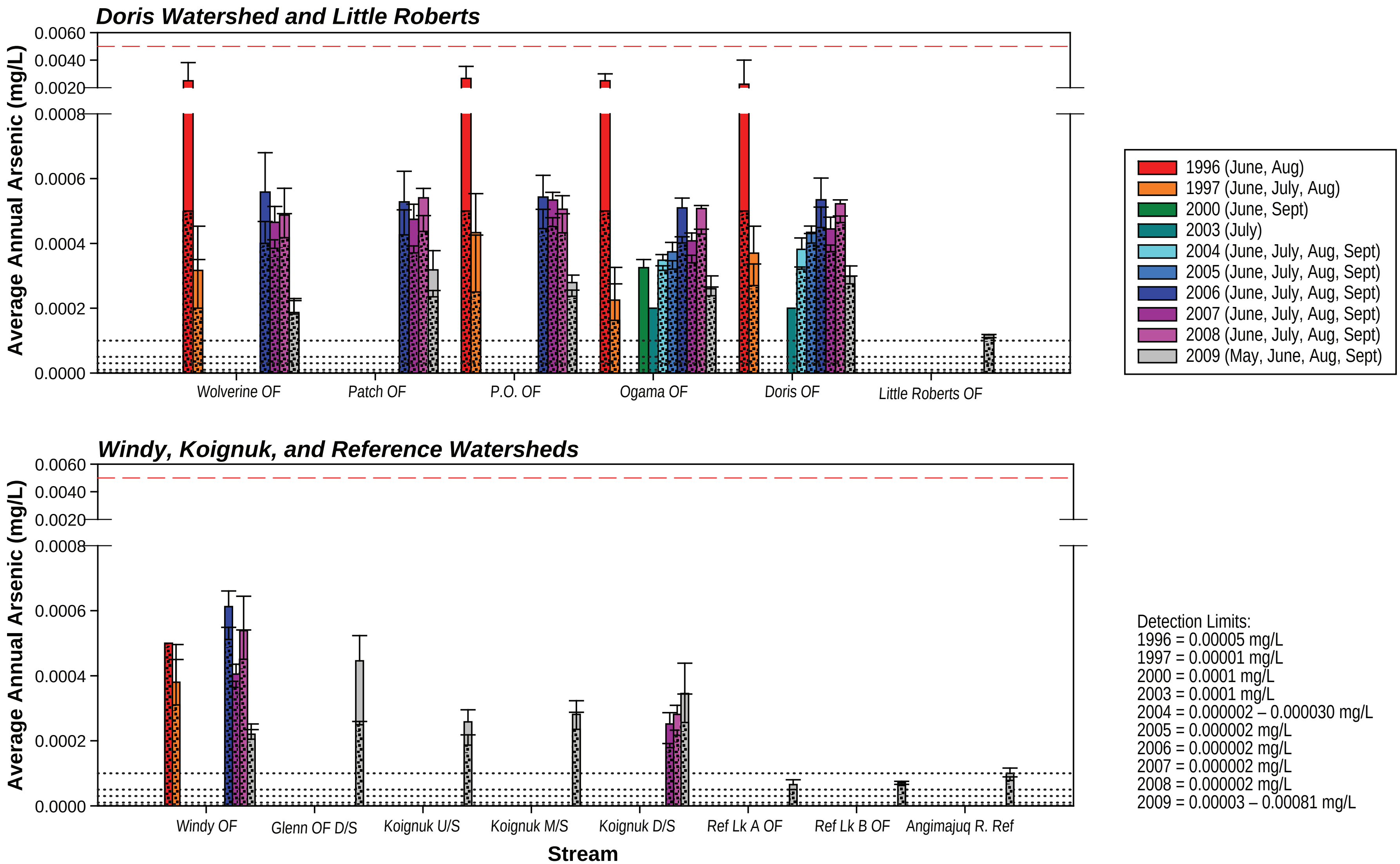


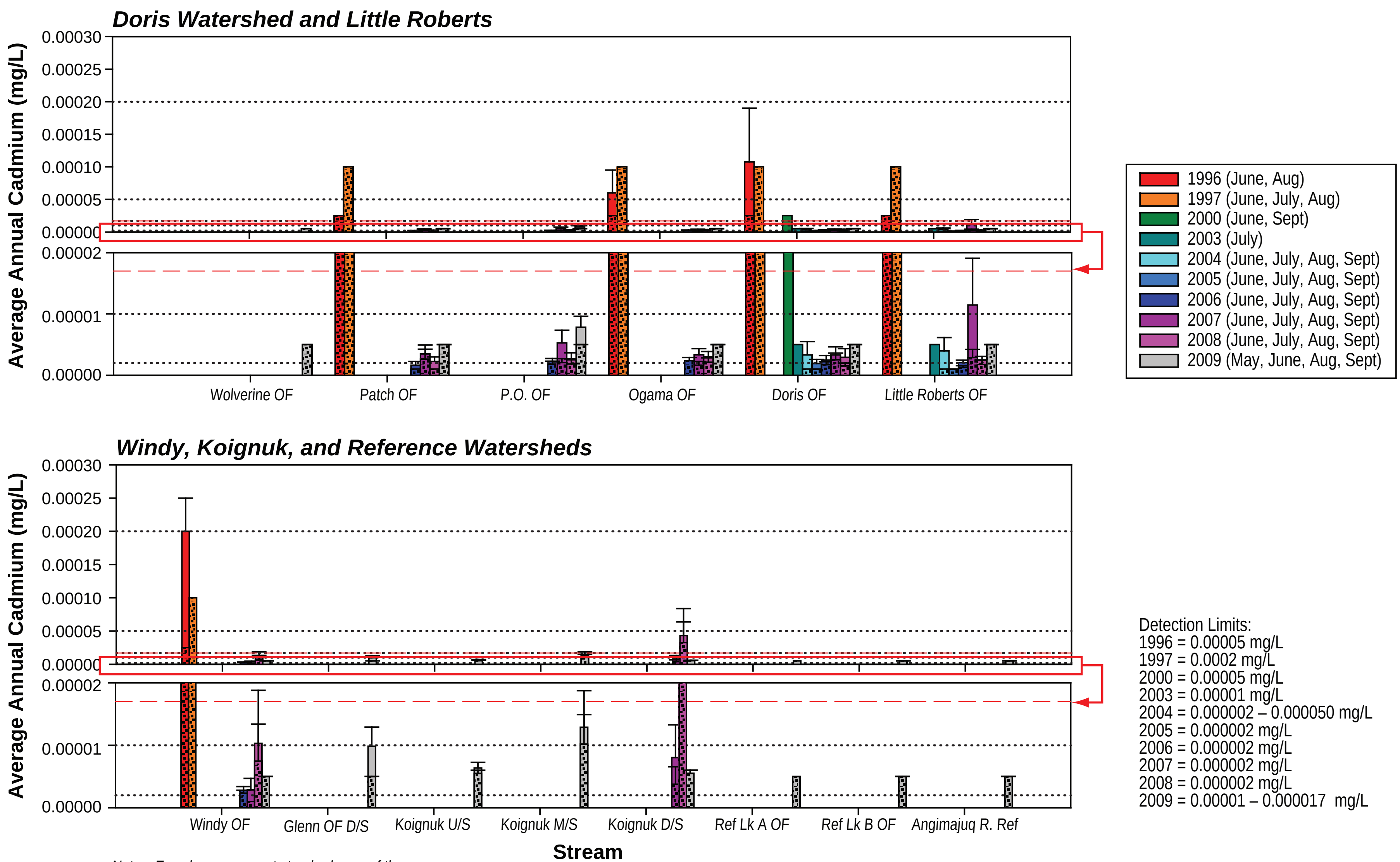
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.005 mg/L).
Dotted lines represent detection limits.
Solid columns represent total As and superimposed dotted columns represent dissolved As. In some cases, dissoved As was equal to or slightly exceeded total As, and the total As column is hidden.

Figure 3.3-2k

NEWMONT NORTH AMERICA

Average Annual Arsenic, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



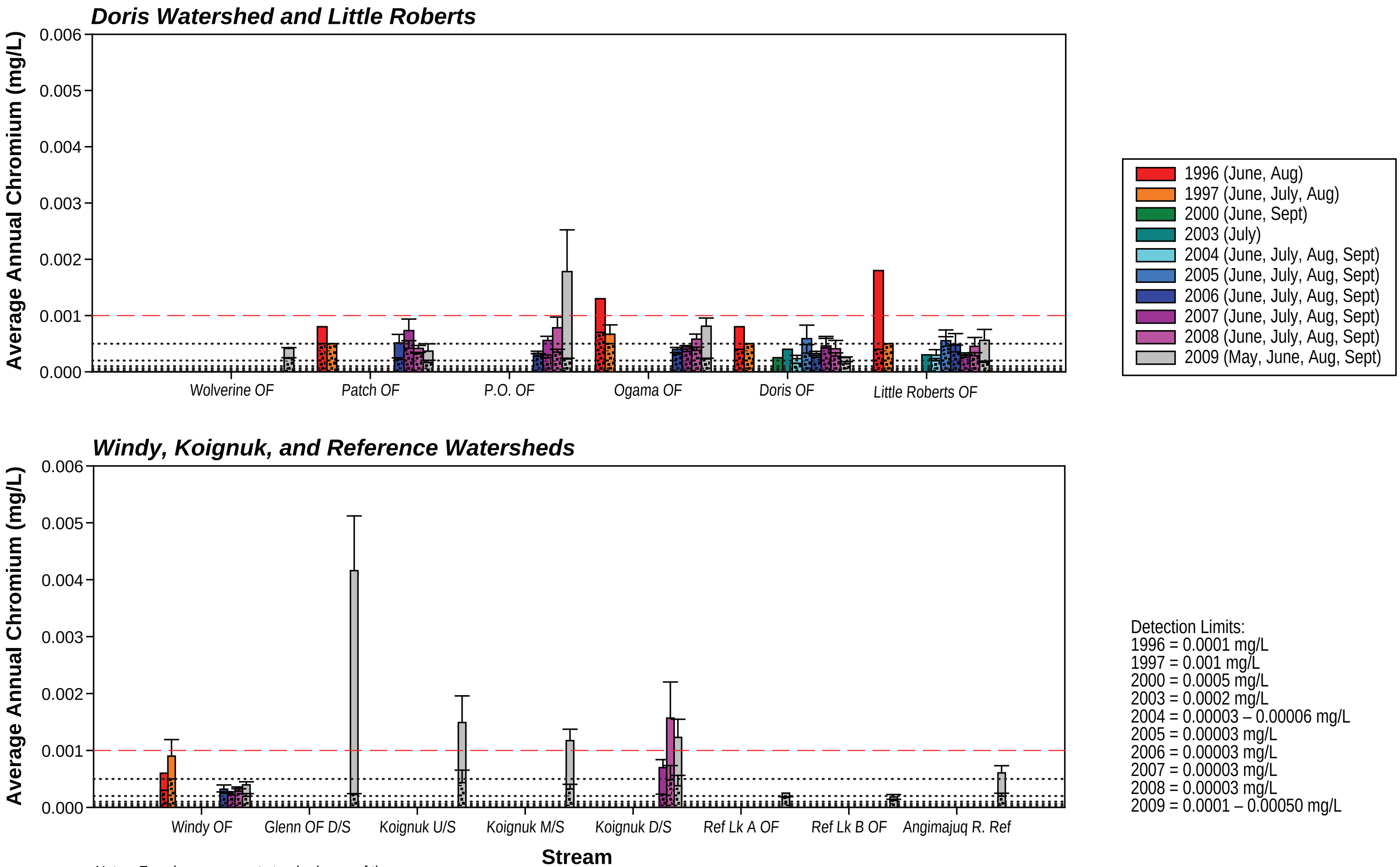
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.000017 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cd and superimposed dotted columns represent dissolved Cd. In some cases, dissoved Cd was equal to or slightly exceeded total Cd, and the total Cd column is hidden.

Figure 3.3-2l

NEWMONT NORTH AMERICA

Average Annual Cadmium, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cr and superimposed dotted columns represent dissolved Cr. In some cases, dissoved Cr was equal to or slightly exceeded total Cr, and the total Cr column is hidden.

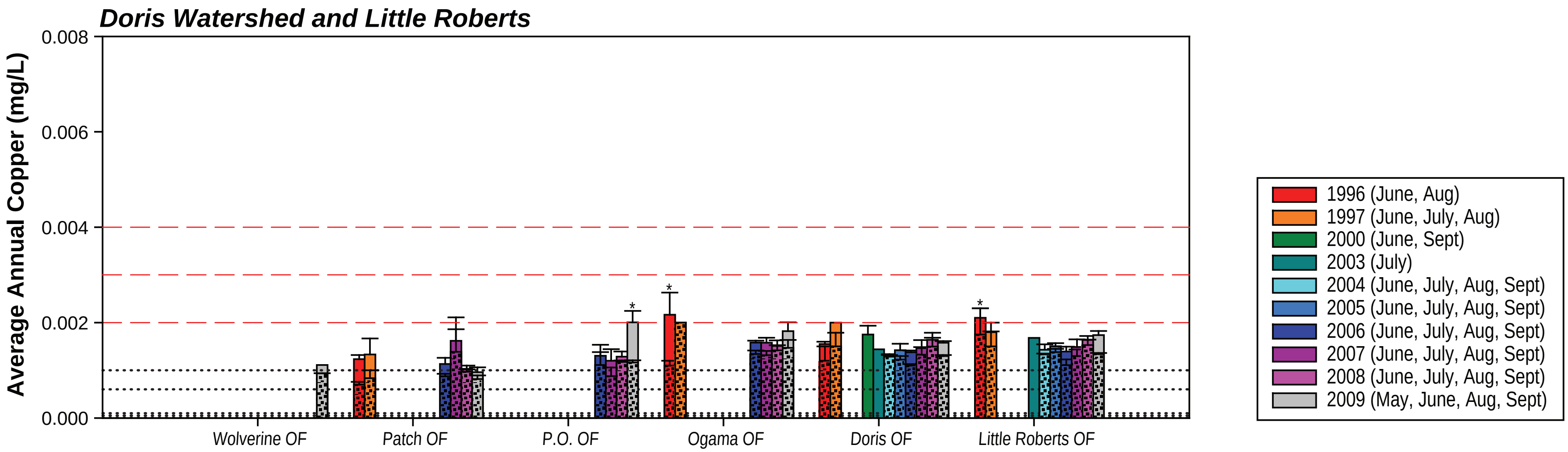
Figure 3.3-2m

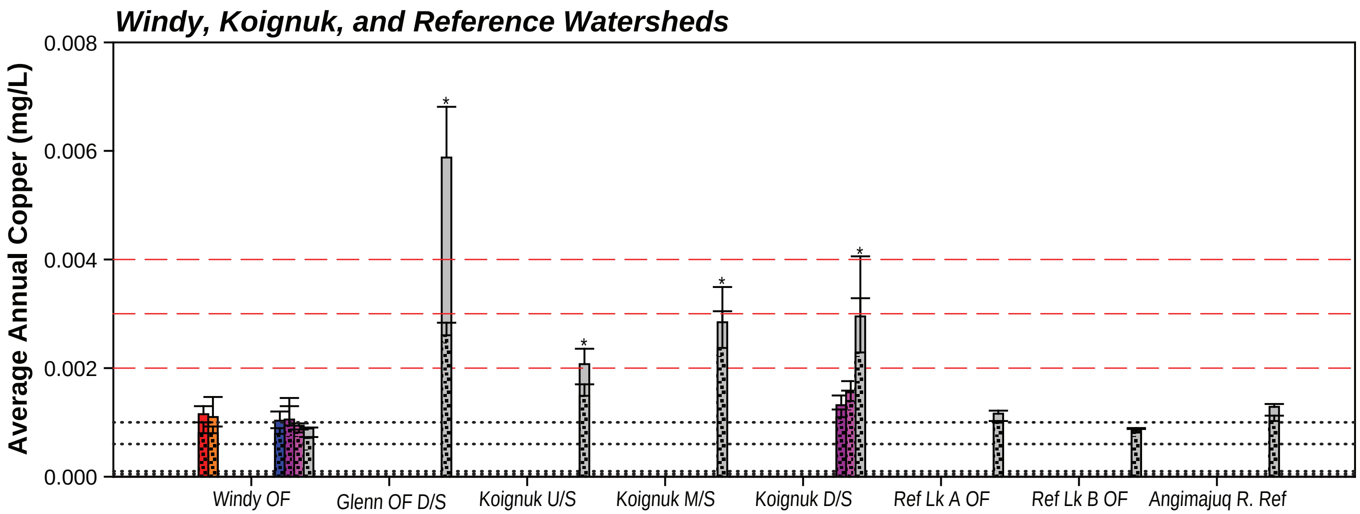
NEWMONT NORTH AMERICA

Average Annual Chromium, Hope Bay Streams, 1996 to 2009

Figure 3.3-2m

Rescan Engineers & Scientists





Detection Limits:
1996 = 0.0001 mg/L
1997 = 0.001 mg/L
2000 = 0.0001 mg/L
2003 = 0.00005 mg/L
2004 = 0.00005 – 0.00060 mg/L
2005 = 0.00005 mg/L
2006 = 0.000005 – 0.00010 mg/L
2007 = 0.00005 mg/L
2008 = 0.00005 mg/L
2009 = 0.0001 mg/L

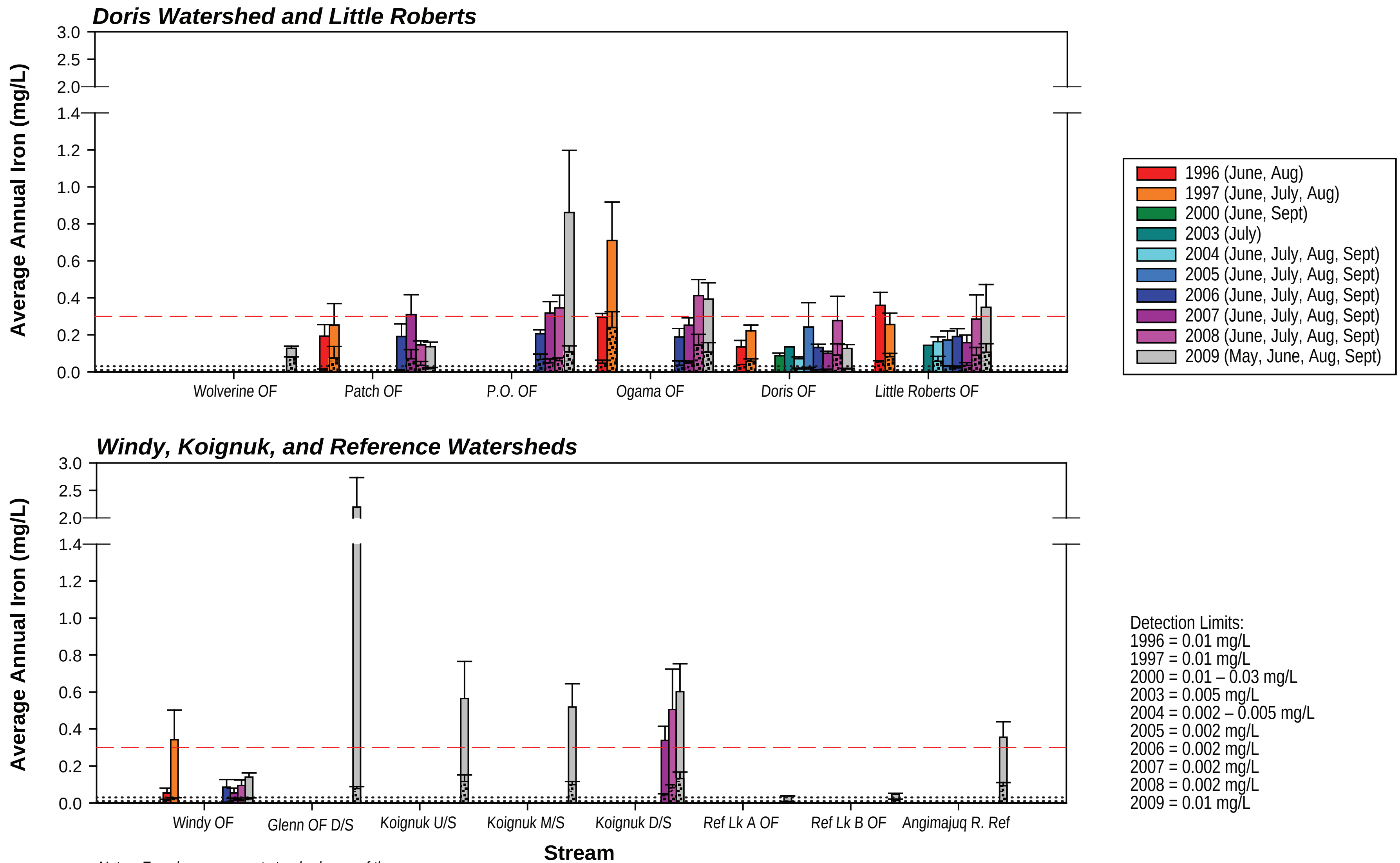
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.002 mg/L at [$CaCO_3$] of 0–120 mg/L; 0.003 mg/L at [$CaCO_3$] of 120–180 mg/L; 0.004 at [$CaCO_3$] of >180 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cu and superimposed dotted columns represent dissolved Cu. In some cases, dissoved Cu was equal to or slightly exceeded total Cu, and the total Cu column is hidden.
** Indicated values are higher than their sample guideline.*

Figure 3.3-2n

NEWMONT NORTH AMERICA

Average Annual Copper Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.3 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Fe and superimposed dotted columns represent dissolved Fe.

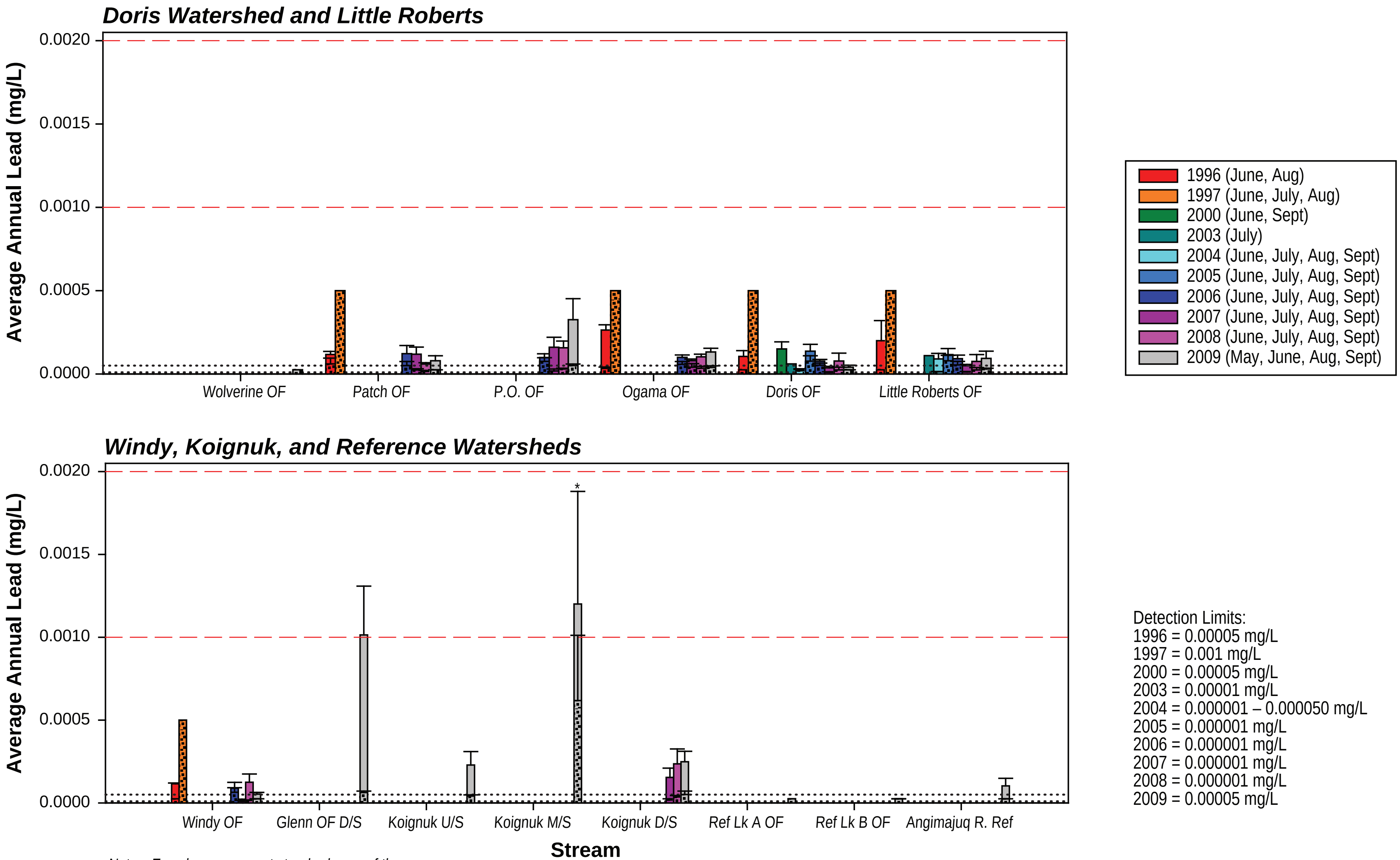
Figure 3.3-2o

NEWMONT NORTH AMERICA

Average Annual Iron Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists

Figure 3.3-2o



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L at [$CaCO_3$] of 0–60 mg/L; 0.002 mg/L at [$CaCO_3$] of 60–120 mg/L; 0.004 mg/L at [$CaCO_3$] of 120–180 mg/L; 0.007 at [$CaCO_3$] of >180 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Pb and superimposed dotted columns represent dissolved Pb. In some cases, dissoved Pb was equal to or slightly exceeded total Pb and the total Pb column is hidden.
** Indicated values that are higher than their sample guideline.*

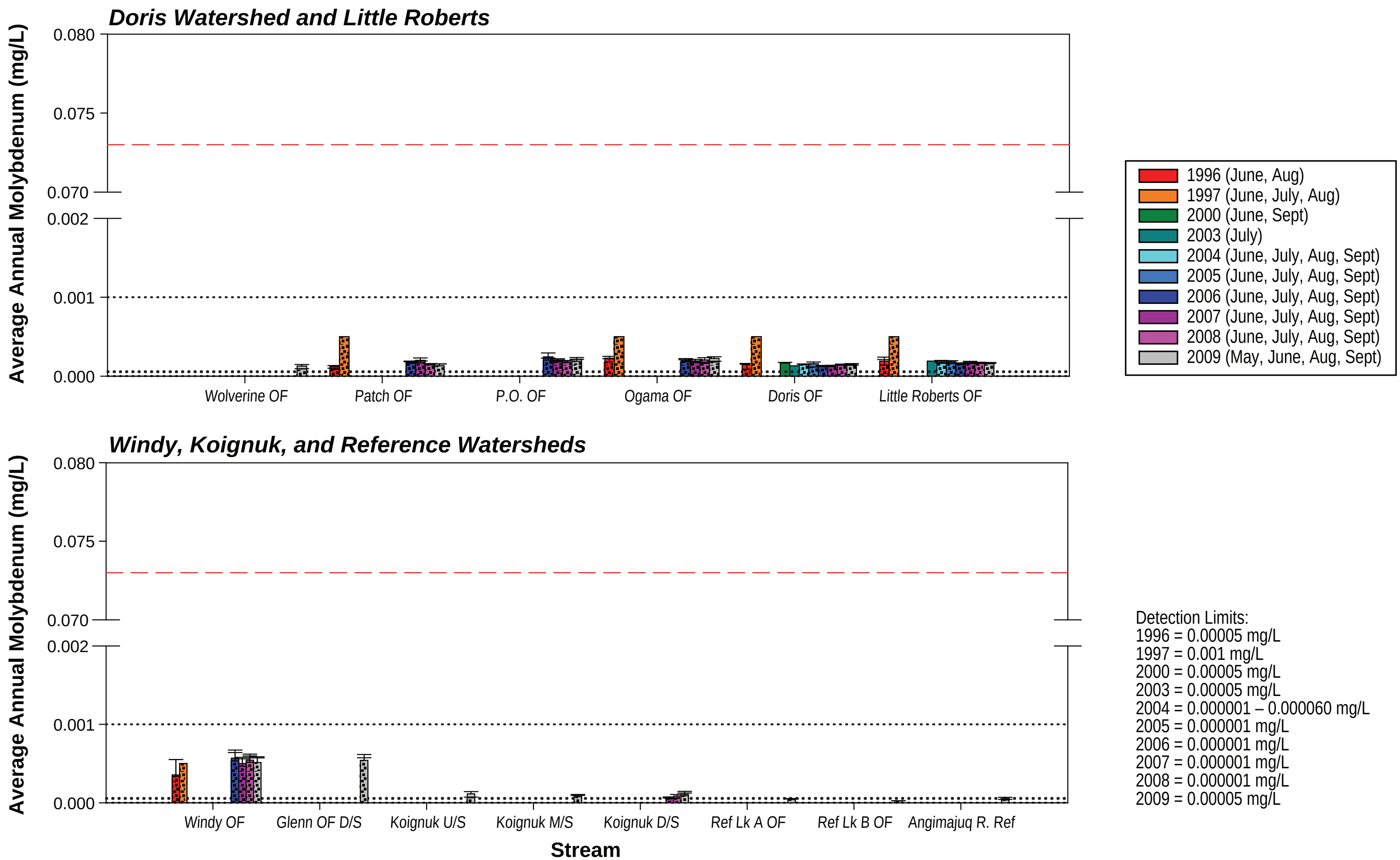
Figure 3.3-2p

NEWMONT NORTH AMERICA

Average Annual Lead, Hope Bay Streams, 1996 to 2009

Figure 3.3-2p

Rescan Engineers & Scientists



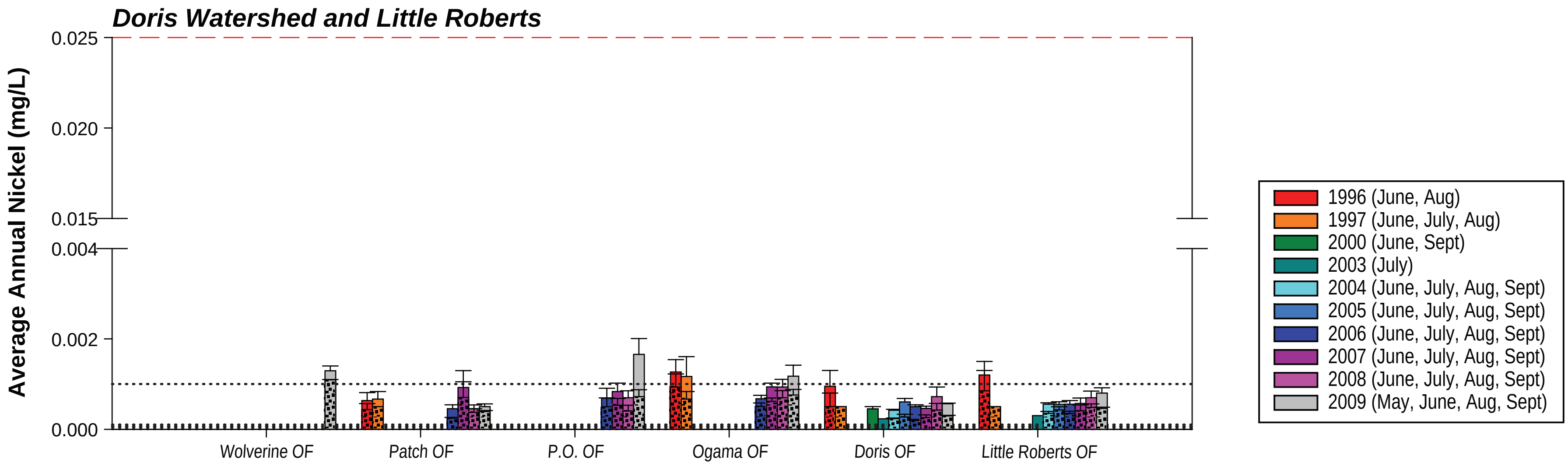
Notes: Error bars represent standard error of the mean.
CCME guideline = 0.073 mg/L.
Dotted lines represent detection limits.
Solid columns represent total Mo and superimposed dotted columns represent dissolved Mo. In some cases, dissoved Mo was equal to or slightly exceeded total Mo and the total Mo column is hidden.

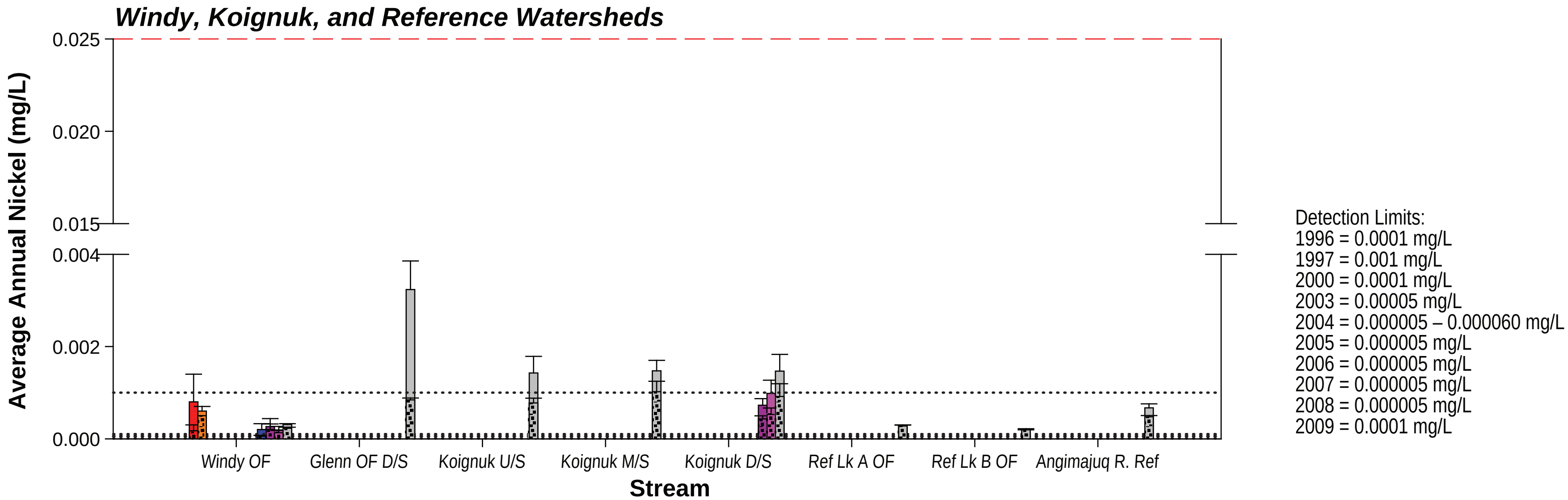
Figure 3.3-2q

NEWMONT NORTH AMERICA

Average Annual Molybdenum, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists





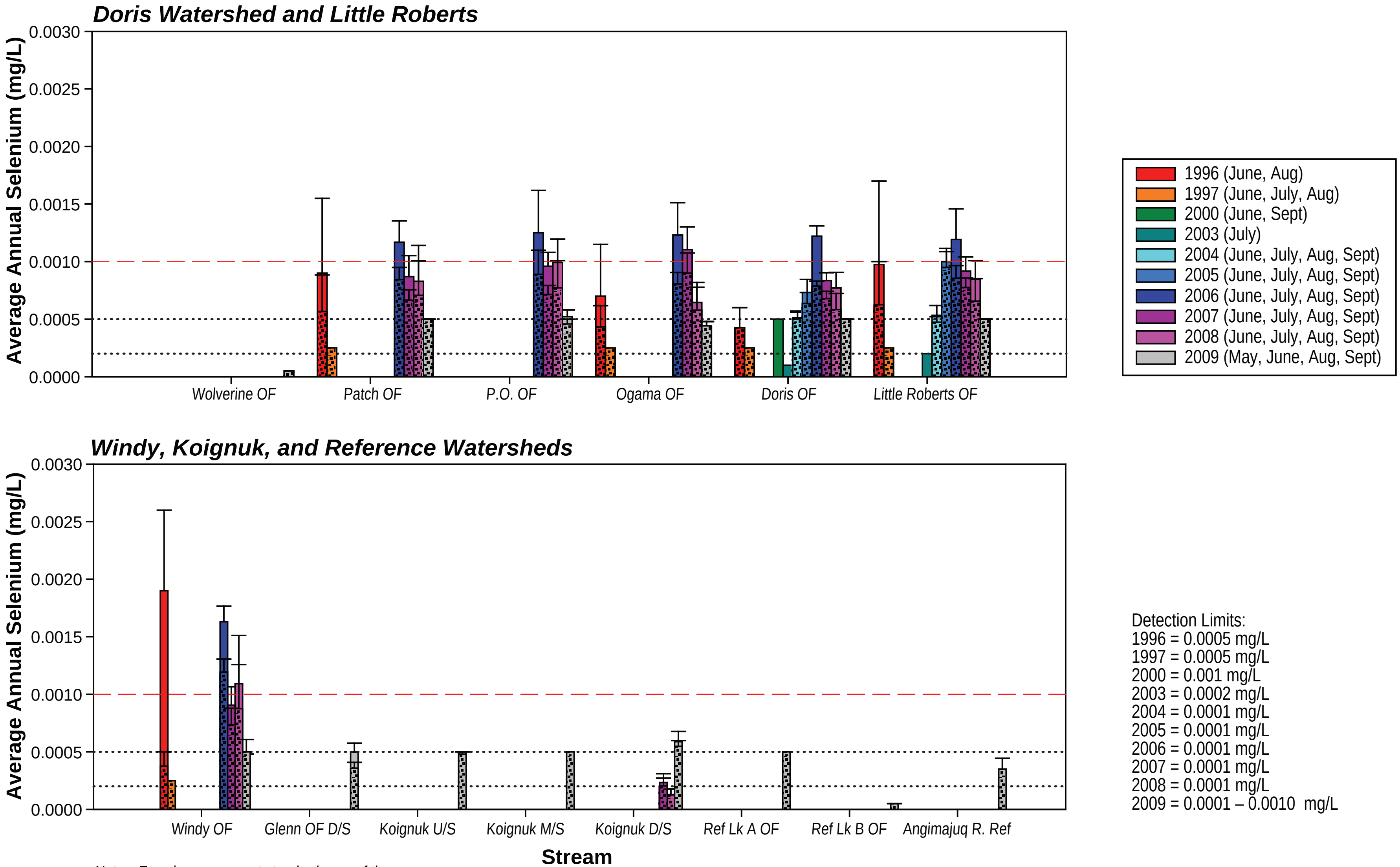
Notes: Error bars represent standard error of the mean.
CCME guideline = 0.025 mg/L at [$CaCO_3$] of 0–60 mg/L; 0.065 mg/L at [$CaCO_3$] of 60–120 mg/L; 0.110 mg/L at [$CaCO_3$] of 120–180; 0.150 mg/L at [$CaCO_3$] of >180 mg/L.
Dotted lines represent detection limits.
Solid columns represent total Ni and superimposed dotted columns represent dissolved Ni. In some cases, dissoved Ni was equal to or slightly exceeded total Ni and the total Ni column is hidden.

Figure 3.3-2r

NEWMONT NORTH AMERICA

Average Annual Nickel, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



Detection Limits:
1996 = 0.0005 mg/L
1997 = 0.0005 mg/L
2000 = 0.001 mg/L
2003 = 0.0002 mg/L
2004 = 0.0001 mg/L
2005 = 0.0001 mg/L
2006 = 0.0001 mg/L
2007 = 0.0001 mg/L
2008 = 0.0001 mg/L
2009 = 0.0001 – 0.0010 mg/L

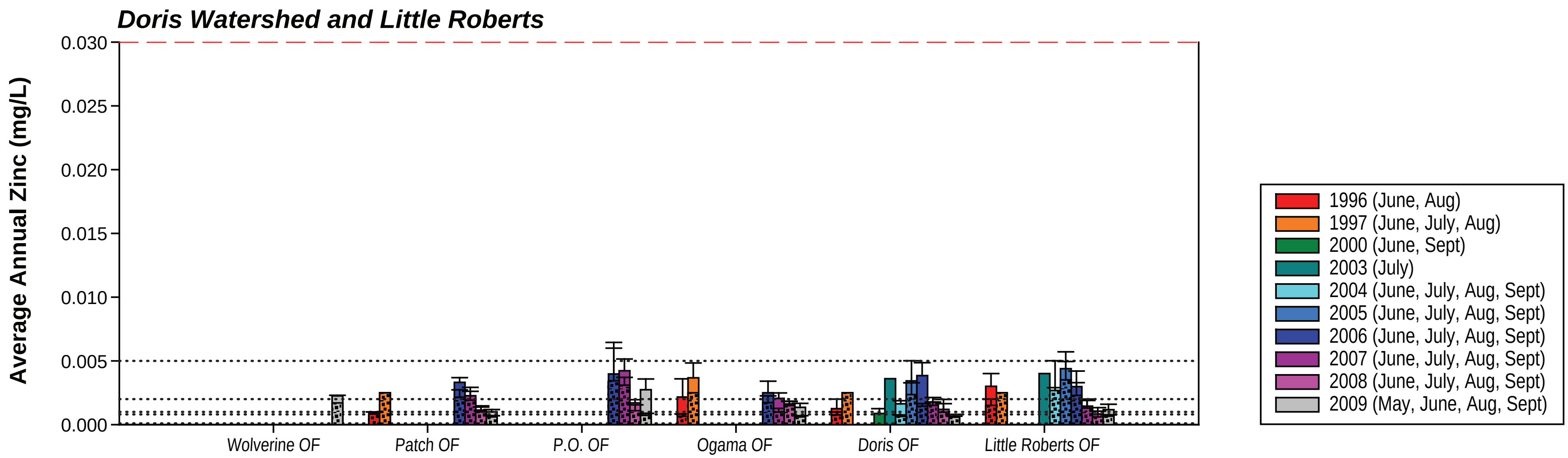
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Se and superimposed dotted columns represent dissolved Se. In some cases, dissoved Se was equal to or slightly exceeded total Se and the total Se column is hidden.

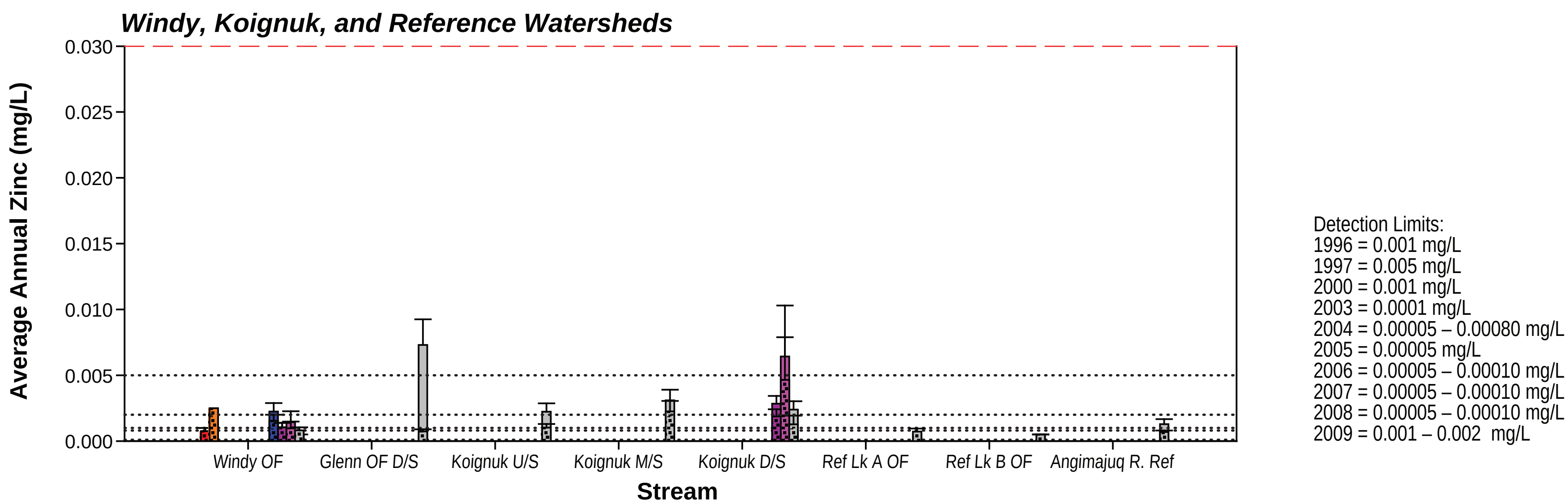
Figure 3.3-2s

NEWMONT NORTH AMERICA

Average Annual Selenium, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists





Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.03 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Zn and superimposed dotted columns represent dissolved Zn. In some cases, dissoved Zn was equal to or slightly exceeded total Zn and the total Zn column is hidden.

Figure 3.3-2u

NEWMONT NORTH AMERICA

Average Annual Zinc, Hope Bay Streams, 1996 to 2009

Figure 3.3-2t

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Glenn OF D/S runs from Glenn Lake, through soft marine sediments, to Roberts Bay. Samples taken from Glenn OF D/S exhibited clear seasonality in many water quality parameters. Levels of turbidity, total phosphorus, aluminum, chromium, copper, iron, nickel, lead, and zinc peaked during the June freshet sampling season, and then declined in subsequent summer samples. These peak freshet concentrations were often the highest observed during the entire 2009 stream sampling program. Based on the CCME's recommended trigger ranges for total phosphorus, Glenn OF D/S would be categorized as a eutrophic waterway during freshet (TP concentration of 0.053 mg/L), while the same stream would be considered mesotrophic in September (TP concentration of 0.018 mg/L). Similar (though less pronounced) seasonal trends were also seen in other streams and rivers (e.g., Little Robert OF, Angimajuq R. Ref).

The trend at P.O. OF was often the opposite of that seen in other streams, as peak levels of turbidity, total phosphorus, aluminum, chromium, and iron occurred in samples taken during September. Increases in molybdenum, TDS, and sulphate concentrations were also observed from June freshet to September in Windy OF and Glenn OF D/S.

3.3.2 Spatial Variation

All streams surveyed were similar in pH, with near neutral to slightly basic pH levels ranging from 6.9 (Koignuk U/S in May) to 8.1 (Patch OF in September). Turbidity was highly variable across sites, ranging from 0.37 NTU (Ref Lk B OF in August) to 215 NTU (Glenn OF D/S in June). Glenn OF D/S was a particularly turbid stream, averaging 102 NTU over all seasons sampled. The average turbidity in all other streams and rivers did not exceed 14 NTU.

Total phosphorus (TP) levels were variable across stream sites, ranging from 0.002 mg/L (Wolverine OF in June) to 0.053 mg/L (Glenn OF D/S in June). Within a watershed, TP concentrations generally increased with distance downstream. In the Doris Watershed, the lowest levels of TP were observed in Wolverine and Patch outflows, which would be categorized as ultra-oligotrophic and oligotrophic, respectively, based on the CCME trigger ranges for TP (CCME 2004). Stream sites located furthest downstream in the Doris and Little Roberts watersheds (Doris OF and Little Roberts OF) would be categorized as mesotrophic to meso-eutrophic. A similar trend was apparent in the Windy watershed, where the upstream Windy OF would be categorized as ultra-oligotrophic to oligotrophic, while the downstream Glenn OF D/S would be considered mesotrophic to eutrophic. River sites ranged from oligotrophic to mesotrophic in the Angimajuq and from oligotrophic to meso-eutrophic in the Koignuk (depending on the season).

Within the Koignuk River, several winter water quality parameters tended to increase in an upstream to downstream direction (e.g., TDS, TOC, nitrate, ammonia, sulphate, copper, iron, molybdenum, and nickel). During the freshet and summer sampling periods, there were no discernible spatial trends along this river.

In general, metal concentrations within Doris Watershed streams tended to be similar. A notable exception to this was P.O. OF samples taken in September, which contained elevated levels of aluminum, chromium, copper, iron, lead, nickel, and zinc compared to the other Doris Watershed stream samples. Within the Windy Watershed, total metal concentrations were markedly different between streams. Concentrations of aluminum, chromium, copper, iron, lead, nickel, and zinc in Glenn OF D/S were always the highest or among the highest measured in any stream in the study area, while Windy OF had among the lowest measured concentrations of these metals. Molybdenum was an exception to this pattern, as elevated concentrations of molybdenum were measured in both of these Windy Watershed streams (although still well below CCME guidelines). As seen for lake water quality, the

Windy Watershed as a whole had much higher molybdenum concentrations that the other watersheds in the study area. The Windy Watershed also contained higher levels of sulphate than the other watersheds.

3.3.3 Comparison with CCME Guidelines

Nitrate, nitrite, and ammonia concentrations in all streams and rivers were below CCME guidelines. Winter total copper concentrations along the Koignuk River ranged from 0.00301 to 0.00948 mg/L. These copper levels are elevated compared to the hardness dependent CCME guideline of 0.002 mg/L. At the midstream Koignuk site, the winter lead concentration of 0.00415 mg/L is higher than the hardness dependent CCME guideline of 0.002 mg/L.

During the June freshet at Glenn OF D/S, concentrations of aluminum, chromium, copper, iron, and lead were all higher than their respective CCME guidelines. While concentrations of these metals declined somewhat between freshet and late summer, all except lead continued to be higher than CCME guidelines during late summer.

With the exception of Ref Lk A and B OF, Doris OF, and Wolverine OF, average aluminum concentrations were higher than the CCME guideline of 0.1 mg/L in all streams and rivers surveyed. Concentrations of chromium, copper, and iron were also high relative to CCME guidelines in the Koignuk River, Glenn OF D/S, P.O. OF (chromium and iron only), Ogama OF (iron only), Little Roberts OF (iron only), and the Angimajuq R. Ref (iron only). Levels of aluminum, chromium, copper, andiron in Glenn OF D/S consistently surpassed guideline concentrations by the greatest factor. The average lead concentration in the Koignuk M/S site was higher than the hardness depended guideline for lead.

Table 3.3-1 gives the percentage of stream water quality samples in which parameter concentrations are higher than CCME guidelines, and Table 3.3-2 shows the factor by which average concentrations are higher than CCME guidelines (using the average concentration of each parameter within a stream/river site across various depths and seasons).

3.3.4 2009 Stream Water Quality Assurance/Quality Control

Travel and field blank data for the 2009 stream water quality sampling program are presented in Appendix 3.3-2. Three travel and three field blanks were collected in 2009, making up approximately 7% of samples analyzed. Only 2% of analytical results for field and travel blanks were above detection limits, and all of these were within 5x the detection limits. Variables above detection limits included ammonia, total boron, dissolved nickel, and zinc. Total boron concentrations were above detection limits in four out of the six blanks. No modifications were made to the dataset as a result of QA/QC samples.

3.3.5 Annual Variation

Historical data are available from some streams and rivers in the study area for the following periods: June and August 1996; June, July, and August 1997; June and September 2000; July 2003; June, July, August, and September 2004; June, July, August, and September 2005; June, July, August, and September 2006; June, July, August, and September 2007; June, July, August, and September 2008; and May, June, August, and September (this study). Figure 2.13-1 provides a summary of the historical water quality sampling locations. Table 2.13-2 presents a summary of the historical sampling times and methods. Only historical sampling locations that were also sampled in 2009 are discussed in this report. Note that historical sampling sites may not correspond exactly with those sampled in 2009, and this may contribute to the variability observed among years.

The differences among data sets in terms of when (months of collection) and where samples were collected can have a significant effect on annual averages for many parameters. Under-ice water samples can contain higher metal and nutrient concentrations than those collected in the summer, and parameters can also vary spatially along streams or rivers. Comparisons between years are further complicated by differences in analytical methodology and detection limits.

Since differences in sampling times, locations, and methodology have such a large effect on annual averages, the sampling information for each year, presented in Table 2.13-2, should be taken into consideration when reviewing annual stream water quality data presented in Figures 3.3-2a to 3.3-2t.

Historical concentrations of aluminum were frequently high in many Project area streams and rivers compared to the CCME guideline. As seen in 2009, Mo and sulphate concentrations in the Windy Watershed were consistently higher than molybdenum and sulphate concentrations in other watersheds in the study area during the years for which data are available.

3.3.6 Stream Water Quality Summary

Streams and rivers in the study area were neutral to slightly basic (with pH ranging from 6.9 to 8.1). Seasonal trends were apparent in some Hope Bay Belt streams and rivers. Parameters such as nitrate, ammonia, total phosphorus, copper, chromium, and nickel tended to be highest in winter or during freshet and lowest during the summer. These trends were most apparent in Glenn OF D/S and the Koignuk River. Turbidity levels were variable across streams, and were particularly high in Glenn OF D/S during freshet.

Nitrate and ammonia concentrations were frequently below detection limits, and reached maximum levels of 0.56 and 0.044 mg/L (for nitrate and ammonia respectively) in Koignuk River Upstream during winter. Nitrite concentrations were always below detection limits. Total phosphorus levels were variable across stream sites, ranging from 0.002 mg/L (Wolverine OF in June) to 0.053 mg/L (Glenn OF D/S in June). Within a watershed, total phosphorus concentrations generally increased with distance downstream. In the Doris Watershed, the lowest levels of total phosphorus were observed in Wolverine and Patch outflows, which would be categorized as ultra-oligotrophic and oligotrophic, respectively, based on the CCME trigger ranges for phosphorus (CCME 2004). Stream sites located furthest downstream in the Doris and Little Roberts watersheds (Doris OF and Little Roberts OF) would be categorized as mesotrophic to meso-eutrophic. A similar trend was apparent in the Windy Watershed, where the upstream Windy OF would be categorized as ultra-oligotrophic to oligotrophic, while the downstream Glenn OF D/S would be considered mesotrophic to eutrophic. River sites ranged from oligotrophic to mesotrophic in the Angimajuq and from oligotrophic to meso-eutrophic in the Koignuk (depending on the season).

In general, concentrations of total metals were highest in Glenn OF D/S and lowest in Windy OF. Molybdenum levels tended to be highest within the streams of the Windy Watershed compared to the other watersheds. These trends are consistent with the lake water quality data, indicating that the water quality of streams reflects the water quality of the upstream lakes that feed them. Average metal concentrations in streams and rivers were generally below CCME guidelines, with the following exceptions: aluminum in all streams/rivers except Wolverine OF, Doris OF, and Ref Lk A and B OF; chromium in P.O. OF, Glenn OF D/S, and the Koignuk River sites; copper in Glenn OF D/S, and Koignuk M/S and D/S; iron in P.O. OF, Ogama OF, Little Roberts OF, Glenn OF D/S, and the Angimajuq and Koignuk River sites; and lead in Koignuk M/S. These elevated concentrations occur naturally within study area streams and rivers.

Table 3.3-1. Stream Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline Valuea:	pH 6.5-9.0	Ammonia (as N) worst case 5.86 mg/L (assumes T=0, pH = 7.5)	Nitrate (as N) 2.93 mg/L	Nitrite (as N) 0.06 mg/L	Total Phosphorus Trophic Statusb	Aluminum (Al) - Total 0.005-0.1c mg/L	Arsenic (As)-Total 0.005 mg/L	Cadmium (Cd)-Total 0.000017 mg/L	Chromium (Cr)-Total 0.001 mg/L
Doris											
Wolverine OF	2		0	0	0	0	Ultra-oligotrophic	0	0	0	0
Patch OF	6		0	0	0	0	Oligotrophic	33	0	0	0
P.O. OF	6		0	0	0	0	Oligotrophic to Eutrophic	100	0	0	33
Ogama OF	6		0	0	0	0	Meso-eutrophic	100	0	0	17
Doris OF	6		0	0	0	0	Mesotrophic to Meso-eutrophic	0	0	0	0
Little Roberts											
Little Roberts OF	6		0	0	0	0	Mesotrophic to Meso-eutrophic	67	0	0	33
Windy											
Windy OF	6		0	0	0	0	Ultra-oligotrophic to Oligotrophic	67	0	0	0
Glenn OF D/S	6		0	0	0	0	Mesotrophic to Eutrophic	100	0	33	100
Koignuk River											
Koignuk U/S	7		0	0	0	0	Oligotrophic to Meso-eutrophic	100	0	0	43
Koignuk M/S	8		0	0	0	0	Oligotrophic to Meso-eutrophic	100	0	25	75
Koignuk D/S	7		0	0	0	0	Oligotrophic to Meso-eutrophic	100	0	0	43
Ref A											
Ref Lk A OF	4		0	0	0	0	Oligotrophic	0	0	0	0
Ref B											
Ref Lk B OF	6		0	0	0	0	Ultra-oligotrophic to Oligotrophic	0	0	0	0
Angimajuq											
Angimajuq Riv Ref	6		0	0	0	0	Oligotrophic to Mesotrophic	67	0	0	0
Total Sites			**0**	**0**	**0**	**0**	-	**10**	**0**	**2**	**7**

All values represent percentages of 2009 samples higher than CCME guidelines

(continued)

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.3-1. Stream Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Stream	Total Number of Samples Collected	CCME Guideline Valuea:	Copper Cu)-Total 0.002-0.004d mg/L	Iron (Fe)-Total 0.3 mg/L	Lead (Pb)-Total 0.001-0.007e mg/L	Mercury (Hg)-Total 0.000026 mg/L	Molybdenum (Mo)-Total 0.073 mg/L	Nickel (Ni)-Total 0.025-0.110f mg/L	Selenium (Se)-Total 0.001 mg/L	Silver (Ag)-Total 0.0001 mg/L	Thallium (Ag)-Total 0.00088 mg/L	Zinc (Zn)-Total 0.03 mg/L
Doris												
Wolverine OF	2		0	0	0	0	0	0	0	0	0	0
Patch OF	6		0	0	0	0	0	0	0	0	0	0
P.O. OF	6		33	67	0	0	0	0	0	0	0	0
Ogama OF	6		33	67	0	0	0	0	0	0	0	0
Doris OF	6		0	0	0	0	0	0	0	0	0	0
Little Roberts												
Little Roberts OF	6		17	33	0	0	0	0	0	0	0	0
Windy												
Windy OF	6		0	0	0	0	0	0	0	0	0	0
Glenn OF D/S	6		100	100	33	0	0	0	0	0	0	0
Koignuk River												
Koignuk U/S	7		43	71	0	0	0	0	0	0	0	0
Koignuk M/S	8		63	50	25	0	0	0	0	0	0	0
Koignuk D/S	7		43	71	0	0	0	0	14	0	0	0
Ref A												
Ref Lk A OF	4		0	0	0	0	0	0	0	0	0	0
Ref B												
Ref Lk B OF	6		0	0	0	0	0	0	0	0	0	0
Angimajuq												
Angimajuq Riv Ref	6		0	33	0	0	0	0	0	0	0	0
Total Sites			**7**	**8**	**2**	**0**	**0**	**0**	**1**	**0**	**0**	**0**

All values represent percentages of 2009 samples higher than CCME guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophi

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.3-2. Stream Water Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline Value[a]:	pH 6.5-9.0	Ammonia (as N) worst case 5.86 mg/L (assumes T=0, pH = 7.5)	Nitrate (as N) 2.93 mg/L	Nitrite (as N) 0.06 mg/L	Total Phosphate (as P) Trophic Status[b]	Aluminum (Al) -Total 0.005-0.1[c] mg/L	Arsenic (As) -Total 0.005 mg/L	Cadmium (Cd) -Total 0.000017 mg/L	Chromium (Cr) -Total 0.001 mg/L
Doris											
Wolverine OF	2		-	-	-	-	Ultra-oligotrophic	-	-	-	-
Patch OF	6		-	-	-	-	Oligotrophic	1.3	-	-	-
P.O. OF	6		-	-	-	-	Oligotrophic to Eutrophic	8.7	-	-	1.8
Ogama OF	6		-	-	-	-	Meso-eutrophic	3.2	-	-	-
Doris OF	6		-	-	-	-	Mesotrophic to Meso-eutrophic	-	-	-	-
Little Roberts											
Little Roberts OF	6		-	-	-	-	Mesotrophic to Meso-eutrophic	2.5	-	-	-
Windy											
Windy OF	6		-	-	-	-	Ultra-oligotrophic to Oligotrophic	1.3	-	-	-
Glenn OF D/S	6		-	-	-	-	Mesotrophic to Eutrophic	20.7	-	-	4.2
Koignuk River											
Koignuk U/S	7		-	-	-	-	Oligotrophic to Meso-eutrophic	5.0	-	-	1.5
Koignuk M/S	8		-	-	-	-	Oligotrophic to Meso-eutrophic	4.4	-	-	1.2
Koignuk D/S	7		-	-	-	-	Oligotrophic to Meso-eutrophic	5.3	-	-	1.2
Ref A											
Ref Lk A OF	4		-	-	-	-	Oligotrophic	-	-	-	-
Ref B											
Ref Lk B OF	6		-	-	-	-	Ultra-oligotrophic to Oligotrophic	-	-	-	-
Angimajuq											
Angimajuq R. Ref	6		-	-	-	-	Oligotrophic to Mesotrophic	2.0	-	-	-
Total Sites			**0**	**0**	**0**	**0**	**-**	**10**	**0**	**0**	**5**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines

(continued)

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be

Dashes represent averages that are not higher than guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.3-2. Stream Water Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Stream	Total Number of Samples Collected	CCME Guideline Value[a]:	Copper (Cu)-Total 0.002-0.004[d] mg/L	Iron (Fe)-Total 0.3 mg/L	Lead (Pb)-Total 0.001-0.007[e] mg/L	Mercury (Hg)-Total 0.000026 mg/L	Molybdenum (Mo)-Total 0.073 mg/L	Nickel (Ni)-Total 0.025-0.110[f] mg/L	Selenium (Se)-Total 0.001 mg/L	Silver (Ag)-Total 0.0001 mg/L	Thallium (Ag)-Total 0.00088 mg/L	Zinc (Zn)-Total 0.03 mg/L
Doris												
Wolverine OF	2		-	-	-	-	-	-	-	-	-	-
Patch OF	6		-	-	-	-	-	-	-	-	-	-
P.O. OF	6			2.9	-	-	-	-	-	-	-	-
Ogama OF	6		-	1.3	-	-	-	-	-	-	-	-
Doris OF	6		-	-	-	-	-	-	-	-	-	-
Little Roberts												
Little Roberts OF	6		-	1.2	-	-	-	-	-	-	-	-
Windy												
Windy OF	6		-	-	-	-	-	-	-	-	-	-
Glenn OF D/S	6		2.9	7.3		-	-	-	-	-	-	-
Koignuk River												
Koignuk U/S	7			1.9	-	-	-	-	-	-	-	-
Koignuk M/S	8		1.4	1.7	1.2	-	-	-	-	-	-	-
Koignuk D/S	7		1.5	2.0	-	-	-	-	-	-	-	-
Ref A												
Ref Lk A OF	4		-	-	-	-	-	-	-	-	-	-
Ref B												
Ref Lk B OF	6		-	-	-	-	-	-	-	-	-	-
Angimajuq												
Angimajuq R. Ref	6		-	1.2	-	-	-	-	-	-	-	-
Total Sites			**3**	**8**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be

Dashes represent averages that are not higher than guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

The 2009 sampling program supplemented the historical water quality database and provided low-detection limit data for an expanded number of streams and rivers.

3.4 LAKE SEDIMENT QUALITY

Lake sediment samples were collected from a total of 15 sites in 13 lakes, during August 2009 (see Table 2.1-4 for locations and dates of collection). All sediment samples collected were compared to CCME guidelines for the protection of aquatic life: the interim sediment quality guidelines (ISQGs) and the probable effects levels (PELs; CCME 2002). The more conservative ISQGs are levels below which adverse biological effects are rarely observed, whereas the higher PELs correspond to concentrations above which negative effects frequently occur.

The 2009 sediment quality program focused on characterizing the natural variation in lake sediments with depth and by lake. Lakes sampled resided within a number of different watersheds and included two reference lakes located ~10 km away from the location of potential mining activities.

Lake sediment descriptions and photographs can be found in Appendix 3.4-1 and 3.4-2, respectively. All lake sediment quality analytical data for 2009 are provided in Appendix 3.4-3. Figure 3.4-1 presents results from particle size analyses. Graphical representations of selected sediment quality variables are presented in Figures 3.4-2a to 3.4-2l. Historical data are presented in Figures 3.4-3a to 3.4-3l.

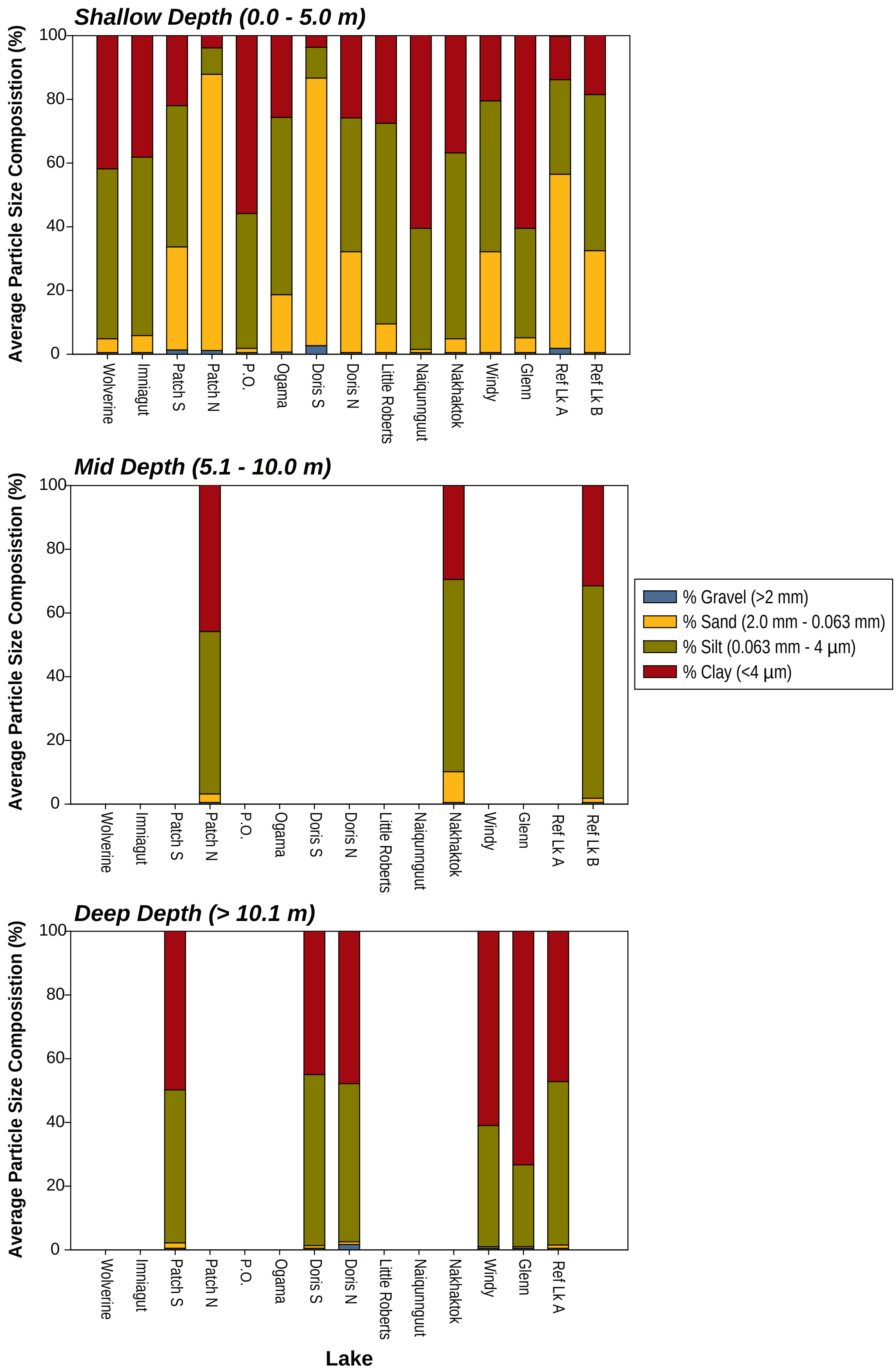
3.4.1 Depth Variation

Lake sediments were largely composed of clay and silt, with lesser amounts of sand and little gravel. Finer sediments (silt and clays) were more dominant at depth, with sands and gravels accounting for less than 4% of the particle size composition at depths greater than 5 m at all sites except Nakhaktok Lake (sand + gravel = 11% at >5 m depth, 5% at <5 depth). Sands were dominant in the shallow depth zones of Patch N, Doris S, and Ref Lk A.

Many sediment parameters had higher concentrations at mid- to deep depth (>5 m) zones than in the shallow depth zone, likely due to the increase in finer sediments with depth. Parameters that increased in concentration with depth included: TOC, ammonium, total nitrogen, total sulphur, arsenic, cadmium, chromium, copper, lead, mercury, and zinc. This was consistent across all sites, except for Nakhaktok Lake, where the opposite was always observed, and Glenn Lake, which showed little difference with depth. Total phosphorus did not consistently increase with depth, although the highest concentration observed was at Ref Lk A, deep depth (77.2 mg/L).

3.4.2 Spatial Variation

There were few clear trends in parameter concentrations among sites. Spatial differences in parameters such as TOC, and nitrogen and phosphorus were relatively greater than differences in metal concentrations. Compared to other lakes, the upstream Windy Watershed lakes, Wolverine and Imniagut, had higher concentrations of TOC (averages of 7.83 and 7.82%, respectively), ammonium (averages of 73.3 and 66.2 mg/kg, respectively), total nitrogen (averages of 0.78 and 1.00 mg/kg, respectively), and total sulphur (averages of 2,010 and 3,500 mg/kg, respectively). No obvious watershed-wide patterns were observed.



NEWMONT NORTH AMERICA

Sediment Particle Size Composition, Hope Bay Lakes, August 2009

Figure 3.4-1

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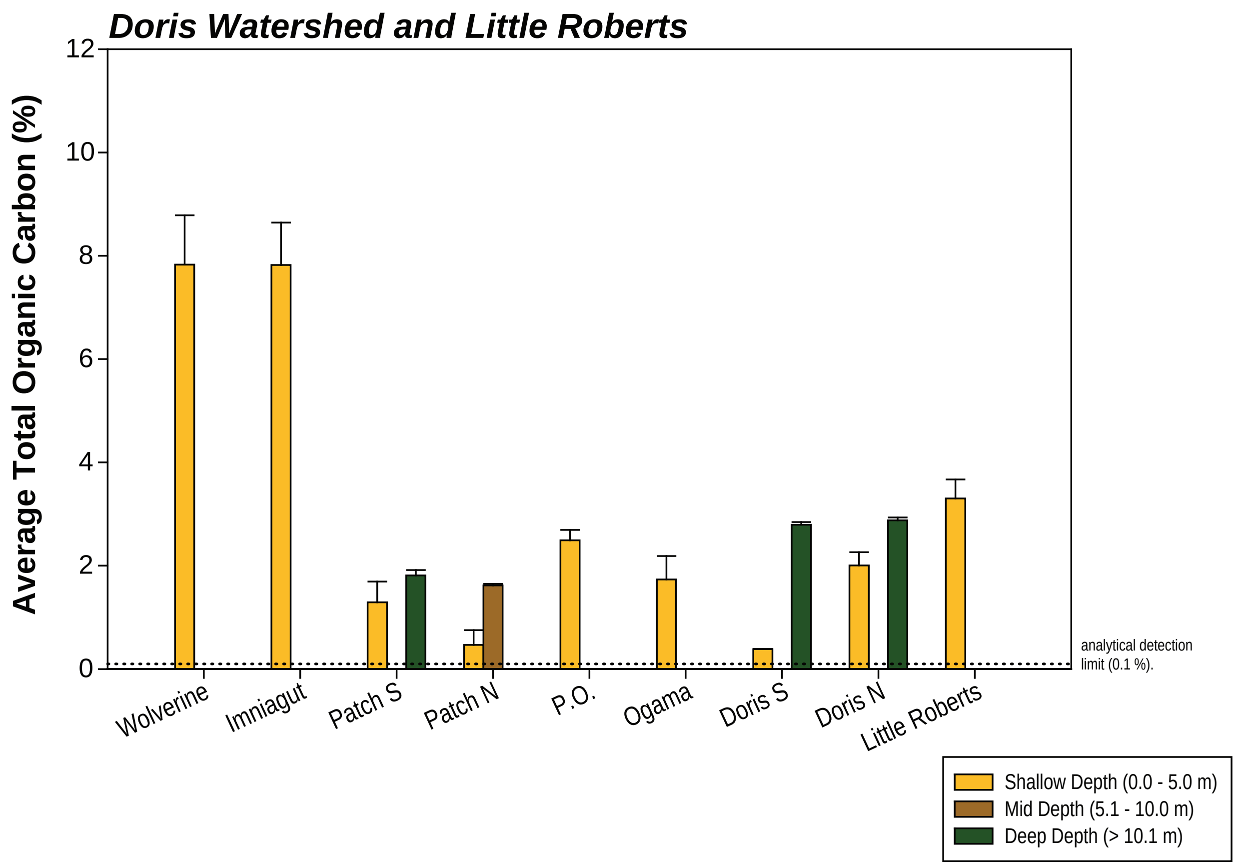
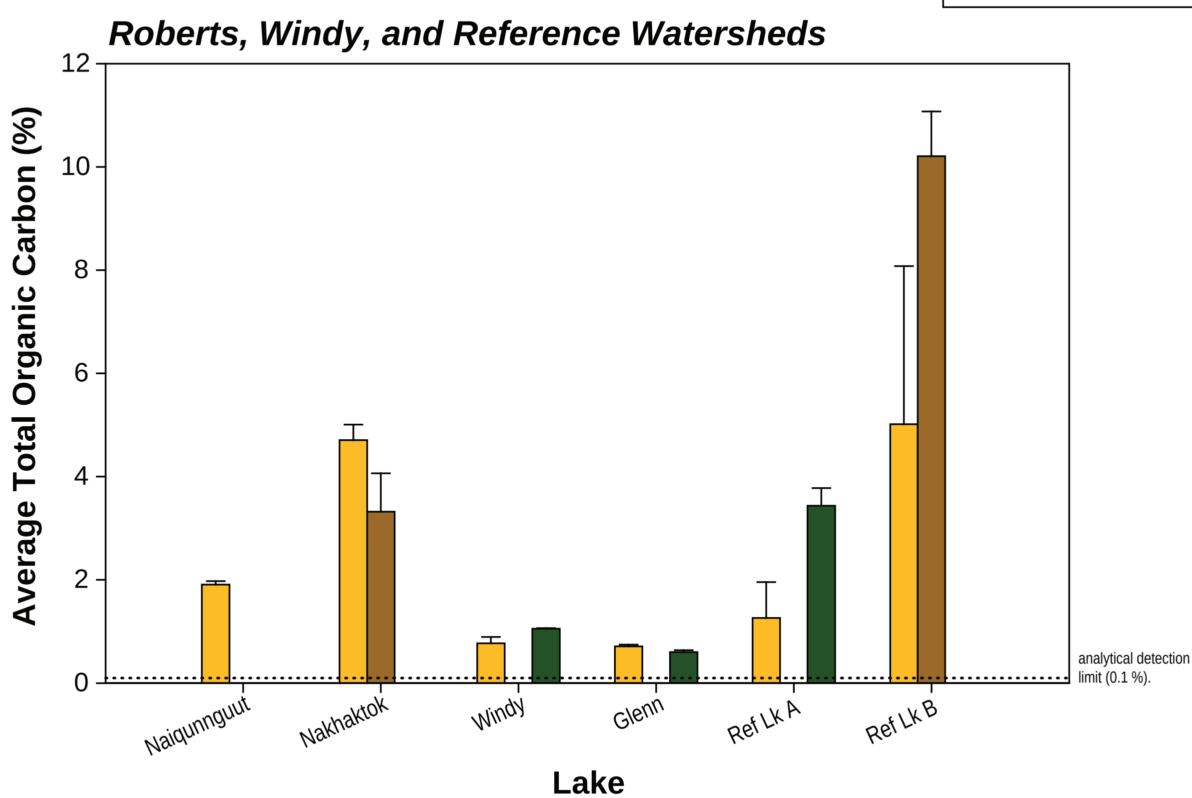




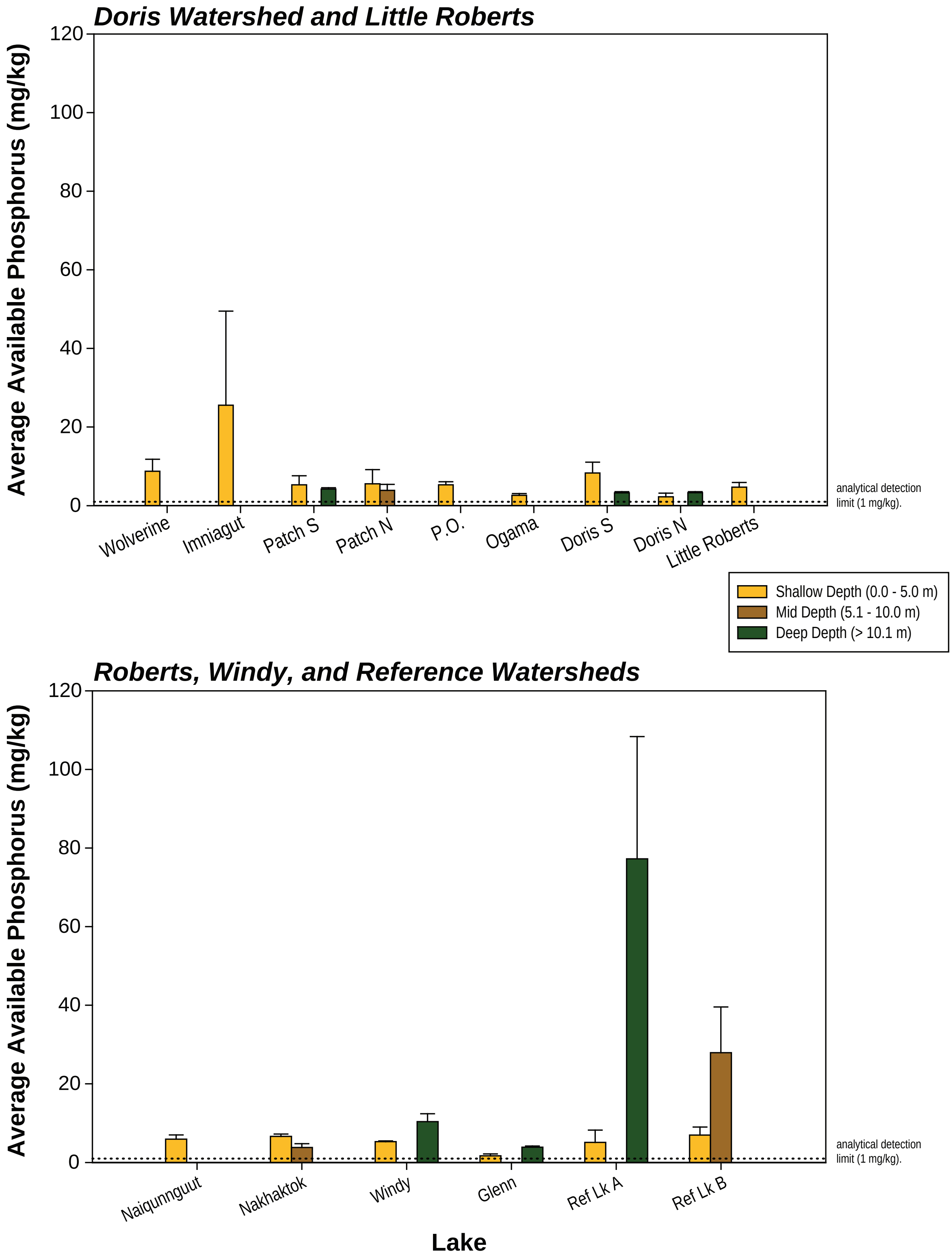
Notes: Error bars represent standard error of the mean.
No SQGs exist for total organic carbon.

NEWMONT NORTH AMERICA

Average Concentration of Total Organic Carbon in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2a

Rescan Engineers & Scientists



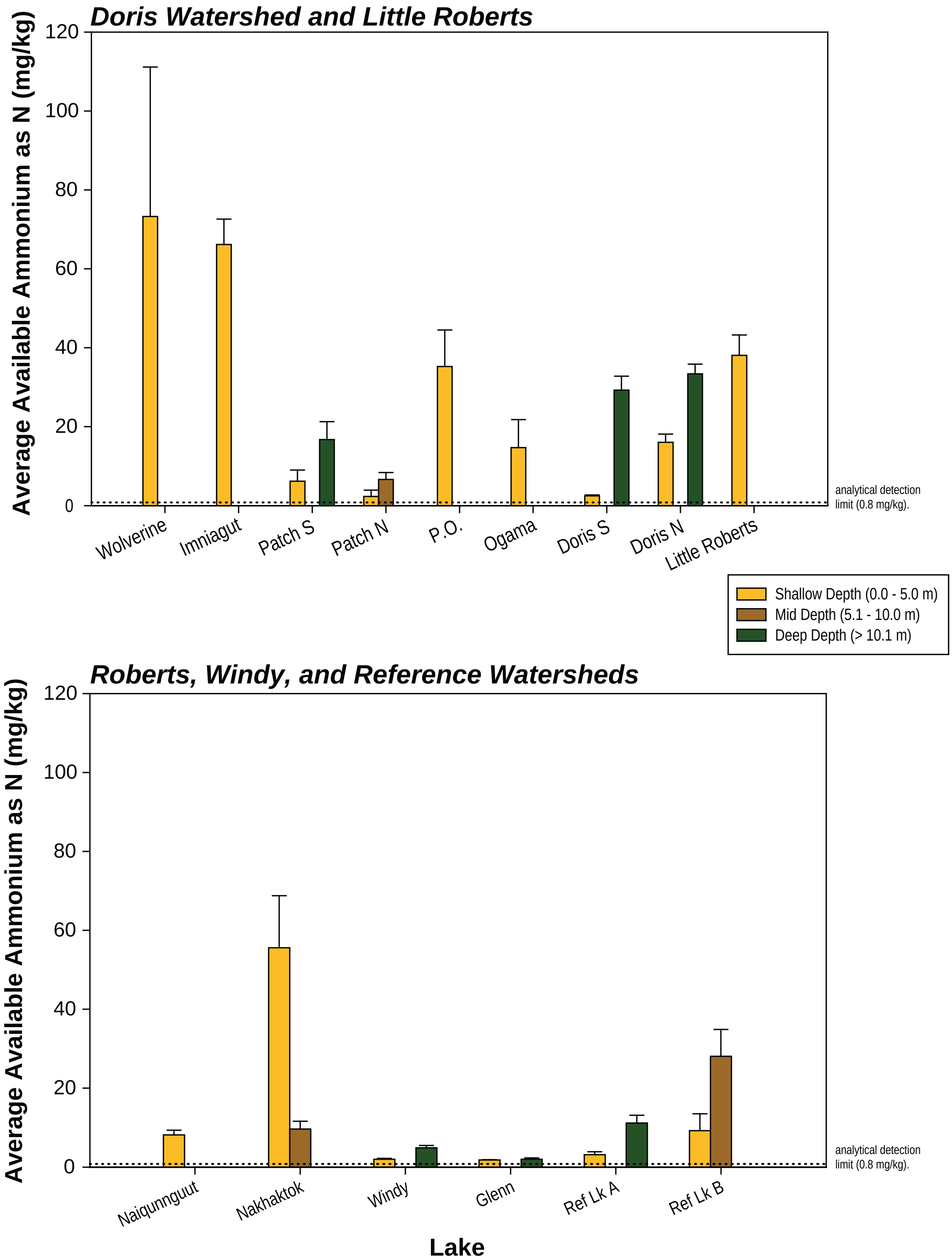
Notes: Error bars represent standard error of the mean.
No SQGs exist for available phosphorus.

NEWMONT NORTH AMERICA

Average Concentration of Available Phosphorus in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2b

Rescan Engineers & Scientists



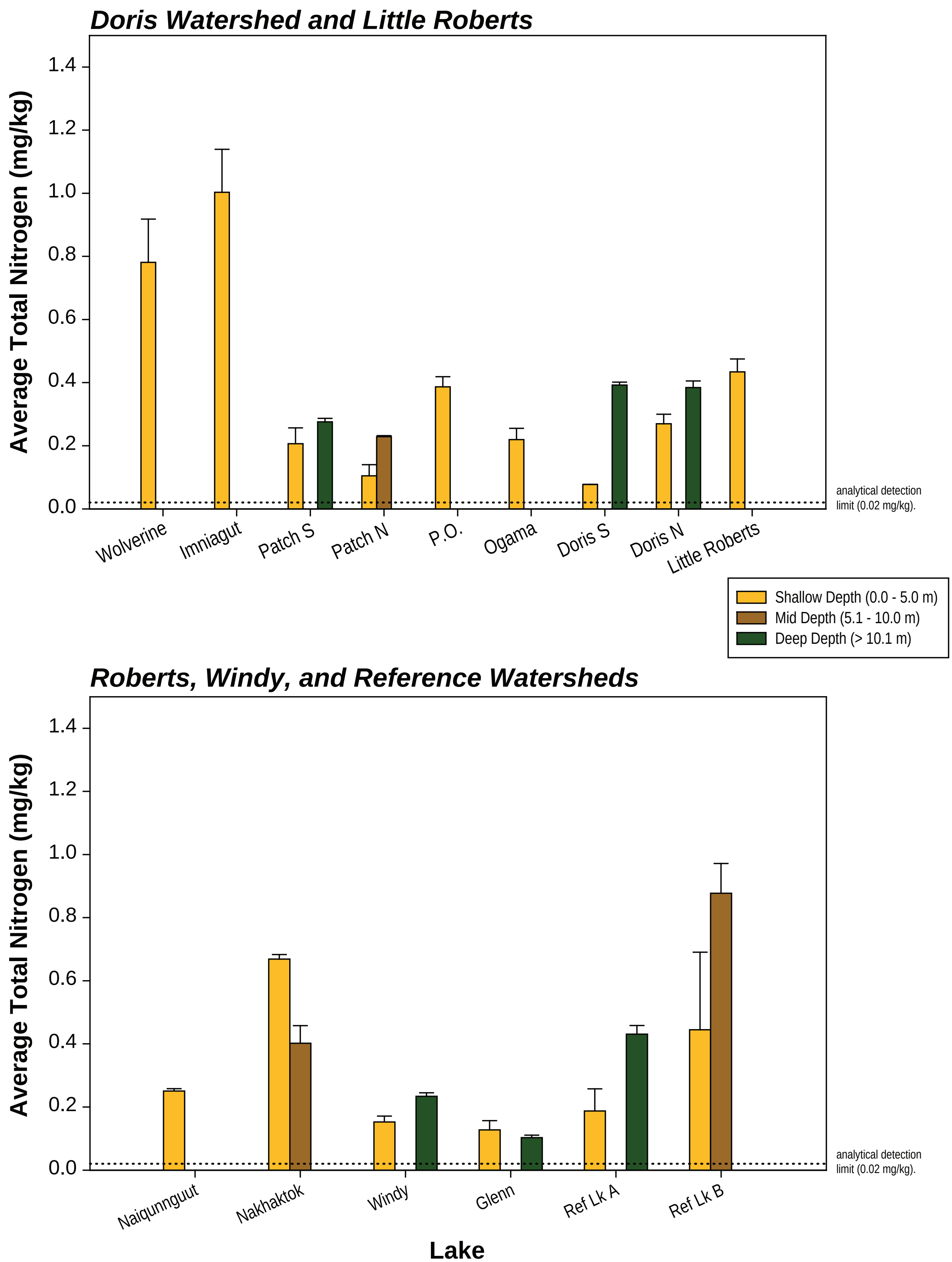
Notes: Error bars represent standard error of the mean.
No SQGs exist for ammonium as N.

NEWMONT NORTH AMERICA

Average Concentration of Available Ammonium as N in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2c

Rescan Engineers & Scientists



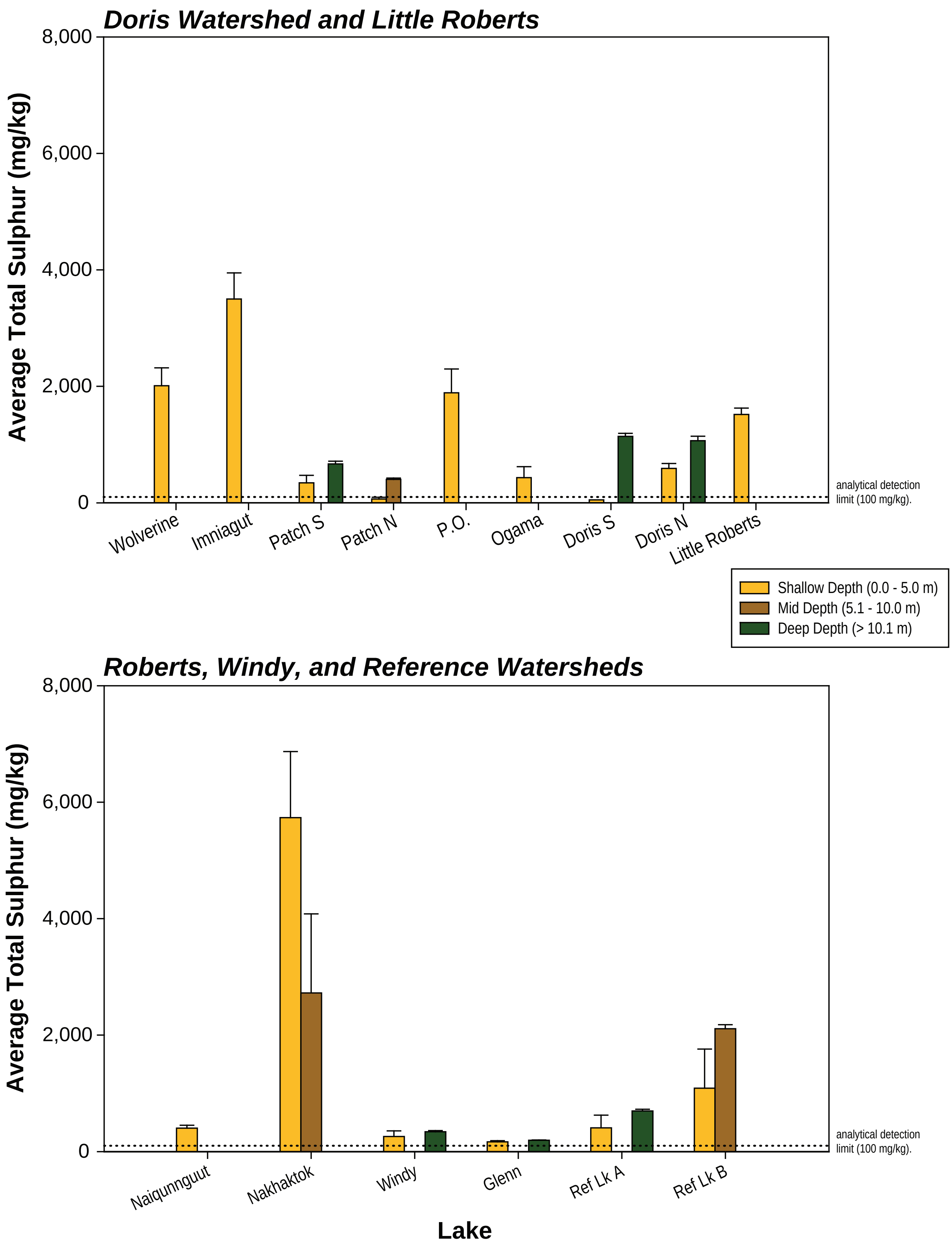
Notes: *Error bars represent standard error of the mean.*
No SQGs exist for total nitrogen.

NEWMONT NORTH AMERICA

Average Concentration of Total Nitrogen in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2d

Rescan Engineers & Scientists



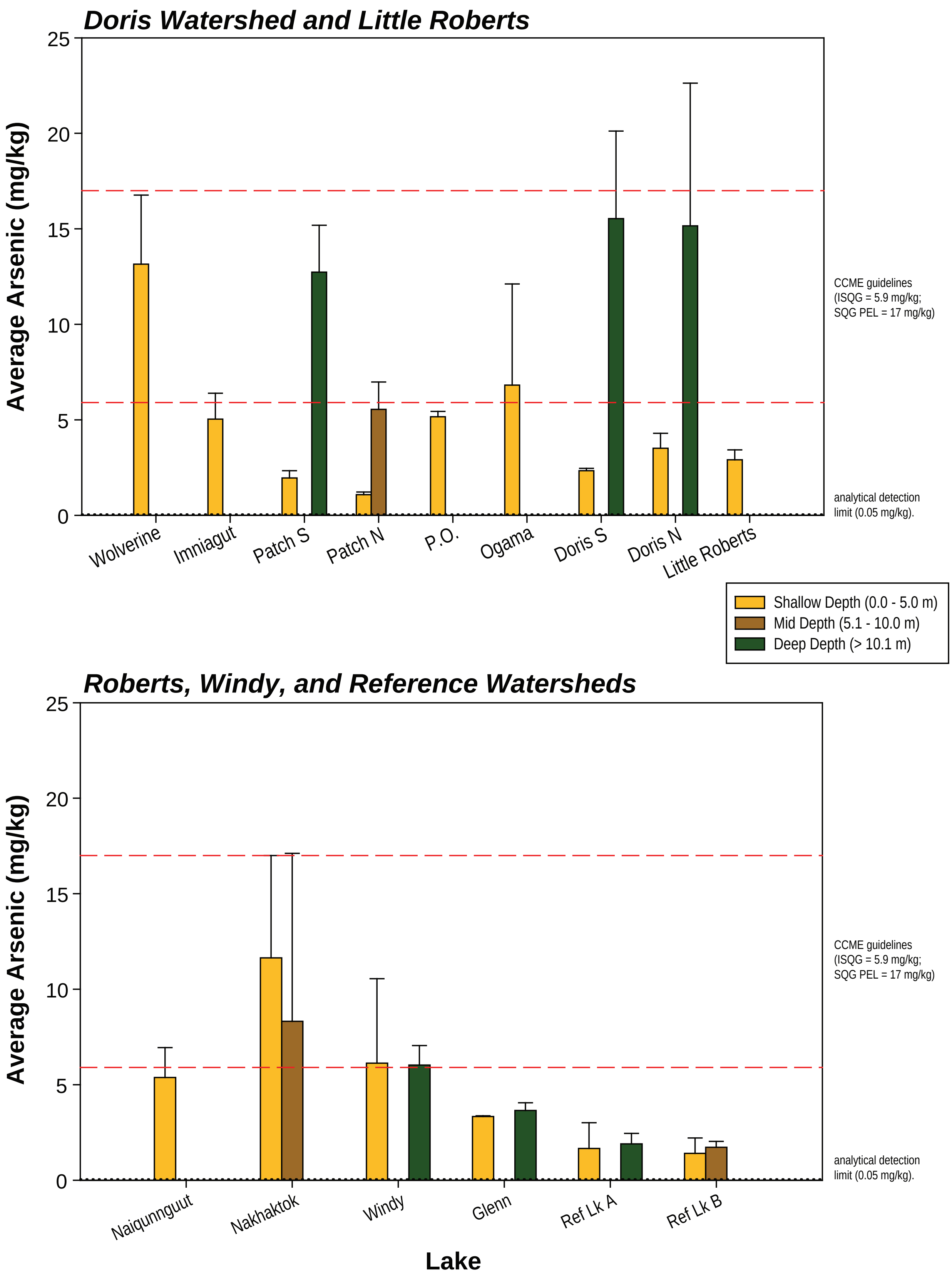
Notes: Error bars represent standard error of the mean.
No SQGs exist for total sulphur.

NEWMONT NORTH AMERICA

Average Concentration of Total Sulphur in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2e

Rescan Engineers & Scientists



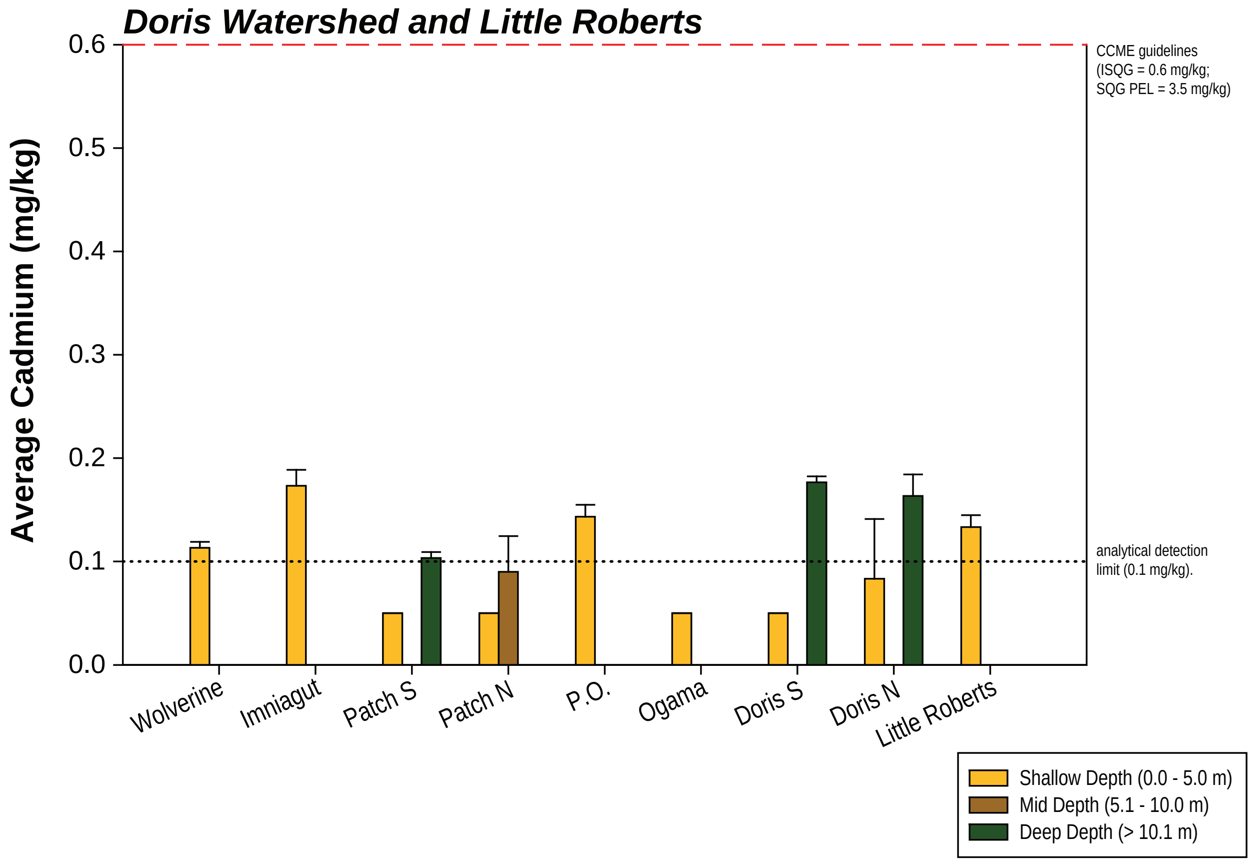
Note: Error bars represent standard error of the mean.

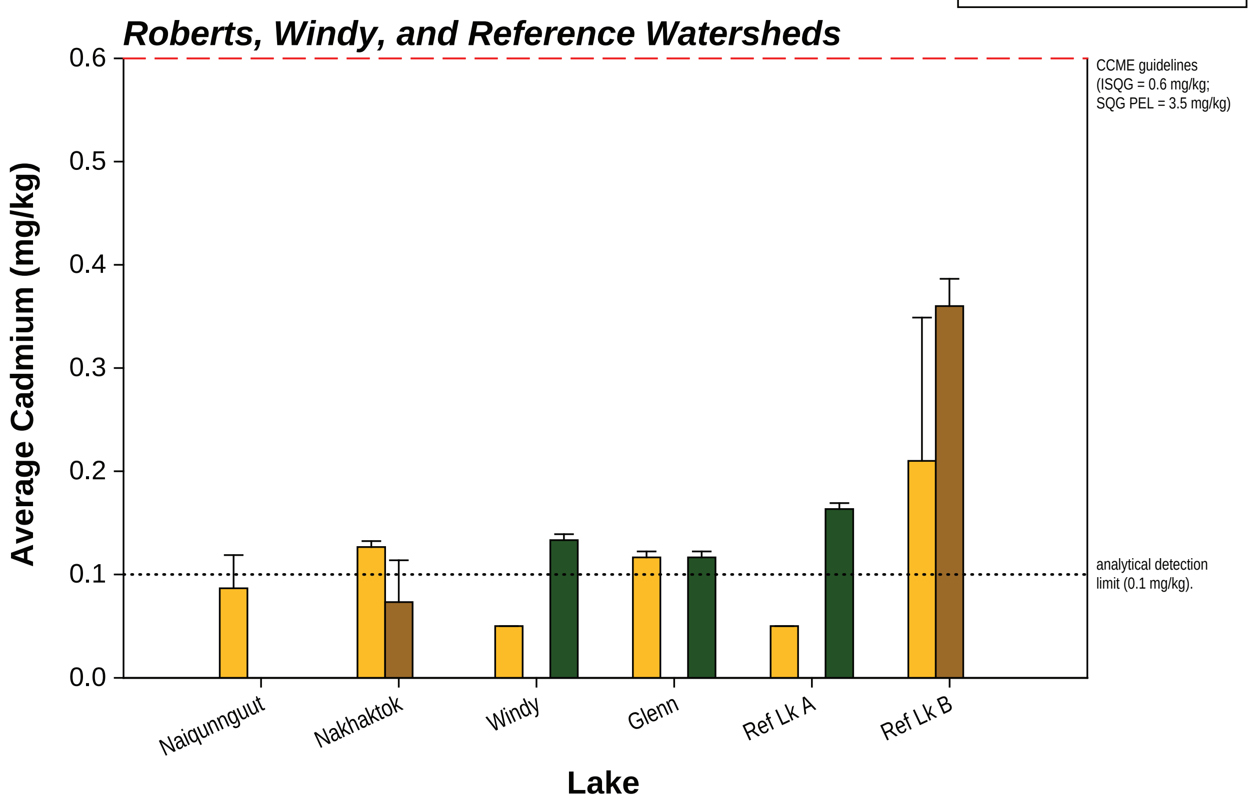
NEWMONT NORTH AMERICA

Average Concentration of Arsenic in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2f

Rescan Engineers & Scientists





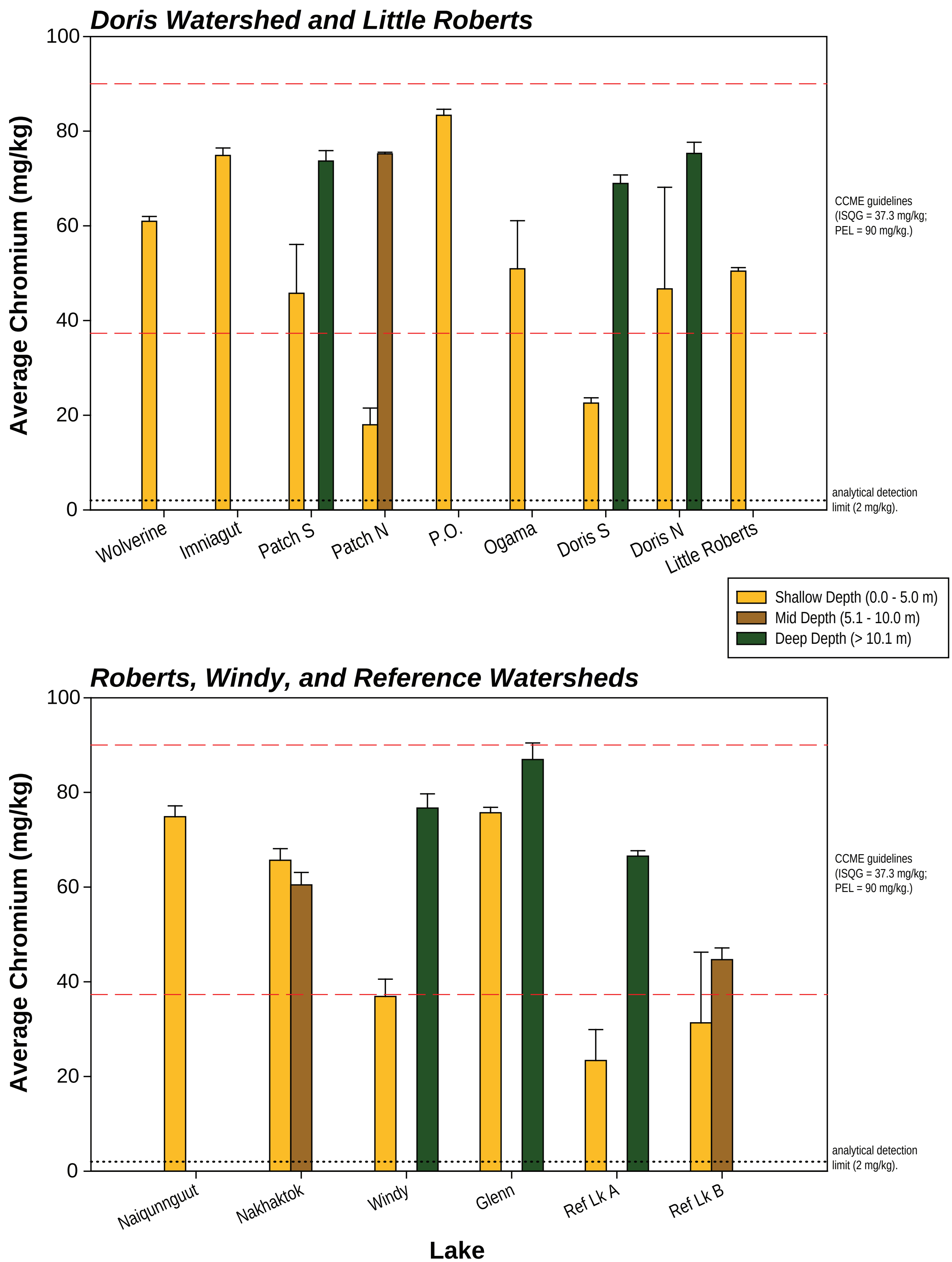
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Cadmium in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2g

Rescan Engineers & Scientists



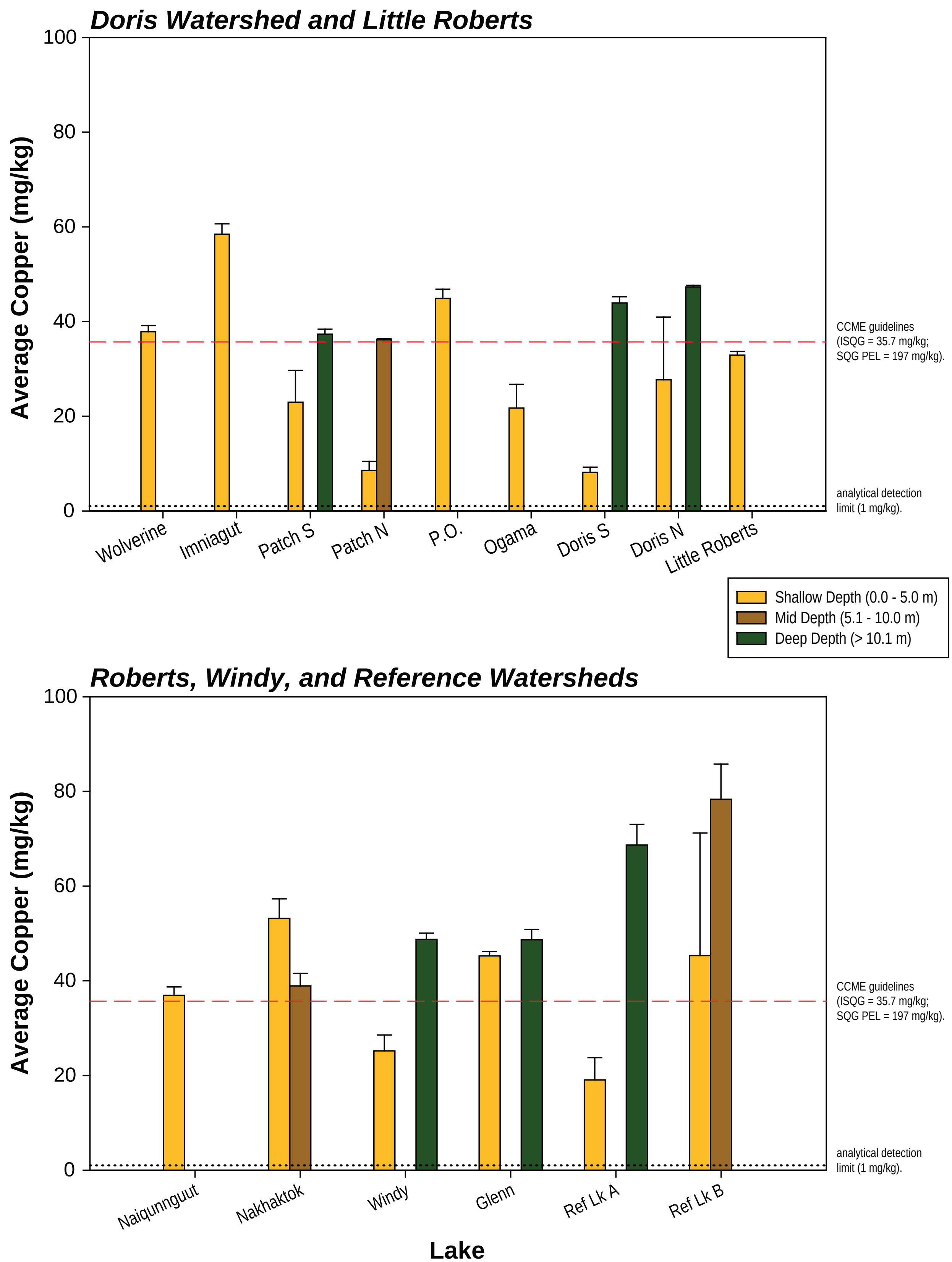
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Chromium in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2h

Rescan Engineers & Scientists



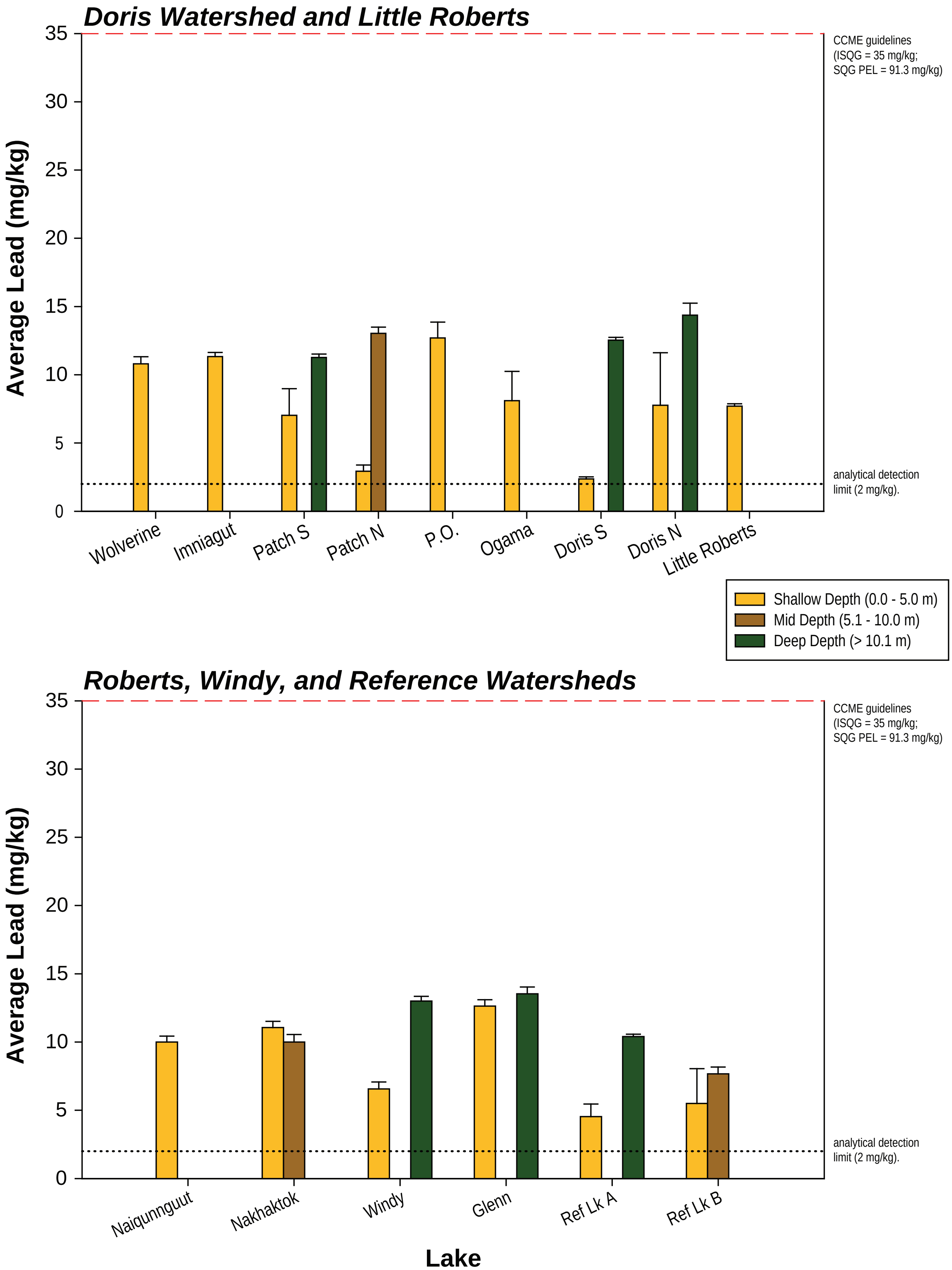
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Copper in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2i

Rescan Engineers & Scientists



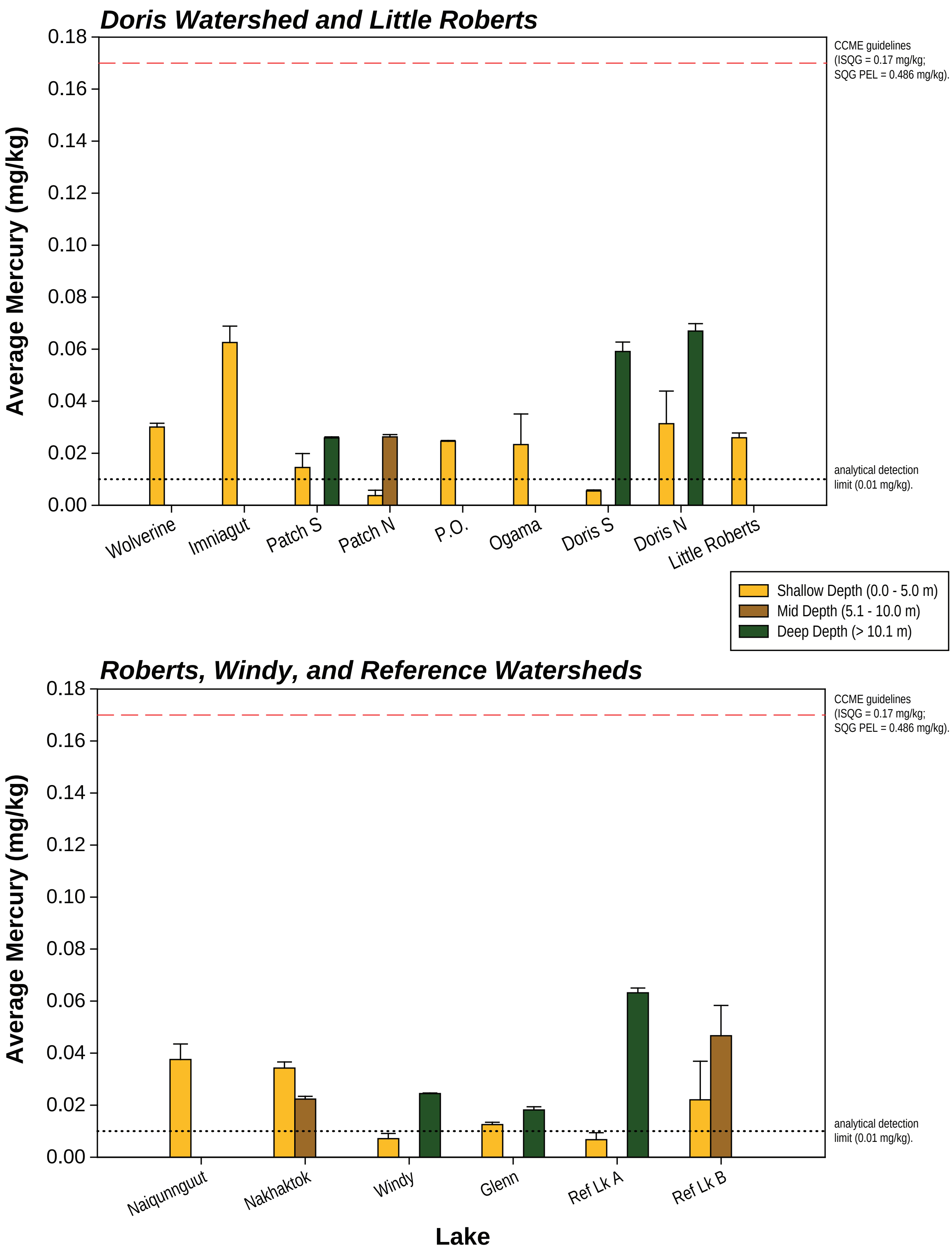
Notes: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Lead in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2j

Rescan Engineers & Scientists



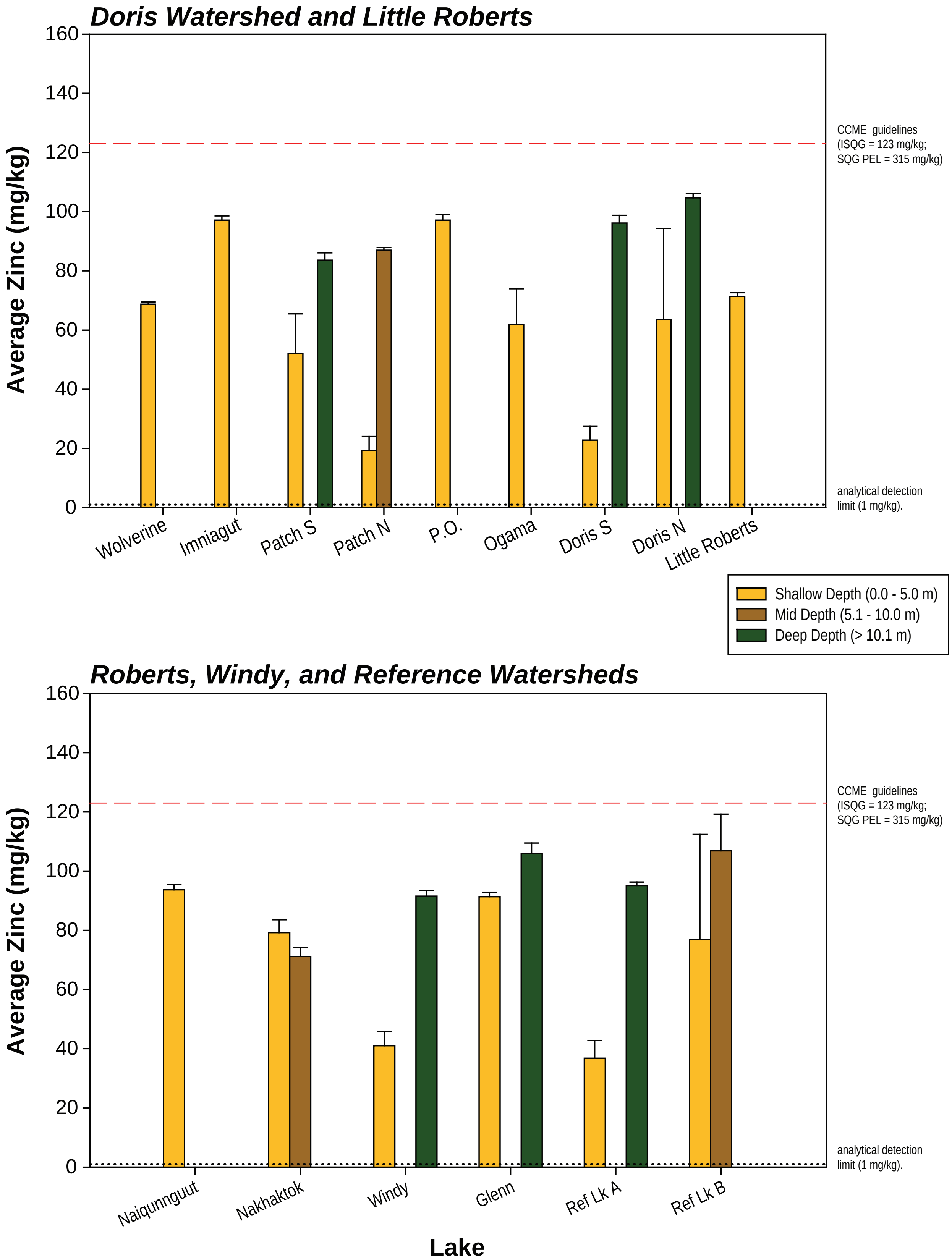
Notes: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Mercury in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2k

Rescan Engineers & Scientists



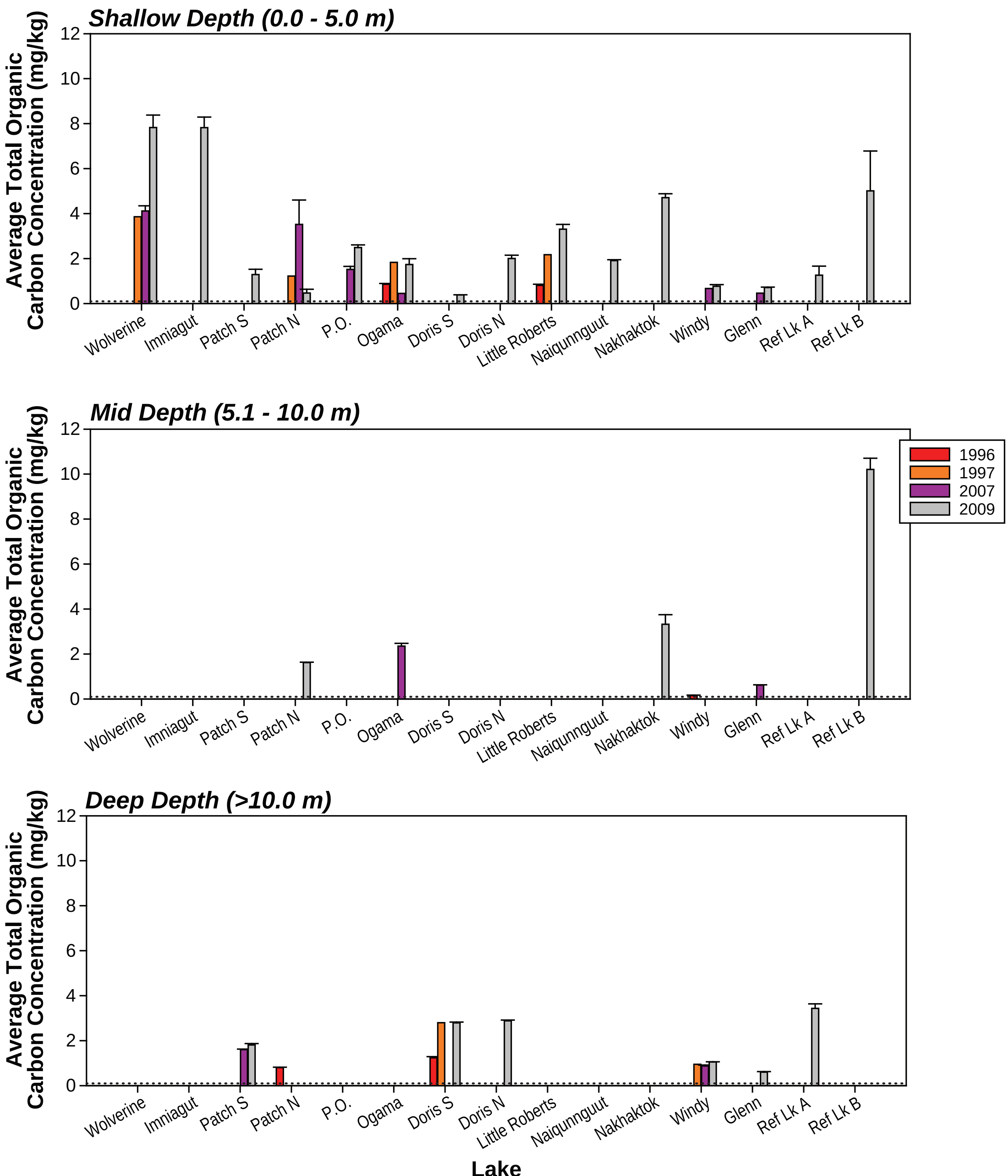
Note: Error bars represent standard error of the mean.

Figure 3.4-2l

Average Concentration of Zinc in Lake Sediments, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



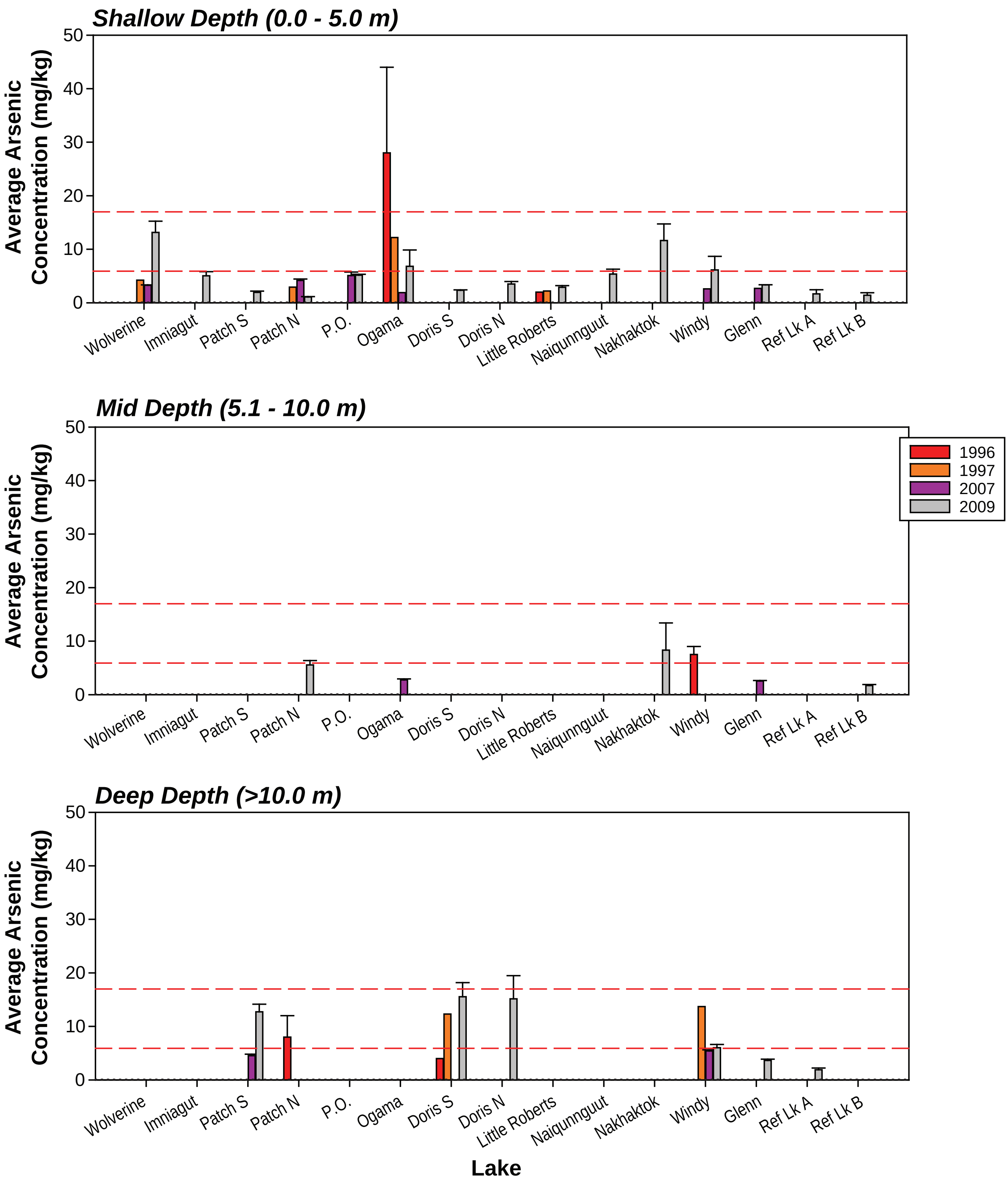
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (0.1 %).
No SQGs exist for total organic carbon.

NEWMONT NORTH AMERICA

Average Annual Concentrations of Total Organic Carbon in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3a

Rescan Engineers & Scientists



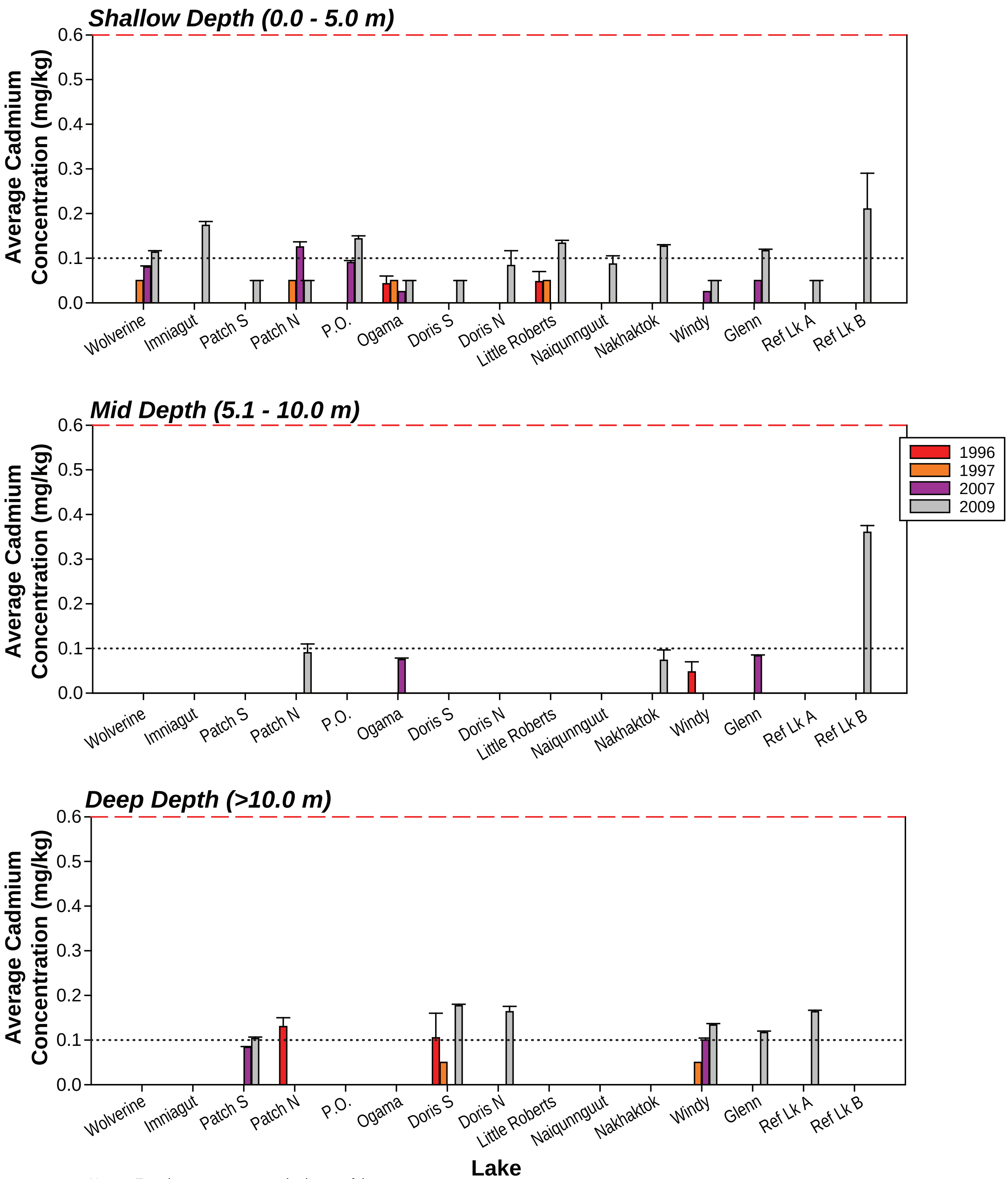
Notes: *Error bars represent standard error of the mean.*
Dotted line represents analytical detection limit (0.05 mg/kg).
Dashed line represents CCME guidelines (ISQG = 5.9 mg/kg; SQG PEL = 17 mg/kg)

NEWMONT NORTH AMERICA

Average Annual Concentrations of Arsenic in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3b

Rescan Engineers & Scientists



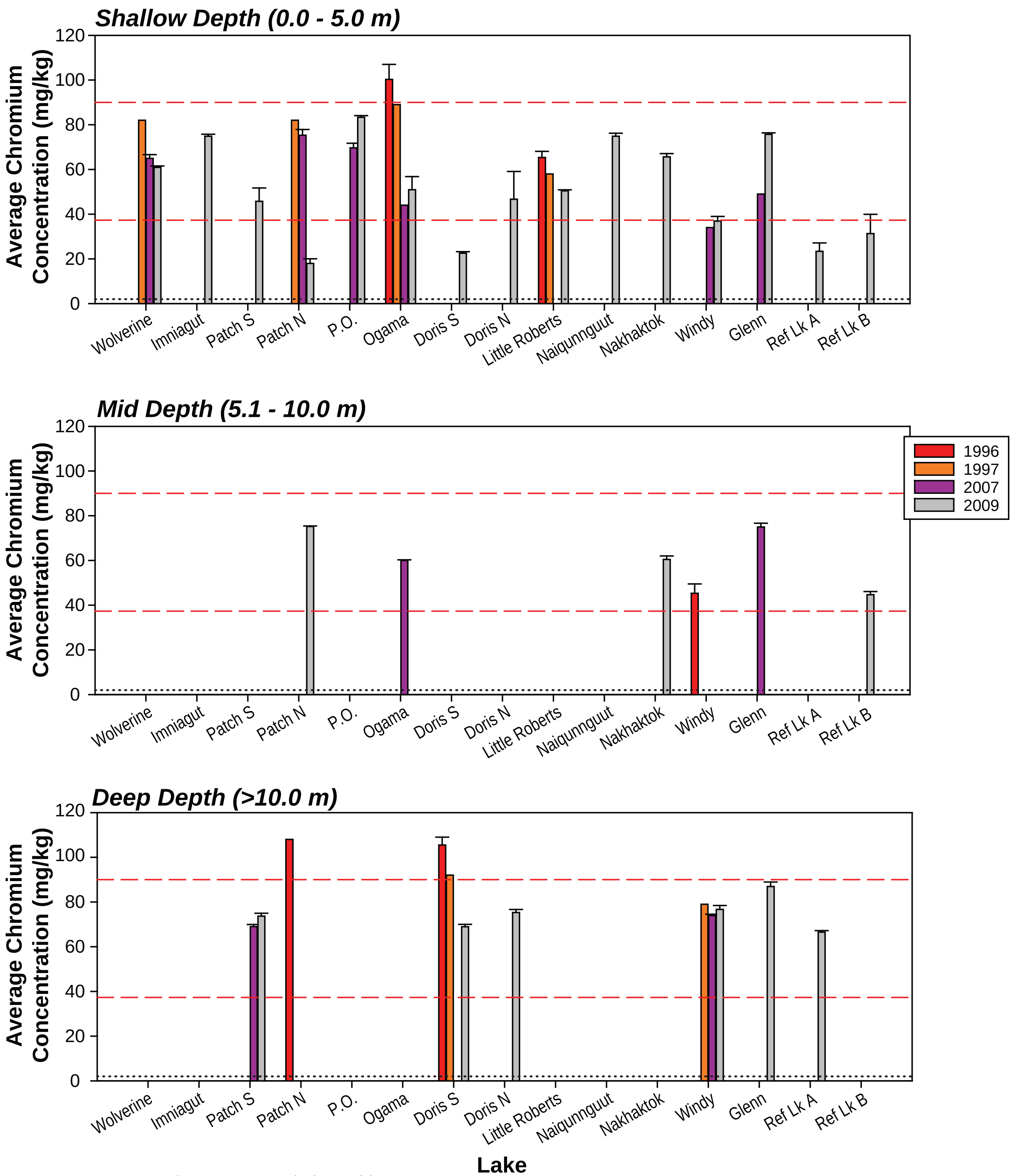
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (0.1 mg/kg).
Dashed line represents CCME guidelines (ISQG = 0.6 mg/kg; SQG PEL = 3.5 mg/kg)

NEWMONT. NORTH AMERICA

Average Annual Concentrations of Cadmium in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3c

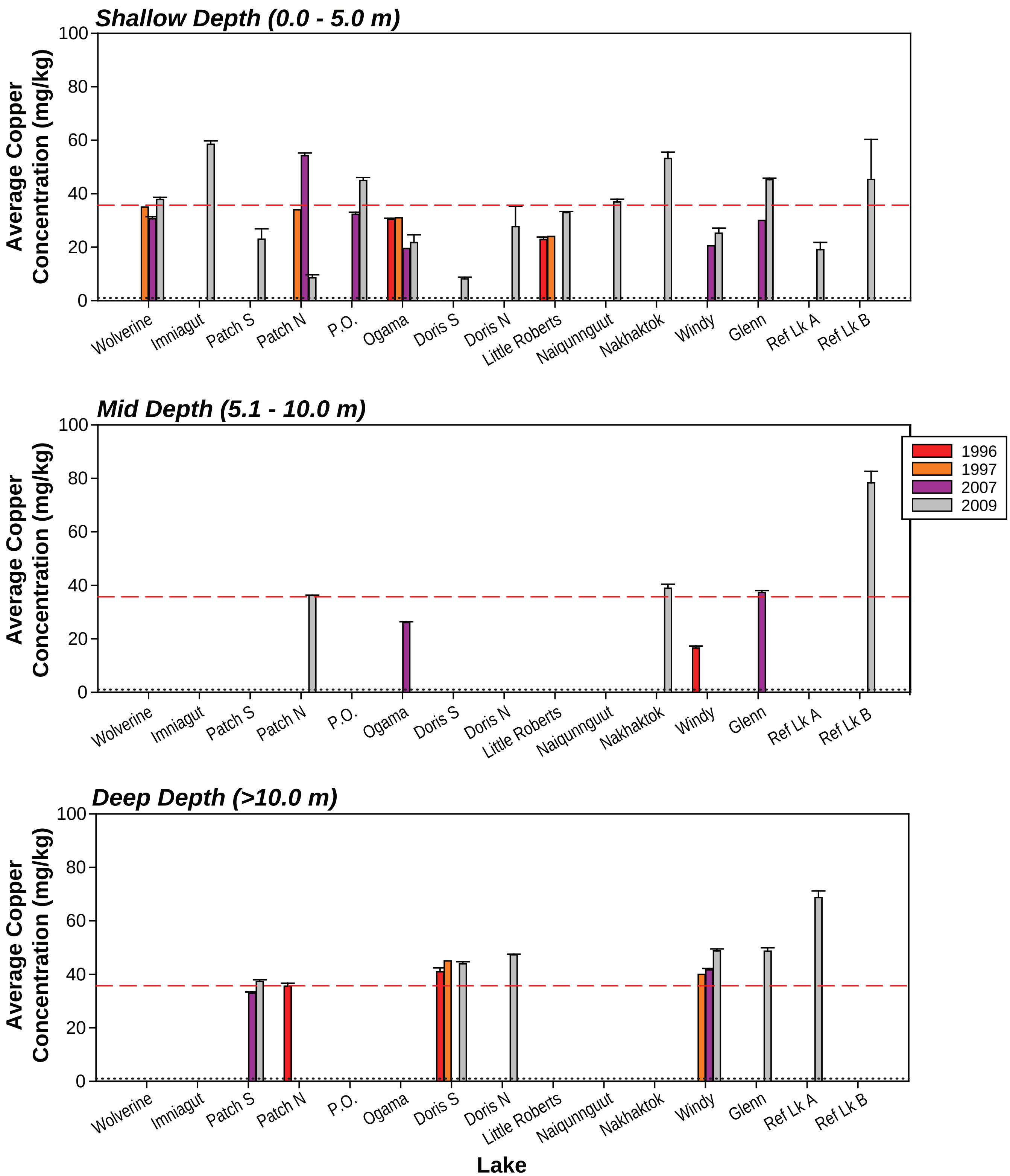
Rescan™ Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (2 mg/kg).
Dashed lines indicates CCME guidelines (ISQG = 37.3 mg/kg; PEL = 90 mg/kg.)

Figure 3.4-3d

Average Annual Concentrations of Chromium in Lake Sediments, Hope Bay Belt Project, 1996 - 2009



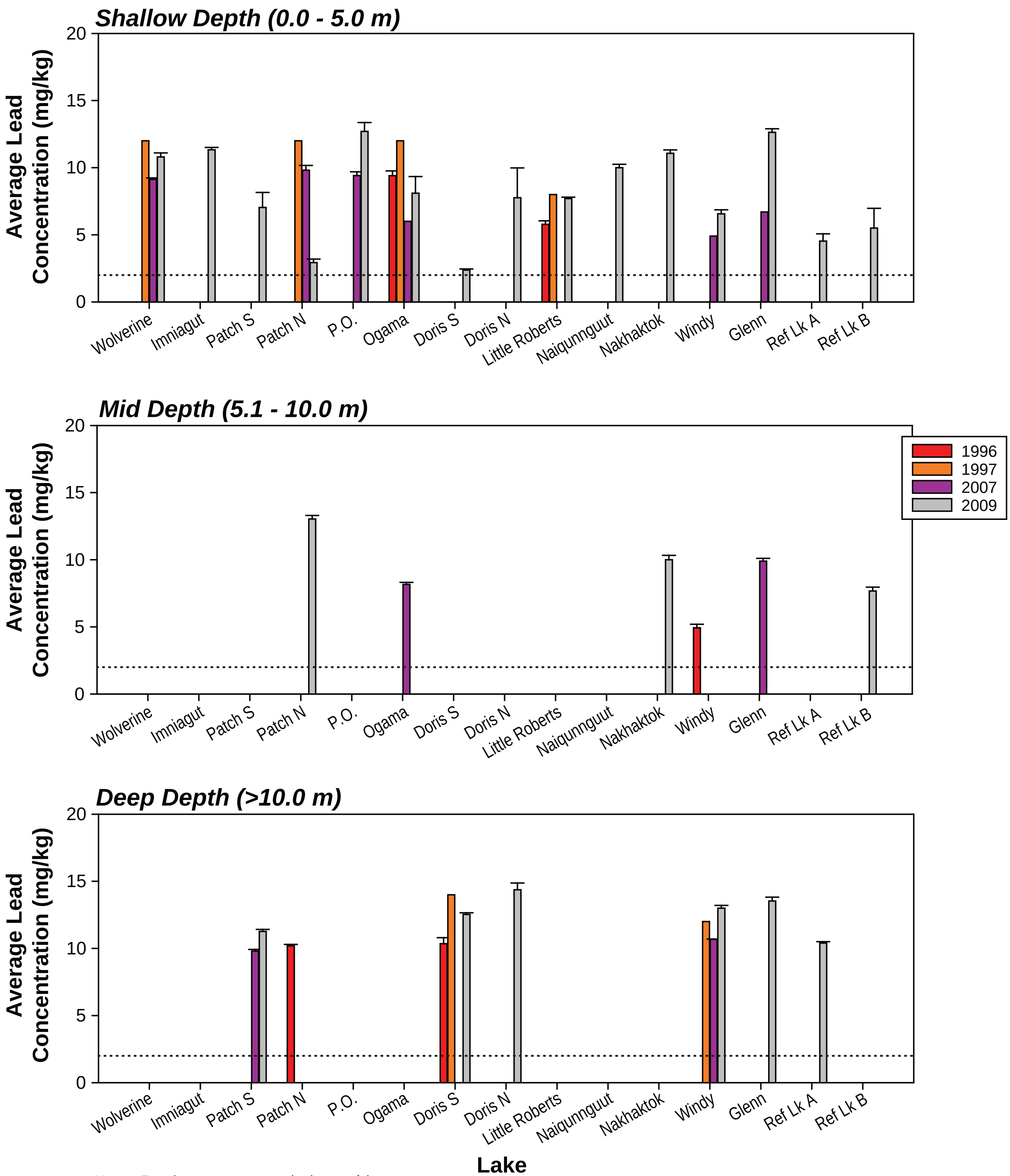
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (1 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 35.7 mg/kg; SQG PEL = 197 mg/kg).

NEWMONT NORTH AMERICA

Average Annual Concentrations of Copper in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3e

Rescan Engineers & Scientists



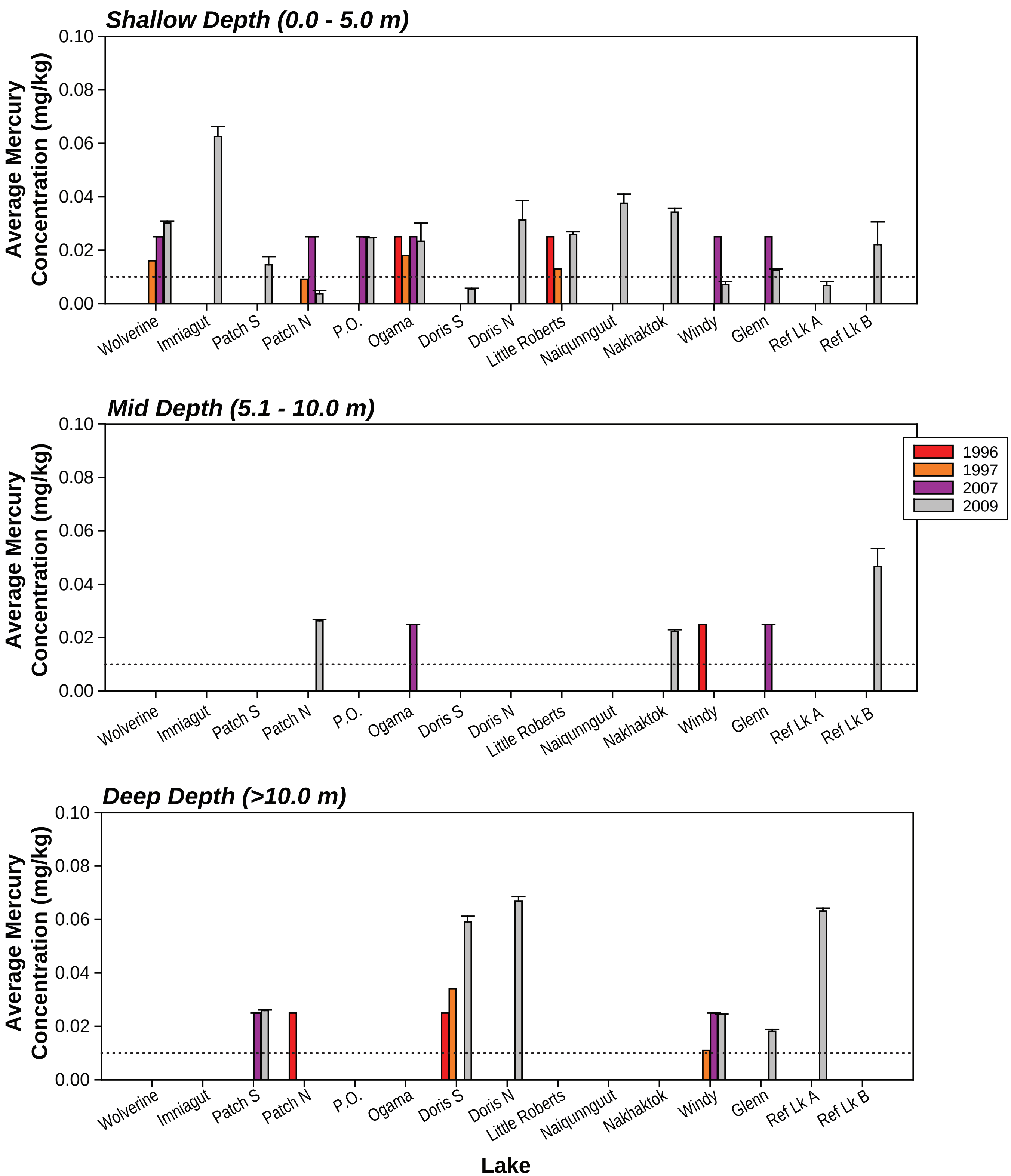
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (2 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 35 mg/kg; SQG PEL = 91.3 mg/kg)

NEWMONT NORTH AMERICA

Average Annual Concentrations of Lead in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3f

Rescan Engineers & Scientists



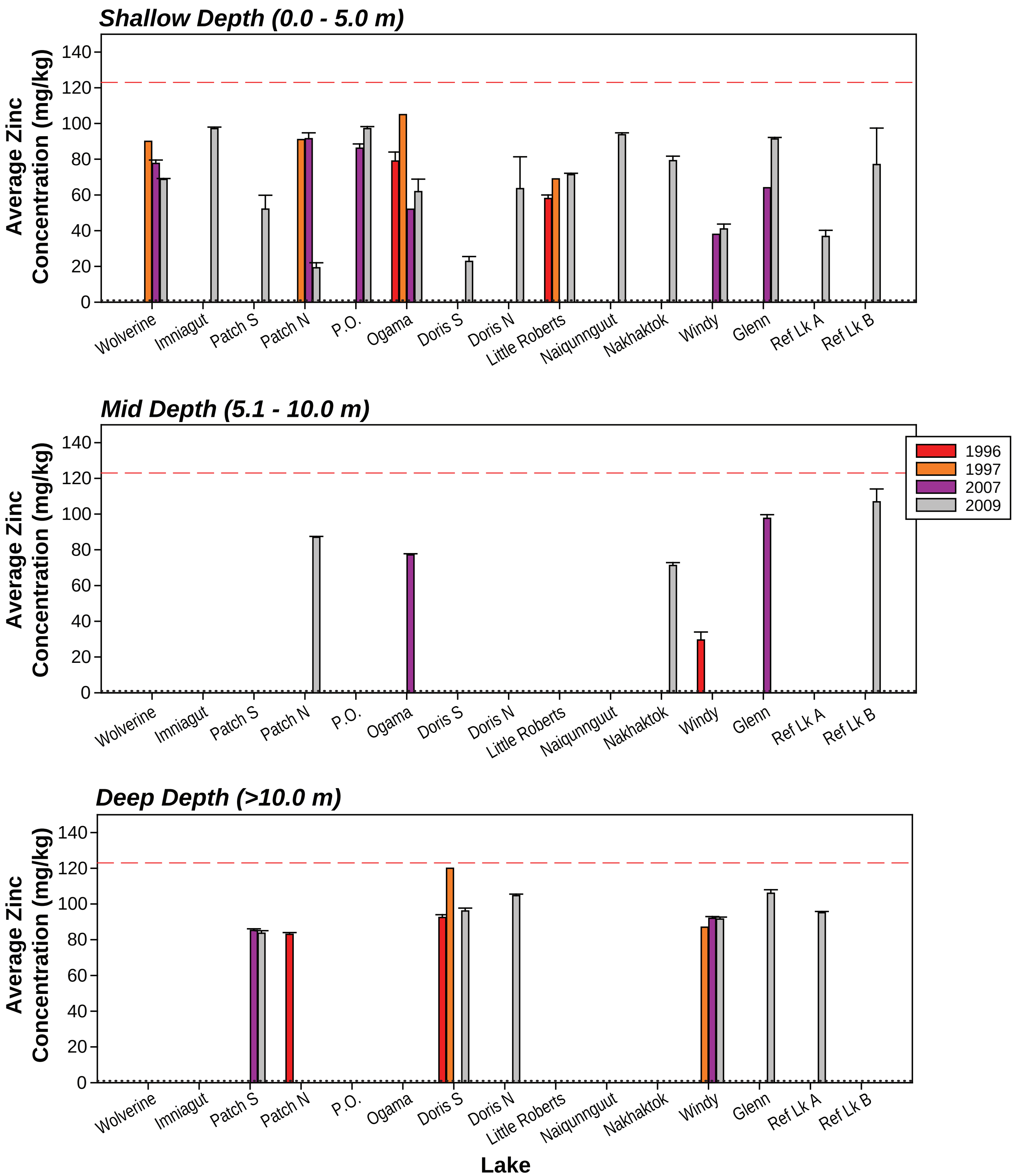
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (0.01 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 0.17 mg/kg; SQG PEL = 0.486 mg/kg).

Figure 3.4-3g

Average Annual Concentrations of Mercury in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (1 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 123 mg/kg; SQG PEL = 315 mg/kg)

NEWMONT NORTH AMERICA

Average Annual Concentrations of Zinc in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3h

Rescan Engineers & Scientists

Table 3.4-1. Lake Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Lake	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Percent of samples higher than ISQG[b] guidelines Arsenic (As) 5.9	Cadmium (Cd) 0.6	Chromium (Cr) 37.3	Copper (Cu) 35.7	Lead (Pb) 35	Mercury (Hg) 0.17	Zinc (Zn) 123
Doris									
Wolverine	3		100	0	100	100	0	0	0
Imniagut	3		33	0	100	100	0	0	0
Patch S	6		50	0	83	50	0	0	0
Patch N	6		17	0	50	50	0	0	0
P.O.	3		0	0	100	100	0	0	0
Ogama	3		33	0	100	0	0	0	0
Doris S	6		50	0	50	50	0	0	0
Doris N	6		50	0	83	67	0	0	0
Little Roberts									
Little Roberts	3		0	0	100	0	0	0	0
Roberts									
Naiqunnguut	3		33	0	100	67	0	0	0
Windy									
Nakhaktok	6		67	0	100	100	0	0	0
Windy	6		33	0	67	50	0	0	0
Glenn	6		0	0	100	100	0	0	0
Ref A	6								
Ref Lk A			0	0	50	50	0	0	0
Ref B									
Ref Lk B	6		0	0	83	83	0	0	0
Total Sites			**10**	**0**	**15**	**13**	**0**	**0**	**0**

(continued)

Table 3.4-1. Lake Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Lake	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Percent of samples higher than PEL[c] guidelines Arsenic (As) 17	Cadmium (Cd) 3.5	Chromium (Cr) 90	Copper (Cu) 197	Lead (Pb) 91.3	Mercury (Hg) 0.486	Zinc (Zn) 315
Doris									
Wolverine	3		0	0	0	0	0	0	0
Imniagut	3		0	0	0	0	0	0	0
Patch S	6		0	0	0	0	0	0	0
Patch N	6		0	0	0	0	0	0	0
P.O.	3		0	0	0	0	0	0	0
Ogama	3		0	0	0	0	0	0	0
Doris S	6		17	0	0	0	0	0	0
Doris N	6		17	0	0	0	0	0	0
Little Roberts									
Little Roberts	3		0	0	0	0	0	0	0
Roberts									
Naiqunnguut	3		0	0	0	0	0	0	0
Windy									
Nakhaktok	6		33	0	0	0	0	0	0
Windy	6		0	0	0	0	0	0	0
Glenn	6		0	0	17	0	0	0	0
Ref A	6		0	0	0	0	0	0	0
Ref Lk A									
Ref B									
Ref Lk B	6		0	0	0	0	0	0	0
Total Sites			**3**	**0**	**1**	**0**	**0**	**0**	**0**

All values represent percentages of 2009 samples that are higher than CCME guidelines.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

Table 3.4-2. Lake Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

		CCME Guideline	Factor by which samples are higher than ISQG[b] guidelines						
	Total Number of	Value[a]:	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
Lake	**Samples Collected**	**(mg/kg):**	**5.9**	**0.6**	**37.3**	**35.7**	**35**	**0.17**	**123**
Doris									
Wolverine	3		2.23	-	1.63	1.06	-	-	-
Imniagut	3		-	-	2.01	1.64	-	-	-
Patch S	6		1.24	-	1.60	-	-	-	-
Patch N	6		-	-	1.25	-	-	-	-
P.O.	3		-	-	2.24	1.26	-	-	-
Ogama	3		1.16	-	1.37	-	-	-	-
Doris S	6		1.51	-	1.23	-	-	-	-
Doris N	6		1.58	-	1.64	1.05	-	-	-
Little Roberts									
Little Roberts	3		-	-	1.35	-	-	-	-
Roberts									
Naiqunnguut	3		-	-	2.01	1.03	-	-	-
Windy									
Nakhaktok	6		1.69	-	1.69	1.29	-	-	-
Windy	6		1.03	-	1.52	1.04	-	-	-
Glenn	6		-	-	2.18	1.32	-	-	-
Ref A									
Ref Lk A	6		-	-	1.21	1.23	-	-	-
Ref B									
Ref Lk B	6		-	-	1.02	1.73	-	-	-
Total Sites			**7**	**0**	**15**	**10**	**0**	**0**	**0**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines.

(continued)

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

Table 3.4-2. Lake Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Lake	Total Number of Samples Collected	CCME Guideline Value[a]: (mg/kg):	Arsenic (As) 17	Cadmium (Cd) 3.5	Chromium (Cr) 90	Copper (Cu) 197	Lead (Pb) 91.3	Mercury (Hg) 0.486	Zinc (Zn) 315
			Factor by which samples are higher than PEL[c] guidelines						
Doris									
Wolverine	3		-	-	-	-	-	-	-
Imniagut	3		-	-	-	-	-	-	-
Patch S	6		-	-	-	-	-	-	-
Patch N	6		-	-	-	-	-	-	-
P.O.	3		-	-	-	-	-	-	-
Ogama	3		-	-	-	-	-	-	-
Doris S	6		-	-	-	-	-	-	-
Doris N	6		-	-	-	-	-	-	-
Little Roberts									
Little Roberts	3		-	-	-	-	-	-	-
Roberts									
Naiqunnguut	3		-	-	-	-	-	-	-
Windy									
Nakhaktok	6		-	-	-	-	-	-	-
Windy	6		-	-	-	-	-	-	-
Glenn	6		-	-	-	-	-	-	-
Ref A									
Ref Lk A	6								
Ref B									
Ref Lk B	6		-	-	-	-	-	-	-
Total Sites			**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines.

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

3.4.3 Comparison with CCME Guidelines

Lake sediments were naturally elevated in arsenic, chromium, and copper, and concentrations of these metals were often higher than CCME ISQGs. Chromium concentrations were higher than the ISQG for chromium (37.3 mg/kg) at all lake sites surveyed (generally at deep depth), and copper concentrations were higher than the ISQG for copper (35.7 mg/kg) at all lakes except for Ogama and Little Roberts. Arsenic concentrations were higher than the ISQG for arsenic (5.9 mg/kg) at Wolverine, Patch S, Ogama, Doris S and N, Nakhaktok, and Windy lakes. Although elevated levels of arsenic, chromium, and copper were observed across the study area, no site averages exceeded any CCME PELs (though some replicate samples did, particularly for arsenic). Table 3.4-1 summarizes the percentage of sediment samples in which metal concentrations were higher than CCME guidelines, and Table 3.4-2 presents the factor by which sediment metal concentrations were higher than CCME guidelines.

3.4.4 Annual Variation

Table 2.13-3 outlines the years for which historical sediment data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-2 provides a summary of the historical sediment quality sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this, in addition to methodological differences, may contribute to variability observed between years.

Historical sediment quality data are available from 1996, 1997 and 2007, although not all parameters analyzed in 2009 were analyzed historically. Phosphorus, sulphur, ammonium and total nitrogen were not sampled prior to 2009, and therefore these graphs have not been presented in this section. Of the parameters for which historical data are available, notable differences were observed between years. Concentrations of all parameters graphed varied by as much as two-fold between years, making within-site annual variability comparable in magnitude to between-site variability. The variability observed between years may be a product of differences in sampling location; however, the sites which encompassed the most spatial variability in sampling sites (e.g. Doris and Patch), were not significantly more variable than lakes with little sampling location difference between years (e.g., Little Roberts, Wolverine). Similarly, other differences in sampling methodology between years (e.g., sampling with the use of a corer (in 2007) as opposed to an Ekman grab (other years), or collection of deeper sediment horizons (2007 vs. other years)) did not obviously affect annual variability.

3.4.5 Lake Sediment Quality Summary

Lake sediments were largely composed of clay and silt, with lesser amounts of sand and little gravel. The proportion of fine particles in sediments increased with depth, except at Nakhaktok Lake. An increase in fine sediments (clay and silt) within a lake was generally associated with an increase in all parameters evaluated with the exception of phosphorus. There were few clear trends in sediment chemistry among lake sites, though sediments from Wolverine and Imniagut lakes in the Doris Watershed contained relatively high concentrations of TOC, ammonium, total nitrogen, and total sulphur. Lake sediments were naturally elevated in arsenic, chromium, and copper, and concentrations of these metals were often higher than CCME ISQGs. Within-site annual variability was comparable in magnitude to within-year variability observed among sites.

3.5 STREAM AND RIVER SEDIMENT QUALITY

Stream and river sediment samples were collected in July, 2009 at all locations sampled for summer water quality. Sampling dates and locations can be found in Table 2.1-5.

Fourteen stream sites were sampled for sediment quality, including a reference river station (on the Angimajuq River) as well as two reference lake outflows (Ref Lk A and B). An 'upstream' location on the Koignuk River (Koignuk U/S) was also sampled to represent conditions upstream of any potential impact in the northern portion of the Hope Bay Belt (but this location may be downstream of potential future developments in the southern portion of the belt).

All raw sediment quality data are presented in Appendix 3.5-1. Figure 3.5-1 presents stream sediment particle size composition. Figures 3.5-2a to 3.5-2k present 2009 stream sediment quality results. No historical stream sediment quality data have been collected for the locations discussed in this report.

3.5.1 Spatial Variation

Stream sediments sampled in 2009 were a highly variable mixture of gravel, sand, silt and clay. Sediments in Ref Lk A OF were predominantly composed of sand, while sediments in the Angimajuq River Ref and in Ref Lk B OF, Ogama OF, and Doris OF were mainly composed of gravel and sand. In all other surveyed streams, sediments were predominantly composed of a sand-silt mixture. There was no apparent relationship between sediment particle size distribution and other chemical constituents.

There were few apparent trends in sediment chemistry among streams; however, stream sediments were generally lower in metal concentrations compared to lake sediments.

3.5.2 Comparison with CCME Guidelines

Stream and river sediments were naturally high in chromium. Concentrations of chromium in sediments collected from Ogama OF, Windy OF, Koignuk U/S, and Koignuk D/S were occasionally higher that the CCME ISQG for chromium (ISQG = 37.3 mg/kg). Sediment metal concentrations were always below the CCME PELs. Table 3.5-1 summarizes the percentage of sediment samples in which metal concentrations were higher than CCME guidelines, and Table 3.5-2 presents the factor by which sediment metal concentrations were higher than CCME guidelines.

3.5.3 Annual Variation

Prior to 2009, no stream sediment quality samples had been collected. To maintain consistency with other sections, Table 2.13-4 outlines the sampling methodology employed in 2009.

3.5.4 Stream and River Sediment Quality Summary

Stream sediments consisted of a highly variable mixture of gravel, sand, silt and clay. There were few apparent trends in sediment chemistry among streams; however, stream sediments generally contained lower metal concentrations than lake sediments. Chromium concentrations in sediments were naturally elevated and were occasionally higher than CCME ISQG guidelines. Annual variability in sediment quality could not be assessed because no stream sediment quality samples were collected prior to 2009.

3.6 PHYTOPLANKTON

Phytoplankton are free-floating autotrophic algae that play an important role in many aquatic systems as primary producers and prey for higher trophic levels. As well, phytoplankton have short generation times, and can respond rapidly to environmental change. Accordingly, they are key indicators of ecosystem health, particularly with regard to alterations in nutrient and metal chemistry.

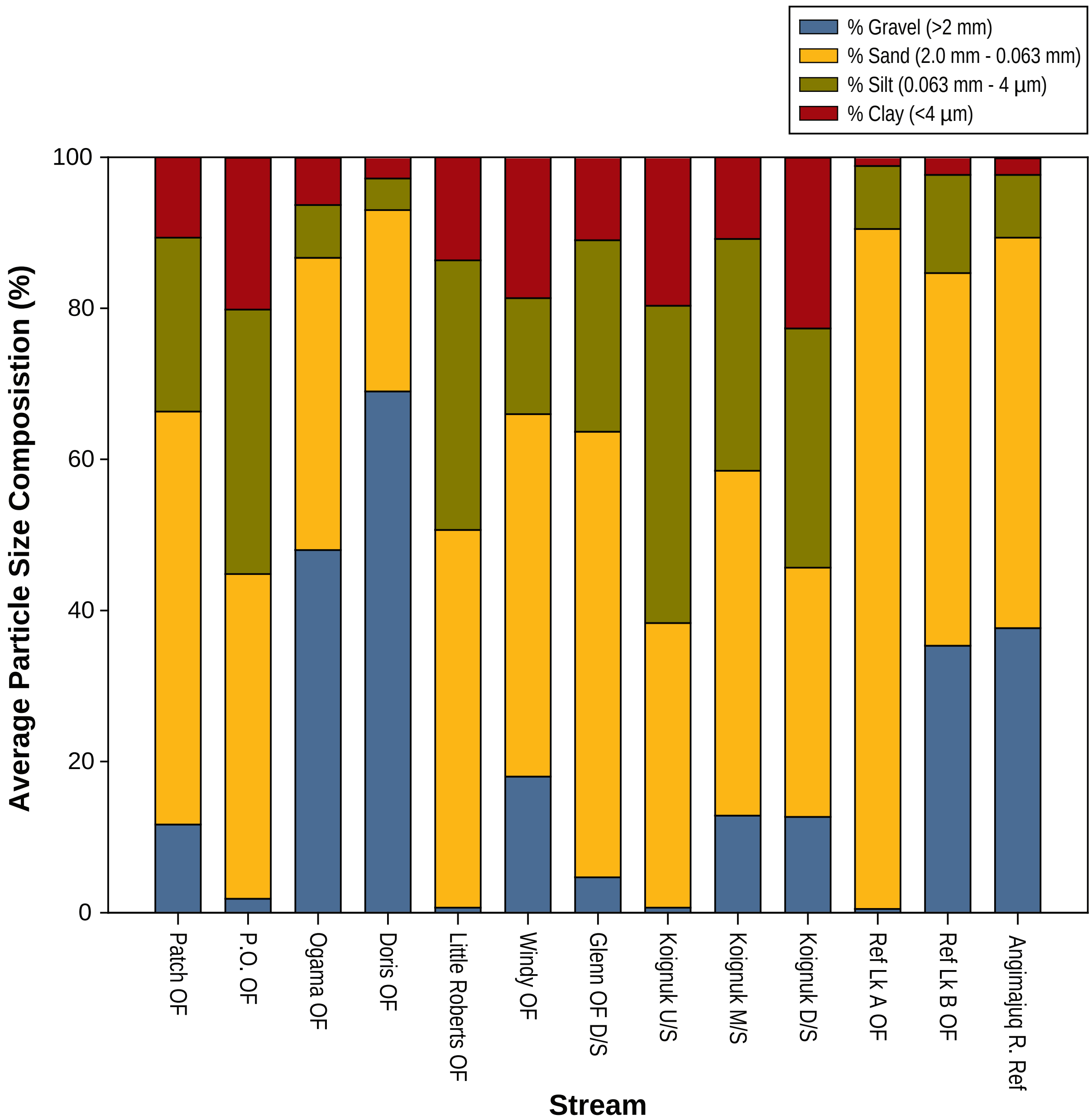


Figure 3.5-1

Sediment Particle Size Composition, Hope Bay Streams, 2009

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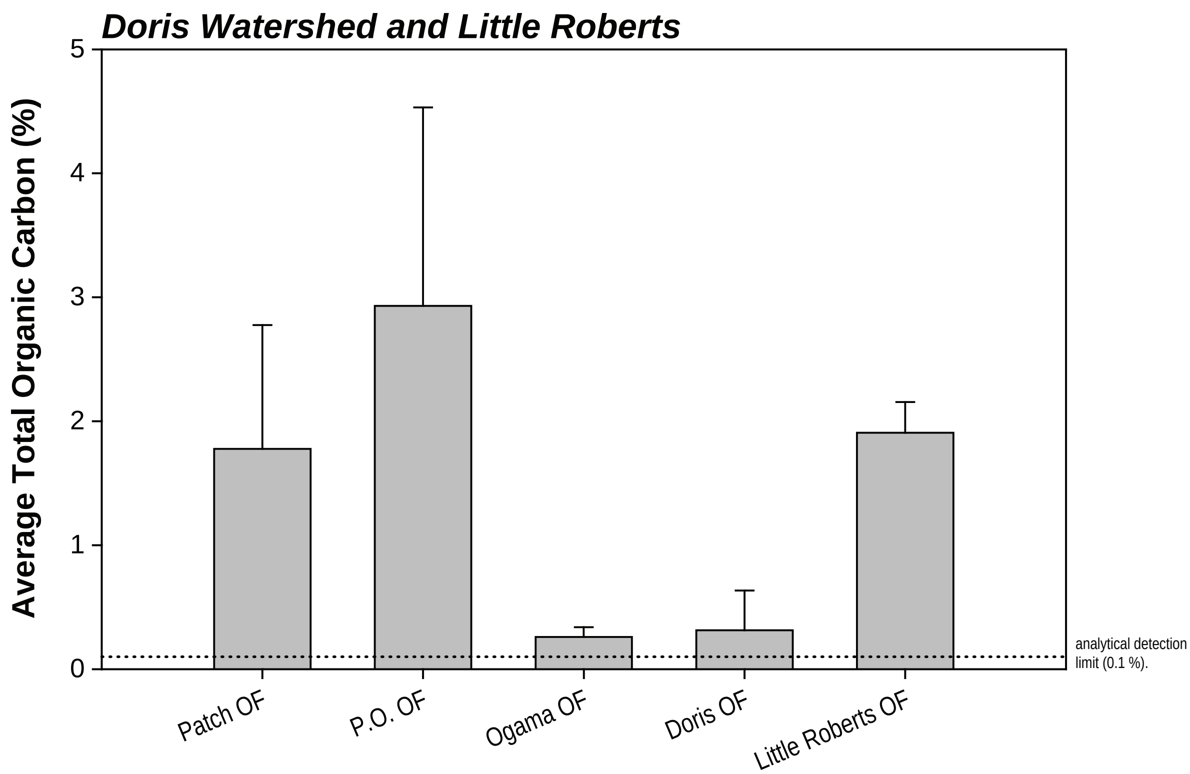
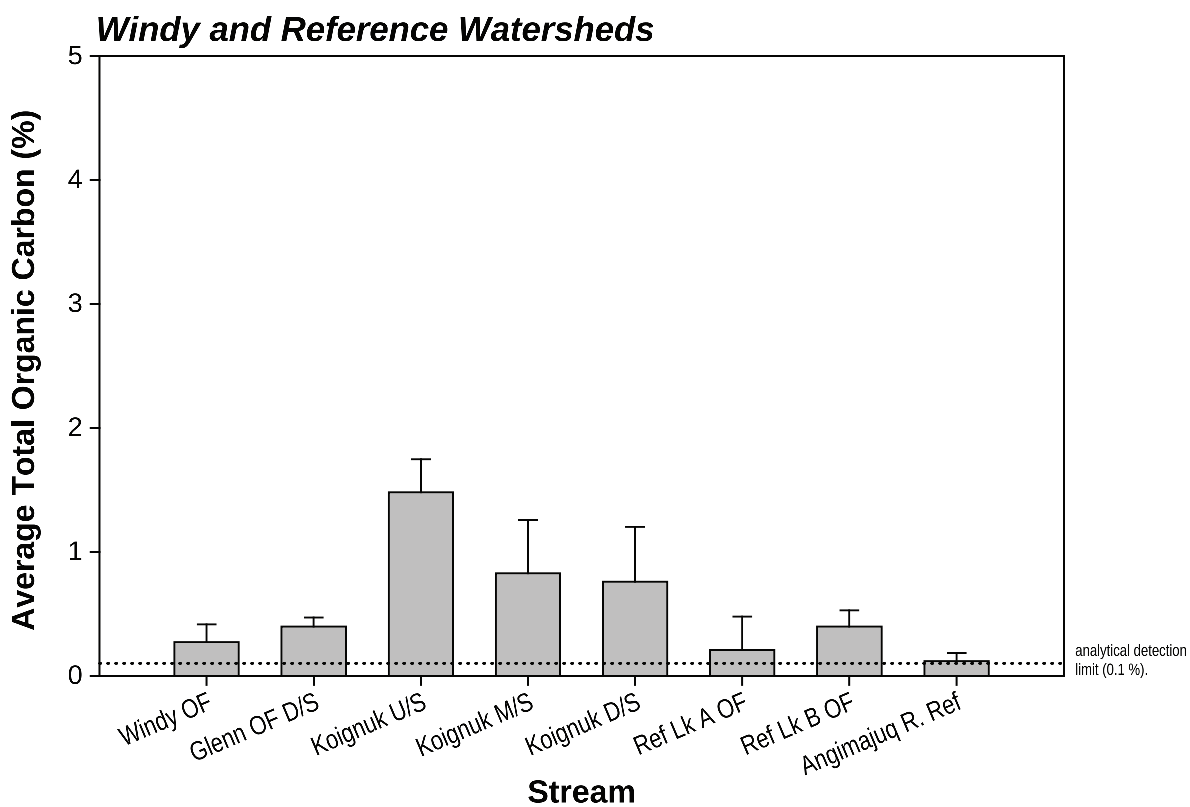




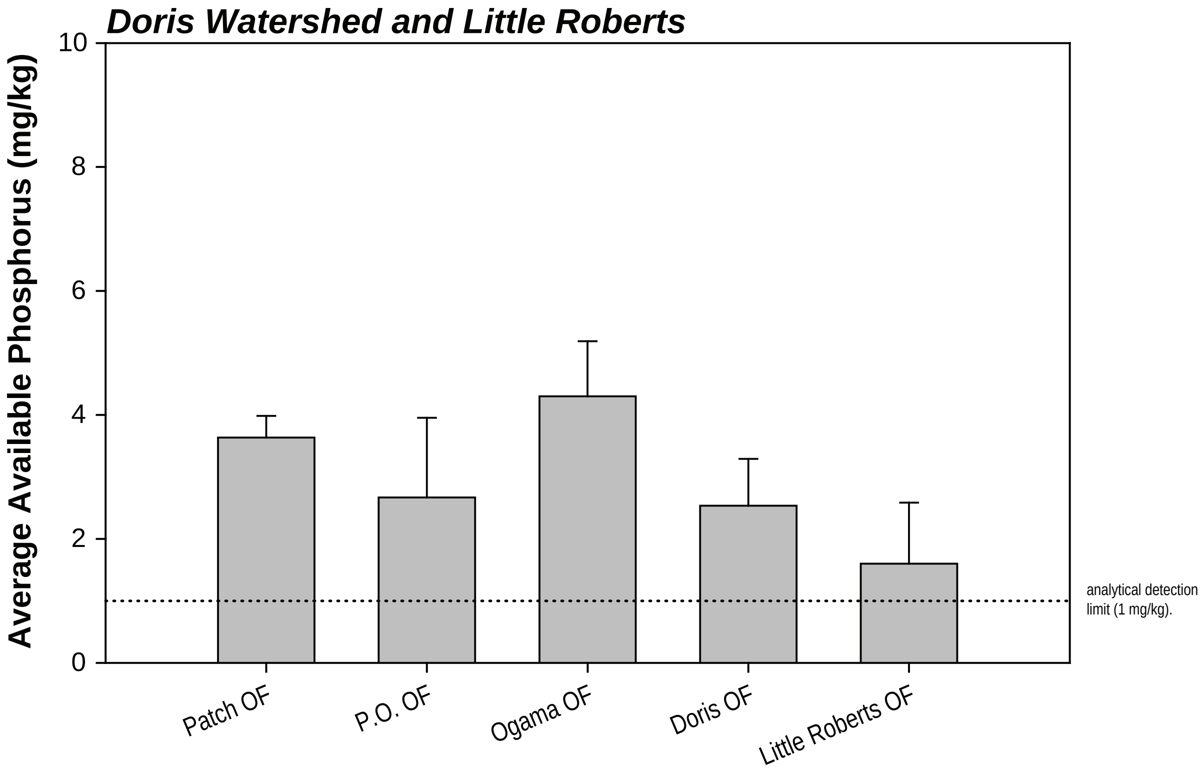
Notes: Error bars represent standard error of the mean.
No SQGs exist for total organic carbon.

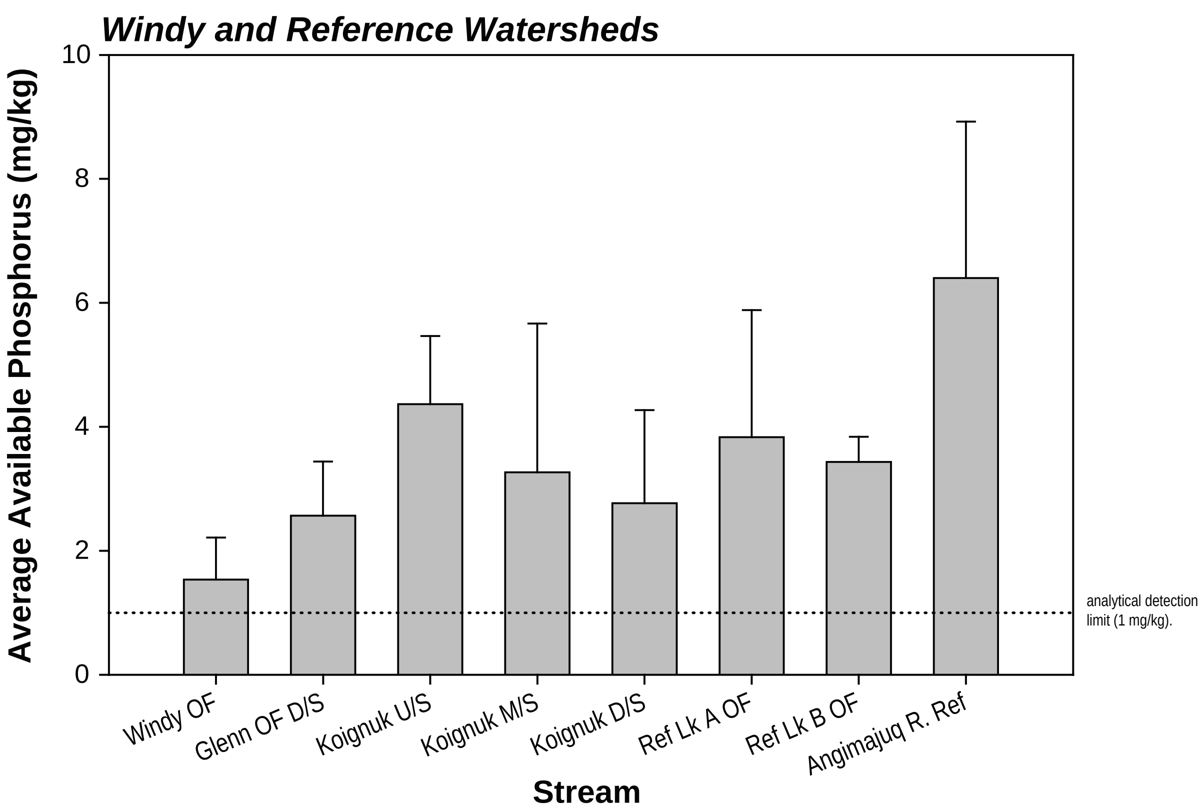
NEWMONT NORTH AMERICA

Average Concentrations of Total Organic Carbon in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2a

Rescan Engineers & Scientists





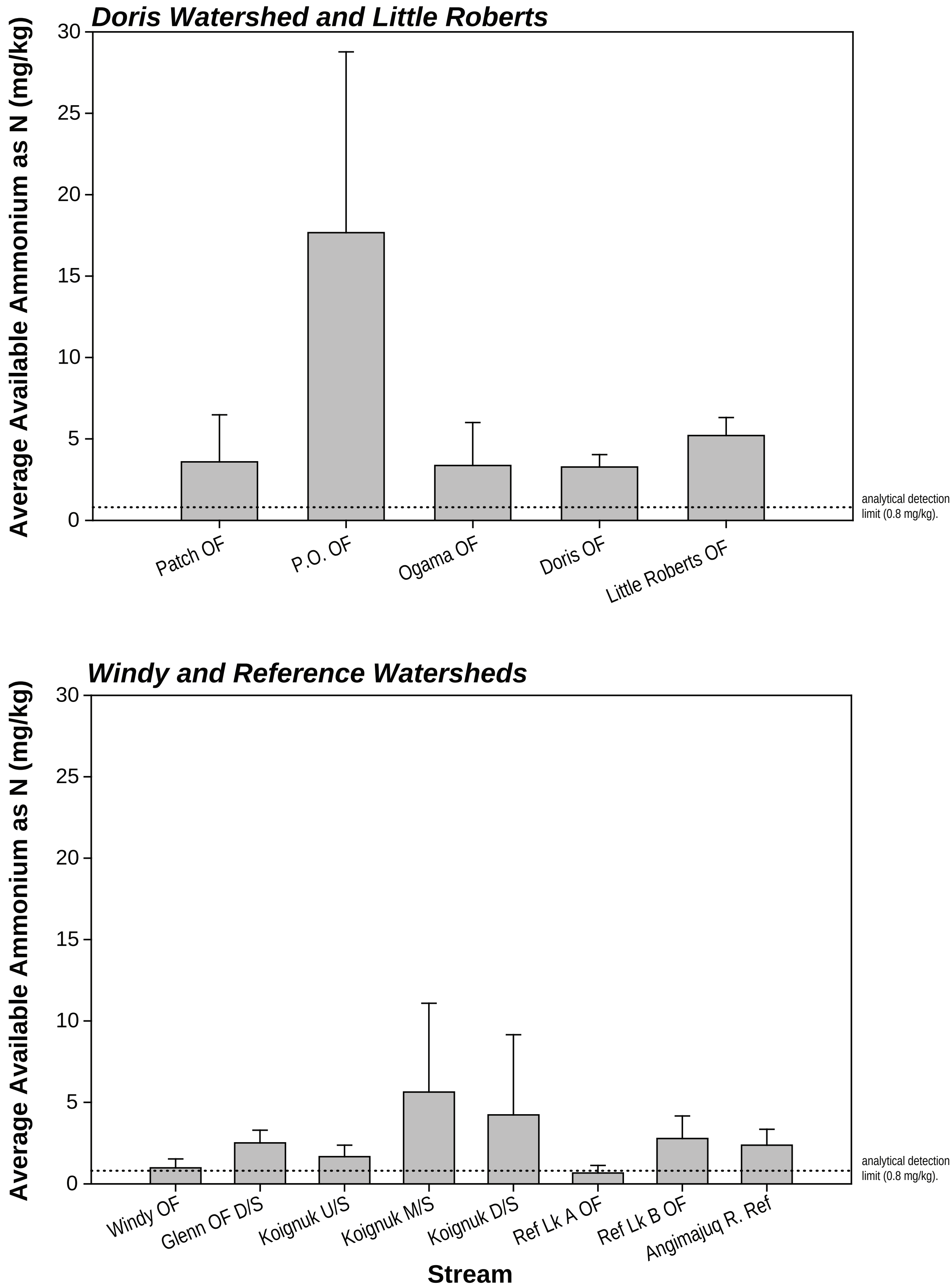
Notes: Error bars represent standard error of the mean.
No SQGs exist for available phosphorus.

NEWMONT NORTH AMERICA

Average Concentrations of Available Phosphorus in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2b

Rescan Engineers & Scientists



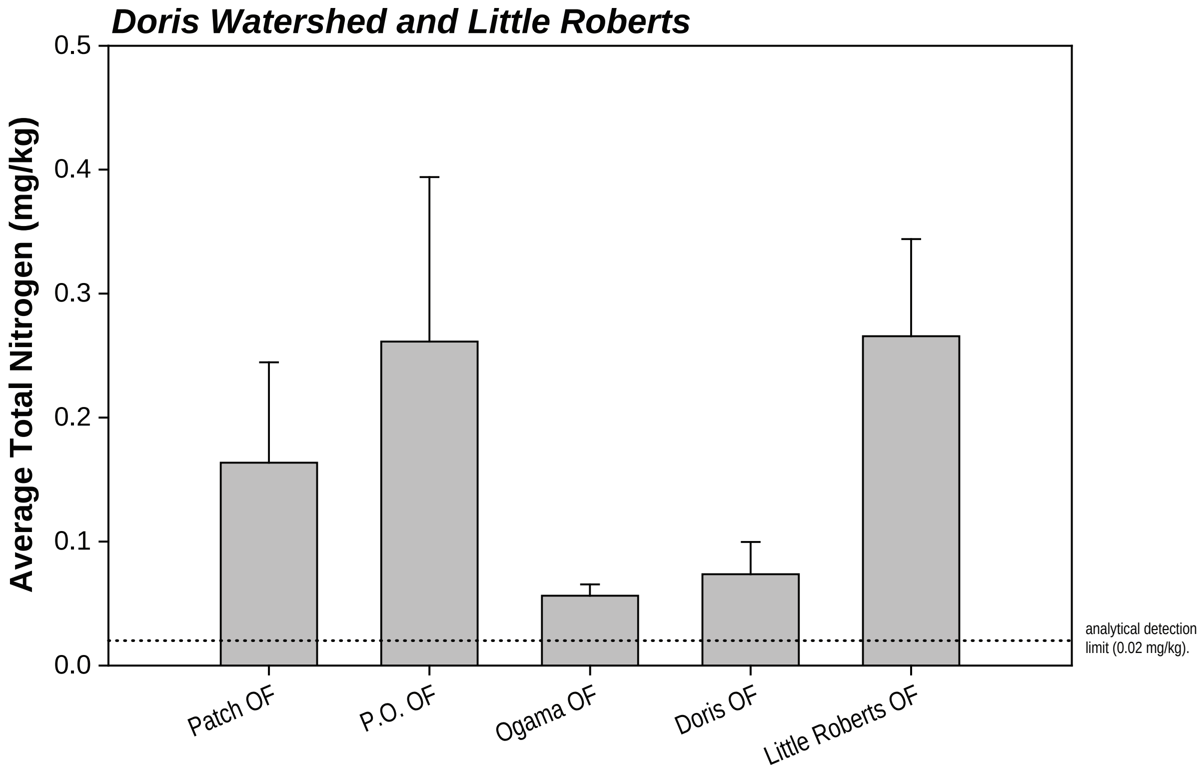
Notes: Error bars represent standard error of the mean.
No SQGs exist for ammonium as N.

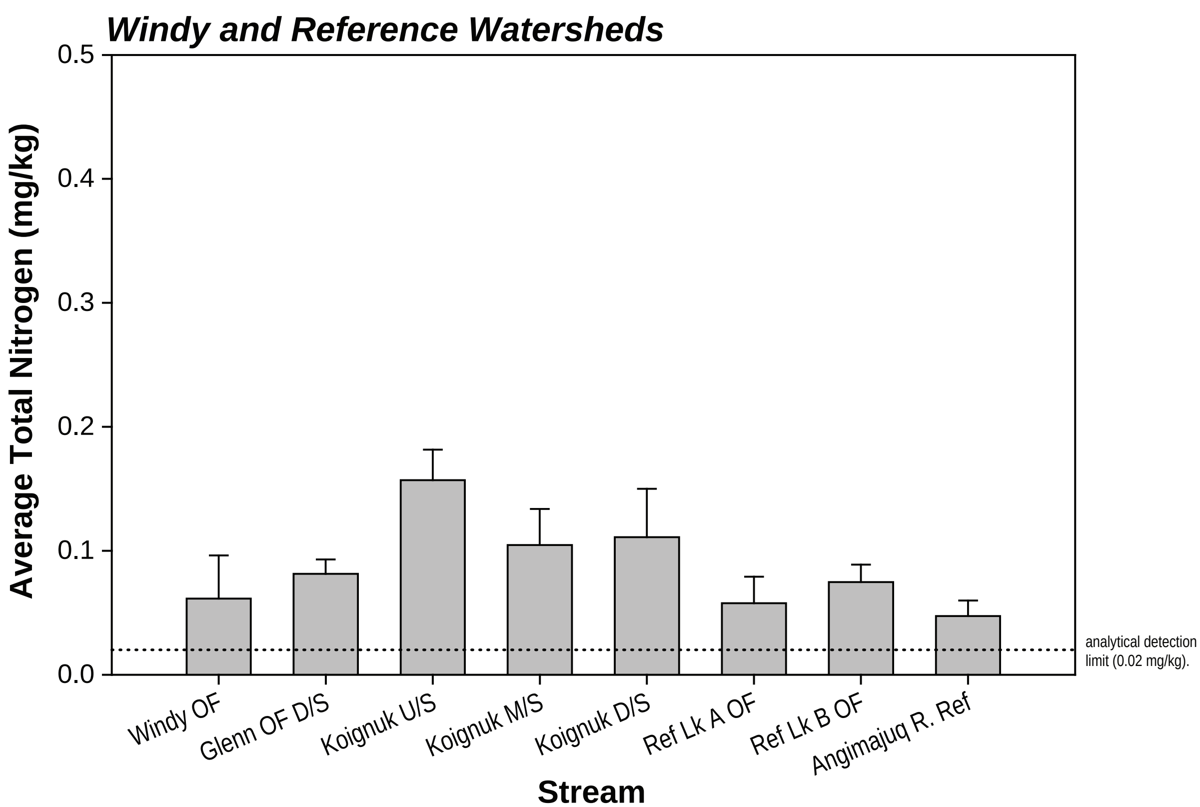
NEWMONT NORTH AMERICA

Average Concentrations of Average Available Ammonium as N in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2c

Rescan Engineers & Scientists





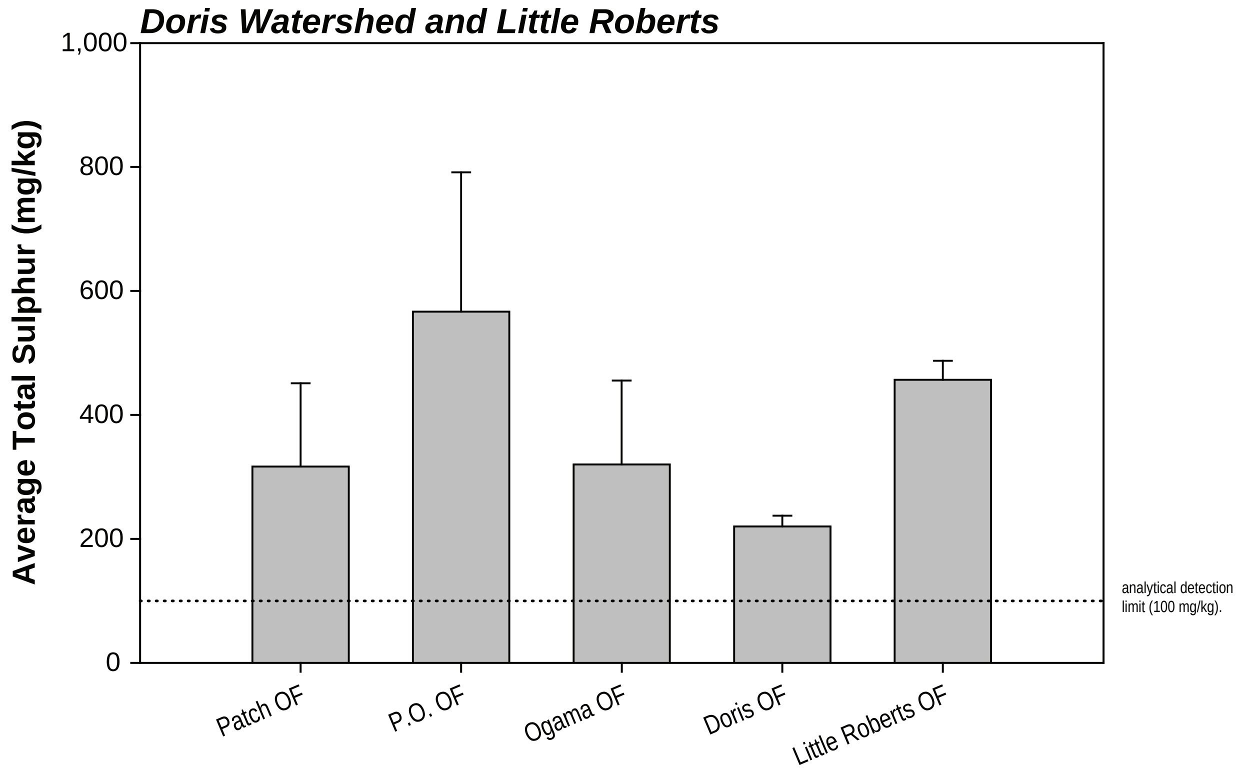
Notes: Error bars represent standard error of the mean.
No SQGs exist for total nitrogen.

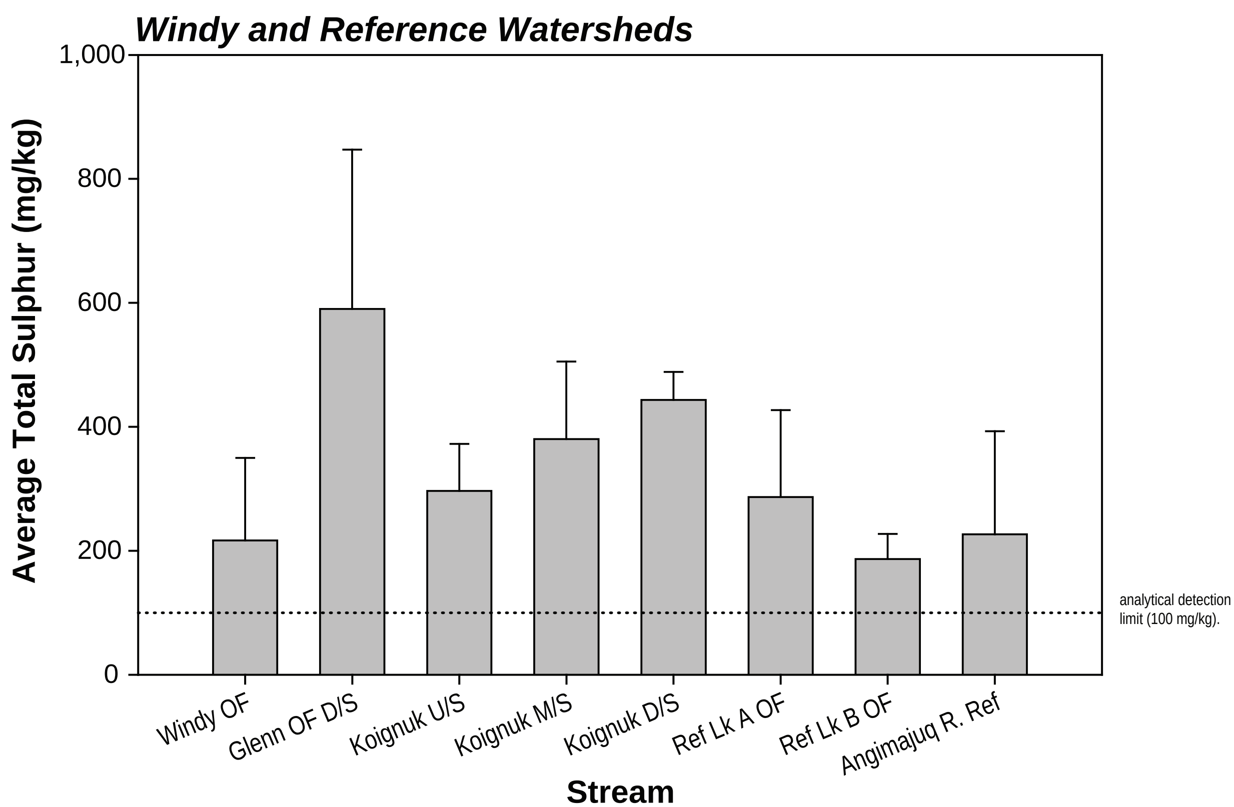
Figure 3.5-2d

NEWMONT NORTH AMERICA

Average Concentrations of Total Nitrogen in Stream Sediments, Hope Bay Belt Project, 2009

Rescan Engineers & Scientists





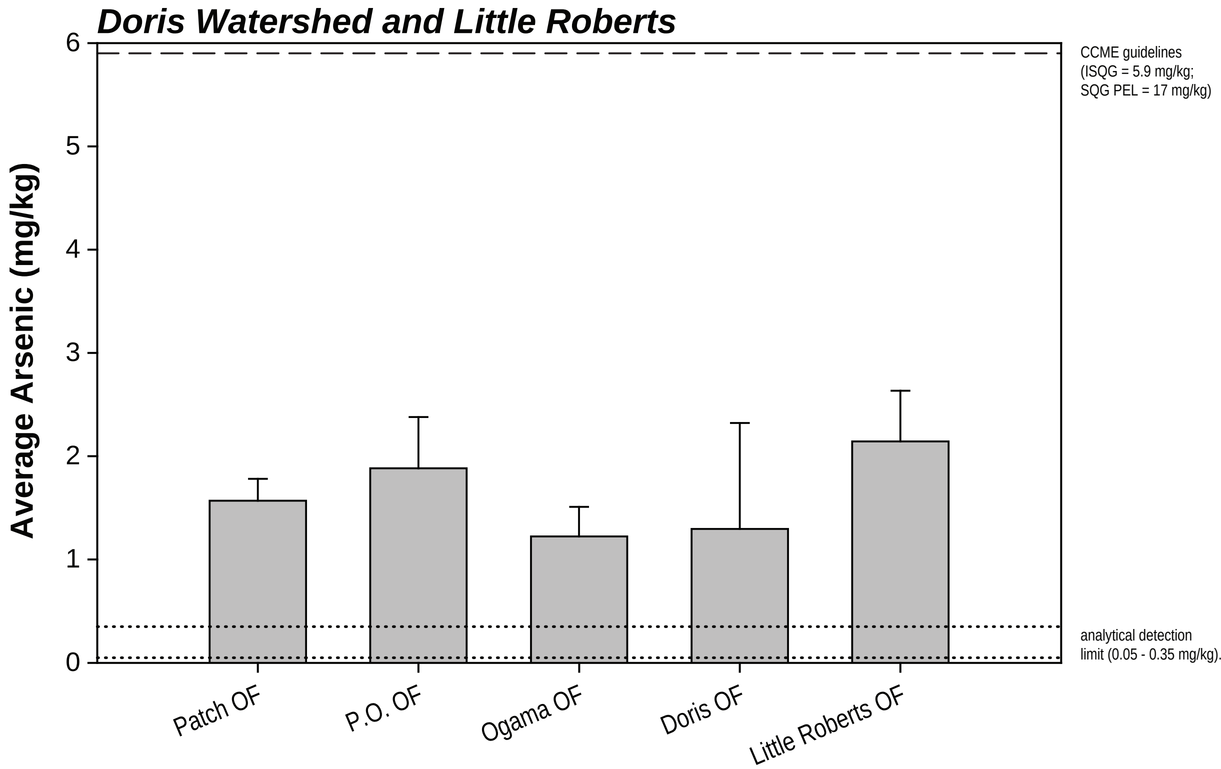
Notes: Error bars represent standard error of the mean.
No SQGs exist for total sulphur.

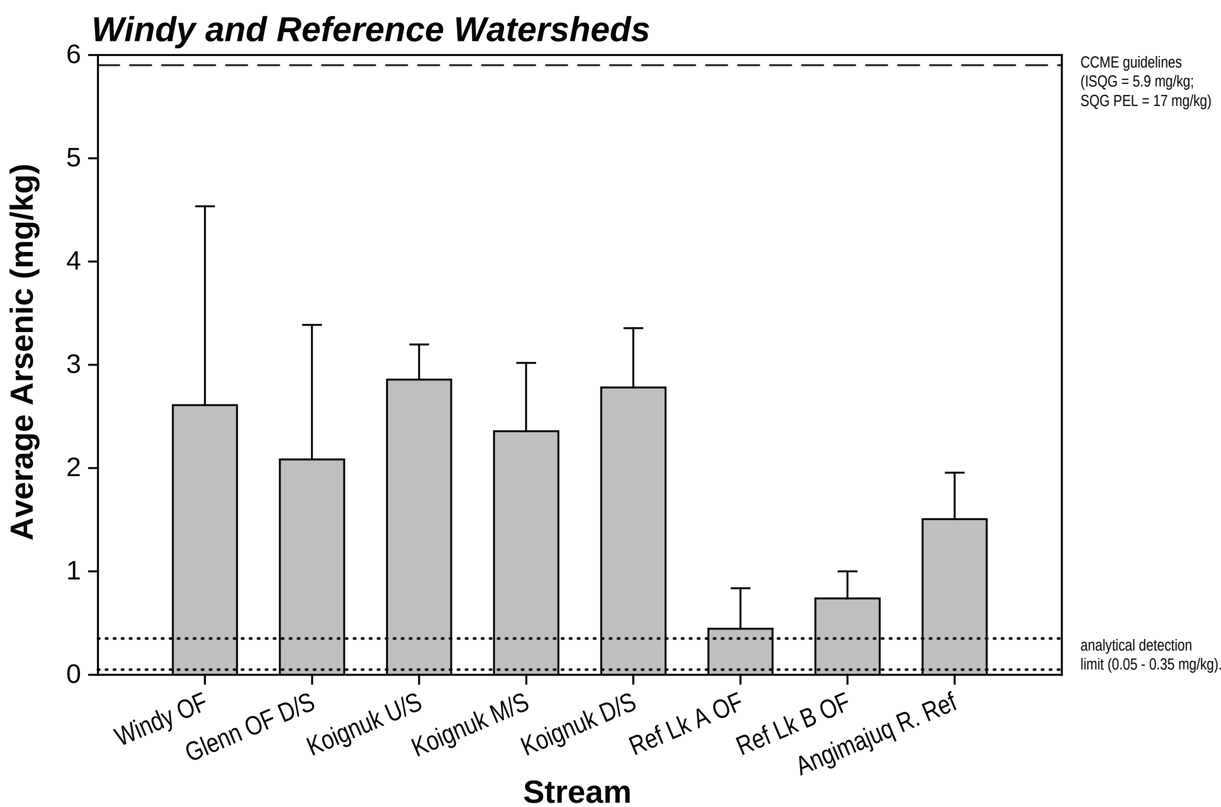
NEWMONT NORTH AMERICA

Average Concentrations of Total Sulphur in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2e

Rescan Engineers & Scientists





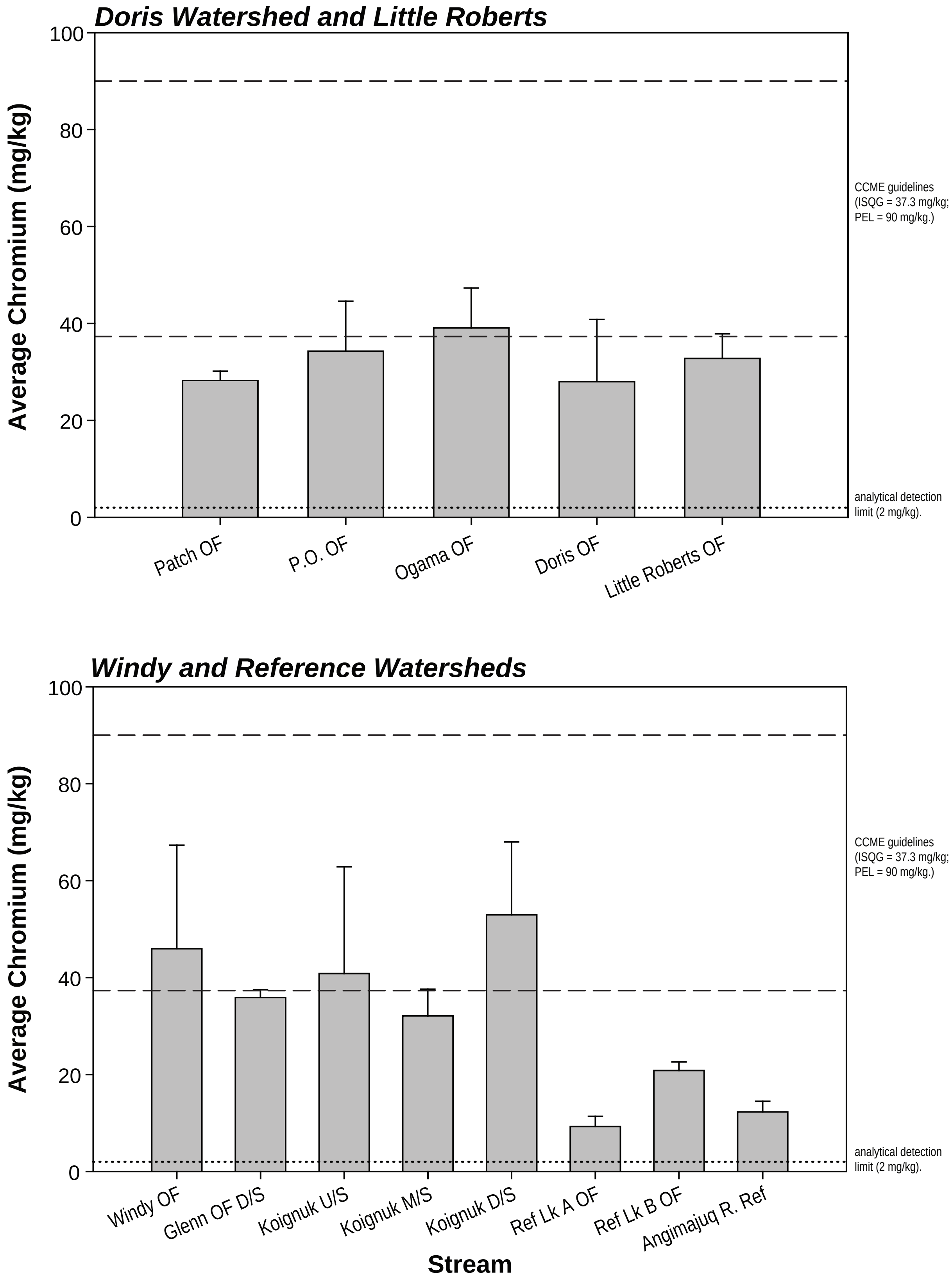
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentrations of Arsenic in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2f

Rescan Engineers & Scientists



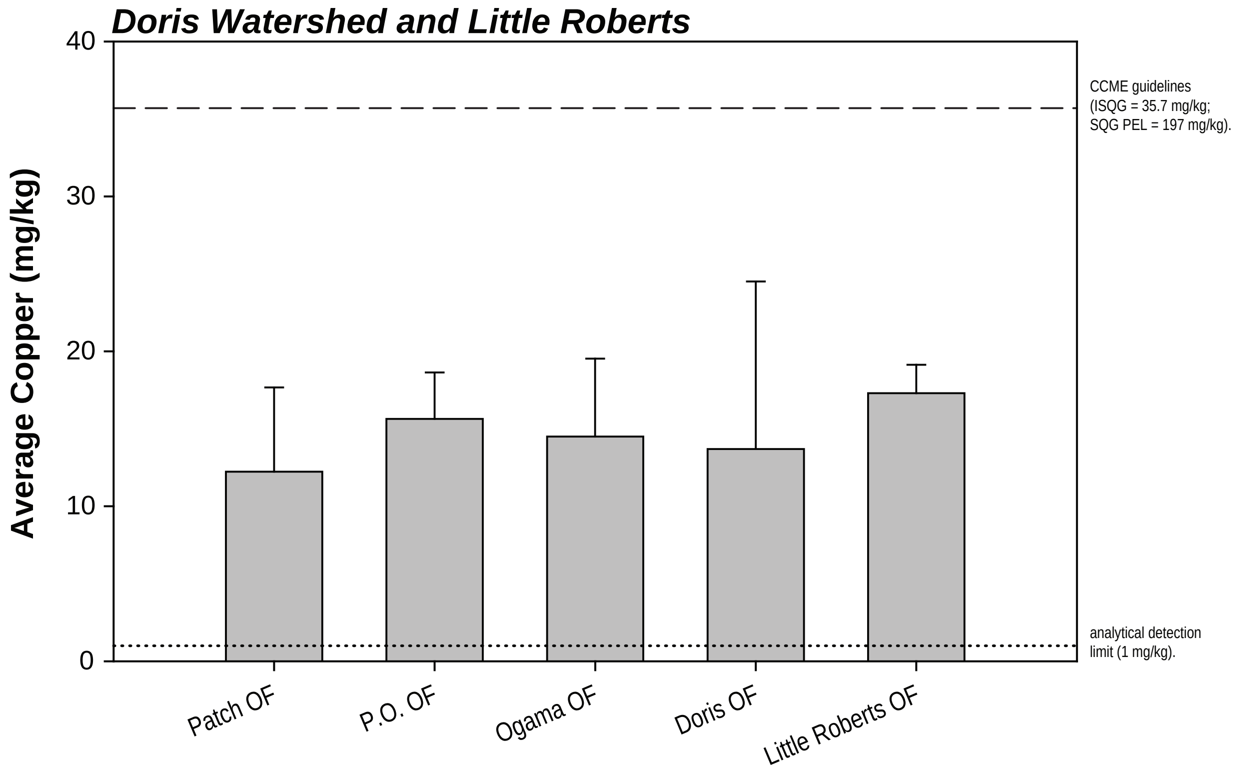
Notes: Error bars represent standard error of the mean.

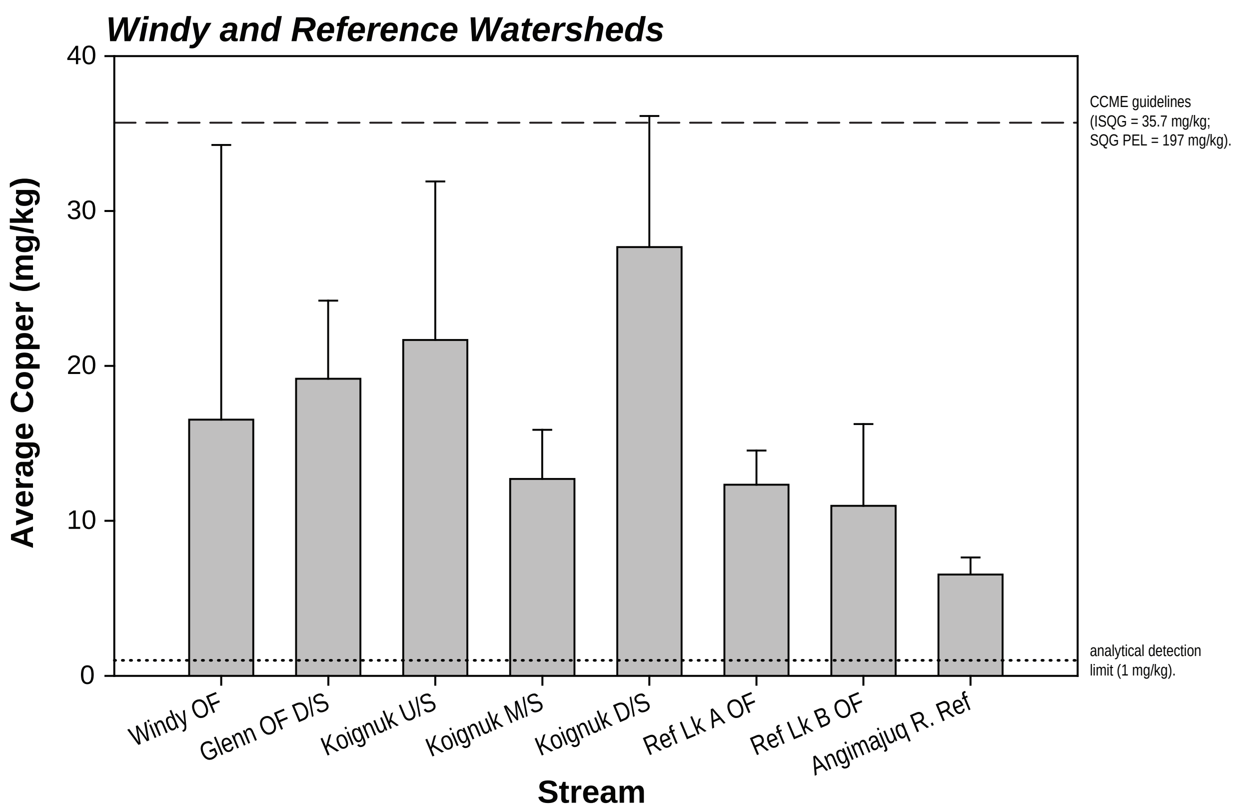
NEWMONT NORTH AMERICA

Average Concentrations of Chromium in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2g

Rescan Engineers & Scientists





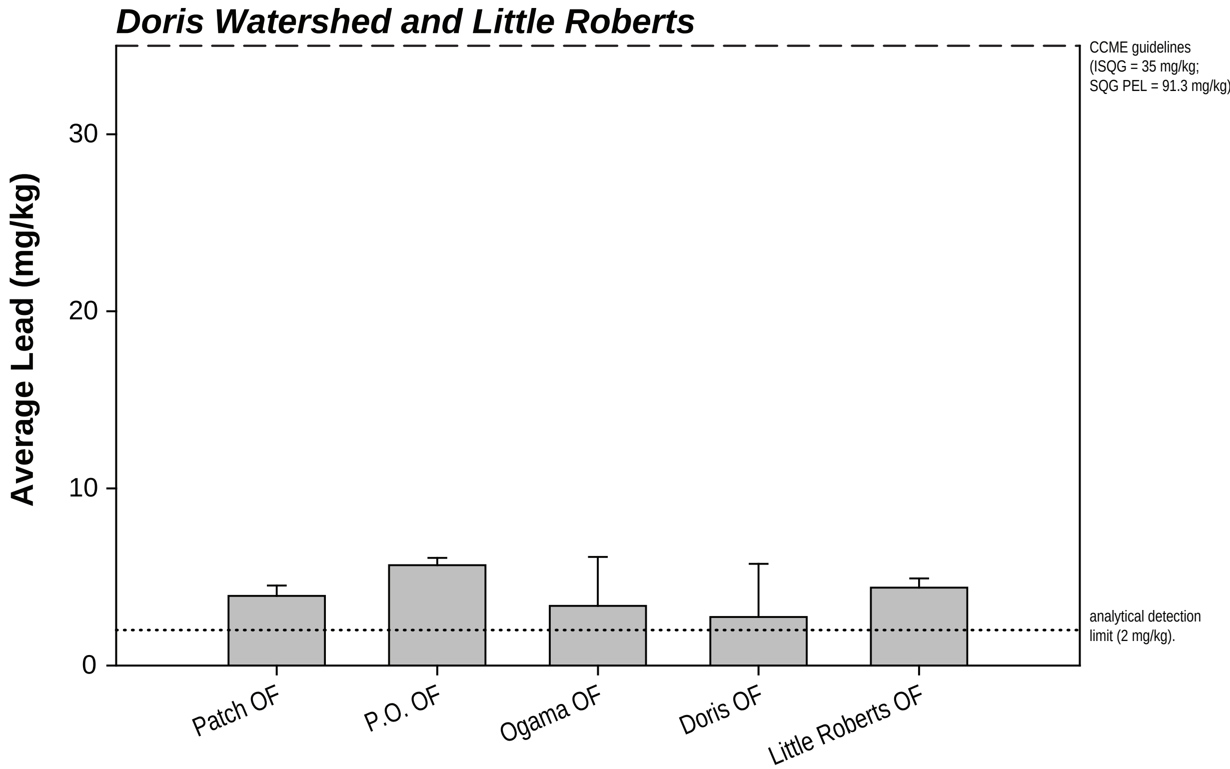
Notes: Error bars represent standard error of the mean.

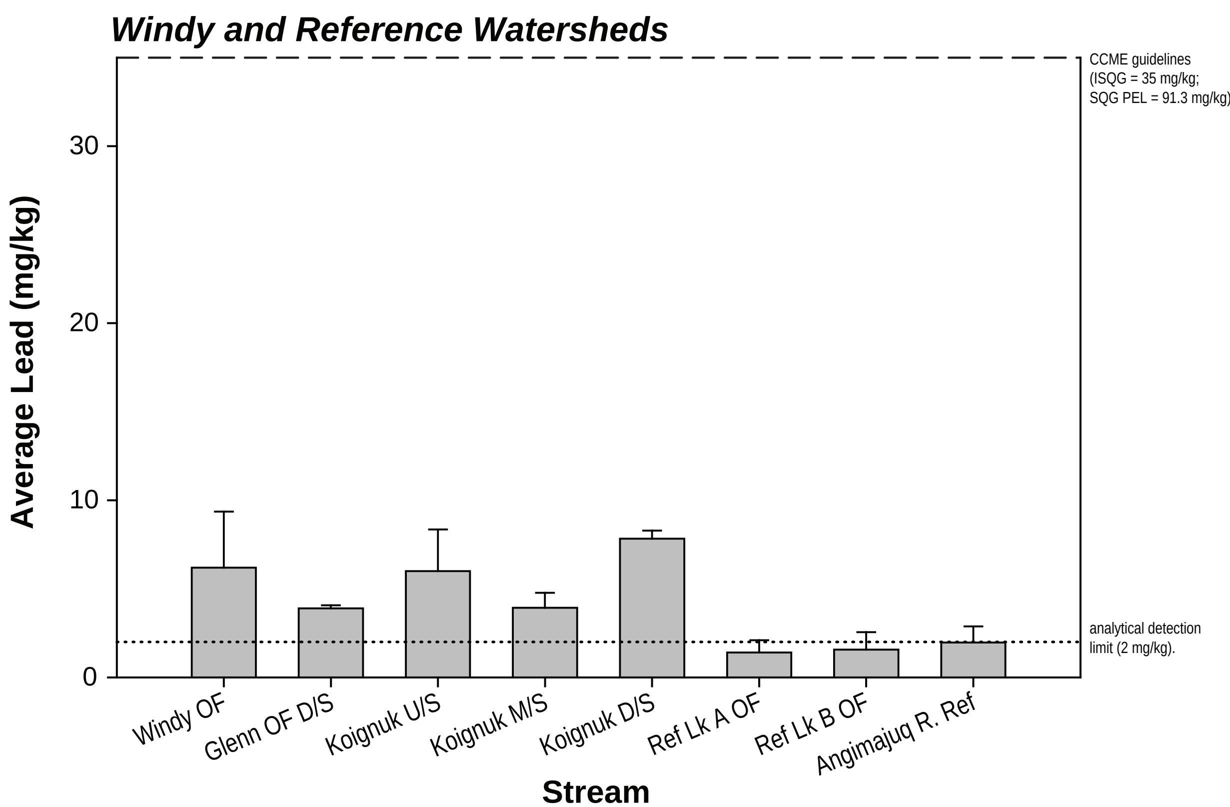
Figure 3.5-2h

Average Concentrations of Copper in Stream Sediments, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists





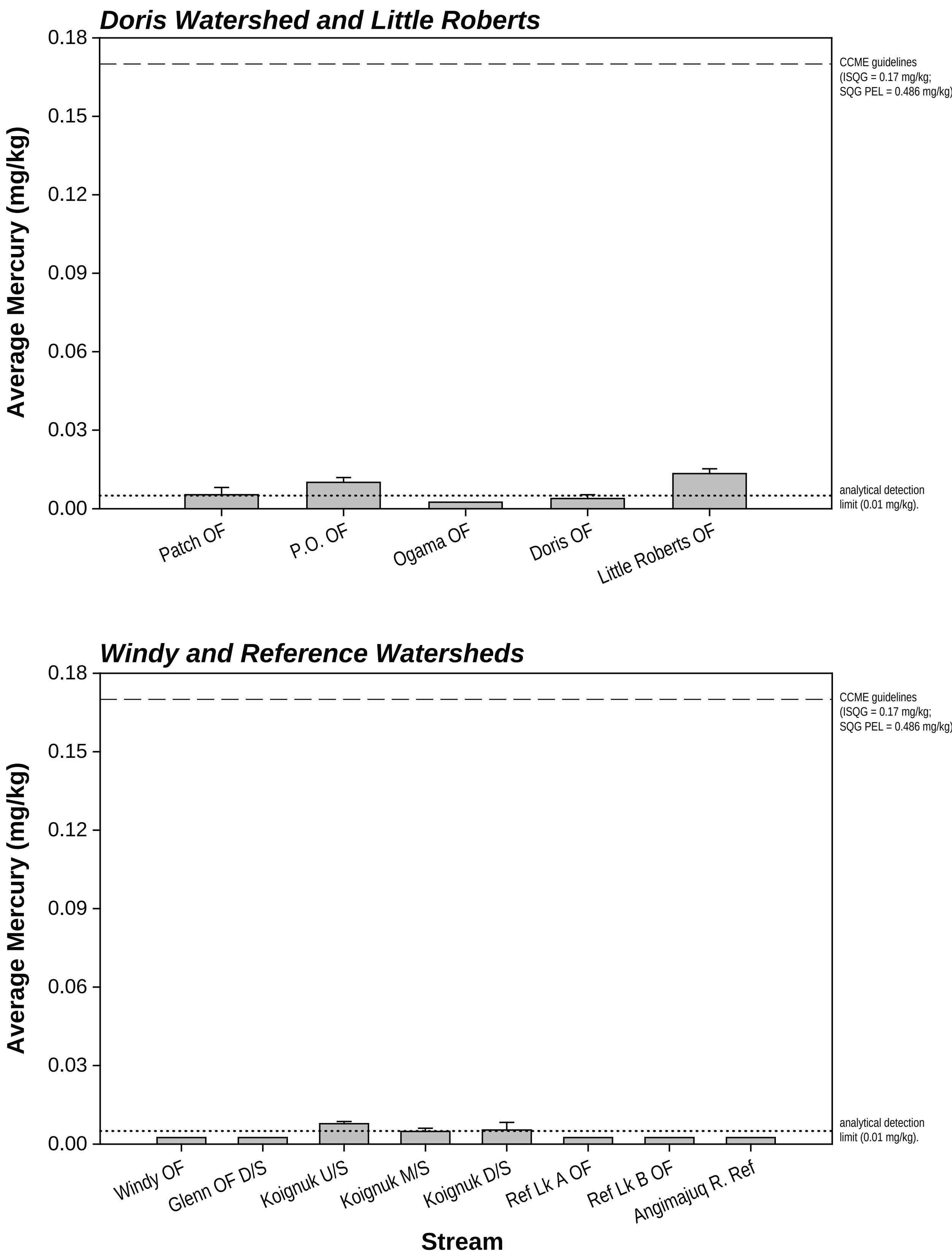
Notes: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentrations of Lead in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2i

Rescan Engineers & Scientists



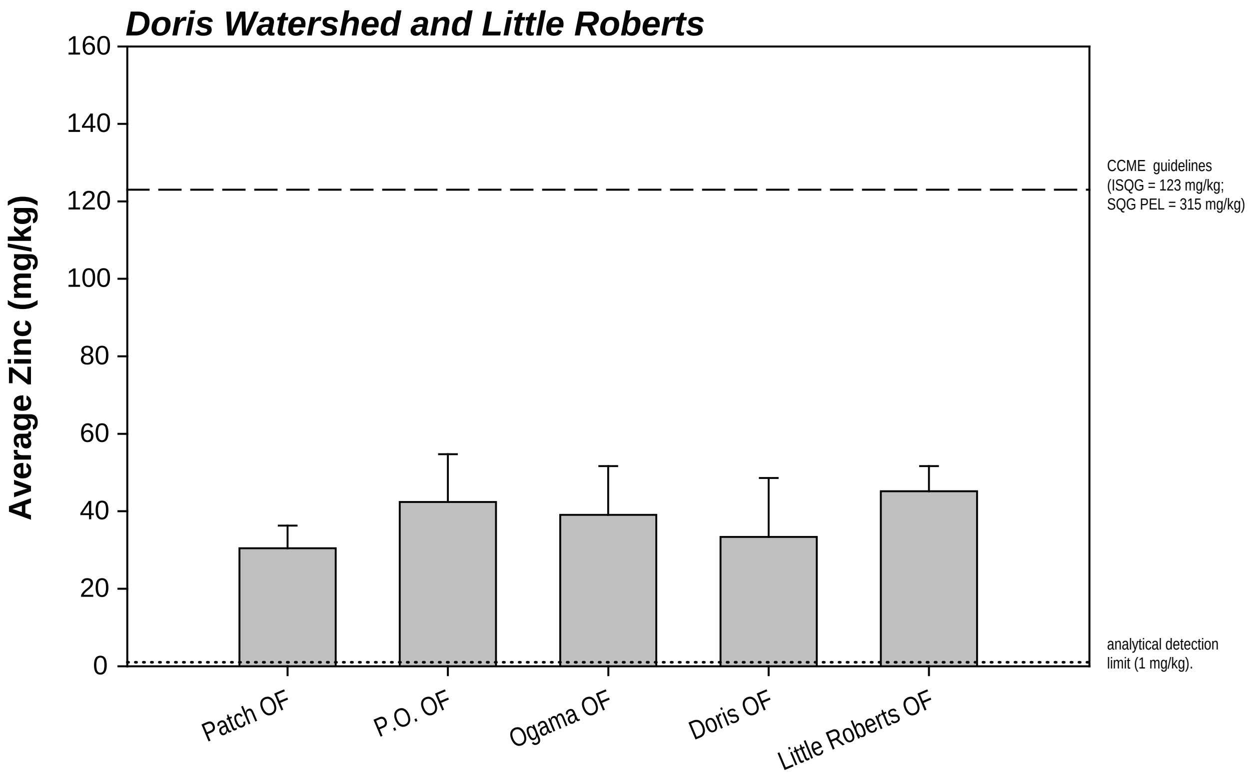
Note: Error bars represent standard error of the mean.

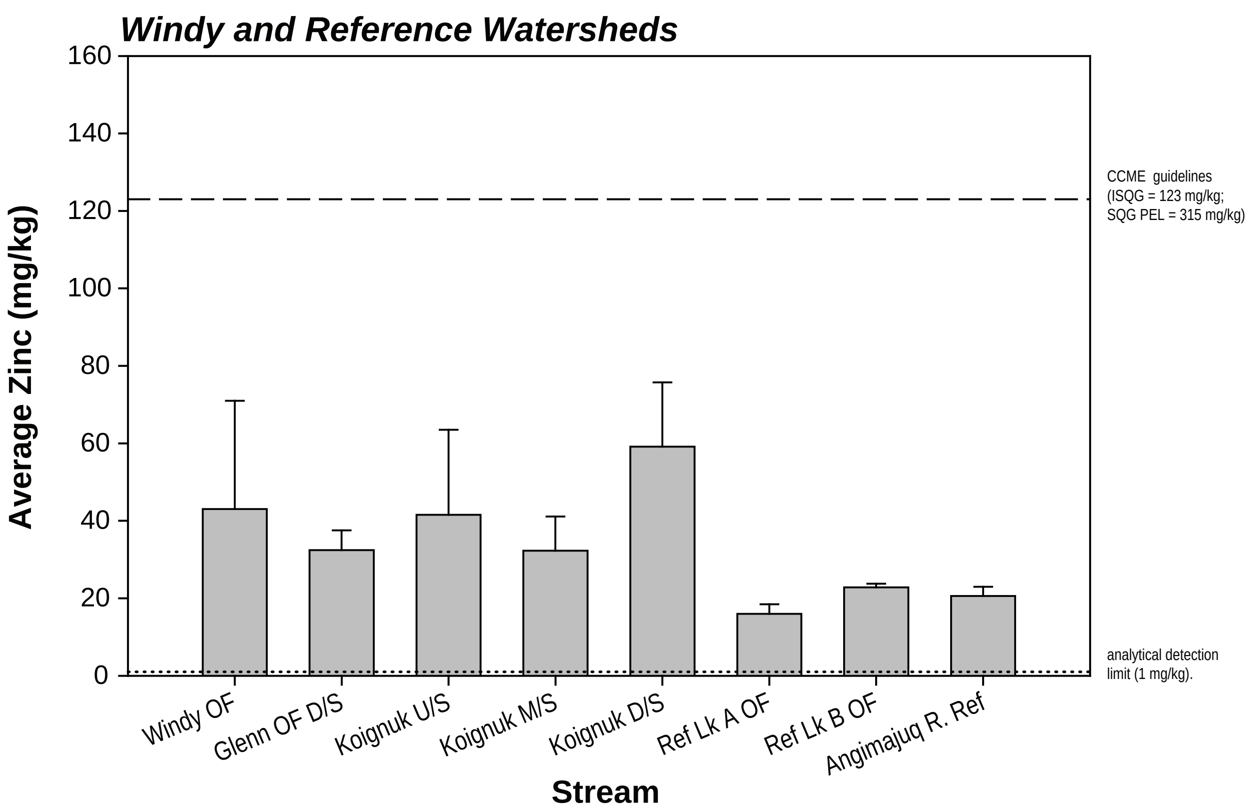
NEWMONT NORTH AMERICA

Average Concentrations of Mercury in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2j

Rescan Engineers & Scientists





Notes: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentrations of Zinc in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2k

Rescan Engineers & Scientists

Table 3.5-1. Stream Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Arsenic (As) 5.9	Cadmium (Cd) 0.6	Chromium (Cr) 37.3	Copper (Cu) 35.7	Lead (Pb) 35	Mercury (Hg) 0.17	Zinc (Zn) 123
			Percent of samples higher than ISQG[b] guidelines						
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		0	0	0	0	0	0	0
P.O. OF	3		0	0	33	0	0	0	0
Ogama OF	3		0	0	0	33	0	0	0
Doris OF	3		0	0	33	0	0	0	0
Little Roberts									
Little Roberts OF	3		0	0	33	0	0	0	0
Windy									
Windy OF	3		0	0	67	33	0	0	0
Glenn OF D/S	3		0	0	33	0	0	0	0
Koignuk River									
Koignuk U/S	3		0	0	33	0	0	0	0
Koignuk M/S	3		0	0	33	0	0	0	0
Koignuk D/S	3		0	0	67	0	0	0	0
Ref A									
Ref Lk A OF	3		0	0	0	0	0	0	0
Ref B									
Ref Lk B OF	3		0	0	0	0	0	0	0
Angimajuq									
Angimajuq R. Ref	3		0	0	0	0	0	0	0
Total Sites			**0**	**0**	**8**	**2**	**0**	**0**	**0**

All values represent percentages of 2009 samples that are higher than CCME guidelines.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

(continued)

Table 3.5-1. Stream Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Stream	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Percent of samples higher than PEL[c] guidelines Arsenic (As) 17	Cadmium (Cd) 3.5	Chromium (Cr) 90	Copper (Cu) 197	Lead (Pb) 91.3	Mercury (Hg) 0.486	Zinc (Zn) 315
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		0	0	0	0	0	0	0
P.O. OF	3		0	0	0	0	0	0	0
Ogama OF	3		0	0	0	0	0	0	0
Doris OF	3		0	0	0	0	0	0	0
Little Roberts									
Little Roberts OF	3		0	0	0	0	0	0	0
Windy									
Windy OF	3		0	0	0	0	0	0	0
Glenn OF D/S	3		0	0	0	0	0	0	0
Koignuk River									
Koignuk U/S	3		0	0	0	0	0	0	0
Koignuk M/S	3		0	0	0	0	0	0	0
Koignuk D/S	3		0	0	0	0	0	0	0
Ref A									
Ref Lk A OF	3		0	0	0	0	0	0	0
Ref B									
Ref Lk B OF	3		0	0	0	0	0	0	0
Angimajuq									
Angimajuq R. Ref	3		0	0	0	0	0	0	0
Total Sites			**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent percentages of 2009 samples that are higher than CCME guidelines.
a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)
b) ISQG = Interim sediment quality guideline
c) PEL = Probable effects level

Table 3.5-2. Stream Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Factor by which samples are higher than ISQG[b] guidelines: Arsenic (As) 5.9	Cadmium (Cd) 0.6	Chromium (Cr) 37.3	Copper (Cu) 35.7	Lead (Pb) 35	Mercury (Hg) 0.17	Zinc (Zn) 123
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		-	-	-	-	-	-	-
P.O. OF	3		-	-	-	-	-	-	-
Ogama OF	3		-	-	1.05	-	-	-	-
Doris OF	3		-	-	-	-	-	-	-
Little Roberts									
Little Roberts OF	3		-	-	-	-	-	-	-
Windy									
Windy OF	3		-	-	1.23	-	-	-	-
Glenn OF D/S	3		-	-		-	-	-	-
Koignuk River									
Koignuk U/S	3		-	-	1.09	-	-	-	-
Koignuk M/S	3		-	-	-	-	-	-	-
Koignuk D/S	3		-	-	1.42	-	-	-	-
Ref A									
Ref Lk A OF	3		-	-	-	-	-	-	-
Ref B									
Ref Lk B OF	3		-	-	-	-	-	-	-
Angimajuq									
Angimajuq R. Ref	3		-	-	-	-	-	-	-
Total Sites			**0**	**0**	**4**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 stream averages are higher than CCME guidelines. *(continued)*

Even though a percentage of samples may be higher than a guideline amount, the calculated stream average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable Effects Level

Table 3.5-2. Stream Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Stream	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
			Factor by which samples are higher than PEL[c] guidelines						
			17	3.5	90	197	91.3	0.486	315
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		-	-	-	-	-	-	-
P.O. OF	3		-	-	-	-	-	-	-
Ogama OF	3		-	-	-	-	-	-	-
Doris OF	3		-	-	-	-	-	-	-
Little Roberts									
Little Roberts OF	3		-	-	-	-	-	-	-
Windy									
Windy OF	3		-	-	-	-	-	-	-
Glenn OF D/S	3		-	-	-	-	-	-	-
Koignuk River									
Koignuk U/S	3		-	-	-	-	-	-	-
Koignuk M/S	3		-	-	-	-	-	-	-
Koignuk D/S	3		-	-	-	-	-	-	-
Ref A									
Ref Lk A OF	3		-	-	-	-	-	-	-
Ref B									
Ref Lk B OF	3		-	-	-	-	-	-	-
Angimajuq									
Angimajuq R. Ref	3		-	-	-	-	-	-	-
Total Sites			**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 stream averages are higher than CCME guidelines.

Even though a percentage of samples may be higher than a guideline amount, the calculated stream average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable Effects Level

3.6.1 Phytoplankton Biomass

Surface phytoplankton biomass (as chlorophyll *a*) ranged from 0.3 to 26.9 µg chl *a* /L in surveyed lakes, and was generally similar during summer and winter for the lakes sampled during both periods (Figure 3.6-1). The exception was at Little Roberts Lake, where biomass was markedly higher in winter (26.9 µg chl *a* /L) than in summer (2.1 µg chl *a* /L). Little Roberts Lake had a very transparent ice cover at the time of winter sampling, with little snow cover (due to strong winds); therefore, light penetration into the water column would likely have been sufficient to support photosynthesis year-round. Field observations made at the time of sample collection confirmed the greenish colour of the water, which suggests high algal densities. Relatively high phytoplankton biomass was also found at Nakhaktok Lake (18.0 µg chl *a* /L in summer), Doris N (7.6 and 8.1 µg chl *a* /L in winter and summer, respectively), Doris S (12.9 and 8.8 µg chl *a* /L in winter and summer, respectively), and Ogama (5.6 µg chl *a* /L in summer) lakes.

3.6.2 Phytoplankton Abundance

Patterns of phytoplankton abundance generally followed those seen for phytoplankton biomass. Summer phytoplankton abundance was highest at Nakhaktok Lake (16,900 cells/mL) and the downstream Doris Watershed lakes: Ogama (5,000 cells/mL), Doris S (4,500 cells/mL) and N (4,800 cells/mL), and Little Roberts (1,900 cells/mL; Figure 3.6-1). Summer phytoplankton abundance at all other sites surveyed did not exceed 550 cells/mL.

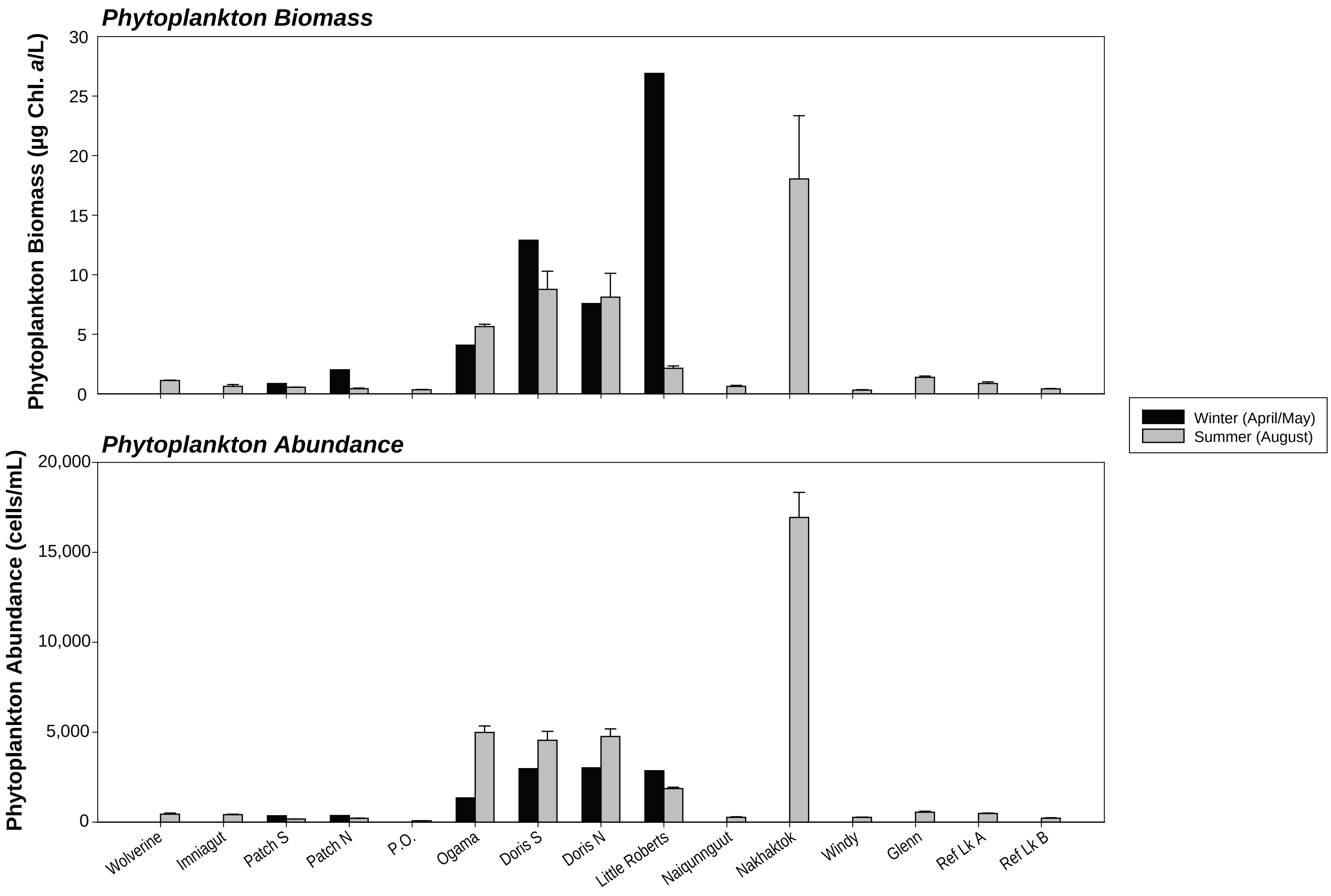
Winter phytoplankton abundance followed the trends observed during summer months, with Ogama, Doris, and Little Roberts lakes having elevated levels of abundance compared to Patch Lake. Phytoplankton biomass observed at Little Roberts Lake was disproportionally high relative to phytoplankton abundance data collected at the same time, and suggests the presence of large or chlorophyll *a*-rich phytoplankton during the winter.

3.6.3 Phytoplankton Taxonomic Composition

Lakes in the study area contained a diverse assemblage of phytoplankton taxa (Figure 3.6-2). During the summer, lakes with the highest levels of phytoplankton biomass and abundance (Ogama, Doris S and N, Little Roberts, and Nakhaktok) were dominated by cyanobacteria (blue-green algae), a taxa known to be dominant in eutrophic sites. Cyanobacteria, largely the nitrogen-fixing *Aphanizomenon flos-aquae*, comprised 60 to 88% of the phytoplankton communities at these lakes. Cyanobacteria were also abundant at these five sites during the winter, though Ogama Lake contained a relatively even mix of cyanobacteria (31%), chrysophytes (26%), and cryptophytes (27%), and Little Roberts Lake had high numbers of dionflagellates (31%) and chrysophytes (41%). Cyanobacteria made up less than 2% of the phytoplankton community at other sites. Diatoms, chlorophytes (green algae), and cryptophytes where also abundant in study area lakes.

3.6.4 Phytoplankton Richness and Diversity

During the summer, genera richness ranged from 8 genera/sample at Nakhaktok Lake to 20 genera/sample at Patch S and N, and averaged 15 genera/sample across all sites. Winter richness ranged from 6 to 17 genera/sample. Summer richness exceeded winter levels at all lakes except Ogama Lake (Figure 3.6-3).



Note: Error bars represent standard error of the mean
For each site, n=1 in winter; n=3 in summer

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Winter and Summer Phytoplankton Biomass and Abundance, Hope Bay Lakes, 2009

Figure 3.6-1

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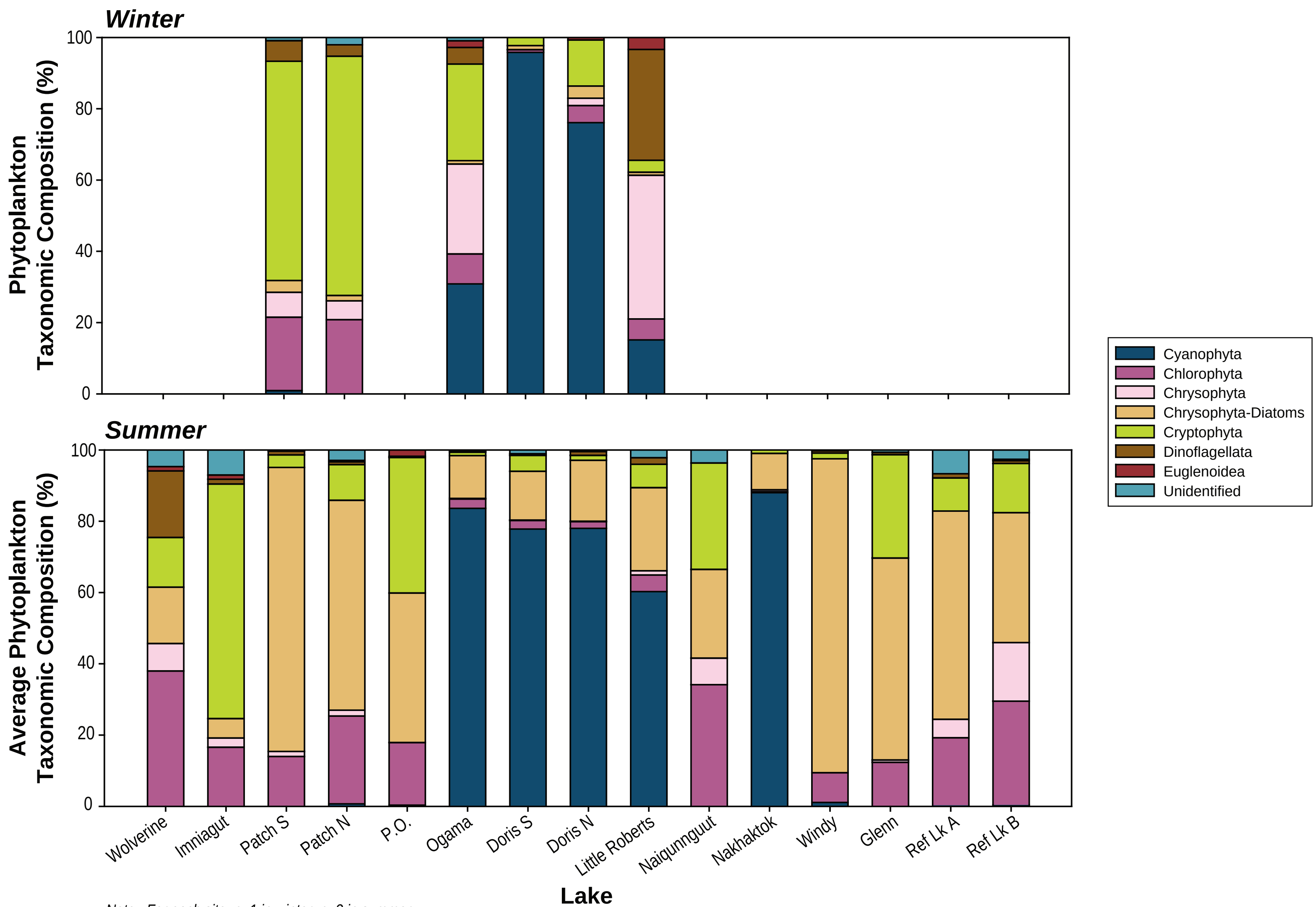

Note: For each site, n=1 in winter; n=3 in summer

Winter and Summer Phytoplankton Taxonomic Composition, Hope Bay Lakes, 2009

Figure 3.6-2

NEWMONT NORTH AMERICA

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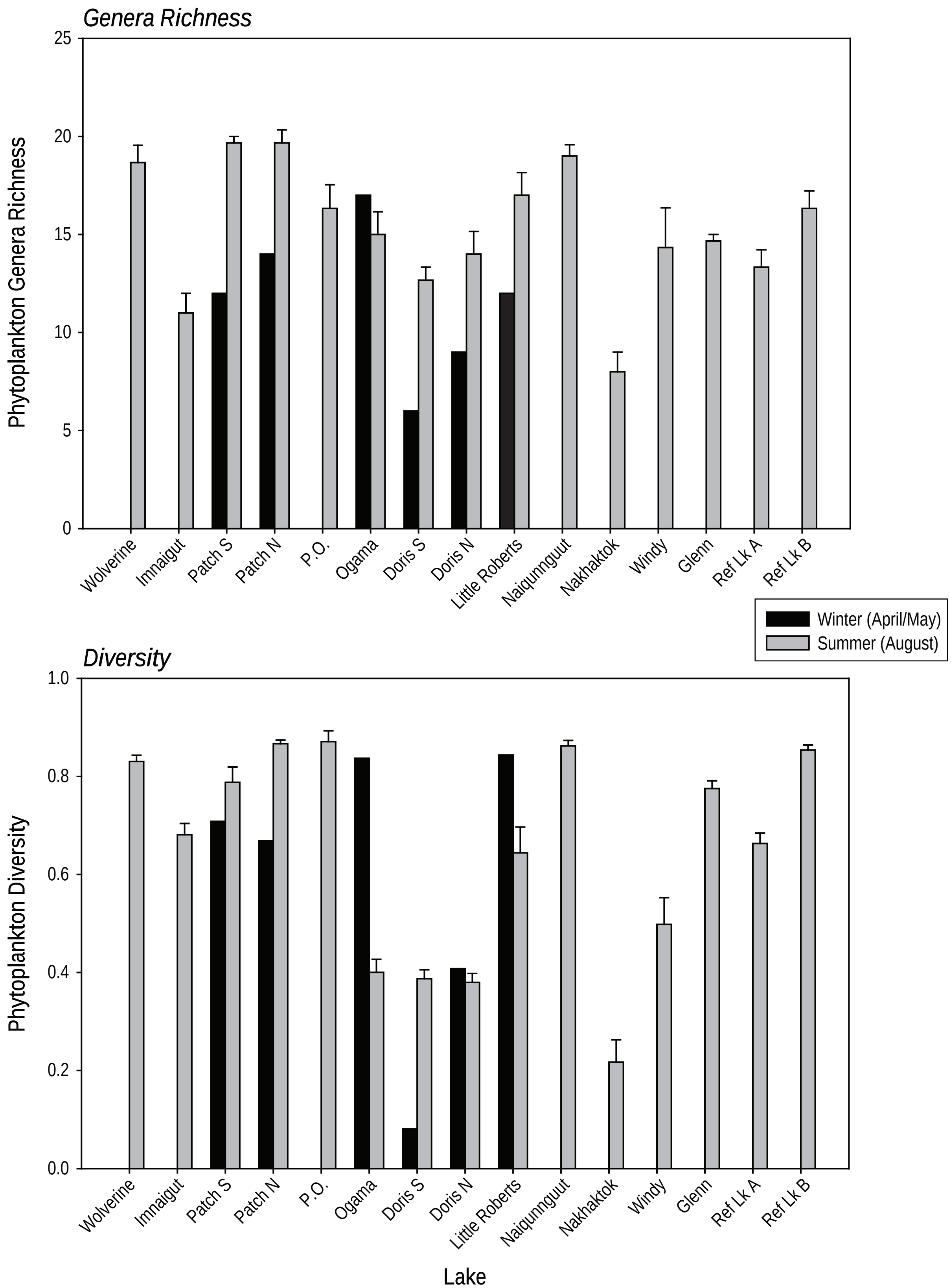

Note: Error bars represent standard error of the mean
For each site, n=1 in winter; n=3 in summer

Figure 3.6-3

Winter and Summer Phytoplankton Richness and Diversity, Hope Bay Lakes, 2009

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Simpson's diversity index is a combined measure of genera richness and the evenness with which abundances are distributed among these genera. During the summer, phytoplankton diversity was lowest at Nakhaktok Lake (0.22) and highest at Patch S and N (0.87; Figure 3.6-3). At Ogama and Little Roberts lakes, diversity was notably higher in the winter than summer (winter diversity of 0.84 at both sites), while the opposite was true at Doris S (winter Simpson's diversity index of 0.08).

3.6.5 Epontic Algae Taxonomic Composition and Diversity

Samples of epontic algae (algae living on the underside of the ice) were collected from six lake sites by scraping the underside of the lake ice. Because these were qualitative samples, epontic algal densities were not calculated.

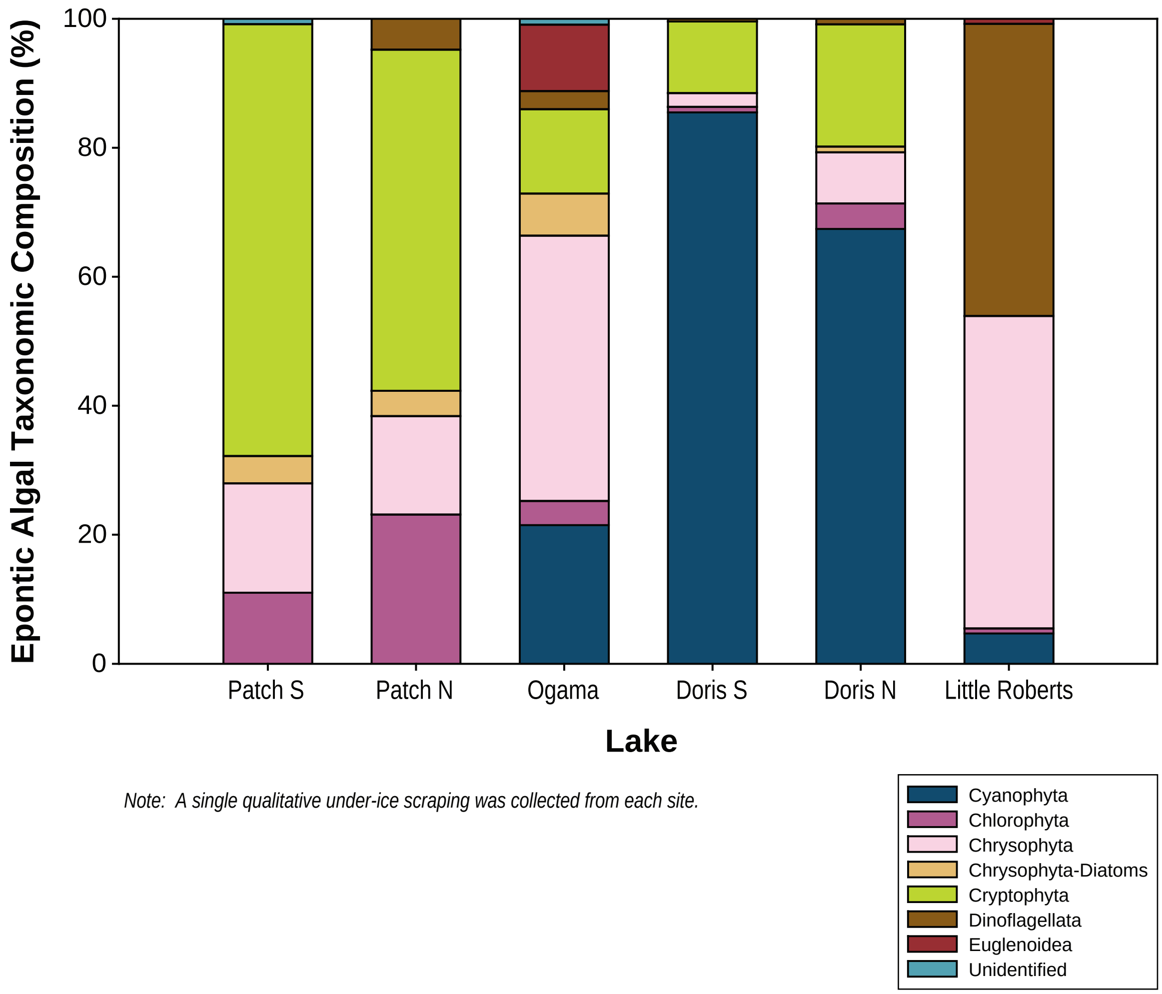
Epontic communities corresponded closely, in terms of broad taxonomic composition (i.e., percentages of cyanobacteria, chrysophytes, dinoflagellates, etc.), to winter phytoplankton communities (Figure 3.6-4). Epontic algal richness ranged from 6 genera/sample at Doris S to 17 genera/sample at Ogama Lake (Figure 3.6-5). Epontic algal diversity ranged from 0.26 at Doris S to 0.88 at Ogama Lake (Figure 3.6-5). Differences in epontic algal richness and diversity among lake sites followed similar trends.

3.6.6 Annual Comparison

Table 2.13-5 outlines the years for which historical phytoplankton data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-3 provides a summary of the historical phytoplankton sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to variability observed between years. Winter phytoplankton data were not included in the annual averages as winter samples were collected only in 2009.

Prior to 2009, phytoplankton biomass data were only collected in 2000 and 2007, and only at Doris and Little Roberts lakes (Figure 3.6-6). Despite annual differences in sample collection location (see Figure 2.13-3), sampling date, and sampling methodologies (e.g., discrete samples vs. integrated sampler used in 2007), historical data supported 2009 findings that these two lakes have elevated levels of phytoplankton biomass.

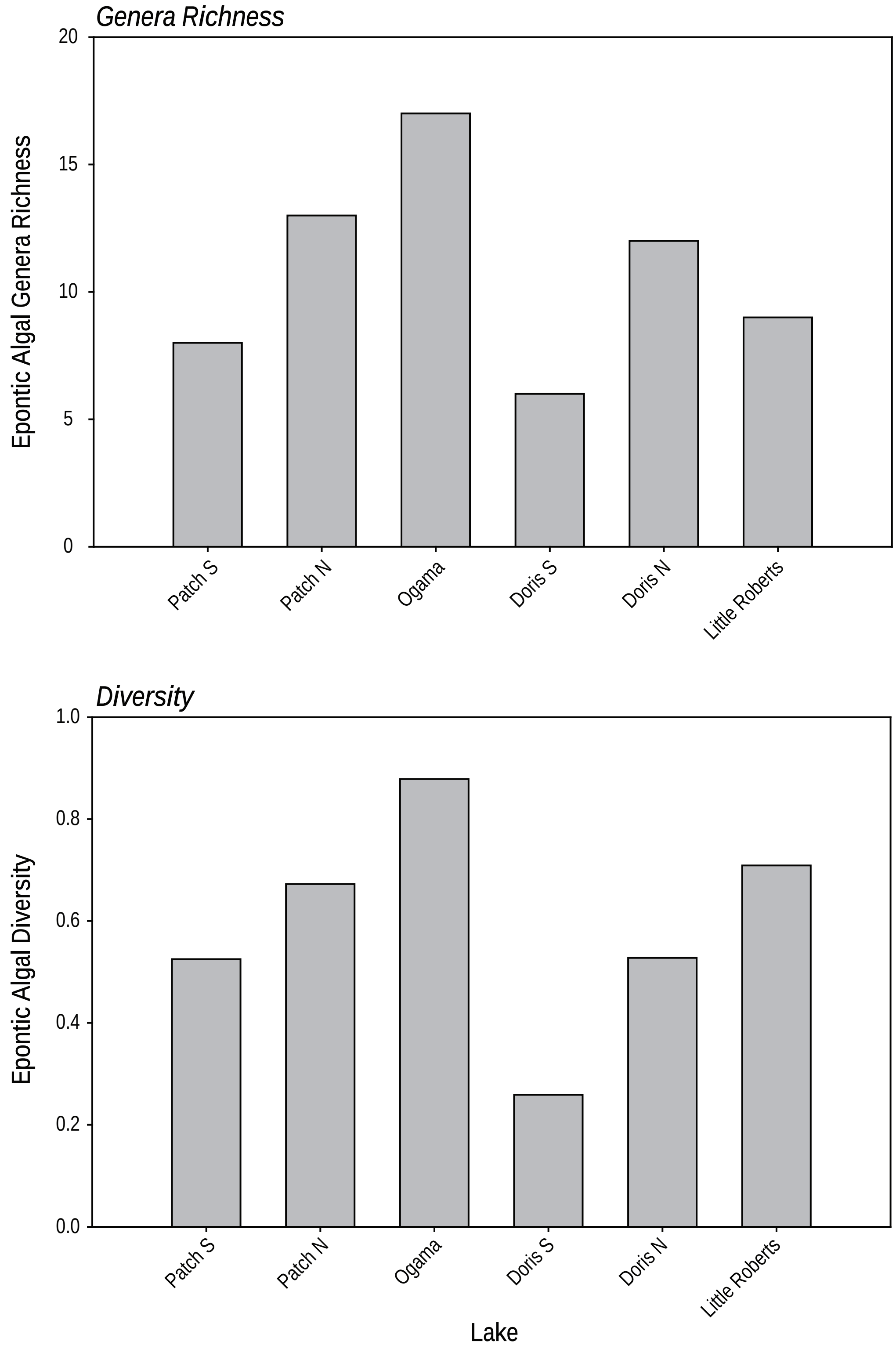
Phytoplankton abundance data were collected in more years and at more sites than phytoplankton biomass data (Figure 3.6-7). Annual data were variable; however, Ogama, Doris S and N, Little Roberts, and Nakhaktok lakes tended to have historically high levels of abundance compared to other sites. The 2007 phytoplankton abundance data were notable since they tended to have the highest within-site variability (partially a product of combining samples from different months) and higher abundances than those observed in other years. In 2007, phytoplankton were collected from the entire euphotic zone with the use of a depth-integrated sampler, as opposed to the discrete samples collected in other years (from 1 m depth in 1997, 2000, and 2009; from 0.5 m in 1996). In addition, samples were collected in July, August, and September in 2007, while in other years, samples were collected in a single month (July in 1997 and 2000; August in 1996 and 2009).



Note: A single qualitative under-ice scraping was collected from each site.

Figure 3.6-4

Epontic Algal Taxonomic Composition, Hope Bay Lakes, April/May 2009



Note: A single qualitative under-ice scraping was collected from each lake

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Figure 3.6-5

Epontic Algal Richness and Diversity, Hope Bay Lakes, April/May 2009

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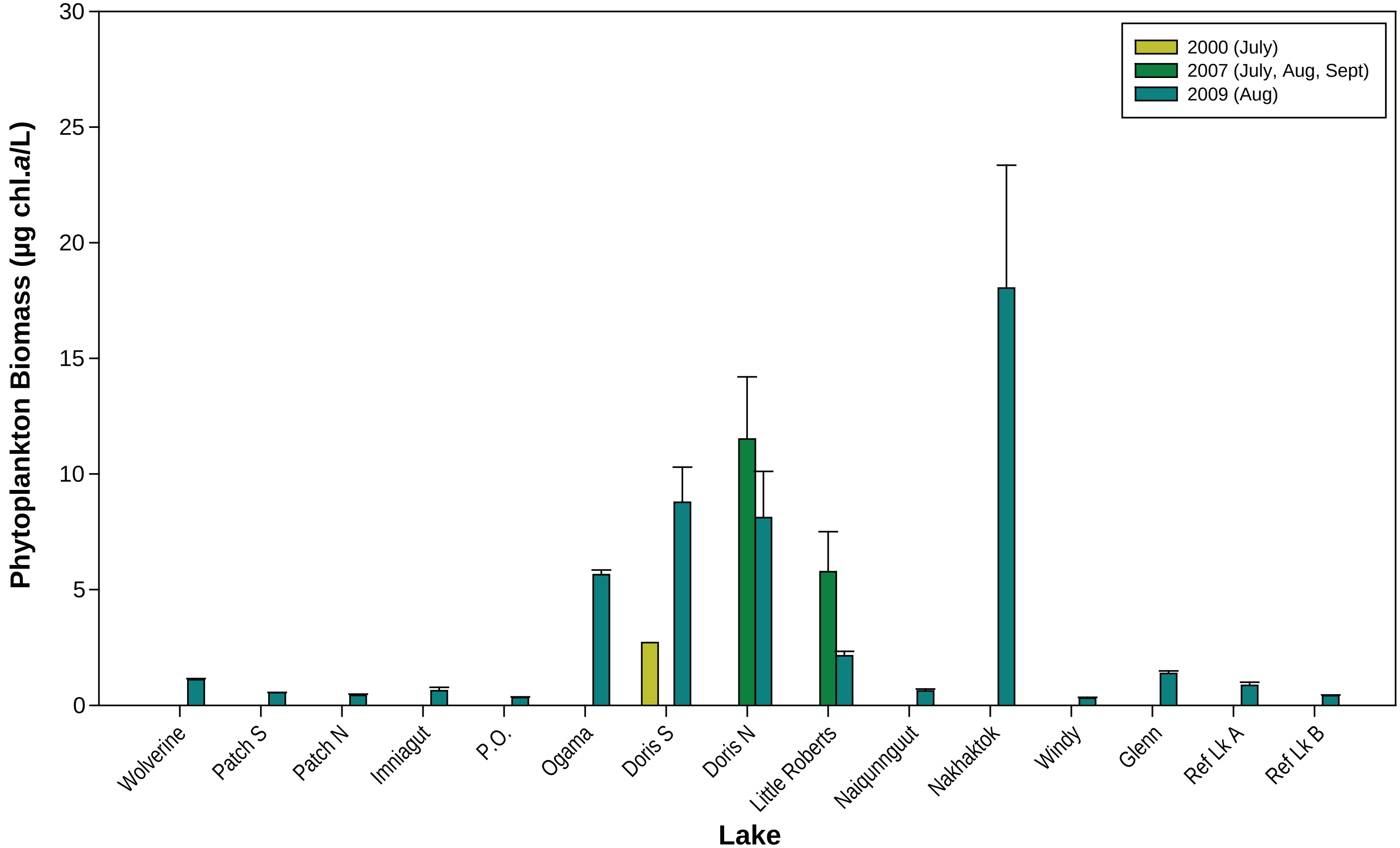

Note: Error bars represent standard error of the mean
Winter phytoplankton samples (collected in 2009) are not included in the annual averages

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Average Annual Phytoplankton Biomass, Hope Bay Lakes, 1996 - 2009

Figure 3.6-6

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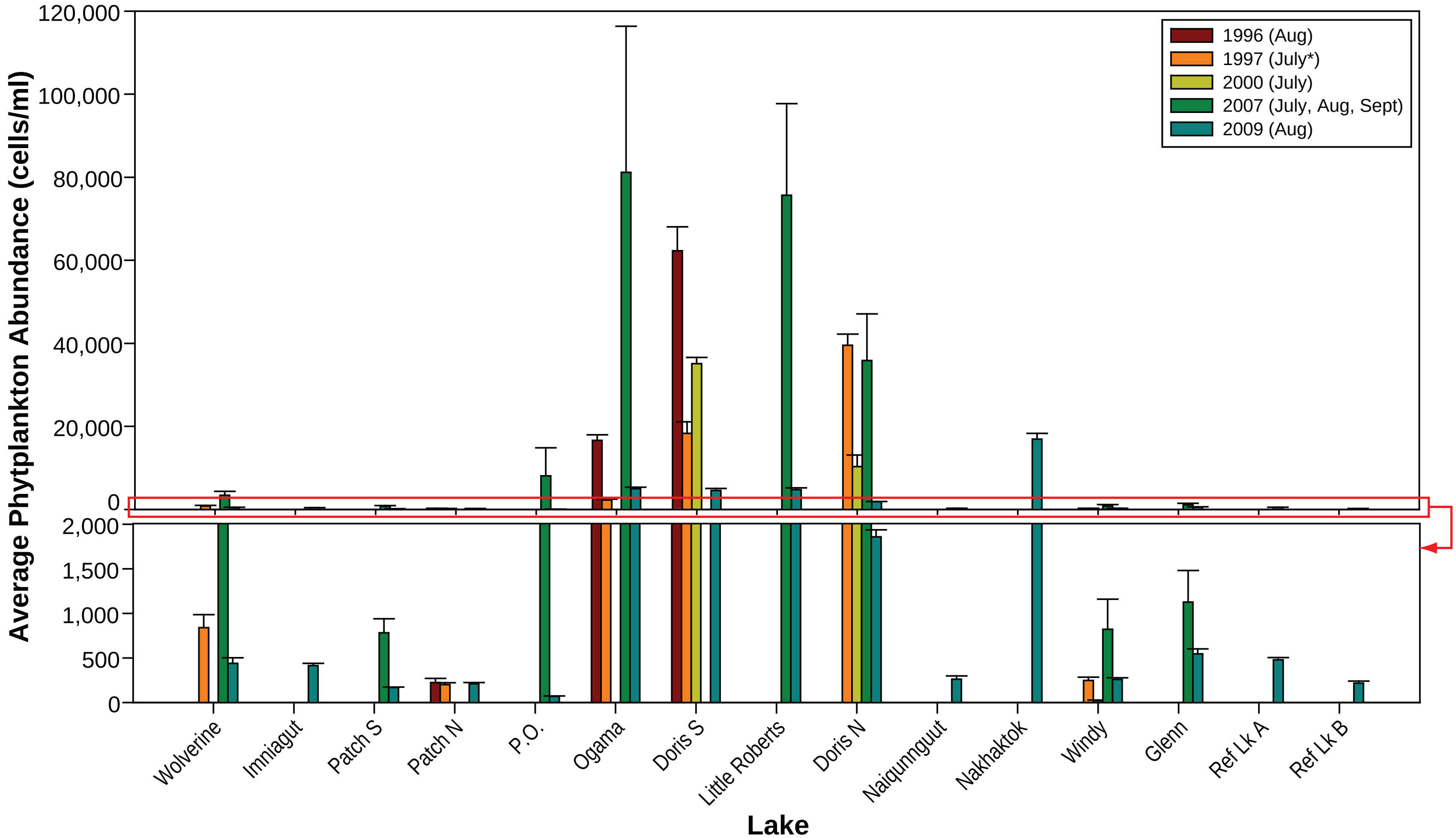

Note: Error bars represent standard error of the mean
** samples were also collected from Doris S in August 1997*
Winter phytoplankton samples (collected in 2009) are not included in the annual average

Figure 3.6-7

NEWMONT NORTH AMERICA

Average Annual Phytoplankton Abundance, Hope Bay Lakes, 1996-2009

Figure 3.6-7

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3.6.7 Phytoplankton Summary

Lake phytoplankton biomass (as chlorophyll *a*) ranged from 0.3 to 26.9 µg chl *a*/L, and was highest in Ogama, Doris N and S, and Little Roberts lakes (in the Doris Watershed) and Nakhaktok Lake (in the Windy Watershed). Trends in phytoplankton abundance and biomass were similar. Phytoplankton taxonomic composition varied substantially among lakes, though cyanobacteria were consistently dominant at sites with high levels of phytoplankton abundance and biomass. In other lakes, the taxonomic assemblage was mainly composed of chlorophytes, cryptophytes, and diatoms. Phytoplankton richness and diversity ranged from 6 to 20 genera/sample and from 0.08 to 0.87, respectively, across all sites and seasons. Genera richness and diversity were consistently lowest at Nakhaktok and Doris N and S lakes. Phytoplankton diversity and richness generally followed similar trends.

The taxonomic composition of epontic algae in a particular lake was similar to the winter phytoplankton composition in that lake. The assemblage of epontic algae was mainly composed of cyanobacteria in Doris N and S, chrysophytes and dinoflagellates in Little Roberts Lake, cryptophytes in Patch N and S, and chrysophytes in Ogama Lake. Epontic richness ranged from 6 to 17 genera and followed a similar trend as diversity, which ranged from 0.26 to 0.88. Richness and diversity levels were consistently lowest at Doris S and highest at Ogama Lake.

Limited historical phytoplankton biomass and abundance data were collected from the study sites. Overall, among-site differences in abundance observed in 2009 were similar to those observed in previous years, except in 2007 when sample collection methodologies deferred substantially from those used in other years.

3.7 PERIPHYTON

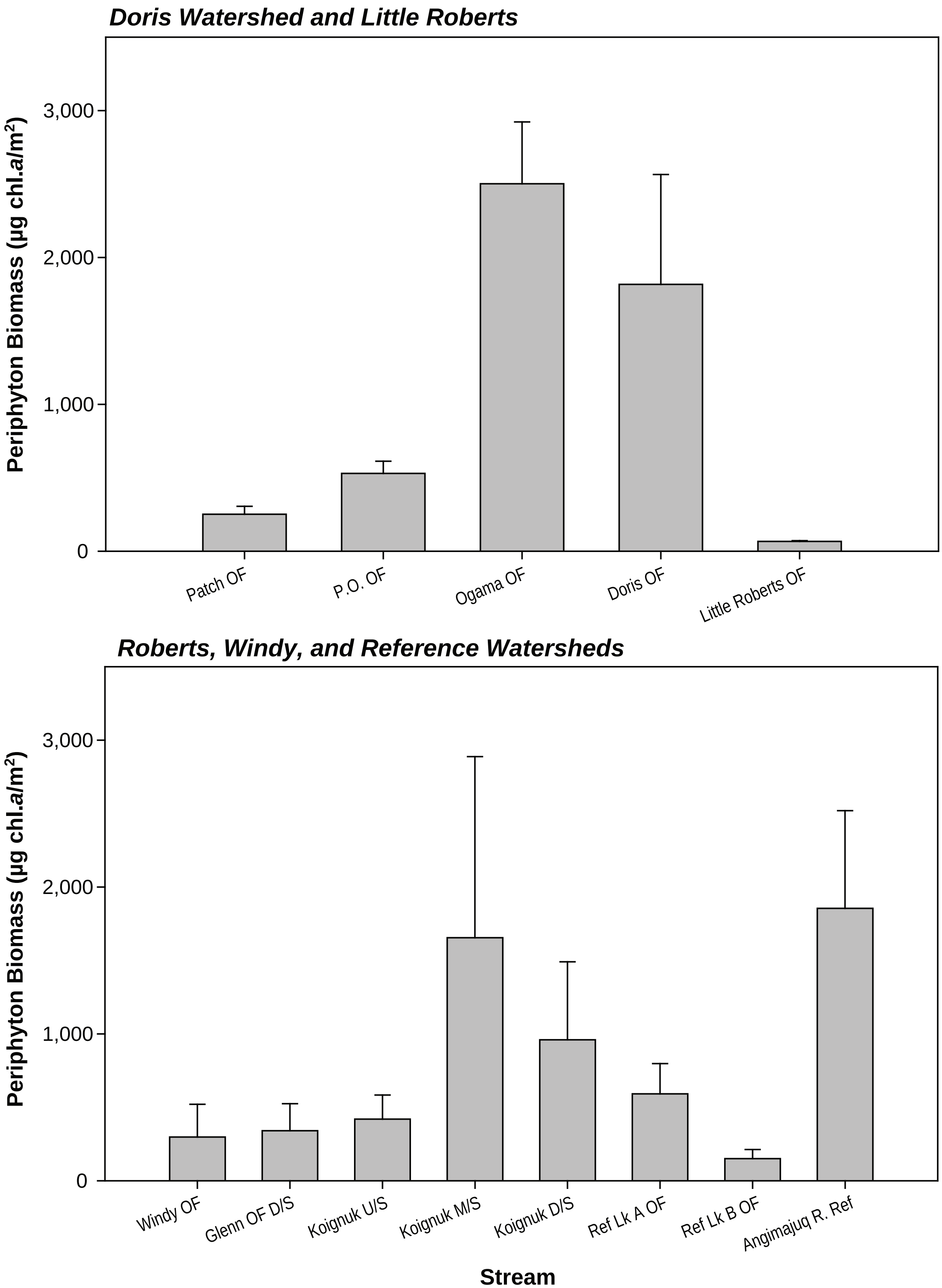
Periphyton are algae that grow on the surfaces of rocks or larger plants and are an important food item for many benthic invertebrates, which are in turn the main food source for fish in streams and rivers. Because of their short life cycles, periphyton are among the first organisms to respond to environmental stressors, and can exhibit taxon-specific changes to stressors, making them good indicators of current environmental conditions.

Periphyton samples were collected from 14 stream sites in the study area, including two reference streams located ~10 km away from potential mining activities, and a reference river station on the Angimajuq River. Periphyton samples were collected using artificial sampling plates that were installed between late July and late August. Although five samplers were placed at each sampling site, only three replicates were analyzed per site.

Appendices 3.7-1 and 3.7-2 present periphyton biomass and taxonomic data respectively. Table 2.1-5 provides sampling dates and locations.

3.7.1 Periphyton Biomass

Periphyton biomass (as chlorophyll *a*) ranged from a low of 66 µg chl a/m^2 at Little Roberts OF, to 2,500 µg chl a/m^2 at Ogama OF (Figure 3.7-1). Average concentrations over 1,500 µg chl a/m^2 were also found at Doris OF, Koignuk M/S, and Angimajuq R. Ref. The average periphyton biomass for all the streams sampled was 880 µg chl a/m^2.



Note: Error bars represent standard error of the mean
Samplers were immersed for 26-29 days between late July and late August.

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Average Periphyton Biomass Hope Bay Streams, 2009

Figure 3.7-1

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3.7.2 Periphyton Density

Periphyton density ranged from 58,400 individuals/cm^2 at Little Roberts OF to approximately 400,000 individuals/cm^2 at Ogama OF, Koignuk U/S, and Angimajuq R. Ref (Figure 3.7-2). Despite being collected at the same time and from the same plates, periphyton density and biomass were weakly correlated (r = 0.26). Overall, periphyton density averaged 184,000 individuals/cm^2 across all sites, and there were no apparent watershed-specific density differences.

3.7.3 Periphyton Taxonomic Composition

Stream periphyton assemblages were almost exclusively composed of diatoms, which made up more than 96% of individuals of all stream site communities, with the exception of the Angimajuq R. Ref site (Figure 3.7-2). The taxonomic assemblage at Angimajuq R. Ref consisted of 88% diatoms, 9% chlorophytes (green algae), 2% non-diatom chrysophytes, and 1% cryptophytes. Green algae also composed between 1 and 3% of the periphyton at Koignuk U/S, M/S, and D/S, and at Ref Lk B OF. Low densities of cyanobacteria were also found at Ogama OF, Little Roberts OF, Glenn OF D/S, and Ref Lk A OF. The main diatom species found in stream periphyton communities were: *Diatoma tenue* (19% of all algae found), *Achnanthes minutissima* (13%), *Diatoma tenue elongatum* (12%), *Tabellaria flocculosa* (8%), *Synedra rumpens* (5%), *Gomphonema angustatum* (5%), and *Nitzschia frustulum* (4%). The dominant green alga was *Scenedesmus quadricauda* (0.7%), the dominant chrysophyte was *Kephyrion littorale* (0.3%), and the dominant cyanobacterium was *Oscillatoria sp.* (0.3%).

3.7.4 Periphyton Richness and Diversity

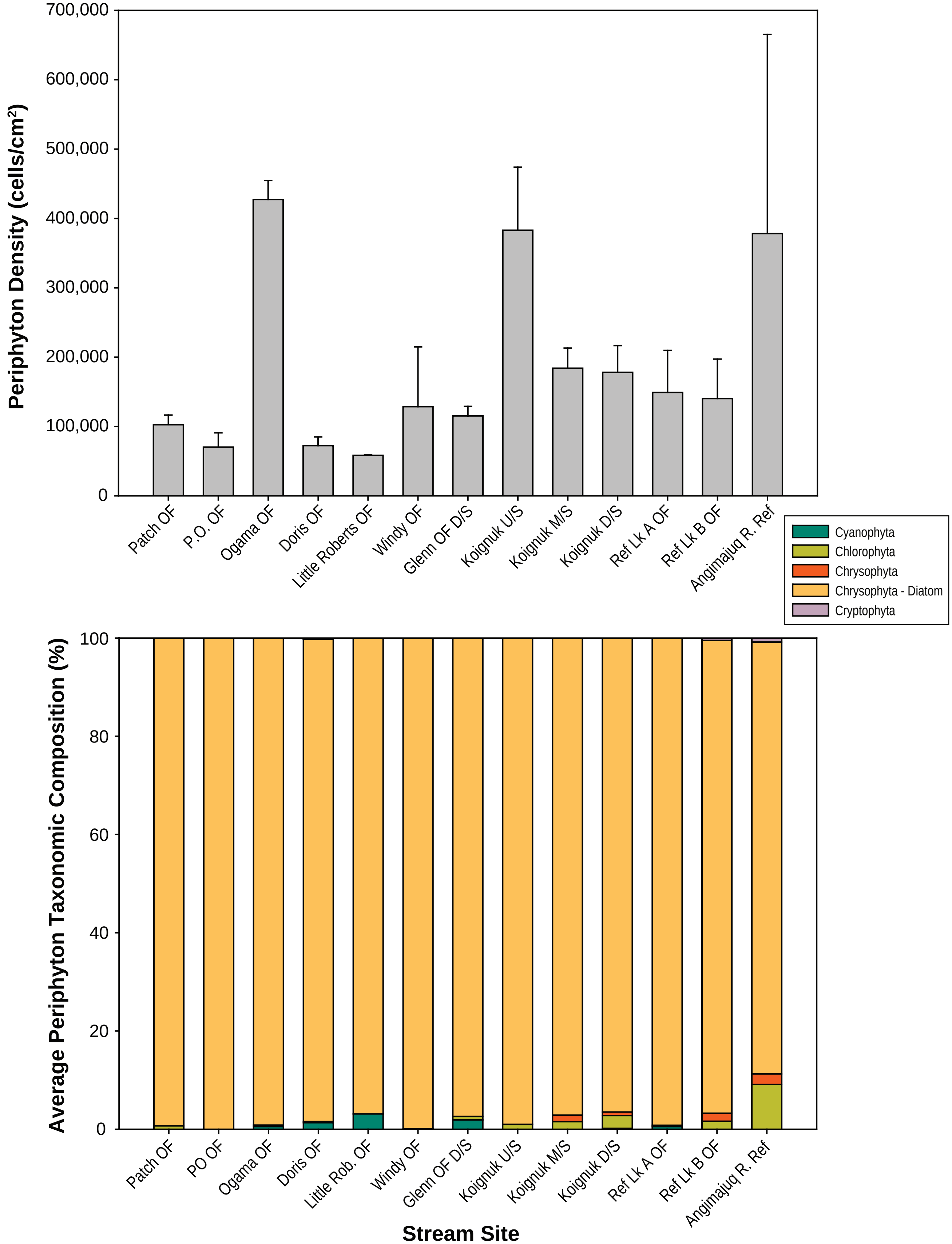
Average periphyton genera richness ranged from a low of 8 genera/sample at Windy and Ref Lk A outflows, to a high of 16 genera/sample at Little Roberts OF and Koignuk D/S. (Figure 3.7-3). Simpson's diversity was relatively high at all sites except Windy OF. At Windy OF, periphyton diversity averaged 0.32, but there was a high degree of variability between replicate samples. Diversity at all other sites ranged from 0.57 to 0.87, with an average of 0.78.

3.7.5 Annual Comparison

Table 2.13-6 outlines the years for which historical stream periphyton data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-3 provides a summary of the historical periphyton sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to variability observed between years.

Historically, periphyton biomass has only been sampled once before: at Doris OF in 2000. The methodology used in 2000 was generally comparable to that used in 2009. In 2000, periphyton biomass at Doris OF averaged 5,300 µg chl *a*/m^2, which is higher than the biomass level observed in 2009 (1,800 µg chl *a*/m^2).

Periphyton density data were collected in 1996, 1997, 2000, and 2009 (Figure 3.7-4). In 1996, periphyton samples were collected by taking scraping from rocks collected within each stream. In all other years Plexiglas artificial substrate samplers were used to collect periphyton over an immersion time of approximately one month. As a result, periphyton density values collected in 1996 were markedly higher and more variable than those observed in other years.



Note: Error bars represent standard error of the mean of the total density
Samplers were immersed for 26-29 days between late July and late August

Figure 3.7-2

Periphyton Density and Taxonomic Composition, Hope Bay Streams, 2009

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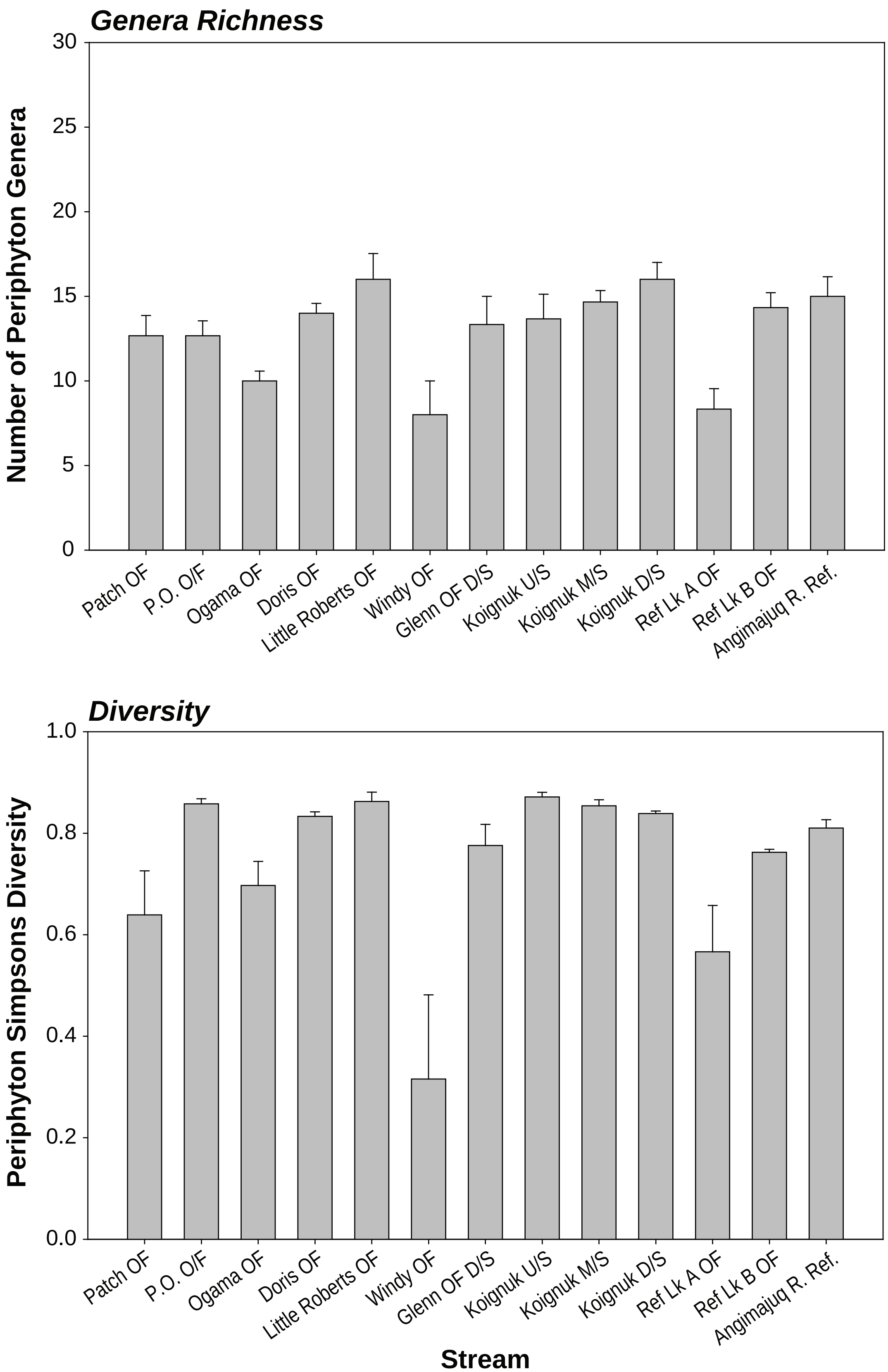

Note: Error bars represent standard error of the mean
Samplers were immersed for 26-29 days between late July and late August

Periphyton Richness and Diversity, Hope Bay Streams, 2009

Figure 3.7-3

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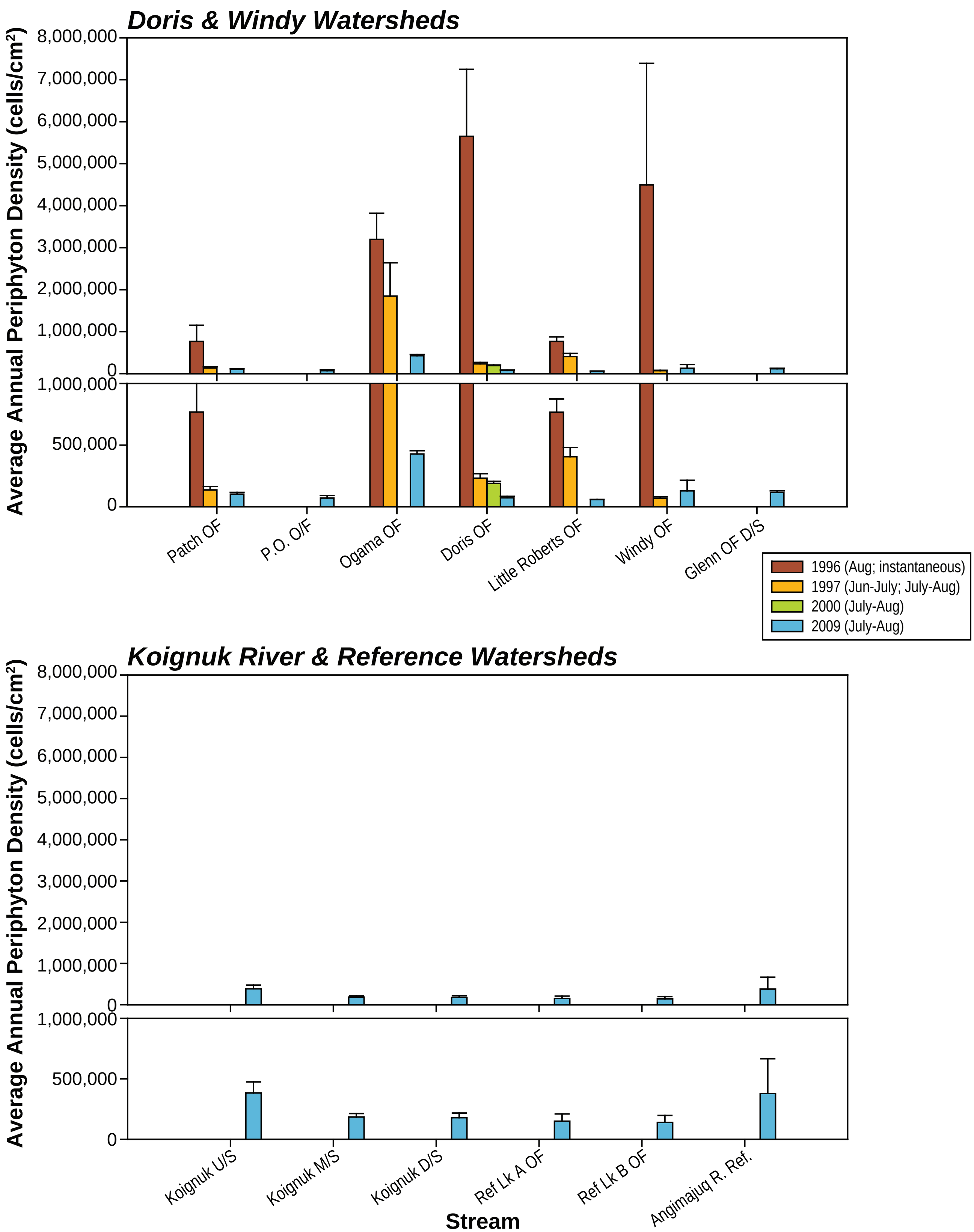

Note: Error bars represent standard error of the mean
1996 samples were collected as instantaneous rock scrapings
1997, 2000, and 2009 samples were collected with plexiglass samplers immersed for ca. 1 month;from June - July and July - August in 1997; from July - August in 2000 and 2009

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Average Annual Periphyton Density, Hope Bay Streams, 1996-2009

Figure 3.7-4

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3.7.6 Periphyton Summary

Periphyton biomass ranged from approximately 66 to 2,500 µg chl *a*/m^2, while density ranged from 58,000 to 400,000 individuals/cm^2 among stream sites. Biomass and density levels were particularly high in Ogama OF, the Koignuk River, and the Angimajuq R. Ref. Diatoms were the dominant periphyton taxa in all streams surveyed. Genera richness ranged from 8 to 16 genera/sample and averaged 13 genera/sample. Periphyton diversity was relatively high at all sites (Simpson's diversity index between 0.57 and 0.87) except Windy OF (0.32).

3.8 ZOOPLANKTON

Zooplankton, the heterotrophic component of aquatic plankton, are an important link in the aquatic food web, acting as consumers of phytoplankton and prey to many fish species. Zooplankton samples were collected from 15 lake sites in the study area in August, 2009, including two reference lakes. All raw zooplankton taxonomic data are presented in Appendix 3.8-1. Table 2.1-4 provides sampling dates and locations.

3.8.1 Zooplankton Abundance

Zooplankton abundances within the study area averaged 64,000 organisms/m^3, but were highly variable among lakes (Figure 3.8-1). Imniagut and Nakhaktok lakes had the highest zooplankton abundances of the lakes surveyed (~255,000 and 282,000 organisms/m^3, respectively). The lowest abundances were observed at Windy (~2,200 organisms/m^3) and Glenn (~2,900 organisms/m^3) lakes. Zooplankton abundances at other sites ranged between ~4,200 and 95,000 organisms/m^3.

3.8.2 Zooplankton Taxonomic Composition

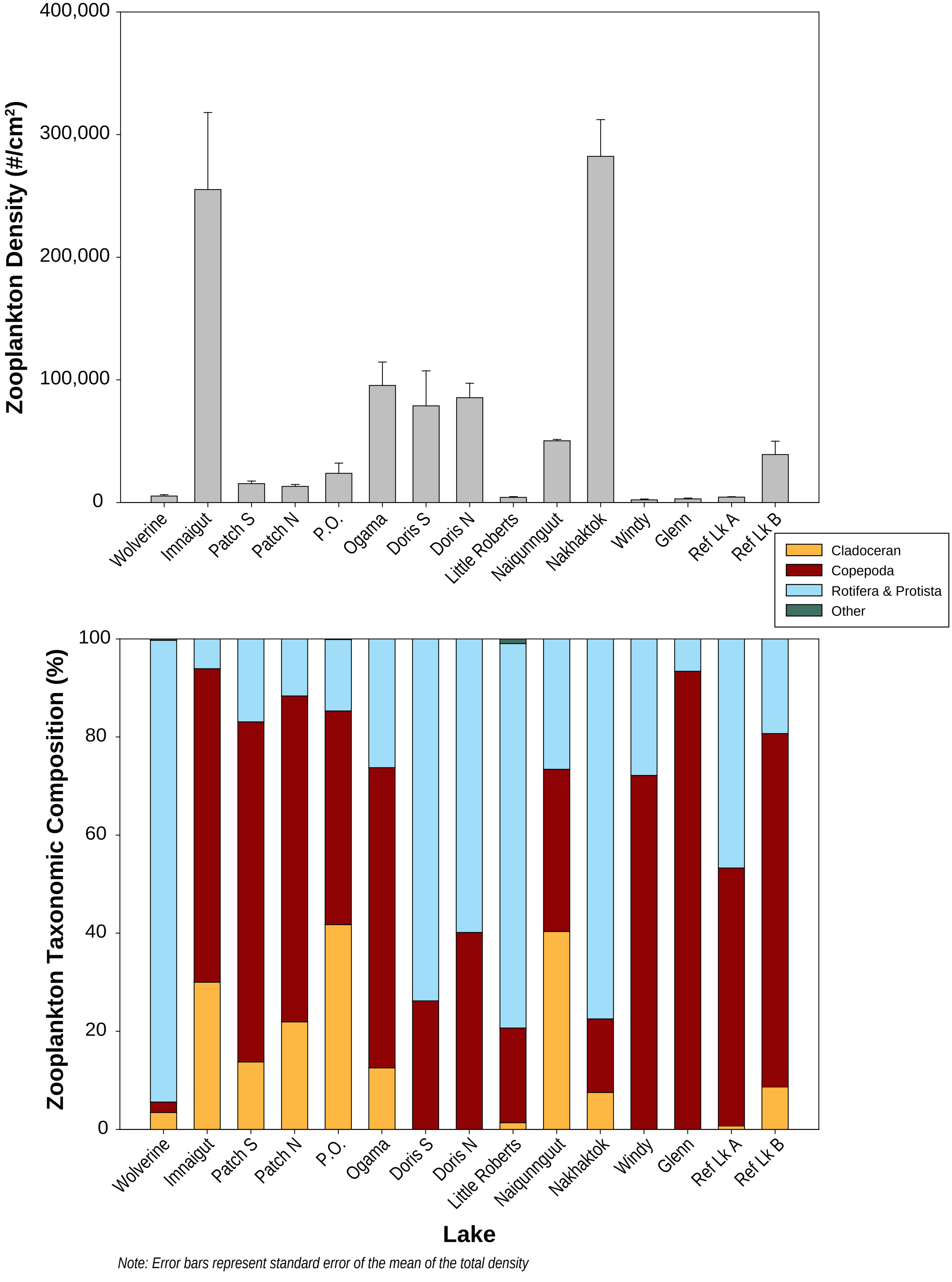
In general, lake zooplankton assemblages were composed mainly of cladocerans, copepods, and rotifers and protists (Figure 3.8-1). The zooplankton assemblage at Wolverine Lake was dominated by rotifers and protists, while Glenn Lake was heavily dominated by copepods. Many of the lakes in the Doris Watershed (Imniagut, Patch S and N, P.O., and Ogama lakes) and Naiqunnguut Lake in the Roberts Watershed were similar in their broad taxonomic composition, with a relatively even composition of cladocerans, copepods, rotifers and protists.

Common zooplankton species encountered in the area included: *Kellicottia longispina* (20% of zooplankton individuals found), *Keratella quadrata* (17%), and *Bosmina longirostris* (11%).

3.8.3 Zooplankton Richness and Diversity

For zooplankton diversity calculations (genera richness and Simpson's diversity index), cyclopoid copepodites and copepod nauplii were analyzed as independent genera, since they could not be correctly assigned to other copepod genera (because copepodites and nauplii are early developmental stages). An unidentified rotifer (which was only found in one sample and made up 0.3 % of that sample's assemblage), was removed from the dataset since it could not be allocated accurately to a genera-group.

Zooplankton genera richness varied greatly between lakes, with a low of 3 genera/sample at both Windy and Glenn Lakes, to a high of 12 at Wolverine, Little Roberts, Niaqunnguut, and Ref B lakes (Figure 3.8-2). The low richness observed at Windy and Glenn lakes was particularly conspicuous as all other sites possessed at least 7 genera, including Nakhaktok Lake (located just upstream of Windy Lake), which had an average of 11 genera.



Note: Error bars represent standard error of the mean of the total density

Figure 3.8-1

Zooplankton Abundance and Taxonomic Composition, Hope Bay Lakes, August 2009

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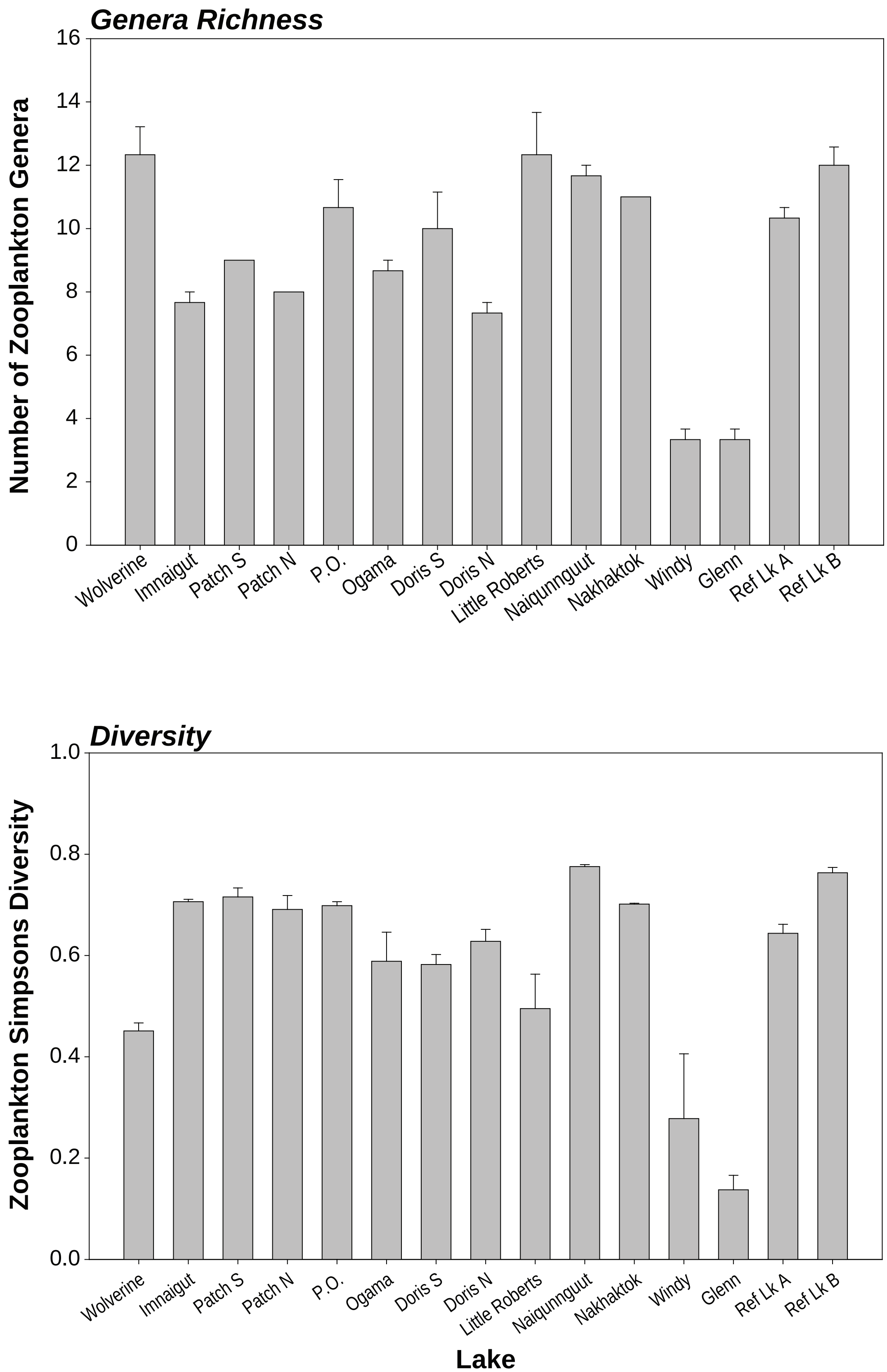

Note: Error bars represent standard error of the mean

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Zooplankton Richness and Diversity, Hope Bay Lakes, August 2009

Figure 3.8-2

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Lake zooplankton diversity was similar across most lakes, with the exception of Windy and Glenn lakes, where diversity levels were very low (0.28 and 0.14, respectively; Figure 3.8-2). Notably, the diversity at Nakhaktok Lake, located just upstream of Windy Lake, was quite high (0.70). Diversities at all other sites were ≥ 0.45, with the highest diversity observed at Naiqunnguut Lake (0.78) and Reference Lake B (0.76). No watershed-specific differences in diversity were observed.

3.8.4 Annual Comparison

Table 2.13-7 outlines the years for which historical zooplankton data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-4 provides a summary of the historical zooplankton sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to the variability observed between years.

Zooplankton abundance was highly variable among years, and no consistent annual trends were apparent (Figure 3.8-3). Zooplankton abundances at P.O., Ogama and Doris lakes were higher in 2009 than other years observed, while at all other sites, zooplankton abundances were lowest in 2009. Differences in methodology (i.e., zooplankton net mesh sizes, timing of sampling, vertical vs. horizontal tows) could contribute to the high level of annual variability.

3.8.5 Zooplankton Summary

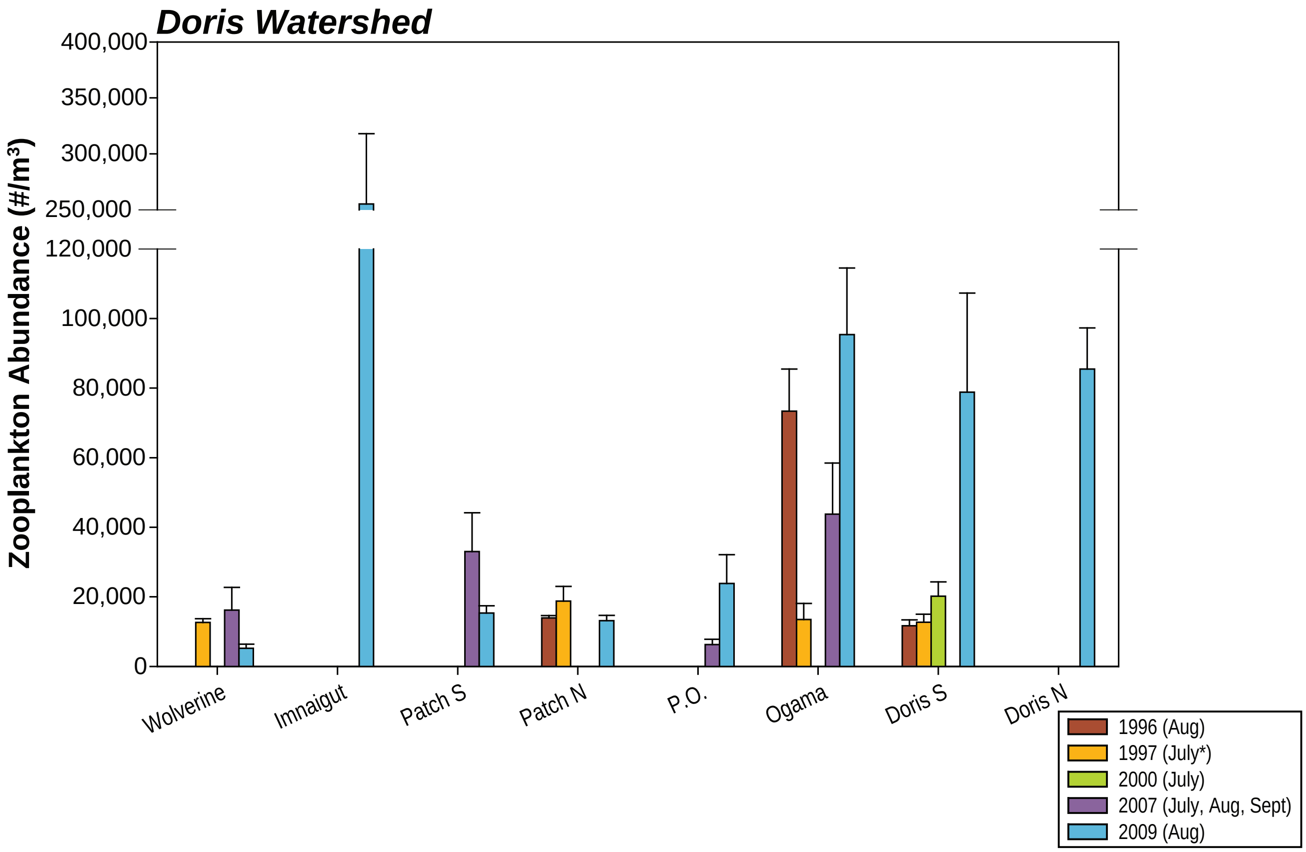
In general, zooplankton abundance varied widely among lakes with no obvious watershed-specific trends. Zooplankton abundance ranged from 2,200 to 282,000 organisms/m^3, and Imniagut and Nakhaktok lakes contained the highest abundance levels. The zooplankton assemblage in lakes typically consisted of cladocerans, copepods, rotifers and protists. Zooplankton genera richness ranged from 3 to 12 genera/sample, and diversity ranged from 0.14 to 0.78. Richness and diversity were particularly low in Windy and Glenn lakes, but were relatively similar among the other sites surveyed. Historical levels of zooplankton density were highly variable, and there were no discernible annual trends.

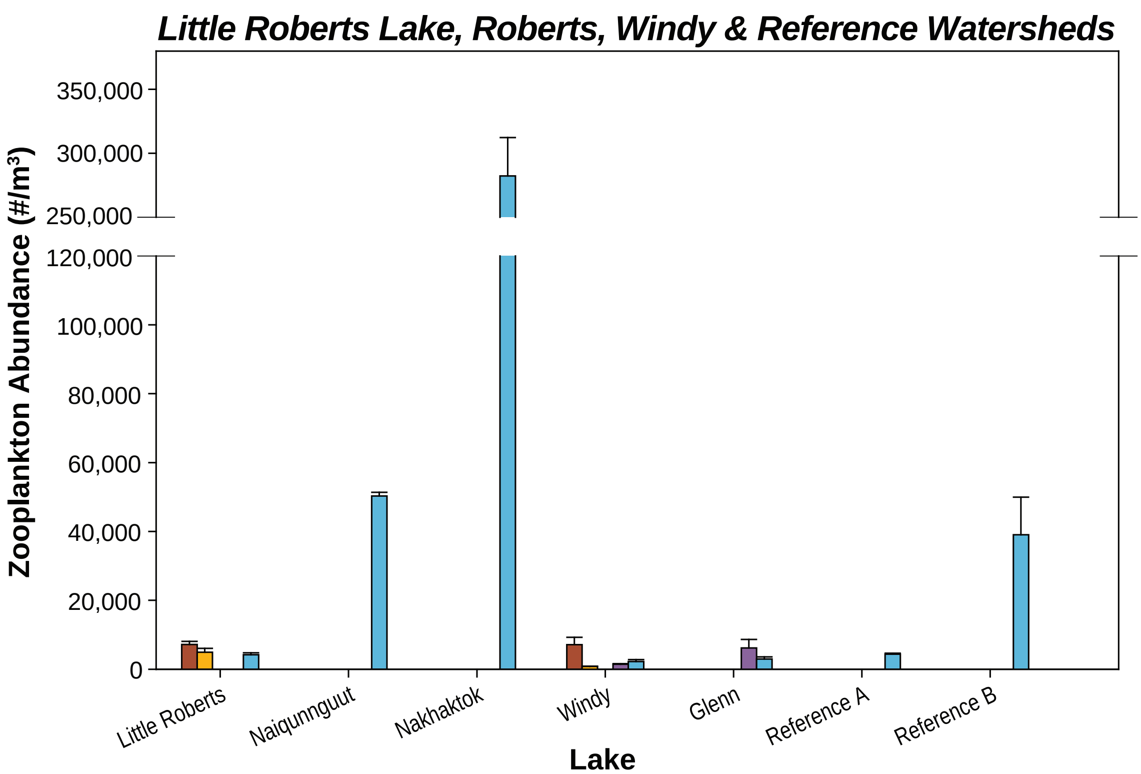
3.9 LAKE BENTHOS

Benthic macroinvertebrates (benthos) are organisms greater than 0.5 mm in size that inhabit lake and stream bottoms. Benthos are good indicators of environmental change as these organisms are in close contact with the sediments and feed on algae, bacteria, and detritus. Benthos also tend to be less mobile than fish, making them good indicators of local conditions. In addition to their potential use as indicator species, benthic organisms are important food sources for fish, particularly in streams.

Lake benthos samples were collected from 15 lake sites in August, 2009, including two reference lakes located ~10 km away from the location of potential mining activities. Benthos samples were collected from the same depth zones and locations as the sediment samples (shallow depth (0 to 5 m), mid depth (5.1 to 10 m), and/or deep depth (>10.1 m)). This sampling design allowed characterization of the potential natural variation in lake benthos with bathymetry and geographic location.

All raw lake benthos taxonomic data are presented in Appendix 3.9-1. Table 2.1-4 provides sampling dates and locations.





Note: Error bars represent standard error of the mean of the total density
** samples were also collected from Doris S in August 1997*

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Average Annual Zooplankton Abundance, Hope Bay Lakes, 1996-2009

Figure 3.8-3

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3.9.1 Lake Benthos Density

Lake benthos density ranged from 116 organisms/m^2 at Ref Lk A (deep depth) to 23,600 organisms/m^2 at Imniagut Lake (shallow depth; Figure 3.9-1). The highest levels of benthos density were found in Wolverine (13,300 organisms/m^2), Imniagut (23,600 organisms/m^2), Nakhaktok (7,700 organisms/m^2), and Little Roberts lakes (11,800 organisms/m^2). All other lakes had densities lower than 4,000 organisms/m^2. With the exception of Reference Lake B, benthos density tended to decrease slightly with depth. No watershed-specific density differences were apparent.

3.9.2 Lake Benthos Taxonomic Composition

Figures 3.9-2a–d present the taxonomic composition of the lake benthos communities surveyed. Lake benthic communities were generally dominated by dipterans (making up ~80% of individuals found). Pelecypoda, Ostracoda, and Oligochaeta (5%) were also common.

A few lakes differed conspicuously from other sites. The lakes with low benthos density, Windy and Glenn, were notable in that dipterans were the only benthic group found at deep depth, and dipterans and ostracods were the only taxa found at shallow depths. Reference Lake A (deep depth), and Reference Lake B (shallow depth) were also relatively taxon-poor, with only dipterans and oligochaetes found at Reference Lake A (deep depth), and only dipterans and pelecypods found at Reference Lake B (shallow depth). In contrast, the benthic assemblages at Wolverine, P.O., and, to a lesser extent, Imniagut lakes were not dominated by dipterans and included a more even mix of taxa.

3.9.3 Lake Benthos Diversity

Dipterans were typically the dominant taxonomic group in lake benthos samples. For this reason, benthic diversity (at the level of genus) was analyzed for both the whole community and the dipteran subset (Figure 3.9-3).

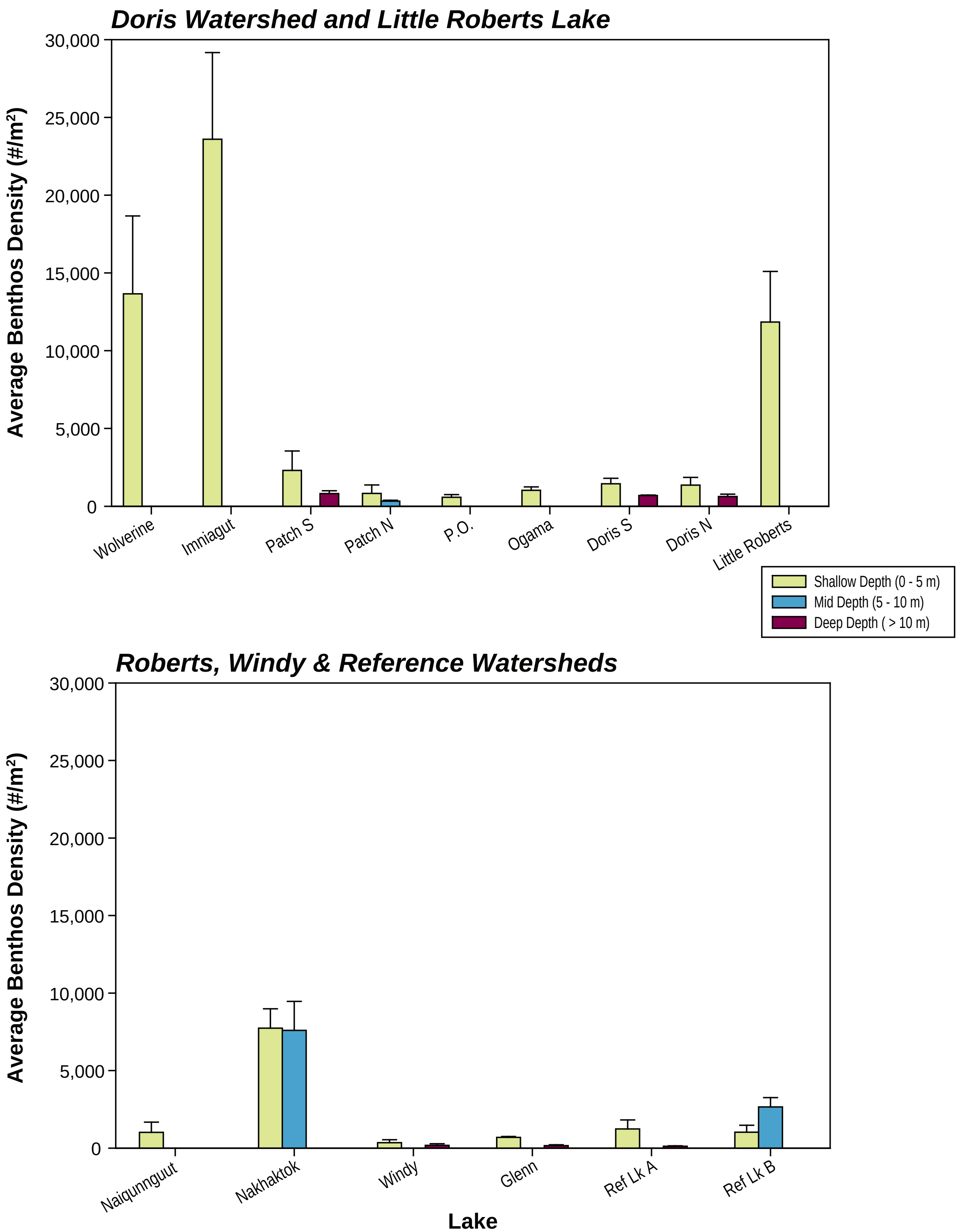
3.9.3.1 Community Diversity

Lake benthos genera richness averaged 6 genera/sample. Community richness was lowest at the deep depth locations in Windy and Glenn lakes, where an average of 1 genera/sample was found. Windy and Glenn lakes were also the most genera-poor sites sampled in the shallow depth zone, with an average richness of only 2 genera/sample. This is similar to the results from zooplankton surveys, in which Windy and Glenn lakes were found to have the lowest abundance and genera richness of all lakes surveyed. The highest genera richness was found at Little Roberts and Nakhaktok lakes (11 genera). Overall, average genera richness was highest at shallow depths (7 genera/sample) compared to the mid (5 genera/sample) or deep (4 genera/sample) depths. Within-site variability was relatively high at most sites.

Diversity was generally highest in the shallow depth zone (0.62) compared to the mid (0.44) and deep (0.42) depths. Within the shallow depth zone, diversity was lowest in Windy and Glenn lakes (0.40 and 0.30, respectively), but most lakes had comparable levels of diversity.

3.9.3.2 Dipteran Diversity

Mean dipteran richness was relatively low (3 genera/sample) and ranged from 1 to 7 genera/site. Dipteran diversity ranged from 0.03 at Nakhaktok Lake (mid depth), to a maximum of between 0.61 and 0.65 at Ref Lk B (shallow and mid depths), and Doris N (shallow depth).



Note: Error bars represent standard error of the mean

Average Benthos Densities by Depth Strata, Hope Bay Lakes, August 2009

Figure 3.9-1

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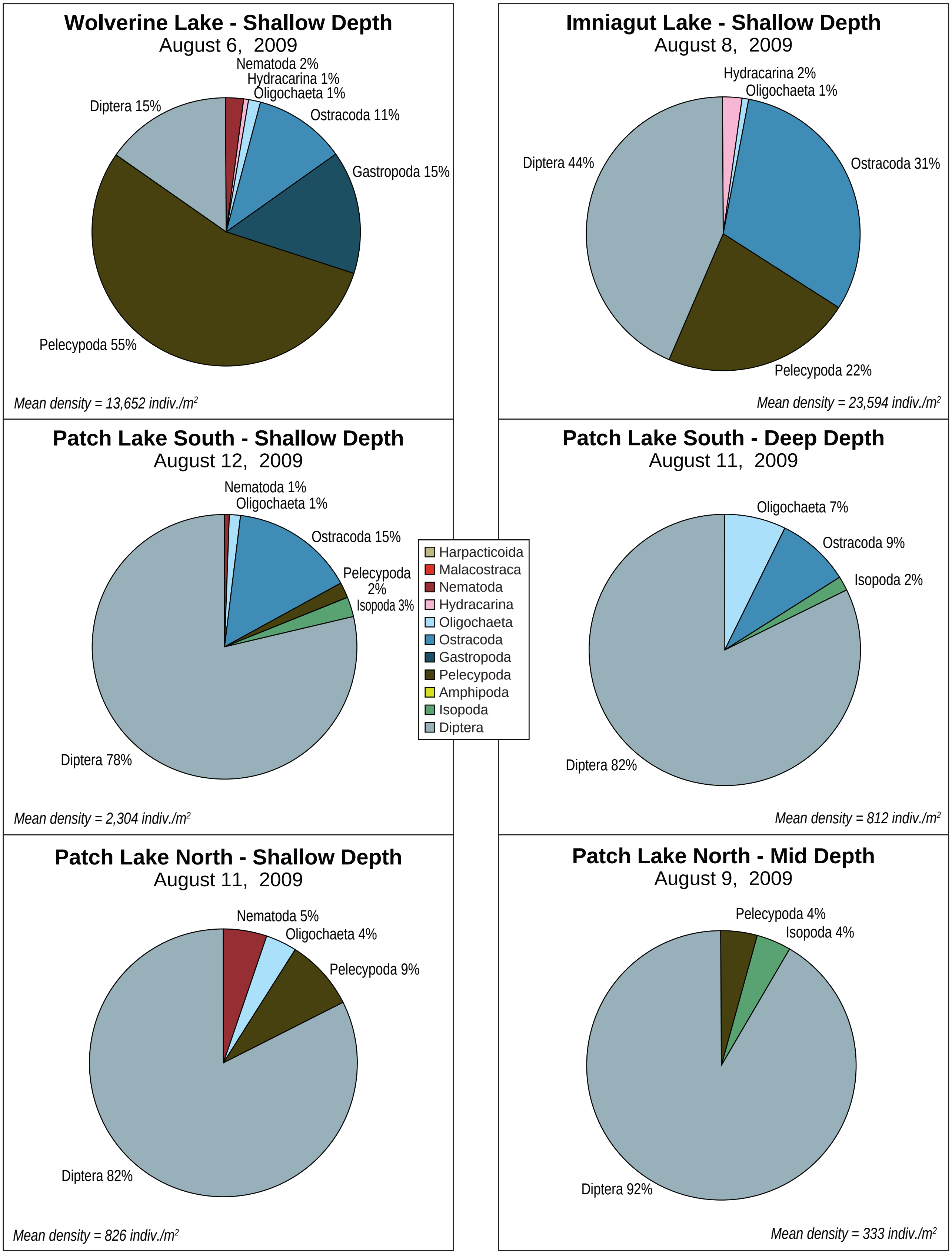

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Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009

Figure 3.9-2a

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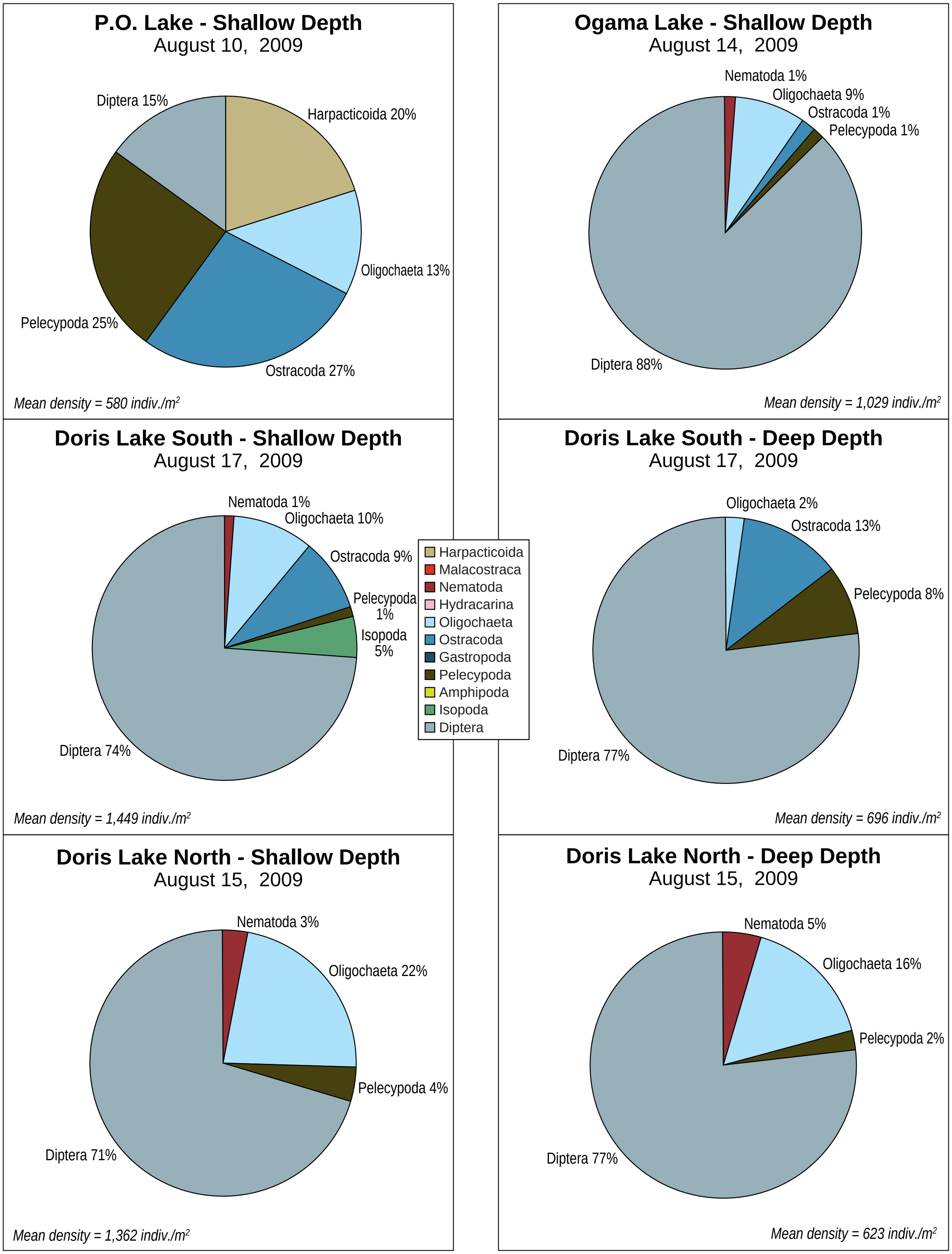
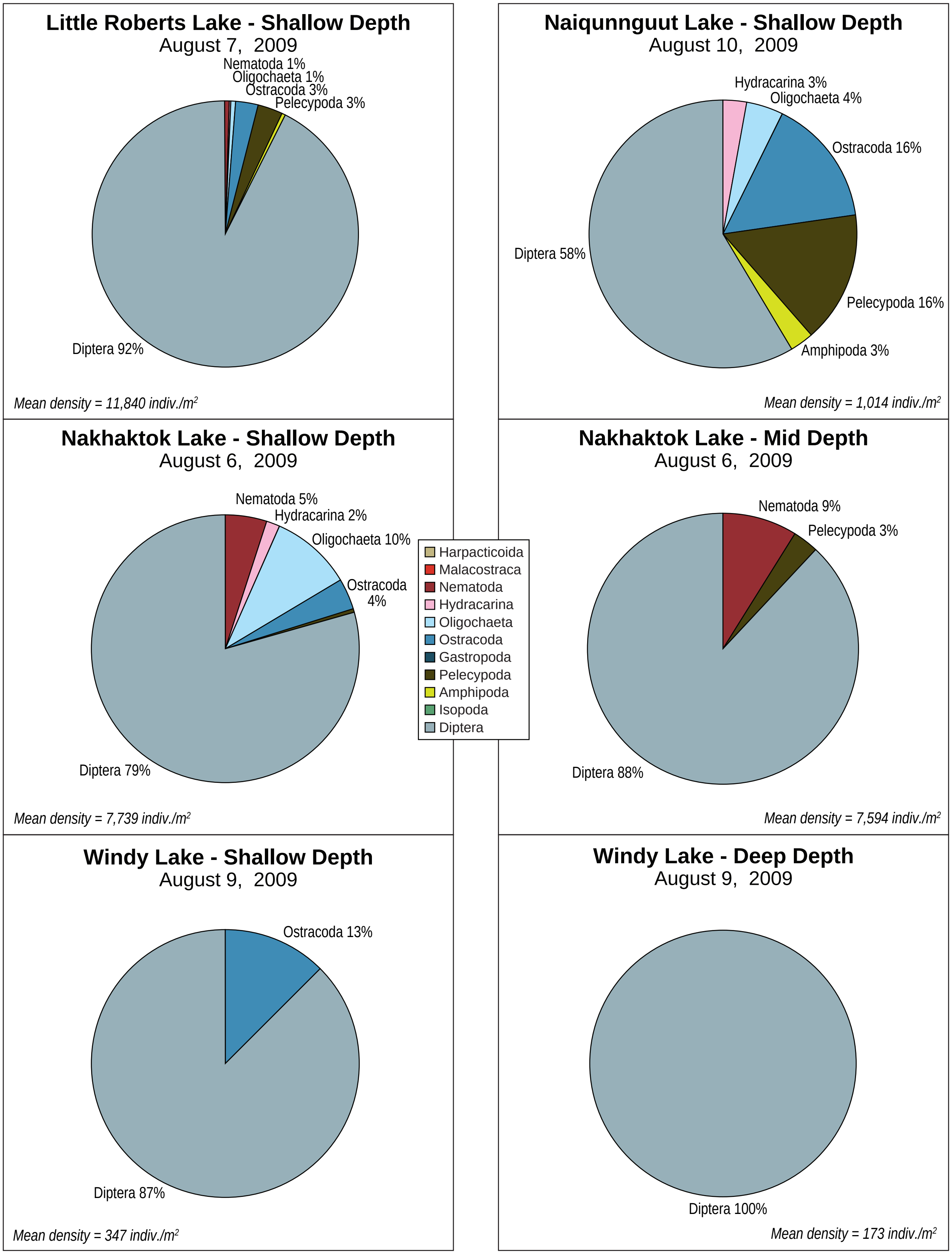


Figure 3.9-2b

Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009



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Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009

Figure 3.9-2c

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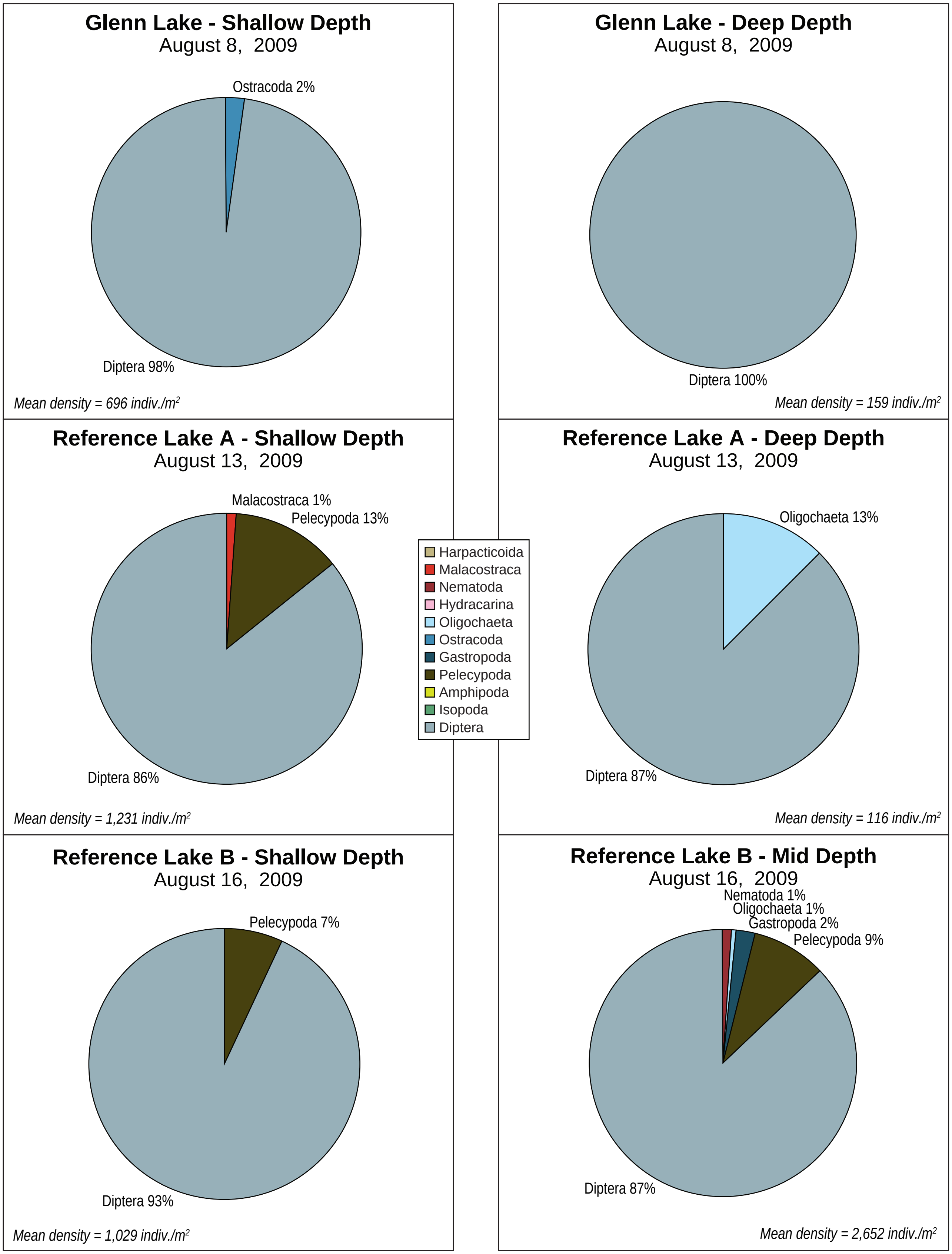

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Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009

Figure 3.9-2d

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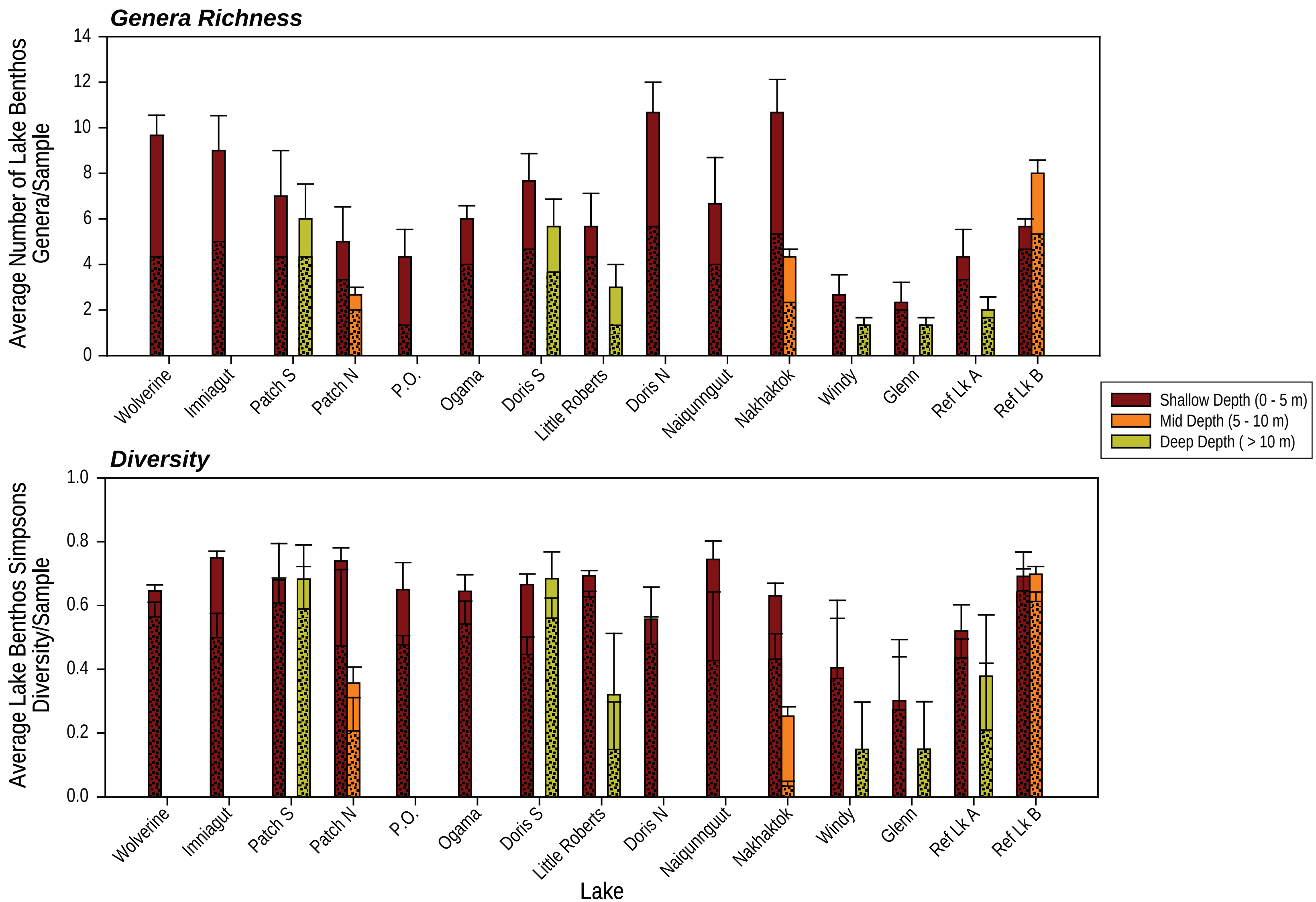

Note: Error bars represent standard errof of the mean of the total abundance
Superimposed bars represent the dipteran contribution to the benthos community total.

Average Benthos Richness and Diversity by Depth Strata, Hope Bay Lakes, August 2009

Figure 3.9-3

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3.9.4 Annual Comparison

Table 2.13-8 outlines the years for which historical lake benthos data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-5 provides a summary of the historical benthos sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to variability observed between years.

Lake benthos samples have been collected in the Project area on five occasions since 1996. The lakes in the 2009 baseline program were not all sampled in the past, and the majority of the lakes only have one or two years of baseline data. Differences in sampling methodology and timing of sample collection (Table 2.13-8) are important to consider during the examination of historical trends.

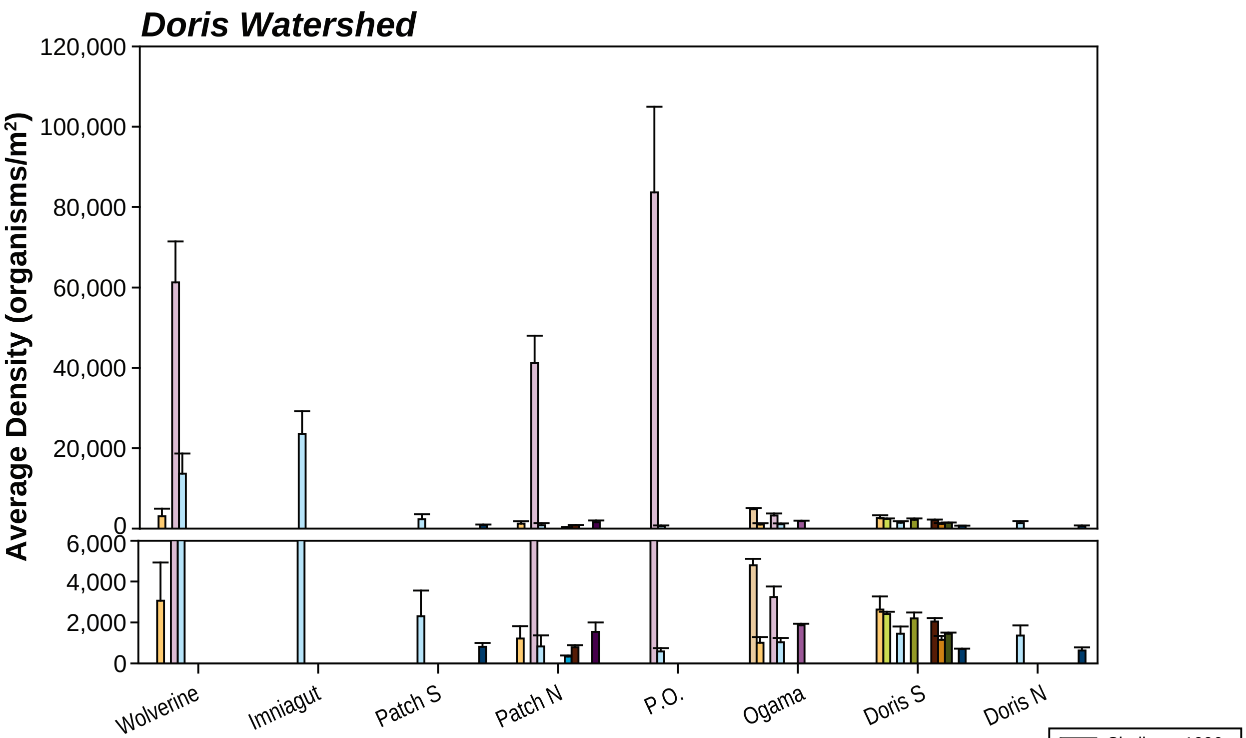
Wolverine, Imniagut, Little Roberts, and Nakhaktok lakes tended to have higher densities than the other lakes (max. 28,600 organisms/m^2 at Little Roberts Lake in 1996; Figure 3.9-4). Windy and Glenn lakes had consistently low benthos densities (<700 organisms/m^2), while Ogama, Doris Lake (S and N) and the reference lakes had densities ranging from 115 to 3,500 organisms/m^2. P.O. Lake and Patch Lake N (shallow) had high densities in 2007 and considerably lower densities in other study years.

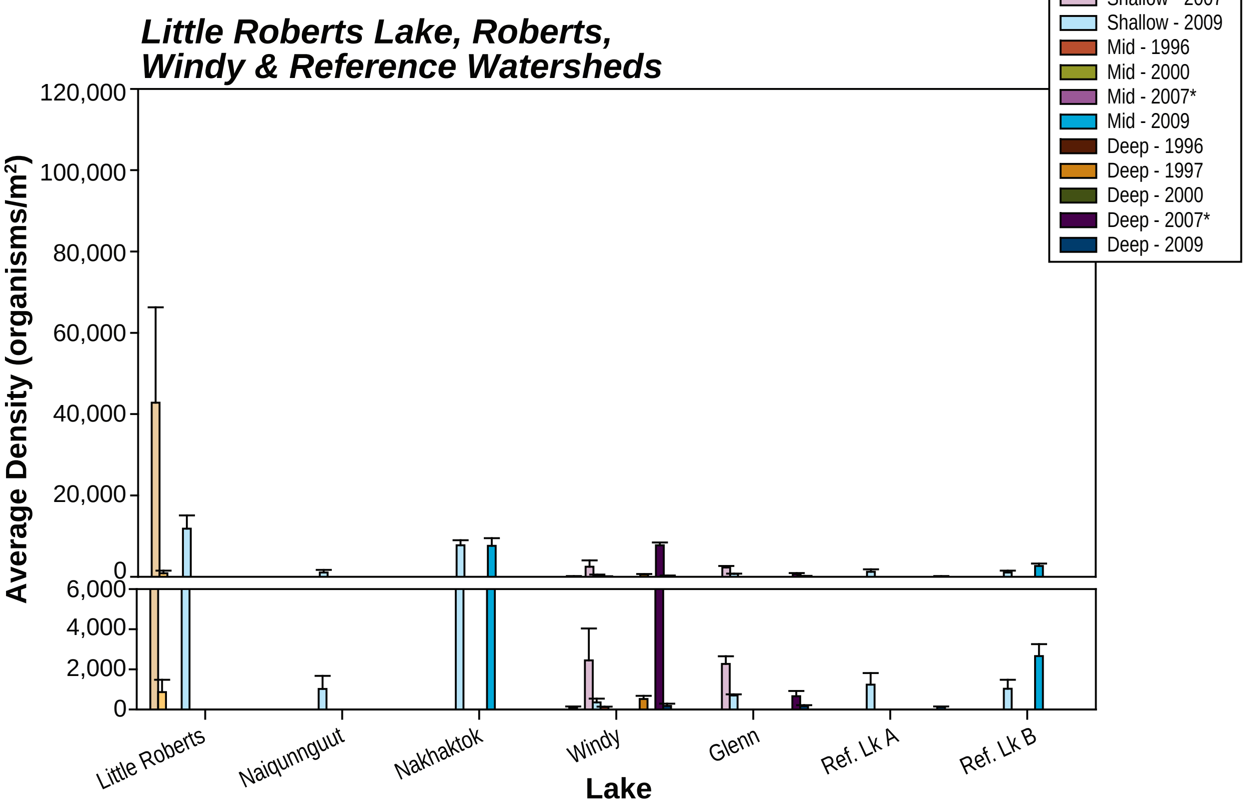
In many study area lakes, benthos densities measured in 2007 were particularly high. This is likely due to the difference in sieve size employed (243 µm in 2007 compared to 500 or 493 µm in all other years). The smaller sieve size used in 2007 would have retained many smaller benthic invertebrates, such as ostracods, small hydracarina, small nematodes, and early instars of chironomids, which would not have been collected in other years. Wolverine Lake, Patch Lake N (shallow), and P.O. Lake each had densities of over 40,000 invertebrates/m^2 in 2007, with ostracods making up approximately 65% of the benthic organisms. In all other years, ostracods made up only 0 to 6% of the benthos.

The timing of the sampling was also different between years. Climate and food availability can influence the seasonal recruitment cycle of benthic organisms. In many lentic habitats, sampling is conducted during the late summer/early fall when the majority of taxa are present and in more mature developmental stages (which facilitates taxonomic identification). The timing of benthos sampling in the Hope Bay Belt ranged from mid-July to late August (see Table 2.13-8), which may contribute to the variability observed among years.

3.9.5 Lake Benthos Summary

Lake benthos densities ranged from 116 to 23,600 organisms/m^2. The highest levels of benthos density were found in Wolverine (13,300 organisms/m^2), Imniagut (23,600 organisms/m^2), Nakhaktok (7,700 organisms/m^2), and Little Roberts lakes (11,800 organisms/m^2). Lake benthic communities were generally dominated by dipterans (80% of individuals found), although pelecypods, ostracods, and oligochaetes were also prevalent. Benthic genera richness averaged 6 genera/sample, with an average diversity of 0.54. Benthic diversity and richness were generally highest in samples collected from the shallow depth zone, and Windy and Glenn lakes tended to have the lowest levels of diversity and richness. Annual benthos densities were highly variable, which may be due to differences in sampling methodology and timing.





Note: Error bars represent standard error of the mean of the total density
Shallow = 0 - 5m; Mid = 5 - 10 m; Deep = > 10 m
** Samples collected in 2007 were sieved to 243 µm; samples collected in all other years were sieved to 500 µm*

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Figure 3.9-4

Average Annual Benthos Densities by Depth Strata, Hope Bay Lakes, 1996-2009

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3.10 STREAM BENTHOS

Stream benthos samples were collected from 13 stream locations in August, 2009, including two reference outflow sites and a reference river site along the Angimajuq River. Streams sampled for benthos were the same as those sampled for other parameters such as water quality, sediment quality, and periphyton.

All raw stream benthos taxonomic data are presented in Appendix 3.10-1. Table 2.1-5 provides sampling dates and locations.

3.10.1 Stream Benthos Density

Stream benthos density ranged from a high of 25,100 organisms/m^2 at Doris OF, to lows of 770 organisms/m^2 at both Koignuk D/S and Angimajuq R. Ref (Figure 3.10-1). Benthos densities were highly variable along the Koignuk River, with the midstream location having more than 10 times higher benthos density than the upstream or downstream locations.

3.10.2 Stream Benthos Taxonomic Composition

Stream benthos communities were dominated by dipterans, which represented~70% of the stream benthic organisms (Figure 3.10-2). Nematodes, oligochaetes, and ostracods were also common in the study area, although they were not present at all sites.

3.10.3 Stream Benthos Diversity

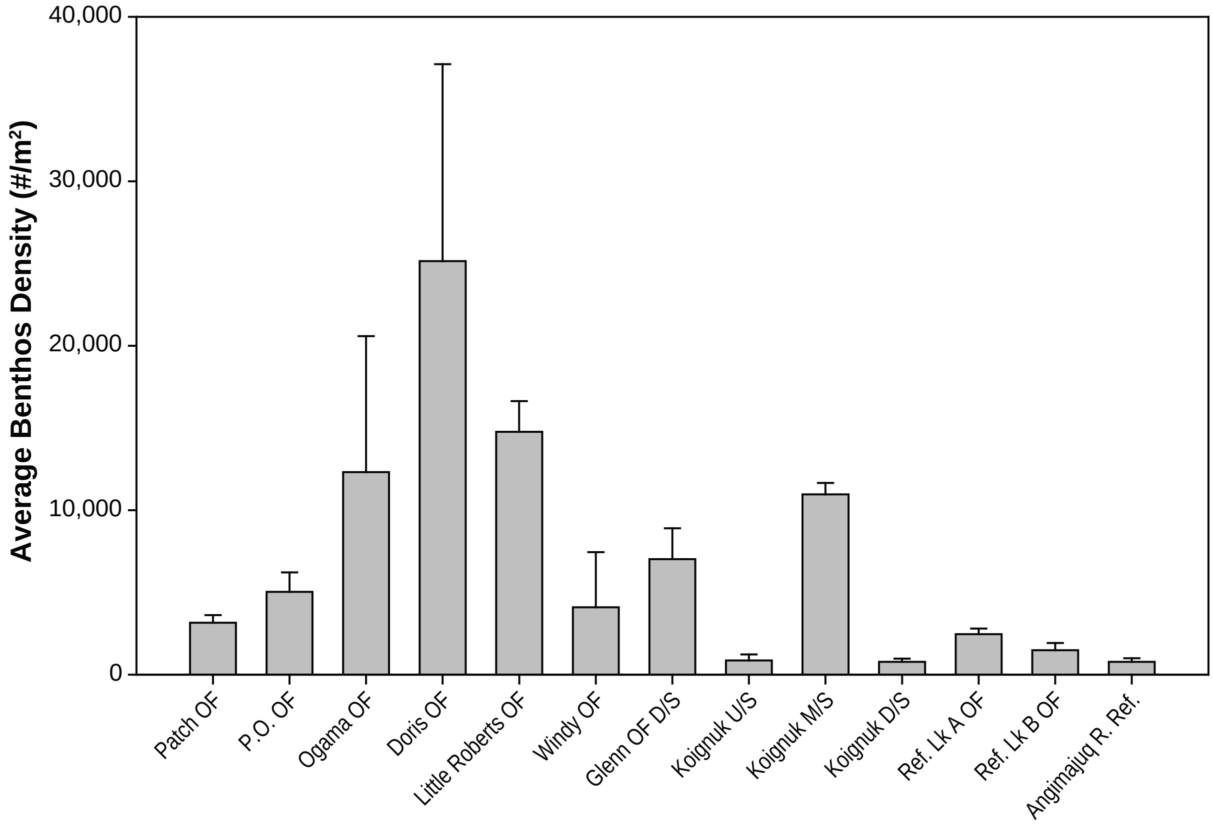
Similar to the lake benthos communities, dipterans were the dominant taxa found in stream benthic samples. Thus, benthic diversity was calculated for the whole community as well as the dipteran subset. Generally, Ephemeroptera, Plecoptera, and Trichoptera (EPT) are also common in streams; however, no more than one genera/sample of Ephemeroptera, Plecoptera or Trichoptera was found at any site. Accordingly, no separate analyses of EPT diversity and richness were conducted.

3.10.3.1 Community Diversity

Stream benthic richness was higher than lake richness, ranging from 9 to 21 genera/sample and averaging 15 genera/sample (Figure 3.10-3). Variability in richness among sites was lower in streams than in lakes. The lowest richness recorded was at Glenn OF D/S (10 genera/sample) and Ref Lk A OF (9 genera/sample). Richness tended to increase in an upstream to downstream direction within in the Doris Watershed, as 14 genera/sample were found in Patch and P.O. outflows, and 21 genera/sample were counted in Little Roberts OF. Diversity did not always correspond with richness, indicating that some genus-rich sites were dominated by few genera (or a single genus) or, alternatively, that some genus-poor sites contained a relatively even distribution of genera. Simpson's diversity index averaged 0.73 across stream sites.

3.10.3.2 Dipteran Diversity

Dipteran genera richness followed a similar trend as overall benthic richness (Figure 3.10-3). Dipteran richness ranged from 6 genera/sample at Glenn OF D/S and Ref Lk A OF to 15 genera/samples at Little Roberts OF, and averaged 10 genera/site. Dipteran diversity was similar community diversity at most sites, and averaged 0.66.



Note: Error bars represent standard error of the mean.

Average Benthos Densities, Hope Bay Streams, July 2009

Figure 3.10-1

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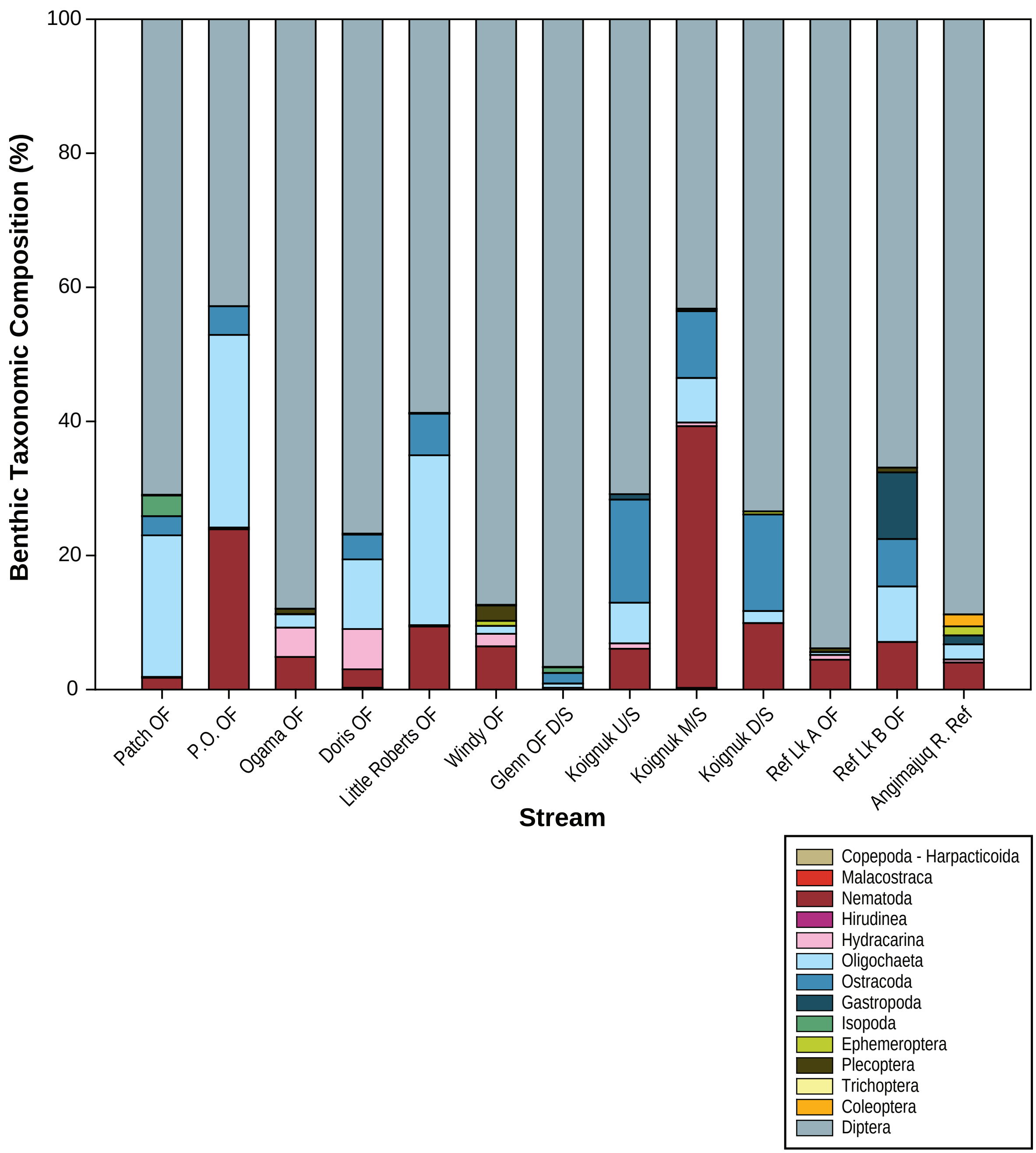

Figure 3.10-2

Taxonomic Composition of Benthos Assemblages, Hope Bay Streams, July 2009

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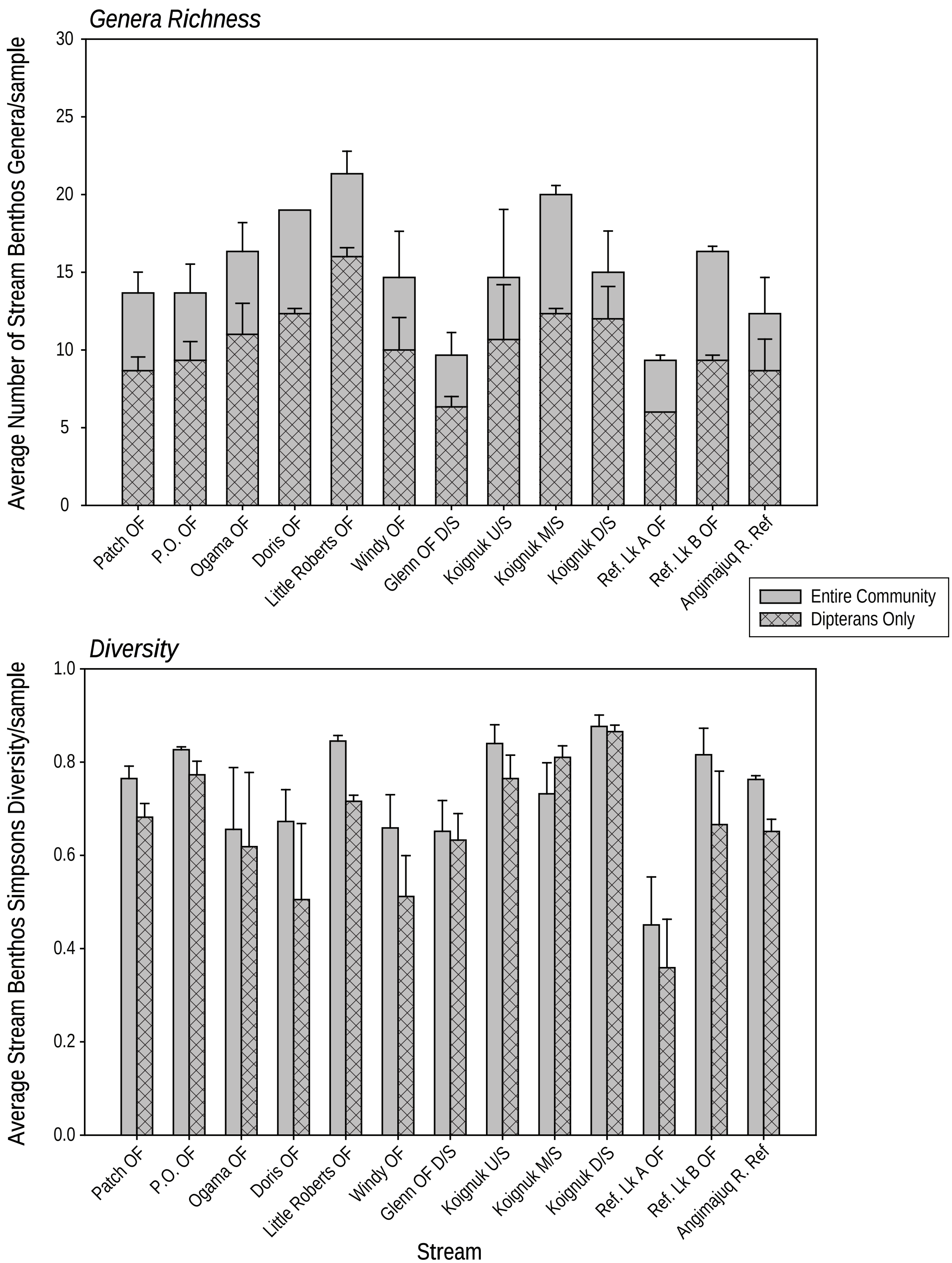

Note: Error bars represent standard errof of the mean of the total abundance
Superimposed bars represent the dipteran contribution to the benthos community total.

Figure 3.10-3

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Average Benthos Richness and Diversity, Hope Bay Streams, July 2009

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3.10.4 Annual Comparison

No comparable historical data for stream benthic communities are available. Stream benthos samples were collected in 1996, 1997, and 2000 from as many as 5 of the 13 streams studied in 2009 (Table 2.13-9, Figure 2.13-5). However, these samples were collected using Hester-Dendy artificial substrate samplers, which tend to sample species that favour smooth hard substrates for colonization. *In situ* sampling methods were used in 2009 in order to better synchronize with possible future Metal Mining Effluent Regulations (MMER) monitoring requirements. Therefore, benthos data collected in 2009 using a Hess sampler were not compared with historical data.

It is preferable to remain consistent in sampling methodologies between years in order to retain as much historical comparability as possible. However, the benefits of historical comparability were outweighed by the following considerations:

- only a small amount of historical stream benthic data had been collected prior to 2009;
- prior to 2009, the most recent data collected was in 2000 (a large data gap);
- samples collected using Hess samplers (as collected in 2009) better reflect the full benthic community at each site; and
- the use of *in situ* methods such as the Hess sampler for benthos quantification is preferred in Environment Canada's Environmental Effects Monitoring (EEM) guidance document (Environment Canada 2002).

For these reasons, Hess samplers were used in 2009 instead of Hester-Dendy artificial substrate samplers.

3.10.5 Stream Benthos Summary

Stream benthos density ranged from 770 to 25,100 organisms/m^2. Benthos density was highest in Doris OF. Ogama OF, Little Roberts OF, and the midstream portion of the Koignuk River also contained dense benthos communities. Stream benthos assemblages were dominated by dipterans, which represented~70% of the stream benthic organisms. Nematodes, oligochaetes, and ostracods were also common in study area streams. Benthic community richness ranged from 9 to 21 genera/sample, with an average of 15 genera/sample. Dipteran richness generally corresponded closely with community richness, and averaged 10 genera/sample. Simpson's diversity index averaged 0.73 for the entire benthic community, and 0.66 for dipterans.

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