spawning Time Sp.	S	F	W	Spawning Substrate	Spawning Current Velocity cm/sec	Spawning Temp °F	Spawning Type	Food Habit Type	Movement Type
Pumpkinseed	—	—			clay, sand, gravel, rubble	weak	68° - 82°	GNB-B	Aquatic insects	sed.
Bluegill	—	—			gravel, sand mud	still	67° - 76°	GNB-B	Opportunist	sed.
Smallmouth bass	—	—			gravel, sand rubble	11	61° -65°	GNB-B	F.-Aq.in.	sed.
Largemouth bass	—	—			gravel, sand, mud, marl, near vegetation	still	62° - 65°	GNB-B	Fish	sed.
Black crappie	—	—			gravel, sand, mud	still	66° - 68°	GNB-B	F.-Aq.in.	sed.
Yellow perch	—				gravel, sand near vegetation	still	44° - 54°	NES-G	F.-Aq.in.	semimobile
Walleye	—				gravel, rubble, sand vegetation	0-50	45° - 50°	NES-G	Fish	semimobile
Iowa darter	—				organic debris, fibrous roots	still		NES-V	Aquatic insects	sed.
Johnny darter	—				undersides of rocks	still to moderate		GNB-H	Aquatic insects	sed.
Log perch		—			sand	still to moderate		NES-V	Aquatic insects	sed.
Mottled sculpin	—	—			undersides of rocks	weak	50°	GNB-H	F.-Aq.in.	sed.
Slimy sculpin	—				undersides of rocks	weak	41° - 50°	GNB-H	F.-Aq.in.	sed.

LITERATURE CITED

Allan R.C. and Romero J. 1975. Underwater observations of largemouth bass spawning and survival in Lake Mead in H. Clepper ed. Black Bass Biology and Management. Sport Fish. Inst. Washington D.C.

Bailey M.M. 1972. Age, growth, reproduction, and food of the burbot Lota lota in southwestern Lake Superior. Trans. Am. Fish. Soc. 101(4):667-674.

Bailey R.G. 1966. Observations on the nature and importance of organic drift in a Devon river. Hydrobiologia, 27:353-367.

Balon E.K. 1973. Ecological guilds of fishes: a short summary of the concept and its application. Verh. Internat. Verein. Limnol. 19:2430-2439.

Berner, L.M. 1951. Limnology of the lower Missouri River. Ecology, 32:1-12.

Beyerle G.B. and J.E. Williams. 1968. Some observations of food selectivity by northern pike in aquaria. Trans. Am. Fish. Soc. 97(1):28-31.

Bishop J.E. and H.B. Hynes. 1970. Downstream drift of the invertebrate fauna of a stream ecosystem. Arch. Hydrobiol. 66:56-90.

Bonneau D.L., J.W. McGuire, O.W. Tiemeier, and C.W. Deyoe. 1972. Food habits and growth of channel catfish fry, Ictalurus punctatus, Trans. Am. Fish. Soc. 101(4):613-619.

Bovee K.D. 1975. The determination, assessment, and design of "in stream value" studies for the northern great plains region. Univ. of Montana, Missola. Northern Great Plains Resources Program, Denver, Colorado.

Brasch J., J. McFadden, and S. Kimiotek. 1958. The eastern brook trout, its life history, ecology, and management. Wis. Cons. Dep. Publ. No. 226.

Brocksen R.W., G.E. Davis, and C.E. Warren. 1968. Competition, food consumption, and production of sulpins and trout in laboratory stream communities. J. Wildl. Manage. 32:51-75.

Brown E.H., Jr. 1961. Movement of native and hatchery reared gamefish in a warm-water stream. Trans. Am. Fish. Soc. 90(4):449-456.

Bulkley R.V., V.L. Spykermann, and L.E. Inmon. 1976. Food of pelagic young of walleyes and five cohabiting fish spp. in Clearlake, Iowa. Trans. Am. Fish. Soc. 105(1):77-83.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. American Naturalist 100:345-357.

REFERENCES CITED (contd.)

Clifford H.F. 1972. Downstream movements of whitesucker, Catostomus commersoni in a brown-water stream of Alberta. J. Fish. Res. Board of Can. 29(7):1091-1093.

Crowe W.R. 1962. Homing behavior of walleyes. Trans. Am. Fish. Soc. 91(4):350-354.

Daly R., V.A. Hacker, and L. Wiegert. 1962. The lake trout, its life history, ecology, and management. Wis. Cons. Dep. Publ. No. 233.

Dendy J.S. 1944. The fate of animals in stream drift when carried into lakes. Ecol. Monogr. 14:333-357.

Dennison S.G. and R.V. Bulkley. 1972. Reproductive potential of the black bullhead, Ictalurus melas, in Clear Lake, Iowa. Trans. Am. Fish. Soc. 101(3):483-487.

Dineen C.F. 1951. A comparative study of the food habits of Cottus bairdi and associated species of Salmonidae. Am. Midl. Nat. 46(3): 640-645.

Dobie J. 1966. Food and feeding habits of the walleye, Stizostedion vitreum, and associated game and forage fish in Lake Vermillion, Minnesota, with special reference to the tullibee, Coregonus (Leucichtys) artedii p. 39-71. in C. Burrows ed. Minnesota Fisheries Investigations. Minn. Dept. Cons. Div. Game and Fish, No. 4.

Dryer W.R., L.F. Erkkila, and C.L. Tetzloff. 1965. Food of the lake trout in Lake Superior. Trans. Am. Fish. Soc. 94(2):169-176.

Elliot J.M. 1967. The food of trout (Salmo trutta) in a Dartmoor stream. J. Appl. Ecol. 4:59-71.

Elliot J.M. 1973. The food of brown and rainbow trout in relation to the abundance of drifting invertebrates in a mountain stream. Oecologia (Berl.) 12:329-347.

Engel S. and J.J. Magnuson. 1976. Vertical and horizontal distribution of coho salmon (Oncorhynchus kisutch), yellow perch (Perca flavescens), and cisco (Coregonus artedii) in Pollette Lake, Wisc. J. Fish. Res. Board Can. 33:2710-2715.

Fajen O.F. 1962. The influence of stream stability on homing behavior of two smallmouth bass populations. Trans. Am. Fish. Soc. 91(4):346-349.

Forbes S.A. 1883. The first food of the common whitefish. Ill. Nat. Hist. Surv. Bull. 1(6):95-109.

Forney J.L. 1963. Distribution and movement of marked walleyes in Oneida Lake, New York. Trans. Am. Fish. Soc. 92(1):47-52.

REFERENCES CITED (contd.)

Franklin D.R. and L.L. Smith, Jr. 1963. Early life history of the northern pike, Esox lucius, with special reference to the factors influencing the numerical strength of year classes. Trans. Am. Fish. Soc. 92(2): 91-110.

Funk J.L. 1957. Movement of stream fishes in Missouri. Trans. Am. Fish. Soc. 85:39-57.

Gard R. 1961. Effects of beaver on trout in Sagehen Creek, California. J. Wildl. Manage. 25(4):384-390.

Gerking S.D. 1950. Stability of a stream fish population. J. Wildl. Manage. 14:193-202.

Gerking S.D. 1953. Evidence for the concepts of home range and territory in stream fishes. Ecology 34:347-365.

Green G.H., T.G. Nortcote, G.F. Hartman, and C.C. Lindsey. 1966. Life histories of two species of catostomid fishes in 16 mile lake, British Columbia, with particular reference to inlet stream spawning. J. Fish Res. Board Can. 23(11):1761-1788.

Griffith J.S. 1974. Utilization of invertebrate drift by brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in Idaho. Trans. Am. Fish. Soc. 3:440-447.

Heidinger R.C. 1975. Life history and biology of the largemouth bass. in H. Clepper ed. Black Bass Biology and Management. Sport Fishing Institute. Washington, D.C. 1975.

Herman E.W., W. Wisby, L. Wiegert, and M. Burdick. 1959. The yellow perch, its life history, ecology, and management. Wis. Cons. Dep. Publ. No. 228.

Hooper D.R. 1973. Evaluation of the effects of flows on trout stream ecology. Pacific Gas and Electric Co. Dept. of Engineering Research. Emeryville, California.

Hunt R.L. 1965. Surface-drift insects as a trout food in the Brule River. Trans. Wis. Acad. Sci. Arts Lett. 54:51-61.

Ide F.P. 1942. Availability of aquatic insects as food of the speckled trout (Salvelinus fontinalis). Trans. No. Am. Wildl. Nat. Resour. Conf. 7:442-450.

Jenkins T.M., C.R. Feldmeth, and G.V. Elliott. 1970. Feeding of rainbow trout (Salmo gairdneri) in relation to abundance of drifting invertebrates in a mountain stream. J. Fish. Res. Board Can. 27(12):2356-2361.

Karr J.R. 1963. Age, growth, and food habits of johnny, slenderhead, and blacksided darters of Boone County, Iowa. Proc. Iowa Acad. Sci. 70:228-236.

Kramer R.H. and L.L. Smith, Jr. 1960. First-year growth of the largemouth bass, (Micropterus salmoides) and some related ecology factors. Trans. Am. Fish. Soc. 89(2):222-233.

Laarman P.W. and J.C. Schneider. 1972. The food and feeding habits of the bluegill and yellow perch in lakes with good and bad fishing. Mich. Dept. of Natural Resources Research and Development Report No. 279, 29p.

Lamsa A. 1963. Downstream movement of the brook stickleback, Eucalia inconstans (Kirtland) in a small southern Ontario stream. J. Fish. Res. Board Can. 20(1):587-589.

Leonard J.W. 1942. Some observations on the winter feeding habits of brook trout fingerlings in relation to natural food organisms present. Trans. Am. Fish. Soc. 71:219-227.

Lewis W.M., G.E. Gunning, E. Lyles, and W.L. Bridges. 1961. Food choice of largemouth bass as a function of availability and vulnerability of food items. Trans. Am. Fish. Soc. 90:277-280.

Loftus K.H. 1958. Studies on river spawning populations of lake trout in eastern Lake Superior. Trans. Am. Fish. Soc. 87:259-277.

Manion P.J. 1977. Downstream movement of fish in a tributary of southern Lake Superior. Prog. Fish-Cult. 39(1):14-16.

Martin N.V. 1952. A study of the lake trout, Salvelinus namaycush, in two Algonquin Park, Ontario, lakes. Trans. Am. Fish. Soc. 81(1951):111-137.

Meyer W.H. 1962. Life history of three spp. of redhorse (Moxostoma) in the Des Moines River, Iowa. Trans. Am. Fish. Soc. 91(4):412-419.

Miller J.M. 1974. The food of the brook trout (Salvelinus fontinalis) fry from different subsections of Lawrence Creek, Wisconsin. Trans. Am. Fish. Soc. 103(1):130-134.

Moyle P.B. 1973. Ecological segregation among three spp. of minnows (Cyprinidae) in a Minnesota lake. Trans. Am. Fish. Soc. 1973(4):794-805.

Mraz D., S. Kimiotek, and L. Frankenberger. 1961. The largemouth bass, its life history, ecology, and management. Wisc. Cons. Dept. Publ. No. 232.

Muller K. 1954. Investigations on the organic drift of north Swedish streams. Rep. Inst. Freshwater Res. Drottningholm. 35:133-148.

Mundie J.H. 1971. The diel diet of Chironomidae in an artificial stream and its relation to the diet of coho salmon fry (Oncorhynchus kisutch) Can. Entomol. 103(3):289-297.

Ney J.J. and L.L. Smith, Jr. 1975. First year growth of the yellow perch Perca flavescens in the Red Lakes, Minnesota. Trans. Am. Fish. Soc. 104(4):718-725.

Niemuth W., W. Churchill, and T. Wirth. 1959. The walleye, its life history, ecology, and management. Wis. Cons. Dept. Publ. No. 227.

Noble R.L. 1975. Growth of yellow perch (Perca flavescens) in relation to zooplankton populations. Trans. Am. Fish. Soc. 104(4):731-741.

Olson D.E. and W.J. Scidmore. 1962. Homing behavior of spawning walleyes. Trans. Am. Fish. Soc. 91(4):355-361.

Peterson G.R. 1966. The relationship of invertebrate drift abundance to the standing crop of benthic organisms in a small stream. M.S. Thesis, University of British Columbia.

Petrosky C.E. and T.F. Waters. 1975. Annual production by the slimy sculpin population in a small Minnesota trout stream. Trans. Am. Fish. Soc. 104(2):237-244.

Priegel G.R. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Wis. Dep. Nat. Resour. Tech. Bull. 45. 105p.

Qadri S.U. 1961. Food and distribution of lake whitefish in Lac La Ronge, Saskatchewan. Trans. Am. Fish. Soc. 90:303-307.

Rahrer J.F. 1968. Movements of adult lake trout in Lake Superior. U.S. Bureau of Commercial Fisheries, Ann Arbor Biol. Lab. No. 373.

Raney E.C. and D.A. Webster. 1940. The food and growth of the young of the common bullhead, Ameiurus nebulosis nebulosis (Le Sueur), in Cayuga Lake, New York. Trans. Am. Fish. Soc. 1940:205-209.

Rawson D.S. 1956. The life history and ecology of the yellow walleye, Stizostedion vitreum, in Lac La Ronge, Saskatchewan. Trans. Am. Fish. Soc. 86:15-37.

Reisen W.K. 1972. The influence of organic drift on the food habits and life history of the yellowfin shiner (Notropis lutipinnis). Am. Midl. Nat. 88:376-383.

REFERENCES CITED (contd.)

Repsys A.J., R.L. Applegate, and D.C. Hales. 1976. Food and food selectivity of the black bullhead, Ictalurus melas, in the Lake Poinsett South Dakota. J. Fish. Res. Board Can. 33:768-775.

Sadzikowski M.R. and D.C. Wallace. 1976. A comparison of the food habits of size classes of three sunfishes (Lepomis macrochirus, Lepomis gibbosus, Lepomis cyanellus). Am. Midl. Nat. 95(1):220-225.

Schneberger E. 1972a. Smallmouth bass, its life history, ecology, and management. Wis. Dep. Nat. Resour. Publ. No. 242.

Schneberger E. 1972b. The white sucker, its life history, ecology, and management. Wis. Dep. Nat. Resour. Publ. No. 245.

Scott W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bul. 184:966pp.

Siefert R.E. 1972. First food of larval yellow perch, white sucker, bluegill, emerald shiner, and rainbow smelt. Trans. Am. Fish. Soc. 101(2):219-225.

Snow H., A. Ensign, and J. Klingbiel. 1960. The bluegill, its life history, ecology, and management. Wis. Cons. Dep. Publ. No. 230.

Swenson W.A. In press. Food consumption and feeding behavior of walleye and sauger in relation to food availability and certain physical conditions in Lake of the Woods, Minnesota, Shagawa Lake, and Western Lake Superior. Univ. of Wisc. Center for Lake Superior Environmental Studies Contribution No. 15.

Threinen C.W., C. Wistrom, B. Appelgren, and H. Snow. 1966. The northern pike, its life history, ecology, and management. Wis. Cons. Dep. Publ. No. 235.

Waters T.F. 1969. Invertebrate drift-ecology and significance to stream fishes. Pages 121-134 in symposium on salmon and trout in streams. H.R. Macmillan lectures in fisheries. Univ. British Columbia.

Webster D.A. and G. Eiriksdottir. 1976. Upwelling water as a factor influencing choice of spawning sites by brook trout (Salvelinus fontinalis). Trans. Am. Fish. Soc. 105(3):416-421.

Whitaker J.O., Jr. 1977. Seasonal changes in food habits of some cyprinid fishes from the White River at Petersburg, Iowa. Am. Midl. Nat. 97(2):411-418.

Winn H.E. 1958. Observations on the reproductive habits of darters (Pisces-Percidae). Am. Midl. Nat. 59:109-212.

Winn H.E. 1960. Biology of brook stickleback (Eucalia inconstans) (Kirtland). Am. Midl. Nat. 63:424-438.

	FOOD				SPAWNING: TIME				SPAWNING: SUBSTRATE								SPAWNING: CURRENT					SPAWNING: TEMPERATURE °F					SPAWNING: HABIT					MOTION		
SPECIE	ALGAE	ZOOPLANKTON	AQUATIC INSECTS	FISH	SPRING	SUMMER	FALL	WINTER	CLAY, MARL, MUD, SILT	SAND	GRAVEL	RUBBLE, BOULDER	MIDWATER	ORGANIC DEBRIS	VEGETATION, ALGAE	UNDERSIDE-ROCKS, ETC.	INDIFFERENT	STILL	WEAK	MODERATE	FAST	35-45	45-55	55-65	65-75	75-85	HIDERS	SCATTERERS-GRAVEL	SCATTERERS-VEGETATION	SUBSTRATE NESTERS	BURROW NESTERS	SEDENTARY	SEMI-MOBILE	MOBILE
N. redbelly dace	X				X	X									X			X											X			X		
Brassy minnow	X				X	X			X									X											X			X		
Fathead minnow	X					X										X		X						X							X	X		
Pugnose shiner		X			X																											X		
Blackchin shiner		X			X	X												X														X		
Pearl dace		X			X					X	X								X	X				X			X					X		
Rainbow smelt			X		X						X										X		X					X						X
Central mudminnow			X		X										X				X					X					X			X		
Finescale dace			X		X																											X		
Longnose dace			X		X	X					X								X	X			X					X				X		
Creek chub			X		X	X					X									X	X			X			X					X		
Lake chub			X		X							X							X	X								X					X	
Common shiner			X		X	X				X	X									X				X						X		X		
Spottail shiner			X		X	X									X			X	X										X			X		
Pumpkinseed			X		X	X			X	X	X	X							X						X	X				X		X		
White sucker			X		X	X					X									X			X					X					X	
Tadpole madtom			X			X												X													X	X		
Iowa darter			X		X									X				X											X			X		
Johnny darter			X		X											X		X	X	X											X	X		
Log perch			X			X				X								X	X	X									X			X		
Blacknose dace			X		X	X					X										X				X			X				X		
Brook trout			X	X			X				X								X	X	X	X					X					X		
Lake herring			X	X			X	X			X	X						X	X	X		X						X						X
Lake whitefish			X	X			X	X		X	X	X						X	X	X		X						X						X
Trout-perch			X	X	X					X	X	X								X								X					X	
Rock bass			X	X	X	X			X	X	X	X	X	X	X	X		X	X					X	X					X		X		
Smallmouth bass			X	X	X	X				X	X	X							X					X						X		X		
Black crappie			X	X	X	X			X	X	X							X							X					X		X		
Yellow perch			X	X	X					X	X							X					X					X					X	
Mottled sculpin			X	X	X	X										X			X				X								X	X		
Slimy sculpin			X	X	X											X			X			X	X								X	X		
Lake trout				X			X					X							X	X			X				X							X
Northern pike				X	X										X			X				X	X						X			X		
Burbot				X	X			X		X	X							X	X	X		X						X				X		
Largemouth bass				X	X	X			X	X	X							X						X						X		X		
Walleye				X	X					X	X	X			X			X	X	X			X					X					X	
Golden shiner	X	X	X	X		X									X			X							X				X				X	
Emerald shiner	X	X	X	X	X	X							X																				X	
Shorthead redhorse	X	X	X	X	X						X									X			X					X					X	
Blacknose shiner	X	X	X	X	X	X				X								X											X			X		
Bluntnose minnow	X	X	X	X	X	X										X		X							X						X	X		
Brook stickleback	X	X	X	X		X									X			X					X	X						X		X		
Bluegill	X	X	X	X	X	X			X	X	X							X							X					X		X		
Black bullhead	X	X	X	X	X	X			X	X	X							X							X						X	X		
Yellow bullhead	X	X	X	X	X	X			X	X					X			X							X						X	X		
Brown bullhead	X	X	X	X	X	X			X	X					X			X							X						X	X		
Channel catfish	X	X	X	X	X	X			X	X					X			X								X					X		X	