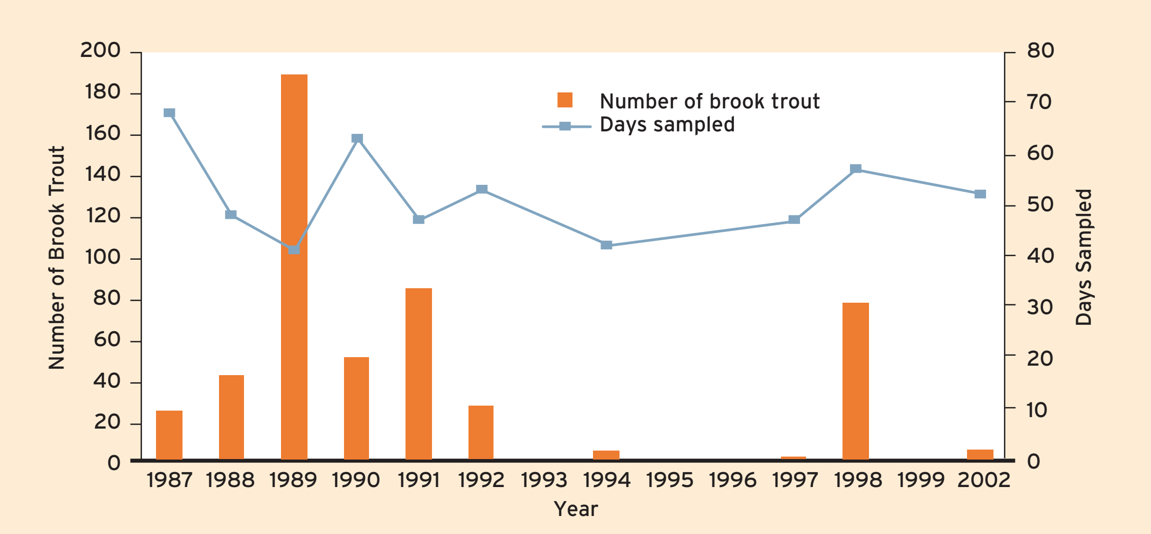


FIGURE 7-4 Brook trout abundance recorded from a fish weir set near the mouth of Sky Pilot Creek during fall, 1987-2002. Zero values indicate years when the creek was not surveyed.

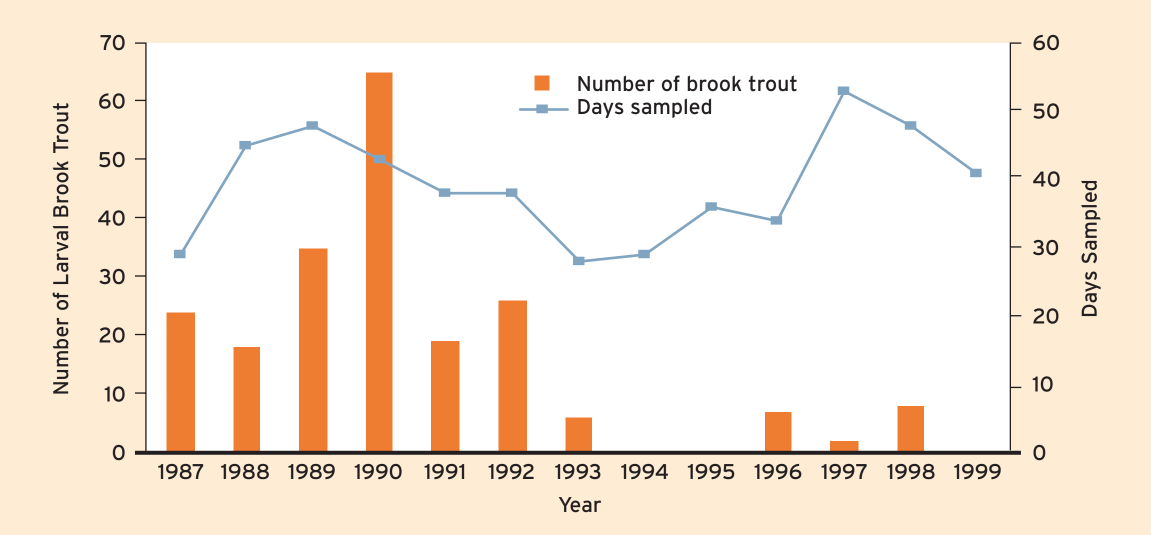


FIGURE 7-5 Larval brook trout abundance in Leslie Creek from 1986 to 1999. Larval drift was sampled in all years and the same number of drift traps (n = 2) was used each year.

Also, the effects of genetic isolation on such small populations remain uncertain and may not become apparent for many years to come. There appeared to be only a remnant brook trout population in Wilson Creek shortly after impoundment, which may be attributable to heavy angling pressure in the 1970s and 1980s. Because of their isolation, these populations remain extremely vulnerable to exploitation and habitat degradation.

While there has been little change in the mean size of trout in any stream since construction of the Limestone G.S., there are some indications that the mean age of brook trout increased after impoundment downstream of the generating station (Figure 7-5). This may have been a reflection of reduced mortality rates following the departure of large numbers of construction workers.

Located approximately midway down the Limestone Forebay, Leslie Creek was subject to a much larger degree of habitat loss than creeks at the upstream end of the forebay. Prior to impoundment, the lower reach of Leslie Creek was comprised of riffle-pool-run habitat sequences that offered optimal brook trout habitat. Impoundment of the forebay inundated approximately 2.5 km of Leslie Creek to a point just downstream of a known spawning pool, leaving less than 1 km of optimal habitat unaffected. Inundation of riffles and decreases in water velocities also

FIGURE 7-6 Number of adult brook trout captured moving upstream in fish weirs set in the Limestone and Weir rivers during fall, 1990-2003

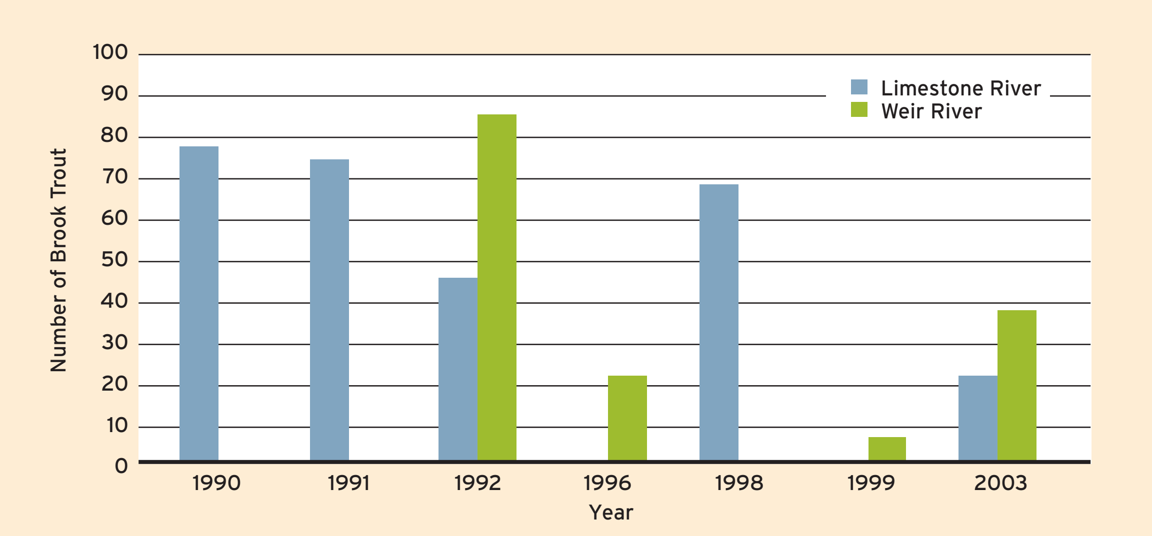
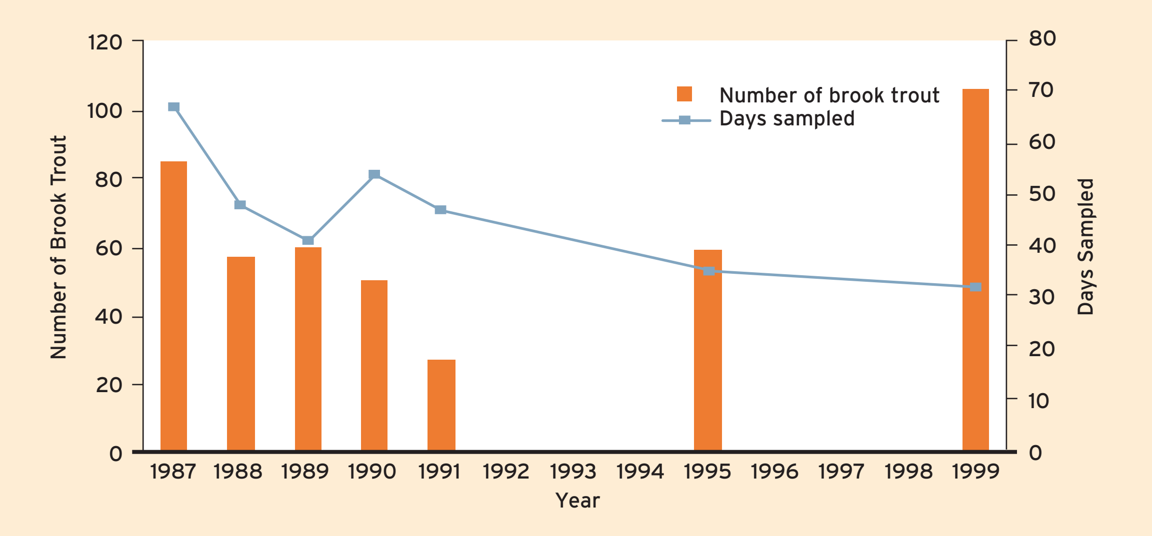


FIGURE 7-7 Brook trout abundance recorded from a fish weir set near the mouth of 9-Mile Creek during fall, 1987-1999. Zero values indicate years when the creek was not surveyed.



effectively removed any predator barrier that may have existed in the lower reach of the creek prior to impoundment.

Leslie Creek continued to support brook trout ten years after impoundment, although in reduced numbers. Reproductive activity in the creek appeared to decrease substantially after impoundment (Figure 7-6), but was still occurring ten years later. Juvenile brook trout abundance was relatively low compared to spawning tributaries downstream of the Limestone G.S. (e.g., Moondance and CN creeks).

Although Leslie Creek continues to support a brook trout population, its capacity to produce and support brook trout has been lowered by the proportion of habitat lost in the lower reach. The brook trout population has become extremely vulnerable because of its small size and isolation within the forebay reach, and may be subject to future impacts of genetic isolation.

Brook trout populations downstream of the Limestone G.S. did not change substantially in the ten years following construction. Fall movements into the Weir and Limestone rivers remained similar, with approximately 50-100 brook trout migrating up each river between August 22 and October 10 annually (Figure 7-7). Fall brook trout catches in 9-Mile and

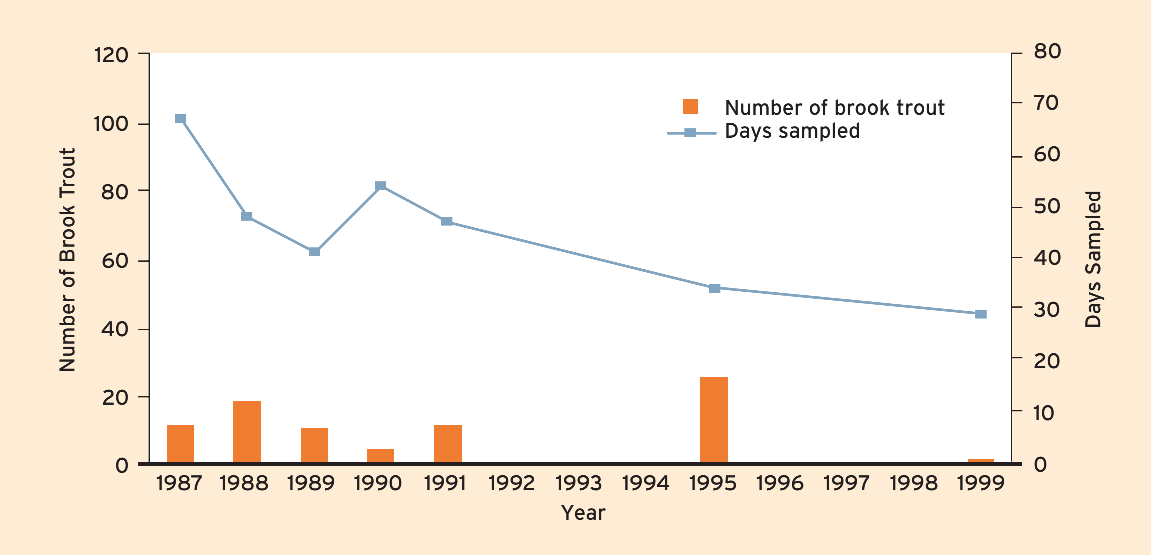


FIGURE 7-8
Brook trout abundance recorded from a fish weir set near the mouth of 12-Mile Creek during fall, 1987-1999. Zero values indicate years when the creek was not surveyed.

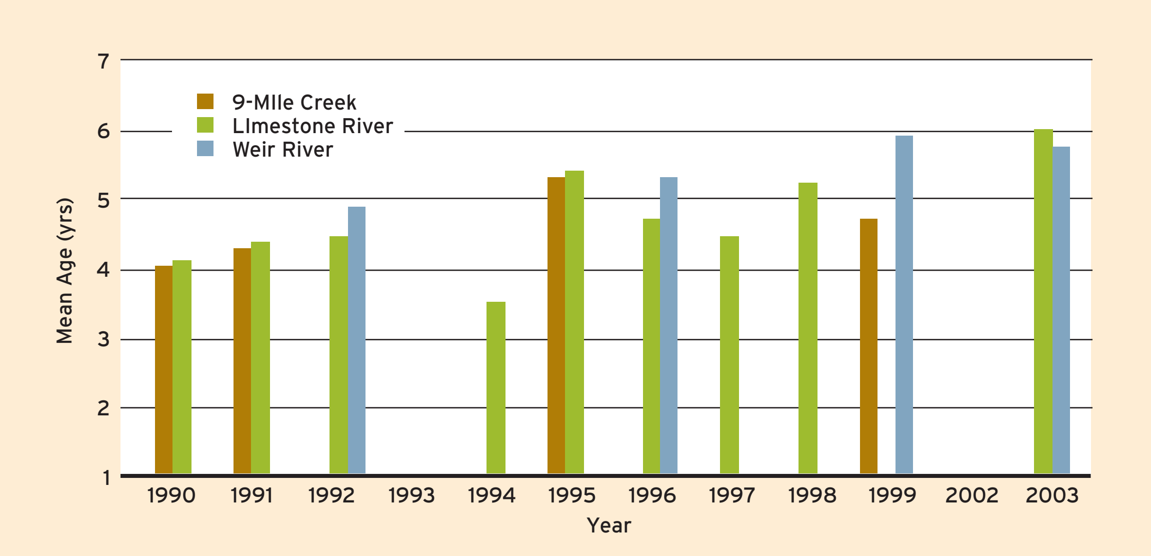


FIGURE 7-9
Mean age of brook trout captured in fish weirs or hoop nets set in 9-Mile Creek and in the Limestone and Weir rivers, 1990-2003.

12-Mile creeks also remained similar following construction of the generating station (Figures 7-8 and 7-9).

Construction of an access road to facilitate investigation of the Conawapa site in 1991 required the installation of large culverts on several brook trout nursery streams (i.e., Sundance, Beaver, Swift, Tiny, Goose, and Fifteen creeks). Concrete aprons at the entrances and exits of the culverts were modified to contain flows during low-flow periods to enable fish passage (Photo 7-14). Studies following construction showed that brook trout could move both upstream and downstream through the culverts at moderate discharges. At low flows, fish passage was thought to be limited by both the culverts and natural obstructions in the stream channel. Small but stable electrofishing and hoopnet catches in the nursery streams since construction of the generating station reflect the ability of the Conawapa access road culverts to provide adequate fish passage to the local brook trout populations.

Moondance and CN creeks are relatively small tributaries that support spawning populations of brook trout downstream of the Limestone Generating

FIGURE 7-10
Juvenile brook trout abundance in Moondance and CN creeks, 1987-2002. Zero values indicate years when backpack electrofishing surveys were not conducted. Sampling locations and effort were constant among survey years.

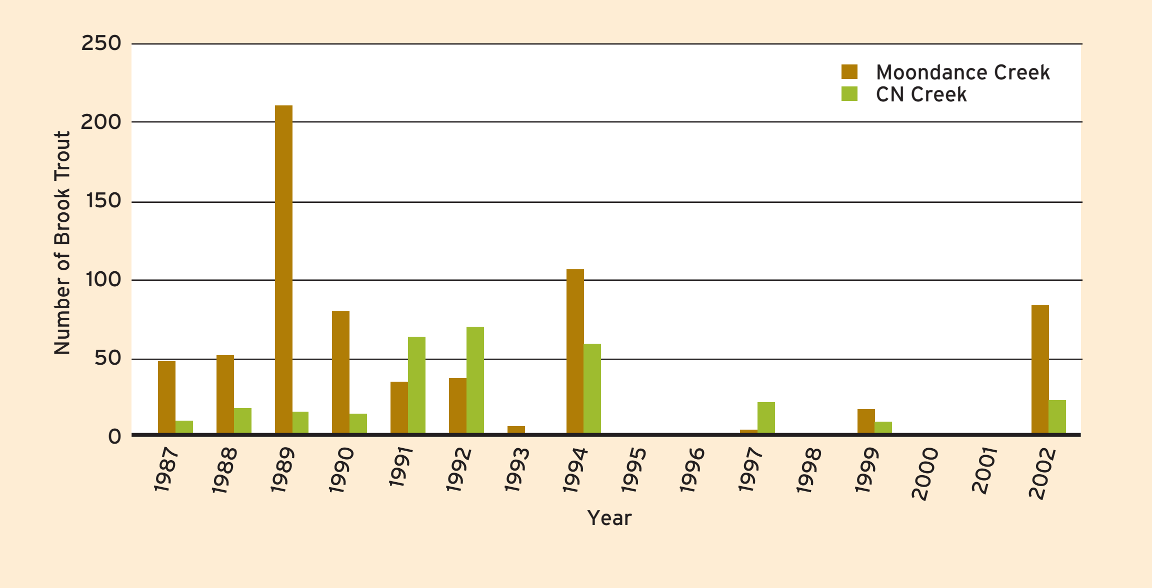


PHOTO 7-14
Culvert under the Conawapa access road that crosses over a brook trout nursery tributary of the lower Nelson River.

Station. Trout populations in both creeks have shown a high degree of variability during the aquatic monitoring programs (Figure 7-10). These findings could be related to natural annual variation in brook trout abundance or to natural environmental factors. For example, decreased catches of larval and juvenile trout in CN Creek from 1996 to 1999 were attributed to the effects of a large beaver dam near the mouth of the tributary (Photo 7-15). It was surmised that the dam was affecting drift catches by:

i) creating a barrier to mature brook trout moving upstream from the Limestone River in the fall thereby decreasing spawning activity in the creek;

ii) preventing downstream drift of larval trout from upstream of the dam; and/or

iii) altering and/or decreasing flow rates thereby decreasing sampling efficiency of traps.

Although the 1997, 1999, and 2002 electrofishing catches of juvenile trout also suggested that recruitment had decreased in CN Creek, the catches were not notably lower than pre-construction catches. The natural variability of brook trout production, especially in smaller streams (due to beaver dams and other factors) adds to the difficulty of determining how individual factors such as hydroelectric development are influencing brook trout populations in the lower Nelson River area.

7.3.2 Lake Sturgeon

Lake sturgeon (*Acipenser fulvescens*) is one of Canada's largest species of freshwater fish. Once widespread in Manitoba, overexploitation and habitat degradation over the past century have severely impacted regional and provincial populations. The

Nelson River is one of a half dozen river systems in western Canada where sturgeon continue to be found in notable numbers (Photo 7-16).

Lake sturgeon inhabit the Nelson River from its source at Lake Winnipeg to its mouth at Hudson Bay. Sturgeon in the reach of the river upstream of the Limestone G.S. have been subjected to substantial habitat alterations as a result of hydroelectric development (also see Khoroshko 1972; Apperson and Anders 1991; Parsley and Beckman 1994) and a long history of commercial and domestic exploitation. Downstream of the Limestone G.S., sturgeon have seen fewer habitat alterations, lower exploitation, and represent the least affected riverine population in the Nelson River. During his investigation of Hudson Bay fisheries in 1914, Comeau (1915) reported that lake sturgeon were "abundant in the upper waters of the Nelson (River) . . . An odd one is sometimes taken in . . . the estuaries but the proper fishing grounds are said to be at and above the Limestone Rapids". Although apparently never abundant near the mouth, sturgeon were, and still are, relatively common in the lower reach of the Nelson River between its confluence with the Limestone River (immediately downstream of the Limestone G.S.) and Deer Island, which is located approximately 80 km farther downstream (Figure 7-11).

Lake sturgeon spawn at depths of 0.5-5.0 m in areas of swift, turbulent flow or at the base of falls or obstructions that prevent further upstream movement. At completion of the Limestone Monitoring Program in 2003, the only confirmed spawning location in the lower Nelson River system was the lower reach of the Weir River (Photo 7-17), although spawning behaviour had been observed at Lower Limestone Rapids. Spawning has since been confirmed at Lower Limestone Rapids (Photo 7-18) and at the mouth of the Angling River (Figure 7-11) from lake sturgeon population surveys conducted as part of the Conawapa aquatic studies program that began in 2004. Spawning also probably occurs along the rock riprap in areas peripheral to generating station tailraces.

PHOTO 7-15
Beaver dam across a brook trout spawning tributary.

PHOTO 7-16
Lake sturgeon from the lower Nelson River.

Sturgeon generally begin to congregate near spawning areas (e.g., the mouth of the Weir River) in May and spawn in the middle of June at water temperatures of 11-17°C (Figure 7-12). Exact timing varies annually based on water temperature. Individual lake sturgeon do not spawn every year. In general, spawning periodicity is 2-3 years for males and 4-7 years for females (Harkness and Dymond 1961). Females are in spawning condition for only a brief time and seldom have free-running eggs when captured. Sturgeon generally remain in the vicinity of the spawning location for approximately two weeks and may make several forays onto the spawning

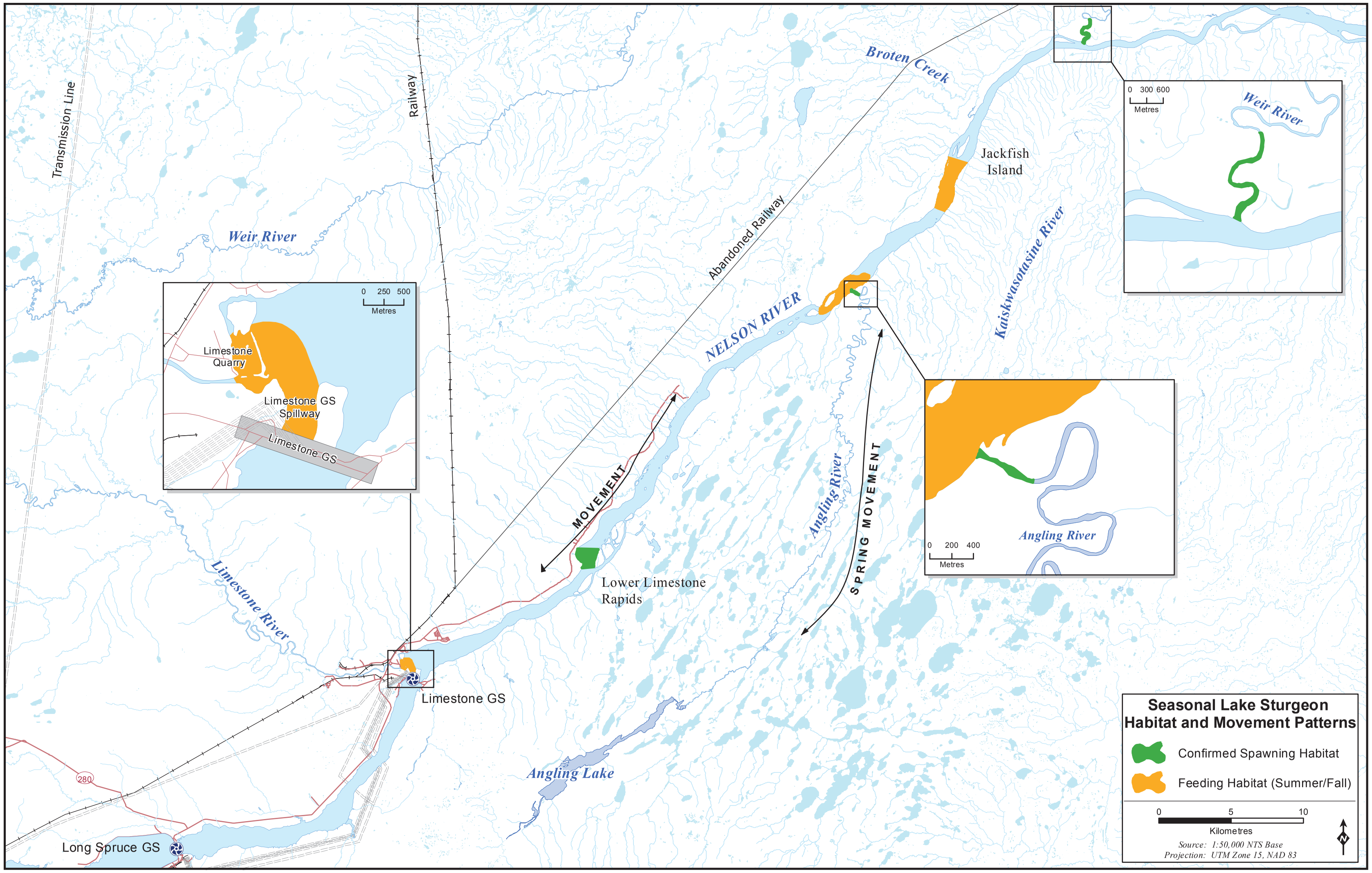


FIGURE 7-11 Seasonal lake sturgeon habitat use and movement patterns in the lower Nelson River from the Limestone G.S. downstream to the mouth of the Weir River.

PHOTO 7-17
Lake sturgeon spawning area in the Weir River.

PHOTO 7-18
Lower Limestone Rapids – a spawning area for lake sturgeon.

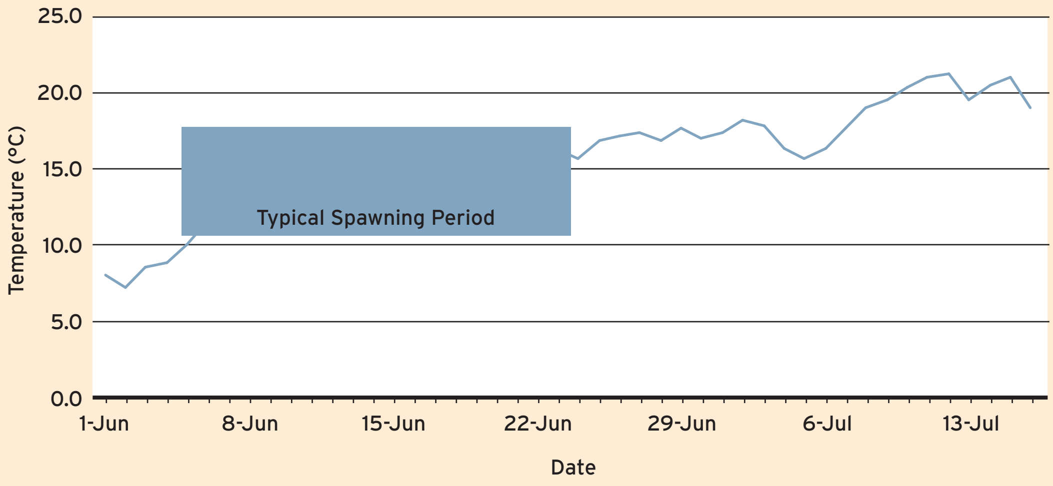


FIGURE 7-12
Mean daily water temperatures from the Weir River (1994, 1996-1998) and associated spawning periodicity for lake sturgeon.

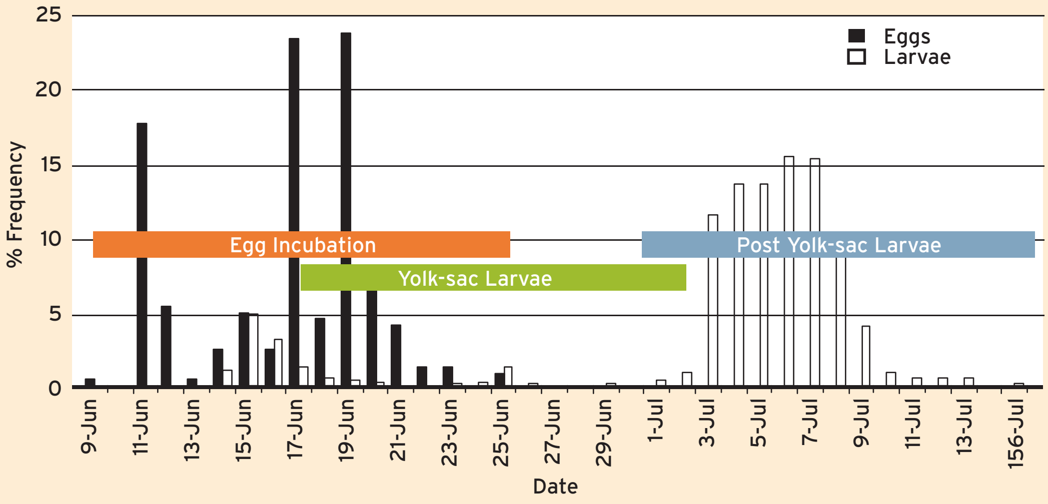


FIGURE 7-13
The daily proportion of lake sturgeon eggs and larvae captured in drift traps set in the Weir River (1994, 1996-1998) and the typical timing of egg incubation and the appearance of yolk-sac and post yolk-sac larvae in the lower Nelson River area.

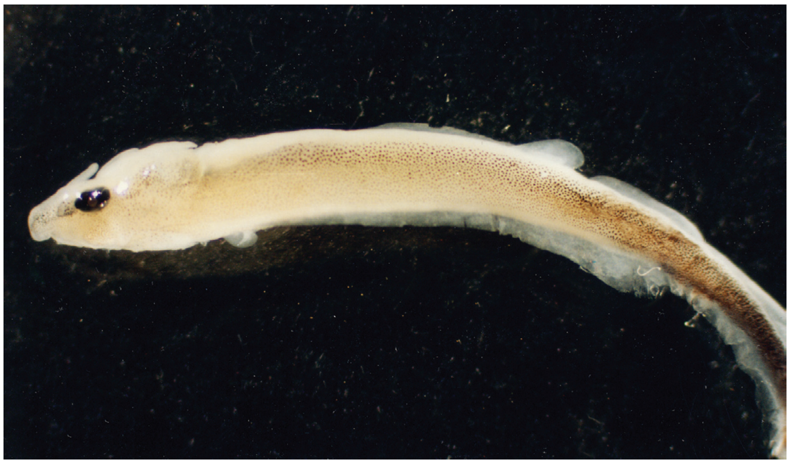


PHOTO 7-19
Post yolk-sac larval lake sturgeon.

PHOTO 7-20
Large adult lake sturgeon from the lower Nelson River.

grounds during this time. Spawning occurs within the lower 3-km reach of the Weir River, but the actual location varies annually depending on discharge and Nelson River stage. Possible spawning areas in Lower Limestone Rapids on the Nelson River mainstem can be dewatered for periods of 2-20 hours daily due to hydroelectric generating station operating patterns (Swanson et al. 1990).

Fertilized sturgeon eggs incubate for 8-10 days prior to hatching (Figure 7-13). After emerging, most sturgeon larvae remain in the gravel for approximately two weeks until their yolk sacs are depleted (Kempinger 1988). Larvae emerging from the gravel drift downstream in the current (Kempinger 1988). Yolk-sac larvae, which are 10-12 mm in length, are generally captured one to two weeks after commencement of spawning, while post yolk-sac larvae (Photo 7-19), which are 16-22 mm in length, are generally captured three to four weeks following the onset of spawning (Figure 7-13).

Little is known of the life history needs and behaviour of juvenile sturgeon in the wild. They appear to prefer substrates comprised of coarse sand or pea-sized gravel and avoid uneven bottoms and vegetation; depth preferences are unknown. In contrast to adult sturgeon, which are opportunistic feeders and consume a wide variety of organisms, juvenile sturgeon have a much more restricted diet. Larval ephemeropterans and dipterans are two of the more important food items (Kempinger 1996).

Young-of-the-year sturgeon in the Nelson River can reach 140 mm in length by October (MacDonell 1998). Growth of sturgeon in the Nelson River is slower than for more southerly populations in the province, averaging approximately 0.5 kg and 5 cm per year until maturity (Sunde 1959). However, growth is highly variable as sturgeon less than 80 cm in length and 2.5 kg in weight can be as old as 24 years of age (MacDonell 1997). Lake sturgeon are known to reach weights in excess of 100 kg, although most mature lake sturgeon in the Nelson River range from 6-15 kg in weight, with a few reaching the 35-kg range (Photo 7-20). Lake sturgeon mature between 12 and 26 years of age with males maturing earlier and at smaller sizes than females. Although sturgeon are known to reach 100 years of age, few over 50 years of age are captured in the Nelson River.

Lake sturgeon are bottom dwellers and tend to be relatively sedentary when in locations that fulfill their life history requirements. They can be found throughout the mainstem of the lower Nelson River, but are most abundant in the deeper areas of slower velocity such as the Limestone Quarry (near the mouth of the Limestone River), the Limestone G.S. spillway (when it is not in use), near the mouth of the Angling River, and just upstream of Jackfish Island where river depths are in excess of 20 m (Figure 7-11). Some sturgeon have been found to venture into the Limestone and Weir rivers during summer. Angling Lake provides an important off-current refuge for Nelson River sturgeon. Sturgeon migrate up the Angling River during high-water levels in spring and may remain in the lake for periods in excess of five years. There are no known sturgeon spawning locations in the upper Angling River system and, consequently, it is thought that mature sturgeon migrate back to the Nelson River mainstem during

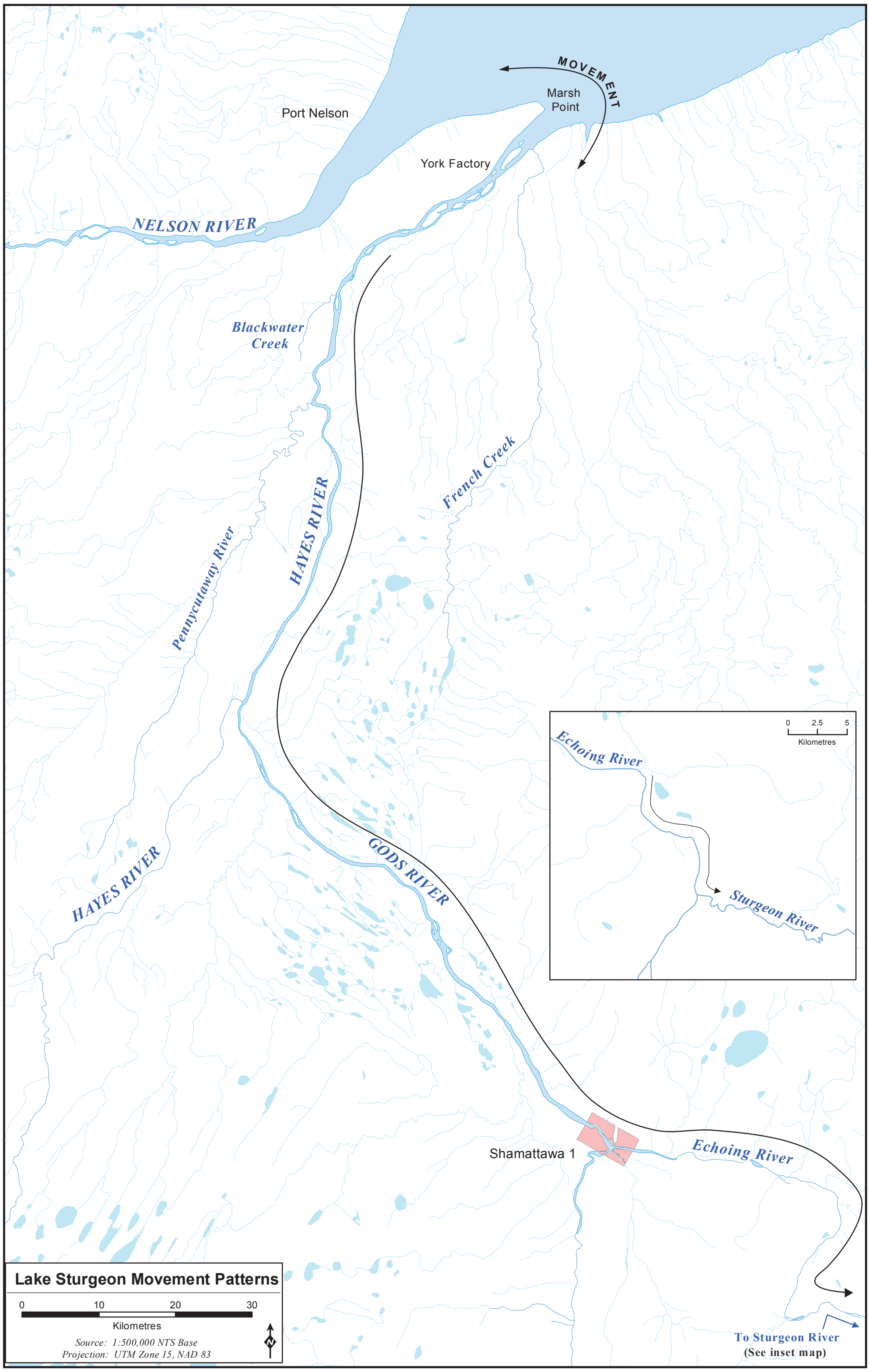


FIGURE 7-14 Seasonal lake sturgeon movement patterns between the lower Nelson River and the Hayes River.

PHOTO 7-21 Aerial view of the Limestone Forebay.

the spring of the years in which they are prepared to spawn (Figure 7-11). Nelson River sturgeon are known to overwinter in Angling Lake, the Nelson River mainstem, and the Nelson River Estuary. Lake sturgeon can tolerate **brackish water** and tagged fish have moved into the Nelson River Estuary and travelled around Marsh Point and up the Hayes River as far as the Sturgeon River (Figure 7-14). Consequently, sturgeon in the Nelson and Hayes rivers may be considered as one stock.

At the completion of the Limestone Monitoring Program in 2003, there were insufficient data to provide an accurate population estimate for lake sturgeon in the lower Nelson River (sufficient data have been collected in more recent years to provide an accurate estimate). Over 350 adult sturgeon have been known to congregate at the mouth of the Weir River during spring. Tag return data suggest that exploitation may be as high as 4% of the adult population annually.

Changes Following Construction of the Limestone Generating Station

At the time of construction, it was concluded by Manitoba Hydro and the provincial Fisheries Branch that it was not biologically or financially feasible to successfully provide upstream fish passage for lake sturgeon or most other fish species over the 30-m head created by the Limestone G.S. Consequently, fish passage was not incorporated into the design. As a result, the Limestone G.S. contributed to fragmentation of lake sturgeon habitat on the lower Nelson River and created a semi-isolated population between the Long Spruce and Limestone generating stations. Although this population was still subject to **immigration** from upstream and downstream emigration, the generating station blocked immigration from downstream and emigration to upstream areas.

Tagging studies have confirmed downstream movement of lake sturgeon from the Long Spruce and Limestone forebays to the lower Nelson River. A sturgeon tagged below the Kettle G.S. spillway in 1992 was recaptured at the Long Spruce G.S. spillway in 1993, and three sturgeon tagged in the Limestone Forebay were later recaptured downstream of the Limestone G.S. Because the generating station spillways were in operation during the time between tagging and recapture, it is not known whether these individuals passed over the spillways or through the turbines. These movements represent a loss to the forebay populations, which can only be replaced by downstream movements from farther upstream. Transfers of adult lake sturgeon from the lower Nelson River and Angling Lake into the Long Spruce Forebay (Swanson et al. 1988) proved unsuccessful as most moved back downstream within the first year. It was concluded that adult transfer would not be a viable mitigation method for re-establishing depleted lake sturgeon populations within Nelson River forebays. However, because sturgeon inhabit the entire length of the Nelson River, it is possible that downstream immigration may partially offset population reductions caused by downstream emigration.

The sustainability of lake sturgeon stocks in lower Nelson River forebays is dependent on whether habitat within the forebays can fulfil all the life history requirements of sturgeon (Photo 7-21). It has been suggested that a minimum of 250-300 km of barrier-free river and lake habitat is necessary to support a self-sustaining lake sturgeon population (Auer 1996). However, some lake sturgeon populations, such as the one located between Pointe du Bois and Slave Falls on the Winnipeg River, thrive in much smaller reaches. Of most importance is whether suitable spawning and rearing habitat are present. As of the conclusion of the Limestone Monitoring Program, there was no evidence that successful lake sturgeon recruitment was occurring within the Long Spruce or Limestone forebays.

Lake sturgeon continue to be captured in the Long Spruce and Limestone forebays more than 24 and 14 years after impoundment, respectively. The majority of the sturgeon are taken in the upper end of the forebays immediately downstream of the generating stations. Researchers on the Winnipeg River have also found that sturgeon are most abundant in the upper reaches of reservoirs where conditions are more characteristic of riverine conditions.

Although catches suggest that populations in the Long Spruce and Limestone forebays are small, many of the sturgeon captured are younger than the age of the forebay. It remains unclear whether the young sturgeon are a product of spawning within the forebays or immigrants from upstream (Photo 7-22).

Because of their long life-span, it may take several decades for the eventual fate of lake sturgeon in the lower Nelson River forebays to become apparent. The small, semi-isolated populations are extremely vulnerable to exploitation and environmental perturbations, and the genetic implications of isolation remain uncertain.

There are no indications that lake sturgeon abundance downstream of the Limestone G.S. has changed significantly since construction. An incremental increase in water level fluctuations as a result of generating station operation may be contributing to negative effects on lake sturgeon spawning habitat in the Nelson River mainstem and may cause lake sturgeon eggs to be more susceptible to exposure and desiccation. Loss of access to potential spawning areas below the Long Spruce G.S. has been offset by the creation of similar conditions downstream of the Limestone G.S. The extent to which lake sturgeon utilize the upper Limestone Rapids for spawning prior to construction is unknown, but the loss of such potential spawning habitat may have increased utilization and the importance of other downstream spawning habitats. In addition, the generating station has created a barrier and has essentially caused a permanent loss of habitat to the downstream sturgeon population. While habitat between the Long Spruce and Limestone generating stations represents approximately 14% of large river habitat available to sturgeon from the Long Spruce G.S. to the coast, it only represents approximately 1-2% of available habitat in the Nelson and Hayes River systems combined (figures 7-11 and 7-14).

PHOTO 7-22
A juvenile lake sturgeon from the lower Nelson River.

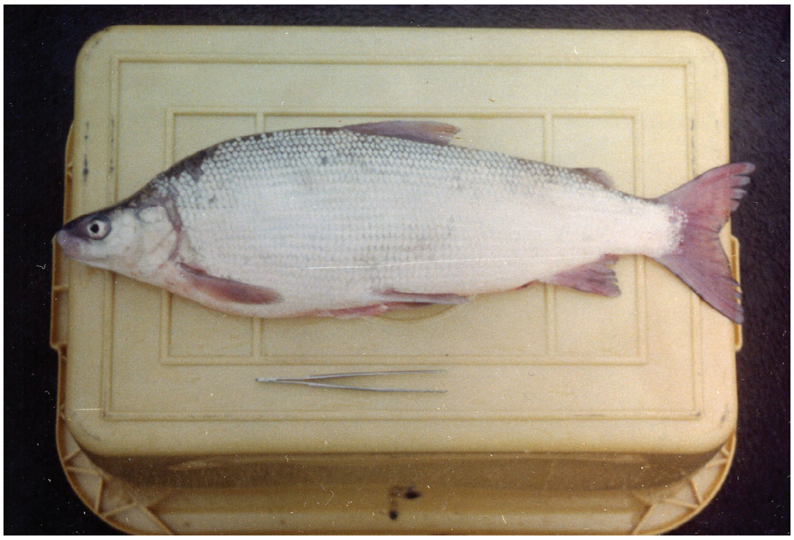
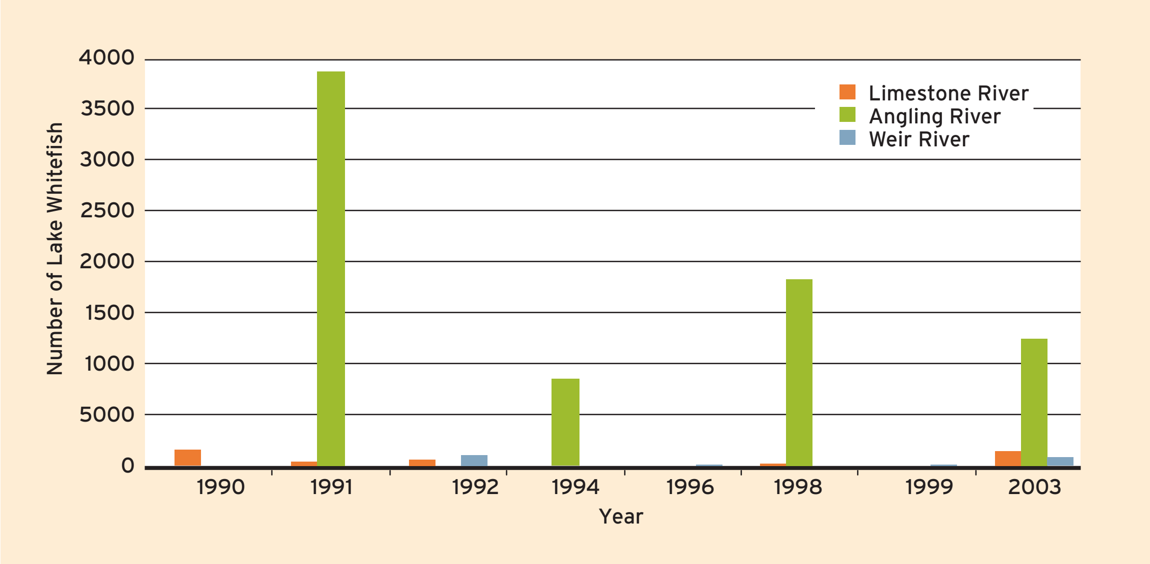


PHOTO 7-23
Adult lake whitefish.

FIGURE 7-15 Upstream fall spawning migrations of lake whitefish in the Limestone, Angling, and Weir rivers, determined from fish weirs between 1990 and 2003. Zero values indicate years when rivers were not surveyed.



7.3.3 Lake Whitefish

Lake whitefish (*Coregonus clupeaformis*) are found in waterbodies throughout eastern and northern Manitoba, and are the third most important fish species in terms of weight and economic value in the provincial commercial fishery (Photo 7-23). They are common in Nelson River waters from Lake Winnipeg to Hudson Bay and rank behind only longnose suckers as the most numerous large-bodied species of fish found in the lower Nelson River.

Lake whitefish are typically a lacustrine fish, but are also found in riverine environments, particularly during migrations to and from spawning grounds. They are fall spawners and lay their eggs in shallow water over granular substrates at water temperatures below 8ºC. In the lower Nelson River, lake whitefish are thought to spawn in the mainstem and in some of the larger lower Nelson River tributaries (i.e., primarily the Angling River and, to a lesser extent, the Limestone, Weir, and Kaswasotasine rivers), although specific spawning locations have

PHOTO 7-24 The Angling River – an important tributary for spawning lake whitefish.

not been identified. Upstream spawning movements commence during late August, and peak during mid September. In Nelson River tributaries, the magnitude of lake whitefish spawning migrations range from less than 200 fish in the Limestone and Weir rivers to nearly 4,000 fish in the Angling River (Figure 7-15, Photo 7-24). Angling Lake, located about 45 km upstream of the mouth of the Angling River, may provide suitable spawning habitat and could explain the higher utilization of that stream. The number of fish moving into tributaries in the fall appears to be larger during years when streams have higher discharges. Eggs are deposited randomly over the spawning grounds and incubate over the winter before hatching in April or May. Larval lake whitefish have been captured in drift traps in larger Nelson River tributaries from ice break-up to early July.

Juvenile lake whitefish can be found in the Nelson River mainstem and are particularly abundant in the Nelson River Estuary during summer, but are uncommon in lower Nelson River tributaries. Most lake whitefish that have been captured in the estuary were less than 200 mm in length and between 2-3 years of age. Strontium concentrations suggest that most juvenile lake whitefish do not venture extensively into Hudson Bay (Figure 7-16).

Older, immature lake whitefish (3-5 years of age) can be found migrating up lower Nelson River tributaries during spring; they are also common in the Nelson River mainstem. When lower Nelson River lake whitefish mature at approximately five years of age, a small proportion of them venture into Hudson Bay; however, the majority appear to remain in fresh water throughout their life cycles.

Lower Nelson River lake whitefish are opportunistic feeders, exploiting whatever food source is abundant at the time of consumption. Primary dietary items include bivalves, gastropods, conchostracans (clam shrimps), ephemeropterans, trichopterans, plecopterans, hemipterans, chironomids, and fish.

Changes Following Construction of the Limestone Generating Station

Immediately following impoundment of the Limestone Forebay, lake whitefish comprised less than 4% of the index gillnet catch and were primarily found in the upper region of the forebay. Lake whitefish were considerably more abundant in the lower Nelson River mainstem (comprising 8-16% of the index gillnet catch) and therefore, it is suspected that a substantial portion of the lake

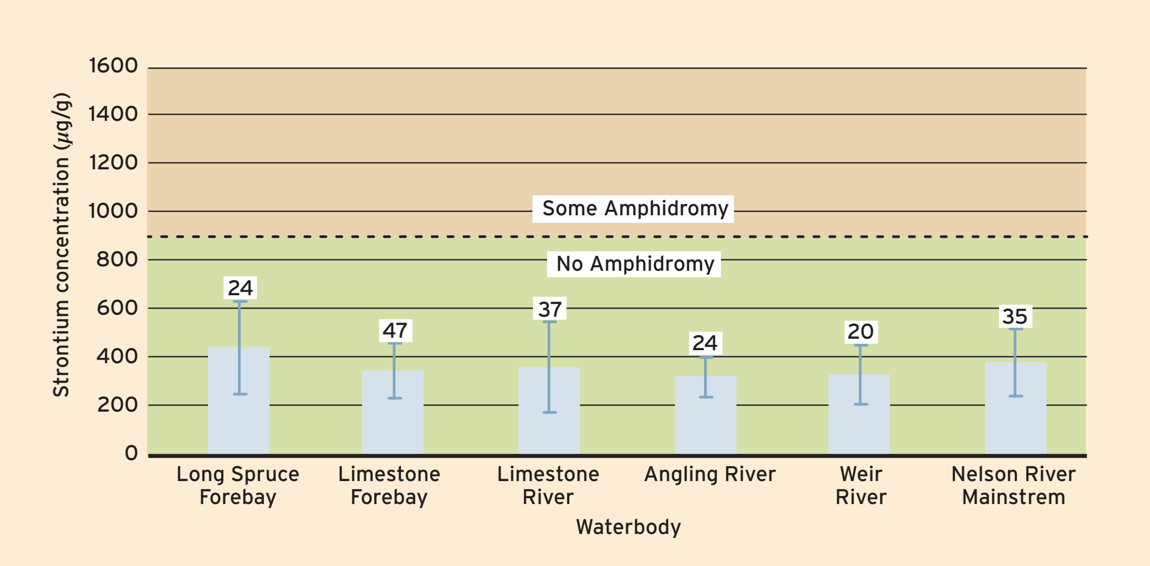


FIGURE 7-16
Pelvic fin strontium concentrations [mean and standard deviation (SD)] from lake whitefish captured in the Long Spruce and Limestone forebays, the Limestone, Angling, and Weir rivers, and in the Nelson River mainstem below the Limestone G.S., 1990-1992. Strontium concentrations in excess of 900 µg/g appear to be a good indication of some degree of amphidromy. Sample size is indicated above SD bars.

whitefish population that was impounded in 1989 moved downstream of the Limestone G.S. during the first year. Little change in lake whitefish abundance occurred in the Limestone Forebay thereafter and, based on results from the Long Spruce Forebay, little change is expected in the near future. In 2003, lake whitefish were the fifth most abundant species in the Limestone Forebay and comprised the same proportion of the catch and had the same **catch-per-unit-effort** (CPUE; no. fish/100 m/24 h) value as in the Long Spruce Forebay.

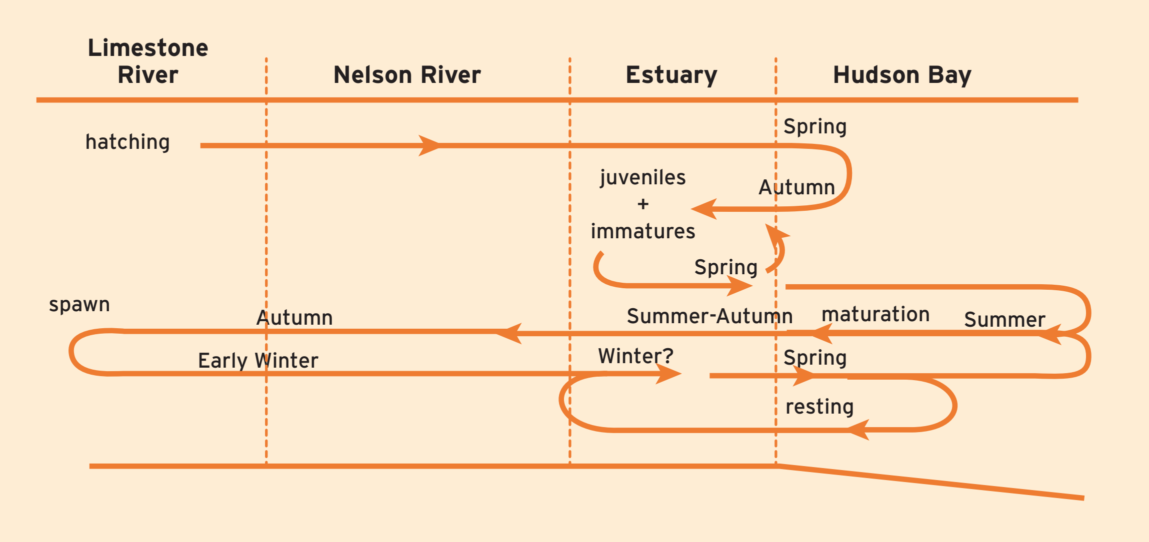
Lake whitefish distribution within the Limestone Forebay appears to have become more widespread over the course of the aquatic monitoring studies. It is expected that this trend may continue as lake whitefish catches in the Long Spruce Forebay were more consistent between the upper to lower reaches.

Size and age of lake whitefish upstream of the Limestone G.S. changed little during the period of study. Limestone Forebay lake whitefish have shown a large degree of variation in dietary preferences since impoundment both annually and seasonally, illustrating the opportunistic nature of their feeding behaviour.

Length standardized mercury concentrations in lake whitefish increased within the first two years (i.e., in 1991) following impoundment from 0.08 to 0.14 ppm, remained fairly stable until 1994, and by 2003 had returned to 0.08 ppm. The 2003 concentration was similar to that observed for lake whitefish from the Nelson River mainstem downstream of the Limestone G.S. in the same year (0.11 ppm). Based on the overlapping 95% confidence intervals (CI), the 2003 mean concentration (CI: 0.05-0.12 ppm) was also not statistically different from the mean of 0.05 ppm (CI; 0.03-0.06 ppm) obtained from a set of 13 waterbodies that, according to Bodaly et al. (2007), represent natural background levels for lake whitefish from the Churchill-Burntwood-Nelson River region. Concentrations in lake whitefish within the area of the Limestone G.S. remained at all times well below 0.2 ppm, a level generally considered safe for regular fish consumption by health organizations.

Lake whitefish abundance downstream of the Limestone G.S. appeared to change little following construction. Lake whitefish continued to be the second most abundant species in the 2003 lower Nelson River index gillnetting catch, comprising approximately 17% of the total. Variations in numbers of fall migrant lake whitefish into Nelson River tributaries (i.e., the Angling, Limestone, and Weir rivers) over the course of the monitoring studies were primarily attributed to variations in annual discharge. The largest catch of lake whitefish moving into the Angling River occurred in 1991 (n = 3,871) and the lowest in 1994 (n = 859) (Figure 7-15), which were the years of the highest and lowest discharges recorded during monitoring, respectively.

FIGURE 7-17
Possible life cycle of lower Nelson River cisco that spawn in the Limestone River [based on life cycle of anadromous cisco in coastal James Bay as described by Morin et al. (1981)].



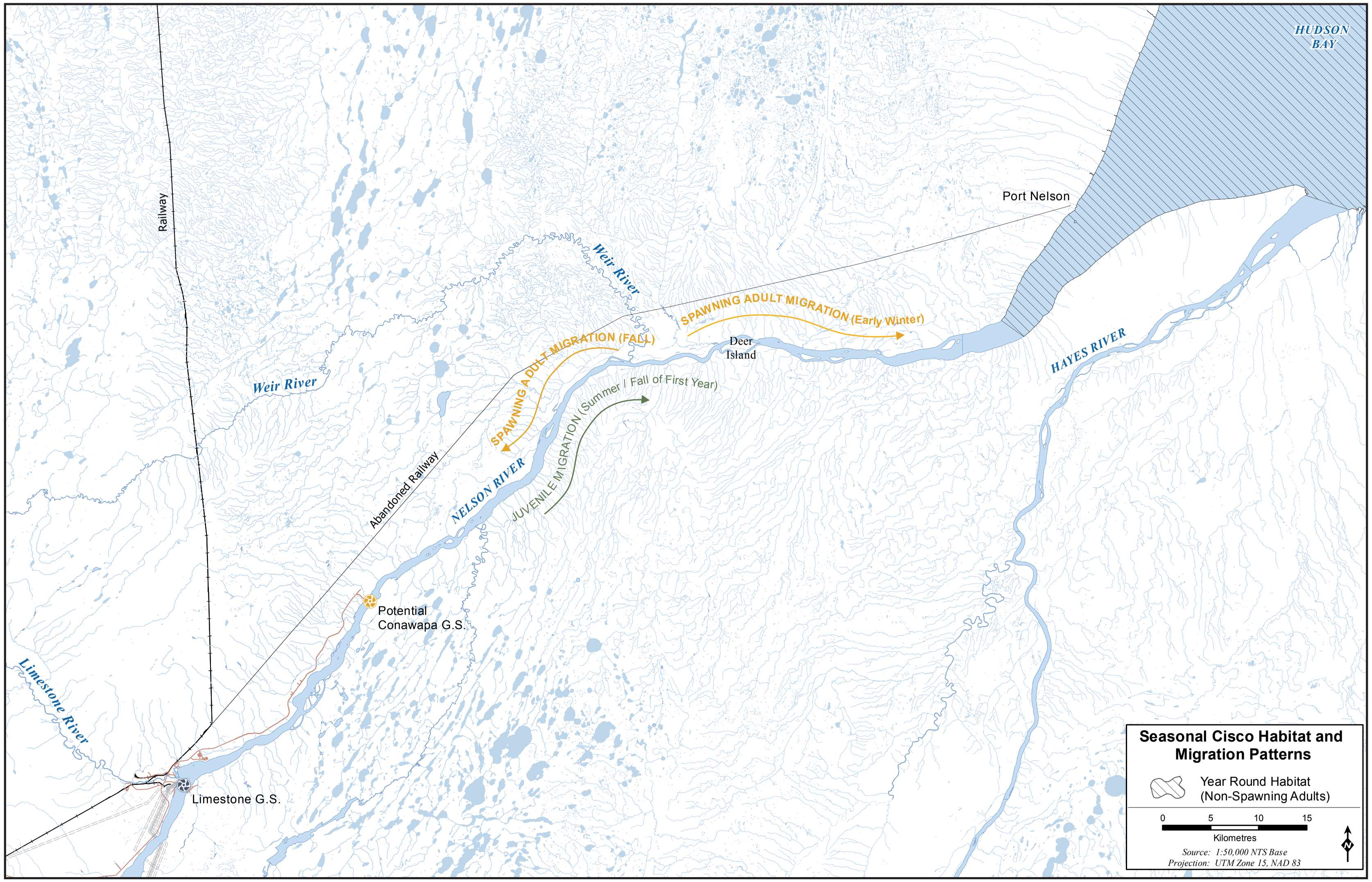


FIGURE 7-18 Seasonal cisco habitat use and migration patterns in the lower Nelson River downstream of the Limestone G.S.

PHOTO 7-25
Cisco captured in a two direction fish weir while migrating up the Limestone River during fall.

7.3.4 Cisco

Cisco (*Coregonus artedi*), like lake whitefish, are commonly found throughout eastern and northern Manitoba. Often referred to as tullibee or lake herring, they are typically a lake-dwelling species, but are also common in rivers and the coastal waters of Hudson Bay. They are one of the five most common large-bodied species in the upper Nelson River (the portion of the river from Lake Winnipeg to Split Lake), but abundance in the lower portion of the river is primarily seasonal as adults migrate into Hudson Bay to feed during summer.

Species within the genus *Coregonus* are often characterized by a number of different forms. Although most of the variation is geographic and mainly phenotypic, two forms can often live within the same area or lake. Some fish captured in the lower Nelson River display morphological features that are intermediate between cisco and lake whitefish. For example, gillraker counts for these fish (n = 34-37) fall between those reported by Scott and Crossman (1973) for lake whitefish ($n \leq 33$) and cisco ($n \geq 38$). The "hybrids" are generally encountered in concert with upstream movements of cisco into Nelson River tributaries during fall and comprise less than 1% of all coregonine fish enumerated. Shortjaw cisco (*Coregonus zenithicus*), which have been reported from Lake Winnipeg and are considered a "Threatened" species by COSEWIC, have not been reported from the lower Nelson River.

Lower Nelson River cisco spawn during mid to late October and into November at water temperatures less than 4°C (Photo 7-25). Spawning is thought to take place in 1-3 m of water over gravel, stony or rocky substrates in the Limestone and Weir rivers and in the Nelson River mainstem. Exact spawning locations have not been identified.

Cisco eggs hatch during spring as ice-cover breaks. Larvae drift downstream and can be caught in drift traps in the Limestone and Weir rivers beginning in early June. After drift is complete, juvenile cisco are uncommon in the Nelson River tributaries, but are found in the Nelson River mainstem and are abundant in the Nelson River Estuary and coastal creeks during summer (figures 7-17 and 7-18). The

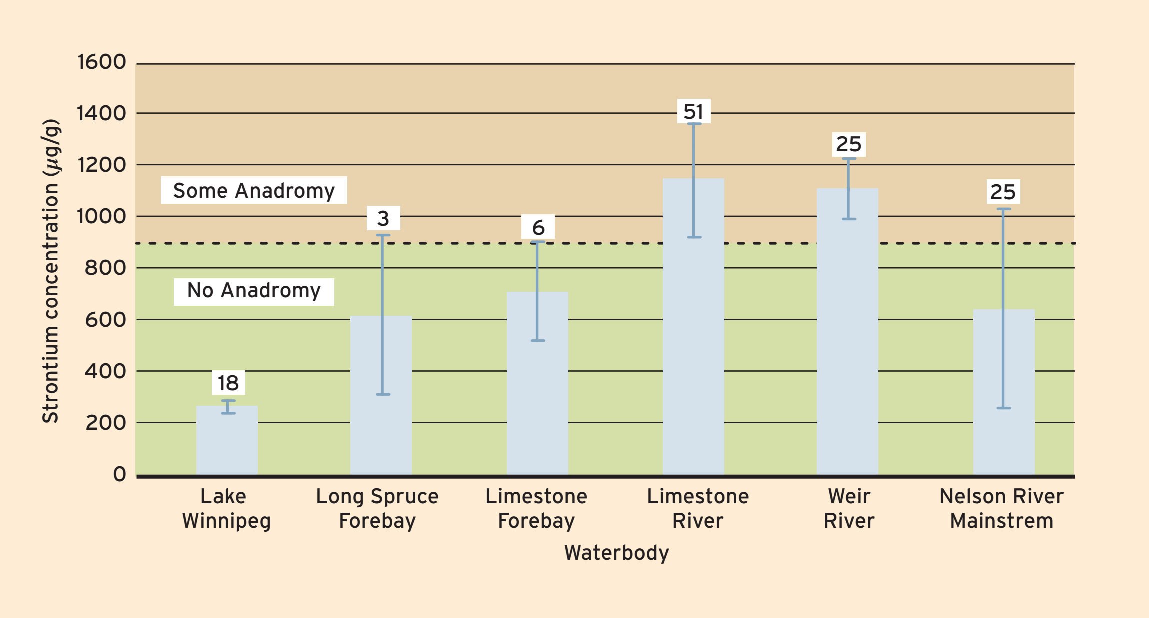


FIGURE 7-19
Pelvic fin strontium concentrations [mean and standard deviation (SD)] from cisco captured in Lake Winnipeg, the Long Spruce and Limestone forebays, the Limestone and Weir rivers, and in the Nelson River mainstem below the Limestone G.S., 1990-1992. Strontium concentrations in excess of 900 μg/g appear to be a good indication of some degree of anadromy. Sample size is indicated above SD bars.

estuary is thought to act as an important nursery area for this species.

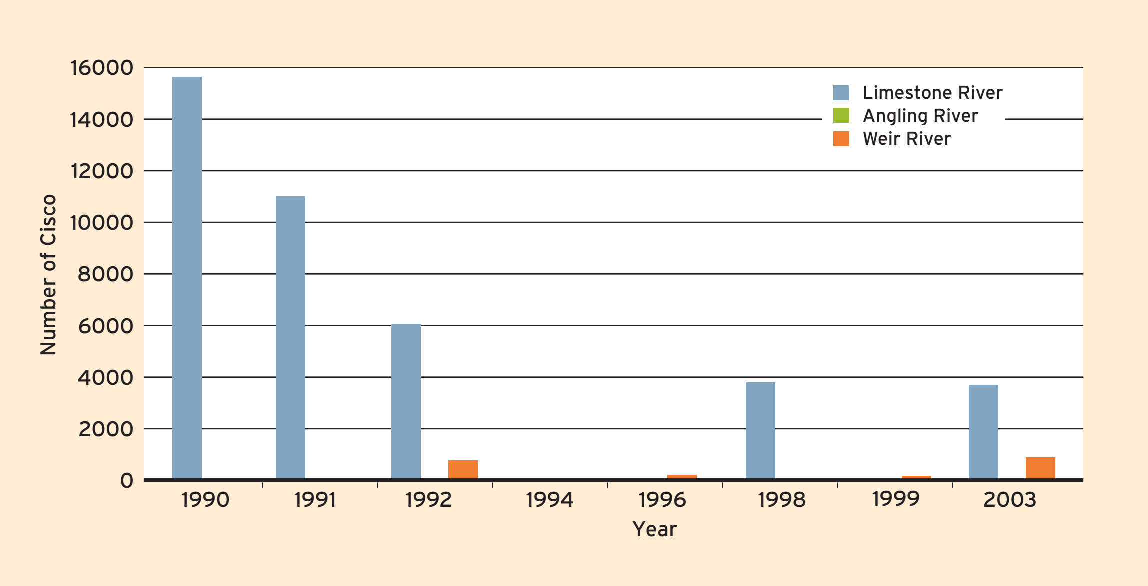
Cisco reach sexual maturity at about four years of age. Strontium concentrations suggest that a portion of lower Nelson River cisco population ventures into salt water to feed for the first time during the summer preceding their first spawn (Figure 7-19). Comeau (1915) described large numbers of "herring" (which were presumably cisco) offshore in Hudson Bay during summer. Few mature cisco are captured in Nelson River tributaries, the Nelson River mainstem or in the Nelson River Estuary during spring and summer.

Cisco that enter Hudson Bay from the Nelson River system have been found to travel great distances along the coastline. Cisco that have been tagged in the Limestone River during fall have been captured more than 500 km away at Hubbard Point north of Churchill the following summer. One cisco tagged in the Churchill River during July took 74 days to travel the 450 km back to the Limestone River.

Mature cisco begin returning to fresh water during late August (figures 7-17 and 7-18). Comeau (1915) described large upstream migrations of cisco and/or lake whitefish into the Nelson River during fall. In more recent Nelson River mainstem gillnetting and electrofishing studies, the proportion of mature cisco in the catch increased substantially during fall. Cisco begin to appear in the Weir and Limestone rivers during the last few days of August, with peak upstream movement usually occurring during the third and fourth weeks of September. Upstream movements into the tributaries are comprised almost exclusively of fish that are sexually mature. Tagging data show that only 20% of spawners return two years in a row, suggesting that spawning periodicity for most cisco is in excess of one year and/or that post-spawning mortality is high. It is surmised that resting cisco remain in the Nelson River mainstem, the Nelson River Estuary or in other river systems during fall and winter (figures 7-17 and 7-18).

In excess of 15,000 cisco have been enumerated migrating into the Limestone River during fall (Figure 7-20). Cisco also migrate up the Weir River, although the magnitude of this run is in the hundreds of fish rather than the thousands. Cisco do not utilize the Angling River for spawning. It is not clear why the Limestone River is so heavily utilized by cisco compared to other lower Nelson River tributaries, although it is the largest and most upstream tributary below the Limestone G.S. The prevalence of groundwater in the Limestone River also may be an attractant to spawning cisco.

FIGURE 7-20 Upstream fall spawning migration of cisco in the Limestone, Angling, and Weir rivers, determined from fish weirs. Fish weirs were operated in the Limestone River during 1990, 1991, 1992, 1998, and 2003; in the Angling River during 1991, 1994, 1998, and 2003; and in the Weir River during 1992, 1996, 1999, and 2003.



Changes Following Construction of the Limestone Generating Station

With the exception of Comeau's observations from early in the 20th century, little was documented of cisco abundance and habitat utilization in the lower Nelson River before the construction of the Limestone G.S. Consequently, it is uncertain whether anadromous cisco utilized habitat in the Nelson River mainstem upstream of the confluence with the Limestone River prior to hydroelectric development.

Construction of the Limestone G.S. created a barrier for fish moving upstream into the forebay area of the Nelson River. Impoundment occurred during summer; therefore, it is unlikely that anadromous cisco would have been upstream of the station at the time. Any anadromous cisco that were impounded would likely have moved downstream of the Limestone G.S. within the first year.

Since the Limestone Forebay was no longer accessible to anadromous cisco, any individuals inhabiting the forebay after impoundment were likely freshwater residents. Immediately following impoundment, cisco comprised less than 3% of gillnet catches from the Limestone Forebay and less than 1% of the gillnet catch through the fall. The proportion of cisco in gillnet catches during two subsequent years of sampling was less than 1% each time. In 1993, no cisco were captured in the forebay. Since 1993, cisco have generally comprised no more than 3% of the annual gillnet catch in the forebay and the majority caught are relatively small, averaging less than 200 mm in length. Cisco comprise a similarly small proportion of the Long Spruce Forebay gillnet catches. Populations are substantially higher in lake habitats found farther upstream in the Nelson River mainstem (e.g., Stephens and Split lakes), which offer slower water velocities than the downstream forebay habitats (i.e., Long Spruce and Limestone). Emigration of cisco from upstream may contribute to existing populations in the Long Spruce and Limestone forebays.

Non-anadromous cisco are essentially pelagic lake dwellers (McPhail and Lindsey 1970; Scott and Crossman 1973). Although the Limestone Forebay became more lentic because of impoundment, its **run-of-the-river** nature – with a water retention time of less than thirty hours – retains some lotic qualities. Consequently, habitat in the forebay may be considered sub-optimal for cisco, and it is unlikely that the species will do as well in the forebay as in expanded sections of the Nelson River. It is expected that as the fish population evolves, cisco will continue to comprise less than 10% of the overall large-bodied fish population in the forebay.

Except for the 16 cisco collected in 1996, sample size for mercury analysis was generally small (n=1-7) and the relationship between mercury concentration and fish length was mostly not significant. Thus, length standardized concentrations could not be used for comparisons. Arithmetic concentration indicated that mercury concentrations in cisco from the Limestone Forebay were generally at or below 0.1 ppm and were similar to the concentrations measured in conspecifics from the Long Spruce Forebay (0.07-0.10 ppm) and the Nelson River mainstem downstream of the Limestone G.S. (0.10-0.13 ppm) for samples with adequate size collected between 1986 and 2004.

Downstream of the Limestone G.S., anadromous cisco continue to utilize the Limestone and Weir rivers for spawning. Fall upstream migrations are variable and appear to be partially related to discharge. However, similar discharges in the Limestone River in 1990 and 1998 yielded migrations that were significantly different sizes (i.e., 15,717 in 1990 and 3,811 in 1998) (Figure 7-20). These data suggest that fall utilization of the Limestone River by cisco has decreased since impoundment. A similar, but less distinct, proportional decrease in utilization has also occurred in the much smaller run in the Weir River. Reasons for the decreases are uncertain. Further investigation is required to determine the relative importance of the tributaries and the Nelson River mainstem to anadromous cisco spawning.

PHOTO 7-26
Adult longnose sucker (top) and white sucker (bottom).

7.3.5 Catostomids

Three species of the sucker family, Catostomidae, are found in the lower Nelson River. The longnose sucker (*Catostomus catostomus*) is the most abundant large-bodied fish species in the river, comprising 50-75% of the electrofishing and gillnet survey catches from the mainstem; white sucker (*Catostomus commersonii*) are also common, comprising 5-16% of survey catches (Photo 7-26). Shorthead redhorse (*Moxostoma macrolepidotum*) have been reported from the lower Nelson River, but are relatively uncommon.

Suckers undertake migrations into Nelson River tributaries to spawn during spring. Migrations occur in tributaries as large as the Limestone River and as small as Swift Creek, with the magnitude of the migration proportionate to the size of the tributary. More than 1,000 longnose sucker and 100 white

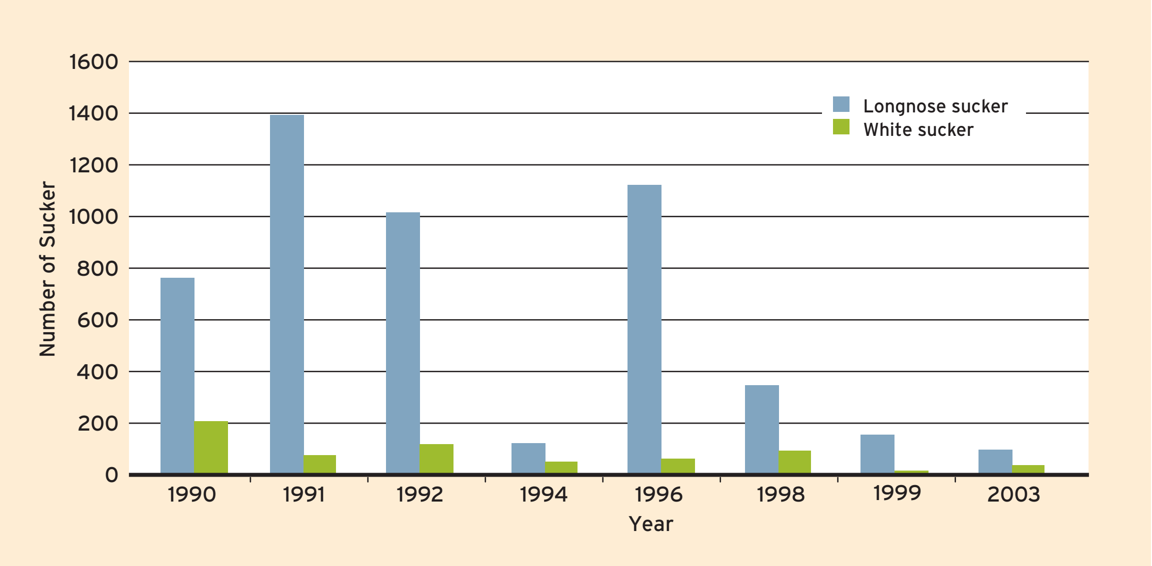


FIGURE 7-21
Spring spawning migration of longnose sucker and white sucker in Moondance Creek, determined from fish weirs from 1990 to 1998. Numbers of sucker shown are the maximum number captured moving in either an upstream or a downstream direction.

sucker migrate into Moondance Creek each spring (Figure 7-21). The magnitude of migrations in smaller tributaries is largely dependent on spring discharge. Based on hoopnet catches, longnose sucker migrations into the larger tributaries such as the Limestone and Weir rivers are thought to be comprised of several thousands of fish. The degree to which suckers utilize the Nelson River mainstem for spawning is unknown.

Longnose sucker are the first to migrate upstream, moving into tributaries during May when water temperatures approach 5ºC. Peak upstream movement usually occurs when water temperatures range between 6 and 10ºC and are generally complete by June 25. White sucker movements overlap with longnose sucker but are typically 5-10 days later.

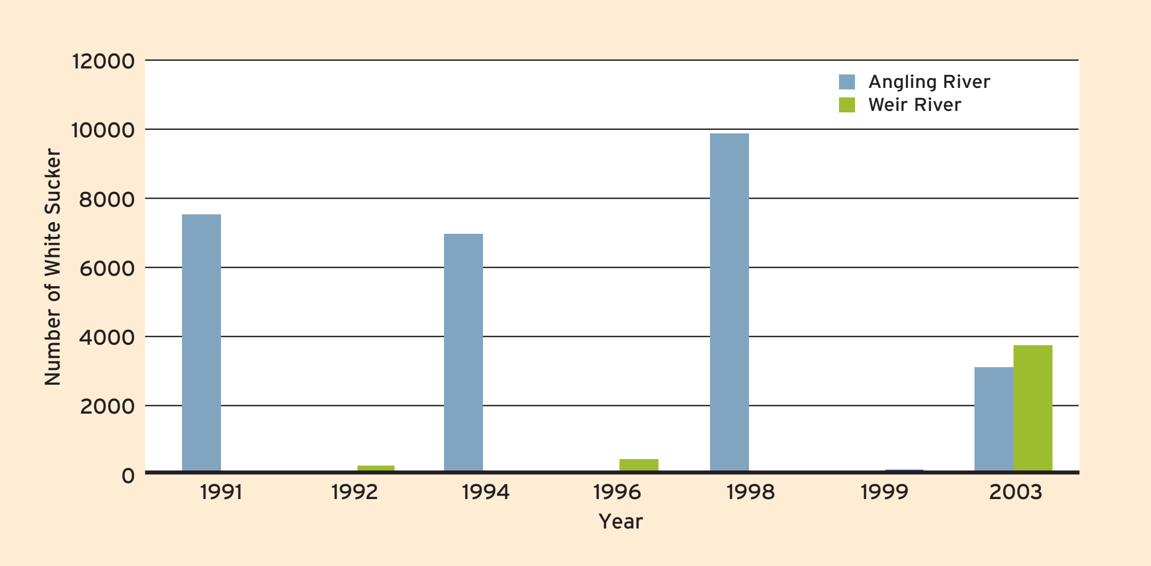
Suckers spawn over gravel in shallow areas of turbulent flow. Spawning is usually complete by mid June and the majority of suckers move downstream by early July. Post-spawning mortality is thought to be high, as 40% as of those individuals moving up Moondance Creek during spring do not return downstream prior to freeze-up. A small number of mature suckers remain upstream through the summer and the following winter, and return downstream in the spring. At this time, individuals weigh less than they had the previous year. Large numbers of white suckers (3,000-10,000) migrate out of the Angling River each fall (Figure 7-22), presumably to overwinter in the Nelson River. It is assumed that these fish ascend the river during spring and spend the summer foraging in Angling Lake. Substantial numbers of white suckers (>3000) were captured migrating out of the Weir River during fall 2003, but not in previous sampling years (i.e., 1992, 1996, and 1999) (Figure 7-22). A similar downstream movement of suckers has not been seen in the Limestone River.

Sucker eggs generally hatch within two weeks. Larvae are captured in drift traps in Nelson River tributaries through June until they become free swimming. Sucker larvae are common in the peripheral areas of spawning tributaries throughout the summer.

Juvenile suckers are known to use most Nelson River tributaries, the Nelson River mainstem, and the Nelson River Estuary as nursery habitat. Juvenile longnose sucker 1-2 years of age and less than 100 g in weight are particularly abundant in the estuary. These juveniles comprised over half of the gillnet catch during a 1989 survey.

Lower Nelson River suckers generally become sexually mature at five years of age and have a life expectancy of 16-19 years. Mature longnose sucker range from 275 to 400 mm in length, and mature white sucker range from 300 to 425 mm in length. Mature suckers are thought to utilize the entire reach

FIGURE 7-22
Fall emigration of white sucker out of the Angling and Weir rivers, determined from fish weirs between 1991 and 2003. Zero values indicate years when rivers were not surveyed.



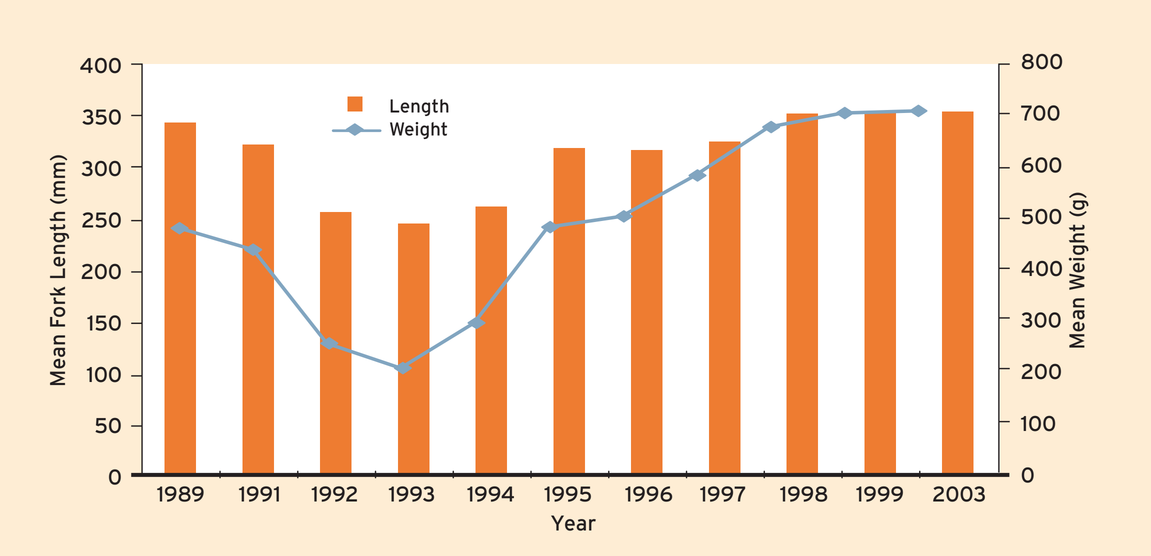


FIGURE 7-23 Mean length and weight of longnose sucker in the Limestone Forebay, 1989-2003.

of the lower Nelson River for foraging. Longnose sucker are believed to take advantage of the extensive periphyton growth in the river during summer.

Although some suckers will return to the same creek or river to spawn in successive years, spawning periodicity within the same creek is usually two years or more.

Changes Following Construction of the Limestone Generating Station

The longnose sucker population in the lower region of the Limestone Forebay was estimated at approximately 40,000 fish immediately following impoundment in 1989. Tag recaptures suggested that a substantial portion of the population may have moved downstream during the first year after impoundment, but there was little evidence of downstream movements thereafter. Nearly 1% of longnose sucker (6 of 1,257) tagged in the Limestone Forebay during fall 1989 were recaptured in Moondance Creek downstream of the generating station in the first two springs after impoundment. In contrast, none of the 1,368 longnose sucker tagged in the forebay three successive years thereafter were recaptured downstream, despite similar levels of fishing effort. Downstream movement out of the forebay may have decreased in June 1991 when the forebay operating level was attained and construction-related spills were terminated.

Longnose sucker are generally larger in more lentic environments. Mean length of longnose sucker is highest in the Kettle Forebay (i.e., Stephens Lake), followed by the Long Spruce Forebay, the Limestone Forebay, the Limestone River, and lastly, Moondance Creek. Mean length of Limestone Forebay longnose sucker decreased during the first few years after impoundment, possibly as a result of larger older individuals emigrating downstream (Figure 7-23). In more recent years, mean length has been increasing as the population ages. The absence of younger year classes in the length frequency distributions may be an indication that recruitment has decreased (figures 7-24a and 7-24b). A large proportion (61%) of female longnose suckers captured one year following impoundment contained reabsorbed eggs. This suggests that suitable spawning conditions were not available within the forebay (or its tributaries), possibly as a result of flooding and siltation, and/or the species' inability to locate their natal streams (e.g., Limestone River, Moondance Creek). These conditions likely prompted the downstream emigration of larger fish out of the forebay and past the Limestone GS.

Despite changes in size, the relative abundance of longnose sucker in the Limestone Forebay changed little during the first seven years following impoundment, ranging from 46 to 68% of the index gillnetting catch. Longnose sucker remained most abundant in the middle and lower reaches of the forebay where they comprised 41 and 96% of the

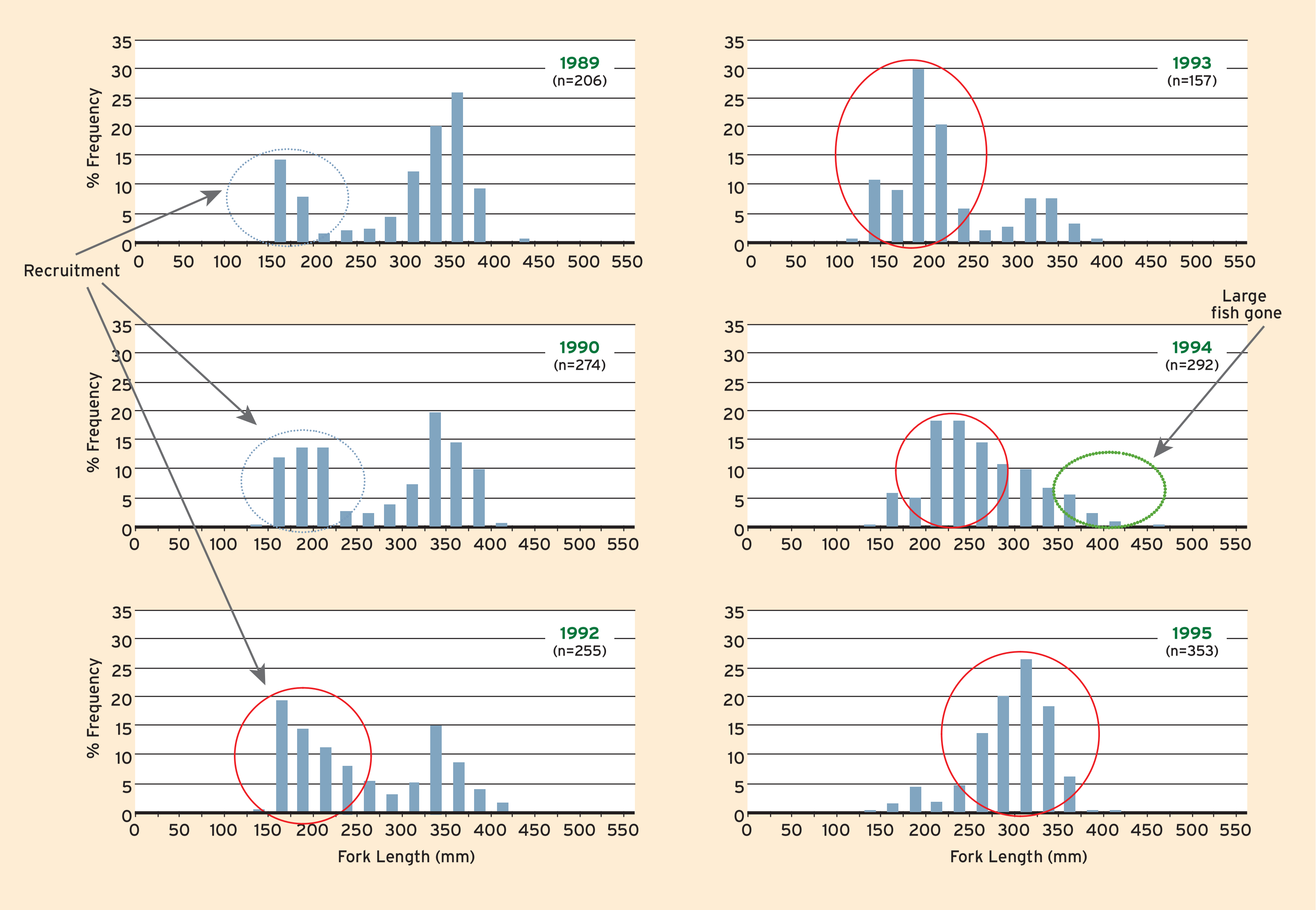


FIGURE 7-24a
Comparison of length-frequency distributions for longnose sucker from the Limestone Forebay, 1989, 1990 and 1992-1995. Note the decrease in recruitment after 1993 and the absence of large specimens by 1994. Also note the smaller length group circled in 1992 as it increases in size yearly and becomes the dominant length class as early as 1993.

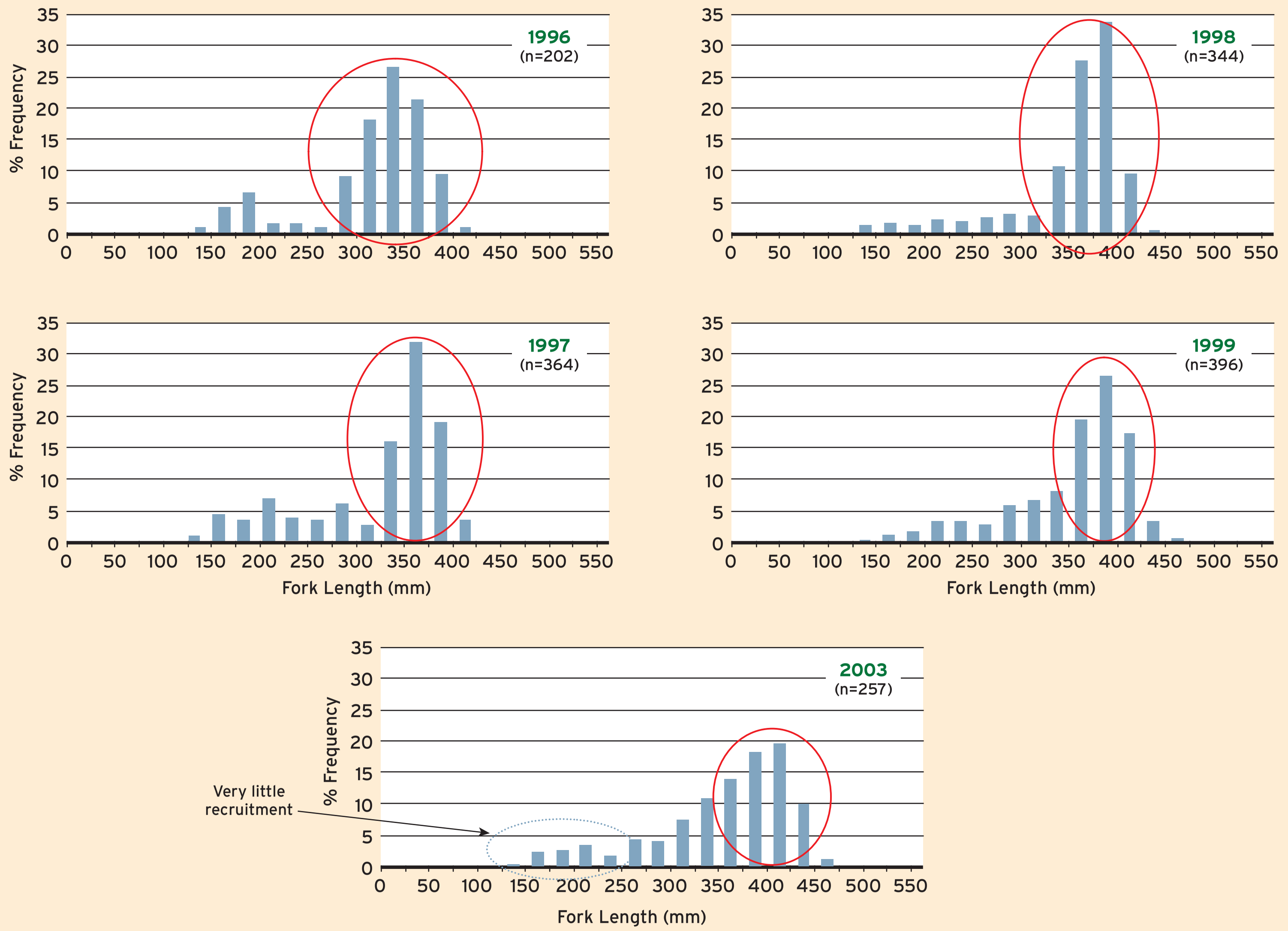
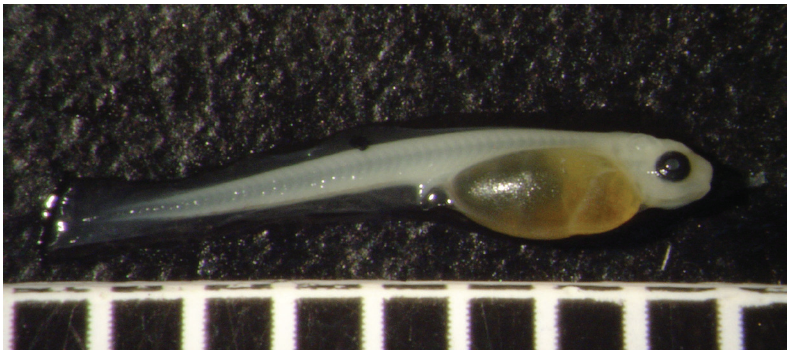


FIGURE 7-24B
Comparison of length-frequency distributions for longnose sucker from the Limestone Forebay, 1996-1999 and 2003. Note the low level of recruitment from 1996 to 2003 and the annual increase in size of a dominant length group (circled) that was specifically tracked since 1992 (see previous figure).



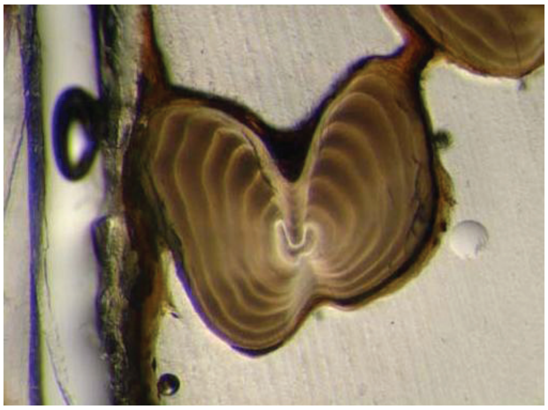


PHOTO 7-27
Adult walleye.

PHOTO 7-28
A walleye larva.

PHOTO 7-29
Cross-section of a dorsal spine of a 7-year-old walleye.

catch, respectively, in 2003. Longnose sucker were considerably less abundant in the middle and lower reaches of the Long Spruce Forebay where they typically comprised less than 10% of the index gillnet catch. It is expected that as the Limestone Forebay matures, longnose sucker abundance and distribution will become more similar to the Long Spruce Forebay. A similar decrease in longnose sucker abundance was observed following formation of reservoirs associated with the La Grande hydroelectric development in Quebec (Deslande et al. 1995).

White sucker abundance has changed little in the Limestone Forebay since impoundment. With the exception of 1990, this species comprised 2 to 8% of the annual index gillnet catch. Abundance was highest in the upper and middle portions of the forebay. Similar to longnose sucker, mean length showed an increasing trend during the last three years of monitoring. Over the long-term, it is expected that the relative abundance and distribution of white sucker in the Limestone Forebay will become more similar to those observed in the Kettle and Long Spruce forebays. White sucker in these reservoirs normally comprise 10-20% of index gillnet catches.

Mercury concentrations in longnose sucker increased from 0.06 to 0.21 ppm between 1989 and 1993 and then decreased to 0.10 ppm by 1996. White sucker also had relatively high mercury concentrations of 0.29-0.40 ppm in 1992 and 1993 and lower concentrations in 1996 (0.11 ppm); however, only three data years exist for this species and in two of these years the relationship between mercury concentration and fish length was not significant. For both catostomid species, mercury concentrations in years other than 1992 or 1993 were generally similar to those measured in their conspecifics from the Long Spruce Forebay from 1992 to 1996 (0.09-0.18 ppm) and the Nelson River mainstem below the Limestone G.S. in 1981 (white sucker, 0.12 ppm) and 1992 (longnose sucker, 0.22 ppm).

7.3.6 Percids

Members of the Percidae family are extremely important to Manitoba's commercial, recreational, and domestic fisheries. Walleye (*Sander vitreum*; formerly *Stizostedion vitreum*) and sauger (*Sander canadense*; formerly *Stizostedion canadense*) combined to account for 52% of the total provincial commercial catch (largely driven by the Lake Winnipeg fishery) by weight and 81% of the value in 2006/2007 (Manitoba Water Stewardship 2008) (Photo 7-27).

Three species of large-bodied percids are found in the lower Nelson River. Walleye are the most common, comprising 1-4% of mainstem index gillnetting and electrofishing catches. Sauger and yellow perch (*Perca flavescens*) are relatively uncommon in the non-impounded portion of the lower Nelson River;

together, comprising less than 1% of survey catches. Small numbers of all three species also inhabit larger lower Nelson River tributaries throughout the summer. Percids comprised about 20% of gillnet catches from Angling Lake (Swanson et al. 1991). Percid production in Angling Lake is thought to contribute to a higher abundance of percids in the Angling River compared to the Nelson River mainstem and other lower Nelson River tributaries (e.g., Limestone and Weir rivers). The lower Nelson River is near (for walleye) or at (for sauger and yellow perch) the northern edge of the geographical distribution of all three percid species.

Little is known of the life history of percids in the Nelson River. All three species spawn during spring; walleye and sauger first at water temperatures of approximately 6ºC, followed by yellow perch at water temperatures of 6-10ºC. Small numbers of walleye are known to move up the Limestone, Weir, and Angling rivers during May and June. Adult yellow perch and sauger have not been captured in tributaries during spring.

Walleye eggs incubate for approximately 18-21 days before hatching. Larval walleye have been captured in drift traps in the Angling River from mid June into early July (Photo 7-28). Juvenile walleye have been captured in the Nelson River mainstem, the Nelson River Estuary, and the Angling River during summer. Juvenile yellow perch were captured in coastal creeks during a summer seining survey in 1989.

Lower Nelson River walleye mature at about four years of age. Adult walleye can reach lengths of 250 to 650 mm, and have a life expectancy of approximately 16 years (Photo 7-29). Adult sauger reach lengths of 225 to 400 mm and have a life expectancy of approximately 14 years.

Fish are the most important and common food item for walleye and sauger in the lower Nelson River. Crustaceans, hemipterans, and ephemeropterans also represent a small proportion of their diets.

Changes Following Construction of the Limestone Generating Station

Impoundment of the Nelson River is expected to improve conditions for percids. Although each species can be found in a range of environmental conditions, walleye, sauger, and yellow perch are typically most abundant in large, shallow, and turbid lakes (Scott and Crossman 1973). Consequently, the depths and water velocities found in the Limestone Forebay are likely more suitable for percids than those in the mainstem of the river.

For the first two years after impoundment, catches of percids in Limestone Forebay index gillnetting surveys remained similar to catches from the Nelson River mainstem (i.e., <2% of the total catch). By 1992, walleye and sauger abundance appeared to increase and both species combined comprised 5-13% of the catch annually to 1997. By 1998, relative

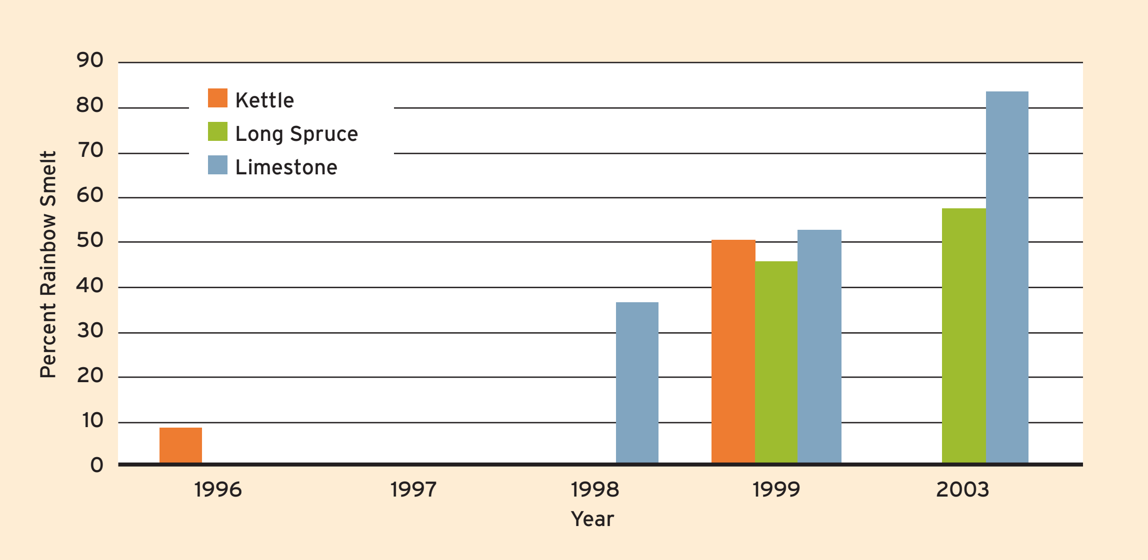


FIGURE 7-25
Percent composition of rainbow smelt in the diet of walleye in the Kettle, Long Spruce, and Limestone forebays. The Kettle Forebay was sampled in 1996 and 1999; Long Spruce in 1996, 1999, and 2003; and Limestone from 1996-1999 and in 2003.

PHOTO 7-30
Adult northern pike.

abundance of walleye increased further to nearly 15% of the annual catch, and in 1999 and 2003, walleye comprised 22% and 37% of the catch, respectively. Yellow perch remained scarce in the Limestone Forebay 15 years after impoundment, likely because they are less adapted to higher velocity habitats than walleye or sauger.

The increased walleye catches during the latter years of monitoring were attributed to strong year classes from 1995 onward. Less than 1% of walleye captured in the forebay in 1999 were older than ten years of age (the age of the forebay). Although the Kettle Forebay also contained evidence of similar strong year classes in 1999, 40% of the walleye catch was comprised of fish greater than ten years of age. Increased abundance and relative abundance of percids (walleye in particular) in the Limestone Forebay appears to be related to an increase in recruitment. The relative abundance of percids in the Limestone Forebay is expected to approach that observed in the Long Spruce Forebay, where percids now comprise approximately 40-50% of the index gillnetting catch.

Concurrent with the increase in abundance, Limestone Forebay sauger also appear to be increasing in size. Mean length of sauger captured in the Limestone Forebay has increased by approximately 20% since 1989. The mean size of walleye does not appear to have changed since impoundment.

Fish remained the most important food source for walleye in the lower Nelson River forebays. However, species composition of the fish consumed by walleye has changed dramatically since impoundment. For the first seven years after impoundment, cisco, lake chub (*Couesius plumbeus*), lake whitefish, burbot, white sucker, yellow perch, and brook stickleback (*Culaea inconstans*) comprised most of the diet. Rainbow smelt (*Osmerus mordax*) first appeared in walleye stomachs in 1996, and by 1999, comprised 50, 45, and 52% of the walleye diet in the Kettle, Long Spruce, and Limestone forebays, respectively (Figure 7-25). The presence of rainbow smelt in the forebays is expected to benefit walleye by enhancing feeding opportunities.

Length-adjusted mean mercury concentrations of walleye increased significantly between 1991 and 1994 to levels above the Health Canada standard of 0.5 ppm for retail fish (Figure 7-31). By 1996, mercury concentrations had decreased to 0.37 ppm and continued to do so through 1998 and 2001 when they reached 0.27 ppm. A non-significant increase in concentration to 0.33 ppm was recorded for 2003. The 2003 mercury concentration was higher than those for walleye from the Long Spruce Forebay (0.24 ppm) and the Nelson River mainstem downstream of the Limestone G.S. (0.25 ppm) for the same year, the difference being significant compared to Long Spruce. Based on the overlapping 95% CI, the 2003 mean concentration (CI: 0.27-0.41 ppm) was not statistically different from the mean of 0.41 ppm (CI; 0.35-0.47 ppm) obtained from a set of 61 waterbodies that, according to Bodaly et al. (2007), represent natural background levels for walleye from the Churchill-Burntwood-Nelson River region.

A sample of 16 sauger (the only time more than five fish were available for mercury analysis) from the Limestone Forebay in 1993 resulted in a mean mercury concentration of 0.60 ppm, which was similarly high as for walleye from the Limestone Forebay and sauger from the Long Spruce Forebay (0.61 ppm) for the same year.

Monitoring data show little evidence that percid populations have changed downstream of the Limestone G.S. since construction. While gillnet catches showed a slight proportional increase of walleye and sauger in 2003, this may be attributable to downstream emigration of the growing percid populations upstream of the generating station.

7.3.7 Northern pike

Northern pike (*Esox lucius*) prefer warm, slow, meandering, and heavily vegetated river habitats or warm, weedy bays of lake habitats; however, this species occurs in a wide range of habitats over the whole of their distribution (Scott and Crossman 1973). Although northern pike are common in the lower Nelson River (Photo 7-30), they are not abundant, as optimal habitat is rare. This species comprised 2-8% of electrofishing and gillnetting survey catches from the lower Nelson River mainstem. It was found primarily in tributary confluence habitats and in backwater areas of relatively low-water velocity. Pike are more abundant in large Nelson River tributaries (i.e., Limestone, Weir, and Angling rivers). For example, pike comprised 10% of hoopnet catches from the upper Limestone River in fall 1991 and about 30% of gillnet catches from the Angling River in 1987 and 1989 (Swanson et al. 1988, 1991).

Northern pike spawn during spring as water temperatures reach 4ºC. Marshes, the bays of lakes, and the vegetated floodplains of rivers are optimal spawning habitats. Specific spawning locations in the lower Nelson River are unknown, although small numbers of northern pike are known to migrate up larger Nelson River tributaries during May and June. Northern pike spawned in the Angling River during the last week of May and first week of June in 1991.

Pike eggs incubate for about two weeks before hatching. Free-swimming young-of-the-year and juvenile pike inhabit shallow, heavily vegetated waters in the periphery of streams and lakes. Young-of-the-year pike inhabit tributaries such as the Limestone, Angling, Weir, Roblin, and Kaiskwasotasine rivers as well as Sky Pilot, Wilson, and Leslie creeks. Northern pike are uncommon or absent in smaller tributaries, including, among others, Moondance, Beaver, and Swift creeks.

Lower Nelson River northern pike mature at approximately 4-5 years of age. Adult pike can reach lengths in excess of 1 m and have a maximum life expectancy of 17-20 years. Fish and crayfish are the most common dietary items for northern pike in the lower Nelson River. Fish movement data from the lower Nelson River show that most pike are recaptured in the same general area where they were tagged suggesting relatively limited home ranges. However, one northern pike was recaptured approximately 40 km from the location where it was tagged. Northern pike residing in tributaries during the open-water season are known to migrate downstream to larger tributary habitat during fall. In 2003, approximately 1000 northern pike migrated out of the Weir River from late August through mid October.

Changes Following Construction of the Limestone Generating Station

Northern pike are generally more abundant and larger in lake environments than in river environments. Consequently, it was expected that impoundment of the Limestone Forebay would result in greater pike abundance and larger-sized individuals than in the Nelson River mainstem.

For the first two years after impoundment, index gillnet catches of northern pike from the lower portion of the Limestone Forebay were similar to mainstem catches (<2% of the catch). Large increases in northern pike catches during the third and fourth years after impoundment (to approximately 20% of the catch) were at least partially attributable to increased sampling in the upper reaches of the forebay where pike are most abundant. Thereafter, pike catches ranged from 4-11% of the total catch annually.

A steady decrease in the catch of juvenile pike moving downstream in Sky Pilot Creek during fall from 1989 to 1997 suggested that there may have been a decrease in recruitment of northern pike after impoundment. However, a record catch of juvenile pike in Sky Pilot Creek in 1998 suggested that recruitment may be higher than before impoundment.

Northern pike have comprised 10-20% of the catch from the Long Spruce Forebay each year that index gillnetting has been conducted since 1985. As the Limestone Forebay matures, it is expected that northern pike abundance may increase. However, because the Limestone Forebay has a smaller littoral zone than the Long Spruce Forebay, pike abundance

PHOTO 7-31
Adult carp.

PHOTO 7-32
Adult freshwater drum.

PHOTO 7-33
Adult mooneye.

in the Limestone Forebay is expected to remain lower than in the Long Spruce Forebay.

Although size data have shown no distinct trend, mean lengths of pike sampled from the Limestone Forebay during the last three years of monitoring (550 mm in 1998, 545 mm in 1999, and 527 mm in 2003) were among the highest on record. Northern pike captured during index gillnetting in Stephens Lake during the mid to late 1990s and early 2000s have similar mean lengths to those found in the Limestone Forebay.

Length-adjusted mean mercury concentrations of northern pike from the Limestone Forebay increased significantly from 0.29-0.34 ppm from 1989-1992 and to 0.45 ppm in 1994 (Figure 7-31). Similar to the temporal trend in mercury levels observed for walleye, mean concentrations decreased consistently thereafter, reaching a minimum of 0.19 ppm in 2001. Also similar to walleye, mercury concentrations in pike increased to 0.24 ppm in 2003, but this increase was not significant. Based on the non-overlapping 95% CI, the 2003 mean concentration (CI: 0.21-0.29 ppm) was significantly lower than the mean of 0.42 ppm (CI; 0.36-0.47 ppm) obtained from a set of 64 waterbodies that, according to Bodaly et al. (2007), represent natural background levels for pike from the Churchill-Burntwood-Nelson River region.

Fish and crayfish remained the most important food items for northern pike throughout the aquatic monitoring studies. Rainbow smelt began to appear in fish stomachs in 1996, and by 1999, comprised 25, 12, and 70% of the relative abundance of dietary items in northern pike from the Kettle, Long Spruce, and Limestone forebays, respectively. While the spread of rainbow smelt is unrelated to hydroelectric development, the presence of this species is expected to have a large influence on the lower Nelson River fish community.

Northern pike abundance downstream of the Limestone G.S. does not appear to have changed since impoundment. Movements in and out of lower Nelson River tributaries changed little over the course of the aquatic monitoring studies. The one exception would be the large downstream fall migration of northern pike (>1,000) in the Weir River in 2003.

7.3.8 Other Large-bodied Species

A number of large-bodied fish species found in the lower Nelson River are at the northeastern edge of their geographical ranges. These species include: carp (*Cyprinus carpio*); lake chub (*Couesius plumbeus*); freshwater drum (*Aplodinotus grunniens*); goldeye (*Hiodon alosoides*); and mooneye (*Hiodon tergisus*). Combined, these species generally comprise less than 1% of index gillnetting and electrofishing catches from the Nelson River mainstem. Because of their scarcity, little is known of the life history characteristics of these species in the lower Nelson River area. Carp, lake chub, goldeye, and mooneye have only been captured in the Nelson River mainstem, while freshwater drum have been captured in the mainstem and moving in and out of the Limestone River (photos 7-31 to 7-33).

Burbot (*Lota lota*) have comprised less than 3% of mainstem index gillnetting catches and have been found as far downstream as the Nelson River Estuary. Burbot also comprise about 1% of fish movements in larger tributaries to the lower Nelson River. Burbot spawn under the ice during winter, but exact spawning locations in the lower Nelson River area are unknown. Spawning is thought to occur in the larger Nelson River tributaries such as the Limestone, Angling, and Weir rivers. Juvenile burbot comprised roughly 2% of the backpack electrofishing catch in the Weir River in 1992. Juvenile burbot are also known to utilize small lower Nelson River tributaries (e.g., Leslie, Sky Pilot, and Beaver creeks) as nursery habitat (Photo 7-34).

Rainbow smelt are an invasive species native to the east and west coasts of North America (Photo 7-35). Introduced into the Great Lakes during the early 1900s, its distribution has been gradually spreading westward. First found in Lake Winnipeg in 1990 (Remnant 1991; Campbell et al. 1991), rainbow smelt continued down the Nelson River to Split Lake by 1996, the mouth of the Angling River by 1997, and to the Nelson River Estuary by 1998. Upstream abundance has steadily increased as the species has extended its range downstream.

PHOTO 7-34
Juvenile burbot captured in a small tributary to the lower Nelson River.

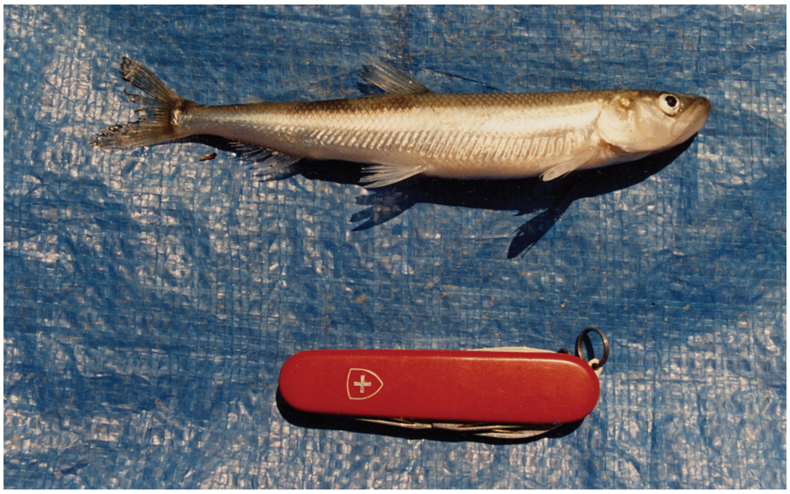


PHOTO 7-35
Adult rainbow smelt.

It is not yet clear how the invasion of rainbow smelt will affect fish populations in the lower Nelson River. Though smelt may serve as an alternate food source for piscivorous fish, they may also escalate competition for food and habitat (Rooney and Paterson 2009). Increases in the condition factor of walleye have been attributed to the availability of rainbow smelt as prey. It has also been suggested that rainbow smelt prey on larvae of other fish species (Rooney and Paterson 2009). The invasion of rainbow smelt presents a confounding factor in the analysis of the long-term effects of hydroelectric development on the aquatic ecology of the lower Nelson River.

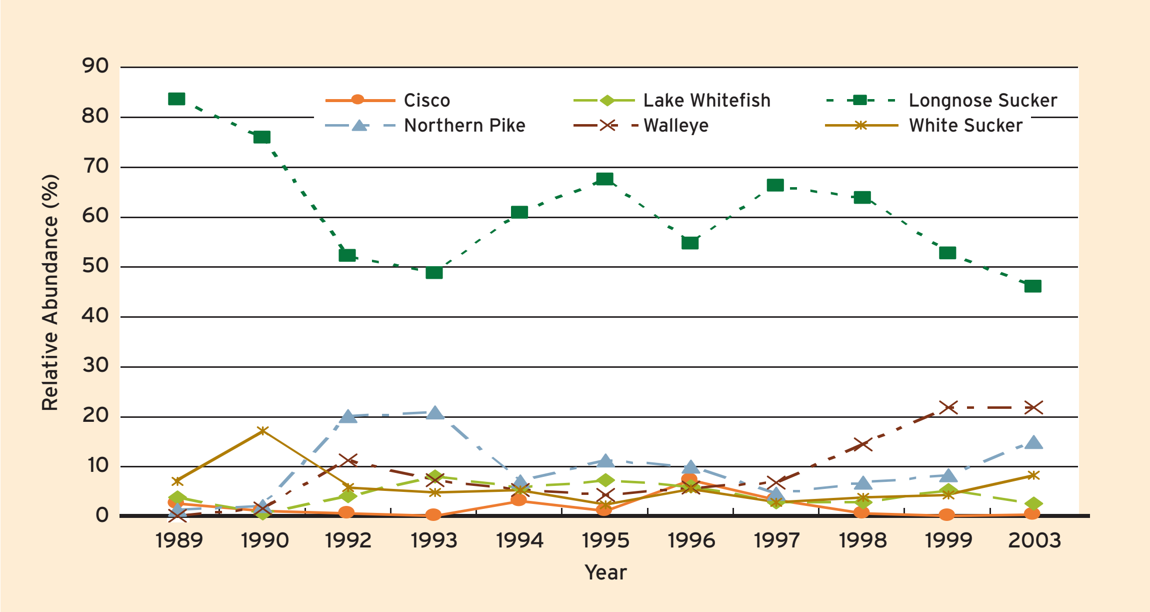
Changes Following Construction of the Limestone Generating Station

Impoundment of the Limestone Forebay is thought to have improved habitat conditions for a number of less abundant large-bodied species in the lower Nelson River. While these species have comprised an average of less than 1% of the index gillnet catch in the Limestone Forebay from 1989 to 1999, these species comprised 3-4% of catches from the Kettle and Long Spruce forebays from 1985 through 1999. It is expected that species such as lake chub, freshwater drum, goldeye, and mooneye will respond favourably to the decreased water velocities and increased depths in the forebay. Burbot, however, are not expected to benefit from impoundment. This species does best in large, deep lakes that stratify during summer; stratification does not occur in the Limestone (and Long Spruce) Forebay. Catches of burbot in the Kettle and Long Spruce forebays are similar to those from the Limestone Forebay and the Nelson River mainstem.

While forebays are not expected to facilitate the geographical range extension of rainbow smelt, increased depths resulting from impoundment are expected to contribute to increased abundance compared to the riverine environment. Smelt are a schooling, pelagic fish that inhabit the midwaters of lakes and are uncommon in flowing waters of streams and rivers, except during spawning (Scott and Crossman 1973). Although forebay habitat is not considered optimal for smelt, it may be more suitable than Nelson River mainstem habitat. As of 2003, data were insufficient to compare abundance of rainbow smelt in different areas of the lower Nelson River.

With the exception of rainbow smelt, there is no evidence to suggest that there has been a change in the abundance of any species downstream of the Limestone G.S. since construction.

FIGURE 7-26 Relative abundance of selected fish species in the Limestone Forebay between 1989 and 2003.



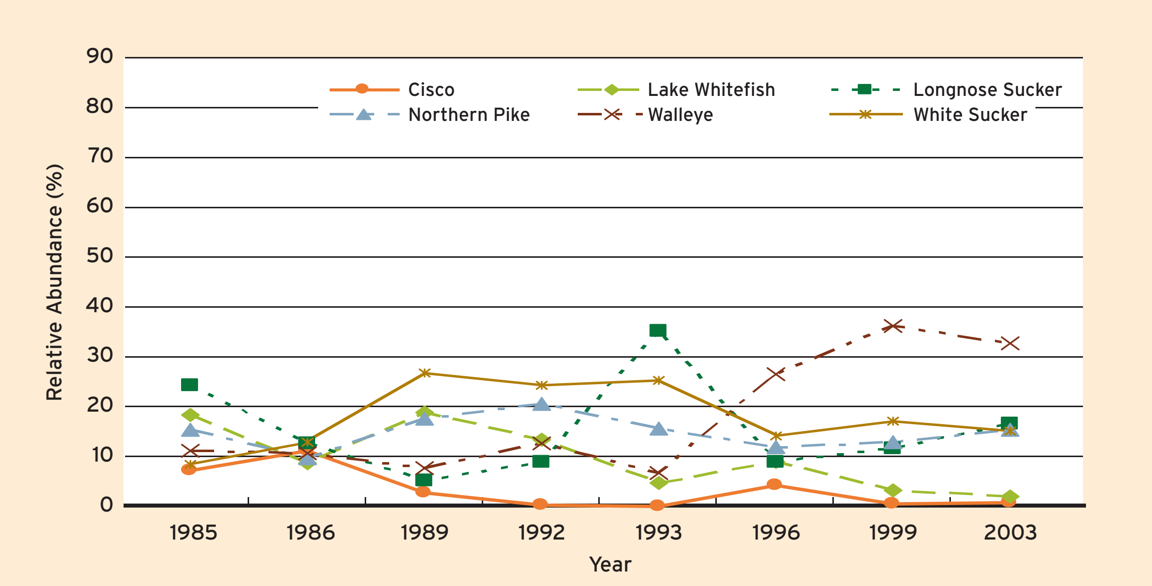


FIGURE 7-27
Relative abundance of selected fish species in the Long Spruce Forebay between 1985 and 2003.

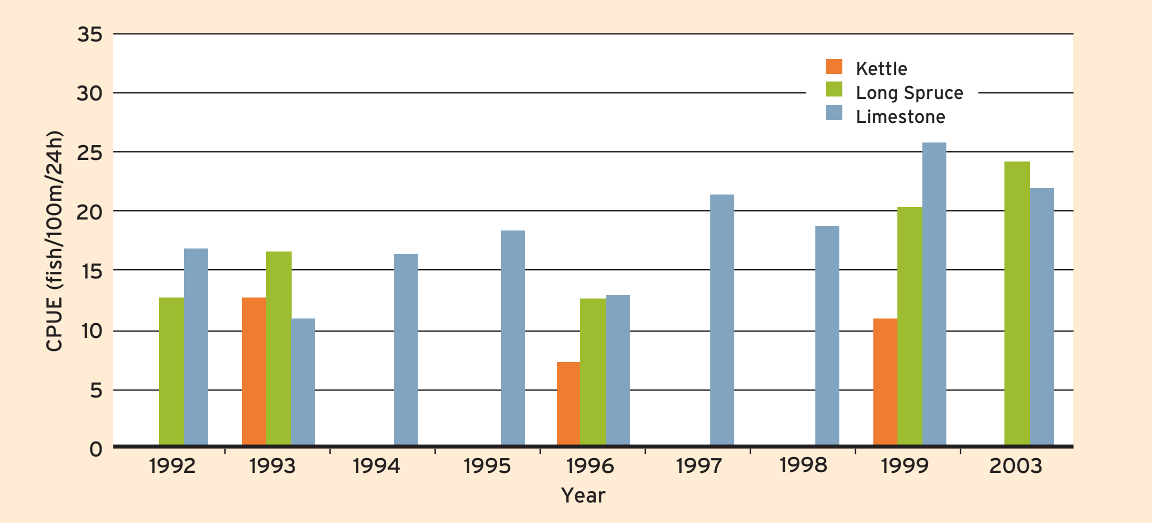


FIGURE 7-28
Mean catch-per-unit-effort (CPUE) for fish captured in gill nets set in the Kettle, Long Spruce, and Limestone forebays between 1992 and 2003. Zero values indicate years when forebays were not sampled.

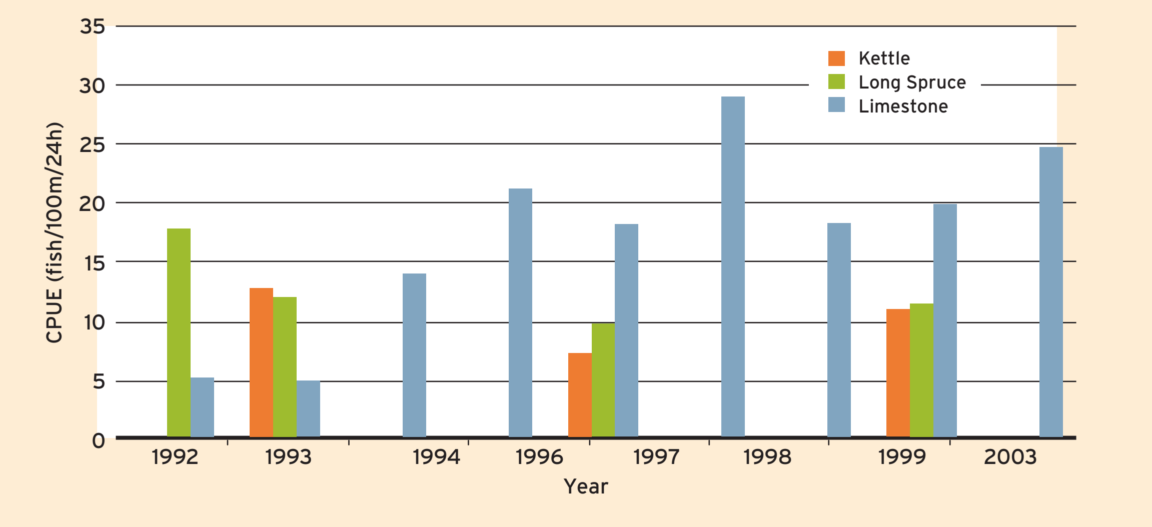


FIGURE 7-29
Mean catch-per-unit-effort (CPUE) for fish captured in gill nets set in the lower regions of the Kettle, Long Spruce, and Limestone forebays between 1992 and 2003. Zero values indicate years when lower forebay regions were not sampled.

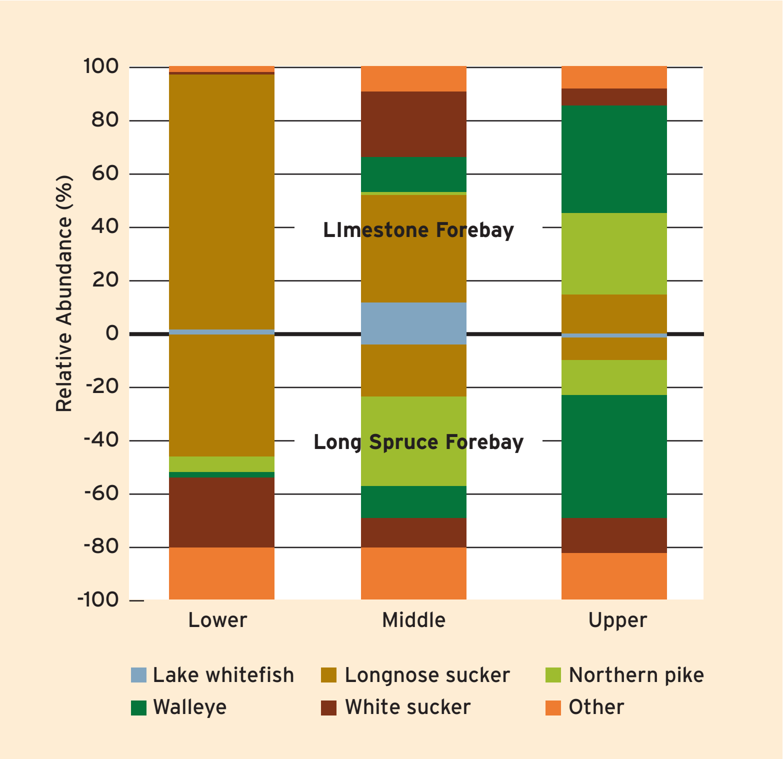


FIGURE 7-30 Fish species composition from gillnet catches by region in the Limestone and Long Spruce forebays (top and bottom, respectively) in 2003.

7.3.9 Forage Species

Small-bodied fish that serve as prey for larger piscivorous fish are classified as forage species. Lower Nelson River forage fish include the following groups: minnows (Cyprinidae); sticklebacks (Gasterosteidae); darters (Percidae); sculpins (Cottidae); and troutperches (*Percopsidae*). In addition, invasive rainbow smelt have continued to increase in abundance throughout the lower Nelson River and are becoming "naturalized" in the system.

No studies were conducted over the course of the aquatic monitoring programs that focused on the forage fish community in the Nelson River system. The majority of information on forage species was garnered from brook trout monitoring studies in Nelson River tributaries and incidental catches during electrofishing and index gillnetting studies focusing on other large-bodied species.

Changes Following Construction of the Limestone Generating Station

As discussed above, information on forage species is insufficient to determine if abundance has changed in the lower Nelson River following construction of the Limestone G.S. However, it is expected that species such as shiners (*Notropis* spp.) and troutperch (*Percopsis omiscomaycus*), preferring lacustrine environments to riverine environments, will do well in the Limestone Forebay. In contrast, habitat within forebays may become less suitable for species such as sculpins (*Cottus* spp.) and longnose dace (*Rhinichthys cataractae*) that often do well in swiftly flowing, well oxygenated, shallow waters. Monitoring data showed no evidence of decreasing numbers of forage species in unimpounded sections of Leslie Creek, a tributary of the Limestone Forebay. Similarly, forage species composition in Moondance Creek, which is located downstream of the Limestone G.S. does not appear to have changed since construction.

7.4 Summary of Effects

The following sections discuss how the Nelson River fish community as a whole has changed since construction of the Limestone G.S.

7.4.1 Upstream of the Limestone Generating Station

Impoundment of the Limestone Forebay essentially transformed a large, relatively shallow, riverine habitat into forebay habitat, which is characterized by deeper water and slower velocities. It was expected that these changes would be reflected in the fish community, via increases in the abundance of lentic species and decreases in the abundance of species that prefer lotic conditions.

Changes to fish communities prompted by habitat changes usually do not occur over the short term. Generally, riverine fish species are adapted to a variety of habitats, doing better in some habitats than in others. Changes to the fish community upstream of a generating station can occur

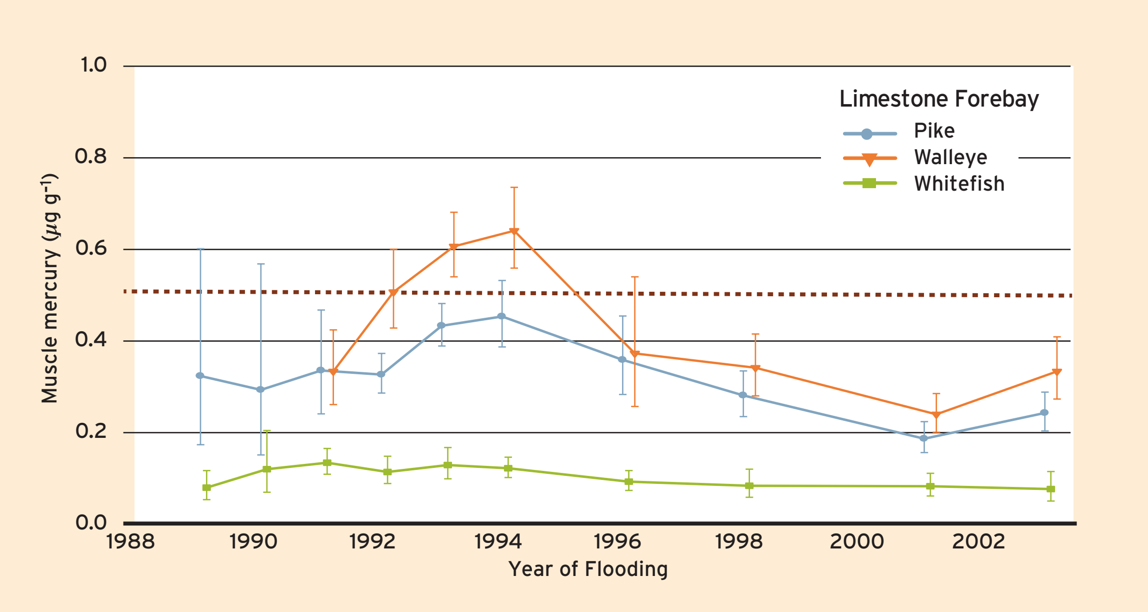


FIGURE 7-31 Length standardized mean mercury concentrations (± 95% confidence limits) for lake whitefish (standard length: 350 mm), northern pike (550 mm), and walleye (400 mm) from the Limestone Forebay, 1989-2003. The Health Canada standard for retail fish of 0.5 µg/g is indicated. Concentrations of 0.62 µg/g for three walleye in 1989 and of 1.31 µg/g for one walleye in 1990 are not shown.

because of:

i) emigration out of the forebay;

ii) changes in feeding conditions and food base;

iii) changes to predator/prey relationships; and

iv) changes to recruitment due to loss of spawning and/or nursery habitat.

As has been illustrated for longnose sucker (in Section 7.3.1.5), some of these changes may require more than one generation to become evident. Since most fish have life spans of 7-15 years, changes in fish abundance may not be noticeable for up to 20 years. This lag time is evident in the monitoring data collected from the Limestone Forebay.

Limestone G.S. aquatic environment monitoring program data suggest that some proportion of fish migrated out of the Limestone Forebay during the first year after impoundment. These downstream movements (and/or blockage of upstream fish movement by the Limestone G.S.) primarily affected the upstream abundance of large longnose sucker, lake whitefish, lake sturgeon, brook trout, and cisco. The fish population appeared to stabilize for a period thereafter. A comparison of index gillnetting caches from the Limestone Forebay between the years 1989-1999 and again in 2003 showed that, despite some annual variation, few changes occurred in species composition during the first eight years following impoundment (Figure 7-26). However, catches in the final three years of the Limestone Monitoring Program suggested that species composition was shifting. The frequency of occurrence of walleye in catches from 1998, 1999, and 2003 were the highest on record, and the average across these years was three times greater compared to the previous six-year average (1992-1997). In contrast, the frequency of occurrence of longnose sucker in the 1999 and 2003 catches decreased by approximately 10 and 22%, respectively, when compared to the six-year average from 1992 to 1997. This trend was expected to continue based on results from the Long Spruce Forebay, where walleye represented 33% and longnose sucker 17% of the catch in 2003 (Figure 7-27). The frequency of occurrence of white sucker, which comprised 8% of the 2003 total gillnet catch, is expected to increase and approximate the proportion observed in the Long Spruce Forebay (15%). The proportion of northern pike currently in the forebay is expected to increase slightly, but not approach the proportion seen in the Long Spruce Forebay due to limited littoral zone and aquatic vegetation.

In 2003, overall CPUE in the Limestone Forebay was 21.7 fish/100 m/24 h compared to 31.9 fish/100 m/24 h in the portion of the river downstream of the Limestone G.S. It is believed that overall abundance of fish in the Limestone Forebay likely decreased suddenly during the first year of impoundment due to downstream emigration. Although there was some annual variation by forebay region, there was little change in overall forebay CPUE from 1992 to 2003 (mean of 18.4 fish/100 m/24 h with a range of 12.7-25.6) (Figure 7-28). Catch-per-unit-effort in the Long Spruce Forebay also remained relatively stable from 1992 to 2003 (Figure 7-28). Further changes in overall CPUE in the Limestone Forebay are expected to remain minimal.

A higher CPUE in the lower region of the Limestone Forebay compared to the Long Spruce Forebay during the latter years of the Limestone Monitoring Program (Figure 7-29) may have been attributable to the vestigial population of longnose sucker. As these fish expire, it is expected that CPUE in the lower reach will become more similar to the downstream sections of the Kettle and Long Spruce forebays. It is also expected that the distribution of species within the Limestone Forebay will become more uniform, similar to the distributions seen in the Long Spruce Forebay (Figure 7-30). Fish, such as mooneye, will fill the pelagic midwater niche that has been created in the lower portion of the forebay, which will contribute to the overall fish production per square metre of wetted area.

Standardized mercury concentrations in piscivorous fish (i.e., walleye and northern pike) increased following impoundment, peaking in 1993 and 1994 (Figure 7-31). While mercury concentrations for northern pike never exceeded the Health Canada guideline for commercial sale in Canada, they were above the guideline limit for walleye during the two peak years. Mercury concentrations for both species returned to background levels within seven years of impoundment.

7.4.2 Downstream of the Limestone Generating Station

The Nelson River fish community is adapted to a large and shallow river environment with high daily and seasonal water level fluctuations. Construction of the Limestone G.S. has added to the volatility of this environment by causing incremental changes to the magnitude and duration of water level fluctuations.

Tag returns suggest that emigration out of the Limestone Forebay may have contributed to a short-term increase in fish abundance downstream of the generating station immediately after impoundment. However, monitoring of fish movements in tributaries downstream of the generating station and periodic sampling in the Nelson River mainstem has provided little evidence of any substantial long-term change in abundance or relative abundance for most species since construction. One exception may be anadromous cisco that migrate to Hudson Bay to forage during summer and into the Limestone and Weir rivers to spawn during fall. Cisco utilization of both these Nelson River tributaries, particularly the Limestone River, decreased substantially from 1990-1992 to 2003. Cisco also comprised a smaller proportion of the fall experimental gillnet catch from the Nelson River mainstem in 1997 compared to 1991. At this time, data are insufficient to determine whether the decrease is linked to the Limestone G.S. or some other unknown factor. The lack of pre-project data with regard to cisco in the Nelson River limits our ability to interpret post-project changes in cisco abundance. Walleye abundance may be increasing downstream of the Limestone G.S. as a result of downstream transfers of walleye from increasing populations upstream.

TABLE 7-1 Summary of fish population studies conducted in the Kettle, Long Spruce, and Limestone forebays, and in tributaries to these forebays, from 1985 to 2003.

		Year																
Waterbody	Study type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2002	2003
Brooks Creek	Larval drift				+													
	Electrofishing				+													
Kettle Forebay	Gillnet									+			+			+		
Kettle River	Gillnet	+								+			+			+		
	Radio-telemetry	+		+	+													
Leslie Creek	Larval drift			+	+		+	+	+	+	+	+	+	+	+	+		
	Electrofishing							+	+	+				+		+		
	Weir/hoopnet							+	+									
	Stream habitat			+														
Limestone Forebay	Gillnet				+	+	+	+	+	+	+	+	+	+	+	+		+
	Radio-telemetry	+	+	+														
Long Spruce Forebay	Gillnet	+	+			+			+	+			+			+		+
	Radio-telemetry			+	+													
Sky Pilot Creek	Larval drift			+	+		+		+				+					
	Weir/hoopnet						+	+	+		+			+	+		+	
	Stream habitat			+														
Wilson Creek	Larval drift			+	+		+									+		
	Stream habitat			+	+													

TABLE 7-2 Summary of fish population studies conducted in the lower Nelson River region downstream of the Limestone G.S. from 1985 to 2003.

		Year																
Waterbody	**Study Type**	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2002	2003
Nine-Mile Creek	Larval drift		+	+	+	+	+											
	Electrofishing						+											
	Weir/hoopnet			+	+	+	+	+				+				+		
	Radio-telemetry	+																
	Brook trout							+				+				+		
	Habitat studies			+														
Twelve-Mile Creek	Larval drift			+	+	+	+											
	Electrofishing						+											
	Weir/hoopnet			+		+	+	+				+				+		
	Brook trout							+				+				+		
	Habitat studies			+	+													
Fifteen Creek	Electrofishing			+	+		+	+	+								+	
	Brook trout				+	+			+								+	
	Habitat studies					+											+	
	Fish passage					+			+		+							
Angling Lake	Electrofishing					+												
	Gillnet			+														
	Radio-telemetry				+	+												
	Habitat studies					+												
Angling River	Weir/hoopnet							+			+			+	+			+
Anyways Creek	Habitat studies		+															
Beaver Creek	Larval drift			+														
	Electrofishing		+	+	+	+	+	+	+	+	+			+		+	+	
	Weir/hoopnet									+	+						+	
	Brook trout		+			+			+	+	+						+	
	Habitat studies		+			+			+								+	
	Fish passage																+	

Table 7-2 continued

		Year																
Waterbody	**Study Type**	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2002	2003
Broten Creek	Electrofishing								+									
	Weir/hoopnet								+									
CN Creek	Larval drift			+	+		+				+	+	+	+	+	+		
	Electrofishing			+	+		+	+	+		+			+		+	+	
	Brook trout								+			+					+	
	Habitat studies			+														
Goose Creek	Electrofishing	+	+	+	+	+	+	+	+									
	Brook trout	+	+			+			+									
	Habitat studies	+	+	+		+											+	
	Fish passage					+												
Kaiskwasotasine River	Electrofishing								+									
	Weir/hoopnet								+									
Limestone River	Gillnet								+									
	Weir/hoopnet						+	+	+		+	+	+	+	+	+		+
	Radio-telemetry	+	+			+												
	Lake sturgeon											+						
	Habitat studies					+												
McMillan Lake	Habitat studies				+													
Moondance Creek	Larval drift			+			+	+	+	+		+	+	+		+		
	Electrofishing	+	+	+	+	+	+	+	+	+	+			+		+	+	
	Weir/hoopnet						+	+	+	+	+	+		+	+			
	Radio-telemetry	+																
	Brook trout	+	+			+			+	+	+	+					+	
	Habitat studies	+	+	+					+									

Table 7-2 continued

		Year																
Waterbody	**Study Type**	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2002	2003
Nelson River	Gillnet			+	+			+						+				+
	Radio-telemetry	+	+					+										
	Electrofishing								+									
	Lake sturgeon		+															
	Habitat studies								+									
North & South Seal Creeks	Electrofishing																	+
	Habitat studies																	+
Roblin River	Electrofishing								+									
	Weir/hoopnet								+									
Sundance Creek	Electrofishing	+															+	
	Brook trout	+															+	
	Habitat studies		+														+	
	Fish passage					+												
Swift Creek	Electrofishing	+	+	+	+	+	+	+	+								+	
	Weir/hoopnet															+		
	Brook trout	+	+			+			+								+	
	Habitat studies	+	+	+		+											+	
	Fish passage					+												
Tiny Creek	Electrofishing	+	+	+	+	+	+	+	+					+		+	+	
	Weir/hoopnet										+						+	
	Brook trout	+	+			+			+								+	
	Habitat studies	+	+			+											+	
	Fish passage					+			+		+						+	
Weir River	Weir/hoopnet						+		+				+			+		+
	Radio-telemetry		+											+				
	Habitat studies						+											
	Lake sturgeon								+		+		+	+	+			

TABLE 7-3 A list of freshwater fish species identified in the lower Nelson River system from 1985 to 2003 and the relative abundance, by habitat type, of each species.

Family Species	Common name	Abbreviation	Relative abundance by habitat type M-L	M-R	T-L	T-S
Petromyzontidae						
Ichthyomyzon unicuspis	Silver lamprey	SLLM	R	R	R	-
Acipenseridae						
Acipenser fulvescens	Lake sturgeon	LKST	U	U-C	C[1]	-
Hiodontidae						
Hiodon alosoides	Goldeye	GOLD	R	R	-	-
Hiodon tergisus	Mooneye	MOON	U	U	-	-
Cyprinidae						
Couesius plumbeus	Lake chub	LKCH	C	C	C	R
Cyprinus carpio	Carp	CARP	R	R	-	-
Margariscus margarita	Pearl dace	PRDC	C	-	R	A
Notropis atherinoides	Emerald shiner	EMSH	A	U-C	R	-
Notropis heterolepis	Blacknose shiner	BLSH	U	-	-	R
Notropis hudsonius	Spottail shiner	SPSH	C	R	-	-
Phoxinus eos	Finescale dace	FNDC	-	-	-	U
Phoxinus neogaeus	Northern redbelly dace	NRDC	-	-	-	R
Pimephales promelas	Fathead minnow	FTMN	C	-	-	U
Rhinichthys cataractae	Longnose dace	LNDC	A	R	R-U	C-A
Rhinichthys obtusus	Western blacknose dace	WBDC	-	-	R	R
Catostomidae						
Catostomus catostomus	Longnose sucker	LNSC	A	A	C	U-C
Catostomus commersonii	White sucker	WHSC	C-A	A	A	C
Moxostoma macrolepidotum	Shorthead redhorse	SHRD	R	R	-	-
Esocidae						
Esox lucius	Northern pike	NRPK	A	C	C	A
Osmeridae						
Osmerus mordax	Rainbow smelt	RNSM	A	C	R	R
Salmonidae						
Coregonus artedi	Cisco	CISC	U	U-C	U-C	-
Coregonus clupeaformis	Lake whitefish	LKWH	U-C	C-A	U-C	-
Salvelinus fontinalis	Brook trout	BRTR	R	R	C[2]	C
Percopsidae						
Percopsis omiscomaycus	Troutperch	TRPR	U	U	R	-
Gadidae						
Lota lota	Burbot	BURB	U-C	U	U	R

Table 7-3 continued

Family Species	Common name	Abbreviation	Relative abundance by habitat type M-L	 M-R	 T-L	 T-S
Gasterosteidae						
Culea inconstans	Brook stickleback	BRST	R	R	U	A
Pungitius pungitius	Ninespine stickleback	NNST	R	R	-	-
Cottidae						
Cottus cognatus	Slimy sculpin	SLSC	C	U-C	U-C	C-A
Cottus ricei	Spoonhead sculpin	SPSC	U	U	U-C	-
Percidae						
Etheostoma exile	Iowa darter	IWDR	-	-	-	U
Etheostoma nigrum	Johnny darter	JHDR	-	-	R	U
Perca flavescens	Yellow perch	YLPR	U	R	R	-
Percina caprodes	Logperch	LGPR	R	R	R	-
Percina shumardi	River darter	RVDR	-	R	-	-
Sander canadensis	Sauger	SAUG	U-C	U	R	-
Sander vitreus	Walleye	WALL	A	C	C	-
Sciaenidae						
Aplodinotus grunniens	Freshwater drum	FRDR	U	R	R	-

[1] Primarily in the Weir River

[2] Limestone and Weir rivers only

M-L = Mainstem-Lacustrine (i.e., Kettle, Long Spruce, and Limestone forebays)

M-R = Mainstem-Riverine

T-L = Tributaries-Large (i.e., Limestone, Weir, and Angling rivers)

T-S = Tributaries-Small (i.e., Beaver Creek, Swift Creek, Tiny Creek)

R = Rare

U = Uncommon

C = Common

A = Abundant

8.0

NELSON RIVER ESTUARY

8.1 Introduction

Estuaries form where the flow of a river meets the flood of the ocean tide, and marks the transition from freshwater to marine environments. These areas are generally more productive than adjacent marine waters due to the concentration of nutrients from river inflow, terrestrial runoff, and upwelling of deep marine waters. Freshwater inflow is the most important determinant of estuarine characteristics because of its effect on total **salinity**, ice formation, accumulation of nutrients and organic substances, and water circulation and residence time.

The Nelson River Estuary is formed in the broad funnel-shaped mouth of the Nelson River where it enters the western shore of Hudson Bay (Figure 8-1, Photo 8-1). The coastal region of the estuary has little relief with a gradient of only one metre per kilometre (Tarnocai 1982). Landforms consist of raised beaches, palsas, and peat plateaus. The nearest communities are Bird and Gillam, both more than 100 km inland.

The primary landmark in the estuary is the historical settlement of Port Nelson, which was the planned port for northern grain shipments during the early 1900s. By 1926, it was determined that Port Nelson was not suitable for port development and it was abandoned in favour of Churchill. An artificial island, connected to the north shore by an 800-m trestle bridge, remains at the site (Photo 8-2).

Very little was known of the Nelson River Estuary, the largest estuary in western Hudson Bay, prior to hydroelectric development on the Nelson River. Some information on the bathymetry and fish resources was collected by the Burleigh expedition in 1914 (Comeau 1915) and Manitoba Fisheries Branch conducted limited fish collections in the estuary and nearby tributaries in 1979 (Gaboury 1980a).

As part of the study program in preparation for construction of the proposed Conawapa G.S., a multi-disciplinary physical and biological study of the estuary was undertaken in 1988 (Baker 1989). Further studies on oceanography, plankton, and fish were conducted in 1989 (Baker 1990a) and 1992 (Baker et al. 1993). The objective of these studies was to collect **baseline information** to describe the existing physical and biological nature of the Nelson River Estuary as it was after construction of the Limestone G.S.

PHOTO 8-1
Aerial view of the Nelson River Estuary (exposed tidal flats north of Fort Nelson).

PHOTO 8-2
Artificial island near Port Nelson.

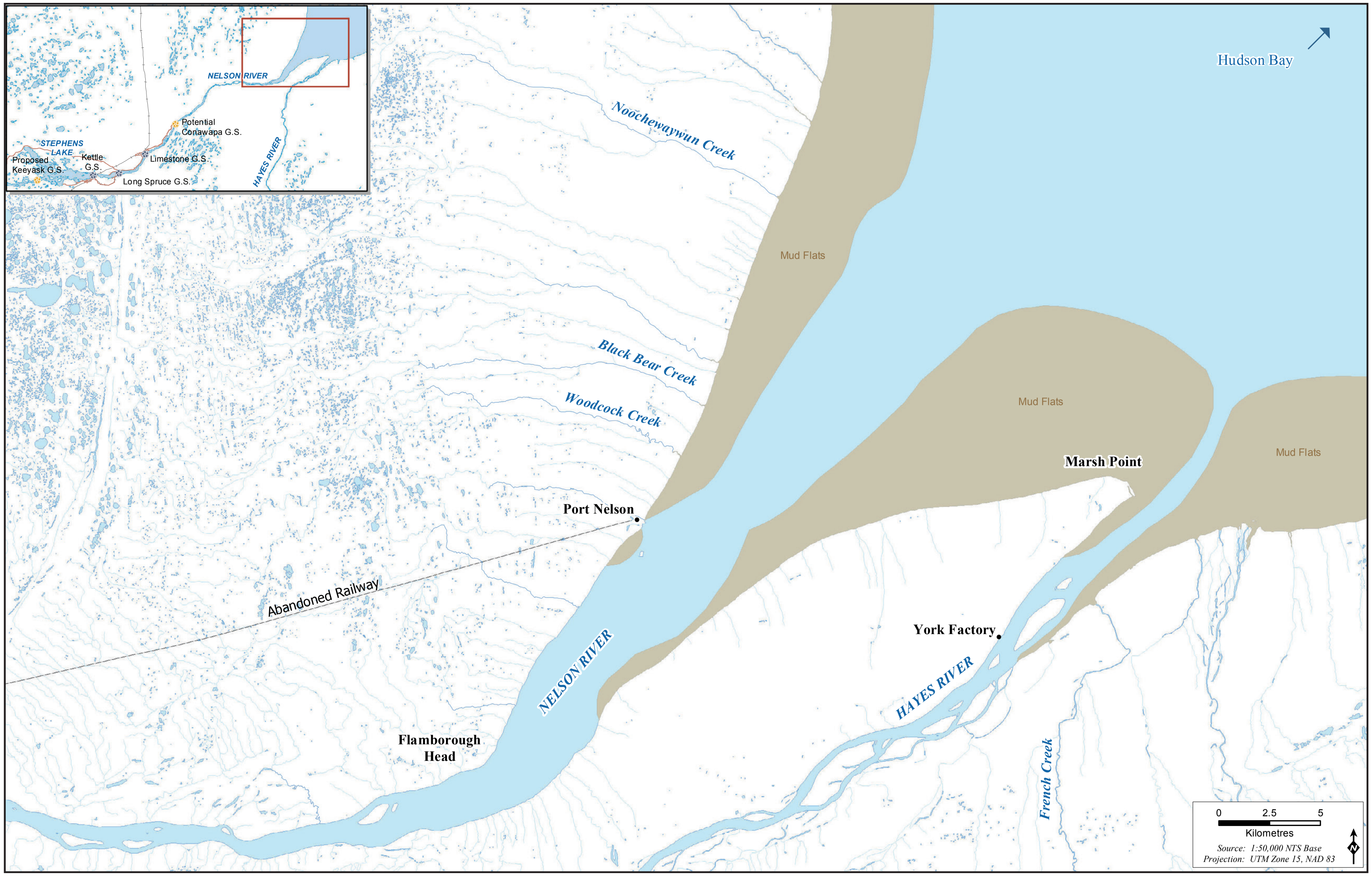


FIGURE 8-1
Map of the Nelson River Estuary and its location in relation to the Limestone G.S. and the potential location of the Conawapa G.S.

In 1995, a multi-year program was initiated to establish an environmental database for the estuary that could be used for monitoring potential effects of future developments. A pilot study assessed various sampling techniques, identified suitable monitoring components of the estuarine environment, and established a consistent protocol for data collection. Subsequent studies conducted from 1996 to 1999 documented:

- i) temperature and salinity profiles;
- ii) water quality; and
- iii) zooplankton community composition and abundance in the estuary.

A study on beluga whale abundance in the Nelson River Estuary also was carried out in 2003. Monitoring of the fish community was not conducted as part of these studies, although incidental catches of planktonic fish were documented in studies carried out from 1995 to 1999.

The following sections provide:

- a brief description of the sampling methods utilized in the Nelson River Estuary during the course of studies conducted from 1988 to 2003; and
- the current understanding of the physical and biological conditions within the estuary based on historical studies and those studies conducted as part of the Conawapa G.S. program and a brief perspective on interpreting those data in relation to hydroelectric development on the Nelson River.

8.2 Methods

8.2.1 Physical Environment

Detailed information relating to topography, bathymetry, sediments, and water circulation and flow was generated from published information and on physical data (i.e., water temperature, salinity, and conductivity) collected throughout the estuary. Temperature, salinity, and conductivity vertical profiles were measured *in situ* with water quality meters each time water quality samples were collected (see Section 8.2.2 for sampling years).

8.2.2 Water Quality

Water quality sampling was an integral component of all studies conducted in the Nelson River Estuary since 1988. Although the location and number of sites varied among years, all studies included nearshore and offshore sampling sites to provide an understanding of water movements and vertical and lateral stratification. In all years except 1989, water samples also were collected at depths 0.5 to 2.0 m above the sediment surface (Photo 8-3). The following water quality parameters were measured in each sample: nitrate; nitrite; ammonia; dissolved organic and inorganic carbon; total suspended solids; pH; and chlorophyll a. Total dissolved nitrogen, total and dissolved Kjeldahl nitrogen, suspended nitrogen, suspended phosphorus, total dissolved phosphorus, suspended carbon, total organic carbon, soluble reactive silica, chlorine, sulphate, sodium, potassium,

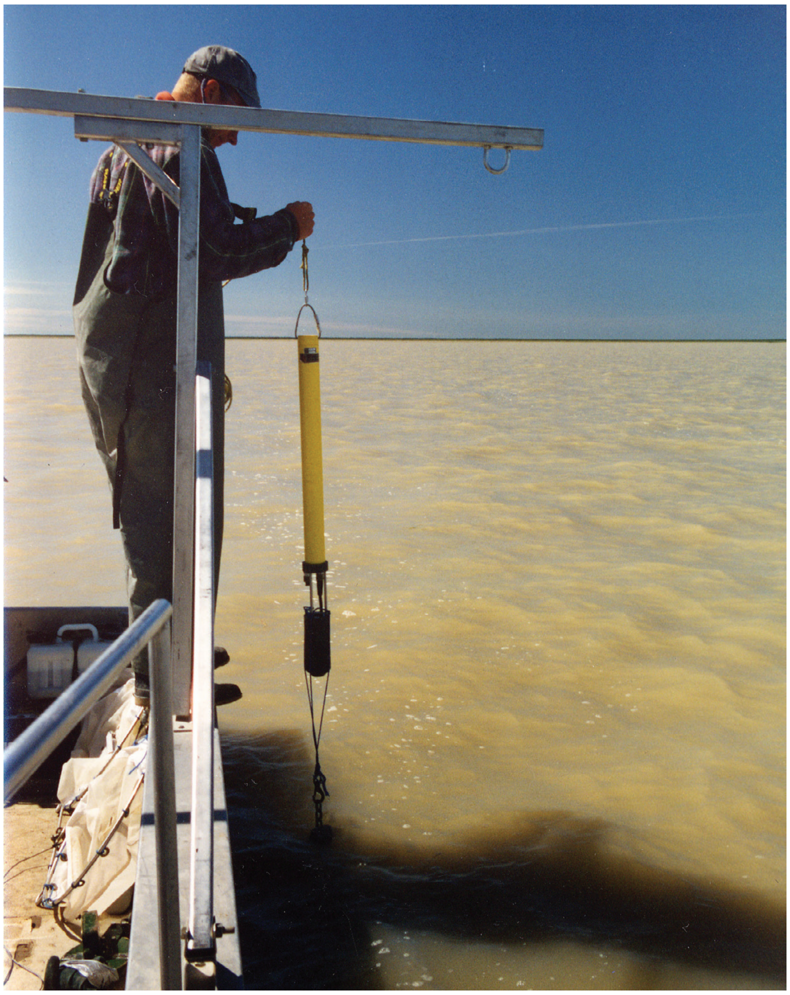


PHOTO 8-3
Water quality sampling in the Nelson River Estuary.

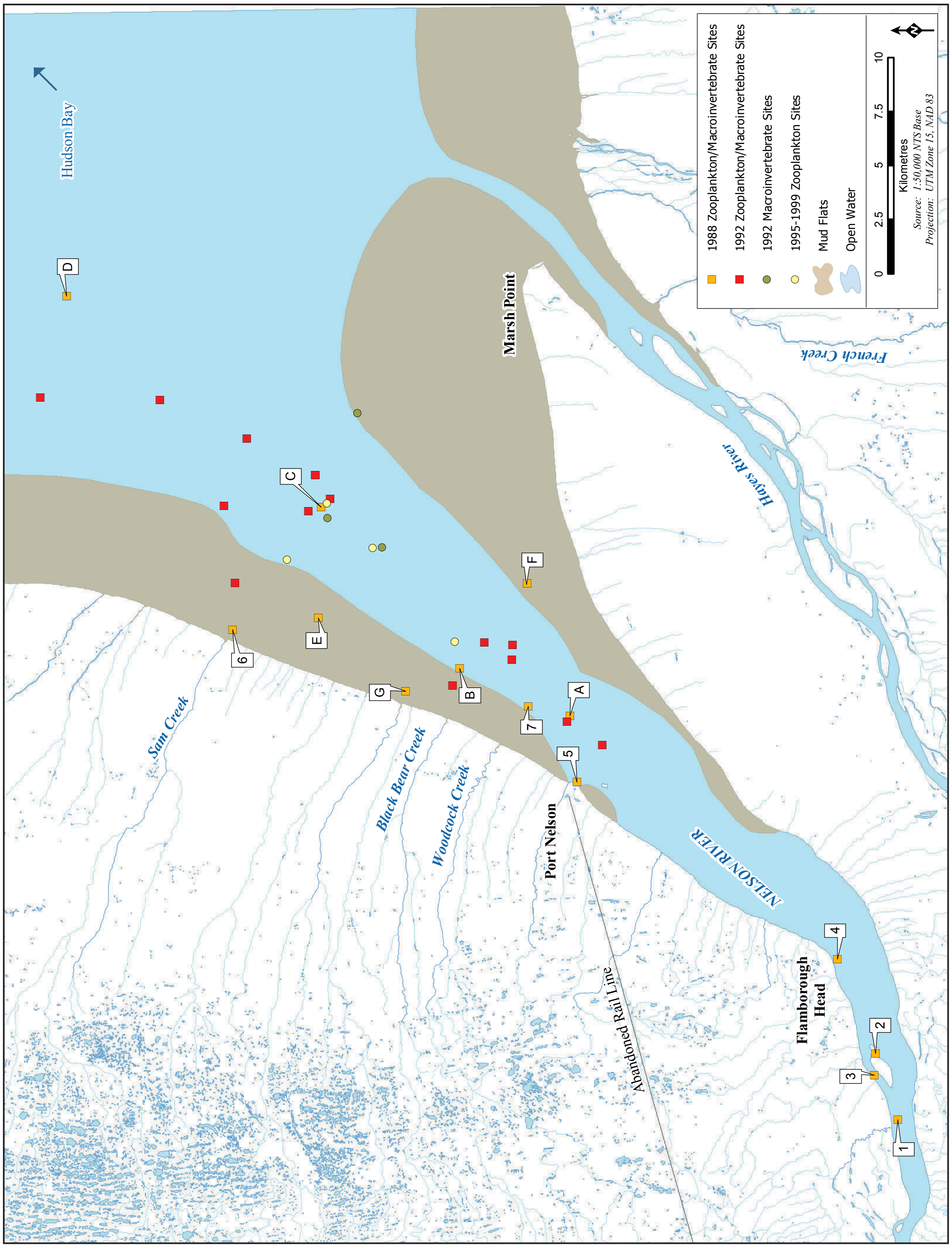


FIGURE 8-2
Zooplankton and macroinvertebrate sampling sites in the Nelson River Estuary, 1989, 1992, and 1995-1999.

magnesium, calcium, iron, and alkalinity were also measured in some years.

8.2.3 Lower Trophic Levels

8.2.3.1 Phytoplankton

Phytoplankton biomass can be estimated by measuring the levels of chlorophyll *a* in the water. Chlorophyll *a* was monitored intermittently in water samples collected from 1988 to 1999. In 1992 and 1995, phytoplankton species composition, abundance, and biomass were determined from surface and bottom water samples.

8.2.3.2 Zooplankton

The abundance and diversity of zooplankton species were determined from samples collected in both mud-flat and open-water estuarine habitats in 1988, 1992, and from 1995 to 1999 (Figure 8-2). Vertical and horizontal zooplankton tows were conducted at both high and low tides using 243-µm mesh Wisconsin-style plankton nets (Photo 8-4). Horizontal tows incorporated a General Oceanic digital flow meter to record the amount of filtered water and a cable inclinometer to calculate tow depth.

8.2.3.3 Macroinvertebrates

Macroinvertebrate samples were collected in 1988 and 1992 from several sites located throughout the estuary (Figure 8-2). Samples were collected using a Burton-Flannagan modified Ekman grab (collected sediments from the mud flats), an **epibenthic** sampling sled (collected invertebrates just above the bottom substrate) or an Isaacs-Kidd trawl net [collected invertebrates (and planktonic fishes) from the water column].

8.2.4 Fish Community

Fisheries surveys were conducted in the Nelson River Estuary in 1988, 1989, and 1992. Sampling methods included beach seining, gillnetting, and an Isaacs-Kidd trawl net (Photo 8-5). Fish collections occurred during July, August, and October. Fishing was conducted throughout the estuary and in coastal creek mouths. All fish captured were identified to species and enumerated. Fish captured in gill nets were measured, weighed, and classified for sexual maturity. Fish captured in beach seines and trawl nets were fixed in formalin and transported to Winnipeg prior to species identification and enumeration. Stomach contents were removed and identified. Ages and muscle mercury concentrations were determined for a subsample of selected species. Incidental fish catches also occurred during zooplankton monitoring studies in the estuary between 1995 and 1999. Although not targeted specifically, all fish (predominately larvae) captured in zooplankton sampling gear were identified and enumerated.

PHOTO 8-4
Collecting zooplankton samples with a net tow.

PHOTO 8-5
Fish sampling using an Isaac-Kidd trawl net in the Nelson River Estuary.

8.2.5 Marine Mammals

The presence and abundance of two marine mammals, beluga whale (*Delphinapterus leucas*) and bearded seal (*Erignathus barbatus*), were first noted on an opportunistic basis during studies conducted in 1988 and 1989 (photos 8-6, 8-7, and 8-8). Observations were made from helicopter and boat. Beluga whale utilization of the Nelson River Estuary was investigated during a more intensive aerial survey in 2003. Surveys were flown at different combinations of tide state and Nelson River flow rate during late July and early August. The surveys covered an area of approximately 150 km^2 and extended from Port Nelson to about 40 km into Hudson Bay. Observational surveys were carried out via float plane.

PHOTO 8-6
Beluga whale in the Nelson River Estuary.

PHOTO 8-7
Bearded seals basking along the shoreline of the Nelson River Estuary.

PHOTO 8-8
Close-up of a bearded seal.

8.3 Results

8.3.1 Physical Zones and Water Movements

As the Nelson River enters Hudson Bay, it broadens from approximately 2.5 km across at Flamborough Head to over 20 km across at Marsh Point. The "trumpet-shaped" estuary is shallow (seldom exceeding 5 m in depth) and has little bottom relief with the exception of a narrow and deep (15-30 m) central channel that extends from just upstream of Port Nelson through the outer estuary and into Hudson Bay. The broad shallow nature of the river mouth and large tides make it difficult to define the extent of brackish conditions as the river enters Hudson Bay.

Extensive mud flats dominate the nearshore region of the Nelson River Estuary up to 10 km or more offshore. Much of the mud-flat region is alternately exposed and flooded during the tidal cycle. The bottom of the estuary is generally hard and subject to scouring action by the tide-generated current. Substrate is composed primarily of compacted fine silts and clays with numerous boulders and gravel shoals.

Mean annual freshwater inflow to the estuary is 2,975 m^3/sec (1977-1990). In 1978, discharge to the estuary increased by approximately 26% following flow regulation at Lake Winnipeg and flow augmentation by diversion of the Churchill River. Regulation of Nelson River flows resulted in a seasonal reversal of peak flows, which now occur during winter in concert with peak energy demands. Despite the size of the Nelson River, freshwater input to the estuary constitutes only 3-4% of the total water volume moving on- and off-shore in a single tide. Consequently, Nelson River flows have only a small effect on stage and water movements in the estuary.

Water movements in the Nelson River Estuary are primarily affected by three main forces:

i) tides;

ii) the **Coriolis force**; and

iii) weather-related effects (i.e., wind and air pressure).

The tides at Port Nelson have maximum amplitudes of 4.3 m and are semi-diurnal, with two complete high and low tides every 25 hours. Because of the shallowness and broad shape of the estuary, the tides cause large volumes of water to move on- and offshore, creating water velocities of up to 2.0 m/sec. The times between high and low tides and between low and high tides are not equal. On average, 7.5 hours separate a high tide from the next low tide, while 4.8 hours separate a low tide from the next high tide. The strong currents circulate and mix water in a vertical (top to bottom) and lateral (onshore and offshore) direction. The Coriolis force, generated by the earth's rotation, causes water to circulate in a counter-clockwise direction around Hudson Bay. Water flowing out of the Nelson River (and the adjacent Hayes River) is pulled in a southeasterly direction, causing a horizontal separation of flow. This results in fresh, riverine water being drawn along the south shore of the estuary around Marsh Point, and causes an intrusion of more saline, marine water along the north shore of the estuary. Weather-related effects increase lateral and vertical circulation of water. Strong northeasterly winds can exacerbate the effects of tides by causing higher stages and increased mixing of fresh and saline water.

The Nelson River Estuary is intermediate between a partially mixed estuary and a homogenous estuary. Water is particularly well-mixed in the shallow, mudflat region of the estuary, while vertical temperature and salinity profiles are roughly uniform over much of the estuarine environment. A vertically stratified region exists in the deeper central channel. The magnitude of vertical stratification is positively correlated with water depth and the strength of the incoming tide.

Water temperature generally decreased with increasing distance from shore, while salinity and conductivity increased (Table 8-1). Temperature, salinity, and conductivity all increased with increasing depth, with warmer fresh water overlying cooler marine water during high tide in areas of low to moderate salinity. At low tide, the water column was:

i) completely mixed;

ii) uniform in temperature;

iii) dominated by fresh water; and iv) usually warmer than during high tide (Figure 8-3).

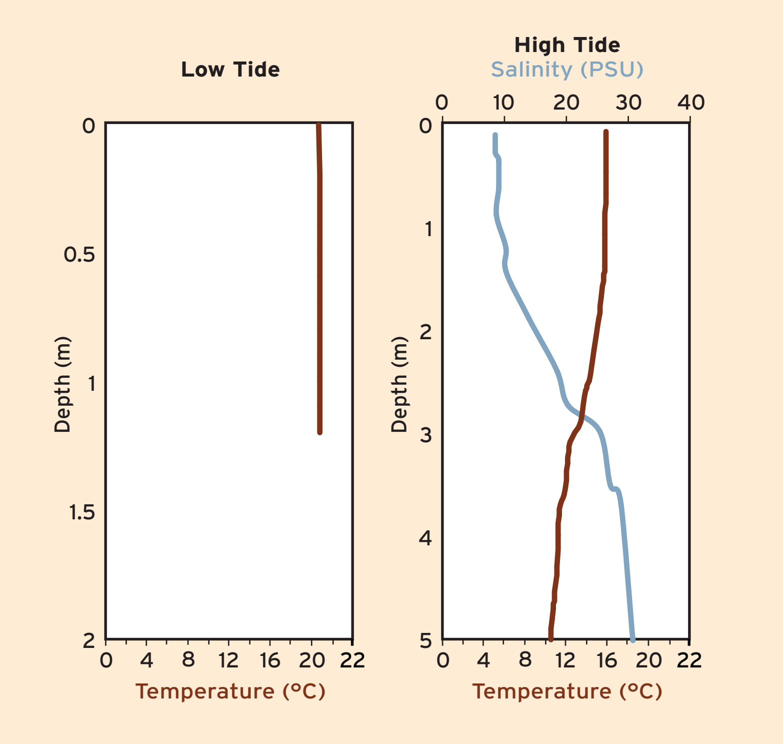


FIGURE 8-3 Vertical temperature (°C) and salinity (Practical Salinity Units) profiles at a nearshore site during low and high tides, July 1997.

Salinities increased more rapidly in an easterly direction along the north coast of the Nelson River than along the south coast toward Marsh Point due to the Coriolis force. As fresh water moves along the south coast toward Marsh Point, marine water enters from the northeast and moves along the north coast toward the mouth of the Nelson River. High tide, in conjunction with the Coriolis force, acts to raise salinities in the nearshore estuarine and stratified regions. Salinity intrusion occurred at least as far upstream as Port Nelson.

Based on salinity profiles and mixing patterns, four physical zones are described in the estuary (Figure 8-4):

- a "riverine zone" composed entirely of fresh water that extends from Gillam Island to Port Nelson;
- a "nearshore estuarine zone" with water of low salinity (1-8 **ppt**) that is completely vertically mixed;
- a narrow, "stratified zone" between the nearshore and offshore zones that contains water of moderate salinities (8-20 ppt) and is vertically stratified; and

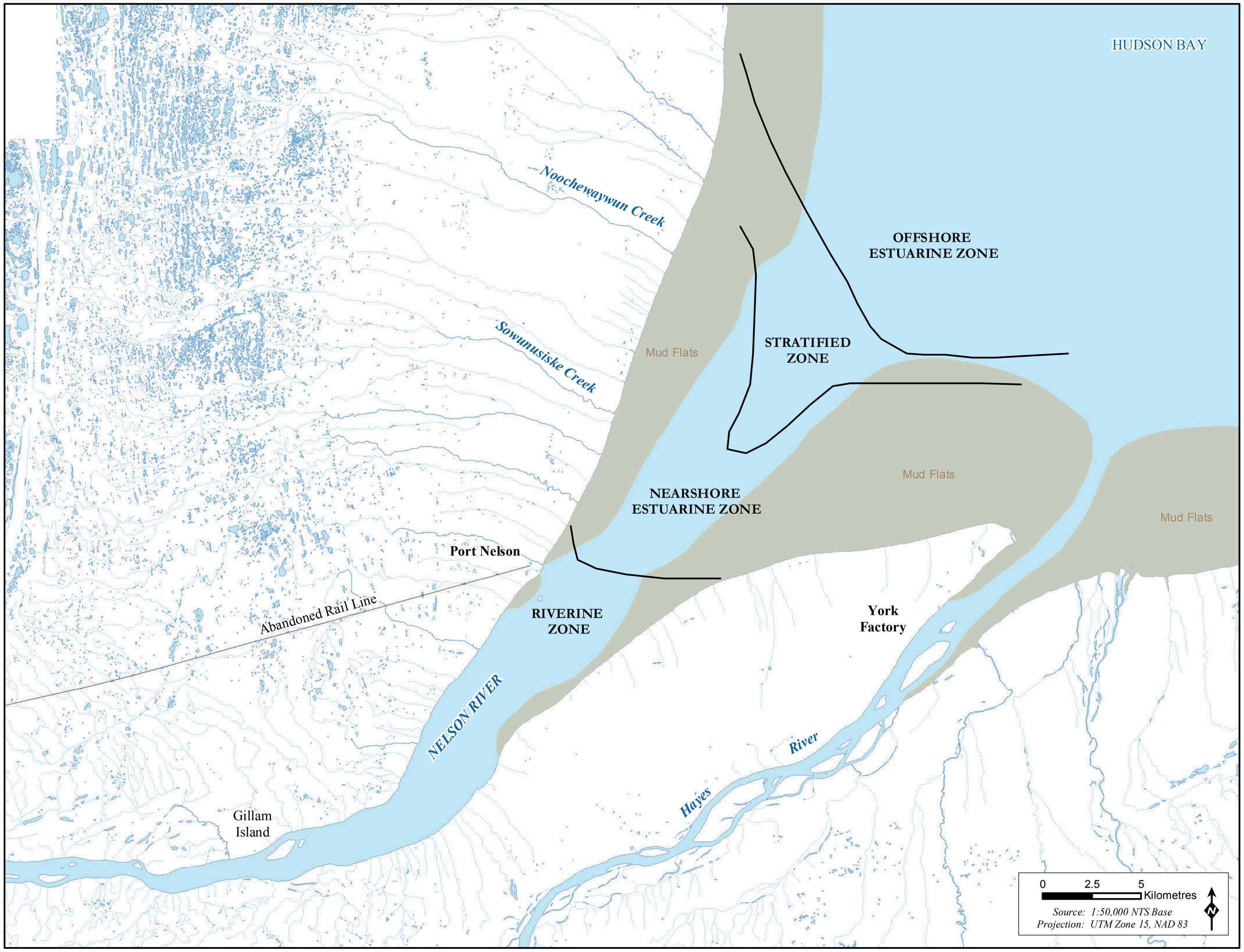


FIGURE 8-4
Illustration of the riverine, nearshore estuarine, stratified, and offshore estuarine zones of the Nelson River Estuary during a high tide.

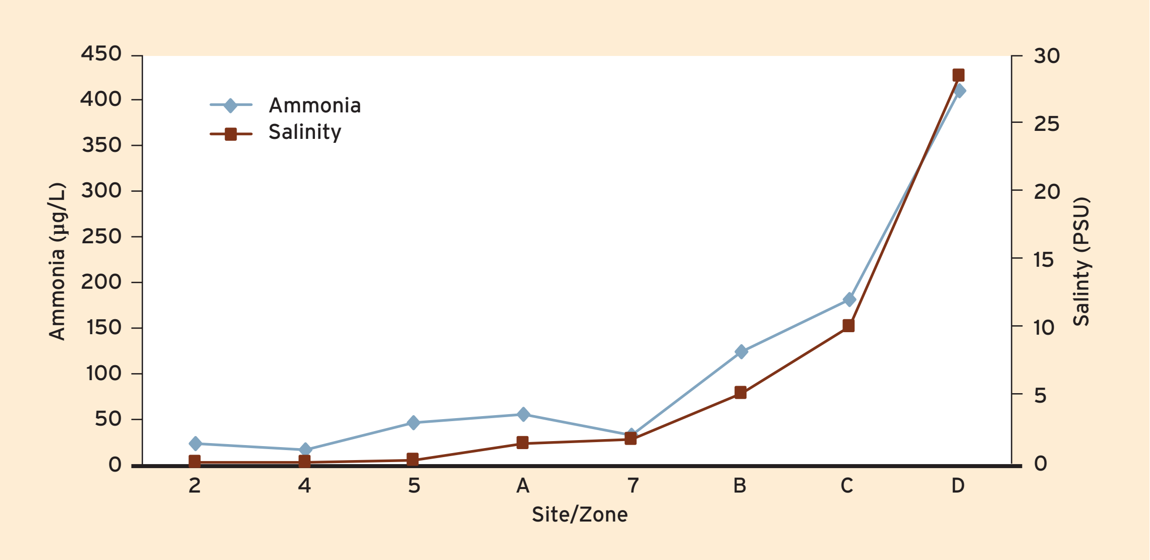


FIGURE 8-5 Relationship between ammonia and salinity concentrations in the Nelson River Estuary.

- a large "offshore estuarine zone" that is vertically mixed with cool waters of high salinity (>20 ppt), extending to the marine waters of Hudson Bay.

The locations, size, and stability of these zones are strongly influenced by tidal amplitude. Much of the chemical and biological sampling conducted from 1988 through 1999 was conducted in relation to these zones and tides.

8.3.2 Water Quality

8.3.2.1 Oxygen

Oxygen concentrations in the Nelson River Estuary were high (ranging between 8.4 and 12.3 mg/L) and varied little from spring to fall or between physical zones.

8.3.2.2 Total Suspended Solids

Total suspended solids (TSS) were generally lowest in the riverine zone where **Secchi disk** transparencies were in the 0.8-1.1 m range. In the intertidal nearshore estuarine zone, TSS rose dramatically (and Secchi disk transparencies dropped to between 0.2-0.4 m). Although water clarity increased significantly in the offshore estuarine zone (where Secchi disk transparencies were at times in excess of 1.8 m), TSS generally remained higher than in the riverine zone. Although TSS levels were generally highest during high tide, elevated levels occasionally occurred in the shallow mud-flat areas during low tide. The high concentrations at low tide were attributable to wind events or water circulation patterns that caused agitation and resuspension of bottom substrates in the shallow water. Where vertical stratification occurred in the water column, (i.e., in the nearshore estuarine and stratified zones), TSS tended to be higher in the deeper waters. This suggests that the Nelson River delivers low quantities of suspended material to the estuary relative to the amount resuspended by disturbance of bottom sediments.

8.3.2.3 Nitrogen, Phosphorus, and Organic Carbon

Ammonia, the primary end-product of decomposition of organic matter by bacteria, showed a strong positive correlation with increasing salinity in the Nelson River Estuary (Figure 8-5). Consequently, concentrations were lowest in the riverine zone and highest in the offshore estuarine zone. Ammonia concentrations varied with season in the stratified and offshore estuarine zones, peaking in summer at concentrations up to 410 µg/L. Ammonia concentrations were stratified in both the nearshore estuarine and stratified zones, where concentrations were lower in surface waters and higher in bottom waters.

Nitrites and nitrates are intermediate nitrogenous compounds produced during the oxidation of ammonia to nitrogen by nitrifying bacteria. Concentrations of both compounds increased from the riverine to the offshore estuarine zones and showed little variation between seasons. Concentrations of nitrates and nitrites were typically low throughout most of the estuary, ranging from 1 to 15 µg/L.

Total dissolved nitrogen (TDN) is the total sum of nitrogenous compounds (ammonia, nitrate, nitrite, amino acids, proteins, and nitrogen gas). Although trends were not consistent between years, TDN concentrations generally increased with increasing distance from the nearshore zones.

Suspended nitrogen levels were lowest in the riverine and offshore estuarine zones and highest in nearshore estuarine and stratified zones. More specifically, the highest levels of suspended nitrogen occurred in the mud-flat areas along the north shore, within the nearshore estuarine zone, and in bottom waters. Suspended nitrogen levels varied little seasonally.

Total Kjeldahl nitrogen (TKN) and total nitrogen (TN) in the Nelson River Estuary appeared to be negatively correlated to conductivity (Table 8-1); the higher the conductivity (i.e., the more marine), the lower the concentration of nitrogen. During low tides, when sites were dominated by fresh water, concentrations of TKN and TN tended to be higher.

Concentrations of dissolved and total phosphorus in the estuary (<0.120 mg/L) were relatively high (when compared to values in the lower Nelson River mainstem), highly variable, and showed little correlation with conductivity, tides or water depth.

Concentrations of total organic carbon were highly dependent on tide, being considerably higher during low tide than during high tide (Table 8-1). The Nelson River is the main source of organic carbon to the estuary, and as a result, concentrations of total organic carbon were strongly influenced by seasonal discharge rates and by tides.

8.3.2.4 Soluble Reactive Silica, Major Ions and Metals, pH, and Alkalinity

Silica concentrations gradually declined from the riverine zone to the offshore estuarine zone, with similar concentrations in the riverine and nearshore estuarine zones. Pronounced seasonal differences were also observed, as silica concentrations doubled from spring (0.3 mg/L) to summer (0.6 mg/L) and from summer to fall (1.15 mg/L).

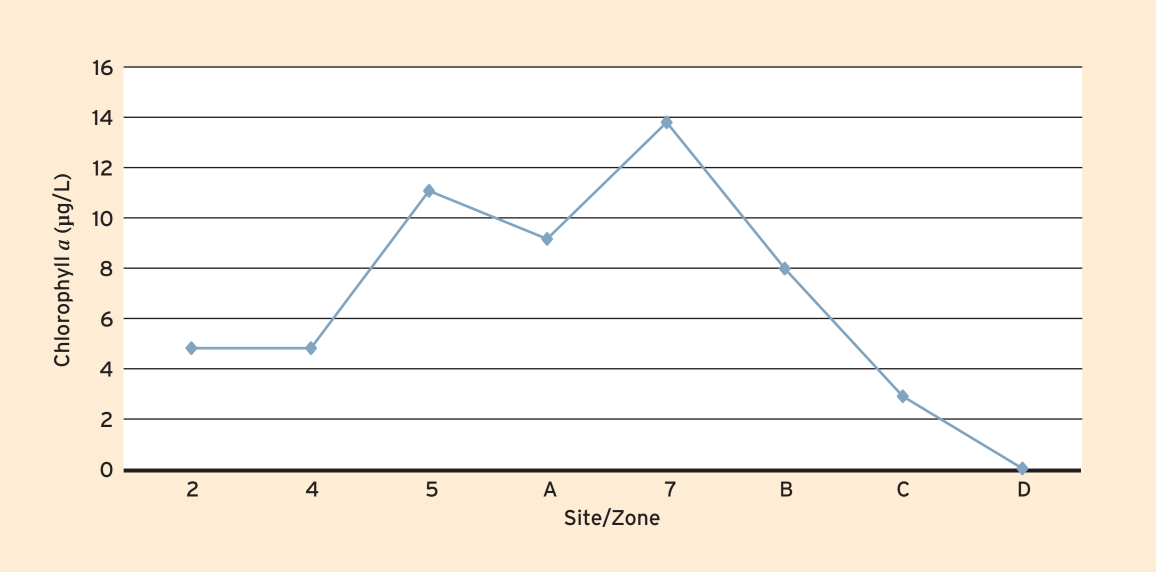


FIGURE 8-6
Mean chlorophyll *a* concentrations measured in 1988 at sites along a transect between the Nelson River (Site 2 near Gillam Island) and The Nelson River Estuary (sites C and D). See Figure 8-2 for site/zone locations in the Nelson River Estuary.

Although data were limited, concentrations of major ions (calcium, chlorine, magnesium, potassium, sodium, and sulphate) and iron tended to increase with increasing salinity and distance from the riverine zone.

pH was generally highest in the riverine zone and decreased closer to the offshore estuarine zone (Table 8-2). pH was also slightly higher in surface waters than in bottom waters in the nearshore estuarine and stratified zones (Table 8-2). Alkalinity mirrored site-specific concentrations of major ions, increasing from the riverine zone (1,710 μeg/L) to the offshore estuarine zone (2,070 μeg/L). Slight seasonal and interannual differences in alkalinity occurred as well.

8.3.2.5 Chlorophyll a

Chlorophyll *a* concentration is a relative indicator of primary productivity. Concentrations in the Nelson River Estuary were similar to those in the Nelson River, but became somewhat elevated in the nearshore estuarine zone (Figure 8-6). Concentrations in the offshore estuarine zone were extremely low or undetectable. Concentrations were generally highest at low tide. At low tide, concentrations were generally higher at the nearshore sites than the offshore ones (Table 8-1).

8.3.3 Lower Trophic Levels

Species composition, abundance, and distribution of lower trophic biota were virtually unknown prior to the late 1980s. Baseline studies and monitoring programs from 1988 to 1999 revealed a diverse community of freshwater, brackish, and marine planktonic and benthic invertebrates from at least 300 taxa.

8.3.3.1 Phytoplankton

Species composition, distribution, and abundance of phytoplankton in the Nelson River Estuary were strongly influenced by distance from shore (primary productivity measured higher in nearshore areas than in offshore areas – see Section 8.3.2.5) and oceanographic parameters. Freshwater inflow was the most important factor influencing phytoplankton due to its effect on salinity, nutrient input, and water circulation patterns.

Ninety-four species of phytoplankton were documented from the Nelson River Estuary in samples collected in 1992 and 1995 (Table 8-3). Collectively, these species are categorized under seven classes and include both freshwater and marine organisms. The greatest species diversity was observed among the diatoms (Bacillariophyceae). Within the stratified zones of the estuary, freshwater diatom species were more predominant in surface waters, while marine diatom species were more predominant in the deeper, more saline waters.

Phytoplankton abundance was found to be lowest in the riverine zone, peaking in the nearshore and stratified estuarine zones, and dropping again in the offshore estuarine zone. Overall, green algae (Chlorophyceae) and golden-brown algae (Chrysophyceae) were highest in abundance, but due to their small size, contributed little to overall phytoplankton biomass. Phytoplankton biomass was highest in the nearshore estuarine zone, lowest in the offshore estuarine zone, and intermediate in the riverine zone. Diatoms contributed the most to overall phytoplankton biomass due to their larger size. Freshwater species of diatoms were high in both abundance and biomass in the riverine and nearshore estuarine zones, but low in the offshore estuarine zone. The biomass of green algae was next highest, increasing from the riverine to stratified zones and decreasing in the offshore estuarine zone. The remaining taxa made up a very small portion of the total biomass.

8.3.3.2 Zooplankton

Zooplankton fauna found within the Nelson River Estuary included 58 taxa that consisted of freshwater, brackish, and marine species (Table 8-4). In terms of species diversity, the estuary was dominated by copepods, followed by diplostracans (water fleas) and cnidarians (hydra). Diplostracans plus cyclopoid and harpacticoid copepods included only freshwater species, and, therefore, were largely restricted to the riverine zone. Amphipods and calanoid copepods included freshwater, brackish, and marine species, and were distributed throughout all four estuarine zones.

Zooplankton densities in the Nelson River Estuary during July and August were generally highest in the stratified and offshore estuarine zones, lowest in the riverine zone, and at intermediate levels in the nearshore estuarine zone. High zooplankton densities in three of the four physical zones were largely due to the abundance of a few brackish species of copepods, namely *Eurytemora affinis* in the nearshore zone and both *Acartia bifilosa* and *A. clausi* in the stratified and offshore zones (Figure 8-7). Marine mysids (fairy shrimps) also accounted for a considerable portion of the overall abundance of zooplankton in the nearshore estuarine, stratified, and offshore estuarine zones during August.

Because salinity within the estuary was affected by tide, zooplankton abundance was also affected. Zooplankton abundance was typically greatest during high tide due to high densities of brackish and marine species of Calanoid copepods. However, there was considerable year-to-year and seasonal variability. During low tide, the majority of zooplankters sampled in the estuary were made up of freshwater cyclopoid copepods.

8.3.3.3 Macroinvertebrates

Over 150 macroinvertebrate taxa were recorded in the Nelson River Estuary, the majority of which were from Ekman grab and epibenthic sled samples in 1988 (Table 8-5). Highest macroinvertebrate numbers also were collected from these sampling gears. Aquatic insects (n = 78) accounted for over half of the total taxa, many of which were chironomid larvae (n = 42). Oligochaetes (n = 19) comprised the next highest number of taxa, followed by molluscs (n = 16) and amphipods (n = 10). Remaining benthic/epibenthic invertebrate taxa identified in the estuary (n = 28) were represented by another 19 taxonomic groups. Ninety-nine percent of a smaller sample of macroinvertebrates collected from the water column in 1992 was comprised of the crustacean, *Mysis littoralis*.

Benthic/epibenthic invertebrate distribution in the Nelson River Estuary was patchy and species composition varied with habitat and estuarine zone. Insect larvae occurred primarily in the freshwater riverine zone, although chironomids also were found in the nearshore mud flats. Annelids were found throughout the estuary, with polychaetes (lugworms) primarily occurring in the mud flats of the nearshore estuarine zone. Amphipod species were strictly marine and found in the stratified zone and the nearshore and offshore estuarine zones. Gastropods were only found in the freshwater riverine zone. Species diversity was highest in the mud-flat areas of the nearshore estuarine zone, while lowest diversity occurred in the main river channel and in the offshore estuarine zone.

The abundance of benthos in the Nelson River Estuary varied both spatially and temporally. For example, at one site sampled in 1988, annelid numbers were as high as 170,000 individuals in an epibenthic sled sample, whereas at other adjacent sites with similar habitat, annelid numbers were very low to absent. In 1988, the mud-flat area of the nearshore estuarine zone supported the highest densities of benthic invertebrates in the estuary. In descending order, the most common macroinvertebrates sampled in the nearshore estuarine zone included oligochaetes, polychaetes, chironomids, mysids, and amphipods.

Based on sample data from 1998, trichopteran, ephemeropteran, and chironomid larvae were the most abundant taxonomic groups in the riverine zone during summer, whereas chironomid larvae and oligochaetes dominated during fall. In the nearshore estuarine zone, mysids and polychaetes were the most abundant species during summer, while chironomid larvae, oligochaetes, polychaetes, and mysids were most abundant during fall.

8.3.4 Fish Community

The "Burleigh" expedition to Hudson Bay in 1914 was the only aquatic ecology survey conducted in the Nelson River Estuary prior to hydroelectric development on the Nelson River. The expedition documented the occurrence of brook trout, whitefish, lake sturgeon, northern pike, cisco, capelin (*Mallotus villosus*), sucker, sculpin, goldeye, and an unidentified species of "rock-cod" in the estuary. Populations of brook trout, whitefish, and northern pike were considered abundant; however, little information was provided on life history, diet, and preferred habitat of these species. With the exception of two studies conducted by the Manitoba government, one in 1974 (Didiuk 1975) and another in 1978 (Gaboury, unpubl. data), comprehensive investigations of the fish populations within the Nelson River Estuary were not conducted until 1988 (Baker 1989).

Fisheries surveys conducted in the Nelson River Estuary in 1988, 1989, and 1992 resulted in the identification of 29 fish species. Zooplankton surveys conducted in 1992 and from 1995 to 1999 yielded another four new species and 14 species in total; these incidental captures were predominately made up of larval fish. Of the total number of fish species captured (n = 33), over half (n = 21) were classified as freshwater species, carrying out all important life history functions such as reproduction, rearing, feeding, growth, etc. in fresh water (Table 8-6). Within this group, however, there was a wide range of tolerance and degree of utilization of marine and brackish waters. Several freshwater species are amphidromous, making daily or seasonal migrations between fresh and brackish or marine water (e.g., brook trout, lake whitefish). Within species, some fish are strictly freshwater residents while others are anadromous, migrating to Hudson Bay to forage during summer and back to fresh water to spawn and overwinter (e.g., cisco).

The fourhorn sculpin (*Myoxocephalus quadricornis*) was the only truly estuarine species captured, conducting all life history functions in an estuarine environment. Six species were classified as marine, including capelin, American and Pacific sand lance (*Ammodytes americanus* and *A. hexapterus*, respectively), slender eelblenny (*Lumpenus fabricii*), Arctic shanny (*Stichaeus punctatus*), and shorthorn sculpin (*Myoxocephalus scorpius*). These species perform the majority of their life history functions in the marine environment, but may spend some time feeding in brackish, estuarine water or spawning along coastal beaches.

American sand lance was the most abundant fish species captured in Isaacs Kidd trawls and in zooplankton net tows in the Nelson River Estuary (Table 8-7). Sand lance are schooling, bottom dwelling or burrowing marine fish that are common in littoral and shoal water of the world's oceans, including the Arctic Ocean. Abundance of sandlance in the estuary was patchy, although they were consistently captured at shallow depths (3-6 m) with intermediate salinities (15-20 ppt). They were most common in the stratified and offshore estuarine zones. Fourhorn sculpin, ninespine stickleback (*Pungitius pungitius*), threespine stickleback (*Gasterosteus aculeatus*), slender eelblenny, Arctic shanny, shorthorn sculpin, and capelin also occurred in the offshore estuarine zone.

Longnose sucker were most abundant in beach seines within the estuary during spring and summer, followed by, in decreasing order, emerald shiner (*Notropis atherinoides*), ninespine stickleback, and threespine stickleback (Table 8-8). In fall beach seines, emerald shiner dominated, followed to a lesser extent by cisco. In coastal creeks, emerald shiners dominated, followed by small numbers of several other species (Table 8-8). Longnose sucker dominated in gill nets set within the estuary, followed by cisco and lake whitefish (Table 8-9).

Data from fisheries surveys in 1988, 1989, and 1992 suggest that the majority of the fish using the Nelson River Estuary include the young-of-the year and juveniles of several large-bodied species, as well as two forage fish taxa (i.e., emerald shiner and sticklebacks). Juvenile lake whitefish and longnose sucker were abundant in the nearshore estuarine zone where they actively fed on chironomids, gastropods, bivalves, and mysids. Few sexually mature longnose sucker or lake whitefish were present. The estuary was also considered an important rearing location for juvenile cisco. Adult cisco were virtually absent except during late August and September when mature adults returned from Hudson Bay and migrated through the estuary to spawning locations farther upstream in the Nelson River (e.g., Limestone and Weir rivers). Large numbers of larval capelin were captured in the estuary, but adults and juveniles were absent. In contrast to earlier studies, only one brook trout was captured in the estuary during fisheries surveys conducted in 1988, 1989, and 1992. Radio telemetry studies have shown that some lake sturgeon will overwinter in the estuary (Swanson et al. 1988).

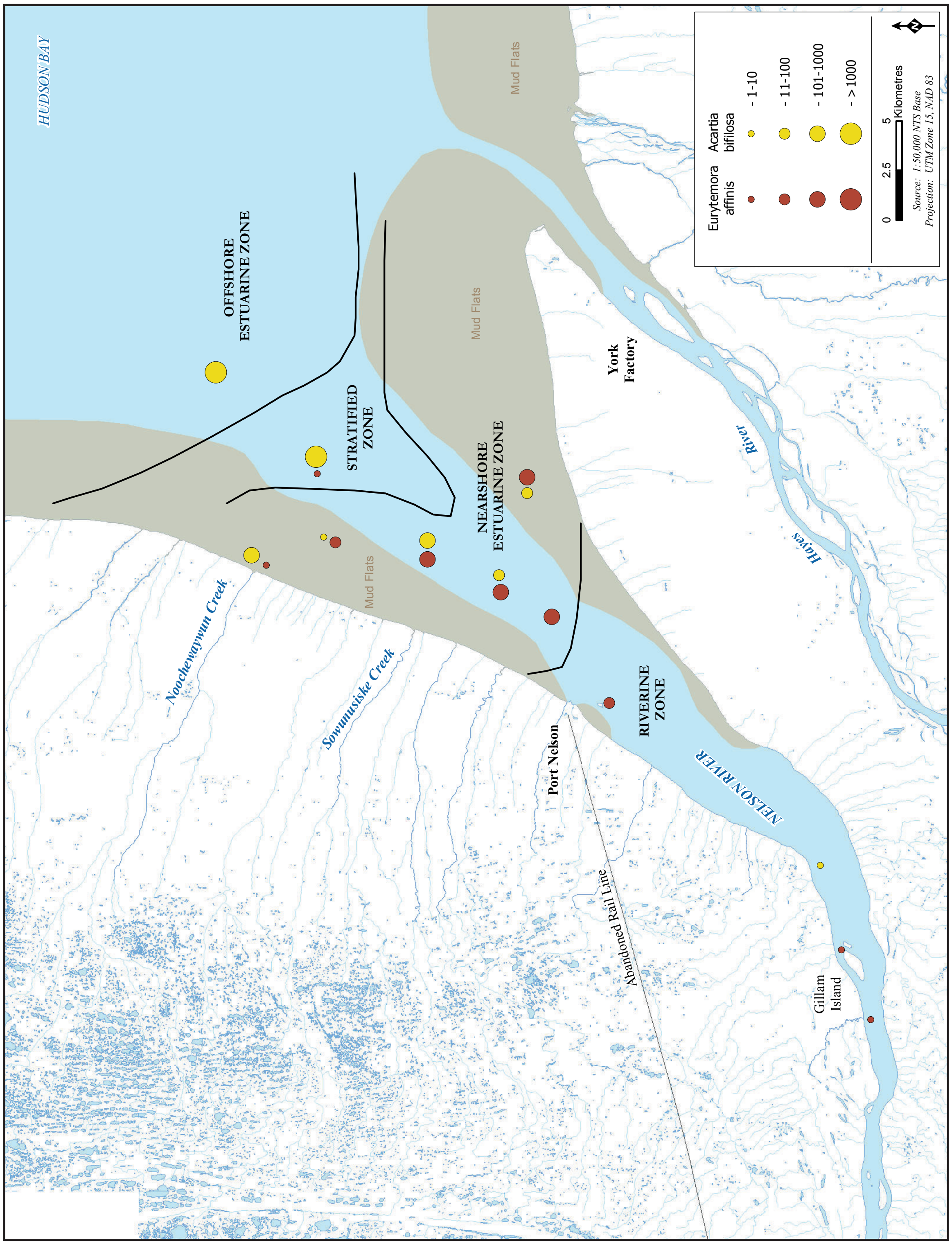


FIGURE 8-7
Densities of *Eurytemora affinis* and *Acartia bifilosa* in the Nelson River Estuary during August 1988.

8.3.5 Marine Mammals

During the summer months, large concentrations of beluga can be observed in estuaries along the east and west coasts of Hudson Bay (Sergeant 1973; Finlay et al. 1982; Watts and Draper 1988). The reasons for beluga using the estuaries are unknown, but may include feeding, reproduction and/or growth (Sergeant 1973; Fraker et al. 1979). While depth, salinity, **turbidity**, and shelter have all been discounted as significant reasons (Fraker et al. 1979), temperature has been shown to be highly correlated with beluga movements within both the Mackenzie (Fraker et al. 1979) and Churchill (Watts and Draper 1988) river estuaries. Estuaries are believed to be important nursery areas for the beluga whale, providing protection and thermodynamic advantages for newborn calves. Though calving has never been observed in an estuary, it is believed that some calving likely takes place there. It is generally believed that most calving takes place farther offshore in marine water during early spring, after which the whales congregate in warmer estuarine waters for maximum growth potential.

Beluga whales were highly visible during all summer studies of the Nelson River Estuary and actually represented a sampling constraint during fisheries surveys. Field observations from 1988 and 1989 indicated that beluga were most abundant between early July and mid August. The farthest observation upstream was within 1 km of Flamborough Head (Figure 8-1).

During the intensive summer survey of 2003, the estimated number of beluga in the Nelson River Estuary ranged from approximately 5,900 to 10,500 animals. Beluga densities ranged from 4.4 to 8.5 beluga/km^2. Beluga were distributed throughout the estuary, but tended to concentrate in large numbers from Port Nelson along the northern shore to White Bear Creek. Smaller groups of beluga also were seen along the southern shore of the estuary near Marsh Point and offshore of the Hayes River. There did not appear to be a discernable change in beluga distribution that could be related to differences in freshwater input from the lower Nelson River or in tide state (high or low tide).

Bearded seals were seen most frequently during the fall season and in the lowest reaches of the Nelson River. More specifically, groups as large as six individuals were commonly seen hauled out on the artificial island at Port Nelson and on beaches in the Gillam Island area. Bearded seals were observed as far as 80 km upstream in the Nelson River (near the mouth of the Angling River) and as far as 30 km off the Hudson Bay coastline. This species was often observed feeding on fish captured in experimental gill nets.

8.4 Summary of Effects

At the outset of the Limestone G.S. aquatic environment monitoring programs, a bathymetrical chart, made by Captain F. Anderson from 1911-1913, was the only pre-development information that could be used to measure of how conditions had changed in the Nelson River Estuary in relation to upstream hydroelectric development. When compared to similar bathymetric data collected in 1988, it was apparent that, on a coarse scale, the morphometry of the estuary had changed little over the subsequent 75 years.

The ability of the aquatic monitoring programs to determine physical and biological impacts to the Nelson River Estuary, resulting from operation of upstream hydroelectric development, was limited by the lack of adequate pre-development studies. Studies conducted were focused on describing the existing environment as it was after construction of the Limestone G.S. and establishing a baseline against which future impacts could be measured. The results of these studies form the bulk of our current understanding of the estuary and have provided a foundation for the design of further studies in relation to understanding impacts of future developments.

TABLE 8-1 Water quality results from surface and bottom samples collected from two nearshore and two offshore sites in the Nelson River Estuary during low and high tides, and from one freshwater site near the mouth of the lower Nelson River, Summer 1988.

Site	Tide	Depth	Date	Conductivity (µs/cm)	TKN (mg/L)	TN (mg/L)	TOC (mg/L)	Chlorophyll *a* (µg/L)
Offshore #1	Low	Shallow	20-Jul	271	0.21	0.21	8.4	3.2
			24-Jul	270	0.21	0.21	8.3	3.7
			26-Jul	265	0.38	0.38	8.3	1.5
		Deep	20-Jul	14500	0.30	0.30	8.6	2.4
			24-Jul	270	0.22	0.22	8.5	3.9
			26-Jul	266	0.34	0.34	8.3	4.1
	High	Shallow	20-Jul	18200	0.18	0.19	<0.5	0.8
			24-Jul	17000	0.12	0.13	<0.5	1.2
			26-Jul	10700	0.46	0.47	9.4	4.0
		Deep	20-Jul	33200	0.06	0.07	<0.5	1.0
			24-Jul	28900	0.15	0.16	<0.5	1.5
			26-Jul	27400	0.27	0.28	<0.5	1.0
Offshore #2	Low	Shallow	18-Jul	1570	0.51	0.51	9.1	3.5
			21-Jul	278	0.14	0.14	8.8	3.8
			25-Jul	268	0.23	0.23	8.4	2.8
		Deep	18-Jul	2060	0.39	0.39	9.3	4.6
			21-Jul	6360	0.16	0.17	9.7	2.8
			25-Jul	274	0.40	0.40	8.4	4.0
	High	Shallow	18-Jul	22500	0.21	0.22	<0.5	1.2
			21-Jul	22000	0.33	0.34	7.6	0.9
			25-Jul	20300	0.27	0.28	11.4	3.7
		Deep	18-Jul	36600	<0.05	<0.05	<0.5	0.8
			21-Jul	36900	0.12	0.13	<0.5	0.9
			25-Jul	30100	0.11	0.12	<0.5	1.0
Nearshore #1	Low	Shallow	18-Jul	3140	0.25	0.25	9.7	5.4
			21-Jul	303	0.36	0.36	9.2	6.0
			25-Jul	324	0.67	0.67	9.3	1.4
	High	Shallow	18-Jul	31800	0.27	0.28	<0.5	0.8
			21-Jul	13500	0.12	0.13	9.3	1.3
			25-Jul	25800	0.25	0.26	<0.5	1.1
Nearshore #2	Low	Shallow	20-Jul	272	0.37	0.37	8.5	3.6
			24-Jul	272	0.27	0.27	8.8	6.2
			26-Jul	263	0.35	0.35	8.4	5.2
	High	Shallow	20-Jul	9180	0.24	0.25	9.8	1.4
			24-Jul	1050	0.27	0.27	9.4	3.9
			26-Jul	442	0.36	0.36	8.3	2.4
Lower Nelson River			18-Jul	266	0.30	0.30	8.5	2.9
			21-Jul	265	0.25	0.25	9.1	2.6
			25-Jul	265	0.34	0.34	9.1	8.0

TKN = Total Kjeldhal nitrogen TN = Total nitrogen TOC = Total organic carbon

TABLE 8-2 Values of pH measured between July and October at various sites/zones in the Nelson River Estuary, 1988 and 1992.

Season/Year Site/Zone[1]	Depth	Date	pH
Spring 1988			
2	Surface	01-Jul	8.35
3	Surface	02-Jul	8.35
4	Surface	02-Jul	8.36
5	Surface	05-Jul	8.50
A	Surface	05-Jul	8.34
B	Surface	05-Jul	8.30
Summer 1988			
1	Surface	07-Aug	8.46
2	Surface	06-Aug	8.46
3	Surface	07-Aug	8.47
4	Surface	08-Aug	8.45
5	Surface	10-Aug	8.43
6	Surface	13-Aug	8.27
7	Surface	15-Aug	8.35
A	Surface	11-Aug	8.35
B	Surface	11-Aug	8.32
C	Surface	12-Aug	8.26
C	Bottom	12-Aug	8.24
D	Surface	12-Aug	8.20
D	Bottom	12-Aug	8.16
E	Surface	12-Aug	8.32
F	Surface	13-Aug	8.38
Fall 1988			
2	Surface	28-Sep	8.48
4	Surface	29-Sep	8.47
5	Surface	01-Oct	8.47
6	Surface	04-Oct	8.33
7	Surface	06-Oct	8.44
A	Surface	02-Oct	8.46
B	Surface	02-Oct	8.38
C	Surface	04-Oct	8.33
E	Surface	04-Oct	8.44
F	Surface	06-Oct	8.35
G	Surface	03-Oct	8.46
Summer 1992			
Riverine	Surface	23 to 25-Aug	8.61
Nearshore	Surface	23 to 25-Aug	8.54
	Bottom	23 to 25-Aug	8.44
Stratified	Surface	23 to 25-Aug	8.50
	Bottom	23 to 25-Aug	8.37
Offshore	Surface	23 to 25-Aug	8.31

[1] See Figure 8-2 for site/zone locations in the Nelson River Estuary.

TABLE 8-3 Species of phytoplankton identified in the Nelson River Estuary in 1992 and 1995. Columns read from top to bottom and from left to right.

CLASS	Species
BACILLARIOPHYCEAE	
	Amphora sp.
	Asterionella formosa
	Asterionella kariana
	Aulocoseira binderana
	Aulocoseira italica
	Chaetoceros gracilis
	Chaetoceros sp.
	Cocconies sp.
	Coseinodiscus eccentrius
	Coseinodiscus sp.
	Cyclotella bodanica
	Cyclotella stelligera
	Cybella sp.
	Epithemia sp.
	Eunotia sp.
	Fragilaria construens
	Fragilaria islandica
	Gomphonema sp.
	Melosira binderana
	Melosira italica
	Meridion circulare
	Navicula sp.
	Nitzschia fonticola
	Nitzschia filiformis
	Nitzschia hybrida
	Nitzschia longissima
	Nitzschia recta
	Nitzschia seriata
	Nitzschia sigmoidea
	Pinnularia viridis
	Pleurosigma sp.
	Rhizosolenia setigera
	Rhizosolenia sp.
	Rhoicosphenia curvata
	Stephanodiscus astreae
	Surirella delicatissima
	Surirella ovata
	Synedra acus
	Synedra ulna
	Tabellaria flocculsa
	Thalassiosira sp.
CHLOROPHYCEAE	
	Ankistrodesmus braunii
	Ankrya judai
	Botryococcus braunii
	Chlamydomonas sp.
	Closterium kutzingii
	Closterium sp.
	Crucigeniella quadrata
	Dictyosphaerium pulchellum
	Monoraphidium contortum
	Monoraphidium setiforme
	Monoraphidium sp.
	Mougeotia sp.
	Oocystis borgei
	Paulschulzia pseudovolvox
	Pediastrum duplex
	Pyramimonas micron
	Tetraedron minimum
	Scenedesmus denticulatus
	Scenedesmus quadricauda
	Staurastrum paradoxum
	Staurastrum sp.
CHRYSOPHYCEAE	
	Chrysidiastrum catenatum
	Dinobryon balticum
CHRYSOPHYCEAE	
	Ochromonas sp.
	Phaeocystis pouchetii
	Phiocytium cochleare
	Stelexomonas dichotoms
	Stichogloea sp.
CRYPTOPHYCEAE	
	Cryptomonas pseudobaltica
	Cryptomonas rostratiform
	Katablepharis ovalis
	Rhodomonas minuta
CYANOPHYCEAE	
	Anabaena skuja
	Anabaena sp.
	Aphanizomenon flosaquae
	Chroococcus limneticus
	Gomphosphaeria sp.
	Merismopedia punctata
	Merismopedia tenuissima
	Nostoc sp.
	Phormidium sp.
	Planktothrix agardhii
DINOPHYCEAE	
	Gymnodinium splendens
	Gymnodinium sp.
	Gyrodinium prunus
	Gyrodinium sp.
	Katodinium glaucum
	Peridinium inconspicum
	Protoperidinium pellucidum
	Peridinium punctulatum
	Peridinium umbonatum
EUGLENOPHYCEAE	
	Euglena proxima
	Trachelomonas volvocina

TABLE 8-4 Species of zooplankton identified in the Nelson River Estuary between 1988 and 1999. Columns read from top to bottom and from left to right.

PHYLUM	SUBPHYLUM	CLASS	ORDER	SUBORDER	FAMILY	SPECIES
ARTHROPODA						
	Crustacea					
		Branchiopoda				
			Diplostraca			
				Cladocera		
						Alona guttata
						Bosmina longirostris
						Bosmina sp.
						Camptocercus rectirostris
						Ceriodaphnia reticulata
						Daphnia middendorffiana
						Daphnia retrocurva
						Daphnia sp.
						Eubosmina longispina
						Eurycercus sp.
						Holopedium gibberum
						Leptodora kindtii
						Sida crystallina
				Spinicaudata		
						Cyzicus setosa
		Copepoda				
			Calanoida			
						Acartia bifilosa
						Acartia clausi
						Acartia longiremis
						Calanus glacialis
			Calanoida (continued)			
						Centropages hamatus
						Diaptomus sicilis
						Diaptomus sp.
						Ectinosomatidae gen. sp.
						Epischura lacustris
						Epischura nevadensis
						Eurytemora affinis
						Eurytemora americana
						Eurytemora herdmani
						Eurytemora raboti
						Eurytemora sp.
						Jaschnovia tolli
						Leptodiaptomus ashlandi
						Limnocalanus macrurus
						Microcalanus pygmaeus
						Pseudocalanus minutus
						Tortanus discaudatus
			Cyclopoida			
						Cyclops bicuspidatus thomasi
						Cyclops vernalis
						Cyclops scutifer
			Harpacticoida			
						Harpacticoida gen. sp.
						Harpacticus uniremis
						Tisbe furcata
		Malacostraca				
			Amphipoda			
						Hyperia galba
						Themisto abyssorum
						Themisto libellula
CHAETOGNATHA						
		Sagittoidea				
			Aphragmophora			
					Sagittidae	
						Parasagitta elegans
CNIDARIA						
		Hydrozoa				
					Aeginidae	
						Aeginopsis laurentii
					Bougainvillidae	
						Bougainvillia principis
						Bougainvillia superciliaris
					Corynidae	
						Sarsia princeps
					Rhopalonematidae	
						Aglantha digitale
					Sertulariidae	
						Abietinaria pulchra
						Hartlaubella gelatinosa
					Sertulariidae (continued)	
						Hartlaubella sp.
		Scyphozoa				
					Cyaneidae	
						Cyanea capillata
CTENOPHORA						
			Cydippida			
					Pleurobrachiidae	
						Pleurobrachia pileus
PROTOZOA						
			Foraminiferida			
						Foraminiferida gen. sp.
CHORDATA						
	Tunicata					
		Appendicularia				
					Frittilaridae	
						Frittilaria borealis
					Oikopleuridae	
						Oikopleura sp.

TABLE 8-5 Species of macroinvertebrates identified in the Nelson River Estuary in 1988 and 1992. Columns read from top to bottom and from left to right.

PHYLUM
CLASS
ORDER
FAMILY
SPECIES

- ANNELIDA
  - Oligochaeta
    - Haplotaxida
      - Naididae
        - *Amphichaeta leydigi*
        - *Bratislavia unidentata*
        - *Chaetogaster diaphanus*
        - *Nais behningi*
        - *Nais communis*
        - *Nais pseudobtusa*
        - *Nais simplex*
        - *Nais variabilis*
        - *Paranais litoralis*
        - *Pristina aequiseta*
        - *Slavina appendiculata*
        - *Specaria josinae*
        - *Uncinais uncinata*
        - *Vejdovskyella intermedia*
      - Tubificidae
        - *Limnodrilus hoffmeisteri*
        - *Limnodrilus profundicola*
        - *Limnodrilus udekemianus*
        - *Tubifex tubifex*
        - *Tasserkidrilus kessleri*
  - Polychaeta
    - Aciculata
      - Phyllodocidae
        - *Eteone* sp.
      - Syllidae
        - *Autolytus alexandri*
        - *Proceraea* sp.
    - Canalipalpata
      - Sabellidae
        - *Manayunkia aestuarina*
      - Spionidae
        - Spionidae gen. sp.
- ARTHROPODA
  - Aracnida
    - Acari
      - Sperchonidae
        - *Sperchon* sp.
        - *Sperchonopsis verrucosa*
    - Araneae
        - Araneae gen. sp.
    - Trombidiformes
        - Hydracarina gen. sp.
    - Sarcoptiformes
        - Oribatida gen sp.
  - Crustacea
    - Maxillopoda
        - Cirripedia gen. sp.
  - Malacostraca
    - Amphipoda
        - *Gammaracanthus loricatus*
        - *Gammarellus homari*
        - *Gammarus oceanicus*
        - *Gammarus setosus*
        - *Gammarus wilkitzkii*
        - *Monoculodes borealis*
        - Oedicerotidae gen. sp.
        - *Onisimus glacialis*
        - *Onisimus litoralis*
        - *Pontoporeia affinis*
    - Cumacea
        - *Diastylis scorpioides*
    - Decapoda
        - *Anomura* sp.
        - *Orconectes virilis*
        - Hippolytidae gen. sp.
        - *Hyas* sp.
    - Isopoda
        - *Saduria* sp.
    - Mysidacea
        - *Mysis litoralis*

PHYLUM
CLASS
ORDER
FAMILY
SPECIES

- Mysidacea (continued)
  - *Mysis oculata*
- Ostracoda
  - Ostracoda gen. sp.
  - Podocopa gen. sp.
- Insecta
  - Diptera
    - Chironomidae
      - *Ablabesmyia* sp.
      - *Chironomus* sp. (s.s.)
      - *Cladotanytarsus* sp.
      - *Conchapelopia* sp.
      - *Corynoneura lobata*
      - *Cricotopus festivellus* (s.s.)
      - *Cricotopus tremulus* gr. (s.s.)
      - *Cricotopus* nr. *triannulatus* (s.s.)
      - *Cryptochironomus* sp.
      - *Cyphomella* sp.
      - *Demicryptochironomus cuneatus*
      - *Eukiefferiella claripennis* gr.
      - *Euryhapsis* sp.
      - *Harnischia* sp.
      - *Microtendipes pedellus*
      - *Monodiamesa* sp.
      - *Nanocladius* cf. *distinctus* (s.s.)
      - *Nilotanypus fimbriatus*

Table 8-5 continued

PHYLUM	CLASS	ORDER	FAMILY	SPECIES
			Chironomidae (continued)	
				Orthocladius cf. *clarkei* (s.s.)
				Orthocladius nr. *dorenus* (s.s.)
				Orthocladius obumbratus (s.s.)
				Paracladius sp.
				Paracladopelma doris
				Paracladopelma cf. *rolli*
				Parakiefferiella sp.
				Paraphaenocladius sp.
				Paratanytarsus sp.
				Paratrichocladius sp.
				Phaenopsectra sp.
				Polypedilum convictum (s.s.)
				Polypedilum laetum (s.s.)
				Polypedilum scalaenum
				Polypedilum simulans
				Potthastia longimana
				Pseudosmittia sp.
				Rheotanytarsus sp.
				Robackia cf. *demeijerei*
				Stictochironomus sp.
				Tanytarsus sp.
				Thienemanniella sp.
				Tvetenia bavarca gr.
				Tvetenia discoloripes gr.
			Cecidomyiidae	
				Cecidomyiidae gen. sp.
			Ceratopogonidae	
				Culicoides variipennis
			Culicidae	
				Aedes sp.
			Empididae	
				Hemerodromia sp.
			Muscidae	
				Muscidae gen. sp.
			Mycetophilidae	
				Mycetophilidae gen. sp.
			Dolichopodidae	
				Dolichopodidae gen. sp.
			Phoridae	
				Phoridae gen. sp.
			Sciaridae	
				Bradysia sp.
			Simuliidae	
				Simulium sp.
			Tabanidae	
				Tabanidae gen. sp.
			Tipulidae	
				Tipulidae gen. sp.
		Ephemeroptera		
			Baetidae	
				Baetis sp.
			Caenidae	
				Caenis sp.
			Ephemerellidae	
				Ephemerellidae gen. sp.
			Ephemeridae	
				Hexagenia sp.
			Heptageniidae	
				Rhithrogena sp.
		Coleoptera		
			Elmidae	
				Elmidae gen. sp.
			Staphylinidae	
				Staphylinidae gen. sp.
		Collembola		
			Entomobryidae	
				Entomobryidae gen. sp.
		Hemiptera		
			Corixidae	
				Arctocorisa sp.
		Homoptera		
			Aphididae	
				Aphididae gen. sp.
			Psyllidae	
				Psyllidae gen. sp.
		Hymenoptera		
				Hymenoptera gen. sp.
		Lepidoptera		
				Lepidoptera gen. sp.
		Plecoptera		
			Chloroperlidae	
				Chloroperlidae gen. sp.
			Perlodidae	
				Isoperla sp.
				Perlodidae gen. sp.
		Thysanoptera		
			Thripidae	
				Frankliniella sp.
		Tricoptera		
			Hydroptilidae	
				Hydroptilidae gen. sp.
			Hydropsychidae	
				Cheumatopsyche sp.
				Hydropsyche sp.
			Leptoceridae	
				Leptoceridae gen. sp.
				Oecetis sp.
				Triaenodes sp.
			Psychomyidae	
				Psychomyidae gen. sp.
CNIDARIA				
	Hydrozoa			
			Sertulariidae	
				Hydra sp.
				Sertularia schmidti
				Sertularia tenera

Table 8-5 continued

PHYLUM	CLASS	ORDER	FAMILY	SPECIES
ECTOPROCTA (BRYOZOA)				
	Gymnolaemata			
		Cheilostomata		
			Cristatellidae	
				Cristatella mucedo
			Hippothoidae	
				Celleporella hyalina
			Scrupariidae	
				Eucratea loricata
NEMATODA				
				Nematoda gen. sp.
MOLLUSCA				
	Bivalvia			
				Bivalvia gen. sp
		Myoida		
			Hiatelloidea	
				Cyrtodaria kurruana
		Mytiloida		
			Mytilidae	
				Mytilus edulis
		Veneroida		
			Pisidiidae	
				Sphaerium rhomboideum
				Sphaerium sp.
		Tellinidae		
				Macoma balthica
	Gastropoda			
		Archaeogastropoda		
			Trochidae	
				Margarites olivaceus
		Basommatophora		
			Ancylidae	
				Ferrissia rivularis
			Lymnaeidae	
				Lymnaea sp.
			Physidae	
				Physa jennessi jennessi
			Planorbidae	
				Gyraulus parvus
		Heterostropha		
			Valvatidae	
				Valvata tricarinata
		Neotaenioglossa		
			Hydrobiidae	
				Probythinella lacustris
			Littorinidae	
				Littorina obtusata
		Stylommatophora		
			Strobilopsidae	
				Strobilops labyrinthica
			Valloniidae	
				Vallonia gracilicosta

TABLE 8-6 List of fish species collected in the Nelson River Estuary between 1988 and 1999.

Family	Species	Common Name
Acipenceridae	*Acipencer fulvescens*	Lake sturgeon
Hiodontidae	*Hiodon alosoides*	Goldeye
Esocidae	*Esox lucius*	Northern pike
Salmonidae	*Coregonus artedi*	Cisco**
	Coregonus clupeaformis	Lake whitefish**
	Salvelinus fontinalis	Brook trout**
Ammodytidae	*Ammodytes americanus*	American sand lance*
	Ammodytes hexapterus	Pacific sand lance*
Osmeridae	*Mallotus villosus*	Capelin*
	Osmerus mordax	Rainbow smelt**
Cyprinidae	*Rhinichthys cataractae*	Longnose dace
	Phoxinus neogaeus	Finescale dace
	Margariscus margarita	Pearl dace
	Notropis hudsonius	Spottail shiner
	Couesius plumbeus	Lake chub
	Notropis atherinoides	Emerald shiner
Catostomidae	*Catostomus catostomus*	Longnose sucker
	Catostomus commersonii	White sucker
Gadidae	*Lota lota*	Burbot
Gasterosteidae	*Culaea inconstans*	Brook stickleback
	Pungitius pungitius	Ninespine stickleback**
	Gasterosteus aculeatus	Threespine stickleback**
Percopsidae	*Percopsis omiscomaycus*	Troutperch
Percidae	*Etheostoma nigrum*	Johnny darter
	Percina caprodes	Logperch
	Percina shumardi	River darter
	Perca flavescens	Yellow perch
	Sander vitreus	Walleye
Cottidae	*Cottus ricei*	Spoonhead sculpin
	Cottus cognatus	Slimy sculpin
	Myoxocephalus quadricornis	Fourhorn sculpin^
	Myoxocephalus scorpius	Shorthorn sculpin*
Stichaeidae	*Lumpenus fabricii*	Slender eelblenny*
	Stichaeus punctatus	Arctic shanny*

* Denotes marine species
^ Denotes estuarine species
** Denotes anadromous/amphidromous species

TABLE 8-7 Total numbers of organisms collected in Isaacs-Kidd trawls from sampling sites within the Nelson River Estuary, August 1992.

PHYLUM CLASS ORDER FAMILY	Riverine zone			Nearshore estuarine zone				Stratified zone					Offshore estuarine zone			
SPECIES	5	17	18	1	2	7	12	3	4	8	15	16	10	11	13	14
Arthropoda																
Crustacea																
Amphipoda																
Gammarus loricatus				1	1										1	
Onisimus glacialis																
Mysidacea																
Mysis litoralis					695196		417366									
Mollusca																
Bivalvia																
Sphaeriidae								2						5		
Chordata																
Pisces																
Salmonidae																
Coregonus artedi	2		2	3	1		10					1				
Osmeridae																
Mallotus villosus														12		
Gasterosteidae																
Pungitius pungitius		1		1	2	1	3		2	46	1	9	1			
Gasterosteus aculeatus			1			1				2						
Cottidae																
Myoxocephalus quadricornis	1			7	24											
Stichaeidae																
Lumpenis fabricii								1								
Ammodytidae																
Ammodytes americanus							7	27	28	386		12		172		
Totals	**3**	**1**	**3**	**12**	**695224**	**2**	**417386**	**30**	**30**	**434**	**1**	**22**	**1**	**189**	**1**	**0**

TABLE 8-8 Total numbers of fish, by species, captured in beach seines from sampling sites and coastal creeks within the Nelson River Estuary during the open-water season, 1988.

	Spring/Summer					Fall								
	Site					Site								
Species	2	3	4	5	6	2	3	4	5	6	Coastal creeks	Summer	Fall	Totals
Northern pike		1										1	0	**1**
Cisco	16		2				1	21			9	18	22	**49**
Lake whitefish	2	2	1	1		5	1	1	1	1	13	6	9	**28**
Longnose dace	1	8	5	14								28	0	**28**
Finescale dace											1	0	0	**1**
Pearl dace											1	0	0	**1**
Spottail shiner						2			1		3	0	3	**6**
Lake chub	4											4	0	**4**
Emerald shiner	13	5	65	25	17	10	90	73	362		376	125	535	**1036**
Longnose sucker	1017	4	22	69		4	1					1112	5	**1117**
White sucker		1				3						1	3	**4**
Brook stickleback		1									4	1	0	**5**
Ninespine stickleback					63	2	1	1		1	2	63	5	**70**
Threespine stickleback				16	42						1	58	0	**59**
Troutperch		1	2						3	1	2	3	4	**9**
Johnny darter	1											1	0	**1**
River darter				2								2	0	**2**
Walleye			2									2	0	**2**
Yellow perch		2	1			1					6	3	1	**10**
Spoonhead sculpin			4	1			1		3	3		5	7	**12**
Slimy sculpin		1	2			3	1					3	4	**7**
Fourhorn sculpin										7		0	7	**7**
Arctic shanny										1		0	1	**1**
Totals	**1054**	**26**	**106**	**128**	**122**	**30**	**96**	**96**	**370**	**14**	**418**	**1436**	**606**	**2460**

TABLE 8-9 Total numbers of fish, by species, captured in gill nets at each site within the Nelson River Estuary during the open-water season, 1988.

	Site					
Species	**2**	**3**	**4**	**5**	**6**	**Totals**
Lake sturgeon	0	1	0	0	0	1
Goldeye	0	0	1	0	0	1
Northern pike	1	0	1	0	0	2
Cisco	1	3	3	13	3	23
Lake whitefish	7	5	21	2	0	35
Longnose sucker	15	26	17	17	0	75
White sucker	2	0	1	0	0	3
Burbot	0	1	0	1	0	2
Fourhorn sculpin	0	0	1	0	0	1
Totals	**26**	**36**	**45**	**33**	**3**	**143**

9.0

LIMESTONE GENERATING STATION – OVERALL SUMMARY OF EFFECTS ON THE AQUATIC ENVIRONMENT

9.1 Upstream of the Limestone Generating Station

The Limestone G.S. was designed to use the natural features of a 20-km reach of the Nelson River bounded by high cliffs to create a forebay that was contained largely within the ice-scoured zone. Despite water levels rising more than 25 m in elevation behind the dam, only 3.1 km^2 of previously undisturbed land were flooded (Manitoba Hydro 1996).

The impoundment of rivers to form reservoirs is often associated with considerable nutrient enrichment and related changes in water quality (e.g., depletion of dissolved oxygen) resulting from flooding of terrestrial environments and increased erosion of shorelines. Although the area flooded was small, formation of the Limestone Forebay may have caused changes in water quality within the project zone of influence that were not detected because of the lack of pre-project data. Similarly, there may have been temporary effects during and/or immediately following impoundment that were not detected by the monitoring programs. However, the post-impoundment data collected in the Limestone Forebay indicated that nutrients were relatively similar to the upstream Long Spruce Forebay and to the downstream environment after impoundment (although interpretations of conditions downstream are more complex due to site relocations and local influences). Similarly, there was no indication that dissolved oxygen was reduced to levels unsuitable for aquatic life in the Limestone Forebay. Therefore, collectively, the post-project monitoring data, in conjunction with knowledge of the magnitude of flooding and changes in hydrology associated with construction of the generating station, indicate that the project did not result in dramatic nutrient enrichment (if at all). Consequently, biotic changes that occurred upstream of the generating station were more likely related to changes in water depth and velocity than they were to changes in water quality.

Impoundment by the Limestone G.S. resulted in only moderate changes in lower trophic level groups within the Limestone Forebay, generally reflecting the change from a riverine to a slightly more lacustrine environment. The absence of a marked increase in phytoplankton biomass was attributable to the short water residence time within the forebay which, although longer than the unimpounded river, was still too short to allow substantial growth. Abundance of aquatic macrophytes was low after impoundment and even by the end of the Limestone Monitoring Program in 2003, plants had colonized only a few sheltered areas. Macrophyte growth is often minimal in reservoirs due to frequent water level fluctuations; in addition, the limited area of fine-textured substratum along the shoreline and ice-scour on the lower Nelson River limits potential habitat for macrophytes. Given that attached algae (periphyton) growth is extensive in the lower Nelson River mainstem (as documented subsequent to 2003), the absence of suitable growing conditions for these organisms following impoundment suggests that there might have been some decline in the production of attached algae.

Typical zooplankters, such as cladocerans, rotifers, and copepods, which were more abundant in the forebays than farther downstream, likely increased as a result of the lower water velocities in the Limestone Forebay.

The lower velocity and inputs from eroding shorelines also caused an increase in the prevalence of soft substrates relative to hard, rocky areas in the forebay and may explain the differences observed in the relative abundance of certain invertebrate groups (e.g., a relatively greater abundance of amphipods and ephemeropterans within the forebays vs. relatively more trichopterans in the mainstem). However, both the Limestone and Long Spruce forebays continue to provide habitat for many riverine species which is indicative of the noticeable water velocities that remain post-impoundment. In general, results of the Limestone G.S. aquatic environment monitoring programs suggest that while there has been a shift in composition, there was no large-scale stimulation of production among lower trophic levels following impoundment of the Limestone Forebay.

The absence of detectable effects to water quality and the subtle changes to lower trophic levels are reflected in the rate and magnitude of change in the forebay fish community. The majority of fish species inhabiting the Nelson River are adapted to a wide variety of habitats and, consequently, could continue to inhabit the forebay in the short term despite the large changes in physical habitat (water depth and velocity). The observed changes in species composition were generally not abrupt, but occurred gradually over time (most of the noticeable shifts in species composition did not occur for over ten years). The primary exception was in species directly affected by the barrier created by the generating station. Where downstream emigration past the Limestone G.S. exceeded immigration from upstream (past the Long Spruce G.S.), populations changed relatively rapidly (i.e., cisco, lake whitefish, lake sturgeon, and brook trout).

Long-term changes to the fish community appeared to arise from subtle effects to the food web and the ability of fish to utilize different components of the food web. Also, changes to the suitability of habitats for spawning and incubation, and as nursery areas, were manifested as changes in recruitment. However, the magnitude of these changes was such that they were not detectable in the aquatic monitoring studies until ten years post impoundment (i.e., >1 generation). Fish adapted to spawning and feeding in slower water [e.g., walleye, mooneye (as documented subsequent to 2003)] increased in the forebay environment relative to those adapted to spawning and feeding in shallow, swift flowing water (e.g., longnose sucker). The reasons for this change can be attributed to multiple environmental factors. For example, as zooplankton increased, so did the abundance of walleye and mooneye, species that typically feed on these organisms during their early life stages. Although not directly linked to changes in the large-bodied fish targeted in the aquatic monitoring programs, results of the benthic invertebrate studies indicate that creation of soft substratum areas in addition to the existing hard substrate areas resulted in increases in amphipods and ephemeropterans, two groups that are valuable food for many species of fish, including forage fish. A small increase in the northern pike population following impoundment was likely attributable to increased feeding efficiency in lower water velocities. However, the northern pike population in the Limestone Forebay will likely continue to be limited by the scarcity of aquatic macrophyte growth, and is expected to remain lower than the population in the Long Spruce Forebay. Suspected reductions in periphyton growth likely limited feeding opportunities for longnose sucker.

As discussed previously, several fish species declined immediately post-impoundment due to the barrier created by the Limestone G.S. Populations of cisco are expected to remain substantially reduced from the peak numbers that may have occurred if cisco had undertaken a fall migration into this reach from the Nelson River Estuary (due to the absence of pre-project data, it is not known if migratory cisco moved this far upstream). The long-term fate of lake sturgeon and brook trout populations is uncertain, but numbers are expected to remain reduced in comparison to pre-impoundment levels. Anadromous cisco and amphidromous brook trout have been extirpated from upstream of the generating station.

Rainbow smelt, which were absent at the beginning of the studies and comprised approximately 50% of the diet of northern pike and walleye by the end of the Limestone Monitoring Program in 2003, may have affected the abundance of these predatory species. The addition of smelt to the fish community was not due to the construction of the Limestone G.S., but rather the northward spread of this invasive species which was first observed in the lower Nelson River in 1996. Smelt generally prefer lacustrine to riverine environments, but whether conditions in the forebays are more suitable than the mainstem is not known.

It is believed that overall abundance of fish in the Limestone Forebay likely decreased suddenly during the first year of impoundment due to downstream emigration. Although there was some annual variation, there was little change in overall forebay catch-per-unit-effort (CPUE) from 1992 to 2003. Further changes in overall CPUE in the Limestone Forebay are expected to remain minimal.

The relatively stable species composition and overall abundance of fish in the Limestone Forebay post-impoundment can be attributed to three factors:

i) despite the large change in the physical environment post-impoundment, a substantial portion of the fish community could still fulfill all its life history requirements in the forebay;
ii) no changes in water quality (e.g., severe decline in dissolved oxygen) occurred that made the forebay unsuitable; and
iii) no large nutrient inputs from flooding of terrestrial habitat resulted in an overall surge in ecosystem productivity (i.e., trophic upsurge).

The small amount of flooding in the Limestone Forebay caused only a small increase in mercury concentrations in piscivorous fish, reaching peak levels within five years of impoundment. At that time, standardized mercury concentrations for all species sampled, with the exception of walleye, remained below the Health Canada guideline for commercial sale in Canada. Within seven years of impoundment, mercury concentrations were at background levels for all species, including walleye.

9.2 Downstream of the Limestone Generating Station

Construction of the Limestone G.S. impounded a section of the Nelson River where water levels and flows were substantially affected by the operation of the Long Spruce G.S. These large and frequent changes to water levels and flows were transferred downstream to a wide and relatively shallow section of the Nelson River that had been affected by operation of the Long Spruce G.S., but to a lesser extent. Operation of the Limestone G.S. added to the volatility of this environment by causing incremental changes to the magnitude and duration of water level fluctuations, which were progressively dampened in a downstream direction. Ice processes also were modified such that ice jams occurred farther downstream and ice scouring was reduced downstream as far as Lower Limestone Rapids and in the lower section of the Limestone River.

Water quality and lower trophic studies conducted downstream of the Limestone G.S. over the course of the aquatic monitoring programs were developed to provide a model of pre-impoundment conditions in the Limestone Forebay rather than assess the effects of modifications to water levels and flows in the mainstem downstream of the generating station. Work initiated at the end of the Limestone Monitoring Program began to address the spatial extent of downstream effects, but additional data are required before effects can be described.

The Nelson River fish community has adapted to living in an environment with large daily and seasonal variations in flow. Consequently, the changes in water levels caused by the project would be expected to have little effect on species composition or abundance of the fish community downstream of the generating station. Tag returns suggest that emigration out of the Limestone Forebay may have contributed to a short-term increase in fish abundance downstream of the generating station immediately after impoundment. However, monitoring of fish movements in tributaries downstream of the generating station and periodic sampling in the Nelson River mainstem have provided little evidence of any substantial long-term change in abundance or relative abundance for most species. The one exception may be anadromous cisco that migrate to Hudson Bay to forage during summer and into the Limestone and Weir rivers to spawn during fall. Cisco utilization of both these Nelson River tributaries, particularly the Limestone River, decreased substantially from 1990-1992 to 2003. Cisco also comprised a smaller proportion of the fall experimental gillnet catch from the Nelson River mainstem in 1997 compared to 1991. At this time, data are insufficient to determine whether the decrease is linked to the Limestone G.S. or some other factor. The lack of pre-project data with regard to cisco in the Nelson River limits the ability to interpret post-project changes in abundance.

Some invasive species are becoming more prevalent in the lower Nelson River (e.g., rainbow smelt, carp) since construction of the Limestone G.S. Although unrelated to hydroelectric development, the presence of these species may affect the lower Nelson River fish population over the next several decades. Furthermore, the downstream transfer of fish that are increasing in abundance in upstream forebays also may result in an increase in abundance of some species (e.g., walleye, mooneye) downstream of the generating station.

10.0

PROGRAM SUMMARY/EVALUATION

Construction of the Limestone G.S. commenced in the late 1970s during a period when the environmental assessment process was in its infancy in both Manitoba and Canada. During the initial stages of the project, there was no formal process in place and construction of the access road and coffer dam occurred without an assessment of the potential environmental effects. When the project was subsequently delayed and recommitted to in the mid 1980s, a joint provincial/federal process had been established and was triggered. However, because the project was already committed to and construction had commenced, the assessment focused on impact management rather than on determining impacts. Impact management was defined to include monitoring programs, mitigation works or projects, and compensation.

As discussed in sections 4.1 and 4.2, a Limestone G.S. aquatic environment monitoring program was initiated in the mid 1980s to address the recommendations by the Provincial Land Use Committee of Cabinet (PLUC) that additional fisheries studies be conducted to identify impacts and to develop and assess mitigation, with particular emphasis on brook trout and lake sturgeon, which were key species of concern. In 1993, the studies were refocused to specifically address the ongoing effects of the Limestone G.S., broadening the objectives of the program (now the Limestone Monitoring Program) to document long-term changes to the aquatic environment in the Nelson River and its tributaries both upstream and downstream of the Limestone G.S.

As described in the preceding chapters, the programs have been effective in describing existing conditions in the Nelson River and documenting changes that have occurred, though determining the causes of observed changes (i.e., as a result of the Limestone G.S. or due to natural variability) has been more difficult due to the primary focus on one component of the aquatic environment (large-bodied fish) and the absence of sufficient pre-project data. Thus, definitive assessment of impacts to the aquatic environment on a species-specific basis is not possible for all cases; however, as discussed in the preceding chapter, general trends can be described. The initial years of the monitoring studies (1980s) were focused on the assessment of mitigative measures, primarily targeting brook trout and lake sturgeon. However, as these efforts proved unsuccessful, the focus of studies was shifted to understanding the existing environment and defining the factors limiting the fish populations.

Information gathered during the evolution of the Limestone Forebay will form a major component of the environmental assessment for the Conawapa project and assist in developing effective mitigation programs in the planning stages of that project. Information gathered during the studies of the Nelson River Estuary has provided a general characterization of the physical, chemical, and biological nature of the estuary and will form the basis of assessment of the potential for impacts from the Conawapa project.

The greatest limitation of the aquatic monitoring programs (1985-2003) was that it was developed with very little baseline information. After monitoring studies were initiated in 1985, there were only five open-water seasons during construction activities to collect data prior to impoundment. In some cases, these data were collected concurrent with the occurrence of residual impacts from previous hydro development that had not been fully assessed (e.g., exploitation of brook trout populations during construction of the Long Spruce G.S.). Much of the baseline data were collected as impacts were occurring and with little opportunity to identify and fill gaps as a better understanding of the environment was developed. While this resulted in the compilation of a comprehensive database to describe the existing environment as the project progressed, the lack of pre-project data and/ or immediate post-project data precluded the assessment of many post-project impacts (e.g., effects on migratory fish in the Nelson River, downstream emigration of fish as the forebay filled).

Another limitation of the program was that it was initially restricted entirely to the study of species of interest to the fishery, although it was eventually broadened to include the entire large-bodied fish community. Additional environmental components, such as water quality and lower trophic levels, were added in the 1990s to support the fisheries studies; however, at that time pre-impoundment data could no longer be obtained. Because the monitoring programs were not habitat-based, it was difficult to link observed changes to the direct or indirect effects of physical changes caused by the project. The presence of other factors unrelated to hydroelectric development (e.g., rainbow smelt) also affected the environment during the programs and further confounded the assessment of project-related impacts.

Despite these limitations, the Limestone G.S. aquatic environment monitoring programs have resulted in an unprecedented compilation of baseline aquatic information from a specific area of the province. Results of aquatic studies conducted from 1985 through 2003 are presented in more than 80 reports, which provide a comprehensive picture of the aquatic environment in the lower Nelson River and a good understanding of the long-term fate of large riverine environment in the face of large-scale hydroelectric development. The studies also provide an understanding of the temporal rate of change within that environment. It has become evident that indirect changes to fish populations resulting from modifications to habitat can require several generations before they are manifested at the population level. Inclusion of the Kettle and Long Spruce forebays in the monitoring programs has provided an even longer-term picture of the ultimate condition of the Limestone Forebay.

Studies associated with ongoing environmental assessments (Keeyask and Conawapa) are continuing on the lower Nelson River and are addressing data gaps that remained at the completion of the Limestone Monitoring Program. The end result will be a better understanding of the long-term effects of existing hydroelectric development and the potential impacts of future development on the Nelson River.

11.0

GLOSSARY

algae (algal) – a group of simple plant-like aquatic *organisms* possessing *chlorophyll* and capable of *photosynthesis*; they may be attached to surfaces or free-floating; most freshwater *species* are very small in size.

alluvium – sediment deposited by flowing water, as in a riverbed, flood plain or delta.

ammonia – a toxic by-product of fish metabolism and the decay of *organic* materials.

amphidromous – fish that move between fresh and salt water during their life cycle, but not to breed.

anadromous – fish that migrate from saltwater to freshwater to breed.

aquatic – living or found in water.

aquatic environment – areas that are permanently under water or that are under water for a sufficient period to support *organisms* that remain for their entire lives, or a significant portion of their lives, totally immersed in water.

aquatic invertebrate – an animal lacking a backbone that lives, at least part of its life, in the water (e.g., aquatic insect, clam, aquatic earthworm, crayfish, scuds).

aquatic monitoring – the primary goal of long-term *monitoring* of lakes and rivers is to understand how *aquatic* communities and *habitats* respond to natural processes and to be able to distinguish differences between human-induced disturbance effects to aquatic *ecosystems* and those caused by natural processes.

bacteria – *microscopic* single-celled *organisms* found in soil, water, *organic* matter, and the atmosphere.

baseline information – information about an area, over a period of time, that is used as background for detecting and/or comparing potential future changes.

benthic – living in or on the bottom substrate of an *aquatic environment.*

brackish water – any mixture of sea water and fresh water with a *salinity* of substantially less than 30 *ppt*, but greater than 3 ppt.

catch-per-unit-effort (CPUE) – the number or weight of fish caught in a given time period with a specific size of net (e.g., # fish/100 m/24 h).

chlorophyll *a* – a group of green pigments present in plant and *algal* cells that are necessary in the trapping of light energy during *photosynthesis*.

cofferdam – an enclosure, usually only partially obstructing a river, from which water is pumped to expose the bottom to permit construction.

conductivity – a measure of the ability of a solution to conduct electrical flow; units are microSiemens per centimetre.

Coriolis force – the deflection of freely moving objects (in this context, water) to the right in the northern hemisphere and to the left in the southern hemisphere, in response to the rotation of the earth.

detritus – particulate and dissolved organic matter that is produced by the decomposition of plant and animal matter.

diadromous – fish that regularly migrate between fresh and salt water.

dissolved organic carbon – *organic* material from plants and animals that is broken down into such small particles that it is "dissolved" into water.

dissolved oxygen – the amount of oxygen freely available in water and necessary for ***aquatic*** life and the oxidation of ***organic*** materials.

dissolved phosphorus – *total phosphorus* content of material that will pass through a filter of a specific size.

ecosystem – all living *organisms* in an area and the non-living parts of the *environment* upon which they depend, as well as all interactions, both among living and non-living components of the ecosystem.

environment – i) the total of all the surrounding natural conditions that affect the existence of living ***organisms*** on earth, including air, water, soil, minerals, climate, and the organisms themselves; and, ii) the local complex of such conditions that affects a particular organism and ultimately determines its physiology and survival.

epibenthic – living on, but not penetrating, the surface of the bottom ***sediments*** in a waterbody.

epilimnion – the layer of water near the surface of a ***stratified*** waterbody that normally has high temperatures and oxygen concentrations.

fish community – all fish *species* living in a particular area.

fetch – the length of water over which a given wind has blown.

fish habitat – *spawning*, nursery, rearing, food supply, and migration areas on which fish depend on for survival.

floating ice pan – agglomeration of ***frazil ice*** into frazil pans and larger ice sheets. Frazil ice, if on the surface long enough, will form a continuous ice sheet over a porous mass of frazil sheets. This ice sheet is known as a frazil pan. As these pans move, they bump and grind, and become somewhat circular in shape. These pans may then freeze together to produce larger ice sheets, typically in slow moving reaches where the contacting pans have had time to freeze together.

forebay – the portion of a ***reservoir*** immediately upstream of a hydroelectric facility.

frazil ice – fine spicular or ground ice (slush) that, when first formed, is colloidal and not visible in the water. Frazil crystals are tiny, discoid in shape, and tend to stick to objects and each other. After forming, frazil crystals continue to grow and agglomerate, initially into small clusters, and then into larger flocs.

glacial till – a mixture of clay, silt, sand, and gravel deposited by receding glaciers.

glacio-lacustrine deposits – soil that originates from lakes that were formed by melting glaciers.

gneissic – coarse-grained, foliated (alignment of the platy and elongate mineral grains), metamorphic rock in which there is banding of light and dark minerals.

granitic – granite rock; hard rock formed from solidification of magma.

habitat – i) the total of environmental conditions of a specific place that is occupied by an ***organism***, by a ***population***, or a community of interest; ii) the "home" or place where animals live, reproduce, and die; and iii) the natural or native ***environment*** of a plant or animal.

hydroelectric generating station – a generating station that converts the potential energy of elevated water or the kinetic energy of flowing water into electricity.

hypolimnion – the lowest layer of a ***stratified*** waterbody; it normally has low temperatures and oxygen concentrations.

hypoxic – deficiency of oxygen.

immigration – the movement of individuals into an area.

immunocompetence – the ability to develop an immune response to infection or disease.

impact – a positive or negative effect of a disturbance on the ***environment*** or a component of the environment.

impoundment – i) to backup flowing water with the construction of a physical barrier such as a dam; and ii) a ***reservoir***.

in situ – in the natural place or position.

inundation – the process of covering dry land with flood waters.

juvenile – the stage in an ***organism's*** life before it is able to reproduce.

kilowatt (kW) – one kilowatt equals 1,000 watts. Ten 100-watt light bulbs would use one kW, as would a typical clothes iron or a large hair dryer. An electrically heated house would use about 10 kW.

lacustrine – referring to freshwater lakes; ***sediments*** generally consisting of ***stratified*** fine sand, silt, and clay deposits on a lake bed.

larvae (larval) – the life stage immediately following the egg in ***species*** where this immature stage has an appearance markedly different from the adults; e.g., found in fish and insects.

lentic – pertaining to very slow moving or standing water, as in lakes or ponds.

life history – the timeline of an ***organism***'s life, including development, maturation, and reproduction.

lotic – pertaining to moving water.

m^3/s – cubic metres per second (a measurement of discharge).

macrophytes – multi-celled ***aquatic*** and terrestrial plants.

mainstem – the unimpeded, main channel of a river.

marine – pertaining to seas or oceans; the saltwater ***environment***.

megawatt (MW) – one megawatt equals one million watts or one thousand ***kilowatts***. For example, 100 electrically heated houses would use about one megawatt as would a small industrial customer. The peak demand on the Manitoba Hydro system is about 3,400 MW.

mercury (Hg) – a metallic element that occurs naturally in rocks, soils, water, and organisms.

microorganisms – ***organisms microscopic*** in size such as ***bacteria***, ***phytoplankton***, and ***zooplankton***.

microscopic – small enough so as to be undetectable with the naked eye.

monitoring – measurement or collection of data to determine whether change is occurring in something of interest.

mud flat – a stretch of muddy land left uncovered by falling water and containing surface material composed predominantly of fine silts and clays with rocks and boulder rubble often scattered along the exposed surface.

nitrate – a form of nitrogen which is readily available to plants as a nutrient. Generally, nitrate is the primary inorganic form of nitrogen in ***aquatic*** systems.

nitrite – converted from free ***ammonia*** during nitrification and is harmful at any level to most creatures.

nutrient – any substance which promotes growth or provides energy for living ***organisms***.

organic – the compounds formed by living ***organisms.***

organism – an individual living thing.

pH – a symbol for the logarithm of the reciprocal of the hydrogen-ion concentration of an aqueous solution, used to express acidity or alkalinity. A neutral solution such as pure water has a pH of 7 at 25ºC, while an acidic solution has a pH under 7 and an alkaline solution has a pH over 7.

photosynthesis – a process which occurs in plants and ***algae*** where, in the presence of light, carbon dioxide, and water are turned into a useable form of energy (sugar) and oxygen.

physico-chemical – relating to both physical and chemical properties.

phytoplankton – small (usually *microscopic*) floating *algae*.

plankton – small, floating or weakly swimming ***aquatic*** plants (*phytoplankton*) and animals (*zooplankton*).

population – a group of interbreeding ***organisms*** of the same ***species*** that occupy a particular area or space.

power – the rate at which electrical energy is produced per unit of time. It is usually expressed in ***kilowatts*** or ***megawatts***.

ppt – parts-per-thousand.

Precambrian – of or relating to the earliest era of geological time from the formation of the earth to the first forms of life.

primary production – the quantity of new *organic* matter created by *photosynthesis*.

reservoir – an artificial lake where water is collected and kept in quantity for use.

riverine – of, pertaining to, or inhabiting rivers.

run-of-the-river – coordinated operation of facilities to allow water to pass down a river through successive plants with little or no intermediate *storage capacity*.

salinity – a measurement of the salt concentration in a solution.

Secchi disk – a 20-cm diameter circular plate, painted alternately black and white, used to determine water transparency.

sediment(s) – material, usually soil or ***organic detritus***, that is deposited at the bottom of a waterbody.

spawn – i) the mass of eggs that is deposited by fishes, amphibians, molluscs, crustaceans, and the like; and ii) to deposit eggs or sperm directly into the water.

spawning – the act of reproducing in fish.

species – a group of ***organisms*** that can interbreed to produce fertile offspring.

species composition – the array of ***species*** that occur in an area.

spillway – a series of chutes in a hydroelectric facility that permit the passage of water out of the *forebay* and is not used to generate power.

storage capacity – the volume of water contained between the maximum and minimum allowable levels in a ***reservoir***.

stratification (stratify) – i) division of a waterbody (or bottom ***sediments***) into distinct layers (strata) on the basis of temperature, salinity, light penetration or density, or some other attribute; and ii) division of an ***aquatic*** or terrestrial community into distinguishable layers on the basis of vegetative structure, temperature, moisture, and light.

strontium (Sr) – a trace element in natural saltwater that acts like calcium by incorporating itself at sites of bone production (e.g., in fish); tracer of fish movement between freshwater and marine ***habitats.***

tide – the periodic rise and fall of sea level observed along the coasts caused by the gravitational pull of the moon.

total suspended solids – the amount of particulate matter that is held in the water column due to movement of the water; measured as the dry weight of suspended material per litre of water.

total organic carbon – the amount of carbon covalently bound in *organic* compounds in a water sample.

total phosphorus – the sum of all phosphorus forms.

tributary – any secondary stream or river that flows into a larger waterway.

trophic level – functional classification of *organisms* in an *ecosystem* according to feeding relationships (e.g., herbivores, carnivores); any of a series of steps in a food chain or food pyramid from producers to primary, secondary, and tertiary consumers.

turbidity – a measure of the relative clarity of water.

turnover – the mixing of lake water from top to bottom after a period of stable ***stratification.*** This typically occurs in fall and is caused by wind and seasonal cooling of surface waters.

velocity – a measurement of speed of flow.

water quality – measures of substances in the water such as nitrogen, phosphorus, oxygen, and carbon.

watershed – the area within which all water drains to collect in a common channel or lake.

weir – a fence or wattle placed in a stream to catch or retain fish.

zooplankton – floating or weakly swimming animals that live in the water column.

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