Spawning Habitat Characteristics Of Great Lakes Fishes

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SPAWNING HABITAT CHARACTERISTICS OF GREAT LAKES FISHES

by

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ABSTRACT

Lane, J.A., C.B. Portt and C.K. Minns. 1996. Spawning habitat characteristics of Great Lakes fishes. Can. MS Rep. Fish. Aquat. Sci. 2368 :v+48p.

A review of the literature was conducted to compile knowledge of spawning habitat characteristics of 139 species of Great Lakes fishes. Water depth, substrate, and vegetation/cover were the habitat variables examined. Nineteen Great Lakes species spawn exclusively in rivers, and one spawns in the marine environment. The majority of the remaining 120 species spawn in shallow water. Most (105) spawn in the spring. Gravel and sand are the most commonly utilized substrates. Bedrock and hard-pan clay are utilized by few species. Aquatic vegetation is an important component of spawning habitat for many species, as are other forms of cover. The majority of these species scatter their eggs, usually over a specific substrate, but 32 species guard nests, and 23 construct redds in which the eggs are concealed. The precision with which spawning habitats are selected by many species cannot be reflected with the limited number of variables which we have used to describe nearshore habitats.

RÉSUMÉ

J.A. Lane, C.B. Portt et C.K. Minns, 1996. Caractéristiques de la zone de frai des poissons des Grands Lacs. Can. MS Rep. Fish. Aquat. Sci. 2368 : v+48p.

Une analyse documentaire a été effectuée pour rassembler les données connues sur les caractéristiques de la zone de frai des poissons des Grands Lacs. Les paramètres étudiés étaient la profondeur de l'eau, le substrat et la couverture végétale. Dix-neuf espèces pondent seulement dans les rivières, une dans un environnement marin. La majorité des 120 autres espèces déposent leurs oeufs dans l'eau peu profonde. Pour la plupart (105 espèces), le printemps est la saison du frai. Les substrats les plus fréquemment utilisés sont le gravier et le sable. Quelques espèces déposent leurs oeufs sur un substrat rocheux ou une carapace d'argile. Pour bon nombre d'espèces, la végétation aquatique, tout comme les autres formes de substrat, est une composante importante de la zone de frai. La majorité de ces espèces dispersent leurs oeufs, normalement au-dessus d'un substrat particulier. Trente-deux espèces, par contre, surveillent un nid et 23 construisent un nid de frai dans lequel elles dissimulent les oeufs. De nombreuses espèces ont des besoins particuliers en ce qui concerne la zone de frai, qui ne sont pas décrits en détail en raison du nombre limité de variables étudiées.

1.0 INTRODUCTION

The nearshore areas are crucial in providing habitat for most of the fish species in the Great Lakes, during at least one life stage. Nearshore areas are also the locations of greatest human interaction with the lakes, and include some of the most degraded habitats in the Great Lakes basin. Effective management strategies of nearshore areas must integrate the preservation of fish habitat and fish populations, and human activity which is concentrated there.

'NO NET LOSS OF THE PRODUCTIVE CAPACITY OF FISH HABITAT' is the guiding principle of the Department of Fisheries and Oceans (DFO) 'Policy for the Management of Fish Habitat' (DFO 1986). The ultimate objectives of this policy are: 1) conservation of habitat; 2) restoration of damaged habitat; and 3) development of new habitat resulting in a net gain of productive capacity (Minns et al. 1995). The difficulty in assessment of individual development projects lies in the lack of a common, quantitative protocol that can be used both by project proponents and habitat managers to assess individual projects.

A prototype methodology developed by Minns et al. (1995) requires pre- and post-development characterizations of fish habitats, and predictions of their relationship to fish populations and communities. These predictions are based on knowledge of spawning, nursery and adult habitat characteristics. To date, reports have been prepared documenting habitats of adult and young-of-the year fishes in the Great Lakes (Lane et al. 1996a, 1996b). This report summarizes the spawning habitat characteristics required for the defensible methods assessment process.

2.0 METHODS

The computer database Aquatic Sciences and Fisheries Abstracts (1978-December 1995) was searched and relevant literature was examined. Secondary sources (Scott and Crossman, 1973; Becker, 1983) were relied upon for summaries of earlier literature. This report presents data for those species which spawn in the lake environment or in estuaries at the mouths of tributary streams or river deltas, which were treated as lentic habitat.

As was done for nursery and adult habitats (Lane et al, 1996a,b), spawning habitat characteristics are characterized by three variables: water depth (0-1, 1-2, 2-5, 5+ metres), substrate (bedrock, boulder, cobble, rubble, gravel, sand, silt, clay, hard-pan clay), and structure/cover (emergent vegetation, submergent vegetation and other e.g. logs, rocks). The depth strata used for spawning are indicated (Table 1), but no attempt was made to assess relative importance. The estimated strength of association with various substrate materials is indicated (low, medium, high; Table 2). Substrate described as detritus or mud in the literature is included in the silt category.

The significance of vegetation or other cover for spawning (Table 1) was estimated based on the available documentation. 'High' indicates a species always, or nearly always, spawns where there is a particular form of cover; 'medium' indicates a species often spawns, and 'low' indicates a species sometimes spawns where a given cover type is present. A dash (-) indicates that cover is discerned to be of no importance. When vegetation is an essential component of spawning habitat, the comments column notes that eggs adhere to vegetation. An index of the utilization of lentic, as opposed to lotic, habitat for spawning is also provided (Table 2).

The range of water temperatures at which spawning occurs is provided, or if this

information was unavailable the temperature at which spawning peaks or commences is given (Table 3). The season during which spawning occurs is also indicated for each species (Table 3). The dates of spawning vary, due primarily to north-south climatic gradients. For the purposes of this report spring is defined as the period during which water temperatures are increasing, fall is defined as the period during which water temperatures are declining, and winter is defined as the period during which water temperatures are at their minimum, and more or less stable.

The spawning behaviour of each species is broadly characterized (Table 3), based on the reproductive guilds of Balon (1975). Species are described as a) broadcast spawners which release their eggs over a given area and do not guard; b) hiders, which typically bury their eggs in redds, and do not guard; and c) nest-builders, which guard their nests.

Information on spawning habitat was readily available for most fish species in the Great Lakes. Those few for which inferences were made are indicated with an asterisk (*). The basis for the inference is indicated in the 'Comments' column.

3.0 RESULTS AND DISCUSSION

The species list used in this report (Appendix A) is the same as was used for the compilations of nursery and adult habitats (Lane et al, 1996a,b). This information is based on the distribution information in Mandrak and Crossman (1992) and information obtained on recently discovered exotics. No information is presented for three species which are considered extirpated from the Great Lakes (deepwater cisco, *Coregonus johannae;* blackfin cisco, *C. nigripinnis;* gravel chub, *Erimystax x-punctata*), or for hybrids. The American eel (*Anguilla rostrata*), which returns

to the marine environment to spawn (Tesch and Greenwood 1977), was also excluded. Information was compiled on the spawning habitat characteristics of 131 species. Inferences were drawn for an additional 8 species based on adult habitat or on the spawning habitat of species with which they are known to hybridize.

Sixty-nine of the species resident in the Great Lakes spawn primarily, if not exclusively, in lentic habitats. Twenty-three species commonly utilize both lake and stream habitats for spawning; 28 species are normally stream spawners but some spawning is known to occur in the lake environment. The remaining nineteen species apparently spawn only in streams and rivers; these species are listed in Appendix B.

Most fish species resident in the Great Lakes spawn on only one occasion during the year, although some species (e.g. fathead minnow, gobies, ruffe) can produce more than one brood during a breeding season. It appears that for most species, the photoperiod determines the overall reproductive state, but water temperature ultimately determines when spawning will occur. Of the species examined, 105 spawn in the spring, twelve spawn in the fall and three spawn during the winter (Table 3). Spawning dates for the same species often differ by more than a month between the upper and lower Great Lakes, and spawning dates in one location can vary by two to three weeks between years for some species, depending upon weather conditions. Sheltered shallow areas and tributaries warm more quickly in the spring than more exposed areas in the lakes. Consequently, water temperature also plays an important role in determining where some species spawn.

Thirty-two of the 120 lake spawning species guard their broods (Table 3). Some of these

species conceal their eggs in existing cavities (i.e. brown bullhead, *Ameiurus nebulosus*) or under objects (i.e. fathead minnow, *Pimephales promelas*). Sticklebacks construct a nest of algae or plant material. In the case of the centrarchids the nest is usually only a shallow depression from which fine sediments have been fanned. All of these species were considered guarding nest spawners (guild B.2.) by Balon (1975) except white crappie (*Pomoxis annularis*), which he considered to be a guarding substratum chooser (guild B.1.). Based on descriptions of the spawning behaviour of white crappie, we consider its reproductive tactics to be similar to those of the other centrarchids and have placed it with them in guild B.2.

Two non-guarding guilds are represented. The majority of the non-guarding species (65) broadcast their eggs rather than actively concealing them. These are, in Balon's terminology, non-guarding open-substratum spawners (guild A.1.). In most cases these eggs settle to the bottom, or onto vegetation which overlies the bottom. Exceptions include freshwater drum (*Aplodinotus grunniens*), whose eggs are positively buoyant and float at the surface, and yellow perch (*Perca flavescens*) whose eggs are contained in gelatinous strings or tubes which attach to vegetation or the bottom. Spawning habitat requirements for this group can be quite precise; for example, northern pike spawn almost exclusively over the previous year's flooded terrestrial or emergent aquatic vegetation; lake trout require shoals with sufficient wave action to remove fine sediment. For other species, such as white perch (*Morone americana*), neither substrate nor vegetation appear to be important.

The remaining twenty-three non-guarding species either bury their eggs in redds (trouts, salmons and charrs) or clear depressions or construct mounds of pebbles over which they spawn,

and among which the eggs are concealed (several cyprinids). This group corresponds to Balon's (1975) non-guarding brood-hiding lithophils (guild A.2.1; the third level of the classification can be included in this case, since all utilize similar substrates). We have included two species in this guild, common shiner (*Luxilus cornutus*) and cutlips minnow (*Exoglossum maxilingua*), which Balon (1975) considered to be guarders. Although the males of both species are territorial during spawning, we interpret the descriptions of spawning behaviour to indicate that neither guards its brood.

There are numerous accounts of more than one minnow species spawning over a particular area at the same time. Male common shiners defended spawning territory on most hornyhead chub (*Nocomis biguttatus*) redds observed by Vives (1990). Although some antagonistic encounters between the two males were observed, most of the common shiners' aggressive behaviour was directed toward other common shiners and female chubs. Rosyface shiners (*Notropis rubellus*) were also observed spawning over chub redds (Vives, 1990).

Goff (1984) reported finding longnose gar (*Lepisosteus osseus*) eggs in association with a significant proportion (14%) of smallmouth bass (*Micropterus dolomieu*) nests. The redfin shiner (*Lythrurus umbratilus*) usually spawns over the nests of actively spawning sunfish especially green sunfish (*Lepomis cyanellus*; Hunter & Hasler 1965; Noltie 1989). Spawning activity of the shiners appears to be initiated by the odour of milt and ovarian fluid from sunfish (Hunter & Hasler 1965). In these cases, the eggs of both species are guarded by the centrarchid. More than one species defending the same spawning territory, or more than one species spawning over the same redd, could be attributed simply to selection of similar spawning habitats. An obligate symbiotic or

parasitic relationship apparently does not exist, as all of these species are reported to spawn independently, but such relationships may be evolving.

Gravel and sand are the most commonly used substrates for spawning. Cobble and silt are also frequently utilized (Table 4), although the number of species using silt is influenced by species which spawn on vegetation, which often grows in silt substrates. Bedrock and hard-pan clay are utilized by few species (Table 4). Many species spawn on, or amongst, both emergent and submergent vegetation. Strong association with cover is also common, with emphasis on fixed objects such as rocks and logs.

For a number of reasons, spawning is typically the most intensively studied aspect of a fishes' life-history. Because they move into either the nearshore areas of the lakes or the tributaries, the adults of many species are more readily observed during spawning than at any other time. They are often also most susceptible to capture during spawning or pre- and post-spawning migrations, when many individuals are concentrated in relatively small areas.

The reproductive behaviour of a species is one component of an evolved 'optimum' strategy for survival, which is bounded by genetic and environmental constraints. As Kryzhanovsky (1949) stated "adaptations of fishes for spawning and development reflect not only the essential ecological factors of the embryonic period, but also the essential factors of all other intervals of life." This is true, but an individual's ability to actively select advantageous habitats and avoid those that are disadvantageous increases with age. Embryos are passive and thus at the mercy of their surroundings. Once exogenous feeding begins, a readily available food supply is essential, or death ensues. The precision of reproductive behaviour and spawning habitat selection exhibited by many

species reflects the vulnerability of the early life stages and the need to position them, in time and in space, where environmental conditions are most conducive to survival and growth.

The characterization of spawning habitats which is provided here does not reflect factors which, for some species, are essential. For example, brook trout (*Salvelinus fontinalis*) select areas of upwelling for spawning (Hartley & Kelso 1991; Scott & Crossman 1973). In fact, the preference for groundwater is so pronounced that substrates of silt and detritus, or even old beaver lodges, will be utilized if seepage is present (Wetzel & MacCrimmon 1983; Webster & Eiriksdotter 1976, Fraser, 1982). Lake trout (*Salvelinus namaycush*) spawning shoals usually are moderately exposed to wave action and associated currents; this is attributed to the need to maintain interstices within the substrate which are free of fine sediments. In contrast, the reproductive success of smallmouth bass is negatively correlated with exposure to strong wind (Goff, 1986).

The homing exhibited by many fish species may be the ultimate in precise spawning habitat 'selection'. For some species, however, precise homing could be a liability. Northern pike typically spawn in shallow water over flooded terrestrial or emergent aquatic vegetation, and the location of these habitats can vary from year to year due to water level fluctuations. There are, of course, species which appear to be true habitat generalists, such as yellow perch and white perch.

As with the reports concerning adult and nursery habitat (Lane et al, 1996a,b), certain conclusions regarding the utilization of various habitats can be drawn from the information compiled, but its limitations must be noted. Our assessment of the relative significance of particular habitats to individual species was necessarily subjective. Even though spawning habitat has often received a disproportionate amount of attention from biologists, relative to other life

stages, descriptions of spawning habitat for some species are vague. The precision with which spawning habitats are selected by many species cannot be reflected with the limited number of variables which we have used to describe nearshore habitats. These limitations notwithstanding, the data contained in this report are useful in assessing the relative significance of various habitats to spawning fishes, particularly when applied at the guild or community level (Lane et al, 1996a; 1996b).

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Table 1. Depth strata and type of cover utilized by spawning Great Lakes fishes. Presence within a depth stratum is indicated with an X. A dash (-) indicates that the species was not reported to utilize a particular depth stratum or cover. For species marked with an asterisk (*), inferences have been drawn, the bases for which are provided in the 'Comments' column. The notation '[C]' indicates additional information is given, also in the 'Comments' column.

Common Name	Water Depth (m)				Cover			References	Comments
	0-1	1-2	2-5	5+	Submergent Vegetation	Emergent Vegetation	Other		
lake sturgeon	X	X	X	-	-	-	rocks, logs	11, 47, 57	adhesive eggs
longnose gar	X	-	-	-	high	high	*Cladophora*	5, 11, 47, 131	eggs adhere to vegetation
spotted gar	X	-	-	-	high	high	brush, debris	47, 111, 131	eggs adhere to vegetation
bowfin	X	X	-	-	high	high	-	11, 47, 136	
alewife	X	X	X	-	low	low	stones, debris	47, 75, 98, 136	eggs broadcast over substrate
gizzard shad	X	X	X	-	high	high	brush, debris	8, 47, 75, 136, 138	adhesive eggs
rainbow trout	X	X	X	X	-	-	-	1, 47, 131	
Atlantic salmon	X	-	-	-	-	-	-	1, 47, 77, 89, 131	
brown trout	X	X	-	-	-	-	-	1, 5, 47, 149	
Arctic charr	-	X	X	X	-	-	-	91, 131	
brook trout	X	X	-	-	-	-	-	24, 47, 52, 121, 144, 149	areas of upwelling
lake trout	X	X	X	X	-	-	crevices, cracks	35, 36, 47, 64, 96	depth a function of race
lake whitefish	X	X	X	X	-	-	-	1, 5, 47, 61, 131	
cisco	X	X	X	X	-	-	-	1, 47, 131	
bloater	-	-	-	X	-	-	-	1, 5, 47, 109	
kiyi	-	-	-	X	-	-	-	47, 54, 110	
shortnose cisco	-	-	-	X	-	-	-	47, 107	

shortjaw cisco	-	-	-	X	-	-	-	47, 58	
pygmy whitefish	X	X	-	X[c]	-	-	-	5, 47, 131	[c]spawning & spent caught at 31-46 m
round whitefish	X	X	X	X	-	-	-	1, 47, 53, 103	
rainbow smelt	X	X	X	X	low	low	-	47, 75, 128	
northern pike	X	X	-	-	-	high[c]	flooded terrestrial vegetation	19, 47, 131, 136, 146	[c]eggs adhere to vegetation.
muskellunge	X	X	-	-	high	high	stumps, logs	32, 33, 47, 131, 146	
grass pickerel	X	-	-	-	-	high[c]	flooded terrestrial vegetation	22, 47	[c]eggs adhere to vegetation
central mudminnow	X	-	-	-	high[c]	high	-	47, 82, 118	[c]eggs adhere to vegetation
quillback	X	X	-	-	-	-	high turbidity	1, 5, 47	
longnose sucker	X	X	X	-	-	-	-	5, 47, 131	
white sucker	X	X	-	-	low	low	-	5, 23, 47, 122, 131, 136	
lake chubsucker	X	X	-	-	high	high	filamentous algae, grass stubble	1, 47, 131	
northern hogsucker	X	-	-	-	-	-	-	5, 23, 47, 131	
bigmouth buffalo	X	X	X	-	high	high	high turbidity	43, 47, 62	
spotted sucker	X	-	-	-	-	-	depressions behind rocks	5, 23, 112	
silver redhorse	X	-	-	-	-	-	-	5, 47	
shorthead redhorse	X	-	-	-	-	-	-	5, 23, 47	
greater redhorse*	X	X	X	-	-	-	-	5, 47, 131	*possibly spawn in lakes

goldfish	X	X	X	-	high	-	undersides of objects, roots	5, 47	eggs adhere to vegetation
northern redbelly dace	X	X	-	-	high	-	-	1, 5, 30, 47, 131	
finescale dace	X	X	-	-	-	-	logs, brush	5, 30, 131, 135	
lake chub	X	X	-	-	-	-	under boulders	12, 47, 131	
common carp	X	X	-	-	high	high	-	47, 131, 136	eggs adhere to vegetation
cutlips minnow	X	-	-	-	-	-	large rocks, logs	131, 139	
brassy minnow*	X	-	-	-	high	high	-	5, 131	*similar to silvery minnow
eastern silvery minnow	X	-	-	-	high	high	-	5, 131	
silver chub	X	X	X	X	-	-	-	5, 47, 115, 131	to 10 m. thought to occur in open water
hornyhead chub	X	-	-	-	low	low	-	5, 25, 83, 140	
golden shiner	X	X	-	-	high	high	organic debris, filamentous algae	14, 47, 60, 146	eggs adhere to vegetation
pugnose shiner	X	X	-	-	high	high	-	5, 47, 76, 114	
emerald shiner	X	X	X	X	low	low	-	17, 47, 136	
bridle shiner	X	-	-	-	high	high	-	47, 51	
common shiner	X	-	-	-	low	low	-	6, 47, 60, 131, 136	often use nests of other minnows
blackchin shiner*	X	-	-	-	high	high	-	5, 47	*adult habitat
blacknose shiner	X	-	-	-	high	high	roots of aquatic vegetation	47, 131	
spottail shiner	X	X	X	-	medium	medium	-	47, 80, 136	
rosyface shiner	X	-	-	-	-	-	-	5, 47, 131,	uses nests of

								140	other minnows
spotfin shiner	X	X	-	-	low	low	undersides of fixed objects	5, 39, 47, 131	adhesive eggs
sand shiner	X	X	-	-	low	low	roots of aquatic vegetation	47, 131	adhesive eggs
redfin shiner	X	-	-	-	-	-	-	81, 99, 102, 131	utilizes sunfish nests
mimic shiner	X	X	X	-	high	high	-	47, 93, 131	eggs scattered
pugnose minnow*	X	X	-	-	medium	medium	-	47, 76, 116	*adult habitat
bluntnose minnow	X	X	X	-	medium	medium	undersides of fixed objects	47, 93, 131, 136	adhesive eggs
fathead minnow	X	X	-	-	medium	medium	undersides of fixed objects	6, 47, 120, 136	adhesive eggs
blacknose dace	X	-	-	-	-	-	-	4, 6, 47, 131	
longnose dace	X	X	-	-	-	-	-	4, 5, 47, 131	
creek chub	X	-	-	-	-	-	-	6, 47, 131	
fallfish	X	-	-	-	-	-	-	47, 123, 131	
pearl dace	X	-	-	-	low	low	-	6, 131	
central stoneroller	X	-	-	-	-	-	-	5, 47, 84, 86, 88	
striped shiner	X	-	-	-	low	low	-	5, 44	
black bullhead	X	X	-	-	high	high	debris, overhanging banks, rocks	5, 47, 131, 146	
yellow bullhead	X	X	-	-	high	high	logs, tree roots, boards, debris	5, 47	
brown bullhead	X	X	-	-	medium	medium	logs, tree roots, boards, debris	7, 47, 136	
channel catfish	X	X	X	-	low	low	undercut banks, log jams, rocks	47, 131	
stonecat	X	X	-	-	-	-	nests under boards, rocks, logs	47, 131, 142	
tadpole madtom	X	X	-	-	medium	medium	under boards, logs, roots	47, 131, 145	

							cans		
brindled madtom	X	X	-	-	medium	medium	under boards, logs, roots, cans	15, 47, 113	
banded killifish	X	-	-	-	high	high	-	47, 59	eggs adhere to vegetation
burbot	X	X	X	[c]	-	-	-	47, 79, 131	may also spawn in deep water
brook stickleback	X	-	-	-	high	high	sticks	47, 124, 131, 150, 151	
threespine stickleback	X	-	-	-	low	low[c]	-	47, 150, 151	[c]favours, but is not restricted to, open areas
ninespine stickleback	X	X	X	X	high	high	between rocks	37, 47, 150, 151	
fourspine stickleback	X	-	-	-	high	high	-	21, 127, 150, 151	
trout-perch	X	X	X	X	low	low	between rocks	5, 47, 131	
white perch	X	X	X	-	medium	medium	-	9, 47, 136	
white bass	X	X	X	X	low	low	-	5, 47, 131, 136	
rock bass	X	X	-	-	low	low	under rocks, logs	47, 49, 101, 136	
green sunfish	X	X	-	-	high	high	rocks, logs, clumps of grass	5, 47, 76, 131	
pumpkinseed	X	X	-	-	high	high	-	47, 67, 136	
bluegill	X	X	X	-	high	high	-	5, 47	
longear sunfish	X	X	X	-	medium	medium	-	5, 67, 87	
smallmouth bass	X	X	-	-	low	low	boulders, docks, logs	5, 47, 97, 129, 131	
largemouth bass	X	X	-	-	medium	high	-	13, 47, 94, 129, 136, 146	
white crappie	X	X	X	-	medium	medium	banks, brush, stumps	47, 50, 131	

black crappie	X	X	X	-	high	high	-	47, 136, 146	
warmouth*	X	X	-	-	high	high	stumps, rocks, clumps of vegetation	5, 131	*hybridizes with pumpkinseed & bluegill
orangespotted sunfish	X	X	-	-	low	low	-	5, 47, 76, 100	
yellow perch	X	X	X	X	medium	medium	rocks, brush, debris	47, 119, 136, 143	
sauger	X	X	X	-	low	low	-	5, 47, 131	
walleye	X	X	X	X	low	low	-	47, 52, 105	
eastern sand darter*	X	X	X	-	-	-	-	56, 69	*adult habitat
greenside darter	X	-	-	-	low	low	algae-covered rocks	29, 47, 69 147, 148	
rainbow darter	X	-	-	-	low	low	-	47, 66, 69, 147, 148	
Iowa darter	X	-	-	-	medium	medium	undercut banks, fibrous roots	47, 69, 147, 148	
fantail darter	X	-	-	-	-	-	undersides of rocks	47, 69, 147, 148	
least darter	X	-	-	-	high	high	-	28, 63, 69, 147, 148	
johnny darter	X	-	-	-	-	-	undersides of rocks, logs	47, 66, 69, 147, 148	
logperch	X	X	-	-	-	-	-	47, 66, 69, 147, 148	
channel darter	X	X	-	-	-	-	near large rock	47, 69, 148	
blackside darter	X	-	-	-	-	-	-	5, 69, 147	
river darter*	X	-	-	-	-	-	-	27, 69	*similar to channel and blackside darters
tesselated darter	X	-	-	-	-	-	undersides of objects	46, 69	
brook silverside	X	-	-	-	high	high	-	42, 47, 75,	eggs adhere to

								95	vegetation
freshwater drum	X	X	X	X	low	low	-	5, 47, 131	eggs pelagic
mottled sculpin	X	-	-	-	-	-	crevices, under rocks, burrows	34, 47, 130	
slimy sculpin	X	X	X	X	-	-	under rocks or logs	47, 133	
spoonhead sculpin	X	X	X	X	-	-	possibly under rocks or logs	47, 133	
deepwater sculpin	-	-	-	X	-	-	-	79, 133	
rudd*	X	X	-	-	high	high	-	14, 76, 125	eggs adhesive *hybridizes with golden shiner
ruffe	X	X	X[c]	-	medium	-	logs, branches, rocks	48, 104, 134	[c]spawn in depths of 3m or less
round goby	X	X	X	-	low	-	undersides of logs, cans	65, 66	
tubenose goby	X	X	X	-	medium	-	undersides of logs, cans	65, 66	

Table 2 Strength of association with substrate types and the importance of lake (versus stream) habitat for spawning Great Lakes fishes. A dash (-) indicates that no information was found to indicate that the species utilizes a particular substrate type. For species marked with an asterisk (*) inferences about relationships have been drawn based on adult habitat or hybridization with other species. The notation '[c]' indicates additional information is given, also in the 'Comments' column. References are listed in Table 1.

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
lake sturgeon	-	high	high	high	high	high	-	-	high	low	
longnose gar	-	-	-	-	medium	high	high	-	-	high	
spotted gar	-	-	-	-	medium	high	high	-	-	high	
bowfin	-	-	-	-	-	high	high	-	-	high	
alewife	-	high	high	high	high	high	high	high	-	high	
gizzard shad	-	-	-	high	high	high	high	-	-	high	
rainbow trout	-	-	-	low	high	-	-	-	-	low	
Atlantic salmon	-	-	-	high	high	-	-	-	-	low	
brown trout	-	-	medium	high	high	low	-	-	-	low	
arctic charr	-	-	-	-	high	medium	-	-	-	medium	
brook trout	-	-	-	high	high	medium	low	-	-	medium	
lake trout	high[c]	high[c]	high	high	low	low	-	-	-	high	[c]with scattered cobble, rubble
lake whitefish	-	high	high	high	high	medium	-	low	-	high	
cisco	-	medium	high	high	high	high	medium	medium	medium	high	

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
bloater	high	high	high	high	high	high	high	high	high	high	
kiyi	-	-	-	-	-	-	high	high	-	high	
shortnose cisco	medium	medium	medium	medium	medium	high	high	high	-	high	
shortjaw cisco	medium	medium	medium	medium	medium	high	medium	high	medium	high	
pygmy whitefish	-	-	-	high	high	high	-	-	-	medium	
round whitefish	-	-	-	high	high	-	-	-	-	high	
rainbow smelt	-	medium	medium	high	high	high	low	-	-	medium	eggs adhere to substrate
northern pike	-	-	-	low	low	high	high	-	-	high	
muskellunge	-	-	-	-	-	medium	high	high	-	high	
grass pickerel	-	-	-	-	-	-	high	high	-	high	
central mudminnow	-	-	-	-	-	-	high	-	-	high	
quillback	-	-	-	-	medium	high	high	high	-	high	
longnose sucker	-	-	-	-	high	high	-	-	-	medium	
white sucker	-	-	-	medium	high	medium	-	-	-	medium	
lake chubsucker	-	-	-	-	medium	high	high	-	-	high	
northern hogsucker	-	-	-	-	high	medium	-	-	-	low	near mouths of

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
											streams
bigmouth buffalo	-	-	-	medium	medium	high	high	-	-	high	
spotted sucker	-	-	-	high	medium	medium	-	-	medium	low	
silver redhorse	-	-	high	high	high	-	-	-	-	low	
shorthead redhorse	-	-	-	high	high	high	-	-	-	low	
greater redhorse*	-	high	-	-	high	high	-	-	-	low	*adult habitat
goldfish	-	-	-	-	medium	high	high	high	-	high	
northern redbelly dace	-	-	-	-	medium	high	high	-	-	high	
finescale dace	-	-	-	-	medium	high	high	-	-	high	
lake chub	-	medium	-	high	high	high	low	-	-	high	
common carp	-	-	-	medium	medium	medium	high	-	-	high	
cutlips minnow	-	-	medium	high	high	-	-	-	-	low	
brassy minnow	-	-	-	-	medium	high	high	-	-	high	
eastern silvery minnow	-	-	-	-	-	-	high	-	-	high	
silver chub	-	-	-	-	high	medium	-	-	-	medium	

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
hornyhead chub	-	-	high	high	high	medium	low	-	-	low	
golden shiner	-	-	-	-	-	high	high	-	-	high	
pugnose shiner	-	-	-	-	medium	high	high	-	-	high	
emerald shiner	-	medium	medium	high	high	high	-	-	-	high	
bridle shiner	-	-	-	-	-	high	high	-	-	high	
common shiner	-	-	-	medium	high	medium	-	-	-	low	
blackchin shiner	-	-	-	-	high	high	high	-	-	high	
blacknose shiner	-	-	-	-	medium	high	-	-	-	high	
spottail shiner	-	-	medium	medium	high	high	-	-	-	high	
rosyface shiner	-	-	high	high	high	high	-	-	-	low	
spotfin shiner	-	-	-	-	high	high	high	-	-	medium	
sand shiner	-	-	-	-	high	high	-	-	-	medium	
redfin shiner	-	-	-	-	high	high	low	-	-	medium	
mimic shiner	-	-	-	-	medium	high	low	-	-	high	
pugnose minnow*	-	-	-	-	-	medium	high	high	-	high	*adult habitat
bluntnose minnow	-	medium	medium	high	high	medium	-	-	-	medium	

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
fathead minnow	-	-	-	-	medium	high	high	-	-	medium	
blacknose dace	-	-	-	high	high	medium	-	-	-	low	
longnose dace	-	-	medium	high	high	medium	-	-	-	low	
creek chub	-	-	-	high	high	high	-	-	-	low	
fallfish	-	-	-	high	high	-	-	-	-	low	
pearl dace	-	-	-	-	high	high	-	-	-	low	
central stoneroller	-	-	-	high	high	high	-	-	-	low	
striped shiner	-	-	-	-	high	high	low	-	-	low	
black bullhead	-	-	low	low	low	high	high	-	-	high	
yellow bullhead	-	-	-	-	medium	high	high	-	-	high	
brown bullhead	-	-	-	-	-	high	high	high	-	high	
channel catfish	-	-	high	high	high	high	high	high	-	medium	
stonecat	-	high	high	high	medium	-	-	-	-	medium	
tadpole madtom	-	-	-	-	medium	high	high	-	-	medium	
brindled madtom	-	medium	medium	medium	medium	medium	high	-	-	medium	
banded killifish	-	-	-	high	high	high	medium	-	-	high	

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
burbot	-	high	high	high	high	medium	medium	-	-	high	
brook stickleback	-	-	-	-	medium	high	high	-	-	high	
threespine stickleback	-	-	-	-	medium	high	high	-	-	high	
ninespine stickleback	-	-	medium	high	high	medium	medium	-	-	high	
fourspine stickleback	-	-	medium	medium	medium	high	high	-	-	high	
trout-perch	-	-	-	high	high	high	high	-	-	medium	
white perch[c]	medium	medium	medium	medium	medium	medium	medium	medium	medium	high	[c]no apparent preference
white bass	high	high	high	high	high	medium	low	low	medium	high	
rock bass	-	-	high	high	high	medium	medium	medium	-	high	
green sunfish	-	-	-	high	high	high	medium	medium	-	high	
pumpkinseed	-	-	-	-	high	high	-	medium	-	high	
bluegill	-	-	-	-	high	high	medium	-	-	high	
longear sunfish	-	-	-	-	high	medium	-	medium	medium	high	
smallmouth bass	medium[c]	-	-	high	high	medium	-	-	-	high	[c]with overlying

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
											gravel
largemouth bass	-	-	-	low	low	high	high	high	-	high	
white crappie	-	-	-	-	medium	low	low	high	high	high	
black crappie	-	-	-	-	high	high	high	-	-	high	
warmouth*	-	-	-	medium	high	high	medium	-	-	high	*hybridizes with pumpkinseed & bluegill
orangespotted sunfish	-	-	-	-	medium	high	high	-	-	high	
yellow perch	-	-	-	medium	high	high	medium	medium	-	high	
sauger	-	medium	high	high	high	medium	low	low	-	medium	
walleye	high[c]	high	high	high	high	high	-	-	high	medium	[c]underlying
eastern sand darter	-	-	-	-	medium	high	low	-	-	low	
greenside darter	-	high	high	high	high	-	-	-	-	low	
rainbow darter	-	-	high	high	high	high	-	-	-	low	
Iowa darter	-	-	-	high	high	high	high	-	-	medium	
fantail darter	-	-	high	high	high	high	-	-	-	low	

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
least darter	-	-	-	-	-	high	high	-	-	medium	
johnny darter	-	-	medium	medium	high	high	medium	medium	-	medium	
logperch	-	medium	medium	high	high	high	-	-	-	medium	
channel darter	-	high	high	high	high	-	-	-	-	low	
blackside darter	-	-	-	-	high	high	-	-	-	low	
river darter*	medium	medium	medium	high	high	-	-	-	-	low	*similar to channel and blackside darters
tesselated darter	-	-	-	high	high	high	-	-	-	low	
brook silverside	-	-	-	medium	medium	high	-	-	-	high	
freshwater drum	medium[c]	medium	medium	medium	medium	medium	medium	medium	medium	high	[c]eggs scattered randomly
mottled sculpin	-	high	high	high	high	high	-	-	-	medium	
slimy sculpin	-	high	high	high	high	low	low	-	-	medium	
spoonhead sculpin	high	high	high	high	low	-	-	-	-	high	
deepwater sculpin	high	high	high	low	-	-	-	high	high	high	
rudd*	-	-	-	-	-	high	high	-	-	high	*hybridizes with golden

Common Name	Substrate									Lake Affinity	Comments
	Bedrock	Boulder	Cobble	Rubble	Gravel	Sand	Silt	Clay	Hard-pan clay		
											shiner
ruffe	-	-	-	-	high	high	medium	high	high	high	
round goby	-	-	high	high	high	medium	-	-	-	high	
tubenose goby	-	-	high	high	high	medium	-	-	-	high	

Table 3 Season, range of water temperature and reproductive guild for Great Lakes fishes. Ranges given indicate temperatures above and below which a species will not spawn. Reproductive guilds correspond to Balon (1975) as follows: A.1 open substratum spawners = broadcast; A.2 brood hider = hide; B.2 nest spawners = nest. Other information is indicated with a [c] and details are given in the 'Comments' column. For species marked with an asterisk (*) inferences about relationships have been drawn. n/a = not available.

Common Name	Season	Temperature °C	Reproductive Guild	Comments
lake sturgeon	spring	13-21	broadcast	
longnose gar	spring	19-29	broadcast	
spotted gar	spring	21-26	broadcast	
bowfin	spring	16-19	broadcast	
alewife	spring	13-21	broadcast	
gizzard shad	spring	16-25	broadcast	
rainbow trout	spring	1-18	hide	
Atlantic salmon	fall	6.7[c]	hide	[c]peak
brown trout	fall	7-13	hide	
arctic charr	fall	0.5[c]	hide	[c]redd construction begins
brook trout	fall	2-13	hide	
lake trout	fall	3-14	hide	
lake whitefish	fall	1-12	broadcast	
cisco	fall	2-5	broadcast	
bloater	winter	n/a	broadcast	
kiyi	fall	n/a	broadcast	
shortnose cisco	spring	4-5	broadcast	
shortjaw cisco	fall	n/a	broadcast	
pygmy whitefish	fall	n/a	broadcast	
round whitefish	fall	2-4	broadcast	
rainbow smelt	spring	1-18	broadcast	
northern pike	spring	2-18	broadcast	
muskellunge	spring	8-18	broadcast	

Common Name	Season	Temperature °C	Reproductive Guild	Comments
grass pickerel	spring	6-12	broadcast	
central mudminnow	spring	13 (approx)	broadcast	
quillback	spring	19-28	broadcast	
longnose sucker	spring	2-15	broadcast	
white sucker	spring	6-23	broadcast	
lake chubsucker	spring	n/a	broadcast	
northern hogsucker	spring	10-16	broadcast	
bigmouth buffalo	spring	13-26	broadcast	
spotted sucker	spring	12-19	broadcast	
silver redhorse	spring	13[c]	broadcast	[c]spawning commences
shorthead redhorse	spring	11-21	broadcast	
greater redhorse	spring	17-19	broadcast	
goldfish	spring	16[c]	broadcast	[c]spawning commences
northern redbelly dace	spring	21-27	broadcast	
finescale dace	spring	13-18[c]	broadcast	[c]possibly triggered by temperature fluctuation
lake chub	spring	above 15[c]	broadcast	[c]commences
common carp	spring	17-28	broadcast	
cutlips minnow	spring	n/a	nest	
brassy minnow	spring	10-13	broadcast	
eastern silvery minnow	spring	13-21	broadcast	
silver chub	spring	19-23	broadcast	
hornyhead chub	spring	18-26	nest	
golden shiner	spring	20-27	broadcast	
pugnose shiner	spring	21-29	broadcast	
emerald shiner	spring	20-23	broadcast	

Common Name	Season	Temperature °C	Reproductive Guild	Comments
bridle shiner	spring	14-26	broadcast	
common shiner	spring	14-28	hide	
blackchin shiner	spring	n/a	broadcast	
blacknose shiner	spring	n/a	broadcast	
spottail shiner	spring	18-22	broadcast	
rosyface shiner	spring	20-29	broadcast	
spotfin shiner	spring	18-29	hide	
sand shiner	spring	21[c]	broadcast	[c]commences
redfin shiner	spring	21[c]	broadcast	[c] commences
mimic shiner	spring	n/a	broadcast	
pugnose minnow*	spring	n/a	broadcast	*adult habitat
bluntnose minnow	spring	20-28	nest	
fathead minnow	spring	16-29	nest	
blacknose dace	spring	12-27	hide	
longnose dace	spring	11-24	hide	
creek chub	spring	13-27	hide	
fallfish	spring	16[c]	hide	[c]commences
pearl dace	spring	17-18[c]	broadcast	[c]commences
central stoneroller	spring	12-27	hide	
striped shiner	spring	15-18[c]	hide	[c]commences
black bullhead	spring	12-25	nest	
yellow bullhead	spring	n/a	nest	
brown bullhead	spring	14-29	nest	
channel catfish	spring	18-29	nest	
stonecat	spring	25[c]	nest	[c]commences
tadpole madtom	spring	n/a	nest	
brindled madtom	spring	25[c]	nest	[c]commences

Common Name	Season	Temperature °C	Reproductive Guild	Comments
banded killifish	spring	21-32	broadcast	
burbot	winter	1-10	broadcast	
brook stickleback	spring	8-19	nest	
threespine stickleback	spring	10-23	nest	
ninespine stickleback	spring	9-17	nest	
fourspine stickleback	spring	n/a	nest	
trout-perch	spring	4-21	broadcast	
white perch	spring	11-15	broadcast	
white bass	spring	13-26	broadcast	
rock bass	spring	14-24	nest	
green sunfish	spring	20-28	nest	
pumpkinseed	spring	13-29	nest	
bluegill	spring	19-27	nest	
longear sunfish	spring	22-25	nest	
smallmouth bass	spring	13-24	nest	
largemouth bass	spring	14-21	nest	
white crappie	spring	14-23	nest	
black crappie	spring	16-26	nest	
warmouth*	spring	21.5[c]	nest	[c]commences *hybridization with bluegill and pumpkinseed
orangespotted sunfish	spring	18-32	nest	
yellow perch	spring	7-22	broadcast	
sauger	spring	4-12	broadcast	
walleye	spring	4-12	broadcast	
eastern sand darter	spring	14-24	broadcast	

Common Name	Season	Temperature °C	Reproductive Guild	Comments
greenside darter	spring	11-19	hide	
rainbow darter	spring	15[c]	broadcast	[c]commences
Iowa darter	spring	12-15	broadcast	
fantail darter	spring	19-24	hide	
least darter	spring	n/a	broadcast	
johnny darter	spring	17-25	nest	
logperch	spring	10-15[c]	hide	[c]commences
channel darter	spring	19-22	hide	
blackside darter	spring	16[c]	hide	[c]commences
river darter*	spring	n/a	hide	*similar to blackside and channel darters
tesselated darter	spring	13-19	nest	
brook silverside	spring	20-23	broadcast	
freshwater drum	spring	19-22	broadcast	
mottled sculpin	spring	6-16	nest	
slimy sculpin	spring	5-10	nest	
spoonhead sculpin	fall	4.5[c]	nest	[c]ripe male caught at this temp.
deepwater sculpin	winter	11[c]	nest	[c]larvae collected
rudd*	spring	20-27	broadcast	*hybridizes with golden shiner
ruffe	spring	6-18	broadcast	
round goby	spring	n/a	nest	
tubenose goby	spring	n/a	nest	

Table 4 Number of species that spawn within each depth stratum.

Water Depth (m)	Present	Not Present
0-1	114	6
1-2	75	45
2-5	38	82
5+	23	97

Table 5 Number of species associated with each substrate and with cover, by strength of association.

Substrate	Strength of Association			
	Low	**Medium**	**High**	**None**
Bedrock	0	6	6	108
Boulder	0	13	16	91
Cobble	1	17	26	76
Rubble	4	15	52	49
Gravel	3	21	82	14
Sand	4	25	77	14
Silt	11	32	43	34
Clay	3	8	17	92
Hard-pan Clay	0	6	7	107
Submergent Vegetation	20	16	33	51
Emergent Vegetation	20	13	36	51
Other Cover	N/A	N/A	45	N/A

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Appendix A

Great Lakes Basin Fish Species List

CODE	Common name	Scientific Name
S011	American brook lamprey	*Lampetra appendix*
S012	Northern brook lamprey	*Ichthyomyzon fossor*
S013	Silver lamprey	*Ichthyomyzon unicuspis*
S014	Sea lamprey	*Petromyzon marinus*
S031	Lake sturgeon	*Acipenser fulvescens*
S041	Longnose gar	*Lepisosteus osseus*
S042	Spotted gar	*Lepisosteus oculatus*
S051	Bowfin	*Amia calva*
S061	Alewife	*Alosa pseudoharengus*
S062	American shad	*Alosa sapidissima*
S063	Gizzard shad	*Dorosoma cepedianum*
S071	Pink salmon	*Oncorhynchus gorbuscha*
S072	Chum salmon	*Oncorhynchus keta*
S073	Coho salmon	*Oncorhynchus kisutch*
S075	Chinook salmon	*Oncorhynchus tshawytscha*
S076	Rainbow trout	*Onchorhynchus mykiss*
S077	Atlantic salmon	*Salmo salar*
S078	Brown trout	*Salmo trutta*
S079	Arctic charr	*Salvelinus alpinus*
S080	Brook trout	*Salvelinus fontinalis*
S081	Lake trout	*Salvelinus namaycush*
S082	Splake	*Salvelinus* hybrid 080x081
S091	Lake whitefish	*Coregonus clupeaformis*
S093	Cisco(lake herring)	*Coregonus artedi*
S094	Bloater	*Coregonus hoyi*
S095	Deepwater cisco(chub)	*Coregonus johannae*
S096	Kiyi	*Coregonus kiyi*
S097	Blackfin cisco	*Coregonus nigripinnis*
S099	Shortnose cisco	*Coregonus reighardi*
S100	Shortjaw cisco	*Coregonus zenithicus*
S101	Pygmy whitefish	*Prosopium coulteri*
S102	Round whitefish	*Prosopium cylindraceum*
S121	Rainbow smelt	*Osmerus mordax*
S131	Northern pike	*Esox lucius*
S132	Muskellunge	*Esox masquinongy*
S133	Grass pickerel	*Esox americanus vermiculatus*
S136	Tiger muskellunge	*Esox* hybrid 131x132
S141	Central mudminnow	*Umbra limi*
S152	Mooneye	*Hiodon tergisus*
S161	Quillback	*Carpoides cyprinus*
S162	Longnose sucker	*Catostomus catostomus*
S163	White sucker	*Catostomus commersoni*
S164	Lake chubsucker	*Erimyzon sucetta*
S165	Northern hog sucker	*Hypentelium nigricans*
S166	Bigmouth buffalo	*Ictiobus cyprinellus*
S167	Spotted sucker	*Minytrema melanops*
S168	Silver redhorse	*Moxostoma anisurum*
S169	Black redhorse	*Moxostoma duquesnei*

S170	Golden redhorse	*Moxostoma erythrurum*
S171	Shorthead redhorse	*Moxostoma macrolepidotum*
S172	Greater redhorse	*Moxostoma valenciennesi*
S173	River redhorse	*Moxostoma carinatum*
S181	Goldfish	*Carassius auratus*
S182	Northern redbelly dace	*Phoxinus eos*
S183	Finescale dace	*Phoxinus neogaeus*
S184	Redside dace	*Clinostomus elongatus*
S185	Lake chub	*Couesius plumbeus*
S186	Common carp	*Cyprinus carpio*
S187	Gravel chub	*Erimystax x-punctata*
S188	Cutlips minnow	*Exoglossum maxillingua*
S189	Brassy minnow	*Hybognathus hankinsoni*
S190	Eastern silvery minnow	*Hybognathus regius*
S191	Silver chub	*Macrohybopsis storeriana*
S192	Hornyhead chub	*Nocomis biguttatus*
S193	River chub	*Nocomis micropogon*
S194	Golden shiner	*Notemigonus crysoleucas*
S195	Pugnose shiner	*Notropis anogenus*
S196	Emerald shiner	*Notropis atherinoides*
S197	Bridle shiner	*Notropis bifrenatus*
S198	Common shiner	*Luxilus cornutus*
S199	Blackchin shiner	*Notropis heterodon*
S200	Blacknose shiner	*Notropis heterolepis*
S201	Spottail shiner	*Notropis hudsonius*
S202	Rosyface shiner	*Notropis rubellus*
S203	Spotfin shiner	*Cyprinella spiloptera*
S204	Sand shiner	*Notropis stramineus*
S205	Redfin shiner	*Lythrurus umbratilis*
S206	Mimic shiner	*Notropis volucellus*
S207	Pugnose minnow	*Opsopoeodus emiliae*
S208	Bluntnose minnow	*Pimephales notatus*
S209	Fathead minnow	*Pimephales promelas*
S210	Blacknose dace	*Rhinichthys atratulus*
S211	Longnose dace	*Rhinichthys cataractae*
S212	Creek chub	*Semotilus atromaculatus*
S213	Fallfish	*Semotilus corporalis*
S214	Pearl dace	*Margariscus margarita*
S215	Silver shiner	*Notropis photogenis*
S216	Stoneroller	*Campostoma anomalum*
S217	Striped shiner	*Luxilus chrysocephalus*
S218	Ghost shiner	*Notropis buchanani*
S231	Black bullhead	*Ameiurus melas*
S232	Yellow bullhead	*Ameiurus natalis*
S233	Brown bullhead	*Ameiurus nebulosus*
S234	Channel catfish	*Ictalurus punctatus*
S235	Stonecat	*Noturus flavus*
S236	Tadpole madtom	*Noturus gyrinus*
S237	Brindled madtom	*Noturus miurus*
S244	Northern madtom	*Noturus stigmosus*
S251	American eel	*Anguilla rostrata*
S261	Banded killifish	*Fundulus diaphanus*
S262	Blackstripe topminnow	*Fundulus notatus*
S271	Burbot	*Lota lota*
S281	Brook stickleback	*Culaea inconstans*
S282	Threespine stickleback	*Gasterosteus aculeatus*
S283	Ninespine stickleback	*Pungitius pungitius*
S284	Fourspine stickleback	*Apeltes quadracus*

S291	Trout-perch	*Percopsis omiscomaycus*
S301	White perch	*Morone americana*
S302	White bass	*Morone chrysops*
S311	Rock bass	*Ambloplites rupestris*
S312	Green sunfish	*Lepomis cyanellus*
S313	Pumpkinseed	*Lepomis gibbosus*
S314	Bluegill	*Lepomis macrochirus*
S315	Longear sunfish	*Lepomis megalotis*
S316	Smallmouth bass	*Micropterus dolomieu*
S317	Largemouth bass	*Micropterus salmoides*
S318	White crappie	*Pomoxis annularis*
S319	Black crappie	*Pomoxis nigromaculatus*
S323	Warmouth	*Lepomis gulosus*
S324	Orangespotted sunfish	*Lepomis humilis*
S331	Yellow perch	*Perca flavescens*
S332	Sauger	*Stizostedion canadense*
S334	Walleye	*Stizostedion vitreum vitreum*
S335	Eastern sand darter	*Ammocrypta pellucida*
S336	Greenside darter	*Etheostoma blennioides*
S337	Rainbow darter	*Etheostoma caeruleum*
S338	Iowa darter	*Etheostoma exile*
S339	Fantail darter	*Etheostoma flabellare*
S340	Least darter	*Etheostoma microperca*
S341	Johnny darter	*Etheostoma nigrum*
S342	Logperch	*Percina caprodes*
S343	Channel darter	*Percina copelandi*
S344	Blackside darter	*Percina maculata*
S345	River darter	*Percina shumardi*
S346	Tessellated darter	*Etheostoma olmstedi*
S361	Brook silverside	*Labidesthes sicculus*
S371	Freshwater drum	*Aplodinotus grunniens*
S381	Mottled sculpin	*Cottus bairdi*
S382	Slimy sculpin	*Cottus cognatus*
S383	Spoonhead sculpin	*Cottus ricei*
S384	Deepwater sculpin	*Myoxocephalus thompsoni*
S601	CarpxGoldfish	Hybrid 181x186
S220	Rudd	*Scardinius erythrophthalmus*
S355	Ruffe	*Gymnocephalus cernuus*
S366	Round goby	*Neogobius melanostomus*
S367	Tubenose goby	*Proterorhinus marmoratus*

APPENDIX B
Riverine spawners

Common Name	References
American brook lamprey	1, 78, 132
northern brook lamprey	1, 78, 92
silver lamprey	1, 78
sea lamprey	1, 47, 78
American shad	77
pink salmon	20, 47, 71
chum salmon	11
coho salmon	47
chinook salmon	18, 47
mooneye	1, 47, 141
black redhorse	10, 47, 72, 108
golden redhorse	23, 47, 72
river redhorse	106
redside dace	86, 113
river chub	26, 47, 83
silver shiner	86
ghost shiner	5, 55
northern madtom	45, 126
blackstripe topminnow	85