Biological Synopsis of Largemouth Bass (*Micropterus salmoides)*

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BIOLOGICAL SYNOPSIS OF LARGEMOUTH BASS (*Micropterus salmoides)*

by

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ABSTRACT

Brown, T. G., Runciman, B., Pollard, S., and Grant, A.D.A. 2009. Biological synopsis of largemouth bass (*Micropterus salmoides)*. Can. Manuscr. Rep. Fish. Aquat. Sci. 2884: v + 27 p.

This synopsis reviews biological information on the largemouth bass in support of a risk assessment evaluating the impacts of its expansion into non-native areas of Canada. Largemouth bass is native to the fresh waters of eastern-central North America. Its North American expansion started in the late 1800s and it is now one of the most widely distributed fishes in the world, mainly because of its popularity among anglers. Largemouth bass reside in swamps, ponds, lakes, reservoirs, creeks, estuaries, and large rivers. They are more tolerant of low dissolved oxygen and pH than are smallmouth bass and feed primarily by sight. Adult bass are primarily piscivorous and consume a wide variety of small-bodied and juvenile fish. Introduced bass usually alter fish communities through predation, especially on small-bodied fish such as minnows and can extirpate some populations. Largemouth bass also consume juvenile salmonids, especially when they are migrating.

RESUME

Brown, T. G., Runciman, B., Pollard, S and Grant, A.D.A. 2009. Biological synopsis of largemouth bass (*Micropterus salmoides)*. Can. Manuscr. Rep. Fish. Aquat. Sci. 2884: v + 27 p.

Le présent synopsis examine les données biologiques sur l’achigan à grande bouche pour appuyer une évaluation des risques portant sur les effets de l’expansion de son aire de répartition vers des régions non indigènes au Canada. L’achigan à grande bouche est un poisson d’eau douce indigène du centre-est de l’Amérique du Nord. L’expansion de son aire de répartition en Amérique du Nord a débuté à la fin des années 1800 et il s’agit aujourd’hui de l’un des poissons les plus répandus dans le monde, principalement en raison de sa popularité auprès des pêcheurs à la ligne. L’achigan à grande bouche fréquente les marécages, les étangs, les lacs, les réservoirs, les ruisseaux, les estuaires et les grands cours d’eau. Il est plus tolérant que l’achigan à petite bouche à une faible teneur en oxygène dissous et à un pH faible. Cet achigan dépend de sa vue pour repérer ses proies. L’achigan adulte est surtout piscivore et consomme une grande variété de juvéniles et de poissons de petite taille. Étant de grands prédateurs, les achigans introduits altèrent les communautés de poissons, particulièrement les poissons de petite taille comme les ménés, et peuvent causer la disparition de certaines populations. L’achigan à grande bouche consomme également des salmonidés juvéniles, particulièrement pendant leur migration.

1.0 INTRODUCTION

The introduction of non-native species is a serious threat to fish communities in Canadian lakes and rivers. Highly adaptable species can spread far beyond their initial point of introduction, along many pathways, with effects that range from simple competition and predation to subtle but far-reaching alterations of communities and ecosystems.

Largemouth bass *Micropterus salmoides* is native to North America. It is a capable invader, a strong competitor, and a known predator on native fish species. Its range in Canada has expanded west to British Columbia and east into New Brunswick. Invasive largemouth bass should be considered a potential threat to freshwater biodiversity not only through its ability to alter native minnow communities but also for the potential to impact salmonid populations.

The purpose of this synopsis is to provide background biological information that can be used to estimate the level of risk inherent in expansion of largemouth bass range in Canada. The synopsis summarizes the biology, life history, current distribution and known impacts of the species.

1.1 NAME, CLASSIFICATION, AND IDENTIFIERS

Kingdom: Animalia
Phylum: Chordata
Subphylum: Vertebrata
Class: Actinopterygii
Order: Perciformes
Suborder: Percoidei
Family: Centrarchidae
Genus: *Micropterus*
Species: *salmoides*

Scientific Name: *Micropterus salmoides* Lacepède (1802)
Common name (English): largemouth bass
Common name (French): achigan à grande bouche

Integrated Taxonomic Information System Serial Number: 168160
Sources: Zip Code Zoo; Animal Diversity Web (all 2008).

The scientific name for largemouth bass is derived from the Greek *micropterus*, “small fin” and the Latin *salmoides*, “trout-like.” The “small fin” naming is a misnomer based on a specimen with a damaged fin. The common name describes its most obvious physical characteristic; numerous other regional common names can be found in Scott and Crossman (1973).

1.2 DESCRIPTION

Members of the sunfish family have two dorsal fins that appear joined. The anterior fin has spines and the posterior one has soft rays (Scott and Crossman 1973). Although members of the sunfish family are usually laterally flattened (compressiform), basses tend to be slightly more fusiform (streamlined), with an emarginated tail. This implies that they can swim faster in open water and have excellent acceleration.

The body of largemouth bass is slightly compressed laterally, but oval in cross section (Scott and Crossman 1973). In Canada, the species is most commonly caught between 200 and 380 mm in length, although larger fish are taken in tournaments (Scott and Crossman 1973). Specimens up to 500 mm long have been caught in British Columbia (McPhail 2007). The present record largemouth bass was caught in Georgia in 1932; it was 827 mm long and weighed 10.1 kg (Scott and Crossman 1973).

The most distinctive feature of the largemouth bass is its very large, sloping mouth that extends past the eye. The pharyngeal jaws are well-developed, with fine brush like teeth in the upper and lower pharynx (Scott and Crossman 1973). No teeth are found on the tongue. The notch between the anterior and posterior dorsal fins is deep.

The top of the head and back of largemouth bass are dark to light green (Figure 1), while the underside of the head and belly are lighter (Scott and Crossman 1973). A lateral stripe or black shading may run along the lateral line from the snout to the tail, especially in juveniles (Moyle 2002). The eye may have a black opercular spot. Males tend to be darker during breeding, and bass will vary in colouration when taken from lakes with different substrates (Scott and Crossman 1973).

Smallmouth and largemouth bass can be easily told apart. While the maxilla of the smallmouth is roughly even with the pupil of the eye and the upper jaw reaches to near the rear margin of the eye, the largemouth bass upper and lower jaws extend past the back edge of the eye. The largemouth has a more pronounced notch between the spiny and soft parts of the dorsal fin irregular bars forming a strip along the side. The eye of largemouth is gold, while the smallmouth bass eye is often red.

Figure 1. Largemouth bass *Micropterus salmoides*. Image courtesy of the New York State Department of Environmental Conservation, Albany NY.

1.2.1 Taxonomy and genetics

The Centrarchidae or sunfish family is native to North America and is the second largest on the continent, with 30 species (Scott and Crossman 1973). Male centrarchids build nests and guard eggs (McPhail 2007). The genus *Micropterus* contains eight species of bass (Near et al. 2003) one of which is the largemouth bass.

There are two subspecies of largemouth bass, commonly referred to as the Northern and Florida subspecies (Bailey and Hubbs 1949). *Micropterus salmoides salmoides* Smith (1965) originally inhabited the lower Great Lakes drainage, middle Mississippi system, Florida, and coastal watersheds from Georgia to Virginia. This Northern subspecies has 15 abdominal vertebrae. The Florida subspecies *Micropterus salmoides floridanus* LeSueur (1949) now inhabits Florida and some parts of Georgia. The two subspecies will hybridize, with the Florida strain becoming dominant (Moyle 2002).

2.0 DISTRIBUTION

2.1 GLOBAL NATIVE DISTRIBUTION

Largemouth bass are native to North America, and its native range was generally restricted to the fresh waters of eastern-central North America including the lower Great Lakes (Scott and Crossman 1973; Figure 2). The native range extended south from Ontario to Iowa, through Texas and into north-eastern Mexico, and east to Florida and Virginia (McPhail 2007).

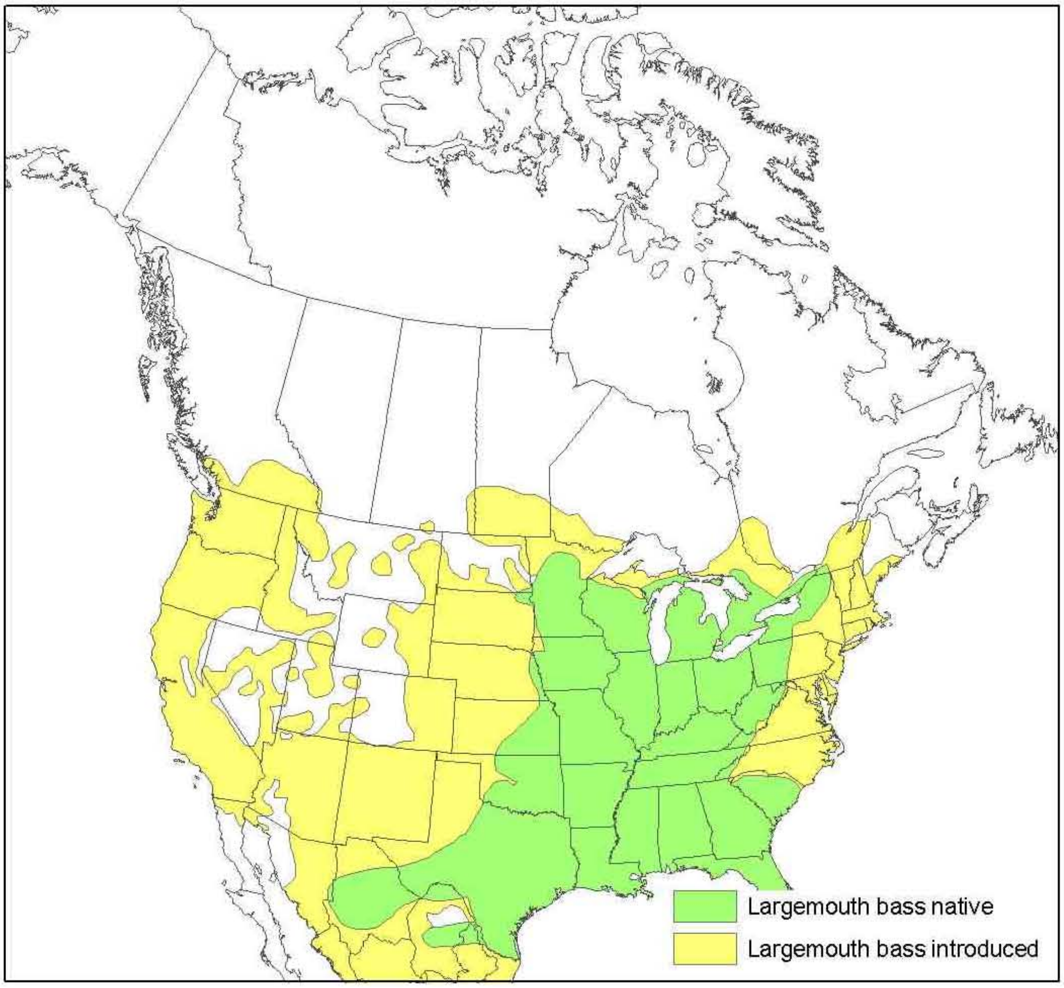

Figure 2. Native and non-native range of largemouth bass from Tovey et al. (2008).

2.2 NON-NATIVE DISTRIBUTION

Largemouth bass is now one of the most widely distributed freshwater fishes in the world, mainly because of its popularity as a sports fish. In the U.S., it is absent from only Alaska (Scott and Crossman 1973). Its North American expansion started in the late 1800s, aided by extensive stocking and the species' adaptable nature. It is now abundant throughout the Appalachian and Ozark Ranges, most of the north-eastern U.S. from Maryland to Maine, and eastern Canada. A largemouth bass was captured in the Magaquadavic River, New Brunswick, in 2006 (ASF 2006). Largemouth bass are now available to more U.S. anglers than any other species of fish.

In Ontario, largemouth bass are found in the lower Great Lakes and inland waters of southern Ontario, and have expanded their range further north in eastern Ontario and into south-western Ontario. In 1990, they were estimated to inhabit 1,275 lakes in the province (Ontario Ministry of Natural Resources 1990).

In Quebec, largemouth bass are found in the Saint Lawrence River and in the Richelieu-Lake Champlain system (Scott and Crossman 1973). Expansion to the north has been more limited.

Largemouth bass have been introduced into the Prairie Provinces. Langhorne et al. (2001) and Nelson and Paetz (1992) described their introduction into Alberta as unsuccessful; the attempts included Lakes Minnewanka, Sylvan, Gull, Pine, Buffalo and Cooking (in 1908), Ministik Lake in 1924 and Pigeon, Wabamun and Lac La Nonne in the 1990s. In Saskatchewan, successful introductions were made into Boundary Reservoir on the Souris River (Langhorne et al. 2001). In Manitoba, largemouth bass were introduced into Fort Whyte Nature Centre, Lake Minnewasta, and Lake of the Woods; pockets of survivors persist (Langhorne et al. 2001).

Both large and smallmouth bass are thought to have entered southern B.C. through natural dispersal from Idaho by way of Washington (Scott and Crossman 1973; McPhail 2007), where non-native centrachids, ictalurids, percid, and salmonids were introduced by the U.S. Fish Commission during the late 19th and early 20th centuries (Wydoski and Whitney 2003; Bonar et al. 2005). The first largemouth bass in B.C. were recorded in Vaseaux Lake in 1909 (Field and Dickie 1987) and in the Kootenay River system in 1921 (Dymond 1936). Bass have dispersed within the Columbia, Kootenay and Okanagan regions through natural movements and illegal introductions. In the Fraser Valley, largemouth bass were introduced into the Sumas River and have spread into numerous water bodies including Hatzic and Silvermere Lakes and the Pitt and Salmon Rivers (McPhail 2007; Runciman and Leaf 2009). The species has recently been confirmed in two Vancouver Island lakes (Runciman and Leaf 2009).

Brown et al. (2009a,b) discuss modes of invasion and rate of spread of yellow perch and smallmouth bass. Seven key non-authorized pathways for introduction and spread were examined; authorized introductions were also considered. Largemouth bass introductions are likely to follow a similar pattern. In British Columbia spread likely occures through illegal introductions into new water bodies, from which they can move through interconnected waterways to invade adjoining streams and lakes.

Authorized introductions or transfers of largemouth bass have been made in B.C. Five such recorded transfers took place between 1987 and 1993 in the Okanagan and Kootenay regions. A transfer of largemouth bass from Osoyoos Lake to landlocked Deadman Lake in 1987 was the only recorded transfer in the Kootenay Region. Several transfers of largemouth bass were made in the Okanagan Region in 1988-89. Largemouth bass have also invaded many of the streams and backwaters of the lower Fraser River Basin. McPhail (2007) concluded that illegal introduction of bass and perch species is of particular concern to fisheries and ecosystems managers.

3.0 BIOLOGY AND NATURAL HISTORY

3.1 AGE AND GROWTH

Rapid growth of bass fry is critical to their surviving the first winter. Growth of young-of-the-year bass was positively related to water and air temperatures in June-August (Scott and Crossman 1973). Length of the growing season determined the size of bass fry entering winter, and size of young-of-the-year in autumn is linked to over-winter survival (Jackson and Mandrak 2002). Shuter et al. (1980) noted that growth of smallmouth bass ceased and the winter starvation period began when temperatures dropped below 7-10^{O}C. The critical size at the end of the growing season was dependent upon the length of the starvation period. Winter temperature and duration, combined with factors such as geographic origin, food availability, and initial body size were major factors influencing recruitment of age-0 largemouth bass (Fullerton et al. 2000). A young-of-the-year recruitment index has been developed for largemouth bass in Ontario lakes (Minns et al. 2005).

Growth rates and body size at age vary throughout the bass range (Garvey and Marschall 2003). Growth rate is typically higher in southern regions, and depends more on availability of the right size of forage. Hill and Cichra (2005) presented a table of length to weight for largemouth bass. In Lake Washington, Stein (1970) measured growth rates and developed size tables for nine year-classes of largemouth bass. A rough estimate of largemouth biomass for Lake Washington was 1,340 kg or 0.5 kg/acre. In Ontario, it takes largemouth bass 4-5 years to reach 30 cm (Scott and Crossman 1973), and average normal adult growth over a wide mid-eastern area was estimated to be 450 g/year (Stuber et al. 1982). It takes about 1.8 kg of food to produce 0.5-kg of largemouth bass (Scott and Crossman 1973).

The maximum age of largemouth bass in Ontario is 13-15 years, at which time the fish may reach 55 cm and weigh around 2 kg. The largest Canadian largemouth bass was caught in Preston Lake, Ontario in 1948, and weighed 4.7 kg (Scott and Crossman 1973).

3.2 PHYSIOLOGICAL TOLERANCES

3.2.1 Temperature

Temperature requirements vary depending upon the life stage and activity. The temperature for optimal growth of adult largemouth bass is 24-30 ^{O}C (Venables et al. 1978; Stuber et al. 1982). The minimum temperature that permits growth is 15 ^{O}C and the maximum is 36 ^{O}C (Stuber et al. 1982). For spawning and incubation, optimal temperature is 20-21 ^{O}C (Clugston 1964) with a range of 13-26 ^{O}C (Kelley 1968). Survival of eggs and embryos is unlikely above 30 ^{O}C (Kelley 1968) or below 10 ^{O}C (Kramer and Smith 1960). Fry growth is optimal between 27 and 30 ^{O}C, and growth will cease below 15 ^{O}C and above 32^{O}C (Strawn 1961; Stuber et al. 1982). The growth rate of sub-adult largemouth bass was fastest at temperatures between 26 and 28 ^{O}C (Coutant and Cox 1976).

3.2.2 Dissolved oxygen and pH

Largemouth bass are more tolerant of low dissolved oxygen and pH than are smallmouth bass (Scott and Crossman 1973; Lasenby and Kerr 2000). Largemouth bass avoid waters with dissolved oxygen below 3 mg/l but can survive at 1.5 mg/l when temperatures are optimal (Scott and Crossman 1973). Levels below 1.0 mg/l are lethal (Stuber et al. 1982). Lower oxygen levels, plus the weedy environment they prefer, may subject largemouth bass to winterkill (Scott and Crossman 1973).

The optimal pH range for largemouth bass is 6.5-8.5 (Stroud 1967). They will tolerate short-term exposure to a pH minimum of 3.9 and maximum of 10.9; however, bass will not spawn at pH less than 5.0, and eggs do not survive at pH above 9.6 (Stuber et al. 1982).

3.2.3 Turbidity

Largemouth bass are intolerant of high turbidity (suspended solids) and do best at turbidities below 25 ppm, although some growth can occur in ponds between 25-100 ppm (references cited in Stuber et al. 1982). No young-of-the-year were found above 100 ppm. Optimum suspended solid levels were assumed to be between 5 and 25 ppm, with low productivity at the minimum value (references cited in Stuber et al. 1982).

3.2.4 Salinity

Largemouth bass generally inhabit waters that range from fresh to oligohaline (0.5-5.0 ppt), although some individuals have been reported from tidal freshwater and estuaries with salinities up to 24 ppt (Moyle 2002; Peer et al. 2006). Tebo and McCoy (1964) noted that largemouth bass abundance declined above approximately 4 ppt. Embryonic development was impaired at 1.5 ppt, and survival was zero at salinities above 10.5 ppt. Fry growth declined at 1.7 ppt and was zero at 6 ppt (Tebo and McCoy 1964).

3.3 REPRODUCTION

Female largemouth bass commonly attain nine years of age, while males reach six years. In Canada, males reach sexual maturity by ages three to four, and females at four to five (Scott and Crossman 1973; Roberge et al. 2001; McPhail 2007). In warmer southern regions, females can mature much faster, allowing for year-round growth (Stuber et al. 1982).

3.3.1 Spawning behaviour

Spawning starts in late spring and continues into early summer or even August, with peak spawning in mid-June (Scott and Crossman 1973). Nest selection and construction by males commences when water temperature reaches at least 15.6^{O}C (Roberge et al. 2001; McPhail 2007). The male begins the spawning process by clearing out a nest or small saucer-shaped depression with its tail about 1 m in diameter (Moyle 2002). Nests are generally found in sand, gravel, debris and soft mud near reeds, bulrushes and water lilies (Roberge et al. 2001; Moyle 2002; McPhail 2007). The nests are constructed in shallow water, often around 1 m deep (Moyle 2002; McPhail 2007). Suitable spawning areas may hold multiple bass nests but these will be about 2 m apart due to the aggressive nature of the males (Scott and Crossman 1973; Moyle 2002; McPhail 2007). Scott and Crossman (1973) stated that largemouth bass may spawn with very little nest preparation, and eggs can be deposited on submerged rootlets, logs, as well as submerged vegetation in the prepared site.

Most spawning occurs at dusk or dawn (McPhail 2007). Courtship begins when a gravid female approaches a nest. Not all eggs are shed in the first spawning and females may spawn again with the same or another male (Roberge et al. 2001; McPhail 2007). A female largemouth bass may lay 4,000-14,000 eggs per kg of body weight (Scott and Crossman 1973). As body size is highly variable, this may represent from 2,000 to 94,000 or more eggs (Moyle 2002). Stein (1970) reported bass fecundity in Lake Washington by age as ranging from 21,000 at age 3 to 46,015 at age 7. Large adults spawn earlier, which may advance the time of swim-up for larval bass, thus improving growth rate and next year's recruitment (Goodgame and Miranda 1993).

3.3.2 Larval care and development

After the female bass leaves the nest, the male guards the eggs and developing larvae. Eggs hatch within three to five days (Scott and Crossman 1973; Roberge et al. 2001) at the water temperatures typically found in Canada. Upon hatching, young largemouth bass fry are transparent and approximately 3 mm in length (Hardy 1978). The young remain in the nest until the yolk is absorbed (10 days), then rise from the nest (Hardy 1978), by which time they are 5.9-6.3 mm long (Scott and Crossman 1973) and have turned a light brown to pale green (McPhail 2007).

Scott and Crossman (1973) noted that predation on young bass and nest deterioration were two of the major causes for poor survival of eggs and young-of-the-year. While the larvae of most sunfish species disperse soon after rising from the nest, largemouth bass larvae stay in a protected "brood swarm" for 3-4 weeks (Scott and Crossman 1973). On average there are about 5-7,000 fry per nest (Scott and Crossman 1973), dispersed during the day, but the swarm becomes more compact at night (McPhail 2007). After the swarm disperses, the male bass resumes feeding and may even consume young bass.

3.3.3 Factors affecting reproductive success

Like smallmouth bass, largemouth spawning success can be attributed to good spawning locations and stable weather during spawning. Factors affecting reproduction and survival include water-level fluctuation (Hill and Cichra 2005), wind and wave action, water quality, cover, temperature (especially a rapid drop), predation and human activities (Allan and Romero 1975). If conditions are not favourable, largemouth males may abandon the nest and the eggs and fry can be consumed by other fish.

3.4 FEEDING AND DIET

3.4.1 Juvenile diet

Stein (1970) examined the feeding and diet of largemouth bass young in Lake Washington, dividing the fry (< 100 mm) into 20 mm size classes. The smallest size class (21-40 mm) consumed cladocera, copepoda, dipteran larvae, dipteran pupae, and amphipoda. When fry reached 61-80 mm, they ate less cladocera, copepoda and dipteran larva, and more dipteran pupae, ephemeropteran nymphs and small cottid fish (5%). By the time the bass were 81-100 mm, fish are found in 29% of the stomachs, along with mysids, ephemeropteran nymphs,, isopoda , dipteran larvae and pupae, cladocera and copepoda. There was thus a continuing diet shift from small zooplankton to small insect larva to larger insect pupae and nymphs to larger mysidacea and isopoda, and finally to fish.

3.4.2 Transition to piscivory

Stein (1970) examined adult largemouth bass diet in Lake Washington, and found fish in 57% of the stomachs of bass > 10 cm in length. In the larger bass, fish prey represented 87% of total gut volume. The main fish species found in adult largemouth bass stomachs were cottidae (44.6%), salmonidae (13.9%), cyprinidae (11.7%) and centrarchidae (5.6%). Crustacea (13% by volume) were also a major food item. Insecta represented only 0.6% of the gut volume; chironomid pupae and larvae were the most frequent items.

The dietary shift from insects to fish appears to be crucial to growth and survival (Post 2003). A diet of fish provides higher energy and corresponds to faster growth later in the season (Keast and Eadie 1985). In Lake Opinicon, Ontario, a growth discrepancy of 26 mm in young-of-the-year largemouth bass in September was attributed to size-dependent differences in diet and prey availability (Keast and Eadie 1985). Post (2003) felt that a 10-day variation in hatching dates and a higher than average growth rate was required to cause an early switch in diet, sustain piscivory in the first summer, increase growth rate, and decrease mortality. The availability of specific prey items may also be critical in the transition from an entomostracan diet to a diet of fish; Applegate and Mullan (1967) noted that chironomid larva could “bridge the gap” at this crucial time.

Largemouth bass swallow prey whole, and the ratio between gape and prey size is critical in determining when largemouth bass become piscivorous (Hill and Cichra 2005). The size at niche shift (to fish diet) is highly variable. The shift from insects to gizzard shad in an Arkansas reservoir occurred at 40 mm (Applegate and Mullan 1967), earlier than the Lake Washington study cited above (Stein 1970). In a non-vegetated lake in Florida, the shift took place at 60 mm, while in a vegetated lake in Florida it occurred at 120 mm. In a vegetated Texas Lake, a shift to a fish diet did not occur until 140 mm (Hill and Cichra 2005).

3.4.3 Adult diet

Adult bass are primarily piscivorous and consume a wide variety of small-bodied and juvenile fish; prey items and the authorities cited can be found in Lasenby and Kerr (2000), who list more than 20 species including minnow, bullhead, yellow perch, other sunfish and rainbow trout. Largemouth bass are also cannibalistic; Scott and Crossman (1973) stated that cannibalism is higher than in smallmouth bass, and that up to 10% of the food of largemouth bass 203 mm and over was fry of the same species. Crayfish, frogs, and salamanders are also consumed (Scott and Crossman 1973; Hickley et al. 1994; Lasenby and Kerr 2000). Schindler et al. (1997) reported that the aggregate bass diet did not change over 10 years of study, although each bass sampled might consume different items. Re-examination of individual bass revealed that a given fish exhibited high diet consistency, independent of population densities.

Crayfish may play an important role in adult largemouth bass diet, but are more likely to represent a higher portion of the smallmouth bass diet (Scott and Crossman 1973; Moyle 2002). This may be due to differences in the preferred habitat types: crayfish are abundant in rocky areas that would be preferred by smallmouth bass, while minnows are more abundant in the weedy habitats favoured by largemouth bass (Mueller and Rothaus 2001).

For the two years examined, fish represented 80% and 88% of largemouth bass diet in Lake Sammanish, Washington (Pflug 1981). Largemouth bass consumed a higher percentage salmonids than did smallmouth bass. Bonar et al. (1994) found that largemouth bass diet corresponded to the availability of forage fish in three Washington lakes. If forage fish and insects were abundant, bass diet consisted almost entirely of fish. In a bass-crowded lake, insects were more significant. As largemouth bass size increased, so did prey size.

3.5 HABITAT REQUIREMENTS

Largemouth bass reside in all types of water, including swamps, ponds, lakes, reservoirs, creeks, estuaries, and large rivers (Scott and Crossman 1973), and have been reported to utilize inundated southern floodplains (Hill and Cichra 2005). Lacustrine environments tend to be preferred (Scott and Crossman 1973; Stuber et al. 1982). The best largemouth bass lakes have considerable shallow littoral zones, extensive submergent vegetation and, in northern latitudes, enough area to provide over-wintering habitat (Winter 1977; Stuber et al. 1982). Pflug (1981) described largemouth bass in Lake Sammamish, Washington as occupying sites with moderate to dense growths of aquatic vegetation, shallow water and substrates of silt and sand.

Lasenby and Kerr (2000) described the general habitat requirements of largemouth bass in Ontario. Largemouth bass prefer ponds greater than 0.1 ha in surface area with a muddy or gravel substrate. They occupy waters generally less than 6 m deep. Preferred habitats exhibit little current, have slight to moderate water clarity, and should support moderate densities of aquatic vegetation. Bass prefer shaded areas and seek protect from light during all stages of life (Baker et al. 1993).

Riverine largemouth bass habitat is characterized as wide and slow-moving, with pools and backwaters, mud/silt bottoms, aquatic vegetation, and relatively clear water (Scott and Crossman 1973; Stuber et al. 1982). The species prefers weedy backwaters of larger systems and clear floodplain lakes (Moyle 2002).

3.5.1 Aquatic vegetation

The importance of aquatic vegetation for largemouth bass has been well documented (Scott and Crossman 1973; Stuber et al. 1982; Roberge et al. 2001), and the relationship between bass and rooted aquatic weeds may be complex. Dense aquatic vegetation may reduce predation on young bass, and prey densities may be higher. Largemouth bass are ambush predators that use the weeds for concealment. Following removal of aquatic vegetation (hydrilla) in Lake Seminole, Georgia, largemouth appeared to change feeding strategies from ambushing to searching, had increased daytime movement, but remained within the treatment area (Sammons et al. 2003). Adult largemouth bass are less accessible to anglers in dense vegetation (Brown and Maceina 2002). In B.C., the spread of aquatic Asian milfoil may enhance largemouth bass habitat (Hatfield Consultants Ltd. 1996).

Deeper Nebraska lakes supported a low density of largemouth bass, but the population contained a high proportion of large fish (Paukert and Willis 2004). Abundance was greater, year class recruitment was more stable, and the proportion of large bass increased with the extent of emergent vegetation cover.

3.6 INTERSPECIFIC INTERACTIONS

Adult largemouth are not normally predated upon because of their size, swimming ability, and spines on their back. Small juvenile largemouth bass are preyed upon by many fish, bird and other vertebrate species including yellow perch, walleye, northern pike, heron, osprey and kingfisher (Scott and Crossman 1973).

3.7 BEHAVIOUR AND MOVEMENTS

3.7.1 Translocation

Largemouth bass are active in the warmer seasons and quiescent in the winter (Demers et al. 1996). In Lake Seminole, Georgia, tagged largemouth ranged further in summer than in winter, although less than 50m/hr in all seasons and times of the day (Sammons and Maceina 2005). Funk (1957) noted that each fish species in the Mississippi River had both sedentary and mobile individuals; largemouth bass were characterised as semi-mobile. They seldom traveled more than 40 km.

Acoustic telemetry was used in an eastern Ontario Lake to monitor 20 largemouth bass (Hanson et al. 2007). Individuals exhibited different seasonal movement patterns: some bass held discrete home ranges, while others were transient. Largemouth bass movement was positively correlated with water temperature. Fish movement varied by month. During winter, largemouth bass spent 95% of their time swimming at minimal speeds compared to faster swimming rates in late autumn and spring. Although their spatial distribution is more confined in winter, a few fish did undertake localized movements under the ice.

3.7.2 Diel movements

Largemouth bass move into shallow water at night to feed (Scott and Crossman 1973). During the day, largemouth bass may cruise above aquatic plants at depths of 1-3 m, or rest under lily pads or in the shade of overhanging structures. In Lake Seminole, Georgia, largemouth were offshore in deeper water near woody structures during the day, but moved towards the shoreline at dusk for foraging (Sammons and Maceina 2005). In the more northern waters of eastern Ontario, Hanson et al. (2007) reported similar diel behaviour, but noted that this pattern was only apparent in the spring and was characterized as elevated activity during the day, with slightly higher peaks at dawn and dusk.

3.7.3 Feeding behaviour

Largemouth bass feed primarily by sight, but also sense odours and vibration (Scott and Crossman 1973). McMahon and Holanov (1995) found that largemouth bass foraging success was greater than 95% a light levels ranging from low intensity daylight to moonlight, but foraging success declined to 62% in starlight and was near 0% in darkness. They calculated that differences in water clarity could dramatically limit the feeding depth of largemouth bass, especially at night during a full moon or under starlight. The available feeding depth for low clarity water was 67-75% less than for moderate and high water clarities. McMahon and Holanov (1995) concluded that water clarity and available light could have important ramifications for largemouth bass feeding and predator–prey interactions.

3.8 DISEASES AND PARASITES

In mainland B.C., 48 largemouth bass from three locations were examined for parasites (Bangham and Adams 1954). Although 47 were infected with parasites, infections were considered light, and only four species of parasites were found. Gill flukes were common, and the bass cestode *Proteocephalus ambloplitis* was present as larval cysts but not as adults. This compares to 26 different species in Wisconsin and 18 in Florida, where parasites such as protozoa, copepods, roundworms, tapeworms, flatworms and leeches are common on Florida largemouth bass (Hoffman 1967; Craig 1987). In Florida, the ectoparasitic protozoan *Scyphidia tholiformis* is one of the most common.

3.8.1 Largemouth bass virus

Largemouth bass virus (LMBV) has been responsible for a number of largemouth bass kills in eastern North America from 1995-2002. Since it was first discovered in Florida in 1991, LMBV has spread north into 18 eastern U.S. states including Michigan and Illinois (Grizzle and Brunner 2003; Great Lakes Fishery Commission 2006). The virus is easily transmitted through fish to fish contact, consumption of infected prey or through the water, and it can survive in boat live wells for up to 7 days (Grizzle and Brunner 2003). The virus appears to infect a number of other fish species including smallmouth bass, but has only been associated with the death of largemouth bass (Great Lakes Fishery Commission 2006). The virus has not been found in western North America.

3.8.2 Bass tapeworm

The bass tapeworm *Proteocephalus ambloplitis* life cycle was described by Gillilland and Muzzall (2004). It usually involves a primary host (copepod or amphipod), a secondary host (usually a fish), and a definitive fish host (i.e. largemouth bass or smallmouth bass). Eggs and mature proglottids are shed with the feces of the definitive host and infect the copepod. The overall intensity of infection was higher in smallmouth than in largemouth bass for a Michigan Lake (Gillilland and Muzzall 2004).

The bass tapeworm is considered a problem for trout and salmon management in the Pacific Northwest because the worm can develop after ingestion of copepoda, an important food item for rainbow trout, cutthroat trout and coho salmon (Becker and Brunson 1968; Antipa 1974). Pleroceroid larvae are often found in the body cavities and internal organs of fish, and may cause sterility (Antipa 1974). The tapeworm is currently widespread in North America and considered to be an important issue in Ontario (Fisher and Freeman 1969) and Quebec (Boucher 2005). It may be spreading north with climate change (Marcogliese 2001).

Lasenby and Kerr (2000) felt that the stocking of bass can contaminate native fish. They cite the incidence of largemouth bass not reaching their stocking destinations alive because of a heavy parasite load. They also blame the stocking of largemouth bass for the introduction of parasites into new geographical areas. *Proteocephalus ambloplitis* was introduced into Saskatchewan reservoirs through the release of infected bass fingerlings (Szalai and Dick 1998).

4.0 USE BY HUMANS

4.1 RECREATIONAL FISHING

Largemouth bass are the most popular sport fish in North America (Lasenby and Kerr 2000). Huge recreational fisheries include tournaments and derbies. Fisheries management actions include regulations, habitat enhancement, and hatchery augmentation. In 2001, a survey by the US Fish and Wildlife Service indicated there were 34.1 million anglers who generated $U.S. 35.6 billion; 11.3 million of these people fish for bass (United States Department of the Interior 2002).

4.2 COMMERCIAL FISHING

There is no commercial fishery focusing on largemouth bass in Canada. Like the smallmouth, largemouth bass were targeted as a commercial species until 1936, when they were designated a sport fish (Scott and Crossman 1973). Bass are highly regarded as sport fish and must be released when caught in commercial gear (Smith and Edwards 2002).

4.3 AQUACULTURE

The United Nations Food and Agriculture Organization (FAO 1996) acknowledged that the number of fish species used in aquaculture is continuing to grow, and largemouth bass culture for food was reported by this organization for the first time in 1994. In the U.S., largemouth bass are cultured at private, state, and federal facilities primarily for recreational fish stocking programs

(USDA 2006), although food fish are also sold into Asian markets (Tidwell et al. 2002). In 2005, 192 U.S. farms reared largemouth bass, with estimated sales of $10.6 million (USDA 2006).

The farming of largemouth bass is extremely limited in Canada, with most facilities in Ontario. Farm production of bass in Canada is designed for out-planting for recreational purposes, and smallmouth bass production dominates. An excellent review of bass stocking and transplanting was compiled by Lasenby and Kerr (2000), who noted that survival rates of stocked largemouth bass depended on life stage and habitat type. In ponds, survival ranged from 50 to 90% for fry, 1 to 93% for fingerlings, and 50% for adults. In lakes, survival ranged from 0.13 to 35% for fingerlings and 4-11% for adults. One out of six lake stockings with adult largemouth bass was considered to actually establish a population.

5.0 IMPACTS ASSOCIATED WITH INTRODUCTIONS

5.1 IMPACTS ON FAUNA

5.1.1 Plankton, zooplankton, and macroinvertebrates

Because largemouth bass soon shift to a diet composed primarily of fish (Scott and Crossman 1973), their ability to directly consume small organisms and alter the zooplankton community is limited to young-of-the-year. However, bass consume large numbers of small-bodied fish, many of which are consumers of plankton, algae and zooplankton, so it is not surprising that changes in lake ecosystems have been noted following largemouth bass introductions. Spencer and King (1984) found that ponds with largemouth bass had very low phytoplankton biomass and supported dense populations of submerged macrophytes, while ponds without bass featured intense algal blooms and low zooplankton biomass. Lasenby and Kerr (2000) reported that, following introductions of largemouth bass into Cuba, there was a rise in cases of human malaria attributed to largemouth bass consumption of native fish species that had fed upon mosquito larvae.

5.1.2 Fish other than salmonids

Largemouth bass compete with a number of other fish species for food and space. A list of potential competitors is given by Lasenby and Kerr (2000), who concluded that bass are typically the larger and more aggressive fish species and will out-compete other fish. They also felt that largemouth bass would out-compete smallmouth in the majority of cases if the two were stocked in the same small lake. Kerr and Grant (1999) did not recommend the stocking of largemouth and smallmouth in the same system.

In Southern Africa, largemouth bass were introduced as a sport-fish and have eliminated three native species (Hickley et al. 1994; Impson 1998). The introduction of the largemouth black bass into Lago de Pátzcuaro and Lago Chapala in México has established commercial and sports bass fisheries, with the loss of the local and highly appreciated pescado blanco and charal fisheries (Ciruna et al. 2004).

Black basses are characterized as an invasive alien fish in Japan, and smallmouth bass have been described as the “world’s most disastrous invasive species” by Iguchi et al. (2004). Invasive bass constitute a “serious biohazard” and the bibliography written by Hosoya and Nishi (2003) promotes their eradication in Japan.

In North America, the direct predatory impact of bass on other fish has been documented for lakes (Tonn and Magnuson 1983; Findlay et al. 2000; Jackson 2002) and for streams and rivers (Power et al. 1985; Harvey et al. 1988). In Adirondack lakes, native minnow richness was dramatically reduced when largemouth bass and other predators were present (Findlay et al. 2000). In Clear Lake, California, prickly sculpin *Cottus asper* were uncommon in the stomach of all piscivorous fishes except juvenile largemouth bass, which have reduced sculpin abundance (Broadway and Moyle 1978). In rivers and streams, the effects of largemouth bass on small-bodied fish may be greater than those of smallmouth bass (Harvey et al. 1988).

In Canada, the impacts of bass introductions on native fish species have been well documented (Jackson and Harvey 1989,1993; Crossman 1991; Kerr and Grant 1999; MacRae and Jackson 2001; Jackson and Mandrak 2002; Jackson 2002; Vander Zanden et al. 2004). Introduced bass likely alter the fish community through predation and there is a strong negative association between small-bodied fish (i.e. cyprinids) and largemouth bass (MacRae and Jackson 2001). Lakes containing bass have fewer species of cyprinids than lakes lacking bass. Largemouth bass have been blamed for decimating forage fish species such as fathead minnow and golden shiner (Kerr and Grant 1999).

The negative relationship noted between bass and cyprinids was not apparent for lakes with salmonids and cyprinids (MacRae and Jackson 2001). There is a strong negative association between largemouth bass, dace and fathead minnows, whereas brook trout showed a strong positive association with these cyprinids. A possible reason for these contrasting relationships is habitat overlap. Bass occupy the littoral zone in summer as do most of the cyprinids, whereas trout and cyprinids have limited overlap in their summer habitats.

5.1.3 Salmonids

Largemouth bass consume salmonids, especially when juveniles are migrating. Fayram (1996) found that salmonids were an important diet item for largemouth bass in Lake Washington. Pflug (1981) found a similar situation in Lake Sammamish, although consumption of hatchery salmonids may have contributed to this finding. In a small sample of largemouth bass from Lake Washington, one contained a juvenile chinook salmon (Tabor et al. 2004). The same study examined largemouth diet in Lake Washington from February through June. Salmonid occurrence in largemouth bass varied by season, and was highest in June. Migrating young coho, chinook, and sockeye salmon were all eaten; the major salmonid prey item was coho. Largemouth bass predation on salmonids was observed in fish between 159-264 mm; of the 280 stomachs examined, 31 salmonid smolts were found. Seventy-five percent of the diet consisted of non-salmonids, of which sculpins dominated.

Bonar et al. (2005) examined predation on coho fry and smolts by piscivorous fish in three shallow Pacific Northwest Lakes. An average of 94% of the coho salmon found in the diets of all the fish each year was taken by largemouth bass, who accounted for 51% of the total numeric catch of fish in the three lakes, and 98% of the coho salmon predation after the relative number of bass was taken into consideration. Most predation occurred in spring, when coho smolts were migrating through the lakes or coho fry were moving from creeks into lakes. There were no coho in the stomachs of age-0 largemouth bass.

In Oregon, interactions between largemouth bass and salmonids occur in coastal lakes with tributaries used by coho salmon, steelhead, and cutthroat trout (Temple et al. 1998). The primary introduced predatory species is the largemouth bass. Coho are the native species most susceptible to predation because of their small size as fry and their migratory behaviour into the lake. Summer rearing of coho fry no longer occurs in some lakes. The juvenile coho that enter Oregon coastal lakes in autumn and winter are less susceptible to bass predation because they are larger and more pelagic. Sea-run cutthroat trout and steelhead smolts migrate to the sea at a larger size, spend less time in the lakes, and are less susceptible to predation. Examination of 192 largemouth bass stomachs from Ten Mile Lake in 1989-90 showed salmonids present in 11% of the non-empty stomachs (Temple et al. 1998).

Slaney and Roberts (2005) noted that invasive fish like largemouth bass have been illegally introduced into several urban Lower Mainland lakes and rivers. They felt these invasive fish have the potential to harm juvenile cutthroat trout through competition and predation. Rainbow trout *Oncorhynchus mykiss* and largemouth bass usually do not compete for food because of habitat differences (Scott and Crossman 1973). However, Hodgson et al. (1991) found that, when bass and rainbow trout occupied the same lake, they did compete. Rainbow trout became predominantly zooplanktivores and largemouth bass became more generalized in their prey selection.

Predation on salmonids by introduced species may be an insignificant contributor to the large declines observed in west coast populations when compared to the effects of habitat modification, fishing, and climate change. It can, however, make it harder for salmonids to recover. Alien fish such as largemouth bass are introduced into water-bodies already altered by human activities; once the introduced fish establish thriving populations it is difficult for damaged populations of salmon or trout to become re-established (Lackey 1999).

5.1.4 Wildlife

The reputation that largemouth bass consume very large prey may be exaggerated. The size of their gape limits the size of the prey they are able to consume (Hill and Cichra 2005). Largemouth bass have been reported to consume mussels, snails, frogs, small rodents such as mice, voles and rats, salamanders, small turtles, ducklings, snakes, and small muskrat (Hill and Cichra 2005). Many of these food items are mimicked with bass fishing lures. However, the ability of bass to influence wildlife communities is questionable, as most of this kind of feeding is highly opportunistic.

5.2 IMPACT SUMMARY

Largemouth bass provide recreation throughout North America and are considered to be the premier freshwater game fish. This popularity has given rise to numerous introductions and has resulted in rapid spread of the species.

Largemouth bass are significant predators on small-bodied fish. Their role in alteration of fish communities and reduction in abundance of minnows and other small fish is the biggest reason to consider introductions as potentially detrimental.

There is also ample evidence for impact on salmonid populations, mainly through predation on out-migrating juveniles, although the contribution of large numbers of hatchery-produced salmonids can make the findings difficult to interpret. For already-depressed salmonid populations, recovery can be hindered by the presence of a competent predator like largemouth bass.

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