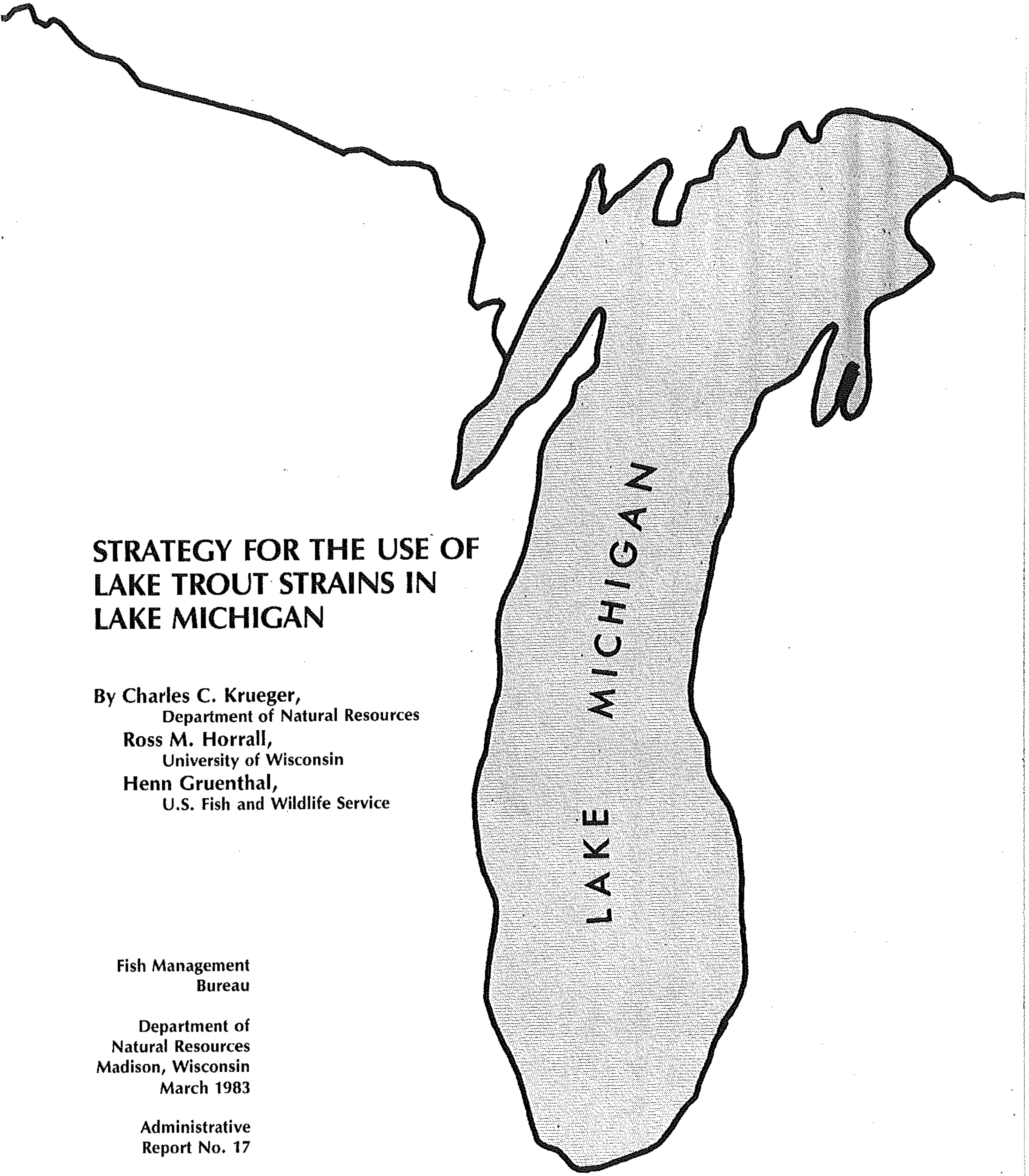

STRATEGY FOR THE USE OF LAKE TROUT STRAINS IN LAKE MICHIGAN

By Charles C. Krueger,
Department of Natural Resources
Ross M. Horrall,
University of Wisconsin
Henn Gruenthal,
U.S. Fish and Wildlife Service

Fish Management
Bureau

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STRATEGY FOR THE USE OF LAKE TROUT STRAINS IN LAKE MICHIGAN

Genetics Segment
of the
Lake Trout Rehabilitation Plan for Lake Michigan

by
Charles C. Krueger
Bureau of Fish Management
Wisconsin Department of Natural Resources
Madison, Wisconsin 53707

Ross M. Horrall
Marine Studies Center and Laboratory of Limnology
University of Wisconsin-Madison
Madison, Wisconsin 53706

Henn Gruenthal
U.S. Fish and Wildlife Service
Fort Snelling
Twin Cities, Minnesota 55111

Report of the Genetics Subcommittee to the
Lake Trout Technical Committee for Lake Michigan
of the Great Lakes Fishery Commission

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ABSTRACT

The stocking of hatchery lake trout has been a primary management tool since 1965 to reestablish populations in Lake Michigan. The lack of significant natural reproduction has been attributed to a variety of causes including the loss or lack of adaptive traits for surviving in the wild. We believe that the genetic characteristics of hatchery trout used for future stocking in Lake Michigan can be enhanced by using genetic variability that is preadapted for survival in the wild and by conserving this genetic variability with hatchery procedures. Based on this theory, several lake trout strains are recommended for hatchery production, and a strategy is proposed for stocking Lake Michigan.

The Gull Island Shoal, Wyoming (Lewis and Jenny Lake), Seneca Lake, and Lake Michigan-Green Lake strains are recommended for initial emphasis in the Lake Michigan stocking program. These wild and semi-wild strains should be compared against Domestic (Superior) strain trout in terms of survival and reproduction in Lake Michigan. Transfers of adult lake trout from Lake Superior wild populations are also proposed for the Lake Michigan stocking program. Each strain is identified as to its suitability for stocking on shallow and deep water reefs. In the final period of the strategy, lake trout for stocking will be produced from gametes collected directly from wild Lake Michigan populations that should have developed from the stocking of one or more of the strains listed.

INTRODUCTION

Lake trout (Salvelinus namaycush) populations in Lake Michigan declined to extinction in the 1950's due to the combined effects of sea lamprey predation and overfishing (Smith 1968; Wells and McLain 1973). Since the early 1960's, state and federal fish management agencies have conducted an active fisheries program to rehabilitate lake trout populations. The goal of the program has been to reestablish self-sustaining lake trout populations capable of supporting a fishing harvest. The principal tools used have been a large-scale sea lamprey control program and the massive stocking of hatchery lake trout. Lakewide plants of lake trout (mostly yearlings) have averaged 2.3 million fish annually during 1965-79 (Brown et al. 1981).

Although stocked lake trout have survived reasonably well in Lake Michigan, naturally produced year classes of lake trout have not been detected after more than 15 years of stocking. Attempts to collect lake trout fry produced in Lake Michigan by mature hatchery trout have met with little success (Wagner 1981; Jude et al. 1981; Dorr et al. 1981). Several suggested causes for the reproductive failure include, for example, pesticide contamination (Stauffer 1979; Berlin et al. 1981), the predation of eggs and fry (Stauffer and Wagner 1979), insufficient number of spawners (Brown et al. 1981; Dorr et al. 1981), inadequate stocking methods (Brown et al. 1981; Horrall 1981), and an inappropriate genetic background in hatchery trout (Loftus 1976; Brown et al. 1981; Hynes et al. 1981).

In this paper, we recommend lake trout strains for stocking and propose a strategy for their use in Lake Michigan. The genetic theory used to choose the strains and develop the strategy will be briefly reviewed first. The document directly incorporates several management recommendations by Brown et al. (1981), Hynes et al. (1981), and Krueger et al. (1981). This paper represents part of a larger lake trout rehabilitation plan for Lake Michigan. The use of the lake trout strains recommended is only one of several management measures that will be required for successful implementation of the overall plan.

GENETIC THEORY

In this document, lake trout strains were chosen based on the theory that the amount of genetic variability* in trout will be related to their capability to survive and reproduce in new environments. The theory has its foundations in the "fundamental theorem of natural selection" (Fisher 1930) and has been tested experimentally with positive results (Ayala 1965; see Krueger et al. 1981 for discussion). Application of the theorem suggests that lake trout strains chosen for population reestablishment should exhibit a level of genetic variability similar to that observed in other wild populations. Conversely, hatchery broodstocks of lake trout that have reduced genetic variability due to inbreeding would be poor choices for use in rehabilitation.

The lake trout strains for use in the rehabilitation program in Lake Michigan were also chosen to make use of genetic variability that is preadapted to wild environments. The genetic fitness of a wild lake trout population (i.e., the capacity to survive and reproduce) derives from a combination of many heritable traits that cannot be genetically partitioned and identified, much less intentionally selected for in the hatchery. Although these traits are unknown, the results of genetic fitness may be evidenced by the juvenile production of wild populations. Thus, naturally reproducing lake trout populations by definition contain the genetic variability that should be in hatchery lake trout stocked for fisheries rehabilitation purposes. By collecting gametes directly from these wild populations for hatchery production and broodstock development, trout that potentially have genetic variability preadapted to wild environments can be produced by hatchery operations and subsequently stocked into the waters to be rehabilitated. The gene combinations successful within the donor wild populations should demonstrate similar fitness after transplantation.

The genetic appropriateness of stocked lake trout may be enhanced further by choosing donor populations that occupy waters environmentally similar to Lake Michigan or that were established by introductions from the once extant Lake Michigan stocks. Within the genetic variability present in wild lake trout populations there will be a subset that represents the genetic combinations best adapted for life in Lake Michigan. The approach just outlined attempts to sample this subset and thus increase the availability of those traits that are adaptive for life in Lake Michigan.

STRAIN RECOMMENDATIONS

The Gull Island Shoal, Wyoming (Lewis and Jenny Lake), Seneca Lake and Lake Michigan-Green Lake strains are recommended for initial emphasis in the future Lake Michigan stocking program (Table 1). Direct transfers of adult lake trout from Lake Superior wild populations are also proposed for

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*Genetic variability refers to the occurrence of alternative genes at chromosomal loci. Although genetic variability at most loci is not measurable with current methodologies, estimates of genetic variability at enzyme loci are readily obtainable through the technique of gel electrophoresis. This technique should be useful for monitoring genetic variability in lake trout propagated for stocking.

TABLE 1. Lake trout strains to be stocked into Lake Michigan for population re-establishment.

Strain	Egg Source	Milt Source	Stocking Habitat	Minimum Strain Introduction Period
Domestic (Superior)	Broodstock	Broodstock	Shallow water	1985-2003
Domestic x Gull Island Shoal	Broodstock	Gull Island Shoal population	Shallow water	1985-2000
Wyoming	Lewis Lake population	Lewis Lake population	Shallow water	1985-2000
Adult Transfer From Lake Superior				
Isle Royale			Shallow water	1985-1987
Caribou Island			Shallow water	1985-1987
Michipicoten			Shallow water	1985-1987
Gull Island Shoal			Shallow water	1985-1987
Seneca Lake	Seneca Lake population	Seneca Lake population	Deep water	1986-2003
Gull Island Shoal	Broodstock	Gull Island Shoal population	Shallow water	1989-2000
Lake Michigan-Green Lake	Broodstock	Broodstock	Deep water	1992-2003
Lake Michigan Shallow Water	Lake Michigan population	Lake Michigan population	Shallow water	Approximately 1997 Until rehabilitation complete
Lake Michigan Deep Water	Lake Michigan population	Lake Michigan population	Deep water	Approximately 1999 Until rehabilitation complete

introduction to Lake Michigan. Domestic (Superior) strain lake trout should be stocked and compared to the other strains in terms of Lake Michigan performance. Lake trout for stocking will be produced from gametes collected from wild populations, captive broodstocks, or combinations of both. The number of strains chosen was kept to a minimum to limit the difficulty of assessment. In addition to these recommendations, the U.S. Fish and Wildlife Service should explore the feasibility of collecting gametes for hatchery production from lake trout at shallow water reef areas of Lake Superior such as those off Caribou Island and Isle Royale.

Each lake trout strain was classified according to whether it prefers shallow or deep water spawning habitat in the wild. Shallow water habitat was roughly defined as waters 3-30 m in depth. Deep water spawning habitat was defined as 30-85 m in depth. Lake trout stocked in Lake Michigan should be placed over reefs that have similar spawning habitat (in terms of depth) as preferred by the particular strain.

The lake trout strains chosen for Lake Michigan stocking are all "lean" lake trout. These strains have a much lower fat content than "fats" or siscowets and are thus more desirable for sport and commercial fishing. The siscowet trout should only be considered for introduction in Lake Michigan after "lean" trout populations have been firmly established. The siscowet trout should be useful in rehabilitating the deep water areas of Lake Michigan and were probably indigenous (Brown et al. 1981).

The hatchery procedures used to produce the lake trout strains should protect against the loss of genetic variability. Hatchery practices often involve some form of selective breeding, either planned, or inadvertent (Hynes et al. 1981). These practices characteristically emphasize single traits such as growth, disease resistance, and early maturity (Donaldson and Olson 1955; Wolf 1953) and foster the loss of genetic variability through inbreeding (e.g. Allendorf and Phelps 1980; Ryman and Stahl 1980). Broodstocks instead should be established by collecting gametes from wild populations and using a large number (greater than 100, 1:1 sex ratio) of parents (Ryman and Stahl 1980). Ideally, gametes should be collected throughout the spawning period and from all mature age classes. Subsequent year classes of broodstocks should be developed directly from the original donor population in the same manner. Similarly, hatchery production of lake trout strains that depend on gamete collections from wild populations rather than broodstocks should also use a large number of parents each year.

The wild lake trout broodstocks developed should be comprised of only females. Eggs from these broodstocks would be fertilized by milt collected each year from male trout of the original donor population. With an all female broodstock, limited raceway space does not have to be used for holding males, and the progeny produced are the result of outbreeding to the wild population. The collection of milt from males in the donor population should not pose a serious problem because males are generally ripe for a longer period of time than females (thus collection timing is less critical), males are easier to catch with gill nets than females, and techniques to preserve milt are available (Swanson pers. comm. 1982; Erdahl and Grahm 1980). A small number (approximately 30) of male broodstock should be kept in the event that wild milt is unavailable some years.

The use of the lake trout strains recommended may result in trout that are ill-adapted to hatchery life. Hatchery production in terms of numbers and weight will likely decline relative to production levels attained with domestic broodstocks. This "cost" in production should result, however, in an increased output of lake trout that have the genetic potential to successfully reestablish lake trout populations.

Domestic (Superior) Strain

The Domestic (Superior) strain has comprised approximately 84% of the lake trout stocked in Lake Michigan over the last 18 years (Brown et al. 1981). The broodstock for this strain was originally derived from shallow water Lake Superior lake trout in 1949 (Fig. 1; see Appendix) and may still contain a portion of the genetic variability required for survival in the wild, even though domesticated for three to four generations. In Lake Ontario this strain has shown better survival for the first three years of life than either the Clearwater or Seneca Lake strains (Elrod et al. 1982). Electrophoretic evidence on the amount of genetic variability of the Marquette strain has been contradictory, indicating levels either similar to or lower than those of wild trout from Lake Superior (Brown, Ann unpublished 1982; Todd, Thomas pers. comm. 1982). The broodstock will be used to produce "pure" Domestic and Domestic x Gull Island Shoal hybrid lake trout for stocking in Lake Michigan. Pure Domestic lake trout will be used as the standard for comparison with other strains.

Domestic x Gull Island Shoal Hybrid

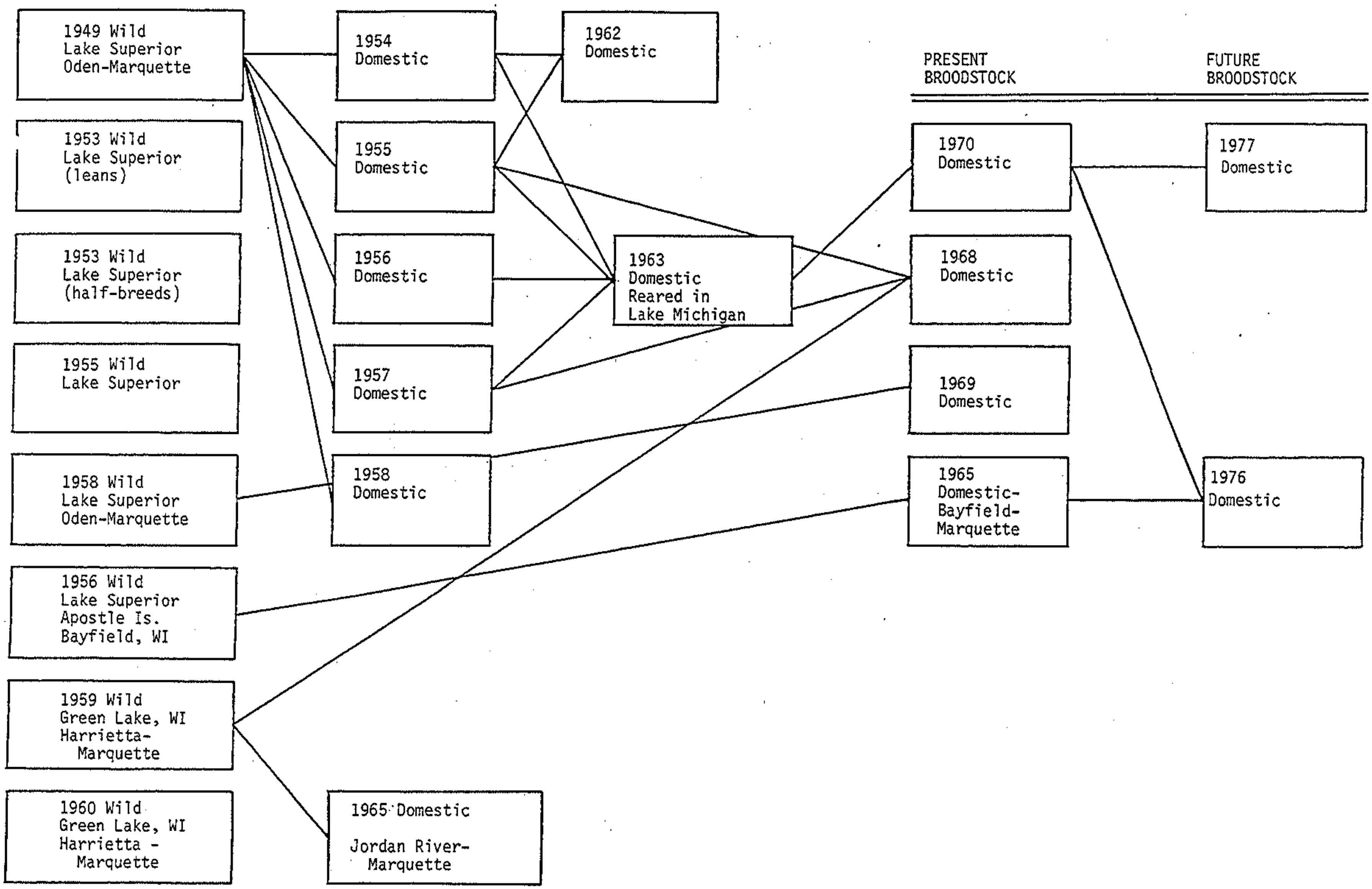
This strain will be a cross between female Domestic (Superior) trout and males from the wild population that spawn on Gull Island Shoal in Lake Superior (Table 1). The use of the hybrid is an attempt to combine the domestic traits of ease in hatchery rearing with the survivability and reproduction traits of a wild population. Similar hybrids have proven useful in the management of brook trout (Webster and Flick 1981). The first stocking of this strain in Lake Michigan is expected in 1985.

Wyoming (Lewis and Jenny Lake)

The Wyoming lake trout for stocking Lake Michigan will be produced from annual collections of gametes from the population in Lewis Lake, Yellowstone National Park, Wyoming (Table 1). This population was established from a single stocking in 1890 of approximately 12,000 lake trout reared from eggs collected from shallow water reefs in northern Lake Michigan near Manistique (Varley 1981; see Appendix). The only other stocking that has occurred in Lewis Lake was a plant of approximately 6,000 fall fingerlings in 1941. These fish were the progeny of a broodstock developed from unknown sources and kept at Bozeman, Montana. The Lewis Lake lake trout population currently supports an important sport fishery yielding approximately 6,000 trout annually (Anonymous 1979). No diseases were detected in this population from collections made in 1982. The intent of the use of the Lewis Lake strain for Lake Michigan is to reintroduce a portion of the original adaptive genetic traits that historically occurred in Lake Michigan lake trout. The first stocking of this strain in Lake Michigan could occur in 1985.

Gametes from the Lewis Lake population may not be collected each year because access to the lake can be hindered by inclement weather that often occurs during the spawning season. In such circumstances Wyoming strain lake trout will have to be produced from the Jenny Lake broodstock held at the Jackson National Fish Hatchery. This broodstock was

FIGURE 1. Historical Origin of Domestic (Superior) Broodstocks.



developed from a lake trout population in Jenny Lake, Wyoming. The lake trout in Jenny Lake are descendants of trout populations in the Lewis Lake watershed (see Appendix).

Lake Superior Strain Adult Transfers

Wild adult lake trout from shallow water reef areas in Lake Superior should be stocked on a single reef in Lake Michigan for three years (Table 1). These fish (not fin clipped) should be captured from the reef areas of Isle Royale, Caribou Island, Michipicoten Island, and Gull Island Shoal. The use of these transfers is intended to avoid the potentially adverse, inadvertent selection processes that occur in hatchery rearing and to directly introduce the genetic variability that occurs in wild Lake Superior populations.

Adult transfers have proven particularly useful in wildlife management. The stocking of domestic and domestic-wild turkeys failed to re-establish the birds within their native range in the 1920-1940's (Hewitt 1967). Excellent success in population establishment occurred, however, in the 1950-1960's when adult birds from wild populations were transferred into suitable habitat.

In order to adequately sample the genetic variability that occurs in the wild lake trout populations, a minimum of 100 adults (1:1 sex ratio) should be captured from each of the Lake Superior reef areas identified above. These transfers could be made as early as 1985, depending on the logistics of capture and on later assessment. Due to the small numbers to be stocked, it is recommended that the adults be stocked in an area afforded complete protection from fishing mortality.

Seneca Lake Strain

Lake trout of this strain for stocking in Lake Michigan would be produced from eggs and milt collected from the deep water spawning population that exists in Seneca Lake, a Finger Lake of New York (Table 1). Seneca strain lake trout spawn in water from 30-65 m in depth from late September through October (Royce 1951). These trout are also known to survive relatively high rates of sea lamprey attack in Seneca Lake. Seneca Lake has been stocked annually since the early 1900's with lake trout produced from gametes collected from the lake each fall. The use of this strain for stocking Lake Michigan is intended to introduce a lake trout genetically capable of deep water spawning and surviving lamprey attacks. If adequate numbers of gametes cannot be obtained from the Seneca Lake population, then a broodstock may have to be developed.

Gull Island Shoal Strain

Lake trout of the Gull Island Shoal strain will be produced from eggs collected from a female hatchery broodstock that are fertilized each year by male trout from Gull Island Shoal in Lake Superior (Table 1). Each year class of female broodstock will be developed from gametes collected from native lake trout (not fin clipped) that use Gull Island Shoal as a spawning ground.

Lake trout gametes are regularly collected from adults on Gull Island Shoal by the Wisconsin Department of Natural Resources. This agency has agreed to provide adequate numbers of the 1982 and 1983 year classes to develop this broodstock in a federal hatchery.

This lake trout strain was chosen for stocking because it has a demonstrated reproductive ability to re-establish populations after declines caused by lampreys and fishing (Swanson and Swedberg 1980), and occupies a shallow water reef similar to many Lake Michigan reefs. The first stocking of this strain could occur as early as 1989.

Lake Michigan-Green Lake Strain

This strain of lake trout will be produced from a broodstock to be developed from gametes collected from feral Green Lake strain trout that were released into Lake Michigan prior to 1977 (Brown et al. 1981). The Green Lake strain trout are descendants of a broodstock developed from eggs collected in 1959 from Green Lake, Wisconsin (Fig. 2). The Green Lake lake trout population was established by stockings from 1886-1943 of trout reared from gametes collected from Lake Michigan populations, probably from the southern deep water spawning grounds (Hacker 1956; see Appendix). In 1944, there was a single stocking of fingerlings originating from Lake Michigan or Lake Superior. Evidence of lake trout spawning in Green Lake has been observed at depths from 20 to more than 30 m (Hacker 1956).

The development of this broodstock will require the collection of gametes from lake trout in Lake Michigan that are the survivors of past stockings of the Green Lake strain. The strain was primarily stocked in the southern one-third of Lake Michigan and should be identifiable by fin clips (see Appendix). Although chemical contaminant levels in eggs may substantially reduce production of fry, broodstock developed from such fry may contain a genetic resistance to the possible detrimental effects of contaminants. If adequate numbers of gametes cannot be collected from Lake Michigan, then the Green Lake strain broodstock held at the Genoa National Fish Hatchery should be used for hatchery production as an alternative.

Use of the feral Lake Michigan trout of the Green Lake strain is intended to reintroduce any retained genetic traits for deep water spawning in Lake Michigan that historically characterized the ancestors of these fish. In addition, the trout so produced for stocking should have enhanced genetic fitness because their parents have survived seven or more years of the selection pressures that exist in Lake Michigan. The first stocking of this strain could occur in 1992.

Lake Michigan Shallow Water and Deep Water Strains

Lake trout of these strains will be produced from gametes taken from the wild Lake Michigan populations that should develop as a result of stocking the other strains listed (Table 1). The Shallow Water strain will be derived from populations that occupy the nearshore areas such as Julian's Reef, Claybanks, and Fox Island Shoals. The Deep Water strain will be produced from gametes collected from deep water reefs in southern Lake Michigan (e.g. Milwaukee and Northeast). Both strains should possess the specific genetic variability suitable for survival and reproduction in Lake Michigan. Stocking of these Lake Michigan strains will probably not occur until the middle 1990's.

STOCKING STRATEGY

The stocking strategy described in Table 2 for the use of lake trout strains in Lake Michigan was based on the overall objective to increase the genetic potential of stocked lake trout to establish self-sustaining populations. The strategy depends on feedback information on the survival and reproductive success of strains stocked to guide strain emphasis in future hatchery production. Moreover, increasing dependence is placed on the Lake Michigan environment to perform the selection of appropriate genetic combinations for use in the hatchery program during each successive period of the strategy.

FIGURE 2. Historical origin of Green Lake Strain Broodstocks.

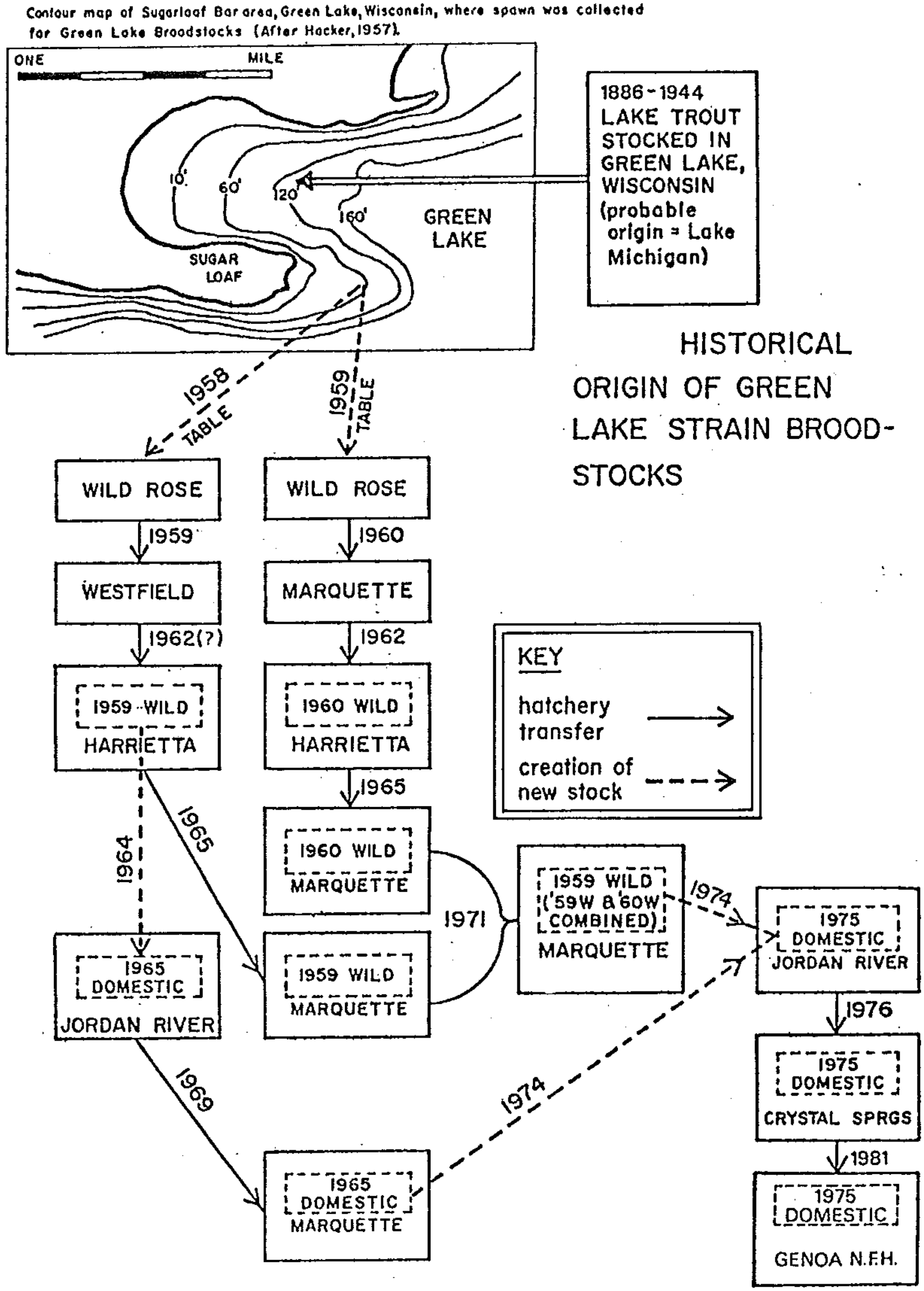


TABLE 2. Schedule for the stocking and broodstock development of lake trout strains to be used to rehabilitate Lake Michigan.

Period	Shallow Water Habitat: Stocking	Shallow Water Habitat: Broodstock Development	Deep Water Habitat: Stocking	Deep Water Habitat: Broodstock Development
First Broodstock Transition Period 1983-90	Domestic Domestic x Gull Is. Shoal Wyoming Adult Transfers (Lake Superior)	Gull Island Shoal	Domestic Seneca Lake	Seneca Lake (?) Lake Michigan-Green Lake
Strain Introduction Period 1992-2003	Domestic Gull Island Shoal Wyoming Domestic x Gull Is. Shoal	None	Domestic Seneca Lake Lake Michigan-Green Lake	None
Second Broodstock Transition Period 1997-2016	Increase stocking of strains that demonstrate superior survival and/or reproduction.	Increase broodstock of strains that demonstrate superior survival and/or reproduction.	Increase stocking of strain that demonstrates superior survival and/or reproduction.	Increase broodstock of strains that demonstrate superior survival and/or reproduction.
"Lake Michigan Strain" Stocking Period 1997-Rehabilitation Complete	Lake Michigan Shallow Water	Broodstocks discount. Gametes collected from Lake Michigan populations.	Lake Michigan Deep Water	Broodstocks discount. Gametes collected from Lake Michigan populations.

Four sequential periods or phases (from 1983 through complete rehabilitation) have been tentatively identified (Table 2). The approximate dates assigned to each period were based on the assumptions that follow. The first is that 8 years of broodstock development are required before yearling lake trout are produced for stocking. The second assumption is that 12 years are required for introducing a strain before successful survival and/or reproduction can be detected.

The strategy does not define the actual proportions, numbers, ages, and sizes of the several strains or their geographic distribution (beyond shallow water and deep water reefs). These stocking details are to be determined by the Lake Trout Technical Committee for Lake Michigan and will have to be closely integrated into the design for assessment. Lake trout strains should be stocked on reef areas that appear to be environmentally similar to those that the original donor populations inhabit (Krueger et al. 1981) and which are known to be historic spawning grounds (see Coberly and Horrall 1980).

The strategy presupposes that an active assessment program will be conducted throughout the four periods of the stocking strategy. Information obtained by investigations into the survival and reproduction of the strains will provide essential information to guide future hatchery production. Lake trout stocked in Lake Michigan should be marked or tagged to identify strain, date, location, number, and size planted.

First Broodstock Transition Period

This phase of the strategy extends from 1983-90 and includes the period of time required to develop new broodstocks. In this interim period the Gull Island Shoal, Lake Michigan-Green Lake, and possibly a Seneca Lake broodstock will be established (Table 2). Lake trout to be stocked in shallow water habitats during this period will include the Domestic, Domestic x Gull Island Shoal, and Wyoming strains, and in addition adults transferred from Lake Superior. Deep water stocking will be of the Seneca Lake strain from gametes collected at Seneca Lake, NY.

Strain Introduction Period

This period of strategy implementation will extend from approximately 1992-2003, during which all the lake trout strains recommended (except adult transfers) will be stocked into Lake Michigan but no broodstock development will occur (Table 2). Stocking into shallow water habitats will include Gull Island Shoal, Wyoming, Domestic x Gull Island Shoal, and Domestic strains. Stocking in deep water habitats will be Seneca Lake, Lake Michigan-Green Lake, and Domestic strains. Assessment of the survival and reproduction of the stocked trout will be crucial during this period, as a guide for hatchery production in the next period.

Second Broodstock Transition Period

In this period additional broodstocks will be developed and stocking rates of those strains that have a demonstrated capability to survive and reproduce in Lake Michigan will be increased (Table 2). The intent of this step is to shift hatchery production of lake trout strains that have comparatively poor survival and reproduction to those strains identified to have high survival and reproduction in Lake Michigan. The future direction of the hatchery program at this stage therefore is guided by the results of an ongoing assessment program.

The increased hatchery production of the successful strains should be first used to increase stocking rates on those reef areas where population re-establishment by these strains has already occurred. Lake trout populations in such areas should be managed to enable population size to increase as rapidly as possible by stocking large numbers of the successful strains and protecting these trout from fishing. An increase in trout numbers in these areas is especially desirable because these populations will be valuable sources of gametes for the final period in the strategy. Hatchery production of the successful strains should increase to levels such that their stocking can be extended to all other similar reef areas in Lake Michigan.

"Lake Michigan Strain" Stocking Period

During this last implementation period, the use of captive broodstocks is discontinued and the Lake Michigan lake trout populations are used as sources of gametes for hatchery production (Table 2). The last step could begin as early as 1997 and would continue until rehabilitation is complete. During this period the Lake Michigan environment becomes the primary agent of selection for hatchery production of lake trout. Hence, all hatchery-reared lake trout should theoretically contain the adaptive genetic traits unique for survival and reproduction in Lake Michigan. The new Lake Michigan Shallow Water and Deep Water strains will be stocked in increasing proportions in this final period.

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LITERATURE CITED

Allendorf, F. W., and S. R. Phelps
1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Trans. Am. Fish. Soc. 109:537-43.

Ayala, F. J.
1965. Evolution of fitness in experimental populations of Drosophila serrata. Science 150:903-05.

Anonymous
1979. Fishery and aquatic management program in Yellowstone National Park. Technical Report for Calendar 1978.

Berlin, W. H., R. J. Hesselberg, and M. J. Mac
1981. Growth and mortality of fry of Lake Michigan lake trout during chronic exposure to PCB's and DDE. Pages 11-22 in The reproduction and survival of lake trout (Salvelinus namaycush) in Lake Michigan. U.S. Fish Wildl. Serv. Tech. Pap. 105.

Brown, E. H., Jr., G. W. Eck, N. R. Foster, R. M. Horrall, and C. E. Coberly
1981. Historical evidence for discrete stocks of lake trout (Salvelinus namaycush) in Lake Michigan. Can. J. Fish. Aquat. Sci. 38:1747-58.

Coberly, C. E., and R. M. Horrall
1980. Fish spawning grounds in Wisconsin waters of the Great Lakes. Mar. Stud. Cent., Univ. Wis., Madison.

Coberly, C.E., and R.M. Horrall
1982. A strategy for re-establishing self-sustaining lake trout stocks in Illinois waters of Lake Michigan. Ill. Coastal Zone Manage. Dev. Proj. and Mar. Stud. Cent., Univ. Wis., Madison. 1-104.

Donaldson, L. R., and R. R. Olson
1955. Development of rainbow trout broodstock by selective breeding. Trans. Am. Fish. Soc. 85:83-101.

Dorr III, J. A., D. V. O'Conner, N. R. Foster, and D. J. Jude
1981. Substrate conditions and abundance of lake trout eggs in a traditional spawning area in southeastern Lake Michigan. No. Am. J. Fish. Mgmt. 1:165-72.

Elrod, J. H., C. P. Schneider, and D. P. Kolenosky
1982. Assessment of juvenile lake trout stocks in Lake Ontario, 1981. Agenda Item No. 14(a), Lake Ont. Comm. Meet. 1982, Great Lakes Fish. Comm.

Erdahl, D. A., and E. F. Grahm
1980. Preservation of gametes of freshwater fish. Ninth Int. Cong. on Anim. Reprod. & A. I. Vol. II. pp. 317-26.

Eschmeyer, P.H., and A.M. Phillips, Jr.
1965. Fat content of the flesh of siscowets and lake trout from Lake Superior. Trans. Amer. Fish. Soc. 94:62-74.

Evermann, B.W.
1893. A reconnaissance of the streams and lakes of western Montana and northwestern Wyoming. Bull. U.S. Fish Comm. Vol. XI (1891):3-60.

Fisher, R. A.
1930. The genetical theory of natural selection. Clarendon Press, Oxford.

Hacker, V. A.
1956. Biology and management of lake trout in Green Lake, Wisconsin. Trans. Am. Fish. Soc. 86:71-83.

Hewitt, O. H.
1967. The wild turkey and its management. The Wild. Soc. 589 pp.

Horrall, R. M.
1981. Behavioral stock-isolating mechanisms in Great lakes fishes with special reference to homing and site imprinting. Can. J. Fish. Aquat. Sci. 38:1481-96.

Hynes, J. D., E. H. Brown Jr., J. H. Helle, N. Ryman, and D. A. Webster
1981. Guidelines for the culture of fish stocks for resource management. Can. J. Fish. Aquat. Sci. 38:1867-76.

Jude, D. J., S. A. Klinger, and M. D. Enk
1981. Evidence of natural reproduction by planted lake trout in lake Michigan. J. Great Lakes Res. 7:57-61.

Krueger, C. C., A. J. Gharrett, T. R. Dehring, and F. W. Allendorf
1981. Genetic aspects of fisheries rehabilitation programs. Can. J. Fish. Aquat. Sci. 38:1877-81.

Loftus, K. H.
1976. Science for Canada's fisheries rehabilitation needs. J. Fish. Res. Board Can. 33:1822-57.

Organ, W.L., G.L. Townes, M.O. Walter, R.B. Pelletier, and D.A. Riege
1978. Past and presently known spawning grounds of fishes in the Michigan coastal waters of the Great Lakes. Mich. Dept. Nat. Res. Tech. Report No. 78-7:1-502.

Roman, B.
1980. Namaycush after ninety years. Wyo. Wild. Apr. 1980. pp. 26-9.

Royce, W. F.
1951. Breeding habits of lake trout in New York. Fish. Bull. 59. Fish and Wild. Serv. 52:59-76.

Rybicki, R., and M. Keller
1978. The lake trout resource in Michigan waters of Lake Michigan, 1970-76. Mich. DNR, Fish. Div. Fish. Res. Rep. No. 1863:1-71.

Ryman, N. and G. Stahl
1980. Genetic changes in hatchery stocks of brown trout (Salmo trutta). Can. J. Fish. Aquat. Sci. 37:82-7.

Smith, H.M. and W.C. Kendall
1922. Fishes of the Yellowstone National Park with description of park waters and notes on fishing. Appendix III, Rept. U.S. Comm. Fish. 1921:3-30.

Smith, S. H.
1968. Species succession and fishery exploitation in the Great Lakes. J. Fish Res. Board Can. 25:667-693.

Stauffer, T. M.
1979. Effects of DDT and PCB's on survival of lake trout eggs and fry in a hatchery and in Lake Michigan 1973-1976. Trans. Am. Fish. Soc. 108:178-86.

Stauffer, T. M., and W. C. Wagner
1979. Fish predation on lake trout eggs and fry in the Great Lakes. 1973-1978. Mich. Dept. Nat. Res., Fish. Div., Fish Res. Rep. 1965, Lansing, Mich.

Swanson, B. L., and D. V. Swedberg
1980. Decline and recovery of the Lake Superior Gull Island Reef lake trout (Salvelinus namaycush) population and the role of sea lamprey (Petromyzon marinus) predation. Can. J. Fish. Aquat. Sci. 37:2074-80.

Varley, J. D.
1981. A history of fish stocking activities in Yellowstone National Park between 1881 and 1980. Nat. Park Ser., U.S. Dept. Inter. Inf. Pap. No. 35. 94 p.

Wagner, W. C.
1981. Reproduction of planted lake trout in Lake Michigan. N. Am. J. Fish. Mgmt. 1:159-64.

Webster, D. A., and W. A. Flick
1981. Performance of indigenous, exotic, and hybrid strains of brook trout (Salvelinus fontinalis) in waters of the Adirondack Mountains, New York. Can. J. Fish. Aquat. Sci. 38:1701-07.

Wells, L., and A. L. McLain
1973. Lake Michigan--man's effects on native fish stocks and other biota. Great Lakes Fish. Comm. Tech. Rep. 20, Ann Arbor, Mich.

Wolf, L. E.
1953. Development of disease-resistant strains of fish. Trans. Am. Fish. Soc. 83:342-439.

APPENDIX

Ancestry of the Domestic (Superior), Green Lake, and Wyoming Strains of Lake Trout

INTRODUCTION

This appendix documents the genetic lineal descent of the Domestic (Superior), Wyoming, and Green Lake strains of lake trout. Determination of the origin and history of the strains was often difficult because of incomplete, absent, or lost records.

Data on the number, sex ratio, and sampling design of trout used to establish broodstocks were not available. However, sources of trout used to establish broodstocks and new populations were identified.

Detailed comparisons of traits among strains were not made due to insufficient information. Hatchery records did show two major differences between the Domestic and Green Lake strains held in the same hatchery environment. Green Lake trout spawned later in the fall and showed a lower percent of eyed eggs than the Domestic (Superior) trout. Other investigators have compared the performance of lake trout in Green Lake and Lake Michigan. In Green Lake, Wisconsin, differences in spawning behavior have been observed between lake trout of Lake Michigan and Lake Superior origin, with Lake Michigan fish spawning later and in deeper water (Hacker 1956; Eschmeyer and Phillips 1965). Rybicki and Keller (1978) found no major differences between the growth of the Green Lake strain and the Domestic (Superior) strain fish collected from the same area in Lake Michigan.

The strain descriptions that follow were compiled from interviews with hatchery personnel, existing hatchery records, and the literature (Coberly and Horrall 1982).

DOMESTIC (SUPERIOR) STRAIN

The Domestic strain broodstock originated primarily from wild eggs collected from southern Lake Superior by commercial fishermen in the fall of 1948 (Fig. 1). These eggs came from three locations: upper Marquette Harbor, Copper Harbor, and a reef east of the Keweenaw Peninsula. Lake trout that inhabited these areas exhibited similar spawning habits and morphology. Fishermen who collected the original spawn reported that the trout spawned in 7-9 m of water over large rubble (John Driver, pers. comm.). Interviews with other fishermen in the area indicated that trout in these regions spawned mainly on rock and gravel in 7-15 m of water (Organ et al. 1978).

The 1948 eggs (1949 WILD broodstock) were hatched at Michigan's Oden Hatchery, and subsequently transferred to Marquette State Hatchery in 1950 (Fig. 1). Between 1954 and 1958, eggs from this lot of fish were used to develop five additional broodstocks. These broodstocks were the source of the majority of Domestic (Superior) strain lake trout used to restock the Great Lakes until 1965 (Tables A1 and A2).

In the mid-1960's lake trout (1965 DOMESTIC) from the Bayfield State Hatchery in Wisconsin were added to the Marquette broodstock (Fig. 1). These fish originated from wild eggs taken from Gull Island Shoal in the Apostle Islands in 1955. Gull Island trout usually spawn from 10 October to 28 October in shallow water over rocky substrate (George King, pers. comm.).

Parents of the 1968 DOMESTIC broodstock included some 1959 WILD Green Lake strain fish derived from Lake Michigan populations (Fig. 1).

The balance of the Marquette broodstocks are of pure Lake Superior genetic background.

The Marquette broodstocks provided fertilized eggs to develop the 1974, 1975, 1977, and 1978 Domestic (Superior) strain broodstocks held at the Jordan River National Fish Hatchery, Michigan. The Marquette and Jordan River broodstocks are currently used to propagate the Domestic strain lake trout for stocking in Lake Michigan.

GREEN LAKE STRAIN

The original Green Lake strain broodstocks (IL(Grn) 59W-WR-Wf-Ha-Mq and IL (Grn) 60W-WR-Mq-Ha-Mq; hereafter referred as 1959 WILD and 1960 WILD) were developed from eggs taken from lake trout in Green Lake, Wisconsin during the 1958 and 1959 spawning seasons by Vernon Hacker of the Wisconsin Department of Natural Resources. Lake trout were stocked in Green Lake, Wisconsin, between 1886 and 1944 (Fig. 2). According to verbal sources (no records are available), these trout came from state hatcheries on Lake Michigan, probably from the Sheboygan and Sturgeon Bay hatcheries in Wisconsin (Hacker 1957).

The lake trout stocked in Green Lake from 1886-1944 appear to have consisted of two major subpopulations (Hacker 1956; Eschmeyer and Phillips 1965):

Form A: "Had fewer spots" (Hacker, pers. comm.); "were light-colored, had pale fins and a thick ventral body wall" (Eschmeyer and Phillips 1965) and were referred as "silver-greys". Trout of Form A tended to spawn near the end of the spawning season (late November and early December) in Green Lake (Table A3). Based on a sample of six fish, Form A had a fat content approximately midway between that of Lake Superior leans and Lake Superior siscowets (Fig. A1).

Form B. "Had many spots" (Hacker, pers. comm.); "with bright orange and white fins, and with a thin ventral body wall" (Eschmeyer and Phillips 1965). In general, trout of Form B spawned earlier than Form A. On the basis of two samples, Form B had a fat content below that of Lake Superior leans (Fig. A1).

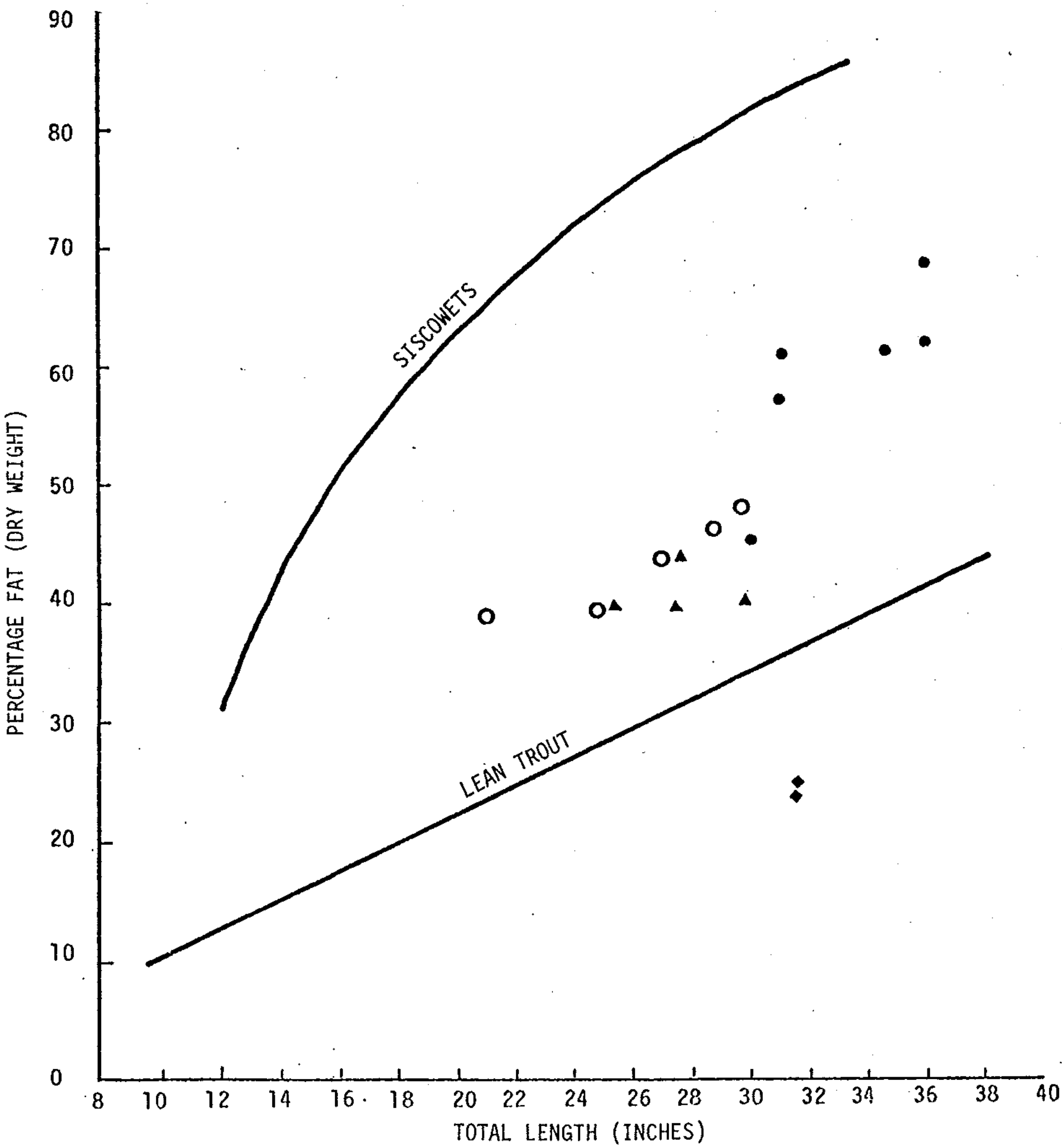
No estimate can be made of the relative abundance of either form, or whether the forms could be distinguished only as older fish. Of the females captured during the 1959 spawning season in Green Lake, 7 of the 78 were identified by Hacker as silver-greys (Form A, Table A3), and these 7 were among the largest of the females.

The lake trout stocked in Green Lake from Lake Michigan may have included as many as three different forms or races: reef or Mackinaw trout; salmon or bay trout; and deep water trout from two hatcheries. The Sturgeon Bay Hatchery received spawn (probably spawn of Mackinaw and bay trout) from fishermen operating in Green Bay, and in Lake Michigan as far south as Manitowoc. The Sheboygan Hatchery received spawn of deep water trout from fishermen at the ports of Sheboygan south to Kenosha.

On the basis of higher fat content and the tendency towards deep water spawning in late autumn, Hacker (1956) has suggested that the lake trout in Green Lake represented by Form A may have been the deep water race of trout from southern Lake Michigan:

> "In Green Lake, lake trout spawned persistently in deep water, over a uniformly smooth and soft bottom which

FIGURE A1. Percentage fat in the flesh of four types of lake trout. Lake Superior siscowets (upper line); Lake Superior lean trout (lower line); Green Lake lake trout Form A (●) and Form B (◆) from Eschmeyer and Phillips (1965). Domestic (Superior) trout in Lake Michigan (O) and Green Lake strain hatchery fish in Lake Michigan (▲).



appeared to be unsuitable for the protection of eggs and fry. Why was this bar used for spawning, when extensive areas of wave-washed rubble were found at many places about the shoreline?

It is likely that all the adult spawning fish at Green Lake originated from plantings made before 1944 of fry and fingerlings obtained from hatcheries on Lake Michigan, particularly at Sturgeon Bay and Sheboygan, Wisconsin. These young trout were obtained on the spawning grounds of southern Lake Michigan in 180-360 feet of water, over hard clay bottom. The 1944 planting was of fry, believed to have originated from Lake Superior adults. The possibility is suggested that strains or races of deep and shallow-water spawning lake trout exist. Inherited tendencies in the progeny of the deep-water spawning fish from southern Lake Michigan may account for their persistence in using a deep-water, but unsuitable location in Green Lake."

Lake trout spawned in 1958 and 1959 for broodstock were probably stocked after 1939. The 1944 plants, the largest in Green Lake for at least 11 years, may have accounted for a large proportion of the lake trout spawned in 1958 and 1959 (Table A4).

Some confusion exists as to the origin of the lake trout stocked in 1944. According to Hacker (1956) this plant was believed to have been fry of Lake Superior origin. Recently discovered stocking receipts indicate, however, that in 1944, 328,664 fingerlings were stocked into Green Lake from the Westfield State Fish Hatchery in Wisconsin. Additional records suggest the possibility that these fingerlings originated from eggs from the Sturgeon Bay hatchery (the Sheboygan hatchery had closed by this time). Sturgeon Bay hatchery records show that in 1943, 499,980 lake trout eggs were transferred from Sturgeon Bay with specific destinations not noted. In 1944, only three Wisconsin hatcheries stocked lake trout (Sturgeon Bay, Westfield, and Bayfield). These eggs were probably not transferred to Bayfield since that hatchery had its own source of spawn from Lake Superior. A more probable destination would have been the Westfield hatchery, located near Green Lake.

A mortality of this magnitude (499,980 to 328,664 or 34%) was not consistent with the mortality rate calculated for this same period from Sturgeon Bay hatchery records (7.7%). Possibly, not all of the 499,980 eggs went to Westfield and/or not all the trout fry hatched at Westfield were stocked in Green Lake. No record has been found of eggs being transferred from Bayfield to Westfield. Thus, evidence suggests that the 1944 plant was not of Lake Superior origin, but from the Sturgeon Bay hatchery, which by 1944 was receiving all spawn taken by Wisconsin commercial fishermen on Lake Michigan.

The 1959 WILD and 1960 WILD Green Lake broodstocks were probably derived from a high proportion of native Lake Michigan stock. Between 1944 and 1953, no lake trout were stocked in Green Lake; in 1953 stocking was resumed using fish of Lake Superior origin, and later fish from eggs taken from Green Lake. At the time spawn was taken to produce the Green Lake strain broodstocks, lake trout of Lake Michigan origin could be distinguished easily from trout stocked in Green Lake during and after 1953 based on fin clips. None of the pre-1944 plants were marked, whereas all plants made in 1953 and after received fin clips. No natural reproduction of lake trout was known to have taken place in Green Lake (Hacker 1956). All females and males spawned in 1958 were unclipped, i.e. probably of Lake Michigan origin (Table A5). In 1959, all females (78) were unclipped except for one of Lake Superior origin (Table A3). This same year, 231 males were collected, 8 of which were of Lake Superior origin. It is not known how many of these males were actually used to fertilize the eggs.

In 1965, the 1959 WILD and 1960 WILD broodstocks were transferred to Michigan's Marquette Hatchery from the Harrietta Hatchery where they had been held since 1962. At Marquette, the broodstocks displayed characteristics which were atypical of the Lake Superior broodstocks also held at the hatchery. The major differences were that the Green Lake strain spawned later in the year (Table A6) and had a lower percent eye-up. These characteristics made the Green Lake strain difficult to integrate into hatchery schedules of spawn collection and stocking.

In 1971, the 1959 WILD and 1960 WILD broodstocks were combined under the name IL(Grn) 59W (hereafter 1959/1960 WILD). According to some hatchery personnel, at that time some Lake Superior males of Apostle Island origin (as many as 10% of the total males) may have been added to the Green Lake broodstock. The 1959/1960 WILD, along with a younger broodstock (Ha(Grn)65D-JR-Mq; hereafter 1965 DOMESTIC) which had been developed from the 1959 WILD, were stocked out in 1975 due to the mentioned difficulties the broodstocks caused in the hatchery.

At the time the Green Lake broodstocks were eliminated from the hatchery system, 10,000 Green Lake strain fingerlings were retained at Jordan River National Fish Hatchery. These fingerlings (Mq(Grn)75D-JR-CS) were either progeny of the 1959/1960 WILD or of the 1965 DOMESTIC broodstock. If these fish were progeny of the 1959/1960 WILD, they would contain a higher percent of Lake Superior genetic background than if they were progeny of the 1965 DOMESTIC.

These trout were transferred as yearlings in 1976 from the Jordan River Hatchery to Crystal Springs State Fish Hatchery in Wisconsin. Some of the fish were removed from the broodstock and stocked in Green Lake (RP clip). In 1981, the broodstock that remained (about 700 fish) were transferred to Genoa National Fish Hatchery. Spawning of the trout was attempted in the autumn of 1981 and 1982 but was unsuccessful possibly due to the "high" water temperatures (about 11°C) at Genoa. The lake trout are still held at this hatchery.

Feral Green Lake strain fish are present in southern Lake Michigan and in Green Lake, Wisconsin. In the fall of 1983, the following year classes of Green Lake strain should be available for gamete collection in southern Lake Michigan waters:

Year Class	Age Group	Fin Clip
1975*	VIII	RP
1974	IX	LP
1973	X	Ad-RV
1972	XI	Ad
1971	XII	RV
1970	XIII	LV

*Last production year class.

If microcontaminants are not a problem, eggs and sperm from these fish should be used to develop a new Green Lake strain broodstock. If microcontaminants are a problem, then sperm could be preserved from Lake Michigan trout for fertilizing eggs collected from Green Lake strain trout stocked in Green Lake.

WYOMING (LEWIS AND JENNY LAKE) STRAIN

The lake trout that occur in Lewis Lake and Shoshone Lake in Yellowstone National Park and in Jenny Lake and Leigh Lake in Grand Teton National Park are descended from native lake trout from Lake Michigan. During the fall of 1889, commercial fishermen collected 3,954,000 fertilized eggs from Lake Michigan lake trout. These eggs were given to personnel of the Alpena Station (Michigan) of the Federal Fish Commission (Part XVII, Report of the Commissioner for 1889 to 1891, U.S. Commission of Fish and Fisheries, Washington 1893). The eggs were received in the port of Thompson (just to the west of Manistique, Michigan) and most likely collected from lake trout spawning reefs west of Beaver Island. The major lake trout spawning reef in this area was Boulder Reef (Big Flat Reef). This extensive reef lies 22-26 miles southeast of Thompson and has a minimum depth of 4.6 m. Trout Island Shoal and Gull Island Reef were also important spawning reefs in this area but were much smaller than Boulder Reef. The eggs were shipped from Thompson to the Northville Station (Michigan) for rearing until eyed. At this developmental stage (eyed) 2,800,000 eggs were still viable (70.8% survival). Of these 2,600,000 eyed eggs were then transferred to other stations and 200,000 eggs were held to be hatched at Northville. Half of these (100,000 eggs) were "held for Yellow- stone National Park."

The 100,000 eggs held for Yellowstone Park could have represented the total egg production of 15-20 females. However, they could have also represented smaller numbers of eggs from a much higher number of females depending on how the eggs were handled and mixed during spawn taking and subsequently reared at the hatchery. The number of males used for fertilizing the eggs varied greatly among the different fishermen and the assumption of a 1:1 sex ratio is probably not realistic.

After the eggs hatched at Northville in the spring of 1890, the fry saved for Yellowstone Park were reared until August. These fry were then shipped by rail to Cinnibar, Montana where they "were transferred into different containers and put on pack horses. They took the Sheridan Trail to Shoshone and Lewis Lakes where the fish were planted" (Roman 1980). The stocking dates and number of fingerlings (5-6 months of age) planted are given below (Evermann 1893):

Date		Location	Number Planted
9 Aug	1890	Shoshone Lake	18,000
23 Aug	1890	Shoshone Lake	7,262
23 Aug	1890	Lewis Lake	7,263
2 Sept	1890	Lewis Lake	4,750
2 Sept	1890	Shoshone Lake	4,750

There were 42,025 fingerlings planted, of which 30,012 were planted in Shoshone Lake and 12,013 in Lewis Lake. Both of these lakes lie within the present boundaries of Yellowstone National Park. Evermann (1893) in his reconnaissance trip of this area in 1891 stated:

> The view of the lake from this trail is a most charming one, for Shoshone Lake is certainly one of the gems of the Rocky Mountains....It (Lewis Lake) is, however, much smaller, its length being but 3 miles and its width not greater than 2 miles. It is essentially the same kind of lake as Shoshone, and, like it, was totally without fish life of any kind until stocked by the U.S. Fish Commission in 1890 with Loch Leven and lake trout. [Lewis Falls blocked fish passage into Lewis and Shoshone Lakes via the Lewis River.]

The lake trout planted in Lewis and Shoshone Lakes became well established within a relatively short period of time.

Smith and Kendall (1922) reported:

> Mr. Clark (l.c.) wrote in 1908 (18 years after their introduction) that the lake trout were plentiful in Shoshone Lake and Lewis Lake and River, and that they could be caught in the canal between Shoshone and Lewis Lakes as fast as one could throw in a trolling spoon, and he remarked that they were large and fat.

Lake trout became abundant enough to be "taken in large quantities to supply the park hotels."

The lake trout moved down the Lewis River from Lewis Lake and "as early as 1901....had become abundant in Lewis River below the upper falls" (Smith and Kendall 1922). They continued to move down the Lewis River to the Snake River and then downstream to below Jackson Lake and eventually up Cottonwood Creek to Jenny and Leigh Lakes. Smith and Kendall (1922) reported that lake trout in Jenny Lake"....occurs in numbers about equal to the native trout (cutthroat)...."

Reintroductions of lake trout occurred in 1941 when 5,890 3-inch lake trout fingerlings from the Bozeman Story Hatchery were stocked into Lewis Lake. These were from eggs collected in 1940 and were purchased from a private hatchery in Wisconsin. At this time, native lake trout eggs were still available from Lake Michigan and Lake Superior but the actual source of the eggs is unknown.

The Jenny Lake strain of lake trout is being maintained as broodstock in the Jackson National Fish Hatchery (Wyoming) and in the Story State Fish Hatchery (Montana). During the fall of 1982, attempts were made to collect lake trout eggs from Lewis Lake in order to propagate lake trout for stocking Lake Michigan. Electroshocking expeditions on 15, 22, and 28 October produced many lake trout, but few eggs. Gamete collections will be attempted again in 1983 and gill netting may be used in addition to electroshocking.

Table A1. History of egg production of the 1949 Wild Superior strain ($Sup\text{-}49W\text{-}Od\text{-}M_q$) lake trout*.

Year	Average Weight (lb)	Group	Eggs Per Female	Egg Production	Percent Eye-up
1954	2.2	V	1,007	18,120	79.1
1955	2.6	VI	1,624	84,465	82.8
1956	3.3	VII	2,010	84,465	78.8
1957	3.6	VIII	2,615	122,904	76.0
1958	3.6	IX	2,976	148,824	88.9
1959	4.2	X	2,475	126,222	92.0
1960	4.5	XI	3,088	142,072	93.4
1961	4.9	XII	3,592	154,456	81.9
1962	5.3	XIII	2,976	No Data	No Data
1963	6.4	XIV	2,931	67,424	82.0
1964	--	XV	4,154	108,016	62.5
1965	--	XVI	3,737	63,700	--
1966	--	XVII	3,651	47,470	--
1967	--	XVIII	2,939	32,356	--

*Data provided by John Driver, Michigan Department of Natural Resources.

Table A2. History of egg production of the 1955 Domestic strain (Mq (Sup) 55D-Mq) held at the Marquette State Fish Hatchery, Michigan.*

Year	Average Weight (lb)	Group	Eggs Per Female	Egg Production	Percent Eye-up
1960	2.1	V	915	137,280	--
1961	2.9	VI	1,481	484,240	82.7
1962	3.0	VII	1,963	921,024	81.7
1963	3.7	VIII	2,345	950,128	89.0
1964	4.4	IX	2,989	1,147,824	80.0
1965	4.4	X	3,049	1,979,700	70.7
1966	5.4	XI	2,939	1,102,400	71.5
1967	5.4	XII	3,365	1,188,100	74.0
1968	5.2	XIII	3,062	1,004,560	67.0
1969	7.0	XIV	3,213	912,542	75.0
1970	6.8	XV	3,221	856,800	57.5

*Data provided by John Driver, Michigan Department of Natural Resources.

Table A3. Timing of spawn taken from lake trout in Green Lake, Wisconsin in 1959.*

Date	Females Spawned	Eggs	Percent Total Eggs In Period	Males In Period
30 Oct	2	4,255		
4 Nov	1	3,825		
5	1	3,960		
6	1	2,800	8.1	89
7	1	3,060		
9	1	5,220		
10	3	4,998		
12 Nov	2	8,170 [a]		
13	5	22,560	10.2	35
14	1	4,600		
16 Nov	2	11,920		
18	4	18,760		
19	3	10,470	21.6	52
20	6	28,620		
21	1	4,680		
23 Nov	1	6,480		
24	4 (1)[d]	19,400		
25	1	2,200	17.3	43[b]
27	6	15,570		
28	5 (2)[d]	16,148		
30 Nov	7	139,402		
1 Dec	10 (3)[d]	46,124		
2	4	24,591	42.8	12[c]
3	3	18,200		
4	3 (1)[d]	19,360		
Total: 30 Oct-4 Dec	78	345,363[e]	100.0	231

* Data provided by Vern Hacker, Wisconsin Department of Natural Resources.
[a] One age VI female (4,870 eggs) was of Lake Superior origin.
[b] Six age VI males were of Lake Superior origin.
[c] Two males, age V and VI were of Lake Superior origin.
[d] Number of silver-grey females.
[e] On 7 January 1960 the Wild Rose Hatchery sent 4 qts, 3 oz of these eggs to Marquette, Michigan (approximately 21,200 eggs).

Table A4. Number of lake trout stocked in Green Lake, Wisconsin, 1933-44.

Year Planted Into Green Lake	Number and Age When Planted	Age if Spawned in 1958	1959
1933	30,000 fingerlings	26	27
1934	100,000 fry	25	26
	6,000 fingerlings	24	25
1935	75,000 fry	23	24
1936	0	0	0
1937	65,000 fingerlings	21	22
1938	5,800 yearlings	21	22
1939	28,788 fingerlings	19	20
1940	76,822 fingerlings	18	19
1941	13,000 yearlings	18	19
1942	0	0	0
1943	65,663 fingerlings[a]	15	16
1944	328,664 fingerlings[b]	14	15

[a] Probably early sac fry stage.

[b] Dates on the planting receipts (13, 17 and 18 April 1944) suggest that these lake trout were in the late sac fry stage or very early fingerling stage. This may also have been true for other years where "fingerlings" are indicated.

Table A5. Timing of spawn taken from lake trout in Green Lake, Wisconsin in 1958*.

Date	Females Spawned	Eggs	Percent Total Eggs In Period	Males In Period
31 Oct	1	2,000		
4 Nov	1	10,800		
7	1	8,640		
12	1	1,080	47.6	119
13	2	9,680		
19	1	5,000		
20	3	12,600		
21 Nov	5	30,348		
22	2	11,960	52.4	48
25	3	12,424		
Total 31 Oct-25 Nov		104,532	100.0	

*Data provided by Vernon Hacker, Wisconsin Department of Natural Resources.

Table A6. Timing of spawn of two groups of Green Lake strain broodstocks held at the Marquette State Fish Hatchery, Michigan in the fall of 1974*.

Date	Broodstock	Females Spawned	Average Eggs Per Female	Egg Production (1,000s)
17 Oct	Ha(Grn)65D[a]	56	2,902	162.5
22 Oct	"	52	3,192	166.0
30 Oct	"	144	2,478	356.8
5 Nov	IL(Grn)59W[b]	295	3,529	1,002.2
12 Nov[c]	"	139	2,810	376.6
19 Nov	"	69	3,530	243.6
25 Nov	"	51	3,106	158.4
2 Dec	"	23	3,860	57.9
Total Egg Production				2,524.0

* Water temperature 43.5°F
[a] Age group IX
[b] Age groups XIV and XV
[c] 60% of the eggs were taken from 30 October-12 November