

Seasonal Summary

Great Lakes

Winter 2021-2022



By the North American Ice Service

Summary for the Great Lakes

The 2021-2022 Great Lakes ice season can be summarized as generally near to above normal ice coverage and near normal thickness over the entire season. Above normal weeks alternated with near normal weeks from late January until mid-March, while the end of the season remained near normal. The above normal peaks coincided with cold-air outbreaks over the regions. The most notable periods were the end of January when Lakes Erie and Ontario reached their maximum ice coverage, in mid-February, when Lakes Huron and Michigan reached peak ice coverage and finally in mid-March when Lake Superior reached maximum ice coverage.

The total accumulated ice coverage (TAC) for the 2021-2022 ice season was 12.6%, which places this season slightly above the 30-year median of 10.7%. By rank, it placed this year's ice season in the middle at 26th out of the last 50 ice seasons since 1972-1973.

The Great Lakes ice season started in the last week of November or one week earlier than normal. Ice growth was minimal through December due mainly to above normal temperatures. This warm trend changed in January and generally below normal temperatures flooded the Great Lakes. The cool trend intensified in the last half of January. This facilitated a very rapid accumulation of ice that outpaced the climatological growth that is typical for the month.

Ice coverage ebbed and flowed through February as low-pressure systems with warm temperatures and strong winds reduced the ice extent followed by periods of calm cold weather conducive to ice growth. During this period of fluctuating ice coverage, very cold temperatures in the second week of February were responsible for the peak ice coverage on the Great Lakes. The maximum ice coverage reached 51%, well above the climatological peak value of 34% and occurred one week earlier than normal on February 19th.

The spring melt started on time in mid-March and proceeded at a slightly faster than normal pace, due in part to very warm temperatures in the third week of March. The melt slowed in the first half of April causing ice to linger slightly longer than normal in parts of Lake Huron, Michigan and

Superior. The spring melt finally finished when the last of the ice on the Great Lakes melted in Thunder Bay by May 21st, bringing a close to the 2021-2022 ice season one week later than normal.

Below are the subdivided temperature anomaly regimes for the winter of 2021-2022 (Figures 1-6).

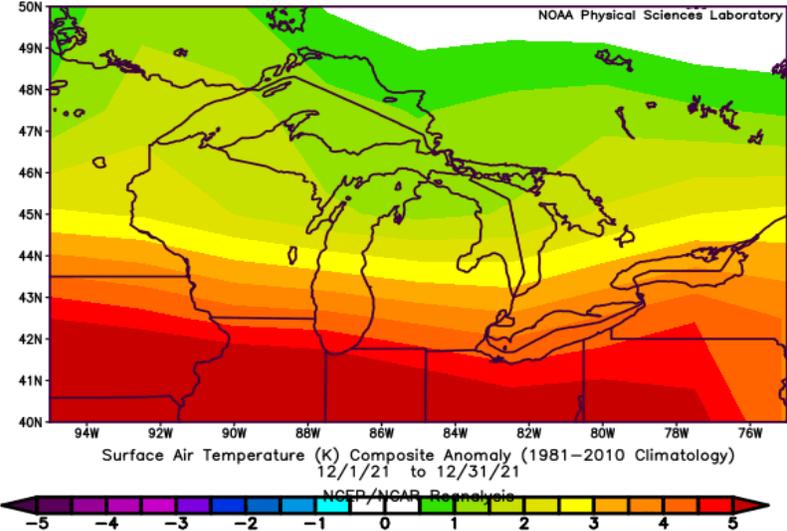


Figure 1: Surface Air Temperature Anomaly for the Great Lakes, 1 December 2021 to 31 December 2021

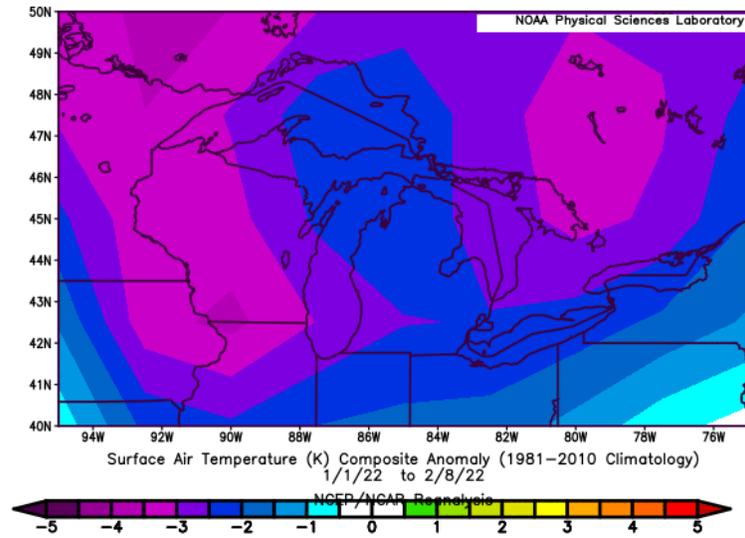


Figure 2: Surface Air Temperature Anomaly for the Great Lakes, 1 January 2022 to 8 February 2022

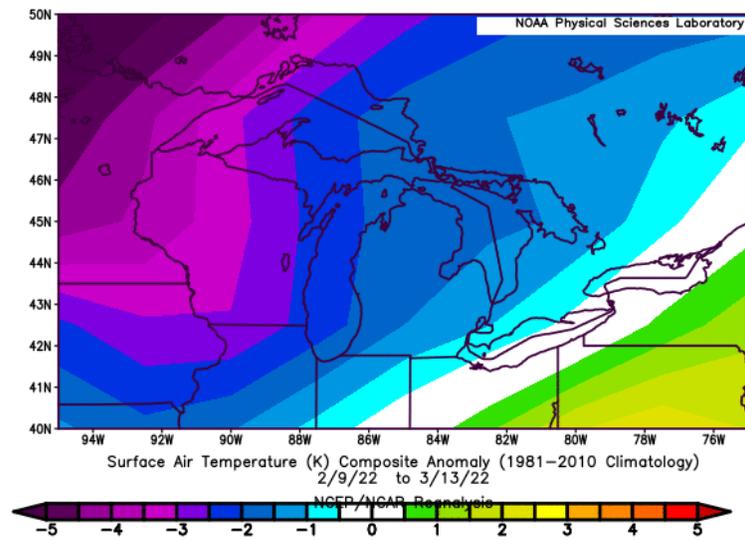


Figure 3: Surface Air Temperature Anomaly for the Great Lakes, 9 February 2022 to 13 March 2022

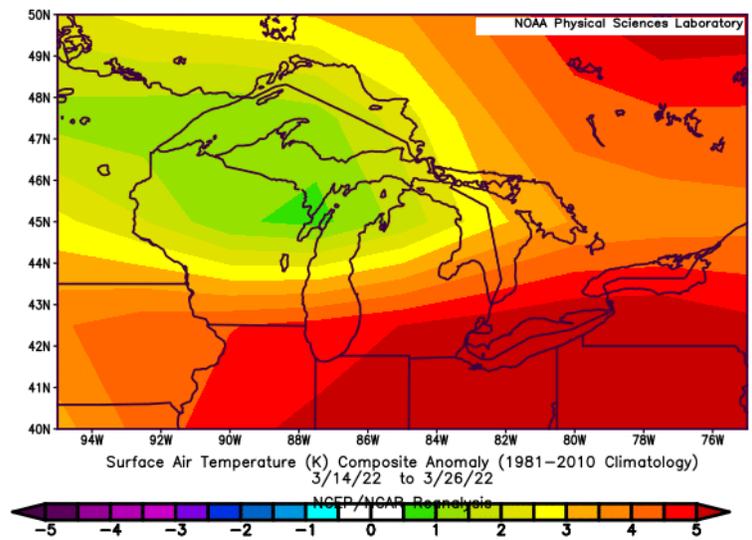


Figure 4: Surface Air Temperature Anomaly for the Great Lakes, 14 March 2022 to 26 March 2022.

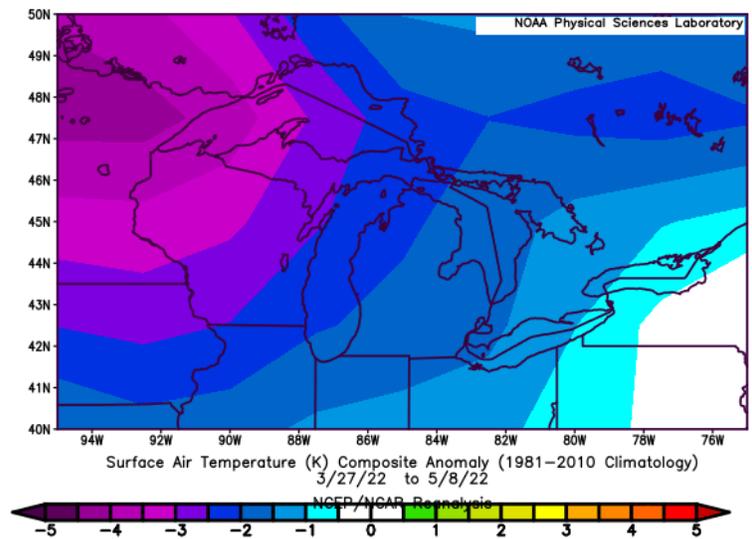


Figure 5: Surface Air Temperature Anomaly for the Great Lakes, 27 March 2022 to 8 May 2022

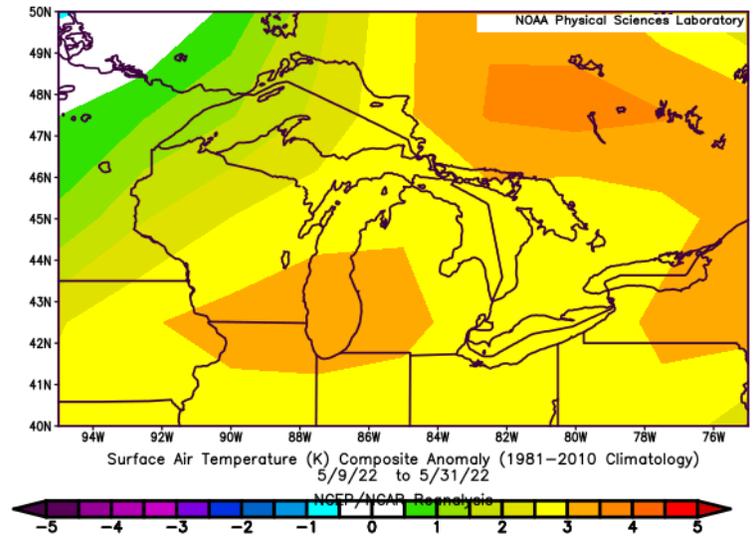


Figure 6: Surface Air Temperature Anomaly for the Great Lakes, 9 May 2022 to 31 May 2022

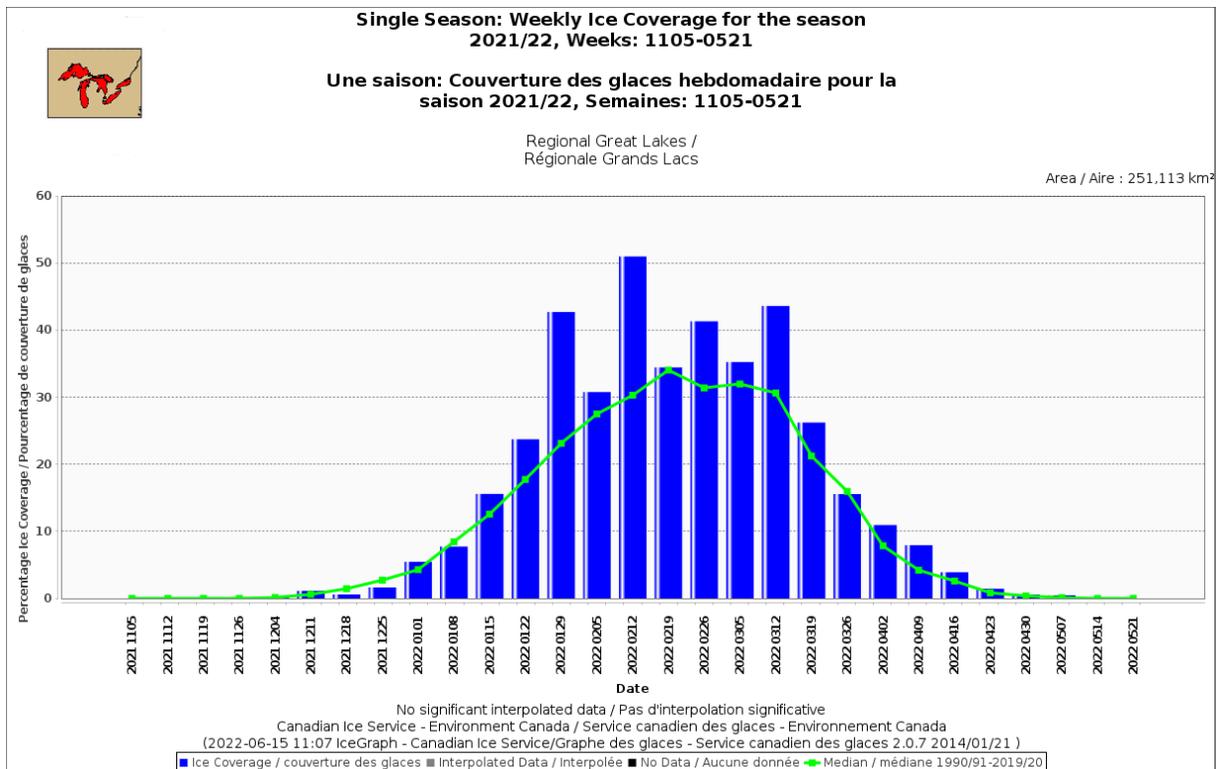


Figure 7: Weekly Ice Coverage for the Great Lakes, winter 2021-2022

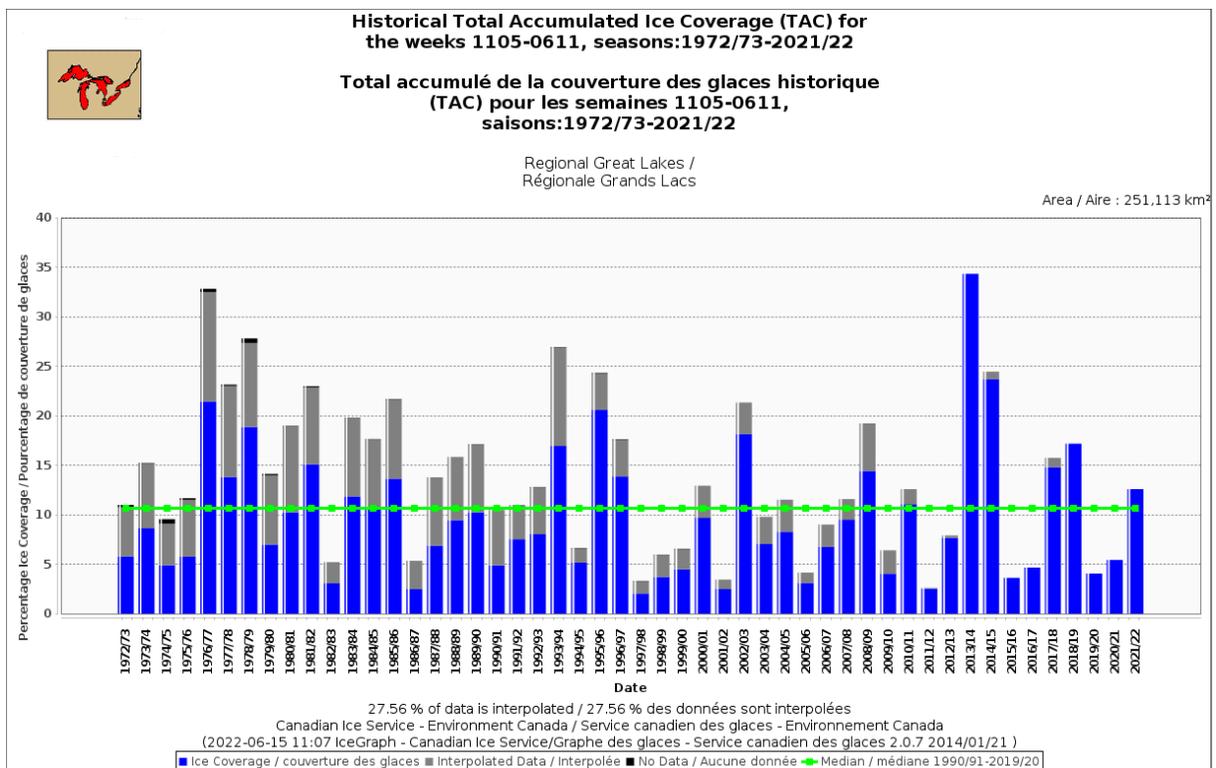


Figure 8: Historical Total Accumulated Ice Coverage on the Great Lakes, 1972-1973 to 2021-2022

Lake Superior

2021-2022 Ice Conditions:

The 2021-2022 Great Lakes ice season started on Lake Superior at the end of November. Above normal temperatures through the northern half of the Great Lakes during the first 3 weeks of November prevented any very early season ice from forming on the lake. The first ice formed in Black Bay on November 26th after a short cold spell. The ice formation occurred within a period of generally near normal temperatures, which had prevailed from late November to early December. During this cold spell, the overnight lows dipped below -10 degrees Celsius, which promoted the formation of ice one week earlier than normal on Lake Superior. Total ice coverage was still less than 0.1% and all the ice was limited to Black Bay. Ice continued to be contained within Black Bay for the week following the initial formation until December 4th when the first measurable concentrations of ice began to form in Nipigon Bay. Shortly afterwards ice formation expanded to a number of bays around the entire lake with small concentrations visible in Thunder Bay, Chequamegon Bay, Dollar Bay as well as Whitefish Bay. Once again, the ice formation was due to a short cold spell. Overnight temperatures fell to below -20 degrees Celsius for the first time during the ice season during this cold spell.

Ice growth largely halted during the second week in December when above normal temperatures flooded the region. The warm spell lasted until the end of December with air temperatures fluctuating between near or above zero for daily highs and generally below -10 degrees Celsius for the lows and resulting in an average mean air temperature of 2.4 degrees Celsius above normal. This cold spell thickened the existing ice and led to ice becoming fasted through most of Black Bay and Nipigon Bay. By the end of December, Black Bay was mainly consolidated medium lake ice everywhere except at the southern entrance where there were smaller concentrations of new and thin lake ice. In Nipigon Bay, the western extreme was consolidated medium lake ice while the central and eastern sections were mobile new and thin lake ice. During this time, Thunder Bay and Chequamegon Bay were partially covered with new and thin lake ice, while lesser concentrations of new and thin lake ice also lined parts of the

southern shore of the lake. December ended with 1.6% ice coverage over Lake Superior, which nearly matched the long-term median of 1.8%.

The beginning of January marked a turning point in the temperature regime over Lake Superior. For the bulk of December, above normal temperatures persisted. However, at the beginning of January, below normal temperatures took over, allowing for ice growth outside of the bays of Superior for the first time in the season. As temperatures dropped, new and thin lake ice filled Thunder Bay and formed in parts of Whitefish Bay and along parts of southern shore, at first only west of the Keweenaw Peninsula, but after a few days, the ice expanded along parts of the shore east of the Keweenaw as well. In this same period, the remaining ice in Nipigon Bay consolidated. In the two weeks following this initial formation, the ice coverage fluctuated slightly as the thin ice was easily broken by winds and warm temperatures as weak low-pressure systems passed over the area. New and thin lake ice would form in the calm cold weather that followed each of these low-pressure systems; however, widespread ice growth was largely limited by warm surface water temperatures. In the second week of January ice coverage fell slightly and then rebounded in the third week of January. By that time, ice coverage had only reached 5.8%, resting just below the climatological value of 8.1%.

Near the end of January, average daily air temperatures dropped even further below normal as a sustained cold air outbreak settled over the lake. Air temperature anomalies were near 3 degrees Celsius below normal for the eastern half of the lake, while in the western half, temperatures were closer to 5 degrees Celsius below normal for the last 10 days of January. This brought about the first substantial increase in ice coverage over the lake. The ice covered area more than doubled in the final two weeks of January. Ice accumulated at a much faster rate than climatology, reaching 26.7% ice covered by the end of the month, which was well above the normal of 11.4%. New and thin lake ice quickly thickened in the cold air to thin and medium lake ice and lined the entire southern shore of the lake, filled the rest of Thunder Bay and spread out to Isle Royale. In the midst of the cold spell, ice began to form along the shore between Whitefish Bay and Michipicoten Bay two weeks earlier than normal.

February began with a slight dip in ice coverage, driven by a few days of above normal temperatures, particularly in the eastern half of the lake. Ice thinned along the southern and eastern shores of Superior, dropping ice cover to 20.8%. The ice extent was quick to recover as average temperatures fell to well below normal over the lake, allowing new ice to expand rapidly along the shores around the entire lake. This new lake ice quickly thickened to thin lake ice and extended far out from the shore. In the northwestern section of the lake, the ice expanded out to completely surrounded Isle Royale. The first half of February saw additional fastening of lake ice in Whitefish Bay and Thunder Bay. By the end of the second week of February, ice coverage more than doubled from the previous weeks, rising to 47.4%. This large jump meant that the ice coverage was more than triple its long-term median of 15.1%.

Ice coverage ebbed once again in the third week of February when the daily high rose to near the freezing point for most of the lake and even above zero degrees Celsius in far eastern Lake Superior. The relatively warm temperatures for this time of year reduced ice concentrations along the shores of the lake. However, despite the above normal temperatures, some of the consolidated ice in Black Bay and Nipigon Bay had thickened to very thick lake ice and more ice in Thunder Bay consolidated into fast ice. Ice coverage dropped to 32.2%, which was much closer to the climatological median of 27.4%. Average air temperatures remained generally below normal through the rest of February and any area that saw a reduction in ice concentration the previous week had filled back in and expanded even further out from the shore. At the end of February, most of the western half of the lake lay covered with thin and medium lake ice including an area of predominantly thick lake ice near Duluth. In the eastern half of the lake, thin and medium lake ice lined the rest of the shore. During this time, Whitefish Bay became completely consolidated with thick lake ice. February finished with an ice extent of 49.4%, which was once again much higher than the climatological median of 25.2%.

Ice growth continued into the first week in March with near normal temperatures across the lake. Ice expanded only slightly in March compared to the end of February; however, it did continue to thicken to thick lake ice, which could be found around the entire lake. This period of ice growth was counter to the climatological trend for Lake Superior.

Normally ice coverage declines slightly at the end of February and early-March as the first spring-like weather systems bring slightly warmer temperatures and strong winds which destroys the ice.

A period of calm and cold weather settled over Lake Superior in the second week of March, allowing a rapid expansion of new and thin lake ice. This ice growth covered the entire western half of the lake and most of the eastern half, leaving only an area of open water in the middle of the eastern half of the lake. As a result, Lake Superior reached its peak ice coverage for the 2021-2022 ice season as thick lake ice was packed along any western facing shores, medium lake ice was pushed to the middle of the lake and new and thin lake ice filled in along most eastern facing shores of the lake. At the peak, ice covered 72.9% of the lake's surface. This peak in ice coverage occurred during the same week when the climatological ice cover peaks. However, the maximum extent this ice season was nearly double the long-term median maximum of 37.2%.

Following the peak ice coverage, above normal air temperatures blanketed the region for nearly two weeks kicking off the spring melt in earnest. With these warm temperatures, daily highs reached 10 degrees Celsius and slightly above that on a few of the days during this period. This led to a rapid decline in ice coverage over the lake with most of the new and thin lake ice being destroyed within the first week of the warm temperatures, dropping ice coverage by one third or down to 50%. By the end of the warm spell most of the medium lake ice was either melted or destroyed. At the end of March, the ice was predominantly thick lake ice and mainly restrained to the shoreline of the lake, with a few areas of strips and patches of thick lake ice in the middle of the lake. Fast ice also began to fracture along the eastern shore of the lake as well as in Whitefish Bay and Thunder Bay. Ice coverage had dropped by half from the previous week, giving an ice coverage of 25.3%. Despite the rapid reduction during the last half of March, the ice extent still remained above the long-term median of 16.7% and roughly one week behind the typical melt.

April began with near normal air temperatures, though the ice extent remained above the climatological median. Within the first week of the month, most of the lake ice along the western and northern shores of the lake had melted and the ice along the eastern shore began to disperse.

The spring melt continued and ice coverage dropped to 17%. The near normal temperatures persisted into the second week of April, further melting the ice along the shore and fracturing the edges of the fast ice in Whitefish Bay and around the Apostle Islands. At the end of this period, ice coverage was reduced to 6%. In mid-April, below normal air temperatures returned to Lake Superior ranging from 3 degrees Celsius below normal in the eastern half of the lake to 5 degrees Celsius below normal in the western half. Despite these below normal air temperatures, the lake ice continued to break up as average daily air temperatures remained above the freezing point. By the end of the month, all of the mobile ice that had lined the shores as well as most of the ice in Whitefish Bay had melted. The remaining ice in Lake Superior was in Chequamegon Bay, Thunder Bay, Black Bay and Nipigon Bay. Ice coverage finished April at 1.7% and registered slightly above the long-term median of 1.1%

The ice melt in Lake Superior slowly continued in the beginning of May, as only the thickest lake ice remained in a few large bays in the western half of the lake. Chequamegon Bay fractured on the last day of April and all of the ice in the bay completely melted by the end of the first week of May. Nipigon Bay was next to fracture with the eastern portion of the bay breaking up on May 10th and requiring nine days to completely melt. On May 13th, Black Bay began breaking up and despite fracturing later than Nipigon Bay; all of the ice had melted by May 19th as well. Even though Thunder Bay began fracturing in late-March, it was the last bay to melt out, becoming free of ice on May 21st.

With the last ice melting in Thunder Bay in mid-May, the 2021-2022 ice season came to an end on Lake Superior. This season was two weeks longer than the long-term median, starting one week earlier than normal and ending one week later. The first two and a half months of the ice season saw a mix of above and below normal ice extents as winter settled in. However, starting in mid-January, ice coverage remained above normal for the rest of the ice season. This led to a total accumulated coverage (TAC) of 15.6% for Lake Superior and just over triple the TAC of last years (2020-2021) season. This was also double the long-term median TAC of 7.8%. The 2021-2022 ice season ranked in the middle of the pack in term of TAC for the Lake Superior. Over the last 50 years, this past season came in as the 24th highest ice season since 1972-1973.

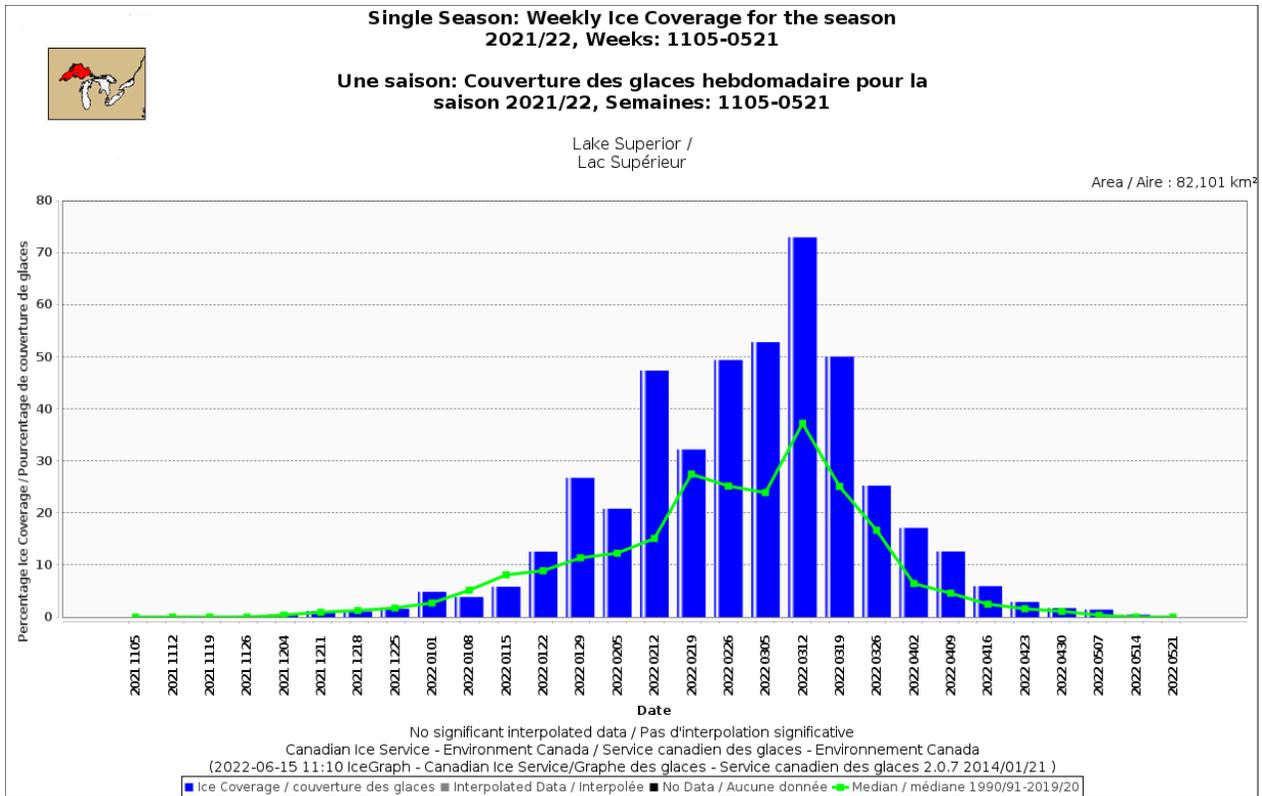


Figure 9: Weekly Ice Coverage in Lake Superior for winter 2021-22.

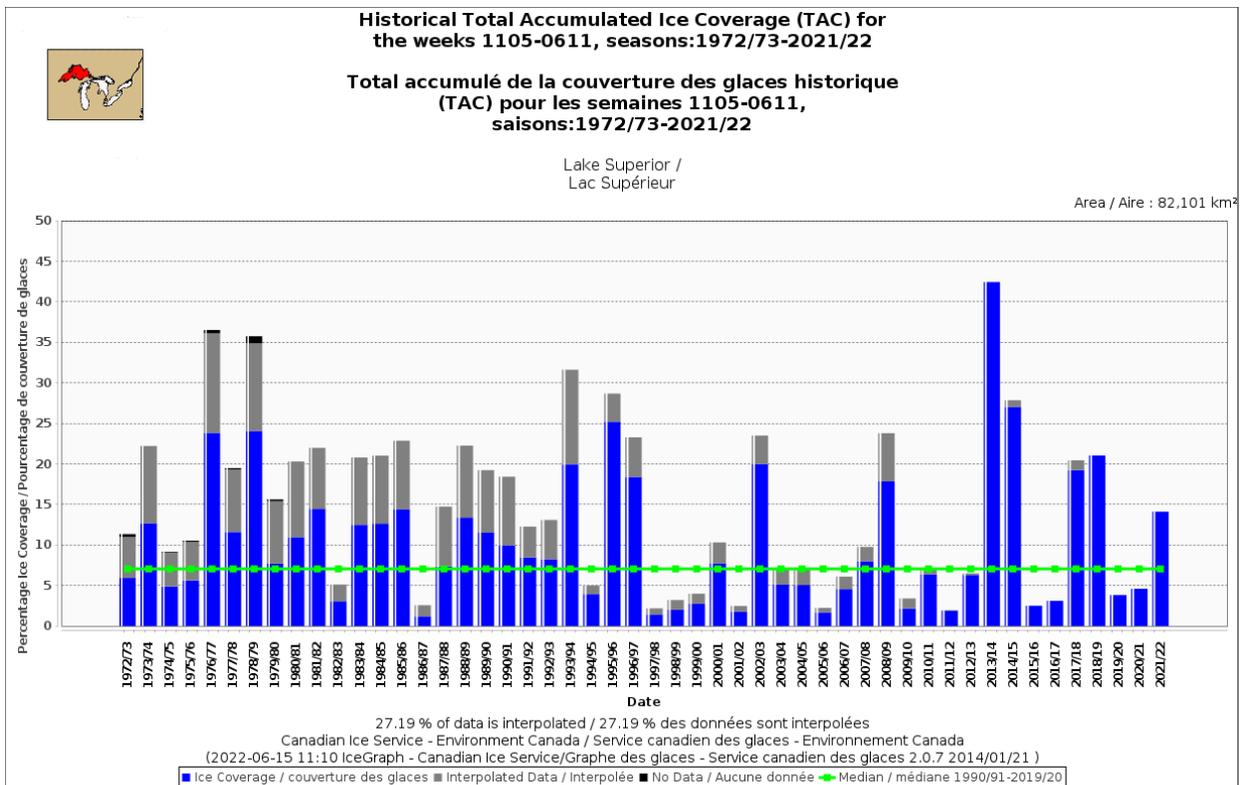


Figure 10: Historical Total Accumulated Ice Coverage in Lake Superior by season, 1972-2022.

Lake Michigan

2021-2022 Ice Conditions:

The Lake Michigan 2021-2022 ice season started on December 5th, 2021 when small concentrations of new lake ice formed in the Bays de Noc and along the northern shore of the lake. This ice formed a week earlier than normal for Lake Michigan. Daily average air temperatures were predominantly above normal for the month of December, meaning that very little ice formation occurred through the month. In fact, nearly all of the ice in Green Bay and the Bays de Noc melted in mid-December as daily high temperatures reached near 20 degrees Celsius on December 15th and 16th. Following these very warm temperatures, daily average temperatures returned to below freezing for the rest of the month, though still above normal, allowing ice coverage to rebound and expand. New and thin lake ice grew to fill the southern portions of Green Bay and the Bays de Noc. By the end of the month, ice also grew along the rest of the shore of Green Bay, along the Door Peninsula and along the shores near the Straits of Mackinac. Despite the above normal temperatures through the month, ice coverage grew close to the climatological pace, finishing the month at 1.8% ice covered compared to the long-term median of 2.1%.

In January, temperatures continued to cool and in the first week, average temperatures fell to below normal, leading to ice growth as ice accumulated in Green Bay and began to form and remain in the northeastern end of the lake. Ice even formed along the western shore down to Chicago as the daytime high dipped to minus 10 degrees Celsius at the end of the first week, well below normal for the area. These below normal temperatures rolled into the first part of the second week of the month as well. This led to Green Bay being completely ice covered with more ice growth along the northern and western shores of the lake. However, the cold did not last the entire week as a brief period of well above normal temperatures swept over Lake Michigan in a period of two days as a low-pressure system passed north of the Great Lakes bringing warm, above freezing temperatures to region. While this brief rise in temperatures was enough to melt the new lake ice along the southwestern shore of the lake, it did not have much of an affect on the thicker ice in Green Bay or the northern shore. By the mid-

point of January, ice coverage had risen to 14%, nearly in line with the long-term median of 12.7%. This mix of above and below normal temperatures continued in the third week of January; however, ice growth was minimally affected. Ice in Green Bay thickened to medium lake ice and to thick lake ice in the Bays de Noc. Most of the northeastern section of the lake was also covered by thin and medium lake ice and some fast ice had begun to form around Beaver Island and in the Straits of Mackinac. The end of January was marked by the coldest temperatures of the entire winter for Lake Michigan. These cold temperatures lead to increased ice growth; new and thin lake ice filled nearly the entire shore of the lake. Much of Green Bay and the rest of the Straits of Mackinac consolidated to fast ice as a result. The month ended with an ice coverage of 31.3%, much higher than the long-term median of 16.8%.

As January turned into February, the air temperatures continued their pendulum swing from above normal temperatures to below normal every few days through the entire month. During the above normal air temperature periods the daily highs were often above the freezing point, while with the below normal temperatures periods daily highs remained below freezing. This led to a similar swing in ice coverage over the lake. With an initial warm spell, ice coverage dropped significantly from the end of January, reducing the total to 17.3%, which dropped the extent below the long-term median for the first time in 4 weeks. The reduction was largely in the mobile ice that lined the shores of the lake, while the thicker fast ice extent, which grew the previous week, remained. Both Green Bay and the Straits of Mackinac saw an increase in fast ice coverage. The following week saw the ebb and flow continue with very cold air temperatures dominating the region leading up to the end of the second week in February. As a result, rapid growth of new and thin lake ice occurred once again along the shores as well as in the northern end of the lake. Ice coverage more than doubled to 37.8% and reached the peak ice coverage for the season. The 2021-2022 peak occurred one week earlier than normal and was nearly double the climatological median peak of 20.5%. Just as quickly as the peak came, the new and thin lake ice was mostly melted and destroyed by the next week as air temperatures warmed up again. This marked the beginning of the spring melt for Lake Michigan. In the final week of February, ice coverage dropped once again when most of

the ice in the southern half of the lake melted and daily average air temperatures continued to rise. The thick fast lake ice in Green Bay and the Straits of Mackinac accounted for the bulk of the ice in Lake Michigan. The month ended with an ice coverage of 18.8% and registered as above normal ice extent compared to the median climatological coverage of 14.6%.

March began with above normal air temperatures and once again reduced the ice coverage for the third week in a row as the ice melt continued. The rest of the ice in the southern half of the lake melted during this time, leaving the remaining ice in the extreme northern section of the lake and in Green bay. The spring melt paused briefly in the second week of March during a brief cold spell that sent daily average air temperatures below the freezing point. This caused the overall ice extent to increase from the first week of the month, bucking the descending trend the lake had experienced since the ice coverage maximum in February. Ice coverage rose to 19.3%, up from 16.8% the week before, keeping ice coverage above normal. The spring melt resumed in the third week as above normal temperatures swept over the area, sending daytime highs to near 20 degrees Celsius in Green Bay and higher in Chicago. These warm temperatures quickly melted the new and thin lake ice; however, the medium and thick lake ice was unaffected. In the wake of these very warm temperatures, the majority of the fast ice in Green Bay fractured at the beginning of the final week of March. The consolidated ice in the Strait of Mackinac soon followed and fractured before the end of the month. By months end, ice coverage had dropped to 10.1%. The bulk of the ice was now mobile as opposed to consolidated and was confined to Green Bay and the entrance to the Straits of Mackinac with looser ice conditions around Beaver Island and just to the south.

The beginning of April, as well as the last week in March, was marked by generally near to below normal air temperatures. This acted to slow the spring melt once again, particularly in the second week of April. While ice coverage did continue to drop, it was less than the normal springtime melt. The lake ice remained confined to the same places as the end of March; however, it was at a lower concentration. This left small concentrations of thick lake ice in the central portion of Green Bay as well as from around Beaver Island to the north and east. The Bays de Noc remained as

consolidated thick lake ice along with a few other small bays in the north end of Lake Michigan. The biggest change of the month occurred after a few days of above normal temperatures, which happened around mid-April. A strong low-pressure system brought warm temperatures and strong winds to Lake Michigan, which led to the rapid decline of the remaining mobile ice in Green Bay and near the Straits of Mackinac. This also caused the fast ice in the Bays de Noc to fracture. By the end of the third week of April, ice coverage had dropped from 5.4% to just 0.8% in the wake of the low-pressure system. The remaining amounts of ice were found in the Bays de Noc as well as along the shore near the Straits of Mackinac and Little Traverse Bay. The little remaining lake ice continued to melt in Lake Michigan as average daily air temperatures continued to rise through the month of April. The last of the ice in the lake melted on the 27th of April, leaving the lake free of ice.

With the final ice melting in late April, the 2021-2022 ice season came to an end. The ice season on Lake Michigan was two weeks longer than the climatological normal, starting one week early and ending one week late. The ice coverage over the lake remained above normal for nearly the entire season, spending only four weeks below normal. The total accumulated coverage (TAC) was 9.4% for Lake Michigan, over double the TAC from last season and just above the long-term median of 6.6%. The 2021-2022 ice season ranked as the 24th highest ice season over the last 50 years, since the 1972-1973 ice season.

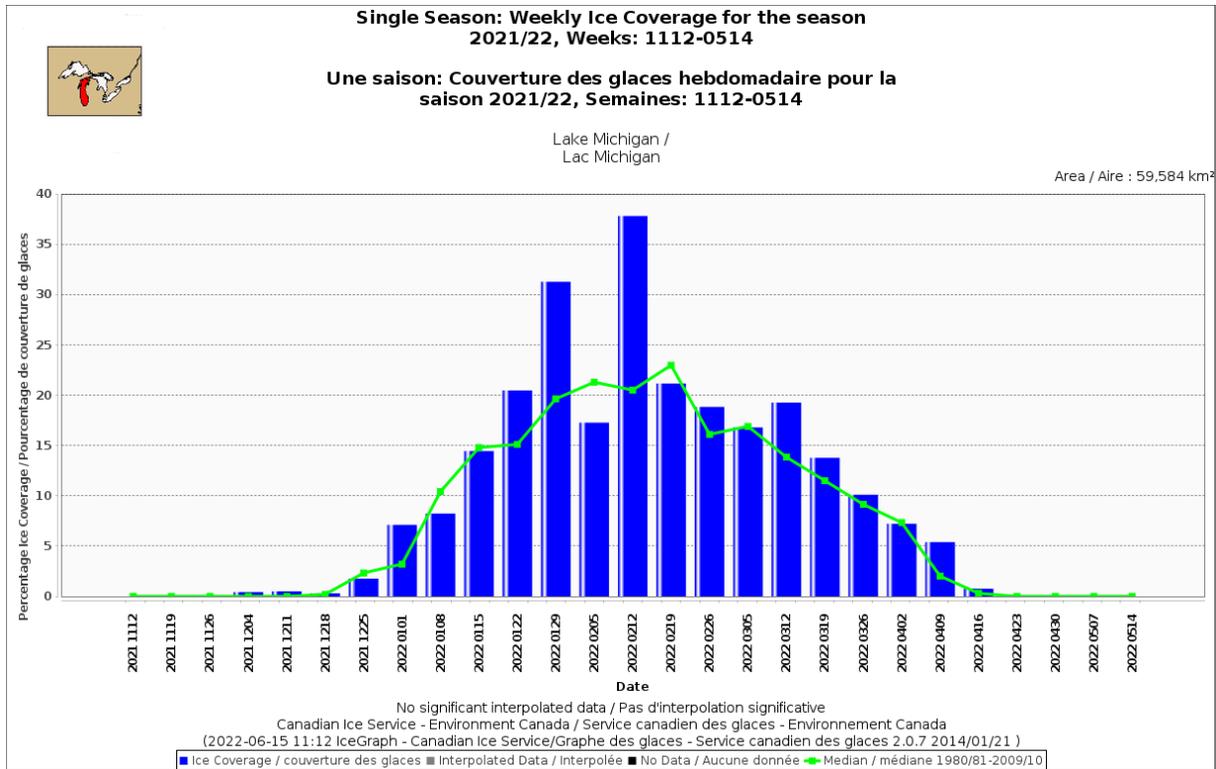


Figure 11: Weekly Ice Coverage in Lake Michigan for winter 2021-22

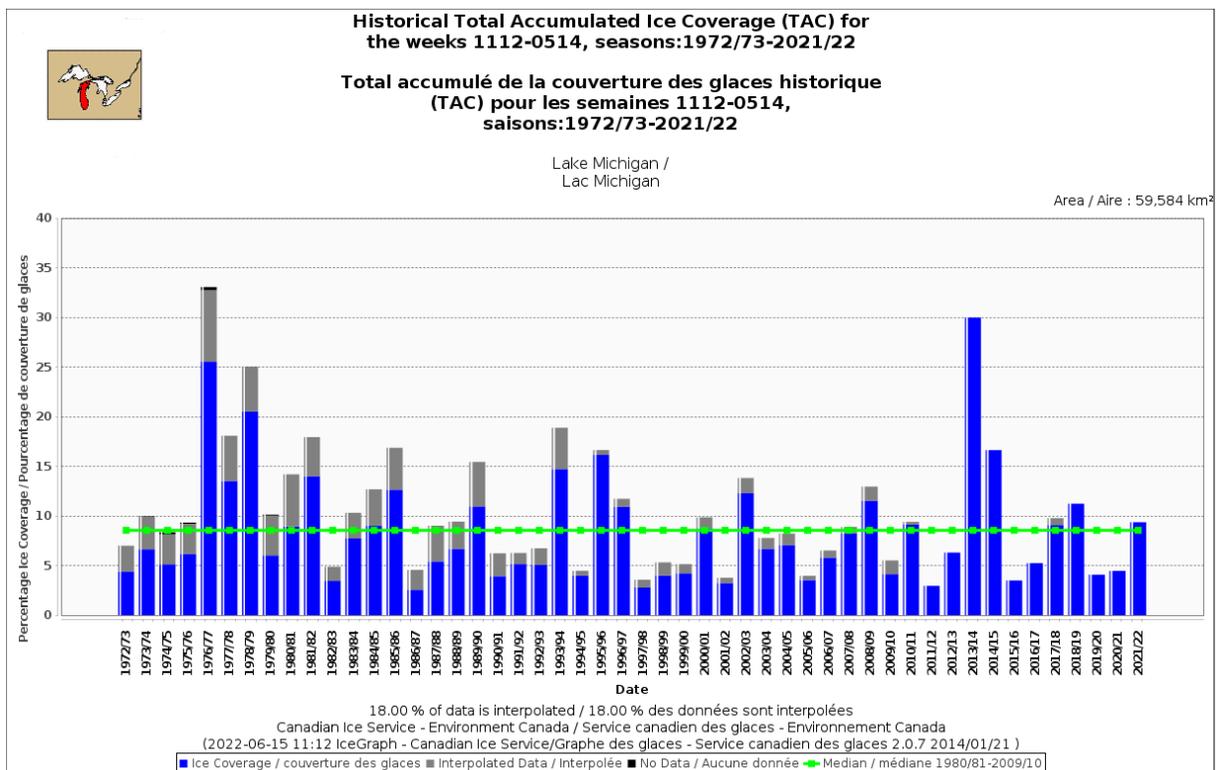


Figure 12: Historical Total Accumulated Ice Coverage in Lake Michigan by season, 1972-2022

Lake Huron

2021-2022 Ice Conditions:

The 2021-2022 ice season started on Lake Huron on November 29th with the first ice forming along the banks of the St. Mary's river. Above normal temperatures prevented any new ice from forming in the remaining days of November and for the first week of December. It was not until the beginning of the second week of December that more new lake ice formed, expanding outside the St. Mary's River, to the North Channel, Georgian Bay and in Saginaw Bay. This expansion of lake ice was driven by 3 days of cold air temperatures across the lake that saw lows dip as low as minus 16 degrees Celsius across parts of the lake. By mid-December, ice coverage rose to an early season high of 2.5%, which was well above normal for that time of year. Typically, ice coverage during this period would register at 0.4%. Following the initial jump in ice coverage, warm, above normal air temperatures settled in across the lake for the rest of the month. Air temperatures were particularly high in the middle of the second week of December. Much of the new ice melted across Lake Huron as temperatures rose to +16 degrees Celsius around parts of the lake. This led to a decrease in ice coverage, falling to 0.7% and below the climatological median for that week. Even with the above normal air temperatures, the temperatures continued to drop and were predominantly below the freezing point in the end of December. Once again, lake ice began to form along the shores of the North Channel, Georgian Bay and Saginaw Bay. At the end of December, ice coverage had recovered to the level it had been two weeks prior, rising to 2.6%. However, this coverage finished 2021 at less than half the long-term median of 5.2%.

The persistent above normal air temperatures finally came to an end at the beginning of January and replaced with near to below normal values. New ice quickly formed in response to these cold temperatures, filling the southern half of Saginaw Bay with new and thin lake ice. Ice formed along much of the eastern shore of Georgian Bay and started to fill in more of the North Channel, where ice was predominantly thin lake ice. The increased ice pushed ice coverage to 8.6% in the beginning of January, just ahead of the climatological median of 7.8%. Ice continued to form due to the cold

January temperatures; however, it was at a slower pace than normal. Ice coverage did not expand much; rather, the ice thickened slightly and saw an increase in the concentration in the existing areas containing ice. By mid-January, still under the influence of predominantly below normal temperatures, ice had completely covered the North Channel and Saginaw Bay. The North Channel consisted of thin and medium lake ice, while Saginaw Bay had new and thin lake ice. All of the ice in the St. Mary's river had consolidated to medium fast ice as well as most bays along the northern and eastern Georgian Bay shores. Mobile new and thin lake ice lined almost the entire shore of the lake. This signified the largest increase in ice coverage of the season to that point. Ice coverage was over double the coverage from the previous week when it jumped to 28.4%. In the last half of January, daily average air temperatures turned even further below normal than the first half of January. This is also when daily average air temperatures reach their coldest point of the winter. These cold temperatures lead ice to grow at a faster than normal pace causing the ice in the North Channel and Saginaw Bay to quickly consolidate. New and thin lake ice filled in along the Michigan portion of the shoreline while thin and medium lake ice covered the Ontario portion. At the end of January, Georgian Bay was over half covered by thin and medium lake ice. The abnormally cold temperatures in the end of January resulted in an ice coverage of 54.9%, nearly double the long-term median of 28.2%.

Much like with the beginning of January, the temperature regime changed at the beginning of February. Below normal air temperatures were swept aside and replaced with predominantly above normal air temperatures for the first week and a half of the month. A sharp decrease in ice coverage resulted from these above normal air temperatures, above the freezing point at times, and associated stronger winds. The ice that lined the shore as well as in Georgian Bay shrank in extent and thinned significantly, while the consolidated ice in the North Channel and Saginaw Bay thickened. The ice coverage fell to 38.3%, which was much closer to the long-term median of 36.1%. These warm temperatures were followed by the coldest temperatures of the winter, with overnight lows dipping below minus 30 degrees Celsius across many parts of the lake in mid-February. New and thin lake ice expanded rapidly in all parts of Lake Huron, once again, lining nearly the entire shore. This left only the middle of the lake and the area

along the Bruce Peninsula in Georgian Bay without any ice. These cold temperatures pushed ice coverage on Lake Huron to its peak for the 2021-2022 ice season. The maximum lake ice coverage reached 61.9%, which occurred one week earlier than normal and significantly higher than the climatological peak ice coverage of 42.7%. As quickly as the ice formed under the calm, cold conditions, much of the relatively fragile new and thin lake ice was destroyed as series of low-pressure systems passed over the Great Lakes in the third week of February. Rather than warm temperatures (as average temperatures remained below normal), the persistent strong winds were responsible for the ice destruction. Ice coverage dropped to near normal levels of 41.3% during the week in which the climatological peak should have happened. The end of February saw slightly calmer weather, with weather features being less intense than the week before accompanied by below normal temperatures. This pattern continued the up and down trend in ice coverage that occurred in February, seeing a slight rise in ice coverage to 46.8%.

March picked up where February left off, continuing the seesaw trend of each week alternating between ice formation and ice destruction. The month opened with near normal temperatures, meaning that the daily highs were hovering near the freezing point and by the end of the first week, surpassing the freezing point across the lake. This led to a reduction in ice coverage, particularly along the shore, excluding Georgian Bay. A late winter cold spell followed in the second week of March, allowing new and thin lake ice to bloom once again, as ice formed in large quantities along the Michigan shoreline of Lake Huron, north of Saginaw Bay. This pushed ice coverage higher to 53.1%. Normally, this period would be the beginning of spring melt season. Following this late season peak, Lake Huron experienced a period of above normal air temperatures where the overnight low temperatures were near or above the freezing point for the first time this winter. This warm spell lasted 10 days and caused the sharpest decline in ice coverage for the entire 2021-2022 ice season. The fast ice in Saginaw Bay fractured and by the end of the third week, ice coverage was reduced by over half that of the previous week, plummeting to 24.5%. The climatological median for that time of year is 29.2%. All of the new and thin lake ice was destroyed, leaving thick lake ice covering most of Saginaw Bay and Georgian Bay. Low concentrations of thick lake ice remained

mobile near the Strait of Mackinaw and medium and thick lake ice lined the shore from Sarnia to the tip of the Bruce Peninsula. The North Channel remained consolidated thick lake ice. As March came to an end, ice continued to deteriorate in Lake Huron. The consolidated ice in the Straits of Mackinac fractured, thaw holes began to appear in the consolidated ice in the St. Mary's River and the western section of the North Channel. Meanwhile, ice thinned in Saginaw and Georgian Bays. The month wrapped up with an ice coverage of 19.1%, remaining below the long-term median for the second week in a row.

April temperatures were near normal for the first half of April, allowing the spring melt to proceed at a near normal pace. In fact, ice coverage remained within 0.2% of the climatological normal for the first 2.5 weeks of April, ending this period at 7.3% ice covered. The remaining ice in Saginaw Bay completely melted by the end of the first week of the month. By the beginning of the third week of April, consolidated ice in the North Channel began to fracture in the central section, while very little mobile ice remained in the northwestern section of Lake Huron or Georgian Bay. The break-up of the ice in the North Channel is usually the last large area of ice in Lake Huron to melt. By the end of the third week, nearly all of the consolidated ice in the North Channel had fractured and almost all of the remaining ice in Georgian Bay had melted. This left the ice coverage at 2% near the end of April and quickly diminishing. It only took another week from this point to finish melting the ice in Lake Huron and by May 2nd, it was free of ice.

As the final ice melted in the first few days of May, the 2021-2022 ice season ended. The ice season on Lake Huron was two weeks longer than the climatological normal, starting two weeks ahead of schedule due to an early season cold spell and coming to an end on the same week as the end of the climatological season. The ice season on Lake Huron was defined by the tumultuous midseason. Many sharp increases and decreases in ice coverage spanned from mid-January to mid-March. The total accumulated coverage (TAC) was 17.4% and over double the TAC from last season. However, it was much closer to the climatological median TAC of 16%. The 2021-2022 ice season ranked as the 29th highest ice season over the last 50 years, since the 1972-1973 ice season.

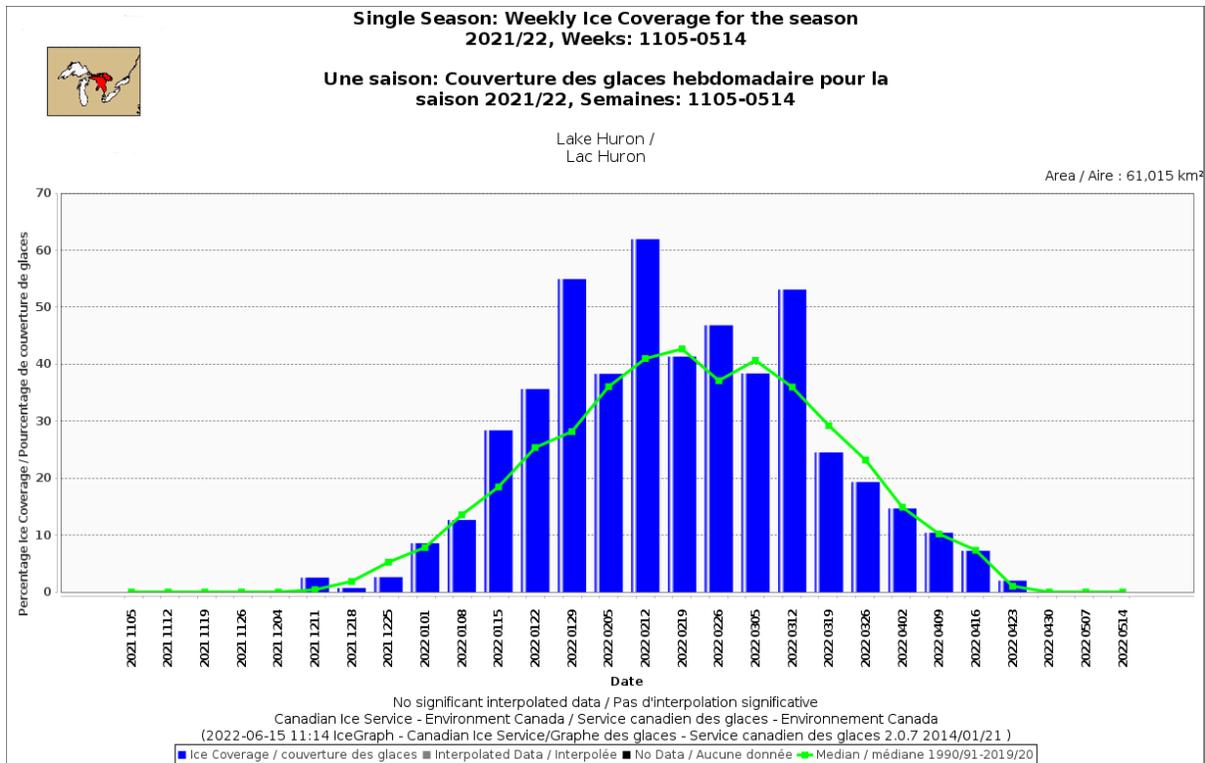


Figure 13: Weekly Ice Coverage in Lake Huron for winter 2021-22

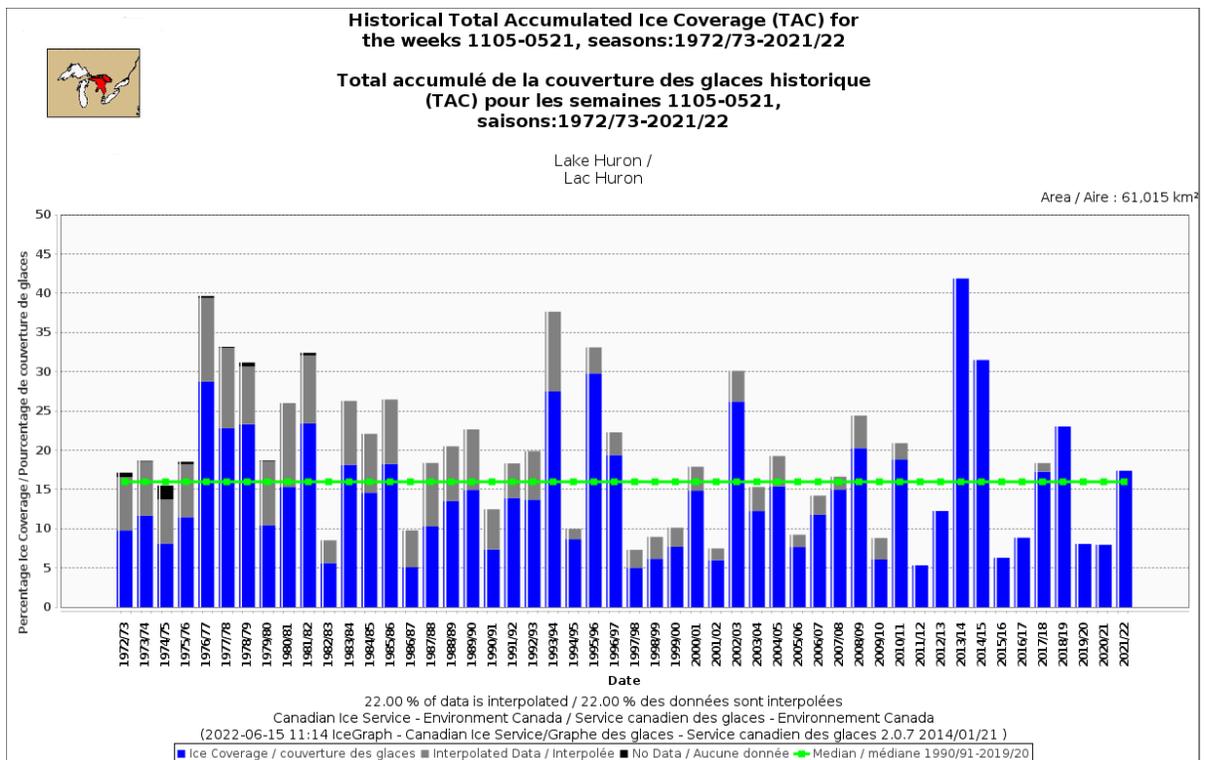


Figure 14: Historical Total Accumulated Ice Coverage in Lake Huron by season, 1972-2022

Lake Erie

2021-2022 Ice Conditions:

The 2021-2022 ice season got underway on Lake Erie and Lake St. Clair when ice formed on December 23rd along the southern and eastern shores of Lake St. Clair and in the shallows of Long Point Bay. This ice, however, was only transient as it melted three days later on the 26th of December. The permanent formation of ice in December was largely prevented by the above normal air temperatures that persisted through the entire month, generally keeping daily average air temperatures above the freezing point. It wasn't until January 4th, a few days after below normal temperatures swept over the Great Lakes, that the first permanent ice formed, once again, along the southern and eastern shore of Lake St. Clair. New and thin lake ice was quick to form under these cool and calm conditions, filling the rest of Lake St. Clair and nearly half of the Western Basin by the end of the first week of January. The first week of the ice season which had measureable amounts of ice, coverage immediately jumped to 10.2%.

As the cold, below normal temperatures continued over Lake Erie, so did the rapid ice growth across the lake. During the second week of January, ice thickened to predominantly thin lake ice in Lake St. Clair. The ice completely covered the Western Basin and began to push east of Point Pelee. Smaller areas of ice also began to form along the northern shore of the lake, east of Long Point. Persistent growth pushed into the following week as new and thin lake ice now lined the entire shore of Lake Erie. Consolidated fast ice covered Sandusky Bay, between the islands just to the north, in Long Point Bay and in Rondeau Bay. In two weeks time, ice coverage had quickly risen to 44.5%. The end of January was the coldest part of the month, made even worse by the well below normal air temperatures that the entire Great Lakes experienced during this period. Ice growth exploded in response to these cold air temperatures. In the last week of January, ice coverage more than doubled to 95.8%. . Lake St. Clair was nearly covered with consolidated medium lake ice, leaving only a small area of mobile medium lake ice in the shipping channel and in the western section. The Western Basin was also full of medium lake ice and

the consolidated ice had expanded, covering from southern Pelee Island to Sandusky and west, past the Bass Islands. The central portion of Lake Erie was also predominantly medium lake ice, while the ice was slightly thinner in the eastern section, being composed of new and thin lake ice. The only area that was not completely covered in ice was the small area from the tip of Long Point and extending east to the shore. This represented the peak ice coverage on Lake Erie and Lake St. Clair for the 2021-2022 ice season. The peak occurred two weeks earlier than the climatological peak and exceeded it by just over 10%. Since Lake Erie and Lake St. Clair are so shallow, it is typical that they will nearly completely freeze over.

The first two days in February reversed the trend of persistent below normal air temperatures, replacing it with warmer temperatures and daily highs that exceeded the freezing point across the lake. These warm temperatures acted immediately to melt and destroy some of the new and thin lake ice that developed at the end of January. The southerly winds associated with the warmer temperatures also pushed ice away from the southern shore of Lake Erie and reduced the amount of consolidated ice in the Western Basin. While air temperatures did cool and ice thickened during the end of the first week, the ice coverage did not rebound to the levels seen at the end of January. Ice coverage was reduced to 81.1% by the end of the first week. In fact, for the rest of the month, ice coverage oscillated between 70-80%. Typically, ice coverage would peak in the second week of the February and begin to decline in terms of ice coverage during the second half of the month. Through the rest of February, winds merely pushed ice around the lake, maintaining openings along the shores from which the winds were originating and around Long Point. While the winds pushed the ice around the lake, air temperatures fluctuated repeatedly between above and below the freezing point, continually melting and forming new and thin ice as the month went on. By the end of February, there was evidence that the spring melt was underway as average daily high temperatures were often above the freezing point. Openings in the Western Basin became more pronounced and the consolidated ice in Lake St. Clair began to fracture. Medium lake ice was evenly distributed across much of Lake Erie, while some consolidated ice was still present around the Bass Islands in the western end of the lake and near Buffalo in the east.

The first week in March saw the first major reduction in ice coverage across Lake Erie and Lake St. Clair. The reduction in ice coverage in large part was due to the very warm air temperatures and strong winds that swept across the lake at the end of the first week. Air temperatures rose above 10 degrees Celsius across much of the lake and to 16 degrees Celsius in Windsor, Ontario, driving ice concentrations down in response. Ice coverage plummeted to 34.5%, dropping by more than half of the previous week's coverage as well as below the long-term median of 46.5%. Over the course of the second week, the remaining consolidated ice in Lake St. Clair fractured. Much of the ice in the Western Basin melted, leaving a small but concentrated area of medium and thick lake ice along the western side of Point Pelee. This left the bulk of the ice predominately in the eastern section of Lake Erie, mainly around Long Point and east to Buffalo. Ice coverage dropped significantly once again, despite the average temperature for the previous week being below the freezing point, falling to 15.5% and maintaining below normal ice coverage for a second week. The spring melt continued its accelerated pace into the third week of March, seeing the rest of the ice in Lake St. Clair and west of Long Point in Lake Erie melt. Ice coverage was reduced to 2% with the remaining ice concentrated near Buffalo. Through the end of March, ice continued to melt in the eastern end of the lake, while the ice shrank in size, it remained highly concentrated. This remaining bit of ice only amounted to 0.5% ice coverage for Lake Erie and Lake St. Clair, well below the climatological normal of 12.3%. A brief cold spell at the end of March did generate some new and thin in Lake St. Clair, but these strips and patches lasted for only a day.

The spring ice melt only required the first week of April as the last of the ice had melted by April 8th, bringing an end to the 2021-2022 ice season on Lake Erie and Lake St. Clair. The ice season on Lake Erie and Lake St. Clair was three weeks shorter than normal, starting two weeks late and ending one week early. While the season was shorter overall, the period of peak ice coverage lasted longer than normal due to the very rapid ice formation through January. This meant that the cold temperatures of February were able to sustain an elevated ice coverage before the rapid decline in March. The total accumulated coverage (TAC) was 19.3%, which was nearly double the amount from the previous season. Despite the

increased TAC over last year, it was still below the climatological normal of 22.4%. The 2021-2022 ice season ranked 30th in terms of TAC over the last 50 ice seasons, since 1972-1973.

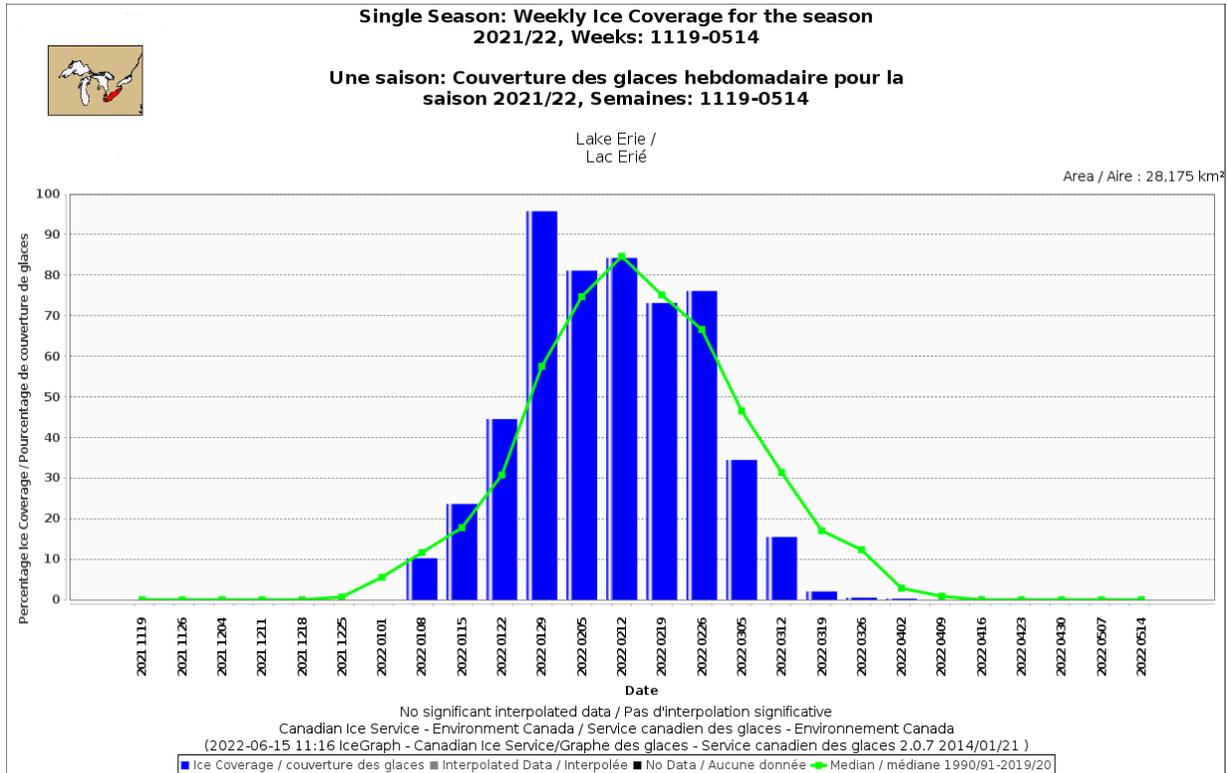


Figure 15: Weekly Ice Coverage in Lake Erie for winter 2021-22

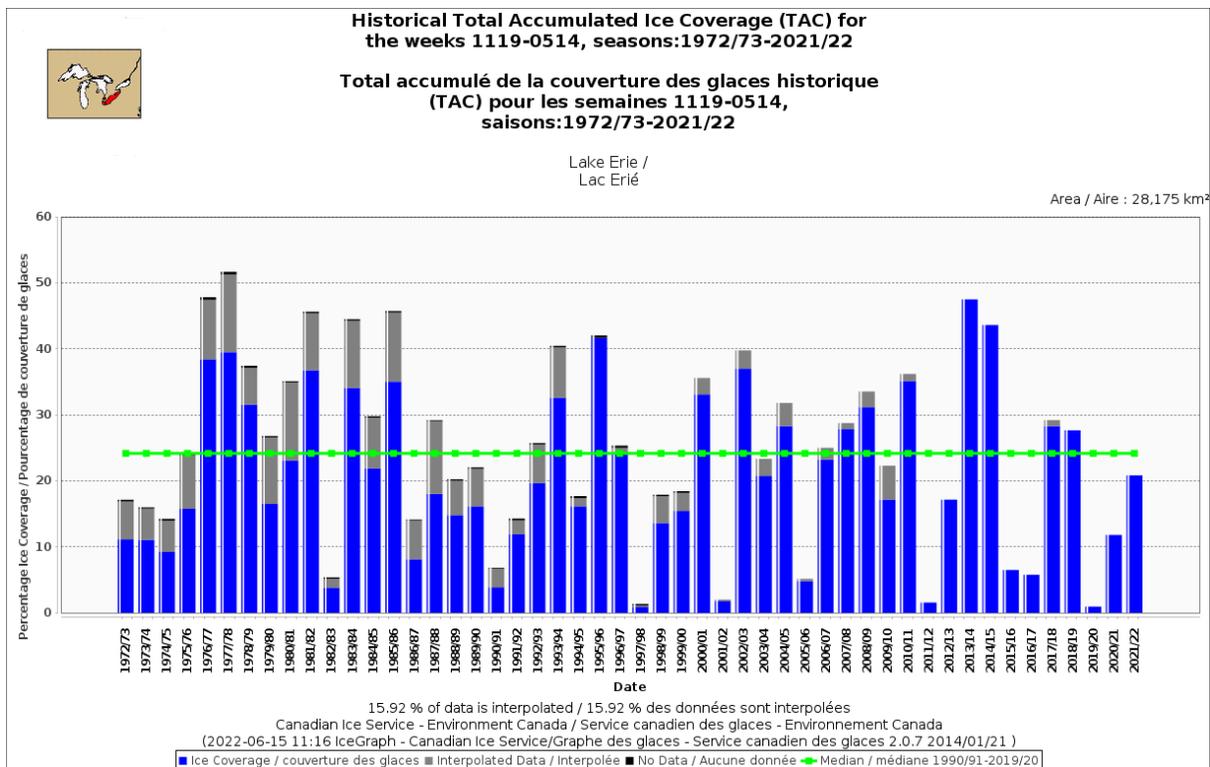


Figure 16: Historical Total Accumulated Ice Coverage in Lake Erie by season, 1972-2022

Lake Ontario

2021-2022 Ice Conditions:

The 2021-2022 ice season began on Lake Ontario on December 22nd with the first ice forming in the Bay of Quinte. Shortly afterwards and through the last week of December, ice began forming in a few more small bays in the eastern extreme of the lake and into the St. Lawrence Seaway. Ice was restricted to these areas as above normal air temperatures that had been present through most of December prevented any wider, early-season growth. December ice coverage finished at 0.8%, which was fairly close to the long-term median of 1.3%.

The first half of January saw a mix of above and below normal temperatures, switching back and forth every couple of days. This trend was reflected in the ice coverage during the first two weeks of January as ice pulsed along with the temperatures. During the below normal periods, ice often forming along parts of the shore and expanding outside of the

bays. The ice would then recede when air temperatures rose above normal. Despite the temperature fluctuations experienced around the lake, the more sheltered bays remained full of ice. For example, in the Bay of Quinte, the ice consolidated and thickened to thin lake ice at that time. In spite of the temperature fluctuations and air temperatures averaging out to be near normal for the first half of the month, ice grew faster than normal, reaching 7.9% by mid-month, a little over double the long-term median coverage. Average air temperatures cooled significantly across Lake Ontario in the second half of January, where the anomaly was 4.5-5 degrees Celsius below normal for Lake Ontario. These colder than normal temperatures drove rapid ice growth in the lake, with new and thin lake ice lining the entire shore of the lake at times, a situation that rarely occurs. As Lake Ontario experienced some of the coldest temperatures of the winter, ice in the St. Lawrence Seaway consolidated and thickened to medium lake ice, while ice in the Bay of Quinte thickened to thick lake ice. By the end of January, with ice lining the shores and filling the northeastern end of the lake, ice coverage reached its peak for the 2021-2022 ice season. Ice coverage more than doubled at the end of the month, from 12.4% the week prior to 29.1% on the last day of the month. The maximum coverage occurred three weeks ahead of the climatological peak, which normally happens near the end of February, and was just over twice the long-term median coverage of 14.2%.

The beginning of February brought a change in the dominant temperature regime as the cold, below normal air temperatures were replaced with warm, above normal temperatures. This led to the first decrease in ice coverage on Lake Ontario for the season as ice concentrations thinned along the shoreline, while remaining nearly unchanged in the northeastern end of the lake. Ice coverage dropped to 16.6%, but still remained above normal for that week. The above normal temperatures lasted for the first 11 days of February. By the time it was over, ice had melted along the shore with the exception of the entrance to the St. Lawrence Seaway. Following this warm spell and first taste of spring, air temperatures cooled once again, allowing ice growth to rebound and generate a second coverage peak for the season by the end of the second week of February. Much of the ice growth occurred in the northeastern section of the lake as northerly winds pushed the ice pack offshore and new lake ice formed in behind.

This pushed ice coverage to 23.7%, still a week ahead of the typical peak in ice coverage. The third week in February had three low-pressure systems pass over the lake that brought a mix of above and below freezing temperatures, but more importantly, strong winds. The final storm brought strong southerly winds to the lake, destroying most of the new and thin lake ice that had formed the week before and compressed the medium lake ice along the northeastern shore. This represented a significant reduction in ice coverage, dropping by more than two thirds from the prior week. The coverage was 6.7%, which was well below the long-term median of 14.2%. Ice coverage recovered slightly in the final days of the month as winds relented and allowed ice to expand southwards slightly and grow to 8.9%, more or less in line with the climatological median.

The first half of March did not bring much in terms of change to the ice coverage on Lake Ontario. The average air temperature for the first two weeks of March remained near normal, as did the daily average air temperatures. The lake ice remained contained in the northeastern section of the lake, with occasional areas of new lake ice forming along various parts of the shore around the lake. Despite the very little change in ice coverage, daily high air temperatures were frequently surpassing the freezing point, causing thaw holes in the consolidated ice in Quinte Bay and the St. Lawrence Seaway by the second week of March. Ice coverage in the first week of March had remained identical to the end of February; however, it did drop slightly to 6.3%, nearly matching the coverage from the previous three weeks. Air temperatures warmed significantly in the third week of March as air temperatures averaged 5-6 degrees Celsius above normal. Daily highs were reaching above 10 degrees Celsius on a number of days while lows generally remained above the freezing point. Most of the remaining mobile ice melted during this time and the consolidated ice continued to deteriorate, allowing thaw holes to expand, especially in the St. Lawrence Seaway. The end of March continued the decline in ice coverage as the consolidated ice in the bays of northeastern Lake Ontario and the St. Lawrence Seaway finally fractured. The more susceptible mobile ice melted quickly, leaving Lake Ontario with just 1.8% ice covered by the end of March.

Very little ice was present on Lake Ontario when April began; all of the ice was contained in either the Bay of Quinte, the St. Lawrence Seaway or

Chaumont Bay. Air temperatures were near to slightly above normal for the first week in April and by April 8th, the remaining ice melted, leaving Lake Ontario ice-free and ending the 2021-2022 ice season. The season was only one week shorter than normal on Lake Ontario with ice forming a week late at the beginning of the season. The first half of the ice season experienced mainly above normal ice coverage, up until mid-February when ice coverage sharply dropped and spent the rest of the season with near to below normal ice coverage. The total accumulated coverage (TAC) for the 2021-2022 ice season on Lake Ontario was 4.7%. This years TAC was just over double that of last year and just above the long-term median of 4.2%. The 2021-2022 ice season ranked 28th in terms of TAC over the last 50 ice seasons, since 1972-1973.

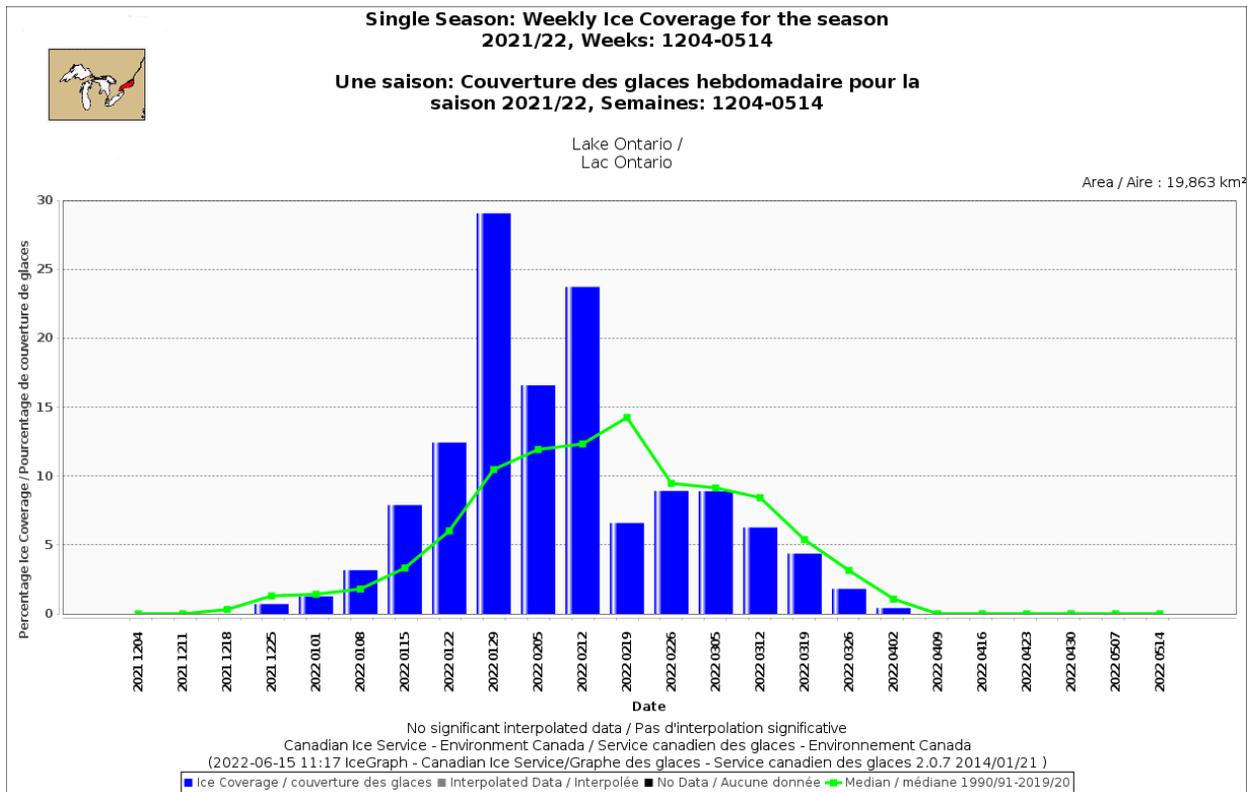


Figure 17: Weekly Ice Coverage in Lake Ontario for winter 2021-2022

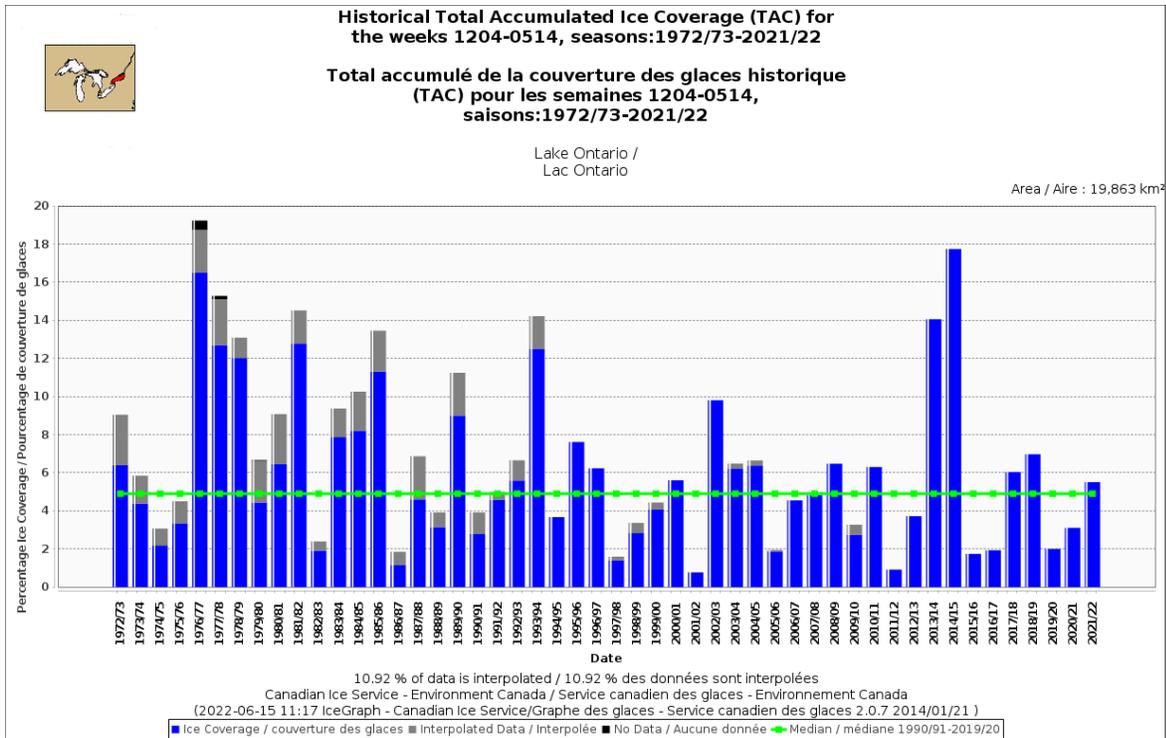


Figure 18: Historical Total Accumulate Ice Coverage in Lake Ontario by season, 1972-2022.