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HUMAN INTERVENTION IN THE THE CLEAR LAKE BASIN OF RIDING MOUNTAIN NATIONAL PARK

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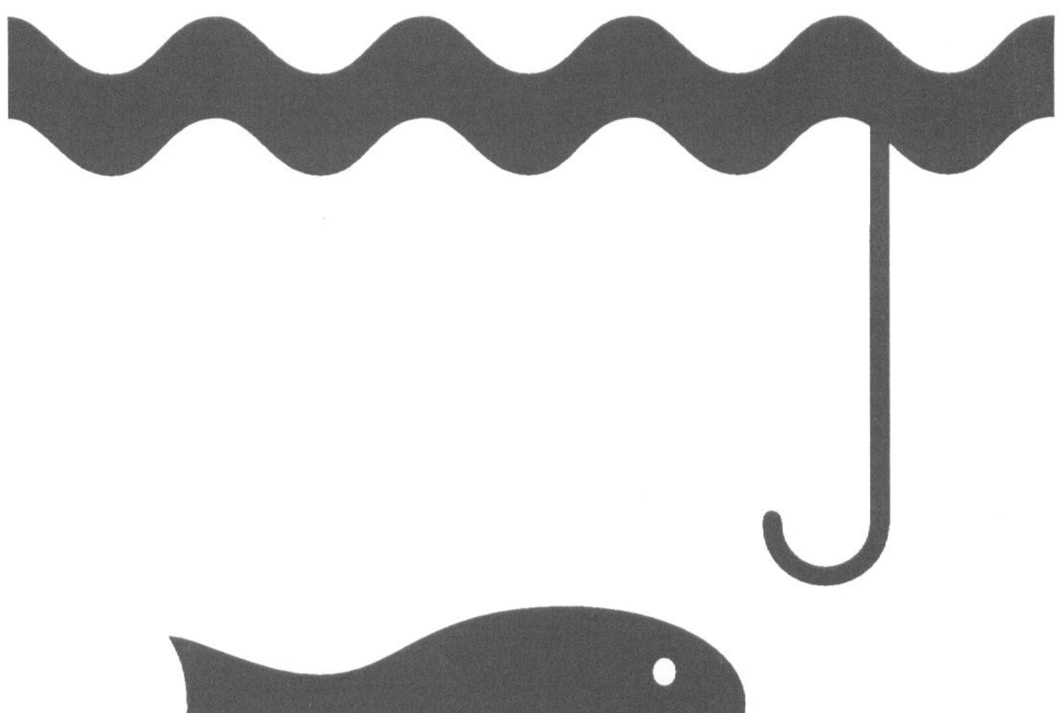

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HUMAN INTERVENTION IN THE FISHERY OF THE CLEAR LAKE BASIN IN RIDING MOUNTAIN NATIONAL PARK

by

Richard C. Rounds, Ph.D.
Director, The Rural Development Institute
Brandon University

Helen Bazillion, B.A., M.L.S.
Professional Librarian
Brandon, Manitoba

and

Connie Braun, B.Mus., M.L.I.S.
Staff Librarian
Brandon University

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PREFACE

Fishing is one of the most popular recreational activities in Canada, and engenders the most frequent requests for information in Riding Mountain National Park. Clear Lake supports the most productive and popular fishery, not only because of it its size and beauty, but also because human activity and development have historically occurred near the Lake. What many people are not aware of is the fact that Clear Lake is fed by a very small watershed that has experienced considerable human intervention during the last 200 years. Agricultural and recreational land use changes on private lands south of the present Park have impacted the Octopus Lake-Octopus Creek system that flows into Ominnik Marsh, South Lake and Clear Lake. Although new development is restricted, early development inside the present Park includes the settlements at Wasagaming, on the north shore, and a series of camps along the south and west shores. A golf course and highway complex adjoins the Lake on the east. In combination, these human activities have had and continue to exert influence on Clear Lake.

The Lake itself has a long and diverse history of exploitation and manipulation. Physical and biological changes involve everything from water flow control efforts to extensive fish introduction programs. This is one of a series of inter-related reports that are meant to review human intervention in the Clear Lake Basin. Emphasis here is placed on the Lake itself and the use and change of the sport fishery. The intent is to provide information for future decisions regarding management of the fishery of Clear Lake.

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INTRODUCTION

Sport fishing has long been a popular activity not only for Canadians, but also for people around the world. Approximately one in four adult Canadians, and most children enjoy angling for both pleasure and food. In 1975, 5.2 million Canadians and 1.2 million non-residents fished in Canada. Angling, therefore, is not only a favourite pastime, but also a major tourist attraction.

The quality of both the general environment and the fish resources make Canada an ideal fishing location (Labuda 1980). The relative value of water for fishing was reflected in a recent study in which the water of 52 of 67 river basins in the Western United States was of greater value for recreational fishing than for agricultural irrigation (Hansen 1991). In 1980, 368,000 Albertans fished an average of 17 days each, and spent $300 million in the process (Alberta 1984). Fishing, therefore, is both a favourite recreational activity and big business.

Anglers have several unusual demographic characteristics. First, there is a little variation in fishing activity through the full age range of 18 - 50 years. Participation rate does decline after 50 years, but it still is a popular recreational pursuit. Good data are not available for children, but they are known to constitute approximately one-quarter of all anglers. About one-third of anglers are female. Of greatest interest is the fact that angling does not relate to income, and is enjoyed almost equally by all socio-economic levels from lower middle to upper class.

In Riding Mountain National Park (RMNP), information on fishing constituted the most frequent request from visitors in 1980, and 5,000 fishing licenses were sold (Labuda 1980). License sales have decreased somewhat in recent years, ranging between 3,500 and 4,500, and averaging 4,008 between 1985-86 and 1990-91 (Parks Canada, unpublished data). Although generally considered a low-impact activity from an environmental perspective, angling may impact fish populations, and management efforts to improve fishing may impact both biological communities and the hydrology of lakes and rivers. The Clear Lake Basin in Riding Mountain National Park has been subjected to a number of activities both before and after establishment of the Park in 1930. Changes include manipulation of water flow, purposeful introduction of new species, recreational use of Clear Lake, and indirect effects from surrounding land use change.

The purpose of this report is to review available documents that record human impact on the fishery of the Clear Lake Basin. The report cites original sources for all information. The authors are responsible for the content of the report. Questions and comments are welcome.

PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF CLEAR LAKE

Clear Lake is different from all other lakes in Riding Mountain National Park. Not only is it the largest (2,947h) and deepest (35m) lake in the Park, but also it is the least productive, yet most diverse biologically. It is atypical for prairie lakes in that the temperature, water clarity and biological processes are more typical of northern lakes. Left as a remnant of glaciation (Bajkov 1932), Clear Lake is maintained by a very small drainage basin of approximately 75 square miles, with three small continuously flowing streams, and three to six small intermittent streams feeding the lake (Figure 1). Wasamin Creek is the only outlet stream, and its flow is not continuous (Rawson 1935). The major hydrologic components of the drainage basin include the Octopus Lake, Octopus Creek, Ominnik Marsh and South Lake complex on the south (Figures 1 and 2).

Early physical and biological surveys commenced during the 1930's when fishermen began requesting improvements to sport fishing through stocking programs. Reported substrate consisted of 60 percent coarse gravel, 30 percent sand and 10 percent emergent vegetation along the 19.9 miles of shoreline (Rawson 1935). Lake bottom was sand, gravel and rock except for the deepest areas where a fine mud overlay was present (Bajkov 1932). Submergent vegetation is common in shallow water areas, but not extensive.

Clear Lake typically freezes in early December, and remains frozen for five to six months, until late April to late May (Rawson 1935). Water temperature increases quickly after ice melt, but annual variation may be considerable owing to weather variations. Early spring mixing often results in a uniform temperature of approximately 5°C at all depths, but subsequent surficial heating begins to initiate temperature stratification, which typically occurs before the end of June. Maximum summer temperatures at the surface occur in late July and early August and range from 20° - 22°C (Bajkov 1932, 1934; Rawson 1935). Deep water temperatures typically range from 8° - 12°C during the warm season. The thermocline is located at between 10m and 20m, depending on season and year. The degree and permanence of stratification, however, was questioned by Rawson as early as 1935 and the importance later emphasized by Kooyman and Hutchison (1979:112) when they stated that "The fact that windstorms of gale proportions can upset the thermal stratification of Clear Lake was unexpected and may be one of the main reasons that lake trout in the long run cannot survive in this lake." Water temperature records change over the years of record, but variation in summer weather patterns appear to cause the changes. Data are not consistant enough to allow determination of long-term trends in water temperature.

Surficial dissolved oxygen records are at or near saturation for given temperatures in most studies, and shallow water dissolved O_2 is never reported as deficient for fish life in Clear Lake (range from 9.0 - 12.5 ppm at various temperatures). Deep water oxygen content ranges from 5.1 - 7.5 ppm below the thermocline, which would support most fish species, but may restrict some. Nearly all acidity measurements in Clear Lake range from pH 8.0 - 8.7, or slightly alkaline. Lower pH readings occur at greater depths, with surface readings typically being 8.5 - 8.7. Salinity readings appeared to vary slightly with season, depth and lake level, but no long-term variation is evident (e.g. Bajkov 1932, 1934; Rawson 1943; Kooyman and Hutchison 1979). Some salinity increase occurred during low water levels (Rawson 1943). Water clarity is one feature that makes Clear Lake unique in RMNP. Early Secchi disk readings, and later colour and turbidity measurements all confirm clear conditions, with allowance given for normal seasonal or temporary weather-induced variations.

Twenty-seven of the 84 species of fish that occur in Manitoba are found in Riding Mountain National Park, and 14 of these occur in Clear Lake (Kooyman and Hutchison 1979). Bajkov (1934) listed the white sucker (*Catostomus commersoni*), lake white fish (*Coregonus clupeaformis*), cisco (tullibee) (*Coregonus artedii*), and yellow perch (*Perca flavescens*) as common fish species in Clear Lake. Northern pike (*Esox lucius*) were present but not common in 1934. The spottail sculpin minnow (*Notropis hudsonicus*), Johnny darter (*Etheostroma nigrum*), stickleback (*Culaea inconstans*), trout-perch (*Percopsis omiscomaycas*) and slimy sailpin (*Cottus cognatus*) also were identified early. Fish identified later include the longnose dace (*Rhinichthys atratulus*), fathead minnows (*Pimephales promelas*) and the Iowa darter (*Etheostoma exile*) (Kooyman and Hutchison 1979). The slimy sculpin, cisco, lake whitefish, troutperch, blacknose shiner and spottail shiner occur only in Clear Lake and adjacent waters. Other fishes that have been introduced will be discussed later.

Although Clear Lake has a wide variety of aquatic organisms other than fishes, the abundance is not adequate to support Bajkov's (1934:2) early statement that "Clear Lake can be placed among the richest Manitoban Lakes." Rawson (1935) provides an early detailed list of the microfauna and microflora of Clear Lake and states that the variety and abundance of bottom fauna is "... about as great as would be expected in a lake of that size and depth."

Figure 1

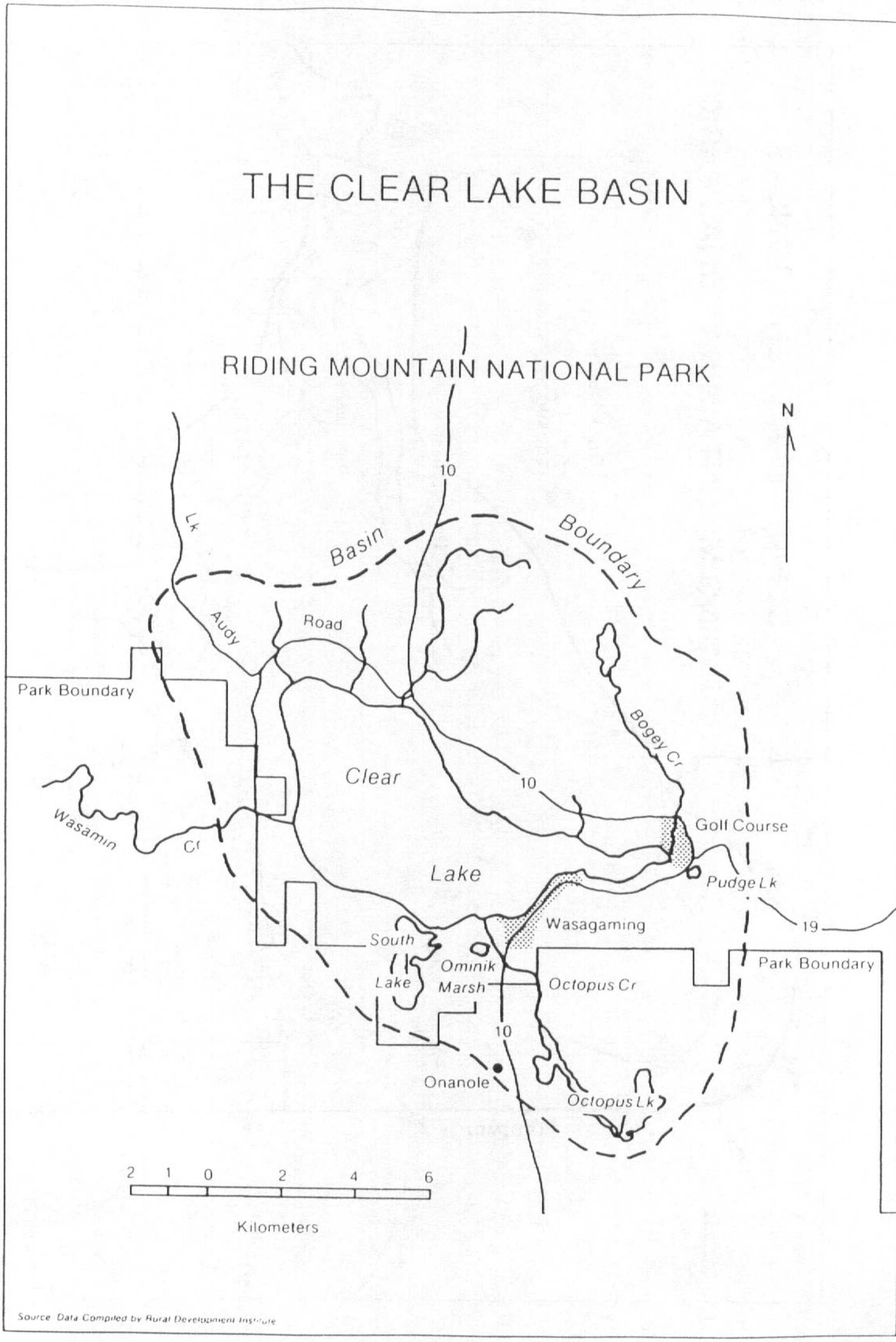
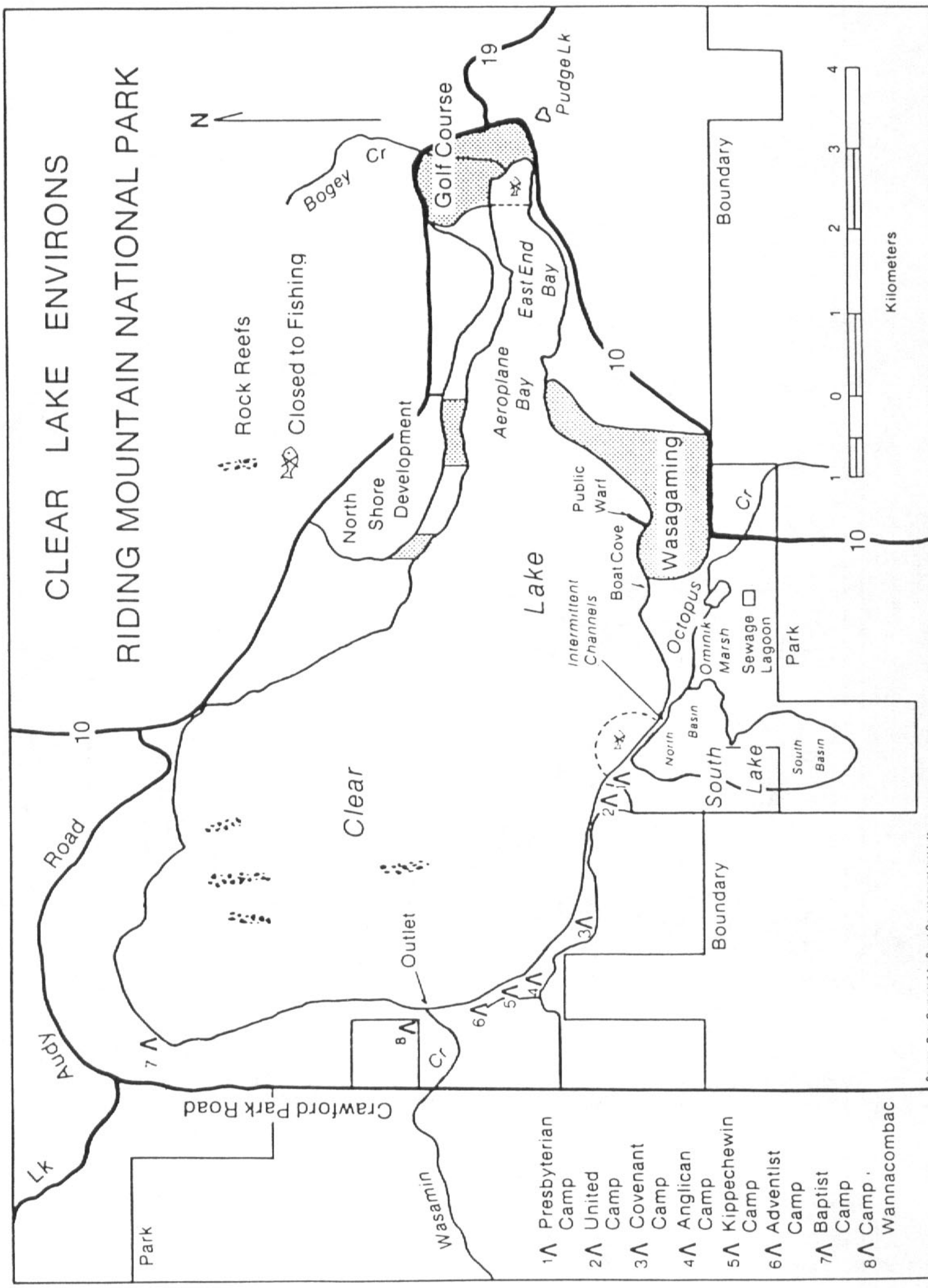

THE CLEAR LAKE BASIN
RIDING MOUNTAIN NATIONAL PARK
N
10
Lk
Basin
Boundary
Audy
Road
Park Boundary
Bogey Cr
Clear
10
Golf Course
Wasamin
Cr
Lake
Pudge Lk
Wasagaming
19
South
Lake
Ominik
Marsh
Octopus Cr
Park Boundary
10
Onanole
Octopus Lk
2 1 0 2 4 6
Kilometers
Source Data Compiled by Rural Development Institute

Figure 2


CLEAR LAKE ENVIRONS
RIDING MOUNTAIN NATIONAL PARK
N
Rock Reefs
Closed to Fishing
Clear
Lake
Golf Course
Bogey Cr
19
Pudge Lk
East End Bay
Aeroplane Bay
North Shore Development
Wasagaming
Public Warf
Boat Cove
Intermittent Channels
Octopus
Ominik Marsh
Sewage Lagoon
North Basin
South Basin
South Lake
Park
Boundary
10
Road
Audy
Lk
Crawford Park Road
Outlet
Cr
Wasamin
Kilometers
0
1
2
3
4
1 Presbyterian Camp
2 United Camp
3 Covenant Camp
4 Anglican Camp
5 Kippechewin Camp
6 Adventist Camp
7 Baptist Camp
8 Camp Wannacombac
Source: Data Compiled by Rural Development Institute

In a more recent and comprehensive search, Kooyman and Hutchison (1979) listed 140 species of phytoplankters and 88 species of aquatic macrophytes. Zooplankton was well-represented with 9 species of rotifers, 7 species of cladocerans, and 6 species of copepods. Although changes occur in species assemblages among studies, changes in classification, capture or sampling methods, and concentration on particular groups obviate direct accurate comparisons over the years.

Early attempts to classify lakes according to types based on productivity often relied solely on the judgement of the researcher. Early thoughts that Clear Lake was a highly fertile and potentially productive lake for fish were not well-grounded. Using a variety of physical and biological parameters, the Ryder morphoedaphic index (MEI) for lake productivity was applied to Clear Lake and other lakes in RMNP (Kooyman and Hutchison 1979). Although there are some limitations to application of MEI to Park lakes, the results are useful on a comparative rather than absolute basis. Of the 19 lakes used for comparison, Clear Lake had an MEI of 19, the lowest score. Seven lakes had MEI's between 23 and 50, five between 51 and 100, four between 100 and 200, and two greater than 200. Clear Lake, therefore, is not highly productive on a per unit volume basis. This result is reinforced by frequent mention in the literature of slow growth in a variety of fish species.

PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF SOUTH LAKE

South Lake is considered to be a recently cut-off shallow bay of Clear Lake (Everett 1970), and is described as a "moderately large, shallow, turbid, coloured lake with a high pH" (Kooyman and Hutchison 1979:39). Everett (1970) described South Lake as very eutrophic, with an organic and gaseous substratum. The maximum depth is 2 m, with general water depth ranging from 0.5 - 1.5 m over the 267 acre area. An isthmus of sand and gravel has been built up by wave action on Clear Lake, and South Lake is effectively isolated. Two approximately equal basins of South Lake lie in north-south orientation. One inlet occurs as Octopus Creek enters the north basin from Ominnik Marsh. One outlet occurs irregularly as the isthmus is breached periodically during spring runoff (Figures 1 and 2).

South Lake is very different chemically from Clear Lake. It is the only lake in RMNP with a pH value higher than 9.0, with values of 9.2 or 9.3 (Kooyman and Hutchison 1979). Dissolved oxygen varied from 9 ppm in mid-summer to <5 ppm in late summer. Winter kill is suspected to occur regularly. Water temperatures reach >23^{0}C at all depths during summer.

The north basin "supports a much greater population of algae and emergent vegetation" (Everett 1970:4). This growth is attributed to the inflow from Octopus Creek which not only passes through the organic substrate of Ominnik Marsh, but also may transport effluent from the sewage lagoon that serves Wasagaming (Foskett 1962; Everett 1970; Kooyman and Hutchison 1979) (Figure 2).

Many of the biological surveys of Clear Lake have included some information for South Lake. Extensive collection, however, has not been common. Lake whitefish, pike, white sucker and yellow perch are native fish that occur in South Lake at least periodically or seasonally (Kooyman and Hutchison 1979). None of the minnows reported in Clear Lake were evident in South Lake. The microfauna and microflora would be difficult to distinguish from those of Clear Lake or Ominnik Marsh, but would likely be diminished by winter kill. For example, South Lake had only one rotifer (Clear Lake had 9), six cladoceran (Clear Lake had 7), and five copepods (Clear Lake had 6). Everett (1970) reported ten shoreline plant species, six aquatic emergents, three submergents and a variety of algae and plankton, but his survey was not extensive. In total, the biological communities of the two lakes are intricately linked by historic and present proximity, and intermittent connection across the isthmus. The significance of the Clear Lake - South Lake relationship to fisheries will be discussed later.

THE FISH OF CLEAR LAKE

Clear Lake was a popular fishing lake long before RMNP was formally established in 1930. Attempts to stock the lake with a variety of non-native game fishes began in 1923 (Table 1). Between 1923 and 1925, 445,000 fry of the walleye (locally pickerel) (*Stizostedion vitreum*) were released, and an additional 650,000 fry were released between 1927 and 1930. Stocking efforts were both common and significant for nearly 50 years as lake trout (*Salvelinus namaycush*), rainbow trout (*Salmo gairdneri*), splake (brook trout x lake trout cross), brook trout (*Salvelinus fontinalis*) and muskellunge (*Esox masquinonges*) were released in varying numbers in Clear Lake. Because of the significance of stocking to the fishery, the history of each native and non-native fish species in Clear Lake will be discussed in detail.

Native Species

Northern pike, lake whitefish, yellow perch, suckers and cisco are the major native fish species in Clear Lake. A variety of sources of information on the absolute and relative populations of these species is available, including observations, gill and seine net samples, and censuses of anglers, commercial fishing records, and research studies.

Northern Pike

Bajkov (1933:5) comments that pike are "... very common in the lake at the present time [1932]." Rawson (1942) stated that pike were common, but apparently declining in number. No young pike were captured during surveys, and Rawson speculated that recent low water levels had stopped successful spawning in shallow shore areas. In 1943, he again mentioned a lack of spawning by pike owing to low water, and said that pike were not abundant. Netting records indicated that only 108 pike (4 percent) were caught among 2,683 total fish.

Creel censuses were conducted on Clear Lake in 1951, 1952 and 1953 (Cuerrier and Ward 1953). Pike were caught commonly, but the number reported varied from 51 in 1952, to 130 in 1951 and 337 in 1953. The differences were partially accounted for by variation in effort, but the catch per hour doubled from 0.30 - 0.40 in 1951 and 1952, to 0.80 in 1953. Pike were the only heavily fished species in the 1950's.

In 1953, Schultz set gill nets at three sites, catching 223 fish, only 11 (4.9 percent) of which were pike. He did speculate, however, that predation by pike might be a reason for failure of lake trout to survive. Atkinson (1958) reported a heavy movement of pike through "Poacher Creek" (Intermittent channel, Figure 2) which connected Clear Lake and South Lake during the spring spawning season.

Foskett (1962:5) stated that pike had borne the brunt of the sport fishery in Clear Lake, but that they were "... contributing as much to the fishery at the present time as at any past time." He mentioned the necessity of South Lake for proper spawning of pike. Unfortunately, accurate population estimates were not made during early years. Pike, however, were apparently common but not overly abundant. In 1970, Kooyman (1970:3) stated that pike were much less numerous than during the 1950's. He explained the decline by loss of access to South Lake for spawning, and that alternative spawning areas in Clear Lake could not compensate for the loss. In 1978, only 97 (2.0 percent) pike were among 4,829 fish that migrated into South Lake in spring (MacLean 1979).

Table 1 Stocking of fish in Clear Lake in Riding Mountain National Park, 1923 - 1969

			Species			
Year	Brook Trout	Muskellunge	Lake Trout	Rainbow Trout	Splake	Walleye (Pickerel)
1923						150,000f[1]
1924						175,000f
1925						120,000f
1926			123,000F[2]			
1927						250,000f
1928						175,000f
1929			110,000F			125,000f
1930			237,000F			100,000f
1937				50,000F		
1938				35,000F		
1939				25,000F		
1940				30,000F		
1942				25,900F		
1943			274A[3]			
1944			296A			
1945			318A			
1946			326A			
1947			339A			
1948			299A			
1950			6,700Y[4]			
1952			5,400Y			
1954			1,395A			
1956						1,272A
1958						900,000f 4,674f
1959					18,289F	4,500,000f
1961			422A			11,500F
1962		500f				
1965	40A					450,000f
1966			4,500Y			500,000f
1967			7,400Y			1,500,000f
1968						1,000,000f
1969	15A		10,000Y			

Adopted from Kooyman 1970 and Briscoe 1979

[1]f = fry
[2]F = fingerlings
[3]A = adults
[4]Y = yearlings

A major survey was conducted in Clear Lake in 1982 (Wickstrom 1983). Gill nets set at nine sites resulted in capture of 1,292 fish, of which only 13 (1 percent) were pike. Accordingly, pike were listed as present although not abundant. During May of 1982, 1,235 pike (11.5 percent) were among 10,785 fish that went through the South Lake channel (Hoggins and Holzmiller 1983). In 1984, the spawn run was late. Eighty four pike that over-wintered were netted in South Lake and they had not spawned out by 5 May. The channel never opened in 1984 and the fate of the pike was not reported. This appears to be the only reference to over-winter survival in South Lake, although some early reports suggested that it might occur.

In 1986, 58 pike (5.6 percent) were reported among 1,033 fish angled by fishermen (Whittaker and Sopuck 1988). In 1987, however, the number of pike decreased to 22 (1.8 percent) of 1,242 fish. Whittaker and Sopuck (1988) expressed concern about the pike population. Heap (1988) mentioned that only large pike were caught in nets in 1987 and 1988, suggesting lack of recruitment of young into the population. He expressed concern for the pike population and stated that the South Lake channel should not only be open during spring spawning, but also during fall to allow fry to return to Clear Lake for winter.

Lake Whitefish

By far the most abundant native fish species in Clear Lake is the lake whitefish. In 1942, 662 whitefish (24.7 percent) were among 2,683 netted fish (Rawson 1943). Rawson reported earlier netting of whitefish (but no numbers) and recommended limited commercial netting in 1935. A single permittee captured 1,450 whitefish (74.1 percent), 500 suckers and 7 pike in 1935. Commercial netting in 1941 resulted in capture of 4,168 whitefish (98.1 percent), 57 suckers, 17 pike and 6 perch. Commercial netting during winter 1942-43 resulted in the capture of 34,678 pounds of whitefish, and 11,633 pounds of suckers (others were recorded by number, not weight as follows: 6,813 perch, 10,038 cisco, 307 pike) (Rawson 1943:18). When converted to weight, whitefish constituted more than two-thirds of the catch, and suckers an additional 23 percent.

In 1945, gill net lifts captured 558 fish, 84 (15 percent) of which were whitefish (Doan 1945). In 1952, Schultz (1953) captured 69.1 percent whitefish in gill net hauls. Even when specifically netting for lake trout, whitefish dominated the catch (56.3 percent) in 1955 (Ward 1956). High populations of whitefish have continued into recent years as migrations into South Lake from Clear Lake included 3,384 whitefish (70.1 percent) in 1979, 3,149 whitefish (58.8 percent) in 1980, and 2,464 whitefish in 1981 (Wickstrom 1983). Hoggins and Holzmiller (1983) reported 7,930 whitefish (73.5 percent) among 10,785 total fish counted in migration studies. When gill nets were set in nine sites in 1982, whitefish constituted 66.3 percent of the catch of 1,292 fish (Wickstrom 1983).

Although numbers should not be considered as reliable population estimates because of changes in purpose and method of capture among studies over the years, it is apparent that lake whitefish always have been and still are the major fish species in number and biomass in Clear Lake. Whitefish are a fine sporting fish, but are not sought by anglers except during infrequent winter fishing. Whitefish in Clear Lake are frequently infected with parasites reducing both recreational and food value for the species (Doan 1945). Recent research has centred on other species, but evidence suggests that whitefish remain "very numerous" in Clear Lake (Heap 1988).

Yellow Perch

Yellow perch also have been common in Clear Lake since early records were kept. Bajkov (1934) lists perch as very common. Perch constituted 25.6 percent of the total number of fish caught in gill nets in 1934 (Rawson 1935). Rawson (1942) reported a "very heavy population" of perch in Clear Lake. Doan (1945:5) reported that perch "were most commonly observed in the water of Clear Lake." This verifies Rawson's gill netting in 1942 which caught 836 perch (31.2 percent) among 2,683 fish (Rawson 1943). Young yellow perch also were "abundant" in seining efforts along shore. Among 310 fish netted in 1946, 271 (87.4 percent) were perch (Solman 1946). Perch constituted 592 (52.5 percent) of 1,128 fish caught in gill nets in 1948, and were by far the most abundant species (Sollman 1948). Cuerrier (1949) listed perch as fairly abundant.

Early creel censuses seldom reported perch among catches (Cuerrier and Ward 1953), but this appears to suggest a lack of interest by fishermen rather than a lack of perch. Foskett (1962) reported that perch were not an important angling species, and that in spite of a "very large" population, the small size of individual fish obviated interest by sportsmen. Small average size probably accounts for lack of perch in several netting studies (e.g. Schultz 1953; Ward 1956). Only small mesh sizes would catch small perch.

Perch are frequently caught by anglers but are not a sought-after fish. Whittaker and Sopuck (1987) list perch between 20 and 25 percent of all fish caught, which puts them second to walleyes, and well ahead of pike. In 1988 large numbers of perch fry were observed in shallow water, and large specimens were seen by divers (Heap 1988). Apparently perch remain numerous in Clear Lake.

Cisco

Cisco (or tullibee) are abundant in Clear Lake, but are not angled. Original populations were high. In 1935, Rawson reported ciscoes as approximately 50 percent of all netted fish. Rawson (1943) later reported cisco as the fourth most common species caught in nets, and that capture always occurred in deep water sets. He postulated that they would be much more commonly caught if nets were set in deeper water. Commercial netting captured more than 10,000 ciscoes in 1942, but their small size placed them well below whitefish and suckers, but above pike and perch in biomass. Cisco commonly dominate deep set nets, but efforts to estimate numbers usually are descriptive terms such as common or abundant (Doan 1945; Solmon 1946; Cuerrier 1949). Solman (1948) reported cisco as the second most numerous fish in gill nets, accounting for approximately 20 percent of all fish caught. Ciscoes are heavily infected with parasites (Rawson 1935), and serve only as a food for game fish among fishery interests. Little attention has been given to the biology or ecological role of cisco in Clear Lake.

White Suckers

White suckers are not considered a game fish, but may be used for food and be commercially fished. Suckers were considered the most common fish in Clear Lake by Bajkov (1934) and were the most frequent fish netted during spring 1942, when they accounted for 34 percent of the catch (Rawson 1943). Suckers were common but not dominant in other early netting surveys (e.g. Rawson 1934, Solman 1948). Commercial netting in the 1940's was regulated to ensure the taking of excess suckers as well as whitefish. Accordingly, 11,633 pounds of suckers were captured in 1942. A healthy population of suckers apparently has survived as spring spawning runs are consistent in high numbers of fish.

Introduced Fish Species

Clear Lake has been a favoured retreat for prairie residents for nearly 100 years. A desire to increase the fishery potential of the lake pre-dates the establishment of the National Park, as calls for the introduction of additional game fish began before 1920. Cuerrier (1949b) suggests that several stockings of pickerel had occurred prior to 1923, the first year for which numbers are available (Table 1). Pressure to introduce new species came from a variety of sources including the Government of Manitoba, the Dauphin Board of Trade and local anglers. Walleye (alternatively called pickerel or yellow walleyes) were first introduced, and were followed by lake trout, rainbow trout, splake, brook trout and muskellunge. Some stocking occurred on a regular basis between 1923 and 1969 (Table 1).

Walleye (Pickerel)

The earliest recorded stocking of walleyes in Clear Lake occurred between 1923 and 1930, when 1,095,000 fry were released during seven of the eight years (Kooyman 1970; Table 1). In 1934, Bajkov recommended against further introduction of walleyes. Rawson (1943:14-15) reported failure of early stockings, and attributed loss to the fry being "at a very early stage" and released "under somewhat unfavourable conditions." He thought that further releases may be successful, and that walleyes would be more likely to survive in Clear Lake than would trout species. Walleyes, however, were deemed "less attractive to anglers and tourists than the lake trout." It is doubtful that any of the fry released prior to 1930 survived, as walleyes do not appear in any of the many gill net, seine net or creel surveys conducted during the 1930's, 1940's and early 1950's (e.g. Rawson 1943; Schultz 1953; Cuerrier and Ward 1953). Foskett (1962) attributed this failure to heavy poaching during spring spawning runs.

Stocking of walleyes was resumed in 1956 with the release of 1,272 adults (Table 1). In subsequent years, 8,850,000 fry and 4,674 fingerlings were released. No additional stocking has occurred since 1968. Eleven pickerel were first counted in the South Lake Channel in 1958 (Atkinson 1958). In the same year a pickerel hatchery setup was tried, but failed. Similar hatchery results occurred in 1959, but later in the summer "a great many 1, 2 and 3 year old yellow walleye ... were taken [in gill nettings] (MacDonald 1959). It was apparent that either the stocked fish had survived, the population was reproducing, or both. Foskett (1962:5) reported that "recent stockings of fry, fingerlings and adults has resulted in good catches ... during the past summer [1961]." He did not know if walleye would spawn and maintain the population.

By 1970, the 1956-68 plantings had resulted in "a thriving population of this species which is producing excellent fishing for anglers. The walleye [was] now firmly established in Clear Lake" (Kooyman 1970:2). Evidence suggested that the population was being maintained at a high level by natural reproduction. Kooyman (1970) felt that the adults were spawning in Clear Lake itself, and recommended no further plantings for 3 to 5 years and a reduction in angling limits from 8 to 5 fish. He felt that the average weight of 3 pounds per fish would offset the reduced limit, and that the consumptive use of fishery resources in National Parks should be de-emphasized. Little information exists in the literature during the 1970's.

Research on walleye populations began in 1978, when MacLean (1979) reported that 1,333 walleyes migrated through the South Lake channel, and 340 were tagged. Fisherman returned 18 tags that year, and MacLean estimated that one-third of the population used South Lake for spawning. In the same year, Kooyman and Hutchison (1979:102) reported that the "present excellent population probably originated from the 1956 adult transfer," and that walleye spawn both in Clear Lake and South Lake when the channel is open. A very heavy run of fish occurred into South Lake in 1980 and 578 walleyes were tagged and released. Tag returns (55 in 1980) resulted in an estimate of one-half of the adult walleyes using South Lake for spawning (Millward 1980).

As early research supplied more questions than answers, additional studies were instituted. In 1983, the channel between the lakes was dredged and the migration monitored. About 15 percent of the fish migrating into South Lake were walleyes, but searches found no spawning walleyes, no eggs, and no fry. Returning adults, however, were spawned-out, and later in the summer, fry of walleye did migrate back into Clear Lake. Observations resulted in an estimate of 44,644 adult walleyes in the population. Nearly all adults (96 percent) were thought to spawn in Clear Lake, and it was recommended that the channel between the lakes be closed for three years (Hoggins and Holzmiller 1983).

In a much more extensive study, Wickstrom (1983) reports on observations from 1979 to 1982. Walleye migrations through the channel varied widely from 1,833 in 1979, to 533 in 1980, 60 in 1981 and 1,583 in 1982. Some young-of-the-year were caught returning to Clear Lake later in the summer. The author states that walleye spawning does occur in South Lake, but thought that closing South Lake might induce the fish to spawn in Clear Lake, where success might be greater. The 1982 population was thought to be "well represented in the various size classes obtained by gill netting" (Wickstrom 1983:57). Using available data, the population was estimated at 44,990 walleyes as a high end estimate, 36,279 walleyes as a moderate estimate, and 18,923 walleyes as a low end estimate (based on gill netting returns). An estimate of 13,786 walleyes resulting from angling tag returns was considered too low. Gross estimates of angling catch was 2,000 - 3,000 walleyes, or approximately 10 percent of the adult population. This was considered moderate angling pressure. Wickstrom concluded that the best population estimate was 30,000 adult walleyes, that the population was increasing, and that "South Lake is not important for maintenance of the walleye population." In 1984, Toews reported that walleye were observed spawning along the north shore of Clear Lake, but no evidence has been reported since the initial observation.

Creel censuses were conducted on Clear Lake in 1986 and 1987 (Whittaker and Sopuck 1987). The 1982 and 1983 age classes were very strong in the catch, but 1984 recruitment was negligible. They state that age class distribution was very uneven, and called for an investigation into fluctuations in year class strengths. Walleyes continued to be by far the most popular species for anglers, as they constituted 67 percent of the 1986 catch, and 76 percent of the 1987 catch.

A survey in 1987 and 1988 (Heap 1988) indicated problems in walleye recruitment into the population. In 1988, the 1983 cohort (5 year old fish) accounted for 69 percent of the catch, and the 1984 and 1985 cohorts were very weak or absent. Since walleyes typically enter the catchable population in three years, recruitment obviously was truncated. Heap (1988:18) stated that the South Lake channel may be more important than suspected "because when it ran well in 1983, reproduction was good, but recruitment in 1984 and 1985 was poor and the channel never opened.

Lake Trout

Lake trout fry were first introduced to Clear Lake in 1926, and 470,000 fry were planted by 1930 (Table 1). Bajkov (1934)felt that obvious failure resulted from incorrect introduction and fry in poor condition. He did not recommend further stocking because lake trout are not a preferred game fish. In 1943, however, Rawson recommended that lake trout be tried again as "the best choice of several not too promising alternatives" (Rawson 1943:10). He suggested holding fry in rearing ponds over summer for release in fall. The Manitoba government offered adult lake trout, and beginning in 1943, adults were stocked directly into Clear Lake. Between 1943 and 1954, more than 3,000 adult fish and 12,000 yearlings were released.

As early as 1945, eight adult lake trout were captured in gill nets, suggesting "excellent survival of adults" (Rawson 1945). Doan (1945) thought the lake trout showed promise, but he saw "no proof that these fish have reproduced." In 1948, Solman counted 15 lake trout (1.3 percent) among 1,128 fish in gill nets. No eggs or young lake trout were found, but the adults appeared healthy, and eggs and young can be very difficult to find.

An extensive search was conducted for evidence of reproduction in lake trout in 1949 (Cuerrier 1949a). Adult fish were caught at various depths. It was surmized that the lake trout population was living at temperatures of 55^0 - 60^0 F during summer. This is considered a very high temperature for the species. In September, adult trout gathered at Bogey Creek, and appeared ready for spawning. Females examined showed evidence of having spawned in previous years. Extensive searching found no eggs or young trout.

In 1950, an intensive search was conducted to find young trout but none were captured (Gilmour 1950). Anglers reported catching 59 adults in 1951, but only 4 in 1952 (other records suggest 12 - 15 in 1952). In 1953, Schultz looked for the 12,000 yearling lake trout released between 1950 and 1952. He found none, and blamed predation by pike and perch for the loss. He concluded that stocking adults was the most functional practice. The adults survived for many years as 670 adults were captured in Bogey Creek in 1967 for egg collection. Between 1961 and 1970, 422 more adults and 22,000 yearlings were released (Table 1).

By 1970 it was obvious that the lake trout were either not reproducing at all, or were not very successful in reproduction. Kooyman (1970) reviewed all records and saw little evidence over 15 years that lake trout were reproducing. Boulders and cobbles were placed over one sandy bottom area where trout were thought to spawn, but no results were apparent. It was stated that even minor recruitment might be sufficient to sustain the population because it was "lightly exploited by anglers."

Between 1970 and 1979 no further stocking occurred. In 1979, Kooyman and Hutchison (1979) stated that the lake trout population was "not thriving". Gill netting captured 15 lake trout in 1973, some of which were marked as yearlings and some believed to be adult survivors of original releases. There was no firm evidence of reproduction, and as stocking was discontinued, the number caught by anglers declined steadily. Even the annual fall runs at Bogey Creek were not evident in the late 1970's.

Kooyman and Hutchison postulated that an unusual characteristic observed in Clear Lake may explain the lack of recruitment from lake trout. In mid-summer, gale-force windstorms destroyed the thermal stratification of the lake. Bottom water exchanged completely with surface water and a uniform temperature of 17.2°C existed at all depths for several days. This temperature is near the upper limit for survival of young lake trout and may cause high mortality rates. If this phenomenon occurs periodically, it easily could obviate a permanent lake trout population in Clear Lake.

Only one lake trout was among 1,000 fish caught in gill nets in 1983 (Wickstrom 1983). Creel censuses conducted in 1986 and 1987 included no lake trout (Whittaker and Sopuck 1987). The most recent report included four lake trout caught in gill nets in 1988 (Heap 1988). Only one of the fish was marked, so the other three may indicate limited reproduction and recruitment into the population.

Rainbow Trout

The desire to stock rainbow trout in Clear Lake dates back to the 1920's (Bajkov 1932). It was recommended that a small hatchery be established on Clear Lake, and Rogers (1940) called for the rearing and release of 350,000 two-inch fish per year for four years (1.4 million in total). Attempts to produce, hold and release rainbows were not very successful, and between 1937 and 1942, only about 140,000, or 10 percent of the suggested number were released (Table 1). Gill netting in 1940 produced no rainbow trout, and only two two-inch fish were caught in seines. Better survival than indicated was thought to occur because anglers had caught several three-year old rainbow trout during the summer, and one, two, and three-year old trout had been observed in inflowing freshets.

Netting and seining during spring 1942 yielded no adult fish. After extensive searching, Rawson (1943) stated that "it was quite clear that there was no spawning run of rainbow trout in Clear Lake in 1942." Further sample netting of 2,683 fish also produced no rainbow trout. Although three small trout were seined, two of them had been released recently, and the third was only one year older. During winter 1941 - 42, 35,000 fish had been removed by commercial fishermen and not one rainbow trout was caught. Failure was attributed to predation by yellow perch. Further release was not recommended, and Doan (1945) termed the rainbow trout release a failure in 1945. Rainbow trout have never shown up in gill nets or seines since the early 1940's.

Splake and Brook Trout

According to Kooyman (1970), 18,289 splake fingerlings were released in Clear Lake in 1959. Original references for the release were not available, but Foskett (1962) mentions "the recently stocked splake." Lake trout were captured in 1965 and 1969 for egg stripping and cross-fertilization by eastern brook trout (*Salvelinus fontinalis*) to derive splake. Forty adult male brook trout were released in Clear Lake following milt stripping in 1965, and 15 more in 1969. Kooyman (1970:2) states that splake and brook trout "have shown up as occasional specimens when trout are trapped for spawn-taking purposes in some fall seasons." Briscoe (1979:9) said that "no catches of adult splake have been recorded for Clear Lake "... and that "brook trout probably no longer occur in Clear Lake."

Muskellunge

Briscoe (1979) reports that 500 muskellunge (*Esox masquinongy*) fry were released in Clear Lake in 1962, but that the release was unsuccessful. The original reference for the release was not found, and was not reported by Kooyman (1970).

FISHING IN CLEAR LAKE

Commercial Fishing in Clear Lake

Some commercial netting of fish apparently occurred in Clear Lake prior to establishment of the Park in 1930, and during the 1930 - 1935 period. The records of catches are available, but the fish were known to have been used as food for relief camps. Early studies suggested that an over-abundance of whitefish and coarse fish (primarily suckers and yellow perch) could jeopardize fish stocking efforts, and extensive commercial netting was recommended. In 1935, a summer permit was issued and 1,450 whitefish, 500 suckers and 7 pike were netted. Records are not available for the catch from a 1936 summer permit. During summer of 1941, 4,168 whitefish, 57 suckers, 17 pike and 6 perch were netted. A winter permit was issued for 1942 - 1943 with the proviso that mesh sizes capable of catching perch and suckers be included in net gangs. During that winter the following fishes were netted: lake whitefish (34,678 lbs.), suckers (11,613 lbs.), yellow perch (1,600 lbs.), ciscoes (2,100 lbs.), and pike (1,300 lbs.) (Rawson 1943).

In reviewing commercial fishing on Clear Lake, Doan (1945) estimated that 74,100 pounds of whitefish had been removed between 1941 and 1943. He reported that Rawson had tested whitefish for cysts of tapeworms (*Triasrophorus crassus [robustus]*) and found one-half of the fish infected, and one-fifth heavily parasitized (5 - 20 cysts/fish). Similarly, commercial fisherman reported that 50 - 60 percent of the whitefish were infected, with about half of these heavily infested. In 1945, 66 whitefish were examined, with 56 infected and 10 clear of cysts. In total, whitefish averaged 530 cysts per 100 fish, or 300 cysts per 100 pounds of fish. This degree of infestation obviated either interprovincial or international shipments. Doan (1945) recommended against further commercial fishing not only because of parasitism, but also to protect introduced lake trout. Apparently, no commercial fishing has occurred since 1943.

Angling Regulations for Clear Lake

Fishing has been popular in Clear Lake since well before Riding Mountain National Park was established in 1930, and public demand for an improved and diversified fishery was the base for most stocking efforts over the years (e.g. Bajkov 1932, 1934; Rawson 1943; Doan 1945). Apparently there was little control or enforcement during early years as records were not kept, and poaching during spawning runs is often mentioned as a problem. As popularity increased and Parks Canada developed regulatory control, a greater need for management of angling was apparent.

Doan (1945) first recommended legalizing fishing for lake trout as soon as they were known to be reproducing. Although reproduction was not assured, Solman (1947) recommended a "small amount" of angling for lake trout in 1947. A similar request in 1949 was denied by the Park Superintendent because reproduction was not yet verified. In 1949, however, anglers were known to be taking lake trout illegally, and it was recommended that a season be opened in 1950 with strict seasons, limits and areas (Cuerrier 1949b). Ultimately lake trout fishing opened from 1 June to 31 August in 1950, with a one fish daily limit of a trout greater than 15 inches in length. The East End Bay of Clear Lake was closed to all fishing to protect the lake trout. Although catches had been minimal and decreasing, Schultz (1952) recommended continuation of the lake trout regulations.

The first organized creel censuses were conducted on Clear Lake in 1951, 1952 and 1953 (Cuerrier and Ward, 1953). The 1951 census showed pike were the most commonly reported species, with 130 fish reported, or 0.40 fish per hour of fishing. Lake trout records were not clearly reported, but at least 48 fish were caught (probably 59 fish) for a return of about 0.50 fish per hour of fishing. Spring fishing was most productive (15 - 30 June) for pike (0.80 fish/hour), but angling effort was much greater in late July (15 - 31 July). Most lake trout fishing occurred between 15 - 30 June, but catches never deviated much from 0.50 fish/hour.

A similar census in 1952 recorded 51 pike (0.30 per hour) and only 4 lake trout caught in Clear Lake. The number of fish reported dropped considerably between 1951 and 1952. In 1953 the number of reports increased greatly, and 337 pike were reported caught in Clear Lake. The catch per hour increased to 0.90. However, only three lake trout were reported. Fishing effort peaked in July and August (Cuerrier and Ward 1953). Very little additional information was either gathered or published during the 1950's and 1960's. Kooyman (1970) stressed a need for angler harvest surveys in 1970.

In 1967, regulation became more active with issuance of the National Parks Fishing Regulations. Clear Lake was the only fishery in Riding Mountain National Park that was open all year for angling (Table 2; adapted from Briscoe 1979:3). East End Bay remained closed to protect lake trout, and South Lake and its outlet were closed (Figure 2). Limits were established for all species of fish except perch. In 1969, closed areas were extended to include a 300 yard radius around the outlet of South Lake which extended well into Clear Lake. This was done to protect the vulnerable aggregated populations of pike and walleye during and after the spawning run.

The first major regulation change occurred in 1975, when the season in Clear Lake was limited to 15 May - 31 March. The six-week closure was meant to 1) coordinate Clear Lake with Manitoba provincial regulations, 2) more fully protect spawning populations, and 3) to protect anglers from unsafe ice conditions during spring break-up (Briscoe 1979:6). Also, the separate limit for lake trout and splake was removed, and an all trout limit of 10 was established. By this time, trout were very unimportant in the Clear Lake fishery.

In 1977, the closed area around the South Lake channel was extended to 500 yards (Figure 1), and the all trout limit was reduced to 5 fish. To guard against potential introduction of unwanted species, a regulation that prohibited use of live fish for bait was enacted in 1978. The limit for walleyes (pickerel) was reduced from 8 to 5 per day in 1983. No further changes were enacted until 1989, when two regulations were changed.

Table 2 A summary of recent major sport fishing regulations for Clear Lake in Riding Mountain National Park, 1967 - 1990

Year	Category	Regulation	
1967	Seasons:	1 April - 30 September	
	Closed areas:	East End Bay	
		South Lake and outlet stream	
	Species catch limits/day:	Lake trout and splake - 5	All other trout - 10
		Pike and muskellunge - 5	Walleye (pickerel) - 8
		Whitefish - 10	Perch - no limit
		Aggregate (excluding perch) - 10	
1969	Seasons:	No change	
	Closed areas:	Same as 1967 plus 300 yd. radius from South Lake outlet into Clear Lake	
	Species catch limits/day:	No change	
1975	Seasons:	15 May - 31 March	
	Closed areas:	No change	
	Species catch limits/day:	All trout - 10	
		No other changes	
1977	Seasons:	No change	
	Closed areas:	Same as 1969 except 500 yd. radius from South Lake outlet into Clear Lake	
	Species catch limits/day:	All trout - 5	Yellow perch no longer a game fish
		No other changes	
1978	Seasons:	No change	
	Closed areas:	No change	
	Species catch limits/day:	No other change	
	Angling limitations:	No live bait fish may be used	
1983	Seasons:	No change	
	Closed areas:	No change	
	Species catch limits/day:	Walleye - 5	
	Angling limitations:	No change	
1989	Seasons:	No change	
	Closed areas:	Same as 1969 except 500 yd. radius closure from South Lake outlet removed	
	Species catch limits/day:	No other change	
	Angling limitations:	No live fish or fish bait parts, live or dead may be used	
1990	Seasons:	No change	
	Closed areas:	No change	
	Species catch limits/day:	All trout - 3	

First, the 500 yard protected zone around the South Lake outlet was removed. Second, the no use of live fish bait was extended to include all fish or fish parts, whether frozen, freshly dead, or live. In 1990 the daily limit for all trout was reduced to 3.

Recent creel surveys show that major changes have occurred in angler preferences since the early 1950's (Whittaker and Sopuck 1987, 1988). In 1987, 995 anglers were surveyed as they left Clear Lake. Most (94.4 percent) were seasonal or local residents of Wasagaming and Onanole. Total fishing was estimated at 14,662 hours, or 5 hours/hectare of lake. This is considered light angling pressure. Whereas pike constituted virtually all of the fish taken in earlier creel censuses, walleyes were by far the most common fish caught in 1987 (67 percent), with yellow perch second most common (25 percent), and pike a distant third (6 percent). Pike, therefore, have been replaced by walleye as the most popular and numerous fish caught.

The overall catch rate of 0.36 fish/hour is somewhat lower than catch rates from the 1950's, and the catch rate for pike (0.02) was very much lower. Pike, however, are seldom fished for exclusively, and catch per hour may reflect incidental catches while walleye fishing. Whittaker and Sopuck (1987) reported that an earlier creel census taken in 1968 resulted in an overall mean catch rate of 0.16 fish/hour. They concluded that the Clear Lake sport fishery was not declining, and, when compared to other fisheries, was somewhat lower in catch rate per unit effort, but produced larger sized fish.

Winter fishing occurs during all months with safe ice, but is not intensive. The entire lake was fished only an average of 5.2 hours per day during December, January and February. The catch per hour was 0.26 fish, most of which were perch. Fishing increases in March with an average of 67.4 hours per day, the catch decreases to 0.12 fish per hour, but mostly walleye and whitefish are caught. Nearly all winter anglers are local residents (Whittaker and Sopuck 1987).

The total harvest estimate for 15 May - 15 October 1986 was 1,044 walleyes representing 1,124 kg of biomass. The average weight of walleye was 1,077 grams (approximately 2 1/2 lbs), which is larger than that in most sport fisheries. Growth rates for walleyes were excellent in Clear Lake. The extraction rate of 0.38 kg per hectare is "extremely light" harvest. Two-hundred and twenty-six pike (520 kg) and 209 perch (15.6 kg) also were caught. Pike constituted only 15 percent of the fish, but 26 percent of the biomass. Whitefish are common only in winter fishing. They constitute about 40 percent of the March harvest.

A less extensive creel survey during summer 1987 verified the 1986 findings. The 727 anglers surveyed were primarily Manitobans who were seasonal or local residents (87 percent). Both angling effort and success were higher in 1987. An average 0.41 fish were caught per hour, with walleyes at 0.39 fish per hour. Walleyes constituted 76 percent, and pike only 1.8 percent of all fish harvested. A noticeable decrease in average weight from 1077 g in 1986 to 728 g in 1987 reflected recruitment of younger age classes into the harvest. This was viewed as reflecting both a healthy and sustainable population in at least the short term (Whittaker and Sopuck 1987).

WATER LEVEL CHANGES AND THE SOUTH LAKE - CLEAR LAKE CONNECTION

It should be obvious that the water level in Clear Lake and the channel between South Lake and Clear Lake have long been considered important physical elements in not only the native, but also the introduced fish populations. Although the literature is repleat with references to these related aspects of the Clear Lake Basin, it is difficult to recreate accurate histories. The real or perceived importance of water levels and flows, however, make them worthy of review.

Clear Lake has a relatively small drainage of approximately 75 square miles. Water inflow is "rather limited," as only three permanent and three small intermittent streams, and springs feed the lake. Early water level changes suggest that Clear Lake had no outflow through Wasamin Creek between 1930 and 1935 (Rawson 1935). The level of the lake dropped two feet. A barrier that had been constructed across the outlet at Wasamin Creek stood high above the water line and the original channel had filled with sand, but the lake level was too low for outflow even if the barrier had not existed. Rawson (1935) reported that heavy rains during summer 1935 caused temporary outflow.

During the 1930 - 35 period, South Lake was cut off by low water. The weedy bottoms of the northwestern shore were damaged and pike had spawning problems. At this time, an investigation was looking into the possibility of diverting more water into Clear Lake, but details were not available. By 1943, the Lake level had dropped an additional one and one-half to two feet, putting it three and one-half to four feet below pre-drought level. Much beach was exposed and "the public wharf was quite shallow" (Rawson 1943). Inflowing streams decreased both in number and volume of flow, and salinity increased from 240 total solids in 1932 to 274 total solids in 1942 (14 percent). During this period the rock reefs in the west end of Clear Lake were above water level. By 1945, however, Doan (1945) reported that pike had access to South Lake as a slight current was flowing into Clear Lake in late July. The water level in Clear Lake was "reportedly two to three feet higher in the summer of 1945," and reefs were again submerged in the west end of the lake.

Further reports do not appear until 1958, when heavy spring runoff allowed fish migration into South Lake, and a trap was set to monitor fish movements on what was termed Poacher Creek (Atkinson 1958). The name apparently was given to the channel between the lakes because locals habitually poached fish during spring spawning runs.

Spring spawning, however, must have been a hit-and-miss proposition during the 1950's, because a recommendation was made to install a three foot culvert between the lakes (Foskett 1962). Low water levels in 1961 had allowed spring spawning, but flow stopped during summer and pike were stranded in South Lake. A call for more migration and spawning studies were based on "... extensive changes which have occurred in South Lake and the creek from Octopus Lake with the changing sewage disposal from Wasagaming" (Foskett 1962:6).

Access to South Lake must have been irregular during the 1960's as well, because Kooyman (1970) stated that decline in the pike population was caused by loss of access to South Lake. He stressed that wave action filled the channel with sand, and that clearing was unsuccessful because one overnight storm could refill the channel. A permanent channel was recommended. Apparently annual efforts were made to clear the channel between 1962 and 1972, and a "sand spit with concrete groins" was constructed to protect the mouth of the channel in 1972-73 (Briscoe 1979). Between 1974 and 1979 a channel had evolved near the western extremity of the "ice-push ridge" (MacLean 1979). The spring runoff of 1979 was both heavy and late, and a second channel opened 200m to the east of the culvert. The water level in South Lake was very high and a strong flow persisted until mid-July, and then lessened considerably, but continued into late summer.

Water levels were much lower in spring 1980, but in-migration of fish occurred through the culvert. Many fish, however, appeared to avoid entering the culvert and turned away. Out-migration of adult fish began before in-migration was complete (Millward 1980). Annual observation that began in 1979 provided more complete records. Wickstrom reviewed reports and substantiated the 1979 and 1980 runs mentioned above, as well as channel flow in 1981 and 1982. He states, however, that "discharge from South Lake has not had sufficient volume or duration of flow to prevent the outlet channel from being infilled by wave-borne sand on the Clear Lake side each year" (Wickstrom 1983:86).

In 1982, the culvert was removed and the channel dredged with a dozer. Continuous dredging was necessary to keep the channel open on the Clear Lake side. The channel was later dredged to let fish out of South Lake, but it infilled in three days. The authors state that low spring runoff and beaver dams have prevented pike from migrating any further than South Lake over the past couple of years (Hoggins and Holzmiller 1983). The channel was closed in 1984 (Toews 1984) and 1985 (Toews 1985). It re-opened in 1986, and flowed for only six days in 1987. It again closed in 1988 (Heap 1988).

OTHER HUMAN INTERVENTIONS IN THE FISHERY OF CLEAR LAKE

Fish rearing ponds along the shore of Clear Lake were recommended in 1932 (Bajkov 1932) and constructed in 1937 to raise rainbow trout fingerlings. Operations occurred from 1937 to 1940, and in 1942, but the project had poor success and was discontinued in 1942. A temporary fish hatchery for walleye was operated on the shores of Aeroplane Bay in 1958 - 1960, and 1965. Again success was so low that the hatchery was considered non-viable (Briscoe 1979). These projects apparently have had no lasting effects.

During winter 1966-67, 80 truck loads of boulder and gravel material were dumped on the ice in East End Bay in hopes of providing proper substrate for lake trout spawning. The artificial spawning reef was constructed in an area of suspected breeding activity, but no spawning has been observed since construction (Briscoe 1979). The reef is permanent, but its ecological or biological ramifications are unknown.

Bluestone (copper sulfate) was distributed in Clear Lake in the beach area for many years to prevent "swimmers itch." Cuerrier (1949b) reported no detrimental effects on fish. In 1949, however, bluestone was applied between 29 June and 1 July. A month later "a great number of dead fish" were found in East Bay. It was thought that an overdose of bluestone was applied by an inexperienced employee. An early migration of lake trout occurred at Bogey Creek, but bluestone was not thought to be involved. Extremely warm weather occurred in 1949, and normal temperature stratification apparently broke down in Clear Lake. [It is questionable whether bluestone caused any problems as later evidence suggests that Clear Lake may mix during strong wind conditions. Temperature changes, or tolerance, therefore, could cause great disruption in some fish species]. The use of copper sulfate apparently continued at least until 1958, when Park Wardens spread bluestone, which "all but eliminated the itch in swimming areas (Atkinson 1958:10). Also, 2-4D was used on aquatic weed concentrations at the east end of Clear Lake in 1958, with unclear results and unknown effects.

Mercury contamination was first discovered in suckers from the east end of Clear Lake in 1970 (Kooyman 1970). Other species were subsequently collected and analyzed. Larger specimens of all sport fish (except whitefish) contained more than allowable mercury levels and warning signs were posted around Clear Lake. Originally, fungicides used on the Golf Course at Bogey Creek (Figure 2) were suspected sources, but assessment could not confirm this. Subsequent search for the source of mercury contamination was unsuccessful in Clear Lake, but the waters of Pudge Lake and South Lake contained high levels. Pudge Lake receives runoff from the Golf Course area, so the fungicides were again suspected. No explanation was offered for South Lake concentrations (Kooyman and Hutchison 1979). Most other lakes had only normal levels of mercury in fish, but some larger pike from Long Lake exceeded acceptable limits. There is no connection between Long Lake and any known human intervention involving mercury. Because the use of fungicides containing mercury had been discontinued in 1968, concentrations in fish tissue should decrease through time if this was the contaminating source.

Further tests were conducted in 1986 (Lockhart et al 1986). Results clearly show that mercury contamination remains high in Clear Lake fish and the authors do not recommend removal of warning signs. In fact, 13 of 40 walleyes were over the acceptable mercury concentration limit in 1973, 18 of 21 in 1980, and 25 of 27 in 1986. These data, however, do not account for weight (age) differentials of the samples, and mercury accumulates with age. It is apparent that either residual fungicide is still present in Clear Lake, other sources are causing the mercury poisoning (including natural sources), or both. Mercury contamination has not decreased since 1970. Water testing suggested that pollution from petroleum products was not obvious in Clear Lake, but further tests were needed (Lockhart et al 1986).

The only other chemical pollution mentioned for the Clear Lake Basin is several comments to the effect that leakage may be occurring from the Wasagaming sewage lagoon into Octopus Creek and eventually into South Lake. If true, this could exacerbate eutrophication of South Lake. Increased algae growth was reported in the receiving north basin of South Lake. Agri-chemicals from adjacent land use also could be washing into the Clear Lake drainage, but no analysis of potential concentration and effect has been completed.

SUMMARY

1) Man has enacted several physical changes on Clear Lake. At some time before 1930, a barrier was erected at the outlet of Wasamin Creek. The channel subsequently filled with sand. Whether or not the structure still exists, and the role of obstruction in changing the ultimate lake level are unknown. The ultimate effect would be an increase in the surface level of the lake, which may preclude drainage and movement of organisms at a level between the present height of the outlet and the original (unknown) height of the outflow channel.

2) Of greater potential concern may be physical changes that have occurred in the Octopus Lake-Octopus Creek-Ominnik Marsh-South Lake-Clear Lake complex along the south shore. Long-term residents claim that the small stream now entering Clear Lake at the Boat Cove was the original mouth of Octopus Creek. A dike was constructed along the south shore of Clear Lake and drainage was deflected through Ominnik Marsh and Octopus Creek emptied into South Lake (W. Harwood, pers. comm.). None of this disturbance is cited in the literature, and ostensibly occurred prior to 1930. A detailed study of the old drainage and dike should be completed in order to verify changes. If these changes were made, they could have pronounced effects on both the hydrology and ecology of Clear Lake, and on the South Lake-Clear Lake relationship.

3) The construction and use of rearing ponds and hatchery facilities have had no lasting effect on Clear Lake or its biology. Real or potential impacts of shoreline development were not mentioned in the fishery literature, suggesting that observers over the years did not consider development a problem. In one instance increased runoff from developed areas was mentioned. Potential impacts of shoreline development will be considered in a separate report.

4) The fishery has been impacted by either natural or man-induced chemical pollution in one instance, and may or may not be impacted in three others. First, mercury contamination of fish is definitely verified in Clear Lake. Tests in 1970 have been repeated on several occasions, and as recently as 1986, high levels of mercury were found in larger fish of several species. The source of mercury pollution has not been located, but early suspicions of a fungicide used on the greens of the golf course adjacent to the lake has not been ruled out. This also could explain high mercury levels in Pudge Lake, but not those in South Lake. It also is possible that high mercury levels are natural, because they also were found in Long Lake, which has no connection with the Clear Lake Basin.

   Early contamination by improper use of copper sulfate (bluestone) to control "swimmer's itch" may have had an immediate effect in the 1940's, but should have no long-term residual impact on the fishery. Similarly, no overt evidence appeared in 1986 tests to suggest significant pollution by fossil fuel products, but some chemical residues were found in the water. Further testing specifically for fossil fuel contamination may be warranted.

Although no data were presented, several researchers alluded to the fact that sewage effluent was seeping from the Wasagaming lagoon into Octopus Creek and Ominnik Marsh, and ultimately into South Lake and Clear Lake. The most notable mention was an observation of increased aquatic plant production in the north basin of South Lake into which the marsh empties. Since the lagoon was established in the 1960's, considerable damage could have resulted if seepage is either periodically significant or constant. Additional nutrification in South Lake would increase biological problems, especially the probability of winter kill. If the lagoon is still seeping into the Marsh complex, remedial action should be taken.

5) Man has interfered on many occasions with the flow of water between South Lake and Clear Lake. Variously know as the South Lake Channel or Poacher Creek, the intermittent flow across the isthmus between the lakes has been the site of extensive poaching, dredging by bulldozers, opening by manual labour, and installation of concrete groins and culverts. None of these modifications has resulted in permanent flow, as the amount of basin runoff appears to control openings, and wave action, ice push during breakup and storms appear to close the channel. The importance of allowing fish migration into and out of South Lake is not known, as all studies of spawning appear inconclusive or even contradictory. The importance to spawning of northern pike appears well-grounded, but the complicating factors of blocked entry into Octopus Creek, Ominnik Marsh and Octopus Lake also may be a factor in pike population variations. In total, human intervention has been extensive on the South Lake-Clear Lake connection, but the consequences of opening or not opening the channel are poorly understood.

6) The introduction of non-native fish species has had differential effects. Attempts to introduce rainbow trout, brook trout and splake were totally unsuccessful. At best a few fish survived for a few years, as only incidental records occur after initial release. Muskellunge never were stocked in numbers to have a significant effect and never established a population in the lake.

   Lake trout adults survived well, but there is little if any evidence that reproduction occurred. The adult fish, however, have survived for many years, were lightly angled during the 1950's and 1960's, and appear to be slowly dying out. The lack of fall aggregations at Bogey Creek during recent years suggests that lake trout are virtually gone from Clear Lake. Occasional sightings, however, occured as recently as winter 1990.

   Walleye are the one introduction that not only survived to establish a population, but also significantly changed the sport fishery in Clear Lake. Once established, walleye became the most sought after species by anglers. Since no stocking has occurred since 1968, it is obvious that walleye are reproducing at least often enough to sustain a viable and harvestable population. There are, however, indications that reproduction is periodic rather than consistent, and extensive searches for information on spawning have not answered many questions. The stocking of walleye certainly must have had pronounced effects on the entire fish community. The native whitefish, ciscoes and suckers appear to be maintaining original populations, but the northern pike population appears to be declining. Whether or not walleye predation or competition is hurting the pike population is unknown. Of all the biological interventions, the introduction of walleye has had the most pronounced effects.

7) Both past and recent studies suggest that sport fishing pressure on Clear Lake is not excessive. Because of population fluctuations in walleye, and apparent long-term decline in pike, however, sport fishing should be promoted as a recreational activity rather than a source of food. Fishing of any kind is a human intervention in an aquatic ecosystem, and, if allowed, must be controlled and monitored and regulated to assure continuation of fish populations.

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