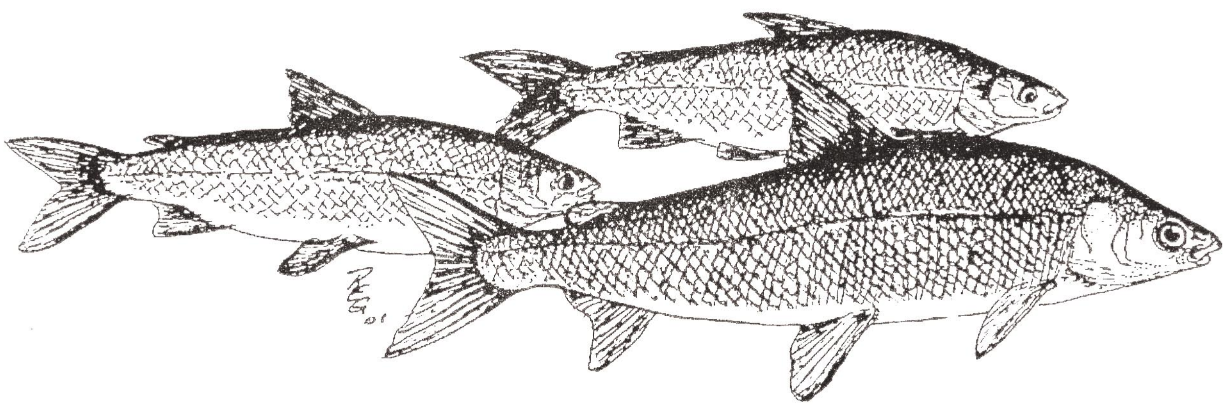
Lake Whitefish Culture and Stocking: An Annotated Bibliography and Literature Review



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Preface

This bibliography and literature review is the eighth in a series of reference documents developed in conjunction with a review of fish stocking policies and guidelines for the Province of Ontario. It has been prepared to summarize information on the current state of knowledge regarding the culture and stocking of lake whitefish (*Coregonus clupeaformis*) in a form which can be readily utilized by Ontario Ministry of Natural Resources (OMNR) field staff and external stocking proponents.

Material cited in this bibliography includes papers published in scientific journals, magazines and periodicals as well as “gray” literature such as file reports from OMNR field offices. Unpublished literature was obtained by soliciting information (i.e., unpublished data and file reports) from OMNR field biologists from across Ontario. The majority of published information was obtained from a comprehensive literature search conducted in the OMNR corporate library in Peterborough. Twenty-one major fisheries journals were reviewed as part of this exercise. These included: Aquaculture (1972-1998), California Fish and Game (1971-2000), Copeia (1913-2000), Environmental Biology of Fishes (1976-2000), Fishery Bulletin (1963-2000), Fisheries Management (1975-1984), Journal of Freshwater Ecology (1981-2000), New York Fish and Game Journal (1954-1985), North American Journal of Fisheries Management (1981-2000), Journal of the Fisheries Research Board of Canada/Canadian Journal of Fisheries and Aquatic Sciences (1950-2000), Progressive Fish Culturist/North American Journal of Aquaculture (1940-2000), and Transactions of the American Fisheries Society (1929-2000). Material was also obtained from other journals such as the Journal of Wildlife Management, Fisheries, Sylva, Journal of Freshwater Fishing, Wisconsin Conservation Bulletin and Canadian Fish Culturist. Searches were also made of other publications including: Proceedings of the Annual Meeting of the Southeastern Association of Fish and Wildlife Agencies, Proceedings of the Annual Meeting of the Western Association of Fish and Wildlife Agencies, Transactions of the Annual North American Fish and Wildlife Conference, Transactions of the Annual Midwest Fish and Wildlife Conference, United States Department of the Interior Fisheries Technical Papers, FAO Fisheries Technical Papers and Circulars, and reports published under the Canadian Technical Report Series of Fisheries and Aquatic Sciences. A search of the World Wide Web was conducted to obtain any pertinent abstracts from papers presented at Division meetings of the American Fisheries Society as well as the 2000 Annual Meeting. Finally, some information was acquired through a search of the Fish and Fisheries Worldwide Database (1971-2000) and Cambridge Scientific Abstracts via the Internet.

Included are approximately 170 citations, most of which contain a synopsis or annotation. Many papers are of European and Scandinavian origin. In cases where abstracts were unavailable, pertinent information from the document was extracted to provide a summary of the findings. Finally, in some cases, we were unable to acquire a copy of the document and have simply included the citation for future reference.

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History of Lake Whitefish Stocking in Ontario

The name "whitefish" typically applies to several Coregonid species. The lake whitefish (*Coregonus clupeaformis*) which is present in Canada has been cautiously equated with the European whitefish (*Coregonus lavaretus*) (McPhail and Lindsay 1970), and for this reason both species are addressed equally in this document.

The artificial rearing of the "whitefish of America" (*Coregonus albus*) was first attempted by Samuel Wilmot in 1867, at the Newcastle hatchery (Anonymous 1876). It is highly unlikely that the species in question was the same as what is now referred to as *Coregonus clupeaformis*. Both lake whitefish and lake herring were apparently known as *C. albus* at one time, and it is believed that this reference was to lake herring. In the late 1800s, lake whitefish were stocked into many Ontario coldwater lakes which were deemed suitable for the species as well as some waterbodies with existing populations (Table 1).

Table 1. Some early stocking records of lake whitefish (*Coregonus clupeaformis*) fry in Ontario waterbodies.

Year	Waterbody (County/Area)	Number stocked	Reference
1884	Lake Ontario (West Durham, East Northumberland, York and Lincoln)	4,000,000	Anonymous (1885)
1884	Lake Erie (Essex, Elgin and Kent)	6,000,000	Anonymous (1885)
1884	Detroit River (Peaché Island, Fighting Island, Bois Blanc Island, Belle Isle and Essex)	16,000,000	Anonymous (1885)
1885	Bay of Quinte (Hastings and Prince Edward)	500,000	Anonymous (1886)
1887	Lake Huron	2,000,000	Anonymous (1888)
1887	Lake St. Clair	1,000,000	Anonymous (1888)
1888	Lake Simcoe (Simcoe and York)	200,000	Anonymous (1889)
1888	Charleston Lake (Leeds)	100,000	Anonymous (1889)
1888	Lake Couchiching (Simcoe and Ontario)	300,000	Anonymous (1889)
1889	Georgian Bay (Grey)	400,000	Anonymous (1890)
1891	Mississippi Lake (Lanark)	420,000	Anonymous (1892)
1891	Consecon Lake (Prince Edward)	1,000,000	Anonymous (1892)
1893	Long Lake (Prince Edward)	800,000	Anonymous (1894)
1893	Green Lake (Stormont)	480,000	Anonymous (1893)
1894	Lake Rosseau (Muskoka)	250,000	Anonymous (1895)
1894	Sharbot Lake (Frontenac)	400,000	Anonymous (1895)
1895	Lake Gillies (Lanark)	300,000	Anonymous (1896)
1895	Upper Rideau Lake (Leeds and Lanark)	300,000	Anonymous (1896)
1895	Lower Rideau lake (Leeds and Lanark)	300,000	Anonymous (1896)

Early lake whitefish plantings involved the release of eyed eggs or fry for over fifty years before studies demonstrated that fry plantings made no significant contribution to established whitefish populations in the Great Lakes (Van Oosten 1941, Lapworth 1956, Dymond 1957, Christie 1963). This evidence greatly reduced the amount of artificial whitefish propagation conducted in Ontario from that point in time (MacKay 1963).

In the past, lake whitefish fry were propagated by provincial and federal hatcheries and stocked in large quantities into Lake Ontario and Lake Erie (Table 2).

Table 2. The propagation of lake whitefish in Ontario government hatcheries, 1867-2000.

Name	Years of Operation	Known Year(s) of Lake Whitefish Propagation
Newcastle	1965-1914	1867-85, 1887-1901
Sandwich	1876-1916	1876-85, 1887-1905, 1907-1908, 1910
Ottawa	1890-?	1891-1902, 1907-1908
Sarnia	1908-1926	1909, 1947, 1950, 1954**
Collingwood	1912-1956	1930*-32, 1947, 1950, 1954**
Belleville	1915-?	1930*-32
Kenora	1915-?	1930*-32, 1938, 1943, 1950, 1954, 1961**
Kingsville	1917-?	1930*-32, 1943, 1947, 1950, 1954**
Normandale	1917-	1920-25, 1930-32, 1647, 1950, 1954**
Port Arthur	1919-?	1919-31, 1947, 1950, 1954**
Sault Ste. Marie (Hatchery)	1921-1956	1930*, 1947, 1950, 1954**
Glenora	1923-1955	1924, 1930-32, 1954**
Fort Frances	1930-1957	1930, 1938, 1947, 1950, 1954**
Little Current	1934-1968	1934, 1943, 1947, 1950, 1954, 1961-67**
White Lake	1934-	1986-
Chatsworth	1936-	1982-1986

* It is likely that lake whitefish propagation occurred prior to the stated year.
** Although documentation was unavailable for many years, it is assumed that lake whitefish culture was generally ongoing between the earliest and latest dates given.

Currently, the only lake whitefish stocking which occurs in Ontario takes place in Lake Simcoe, where the native population was in a state of decline during the 1960s and 1970s. Historical whitefish stocking in Lake Simcoe took place during the late 1800s and the first half of the twentieth century. A total of 28,144,000 fry were stocked into Lake Simcoe from 1888-1955 (McMurtry et al. 1997). The fear of the resident population becoming extinct prompted the Ontario Ministry of Natural Resources to begin a pilot lake whitefish stocking project with yearlings in 1982 (Evans et al. 1987). In 1981, the Whitefish Culture Project was established at the Glenora Fisheries Research Station with a mandate to investigate, develop, and perfect the largely unknown techniques of intensive whitefish culture. Early success at Glenora was obtained by using brine shrimp eggs and encapsulated cysts as feed. The project was transferred to a specially constructed pilot production facility at the White Lake Fish Culture Station in 1985.

Today, lake whitefish are reared only at White Lake fish culture station, using Lake Simcoe stock. In 2000, 164,190 fall fingerlings were stocked into Lake Simcoe (refer to Appendix 2).

Synthesis of Selected Literature

This section will attempt to summarize selected lake whitefish culture and stocking information under the following categories:

1. Lake whitefish culture and rearing practices
2. Contributions of stocked lake whitefish to the fishery
3. Factors influencing stocking success
4. Potential impacts of stocked lake whitefish
5. Best management practices for lake whitefish culture
6. Best management practices for lake whitefish stocking
7. Stocking assessment

Lake Whitefish Culture and Rearing Practices

Lake whitefish can be reared both intensively and extensively, the former being the method used in Ontario. In the first half of the twentieth century the Canadian and Provincial governments did not have the expertise to rear lake whitefish past the fry stage (Van Oosten 1937). It was unknown at the time that fry plantings were contributing little, if anything, to stocked fisheries (MacKay 1963). In the past twenty years, more advanced rearing methods have allowed for the culture of whitefish to the yearling stage. In Ontario, whitefish rearing is restricted to intensive culture, while in Europe pond and cage culture is being employed (Flüchter 1982, Huner and Lundquist 1983, Rasmussen 1988). Artificial lake whitefish production varies by jurisdiction (Table 3).

Table 3. Highlights of lake whitefish (*Coregonus clupeaformis*) culture in selected jurisdictions.

	Hatchery feeding		Hatchery survival		
Location	Initial fry diet	Age converted to dry feed	Time	% Mortality	Reference
Alberta	*Artemia*	7 weeks	9 weeks	<7%	Drouin et al. (1986)
Michigan	Zooplankton	13 weeks	24 weeks	96.0%	Raisan and Behmer (1982)
North Dakota	Dry feed	-	50 days	32.3-73.0% 2.3-4.0%	Zitzow and Millard (1988)
Ontario	*Artemia*	-	3 weeks	2%	Anonymous (1966)
Ontario	*Artemia*	8 weeks	8 weeks	<5%	Harris (1992)
Ontario	Dry feed	-	28 weeks	<5%	OMNR (2000)

The diet, which is fed young lake whitefish, can be key to the success of intensive culture. It was found that, if first feeding is delayed past the yolk absorption stage, excess deaths will result (Anonymous 1966). Dry diets which are deficient in nutrients lead to lower levels of health, growth and survival (Zitzow and Millard 1988). In one experiment it was demonstrated that the survival rates of larvae were slightly higher in those fed dry food than zooplankton (Luczynski et al. 1986), while another showed the opposite results (Enz et al. 2000). *Artemia* (brine shrimp) are the most commonly used live hatchery food (Anonymous 1966, Drouin et al. 1986, Harris 1992, Enz et al. 2000). Whitefish fry can distinguish between live and dead shrimp and will not ingest those which are immobile (Anonymous 1966). In certain rearing situations, the provision of live feed may be necessary for high survival rates.

While a combination of live and dry feed remains widely used worldwide, Ontario has further intensified its whitefish culture practices. Currently, lake whitefish are successfully reared solely on a dry diet. A larva-specific formula is utilized during the most crucial development period, the first four weeks of life, prior to substituting another dry feed, which carries the fish to the fall fingerling stage.

Contributions of Stocked Lake Whitefish to the Fishery

Stocking whitefish fry was found to contribute little to commercial fisheries (Van Oosten 1937, 1947; Lapworth 1956; Christie 1963; MacKay 1963; Wanzenboeck and Jagsch 1998), whereas an increase in the catch was found with the stocking of fingerling fish (Klein 1980, Tuunainen 1982, Salojarvi and Huusko 1990). Salonen et al. (1998) ascertained that fingerling stocking did not have a great impact on the fishery when high natural reproduction was occurring, however. Although impacts of stocked fish on a fishery vary, Salojarvi (1992_d) found that when forecasting yields, those from juvenile whitefish stocking endeavours are more predictable than those of adult transfers and fry stockings (Table 4).

Table 4. Yield of *Coregonus lavaretus* from selected stocking projects.

Waterbody	Yield	Reference
Lake Geneva (Poland)	• 20-25 kg per 1,000 spring pre-fed fry	Champigneulle and Gerdeaux (1992)
Lake Paasivesi (Finland)	• 20-30 kg per 1,000 summer fingerlings	Heikinheimo (1992)
12 unnamed lakes (Poland)	• 2.35-55.66 fish per ha from a stocking rate of 4-1,924 autumn fry per ha	Falkowski (1998)
Lake Peranka (Finland)	• 155 kg per 1,000 fingerlings (high stocking rate) • 10 kg per 1,000 fingerlings (low stocking rate)	Salojarvi (1988)
Lake Kallioinen (Finland)	• 83-235 kg per 1,000 fingerlings	Salojarvi (1991)
Lower Sotkamo watercourse (Finland)	• 57 ± 18 kg per 1,000 fingerlings	Salojarvi and Huusko (1990)
Lake Inari (Finland)	• 9-26 kg per 1,000 fingerlings	Salonen et al. (1998)

Through experimentation, higher whitefish stocking densities were found to give greater annual catches than lower densities, yet much lower yields (Salojarvi 1988). Catch was determined to be related to stocking densities; with a decrease in stocking rates there was a correlated decrease in landings (Falkowski 1998). Lake whitefish can remain a large part of the fishery for many years following stocking. Gerdeaux et al. (1998) found that C. lavaretus, when planted at ages II and III into reservoirs, contributed to the fishery in the season following planting, and continued to do so for an additional two seasons.

Factors Influencing the Stocking Success

The stocking success of lake whitefish is highly dependent upon the method of stocking, as well as the features of the fish being stocked (Table 5). The presence of native whitefish populations, the quality of the water, habitat characteristics and availability of food are also vital in determining the success of a stocking venture.

Table 5. Factors influencing the stocking success of lake whitefish.

Factor	Reference(s)
Poor habitat and/or water quality	Marshall and Johnson (1971), Hindley (1984), Heikinheimo-Schmid and Huusko (1988), Rask et al. (1992), Raitaniemi et al. (1999)
Age/size of fish when stocked	Van Oosten (1937), Miller (1946), Tuunainen (1982), Salojarvi (1991, 1992), Champigneulle and Gerdeaux (1992), Falkowski (1998), Falkowski and Wolos (1998)
Genetic strain	Heikinheimo (1992), Lehtonen et al. (1998), Heikinheimo et al. (2000)
Stocking technique:	
Time of stocking	Butler (1940)
Stocking rates	Falkowski (1988), Salojarvi (1988, 1991)
Stocking sites	Downing (1904), Hart (1930)
Marking technique	Butler (1930), Hoeglund and Wahlberg (1997), Friman and Leskelae (1998), Leskelae et al. (1998)
Diet conversion/starvation	Parker (1888), Butler (1940), Carl and Clemens (1948), Scott and Crossman (1964), Heikinheimo-Schmid (1985), Rasmussen (1988), Turunen and Viljanen (1988), Davis and Todd (1998), Heikinheimo et al. (2000)
Competition	Eckmann et al. (1988), Rask et al. (1992), Davis and Todd (1998), Lehtonen et al. (1998), Amtstaetter (1999b), Raitaniemi et al. (1999)
Predation	Hart (1930), Gray (1980), Hindley (1984), McMurtry (1989)
Movements of stocked fish	Ikonen (1984), Jokikokko and Huhmaniemi (1998)
Fish health and disease	MacKay (1963), Raisan and Behmer (1982)

Habitat and Water Quality – The nature of the receiving waterbody is of great importance when planning to stock lake whitefish. Some optimal habitat conditions for lake whitefish are summarized in Table 6. High levels of acidity have been attributed to delayed growth and overall stocking failure (Rask et al. 1992, Raitaniemi et al. 1999). In Saskatchewan, introductions have failed due to high levels of salinity and low levels of dissolved oxygen (Marshall and Johnson 1971). It is essential that artificial regulation of the receiving waterbody be considered, given that fluctuating water levels can destroy spawning grounds (Heikinheimo-Schmid and Huusko 1988). High concentrations of aluminum have also been blamed on whitefish stocking failures (Rask et al. 1992).

Table 6. General habitat requirements for stocked lake whitefish.

Parameter	Requirement
Waterbody	• Preferably large, cold lakes.
Water depth	• Waters should be deep (re. > 12 m) for non-spawning periods; whitefish spawn in water 6-14 m deep.
Water clarity	• Can tolerate high (>3,000 mg L^{-1}) levels of total dissolved solids.
Water temperature	• Preferred temperatures for lake whitefish vary from 11.9-17.0º C. • Spawning occurs at temperatures less than 6º C.
Substrate	• Optimal spawning habitat includes gravel, stones and/or sand.
pH	• pH should be greater than 5.4.

Age and Size of Fish Stocked – Early life stages of lake whitefish have been found to be inefficient at contributing to a fishery. In Alberta, the stocking of eyed-eggs did nothing to enhance “native” year classes (Miller 1946). Fry do not add to populations where natural reproduction is present (Van Oosten 1937, 1942; Christie 1963; Marshall and Johnson 1971; Tuunainen 1982; Salojarvi 1991). Of the 109 lakes on the Oulujoki watercourse, Finland, into which fry were introduced, recaptures of fish occurred in 91 lakes, 56 lakes experienced natural reproduction and 18 were considered a failure (Tuunainen 1982). The stocking of fingerlings, however, are likely to have a positive impact on lake whitefish catch rates (Salojarvi and Huusko 1990). Flüchter (1982) determined that in Bavaria, Germany, plantings of 5 cm fingerlings experienced a survival rate 1,500 times greater than that of stocked fry. While fry stockings have little chance of damaging a native population, fingerling plantings can cause a decrease in the native stock (Tuunainen 1982). Returns from stocking spring yearlings and fall fingerlings has proven to be proportional in Lake Simcoe (Amtstaetter 1998). As a result the decision was made to continue whitefish stocking in Lake Simcoe only in the form of fall fingerlings. This decision was made due to rearing constraints at the White Lake fish culture station as well as enforcement issues; anglers were removing newly-stocked yearlings while mistaking them for smelt.

Genetic Strain – Taxonomy of the coregonid family is highly controversial due to the groups’ diversity and complicated variations in form. Over the past half century species nomenclature has changed several times. Through electrophoretic studies, Bodaly et al. (1991) categorized Coroninae species into six groups. This system of classification demonstrated that C. lavaretus and C. clupeaformis are exceedingly similar. It was determined that lake whitefish from northwestern North America were more closely related to *C. lavaretus* than to *C. clupeaformis* from central North America. It was further hypothesized that the two "species" actually represent extrema of a single species. *C. lavaretus* itself has numerous recognized forms, generally based upon the average number of gill rakers and/or where they spawn and reside during their adult lives (Heikinheimo 2000). Heikinheimo (1992) found that *C. l. wartmanni* were more susceptible to capture by seining and trawling than *C. l. pallasi*. It was also determined that whitefish forms with the most numerous (i.e., densest) gill rakers grew the fastest (Lehtonen et al. 1998, Heikinheimo 1992). Those whitefish four and five years-old with 50-51 gill rakers consumed nearly twice the amount of food than those forms with fewer gill rakers. In lakes were there exist more than one stock of *C. lavaretus*, habitat segregation occurs (Heikinheimo 1992). Forms of *C. lavaretus* dealt with in this publication include: *C. l. lavaretus*, *C. l. pidschian*, *C. l. pallasi, C. l. wartmanni* and *C. l. maraena*. Other coregonines including *C. albula* (vendace), *C. peled* (peled), *C. muksun* (muksun) and *C. nasus* (broad whitefish) are mentioned, yet, are not considered to be "lake whitefish".

Many stocks of lake whitefish are believed to be genotypically and/or phenotypically discrete (Casselman et al. 1981; Evans et al. 1988; Bodaly, Vuorinen and Macins 1991). The Great Lakes lake whitefish are known to be genetically distinct from the Lake Simcoe, Ontario, stock (Evans et al. 1988). For this reason, selection of the most appropriate genetic strain is imperative in any stocking project involving lake whitefish.

Stocking Site – When fry are stocked they should not be concentrated in one area. Hart (1930) suggested that by distributing lake whitefish fry over a large area, predation can be reduced. Similarly, Downing (1904) found that by widely dispersing fry it was assured there would be adequate food for the planted lot. On Lake Simcoe, fall fingerlings are released in close proximity to the spawning shoals where eggs and milt had been collected.

Time of Stocking – Lake whitefish can be stocked in the spring or fall. Ideally, they should be stocked at a time when ample food is available in the waterbody. If lakes are still ice-covered when fry are ready to be stocked, it is beneficial to keep the fry in the rearing facility until it is certain that ample food is available. The feeding of fry prior to release can increase their post-stocking survival (Butler 1940). In Lake Simcoe, success, in terms of contribution to trap net catches, has been had with both spring-planted yearlings and fall fingerlings (Amtstaetter 2000_a).

Stocking Rates – Lake whitefish have been stocked at various rates across Europe, Scandinavia and North America (Table 7). Generally, stocking rates decrease as age/size of fish increases. Falkowski (1998) found that lowered stocking rates were related to a rapid decrease in angler catch of whitefish. Salojarvi (1990) believed that, in many instances, whitefish yields could decrease due to a high stocking density. Experimental stocking projects have demonstrated that a greater yield could be achieved from a planting rate of 4 fingerlings per hectare than 200 fingerlings per hectare (Salojarvi 1988).

Table 7. Lake whitefish stocking rates reported for various projects.

Waterbody	Life stage	Rate	Purpose	Reference
Fertilized ponds (Finland)	Fry	30,000 per ha	Rearing	Huner and Lindquist(1983)
Lake Kallioinen (Finland)	Summer fingerlings	100-160 per ha	Put-grow-and-take fisheries	Salojarvi (1991)
Lake Mondsee (Austria)	Larvae	148-798 per ha	Put-grow-and-take fisheries	Wanzenboeck and Jagsch (1998)
Lake Peranka (Finland)	Fingerlings	4 per ha 200 per ha	Experimental: density/yield	Salojarvi (1988)
Lake Simcoe (Ontario)	Fall fingerlings or yearlings	~0.8-1.1 per ha	Rehabilitation stocking	Willox (1991)
	Fall fingerlings	~2-2.5 per ha	Rehabilitation stocking	Unpublished data (2001)
Twelve lakes (Poland)	Larvae	3-12,480 per ha	Put-grow-and-take fisheries	Falkowski (1988)
	Summer fry	4-3,445 per ha	Put-grow-and-take fisheries	
	Autumn fry	4-1,924 per ha	Put-grow-and-take fisheries	

Marking Techniques – The method in which a hatchery-reared whitefish is marked can influence post-stocking success. Table 8 describes frequently-employed methods of marking hatchery-reared whitefish. It is important that the marking system be appropriate for the stocking project (i.e., the time between stocking and recapture/sampling be appropriate to the marking method). Life stage vulnerabilities must also be taken into account. The marking of fry is usually difficult. With fin-clips there is the possibility of fin regeneration (Butler 1930). Otolith marking is intended for young fish and has a high success rate (Hoeglund and Wahlberg 1997). Certain marking procedures can have more of a negative influence on post-stocking survival than others. The spray pressure used in fluorescent marking has caused prohibitive levels of post-stocking mortality (27.2-67.4% after twenty-four hours) when the air pressure used was too high (Friman and Leskelae 1998).

Table 8. Various marking methods used to identify hatchery-reared lake whitefish.

Method	Age/life stage	Retention	Reference
Burning the adipose fin	Fry	Unknown	Champigneulle and Gerdeaux (1992)
Coded wire tags injected into snout	Juveniles	Unknown	Lehtonen et al. (1998)
Nose tags	Fingerlings	Unknown	Salonen et al. (1998)

Continued…

Table 8 (cont'd)

Method	Age/life stage	Retention	Reference
Fin clip (single pectoral)	Fry	Unknown	Butler (1930)
Various fin clips	Fingerlings and yearlings	Unknown	Willox (1991)
	Fingerlings (~10 g)	95% after 3 months	Unpublished data (2001)
Otolith marking by immersion in alizarin complexone solution	Newly hatched larvae	~100% after 4 months	Hoeglund and Wahlberg (1997)
Fluorescent spray-pressure marking	One summer-old fish	99-100% after 3 years	Friman and Leskelae (1998)
	One summer-old fish	Unknown	Leskelae et al. (1998)

Competition – Lake whitefish experience both interspecific and intraspecific competition. Potential competitors of lake whitefish are summarized in Table 9. Older lake whitefish (ages I and II) have been found to have a negative influence on age-0 whitefish (Eckmann et al. 1988). In large lakes, the problem of competition between two or more forms of lake whitefish could occur if there are resource shortages (Heikinheimo-Schmid 1985). Other coregonids such as vendace (*Coregonus albula*) and lake herring (*Coregonus artedi*) may influence the survival of whitefish. Raitaniemi et al. (1992) found that competition with vendace delayed the growth of young whitefish, as did the presence of roach.

Table 9. Competitors of stocked lake whitefish.

Competitor	Reference(s)
Arctic charr	FAO (1994)
Lake whitefish	Heikinheimo-Schmid (1985), Eckmann et al. (1988)
Lake herring	Davis and Todd (1998), Kerr and Grant (2000)
Vendace	Raitaniemi et al. (1999)
Rainbow smelt	Amtstaetter (1999_b), Kerr and Grant (2000)
Perch	Rask et al. (1992)
Suckers	MacCrimmon and Skobe (1970)

Predation – Although there is little data available on predation which deals specifically with stocked lake whitefish, they have many known predators (Table 10). In the Great Lakes, the sea lamprey (*Petromyzon marinus*) is known to prey on larger adult whitefish (Gray 1980). Lake whitefish survival can also be endangered at a much earlier age since spawning grounds are assaulted by numerous species such as the yellow perch (*Perca flavescens*) (Hart 1930).

Table 10. Potential predators of stocked lake whitefish.

Predator	Life stage	Reference(s)
Ciscoe	Eggs	Hart (1930)
Crayfish	Eggs	Kerr and Grant (2000)
Lake whitefish	Eggs	Scott and Crossman (1973)
Longnose suckers	Eggs	Kerr and Grant (2000)
Sculpins	Eggs	Kerr and Grant (2000)
Rainbow smelt	Eggs	Kerr and Grant (2000)
Yellow perch	Eggs	Hart (1930)
Rainbow smelt	Larvae	Loftus and Hulsman (1986)
Lake trout	Fry and older	Kerr and Grant (2000)
Muskellunge	Fry and older	Kerr and Grant (2000)
Northern pike	Fry and older	Scott and Crossman (1973), Kerr and Grant (2000)
Seagulls	Fry and older	B. See – White Lake Fish Culture Station, OMNR, Sharbot Lake (personal communication – 2001)
Sea lamprey	Adults	Gray (1980)
Burbot	Unspecified	Scott and Crossman (1973)
Lake Herring	Unspecified	Scott and Crossman (1973)
Walleye	Unspecified	Scott and Crossman (1973)

Movements of Stocked Fish – The movements of stocked lake whitefish should not pose a problem in terms of stocking success unless the fish are of an anadromous form. Ikonen (1984) found that fingerlings stocked in rivers which emptied into the Baltic Sea produced poor fishing conditions in the river mouths, due to their significant downstream movements and the high fishing pressure in the Baltic Sea.

Diet of Stocked Fish – Lake whitefish consume a wide variety of invertebrates. Younger fish commonly eat zooplankton and at lengths greater than 35 cm their diet is mainly composed of zoobenthos (Gerstmaier 1985). Various studies have indicated that the intensity of whitefish predation is dependent upon the prey density (Hanazato et al. 1990). Lack of available food has been blamed for the failure of several stocking projects (Carl and Clemens 1948, Scott and Crossman 1964). However, Turunen and Viljanen (1988) believe that lake whitefish are a superior fish for introductions because their diet is highly flexible. Lake whitefish adults are predominantly bottom feeders and as such have been employed in Denmark to control chironomid numbers (Rasmussen 1990). The summer months force lake whitefish into deeper, cooler waters and this may cause a shift in diet, thus making for contrasts between seasonal diets (Amtstaetter 2000_b). Typical prey consumed by lake whitefish appear in Table 11.

Table 11. Potential food items of stocked lake whitefish.

Food item	Reference(s)
Zooplankton (various)	Hart (1931), Scott and Crossman (1973), Flüchter (1982), Huner and Lindquist (1983), Gerstmaier (1985), Heikinheimo-Schmid (1985), Rasmussen (1988), Hanazato et al. (1990), Davis and Todd (1998), Amtstaetter (1999_c)

Continued…

Table 11 (cont'd)

Food item	Reference(s)
Spiny water flea	Amtstaetter (2000_b)
Snails	Carl and Clemens (1948), Scott and Crossman (1973), Amtstaetter (1999_c)
Fingernail clams	Amtstaetter (2000_b)
Terrestrial/emerging insects	Heikinheimo-Schmid (1985)
Aquatic insects: larvae, nymphs	Carl and Clemens (1948), Scott and Crossman (1973), Amtstaetter (2000_b)
Midge larvae	Amtstaetter (1999_c)
Hemiptera nymphs	Amtstaetter (1999_c)
Chironomids	Heikinheimo-Schmid (1985), Rasmussen (1988)
Isopods	Amtstaetter (1999_c)
Annelids	Davis and Todd (1998)
Leeches	Scott and Crossman (1973)
Zebra mussels	Amtstaetter (1999_c), Amtstaetter (2000_b)
Rainbow smelt	Amtstaetter (1999_c), Amtstaetter (2000_b)
Miscellaneous fish	Amtstaetter (2000_b)
Trout and salmon eggs	Whitehouse (1948)
Diatoms	Parker (1888)
Vegetation	Parker (1888)

Fish Health and Disease – There is a frequent parasite found in the immature stages of lake whitefish, although it has not been specifically related to those fish which have been stocked. The tapeworm *Triaenophorus* crassus cycles through planktivorous and piscivorous feeders and is common in some Canadian lakes. While the parasite is harmless to people, fish which are highly infected are unmarketable, because the parasite is visible as large, yellow, cysts (MacKay 1963). Hart (1931) found that 95% of the whitefish examined from Ontario waters were heavily infected with either the tapeworms *Cyathocephalus americanus* or *Ichthyotaenia larvei*. Raisan and Behmer (1982) found that hatchery mortality of larval whitefish stages can be caused by gill disease and fin rot. It is of no benefit to stock whitefish into infected areas. Prior to stocking, native species should be tested for the presence of parasites.

Potential Impacts of Stocked Lake Whitefish

The introduction of lake whitefish can have numerous negative impacts on the resident aquatic community (Table 12).

Table 12. Potential impacts of lake whitefish stocking.

Potential impact	Reference(s)
Predation on established species	Fott (1987), Hanazato et al. (1990), Rasmussen (1990), Berg et al. (1994)
Competition/displacing other fish	MacCrimmon and Skobe (1970), Tuunainen (1982), Gerstmaier (1985), Lehtonen and Niemelae (1998), Kerr and Grant (2000)
Hybridization	Luczynski et al. (1992), Kerr and Grant (2000)
Disease transmission	MacKay (1963)

Lake whitefish are not highly piscivorous and, therefore, will generally have little if any direct impact on the other fish species in a receiving waterbody. However, the presence of whitefish can alter the aquatic community. Fott (1987) suggested that the introduction of whitefish into ponds could have a top-down effect and ultimately determine the phytoplankton biomass. Heavy predation by whitefish on zooplankton such as *Daphnia* can cause cascading effects on the characteristic properties of a lake. Berg et al. (1994) found that the elimination of large *Daphnia* species caused an increase in chlorophyll *a* levels, a decrease in Secchi depth and an overall increase in lake eutrophication. The effects of predation on plankton communities are more evident with increasing prey density (Hanazato et al. 1990). Benthic invertebrate and zooplankton assemblages can be altered through the elimination of prey species by the lake whitefish (Hanazato et al. 1990, Berg et al. 1994).

Competition exists between coregonids and other fish species. There is a large (70-90%) diet overlap between larval lake whitefish and lake herring and this could be advantageous to the whitefish, which are of greater size, thus allowing them to feed earlier than the herring (Davis and Todd 1998). Gerstmaier (1985) suspected that Arctic charr (*Salvelinus alpinus*) were negatively influenced by whitefish stocking. The FAO (1994) strongly recommends that whitefish not be stocked in waters in which the arctic charr is the preferred catch species. Lake whitefish are also hypothesized to have an impact on native populations. Lehtonen and Niemelae (1998) determined that the growth rates of the native whitefish stock decreased following the introduction of hatchery-reared whitefish and the stocking of fingerlings has been found to reduce native stock numbers (Tuunainen 1982). In Lake Simcoe, suckers may be in competition with whitefish as both are bottom feeders (MacCrimmon and Skobe 1970).

In Europe, the hybridization of whitefish (*C. lavaretus*) with peled (*C. peled*) has caused species identification problems. The inability to recognize each species individually has led to stocking errors, followed by associated management problems (Luczynski et al. 1992). Gerdeaux et al. (1998) found that in two reservoirs where both species and their hybrids had been stocked, only C. lavaretus was caught by anglers. In certain situations the hybridization of these two species could have serious implications for anglers by creating a hybrid which is difficult to catch or has a poor survival rate.

Although there is a lack of information on the transmission of disease from stocked lake whitefish to native species, there is always the possibility of transmission since whitefish can be susceptible to tapeworms such as *Triaenophorus crassus* (MacKay 1963).

Best Management Practices for Lake Whitefish Culture in Ontario

Based on the Ontario experience the following practices of lake whitefish culture are recommended:

> **Egg Handling** – Eggs should be collected during the spawning season (mid November) and incubated in glass bell jars. No anti-fungal treatments need to be applied if dead eggs are removed.
>
> **Rearing Environment** – Larval rearing should occur in waters with an initial temperature of 4.0º C. The temperature should be increased gradually to 14.0º C, to encourage optimal growth. The level of dissolved oxygen in the rearing tank should be no less than 5 mg L^{-1}. Siphoning and draw-down of all tanks must occur when required to maintain a pathogen-free environment.
>
> **Rearing Densities** – Egg density should range from one to three litres of eggs (30,000-90,000 eggs) per 6.5 litre jar. Fry should be reared at a rate of 6,000 larvae per 500 litre unit and approximately 15,000 fingerlings should be placed into each (15,000 litre) raceway with an initial density of 1.3 gm L^{-1}. The fish then continue development until the density reaches 40 gm L^{-1} and are stocked at approximately 20 g in weight and a total length of 12 to 15 centimetres.
>
> **Feeding** – The most successful diet regime is based upon the commercial larval diet, Biokyowa. The introduction of the lower priced Belgian diet (INVE) at week four will reduce costs dramatically while maintaining fish quality and survival. Initially, feeding should occur every ten minutes, sixteen hours per day. At age four weeks, intervals should be increased to 20 minutes. For advanced fingerlings, feeding should occur twelve hours per day, with feeding intervals ranging from 30-60 minutes.
>
> **Disease Prevention** – Many incidences of gill infection can be prevented by avoiding excessive handling, overfeeding, unusual activity patterns (whitefish care must be consistent) and water temperatures greater than 15.0º C. Gill disease can be treated by immersion in a 1.0% salt bath for half an hour, followed by a twenty minute flush with 10 mg L^{-1} Chloramine-T ™.
>
> **Fish Handling** – Contact with the fish should be minimized for the first three to four weeks of life. Careless handling can result in lost scales and high susceptibility to infection. Feeding should be stopped at least twenty-four hours prior to handling.

Best Management Practices for Lake Whitefish Stocking

Based on the information reviewed the following practices can be recommended for the stocking of lake whitefish:

Stocking Objective – The objective of a lake whitefish stocking project must be clearly defined when planning the event. The stocking intent will dictate the size of fish needed to achieve the desired goal. It is essential that a method for quantifying the success or failure of the stocking project be identified.

Supplemental Stocking – Unless natural reproduction is non-existent, it is not recommended that supplemental stocking be undertaken with young life stages of whitefish. Fry stockings, along with small fingerlings, have proven to be generally ineffective.

Waterbody Characteristics – Lake whitefish should not be planted into a waterbody whose water levels are regulated to the extent that spawning grounds are threatened. High levels of acidity and contaminants can cause stocking failure, as can elevated salinity and low concentrations of dissolved oxygen. Receiving waters should generally have a depth greater than 12 m. The presence of coldwater summer habitat is necessary.

Strain of Fish – The strain of lake whitefish stocked should be best suited to the receiving waterbody. The European lake whitefish should not be stocked in North America and vice versa. Only the Lake Simcoe strain of the species should be stocked in that lake. It is known to be genetically separate from the Great Lake form and as such the introduction of a foreign strain could cause the elimination of the native variety. Generally, original stocks or those from a nearby source should be used for future re-introductions or rehabilitation programs.

Disease Considerations – Diseases can be easily transmitted from one fish to another both within and among species. It is essential that hatchery-reared fish be monitored on a regular basis for parasites and disease to prevent the entry of pathogens into a receiving waterbody.

Age/Size of Fish to Stock – Fry should not be stocked into waterbodies which contain established whitefish populations. Fry should only be used for introductory stocking endeavours in waters which contain few predators. Fingerlings as well as yearlings can contribute significantly to a fishery and should be considered to provide returns to a fishery. In Ontario fall fingerlings have shown good returns.

Marking – Marking methods should be compatible with the time between stocking and stocking assessment as well as the age and size of the fish being marked. Fin clipping is a fast and simple procedure, however, there is the probability of regeneration. Otolith marking may be appropriate for fry. Fluorescent paint marking is viable for many years, however, if caution is not exercised the fish can suffer excess post-stocking mortality. Coded-wire tags are also suitable for lake whitefish.

Stocking Rate – The optimal stocking rate for a waterbody can vary, depending on the stocking objective. Lake whitefish should always be stocked on a descending basis; i.e.

the larger the size of fish being stocked the lower the stocking rate. Until additional research provides the basis for change, it is generally recommended that whitefish be stocked at the rate of 5-10,000 fry ha^{-1}, and that, based on the Lake Simcoe experience, fall fingerlings and yearlings be stocked at the rate of 2-3 fish ha^{-1}.

Stocking Frequency – Stocking frequency depends upon the stocking objective. Put-and-take fisheries may need to be stocked annually, while put-grow-and-take fisheries may be stocked every two or three years. Each stocking venture should be continued for at least two consecutive years to account for any environmental or climatic factors which may have influenced the initial stocking.

Time of Stocking – The stocking of lake whitefish should occur at a time when there is ample food available in the receiving waterbody. Once again the stocking objective may dictate the appropriate time to stock the fish. Fish should be stocked after dark to avoid avian predators.

Transporting Fish to Stocking Site – Distance should be minimized in order to avoid any negative stress-associated effects caused by high density confinement. Efficient circulation of air and water is essential when being transported in tanks. To reduce the risk of injury the water should contain a 2% salt solution.

Release Sites – Lake whitefish should be liberated in areas of suitable habitat for the particular life stage, i.e. fry should be placed nearshore in areas of emergent vegetation. If possible, fingerlings and yearlings should be stocked in the same area from which the hatchery-destined eggs were collected (i.e., spawning shoals). Fry should not be concentrated in one area when released.

Stocking Technique – Lake whitefish are especially susceptible to scale loss and excessive handling should be avoided. When stocking in mid-lake, visibility of stocked fish should be considered and care should be taken to avoid exposure to predators (i.e., stocking at night). There is evidence that young whitefish should be well dispersed upon release.

Stocking Assessment

Because lake whitefish are primarily a commercial species in many large lakes, the success of a stocking endeavour may be measured from the commercial catch. In large waterbodies, such as the Great Lakes, the effectiveness of fry plantings were investigated by analyzing the commercial catch during the year in which the fry would enter the fishery. In many European waterbodies stocking assessments are based on the estimated contribution to the commercial harvest, where marking methods are occasionally used to identify hatchery-reared whitefish. In Europe a “light trap” may also be employed during the “photo-positive period” to determine the numbers of stocked and naturally-hatched fry in littoral zones. This method of evaluation is only applicable during the fry photoperiod, which typically terminates between age 6-8 weeks.

On Lake Simcoe there are three specific methods which are used to gather data on stocked lake whitefish (results of all three of these methods appear in Appendix 3): Creel surveys, index trap netting, and an “angler catch sampling program”. Creel surveys occur during the winter and summer fishing season to estimate angler catch and harvest of many species, including lake whitefish. Proportion of lake whitefish in the catch is determined at this time. Fall index trap netting is done on spawning shoals (while spawn for rearing purposes is collected) which allows the proportion of lake whitefish in the catch to be calculated along with attributes of the hatchery-reared fish to be collected. Currently, North Georgina Island and Strawberry Island are the spawning locations which are assessed. The angler catch sampling program allows for the compilation of biological data such as length, weight and age of stocked fish.

Annotated Bibliography

ALLEN, R. J. 1985. Analysis of scale age and growth for lake whitefish (*Coregonus clupeaformis*) from Lake Simcoe. Lake Simcoe Fisheries Assessment Unit Report 1985-5. Ontario Ministry of Natural Resources. Sutton West, Ontario. 153 p. + appendices.

Methods and criteria are discussed for routine scale age assessment of Lake Simcoe lake whitefish (*Coregonus clupeaformis*). This is accomplished through a comprehensive interpretation of the surface configurations. For scales not exhibiting distinct annuli, an alphabetical ranking system is introduced to establish a range of possible ages. The scale surface is quantified with counts and measurements of the circuli and growth zones, respectively. Measurement data indicated that Lee's phenomena may be present in the scale analysis of the population. Inter- and intra- observer testing was conducted to determine repeatability of scale age assessment. Results indicate that agreement was best for observers using the same aging methods regardless of experience. Scale growth and annuli formation were examined for a sample of twenty hatchery-reared lake whitefish of Lake Simcoe parental origin, at time of release, and for seventeen recaptures up to three years later. The correct number of annuli was obtained for these individuals. The four basic checks used for annulus identification were: 1) changes in circuli spacing, 2) crossing over of circuli, 3) fragmented and irregular circuli, 4) hyaline (space devoid of circuli). Seven tagged-recaptured native lake whitefish were also examined in an attempt to validate the scale method of age assessment. Often, scales contained fewer annuli than expected for the number of years that had elapsed. Only two of the seven scales contained the expected number of annuli.

ALLEN, R. 2001. Lake Simcoe: Lake whitefish stocking records 1982-2000. Lake Simcoe Fisheries Assessment Unit, Ontario Ministry of Natural Resources. West Sutton, Ontario. 3 p.

This documents the stocking of lake whitefish into Lake Simcoe since 1982 and includes vital information such as number stocked, life stage stocked, fin clip, and location stocked. In mid-October 2000, 164,190 fall fingerlings were planted, with 82,197 being stocked at Jackson's Point and 81,993 being stocked at Hawkstone. Visual inspection of a sample of the fish concluded that over 93% of the fish had greater than 90% of the right ventral fin removed, while the remaining 7% were missing more than 50% of this fin.

AMTSTAETTER, F. 1998. Comparison of growth and survival of lake whitefish stocked as fall fingerlings versus spring yearlings in Lake Simcoe. Presented at the Ontario Ministry of Natural Resources Research-Assessment meeting, Frost Centre, March 31, 1998, Dorset, Ontario.

Six year classes of hatchery-reared lake whitefish (*Coregonus clupeaformis*) (1986 to 1991) were stocked into Lake Simcoe in the fall at 6 months of age and in the spring at 12 months of age. Comparisons of abundance and size between fish stocked in the fall and fish stocked in the spring were made using six year old lake whitefish captured with trap nets during the fall season from 1992 to 1997. Differences in abundance were detected within five of six year classes. Two year classes indicated greater abundance of lake whitefish stocked at 6 months of age, and three indicated greater abundance of lake whitefish stocked at 12 months of age. No difference in length was detected between six year old lake whitefish stocked at 6 months of age from those stocked at 12 months of age. Since there was no difference in abundance or size of lake whitefish at 6 years of age between the two rearing practices, stocking lake whitefish into Lake Simcoe at 6 months of age was the most cost effective option.

AMTSTAETTER, F. 1999$_a$. Fall trapnetting on the spawning grounds of lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*) and cisco (*C. artedii*) in Lake Simcoe, 1989-1997. Lake Simcoe Fisheries Assessment Unit Report 1999-1. Ontario Ministry of Natural Resources. Sutton West, Ontario. 36 p.

The number of lake whitefish caught during the fall trapnetting program in Lake Simcoe increased in the early 1990s, yet this was not due entirely to stocking. The number of wild fish caught increased seven-fold from 1989 to 1991.

Lake whitefish catch on the spawning shoals has been affected by stocking. In 1984, only 0.1% of those on the shoal were of hatchery origin, while in 1997, 73.1% were stocked fish. The small stockings of the 1981 to 1985 year classes did not have a great impact on the spawning population. The 1986 year-class was the first large stocking event and the contribution of these fish was apparent on the spawning shoals in 1991, when the catch increased 5.5 fold. The following year the total catch of stocked fish decreased unexpectedly. There appears to be a factor other than the absolute abundance of fish stocked in Lake Simcoe which is affecting the number of fish on the shoals each year.

AMTSTAETTER, F. 1999$_b$. 1999 Lake Simcoe winter creel survey. Lake Simcoe Fisheries Assessment Unit Update No. 1999-3. Ontario Ministry of Natural Resources. Sutton West, Ontario. 2 p.

This update presents the results of the 1999 winter creel survey and summarizes trends of the five most commonly caught species since 1961. During the winter of 1999, 88% of the fish caught were yellow perch and 9% were lake whitefish. Fifty-nine percent of the observed lake whitefish harvested were of hatchery origin. The lake whitefish catch has increased since 1977 and the stocking of this species since 1982 has caused larger catches. Possible competition between smelt and young-of-the-year whitefish may be occurring. A decrease in rainbow smelt abundance may be responsible for an increase in the survival of young whitefish.

It was estimated that there were 23,700 wild lake whitefish captured in the 1999 winter fishery; this is greater than the catch from 1974 to 1993. The catchability of wild whitefish may have been affected by changes in water quality and clarity, increased prey availability and changes in methods of angling and environmental factors. The number of wild whitefish caught on spawning shoals in the fall has decreased since 1991.

AMTSTAETTER, F. 1999$_c$. Lake trout and lake whitefish spring diet study, 1999. Lake Simcoe Fisheries Assessment Unit Update No. 1999-2. Ontario Ministry of Natural Resource. Sutton West, Ontario. 2 p.

It is hypothesized that the introduction of exotics such as the spiny water flea and the zebra mussel to Lake Simcoe, as well as the decrease in numbers of ciscoe and rainbow smelt, may affect the forage base of lake whitefish and lake trout. Stomach samples were collected from both species and analyzed. None of the eight whitefish stomachs sampled were empty and four of the twenty-one lake trout stomachs were. All eight lake whitefish were of hatchery origin. Lake whitefish were found to have a more diverse diet than lake trout. The following were taken from the stomachs of lake whitefish: zebra mussels, midge larvae, snails, rainbow smelt, isopods, hemiptera nymphs and *Gammarus*. Zebra mussels were most important by weight, while *Gammarus* individuals were the least. Midge larvae were most important numerically and rainbow smelt the least.

AMTSTAETTER, F. 2000$_a$. Lake whitefish stocking and assessment information for Lake Simcoe. Unpublished Data. Lake Simcoe Fisheries Assessment Unit, Ontario Ministry of Natural Resources. Sutton West, Ontario.

In an effort to restore resident lake whitefish stocks, Lake Simcoe has been stocked with yearling or fall fingerling lake whitefish on an annual basis since 1982. Stocking rates have ranged from 13,222 fish (1982) to 188,068 fish in 1999. Since 1986, annual stocking rates have generally exceeded 120,000 fish. All whitefish stocked have been marked for subsequent assessment. Evaluation of stocked fish has been through creel surveys of the winter fishery as well as fall trap netting projects. Since 1990, stocked whitefish have made important contributions to trap net catches (25.3-79.8% of the catch) and to the winter fishery (17.9-62.2% of the observed catch).

AMTSTAETTER, F. 2000$_b$. Lake trout and lake whitefish summer diet study, 1999. Lake Simcoe Fisheries Assessment Unit Update No. 2000-1. Ontario Ministry of Natural Resources. Sutton West, Ontario. 2 p.

The stomach contents of 32 lake trout and 62 lake whitefish (the majority of which were of hatchery origin) from Lake Simcoe were analyzed. It was found that there exists a difference in the stomach contents of both species between the late 1970s, the early 1980s and spring 1999.

Zebra mussels were found to be the most important food item by weight, while fingernail clams were the second in the diet of lake whitefish. However, it is important to note that weights included the shells of these organisms (not considered to be of nutritious value), perhaps accounting for their status by weight in the diet. Other items found in the stomachs of lake whitefish included: miscellaneous fish, rainbow smelt, spiny water fleas, insect larvae, snails and beetles. These food items differed in their number and composition from those discovered in whitefish stomachs during the spring of 1999. This is likely because during the summer the whitefish are driven into deeper, cooler waters where there exists a dissimilar variety of forage. In contrast to the 1983 diet study, zebra mussels and spiny water fleas are now present in the lake whitefish diet. The whitefish are also eating fewer insects and no worms were present.

ANONYMOUS. Undated$_a$. Charleston Lake historical events. File Report. Ontario Ministry of Natural Resources. Kemptville, Ontario.

In 1891, whitefish were successfully stocked in Charleston Lake. The whitefish population was considered high for the following 25 years. Currently a few whitefish are still caught.

ANONYMOUS. Undated$_b$. Lake Simcoe stocked whitefish study. Fact Sheet. Lake Simcoe Fisheries Assessment Unit, Ontario Ministry of Natural Resources. Sutton West, Ontario. 3 p.

Each winter since 1985, the Lake Simcoe Fisheries Assessment Unit (LSFAU) has conducted an angler participation program. The purpose of this program is to collect biological information such as length, weight and age from lake whitefish that have been stocked into Lake Simcoe. Winter anglers who catch stocked whitefish and bring then to the LSFAU for sampling, receive a Ministry of Natural Resources crest acknowledging their participation. Stocked fish can be recognized because they are missing one or two fins. Fin-clipping is done while the fish are still in the hatchery.

ANONYMOUS. 1885. Annual Report of the Department of Fisheries, Dominion of Canada for the year 1884: Report on Fish Breeding in the Dominion of Canada. Ottawa, Ontario.

Some of the major waters stocked with lake whitefish fry in 1884 included Lake Ontario (four million), Lake Erie (six million) and the Detroit River (16 million). Numerous locations on each waterbody were stocked.

ANONYMOUS. 1886. Annual Report of the Department of Fisheries, Dominion of Canada for the year 1885: Report on Fish Breeding in the Dominion of Canada. Ottawa, Ontario.

The Bay of Quinte at Belleville was one of the numerous places on Lake Ontario stocked with lake whitefish fry during the year 1885.

ANONYMOUS. 1888. Annual Report of the Department of Fisheries, Dominion of Canada 1887: Report of Mr. Samuel Wilmot Superintendent of Fish Culture for the Dominion of Canada. Ottawa, Ontario.

Lake Huron and Lake St. Clair were among the larger waterbodies which were stocked with lake whitefish fry (two million and one million, respectively) in 1887.

ANONYMOUS. 1889. Annual Report of the Department of Fisheries, Dominion of Canada 1888: Report of Mr. Samuel Wilmot Superintendent of Fish Culture for the Dominion of Canada. Ottawa, Ontario.

Lakes Simcoe, Charleston and Couchiching were among the Ontario waterbodies stocked with lake whitefish in 1888.

ANONYMOUS. 1890. Annual Report of the Department of Fisheries, Dominion of Canada for the year 1889: Report on Fish Breeding Operations in the Dominion of Canada. Ottawa, Ontario.

Georgian Bay at Meaford and Thornberry was stocked in 1889 with 400,000 whitefish fry, as were numerous other Ontario waterbodies.

ANONYMOUS. 1892. Annual Report of the Department of Fisheries, Dominion of Canada for the year 1891: Report of Mr. Samuel Wilmot Superintendent of Fish Culture for the Dominion of Canada. Ottawa, Ontario.

Among the waters planted with whitefish were Mississippi Lake and Consecon Lake, with 420,000 and one million fry, respectively.

ANONYMOUS. 1894. The 26th Annual Report of the Department of Marine and Fisheries, 1893: Fisheries. Ottawa, Ontario.

Among the provincial waters of Ontario planted with lake whitefish fry were Long Lake and Green Lake, with 800,000 and 480,000, respectively.

ANONYMOUS. 1895. The 27th Annual Report of the Department of Marine and Fisheries, 1894: Fisheries. Appendix No. 14 : Fish breeding. Ottawa, Ontario.

During the year 1894, 250,000 lake whitefish fry were planted into Lake Rosseau, and 400,000 into Sharbot Lake. These were only two of the many provincial waters stocked.

ANONYMOUS. 1896$_a$. Whitefish. Report of the United States Commission of Fish and Fisheries Part XXI : 50.

There was a total output of 28,500,000 fry from Alpena Station in 1885. Ten trips were made and a total of 7,020 miles traveled. On March 11, 1895, 2,000,000 whitefish eggs were shipped on car No. 3 to Salt Lake City, Utah. The eggs hatched en route and the fry were stocked into Utah waters. The average water temperature during transportation was 43º F.

ANONYMOUS. 1896$_b$. The 28th Annual Report of the Department of Marine and Fisheries, 1895: Fisheries. Ottawa, Ontario.

During the year 1895, a total of 900,000 lake whitefish fry were stocked into the Upper and Lower Rideau lakes, as well as Lake Gillies, in Lanark and Leeds counties.

ANONYMOUS. 1898. Investigations of the northwestern states, 1896. Report of the United States Commission of Fish and Fisheries Part XXII : 114-116.

Examinations of the fisheries in Lake Washington, at Seattle, and Lake Pend d'Oreille, Oregon, were conducted to determine the presence or absence of the common whitefish (*Coregonus clupeaformis*). Common whitefish fry were planted into Lake Washington several years ago and between May 28 and June 17, 1896, the waterbody was sampled using gill nets with a 3.5 inch mesh. No whitefish were caught.

Whitefish fry were stocked into Lake Pend d'Oreille by the Commission in 1889 and the lake was sampled to determine the survival of those fish. No whitefish were found.

ANONYMOUS. 1900. Biological inquiries. Report of the United States Commissioner of Fish and Fisheries XXV : XXI-XXIII.

Biological surveys were conducted on selected interior waters of the Northwest; during 1898 the lakes concerned were Chelan, Kootenay and Coeur D'Alene. In Lake Coeur D'Alene, Idaho, it was determined that none of the whitefish from previous plants had survived, however, further investigations are planned.

ANONYMOUS. 1931. Ontario Department of Game and Fisheries Annual Report, 1930. Toronto, Ontario.

There was a decline in the total number of whitefish distributed in comparison with previous years due to weather conditions on Lake Erie which prevented spawning. In 1930, whitefish were being propagated at the following Ontario fish hatcheries (for the stocking of provincial waters): Fort Frances Hatchery, Port

Arthur Hatcheries (provincial and federal), Sault Ste. Marie Fish Hatchery, Belleville Hatchery, Glenora Hatchery, Normandale Hatchery, Kingsville Hatchery, Sarnia Hatchery and the Collingwood Hatchery.

ANONYMOUS. 1963$_a$. A history of Lake Simcoe forest district. District History Series No. 7. Ontario Department of Lands and Forests. Toronto, Ontario.

The Collingwood fish hatchery was established primarily for the rearing of whitefish and restocking the waters of Georgian Bay with their eyed eggs and fry. It was thought that such an operation contributed to the maintenance of the whitefish fishery and in turn benefited commercial fishermen. The whitefish eggs used for artificial rearing were removed from the areas of Penetang, Parry Sound, Thornbury, Collingwood, Britt and Key Junction. Whitefish eggs and/or fry were regularly planted in Kempenfeldt Bay and Lake Simcoe, although the majority were returned to Georgian Bay waters. Between 1945-1955 24 million whitefish eyed eggs and 396,551,500 fry were distributed from the Collingwood hatchery. During the latter part of 1956, and a few years preceding that, there were problems collecting adequate pickerel and whitefish spawn and the Collingwood hatchery was closed in 1957.

ANONYMOUS. 1963$_b$. A history of Kenora forest district. District History Series No. 10. Ontario Department of Lands and Forests. Toronto, Ontario.

The Kenora Fish Hatchery was used primarily for the hatching of pickerel and whitefish eggs for distribution to provincial waters. It was built in 1914 and altered in 1928 to also accommodate lake and speckled trout.

ANONYMOUS. 1966. Status of fisheries research projects, 1966. Section Report (Fisheries) No. 64. Ontario Department of Lands and Forests. Toronto, Ontario. 150 p.

In 1966, the gillnet fishery for whitefish on Lake Ontario experienced a virtual collapse. It appeared that the failure of whitefish (*Coregonus clupeaformis*) stocks may have been related to unsuccessful reproduction. Laboratory experiments were conducted to determine the survival of fry based on varying ration levels and stocking densities. Results showed that growth was linearly related to feeding intensity and survival was related to food abundance. Half of the fry in unfed lots died during a three week period, but only 2% of those fed at 20% of their body weight per day died. The fry were fed brine shrimp (*Artemia*) and it was determined that in delaying the first feeding past the yolk absorption period higher mortality would occur. Fry would not eat dead *Artemia*. These findings can be used in the experimental culture of whitefish.

ANONYMOUS. 1997. 1997 Lake Simcoe winter creel survey. Lake Simcoe Fisheries Assessment Unit Update No. 1997-3. Ontario Ministry of Natural Resources. Sutton West, Ontario. 2 p.

Lake Simcoe supports a large winter sport fishery and in order to investigate the specifics of this fishery a winter creel survey was conducted between January 25 and March 15, 1997. It was found that while 100% of the lake trout harvested were of hatchery origin, only 62% of those whitefish captured were of hatchery origin.

BERG, S., E. JEPPESEN, M. SONDERGAARD and E. MORTENSEN. 1994. Environmental effects of introducing whitefish (*Coregonus lavaretus*) in Lake Ring. *In* E. Morensen, E. Jeppesen, M. Sondergaard and L. K. Nielsen [eds.]. Nutrient Dynamics and Biological Structure in Shallow Freshwater and Brackish Lakes. Hydrobiologia 275-276 : 71-79.

The impact of whitefish (*Coregonus lavaretus*) on the trophic structure of eutrophic lakes was studied in Lake Ring, a small eutrophic Danish lake (22.5 ha, mean depth 2.9 m) in which the natural fish fauna is dominated by pike (*Esox lucius*), perch (*Perca fluviatilis*), and eel (*Anguilla anguilla*); roach (*Rutilus rutilus*) and burbot (*Lota lota*) being the only other fish species present. A total of 10,993 age-0+ whitefish were stocked in the lake from October 1989 to July 1990 and the structure of the fish, zooplankton and benthic invertebrate communities were studied during the period 1989-91. Stomach content analysis revealed that the whitefish mainly ate *Daphnia* and copepods in 1990-91, the proportion of copepods decreasing with increasing size of the fish and *Daphnia* being the overall most important food source. The density of *Daphnia* in the lake decreased from 72 individuals L^{-1} in 1989 to 9 individuals L^{-1} in 1991; concomitantly the largest species *Daphnia magna* and *D. pulex* almost disappeared and the density of cyclopoid copepods increased from 72 to 101 individuals L^{-1}, presumably because of improved food conditions, while that of calanoid copepods remained virtually unchanged. As a result chlorophyll *a* increased from 19 to 47 mu g L^{-1} and Secchi depth decreased from 2.4 m to 1.7 m, despite there being no change in total phosphorous (P) and total nitrogen (N) (0.6 mg P L^{-1} and 1.3 mg N L^{-1}, respectively). Changes were also observed in the benthic invertebrates; *Chaoborus*, oligochaetes, and chironomids all decreased, whereas *Pisidium* increased. It is concluded that the stocking of whitefish in eutrophic lakes for commercial purposes may delay their recovery, or even lead to enhanced eutrophication.

BISSELL, J. H. 1891. The Detroit whitefish station. Transactions of the American Fisheries Society 19 : 16-20.

The inception of the whitefish station occurred in 1873 when the Legislature supported the Fishery Commission in its goal in establishing a whitefish culture station in the area. The hatching-house was finally constructed and fully equipped in 1883. Presently the system has grown to 900 jars, of which all eggs are taken from the Detroit River. In an average year 121,566,000 white-fish fry will be planted during April and May into Michigan waters.

BODALY, R. A., J. VUORINEN and V. MACINS. 1991. Sympatric presence of dwarf and normal forms of the lake whitefish (*Coregonus clupeaformis*) in Como Lake, Ontario. The Canadian Field Naturalist 105(1) : 87-90.

The presence of a dwarf form of the lake whitefish, living sympatrically with a normal sized lake whitefish form, is documented for Como Lake, northern Ontario. Gillnet catches on a shoal revealed two distinct size classes of spawning fish, with modal sizes of 170-179 mm and 280-289 mm fork length. Dwarfs grew more slowly and had shorter lifespans as compared to normals. Gill raker numbers for the two forms were slightly different ($p = 0.025$) with a mean of 24.4 for dwarfs and a mean of 25.0 for normals. Both forms had modal gill raker counts of 24. The dwarf whitefish of Como Lake are the only sympatric dwarf whitefish known in the central part of the range of the species outside Algonquin Park, Ontario.

BODALY, R. A., J. VUORINEN, R. D. WARD, M. LUCZYNSKI and J. D. REIST. 1991. Genetic comparisons of New and Old World coregonid fishes. Journal of Fish Biology 38(1) : 37-51.

Through electrophoretic studies, it was found that coregonids could be placed into six groups: (1) Inconnu (*Stenodus leucichthys*); (2) the arctic cisco (*Coregonus autumnalis*), the North American lake cisco (*C. artedii*) and the Irish pollan (*C. autumnalis pollan*); (3) the European whitefish (*C. lavaretus*) and the North American lake whitefish (*C. clupeaformis*); (4) the broad whitefish (*C. nasus*), (5) the peled (*C. peled*), and (6) the least cisco (*C. sardinella*) and vendace (*C. albula*).

It was found that the whitefish from northwestern North America were more closely related to the European whitefish, that to those from central North America. It is hypothesized that these two species are actually polar opposites on a broad spectrum of a single species. The broad whitefish it more closely related to the North American and European lake whitefishes.

BRENNER, T. 1983. Successful stocking operations with whitefish (*Coregonus lavaretus*) in the Wahnbach Reservoir and first data on whitefish fry in the Rur Reservoir. Fischwirt 33(6) : 45-46.

Since 1957, in the Wahnbach Reservoir, and 1976 in the Rur Reservoir, stocking operations with whitefish smolt (*C. lavaretus*) from the Laacher Lake have been carried out. In the Wahnbach Reservoir, in 1972, whitefish were caught for the first time. In the Rur Reservoir in 1980 whitefish fry were caught. In 1982, some adult male specimens (31-36 cm, 250-370 g) were caught.

BUTLER, G. E. 1930. Fish culture in the prairie provinces, and some of its results. Transactions of the American Fisheries Society 60 : 119-120.

The first fish culture station to be erected in the prairie provinces was that of Selkirk Hatchery, on the Red River tributary to Lake Winnipeg, in 1893. During its first season (1894) the output was 14,500,000 whitefish fry. Also in Manitoba, there were hatcheries located on Lake Winnipeg and Lake Winnipegosis, both which reared whitefish fry. There have been reports on both of these lakes of increased whitefish production due to hatchery contributions. Unfortunately, these are difficult to substantiate because marking fish at such an early stage (right after hatching) is not normally performed. In 1928, marking by removal of one pectoral fin was performed on 1,000 whitefish fry, however it is too early for these fish to be captured.

Whitefish fry have had some success in the Quill Lakes of Saskatchewan. These fry were found to grow at a rate 50% faster than the whitefish in Lake Winnipeg.

BUTLER, G. E. 1940. Artificial feeding of whitefish fry. Transactions of the American Fisheries Society 70 : 180-182.

Through experiments conducted at the Winnipegosis and Dauphin River hatcheries in Manitoba, it has been determined that the artificial feeding of whitefish fry (*Coregonus clupeaformis*) is of value in those localities where the eggs hatch early in the spring and fry must otherwise be planted while the lakes are covered with ice. At that time the existence of an adequate supply of food organisms is uncertain. Various artificial foods were tried in the experiments but the most satisfactory results were obtained with: (1) Natural plankton (principally *Daphnia pulex*), and ground beef heart, and (2) natural plankton alone. During the hatching period three successive batches of fry may be held in tanks and fed for a ten-day period before they are released. Fry gain in length, weight and viability during the period of artificial feeding and are better fitted for survival in the natural environment. Through the delay in planting, the supply of available natural food and the temperature of the water in the lake environment are enabled to become more favourable by the time the fry are ready to be transferred from the tanks to the lake.

CARL, G. C. and W. A. CLEMENS. 1948. The freshwater fishes of British Columbia. British Columbia Provincial Museum Department of Education Handbook No. 5. Victoria, British Columbia. 132 p.

The common whitefish (*Coregonus clupeaformis*) is native to the northern portion of British Columbia but was introduced into the southern areas from eastern Canada for the purpose of developing a commercial fishery in selected lakes. Unfortunately, the fish have not grown very large or become very abundant, possibly due to a lack of available food. The whitefish is known to be a bottom feeder and relies on snails, small clams, insect larvae and worms for their diet.

CASSELMAN, J. M., J. J. COLLINS, E. J. CROSSMAN, P. E., IHSSEN and G. R. SPANGLER. 1981. Lake whitefish (*Coregonus clupeaformis*) stocks of the Ontario waters of Lake Huron. Canadian Journal of Fisheries and Aquatic Sciences 38 : 1772-1789.

Historical and contemporary data on lake whitefish (*Coregonus clupeaformis*) from the Ontario waters of Lake Huron were examined for evidence of stocks with the objective of defining population boundaries. We delineated the spatial distribution of five stocks from tag-recapture data and the general location of six additional stocks on the basis of population parameters such as growth rate, age structure, and abundance trends.

Samples of fish collected (summer and fall) from 5 of 11 potential stocks were evaluated on the basis of 11 morphometric and 7 meristic characters. We also examined osseometric features such as shape of scales and otoliths, and electrophoretic characteristics at 32 loci associated with 12 enzyme systems.

The summer and fall samples for each group were generally not significantly different. For the phenotypes examined electrophoretically, each stock was in Hardy-Weinber equilibrium; 12 of the 32 loci considered were polymorphic and 4 of the 10 possible genetic distances differed significantly from zero.

The Inner Basin stock was distinctly different from all other stocks. The Blind River stock was also found to be different by osseometrics, but not by morphometrics or electrophoresis. Osseometrics separated the stocks by basin of origin. Two stocks, Outer Basin and Burnt Island, appeared to be the most similar and could be separated from each other only on the basis of growth rate and tagging data. These two stocks are adjacent to each other in the main basin of Lake Huron, along the south shore of Manitoulin Island.

Whitefish stocks of Lake Huron represent groups of fish that differ phenotypically and genotypically in varying degrees, are spatially separated, and behave as cohesive units. We conclude that they should be regarded as functional units for management purposes.

CHAMPIGNEULLE, A. and D. GERDEAUX. 1992. Survey of experimental stockings (1983-85) of Lake Geneva with spring-prefed *Coregonus lavaretus* fry (3-4.5 cm). Biology and Management of Coregonid Fishes – 1990. Polskie Archivum Hydrobiologii 39(3-4) : 721-729.

From 1983 to 1985, most of the spring-prefed fry of *Coregonus lavaretus* raised in experimental illuminated net-cages were marked by burning the adipose fin before being stocked in Lake Geneva. The contribution of these prefed fry to the 1983-1985 cohorts was surveyed from adult spawning runs on the French shore of Lake Geneva in 1985-1988. In spite of their initial small size and number, each stocking's contribution was 1.6-3.5% of the three respective cohorts. The recapture rate of stocked fry by the drift net fishery was estimated at 4-5% corresponding to 20-25 kg per 1,000 spring-prefed fry released.

CHRISTIE, W. J. 1963. Effects of artificial propagation and the weather on recruitment in the Lake Ontario whitefish fishery. Journal of the Fisheries Research Board of Canada 20(3) : 597-646.

No significant relationship could be found between variations in the level of fry planting and ensuing variations in the level of catch in the long-term statistics of the Lake Ontario whitefish gill net fishery. An alternate-year planting experiment in which fry were planted in the even-numbered years 1944-1954, similarly failed to show a detectable level of contribution of the hatchery fish to the fishery. The supported year-classes averaged larger than those not given hatchery support but this was judged coincidental because of a phasing with an alternate-year periodicity which characterized the catch statistics over the whole series examined, and was present in the six years prior to the start of the alternate-year plantings. Estimates of spawning stock were calculated and it was not found that the progeny-per-parent ratios were significantly affected by the fry plantings.

A possible explanation for the periodicity was suggested by a significant correlation between air temperatures at the times of spawning and hatching, and the strengths of the produced year-classes. Cold Novembers followed by warm Aprils appeared to provide conditions associated with the production of larger year-classes, with the opposite combinations relating to the weaker broods.

The disappearance of lake trout and ciscoes from the commercial catch resulted in increased fishing pressure directed towards the capture of the whitefish. Increases in the efficiency and the intensity of the fishing were observed during the period of the study and these were likely responsible for the reduction of the average age of the fish in the catch by almost one year, and the resultant restriction of the annual catch to one year-class in recent years. Probably because most of the fish are currently caught before first spawning, a decline in spawning stock was almost continuous during the study period. The year-to-year fluctuations in the level of the catch increased both because of the reduced average age, and because of a greater variation in year-class strength. The year-classes produced in favourable years tended to increase, down to quite low levels of stock. This gave a configuration similar to Ricker's Type C reproduction curve, and which differed chiefly in that the limiting diagonal representing minimum reproduction fell below the replacement diagonal. It was suggested that the whitefish may require more than one spawning, to achieve stock replacement. The present instability of the catch, and the potentially serious effect of any substantial break in the rhythm of the climatic conditions suggest a condition of over-exploitation in this case.

CLARK, F. N. 1885. Results of planting whitefish in Lake Erie. Transactions of the American Fisheries Society 14 : 40-50.

Between 1875 and 1882, 81.9 million lake whitefish fry were planted during the springtime into Lake Erie by the United States, Ohio and Michigan Fish Commissions. The numbers ranged from 150,000 to 42,000,000 annually. Unfortunately, there is some doubt towards the accuracy of these numbers, and it is likely that actual numbers planted are lower. Following the closing of the 1884 fishing season it was noticed that the aggregate catch far exceeded that of any recent years. This is a documentation of the comments of dealers and fishermen concerning the catch and value of whitefish propagation and planting.

CUCIN, D. and H. A. REGIER. 1965. Dynamics and exploitation of lake whitefish in southern Georgian Bay. Journal of the Fisheries Research Board of Canada 23(2) : 221-274.

Instability of the population of *Coregonus clupeaformis* in southern Georgian Bay from 1948 to 1964 was evidently partly due to intensive fishing.

The population was discrete at least from 1956 to 1964 as determined by extensive tagging. From 1948 to 1964, estimated effective fishing effort varied 10-fold and annual yields almost 20-fold, with two cycles of abundance and scarcity. Strength of 1951-1959 year-classes, defined as population size at age-III, varied 40-fold. In spite of the marked instability, the population was in recent years more stable than any other whitefish population in Georgian Bay or Lake Huron.

Combining growth and natural mortality rates in a biomass curve indicated that individual year-classes would provide highest yields when fished intensively at age-IV, or slightly earlier than they were fished in the early 1960s. Yet the only hypothesis that might explain the continued existence of a fishable population was that relatively large parts of the habitat were either legally closed or unsuitable for fishing. Evidently the fishing was intense and increasing the effort would mean risk of a population collapse.

The contribution of hatchery fish to the whitefish fishery is questionable. Lake Erie whitefish were used primarily for propagation and planted into numerous inland lakes. These fish were distinguishable from native stocks and it was by sight that stocking success was judged. It is not known whether any Lake Erie whitefish were planted into Georgian Bay. The Collingwood hatchery, however, collected eggs from Lake Huron and Georgian Bay and a portion of the fry and eyed eggs reared were typically released onto the spawning areas from which they had been taken. Other areas may have been stocked such as shoal areas off diverse islands and points. Based on the data collected there is no evidence that the whitefish population of Georgian Bay was either positively or negatively affected by hatchery plantings.

DAVIS, B. M. and T. N. TODD. 1998. Competition between larval lake herring (*Coregonus artedi*) and lake whitefish (*Coregonus clupeaformis*) for zooplankton. Canadian Journal of Fisheries and Aquatic Sciences 55 : 1140-1148.

Diet and growth of larval lake herring and lake whitefish were compared in mesocosm experiments in a small mesotrophic lake in southeastern Michigan. Fish were sampled from single-species and mixed assemblages in 2 m^3 cages for 8 weeks during April and May. Both species initially ate mostly cyclopoid copepodites and small cladocerans (*Bosmina* spp.). Schoener's index of diet overlap showed considerable overlap (70-90%). Lake whitefish ate *Daphnia* spp. and adult copepods about 2 weeks earlier than did lake herring, perhaps related to their larger mean mouth gape. Lake whitefish were consistently larger than lake herring until the eighth week, especially in the sympatric treatments. Lake whitefish appeared to have a negative effect on the growth of lake herring, as lake herring in mixed-species treatments were smaller and weighed less than lake herring reared in single-species treatments. The diet similarities of lake whitefish and lake herring larvae could make them competitors for food in the Great Lakes. The greater initial size of lake whitefish could allow them to eat larger prey earlier and thereby limit availability of these prey to lake herring at a crucial period of development.

DAWSON, B. Undated. Simcoe's superb fishing sits on the brink. Ontario Out of Doors January/February : 62-64.

Although, lake whitefish have for a long time been the anchor of Lake Simcoe's winter fishery, problems with their population have arisen during the past few decades. Studies demonstrate that although the whitefish spawning shoals are producing adequate numbers of fry, survival during the first year of life is low. Lake whitefish stocking on the lake was initiated in 1982. During the winter of 1989-90, approximately 11% of those whitefish angled were of hatchery origin.

An annual hatchery output target of 200,000 whitefish yearlings has never been realized because of space limitations and financial restraints. Autumn-stocked fingerlings are surplus fish which cannot be overwintered at the hatchery. Unless there is a vast improvement in natural reproduction, the whitefish fishery will be depending more and more upon hatchery plantings.

DeGROOT, S. J. 1985. Introductions of non-indigenous fish species for release and culture in the Netherlands. Aquaculture 46 : 237-257.

A total of 27 non-indigenous fish species have been introduced into the waters of the Netherlands, mainly during the 19th and 20th centuries: 12 European, 11 North American, 3 Asian and 1 South African species.

In 1881, eggs of *Coregonus clupeaformis*, the American species of whitefish, were transferred to Germany and France; in 1886 to the United Kingdom; and in 1887 to Switzerland. In 1907, 50,000 of these fry were released in the rivers Meuse and Ijssel in the Netherlands and the following year 400,000 1-month-old fry were released in the same waters. No population increases were visible. The final mass stocking of whitefish (*Coregonus lavaretus*) took place in 1937, when 400,000 eggs were planted in the Ijsselmeer and 50,000 in six smaller lakes, with no results.

DeROCHE, S. 1976. Togue food airlift: "Dwarfed" whitefish may supplement smelts. Maine Fish and Wildlife 18(2) : 18-19.

In 1962, Owen Fenderson, a fisheries biologist, discovered that "dwarfed" forms of lake whitefish existed in 22 lakes in northwestern Maine. In contrast to the 20 inches or more in length that a normal lake whitefish will reach in its lifetime, dwarf rarely reach 10 inches.

With the idea of using dwarf populations to provide food for lake trout 1,200 adult dwarfs were transplanted from Second Musquacook Lake to Great East Lake between October 27 and 31, 1975. There were little, if any, in-flight mortalities reported. It is hoped that enough fish survive the transplant to spawn. Indications by other transplants made that dwarfed populations do not always remain so and that when placed into a new environment the fish may not remain dwarfed, as the parents were. It is anticipated that if transplants of smelt and lake whitefish are successful, then the lake trout population of Great East Lake will benefit significantly.

DesJARDINE, R. L. and J. N. LAWRENCE. 1977. An evaluation of the status of lake whitefish (*Coregonus clupeaformis*) in Lake Simcoe, 1964-1977. Lake Simcoe Fisheries Assessment Unit, Ontario Ministry of Natural Resources. Sutton West, Ontario.

To continue reign as a major angling species on Lake Simcoe recruitment levels of lake whitefish must be restored. Although there is a 90% hatching success for Lake Simcoe lake whitefish in a hatchery environment it is suspected that adolescent and larval mortalities may be high. Stocking is one rehabilitative option, however, studies have shown that fry or egg stocking contribute nothing to established populations. Other studies have shown that rehabilitation with hatchery whitefish is possible. Past failures were attributed to such factors as climate conditions and little available plankton.

It is thought that at this time it would be appropriate to consider an artificial breeding program to maintain and, hopefully, rebuild the whitefish population in Lake Simcoe. Numbers of fish to be stocked per acre, stocking times, locations and schedules, hatchery design and location require further evaluation.

DOWNING, S. W. 1904. The whitefish: Some thoughts on its propagation and protection. Transactions of the American Fisheries Society 33 : 104-110.

When whitefish fry are ready for distribution they should be spread over as large an area as possible. If they are all placed in one area there may be a food shortage. The fry from Put-in-Bay station are currently distributed over an area of 80 square miles.

DROUIN, M. A., R. B. KIDD and J. D. HYNES. 1986. Intensive culture of lake whitefish (*Coregonus clupeaformis*) using *Artemia* and artificial feed. Aquaculture 59(2) : 107-118.

Whitefish larvae (*Coregonus clupeaformis*) were reared using combinations of live *Artemia nauplii* and trout starter. In all cases survival was > 93% at 9 weeks of age. Growth did not differ significantly ($P > 0.1$) between high and low feeding rates of live *nauplii*; however, an opercular cover malformation was detected at the lower rate. A conversion program was developed for the practical use of *Artemia nauplii*. Whitefish were successfully converted to trout starter at 7 weeks of age and 140 mg. Trout starter alone was inadequate for early rearing. Decapsulated, lyophylized cysts of *Artemia* were almost a replacement for live *Artemia nauplii* except for a low incidence of opercular cover malformation. Advanced rearing to yearling size was easily performed with trout feed. Additional mortalities were < 3% to 14 months of age at stocking.

DYMOND, J. R. 1956. Artificial propagation in the management of Great Lakes fisheries. Transactions of the American Fisheries Society 86 : 384-392.

No positive evidence has been found to suggest that artificial propagation has ever been successful in significantly increasing the yield of a native species in the Great Lakes.

The possible contribution of artificial propagation to the populations of Great Lakes fish has been investigated in three ways: by looking for correlations between the numbers of fry planted and the size of commercial catch in the years when the resulting individuals would have entered the fishery in the greatest numbers; through experiments in which fry are planted only in alternate years; and the relative strengths of year classes in appropriate number of years later determined; through experiments in which marked lake trout fingerlings are planted and the number subsequently caught recorded. Unfortunately, in the case of most commercial species planted in the Great Lakes – whitefish, lake herring, and walleye, the fry are planted at such a small size that marking is impossible.

Studies done on Lake Erie and on Lake Ontario have failed to demonstrate any correlation between the number of whitefish planted and the number recaptured in the commercial fishery. Alternating year experiments in Alberta have failed to show increases in commercial catch of whitefish. The results of the alternate year experiment on Lake Ontario are not yet fully available.

ECKMANN, R., U. GAEDKE and H. J. WETZLAR. 1988. Effects of climatic and density-dependent factors on year-class strength of *Coregonus lavaretus* in Lake Constance. Canadian Journal of Fisheries and Aquatic Sciences 45(6) : 1088-1093.

The influences of density-dependent and density-independent factors on year-class strength (YCS) of *Coregonus lavaretus* in Lake Constance were studied by multiple linear regression analyses for the period from 1962 to 1982. Meteorological conditions that lead to early thermal stratification of the lake in April are of prime importance for YCS and account for 41% of the total YCS variance. Zooplankton concentration during spring has no significant influence on YCS. The extensive stocking program on the lake (50-200 million larvae stocked per year) significantly supports YCS, but this relationship becomes apparent only after the influence of meteorological conditions are removed from the data. Conspecifics of age-classes 1 and 2 have a negative influence on the age-0 year-class, but the nature of this intraspecific competition remains unknown.

EDDY, S. and T. SURBER. 1960. Northern fishes, with special reference to the Upper Mississippi Valley. Charles T. Brandford Company. Newton Centre, Massachusetts. 276 p.

Great Lakes whitefish (*Coregonus clupeaformis clupeaformis*) are abundant in Red Lake, Minnesota and are a source of supply of whitefish eggs for hatchery operations conducted by the State. Thousands of fry from Red Lake have been planted into Lake Superior to re-establish its fisheries. Success has thus far been mediocre.

ELSEY, C. A. Undated. The effect of distributing eyed whitefish (*Coregonus clupeaformis*) and yellow pickerel (*Stizostedion vitreum*) eggs on the commercial fisheries of Rainy Lake, Ontario. Ontario Department of Lands and Forests. Fort Frances, Ontario. 4 p.

The stocking of yellow pickerel and lake whitefish eggs has been carried on since 1921 in Rainy Lake as a management practice. There has been no proof demonstrated, which show that the stocking of lake whitefish benefits the commercial fishery on the Great Lakes. It was decided that stocking on Rainy Lake would continue until it could be proven whether or not stocking was having an impact on the commercial fisheries for both species.

As in the past, eggs are collected on Rainy Lake. They are reared in the Kenora Hatchery and are stocked in alternate years in Lake of the Woods and Rainy Lake (i.e., a lake would receive pickerel one year and whitefish the next, the two lakes never receiving the same species in the same year).

An evaluation was conducted to determine the contribution of the stocked fish to the Rainy Lake commercial fishery. The only significant correlation which existed was a negative one between the stocking of whitefish eggs in the entire lake and the catch six years later. This was opposite to the beneficial effect expected.

ENZ, C. A., E. SCHAFFER and R. MULLER. 2000. Growth and survival of Lake Hallwil whitefish (*Coregonus* spp.) larvae reared on dry and live food. Archiv fur Hydrobiologie 148(4) : 499-516.

Two commercial dry diets and live zooplankton were tested as initial food for larvae of Lake Hallwil whitefish (*Coregonus* spp.) in comparison with a reference food type (*Artemia nauplii*). The ability of the larvae to switch from dry diet to live zooplankton was also investigated. After three weeks of feeding, the diets in all experimental tanks were changed to live zooplankton caught in Lake Hallwil and larvae were fed for another three weeks. Mean total length and dry weight of the *Artemia* prefed larvae at the end of the experiment were 18 mm and 3 mg at 5º C, and 30 mm and 23 mg at 13º C. Dry-diet prefed larvae were 15 mm and 1.5 mg at 5º C, and 25 mm and 12.5 mg at 13º C. Zooplankton-prefed larvae reached 17 mm and 2.5 mg at 5º C, and 27 mm and 19 mg at 13º C. Overall mortality varied between 5 and 45%. Larvae fed live zooplankton suffered less mortality than those fed dry diets. Feeding conditions during the first three weeks after hatching affected larval growth: after the switch to the zooplankton diet at the end of the third week, slower growth of *Artemia* and dry-diet prefed larvae was recorded. We conclude that the dry diets tested give satisfactory rearing results, but zooplankton is still the best diet for mass rearing of whitefish.

EVANS, D. O. 1978. An overview of the ecology of the Lake Whitefish (*Coregonus clupeaformis*) in Lake Simcoe, Ontario, with special reference to water quality and introduction of the rainbow smelt. Ontario Ministry of Natural Resources. Richmond Hill, Ontario. 132 p.

Lake Simcoe whitefish are identified as an endangered population and their management and possible means of rehabilitation are discussed. Preservation of the unique Lake Simcoe whitefish stock is identified as an immediate management objective. Artificial culture and stocking of advanced fry or yearling lake whitefish is suggested as a possible short term rehabilitation technique. Improved water quality control in the Lake Simcoe watershed is also required if self sustaining populations of lake trout and lake whitefish are to survive in the lake.

EVANS, D. O. 1984. Stocking rates for lake whitefish in Lake Simcoe: Estimation of population parameters and calculation of survivorship curves. Unpublished Manuscript. Fisheries Research, Ontario Ministry of Natural Resources. Maple, Ontario. 11 p.

The purpose of this paper is to establish fish production requirements for stocking of yearling lake whitefish in Lake Simcoe. Two models have been developed based in part on actual field data for the Lake Simcoe whitefish stock. Model 1 sets a lower mortality schedule and, hence, generates an upper estimate of the stock size while Model 2 sets an upper mortality schedule and a lower estimate of stock size. The models and calculations assume density independent mortality relations over the prevailing population densities. Based on these calculations and in the absence of natural recruitment, I would recommend a minimum stocking rate of 1.0×10^5 yearlings per year with a preferred target of 2.0×10^5 yearlings per year.

EVANS, D. O., R. L. DesJARDINE, B. A. POTTER and P. WARING. 1985. Stocking rates for yearling lake whitefish on Lake Simcoe. File Report. Ontario Ministry of Natural Resources. Maple, Ontario.

EVANS, D. O., J. J. HOUSTON and G. N. MEREDITH. 1988. Status of the Lake Simcoe whitefish (*Coregonus clupeaformis*) in Canada. The Canadian Field Naturalist 102(1) : 103-113.

The Lake Simcoe whitefish (*Coregonus clupeaformis*) stock is particularly isolated and separated from adjacent Great Lakes whitefish stocks by geographic and man-made barriers, and has been reported to be genetically distinct from adjacent allopatric stocks. The population was estimated to number 250,000 in 1979, a decline of 85% since 1963 to 1965. Recruitment has been very low since 1970 even though spawning occurs and larvae are present in the surface waters during early spring (May). The spawning substrate utilized by the Lake Simcoe whitefish consists of cobble-boulder limestone over a sand, clay, or bedrock base extending from the shoreline to a depth of several meters. Deterioration of habitat quality has occurred, but the effect on reproductive success is unknown. Ecological stresses, including eutrophication, and the introduction of rainbow smelt (Osmerus mordax), appear to be the primary factors limiting the success of the population. Whitefish is the major species of interest to winter anglers in Lake Simcoe and the fishery generates considerable revenue to local business. The continued existence of the Lake Simcoe whitefish is threatened by environmental stresses and, because of low population numbers, is in danger of extinction. The Ontario Ministry of Natural Resources initiated a stocking program in 1982, with the aim of maintaining the native stock until such time that natural reproduction can be restored.

FALKOWKSI, S. 1998. Effectiveness of whitefish (*Coregonus lavaretus*) management in lakes with the highest yields of fish in Poland. Archiwum Rybactwa Polskiego 6(2) : 361-379.

Commercial catch statistics were used to analyze the landings, stocking rates and their effectiveness in a group of 12 Polish lakes with the highest commercial yields of whitefish (*Coregonus lavaretus*) in the period 1967-1994. Attention was paid to the type of stocking material as well as stocking rates, the latter varying from 3 to 12,480 fish/ha in the case of larvae, from 4 to 3,445 fish/ha in the case of summer fry, and from 4 to 1,924 fish/ha in the case of autumn fry. Mean effectiveness of stocking, expressed in terms of autumn fry, ranged from 2.35 to 55.66 fish/ha of the catch. Most of the lakes were stocked with a variety of stocking material and no data were available on the intensity of whitefish exploitation. This hampered the analysis and reliable estimates of the effectiveness of whitefish production in lakes. It was found that a rapid decrease of whitefish landings in the recent years was related not only to lower stocking rates, but also to low intensity of exploitation.

FALKOWSKI, S. and A. WOLOS. 1998. Analysis of whitefish (*Coregonus lavaretus*) landings and stockings in 106 lakes in 1967-1994. Archiwum Rybactwa Polskiego 6(2) : 345-360.

Based on the fishery records, analyses were performed on the relationships between whitefish (*Coregonus lavaretus*) landings, stocking rates and effectiveness of stocking in 106 Polish lakes. The lakes were divided into 6 classes based on their individual area. Mean values were calculated for each lake of the level of whitefish landings and stocking rates (quantity and kind of stocking material) from 1 ha of lake area. Effectiveness of stocking was expressed as the level of stocking needed to produce 1 kg of commercial whitefish catch. Using standard prices, the three basic forms of the stocking material used were recalculated into standard autumn fry; reliability of this approach has been discussed. The results suggest that there were several reasons for the observed breakdown of whitefish production in Polish lakes. These embrace quantity and type of the stocking material used and broadly understood effectiveness of the fishery management.

FLÜCHTER, J. 1982. Rearing of whitefish fry in ponds. Fischwirt 32(8) : 57-60.

In numerous lakes the amount of zooplankton would be sufficient for large stocks of Coregonidae. Because natural reproduction in the lakes is unsatisfactory, conditions for artificial stocking of whitefish have been studied: food preferences, stocking density and demands to water quality. Stocking operations in several successive years resulted in a fishable stock in Pilsen Lake (Germany, Federal Republic of Bavaria). The survival rate of fingerlings (about 5 cm) was about 1,500 fold higher than of larvae. The effect of whitefish stocks on the trophic status of eutrophic lakes is discussed.

FOOD AND AGRICULTURE ORGANIZATION (FAO). 1994. Guidelines for the stocking of coregonids. European Inland Fisheries Advisory Commission/Commission Européenne Consultative pour les Pêches dans les Eaux Intérieures. Occasional Paper No. 31. Rome, Italy. 21 p.

These guidelines deal with 3 species: vendace (*Coregonus albula*), whitefish (*C. lavaretus*) and peled (*C. peled*). The transfer of whitefish and vendace has been practiced for centuries and has considerably extended the distribution area of coregonids in Europe. The present guidelines are based on practical experience and research work. Large-scale vendace stocking is practiced in Poland and Finland, and whitefish and peled are stocked in many European countries. A scheme is provided for planning coregonid stocking and management policies. Four major sections deal with ecological considerations, fisheries considerations, social costs and effects, and evaluation of the available information and methods. These guidelines are addressed mainly to fisheries managers and administrators in order to assist them in the development of efficient and economic stocking policies and practices.

FOTT, J. 1987. Phytoplankton of carp ponds. Wetlands and Wetland Processes 27 : 251-256.

Fish ponds that are similar in morphometry, geology and nutrient status may differ considerably in phytoplankton biomass and species composition. The basic reasons are different fish stocks. Two examples are given on how the stocking of a pond with carp and whitefish may determine the level of phytoplankton biomass.

FRIMAN, L. T. and A. J. LESKELAE. 1998. Spray-marking one-summer-old coregonid fish with fluorescent pigment. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 471-477.

Experiments on mass marking one summer-old coregonids with a spray marking method using fluorescent pigments were started in 1993. The objectives were to develop a technique suitable for the mass marking of coregonids, to evaluate the possible effects of marking on the survival of fish and the retention of marks. The most important modifications that were done to the marking fish technique were “wet” spraying (pigment mixed with water), and adjusting the spraying pressure to be suitable for coregonids. Markings were done for different stocks of whitefish (*Coregonus lavaretus*) and vendace (*Coregonus albula*). The fish were reared in natural food ponds or in cages in a lake or the sea. In the first experiment, the acute mortality (24 hours after marking) was considerably high (27.2%-67.4%) because the applied compressed air pressure that is used to spray the pigment appeared to be too high for coregonids. Later markings were done using lower air pressure and, after that, the acute mortality (24 hours after marking) was between 0% and 3% in all markings, when the fish density after marking and the water temperature were not too high (10º C). No long-term mortality has been detected. The retention of marks has been 99%-100% three years after marking for two control lots of whitefish marked in 1993, and 89%-97% one year after marking for three control lots of vendace marked in 1993. In 1994 and 1995, fluorescent spray marking was used for mass markings of whitefish for stocking in the Finnish Gulf and Gulf of Bothnia.

GERDEAUX, D., P. GERALD, B. GROLLINGER and Th. NAMECHE. 1998. Survey of coregonid stocking in two reservoirs in Belgium. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 487-495.

Coregonids have been stocked into two reservoirs in Belgium for 10 years. They are produced in a hatchery in the Czech Republic. The fish are young adults (age 2+, 3+). Two species have been introduced; *Coregonus lavaretus* and *Coregonus peled* with some hybrids. Some information has been collected at the time of stocking and through the catch by sport fishermen. Some of the fish are caught in the year following the stocking, but a part of the catches are made one or two years after. The largest part of the catches consists of *C. lavaretus*. The species *C. peled* is rarely caught. Although the fish could grow in these dams, there is no evidence that reproduction takes place and is successful. Nevertheless, the sport fishermen are satisfied.

GERSTMAIER, R. 1985. Feeding biology of lake whitefish and charr in Bavarian lakes. Koenigssee Lake and Obersee Lake in national park Berchtesgarden. Fischer und Teichwirt 36(1) : 13-18.

Forty years after stocking, lake whitefish (*Coregonus* spp.) is a well established species in Koenigssee Lake (Bavaria, Federal Republic of Germany), but does not occur in Obersee Lake. In both lakes the charr (*Salvelinus salvelinus*) naturally represents the dominant pelagic species with similar habitat requirements. In Koenigssee Lake, lake whitefish feeds predominantly on zooplankton, but specimens bigger than 36 cm were found to graze on zoobenthos. Charr on the other hand also feed mainly on plankton during younger stages, but turns to nekton after reaching approximately 25 cm. Based on the presented data it presently cannot be decided if the charr population is negatively influenced by lake whitefish stocking, or if both species coexist more or less uninfluenced.

GRAY, J. E. 1980. Coldwater community rehabilitation: Lake whitefish. Lake Ontario Tactical Fisheries Plan Resource Document No. 7. Ontario Ministry of Natural Resources. Toronto, Ontario. 35 p.

An historic overview of the lake whitefish (*Coregonus clupeaformis*) in Lake Ontario is presented, with details of the dynamics of the fishery. Catch statistics are given indicating the decline in the fishery from its peak in the 1920s to the low harvest in 1978. Decline was, in part, due to the collapse of the lake trout (*Salvelinus namaycush*) and cisco (*Coregonus artedii*) fisheries creating intense fishing pressure on the lake whitefish. Sea lamprey (*Petromyzon marinus*) predation was also a major source of adult whitefish mortality. Eutrophication of the spawning and nursery areas occurred adding to the poor conditions for survival of this species. Recommendations for rehabilitation include that the lamprey control program be continued, stocking programs continue and quota regulations be set to build and maintain a large pool of large, older fish to absorb lamprey parasite pressure.

HANAZATO, T., T. IWAKUMA and H. HAYASHI. 1990. Impact of whitefish on an enclosure ecosystem in a shallow eutrophic lake: Selective feeding of fish and predation effects on the zooplankton communities. Hydrobiologia 200/201 : 129-140.

Bag-type enclosures (75 m^3) with bottom sheets and tube-type enclosures (105 m^3) open to the bottom sediment were stocked with exotic whitefish (*Coregonus lavaretus maraena*) to study their predation effects on the plankton community. The fish fed mainly on adult chironomids during the period of their emergence (earlier part of the experimental period). Thereafter, the food preference was shifted to larvae of chironomids and crustacean zooplankters. The predation effects on the plankton community were not evident in the bag-type enclosures where zooplankton densities were consistently low. The fish reduced the crustacean populations composed of *Bosmina fatalis*, *B. longirostris* and *Cyclops vicinus* in the tube-type enclosures where the prey density was high (above 50 individuals L^{-1}). The results suggested that the intensity of predation depended on the prey density. Rotifers increased in the fish enclosure, probably because *Coregonus* reduced the predation pressure by *Cyclops vicinus* on rotifers and allowed the latter to increase. In the fish enclosures, no marked changes in species composition were observed. Zooplankton predated by the fish seemed to be distributed near the walls of the enclosures. Problems of enclosure experiments for examining the effects of fish predation on pelagic zooplankton communities are discussed.

HARRIS, K. C. 1992. Techniques used for fully-intensive culture of lake whitefish (*Coregonus clupeaformis*) larvae and yearlings in Ontario, Canada. Proceedings of the Fourth International Symposium: Biology and Management of Coregonid Fishes – 1990. Polskie Archiwum Hydrobiologii 39(3-4) : 713-720.

The Ontario Ministry of Natural Resources has been developing large-scale coregonid culture techniques since the early 1980s as part of an ongoing lake whitefish (*Coregonus clupeaformis*) rehabilitation program in Lake Simcoe, Ontario. The program has now developed a completely intensive, dry-diet-based, early rearing regime. In recent production years, survival of lake whitefish through the critical first eight weeks of rearing has been >95%, with final individual fish weights of 800-1,000 mg. Advanced rearing to yearling size using a standard salmonid grower diet has likewise been very successful, with survival >95% and final fish weights of 50-60 g. Up to 180,000, 30-50 g lake whitefish have been produced annually over the last four years of the program. This paper presents the methodology (feed regimes, fish handling, disease prevention) and the materials (rearing tank designs, feed distribution, feeds, lighting, etc.) employed to achieve the current successful status of the program, which is presently the largest coregonid culture program in North America.

HART, J. L. 1930. Spawning and early life history of the whitefish (*Coregonus clupeaformis*) in the Bay of Quinte, Ontario. Contributions to Canadian Biology and Fisheries VI(7) : 50 p.

The spawning run of whitefish is described in respect to the details of the migration and sex ratio, age and size, and breeding characters of the fish. An investigation of the eggs in the spawning grounds by the use of a pump indicated that the proportion of eggs to be fertilized is high but that there is a high mortality during the development. Many whitefish eggs are eaten on the spawning grounds by the common perch (*Perca flavescens*). For the first time there is recorded the capture of a complete series of whitefish young-of-the-year. Based on this material are descriptions of the stages of the young from the twelve millimeter to eighty millimeter stages and the characters differentiating whitefish from cisco. The rate of growth of the fry is slow at first but is much accelerated in the latter part of May and until the end of July. The food from the first consists of Entomostraca, chiefly *Bosmina*, *Daphnia* and *Cyclops*. The first movement of the newly hatched fry is inshore close to the surface. Later they form schools and finally take to deeper water. Records of physical condition in the habitat of young whitefish are recorded. Consideration of the food and other habits and the concentration of predaceous species where young whitefish are abnormally abundant leads to the recommendation that hatchery fry should be widely distributed in shallow water.

HART, J. L. 1931. The food of the whitefish (*Coregonus clupeaformis*) in Ontario waters, with a note on the parasites. Contributions to Canadian Biology and Fisheries 21 (Series A, No. 6) : 445-454.

A study of the food of whitefish from various localities shows that the whitefish is a bottom feeder, showing little selectivity, accepting the most abundant animal food in the locality. The diet for the first five years in one locality included considerable amounts of plankton. Whitefish eat little on the spawning migration but feed to some extent at least, during the winter.

Ninety-five percent of whitefish examined were parasitized by large numbers of the tapeworms *Cyathocephalus americanus* or *Ichthyotaenia laruei*. A similar number were parasitized by a species of *Echinorhynchus*. Nematode parasites were found in fewer specimens and in smaller numbers. Crustacean parasites were comparatively rare.

HARTMANN, J. 1990. Did stocking augment whitefish (*Coregonus* spp.) yield of the lower lake of Lake Constance? Oesterreichs Fischerei 43(4) : 86-88.

Lower Lake (Untersee) of Lake Constance (Bodensee) should not be taken as an example of effective stocking with juvenile whitefish (*Coregonus*) in the Alpine region.

HEIKINHEIMO, O. 1992. Management of European whitefish (*Coregonus lavaretus*) stocks in Lake Paasivesi, eastern Finland. Proceedings of the Fourth International Symposium: Biology and Management of Coregonid Fishes – 1990. Polskie Archiwum Hydrobiologii 39(3-4) : 827-835.

Lake Paasivesi contains two indigenous forms of the European whitefish, *Coregonus lavaretus* (*C. wartmanni* and *C. pallasi sensu*). Growth rates of both species decreased from year class to year class in the early 1980s, probably due to increasing vendace (*C. albula*) stocks. Stocking with one-summer-old *C.*

pallasi fingerlings (6 ha^{-1}) since 1979 has yielded 20-30 kg per 1,000 released fingerlings. The yield could be increased by more intensive gill net fishing. Gillnet catches of *C. wartmanni* declined because of incomplete recruitment to the fishery, but catches of *C. pallasi* increased as a result of stocking. In some years, much of the *C. wartmanni* catch was taken as bycatch in seine and trawl fishing. In contrast, *C. pallasi* was rare in the seine and trawl catches. Trawling is advantageous to the *C. wartmanni* stock, because it thins out the slow-growing population.

HEIKINHEIMO, O. 2000. Management of coregonid fisheries: Multiform and multispecies problems. Academic Dissertation in Fisheries Science, University of Helsinki. Helsinki, Finland. 44 p.

The polymorphism of the whitefish (*Coregonus lavaretus*) complicates fisheries management. In the same lake there are often several sympatric whitefish forms, with different growth rates and living habits. In many cases, some of these whitefish stocks reproduce naturally, while some are maintained by stocking. The density of the whitefish stock may vary greatly, especially in the pelagic stocks of small-sized fish. The growth of whitefish is generally density-dependent. Fluctuation in the vendace (*Coregonus albula*) stocks affect whitefish and the fishery. During periods of abundant vendace, the growth of whitefish may be reduced, and vice versa. The gill-net fishing of whitefish is a problem in the enhancement of salmonid predators such as the brown trout (*Salmo trutta lacustris*). Many brown trout young that are still below the allowable catch size are taken as a by-catch in whitefish gill nets of small mesh sizes. This decreases the profitability of brown trout stocking and weakens the potential for recreational fishing on brow trout. On the other hand, large mesh sizes in gill-net fishing may lead to the underexploitation of whitefish, which in extreme cases causes dwarfing.

Through modeling, it was found that it is possible to regulate the gill-net fishery so that stocking with both the whitefish and the brown trout is profitable. However, the mesh size restrictions needed depend on the growth rate of the whitefish, the significance of recreational fishing on brown trout, and the existence of commercial fishing on whitefish. The uncertainty and variability in the different factors affecting a stocking results is large, and therefore the effect of fisheries management may be difficult to detect in the short term. Adaptive management for the whitefish is recommended. Whitefish are sensitive to disturbances in the environment or fish assemblage, and management should be able to adapt to the any new situation. Different decision rules are needed for the low and high density states of vendace. This presumes a flexible fisheries management system.

Dynamic modeling was used to examine the effects of predation on vendace in more detail. The results indicate that the role of perch (*Perca fluviatilis*) is more crucial than that of brown trout in maintaining recessions in vendace stocks. This study emphasizes the importance of dynamic modelling in studies on complex interactions between fish stocks, and on the effects of fishing and fisheries management.

HEIKINHEIMO, O., M. MIINALAINEN and H. PELTONEN. 2000. Diet, growth and competitive abilities of sympatric whitefish forms in a dense introduced population: Results of a stocking experiment. Journal of Fish Biology 57(3) : 808-827.

The food of five whitefish stocks (*Coregonus lavaretus*) planted in Lake Vuokalanjærvi consisted mainly of zooplankton and insects taken from the water surface. The amount of benthic food in the diet of the two sparsely gill-rakered (23 and 28 rakers) stocks increased from the age of 2 years onwards. The growth of whitefish was slow in all stocks. The densely gill-rakered stock (50-51 rakers) originating from the same lake system as Lake Vuokalanjærvi grew faster than the other stocks, and the food consumption of 4- and 5-year-old fish belonging to this stock was nearly double compared with the other stocks. The habitat choice of the whitefish differed between the stocks even in the densely-rakered stocks classified as the same form. A stock with flexible habitat use and feeding habits is most likely to succeed. Introducing whitefish stocks from distant areas is not advisable.

HEIKINHEIMO, O. and J. RAITANIEMI. 1998. Decision analysis as a tool in planning fisheries management, exemplified by the whitefish and brown trout fishery in Lake Lappajærvi, Finland. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 401-417. (2.13, 3.4)

In Finnish inland waters, brown trout (*Salmo trutta lacustris*) stocking often yields low catches if there is gill net fishing for whitefish (*Coregonus lavaretus*) in the same lake. A great deal of brown trout young are taken as a by-catch with gill nets of small mesh sizes when still below the allowable catch size (40 cm). On the other hand, mesh size restrictions for gill nets may lead to underexploitation of whitefish. In Lake Lappajærvi, whitefish are mostly caught by professional fishermen with gill nets and pound nets, while 45-70% of the brown trout catch is taken by recreational fishermen with gill nets and rods. In order to determine the optimal policy for obtaining the maximum benefit of whitefish and brown trout stocking, we compiled an influence diagram and applied decision analysis. The decision variables in the model were mesh size restriction for gill nets, fishing effort with gill nets and pound nets, and stocking size for brown trout. The data needed for calculating the total benefit consisted of growth data, fishing and natural mortalities, catchabilities by age-group, prices paid to fishermen for the catches, and market prices for the stocking material of both species. The recreational value of brown trout fishing was taken into account as a coefficient of the price of the brown trout catch. According to the decision analysis, the smallest allowable mesh size of gill nets should be 55 mm and the fishing effort should be lower than it is at present. Pound net fishing is advantageous if the whitefish grow slowly, but in the case of rapid whitefish growth, pound net fishing would decrease the economic benefit from stocking. If there was no fishing with pound nets, the minimum mesh size for gill nets should be lower in periods of slow whitefish growth to ensure the profitability of whitefish stocking.

HEIKINHEIMO-SCHMID, O. 1985. The food of whitefish (*Coregonus lavaretus*) in two neighbouring lakes, one regulated and the other natural. p. 186-194. *In* J. S. Alabaster [ed.]. Habitat Modification and Freshwater Fisheries.

The diet of whitefish was studied in two lakes drained by the Oulujoki River, northern Finland. Lake Änättijärvi is in its natural state, and the mean number of gill rakers of whitefish was 45. The water level of Lake Kiantajärvi is regulated for hydroelectric power and a stocking programme with fingerling *Coregonus pallasi* has been continuous since the 1970s. Two types of whitefish are found in this lake with an average of 30 and 42 gill rakers, respectively.

In Lake Änättijärvi, the most important food organisms were fish eggs in spring, bottom animals (especially Mollusca, Ephemeroptera nymphs and Trichoptera larvae) in summer and late autumn, and zooplankton in early autumn. In the regulated Lake Kiantajärvi, zooplankton made up the bulk of the stomach contents of both whitefish groups during the summer. Bottom animals, mostly chironomid larvae, were scarce in the diet in the summer, but increased towards the autumn. Mollusca and large insect larvae and nymphs were almost entirely lacking. Terrestrial or emerging insects were important food organisms in June and September. The diets of the two types of whitefish partly overlapped, but those with 24-34 gill rakers utilized more bottom food than those with 35-49 gill rakers, and also preferred different zooplankton species.

It was concluded that bottom animals important as fish food (Mollusca, large insect larvae and nymphs) had declined in the regulated Lake Kiantajärvi, which had led to more severe food competition between the two whitefish populations.

HEIKINHEIMO-SCHMID, O. and A. HUUSKO. 1988. Management of coregonids in the heavily modified Lake Kemijaervi, northern Finland. Finnish Fisheries Research 9 : 435-445.

About 40% of the spawning grounds of vendace (*Coregonus albula*) and 90% of those of the lake-spawning whitefish (*C. lavaretus*) have been destroyed by water level regulation. The original, river-spawning whitefish are still able to reproduce in the Kemijoki River which empties into the lake. Stocking with one-summer-old fingerlings of different whitefish forms has been carried out since the late 1960s. Exploitation of coregonid stocks is not very intensive. Off-flavours caused by pulp mill effluents, and the rather high mercury contents found in predator fishes, have reduced interest in fishing in general although these defects do not occur in the coregonid species. Intensified fishing, reduction of whitefish stockings, use of exclusively planktivorous dense ill raker whitefish for stocking, and clearing the shores for seine fishing of vendace, are recommended to increase the yield and catch of coregonid fishes.

HINDLEY, B. A. 1984. Lake trout and lake whitefish egg survival in Lake Simcoe. M. Sc. Thesis, York University. Toronto, Ontario. 78 p.

In Lake Simcoe, lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*) are suffering severe recruitment failure caused probably by changes in species interactions and deterioration of the physical environment acting on the early life stages of these fish.

The objectives of this study were to determine if the decline of the lake trout and the lake whitefish populations can be attributed to the failure of their eggs to hatch, to describe the pattern of egg mortality and to assess the effects of predation and siltation on eggs.

Wire mesh cages were partitioned: one-half was covered, the other allowed free access by predators. Baskets were placed on the shoals and filled with rocks. Divers placed eggs of both species in the baskets. They removed samples of baskets periodically throughout the incubation period to monitor egg survival. Percent hatch of lake whitefish eggs was 0-23% with most losses occurring in the first few weeks. Percent hatch of lake trout eggs averaged 12% in compartments with no predator control, but 46% in compartments which were covered.

Bioassays showed that 5 mm of silt caused 100% mortality of lake trout eggs but caused less than 10% mortality of lake whitefish eggs. Since silt depths of 5 mm occur on Lake Simcoe shoals, this is probably a major cause of mortality in lake trout eggs, but not in whitefish eggs. However, an additional 1-2 mm of silt would cause substantial mortality in whitefish eggs. Egg survival has probably not contributed to lake whitefish population declines since egg densities are similar to previous years, siltation is not causing mortalities and percent hatch is typical for the species.

HOEGLUND, E. and B. WAHLBERG. 1997. A method for mass-marking newly hatched whitefish (*Coregonus lavaretus*) larvae. Laxforskningsinstitutet Meddelande 1. 12 p.

Laboratory tests showed that immersion of newly hatched whitefish larvae in a buffered (pH 7) solution of 50 mg alizarin complexone (ALC) per liter during 7.5 hours in the temperature range 5 to 15° C produced a clear and easily identified check mark in the otoliths, apparently without affecting the survival or behaviour of the fish. Mark retention and possible long-term effects of the marking procedure on survival and growth were examined by stocking a pond with equal proportions of marked and unmarked whitefish larvae and rearing them there for four months. After that period a random sample of 300 individuals was withdrawn for analysis. As there were no significant differences between the two groups, neither regarding individual size nor number, we conclude that the growth and the survival rate of the fry were virtually unaffected by the marking procedure and that the mark retention was close to 100%. In a subsequent appendix a working routine for a future mass-marking operation on whitefish larvae is proposed, based on the results from this report.

HUNER, J. V. and O. V. LINDQUIST. 1983. Public and private sectors in Finland develop whitefish and trout culture. Aquaculture Magazine 9(2) : 22-24.

In Finland, in 1980, fry and fingerlings of 20 species of fish and crayfish were reared at the nine government hatcheries. Whitefish (*Coregonus* spp.) were the most important group, numerically, with over 173 million fry hatched and planted and 28 million one-summer fingerlings being stocked. Whitefish are stocked at the rates of 30,000 fry per hectare into fertilized ponds to grow to the fingerling stage. During this time they feed on zooplankton and some species switch to benthic food following mid-summer. The following year these fish are planted as fingerlings.

IKONEN, E. 1984. Migratory fish stocks and fishery management in regulated Finnish rivers flowing into the Baltic Sea. p. 437-451. *In* A Lillehammer and S. J. Saltveit [eds.]. Regulated Rivers.

The demand for hydro-electric power has caused almost total destruction of the migratory fish stocks in Finnish rivers flowing into the Baltic Sea. Before damming and water regulation these rivers supported stocks of salmon (*Salmo salar*), sea trout (*Salmo trutta*), migratory whitefish (*Coregonus lavaretus*) and river lamprey (*Lampetra fluviatilis*). The feeding migration of eels (*Anguilla anguilla*) is also prevented by dams on all the biggest watercourses. Fishways have been built in the older dams, but since all the biggest rivers have been changed into a series of artificial lakes, the spawning and nursery areas have disappeared. To compensate for the deleterious effects of damming and water regulation on migratory fish, the rivers have been stocked with salmon, sea trout and whitefish. During the first part of this century fish were released mainly as fry, but nowadays stocking is mostly performed with salmon and sea trout smolts and whitefish fingerlings. In spite of extensive stocking, the fish catches around the river mouths have been rather poor because of heavy fishing in the Baltic Sea.

JOKIKOKKO, E. and A. HUHMARNIEMI. 1998. Stocking practices of anadromous whitefish (*Coregonus lavaretus lavaretus*) in Bothnian Bay, Finland: Evidence from gill raker numbers. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 507-515.

Anadromous whitefish (*Coregonus lavaretus lavaretus*) are economically one of the most important fish species in the Baltic Sea in Finland. Most of the biggest rivers in the Finnish Bothnian Bay have been blocked by hydropower plants, and natural reproduction of anadromous whitefish can only occur in small areas. Therefore, millions of fry and one summer-old whitefish are stocked in the coastal area of the Finnish Bothnian Bay. The eggs are generally stripped from fish ascending the river at spawning time in October. Many whitefish have been stocked in inland waters and a part of them have descended to the sea and river mouths. These fish are densely-rakered forms, which can be distinguished from sparsely-rakered anadromous whitefish. The proportion of these densely-rakered whitefish was 12.3% in the River Kemijoki and 17.0% in the River Simojoki in samples caught in summer. Likewise in samples caught from the sea, especially in the northern Bothnian h 1: Bay, there were densely-rakered whitefish. Due to these different whitefish forms, a cross-breeding is possible when anadromous whitefish are stripped. Annual examination of gill raker distributions in different rivers showed that artificial breeding has not threatened the stock purity of anadromous whitefish because the number of other whitefish forms caught during spawning time has been only 0.07% The mean number of gill rakers varied from year to year in the rivers studied but no clear trend could be seen.

KENNEDY, W. A. 1954. Tagging returns, age studies and fluctuations in abundance of Lake Winnipeg whitefish, 1931-1951. Journal of the Fisheries Research Board of Canada 11(3) : 284-309.

On the basis of 2,003 lake whitefish (*Coregonus clupeaformis*) tagged in 1938, of which 126 were recovered during the next five years, there is evidence that fish released together tend to stay together for years, and that the proportion of a population captured during a certain time by a unit amount of fishing effort can fluctuate greatly (a plausible explanation is the effect of variations in weather conditions). On the basis of age determinations of 12,975 whitefish in samples taken annually from 1937 to 1951, growth rate was determined. The total annual mortality rate among fully exploited fish was calculated to be 64% over several years, and it appeared that all year-classes had been of about equal strength in recent years. The generally accepted idea that fluctuations in fishing success correspond to fluctuations in abundance of whitefish is probably erroneous. Possibly the Lake Winnipeg whitefish are underfished.

KERR, S. J. and R. E. GRANT. 2000. Lake whitefish. p. 285-300. *In* Ecological Impacts of Fish Introductions: Evaluating the Risk. Fish and Wildlife Branch, Ontario Ministry of Natural Resources. Peterborough, Ontario. 473 p.

Lake whitefish likely compete with lake herring and rainbow smelt due to their overlap in diet and habitat selection. The lake trout also shares similar habitat characteristics with the lake whitefish and the young stages of this species and yellow perch may also be in competition. Lake whitefish have been known to hybridize with the inconnu, lake herring and the round whitefish. All introductions of this species should be carefully weighed against the possible negative consequences associated with interactions of native/established species.

KLEIN, M. 1980. On the situation of whitefish fisheries in Starnberger. Fischer und Teichwirt 31(10) : 294-300.

Stocking with *Coregonus* increased the yield of whitefish by approximately 40% from 1977 to 1979. Fishing intensity is related to population structure and details are given on horizontal and vertical distribution. The yield for 1980 is expected to be as high as in 1979.

KLEIN, M. 1983. Estimation of the efficiency of hatcheries by sampling of whitefish larvae in Lake Starnberg. Fischer und Teichwirt 34(8) : 227-232.

In spring 1982, the relationship between naturally developed and artificially hatched fry of the whitefish (*Coregonus lavaretus*) was investigated in Lake Starnberg (57 km^2) by means of sampling whitefish larvae. Using a three-meter-long larvae net with a diameter of 140 cm, 270 whitefish fry were caught. A catch-per-unit-effort of 1.5 larvae was achieved prior to the stocking date and 7.5 after. That would mean that the population of whitefish larvae in 1982 was composed of 20% of natural production and 80% of hatchery production. Comparing the efficiency of the hatch under natural and artificial conditions it has been calculated that for the 1982 year class the results in the two hatcheries at Lake Starnberg were 30 times higher than at the bottom of the lake.

KLEIN, M. 1987. The relevance of stocking whitefish larvae in lakes for stabilization and improvement of the catches in Starnberg Lake. Fischer und Teichwirt 38(12) : 370-374.

Lake whitefish (*Coregonus* spp.) is a highly interesting commercial species with frequently varying catches in Starnberg Lake (Federal Republic of Germany, Bavaria). As a consequence of increased eutrophication, the eggs of naturally spawning whitefish, which are simply deposited on the bottom, may suffer from oxygen deficiency or predation. Whitefish are therefore annually stripped and hatched larvae are released to the lake. Even though a relatively great number of eggs are naturally produced, it was found that stocking of larvae showed a significant impact on the lake whitefish populations.

KLEIN, M. 1988. Significance of stocking for stabilizing and increasing the yields in the coregonid fishery in Lake Starnberg, Federal Republic of Germany. Finnish Fisheries Research 9 : 397-406.

Lake Starnberg is one of the most intensively exploited lakes in Bavaria, Federal Republic of Germany. Since 1979, whitefish (*Coregonus*) eggs have been incubated in two hatcheries with technically cooled water at a temperature of 1º C. This treatment extends the hatching period by 4-6 weeks compared with hatching in uncooled water. With a total annual capacity of 3,000 liters of eggs, the hatcheries can produce 70-100 million whitefish fry for release into the lake from 15 April onwards. The whitefish catches have escalated since 1980 and have stabilized at a relatively high level. Studies on the population dynamics have shown an increase in the average age of the exploited whitefish, a decrease in the individual growth rates and development of strong year classes. A survey on whitefish larvae has been carried out since 1982 with the purpose of making a quantitative assessment of the stocking measures. The aim is to find out the relation between the number of fry which hatch naturally in the lake and the number of fry produced in the hatcheries.

KLEIN, M. 1998. Sampling whitefish larvae by means of a light trap. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 449-455.

A method for sampling whitefish larvae (*Coregonus lavaretus*) by means of a light trap is presented. This method has been used since 1986 at Lake Starnberg (5,636 ha) for monitoring the development of coregonid larvae in springtime. The aim of the investigation was to find out the relation between the number of fry which hatch naturally in the lake and the number of fry stocked from the hatcheries. The light trap consisted of an underwater pump equipped with an underwater lamp (100 W) which was fixed directly at the opening of the pump for attracting the larvae. At night, water and larvae were pumped into a circular tank with a volume of about 600 L, in which the larvae were retained by a sieve of 0.8 mm mesh size at the outlet. The whole device was situated on a landing stage about 20 m offshore. Due to its construction, it was only possible to collect larvae in the littoral zone. The results are expressed as catch-per-unit-of-effort, (CPUE), in terms of the total number of larvae caught-per-night. The highest CPUE (up to 2,500 larvae) was observed during the periods of stocking. During the times before stocking, the maximum catches amounted to 460 larvae per night. Samples were taken between early February and early June from 1986 to 1996.

KRISTOFFERSON, A. H. and J. W. CLAYTON. 1990. Subpopulation status of lake whitefish (*Coregonus clupeaformis*) in Lake Winnipeg. Canadian Journal of Fisheries and Aquatic Sciences 47 : 1484-1494.

Spawning lake whitefish in Lake Winnipeg from Dauphin River-Lake St. Martin, Traverse Bay, Berens River-Poplar River-Big Black River and Grand Rapids and in Little Playgreen Lake are accorded subpopulation status based on morphometric measurements, meristic counts, and differences in frequencies of alleles at the muscle glycerol-3-phosphate dehydrogenase (*g-3-pdh-b*) locus. The frequency of the *g-3-pdh-b* allele in samples from Dauphin River-Lake St. Martin was 0.77 compared with 0.46 for whitefish from the remainder of Lake Winnipeg and Little Playgreen Lake. Two loci for isocitrate dehydrogenase and one lactate dehydrogenase locus are also polymorphic in these fish but no significant allele frequency differences were found at these loci among the samples of spawners compared above. Hatchery-reared lake whitefish, obtained from stock in Clearwater Lake and William Lake and planted as fry or eyed eggs in Lake Winnipeg at Dauphin River and Grand Rapids, do not appear to have made a detectable genetic contribution to the local whitefish stocks, based on differences in *g-3-pdh-b* and *idh* Bß allele frequencies among parent stock and spawners captured near the release sites.

LAPWORTH, E. D. 1956. The effect of fry planting on whitefish production in eastern Lake Ontario. Journal of the Fisheries Research Board of Canada 13(4) : 547-558.

Whitefish fry were planted in the Bay of Quinte and adjacent waters in numbers varying from 208 million in 1927 to none in 1945. Since 50% of the commercial whitefish catch from these waters consisted of five-year-old fish, whitefish production in each of the years from 1929 to 1951 was compared to the number of fry planted 5 years previously (1924-1946). No correlation could be found between the number of fry planted and the production of whitefish 5 years later. The largest number of fry planted (208 million in 1927) was followed by the lowest production of the entire period (95 thousand pounds in 1932). On the other hand, following no planting in 1945, production in 1950 was approximately normal (162 thousand pounds).

The age composition of the commercial catch in the years 1944-1951 was determined from scale samples. By applying the age composition to the total catches in these years the contributions of the year classes 1940-1945 have been estimated. The number of fry planted probably did not affect the contribution of these year-classes to the fishery.

LAWRENCE, J. N. 1990. Stocked whitefish angler return programs manual. Lake Simcoe Fisheries Assessment Unit Report 1990-8. Ontario Ministry of Natural Resources. Sutton West, Ontario.

The stocked lake whitefish angler return program began in 1985 and has continued each year since. The purpose of this program is to collect biological information such as length, weight and age of lake whitefish that have been stocked into Lake Simcoe. This manual describes procedures to be followed by technical staff as part of this program.

LEHTONEN, H. and E. NIEMELAE. 1998. Growth and population structure of whitefish (*Coregonus lavaretus*) in mountain lakes of northern Finland. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 81-95.

Whitefish (*Coregonus lavaretus*) samples were collected from 70 mountain lakes in Utsjoki, the northernmost municipality of Finland. The mean gill raker numbers varied in most lakes between 19 and 24, but in one lake existed a population having on average 34 gill rakers. In most lakes, there exist only one sparsely-rakered whitefish form. Growth variations between different lakes were considerable. Four main growth rate types were distinguished in 58 lakes. In all cases where material was available before and after stockings, the growth rates both among native and stocked whitefishes were slower after stocking which indicates density-dependent growth. The growth was faster the higher the altitude of the lake. Altitudes ranged from 15-363 m above the sea level. No statistically significant correlations were found between catch-per-unit-effort of whitefish and other fish species in experimental gill net fishing.

LEHTONEN, H., H. PELTON, O. HEIKINHEIMO, E. SAARIJARVI, K. SAULAMO, M. VINNI and T. NURMIO. 1998. Application of coded microtags to study growth rates of stocked sympatric whitefish (*Coregonus lavaretus*) forms. Fisheries Research 39(1) : 9-15.

Five ecologically different whitefish forms were stocked in Lake Vyokalanjärvi in eastern Finland to establish dense populations and to analyze competition between different forms. Altogether, 213,253 whitefish were tagged with coded wire tags (microtags) injected into their snouts in 1987-1988. The highly morphologically similar whitefish forms have different gill raker count distributions, but distributions overlap. In 1989-1992, 12,755 tagged whitefish were recaptured and the codes of the microtags were identified. In this study a growth model was applied to analyze and compare growth rates of different whitefish forms. The model was based on annual length increments. Differences in both the length increments in the youngest age group and also the annual decline in length increments of different forms were statistically significant (F-test, $P<0.0001$). Whitefish forms with the dense gill rakers had the greatest growth rates.

LEOPOLD, M. 1986. The effect of eel stocking on stocking with other fish species. Vie et Milieu 36(4) : 295-297.

Long-term data on fish stocking and commercial catches from 31 lakes of a total area of 5,300 ha were used to analyse the effect of stocking with eel (*Anguilla anguilla*) on other fish species. The effect of stocking at high rates with eel upon the effects of stocking with other fish species was determined. It was found that high rates of stocking with eel affected the effectiveness of stocking with vendace (*Coregonus albula*), whitefish (*C. lavaretus*) and peled (*C. peled*), pikeperch (*Stizostedion lucioperca*) and tench (*Tinca tinca*) positively, while no effect was found with regard to stocking with carp (*Cyprinus carpio*) and crucian carp (*Carassius carassius*).

LESKELAE, A., T. FRIMAN and R. HUDD. 1998. Stress responses of whitefish fingerlings marked with the fluorescent pigment spraying method. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 479-485.

One-summer-old whitefish raised on natural food in ponds were marked with the fluorescent pigment spraying method before stocking. The effect of the marking on the stress level of the fish was analyzed. This was done by comparing the carcass water content of the marked and unmarked fish throughout the capture-marking-loading-transport-stocking procedure. Post-stocking mortality of both groups was followed by keeping the fish in net cages for one week after release at the stocking site in the Gulf of Bothnia. In fish sampled 2-4 hours after marking, the carcass water content of marked fish was higher than that of control fish in two marking lots out of seven. However, in the later phases of the stocking procedure, the differences between marked and unmarked fish leveled off, since the capturing and handling of the fish to be stocked caused the unmarked fish to become stressed as well. Mortalities in net cages during a 7-day post-stocking period were from 1 to 3%, and there was no difference between the marked and unmarked fish.

LIAW, W. K. 1984. Pond rearing of whitefish (*Coregonus clupeaformis*) fingerlings in Saskatchewan. Technical Report 84-2. Department of Parks and Renewable Resources. Saskatoon, Saskatchewan. 42 p.

Whitefish are among the economically valuable species of fish in Saskatchewan. At the present, there are about 1,400 commercial fishermen in the province harvesting about 1.7 million kg of whitefish annually from some 200 lakes. Recently, overfishing and habitat changes appear to have severely affected the whitefish stocks in a number of lakes; in some, the fishery has virtually collapsed.

In order to find a better way to restore a collapsed fishery or a declining fish population, the Fisheries Branch recently carried out a pilot project of growing whitefish fingerlings in rearing ponds for subsequent release into problem lakes. The purpose of this report is to document food habits, the growth and the production of whitefish fingerlings in the rearing ponds.

Two small forest lakes near Buffalo Narrows in northern Saskatchewan and one fertile agricultural pond near Turtle Lake in central Saskatchewan were used as rearing ponds. These rearing ponds are in close proximity to major "problem" lakes. The growth of fry in the ponds was rapid up to 120 days after stocking. By this time, the fingerlings had reached an average of 142-146 mm in fork length and 40-42 g in weight. This growth is nearly twice as fast as that of the wild-stock whitefish in some larger northern lakes. The yield of fingerlings from the small fertile Turtle Lake Pond at the end of the summer amounted to 245 kg/ha (6,136 fish/ha). The survival of the whitefish in this pond from stocking to early July was nearly 100% and was approximately 30% to the time of harvest, possibly due to summerkill. Of the total 13,402 fingerlings harvested from this pond, 6,046 (those caught in traps) were transferred to Turtle Lake. The intensive fishing (with traps and gillnets) recovered 91% of the fingerlings present in the pond at harvest. A small fishing effort managed to harvest a total of 3,481 fingerlings from one of the two northern ponds during its 2 years of operation, 1,556 of which were transferred to Big Peter Pond Lake.

The project has demonstrated clearly that rearing whitefish from fry to fingerling size in suitable waters is feasible in both central and northern Saskatchewan. The growth was rapid; survival and yield were high in the small fertile pond. It appears justifiable to move from this feasibility study into the implementation phase of the enhancement program.

Production and recovery of fingerlings can be increased by adopting the following management techniques:

- Use only naturally fertile and winterkill ponds.
- If ponds are not fertile, but otherwise suitable, consider pond fertilization.
- Increase stocking rate to 30,000 to 40,000 fry per ha.
- Release fingerlings within 4 months after stocking, or when their growth starts to slow down.
- Harvest fingerlings by draining ponds whenever it is feasible to do so. Draining ponds is more effective and less laborious than trapping.

LOCH, J. S. 1971. Phenotypic variation in the lake whitefish as induced by introduction into a new environment. M. Sc. Thesis, University of Manitoba. Winnipeg, Manitoba. 96 p.

LOCH, J. S. 1974. Phenotypic variation in the lake whitefish (*Coregonus clupeaformis*) induced by introduction into a new environment. Journal of the Fisheries Research Board of Canada 31 : 55-62.

Adult lake whitefish (*Coregonus clupeaformis*) from Clearwater Lake and second generation adults of offspring from Clearwater Lake whitefish transplanted to Lyons Lake were compared with respect to morphometric and meristic characters and isozymes of L-glycerol-3-phophate dehydrogenase (GPDH). Feeding habits and abundance of pelagic and benthic foods were compared in the two lakes.

Gill raker number, lateral line scale count, and interorbital width remained constant between parental and offspring populations. Gill raker length was the main character found to differ between the populations. This was found to be related to the percentage and type of benthic food eaten. Abrasion of the gill rakers is offered as an explanation for the differences in gill raker length. Differences were found in various other meristic and morphological characters, as well as in electrophoretic phenotype frequencies of isozymes of GPDH.

LOFTUS, D. H. and P. F. HULSMAN. 1986. Predation on larval lake whitefish (*Coregonus clupeaformis*) and lake herring (*C. artedii*) by adult rainbow smelt (*Osmerus mordax*). Canadian Journal of Fisheries and Aquatic Sciences 43 : 812-818.

Rainbow smelt (*Osmerus mordax*) predation on larval lake whitefish (*Coregonus clupeaformis*) and lake herring (*C. artedii*) in Twelve Mile Lake, Ontario, was intense in 1984. Coregonid larvae hatched in early April as smelt spawning was ending. Predation was continuous for a 7 week period, beginning at the onset of hatching. Numbers of coregonid larvae observed in smelt stomachs were directly proportional ($P \leq 0.005$) to their abundance in the lake. During the week when the larvae were most abundant, they occurred in 93% of the smelt stomachs containing food. The corresponding average daily consumption was 8.4 larvae per smelt. Simulation of the combined effects of smelt predation and "natural" mortality indicated that mortality of lake whitefish may be 100%. Survival of herring larvae must be greatly reduced as well. Rainbow smelt became established in Twelve Mile Lake in the 1950s; their effect on larval whitefish survival may have been aggravated by intensified dipnetting of spawning lake whitefish during the 1960s. There has been little or no recruitment of young whitefish to the population since 1975, although dipnetting for adults ceased in about 1970. Our results support the hypothesis that the primary cause of recruitment failure of this whitefish population is predation by smelt.

LUCZYNSKI, M., S. FALKOWSKI, J. VUORINEN and M. JANKUN. 1992. Genetic identification of European whitefish (*Coregonus lavaretus*), peled (*C. peled*) and their hybrids in spawning stocks of ten Polish lakes. Proceedings of the Fourth International Symposium: Biology and Management of Coregonid Fishes – 1990. Polskie Archiwum Hydrobiologii 39(3-4) : 571-577.

Since the introduction of peled (*Coregonus peled*) to Poland, hybrids with indigenous European whitefish (*C. lavaretus*) have become common in numerous lakes. This has resulted from the stocking of lakes with fish having unknown genetic properties, which, in turn, was due to an inability to identify and eliminate hybrid breeders. To study the status of coregonid populations, samples of 42 to 60 spawners were taken from ten lakes differing in their fishery management. Fish were identified by electrophoretic determination of the phenotype at five loci coding for four enzyme systems known to be diagnostic between European whitefish and peled. The composition of populations studied ranged from pure European whitefish stocks, through various proportions of European whitefish, peled and their hybrids, to a population where hybrids outnumbered their parental species. Morphological analysis showed that gill raker counts overlapped between all groups of fish, preventing the use of this character alone in the identification of European whitefish and peled spawners and their hybrids. Combined examination of the mouth opening position followed by the electrophoretic examination of liver sSOD and sMEP (coded by sSOD* and sMEP*), gave satisfactory accuracy in fish identification and have created possibilities for significant improvement in the management of European whitefish and peled populations.

LUCZYNSKI, M., H. KUZMINSKI, S. DOBOSZ and K. GORYCZKO. 1998. Gene pool characteristics of whitefish (*Coregonus lavaretus*) fingerlings produced in a hatchery for restoration stocking purposes. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 317-321.

Water pollution in the Gulf of Gdansk resulted in the extinction of its whitefish (*Coregonus lavaretus*) population. Environmental reclamation in the 1990s provided opportunities for the program of whitefish restoration. The program has been based on fertilized eggs obtained from wild spawners of Pomeranian whitefish, which were used for development of the farmed broodstock of whitefish. Hatchery produced fingerlings were then stocked into the Gulf of Gdansk. Enzyme gene variation evaluated using electrophoresis revealed that the percentage of polymorphic loci (P = 25.7) and mean heterozygosity (H = 6.8%) estimated in the farmed fingerlings were similar to those (P = 28.6, H = 5.5%) found earlier in Pomeranian natural whitefish. Contingency chi-square analysis at all polymorphic loci revealed no statistically significant divergence between the two populations (Chi-square 19.2090, DF = 15, P = 0.20089), and the genetic distance between them was D = 0.000. This proves that the gene pool of the restored whitefish population may remain as variable as it is in the original wild population.

LUCZYNSKI, M., P. MAJKOWSKI, R. BARDEGA and K. DABROWSKI. 1986. Rearing of larvae of four coregonid species using dry and live food. Aquaculture 56 : 179-185.

After hatching, the larvae of vendace (*Coregonus albula*), whitefish (*C. lavaretus*), muksun (*C. muksun*) and peled (*C. peled*) were fed solely on a dry diet and compared with those fed zooplankton. The survival rates of the fish groups fed zooplankton were similar (vendace and muskun) or lower (whitefish and peled) than those of the groups fed on the dry diet, whereas the growth rate of the fish fed the live prey was better than that of those fed the pelleted food. It is concluded that the larvae of the examined Coregoninae species can be fed solely on a dry food diet after hatching with satisfactory growth and survival.

MacCRIMMON, H. R. and E. SKOBE. 1970. The fisheries of Lake Simcoe. Ontario Department of Lands and Forests. Toronto, Ontario. 140 p.

The first stocking of whitefish (*Coregonus clupeaformis*) fry into Lake Simcoe occurred in 1888, with fish (of Lake Ontario stock) originating from the Newcastle hatchery. A total of 28,134,000 fry were stocked between 1888 and 1955 into Lake Simcoe. During the later years the fish were of Georgian Bay stock and were reared at the provincial hatchery in Collingwood.

The whitefish in Lake Simcoe are the only sport fish species in the waterbody which are adapted to bottom feeding and their only significant competition is with suckers.

MacKAY, H. H. 1963. Fishes of Ontario. Ontario Department of Lands and forests. The Bryant Press Ltd. Toronto, Ontario. 300 p.

The lake whitefish is distributed widely throughout Ontario and in northern Québec out to the Maritimes. It also occupies habitat in the Great Lakes through the inland lakes to Hudson Bay and northwestward to Alaska. The tapeworm *Triaenophorus crassus* can be common in the immature stages of some whitefish. In the earlier part of the twentieth century whitefish fry plantings occurred in Lake Erie and Lake Ontario at the Bay of Quinte, however, there is little evidence to demonstrate that the stockings are having a positive effect on the fishery. Because there exists little positive evidence as to the contribution of these stockings the artificial propagation of lake whitefish has been greatly reduced in Ontario.

MARSHALL, T. L. and R. P. JOHNSON. 1971. History and results of fish introductions in Saskatchewan, 1900-1969. Fisheries Report No. 8. Saskatchewan Department of Natural Resources. Saskatoon, Saskatchewan. 27 p.

Since 1900, 1.6 billion fish comprising 30 species have been introduced to the fresh and saline waters of Saskatchewan. Indigenous species widely distributed into saline and new waters include lake whitefish (*Coregonus clupeaformis*).

Saskatchewan was the last of the Canadian provinces to propagate and distribute fishes. Factors which encouraged participation include: (1) Reported depletion of limited, but esteemed, lake whitefish in the southern settled portion of the province, (2) Absence of familiar game fishes of eastern Canada and, (3) The challenge to utilize numerous fish-barren saline waters.

Lake whitefish are native to most of Saskatchewan waters of adequate depth and size north of 53º30' N along with the southern Lac Pelletier and lakes of the Qu'Appelle drainage. In the early years of artificial propagation it was policy to supplement "depleted" natural populations with additional stockings of whitefish and as a result 35 of the total 48 lakes receiving fry already supported native populations. It was found that these fry did little to contribute to existing established populations and plantings since the 1950s have been mainly into new waters and for the maintenance of non-reproducing stocks.

Nine of the thirteen lakes which received fry introductions have supported hatchery populations for varying lengths of time. Failure of whitefish to survive in at least four lakes has been attributed to excessive salinity or lack of dissolved oxygen. The most successful introductions to saline lakes have occurred in Lake Lenore (1936) and the Redberry Lakes (1940), where salinities vary from 5,490 to 19,900 ppm. Although, TDS in excess of 19,000 ppm is considered the lethal limit for lake whitefish, failure to reproduce at levels above 3,100 ppm is poorly understood.

McMURTRY, M. J. 1989. Fall trapnetting on the spawning grounds of lake trout and lake whitefish in Lake Simcoe, 1985-1988. Lake Simcoe Fisheries Assessment Unit Report 1989-3. Ontario Ministry of Natural Resources. Sutton West, Ontario. 58 p.

Trapnetting of spawning lake trout and lake whitefish has for several decades played an important role in the assessment and management of these species in Lake Simcoe. The objectives of the fall trapnetting program are: 1) To monitor the status of coldwater fish populations in Lake Simcoe, and 2) To collect lake trout and lake whitefish eggs for subsequent reintroduction to the lake. This report summarizes data collected during 1985-1988 and describes trends over a longer period.

Three trapnet sites – North Georgina, Strawberry Island and Willow Rocks – were netted each year during 1985-1988. The timing of spawning activity at these sites has been consistent over the last decade. Lake trout move onto the shoals at about the second week in October and depart two weeks later. Lake whitefish abundance on the spawning shoals increases in mid November and falls again in early December.

The overall catch of lake trout gradually increased from 1978 until 1987. This can be attributed to the number of fish planted as there is no evidence of survival from egg stage to yearling stage in the lake. The catch of lake trout declined sharply in 1988, possibly due to unusually windy conditions which reduced net efficiency. The catch of lake whitefish has declined steadily since 1979.

The proportion of stocked fish in the catch has increased from 89% in 1978 to 99% in 1988 for lake trout, and from 0.1% in 1985 to 8.2% in 1988 for whitefish. The catch of whitefish and the proportion of stocked whitefish in the catch are expected to increase substantially as fish from the 1986-1988 stockings reach reproductive age. There are several signs that recruitment of native whitefish continues to be negligible in Lake Simcoe: the decline in abundance of adults, the low numbers of fish less than 9 years of age in the spawning population, and an increase in the modal length of spawning fish.

Lake trout of Lake Simcoe origin planted in 1978, 1980 and 1982 have had the highest rate of return of stocked trout so far recovered. Few trout of other origins were recovered from 1985-1988. Growth of lake trout from different plantings has been comparable. Of stocked whitefish recovered, those from the 1982 planting showed the highest survival.

Recommendations are made to guide assessment and management of lake trout and lake whitefish populations in the future. These include: 1) Continuing the fall trap netting program using the same sampling sites and data collection methods, 2) Building a mathematical model of the effects of hypothetical stocking regimes and estimating the number of fish required to maintain the lake trout and lake whitefish populations at various levels, 3) Monitoring the condition of spawning shoals for siltation and algae, 4) Reinstating the larval trawling program to monitor survival of larval whitefish and lake trout, 5) Determining the diet of potential predators of lake trout and whitefish, and 6) Continuing to study the growth and calcified structures of whitefish of known age from Lake Simcoe to establish the limits of scale aging techniques.

McMURTRY, M. J., C. C. WILLOX and T. C. SMITH. 1997. An overview of fisheries management for Lake Simcoe. Lake and Reservoir Management 13(3) : 199-213.

Eutrophication, increased fishing pressure, habitat destruction and invasion of non-native plants and animals have transformed Lake Simcoe and its assemblage of fishes over the past 150 years. Notable changes include the extirpation of lake sturgeon (*Acipenser fulvescens*), decline of muskellunge (*Esox masquinongy*), and failure of recruitment of lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*). Many species, including lake trout, lake whitefish, lake herring (*Coregonus artedi*), and yellow perch (*Perca flavescens*), have undergone major fluctuations in abundance. Fisheries management actions have evolved with changes in the lake ecosystem and changes in scientific knowledge. Early regulations substantially restricted the commercial fishery and imposed many of the existing controls on the sport fishery. A long period of adjustment and addition to these regulations along with reliance on supplemental stocking (i.e., stocking of a species where a self-reproducing population of that species exists) of native fish as well as introduction of non-native fish followed. In the last 3 decades, a scientific approach and ample monitoring have been established as basic requirements for making sound management decisions. Supplemental stocking of native species and stocking of non-native species have been largely replaced by stocking of native species for rehabilitation. Successful fisheries management in the future will need to address the uncertainty about the state of complex aquatic ecosystems, and identify the possible states of the system and the probable consequences of specific management actions.

Whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*) are currently stocked in Lake Simcoe. Lake whitefish were stocked in 1888, 1889, 1936-1955 and 1982 to the present day. Stocking numbers approximated 2,010,000 fry annually to 1955, 20,000 yearlings plus some fingerlings from 1982 to 1986 and 146,000 fingerlings and yearlings since 1987.

McPHAIL, J. D. and C. C. LINDSAY. 1970. Freshwater fishes of northwestern Canada and Alaska. Bulletin 173. Fisheries Research Board of Canada. Ottawa, Ontario. 381 p.

Coregonus clupeaformis, or the “humpback whitefish” is distributed across northern North America from the Bering Strait to Labrador. It has also been introduced into cool lakes outside of its natural range. This form of whitefish has been tentatively equated with three different Eurasian species: *C. lavaretus*, *C. nasus* and *C. pidschian*.

MILLER, R. B. 1946. Effectiveness of a whitefish hatchery. Journal of Wildlife Management 10(4) : 316-322.

A long-term experiment to test the effectiveness of the Alberta whitefish hatchery was begun in 1941, by planting “eyed” eggs in a series of lakes on alternate years. Subsequent year class strengths, determined by samples from the commercial catch, were then compared.

The evidence from the first five years indicates rather strongly that the hatchery-supported year classes are no stronger than those not so supported, in a series of five lakes 12 to 462 square miles in area.

Preliminary observations on the efficiency of natural reproduction indicate that about 10% of the eggs survive to become fry. This is sufficient to produce roughly 100 times the number of adult fish which a lake can support.

“Eyed” eggs introduced by the hatchery survive and produce fry, because several lakes formerly without whitefish but stocked with eyed eggs now support commercial fisheries.

The failure of the hatchery products is not due to the method used, as the stock introduced survives; natural reproduction provides more than can survive, hence additional stock from the hatchery cannot change the ultimate result. The data and conclusions presented are preliminary, and the experiment will continue for another five years.

MILLER, R. B. 1949. Problems of the optimum catch in small whitefish lakes. Biometrics 5(1) : 14-26.

Heavy plantings of “eyed” eggs or fry of whitefish are typically planted into a waterbody when it appears that the commercial fishery is failing. However, there is a lack of evidence as to the effectiveness of this method.

The stocking of eggs and fry into Pigeon Lake did not appear to contribute significantly to the fishery. Studies show that this particular fishery did not collapse due to reproductive problems and the planting of additional young life stages of whitefish was possibly not the answer to population restoration. When population collapse is not due to brood problems hatchery plantings do little. By studying the relative strength of year classes in Pigeon Lake from 1938 to 1941, it was found that hatchery stockings did not influence production.

MILLER, R. B. 1952. The relative strengths of whitefish year classes as affected by egg plantings and weather. Journal of Wildlife Management 16 : 39-50.

Over the period 1941-1950, a total of 13,062 whitefish scales have been read; the whitefish were collected in small samples, annually, from each of seven Alberta lakes. The lakes lie between 53º and 56º North latitude and 110º and 116º longitude; they vary from twelve to nearly five hundred square miles in area.

The ages of the fish making up the samples from each lake were used to determine the relative strengths of the year classes of 1935-1945 (in a few cases, to 1947). The relative strengths of the year classes are compared to the hatchery record (i.e., none of the lakes received egg plantings every year) consequently, it is possible to determine if supported year classes tend to be stronger than non-supported year classes. No such tendency is demonstrable. Muriel Lake is of special interest as it contained no whitefish until it was planted with eyed eggs in 1937. These survived, matured and produced strong “natural” year classes. The study proves conclusively that year class strength is completely unaffected by plantings from the hatchery in lakes where a spawning population exists.

A remarkable similarity in the variation of the year classes of six of the lakes was observed; thus, year classes were weak in 1935-36, strong from 1937-40 and generally weaker in 1941, 1942, and 1943.

Somewhat limited meteorological data on temperatures, precipitation and winds were studied in a search for an explanation of this year class "cycle." No conclusive findings were made but there is a reasonable suggestion that year class strength may be inversely correlated with the strength of the winds.

MORRIS, J., L. MORRIS and L. WITT. 1972. The fishes of Nebraska. Nebraska Game and Parks Commission. Lincoln, Nebraska. 98 p.

Since the 1800s there have been many attempts to introduce non-native fish species to the State of Nebraska. The lake whitefish (*Coregonus clupeaformis*) was introduced in Sarpy County in 1883, however this species was unable to establish itself.

MUTENIA, A. and M. AHONEN. 1990. Recent changes in the fishery on Lake Inari, Finland. p. 101-111. *In* Management of Freshwater Fisheries. Proceedings of a Symposium Organized by European Inland Fisheries Advisory Commission, 31 May-3 June, 1988, Goeteborg, Sweden.

Lake Inari (69º N, 28º E) is situated between the sub-Arctic and temperature zones. It covers 115,300 ha and is among the most northern of the large lakes in Finland, and indeed in the world. The lake has survived to the present day as a clean oligotrophic, barren lake, even if water control measures for power production have tended to alter its natural state. In order to mitigate the effects of regulation, whitefish (*Coregonus lavaretus*), migratory brown trout (*Salmo trutta lacustris*), lake trout (*Salvelinus namaycush*) and arctic charr (*Salvelinus alpinus*) have been stocked annually since 1976. Vendace (*Coregonus albula*) was introduced to Lake Inari in the 1960s. Between 1979-1984, the number of nets used for whitefish were reduced, while the numbers used for trout and charr fishing both doubled. Consequently the whitefish catch has not grown, despite heavy stocking. To improve whitefish catches, a new fishing method involving large trap nets was introduced in 1986. By 1987, professional fishermen had 13 such trap nets and catches have since been promising. The present vendace stock is large enough to support professional fishing, but because there was no experience with this species, experiments with winter seines were inaugurated in 1985, and with trawls in 1987. Results have been good and professional fishermen have accepted the new methods.

ONTARIO MINISTRY OF NATURAL RESOURCES. 2000. Fish culture course manual. Course held at the University of Guelph, August 14-18, 2000. Guelph, Ontario.

Lake whitefish reared at the White Lake Fish Culture Station are currently raised solely on dry feed. Their survival to 28 weeks has been greater than 95%.

PARKER, J. C. 1888. Some experiments with the fry of whitefish. Transactions of the American Fisheries Society 17 : 67-69.

The question which was dealt with in this study was whether or not whitefish fry would be able to find food if planted out of season. On March 1, 1887, a small screened cage containing 10,000 whitefish fry was lowered through the ice of Little Traverse Bay, Michigan, to the bottom of the lake, in 100 feet of water. The crate was pulled up periodically and the number of dead fish were counted: March 5 – 6 dead; March 10 – 12 dead; March 14 – 100 dead. On March 10, the fry had turned a light brown and their yolk sacs were nearly absorbed. They appeared to be in good health. On March 12, the stomach contents of one fish was analyzed and was found to contain diatoms and vegetable matter. Water samples were taken and it was discovered that in the winter there should be adequate food for fish survival.

PELCZARSKI, W. 1998. Reintroduction of whitefish (*Coregonus lavaretus*) into Puck Bay (southern Baltic). p. 294-300. *In* I. W. Cowx [ed.]. Stocking and Introduction of Fish. Fishing News Books, Blackwell Science, Ltd. MPG Books, Ltd. Bodmin, Cornwall, Great Britain.

Whitefish (*Coregonus lavaretus*) was common in catches from Puck Bay (southern Baltic) until the 1970s, after which time it became virtually extinct as a result of overfishing and habitat degradation. However, recent improvements in the environmental state of Puck Bay stimulated an attempt to reintroduce the species into the bay. Catches of whitefish in relation to size and type of stocking between 1922 and 1995 are presented. Since 1992, Puck Bay has been stocked with juveniles fed on different artificial feeds in the rearing center as well as on live zooplankton from post-sewage treatment ponds. Experimental catches in 1995 indicated the stocking was successful. The activity will continue for the foreseeable future.

RAISANEN, G. R. and D. J. BEHMER. 1982. Rearing lake whitefish to fingerling size. Progressive Fish Culturist 44(1) : 33-36.

Lake whitefish (*Coregonus clupeaformis*) were reared on zooplankton after hatching until most fish readily accepted a dry diet by 13 weeks, when they averaged 44 mm (total length). Survival to 24 weeks was 4.0% and the fish then averaged 115.3 mm. The high mortality between five and ten weeks was attributed to insufficient zooplankton caused by the high density of fry in the rearing containers: Gill disease and fin rot also contributed to mortality.

RAITANIEMI, J., T. MALINEN, K. NYBERG and M. RASK. 1999. The growth of whitefish in relation to water quality and fish species composition. Journal of Fish Biology 54(4) : 741-756.

Water quality in 16 Finnish lakes did not directly affect densely gill rakered whitefish growth, except possibly in an acid (pH 4.9) lake, Iso Lehmaelampi, where acidity may have retarded the growth of whitefish. The density of roach affected whitefish growth in the second year of life: highest growth rates were in lakes without a roach population and lowest growth rates in lakes having strong roach populations. Competition by vendace also retarded the growth of young whitefish. The efficient mass removal of roach from a eutrophic lake was considered to have increased the growth rate of young whitefish. It is suggested that an examination of the fish species composition and relative abundance, as well as the growth of whitefish, can be used as an aid in predicting the success of stocking with whitefish.

RASK, M. P. J. VUORINEN, J. RAITANIEMI, M. VUORINEN, A. LAPPALAINEN and S. PEURANEN. 1992. Whitefish stocking in acidified lakes: Ecological and physiological responses. The Dynamics and Use of Lacustrine Ecosystems. Hydrobiologia 243/244 : 277-282.

In autumn 1986, six small lakes at different stages of acidification were stocked with one-summer-old whitefish (*Coregonus pallasi*) in order to see whether whitefish stocking would be a suitable method for the mitigation of acidification effects. In two of the lakes the introduction was a complete failure: the whitefish did not survive, evidently due to high acidity and high aluminum concentrations of the lake waters. In one of the most acidified lakes and in two less acidic lakes, introduction was successful. Three years after the introduction, the mean weights of the fish in those three lakes were 580, 250 and 360 g respectively, with the weight and also the condition factor of stocked whitefish being highest in the most acidified lake. In that lake there were few or no fish present during the introduction, whereas in the less acid lakes there were dense populations of perch and therefore a potential interspecific competition for food. Different availability of food in the lakes was presumed to be the main reason for the growth differences. Plasma Na^+

and Cl^- concentrations of whitefish were lower in the acidic lakes than in the lake with pH around 6, three years after stocking.

RASMUSSEN, K. 1988. Results of rearing and releasing whitefish in the hypertrophic Hjarbæk Fjord, Denmark. Finnish Fisheries Research 9 : 417-424.

Since 1984, large numbers of whitefish (*Coregonus lavaretus*) fingerlings have been reared in cages in the hypertrophic Hjarbæk Fjord by attracting zooplankton with light. The stocking program for the fjord has created one of the most productive whitefish populations in Denmark. The growth rate is high, a mean length of 375 mm and a mean weight of 540 g are reached within the second year of life. The whitefish have proved to be fairly tolerant of high temperatures and high pH values.

RASMUSSEN, K. 1990. Some positive and negative effects of stocking whitefish on the ecosystem redevelopment of Hjarbækfjord, Denmark. Hydrobiologia 200/201 : 593-602.

In 1984, the County of Viborg introduced a large-scale program to improve the water quality in Hjarbæk Fjord, a freshwater fjord cut off from the sea in 1964. Measures were taken to reduce the discharges of nutrients from various sources. To reduce the nuisance of chironomids a large release of whitefish (*Coregonus lavaretus*) was incorporated in the programme. The effects of these efforts on the fish, benthos and plankton communities were studied during a period of five years. The whitefish established a self-reproducing population with a very good growth rate, and may have created quantitative and qualitative changes in the plankton community. Observed changes in the benthos community may also be related to predation by whitefish. The study did not confirm that whitefish could actually control the population of chironomids and diminish, thus, the nuisance caused by them. The stocking of whitefish created an exploitable fish stock of a valuable fish species in the hypertrophic Hjarbæk Fjord.

RAWSON, D. S. 1946. Successful introduction of fish in a large saline lake. Canadian Fish Culturist 1 : 5-8.

RINGLE, J. and S. MORTENSON. 1987. Techniques for intensive hatchery production of lake whitefish fingerlings. p. 231. *In* Proceedings of the 49th Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin. (Abstract Only)

Lake whitefish (*Coregonus clupeaformis*) eggs have been successfully incubated and hatched under controlled conditions in the Great Lakes region since the mid to late 1800s. Most fry plantings have not been considered successful. Since 1985, great progress has been made with culturing fry to fingerling size and beyond. Larval whitefish, 5-15 days post-hatch, are fed either brine shrimp or a 250-400 micron formulated feed such as a modified AP-100 or FFKB diet. At 18-20 mm, following metamorphosis, fish can be converted to any regular trout or salmon starter diet and reared to fingerling size. Fish are fed 3-6% body weight in increasing feeding intervals and decreasing percentages of body weight as fish grow. Fish growth rates range from 0.20 mm/day at 9º C to 0.6 mm/day at 14º C. Fish have been successfully reared to 220 mm at densities of over 40 kg/m^3. Water exchange rates are increased during rearing from 1 to 2 tank changes per hour. Whitefish fingerlings are extremely susceptible to low levels of nitrogen gas supersaturation. Bacterial gill disease, which is related to water quality and low dissolved oxygen, can be successfully treated with 1% salt bath or 6.5 ppm Chloramine-T™ for 1 hour.

RODD, J. A. 1930. Unproductive water areas made productive. Transactions of the American Fisheries Society 60 : 116-121.

Big and Little Quill lakes in central Saskatchewan were known to only have sticklebacks living in their waters. Both lakes are strongly saline and it was thought that if fish were planted near inflows, where the salinity is the weakest, populations could develop. In 1924, fry of cisco and whitefish were distributed into creeks flowing into Little Quill Lake. Some whitefish were caught the following year and increasingly larger numbers are being taken each season. Food conditions are satisfactory and natural reproduction is taking place.

RUHLE, Ch. 1998. Morphological differences in slow-growing whitefish (*Coregonus lavaretus*) of the channel-connected Lake Walenstadt and Lake Zurich, Switzerland. Fischokologie Koln 11 : 47-55.

Stocking with slow-growing whitefish (*Coregonus lavaretus*) from one lake to another were frequent during the last few years, and natural propagation from Lake Walenstadt to Lake Zurich by the connecting channel cannot be excluded. Nevertheless, the two populations are morphologically different. Since information on genetics of the two populations are lacking, the dimorphism is considered as an indicator for genetic differences and should be taken as a reason for stock-oriented management.

SALOJARVI, K. 1988. Effect of the stocking density of whitefish (*Coregonus lavaretus*) fingerlings on the field yield in Lake Peranka, northern Finland. Finnish Fisheries Research 9 : 407-416.

The effect of two different whitefish (*Coregonus lavaretus*) stocking density levels (4 individuals/ha and 200 individuals/ha) on the yields of whitefish and other fish species were studied in Lake Peranka, northern Finland. In addition to stocking data, the material included tagging data, fish stock samples, fishing records, and fishing statistics. A VPA-model was used to study the dynamics of the whitefish population in the lake. Fingerling stocking increased the whitefish catch and had no adverse effects on the catch of other species. The yield from whitefish fingerling stocking during the low density phase was 155 kg/1,000 stocked fingerlings, while yield during the high density phase was only 10 kg/1,000 stocked fingerlings. However, the higher stock density gave a much higher annual whitefish catch than did the low density.

SALOJARVI, K. 1991. Compensation in a whitefish (*Coregonus lavaretus*) population maintained by stocking in Lake Kallioinen, northern Finland. Finnish Fisheries Research 12 : 65-76.

Since 1977, the 25 hectare Lake Kallioinen, northern Finland, has been stocked with one-summer-old whitefish (*Coregonus lavaretus*) fingerlings (100-160 individuals/ha every second year). The whitefish population density for 1978-1986 varied between 128 ± 38 and 247 ± 12 individuals/ha, and the biomass between 9.2 ± 1.2 kg/ha and 42.1 ± 5.9 kg/ha. The constant natural mortality varied between 0.07 and 0.3. The mean catch per thousand fingerlings released varied between 83 and 235 kg; 4-12 fingerlings being needed for production of one kilogram of catch. Density-dependent compensatory processes strongly affected recruitment and yield from stocking. Implications of the results for fisheries management are that yield from stocking can be improved by adjusting stocking density and/or fishing effort and can decrease due to too high stocking density, while the size of fingerlings is of secondary importance.

SALOJARVI, K. 1992$_a$. The role of compensatory processes in determining the yield from whitefish (*Coregonus lavaretus*) stocking in inland waters in northern Finland. Finnish Fisheries Research 13 : 1-30.

SALOJARVI, K. 1992$_b$. Compensation in whitefish (*Coregonus lavaretus*) populations in Lake Oulujarvi, northern Finland. Finnish Fisheries Research 13 : 31-48.

SALOJARVI, K. 1992$_c$. Compensation in whitefish (*Coregonus lavaretus*) populations in Lake Kiantajarvi, northern Finland. Finnish Fisheries Research 13 : 49-62.

SALOJARVI, K. 1992$_d$. Whitefish (*Coregonus lavaretus*) stocking as a management tool in small forest lakes. Suomen Kalatalous 60 : 234-245.

The are tens of thousands of small forest lakes (surface area 1-100 hectares) in Finland. Management of these lakes by whitefish (*Coregonus lavaretus*) stockings and factors affecting the success of stockings as well as recommendations for management are dealt with in this article. Naturally reproducing whitefish stocks have been established through transfer of whitefish in many lakes. The efficiency of the stocking of larvae has varied widely. Larvae stockings fail in cases where endemic self-sustaining whitefish stocks exist, but they can succeed in cases where no whitefish exist prior to stocking. The mean yield from whitefish juvenile stocking has been 55 kg and the yields have varied from 2 to 235 kg. Sustainable yields with continuous stocking of juvenile whitefish have been some kilograms per hectare; frequently 4-6 kg/ha per year. The realistic target catch is 5-10 kg/ha per year. Factors affecting the success of transfers and larvae stockings are primarily stochastic density-independent population control mechanisms. Contrary to this, density-dependent population regulation mechanisms play a major role in determining the yield from juvenile stockings. Density-dependent population responses are easier to forecast. This means that the yield from juvenile stockings are more predictable than the yield from the transfer of adult fish and larvae stockings. The recommendations given include both fishing and stocking operations.

SALOJARVI, K. and P. EKHOLM. 1990. Predicting the efficiency of whitefish (*Coregonus lavaretus*) stocking from pre-stocking catch statistics. p. 112-126. *In* Management of Freshwater Fisheries. Proceedings of a Symposium Organized by European Inland Fisheries Advisory Commission, 31 May-3 June, 1988, Goeteborg, Sweden.

Cluster analysis was used to test the possibility of predicting the efficiency of whitefish (*Coregonus lavaretus*) stocking using pre-stocking catch statistics as source material. The clusters formed by the method were also examined in relation to lake regulation. The grouping of the lakes was meaningful, concerning both the predictability of stocking success and the effects of lake regulation. Results confirm earlier observations on stocking efficiency. However, further research using a larger number of lakes is needed, and the impact of different environmental factors on lake classification should be studied.

SALOJARVI, K. and A. HUUSKO. 1990. Results of whitefish (*Coregonus lavaretus*) fingerling stocking in the lower part of the Sotkamo water course, northern Finland. Aquaculture and Fisheries Management 21 : 229-244.

The efficiency of stocking with whitefish (*Coregonus lavaretus*) fingerlings was assessed in a large lake system with a naturally reproducing local whitefish stock. After the start of the stocking program the whitefish catch increased. The proportion of stocked whitefish in the catch was approximately 50%. The calculated yield per thousand released fingerlings was 57 ± 18 kg. Further, the efficiency of stocking may be indicated by the following facts. Prior to stocking, the whitefish catch decreased, evidently due to recruitment overfishing. It was suggested that this situation be corrected by stocking with fingerlings and the whitefish catch then increased. The catch-per-unit-of-effort (CPUE) generally decreases with increasing fishing effort. The growth rate depends on the density of the fish stock. In this case the growth rate declined possibly due to the fact that fingerling stocking increased the population density.

SALOJARVI, A. and M. MUTENIA. 1994. Effects of stocking fingerlings on the recruitment on Lake Inari whitefish (*Coregonus lavaretus*). *In* J. C. Cowx [ed.]. The Rehabilitation of Freshwater Fisheries. Fishing News Books, Blackwell Scientific Publications. Oxford, U. K.

SALONEN, E., M. AHONEN and A. MUTENIA. 1998. Development of whitefish (*Coregonus lavaretus*) population and effect of large-scale compensation stocking in Lake Inari, northern Finland. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 439-448.

Of the several forms of whitefish living in Lake Inari, the study concentrates on the economically most important one: the large sparsely rakered (LSR) whitefish (*Coregonus lavaretus*). The large, oligotrophic lake (area 1,102 km^2) has been regulated for 50 years to generate hydroelectric power, and for 20 years, the subsequent damage to fish populations has been compensated for by extensive stocking. Stockings (0.5-18 million fish/year) have been made with one-summer-old fingerlings (8-10 cm). The whitefish also reproduces naturally, and thus, its population is a mixture of wild and hatchery-reared whitefish. For stock assessment purposes, roughly 1,000-2,000 catch samples were collected annually, among which the share of LSR whitefish was 63-82% during 1980-1994. Data on fishery, catches, and CPUEs (catch per unit efforts) were gathered annually. For estimating the recruitment of different year-classes and stock density, population analysis (VPA) was used. The growth of whitefish was particularly studied in relation to stock density. To evaluate the efficiency of stocking and the catch share, an average of 70,000 fingerlings/year were nose-tagged during 1980-1986. The effects of stocking on whitefish catches turned out to be quite small due to high natural reproduction and density-dependent mechanisms affecting the growth and recruitment in the 1980s. In the beginning of the 90s, growth of whitefish increased because efficient fishing thinned whitefish populations. Simultaneously, the vendace (*Coregonus albula*) stock declined drastically. According to our calculations, the yield of the stocking program, based on taggings, was rather poor: 9-26 kg/1,000 stocked fingerlings in the year-classes 1981-86. Therefore, according to results of population dynamics and taggings, the level of stocking should be reduced.

SCOTT, W. B. and E. J. CROSSMAN. 1964. Fishes occurring in the fresh waters of insular Newfoundland. Royal Ontario Museum Life Sciences Contribution No. 58. Toronto, Ontario. 124 p.

Whitefish (*Coregonus clupeaformis*) are not native to Newfoundland and were introduced in 1886 in the vicinity of St. John's. Two hundred thousand whitefish ova were transported to Newfoundland and distributed as follows: Murray's Pond – 50,000, Hogan's Pond (Broad Cove Road) – 100,000 and South Side Hills Pond – 50,000. These eggs originated from the Newcastle Hatchery in Ontario and it is likely that the eggs were from Lake Erie whitefish. At least one of the plantings is known to be successful. A 1960 survey of Hogan's Pond revealed a population of stunted whitefish, many of whom were emaciated. It is suspected that food may be a limiting factor in the pond and there were no signs of gonadal or egg development even in late July. In 1963, a spawning sample of whitefish were collected from Mitchell's Pond, which adjoins Hogan's Pond.

SCOTT, W. B. and E. J. CROSSMAN. 1973. Lake whitefish. p. 269-277. *In* Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. Ottawa, Ontario. 966 p.

The major predators of lake whitefish are lake trout, northern pike, walleye and even whitefish themselves at times, when they consume their own eggs. Perch and ciscoe are also reported to feed upon larval whitefish.

Copepods, especially *Diaptomus*, and cladocerans were important in the diet of many young whitefish. By early summer bottom organisms became dominant in their diet.

Adult lake whitefish are usually bottom feeders consuming a wide variety of invertebrates and small fishes. This diet can consist of *Pontoporeia*, fingernail clams, gastropods, chironomid larvae, mayfly nymphs, caddisfly larvae, leeches, water boatmen, water mites, mysids and cladocerans.

SHIELDS, B. A., A. R. KAPUSCINSKI and K. S. GUISE. 1992. Mitochondrial DNA variation in four Minnesota populations of lake whitefish: Utility as species and populations markers. Transactions of the American Fisheries Society 121(1) : 21-25.

The Leech Lake band of Chippewa Indians in northern Minnesota fish commercially for lake whitefish and cisco on several reservation lakes. The management of lake whitefish stocks involves harvest quotas and the stocking of hatchery-reared fish. It is important when stocking to consider the possibility of genetic variation within and between populations. This study was conducted to detect the level of genetic variability among whitefish populations.

Restriction fragment length polymorphism (RFLP) analysis was performed on the mitochondrial DNA (mtDNA) of 33 lake whitefish from four spawning populations in north-central Minnesota. Diagnostic differences between the RFLP patterns of mtDNA from lake whitefish and cisco were useful in the identification of fresh fillets and fresh or frozen carcasses. However, mtDNA analysis was of little use for identification of lake whitefish populations because of the low diversity documented among study populations.

SINIS, A. and D. PETRIDIS. 1993. Population structure and reproductive strategy of the whitefish (*Coregonus lavaretus*) in two Greek lakes. Archiv fur Hydrobiologie 128(4) : 483-497.

The biology of whitefish (*Coregonus lavaretus*), an introduced fish species, was investigated in two contrasting environments, the oligotrophic man-made Lake Tavropos and the mesotrophic to eutrophic Lake Vegoritis. Aging of fishes through the length-at-capture data and the length frequency distribution revealed three age classes in Lake Tavropos and four in Lake Vegoritis. Age III+ fishes dominated in the catches while age I+ and II+ contributed the least to the age composition, indicating a poor recruitment and an unsuccessful reproduction. The growth of fishes derived from the body-scale relation was similar but females from Lake Tavropos had lower condition b (derived from the weight-length relationship) and also were hypometric (less than 3). In contrast, ovary weight-per-length cubed was higher, with fewer but larger eggs being produced. This reproductive strategy was connected with the oligotrophic status of the lake, in which the planktonic food for the larvae was low and is needed a larger size to cope with long periods of starvation, or even to match the size of the preferred, but scarce, copepodites and *nauplii*.

SNETKOV, M. A. and Yu. S. RESBLETNIKOV. 1980. Possible use of a modified Beverton-Holt recruitment model to estimate the optimum stocking density of larval coregonids. Journal of Ichthyology 20(6) : 143-146.

In connection with man's economic activity many waterbodies in the northwest of the USSR have been involved to varying extents in the process of cultural eutrophication in recent decades. The water bodies concerned are those that have long been a source of highly valuable fish production (primarily coregonids). The artificial creation of coregonid fisheries requires the production of large quantities of viable young for stocking, mainly pelyad (*Coregonus peled*), whitefish (*C. lavaretus*), muksun (*C. muksun*) and cisco (*C. abdula*). To this end reconstructed small lakes are often used for rearing for monoculture or polyculture.

SIGLER, W. F. and R. R. MILLER. 1963. Fishes of Utah. Utah State Department of Fish and Game. Salt Lake City, Utah. 203 p.

The lake whitefish was introduced numerous times into Utah Lake in 1873, 1895, 1919 and 1921, using fry. In 1934, fry were stocked into Weber River. All of these attempts to establish self-supporting populations were futile.

SMITH, C. L. 1985. The inland fishes of New York State. New York State Department of Environmental Conservation. Albany, New York. 522 p.

There exist lake whitefish populations in a few of the cooler lakes in New York State such as the Great Lakes, Lake Champlain, the Finger Lakes, Ostego Lake and in lakes within the Adirondacks. Those occurring in the Adirondacks are present due to introductions with whitefish from the Great Lakes and were originally stocked with whitefish from Labrador. This species has also been introduced into areas of Montana and Washington.

STEWART, C. A. 1995. Percent stocked Lake Simcoe lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*) calculated from winter angler sampling programs. Lake Simcoe Fisheries Assessment Unit Report 1995-1. Ontario Ministry of Natural Resources. Sutton West, Ontario.

Lake whitefish have been stocked in Lake Simcoe since 1982. Beginning in 1983, surveys were conducted on the winter angler catches to determine the proportion of stocked fish in the catch. Numbers were determined through angler catch sampling and creel censuses. With the exception of 1988, the number of stocked whitefish present in the catch grew from 1987 through 1994 (from 6.6% to 42.6%). Estimated ages of the fish through scale sampling and identification of fin-clips is presented.

STICKNEY, R. R. 1994. Use of hatchery fish in enhancement programs. Fisheries 19(5) : 6-13.

According to the U. S. Commission of Fish and Wildlife, whitefish eggs were stocked in four states, as well as Washington, DC, Germany and France to a total of 2,032,000 eggs. Whitefish young were stocked in three states (a total of 17,750,000) in 1881. In 1906, the number of whitefish stocked in the United States had risen to a total of 336,499,800.

STIRLING, M. 2000. Lake Simcoe: Lake whitefish stocking records, 1982-1999. File Document. Lake Simcoe Fisheries Assessment Unit, Ministry of Natural Resources. Sutton West, Ontario.

The stocking of lake whitefish in Lake Simcoe between the years 1982-1999 is presented in chart form along with the nature of the fin-clip, the number and location planted. Generally, the number planted annually has increased during that time. Since 1992, only fall fingerlings have been planted. Fin clips have been rotated through the pelvic, ventral and adipose fins. Since 1995, the fish have been stocked solely at Jackson's Point and Hawkstone. Between 1982 and 1999, a total of 1,295,698 yearlings and fall fingerlings were stocked into the lake.

STRANAHAN, J. J. 1899. The methods, limitations, and results of whitefish culture in Lake Erie. Bulletin of the U. S. Fish Commission XXIV : LXX-LXXXI.

In addition to the regular whitefish egg collection on Lake Erie, it was decided that a number of fish would be penned and held until ripe in order to obtain more eggs. Lake Erie whitefish eggs are used to supply the hatcheries on Lakes Huron, Ontario and Superior for restocking the Great Lakes.

SURBER, T. 1929. Fish culture in Minnesota, past present and future. Transactions of the American Fisheries Society 59 : 224-233.

The propagation of the commercial species whitefish and wall-eyed pike is carried on extensively in Minnesota hatcheries. During the fiscal year ending June 30, 1929, State waters were planted with 595,843,000 wall-eyed pike and 86,660,000 whitefish fry, a large increase over previous years.

SZCZERBOWSKI, J. 1977. Effectiveness of stocking lakes with lake whitefish. Roczniki Nauk Rolniczych 98(2) : 117-133.

The study was aimed at determining the dependencies taking place between the effects of stocking lakes with *Coregonus lavaretus* and factors which might exert an influence on development of this species. The analyses included 169 lakes from which results after stocking were obtained from catches carried out from 1952 to 1973. It was found that growth of catches depended upon the amount of material used for stocking and upon the number of times the lakes were stocked. The influence of the remaining factors considered, that is mainly area of the lakes stocked, their average and maximal depths, catches of bleak, bream and other fish, were insignificant or showed spurious correlation.

THOMPSON, F. A. 1939. Salmonid fishes in the Argentine Andes. Transactions of the American Fisheries Society 69 : 279-284.

Of the twelve different species of fish imported into Argentina only four have reproduced successfully and become acclimatized. The site of the principal introductions of salmonid fish was the National Park of Hahuel Huapi which is well-suited for trout. Several lakes and streams were examined by the author during 1937 to determine their value for fishing and for the collection of spawn.

Whitefish (*Coregonus clupeaformis*) were received at Bariloche on February 13, 1937. The eggs had been en route for 24 days and upon their arrival it was discovered only 3.05% had survived to any reasonable state. From the 2 million eggs, only 61,000 fry resulted. Although these fry were stocked there is no evidence that the species is still surviving in Argentina.

TODD, T. N. 1986. Artificial propagation of coregonines in the management of the Laurentian Great Lakes. Archiv fur Hydrobiologie 22 : 31-50.

TURUNEN, T. and M. VILJANEN. 1988. Biology of whitefish (*Coregonus lavaretus*) in Lake Suomunjærvi, eastern Finland. Finnish Fisheries Research 9 : 191-195.

The biology of whitefish (*Coregonus lavaretus*) was studied in the mesohumic, oligotrophic Lake Suomunjærvi in 1973-1976, 1981-1982 and 1985. In the 1970s, the whitefish was the third most important species by biomass and in the 1980s it was the most important. The mean gill raker count of the whitefish was 40, the range being 33-45. This whitefish form does not occur in other lakes in eastern Finland, and is quite uncommon in the whole country. Due to their flexible diet and good growth rate, the whitefish of Lake Suomunjærvi could prove productive even when introduced into lakes in which the feeding conditions are poor for other whitefish forms.

TUUNAINEN, P. 1982. Session 1: Stocking with non-salmonids – Coregonids. European Inland Fisheries Advisory Commission Technical Paper 42 : 6-9.

It is obvious that different whitefish species give very different results when stocked or introduced into the same waterbody. Hybridization between native and introduced species or between various introduced species has taken place in some cases, yielding a new stock different from either parent. The results of stockings with fry or fingerlings of species already present in a lake indicate that whereas stockings with fingerlings could decrease the native stock, stockings with fry usually had no effect. With the increase in the size of the fish stocked, the possibility of total failure decreased. In the Oulujoki watercourse, stocking of 109 small forest lakes with whitefish fry resulted in recaptures from 91 lakes, natural reproduction in 56 lakes and failure in only 18 lakes. Based on the influence of stockings on whitefish catches and the costs of fishing, a net profit of about 30-60% on investments for stocking with fingerlings is obtained.

VAN OOSTEN, J. 1937. Artificial propagation of commercial fish of the Great Lakes. Transactions of the Annual North American Wildlife Conference 2 : 605-612.

When planting fish into the Great Lakes, the government cannot afford to rear the fish past the fry stage. Unfortunately, it is not clear whether fry plantings in general contribute to already present fish populations. There is no evidence that whitefish fry plantings into the Great Lakes are contributing to the commercial fishery. Other studies conducted on Ostego Lake, New York and Lake Constance, Germany, have shown no correlation between the number of fry planted and the subsequent contribution to year-class.

VAN OOSTEN, J. 1942. Relationship between plantings of fry and production of whitefish on Lake Erie. Transactions of the American Fisheries Society 71 : 118-121.

An attempt was made to substantiate the repeated assertions of the commercial fishermen on the Great Lakes and of others that there was a direct causal relationship between the plantings of whitefish fry and subsequent catch. The records of whitefish fry plantings in Lake Erie during the years, 1920-1937, were correlated with those of catch during the period, 1923-1940. No causal relationship could be demonstrated between the two sets of data. Whitefish production in Lake Erie is not dependent on or noticeably affected by the planting of fry.

WANZENBOECK, J. and A. JAGSCH. 1998. Comparison of larval whitefish densities in lakes with different schemes of larval stocking and fishing practice. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 497-505.

In order to test the hypothesis that stocking of hatchery reared whitefish (*Coregonus lavaretus*) larvae stabilizes and increases fishery yields, we conducted larval surveys in two lakes differing in their respective schemes of larval stocking and fishery practice. In one lake (Lake Hallstætter See) there is no stocking of whitefish larvae and the fishing effort is confined in order to prevent overfishing of the stock. In the other lake (Lake Mondsee), stocking of hatchery-reared whitefish larvae takes place on a low level (148-798 larvae-per-hectare), compared to other lakes, and fishing effort is much higher. The larval surveys of 1995 and 1996 in Lake Mondsee revealed that no significant increase in catch numbers after stocking unfed larvae was evident and, therefore, no beneficial effects of this stocking on commercial catches can be inferred. This is confirmed by generally low but highly variable yields in Lake Mondsee. The more restricted fishery in Lake Hallstætter See leads to comparatively higher and more stable yields in commercial catches which indicate a higher standing stock. This resulted in much higher densities of larvae during the peak hatching period in March and April. The comparison of the two lakes suggests that restrictive fishing regulations are preferable to stock enhancement by planting of hatchery reared, unfed larvae, at least at the level practiced in Lake Mondsee. However, when compared to literature data, more intense and regular stocking (30 to 60 times more larvae on an areal basis) can lead to even higher and stable yields.

WARING, P. 1985. Preliminary stocking model for yearling whitefish introductions. Lake Simcoe Fisheries Assessment Unit Report 1985-4. Ontario Ministry of Natural Resources. Sutton West, Ontario.

The primary purpose of this work is to establish a reasonable “ball park” estimate of the annual stocking rate for yearling whitefish introductions in Lake Simcoe.

The stocking models developed herein predict the population size and the harvest in numbers for two survivorship scenarios at three stocking levels (1.0×10^5, 3.0×10^5 and 5.0×10^5). They utilize the best estimates of maximum and minimum mortality (A) and exploitation rate for pre-recruits and recruits. The estimates of mortality and exploitation used in the exercise are derived from an assessment and comparison of historical fisheries data.

The only output consideration of the model is the harvest in numbers. Additional considerations for model improvements are listed.

WELCOMME, R. L. 1988. International introductions of inland aquatic species. FAO Fisheries Technical Paper No. 294. Food and Agriculture Organization of the United Nations. Rome, Italy.

The lake whitefish (*Coregonus clupeaformis*) is an important commercial species in oligotrophic lakes throughout its native range (Canada and northern U.S.A.). The species prefers cold temperate conditions and has been stocked into high Andean lakes in two countries in Southern Latin America. It is currently reproducing in Chile where it was originally introduced in 1930.

Coregonus lavaretus, the common whitefish, is native to northern Europe, Great Britain and alpine areas of central Europe. It is an important commercial species in oligotrophic lakes throughout its native range. The species prefers cold temperate conditions and has been stocked into many waters in Europe outside its original range. These attempts have frequently been successful. The common whitefish is a facultative anadrome and the establishment of a riverine stock in the River Danube implies that the species has also become established in other riparian countries of that river from which its presence has not yet been reported.

WHITEHOUSE, F. C. 1948. Sport fishing in Canada. Wrigley Printing Co., Ltd. Vancouver, British Columbia.

The common or eastern whitefish is native to northern British Columbia yet also occurs in the south, by introduction, in lakes such as Okanagan and Shuswap. The fish in Okanagan Lake are not thriving and it appears that they have added a negative element to the fish assemblage by possibly preying upon the eggs of trout and salmon.

WILLOX, C. C. 1990. Lake Simcoe: A case history of fish stocking. File Report. Lake Simcoe Fisheries Assessment Unit, Ontario Ministry of Natural Resources. Sutton West, Ontario.

Lake Simcoe is southern Ontario's largest body of water, excluding the Great Lakes, and is Ontario's fifth largest inland lake, having a surface area of 725 km^2. The watershed (2,840 km^2) is subjected to intensive agriculture and an increasing rate of permanent and seasonal human settlement. These factors contribute to a high rate of nutrient loading and eutrophication-related stresses. Two of the more highly prized fish species, lake trout and lake whitefish, have suffered from recruitment failure and their populations are now supplemented by fish stocking programs.

Lake whitefish were stocked sporadically in Lake Simcoe from 1880 to 1957. During this period, a total of 28 million fry were released. Decreasing catches and increasing growth rates in the late 1960s and early 1970s indicated that this species was now experiencing the reductions in recruitment previously observed in lake trout. Interest in lake whitefish stocking was renewed and in 1982, 13,222 lake whitefish of Lake Simcoe origin were released into the lake. Stocking has continued annually since this time with the numbers increasing to the present level of approximately 160,000 per year. Of this total, 60,000 are planted in the fall as fingerlings and the remaining 100,000 are released the following spring. Some stocked whitefish have been recovered in assessment programs but several more years are required before the success of the stocking efforts can be properly evaluated and comparisons made between fall-fingerling and yearling plants. Natural recruitment of lake whitefish remains very low with only the occasional young whitefish without fin clips being captured.

WILLOX, C. C. 1991. Interim report on the status of hatchery-reared lake whitefish in Lake Simcoe. Presented at the White Lake Fish Culture Research and Development Meeting, May 9, 1991. File Report 1991-8. Ontario Ministry of Natural Resources. Sharbot Lake, Ontario.

Lake whitefish stocking into Lake Simcoe recommenced in 1982 and annual plantings of 60-80,000 yearling or fall fingerling fish have been made since that time. All planted fish originated from Lake Simcoe stock, were reared at the White Lake Fish Culture Station near Sharbot Lake, Ontario, and bore a distinctive fin clip. Stocking locations have varied among 7-8 different sites. Returns of stocked fish have been determined through fall index netting and creel census projects as well as a volunteer angler program. A series of tables are presented outlining the numbers of fish sampled over the past nine year (1983-1991) period.

WILLOX, C. C. 1997. 1996 Lake Simcoe fall index netting program. Lake Simcoe Fisheries Assessment Unit Update No. 1997-2. Ontario Ministry of Natural Resources. Sutton West, Ontario. 2 p.

The Lake Simcoe fall index trap netting program has been an annual event since the 1950s. Between the second week of September (the beginning of the trout spawning run) and the last week of November (the end of the whitefish spawning run), 1996, a ten foot trap net was set on two Lake Simcoe spawning shoals: North Georgina Island and Strawberry Island. Eggs are collected from both species. Of the total catch whitefish composed 47%, while lake trout made up 17%. Of those lake trout caught during this survey 99.76% were of hatchery origin, while only 69.6% of the whitefish were. These egg collections will result in the stocking of approximately 100,000 lake trout yearlings in the spring of 1998 and 140,000 lake whitefish fingerlings in the fall of 1997. The recent increase in lake whitefish numbers is due to stocking and not natural reproduction.

WILLOX, C. and F. AMTSTAETTER. 1997. Update on the status of lake whitefish in Lake Simcoe. Prepared for Committee on the Status of Species at Rick in Ontario (COSSARO) Sub-Committee meeting. Lake Simcoe Fisheries Assessment Unit, Ontario Ministry of Natural Resources. Sutton West, Ontario.

Lake whitefish data is collected twice annually through fall index netting and winter creel surveys. Stocked whitefish first appeared in the winter creel in 1987 and have since increased to a level of 62.2% of the catch in 1997. Age distribution demonstrates that the wild lake whitefish population is older than the stocked population. Fall index netting shows that the proportion of stocked fish has increased from 1984-1996. Although there is a consistent appearance of wild lake whitefish in the fall index netting surveys, there is no evidence that any natural recruitment is occurring.

WILMOT, S. 1877. Report of the Commissioner of Fisheries. Supplement No. 4 to the Ninth Annual Report of the Minister of Marine and Fisheries for the year 1876. Ottawa, Ontario.

In 1876, 8 million whitefish were distributed from the Sandwich fish hatchery in Ontario, while only 200,000 were distributed from the Newcastle hatchery. Since its opening, 1,750,000 whitefish have been stocked from the Newcastle hatchery into Lake Ontario

WOLOS, A., S. FALKOWSKI and A. ABRAMCZYK. 1995. Management of coregonines in the Big State Fish Farm Elk – production, stocking practice and effectiveness. Proceedings of the Fifth International Symposium: Biology and Management of Coregonid Fishes – 1993. Advances in Limnology 46 : 387-396.

The State Fish Farm Elk encompasses about 12,000 ha of lakes and manages populations of *Coregonus* in several of them. Multi-year data on the catches and stocking of coregonines were analyzed and the effectiveness of management practices was evaluated. The most important lake on the farm was Lake Rospuda (2.8% of the total lake area of the farm) that produced landings of vendace (*C. albula*) and European whitefish (*C. lavaretus*). Lake Rospuda also played a key role in larval fish production and supplied more than 40% of the eggs on the farm. The results presented in this paper revealed that comprehensive valuation of stocking and catches was an important tool for enhancing the management of coregonine fishes as well as the efficiency of the whole farm.

WOLOS, A., S. FALKOWSKI and P. CZERKIES. 1998. Changes in whitefish (*Coregonus lavaretus*) and vendace (*Coregonus albula*) fisheries in Lake Goldopiwo due to eutrophication and management practices. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 523-530.

Whitefish (*Coregonus lavaretus*) was introduced (probably from Lake Peipus) into Lake Goldopiwo, Northeast Poland, at the end of the nineteenth century. From 1922 to 1934, the lake constituted a basic source of the stocking material for numerous lakes of the region. Lake Goldopiwo became one of the three Polish lakes with the highest landings and yields of whitefish. In 1951-1995, the average annual catch was 4,778 kg (5.54 kg/ha), and was as much as almost 18% of the total catch. At the same time, the average, especially in the 1990s, catches as well as the effectiveness of whitefish and vendace stocking has declined dramatically. This has been coupled with an increase of cyprinids, reflecting changes in the fish stocks caused by lake eutrophication. The paper presents the history of coregonine management in Lake Goldopiwo from 1951 to 1995, with attention paid to the changes in the effectiveness of whitefish management on the background of eutrophication, changes in the catches of other fish species, and the most important managerial factors.

WRIGHT, B. H. and R. D. SOPUCK. 1979. A history of fish stocking in Northern Manitoba. MS Report 79-6. Manitoba Department of Mines, Natural Resources and Environment, Fisheries Research. Winnipeg, Manitoba. 69 p.

Wapun Lake, which measures 617.5 square acres was stocked with whitefish during the years 1951, 1952, 1953 and 1959, with 850,000 (eggs), 1,850,000 (eggs), 1,500,000 (eyed eggs) and 50,000 (fry), respectively.

ZABLECKIS, J. 1998. Rearing peculiarities of Plateliai whitefish (*Coregonus lavaretus*) underyearlings. Fishery and Agriculture in Lithuania 3(2) : 175-178.

Previous attempts to introduce whitefish (*Coregonus lavaretus*) have shown the introduction of small larvae into water bodies to be ineffective. The control catch results of 1993 speak about the formation of a large maternal flock in the lake. The principle moment in larvae rearing is their early development stages when a sufficient, preferably natural, forage base must be ensured. The forage consisted of infusoria. In the early development stages larvae infusoria or small live organisms are indispensable. Later it is possible and even necessary to replace them by some other food of greater size. A two-week spring period in fish farming and in nature in general is of great significance: the air warms up, fauna revives, zooplankton rapidly develops, therefore, it is an appropriate time to introduce the reared fish into ponds. Natural forage ensures normal nutrition for the whitefish and, thus, increases their vital capacity. The yield of underyearlings in autumn catches made up to 91% of the introduced larvae which indicated quite satisfactory life conditions for underyearlings during vegetation period.

ZITZOW, R. E. and J. L. MILLARD. 1988. Survival and growth of lake whitefish (*Coregonus clupeaformis*) larvae fed only formulated dry diets. Aquaculture 69 : 105-113.

Two separate 50 day trials were conducted to compare survival and growth of lake whitefish (*Coregonus clupeaformis*) larvae fed only various formulated dry diets. At the end of Trial 1 the mean survival (67.7%) and size (185 mg/fish) of larvae fed the commercial diet Larval AP100 were significantly ($P<0.05$) greater than those of larvae fed four other diets (27.0-53.0% survival and 29-54 mg/fish). However, scoliosis, lordosis and erratic swimming behavior were observed in 30-50% of the larvae in all diet groups, indicating possible nutrient deficiencies. At the end of Trial 2 there was no significant difference in survival, which ranged from 96.0-97.7% for all tanks. Larvae fed the commercial diet Fry Feed Kyowa B (FFKB) were significantly larger (622 mg/fish) than larvae fed three other diets (301-464 mg/fish). Slight scoliosis, lordosis and erratic swimming behavior were observed in a few fish in two diet groups near mid-trial but were not evident at the end of the trial. Larvae fed FFKB did not display these abnormalities, fed more aggressively and schooled in a more cohesive manner than larvae fed any of the other diets tested, indicating it may be suitable as an initial diet for rearing lake whitefish larvae.

Acknowledgements

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Subject Key

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1.1 Fish culture and rearing practices
1.2 Reports of stocking activities

2.0 Stocking Guidelines and Practices

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2.2 Stocking Frequency
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2.8 Fish Community in Stocked Waters
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1.0 General References

1.1 Fish Culture and Rearing Practices

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2.1 General

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2.5 Age/Size of Fish Stocked

APPENDIX 1. Lake whitefish stocking in Ontario waters, 1877-2000. Information was obtained through Federal and Provincial Annual Fisheries Reports (1877-1989), OFIS database (1990-1994) and Provincial Fish Culture Station records (1995-2000).

Year	Eggs	Eyed Eggs	Fry	Fingerlings	Yearlings	Unknown	Total
1877	23,500,000	-	7,950,000	-	-	-	31,450,000
1878	-	-	-	-	-	-	-
1879	-	-	-	-	-	-	-
1880	-	-	-	-	-	-	-
1881	-	-	-	-	-	-	-
1882	-	-	-	-	-	-	-
1883	-	-	-	-	-	-	-
1884	-	-	30,500,000	-	-	-	30,500,000
1885	-	-	46,500,000	-	-	-	46,500,000
1886			Information Not Available				
1887	-	-	32,870,000	-	-	-	32,870,000
1888	-	-	44,100,000	-	-	-	44,100,000
1889	-	-	23,800,000	-	-	-	23,800,000
1890	-	-	32,750,000	-	-	-	32,750,000
1891	-	-	37,440,000	-	-	-	37,440,000
1892	-	-	63,360,000	-	-	-	63,360,000
1893	-	-	73,660,000	-	-	-	73,660,000
1894	-	-	52,120,000	-	-	-	52,120,000
1895	-	-	77,800,000	-	-		77,800,000
1896	-	-	65,900,000	-	-	-	65,900,000
1897	-	-	77,300,000	-	-	-	77,300,000
1898			Information Not Available				
1899	-	-	93,350,000	-	-	-	93,350,000
1900	-	-	89,360,000	-	-	-	89,360,000
1901	-	-	87,700,000	-	-	-	87,700,000
1902	-	-	85,000,000	-	-	-	85,000,000
1903	-	-	69,000,000	-	-	-	69,000,000
1904	-	-	-	-	-	-	-
1905	-	-	80,000,000	-	-	-	80,000,000
1906	-	-	-	-	-	-	-
1907	-	-	62,025,000	-	-	-	62,025,000
1908	-	-	79,140,000	-	-	-	79,140,000
1909	-	-	-	-	-	-	-
1910	-	-	76,000,000	-	-	-	76,000,000
1911	-	-	-	-	-	-	-
1912	-	-	-	-	-	-	-
1913	-	-	-	-	-	-	-
1914	-	-	-	-	-	-	-
1915	-	-	-	-	-	-	-
1916	-	-	-	-	-	-	-
1917	-	-	-	-	-	-	-
1918	-	-	15,500,000	-	-	-	15,500,000
1919	-	-	7,740,000	-	-	-	7,740,000
1920	-	-	43,335,000	-	-	-	43,335,000
1921	-	-	115,950,000	-	-	-	115,950,000
1922	-	-	189,775,000	-	-	-	189,775,000
1923	-	-	264,400,000	-	-	-	264,400,000
1924	-	-	437,469,000	-	-	-	437,469,000

Year	Eggs	Eyed Eggs	Fry	Fingerlings	Yearlings	Unknown	Total
1925	-	-	246,126,500	-	-	-	246,126,500
1926	-	-	260,575,000	-	-	-	260,575,000
1927	-	-	312,829,750	-	-	-	312,829,750
1928	-	-	405,572,000	-	-	-	405,572,000
1929	-	-	427,084,000	-	-	-	427,084,000
1930	-	-	277,100,000	-	-	-	277,100,000
1931	1,500,000	-	342,107,000	-	-	-	343,607,000
1932	-	-	229,035,000	-	-	-	239,035,000
1933	-	-	372,111,000	-	-	-	372,111,000
1934	-	-	376,777,000	-	-	-	376,777,000
1935	-	-	296,482,000	-	-	-	296,482,000
1936	-	-	428,402,000	-	-	-	428,402,000
1937	-	-	383,683,900	-	-	-	383,683,900
1938	-	-	323,700,500	-	-	-	323,700,500
1939	-	-	326,657,000	-	-	-	326,657,000
1940	-	-	403,339,000	-	-	-	403,339,000
1941	-	-	375,960,500	-	-	-	375,960,500
1942	250,000	-	394,802,000	-	-	-	395,052,000
1943	1,500,000	-	369,777,500	-	-	-	371,277,500
1944	3,000,000	-	256,035,000	-	-	-	259,035,000
1945	-	-	240,786,775	-	-	-	240,786,775
1946	-	-	205,590,000	-	-	-	205,590,000
1947	-	-	233,316,125	-	-	-	233,316,125
1948	-	-	243,482,000	-	-	-	243,482,000
1949	-	-	245,150,000	-	-	-	245,100,000
1950	-	-	235,200,000	-	-	-	235,200,000
1951	-	-	121,185,000	-	-	-	121,185,000
1952	-	-	200,400,000	-	-	-	200,400,000
1953	-	-	186,700,000	-	-	-	186,700,000
1954	42,665,000	-	139,210,000	-	-	-	181,875,000
1955	67,165,000	-	102,950,000	-	-	-	170,115,000
1956	51,177,500	-	11,130,000	-	-	-	62,307,500
1957	13,435,000	-	67,275,000	-	-	-	80,710,000
1958	30,940,000	-	47,515,000	-	-	-	78,455,000
1959	1,000,000	-	44,985,000	-	-	-	45,985,000
1960	12,000,000	-	62,993,000	-	-	-	74,993,000
1961	13,875,000	-	53,685,000	-	-	-	67,560,000
1962	-	-	46,575,000	-	-	-	46,575,000
1963	-	-	46,350,000	-	-	-	46,350,000
1964	-	-	27,090,000	-	-	-	27,090,000
1965	-	-	24,030,000	-	-	-	24,030,000
1966	-	-	19,845,000	-	-	-	19,845,000
1967	300,000	-	240,000	-	-	-	540,000
1968	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-

Year	Eggs	Eyed Eggs	Fry	Fingerlings	Yearlings	Unknown	Total
1978	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-
1982	-	-	-	-	13,222	-	13,222
1983	-	-	-	-	14,661	-	14,661
1984	-	-	-	-	15,398	-	15,398
1985	-	-	-	-	27,082	-	27,082
1986	-	-	-	67,861	29,971	-	97,832
1987	-	-	-	64,949	99,699	-	164,648
1988	-	-	-	81,909	95,349	-	177,258
1989	-	-	-	53,072	87,789	-	140,861
1990	-	-	-	62,351	73,620	-	135,971
1991	-	-	-	76,862	63,067	-	139,929
1992	-	-	-	141,691	60,480	-	202,171
1993	-	-	-	143,319	-	-	143,319
1994	-	-	-	146,121	-	-	146,121
1995	-	-	-	79,301	-	-	79,301
1996	-	-	-	134,432	-	-	134,432
1997	-	-	-	144,210	-	-	144,210
1998	-	-	-	118,147	-	-	118,147
1999	-	-	-	188,068	-	-	188,068
2000	-	-	-	164,190	-	-	164,190

Appendix 2. Lake whitefish stocking in Lake Simcoe, Ontario, 1888-2000. Information was obtained through Federal and Provincial Annual Fisheries Reports (1877-1989), OFIS database (1990-1994) and Provincial Fish Culture Station records (1995-2000).

Year	Eggs	Fry	Fingerlings	Yearlings	Unknown	Total
1888	-	200,000	-	-	-	200,000
1889	-	200,000	-	-	-	200,000
1890	-	100,000	-	-	-	100,000
1891	-	900,000	-	-	-	900,000
1892	-	250,000	-	-	-	250,000
1893	-	200,000	-	-	-	200,000
1894	-	250,000	-	-	-	250,000
1895	-	300,000	-	-	-	300,000
1896	-	300,000	-	-	-	300,000
1897	-	300,000	-	-	-	300,000
1898				Information Not Available		
1899	-	300,000	-	-	-	300,000
1900	-	300,000	-	-	-	300,000
1901	-	300,000	-	-	-	300,000
1902	-	-	-	-	-	-
1903	-	-	-	-	-	-
1904				Information Not Available		
1905	-	-	-	-	-	-
1906				Information Not Available		
1907	-	-	-	-	-	-
1906	-	-	-	-	-	-
1909	-	-	-	-	-	-
1910	-	-	-	-	-	-
1911	-	-	-	-	-	-
1912	-	-	-	-	-	-
1913	-	-	-	-	-	-
1914	-	-	-	-	-	-
1915	-	-	-	-	-	-
1916	-	-	-	-	-	-
1917	-	-	-	-	-	-
1918	-	-	-	-	-	-
1919	-	-	-	-	-	-
1920	-	-	-	-	-	-
1921	-	-	-	-	-	-
1922	-	-	-	-	-	-
1923	-	-	-	-	-	-
1924	-	-	-	-	-	-
1925	-	-	-	-	-	-
1926	-	-	-	-	-	-
1927	-	-	-	-	-	-
1928	-	-	-	-	-	-
1929	-	-	-	-	-	-
1930	-	-	-	-	-	-
1931	-	-	-	-	-	-
1932	-	-	-	-	-	-
1933	-	-	-	-	-	-
1934	-	-	-	-	-	-
1935	-	-	-	-	-	-

Year	Eggs	Fry	Fingerlings	Yearlings	Unknown	Total
1936	-	3,000,000	-	-	-	3,000,000
1937	-	2,200,000	-	-	-	2,200,000
1938	-	2,500,000	-	-	-	2,500,000
1939	-	1,500,000	-	-	-	1,500,000
1940	-	1,500,000	-	-	-	1,500,000
1941	-	3,000,000	-	-	-	3,000,000
1942	-	-	-	-	-	-
1943	-	-	-	-	-	-
1944	-	1,000,000	-	-	-	1,000,000
1945	-	-	-	-	-	-
1946	-	-	-	-	-	-
1947	-	-	-	-	-	-
1948	-	-	-	-	-	-
1949	-	-	-	-	-	-
1950	-	500,000	-	-	-	500,000
1951	-	-	-	-	-	-
1952	-	-	-	-	-	-
1953	1,000,000	-	500	-	-	1,000,500
1954	750,000	30,000	600	-	-	780,600
1955	-	410,000	900	-	-	410,900
1956	-	-	-	-	-	-
1957	-	-	-	-	-	-
1958	-	-	-	-	-	-
1959	-	-	-	-	-	-
1960	-	-	-	-	-	-
1961	-	-	-	-	-	-
1962	-	-	-	-	-	-
1965	-	-	-	-	-	-
1966	-	-	-	-	-	-
1967	-	-	-	-	-	-
1968	-	-	-	-	-	-
1969	-	-	-	-	-	-
1970	-	-	-	-	-	-
1971	-	-	-	-	-	-
1972	-	-	-	-	-	-
1973	-	-	-	-	-	-
1974	-	-	-	-	-	-
1975	-	-	-	-	-	-
1976	-	-	-	-	-	-
1977	-	-	-	-	-	-
1978	-	-	-	-	-	-
1979	-	-	-	-	-	-
1980	-	-	-	-	-	-
1981	-	-	-	-	-	-
1982	-	-	-	13,222	-	13,222
1983	-	-	-	14,661	-	14,661
1984	-	-	-	15,398	-	15,398
1985	-	-	-	27,082	-	27,082
1986	-	-	67,861	29,971	-	97,832
1987	-	-	64,949	99,699	-	164,648
1988	-	-	81,909	95,349	-	177,258
1989	-	-	53,072	87,789	-	140,861
1990	-	-	62,351	73,620	-	135,971

Year	Eggs	Fry	Fingerlings	Yearlings	Unknown	Total
1991	-	-	76,862	63,067	-	139,929
1992	-	-	141,691	60,480	-	202,171
1993	-	-	143,319	-	-	143,319
1994	-	-	146,121	-	-	146,121
1995	-	-	79,301	-	-	79,301
1996	-	-	134,432	-	-	134,432
1997	-	-	144,210	-	-	144,210
1998	-	-	118,147	-	-	118,147
1999	-	-	188,068	-	-	188,068
2000	-	-	164,190	-	-	164,190

APPENDIX 3. Proportion of hatchery-reared lake whitefish (*Coregonus clupeaformis*) in Lake Simcoe netting and survey programs, 1983-1999 (from Amtstaetter 2000a).

Year	Fall Netting on Spawning Shoals	Winter Angling Creel Surveys	Angler Catch Sampling
1983	0	0	-
1984	0.1	-	0
1985	0.1	-	0
1986	1.8	0	-
1987	8.5	6.6	-
1988	8.2	-	3.5
1989	18.3	11.1	-
1990	25.3	-	29.1
1991	47.4	17.9	-
1992	48.4	-	38.7
1993	55.9	33.4	-
1994	57.2	-	42.6
1995	66.2	-	56.7
1996	69.6	54.2	-
1997	73.1	62.2	-
1998	75.7	-	50.3
1999	79.8	58.8	-

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