Are Sprint Sled Dogs Getting Faster?

The Effect of Temperature and Race Year on Winning Speed at Sprint Races Held at the Alaska Dog Mushers Association, 1988-2021

Jeffery S. Conn

Competitiveness is part of being human. We compete in games and race against each other on foot or with machines. We have also raced each other with our animal work partners. Over time these competitions have become more formalized and culminated in events such as the Olympics for humans, the Kentucky Derby, and other prestigious races for horses.

In the dog mushing world, there was a similar evolution in competition. Dog mushers that carried mail from village to village by dog team and trappers used sled dogs for work but competed with them in informal spring races and winter carnivals. Later, formalized dog mushing clubs were formed that organized prestigious sled dog races such as the Laconia World Championship Sled Dog Derby, Nome Sweepstakes, the Open North American Championship, Anchorage Fur Rendezvous, the Iditarod, and Wyoming Stagestop Race as well as numerous others in Canada, Europe, and Scandinavia.

It is natural that those interested in such competitions should also be interested in how athletic performance has changed over time, the speeds needed to win, and how to improve performance. The quest for greater performance has led to improvements in training, recovery, nutrition, and race strategy. For dog mushing competitions another factor to consider is how successful the breeding program has been.

Sled dog racing success is measured on the race trail by the time it takes the dogs to complete the course in comparison to the times required by the teams of other mushers. Comparing the race results from one race to another on the same trail could be used to determine whether the breeding, training, nutrition and race strategies being employed are improving winning race speeds over time.

The race trails maintained by the Alaska Dog Mushers Association (ADMA) in Fairbanks, Alaska, USA are an ideal venue for examining trends of winning mushing speeds over the years. Snow is consistently present during the race season (December – mid March) and the trails are well groomed. However, there are some factors that can change race speeds from year to year or even minute to minute, such as temperature or snow friction, but the ADMA trails probably provide the most constant conditions in sled dog racing.

Records exist of elapsed times for dog sled races that have been held yearly at the ADMA trails dating from the first Open North American Championship (ONAC) in 1946 and the Limited North American Championship (LNAC) starting in 1975. The exact routes of the race trails prior to 1988 are not well known, but after that, details of the trails are better known, making it possible to determine accurate trail lengths and speeds traveled by teams.

Sled dog races on the ADMA trails fall into several categories: Open Class racing has no restriction on the number of dogs that can be used. This was the first and only class of

racing until 1975 when the seven-dog class was started. Limited Class Races have a restricted maximum number of dogs that can compete. During the 1988-2021 time frame of this study the limited class championship races included separate 10-dog, 8-dog, and 6-dog events. The four-dog class was added in 1992. In multiple-day races mushers can start the 1st day of racing with the maximum number of dogs in the class (for example, four dogs in the four-dog class). If a dog is injured or tired after the first or second day of racing the dog can be left out of the team for subsequent heats, but no new dogs can be added.

The race distances of the classes generally increase with the number of dogs used. The premier ADMA open class race, The Open North American Championship, is a three-day event that runs a 19-20 mile route the first two days and a 27-28 mile route on the third day. The winner is the musher and team that completes the three days of mushing with the lowest elapsed time.

The Gold Run and the Limited North American are the championship races held on the ADMA trails. The Gold Run is a two-day event including 10-dog, 6-dog, and 4-dog classes. The race distances have varied over the years, ranging from approximately 5 – 6 miles for the four-dog class; 6 – 8 mi for the six-dog class, and 12 – 13 mi for the 10-dog class. For the Gold Run these distances are run for two consecutive days. The LNAC is a three-day race where teams run two days at one distance and longer on the third day. Approximate distances for the four-dog class have ranged from four to six miles; The six-dog distances range from six to 10 miles; and the eight-dog distance has been between 10 and 14 miles.

In addition to the Gold Run and the LNAC that occur yearly, the ADMA has hosted three World Championship races. These races are organized by the International Federation of Sled Dog Sports (IFSS) and are held at different locations around the world. These are three-day races and include four-dog, six-dog, eight-dog and open-class events.

Both limited class championships also include skijoring (dog(s) pulling skiers) classes, but this category is not included in this study because the ability of the skier adds an additional layer of complexity and the focus here is more on whether the dog teams have been improving over time.

While teams of purebred Siberian Huskies won major sled dog races in the early 1900s, the Alaska Husky was the dominant winning breed in sled dog teams for most of the 20th century. The Alaska Husky (AH) is a genetically distinct (Huson 2010) canine group and is closely related to malemutes and Siberian Huskies but genetically distinct from Greenland huskies (Brown et al, 2015). The AH is considered an Arctic breed (Brown et al., 2015) but is an admixture of other Arctic breeds such as Siberian husky and malemute plus Eurasian non-arctic breeds such as Irish Setter, Belgian shepherd and saluki, pointer (English and German Shorthair) and greyhound. A recent study (Huson 2012) showed that distance and sprint lines of AH can be discerned by DNA differences. Dogs used for long-distance racing have much less pointer influence than dogs used recently for sprint racing. Sprint racing kennels changed their breeding programs during the study period and bred in more pointer, greyhound and saluki.

The goals of this study were to determine: 1) accurate lengths of trails used during the 1988-2021 time frame for various ADMA races; 2) the winning and top race speeds for each year in each race class; 3) the effects of temperature at race time on race speeds; 4) if race

speeds were increasing over the study period and relate such trends to changes in nutrition, and team pacing, that may have occurred over the 1988-2021 time frame. A final goal was to explore how the addition of new dog breeds such as pointers to the Alaska Husky gene pool that occurred from 1998-2021 may have influenced winning speeds.

METHODS

To study trends in speeds traveled by winning dog teams, a knowledge of accurate race times and distances run is required. Because the ADMA trail system has been rerouted at various times to accommodate development of new subdivisions and roads, it was necessary to review records and historic aerial imagery to determine when and where trail changes were made and how trail distances changed.

ADMA records were consulted to determine the trail changes that were made in 1986-1987. NASA high altitude photography taken in summer 1986 and 1987; ortho photoquads taken in 1993 and 1996-1999 and 2002; and Quickbird satellite imagery were used to verify the timing and location of these changes. Karl Kassel, Doug and Karen Tilton who had worked on the 1986-87 changes were also consulted. Marvin Kokrine provided knowledge of the "20"-mile trail turnaround location prior to 1992. Tom McGrane, who had worked with contractors to do the Henrick Court and Jayne reroutes, was also consulted. The Fairbanks North Star Borough online GIS system and G Map-Pedometer (https://www.gmap-pedometer.com) were used to measure lengths of trail section both before and after reroutes to determine the distances added or subtracted due to the reroutes. Lengths of turnarounds were determined by measuring these segments with the GIS measuring tool of gmap-pedometer.com.

During the study period the ONAC start-finish line has been in three different locations. For most years the start-finish was on 2nd Avenue in downtown Fairbanks. In 2002-2003 the start/finish was on the Chena River in downtown Fairbanks. In 1991, 1998, 2010 and 2015-2021 the start-finish was at the ADMA Mushers Hall. Various "turn arounds" (links between the incoming and outgoing trail) were used to try to keep the trail length for the first two days close to 20mi. Trail segments used for the ONAC from the downtown Fairbanks 2nd Avenue and the Chena River start were drawn and measured using the FNSB GIS system. To determine total trail lengths, individual segment lengths and turnaround distances were added.

Historic trail distances from the Mushers Hall were determined by adding or subtracting appropriate reroute distances from the current trail distances that were measured multiple times using an accurate GPS (Suunto Ambit3 Peak) (https://fellrnr.com/wiki/GPS_Accuracy) and were compared to measurements of the same trail segments measured with Gmap-pedometer. All trail segments measured with the two methods were within 0.02 miles.

Race times were found through the ADMA website (www.alaskadogmushers.com) (race results); Sled Dog Central race results (www.sleddogcentral.com), and from archives of the Fairbanks Daily News Miner newspaper articles. ADMA races are timed using a printing timer. Race teams leave at two-minute intervals and the timer is keyed and bib numbers are

recorded when the first dog in each team breaks the plane of the finish line. Starting intervals are subtracted from the finishing time to determine the time taken for the team to complete the course.

The race times were entered into Excel Spreadsheets along with the appropriate trail length for that year and class. Elapsed times were converted to average speed using: MPH= 60/(elapsed time in minutes/trail time length in miles). Other data that were added to the spreadsheets were temperature at race time and dog type (Alaska Husky, English Pointer, German shorthair pointer, pointer cross, greyster or saluki cross).

Dog type was determined by consulting ONAC and LNAC pedigree books for the years up to and including 2013 (Conn 1987, 1988, 1989a, 1989b, 1990a, 1990b, 1991a, 1991b, 1991c, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012; Van Buren and Borba 1992, 1993, 1994, 1995, 1996, 1998, 2000, 2001, 2002, 2003: Borba 2004, 2005, 2006, 2007, 2008, 2009, 2010). Pedigrees of dogs that ran at the 1993 IFSS races held at ADMA were also used (Van Buren and Borba 1993). Dogs were classified as being composed of pointer (PC) or saluki (SC)crosses if the dog had more than an eighth pointer (English or German shorthair) or saluki ancestry. Dogs were classified as greysters (GR) if they were at least one-eighth greyhound and the rest German shorthair pointer. Pointer cross plus (PC+) were pointer cross individuals with >50% pointer ancestry. After 2012, the pedigree books had been discontinued, so ancestry determinations were by examining pedigrees of dogs in the teams that had been entered in online pedigree databases (dogtec.com; pedigree4dog.net) or by contacting mushers for pedigree information.

Statistical analysis was performed using least squares regression performed with My Curve Fit software (www.MyCurveFit.com). Curves were fit to the data and curves with the highest R^2 (proportion of variability in the data accounted for the curve model) and significance value was chosen. Curves were fit to temperature by speed data to determine whether temperatures at race time have an effect on winning team speed. Curves were also fit to winning team speed over race years to see if there was a trend in winning speeds. Only the speeds for winning teams were used in the analyses. The speed a team travels is dependent on a number of potential variables including team and musher ability, temperature, trail friction, and a number of non-controllable events that may happen to the team while on the trail. To try to analyze speed trends over years in the open class I attempted to correct for temperature affects. To do this, the temperature-winning speed curve was used to predict the speed a winning team would be expected to travel the race course at the temperature observed during the race heat(s). The predicted speed was subtracted from the speed actually traveled by the winning team. Observed minus predicted speeds were calculated for each year and were plotted against years to determine whether winning teams over the years were going increasingly faster than what would be predicted for the temperatures at race time.

I did not use 1994 and 1999 day-one ONAC results due to trail problems that resulted in the first heat results being discarded. Because the ADMA trail is usually fast and therefore provides a good test of the effects of speed over the years, speed data was not used from years when the trail was slow due to deep loose snow. ADMA records usually provide information of trail conditions for each race. Because of slow trail conditions, 1981, 1982,

and 1996 data were not used for analysis of day 1 and overall ONAC speeds. The results from years 1980-1988 were not used to analyze speeds on day 3 or for overall speed because the mileage for the "30-mi" extension varied from year to year and is currently unknown. ONAC times for day three for 1998 and 2019 were not used because the third day "30-mile" heat was shortened to "20 miles" due to concern about high temperatures.

For the limited classes, speeds for winning teams in the four-, six-, and eight-dog classes were determined for the LNAC, Gold Run and IFSS World Championships. Speeds of winning teams for the 10-dog class were determined for the Gold Run. The four-dog class is relatively new. It was included in the Gold Run starting in 2007. The LNAC four-dog class started earlier, beginning in 1992. The data sets for the winning speeds for the 6-, 8- and 10-dog classes were determined for the span 1988-2021.

RESULTS

Trail Lengths from Mushers Hall

Due to changes in trail lengths over the years, trail distances from the Mushers Hall have varied and are shown in Table 1. The reroute of the outgoing trail after the racing season in 1995 eliminated four 90 degree turns around the Mowery property and shortened all the trails by 0.48 miles. The reroute to the incoming trail, which also occurred in the summer of 1995 took the incoming trail further east to avoid Mushers Rd. and new home construction, increasing the distance of all trails by 0.19 miles. In the summer of 1998 the 20-mile trail was rerouted around the golf course when the golf course was expanded which decreased the 20-mile trail by 0.07 mi. In the summer of 2000, the 20-mile trail was rerouted around the expanding peat pit, which increased mileage, by 0.39 miles. In the summer of 2001, a reroute around Henrick Court Subdivision decreased the 20-mile trail by 0.12 miles. In 2009 a reroute of the incoming trail was made around the Jayne's property to eliminate a road crossing. This reroute was not used until the 2010-11 race season and increased all trail distances by 0.19 m.

Table 1. Trail lengths (miles) from ADMA Mushers Hall, fall 1987 – spring 2021.

Trail	Fall 1987-Spring 1993	Fall 1993-Spring 1994	Fall 1994-Spring 1998	Fall 1998 - Spring 2000	Fall 2000 - Spring 2002	Fall 2002 - Spring 2010	Fall 2010-Spring 2021
4.5	4.87	4.38	4.55	4.55	4.55	4.55	4.74
6	6.21	5.72	6.01	6.01	6.01	6.01	6.20
8	8.13	7.64	7.81	7.81	7.81	7.81	8.00
9.5	9.83	9.34	9.49	9.49	9.49	9.49	9.68
11	11.07	10.58	10.72	10.72	10.72	10.72	10.91
12	12.56	12.07	12.24	12.24	12.24	12.24	12.43
14	14.52	14.03	14.09	14.09	14.09	14.09	14.28
16	16.38	15.89	16.02	16.02	16.02	16.02	16.21
20	19.59	19.10	19.28	19.21	19.60	19.48	19.67

Trail Lengths for the ONAC

1980, 1982-1991

Shown in Table 2 are the segments for the ONAC trail during the years 1980-91. During these years the start was in front of the Co-op on 2nd Avenue in downtown Fairbanks, though in 1981 the ONAC started at Mushers Hall due to warm weather. When the ONAC started in downtown Fairbanks, the trail followed 2nd Ave east and then onto the Chena River. The trail then proceeded down river to the entrance of Noyse Slough, turned right and then followed the slough downstream. Before 1992, the race trail proceeded in the slough to where the railroad bridge crosses the slough. Just downstream from the bridge, the trail left the slough and the crossed College Road. The trail then followed an electric utility line and then proceeded on the ADMA race trails. When starting from downtown, the ONAC runs the ADMA trail in the opposite direction (counterclockwise) whereas the trail is normally run from the ADMA Mushers Hall in a clockwise direction. After entering the ADMA trails on the utility line, the ONAC trail continued to follow the line toward Farmers Loop Road and then turned around (cut over from the outgoing to incoming trail) at the "6-mi" turn. The trail length for the "20-mile" was 19.12 mi and the "30-mile" was 27.24 miles. The 1986-87 reroutes changed the trail length. The reroute along the pole line added 0.06 mi and the reroutes around subdivisions near the golf course added another 0.06 mi. for a total of 0.12 added miles, making the "20-mile" trail 19.24 mi. The reroutes on the "30-mile" trail eliminated 0.43 mi of trail, which made the 30-mile 26.93 mi (27.24 mi -0.43 mi+ 0.12 mi).

It should be pointed out that the length of the "30-mile" on the third day changed from year to year prior to 1989 depending on who put the trail in. In some years twisty loops were groomed, and in other years the loops were left out. The history of what happened in each year has been lost, so results from these years are not used for analysis of the ONAC 3rd day speed or for overall speed.

Table 2. 1980 -1991 ONAC Trail from downtown Fairbanks.

Trail Segment	1980, 1982 -1986 Trail Length (mi)	1987 – 1991 Trail Length (mi
Start to Noyse Slough entry	0.82	0.82
Noyse Slough to exit from slough	0.84	0.84
From slough, road crossing, along pole line to 9-mi turn	1.08	1.08
9-mi turn through turn around at 6-mi turn and back to 9-mi turn	3.57	3.63
9-mi turn to 12-mi turn	1.23	1.23
12-mi turn to 16-mi turn	1.73	1.73
16-mi turn to golf course entry	1.84	1.90
Golf Course	0.95	0.95
Golf Course exit to 16-mi turn	1.69	1.69
16.3-mi turn to pole line	2.86	2.86
Pole line to Noyse Slough	0.85	0.85
Noyse Slough	0.84	0.84
Noyse Slough exit to Finish	0.82	0.82
Total Trail Length	19.12	19.24

1992-1997 ONAC Trail

Shown in Table 3 are trail segments and totals for the ONAC run from 1991 to 1997. In 1992 the completion of the Johanson Expressway made the road crossing on College Road to access the pole line very difficult. It was decided to run the trail further down Noyse Slough, under an Expressway bridge, and cross College Road to access ADMA race trails just downstream of the Danby Street Bridge that crosses Noyse Slough. The trail then proceeded through Creamers field on the west side of Fish and Game Buildings to access the ADMA trails. The turn around was near the “8-mile" turn. The “20-mi” trail during this period was 19.75 miles long and the “30-mi” was 27.34 miles

Table 3. 1992-1997 ONAC Trail

Trail Segment	Length (mi)
Start to entrance of Noyse Slough	0.82
Entrance of Noyse Slough to College Rd crossing (Danby Rd. checkpoint 1)	2.41
College Rd. across Creamers Field to the ADMA trail near the 12-mi turn (Creamers 1 checkpoint)	0.76
12-mi turn to 9-mi turn	1.47
9-mi turn through cut-across near 8-mi turn and back to 9-mi turn	2.00
9-mi turn to 12-mi turn (Creamers C.P. 2)	1.23
12-mi turn to 16-mi turn	1.73
16-mi turn to golf course entrance	1.90
Golf course	0.95
Golf course exit to 16-mi turn	1.69
16-mi turn to 14-mi turn	0.76
14 mi turn to College Rd (Danby Rd CP 2)	0.80
College Rd to end of Noyse Slough	2.41
End of Noyse Slough to Finish	0.82
Total Length	19.75

1998 ONAC Trail

In 1998 warm temperatures caused melting in large parking lots adjacent to Noyse Slough and the resulting standing water in the slough caused the race start to be moved to the ADMA Mushers Hall. The first two days of the race were unusually warm (48F, 42F) and some dogs showed symptoms of heat stress. Even though temperatures had cooled to 39F for the third heat, the 30-mile extension was eliminated from the 3rd day of the race. The trail length was 20.02 miles all three days (Table 4).

Table 4. 1998 ONAC "20-mile" Trail Length

Trail Segment	Length (mi)
16-mi trail from Mushers hall and return minus 16-mi turnaround (16.02 mi – 0.54 mi)	15.48
16-mi turn to golf course entry	1.90
Golf course	0.95
Golf course exit to 16-mi turn	1.69
Total Length	20.02

1999-2001 ONAC Trail

The ONAC again started in downtown Fairbanks on 2nd Avenue, but the trail was changed from the 1992-1997 course by the addition of a trail section in Creamers field to allow more viewing by spectators. To compensate for the increased length of this section, the turnaround was moved to the "9 -mi" turn. The ONAC "20-mi trail" was 18.91 mi long in 1999 and the "30-mi" was 26.50mi. Continued development of the Great Northwest Inc. peat pit caused a reroute in summer 1999 which took the trail further south and added 0.39 mi to the overall trail length making the 2000-2001 "20-mile" trail 19.30 mi long and the "30-mi" 26.89 mi. Trail mileage calculations for this time period are shown in Table 5.

2002-2003 River Start

Logistical and monetary problems prevented holding the ONAC start on 2nd Avenue from 2002-2003. The race start was moved to the Chena River just upstream of the Cushman Street Bridge. The ONAC had originally started on the Chena River in the 1940s. The trail proceeded upriver to the entrance of Noyse Slough and then the course was similar to the 2000-2001 trail except that the turnaround was moved to the cut-across by the "8-mi" turn and there were reroutes around the new Henrick Court Subdivision just after the Golf Course. The length of the "20-mile" trail was 20.41 miles The "30-mi" trail was 28.0 miles (Table 6).

Table 5. 1999; 2000-2001 ONAC Trail Length

Trail Segment	1999 Length (mi)	2000-2001 Length (mi)
Start to entrance of Noyse Slough	0.82	0.82
Entrance of Noise Slough to College Rd. crossing (Danby Rd. CP 1)	2.41	2.41
College Rd. through Creamers viewing section ADMA trail near to 12-mi turn (Creamers CP 1)	1.89	1.89
12-mi turn to 9-mi turn	1.45	1.45
9-mi turn	0.05	0.05
9-mi to 12-mi (Creamers CP 2)	1.23	1.23
12-mi to 16-mi	1.73	1.73
16-mi to golf course entrance	1.90	1.90
Golf course	0.95	0.95
Golf course exit to 16-mi	1.69	2.08
16-mi turn to 14-mi turn	0.76	0.76
14-mi turn to College Rd (Danby Rd. CP 2)	0.80	0.80
College Rd to end of Noyse Slough	2.41	2.41
End of Noyse Slough to Finish	0.82	0.82
Total length	18.91	19.30

Table 6. 2002-2003 ONAC Chena River start trail length.

Trail Segment	Length (mi)
Start to entrance of Noyse Slough	0.37
Entrance of Noyse Slough to College Rd crossing (Danby Rd CP 1)	2.41
College Rd. through Creamers Viewing to ADMA trail near the 12-mi turn (Creamers CP 1)	1.89
12-mi turn to 9-mi turn	1.45
9-mi turn through turn-around near 8-mi back to 9-mi turn	2.0
9-mi turn to 12-mi turn (Creamers CP 2)	1.23
12-mi turn to 16-mi turn	1.73
16-mi turn to golf course entrance	1.90
Golf course	1.14
Golf course exit to 16-mi turn	1.95
16-mi turn to 14-mi turn	0.76
14-mi turn to College Rd (Danby Rd CP 2)	0.80
College Rd to end of Noyse Slough	2.41
End of Noyse Slough to Finish	0.37
Total Length	20.41

2004 -2007 ONAC Trail

The ONAC start was again moved to downtown Fairbanks on 2nd Avenue. The trail was similar to the 2000-2001 trail. The turnaround was at the "9-mi" turn. The "20-mile" trail was 19.36 miles long. The “30-mi” trail was 26.95 miles long (Table 7).

Table 7. 2004-2007 "20-Mile" Trail.

Trail Segment	Length (mi)
Start to entrance of Noyse Slough	0.82
Entrance to Noyse Slough to College Rd crossing (Danby Rd CP 1)	2.41
College Rd through Creamers viewing to ADMA trail near 12-mi turn (Creamers CP 1)	1.89
12-mi turn to 9-mi turn	1.45
9-mi turn	0.05
9-mi turn to 12-mi turn (Creamers CP 2)	1.23
12-mi turn to 16-mi turn	1.73
16-mi turn to golf course entrance	1.90
Golf course	1.14
Golf course exit to 16-mi turn	1.95
16-mi turn to 14-mi turn	0.76
14-mi turn to College Rd Danby Rd CP 2)	0.80
College Rd to end of Noyse Slough	2.41
End of Noyse Slough to Finish	0.82
Total Length	19.36

2008-2009 and 2011-2012 ONAC Trail.

The race start was downtown on 2nd Avenue and followed the same route as in 2004-2007 except the golf course section of the course was eliminated. To make up for the milage lost by eliminating the golf course section, the turnaround was moved to the cut-across between the outgoing and incoming trails near the 8-mi trail. The '20-Mi" trail was 20.32 miles The "30-mi" was 27.91 miles (Table 8).

Table 8. 2008-2009 and 2011-2012 ONAC "20-mi" Trail Lengths

Trail Segment	Length (mi)
Start to entrance of Noyse Slough	0.82
Entrance to Noyse Slough to College Rd crossing (Danby Rd CP 1)	2.41
College Rd through Creamers viewing to 12-mi turn (Creamers CP 1)	1.89
12-mi turn to 9-mi turn	1.45
9-mi turn to cut-across near 8-mi turn back to 9 mi turn	2.0
9-mi turn to 12-mi turn (Creamers CP 2))	1.23
12-mi turn to 16-mi turn	1.73
16-mi turn around golf course to 16-mi turn	4.0
16-mi turn to 14-mi turn	0.76
14-mi turn to College Rd (Danby Rd 2 CP)	0.80
College Rd to end of Noyse Slough	2.41
End of Noyse Slough to Finish	0.82
Total Length	20.32

2010 ONAC Trail

The weeks leading up to the 2010 ONAC were very warm leading to flooding in Noyse Slough making it unsafe to run the race from downtown Fairbanks. The race was held at the ADMA mushers hall and as usual, when races are run from there, the trail was run clockwise. Neither the Creamers spectator segment nor the golf course were included in the racecourse. The trail was 19.67 miles long Friday and Saturday and 27.26 miles on Sunday.

2013-2014 ONAC Trail

The race trail started downtown on second avenue and followed the course run from 2004 to 2007 (Table 7). The “20-mi “trail was 19.36 miles long and the “30-mi” was 26.95 miles.

2015-2021 ONAC Trail

The race start was moved to the ADMA Mushers Hall due to continued warm weather that caused the Chena River and Noyse Slough to become unsafe. In 2015 the “20-mi” trail” included the golf course on Friday but not the Creamers viewing segment and was 20. 8 miles long. Because the golf course segment fell apart badly on Friday, the golf course portion of the trail was omitted for the heats on Saturday and Sunday. On Saturday the trail was 19.67 miles long and on Sunday it was 27.26 miles long.

For 2016-2021 the golf course was omitted and the Creamers viewing segment was run instead. GPS -measured distance for the “20-mi” trail in 2016 was 20.30 miles and for the “30-mile” trail 27.90 miles. In 2017-2021 the trail was 20.16 and 20.76 miles and in 2019 the “20-mi” trail was run on the third day due to very warm (47F) temperatures.

The trail distance for ONAC races 1980-2021 is shown in Table 9. The “20-mi” trail ranged from 18.91 mi (1999) to 20.41 mi (2002-2003). The “30-mi” trail ranged from 26.5 mi in 1999 to 28.0 mi in 2002-3003.

Table 9. ONAC Trail Lengths, 1980-2021

Years	Start Location	"20-mi" Trail	"30-mi" Trail
1980	2nd Avenue	19.12	27.24
1981	Mushers Hall	unknown	unknown
1982-1986	2nd Avenue	19.12	27.24
1987-1991	2nd Avenue	19.24	26.93
1992-1997	2nd Avenue	19.75	27.34
1998	Mushers Hall	20.02	20.02
1999	2nd Avenue	18.91	26.50
2000-2001	2nd Avenue	19.30	26.89
2002-2003	Chena River	20.41	28.00
2004-2007	2nd Avenue	19.36	26.95
2008-2009	2nd Avenue	20.32	27.91
2010	Mushers Hall	19.67	27.26
2011-2012	2nd Avenue	20.32	27.91
2013-2014	2nd Avenue	19.36	26.95
2015	Mushers Hall	20.8/19.67	27.26
2016	Mushers Hall	20.30	27.89
2017	Mushers Hall	20.16	27.75
2018	Mushers Hall	20.16	27.75
2019	Mushers Hall	20.16	20.16
2020	Cancelled due to Covid-19 pandemic		
2021	Mushers Hall	20.16	27.75

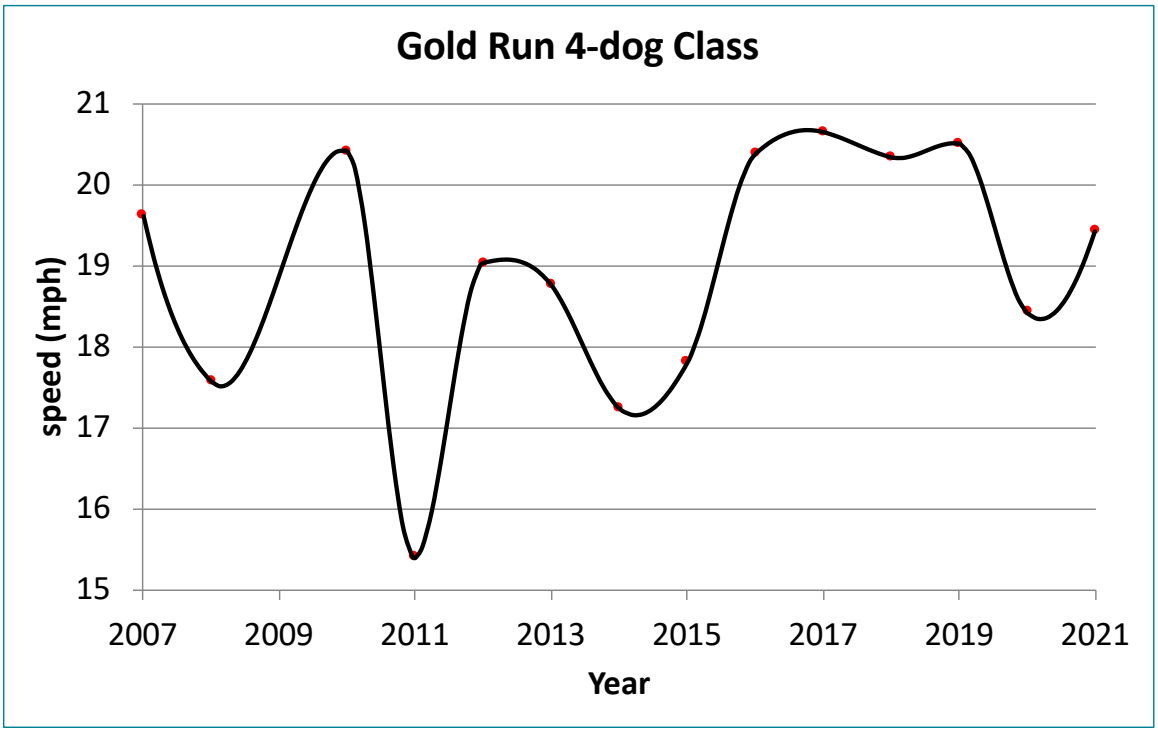
The Effect of Temperature and Race Year on Speed

The effect of temperature and race year on winning speed was examined for the 4-dog, 6-dog, 8-dog, Limited North American Championships (LNAC), the 4, 6 and 10-dog Gold Run, and open class Open North American Championship (ONAC).

4-dog class

There were no significant relationships ($p < 0.05$) between temperature and overall winning speed for the 4-dog class in the Gold Run and LNAC. The lack of a trend with temperature may be due to the Gold Run being held in mid-late February when temperatures are cold. Similarly, the LNAC 4-dog class is held early in the race day when temperatures are colder. The race distance is also quite short (<6.3 mi), perhaps lessening any effect of warm temperatures on dog performance. Winning speeds in the Gold Run 4-dog class appeared to be mainly attributable to the talent of teams that competed and trail conditions and did not show a discernable increasing or decreasing speed pattern over time (Figure 1, Appendix 1). Part of the reason for the lack of a trend may be due to the relatively small data set, only spanning 14 years.

Figure 1. Winning speeds in the 4-dog class Gold Run. No significant tends in winning speed over race year were found.



In contrast to the Gold Run, there was a significant trend of increasing winning speed over the 1992-2021 time span of the LNAC 4-dog class (Figure 2). Winning speeds generally increased over time, especially from 1992 to 2008 and then leveled off before resuming an upward trend in 2015. Lena Boysten-Hillestad's winning overall speed (21.3 mph) in 2013 was the fastest ever for the ADMA 4-dog class and Uwe Radant's 20.75 mph in 2005 was much above the trend line. Pam Schamber has fielded vary fast teams from 2015-2021. Teams with the fastest speeds in the 4-dog Gold Run, LNAC and IFSS World Championships are shown in Table 10 and Appendix 2.

Alaska huskies were initially used in the 4-dog class but after the 1993 IFSS World Championship several Alaska skijorers started experimenting with pointer and pointer-greyhound (greyster) crosses obtained from European stock. These dogs eventually were used in 4-dog and 6-dog racing. Pointer crosses out of Egil Ellis and Helen Lundberg lines also begun to be used in the 4-dog class in the early 2000s. The fastest 4-dog times were posted by greyster crosses (21.13), though teams of pure Alaska Huskies have also been quite fast. Stacey Lanser averaged 20.5 mph in 2010 and Carol Kaynor averaged 20.31 mph in 2001 (Table 10).

Figure 2. Winning speed over race years in the LNAC 4-dog class. Best fit for the data was a cubic polynomial model (R^2 = 0.50, p = 0.0003; speed = -3503256 +5231.355*year-2.603909*year^2+0.004320355*year^3).

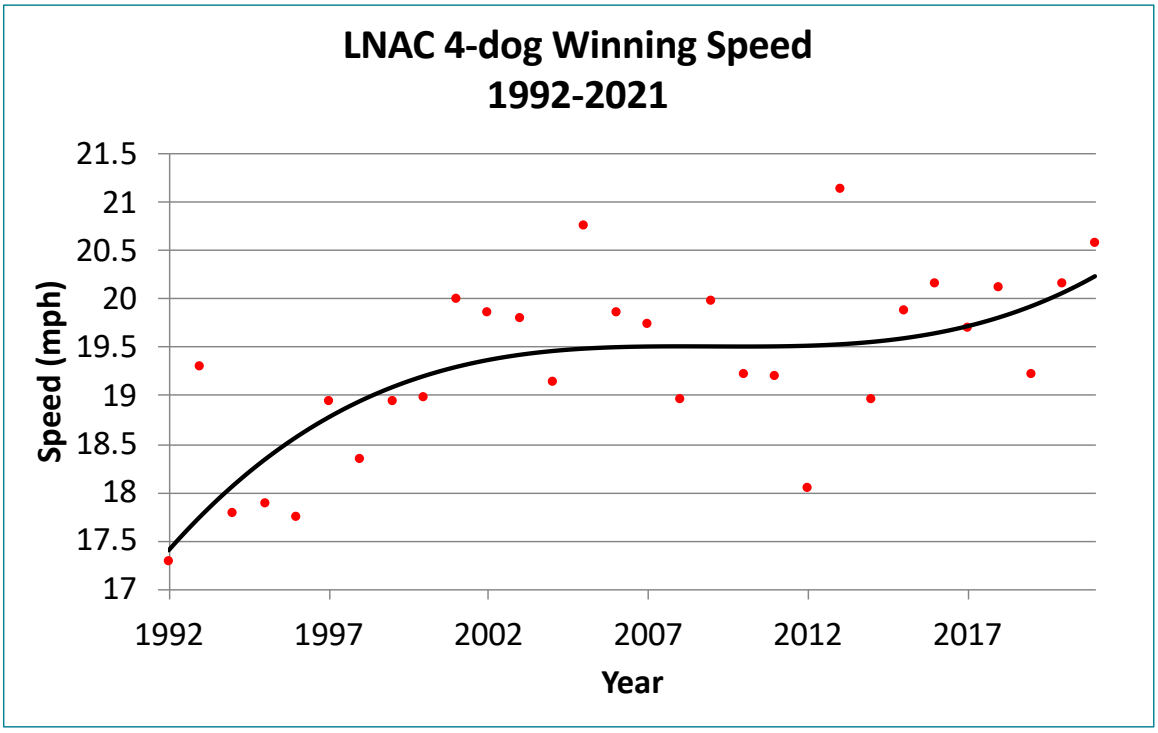


Table 10. Top 20 overall speeds in 4-dog class in ADMA multi-day races 1992-2021.

Musher	Event	Year	Dog Type[1]	Ave Temp (F)	Total Miles	Average Speed (MPH)
Lena Boysten-Hillestad	LNAC/IFSS World Championship	2013	GR	32	15.7	21.13
Uwe Radant	LNAC	2005	GSP-EP, GR	35	15.1	20.75
Pam Schamber	Gold Run	2017	PC, SC, GR	5	12.4	20.64
Pam Schamber	LNAC	2021	PC, SC, GR	-10	15.7	20.57
Elin Bjork	LNAC/IFSS WC	2013	PC+	32	15.7	20.37
Lena Boysten-Hillestad	IFSS World Championship	2001	GR	5	13.7	20.50
Pam Schamber	Gold Run	2019	PC, SC, GR	-1	12.4	20.50
Stacy Lanser	Gold Run	2010	AH	13	10.2	20.40
Pam Schamber	Gold Run	2016	PC, SC, GR	19	12.4	20.36
Pam Schamber	Gold Run	2018	PC, SC, GR	15	12.4	20.33
Carol Kaynor	IFFS World Championship	2001	AH	5	13.7	20.31
Pam Schamber	LNAC	2016	PC, SC, GR	20	15.7	20.15
Pam Schamber	LNAC	2020	PC, SC, GR	18	15.7	20.15
Pam Schamber	LNAC	2018	PC, SC, GR	20	15.7	20.11
Jiri Trinka	LNAC	2005	?	35	15.1	20.06

Table 10 continued. Overall top 20 speeds in the 4-dog class

Musher	Event	Year	Dog Type	Ave Temp (F)	Total Miles	Average Speed (MPH)
Lena Boysten-Hillestad	LNAC	2001	GR	14	15.1	19.98
Jennifer Probert	LNAC	2009	PC	-4	15.1	19.97
Sussie Gronberg	LNAC	2013	PC+	32	15.7	19.91
Amy Dunlap	LNAC	2021	PC, AH	-10	15.7	19.87
Pam Schamber	LNAC	2015	PC, SC, GR	-11	15.7	19.87

[1]Dog Type. EP=English pointer; GSP= German shorthair pointer; GR=greyster (GSP+ greyhound); GSP-EP = German shorthair pointer- English Pointer cross with less than 1/8 Alaska husky; AH= Alaska Husky with less than 1/8 pointer or another non-Arctic breed; PC=pointer cross (either EP, GSP or both with AH); PC+ = pointer crossed with AH, with less than one-half AH.

6-dog Class

Temperature did not have an effect on winning speed for the Gold Run 6-dog class. This may be due to the lack of warm temperatures in the Gold Run which is held in mid February. Temperature did have a significant influence on winning race speed in the LNAC 6-dog class ($p = 0.005$). The LNAC is held the second weekend in March and temperatures can be warm or quite cold. Figure 3 shows a linear decline in average winning speed with increasing temperature. The amount of variability in winning speed accounted for by temperature is only 22% (R^2) possibly because distances run in the 6-dog class are fairly short (≤ 8.0 mi).

For the Gold Run, winning speed for the 6-dog class did not show a significant trend with race years. All six winning speeds exceeding 20 mph occurred in 2001 and later (Fig. 3, Appendix 3) when pointer crosses became common. The fastest speed (21.13 mph) in the Gold Run 6-dog class was posted by Mathieu Devred in 2021.

There was a significant trend in winning speed over years for the LNAC 6-dog class ($p=0.0003$). Winning overall speeds in the LNAC 6-dog class increased over the 1988 to

2021 time period, but the increase in speed was mostly between 1988 and 2013 and the trend upward moderated. As with the Gold Run, the fastest winning speeds occurred after 2001. In 2021 Mathieu Devred posted the fastest ever overall speed (21.45) in the LNAC 6-dog (Table 11).

Figure 3. Overall speed of Gold Run winning 6-dog teams 1988 – 2021.

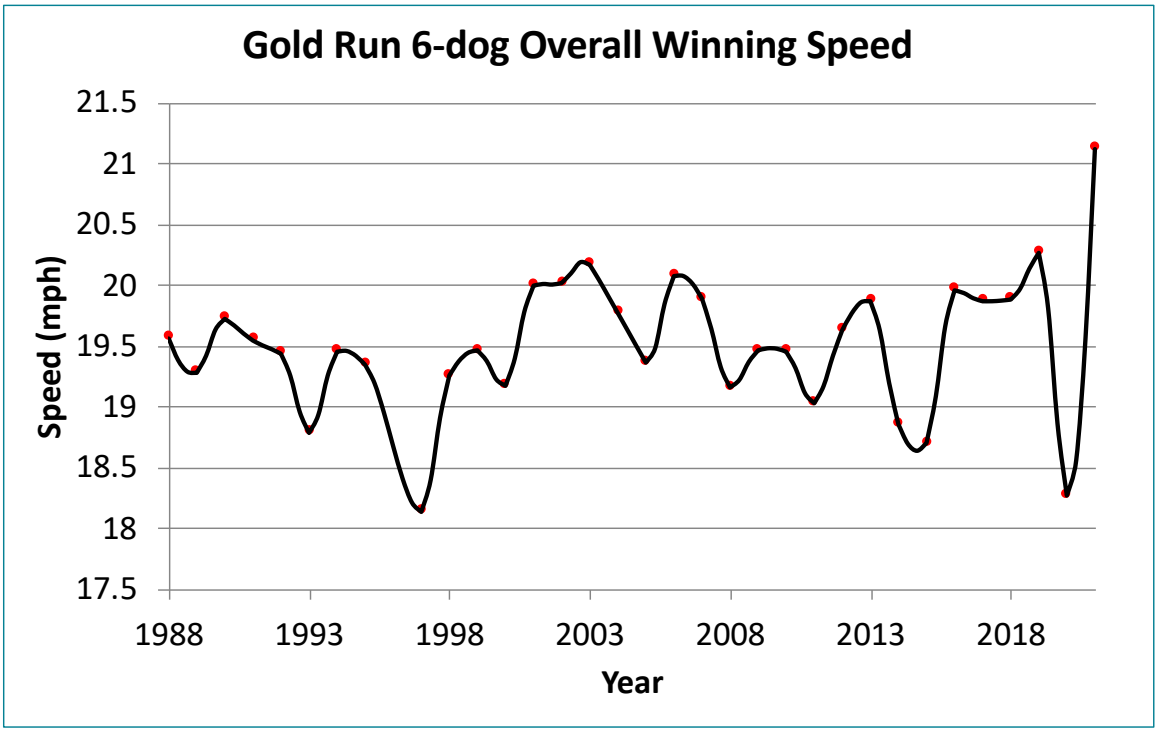


Figure 4. The effect of average temperature at race time on winning speed for the LNAC 6-dog class 1988-2021. The model explaining the most variability was a linear regression (R^2 = 0.22, p = 0.005, predicted speed (mph) = -0.03693* temperature + 20.5404).

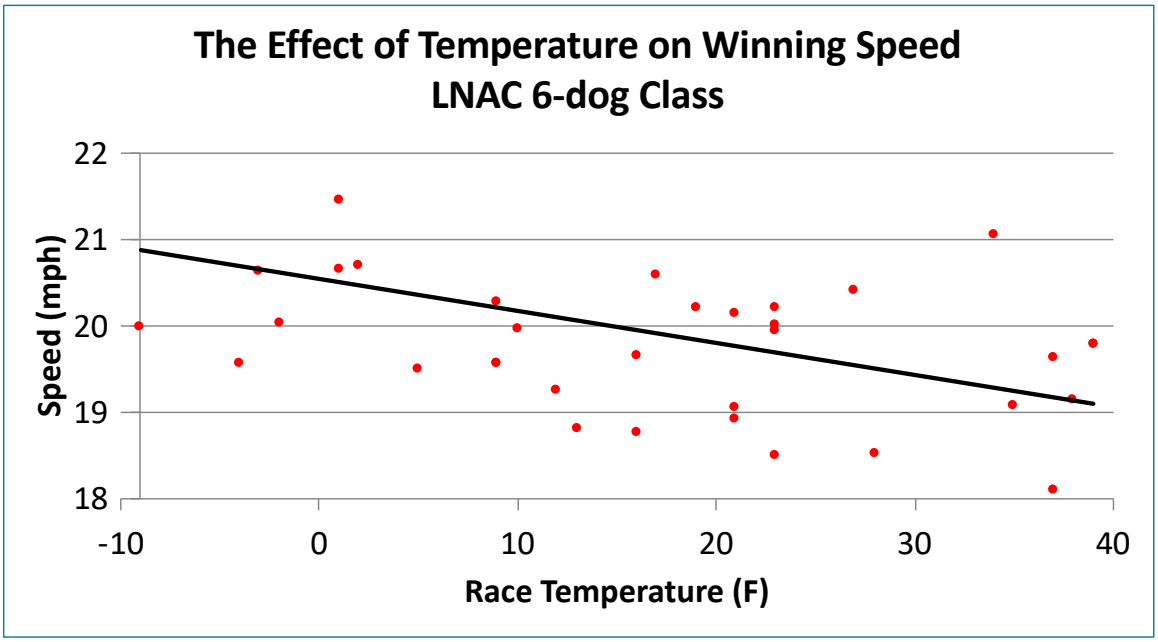
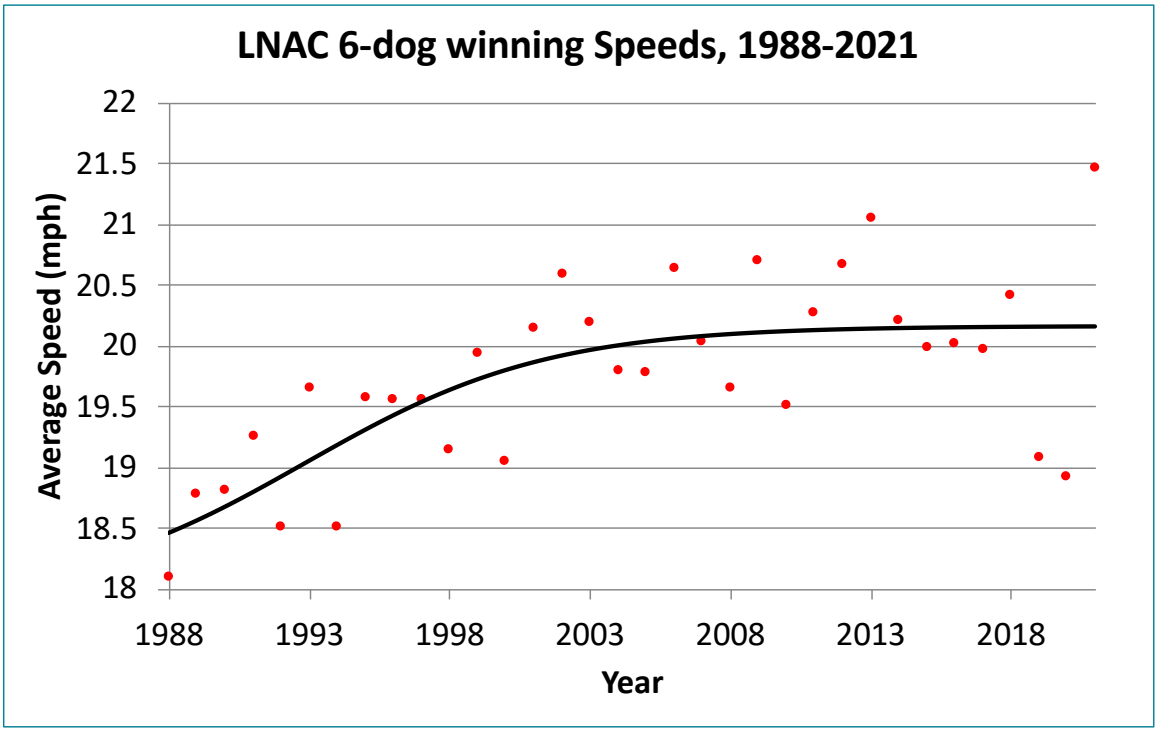


Figure 5. Overall winning speed of LNAC 6-dog class 1988-2021. The best fit model was a symmetrical sigmoidal regression (R^2 = 0.49, p = 0.0003; speed = 20.17276 + (17.92164 – 20.17276)/(1+(year/1992.874)$^{461.9594}$)).



To separate out the effect of temperature on the average speed over race year, winning race times for each year were predicted from the temperature X overall speed curve. These values were then subtracted from the actual overall winning speed. Shown in Figure 5 are the plotted observed-predicted values over 1988-2021. A polynomial cubic regression best fit the data (R^2=0.41, p=0.001). From 1988 to 1997 many of the overall winning speeds were lower than predicted for the temperature at race time. Speeds were mainly higher than predicted from 1998 to 2008, but after 2008, the trend was more level with slightly more years being slower than predicted. However, there were some very fast times posted after 2008 (Table 11, Appendix 4). Jessica Doherty's overall winning speed was 1.8 miles per hour (21.06 mph) faster than the predicted winning speed (19.30 mph) at 34 F, the temperature at race time.

Figure 6. Observed speed minus predicted speed (for temperature at race time) over race years for the LNAC 6-dog class, 1988-2021. The data were best fit by a cubic polynomial regression (R^2 = 0.41, p = 0.001; obs-pred speed=0.185025 + (-0.9979342 – 0.1850251)/(year/1997.267)$^{2527.889}$)

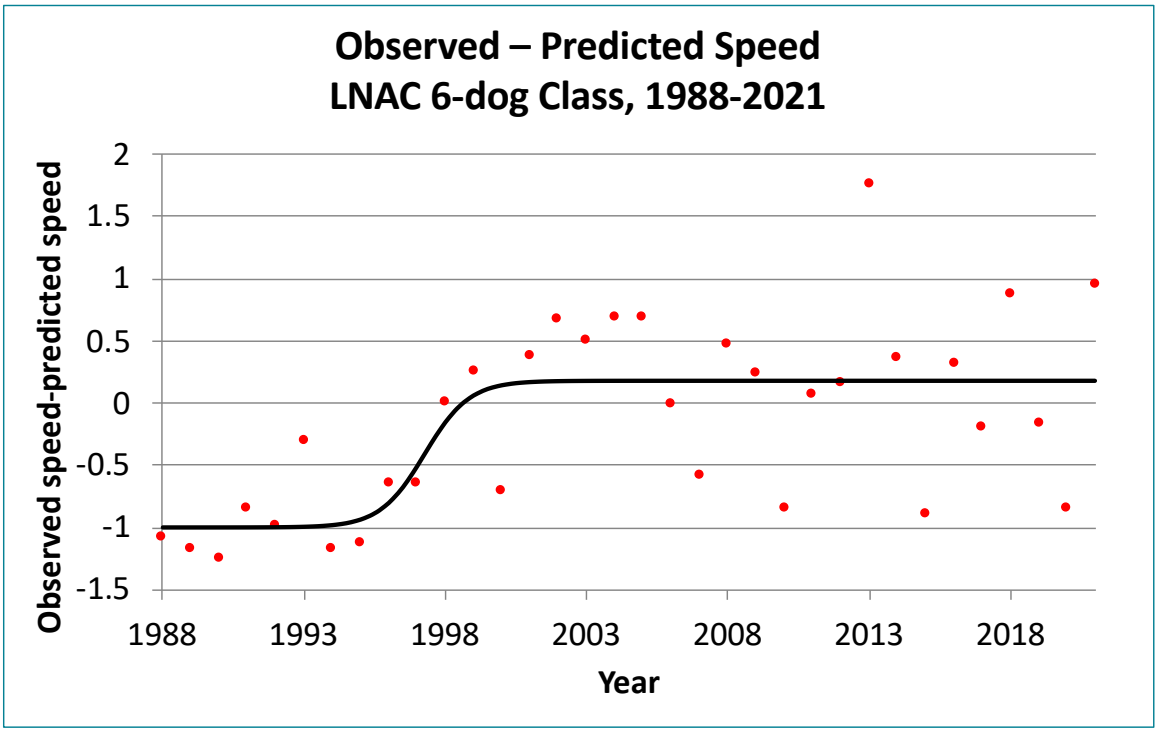


Table 11. Top 20 average speeds in the 6-dog class in ADMA multi-day races 1988-2021

Musher	Event	Year	Dog Type[1]	Ave Temp (F)	Total Miles	Average Speed (mph)
Mathieu Devred	LNAC	2021	PC	1	20.4	21.45
Mathieu Devred	Gold Run	2021	PC	-9	16	21.13
Jessica Doherty	LNAC	2013	PC	34	20.4	21.04
Jennifer Probert	LNAC	2009	PC	2	19.83	20.7
Kati Dagenais	LNAC	2012	PC	1	19.83	20.66
Karoush Partow	LNAC	2006	PC	-3	19.83	20.63
Birgitte Naess	LNAC	2002	PC, GR	17	19.83	20.58
Iwan Schmid	LNAC	2002	PC	17	19.83	20.57
Alex Rochet	LNAC	2021	PC	1	20.4	20.52
Trisha Seibold	LNAC	2009	?	2	19.83	20.46
Mathieu Devred	LNAC	2018	PC	27	20.4	20.41
Jennifer Sterling	LNAC	2009	PC	2	19.83	20.41
Kim Wells	Gold Run	2019	PC	3	16	20.27
Dawn Brown	LNAC	2011	PC	9	20.4	20.26
Kim Wells	LNAC	2014	PC	19	20.4	20.20
Karoush Partow	LNAC	2003	PC	23	19.83	20.19
Egil Ellis	Gold Run	2003	PC	4	15.6	20.18
Stacy Lanser	LNAC	2011	?	9		20.17
Kris Racey	LNAC	2009	PC	2	19.83	20.15
Birgitte Naess	LNAC	2001	PC, GR	21	19.83	20.14

[1]Dog Type. EP=English pointer; GSP= German shorthair pointer; GR=greyster (GSP+greyhound); GSP-EP = German shorthair pointer- English Pointer cross with less than 1/8 Alaska husky; AH= Alaska Husky with less than 1/8 pointer or another non-Arctic breed; PC=pointer cross (either EP, GSP or both with AH); PC+ = pointer crossed with AH, with less than one-half AH.

Eight Dog Class

Winning overall speed in the LNAC 8-dog class was significantly (p=0.001) influenced by temperature at race time (Figure 7). Winning speed declined gradually from 0F to 20F (O.5 mph) but speed decline from 20F to 40F was much greater (1.8 mph).

Overall winning speeds in the LNAC 8-dog class changed significantly (p=0.004) increased rapidly between 1988 and 2000 when the fastest overall speed was posted by Helen

Lundberg (20.44mph). Four winning times in the LNAC 8-dog have exceeded 20 mph, all occurring in the 2000–2009 time period. Prior to 1998, winning teams were composed of Alaska Huskies. Linda Leonard and Terry Killiam posted the fastest speeds (20.01 and 20.00 mph, respectively) with Alaska Huskies at the IFSS World Championship in 1993 (Table 12). After 1998, winning teams were increasingly made up of pointer crosses. Though the fastest overall speeds were posted by pointer cross teams in the 2000-2009 time frame, pointer cross teams after that have never broken 20 mph average speed.

Figure 7. The effect of temperature at race time on overall speed of winning teams in the LNAC 8-dog class. The data were best fit by a quadratic polynomial regression ($R^2 = 0.35$, $p = 0.001$; predicted speed = 19.7096 – 0.002038*temperature – (0.0005614*temperature^2).

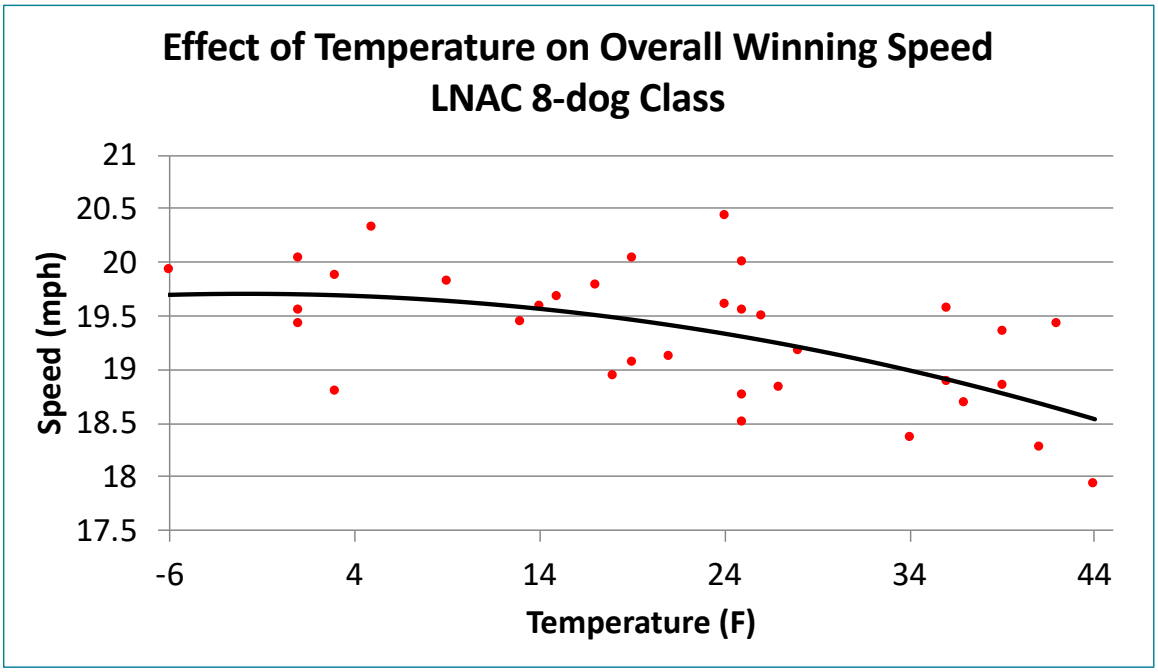
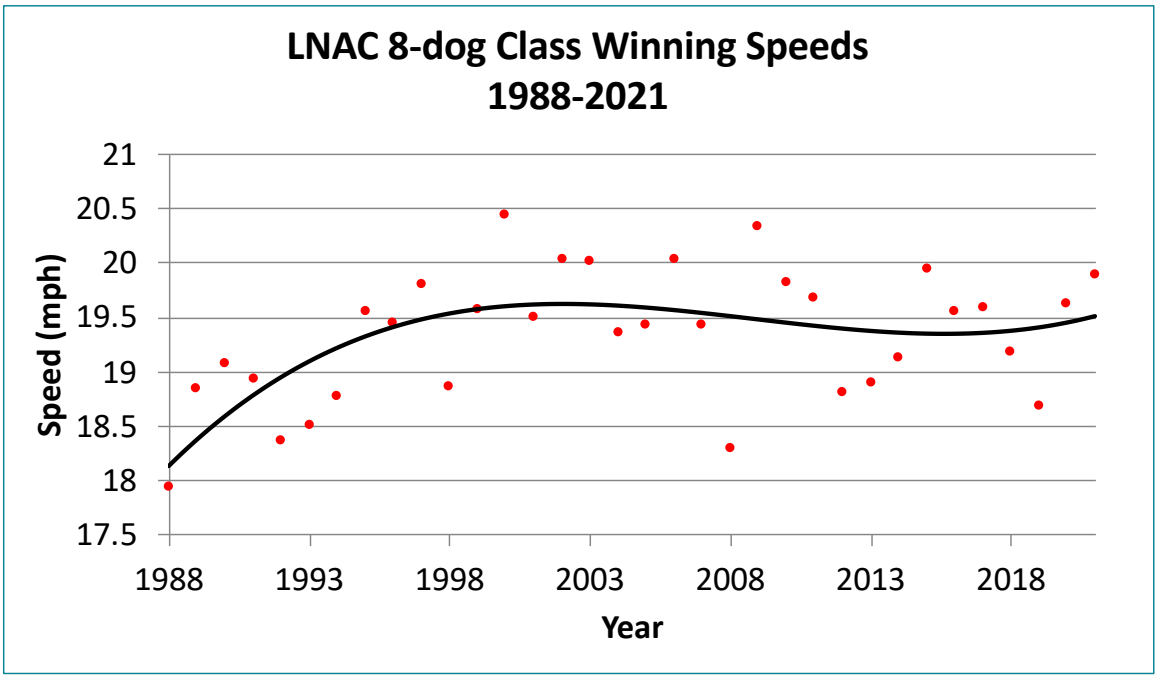


Figure 8. Overall winning speed of LNAC 8-dog class 1988-2021. The best fit model was a cubic polynomial regression (R^2 = 0.36, p = 0.004; speed= -1785882 + 2667.121*year – 1.327706*year^2 + 0.000223102*year^3).



To separate out the effects of temperature on trends of winning race speeds over the years, the observed minus predicted speeds for each year were analyzed. There was a significant (p=0.002) cubic polynomial relationship trend with time, with speeds being below that predicted by race temperature in from 1988–1996, rising to 0.5 mph above the predicted speed in the 1999-2009 period, before dropping again (Figure 9).

Figure 9. Observed speed minus predicted speed over race years for the LNAC 8-dog class, 1988-2021. The data were best fit by a cubic polynomial regression (R^2=0.39, p = 0.002; obs-pred speed = -1535263 + 2292.386*year -1.140946*year^2 + 0.0001892847*time^3).

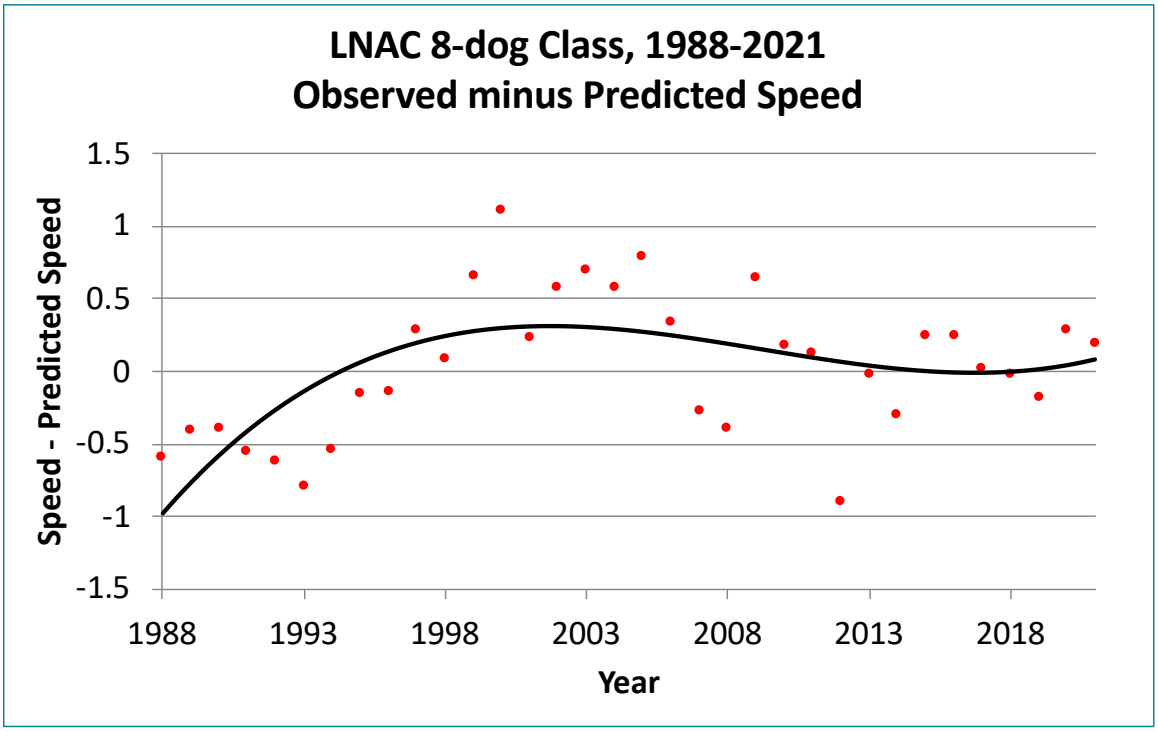


Table 12. Top 20 average speeds in 8-dog class in ADMA 3-day races, 1988-2021.

Musher	Event	Year	Dog Type[1]	Ave Temp (F)	Total Distance (mi)	Average Speed (mph)
Helen Lundberg	LNAC	2000	PC	24	33.68	20.44
Jennifer Sterling	LNAC	2009	PC	5	33.68	20.33
Helen Lundberg	IFSS World Championship	2001	PC	14	32.2	20.25
Helen Lundberg	LNAC	2002	PC	19	33.68	20.03
Ushi Liebhardt	LNAC	2006	PC	1	33.68	20.03
Linda Leonard	IFSS World Championship	1993	AH	10	29.34	20.02
Terri Killam	IFSS World Championship	1993	AH	10	29.34	20.01
Ken Chezik	LNAC	2003	PC	25	33.68	20.00
Jerry Woods	LNAC	2015	PC	-6	34.25	19.94
Karoush Partow	LNAC	2015	PC, SC	-6	34.25	19.90
Karoush Partow	LNAC	2021	PC, SC	3	34.25	19.88
Helen Lundberg	LNAC	2003	PC	25	33.68	19.87
Jennifer Probert	LNAC	2010	PC	9	33.68	19.82
Linda Leonard	LNAC	1997	AH	15	33.68	19.80
Guissepe Nassi	IFSS World Championship	2001	PC	14	32.2	19.78
Dawn Brown	LNAC	2010	PC	9	33.68	19.75
Christain Taveau	LNAC	2010	PC	9	33.68	19.73
Dawn Brown	LNAC	2011	PC	15	34.25	19.67
Terri Killam	LNAC	1997	AH	15	33.68	19.64
Amanda Byrd	LNAC	2011	PC	15	34.25	19.63

[1]Dog Type: AH = Alaska Husky (≤ 1/8 pointer or other non-Arctic breed; PC = pointer cross (> 1/8 English or German shorthair pointer mixed with Alaska husky); SC = saluki cross (> 1/8 saluki crossed with Alaska husky).

10-dog Class

ADMA's only 10-dog race is a two-day event that is a part of the Gold Run Championship held in mid to late February. There was no discernable relationship between winning overall speed and temperature for the ten-dog class, as was also the case for the 4-dog and 6-dog classes at the Gold Run. An analysis of winning speed versus race year also failed to reveal any significant trends. However, the fastest speeds were posted between 1998 and 2007. The two fastest overall winning speeds were posted by Egil Ellis with a team of pointer crosses in 2001 (20.33 mph) and 2003 (20.25 mph). The third fastest overall speed was set by Ross Saunderson (20.18 mph) in 1999. Winning teams after 2007, were mainly composed of pointer crosses but have been slower than pointer cross teams from 2000-2007. These modern teams have not been as fast as Linda Leonard's 1992 (19.81 mph) and Kathy Frost 1998 (20.06) Alaska husky teams.

Figure 10. Overall winning speed in the Gold Run 10-dog class, 1988-2021.

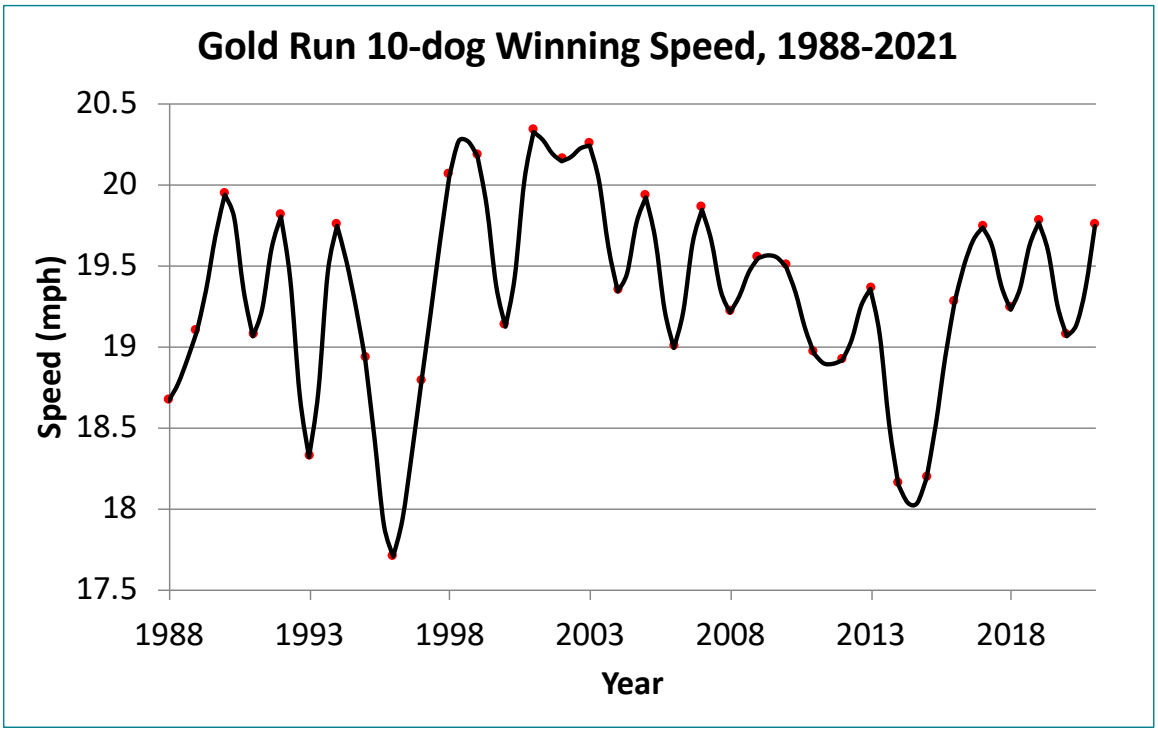


Table 13. Top overall speeds and all winning speeds for Gold Run 10-dog class, 1988 – 2021.

Musher	Year	Dog Type	Ave. Temp (F)	Total Miles	Average Speed
Egil Ellis	2001	PC	14	24.48	20.33
Egil Ellis	2003	PC	8	24.48	20.25
Ross Saunderson	1999	AH	21	24.48	20.18
Iwan Schmid	2002	PC	7	24.48	20.15
Helen Lundberg	2001	PC	14	24.48	20.06
Linda Leonard	1998	AH, PC	4	24.48	20.06
Kathy Frost	1998	AH	4	24.48	20.06
Rudi Ropertz	2005	PC	25	24.48	19.92
Helmut Peer	1998	PC	4	24.48	19.90
Helmut Peer	1999	PC	21	24.48	19.88
Christain Taveau	2007	PC	8	24.48	19.85
Egil Ellis	2005	PC	25	24.48	19.85
Linda Leonard	1992	AH	3	25.06	19.81
Arleigh Reynolds	2001	PC, AH	14	24.48	19.80
Karoush Partow	2019	PC, SC	10	24.86	19.77
Bud Streeper	2001	AH	14	24.48	19.76
Kathy Frost	2001	AH	14	24.48	19.76
Joee Redington	2001	AH	14	24.48	19.76
Linda Leonard	1994	AH	5	25.06	19.75
Marcus Luft	2003	AH	8	24.48	19.75
Anny Malo	2021	PC	-8	24.48	19.75
Dawn Brown	2017	PC	9	24.48	19.74
Kathy Frost	1990	AH	-40	25.06	19.60
Christain Taveau	2009	PC	12	24.48	19.55
Jason Dunlap	2013	AH, PC	1	24.86	19.36
Ken Chezik	2004	PC	28	24.48	19.34

Musher	Year	Dog Type	Ave. Temp (F)	Total Miles	Average Speed
Amy Dunlap	2016	AH, PC	21	24.86	19.28
Dawn Brown	2018	PC	19	24.86	19.23
Christain Taveau	2008	PC	-9	24.48	19.21
Arleigh Reynolds	2000	AH, PC	18	24.48	19.13
Linda Leonard	1989	AH	16	25.06	19.09
Linda Leonard	1991	AH	25	25.06	19.07
Jason Dunlap	2020	PC, AH	-5	24.48	19.07
Rob Downey	2006	PC	28	24.48	18.99
Dori Hollingsworth	2011	PC	4	24.86	18.96
Linda Leonard	1995	AH	2	25.06	18.93
Dori Hollingsworth	2012	PC	9	24.86	18.92
Linda Leonard	1997	AH	37	24.48	18.78
Roxy Wright	1988	AH	14	25.06	18.67
Mari Hoe-Raitto	1993	AH	-1	25.06	18.32
Dawn Brown	2015	PC	6	24.86	18.17
Dawn Brown	2014	PC	4	24.86	18.15

[1]Dog Type: AH = Alaska Husky (≤ 1/8 pointer or other non-Arctic breed; PC = pointer cross (> 1/8 English or German shorthair pointer mixed with Alaska husky); SC = saluki cross (> 1/8 saluki crossed with Alaska husky).

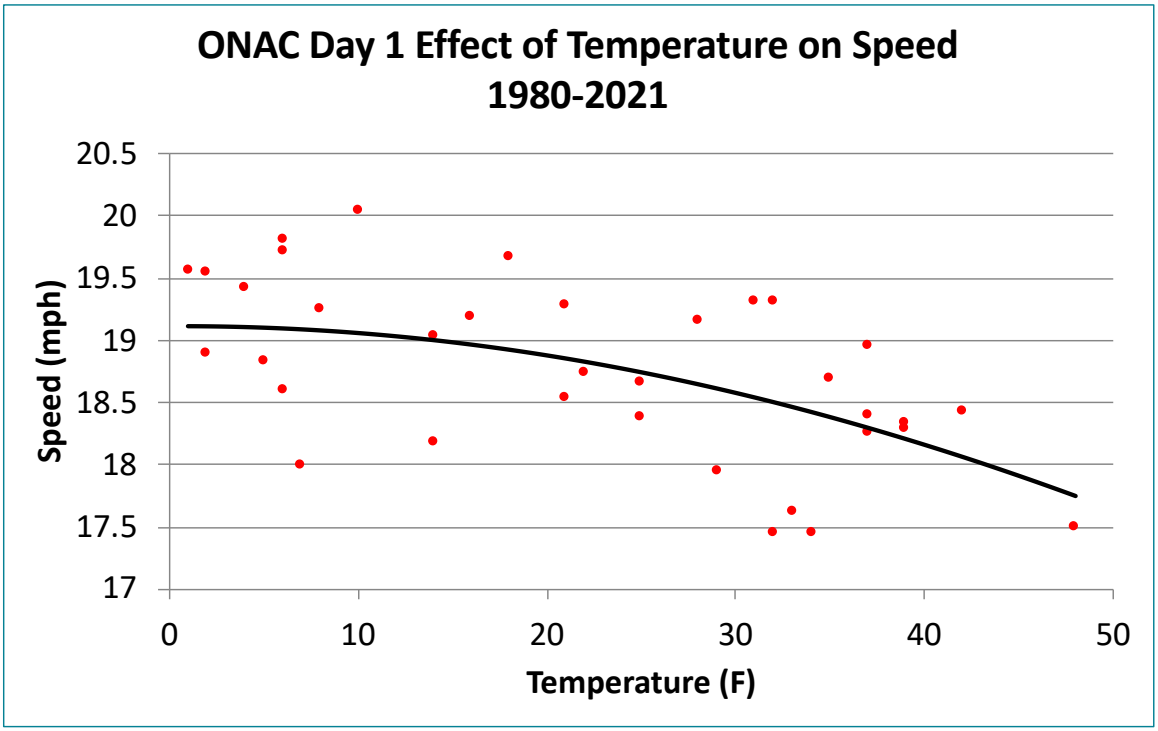
Open North American

The winning speed for the first and third heats and the overall speed for the winning teams were analyzed to determine whether there were trends with temperature and with race year.

ONAC Day One

There was a significant effect of temperature on winning speed for the 1st heat of ONAC (R^2 = 0.46, p = 0.0002). The data were best fit by a gaussian non-linear regression (speed = 19.1069e^(-(temp-0.67983)^2/(2*123.082^2). Winning speeds for day one of ONAC decreased with increasing temperature and the effect increased especially above 20F (Figure 11).

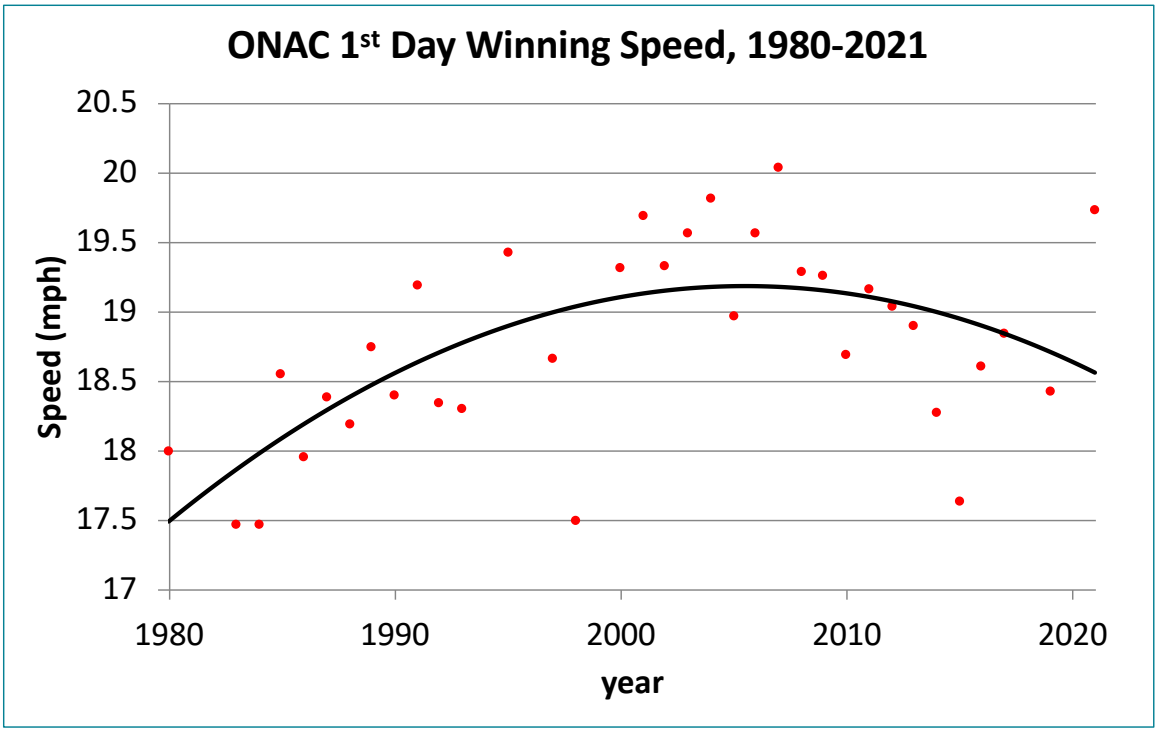
Figure 11. The effect of temperature on winning speed of ONAC, 1988-2021.



There was also a significant temporal trend of winning speed over race years (R^2 = 0.34, p = 0.0002). The data were best fit with a quadratic polynomial regression (Figure 12). Winning speed was predicted by the equation: speed = -10434.08+10.42447*year-0.002598938*year^2. The relationship was curvilinear, with speeds increasing until 2007 (Bud Streeper, 20.03 mph). After 2007, winning first day speeds declined. An exception to this trend occurred in 2021 when Anny Malo ran the third fastest first day heat in ONAC

history. In the 40 year race history between 1980 and 2021 the winner of the first ONAC heat has only won the overall race fifty percent of the time. In 2021 Anny Malo narrowly lost (1.6 seconds overall time) the race to Bud Streeper on the third day despite her lead from day one.

Figure 12. Winning speed on Day One of ONAC, 1980-2021.



The top 25 ONAC day one speeds and for all years 1980-2021 are shown in Table 14. And the winning day one speeds are shown in Table 15. Day one times were steadily increasing in the 1980s and 1990s, with some slower speeds in warm years or with slow trail conditions. The teams during these years were all Alaska huskies. In 1998 Egil Ellis and Asbjorn Erdal-Aase introduced pointer-Alaska husky crosses to the ONAC. Egil went on to dominate the ONAC, winning 12 championships in 14 years. As a result, Bud and Terry Streeper and most other open and limited class mushers began to experiment with English Pointer and German Short Hair crosses with Alaska Huskies. By 2004 there were very few all Alaska husky teams competing and most mushers were running teams with at least some pointers crosses included. The hybrid vigor of the initial husky-pointer crosses may have been responsible for the speed increase that occurred in the 2001-2007 time frame. Since that time, however, line-breeding of the initial crosses may not have perpetuated the hybrid vigor responsible for the record speeds posted from 2001-2007.

Table 14. Top 25 ONAC first day speeds 1980-2021.

Musher	Year	Dog Type[1]	Temperature (F)	Distance	Speed (mph)
Bud Streeper	2007	PC, AH	10	19.36	20.03
Egil Ellis	2004	PC	6	19.36	19.81
Annie Malo	2021	PC	6	20.16	19.71
Egil Ellis	2001	PC	18	19.30	19.67
Egil Ellis	2003	PC	1	20.41	19.55
Bud Streeper	2006	PC, AH	2	19.36	19.55
Bud Streeper	2003	AH, PC	1	20.41	19.53
Larry Tallman	1995	AH	4	19.75	19.41
Egil Ellis	2007	PC	10	19.36	19.40
Arleigh Reynolds	2007	PC	10	19.36	19.35
Egil Ellis	2000	PC	32	19.30	19.31
Egil Ellis	2002	PC	31	20.41	19.31
Egil Ellis	2008	PC	21	20.32	19.29
Bud Streeper	2004	PC, AH	6	19.36	19.29
Eddy Streeper	2007	PC, AH	10	19.36	19.26
Bud Streeper	2009	PC	8	20.32	19.25
Bud Streeper	2008	PC + AH	21	20.32	19.23
Amy Streeper	1995	AH	4	19.75	19.21
Egil Ellis	2008	PC	21	20.32	19.20
Roxy Wright-Champaine	1995	AH	4	19.75	19.19
Ross Saunderson	1991	AH	16	19.24	19.18
Bud Streeper	2021	PC	6	20.16	19.18
Kevin Cook	2004	AH	6	19.36	19.16
Ken Chezik	2011	PC	28	20.32	19.15
Neil Johnson	2001	AH	18	19.30	19.14

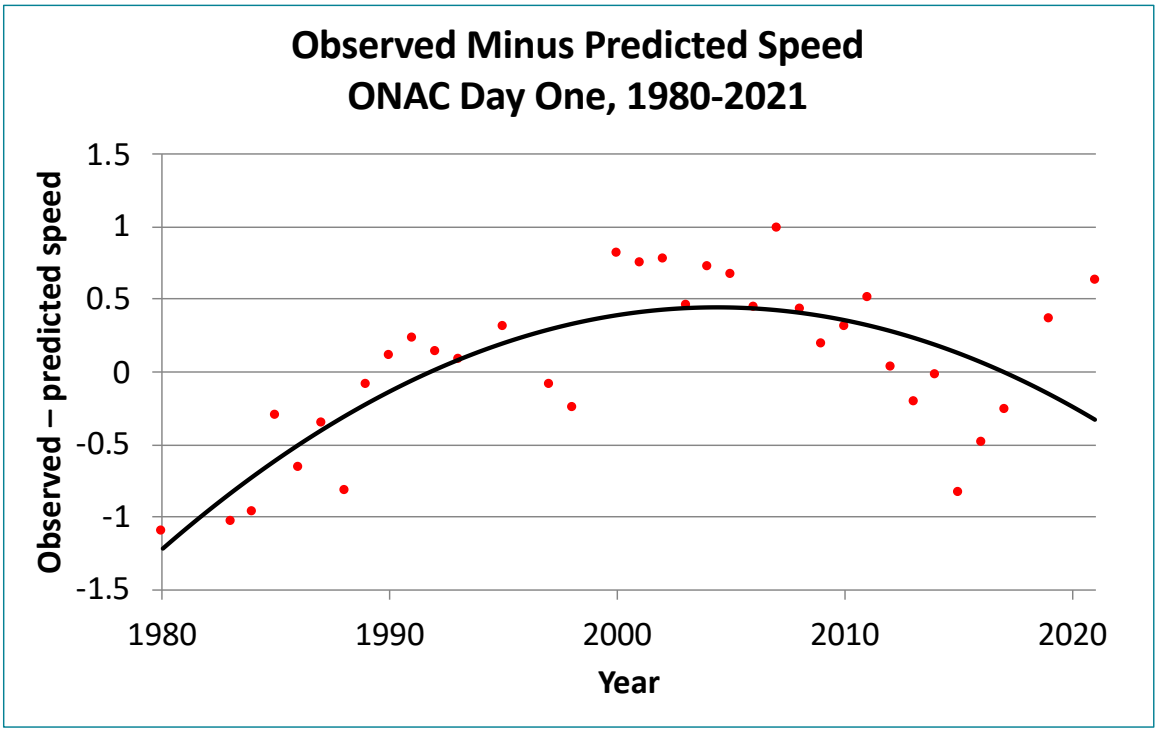
[1]Dog Type: AH = Alaska Husky (≤ 1/8 pointer or other non-Arctic breed; PC = pointer cross (> 1/8 English or German shorthair pointer mixed with Alaska husky).

Table 15. ONAC day-one winning speeds and observed minus predicted speeds.

Year	Day 1 Winner	Dog Type	Temp (F)	Trail Length (mi)	Speed (mph)	Oberved minus Predicted
1980	Harvey Drake	AH	7	19.12	17.98	-1.10
1983	Gareth Wright	AH	32	19.12	17.45	-1.04
1984	Harris Dunlap	AH	34	19.12	17.45	-0.97
1985	Eddy Streeper	AH	21	19.12	18.54	-0.31
1986	George Attla	AH	29	19.12	17.94	-0.67
1987	Len Robb	AH	25	19.24	18.38	-0.36
1988	Len Robb	AH	14	19.24	18.18	-0.82
1989	George Attla	AH	22	19.24	18.74	-0.09
1990	Charlie Champaine	AH	37	19.24	18.39	0.10
1991	Ross Saunderson	AH	16	19.24	19.18	0.22
1992	Terry Streeper	AH	39	19.75	18.33	0.13
1993	Roxy Wright-Champaine	AH	39	19.75	18.29	0.08
1995	Larry Tallman	AH	4	19.75	19.41	0.31
1997	Larry Tallman	AH	25	19.75	18.65	-0.09
1998	Curtis Erhart	AH	48	20.02	17.49	-0.26
2000	Egil Ellis	PC	32	19.3	19.31	0.81
2001	Egil Ellis	PC	18	19.3	19.67	0.75
2002	Egil Ellis	PC	31	20.41	19.31	0.77
2003	Egil Ellis	PC	1	20.41	19.55	0.45
2004	Egil Ellis	PC	6	19.36	19.81	0.72
2005	Egil Ellis	PC	37	19.36	18.96	0.67
2006	Bud Streeper	PC, AH	2	19.36	19.55	0.44
2007	Bud Streeper	PC, AH	10	19.36	20.03	0.98
2008	Egil Ellis	PC	21	20.32	19.28	0.43
2009	Bud Streeper	PC	8	20.32	19.25	0.18
2010	Ken Chezik	PC	35	19.67	18.68	0.30
2011	Ken Chezik	PC	28	20.32	19.15	0.50
2012	Arleigh Reynolds	PC	14	20.32	19.02	0.03
2013	Arleigh Reynolds	PC	2	19.36	18.89	-0.22
2014	Arleigh Reynolds	PC	37	19.36	18.26	-0.03
2015	Mark Hartum	PC	33	20.8	17.61	-0.84
2016	Roxy Wright	PC	6	20.3	18.60	-0.49
2017	Roxy Wright	PC	5	20.16	18.83	-0.27
2018	Rob Pebbles	PC	25	20.16	18.32	-0.42
2019	Bud Streeper	PC	42	20.16	18.42	0.36
2021	Anny Malo	PC	6	20.16	19.71	0.62

Predicted winning speeds for each year were calculated using the temperature at race time for each year and the temperature X speed regression equation (Figure 11). Subtracting the predicted winning speed from actual observed winning speed provides a measure of how the team performed with respect to other winning teams removing some of the differences attributed to temperature. A team that traveled faster than predicted has a positive value. Bud Streeper's run on day 1 of the 2007 ONAC was 0.98 mph faster than predicted for a temperature of 10F (Table 15). In general, observed minus predicted speeds were lowest at the beginning of the study period and became increasingly positive, reaching a peak in 2007. The observed – predicted speeds for day 1 of ONAC declined after 2007, with the exception of 2019 and 2021 (Figure 13).

Figure 13. The trend of observed minus predicted speed for winning teams on day 1 of ONAC over 1980-2021. Teams with faster speeds than predicted for the temperature at race time have positive values. The data were best fit with a quadratic polynomial regression (R^2 =0.56, p=.00002; obs-pred speed = -11260.66 + 11.23656*year -0.002803015*year^2).

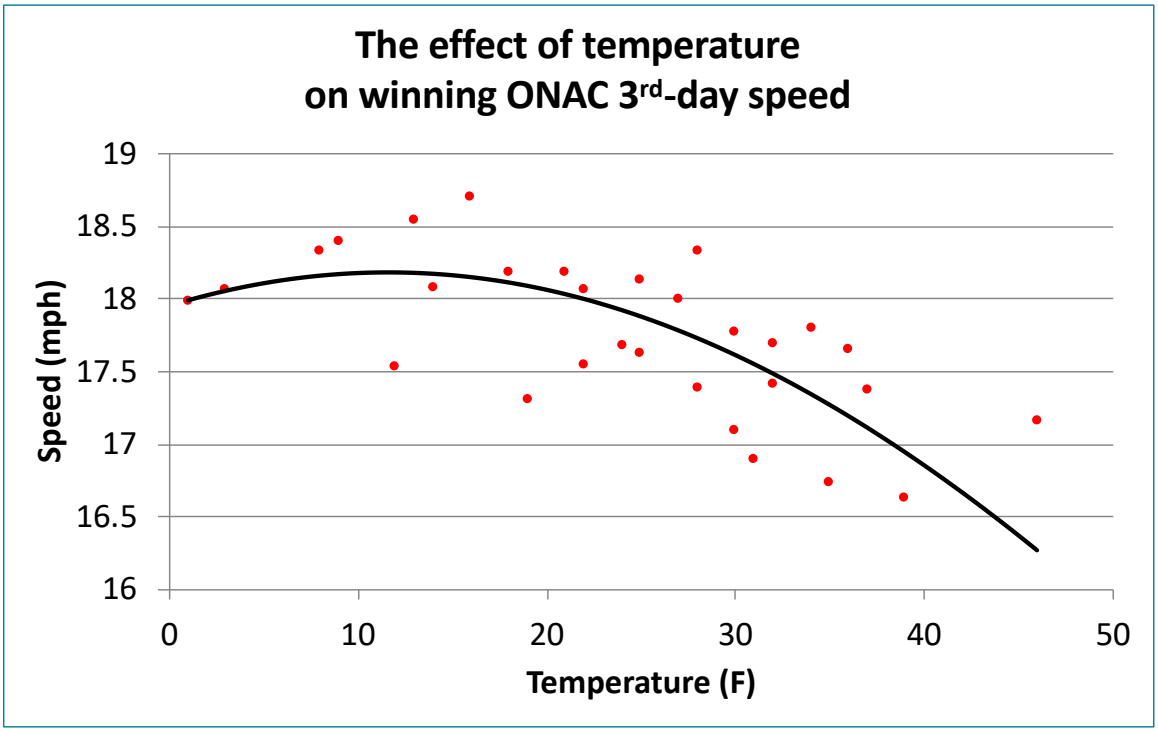


ONAC Day Three

The distance run by teams on the third (and last) day of ONAC increases by 7.6 mi. The winning speed on the third day was 0.2 – 2.4 mph slower than the 1st day due to the increased mileage and the fatigue of running the previous two heats. During the 1989-2021 time period, the winner of the 3rd ONAC heat was also the overall champion 70% of the time.

Winning speed on day 3 increased slightly from 0F to 12F and then declined with increasing temperature (Figure 14). The relationship was best described by a gaussian non-linear regression ($R2 = 0.89$, $p = 6.89 * 10^{-13}$; winning speed = 18.17771*(2.71828)^(-temperature-11.62578)^2/(2*73.0232^2).

Figure 14. The relationship of temperature at race time to winning speed for Day Three of ONAC, 1989-2021.



Similar to the ONAC 1st day winning speeds, winning speed for the 3rd day showed a similar trend of increasing steeply from 1989 to 2007 and then declined (Figure 15). The trend is best described with a quadratic polynomial regression (R^2=0.30, p=0.008; speed= -13536.93 + 13.51391*year – 0.003368246*year^2). The top 3rd day winning speeds occurred from 2003-2012 when pointer cross teams were new. The top third day time was that of Egil Ellis in 2007 (18.70 mph). After 2012 3rd day ONAC winning times have been below the Alaska husky teams of Amy Streeper (1996, 18.13 mph) and Joee Redington (2001, 18.07 mph), (Tables 16 and 17).

Figure 15. Winning speed on day 3 of ONAC over the years 1988-2021.

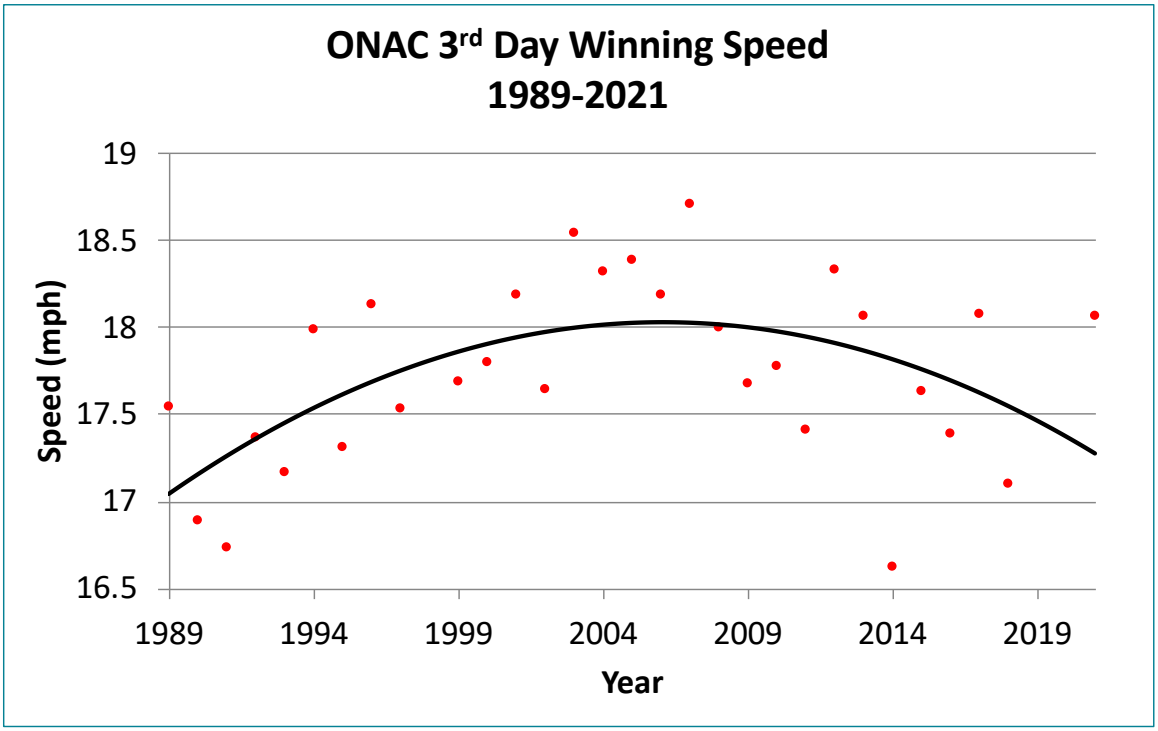
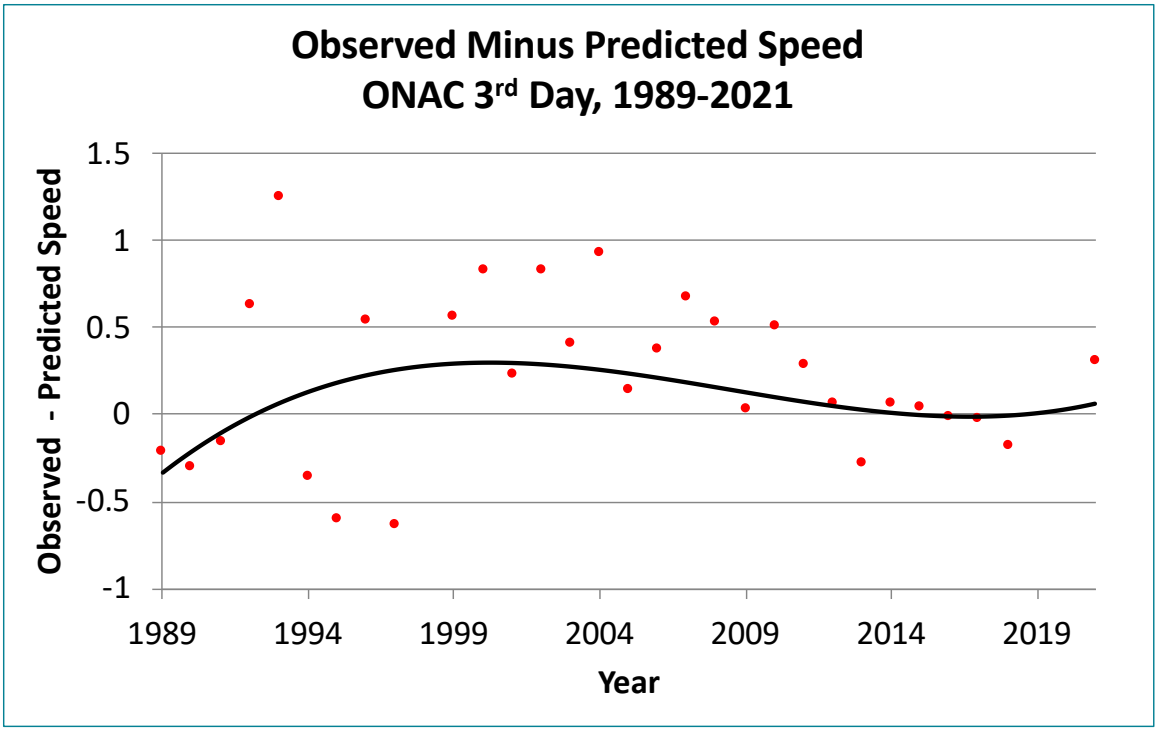


Figure 16. Observed minus predicted (for temperature at race time) winning speeds for Third Day of ONAC over the years 1989-2021.



Predicted three-day winning speeds for each year were calculated using the temperature at race time for each year and the temperature X speed regression equation for the third day. (Figure 14). Subtracting the predicted winning speed from actual observed winning speed provides a measure of how teams performed with respect to other winning teams removing some of the differences attributed to temperature. A team that traveled faster than predicted has a positive value. The observed – predicted winning speed data were best described by a cubic polynomial model (R^2=0.25, p=0.05; observed-predicted speed= -1117928 + 1669.877*year -0.831431*year^2 + 0001379874*year^3). Winning speeds that were slower than expected mainly occurred in the 1989-1997 time period though there were some notable exceptions such as Roxy Wright-Champaine's teams in 1992 (0.62 mph) and 1993 (1.25 mph) and Amy Steeper's team in 1996 (0.54 mph) (Table 17). Teams generally exceeded the predicted speed between 1999 and 2011, but then generally declined thereafter.

Table 16. Top 25 speeds of the 3rd day, ONAC 1989-2021.

Musher	Year	Dog Type[1]	Temperature	Distance (mi)	Speed (mph)
Egil Ellis	2007	PC	16	26.95	18.70
Bud Streeper	2007	PC, AH	16	26.95	18.62
Bud Streeper	2003	PC, AH	13	28.00	18.53
Egil Ellis	2005	PC	9	26.95	18.38
Egil Ellis	2003	PC	13	28.00	18.37
Bud Streeper	2004	PC, AH	28	26.95	18.32
Egil Ellis	2012	PC	8	27.91	18.32
Egil Ellis	2004	PC	28	26.95	18.22
Egil Ellis	2006	PC	21	26.95	18.18
Egil Ellis	2001	PC	18	26.89	18.18
Amy Streeper	1996	AH	25	27.34	18.13
Joee Redington	2001	AH	18	26.89	18.07
Bud Streeper	2021	PC	22	27.75	18.06
Bud Streeper	2001	AH, 2 PC	18	26.89	18.06
Arleigh Reynolds	2013	PC	3	26.94	18.05
Bud Streeper	2008	PC	27	27.91	17.99
Ross Saunderson	1994	AH	0	27.34	17.98
Roxy Wright	2017	PC	14	27.75	17.98
Egil Ellis	2008	PC	27	27.91	17.97
Anny Malo	2021	PC	22	27.75	17.92
Bill Kornmuller	2007	AH, 2 PC	16	26.95	17.91
Egil Ellis	2000	PC	24	26.89	17.79
Neil Johnson	2001	AH, 1 PC	18	26.89	17.78
Arleigh Reynolds	2010	PC	30	27.26	17.77

[1]Dog Type: AH = Alaska Husky (≤ 1/8 pointer or other non-Arctic breed; PC = pointer cross (> 1/8 English or German shorthair pointer mixed with Alaska husky).

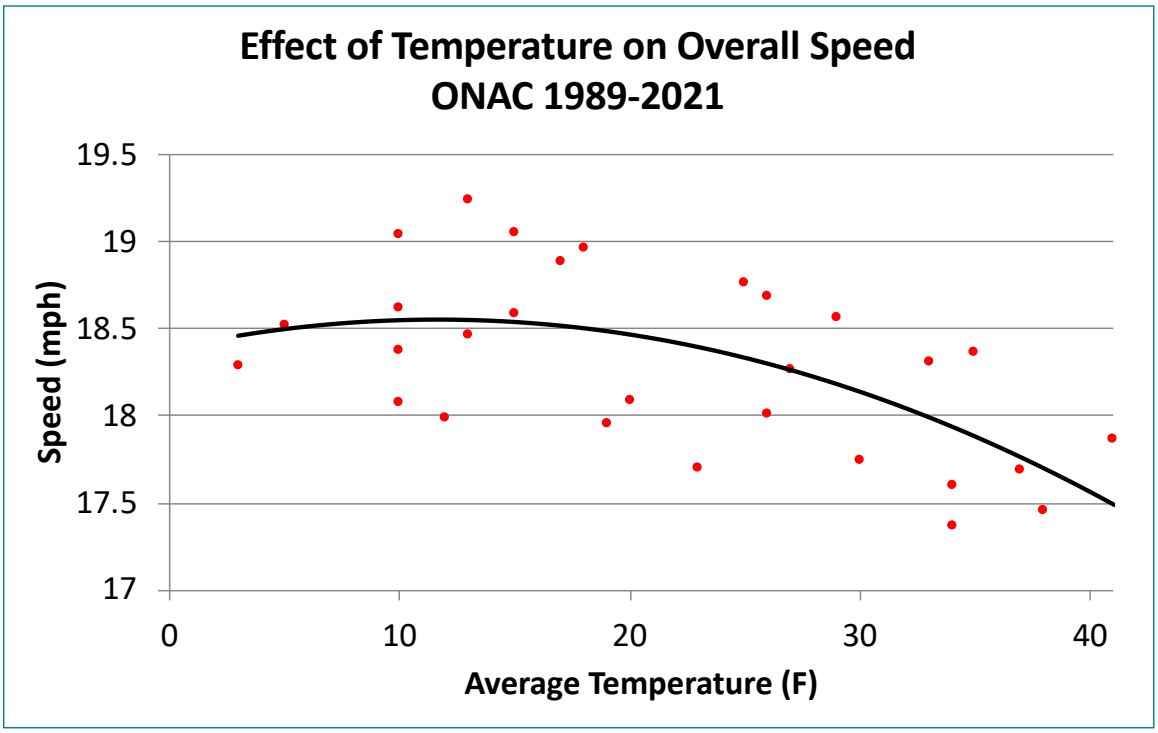
Table 17. ONAC winning speeds and observed minus predicted speed for day 3.

Year	Day 3 Winner	Dog Type	Temp (F)	Trail Length (mi)	Speed (mph)	Observed - Predicted Speed
1989	Roxy Wright-Champaine	AH	22	26.93	17.54	-0.22
1990	Charlie Champaine	AH	31	26.93	16.89	-0.31
1991	Marvin Kokrine	AH	35	26.93	16.73	-0.16
1992	Roxy Wright-Champaine	AH	37	27.34	17.36	0.63
1993	Roxy Wright-Champaine	AH	46	27.34	17.16	1.25
1994	Ross Saunderson	AH	0	27.34	17.98	-0.36
1995	Amy Streeper	AH	19	27.34	17.30	-0.60
1996	Amy Streeper	AH	25	27.34	18.13	0.54
1997	Amy Streeper	AH	12	27.34	17.52	-0.64
1999	Egil Ellis	PC	32	26.5	17.68	0.56
2000	Egil Ellis	PC	34	26.89	17.79	0.82
2001	Egil Ellis	PC	18	26.89	18.18	0.23
2002	Egil Ellis	PC	36	28	17.64	0.83
2003	Bud Streeper	PC, AH	13	28	18.53	0.40
2004	Bud Streeper	PC, AH	28	26.95	18.32	0.92
2005	Egil Ellis	PC	9	26.95	18.38	0.14
2006	Egil Ellis	PC	21	26.95	18.18	0.37
2007	Egil Ellis	PC	16	26.95	18.70	0.67
2008	Bud Streeper	PC	27	27.91	17.99	0.53
2009	Egil Ellis	PC	24	27.91	17.68	0.03
2010	Arleigh Reynolds	PC	30	27.26	17.77	0.50
2011	Arleigh Reynolds	PC	32	27.91	17.40	0.28
2012	Egil Ellis	PC	8	27.91	18.32	0.06
2013	Arleigh Reynolds	PC	3	26.95	18.05	-0.28
2014	Jason Dunlap	AH, PC	39	26.95	16.62	0.06
2015	Bud Streeper	PC	25	27.26	17.53	-0.06
2016	Bud Streeper	PC	28	27.89	17.38	-0.02
2017	Roxy Wright	PC	14	27.75	18.07	-0.03
2018	Lina Streeper	PC	30	27.75	17.09	-0.18
2021	Bud Streeper	PC	22	27.75	18.06	0.31

Overall ONAC Winning Speed

The average winning speed over all three days of the ONAC increased slightly from 3F to 13F and then declined at an increasing rate at higher temperatures (Figure 17). This relationship was best fit with a quadratic polynomial regression (R^2= 0.37, p= 0.003; 18.38908 + 0.0256927*temperature – 0.001160543*temperature^2). The average temperature for the fastest ever ONAC was 13F (2007, Bud Streeper, 19.24 mph). The slowest winning average speed occurred at a. race-time average temperature of 34F (Charlie Champaine, 1990, 17.36 mph).

Figure 17. The effect of temperature on winning average speed of ONAC, 1989-2021.



The average speed to win the ONAC increased from 1989 to 2007 and then declined (Figure 18). A quadratic polynomial regression best fit the data (R^2= 0.36, p=0.003; speed= 13418.58 + 13.39309*year – 0.003337293*year^2). The fastest winning speeds occurred from 2000 to 2013 with the teams of Egil Ellis, Bud Streeper and Arleigh Reynolds with 11, 2, and 1 win respectively during this time period (Tables 18 and 19). The fastest average speed (19.24 mph) was posted by Bud Streeper in 2007. The average speed again went up in 2021 when Bud Streeper and Anny Malo posted an average speed of 18.58 mph.

Table 18. Mushers posting the top 25 fastest overall speeds of the ONAC 1989-2021.

Musher	Year	Dog Type	Average Temp. (F)	Total Distance (mi)	Average Speed (mph)
Bud Streeper	2007	PC + AH	13	65.67	19.24
Egil Ellis	2007	PC	13	65.67	19.11
Egil Ellis	2004	PC	15	65.67	19.04
Bud Streeper	2003	PC + AH	10	68.82	19.04
Egil Ellis	2003	PC	10	68.82	18.98
Egil Ellis	2001	PC	18	65.49	18.96
Bud Streeper	2004	PC	15	65.67	18.92
Egil Ellis	2006	PC	17	65.67	18.88
Egil Ellis	2008	PC	25	68.55	18.76
Egil Ellis	2005	PC	26	65.67	18.68
Egil Ellis	2012	PC	10	68.55	18.62
Bud Streeper	2001	AH	18	65.49	18.59
Bud Streeper	2021	PC	15	68.07	18.58
Anny Malo	2021	PC	15	68.07	18.58
Egil Ellis	2000	PC	29	65.49	18.55
Bud Streeper	2008	PC + Dee (AH)	25	68.55	18.51
Neal Johnson	2001	AH, 1 PC	18	65.49	18.51
Arleigh Reynolds	2013	PC	5	65.64	18.50
Arleigh Reynolds	2012	PC	10	68.55	18.48
Egil Ellis	2009	PC	13	68.55	18.46
Bud Streeper	2009	PC + Dee (AH)	13	68.55	18.45
Joee Redington	2001	AH	18	65.49	18.43
Arleigh Reynolds	2007	PC	13	65.67	18.39
Eric LaForce	2021	PC	15	68.07	18.37
Egil Ellis	2002	PC	35	68.82	18.36

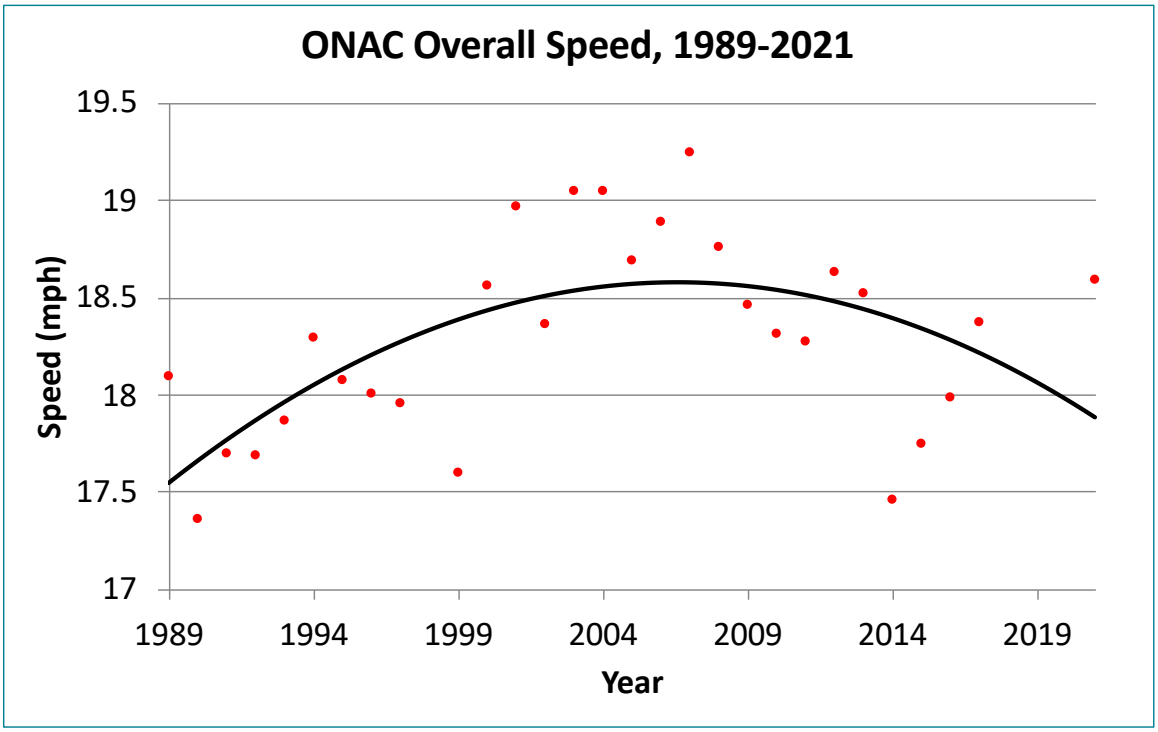
Musher	Year	Dog Type	Average Temp. (F)	Total Distance (mi)	Average Speed (mph)
Bill Kornmuller	2007	AH + PC	13	65.67	18.31
Egil Ellis	2010	PC	33	66.60	18.30
Ross Saunderson	1994	AH	3	66.84	18.29
Curtis Erhart	2001	AH	18	65.49	18.28
Eddy Streeper	2007	AH + PC + G	13	65.67	18.28
Egil Ellis	2011	PC	27	68.55	18.26
Heini Winter	2004	PC	15	65.67	18.26
Roxy Wright	2017	PC	10	68.07	18.26
Arleigh Reynolds	2010	PC	33	66.60	18.24
Ken Chezik	2013	PC	5	65.64	18.24
Egil Ellis	2013	PC	5	65.64	18.24
Rick Taylor	2001	AH	18	65.49	18.23
Arleigh Reynolds	2011	PC	27	68.55	18.22
Stephan Bittl	2004	PC	15	65.67	18.18
Greg Taylor	2012	PC + AH	10	68.55	18.13
Bud Streeper	2016	PC	12	68.49	18.09
Roxy Wright-Champaine	1989	AH	20	65.64	18.09
George Attla	1989	AH	20	65.41	18.06
Amy Streeper	1995	AH	10	66.84	18.07
Mark Hartum	2007	PC + AH	13	65.67	18.07
Ken Chezik	2011	PC	27	65.67	18.07
Ross Saunderson	1995	AH	10	66.84	18.04
Eric Lanser	2005	AH + PC	26	65.67	18.01
Jason Dunlap	2010	AH + PC	33	66.60	18.01
Kevin Cook	2004	AH	15	65.67	18.01
Amy Streeper	1996	AH	26	66.84	18.00

Table 19. ONAC overall winning speeds and observed minus predicted speed, 1989-2021.

Year	Overall Winner	Dog Type	Ave Temp (F)	Total Distance (mi)	Average Speed (mph)	Observed-Predicted Speed
1989	Roxy Wright-Champaine	AH	20	65.41	18.09	-0.35
1990	Charlie Champaine	AH	34	65.41	17.36	-0.56
1991	Ross Saunderson	AH	23	65.41	17.69	-0.67
1992	Roxy Wright-Champaine	AH	37	66.84	17.69	-0.07
1993	Roxy Wright-Champaine	AH	41	66.84	17.86	0.37
1994	Ross Saunderson	AH	3	66.84	18.29	-0.17
1995	Amy Streeper	AH	10	66.84	18.07	-0.46
1996	Amy Streeper	AH	26	66.84	18.00	-0.27
1997	Neil Johnson	AH	19	66.84	17.95	-0.51
1999	Egil Ellis	PC	34	64.32	17.59	-0.33
2000	Egil Ellis	PC	29	65.49	18.55	0.40
2001	Egil Ellis	PC	18	65.49	18.96	0.49
2002	Egil Ellis	PC	35	68.82	18.36	0.49
2003	Bud Streeper	PC/AH	10	68.82	19.04	0.51
2004	Egil Ellis	PC	15	65.66	19.04	0.53
2005	Egil Ellis	PC	26	65.66	18.68	0.41
2006	Egil Ellis	PC	17	65.66	18.88	0.39
2007	Bud Streeper	PC/AH	13	65.66	19.24	0.71
2008	Egil Ellis	PC	25	68.55	18.76	0.45
2009	Egil Ellis	PC	13	68.55	18.46	-0.07
2010	Egil Ellis	PC	33	66.6	18.30	0.33
2011	Egil Ellis	PC	27	68.55	18.26	0.03
2012	Egil Ellis	PC	10	68.55	18.62	0.09
2013	Arleigh Reynolds	PC	5	65.67	18.51	0.02
2014	Arleigh Reynolds	PC	38	65.67	17.45	-0.24
2015	Bud Streeper	PC	30	67.73	17.70	-0.42
2016	Bud Streeper	PC	12	68.49	17.98	-0.55
2017	Roxy Wright	PC	10	68.07	18.37	-0.16
2018	Bud Streeper	PC	30	67.87	17.34	-0.78
2021	Bud Streeper	PC	15	68.07	18.58	0.07

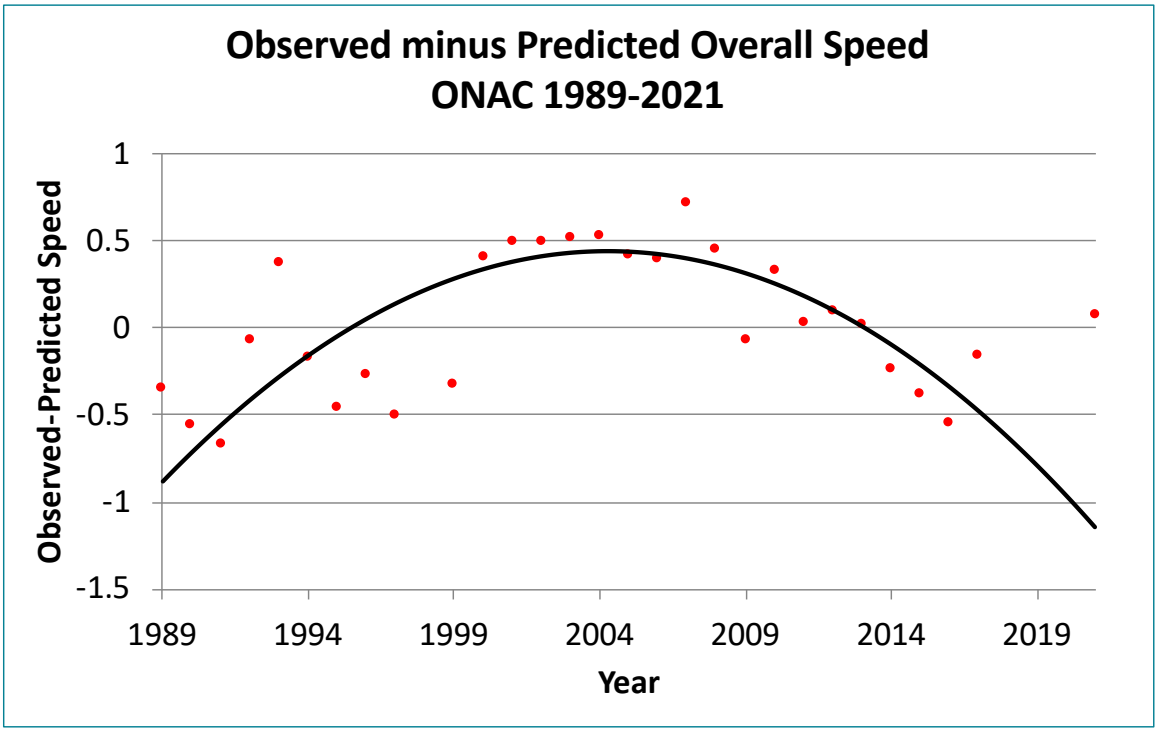
When temperature-adjusted predicted times are subtracted for actual times for winning teams and plotted against year a similar pattern emerged (Figure 19). The data were best fit by a quadratic polynomial regression (R^2= 0.68, p= $3.8*10^{-7}$; observed-predicted speed= -22630.99 + 22.58313*year – 0.005633736*$year^2$). Observed winning speeds were

Figure 18. Overall speed of winning teams over the time period 1989-2021.



generally lower than temperature-predicted winning speeds from 1989 to 1999, were above the predicted winning speed from 2000 to 2010, and then declined to the predicted speed or below. A notable exception to the lower than predicted speeds prior to 2000 occurred in 1993 when Roxy Wright-Champaine exceeded her predicted overall speed by 0.37 mph for the 41F average temperature during the race. The team that exceeded the temperature predicted winning speed by the greatest margin was Bud Streeper in 2007 (0.71 mph faster than predicted).

Figure 19. Observed minus predicted overall speed for ONAC, 1989-2021.



DISCUSSION

Temperature at race time did not have a discernable affect on winning race speed for the four-dog class at the Gold Run or LNAC. Similarly, there was no effect of temperature on the 6-dog or 10-dog winning times at the Gold Run. The Gold Run is held in mid to later February when temperatures are low. In the Gold Run four-dog class race temperatures were all below 20F (Appendix 1). The four-dog class at LNAC is held earlier in the day than the other sled classes and there were only four years out of 29 that temperatures exceeded 22F Appendix 2). Temperatures at the six-dog Gold Run exceeded 20F in only 4 of 33 years (Appendix 3) and only 6 of 33 years for the 10-dog Gold Run (Appendix 6).

Temperature accounted for sizable amount of the variation in winning speed for the LNAC and ONAC races, ranging from 22% for the LNAC six-dog class to 56% for the ONAC third day. Other factors such as trail conditions and team and musher ability contribute to winning speed variability. While this analysis attempts to compare winning times across years it should be noted that every year the trail conditions were different and the race winner ran the trail fastest.

There were significant effects of temperature at race time on winning speed for LNAC six- and eight-dog classes and for the 1st day, 2nd day and overall winning speed at the ONAC. For

the LNAC six-dog class speed decreased in a linear fashion and the predicted speed at -10F was 1.8 mph faster than at 40F. For the 8-dog class at LNAC and for the 1st day, 3rd day, and overall ONAC speed changed with temperature in a curvilinear fashion. For both the eight-dog LNAC and the open-class ONAC there was little change (≤0.2 mph) in predicted winning speeds between 0F and 20F but predicted speeds declined between 20F and 40F by 0.8 mph in the 8-dog class, 0.7 mph for day 1 of ONAC, 1.3 mph for day 3 of ONAC and by 1.0 mph for the overall ONAC.

Several studies have been made of the effects of ambient air temperature on exercising sled dogs. Phillips et al. (1981) studied the change in rectal temperature of Alaska huskies while running. On a 10-mi run the rectal temperature in the sled dogs increased during the initial 15–25 min of running and then the temperature plateaued or decreased slightly. Rectal temperature increases measured after running were correlated with ambient temperature but not with speed or distance. There was variability between dogs in degree of temperature increase but this was not correlated with sex, size, coat color, weight, or pedigree. Previous training at warm temperatures diminished the amount of increase in rectal temperature. Carter and Hall (2018) studied pre- and post-exercise ear canal temperatures in dogs used in canicross races in the UK. Ambient temperatures during the events ranged from 23–52F and distances run ranged from 2.4–2.8 mi. There was a weak correlation between speed and ear canal temperature increase, but there were no correlation of ambient temperature or humidity with body temperature increase. From these studies it appears that there may be a time threshold for body temperature to reach a level where exertion is regulated downward and speed is diminished to keep body temperatures within a normal range.

It is not surprising that in this study that ambient temperature did not affect winning speeds in the four-dog class. The furthest that teams in this class run is 6.2 miles and winning teams take less than 20 minutes to complete the course. Also, ambient temperatures at the Gold Run were usually low enough to prevent teams from slowing down in the 6- and 10-dog classes. At the LNAC and ONAC the temperatures were warm enough in some years for teams to run slower than they would at cold temperatures.

For the 4-, 6-, and 10-dog classes at the Gold Run there were no significant trends in winning speed across years. Pam Schamber had a particularly dominant team at the Gold Run four-dog class from 2016-2021. Stacy Lanser also had a very fast team in 2010 (Appendix 1). The fastest times, reaching over 20 mph, in the Gold Run six-dog class were posted from 2001-2006 by Egil Ellis, Dori Hollingsworth and Karoush Partow (Appendix 3). Average winning speeds declined until 2019 when Kim Well's winning team reached 20.27 mph and in 2021 when Mathieu Devred posted the current fastest winning speed of 21.13 mph. The 10-dog Gold Run fastest winning speeds were posted between 1998-2003 when there were five average winning speeds over 20 mph and winning speeds have not reached that level since.

Four-dog and six-dog winning speeds at the LNAC seem to have trended upward over the study period. Winning speeds increased rapidly from 1988 to 2002, then the upward trend progressed more slowly. In the six-dog class at LNAC and the open class first-day, third-day and overall winning speed at ONAC there was a similar trend rapidly increasing winning speed to 1999, a peak between 2000 and 2013 and then a downward trend.

While the four- and six-dog winning speeds are still increasing, it appears that winning speeds may have peaked and then declined in the 8-dog, 10-dog and open class championship races held on the ADMA race trails.

A number of improvements were made over the period of this study in breeding, race equipment, dog nutrition and race strategy that could have helped teams go faster. Makers of dog sleds changed from using wood for construction to aluminum, carbon fiber and plastic to save weight starting about 1996 and with race winners fully transitioning by 2006. Pully steering systems in sleds were developed and improved cornering and became common from 2000 onward. P-tex and other sled runner surfaces started to be used in the early 1980's and in combination with waxing reduced snow friction. Flouro ski waxes first became generally available in 1990 and further decreased snow friction allowing for faster speeds. Sled bags first became required equipment in 1995 and soon were made with light weight fabrics and utilized aerodynamic designs to reduce drag. Starting about 2003 some of the more competitive mushers learned to squat or kneel behind the aerodynamic bag to further reduce drag. Speeds can increase by 0.5 mph (personal experience) when a musher crouches down behind an aerodynamic sled bag.

GPS technology began to be assimilated into speed mushing about 2001 when hand-held units became generally available. Most speed mushers were using GPS devices by 2005. This technology allowed mushers to know their speed at all times. Prior to this, mushers had to estimate speed by "feel" or could determine if they were going faster or slower than ideal by timing how long it took to go from one mile marker to the next; however, using this method, the musher was 3-4 minutes behind in knowing how fast the team was moving. GPS and sled drag mats gave mushers the ability to govern speed nearly instantly which is important in pacing the team optimally either in training or racing (Welch, 2006). If a team goes too fast in the beginning, they may wind the dogs and decrease speed later in the race.

Improvements in nutrition that helped sled dog performance also occurred during the study period. Studies by Kronfeld et al. (1977) determined that racing sled dogs needed to be fed a high protein diet to maintain optimal red blood cell counts while under the stress of training and racing. Sled dogs were shown to effectively use fat as an energy source for running which can spare glycogen for bouts of high intensity work (Reynolds et al. 1995). Reynolds et al (1997) found that dogs fed a glycogen replacement food, such as maltodextrin, shortly after exercise, replenished their glycogen stores more completely and faster. When mushers started feeding maltodextrin after race heats, starting in 1996-98, dogs recovered faster, and were able to sustain high intensity exercise longer, and fewer dogs "bonked" in subsequent race heats. Researchers also found that supplementation with antioxidants such as vitamin E can reduce muscle damage from the free radicals that are produced with endurance exercise and with aerobic metabolism of a high fat diet (Hinchcliff et al., 2003).

Other advances during the study period were in "dog clothing". Dog booties were developed to protect sled dog feet from frost cracks and abrasions when the dogs ran in certain snow conditions or on rough surfaces. These booties are seldom used in speed races because trails are recently groomed and running in booties at high speed can cause injuries. The booties are helpful in training when conditions may not be as good or in distance races where speeds are slower. Dog coats were also developed which minimize potential for frostbite and allow dogs to train and race at low temperatures.

Advances in nutrition and dog clothing has allowed sled dogs to remain excellent health during training and to helps the dogs perform at a high level over the duration of races without running out energy or experiencing muscle or frost injury.

While winning race speeds of sled dogs in races of four to eight mile are still increasing, race speeds have plateaued for thoroughbred horses running the US Triple Crown races (1.2 -1.5 mi) and greyhounds running sprints of 0.285 – 0.30 mi. in the English Oaks, English Grand National, and English Derby races (Denny 2008). Thoroughbred speeds plateaued at the Kentucky Derby in 1949 (records 1896-2008), the Preakness Stakes (1925-2008) in 1971 and at Belmont (1926-2008) in 1973. Secretariat set the speed record for the Kentucky Derby and Belmont in 1973, and no horse has run faster since in a Triple Crown Race. Greyhound speeds (records from 1927 to 2008) plateaued for the English Oaks in 1966 and for the English Grand National and English Derby in 1971. During the period 1908 to 1976 winning speed at the Kentucky Derby increased by 13% and at the English Grand National, speed for greyhounds increased by 15% in 80 years. The speed increase over time is thought to be due to selective breeding. However, because of the closed gene pool of thoroughbreds and greyhounds it is doubtful speeds will increase much in the future as they are probably very close to their physiological and biomechanical limits for speed (Denny 2008).

Sled dogs do not have the gene pool limitation for speed selection that are found with greyhounds or thoroughbred horses. The Alaska husky is an amalgamation of dog breeds (Huson et al., 2010) and a speed plateau could theoretically be overcome by the addition of genes to the selection pool by crossing in another fast breed of dogs. Such an event happened in the late 1990s when Scandinavian mushers such as Egil Ellis and Helen Lundberg crossed German shorthair and English pointers that had been used for sled dog mushing with Alaska huskies. The resulting hybrids dominated speed mushing races from 2000 to the present. Winning speeds in these races increased rapidly from 1980-1998 with Alaska husky as the dominant breed. Adding the pointer genes increased speeds further, but this increase only lasted for about 10 years in the 8-, 10-, and open-class races.

Why did speeds increase and then fall again? The likely reason is that the crosses with pointers added hybrid vigor, but subsequent breeding of the hybrids to each other did not maintain the hybrid vigor and speeds decreased in spite of advances in equipment and nutrition.

Unfortunately, many of the hybrid crosses have short fur and flopped ears that require more maintenance than Alaska huskies (Welch 2006). Mushers must put coats on them when it is cold, house them inside, and feed more to maintain them. Pointer crosses, even when the percent pointer is brought down to 12.5% can have the short coat and ears of the pointers (Welch 2006). Short coat length and flopped ears are dominant traits (Housky and Venta 2006); Plassais et al., 2019) so it is hard to bring back Arctic-adapted characteristics once a non-polar breed such as a pointer, saluki, or greyhound is crossed in. Its difficult to justify the added maintenance of short-coated crosses when current race speeds for 8-,10 and open class are not higher than before pointers, greyhounds and salukis were bred in.

Many mushers feel that dogs with short coats, such as pointer crosses, have an advantage in warm temperatures over Alaska huskies, but it is very difficult to tell which dogs will have

difficulty running at warm temperatures by how they look (Brown, 2020). Speed mushers were selecting dogs that ran well in warm temperatures well before 2000 when the current round of crossing to pointers began. In 1998, when race temperatures averaged 43F, the ONAC was won by a team of Alaska huskies owned by Joee Redington that did not seem to be bothered by the warmth. In the same race a team of pointer cross sled dogs over-heated during the 2nd heat and did not complete the course. Roxy-Wright Champaine's Alaska husky team won the ONAC in 1993 when the average race-time temperature was 41F. Her team's overall speed was 0.31 mph faster than predicted for the temperature.

The shortest speed races (four- and six-dog) are being won by dogs that are one-half or more pointer. The pointers are from Scandinavian stock that have been bred and selected for pulk racing since the 1960s (Knudsen, 2019). These pointers seem to be bigger than the ones that were used by Egil Ellis. The current speed record in the LNAC 4-dog class is held by Lena Boysten-Hillestad (21.13 mph) with a team that was German shorthair pointer (50-75%) breeding with greyhound (25-50%). Mathieu Devred holds the current speed record for the LNAC 6-dog class. His dogs are a mix of GSP and AH (personal communication).

Prior to 2000, Alaska competitors in the four- and six-dog classes raced with Alaska huskies. The dogs were not purpose-bred for these shorter classes. They were dogs from kennels that specialized in longer open-class races, but lacked endurance or were young dogs that were raced at short distance to gain race experience. Even without breeding for the larger size and strength needed for these races, there were some fast Alaska Husky teams in the four-dog class on ADMA trails. For example, Stacey Lanser averaged 20.4 mph in the 2010 Gold Run and Carol Kaynor averaged 20.31 at the 2001 IFSS World Championship.

In speed sled dog racing it appears that the percent of Alaska husky parentage in sled dogs from winning teams increases with race distance. Four-dog races (<6.3 mi) can be won by dogs without any Alaska husky parentage; Most dogs in six-dog winning teams (<8.1 mi) have at least 25% AH parentage; and dogs competing in 8-, 10-, and open class races (>10.7 mi) have 50% or more AH parentage. Dogs running in ultra-long distance races like the Iditarod have little (<15%) to no pointer parentage due to the difficulty of caring for sled dogs with little fur while camping.

Could the speed of teams have kept increasing if only Alaska huskies had been used for speed racing? The winning speeds in all speed classes were on the increase prior to 2000 and had not plateaued. Bud Streeper's record-holding team from 2007 had three dogs (including the main leader Dee) with no pointer parentage and three others with 1/8 pointer ancestry (Conn 2007). Speeds may well have increased further without pointer influence but it is unknown whether they would have reached the peak achieved by the early pointer crosses.

What does the future hold? Perhaps the speeds reached by Egil Ellis and Bud Streeper could be reached once more by starting again with first generation crosses of Alaska Huskies with pointers. Lena Boysen-Hillestad had to re-create her greyster crosses when hybrid vigor began to dissipate several generations after her initial crosses (Sellentin, 2013). However, the re-creation of the original Ellis-Lundberg crosses is made more difficult by the current scarcity of pure Alaska huskies that have been bred for speed racing. Speed mushers abandoned their husky lines for pointer crosses starting about 1999. Now it is difficult to

find “pure” Alaska huskies running in speed racing teams. The dogs used in long distance mushing came originally from sprint mushing kennels (Welch 2006). Though these dogs were subsequently selected for attributes important to a slower style of racing it may be possible to find some fast Alaska huskies in the kennels of distance mushers that could be used in a speed mushing breeding program.

APPENDICES

Appendix 1. Overall winners and speeds of Gold Run four-dog class, 2007-2021. The Gold Run is a two-day event.

Year	Musher	Dog Type	Ave Temp (F)	Total Distance (mi)	Average Speed (mph)
2021	Pam Schamber	PC	-19	12.4	19.42
2020	Kriya Dunlap	PC	-10	12.4	18.42
2019	Pam Schamber	PC	-1	12.4	20.50
2018	Pam Schamber	PC	15	12.4	20.33
2017	Pam Schamber	PC	5	12.4	20.64
2016	Pam Schamber	PC	19	12.4	20.36
2015	Dawn Brown	PC	8	12.4	17.80
2014	Andrea Swingley	AH	4	12.4	17.24
2013	Dawn Brown	PC	-4	12.4	18.76
2012	Jenifer Probert	PC	4	12.4	19.03
2011	R. Noonan-Apre	?	1	12.4	15.40
2010	Stacy Lanser	?	13	10.2	20.40
2008	Carol Kaynor	?	-14	12	17.57
2007	Scott Campbell	PC	-4	12	19.61

Appendix 2. Overall winners and speeds of LNAC four-dog class, 1988-2021.

Year	Musher	Dog Type	Ave Temp (F)	Total Distance (mi)	Speed (mph)
1992	Mary Arndt	AH	22	12.86	17.27
1993	Lou Serre	AH	11	12.86	19.30
1994	Sue Callihan	AH	20	12.86	17.78
1995	Terri Killam	AH	-7	12.86	17.88
1996	Val Mackler	AH	0	15.11	17.74
1997	Jeorg Homeff	AH	12	15.11	18.92
1998	Carol Klecknor	AH	31	15.11	18.33
1999	Carol Kaynor	AH	19	15.11	18.92
2000	Carol Kaynor	AH	19	15.11	18.97
2001	Lena Boysten Hillestad	GR	14	15.11	19.98
2002	Deanna Partow	PC	14	15.11	19.85
2003	Deanna Partow	PC	21	15.11	19.78
2004	Bev Stevens	PC/AH	31	15.11	19.12
2005	Uwe Radant	PC	35	15.11	20.75
2006	Scott Campbell	PC	-10	15.11	19.85
2007	Malinda Holmes	PC	-6	15.11	19.73
2008	Jennifer Probert	PC	33	15.11	18.95
2009	Jennifer Probert	PC	-4	15.11	19.97
2010	Jennifer Sterling	PC	3	13.65	19.20
2011	Jennifer Sterling	PC	3	15.68	19.19
2012	Karoush Partow	PC	-2	15.68	18.03
2013	Lena Boysten Hillestad	GR	32	15.68	21.13
2014	Dawn Brown	PC	17	15.68	18.96
2015	Pam Schamber	PC+SC+GR	-11	15.68	19.87
2016	Pam Schamber	PC+SC+GR	20	15.68	20.15
2017	Pam Schamber	PC+SC+GR	6	15.68	19.68
2018	Pam Schamber	PC+SC+GR	20	15.68	20.11
2019	Mathieu Devred	PC	28	15.68	19.21
2020	Pam Schamber	PC+SC+GR	18	15.68	20.15
2021	Pam Schamber	PC+SC+GR	-10	15.68	20.57

Appendix 3. Overall winning speeds for the Gold Run six-dog class, 1988-2021.

Year	Musher	Dog Type	Ave Temp (F)	Total Distance (mi)	Ave Speed (mph)
1988	Mari Hoe-Raitto	AH	8	12.6	19.57
1989	Linda Leonard	AH	10	12.6	19.29
1990	Elaine Snyder-Conn	AH	-40	12.6	19.73
1991	Linda Leonard	AH	17	12.6	19.55
1992	Linda Leonard	AH	-3	12.6	19.44
1993	Brenda Richard	AH	-6	12.6	18.79
1994	Jane Cosgrove	AH	-4	12.6	19.46
1995	Magali Phillip	AH	-4	12.6	19.35
1996	Magali Phillip	AH	-10	15.6	17.69
1997	Linda Leonard	AH	33	15.6	18.14
1998	Dawn Simmerman	AH	-4	15.6	19.26
1999	Tammy Saunderson	AH	17	15.6	19.47
2000	Mary Jo Downey	AH	18	15.6	19.18
2001	Egil Ellis	PC	8	15.6	20.00
2002	Dori Hollingsworth	AH/PC	3	15.6	20.03
2003	Egil Ellis	PC	4	15.6	20.18
2004	Karoush Partow	PC	24	15.6	19.78
2005	Rudi Ropertz	PC	24	15.6	19.37
2006	Karoush Partow	PC	28	15.6	20.08
2007	Jennifer Probert	PC	4	15.6	19.90
2008	Angie Fitch	?	-10	15.6	19.17
2009	Jennifer Probert	PC	10	15.6	19.47
2010	Ami Gjetson	PC	19	13.0	19.46
2011	Ami Gjetson	PC	2	16.0	19.04
2012	Ami Gjetson	PC	6	16.0	19.64
2013	Ami Gjetson	PC	0	16.0	19.88
2014	Bonnie Borba	?	5	16.0	18.86
2015	Bonnie Borba	?	9	16.0	18.71
2016	Dawn Brown	PC	20	16.0	19.97
2017	Jennifer Probert-Erhart	PC	5	16.0	19.88
2018	Mathieu Devrid	PC	16	16.0	19.89
2019	Kim Wells	PC	3	16.0	20.27
2020	Terri Cadzow	PC	-8	16.0	18.27
2021	Mathieu Devrid	PC	-9	16.0	21.13

Appendix 4. Overall Winning and Observed – Predicted Speeds in the LNAC six-dog Class, 1988-2021.

Year	Musher	Dog Type	Ave Temp (F)	Total Distance (mi)	Average Speed (mph)	Observed-Predicted Speed
1988	Dorthy Arthurs	AH	37	22.38	18.09	-1.08
1989	Mari Hoe-Raitto	AH	16	22.38	18.77	-1.18
1990	Dorthy Aurthurs	AH	13	20.70	18.80	-1.26
1991	Nancy Nolke	AH	12	20.70	19.25	-0.85
1992	Nancy McKewin	AH	28	20.70	18.51	-0.99
1993	Doris Prefontaine	AH	16	20.70	19.65	-0.30
1994	Kris Strayer	AH	23	20.70	18.51	-1.19
1995	Gerri Hanschen	AH	-4	20.70	19.56	-1.13
1996	Magali Phillip	AH	9	19.83	19.55	-0.66
1997	Nancy McKewin	AH	9	19.83	19.55	-0.66
1998	Angie Fitch	AH	38	19.83	19.14	0.01
1999	Kristen Deutschlader	PC	23	19.83	19.94	0.25
2000	Rex Jones	PC	21	19.83	19.05	-0.72
2001	Birgette Naess	PC	21	19.83	20.14	0.37
2002	Brigette Naess	gsp/GR	17	19.83	20.58	0.67
2003	Karoush Partow	PC	23	19.83	20.19	0.50
2004	Ken Chezik	PC	39	19.83	19.79	0.69
2005	Greg Sellington	PC	39	19.83	19.78	0.68
2006	Karoush Partow	PC	-3	19.83	20.63	-0.02
2007	Jennifer Probert	PC	-2	19.83	20.02	-0.59
2008	Jennifer Probert	PC	37	19.83	19.64	0.46
2009	Jennifer Probert	PC	2	19.83	20.70	0.24
2010	Ami Gjetson	PC	5	23.43	19.50	-0.86
2011	Dawn Brown	PC	9	20.40	20.26	0.06
2012	Kati Dagenais	PC	1	20.40	20.66	0.15
2013	Jessica Doherty	PC/GR	34	20.40	21.04	1.76
2014	Kim Wells	PC	19	20.40	20.20	0.36
2015	Dawn Brown	PC	-9	20.40	19.98	-0.89
2016	Dawn Brown	PC	23	20.40	20.01	0.31
2017	Mathieu Devred	PC	10	20.40	19.97	-0.20
2018	Mathieu Devred	PC	27	20.40	20.41	0.86
2019	Pam Schamber	PC	35	20.40	19.08	-0.17
2020	Kim Wells	PC	21	20.40	18.92	-0.85
2021	Mathieu Devred	PC	1	20.40	21.45	0.94

Appendix 5. Winning overall speeds and observed-predicted speed, LNAC eight-dog class, 1988-2021.

Year	Musher	Dog Type	Ave Temp (F)	Total Distance (mi)	Average Speed (mph)	Observed-Predicted Speed
1988	Linda Leonard	AH	44	36.4	17.94	-0.59
1989	Linda Leonard	AH	27	36.4	18.83	-0.41
1990	Linda Leonard	AH	19	36.4	19.07	-0.40
1991	Kathy Frost	AH	18	36.4	18.93	-0.56
1992	Linda Leonard	AH	34	36.4	18.36	-0.63
1993	Linda Leonard	AH	25	36.4	18.50	-0.80
1994	Carlolyn McCormick	AH	25	32.1	18.76	-0.54
1995	Linda Leonard	AH	0	32.1	19.55	-0.16
1996	Stephan Bittl	AH	13	33.7	19.44	-0.15
1997	Linda Leonard	AH	17	33.7	19.79	0.28
1998	Linda Leonard	AH	39	33.7	18.85	0.08
1999	Helmut Peer	PC	36	33.7	19.56	0.65
2000	Helen Lundberg	PC	24	33.7	20.44	1.10
2001	Helen Lundberg	PC	26	33.7	19.50	0.23
2002	Helen Lundberg	PC	19	33.7	20.03	0.57
2003	Ken Chezik	PC	25	33.7	20.00	0.70
2004	Ushi Liebhard	PC	39	33.7	19.35	0.57
2005	Ushi Liebhard	PC	42	33.7	19.42	0.79
2006	Ushi Liebhard	PC	1	33.7	20.03	0.33
2007	Christain Taveau	PC	1	33.7	19.43	-0.28
2008	Rob Downey	PC	41	33.7	18.28	-0.40
2009	Jennifer Sterling	PC	5	33.7	20.33	0.64
2010	Jennifer Probert	PC	9	33.7	19.82	0.17
2011	Dawn Brown	PC	15	34.3	19.68	0.12
2012	Christain Taveau	PC	3	34.3	18.80	-0.90
2013	Christain Taveau	PC	36	34.3	18.88	-0.02
2014	Dawn Brown	PC	21	34.3	19.11	-0.31
2015	Jerry Woods	PC	-6	34.3	19.94	0.24
2016	Karoush Partow	PC	25	34.3	19.55	0.24
2017	Dawn Brown	PC	14	34.3	19.59	0.02
2018	Dawn Brown	PC	28	34.3	19.18	-0.03
2019	Ken Chezik	PC	37	34.3	18.68	-0.18
2020	Dawn Brown	PC	24	34.3	19.62	0.28
2021	Karoush Partow	PC	3	34.3	19.88	0.18

Appendix 6. Overall winning speed for the 10-dog class at the Gold Run, 1988-2021.

Year	Musher	Dog Type	Ave Temp (F)	Total Distance (mi)	Ave Speed (mph)
1988	Roxy Wright	AH	14	25.06	18.67
1989	Linda Leonard	AH	16	25.06	19.09
1990	Kathy Frost	AH	-40	25.06	19.60
1991	Linda Leonard	AH	25	25.06	19.07
1992	Linda Leonard	AH	3	25.06	19.81
1993	Mari Hoe-Raitto	AH	-1	25.06	18.32
1994	Linda Leonard	AH	5	25.06	19.75
1995	Linda Leonard	AH	2	25.06	18.93
1996	Linda Leonard	AH	-3	24.48	17.70
1997	Linda Leonard	AH	37	24.48	18.78
1998	Linda Leonard	AH	4	24.48	20.06
1999	Ross Saunderson	AH	21	24.48	20.18
2000	Arleigh Reynolds	AH/PC	18	24.48	19.13
2001	Egil Ellis	PC	14	24.48	20.33
2002	Iwan Schmidt	PC	7	24.48	20.15
2003	Egil Ellis	PC	8	24.48	20.25
2004	Ken Chezik	PC	28	24.48	19.34
2005	Rudi Ropertz	PC	25	24.48	19.92
2006	Rob Downey	PC	28	24.48	18.99
2007	Christain Taveau	PC	8	24.48	19.85
2008	Christain Taveau	PC	-9	24.48	19.21
2009	Christain Taveau	PC	12	24.48	19.55
2010	Christain Taveau	PC	27	24.2	19.49
2011	Dori Holligsworth	PC	4	24.86	18.96
2012	Dori Hollingsworth	PC	9	24.86	18.92
2013	Jason Dunlap	AH	1	24.86	19.36
2014	Dawn Brown	PC	4	24.86	18.15
2015	Dawn Brown	PC	6	24.86	18.19
2016	Amy Dunlap	AH/PC	21	24.86	19.28
2017	Dawn Brown	PC	9	24.86	19.74
2018	Dawn Brown	PC	19	24.86	19.23
2019	Karoush Partow	PC	10	24.86	19.77
2020	Jason Dunlap	PC	-5	24.86	19.07
2021	Anny Malo	PC	-8	24.86	19.75

References Cited

Borba, B 2004. 2004 Limited North American Pedigrees. 59p. https://www.sleddogstudio.com/pedigree/index.html

Borba, B 2005. 2005 Limited North American Pedigrees. 72 p. https://www.sleddogstudio.com/pedigree/index.html

Borba, B 2006. 2006 Limited North American Pedigrees. 70p. https://www.sleddogstudio.com/pedigree/index.html

Borba, B 2007. 2007 Limited North American Pedigrees. 70p. https://www.sleddogstudio.com/pedigree/index.html

Borba, B 2008. 2008 Limited North American Pedigrees. 61p. https://www.sleddogstudio.com/pedigree/index.html

Borba, B 2009. 2009 Limited North American Pedigrees. 63p. https://www.sleddogstudio.com/pedigree/index.html

Borba, B 2010. 2010 Limited North American Pedigrees. 61p. https://www.sleddogstudio.com/pedigree/index.html

Brown, D. 2020. Preventing and managing heat stroke in dogs. Mushing 187/188: 41.

Brown, S.K., C.M. Darwent, E.J. Wictum and B.N. Sacks. 2015. Using multiple markers to elucidate the ancient, historical, and modern relationships among North American Arctic dog breeds. Heredity 115: 488-495.

Conn, J.S. 1987. 1987 Kobuk Limited North American Pedigrees. 39p. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1988. 1988 Kobuk Limited North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1989a. 1989 Limited North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1989b. 1989 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1990a. 1990 Limited North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1990b. 1990 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1991a. 1991 Limited North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1992a. 1991 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1992b. Analysis of pedigree information on the open class North American Sled Dog Race, 1980-1991. 111p. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1993. 1993 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1994. 1994 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1995. 1995 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1996. 1996 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1997. 1997 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1998. 1998 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 1999. 1999 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2000. 2000 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2000. 2000 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2001. 2001 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2002. 2002 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2003. 2003 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2004. 2004 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2005. 2005 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2006. 2006 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2007. 2007 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2008. 2008 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2009. 2009 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2010. 2010 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2011. 2011 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Conn, J.S. 2012. 2012 Open North American Pedigrees. Self published. Available from author: PO Box 127, Ester, AK 99725.

Denny, M.W. 2008. Limits to running speed in dogs, horses and humans. J. Exp. Biol. 211: 3836 – 3849.

Hinchcliff, K.W., P.D. Constable, and R.A. DiSilvestro. 2003. Muscle injury and antioxidant status in sled dogs competing in a long distance sled dog race. Equine Comp. Excerc. Physiol. 1: 81-85.

Housky, D.J.E. and P.J. Venta. 2006. The long and short of it: evidence that FGFS is a major determinant of canine 'hair'-itability. Anim. Genet. 37: 309-315.

Huson, H.J., H.J. Parker, J. Runstadler, and E.A. Ostrander. 2010. A genetic dissection of breed composition and enforcement in the Alaskan sled dog. BMC Genet. 11.

Huson, H.J., B.M. vonHoldt, M. Rimbault, A.M. Byers, J.A. Runstadler, H.G. Parker, and E.A. Ostrander. 2012. Breed-specific ancestry studies and genome-wide association analysis highlight an association between the MYH9 gene and heat tolerance in Alaskan sprint racing sled dogs. Mamm Genome 23: 178-194.

Knudsen, I.G. 2019. Historical and Sociological Perspectives in Dog Sledding. Pp. 15-44. In, Dog Sledding in Norway. Multidisciplineary Research Perspectives. R. Woaler and K. Skjesol (eds). Lit Verlag, Zurich.

Kronfeld, D.S., E.P. Hammel, C.F. Ramberg Jr., and H.L. Dunlap Jr. 1977. Hematological and metabolic responses to training in racing sled dogs fed diets containing medium, low, or zero carbohydrate. Am. J. Clin. Nutr. 30: 419-430.

Phillips, C.J., R.P. Coppinger, and D.S. Schimel. 1981. Hyperthermia in running sled dogs. J. Appl. Physiol. 51:135-142.

Plassais, J., J. Kim, B.W. Davis, D.M Karyadi, A.N. Hogan, A.C. Harris, B. Decker, and E.A. Ostrander. 2019. Whole genome sequencing of canids reveals genomic regions under selection and variants influencing morphology. Nature Comm. 10: 1489.

Reynolds, A., L. Fuhrer, H. Dunlap, M. Finke, and F. Kallfelz. 1995. Effect of diet and training on muscle glycogen storage and utilization in sled dogs. J. Appl. Physiol. 79: 1701-1607.

Reynolds, A.J., D.P. Carey, G.A. Rhienhart, R.A. Swenson, and F.A. Kallfelz. 1997. Effect of post exercise carbohydrate supplementation on muscle glycogen repletion in trained sled dogs. Am. J. Vet. Res. 58:1252-1256.

Savage, J. GPS Accuracy of Garmin, Polar, and other running watches. https://fellrnr.com/wiki/GPS_Accuracy.

Sellentin, G. 2013. Race Report. Winter World Championships. Mushing 151: 16-39.

Van Bueren, E. and B. Borba. 1992. 1992 Limited North American Pedigrees. 70p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 1993a. 1993 Limited North American Pedigrees. 91p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 1993b. International Federation of Sledddog Sports 1993 World Championships. 91p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 1994. 1994 Limited North American Pedigrees. 68p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 1995. 1995 Limited North American Pedigrees. 82p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 1996. 1996 Limited North American Pedigrees. 70p. https://www.sleddogstudio.com/pedigree/index.htm

Van Bueren, E. and B. Borba. 1998. 1998 Limited North American Pedigrees. 55p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 2000. 2000 Limited North American Pedigrees. 61p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 2001. 2001 Limited North American Pedigrees. 71p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 2002. 2002 Limited North American Pedigrees. 55p. https://www.sleddogstudio.com/pedigree/index.html

Van Bueren, E. and B. Borba. 2003. 2003 Limited North American Pedigrees. 67p. https://www.sleddogstudio.com/pedigree/index.html

Welch, J. 2006. Another chapter. Sled Dog Sports. 19: 15-19.