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REVIEW OF SMALLMOUTH BASS *(Micropterus dolomieui)* SPAWNING REQUIREMENTS AND FIRST YEAR SURVIVAL IN LAKES

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ABSTRACT

A literature review was conducted to assess current knowledge of smallmouth bass spawning requirements and first year survival in lakes. The review is intended for use in considering research needs for management of smallmouth bass habitat in Wisconsin lakes. While there is considerable information on the requirements for nesting and spawning (including substrate, adjacent cover, water depth, protection from wind and wave action, temperature) and on causes of nest failure, there is relatively little information on nursery habitats. The management of smallmouth bass habitat to encourage natural reproduction by providing spawning substrate or objects for adjacent nest cover appears to be promising. However, the overriding factor affecting year class strength in Wisconsin lakes, which are toward the northern limit of smallmouth distribution, is the temperature regime in the first growing season. Care must be taken not to "improve" habitat when climatic factors rather than physical habitat are implicated as limiting. Where lack of adequate recruitment is a problem, a simple increase in nest number may not increase population size if we do not simultaneously consider habitat requirements for fry and fingerlings and other variables affecting year class strength. Research is needed to select and evaluate techniques and to develop management guidelines.

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INTRODUCTION

Naturally reproducing lake populations of smallmouth bass in North America occur primarily in medium- to large-sized inland lakes and in the bays and inlets of the Great Lakes. Smallmouth occur in 300 Wisconsin inland lakes and in the Lake Michigan waters of Green Bay and Door County (Wisconsin Department of Natural Resources 1979).

The purpose of this paper is to summarize the literature on smallmouth bass spawning requirements and first year survival in lakes as a basis for the consideration of research needs for management of spawning and nursery habitats in Wisconsin. Successful production and survival of young smallmouth are influenced by different factors in lakes as compared to streams, which are threatened by disruptive flooding during the spawning season. This review covers the literature for lake populations only. It is organized under the following major headings: spawning site characteristics, nesting and spawning activities, first year survival, and management and research implications.

SPAWNING SITE CHARACTERISTICS

Substrate

The preferred substrate for smallmouth bass nest construction is gravel. The diameter of good nesting gravel is 1-8 cm (Hubbs and Eschmeyer 1938). It has also been more generally described as "hens-egg" size (Watson 1955) or coarse gravel with fist-sized rubble (Neves 1975).

Although gravel appears to be ideal, coarse sand, bedrock, or a combination of gravel, sand, and bedrock are frequently used substrates. Of 39 nests observed in the outlying waters of Door County, 27 were on gravel or rubble, 8 were on sand, and 4 were on bedrock with gravel (Wiegert 1966). If hard substrate is not available, smallmouth will nest on soft bottoms by exposing roots, twigs, or shells in the nest bottom (Hubbs and Bailey 1938). Stocked smallmouth bass built nests in black silt, clay, or sand and clay in 6 of 12 Illinois ponds (Bennett and Childers 1957).

Location and Depth

Smallmouth bass nesting sites are usually located where they are protected from wind and wave action: in bays, on leeward shores, on the lee side of islands, or protected by islands or points if they occur on windward shores (Tester 1930, Doan 1940, Mraz 1964, Johnson and Hale 1977). Indexes of wind direction were correlated with year class strength in Baie du Dore, Lake Huron; winds acted to move cold water masses into the spawning area and to physically destroy nests through turbulence (Hurley 1975). Although substrate is an important factor for nest location, shelter from wind and waves may be more important, especially in larger lakes and the Great Lakes. Smallmouth at Waugoshance Point, Lake Michigan, seemed to select sites in quieter, warmer waters over sites with bottom substrates reported as preferred in the literature (Latta 1963). A few nests have been observed in open water (Mraz 1964) and up to 0.8 km from shore, unprotected from wave action (Doan 1940).

Nest sites usually occur along shorelines in water less than 2 m deep. For example, nests were 0.6-1.2 m deep and 0.3-2.4 m from shore in Tadenac Lake, Ontario (Turner and MacCrimmon 1970); 0.6-0.9 m deep in Mitchell's Bay, Lake St. Clair (Doan 1940); 0.4-1.1 m deep at Waugoshance Point, Lake Michigan (Latta 1963); 0.5-0.9 m deep and 3-9 m from shore in the Thousand Islands Region of Lake Ontario (Stone, Pasko, and Roecker 1954); 0.8 m deep in South Branch Lake, Maine (Neves 1975) and 1-2 m deep in Katherine Lake, Upper Michigan (Clady 1975). Most nests were 1.8-3.0 m deep in Lake Geneva, Wisconsin, but some were as deep as 6.1 m (Mraz 1964).

Suitable depth for nests seems to be related to water clarity. Trautman (1957) suggested that increased water turbidity in Lake Erie forced smallmouth to spawn in shallower water, thus increasing egg and fry destruction by wind and wave action. Webster (1954) observed nests in shallower water during turbid conditions.

Segments of some lake populations of smallmouth bass spawn in tributaries rather than in the lake itself. There is some evidence that these are separate stocks of lake and river spawners (Robbins and MacCrimmon 1977; Stone, Pasko and Roecker 1954, Webster 1954).

Adjacent Cover

Although the two basic requirements for a smallmouth spawning site are suitable substrate and protection from wind and wave action, there is a definite preference for sites with boulders, stumps, or logs to provide adjacent cover for the male while he protects the nest. Nests have been observed on both sides of a suitable structure (Mraz 1964). While most references mention structures on one side of the nest, Tester (1930) observed that rocks or fallen trees often protect nests on two or three sides in Georgian Bay and Lake Nipissing. Where the ideal conditions of both gravel and adjacent objects occur, a single nest may be used twice in the same season by different males (Watson 1955).

Nest Size and Spacing of Nests

The dimensions of smallmouth nests reflect both the substrate type and the size of the male. Few authors describe the nests in detail. Doan (1940) observed that the nests of Mitchell's Bay, Lake St. Clair, had bottoms of clean sand with stone and some vegetation, average depth of 8.9 cm, average diameter of 0.5 m and 2.5-cm rims of clean sand. Nests were 0.3-0.6 m in diameter in Lake Michigan (Latta 1963), 0.5-0.8 m in Lake Ontario (Stone, Pakso, and Roecker 1954); and 0.6 m in South Branch Lake, Maine (Neves 1975). In the soft-bottomed Illinois ponds, nest diameter was about twice the length of the male, with maximum nest diameters of 0.8 m (Bennett and Childers 1957).

There are a few reports on the density of nests at lake spawning sites. Comparative densities cannot be calculated since different authors report nests/m^2, nests/km shoreline, and nests/lake. In a favorable spawning area in Mitchell's Bay, Lake St. Clair, Doan (1940) observed 1 nest/16 m^2. At least 4,218 nests were built along 59.5 km of suitable shoreline in Big Lake, Maine (Watson 1955). Johnson and Hale (1977) counted 125 nests in Big Lake, Minnesota which has 27.2 km shoreline. Clady (1975) reported 73-90 nests in 19.4-ha Katherine Lake, northern Michigan in 1967-69.

NESTING AND SPAWNING ACTIVITIES

Temperature Requirements for Nesting and Spawning

Smallmouth bass spawn from late April to late June in their native range (Robbins and MacCrimmon 1974), although the exact time is related to the temperature regime at a particular geographical location. Most literature sources agree that nest construction and/or spawning activity begin at about 15.0-15.7 C (Watson 1955, Robbins and MacCrimmon 1974, Mraz 1964, Latta 1963, Turner and MacCrimmon 1970, Rawson 1945, MacLean et al. 1980). Variations may relate to the rate of spring warming; Hubbs and Bailey (1938) reported nesting and spawning at 15.1 C if the rate is slow and at 18.5 C if the rate is fast.

Relationships between temperatures and spawning behavior in Ontario were reviewed by MacLean et al. (1980). Field observations in Lake Opeongo and Baie du Dore, Lake Huron demonstrated an inverse correlation between (1) the rate of spring warming (i.e., the number of degree days over 10 C accumulated by the date temperatures were suitable for spawning -->15 C) and (2) the delay between the date of >15 C temperatures and the onset of nest construction. A second spawning period was observed in Lake Opeongo in late June 1965 after a mid-June cold front dropped temperatures below 15 C and reduced survival of the first eggs. In 1962, temperatures remained above 15 C and there was only one spawning period in late May - early June.

Number of Adult Spawners

There is evidence that only a small portion of an adult smallmouth population spawns in any one year (Regier pers. comm.). Attempts to correlate number of mature adults and year class strength have thus been unsuccessful. For example, year class strength of smallmouth recruited at age 4 or 5 did not correlate to the size of the spawning stock in the year of birth (Watt 1959, Christie and Regier 1973).

Behavior

The description of smallmouth nesting and spawning behavior is beyond the scope of this paper. However, documentation of the behaviors was reported in the early 1900's and several summaries exist (e.g. Breder 1936). More recently, Schneider (1971) made SCUBA observations of naturally spawning smallmouth bass.

FIRST YEAR SURVIVAL

Nest Success

Some investigators have counted the number of smallmouth nests that produce fry in lakes; estimates of percent success range from 44 to 86% (Table 1). Other investigators have estimated the survival of eggs to successive life history stages. Clady (1975) estimated survival from the egg through fall fingerling. The actual deposition of potential eggs was 15-34%; survival from deposited egg to postlarvae was 26-33%; and from deposited egg to fall fingerling was 1-4%. Latta (1963) reported 28% survival from deposited eggs to postlarvae.

TABLE 1. Percentage of smallmouth bass nests producing fry in lakes

Location	Percent Successful Nests	No. Nests Studied	Reference
Mitchell's Bay, Lake St. Clair	86	123	Doan (1940)
Georgian Bay, Lake Huron	64	11	Doan (1940)
Millen Bay, St. Lawrence River	44	16	Stone, Pasko, and Roecker (1954)
Waugoshance Point, Lake Michigan	54-55	20-28	Latta (1963)
Tadenac Lake, Ontario	45	20	Turner and MacCrimmon (1970)
South Branch Lake, Maine	67-68	15-30	Neves (1975)

A number of authors have cited possible reasons for nest failure. These have been summarized below from Webster (1954), Latta (1963), Wiegert (1966), and Carlander (1977); relationships between temperature fluctuation and nest failure were reviewed by MacLean et al. (1980) and Shuter et al. 1980.

Temperature Fluctuation. Field observations indicate that survival of eggs and newly hatched fry are reduced if temperatures drop below 14-15 C. Both field and laboratory studies have shown that temperature fluctuations directly influence survival between fertilization and rising from the nest. Also, males have been reported to desert their nests if temperatures drop below 15.7 C (Rawson 1945, Latta 1963).

Predation. Eggs or fry in unguarded nests are usually consumed by predators. Some predation also occurs in spite of male guardianship, especially when the male must fend off a number of intruders at the same time. Carp, common suckers, white perch, and crayfish are known predators.

Fungal Infections. Failed nests frequently contain heavily fungused eggs. Although fungi are thought to primarily attack dead tissue, the infection may affect adjacent healthy eggs. Males will desert heavily fungused nests.

Bottom Disturbance or Destruction. The disturbance of bottom sediments may increase turbidity and siltation, resulting in a poor hatch of eggs or nest desertion. Carp activity has been cited as a major source of this problem. Carp, common suckers, and white perch have been known to mechanically destroy nests in addition to consuming eggs.

Water Level Decreases. A severe drop in water level may leave nests completely exposed, subject nests to wind and wave action, or force males to desert their nests.

Use of Nests by Other Species. Common shiners spawned in smallmouth nests at Waugoshance Point; nesting success was somewhat lower than in nests without shiners, but this was not a statistically significant difference (Latta 1963). Orangethroat darter fry used smallmouth nests for protection although they were not spawned there (Pflieger 1966).

Fishing Mortality. Angler removal of nest-guarding males leaves eggs and fry completely vulnerable to predation.

Nest Desertion. Many of the above factors result in nests which lack a male guardian. Although nests without males have been observed to produce fry (Webster 1954), it is generally agreed that unguarded nests will fail (Rawson 1945, Mraz 1960, Latta 1963, Neves 1975).

Temperatures During the First Growing Season

There is an extensive body of literature documenting correlations between smallmouth bass year class strength and regional temperatures experienced in the first year of life (reviews by Christie and Regier 1973, Shuter et al. 1980, MacLean et al. 1980). This phenomenon applies in particular to populations near the northern range of smallmouth distribution. Combinations of field and laboratory observations indicate that "temperature can influence the survival of young smallmouth bass directly, during a short period after fertilization, and indirectly, during the first summer and winter of life" (Shuter et al. 1980).

The following summary lists sources of data from which relationships between year class strength and air temperatures are drawn. Author, location, years studied, and months with significant correlations are indicated.

Fry and Watt (1957): South Bay, Lake Huron, 1941-49; Lake Manitou, Ontario, 1947-51.
Year class strength of adults correlates to an air temperature index (sum of the deviations from average monthly air temperature) in year of birth, July-October.

Watt (1959): South Bay, Lake Huron; Ontario, 1947-55.
Number of fish recruited at age 4 correlates to air temperature indexes in year of birth, June-October, June-November, July-October, and July-November.

Christie (1957): Lake Opeongo, Ontario, 1936-53.
Number of fish recruited at age 5 correlates to air temperature indexes in year of birth, May-August.

Forney (1972): Oneida Lake, central New York, 1959-69 (YOY) and 1950-62 (age 4).
Number of young-of-year in August correlates to mean June air temperature. Percent abundance of age 4 fish correlates to mean June temperature in year of birth; no correlations with temperature in other months or groups of months as is true for more northern lakes.

Clady (1975): Katherine Lake, Upper Peninsula, Michigan, 1959-68.
Number of age 4 fish correlates to deviations from mean monthly air temperature in year of birth, July-October.

Shuter et al. (1978*; 1980): Baie du Dore, Lake Huron, 1963-77.
Year class strength relates to air temperatures during the first summer <u>and</u> to indexes of wind direction during spawning.

Serns (unpubl. data): Nebish Lake, Wisconsin, 1970 and 1974-80.
Number of young in September-October samples correlates to mean noon air and water temperatures, June-August.

In two of the above studies (Forney and Serns), the authors estimated the numbers of fingerlings present just before their first winter. In both cases, higher summer temperatures conferred an advantage to population size by the end of the first growing season. Other authors correlated year class strength of adult fish to summer temperatures in the year of birth, indicating that warmer water temperatures in the first summer also contribute to long-term survival of individuals in a year class.

Overwinter Mortality of Young-of-Year

Several authors have considered relationships between overwinter mortality and size of young-of-year smallmouth bass at the end of their first growing season (Christie and Regier 1973, Oliver et al. 1979). Early studies indicated that young-of-year grow faster in warm than cool summers and that the resulting larger fish may be less likely to die over their first winter. The latter hypothesis was tested in the laboratory by Oliver et al. (1979) who demonstrated that longer fingerlings survived over the winter better than shorter finglerings and that there may be critical levels of energy reserves below which young overwintering fish will die. Final wintering temperatures (2, 4, 6 C) did not seem to affect mortality.

MacLean et al. (1980) reanalyzed the data of Oliver et al. (1979) and applied it to a physiological model of overwinter survival. The model predicted that bass less than 5 cm long would have a lower probability of survival than bass greater than 5 cm long. Field observations of actual length distributions of Lake Opeongo young-of-year sampled in August 1976 and after their first winter in May 1977 confirmed this prediction.

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*In McLean et al. (1980).

Habitat of Young-of-Year

Another prerequisite for successful natural reproduction is suitable habitat for the fry and fingerlings in their first year of life. Fry dispersal from the nest is gradual (Latta 1963, Turner and MacCrimmon 1970). The male may remain near the fry for 7-10 days after hatching. During this time, they rise from the nest in schools, but slowly disperse and seek nearby cover. Smallmouth bass are solitary after dispersal. They prefer shallow water, seek cover in recesses around stones or sticks, and avoid the cover of weed beds or dense brush (Hubbs and Bailey 1938, Hubbs and Eschmeyer 1938). Smallmouth bass less than 5 cm long were observed in shallow water over sandy and rocky bottoms in Oneida Lake (Adams and Hankinson 1928); individuals occurred close to the shore or the margins of weedbeds. Density of Oneida Lake young-of-year was greatest inshore, but they occurred at depths of 4.6-6.1 m (Forney 1972). There is little quantitative data on first-year habitat requirements of smallmouth bass.

MANAGEMENT AND RESEARCH IMPLICATIONS

Enhancement of Natural Reproduction

There is considerable information in the literature on the general spawning requirements for smallmouth bass in lakes. The preferred substrates, water depth, adjacent cover, and protection from wind and wave action have been described by many authors. This current knowledge of smallmouth bass spawning preferences in lakes allows us to speculate on some management options for increasing recruitment by modifying existing sites, re-establishing old sites, or creating new sites.

Factors other than temperature may limit smallmouth bass populations in some northern lakes. If biologists identify smallmouth bass lakes with continually poor year classes produced in years of strong regional year classes, these lakes could be considered for habitat assessment and enhancement studies. If spawning habitat appears limited, the literature points to a number of experimental options.

Hubbs and Eschmeyer (1938) described the placement of materials in natural lakes to enhance spawning and nursery areas for self-sustaining populations of smallmouth bass. They suggested placing one-bushel piles of gravel 2.4-3.0 m apart directly on hard bottoms, in wooden boxes or on platforms on soft bottoms, and in boxes suspended from the surface in lakes with severe water level fluctuations. In a later publication, Eschmeyer (1955) mentioned that gravel spawning beds were added to some waters, but no evaluation of the effect on reproduction or population size was reported.

It is important to consider the amount of nearby nursery area in a lake where management to increase the number of nests is considered (Hubbs and Eschmeyer 1938). Although enhancement of nursery habitats has not been studied, it may have equal or greater potential for increasing recruitment than enhancement of nest sites. The young stay close to or hide in recesses close to shore. Hubbs and Eschmeyer (1938) suggested that providing a number of small shelters would be more effective for protection of fingerlings than a few large ones.

There have been no research evaluations of the techniques described by Hubbs and Eschmeyer (1938). In fact, there have been few reported smallmouth bass spawning enhancement studies in lakes. Rawson (1938, 1945) experimented with fenced spawning enclosures in natural lakes to introduce smallmouth bass to Prince Albert National Park, Canada. Artifical nests (0.6 m^2 spawning boxes with two sides and a top) were placed in the enclosure 6 m apart with openings in alternate directions. Although the introduction of smallmouth bass into the cold Canadian waters was not completely successful, the use of rearing enclosures in protected bays was both inexpensive and successful.

Mraz (1960 a, b, 1961, 1964) applied the concept of adjacent cover to a natural setting by placing concrete blocks on the bottom in Lake Geneva in an attempt to concentrate spawning in one area. In 1960, blocks were placed at 3.0-4.6 m depths in both transect and grid arrangements. One block at the shallow end of the transect was used for nesting. Water turbidity prevented counts of total nests in the vicinity of the transect. Of 28 blocks in the grid, Mraz was unable to relocate 6. Five blocks in the shallow area had nests, and 1 additional nest was found in the area. In 1961, 60 blocks were placed at 3 m; 34 could not be relocated and 7 of the 26 remaining were used for nesting. Twenty-five additional active nests were located in nearby water less than 3 m deep. Most of these nests were next to submerged objects.

Mraz's work indicates some potential for increasing the use of spawning habitat by increasing habitat structure, especially if care is taken to place objects at preferred depths. A variety of objects could be used; Mraz observed smallmouth nests with various adjacent structures -- blocks, anchors, cribs, logs, sunken boats, water mains. Design of the structures could utilize natural materials (e.g., logs) and perhaps be placed to encourage bass to nest on both sides. In lakes where crayfish are very abundant, structures should be designed to exclude crayfish from the nest.

Although the improvement of smallmouth spawning habitat by increasing the number of structures for adjacent cover or the amount of suitable nesting gravel are the most obvious management implications, other factors must be considered. These include the water depth and temperature, predictability of spring water level, type of substrate present, vulnerability to wind and wave action, turbidity, siltation (including amount of carp activity), angler exploitation, predators, and the number of young-of-year fish the habitat could support if the number of nests or hatching success increased.

Prediction of Strong Year Classes

The relationship between year class strength and air temperatures may enable managers to predict the strength of each new year class in a region at the end of the first growing season. Christie and Regier (1973) presented Ontario predictions for 1950-55 year class strengths based on actual data from year class: temperature relationships in 1941-49. The six predictions were positively correlated with observations of year class strengths of the 1950-55 cohorts.

The application of this knowledge to management was discussed at a meeting of Ontario researchers in 1979. "Statistical relationships have been known for some 25 years from which researchers could forecast the relative year class strengths of smallmouth bass being recruited into the sport fishery in any particular year. As of yet, managers have not made much use of this capability . . . " and straightforward methods for its application will have to be developed (MacLean et al. 1979).

The application of the regression models of year class strength to management is limited in that the models (1) apply only to the population being monitored, (2) require extensive data collection for a series of years, and (3) do not allow for the effects of short-term, random temperature fluctuations in lhe critical period after fertilization (MacLean et al. 1980). More comprehensive models of the relationship between temperature and first year survival have been developed for and applied to populations in the northern smallmouth range (Shuter et al. 1980). Development of comprehensive smallmouth bass recruitment models continues (MacLean et al. 1980); these will refine the temperature-related aspects of the model but may also include other factors that influence year class strength (e.g., acid precipitation, size and availability of food, competition, and predation).

Selection of Opening Dates

Angler exploitation of nesting bass may potentially affect year class strength in lakes that have well-known and accessible spawning areas and are heavily fished. Most authors agree that nests will fail if the guarding male is removed. Although the timing of the opening date for the fishing season may or may not affect the total annual harvest of adult fish in a single year, an early date may affect year class strength if a significant number of the nesting males are removed. Although a positive relationship between year class strength of adult recruits and numbers of adults present in the year of birth has not been demonstrated, no one has examined the relationship between year class strength and number of successful nests.

There is little existing data that can be used to address this problem. MacLean et al. (1980) used the year class strength model described earlier to predict the impact of variable opening dates on long-term survival of young-of-year smallmouth bass in Baie du Dore. The model assumed that all guarding males were removed, and demonstrated that young-of-year survival would be zero if angling began on June 4 and would not be affected if angling began after July 10. Actual measurement of the exploitation of guarding males would be needed to apply this information to management of lakes on an individual or a regional basis.

Research Requirements

In summary, the management of smallmouth bass habitat to encourage natural reproduction appears promising. However, the overriding factor producing strong year classes in Wisconsin lakes, which are toward the northern limit of smallmouth distribution, is the temperature regime in the first growing season. Care must be taken not to "improve" habitat when climatic factors rather than physical habitat are implicated as limiting. Where lack of adequate recruitment is a problem, a simple increase in nest number may not increase population size if we do not simultaneously consider habitat requirements for fry and fingerlings and other variables affecting year class strength. Research is needed to select and evaluate techniques and to develop management guidelines. Experimental projects would be appropriate, perhaps in lakes where small population size cannot be attributed to climatic factors or where historic spawning or nursery sites have been altered or lost.

The current management practices and the type of fish community present should also be considered in selecting experimental smallmouth bass lakes. Lakes known for "good" smallmouth bass populations have been subject to declines after the introduction and successful establishment of walleyes (Eschmeyer 1950, Kempinger et al. 1975). Smallmouth bass populations have decreased in many Wisconsin lakes after walleyes became abundant, either as a result of walleye stocking or after dramatic increases in natural walleye reproduction (Richard Wendt pers. comm.). Recent attempts to classify lakes on the basis of their limnological properties and their predator fish species associations (Johnson et al. 1977) should be useful in selecting lakes for smallmouth bass studies.

The addition of structures for adjacent cover or the placement of gravel piles in lakes to increase the number of smallmouth bass nests are simple and inexpensive potential management tools. Mraz's (1964) experience with nest sites located next to added concrete blocks offers one possibility. However, there are important gaps in our knowledge. There is inadequate information on the comparative density of nests on excellent, marginal, and poor substrates or on the density of large structures used for protective backs for nests. Authors collecting data on nest density have not been consistent; values have been reported as nests/m^2, nests/km shoreline, and nests/lake. Many investigators have made casual observations of spawning sites in conjunction with other studies, some have measured number or success of nests, but I found little quantitative data that could be used to plan a spawning or nursery habitat improvement project or to predict its success. Rearing pond nest spacings of 3.6 m (Inslee 1975) may not be realistic for natural lakes with their variety of predators. The most useful calculations for nest spacing could be made from Watson (1955) who counted nests in Big Lake, Maine and also measured the amount of suitable shoreline spawning habitat and from Doan (1940) who counted nests in several parts of Mitchell's Bay, Lake St. Clair and estimated the percentage of the bay area considered adequate for spawning.

While providing artificial structures for warmwater fish has been practiced and while it is generally agreed that fish use such structures, there has been no documentation of their function to increase fry production or fingerling survival. Haines and Butler (1969) evaluated the utilization of a variety of artificial coverts by yearling smallmouth bass in artificial streams. The same type of study could be adapted to lab or field projects for fingerling smallmouth bass in lake habitats. Recent authors have pointed out the potential for artificial structures to increase spawning, fingerling, and adult habitats for smallmouth bass and other centrarchids (Ryder 1970, Prince et al. 1975, Prince and Maughan 1978, Hubert and Lackey 1980). However, the needs to experimentally evaluate such management techniques and to determine whether more nests or better protected nests will lead to a population increase are vital.

APPENDIX

Current Research in Ontario -- Smallmouth Bass Reproduction and Year Class Strength in Lakes

The following references were unavailable to me as I completed this review. Although the MacLean et al. (1980) manuscript reviews some of the information, I list them here to record the additional data sources and the active research* continuing in this area.

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