



**Dissolved Oxygen Conditions in the Old and Middle
Rivers in 2011 and 2012**

Report 4.3.1

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List of Acronyms

CDEC	California Data Exchange Center
DMC	Delta Mendota Canal
DO	Dissolved Oxygen
DWR	Department of Water Resources
SpC	Specific Conductance
Chl	Chlorophyll-a
GCT	Grantline Canal at Tracy Road Bridge
GLC	Grantline Canal
MHO	Middle River near Howard Road
MDM	Middle River at Middle River
OAD	Old River near DMC
ODM	Old River at DMC
OH1	Old River at Head
UOP	University of the Pacific
USGS	United States Geologic Survey
SJR	San Joaquin River
TMDL	Total Maximum Daily Load
TWA	Old River at Tracy Wildlife Association

Introduction

The Old River and Middle Rivers, located in the south-east region of the Sacramento-San Joaquin Delta (Figure 1), are hydraulically connected to the San Joaquin River (SJR) up-stream of the Stockton Deep Water Ship Channel (DWSC) and are included on the Clean Water Act section 303(d) list as impaired waterbodies due to low dissolved oxygen (DO) conditions (California State Water Resources Control Board, 2006). Both Old and Middle Rivers are freshwater estuarine rivers subject to tidal flows. Flows to Old River originate from the SJR and net flow direction is influenced by diversion pumps located in the south Delta region (Jassby and Nieuwenhuys, 2005). Because of their hydraulic connectivity, water quality in the Old and Middle Rivers is influenced by the water quality in the San Joaquin River. However the extent and frequency of low DO conditions in these two rivers has not been well characterized. To address this data gap, in 2010 and 2011, water quality monitoring stations were installed in the Old and Middle Rivers by the Department of Water Resources (DWR) and U.S. Geological Survey (USGS).

The objective of this study was to compile and analyze continuous monitoring data from the Old and Middle Rivers for the purpose of more completely characterizing low DO excursions in this region. This study was conducted as part of Task 4.3 of the *San Joaquin River Dissolved Oxygen Total Maximum Daily Load Project* (ERP-08D-SO3; E0883006). All monitoring data that was available from the years 2011 and 2012 was used to compare measured DO concentrations to water quality objectives established for the San Joaquin River.

Using this benchmark, low DO excursions (low DO event) was defined as an occurrence where DO concentrations are less than 5 mg/L. The results of this study show that low DO conditions occurred in both 2011 and 2012, but that DO excursions was more frequent and severe in 2012, a low flow year. This study indicates that low DO conditions are widespread throughout the Old and Middle Rivers.

Methods

Monitoring data from eight water monitoring stations along Old and Middle Rivers were retrieved from CDEC for the years of 2011 and 2012 (California Department of Water Resources, accessed various times). The locations of these monitoring stations are given in Table 1 and shown in Figure 1. Five locations are managed by the Department of Water Resources: Old River at Head (OH1), Old River at Tracy Wildlife Association (TWA), Old River near DMC above Dam (OAD), Grantline Canal at Tracy Road Bridge (GCT), and Middle River near Howard Road (MHO). The other three monitoring stations are managed by the United States Geological Survey (USGS): Old River at Delta Mendota Canal (ODM), Grantline Canal (GLC), and Middle River at Middle River (MDM).

CDEC data included measurements of DO, chlorophyll-a (chl), specific conductance (SpC), pH, turbidity, flow, and temperature, although not all measurements were conducted at each monitoring station. The measurements available for each monitoring station are given in Table 2. All data was collected daily in 15 minute intervals.

Retrieved CDEC data was reviewed and edited to remove outliers due to sensor malfunction. Values from any parameter that were five times above or below a ten point running average were removed, with the exception of pH. Optical sensors were used to monitor DO measurements following monitoring stations: TWA, ODM, OAD, GCT, GLC, and MHO (Table 2). Optical sensors have periodic problems due to blockage by debris or sensor wipers, yielding inaccurate data. DO sensor data that exhibited these signs were removed from the analysis. In addition, due to general sensor malfunctions occasional negative values and data values of 0 were recorded for turbidity, DO, SpC, pH, Chl, and temperature. These were removed before analysis.

Data sets were considered complete when valid data accounted for more than 85% of the total yearly data. The only data sets that fell below these criteria was flow at Old River at Delta Mendota Canal (ODM) and temperature at Old River Near DMC Above Dam (OAC).

Low DO conditions in Old and Middle Rivers were analyzed by daily average and by individual 15 minute measurements. In analysis by day, days with low DO events were compared with the number of days in the year. Low DO “events” were counted for any day on which DO measurements fell below the San Joaquin River DO objective (5 mg/L). The repeated using the 15 minute measurements. Each 15 minute measurement with a low DO event were accounted for and compared to the total number measurements. Statistical analysis was conducted using JMP 10 (SAS Institute Inc, Cary, NC). Tables and figures were created using Grapher ver. 9 (Golden Software, Golden, CO) and Excel 2007 (Microsoft, Redmond, WA).

Results and Discussion

The average daily DO concentrations were consistently above regulatory limits in 2011 and 2012 (Tables 3, 5, 7, 9, 11, and 13). However, average daily values were a poor indicator of low DO events due to statistical effect of the super-saturation of oxygen during the day on the mean DO concentration. Examination of the continuous data shows that low DO events, where DO concentrations fell below 5 mg/L, were common. Most low DO events took place May through November (Table 4, 6, 8, 10, 12, and 14). Temporal plots for DO in 2011 and 2012 for the monitoring stations are presented in Figures 2-7 showing how daily fluctuations resulted in low DO events.

In 2011 the two monitoring stations with the highest number of days with low DO events were ODM and OAD on the Old River. ODM had low DO events 21 days out of the year and OAD had low DO events 43 days of the year (Table 15). The two monitoring stations with the fewest low DO events were GCT and GLC on the Grant Line Canal. GCT and GLC had zero low DO events throughout the year (Table 15). TWA and MHO had low DO excursions; however, the percentage of low DO measurements for 2011 was zero.

In 2012 the number of low DO events increased at all monitoring stations. GCT and GLC on Grant Line Canal had the fewest low DO events in comparison to the other monitoring locations on Old and Middle Rivers. GCT and GCL had low DO events 63 and 65 days of the year, respectively. TWA, ODM, OAD, and MHO had low DO events at least 30% of the days in the year (Table 15).

Low DO levels are associated with high temperature and low flow conditions. There were more low DO events in 2012 than 2011. Monitored flow data revealed higher magnitude flows in 2011 as compared with 2012 (Tables 5, 11, 16, 17 and Figures 8-11). The water index in 2011 was 5.58 and was designated a wet year by CDEC (water year index equal or greater than 3.8). The water index in 2012 was 2.18 and was designated a dry year by CDEC (water year index greater than 2.1, and equal to or less than 2.5). The temperature was also lower in 2011 with an average temperature approximately 4°F lower at each site compared with 2012. OAD was the only monitoring station that had a higher temperature in 2012. Temperature data was not available on CDEC after May 2012. The low DO events occurred primarily between May and November when temperatures are high (Figures 12-18).

Low DO events showed geographic heterogeneity (Figure 19 and 20). Monitoring stations along Old River have more low DO events than monitoring stations on Grant Line Canal or Middle River. Three water monitoring stations on Old River (TWA, ODM, and OAD) also differed from each other. ODM and OAD are located in the same area and are west of TWA. In 2011, the wet year, TWA was below the DO objective 0.3% of the year, while ODM and OAD were below the objective 5.8% and 11.8%, respectively (Table 7) suggesting local inputs or conditions may be contributing to low DO conditions. There was also a decrease in Chl concentrations at ODM and OAD by approximately 50% from TWA (Tables 3, 5, 7), suggesting a settling or other loss of algae in this region. At ODM and OAD, low DO events occurred mainly between August and October (Figures 6 and 7; Table 4 and 6).

In 2012, the dry year, TWA, ODM, and OAD failed to meet the 5 mg/L DO level 40.3%, 31.8%, and 47.4% of the year, respectively (Table 7). Low DO events occurred mainly between July and October (Figures 5-7; Table 4, 6, and 8). Temporal plots for 2011 and 2012 for TWA, ODM, and OAD are presented for Chl concentration and temperature in Figures 20-22 and Figures 16-18, respectively. The Chl values were particularly high at TWA for all of 2012 compared to 2011 (Figure 21; Table 9). The Chl values at ODM and OAD were similar in 2011 until June when Chl increased through the summer months (Figures 22 and 23). Although there was an increase in Chl from 2011 to 2012, Chl along with SpC and turbidity had decreased from TWA when it reached ODM and OAD in 2012 (Tables 3, 5, and 7).

There were two monitoring stations along Grantline Canal: GCT and GLC. GCT is located to the west of GLC. During 2011, neither monitoring station experienced a day where DO concentrations fell below the DO objective (Table 15, Figures 2 and 3). The SpC, turbidity, pH, and temperature were consistent between the two monitoring stations in 2011 with Chl showing a slight decrease at GLC (Tables 9 and 11). In 2012, GCT and GLC were below the regulatory objective for low DO 17.3% and 17.8% of year, respectively, and the majority of low DO events occurred between July and August (Figures 2 and 3; Table 10 and 12). From 2011 to 2012, the mean Chl values increased at both GCT and GLC (Figures 24 and 25; Table 9 and 11).

There was one monitoring station on Middle River, near Howard Road (MHO). MHO DO concentrations fell below the San Joaquin River DO criteria 0.8 % and 46.3% of days in the years 2011 and 2012, respectively (Table 13). In 2011, DO concentrations fell below the 5 mg/L water quality objective only 3 days of the year and the 15-minute measurements accounted for zero percent of the total measurements. In 2012, this location failed to meet DO criteria 169

days of the year. The DO concentrations primarily fell below the regulatory objective between June and October (Figure 4; Table 14). The Chl values slightly increased from 2011 to 2012 (Figure 26; Table 13). There was also a large discrepancy between SpC and turbidity between wet and dry years. The SpC was significantly higher and the turbidity was lower in 2012 (Table 13).

Conclusions

The ambient concentration of DO was investigated in Old and Middle Rivers, located in the south-east region of the Delta (Figure 1). Data from 2011 and 2012 collected by the DWR and USGS at monitoring stations located on the Old River, Middle River, and Grant Line Canal were collected from CDEC and analyzed in the context of the established 5 mg/L water quality criteria for the San Joaquin River.

It was found that DO concentrations fell below the water quality objectives at all stations at least occasionally during the study period and that low DO conditions were common and widespread in 2012. These majority of the low DO events occurred between May and October when temperatures were typically high and flows were low. Temperatures were higher in 2012 than 2011 by an average of approximately 4°F. Due to higher rainfall, flows were higher in 2011 than 2012. Due to this higher flow, in 2011 low DO events were observed less than 12% of the year for all of the sites. In comparison, 2012 low DO events were observed at least 17% of the year for all the sites and above 40% of the year for the more impacted area. There was also an increase in Chl concentrations from 2011 to 2012. TWA had the highest concentration of Chl and showed a 50% increase from 2011 to 2012, while the other monitoring stations had an increased concentration between 5% and 36%.

The most frequent low DO events occurred at monitoring stations along Old River sites TWA, ODM, and OAD. During the wet year (2011) these sites had low DO events falling below the regulatory objective for 0.3%, 5.8 %, and 11.8% of the year. During the dry year (2012) ODM, OAD, and TWA fell below the regulatory objective 31.8%, 47.4%, and 40.3% of the year, respectively.

Acknowledgements

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Table 1. Locations of sites analyzed at Old River and Middle River.

Monitoring Station	CDEC Code	Longitude	Latitude
Old River at Head	OH1	121.329	37.808
Old River at Tracy Wildlife Association	TWA	121.457	37.803
Old River at Delta Mendota Canal	ODM	121.541	37.810
Old River Near DMC Above Dam	OAD	121.542	37.811
Grantline Canal at Tracy Road Bridge	GCT	121.451	37.820
Grantline Canal	GLC	121.549	37.820
Middle River at Middle River	MDM	121.534	37.943
Middle River near Howard Road Bridge	MHO	121.383	37.876

Table 2. Summary of Available Sensors and Old and Middle River Monitoring Stations.

Monitoring Station	CDEC Code	Management	Flow	Stage	Velocity	Conductivity	Temperature	Dissolved Oxygen	pH	Chlorophyll	Turbidity
Old River at Head	OH1	DWR	x	x	x	-	x	-	-	-	-
Old River at Tracy Wildlife Association	TWA	DWR	-	-	-	x	x	x	x	x	x
Old River at Delta Mendota Canal	ODM	USGS	x	x	x	x	x	x	x	x	x
Old River at DMC Above Dam	OAD	DWR	-	x	-	x	x	x	x	x	x
Grantline Canal at Tracy Rd. Bridge	GCT	DWR	-	x	-	x	x	x	x	x	x
Grantline Canal	GLC	USGS	x	x	x	x	x	x	x	x	x
Middle River at Middle River	MDM	USGS	x	x	x	x	x	-	-	-	x
Middle River near Howard Rd. Bridge	MHO	DWR	-	x	-	x	x	x	-	-	-

Table 3. Statistical summary of water quality measurements at Old River near DMC above Dam (OAD) in 2011 and 2012.

Old River near DMC above Dam (OAD)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
DO (mg/L)	34879	8.3	2.0	2.2	15.7	34859	7.0	2.4	0.7	17.0
Chl (µg/l)	33909	4.7	4.5	0.1	55.8	34866	5.6	7.2	0.3	75.3
EC (µS/cm)	34878	378	192	145	1143	34882	714	230	254	1581
pH	34879	7.5	0.4	6.9	8.9	34865	7.6	0.3	6.8	9.5
Turbidity (NTU)	34716	14.0	8.1	1.7	99.8	34777	8.2	7.2	1.0	99.3
Temp (°F)	34878	60.3	8.8	42.4	78.8	11782	55.5	6.4	44.9	71.4

Table 4. The number of days DO concentration fell below regulatory limits at Old River near DMC above Dam (OAD) in 2011 and 2012.

	2011		2012	
	DO Infractions (Days)	Time DO infractions occurred (%)	DO Infractions (Days)	Time DO infractions occurred (%)
January	0	0	0	0
February	0	0	0	0
March	0	0	11	1
April	0	0	12	8
May	0	0	11	5
June	0	0	6	1
July	4	5	23	37
August	4	0	31	65
September	27	59	30	81
October	8	6	31	63
November	0	0	8	4
December	0	0	10	9
Yearly	43	6	173	23

Table 5. Statistical summary of water quality measurements at Old River at Delta Mendota Canal (ODM) in 2011 and 2012.

Old River at Delta Mendota Canal (ODM)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
DO (mg/L)	33735	8.5	1.9	4.2	15.7	33793	7.4	2.2	1.6	15.4
Chl (µg/l)	33519	4.2	3.6	0.1	46.8	33594	5.4	6.1	1.2	57
EC (µS/cm)	34982	371	187	145	1173	33929	689	234	254	1596
pH	35003	7.5	0.3	6.6	8.8	33929	7.7	0.3	7.1	9.2
Turbidity (NTU)	33784	15.5	8.8	1.9	116.7	33111	7.7	5.9	0.2	96.5
Temp (°F)	35008	60.4	8.8	42.9	78.3	34944	63.1	9.3	44.9	80.4
Flow (CFS)	22490	517	1105	-2597	3933	35030	79	868	-2681	3283

Table 6. The number of days DO concentration fell below regulatory limits at Old River at Delta Mendota Canal (ODM) in 2011 and 2012.

	2011		2012	
	DO Infractions (Days)	Time DO infractions occurred (%)	DO Infractions (Days)	Time DO infractions occurred (%)
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	1	0
May	0	0	0	0
June	0	0	0	0
July	0	0	20	20
August	2	0	31	56
September	17	20	30	72
October	2	3	26	48
November	0	0	4	0
December	0	0	4	4
Yearly	21	2	116	17

Table 7. Statistical summary of water quality measurements at Old River at Tracy Wildlife Association (TWA) in 2011 and 2012.

Old River at Tracy Wildlife Association (TWA)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
DO (mg/L)	31654	9.0	1.3	4.9	14.2	34999	8.1	2.8	0.5	23.7
Chl (µg/l)	30745	8.3	5.0	0.5	59.9	34601	16.6	14.2	0.4	85.5
EC (µS/cm)	31706	380	224	125	1277	34984	863	223	331	1443
pH	31707	7.5	0.3	6.9	8.6	35007	7.9	0.4	7.0	9.6
Turbidity (NTU)	31040	19.8	7.6	4.5	73.9	34897	13.5	7.0	1.8	97.1
Temp (°F)	33143	60.4	8.1	42.9	77.2	34972	64.0	10.2	44.4	83.6

Table 8. The number of days DO concentration fell below regulatory limits at Old River at Tracy Wildlife Association (TWA) in 2011 and 2012.

	2011		2012	
	DO Infractions (Days)	Time DO infractions occurred (%)	DO Infractions (Days)	Time DO infractions occurred (%)
January	0	0	0	0
February	0	0	0	0
March	0	0	1	0
April	0	0	17	15
May	0	0	29	16
June	1	0	24	12
July	0	0	22	14
August	0	0	28	52
September	0	0	5	1
October	0	0	10	11
November	0	0	2	0
December	0	0	9	11
Yearly	1	0	147	11

Table 9. Statistical summary of water quality measurements at Grantline Canal at Tracy Road Bridge (GCT) in 2011 and 2012.

Grantline Canal at Tracy Road Bridge (GCT)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
DO (mg/L)	33846	9.5	0.9	6.9	13.0	33990	8.5	2.2	1.3	15.1
Chl (µg/l)	34772	6.3	4.5	0.4	61.1	34027	9.9	9.2	0.4	56.5
EC (µS/cm)	34518	307	189	111	868	33722	688	171	239	1077
pH	33850	7.6	0.2	6.5	8.6	33738	7.8	0.5	6.5	9.4
Turbidity (NTU)	33840	16.6	9.0	0.3	132	33773	10.2	9.2	1.4	176
Temp (°F)	34567	59.2	7.8	44.2	74.7	33748	64.0	9.9	39.2	82.4

Table 10. The number of days DO concentration fell below regulatory limits at Grantline Canal at Tracy Road Bridge (GCT) in 2011 and 2012.

	2011		2012	
	DO Infractions (Days)	Time DO infractions occurred (%)	DO Infractions (Days)	Time DO infractions occurred (%)
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	6	5
May	0	0	0	0
June	0	0	0	0
July	0	0	26	46
August	0	0	29	61
September	0	0	2	0
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
Yearly	0	0	63	10

Table 11. Statistical summary of water quality measurements at Grantline Canal (GLC) in 2011 and 2012.

Grantline Canal (GLC)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
DO (mg/L)	34759	9.1	1.1	5.3	12.6	34998	8.1	1.7	2.2	12.5
Chl (µg/l)	34981	3.9	2.2	0.2	27.5	34911	4.2	4.8	1.0	88.8
EC (µS/cm)	35004	290	164	116	826	34996	598	184	238	1061
pH	35005	7.4	0.2	6.7	8.2	35005	7.7	0.2	7.1	8.8
Turbidity (NTU)	34977	15.9	17.6	1.3	426.9	34947	8.0	12.0	1.4	395.2
Temp (°F)	35005	59.7	8.4	44.2	76.2	35049	63.8	9.7	45.6	82.1
Flow (CFS)	35001	4679	4610.7	-7396	17793	34888	725.6	2979.9	-6880	8630

Table 12. The number of days DO concentration fell below regulatory limits at Grantline Canal (GLC) in 2011 and 2012.

	2011		2012	
	DO Infractions (Days)	Time DO infractions occurred (%)	DO Infractions (Days)	Time DO infractions occurred (%)
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	3	1
May	0	0	0	0
June	0	0	0	0
July	0	0	22	21
August	0	0	29	44
September	0	0	11	7
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
Yearly	0	0	65	6

Table 13. Statistical summary of water quality measurements at Middle River near Howard Road Bridge (MHO) in 2011 and 2012.

Middle River near Howard Road Bridge (MHO)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
DO (mg/L)	34120	9.3	1.3	2.6	16.0	34821	6.8	3.3	0.2	16.5
Chl (µg/l)	34373	4.7	2.8	0.3	21.1	34855	5	4.8	0.1	67.2
EC (µS/cm)	34385	317	162	120	1090	34908	710	239	303	1723
pH	34385	7.5	0.3	6.8	8.7	34908	7.4	0.4	6.6	9.1
Turbidity (NTU)	34320	19.3	12.0	1.3	142.2	34211	4.9	5.1	0.5	75.7
Temp (°F)	34385	59.8	8.7	41.2	77.9	34909	63.7	10.6	41.6	82.9

Table 14. The number of days DO concentration fell below regulatory limits at Middle River near Howard Road Bridge (MHO) in 2011 and 2012.

	2011		2012	
	DO Infractions (Days)	Time DO infractions occurred (%)	DO Infractions (Days)	Time DO infractions occurred (%)
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	8	5
May	0	0	14	9
June	0	0	28	49
July	2	0	31	72
August	0	0	31	97
September	1	0	30	93
October	0	0	23	39
November	0	0	1	0
December	0	0	3	4
Yearly	3	0	169	31

Table 15. The number of days DO concentration was lower than the regulatory limits in 2011 and 2012.¹

Monitoring Station	CDEC Code	2011			2012		
		(Days) ²	Percent of Low DO Days (%) ³	Percent of Low DO Measurements (%) ⁴	(Days) ²	Percent of Low DO Days (%) ³	Percent of Low DO Measurements (%) ⁴
Old River at Tracy Wildlife Association	TWA	1	0.3	0	147	40.3	11
Old River at Delta Mendota Canal	ODM	21	5.8	2	116	31.8	17
Old River Near DMC Above Dam	OAD	43	11.8	6	173	47.4	23
Grantline Canal at Tracy Road Bridge	GCT	0	0	0	63	17.3	10
Grantline Canal	GLC	0	0	0	65	17.8	6
Middle River near Howard Road Bridge	MHO	3	0.8	0	169	46.3	31

¹ Regulatory limits - DO concentrations less than 5 mg/L throughout the entire year.

² Number of days below indicated DO levels for the entire year.

³ Percent of days below indicated DO levels for the entire year.

⁴ Percent of 15-minute measurements below indicated DO levels for the entire year.

Table 16. Statistical summary of water quality measurements at Old River at Head (OH1) in 2011 and 2012.

Old River at Head (OH1)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
Flow (CFS)	34801	4189	2690	308	11484.0	34835	1009	615.9	-1042	3267

Table 17. Statistical summary of water quality measurements at Middle River at Middle River (MDM) in 2011 and 2012.

Middle River at Middle River (MDM)	2011					2012				
	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
EC (μS/cm)	34702	224	51	140	553.0	35034	363	96	184	639
Turbidity (NTU)	34533	5.3	5.5	0.4	142.3	34821	5.3	6.9	0.1	191.6
Temp ($^{\circ}$F)	34709	61.9	10	45	80	34978	63.4	9.6	46.2	78.9
Flow (CFS)	34703	-2375	10246	-21441	18299	35032	-3213	10150	-21502	14826

Figure 1. Location of continuous monitoring stations in Old and Middle River.

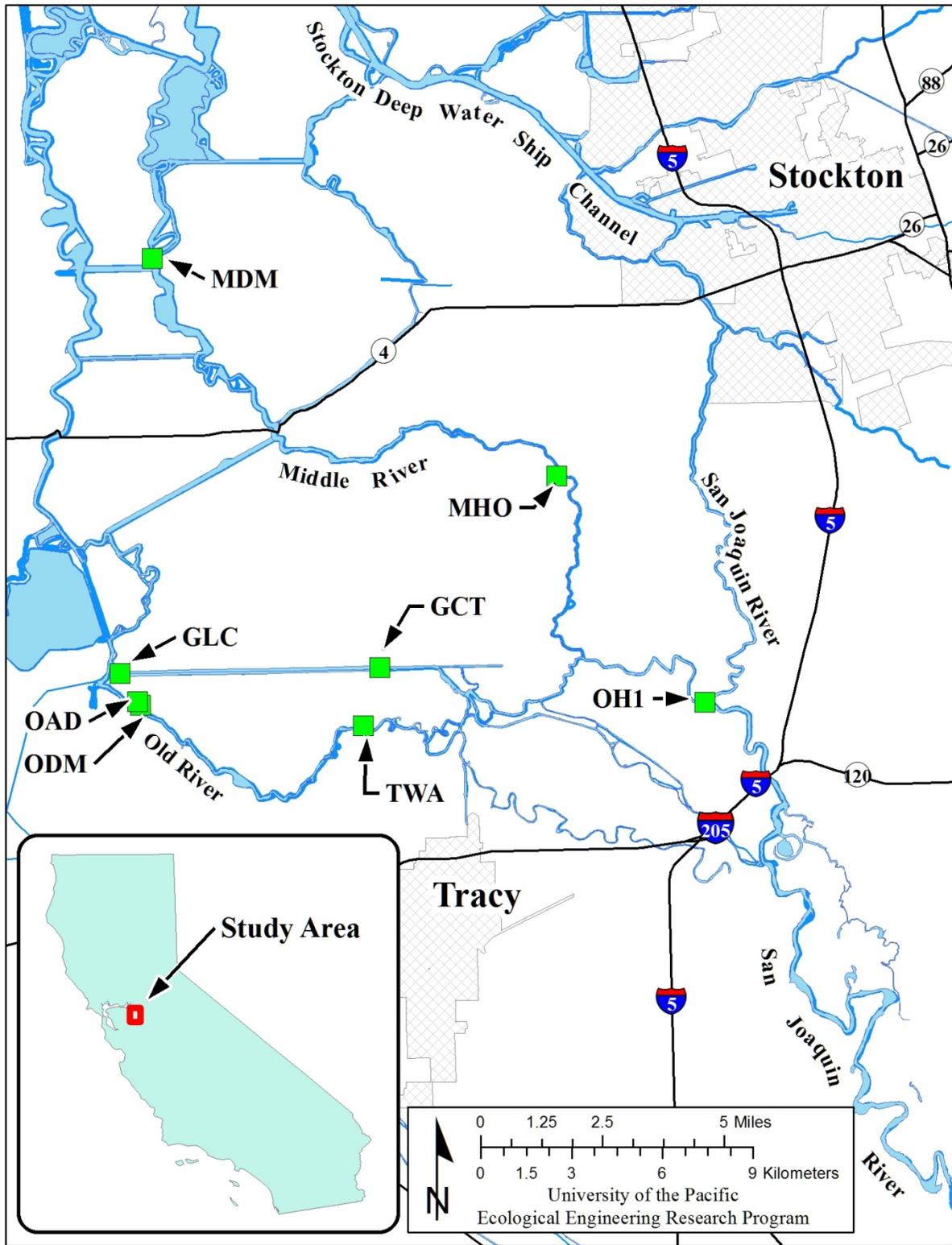


Figure 2. Temporal plots of DO in 2011 at Grantline Canal at Tracy Road Bridge (GCT) with a daily running average in green (for 2011) or blue (for 2012).

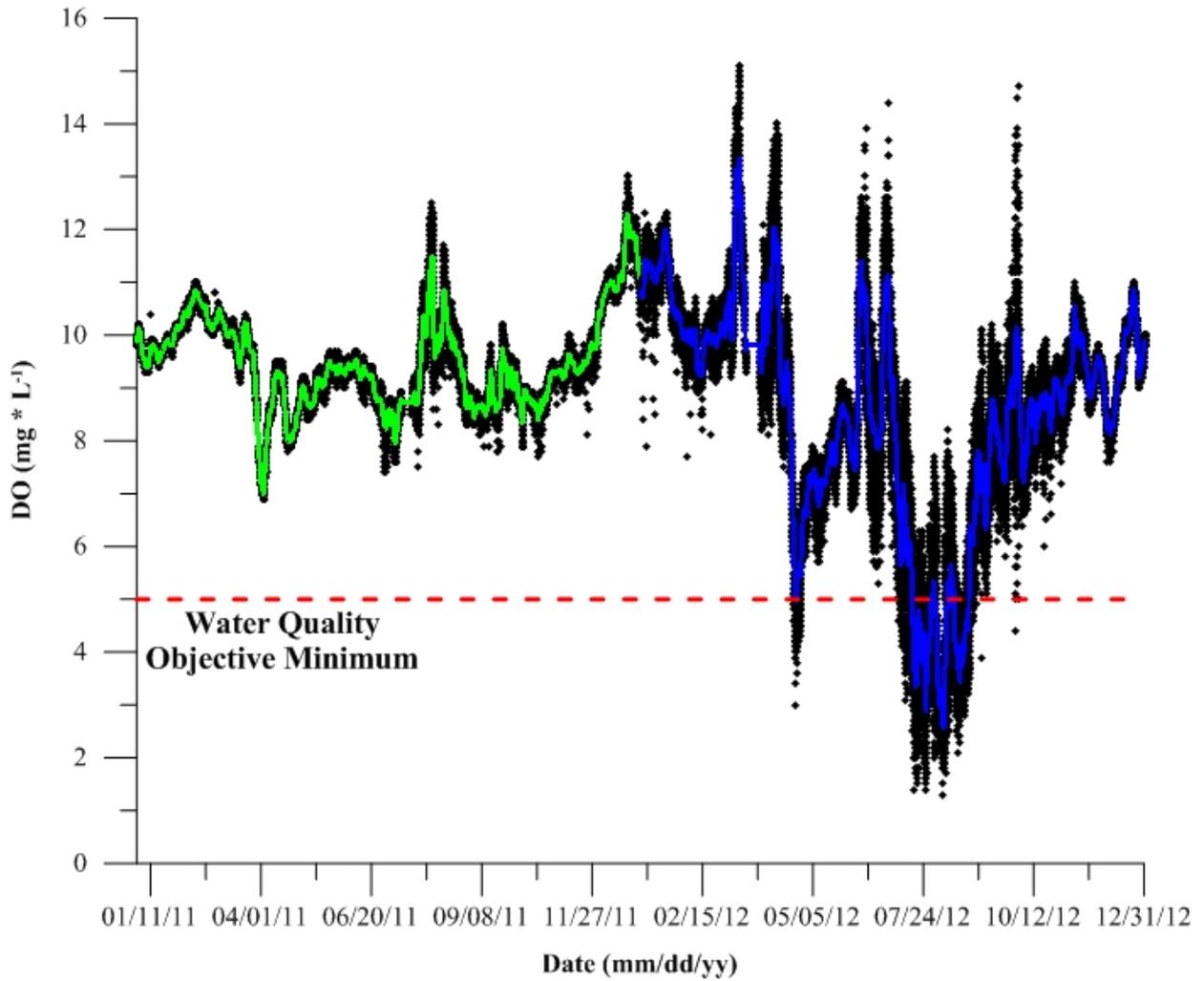


Figure 3. Temporal plots of DO in 2011 and 2012 at Grantline Canal (GLC) with a daily running average in green (for 2011) or blue (for 2012).

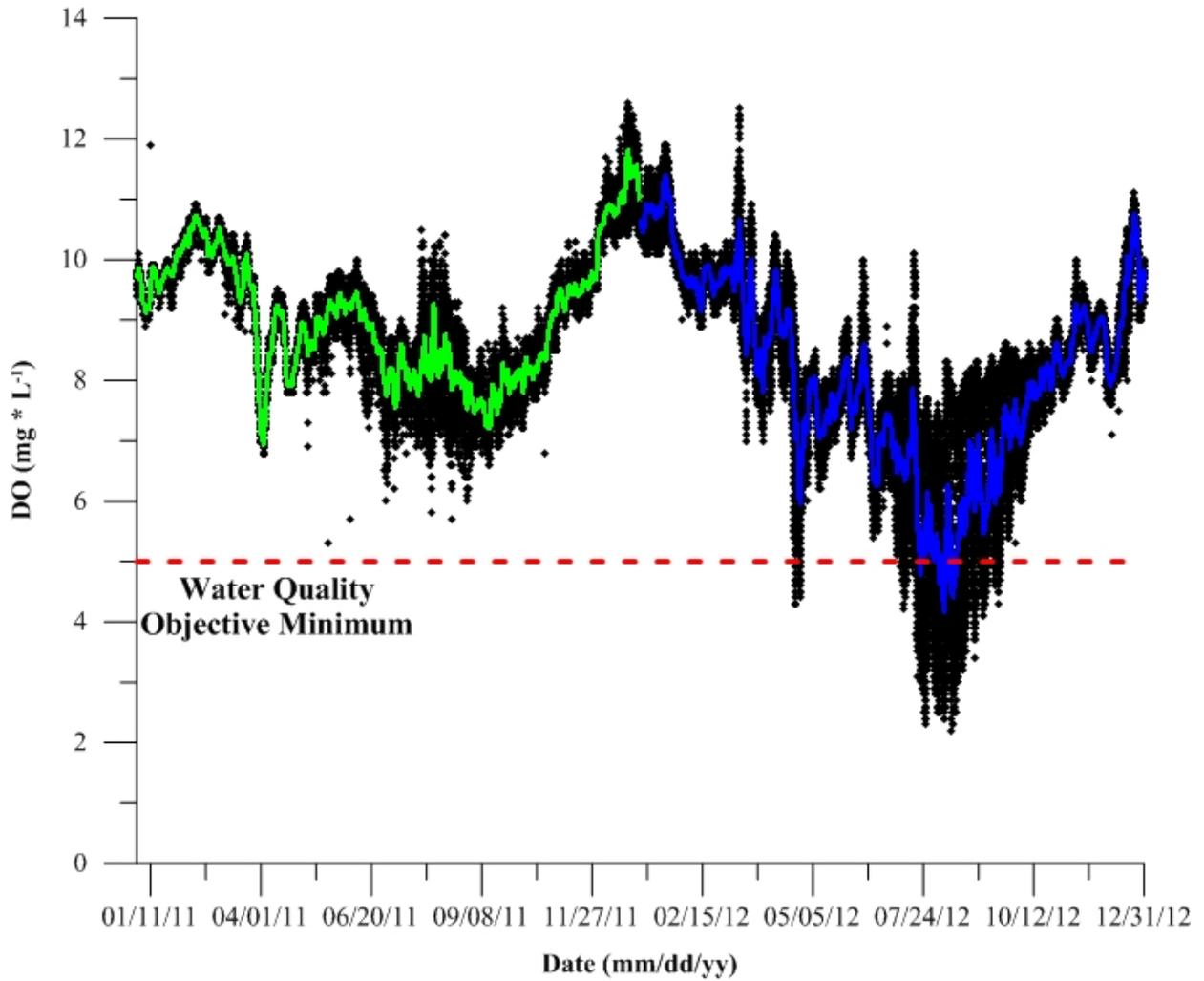


Figure 4. Temporal plots of DO in 2011 and 2012 at Middle River near Howard Road Bridge (MHO) with a daily running average in green (for 2011) or blue (for 2012).

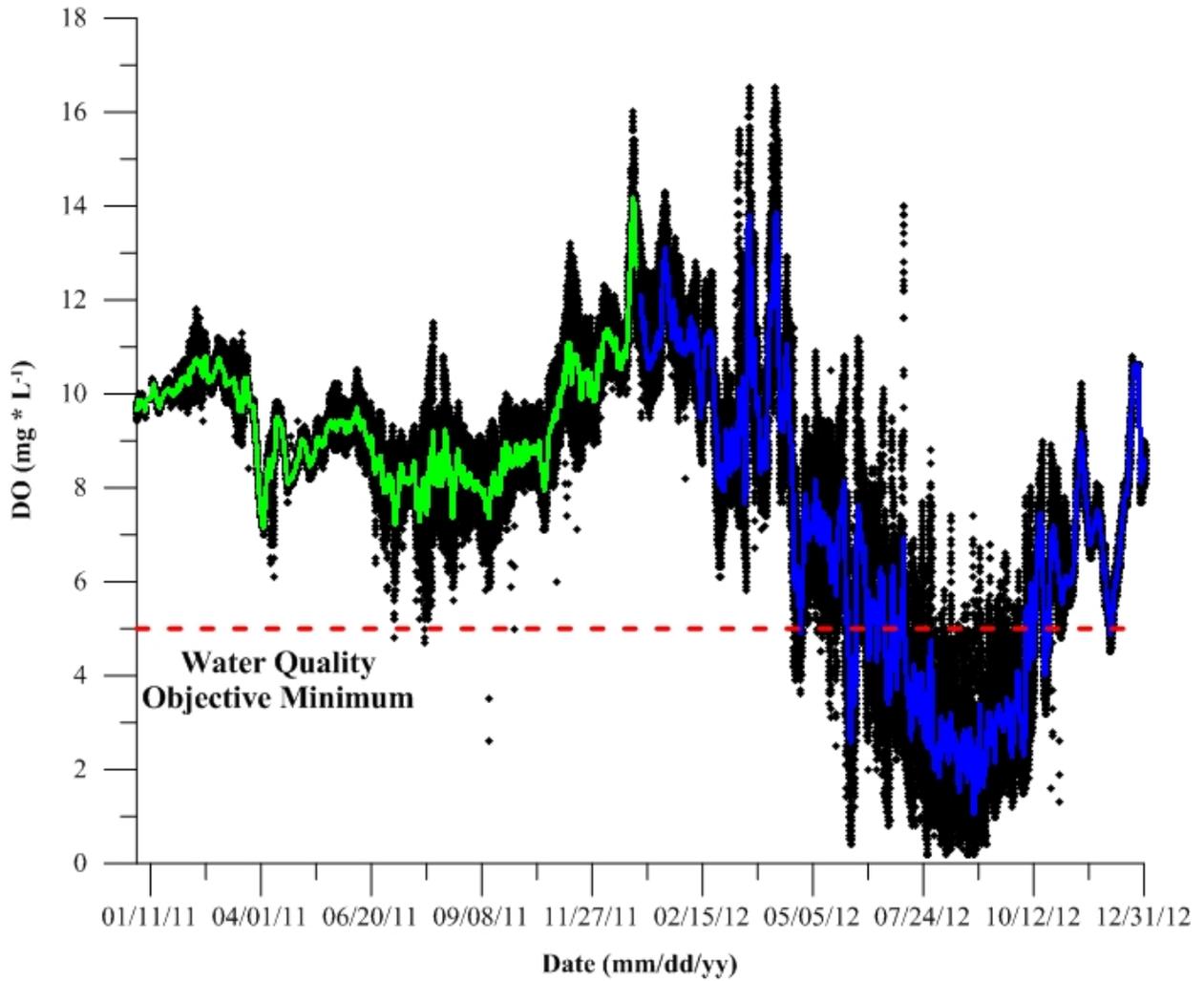


Figure 5. Temporal plots of DO in 2011 and 2012 at Old River at Tracy Wildlife Association (TWA) with a daily running average in green (for 2011) or blue (for 2012).

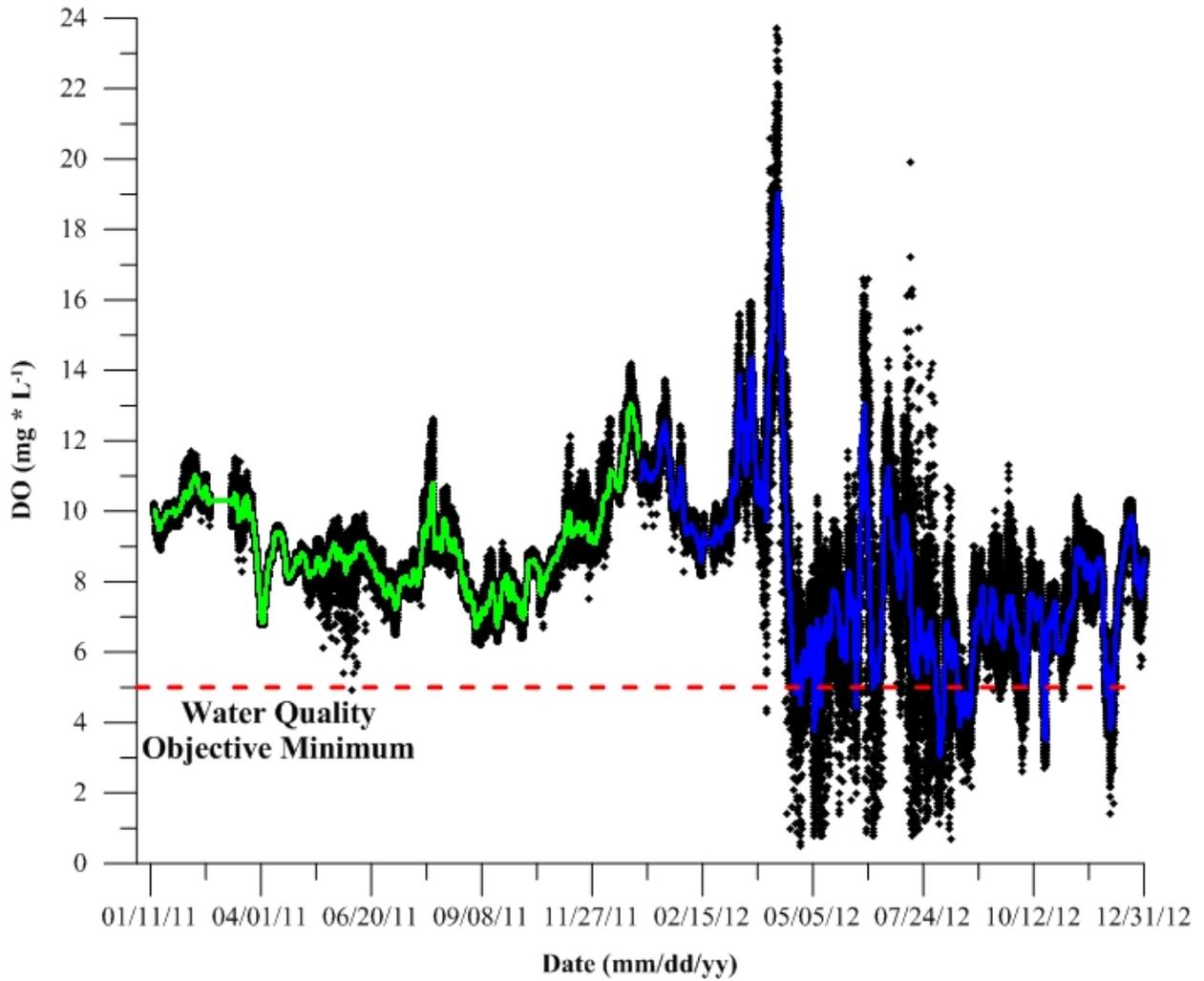


Figure 6. Temporal plots of DO in 2011 and 2012 at Old River near DMC above dam (OAD) with a daily running average in green (for 2011) or blue (for 2012).

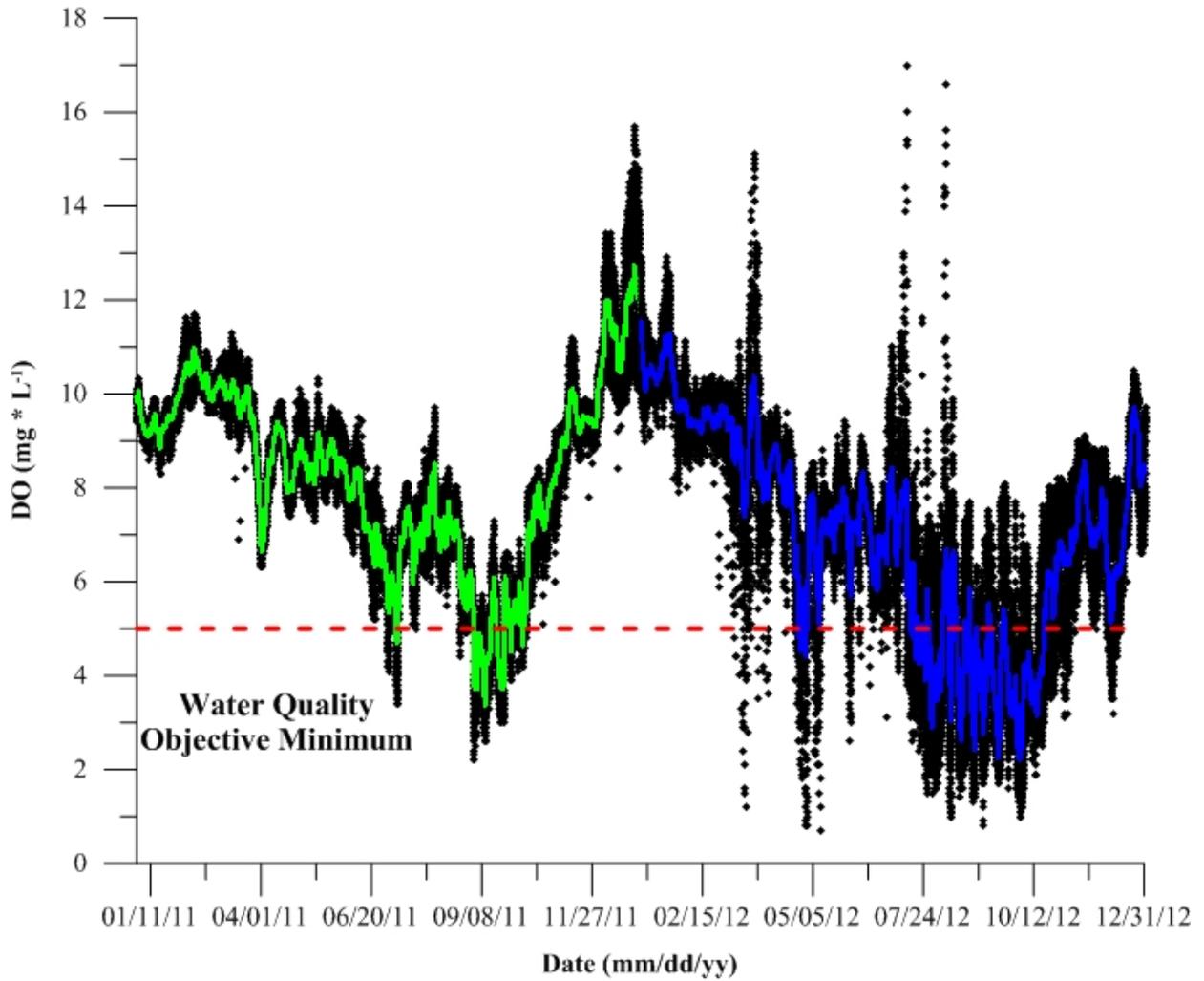


Figure 7. Temporal plots of DO in 2011 and 2012 at Old River at Delta Mendota Canal (ODM) with a daily running average in green (for 2011) or blue (for 2012).

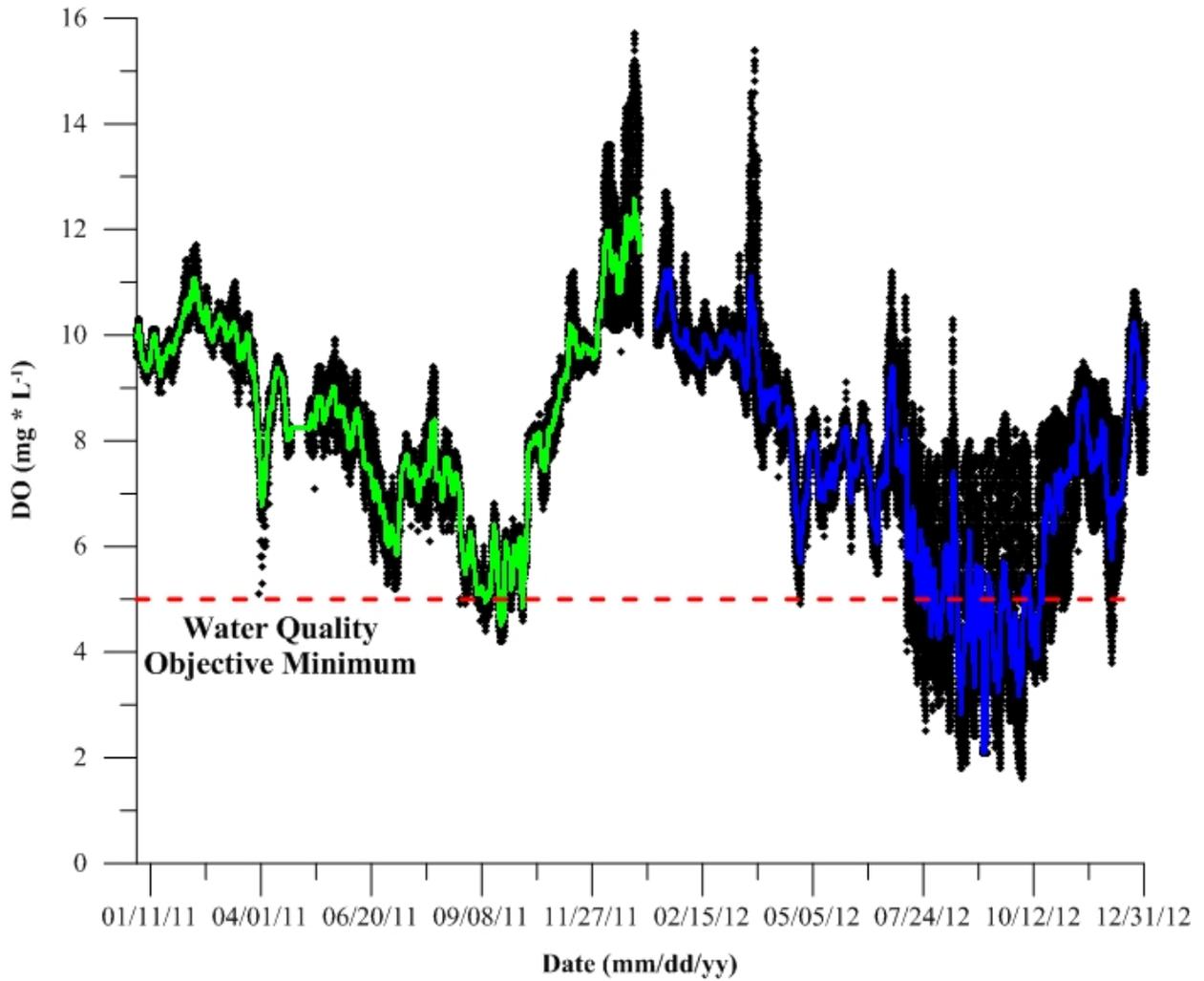


Figure 8. Temporal plots of flow in 2011 and 2012 at Grantline Canal (GLC) with a daily running average in green (for 2011) or blue (for 2012).

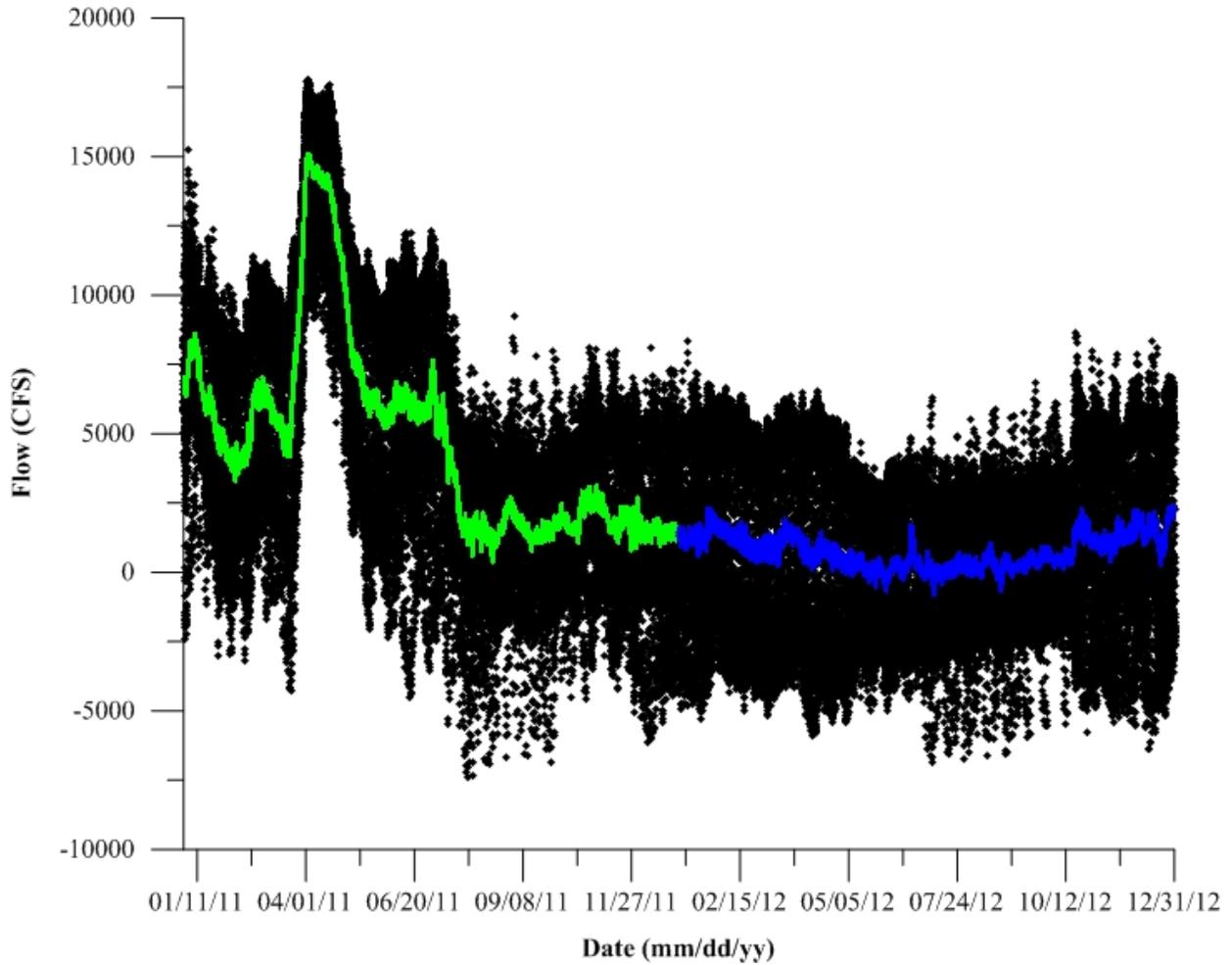


Figure 9. Temporal plots of flow in 2011 and 2012 at Middle River at Middle River (MDM) with a daily running average in green (for 2011) or blue (for 2012).

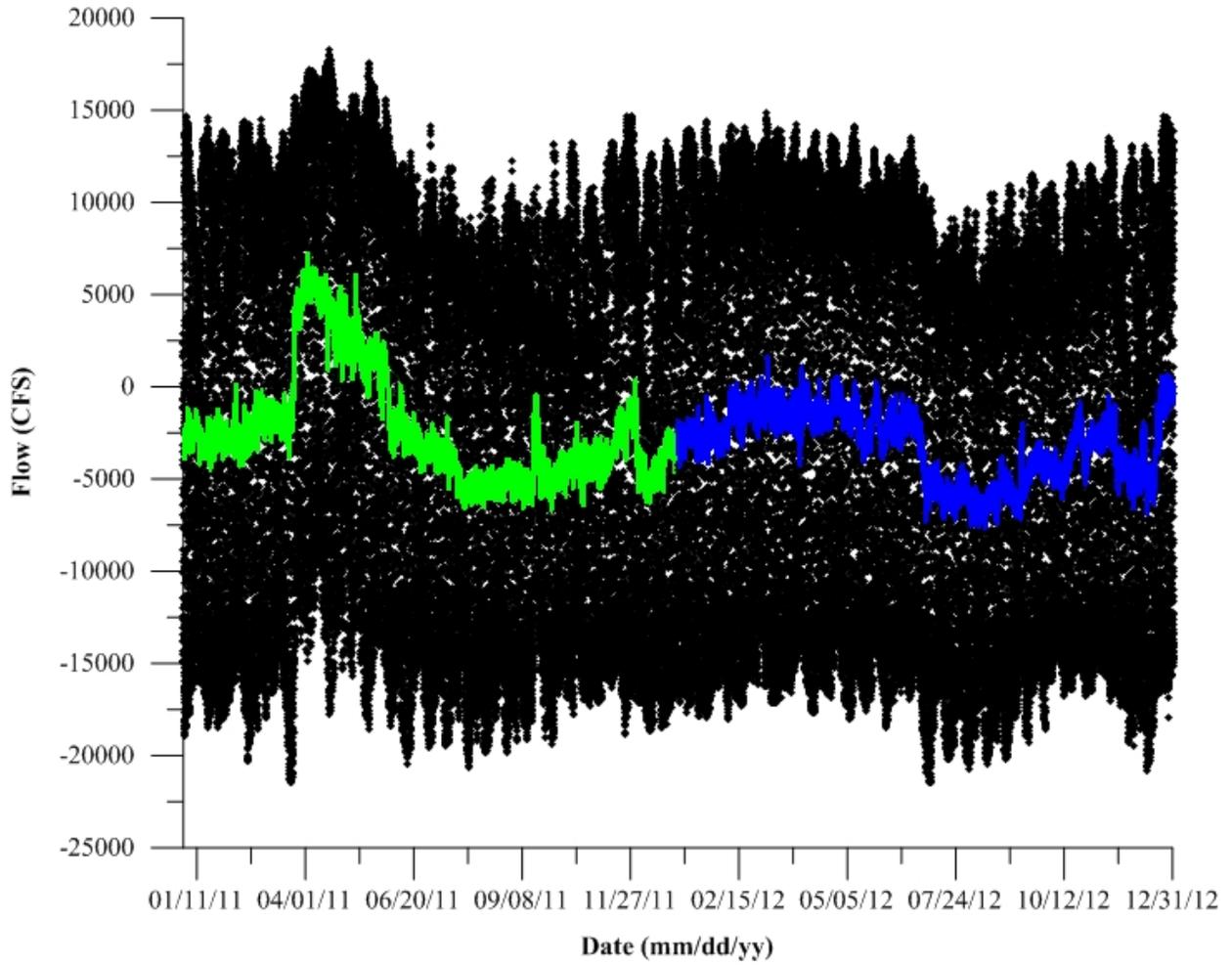


Figure 10. Temporal plots of flow in 2011 and 2012 at Old River at Delta Mendota Canal (ODM) with a daily running average in green (for 2011) or blue (for 2012).

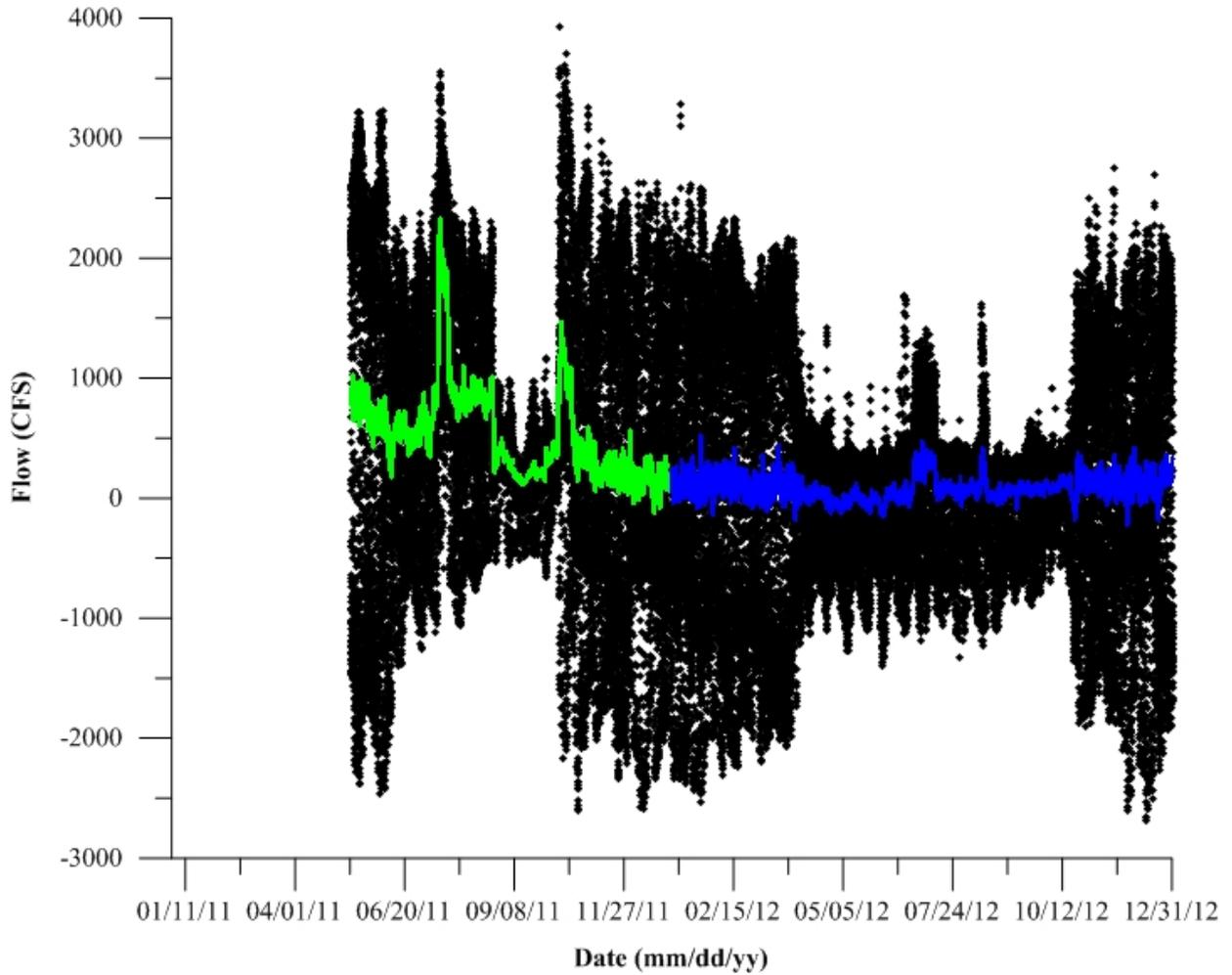


Figure 11. Temporal plots of flow in 2011 and 2012 at Old River at Head (OH1) with a daily running average in green (for 2011) or blue (for 2012).

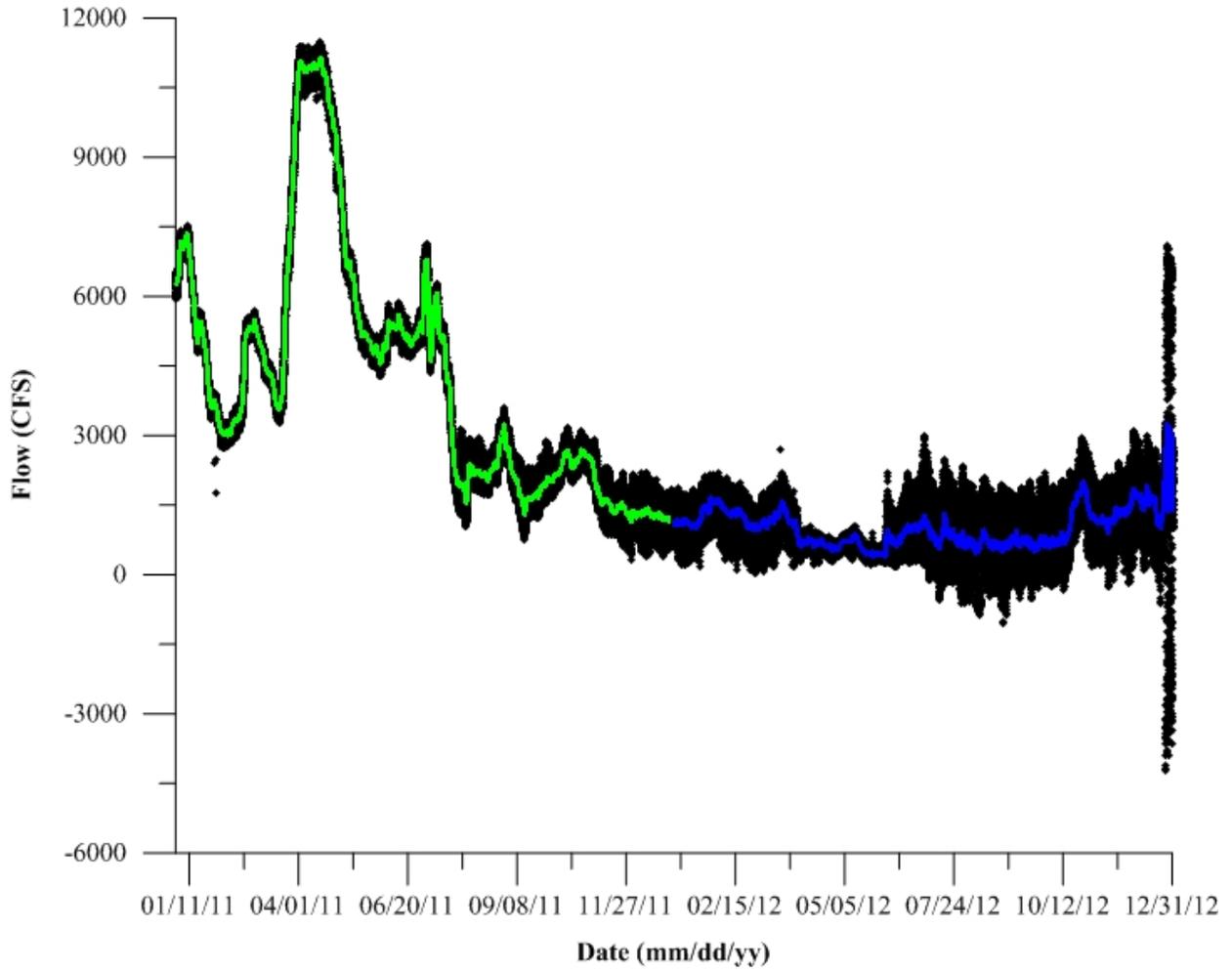


Figure 12. Temporal plots of temperature in 2011 and 2012 at Grantline Canal (GLC) with a daily running average in green (for 2011) or blue (for 2012).

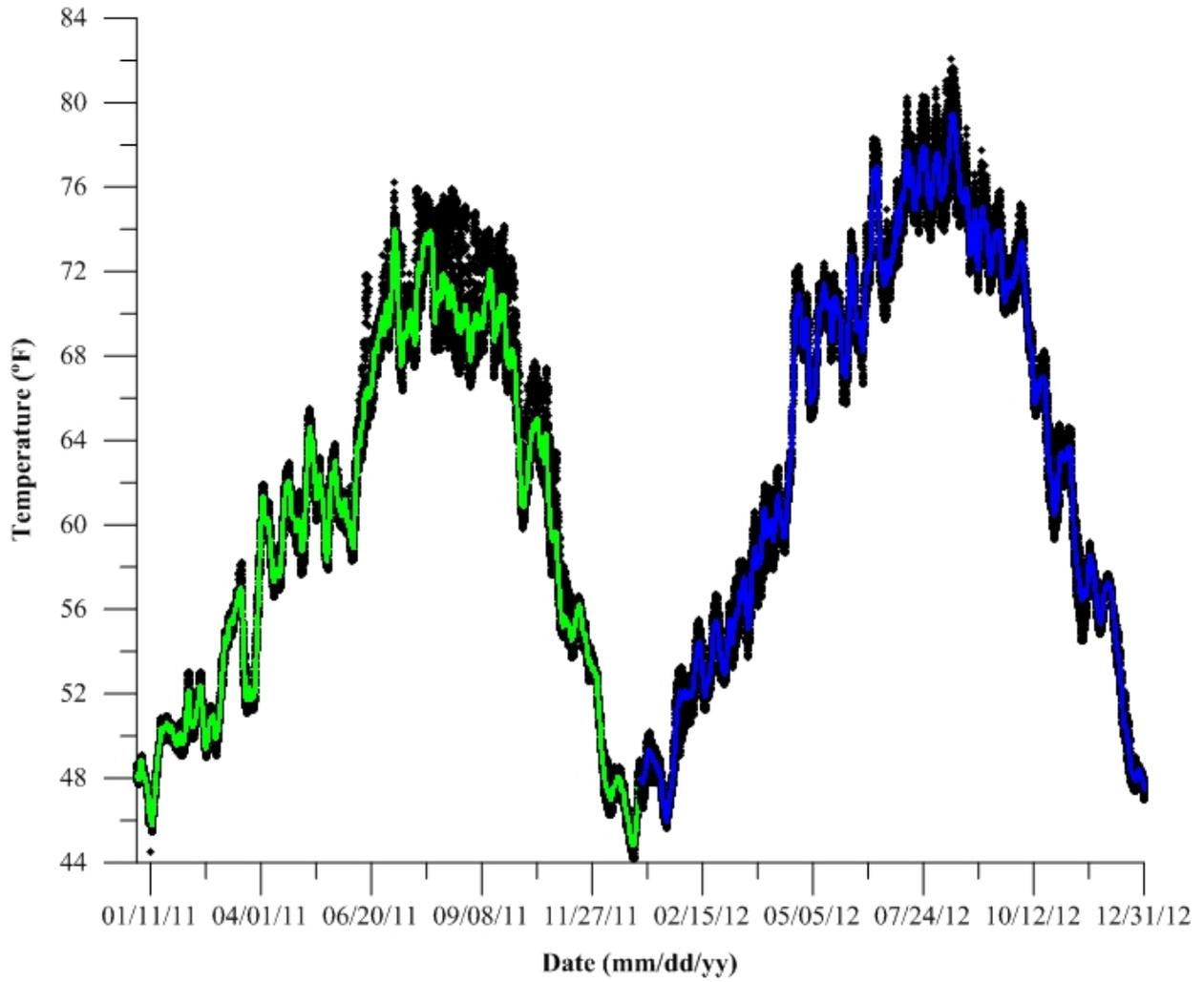


Figure 13. Temporal plots of temperature in 2011 and 2012 at Grantline Canal at Tracy Rd. Bridge (GCT) with a daily running average in green (for 2011) or blue (for 2012).

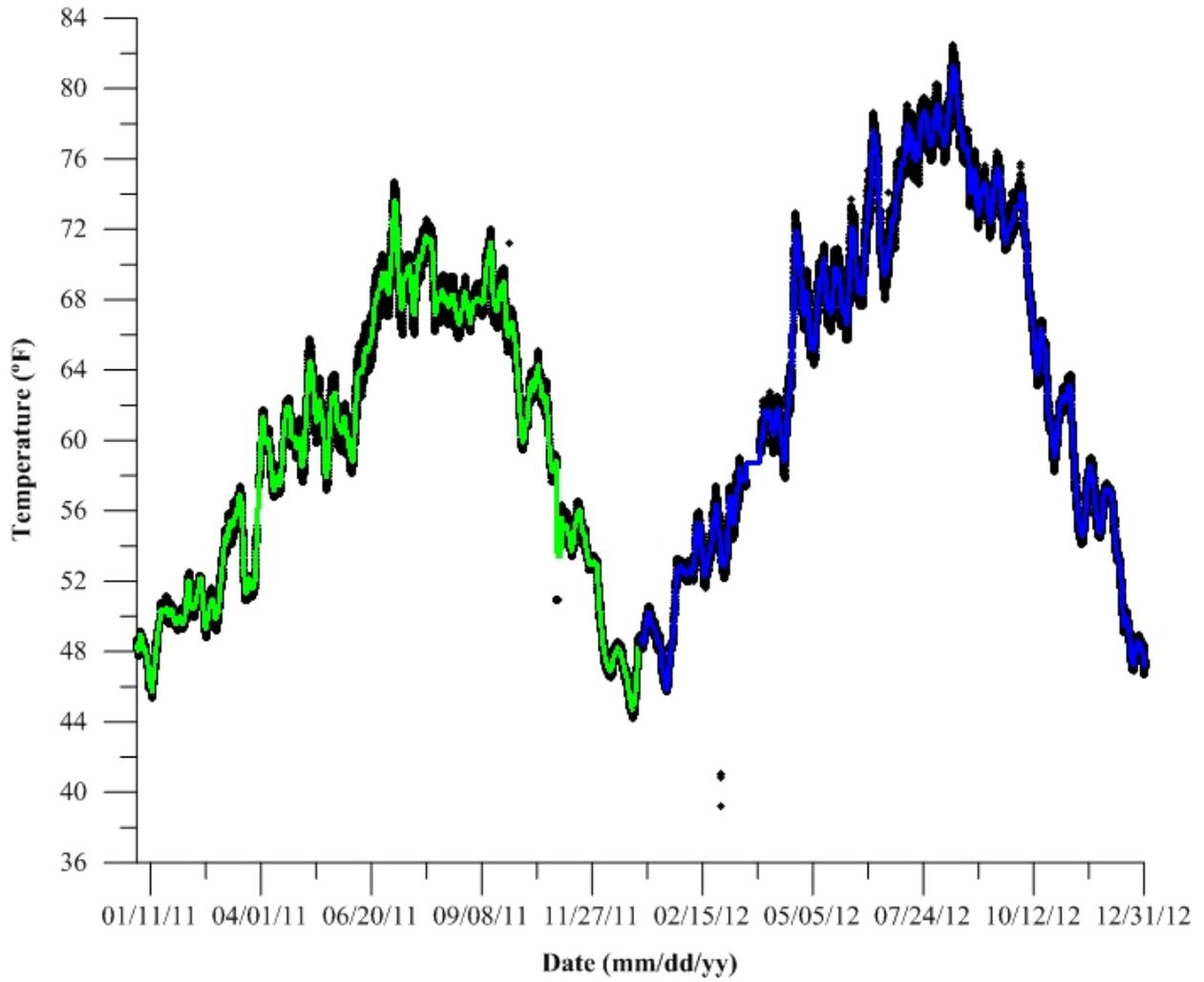


Figure 14. Temporal plots of temperature in 2011 and 2012 at Middle River near Howard Road Bridge (MHO) with a daily running average in green (for 2011) or blue (for 2012).

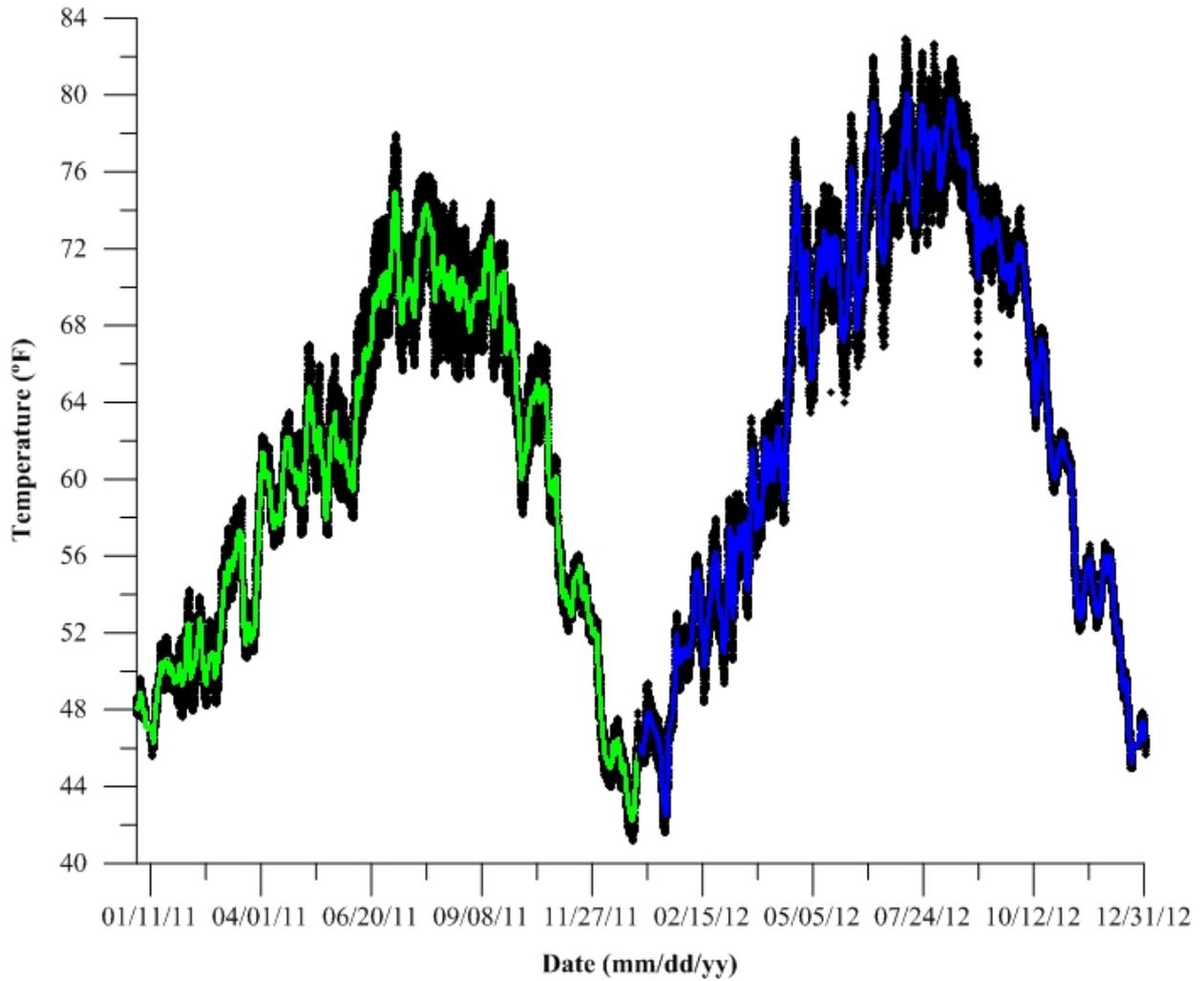


Figure 15. Temporal plots of temperature in 2011 and 2012 at Middle River at Middle River (MDM) with a daily running average in green (for 2011) or blue (for 2012).

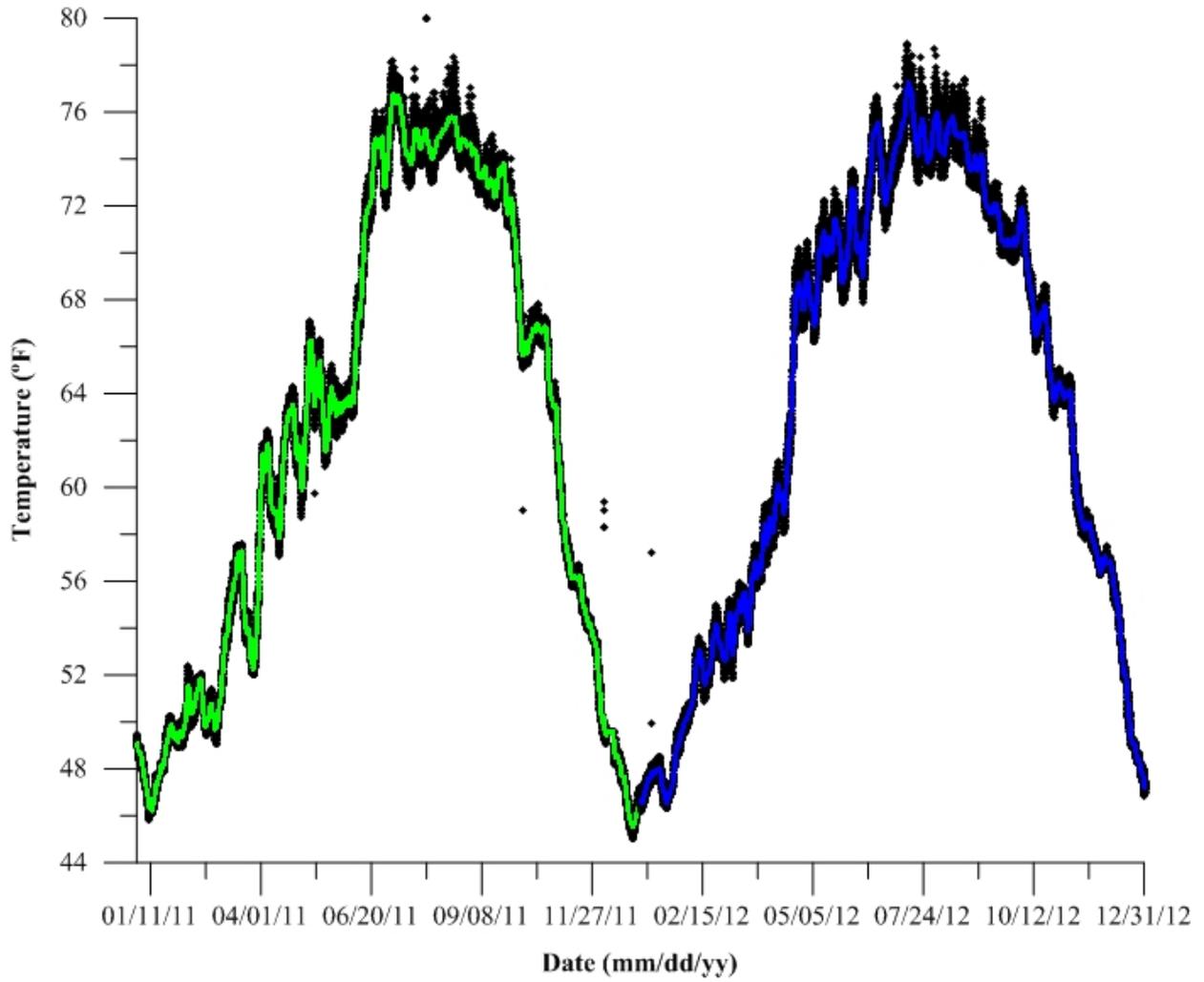


Figure 16. Temporal plots of temperature in 2011 and 2012 at Old River at Tracy Wildlife Association (TWA) with a daily running average in green (for 2011) or blue (for 2012).

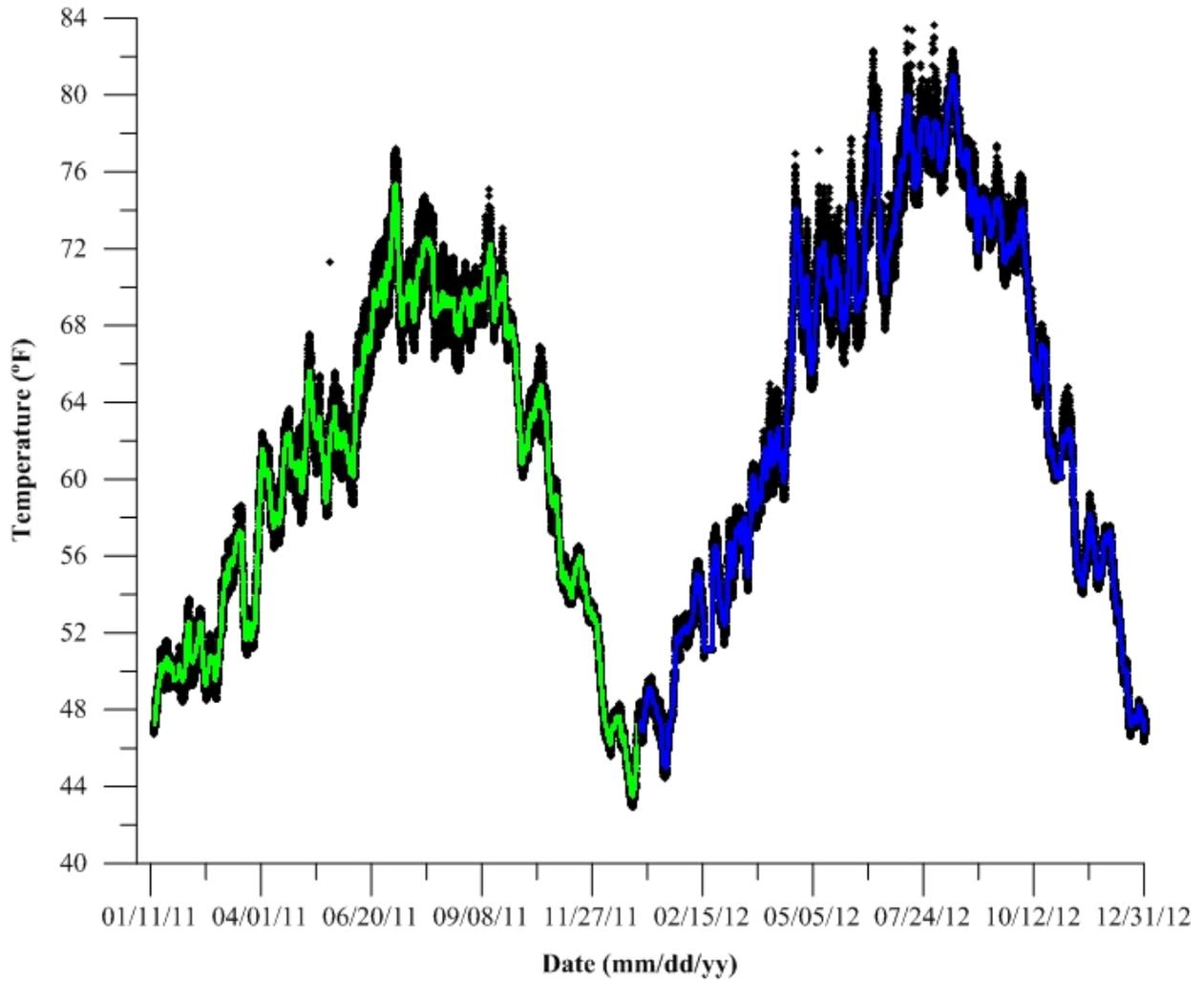


Figure 17. Temporal plots of temperature in 2011 and 2012 at Old River at Delta Mendota Canal (ODM) with a daily running average in green (for 2011) or blue (for 2012).

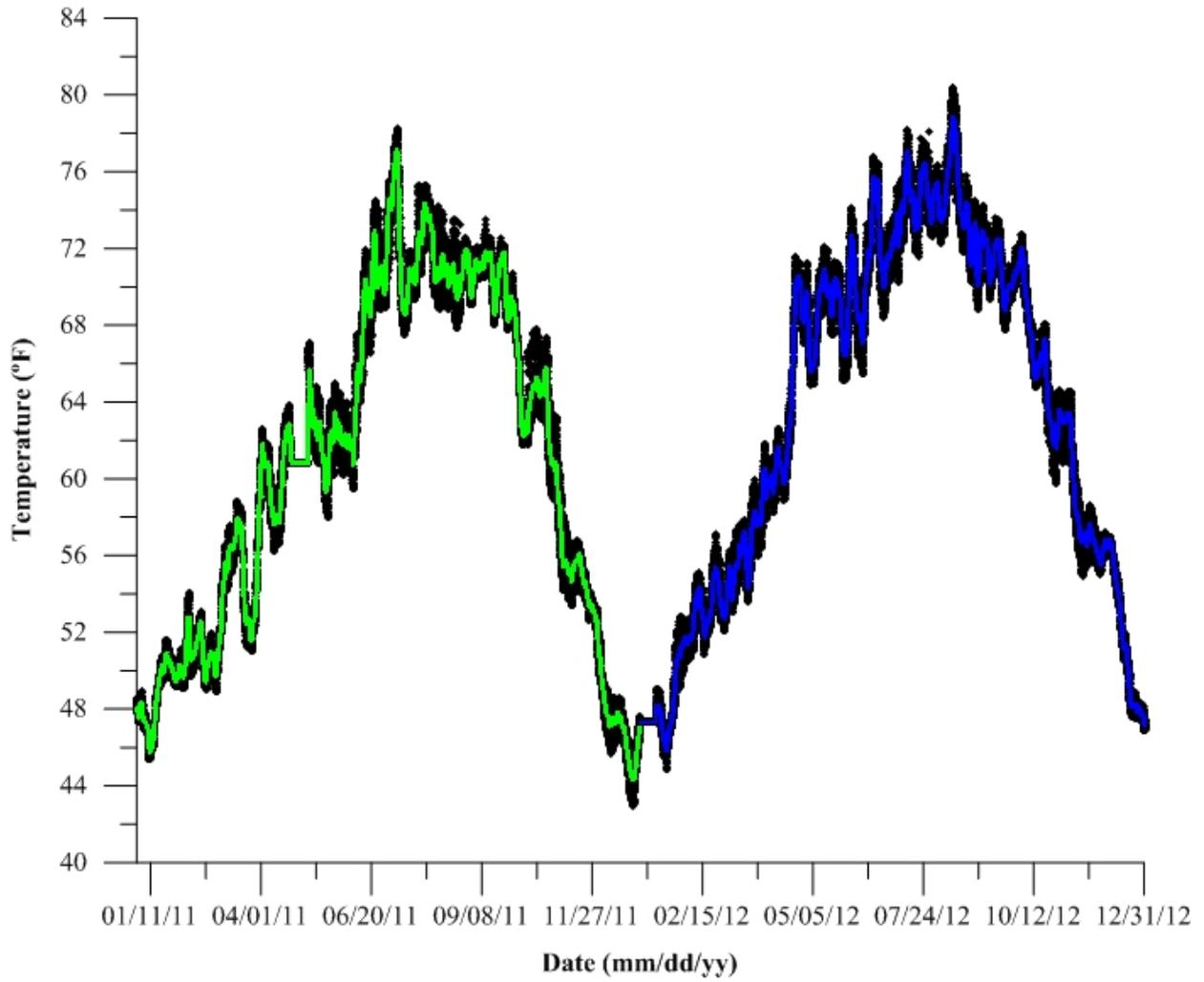


Figure 18. Temporal plots of temperature in 2011 and 2012 at Old River at DMC above dam (OAD) with a daily running average in green (for 2011) or blue (for 2012).

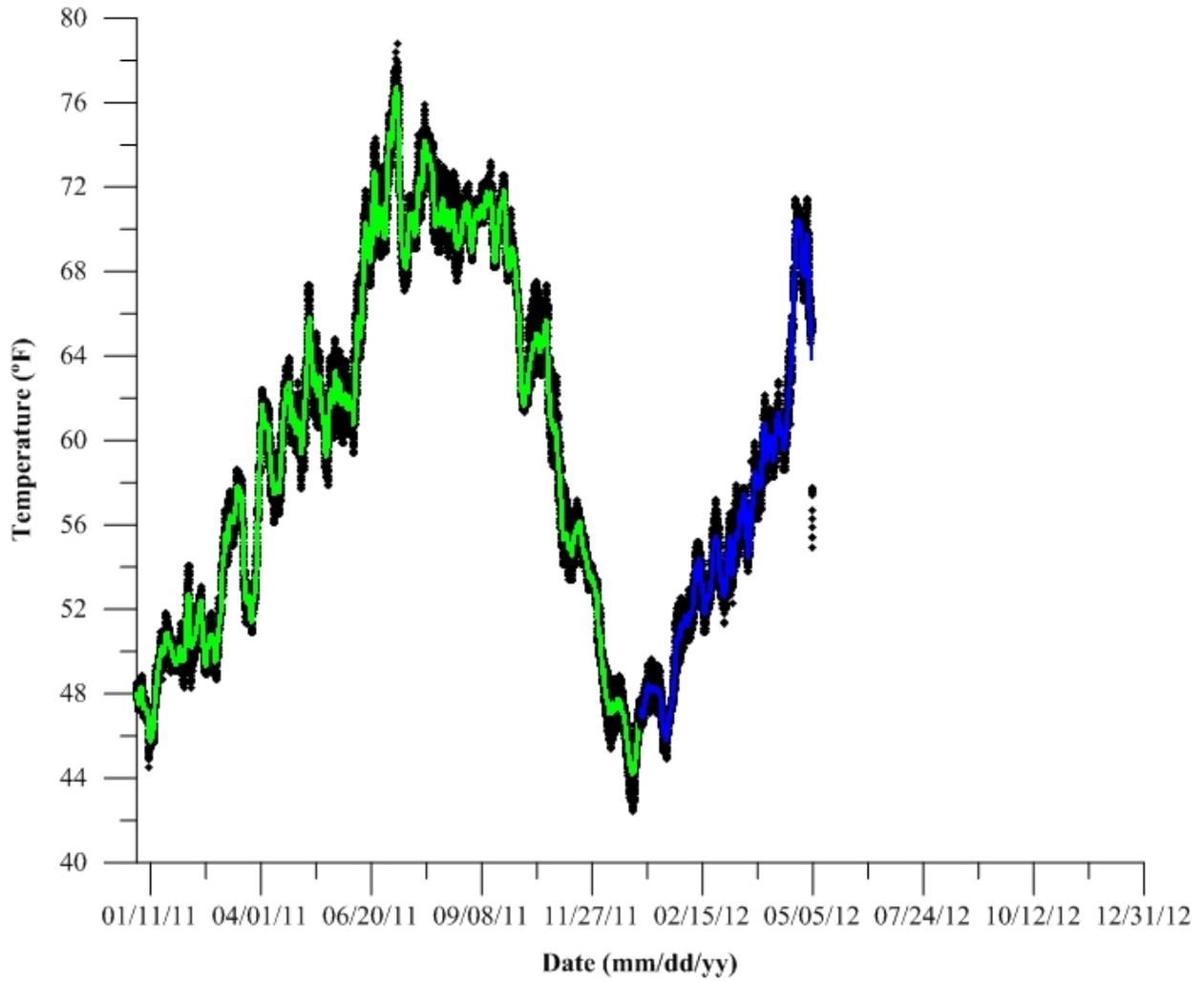


Figure 19. Percent of days below water quality objective of 5 mg L⁻¹ throughout the year.

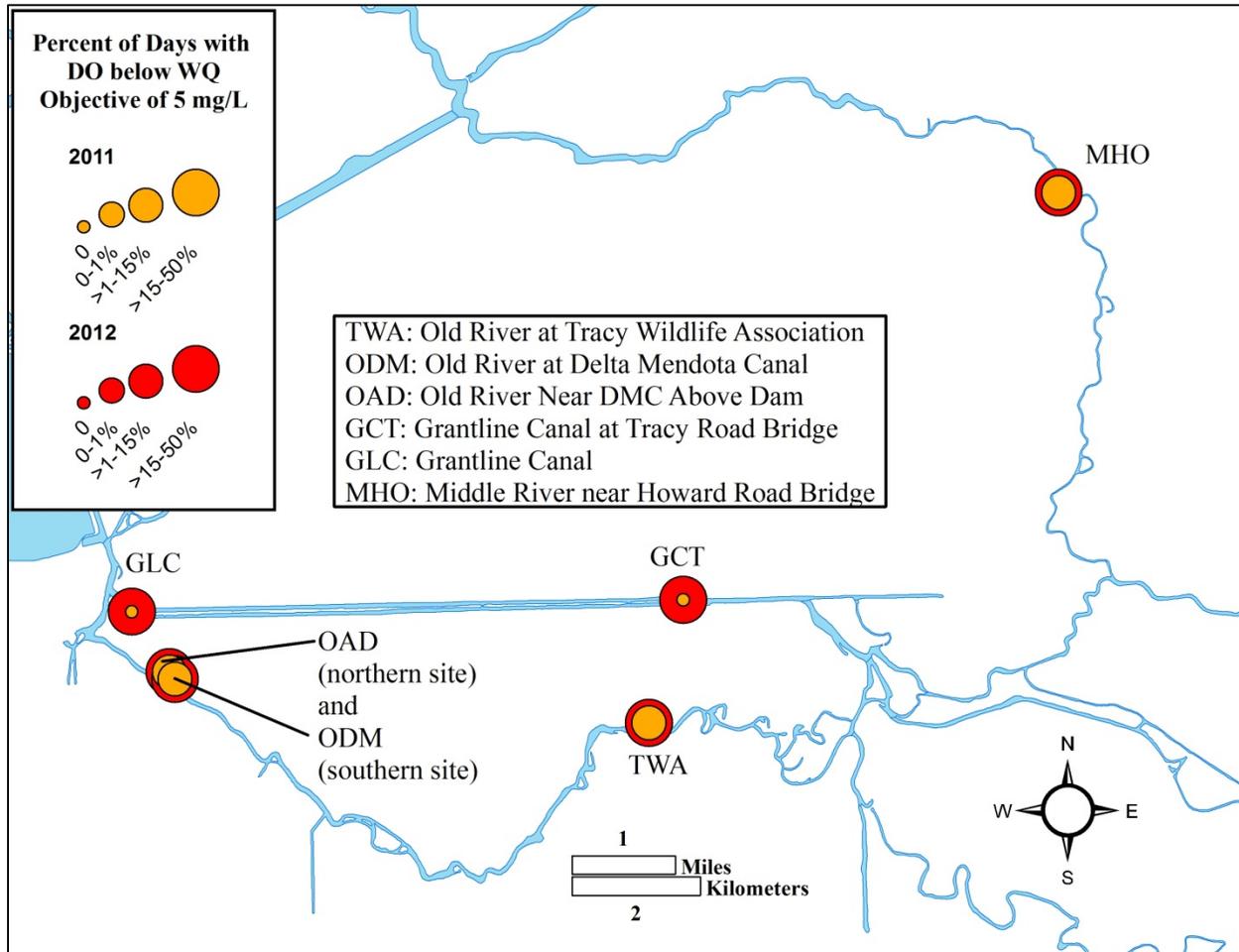


Figure 20. Percent of 15-minute measurements below water quality objective of 5 mg L⁻¹ throughout the year.

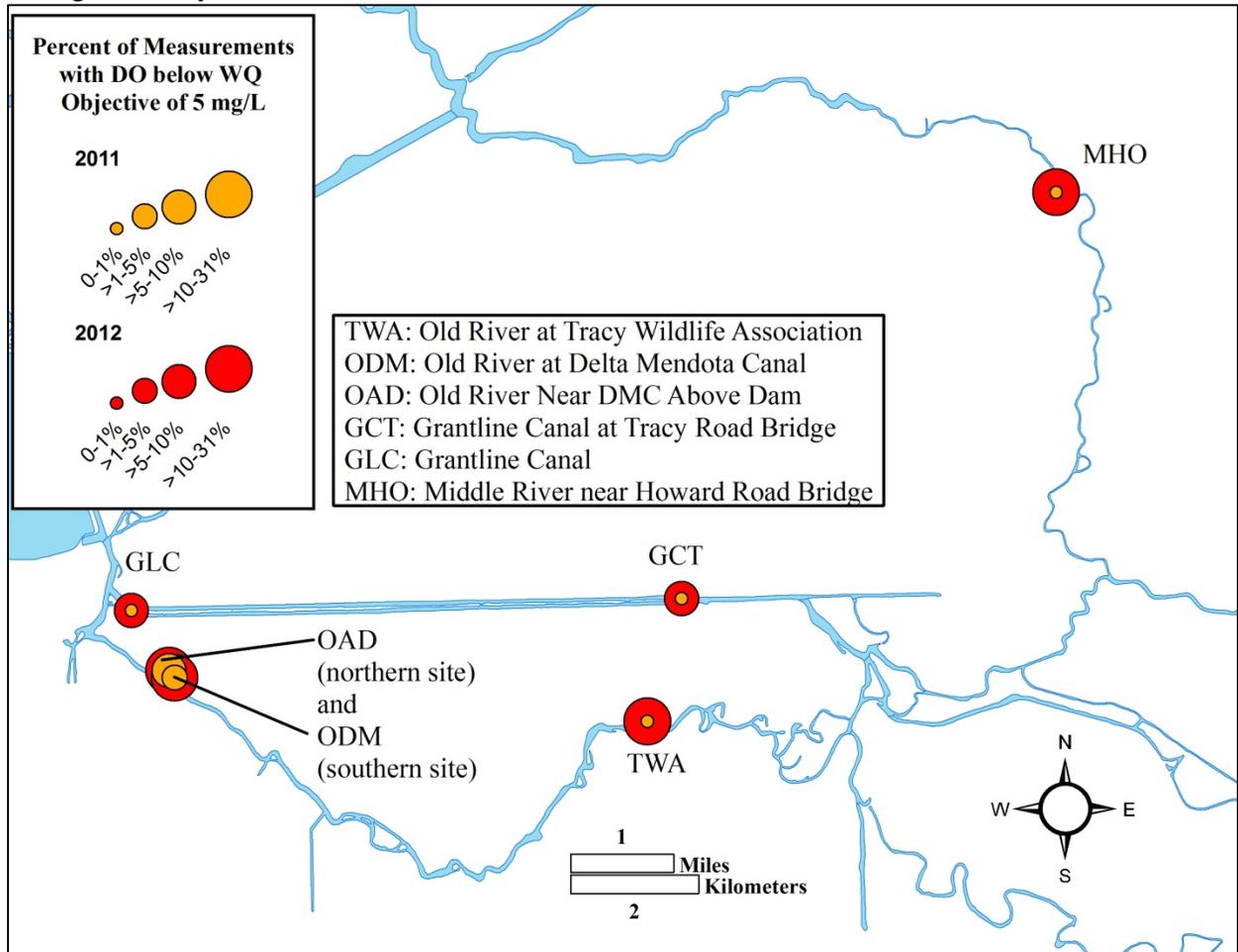


Figure 21. Temporal plots of Chl in 2011 and 2012 at Old River at Tracy Wildlife Association (TWA) with a daily running average in green (for 2011) or blue (for 2012).

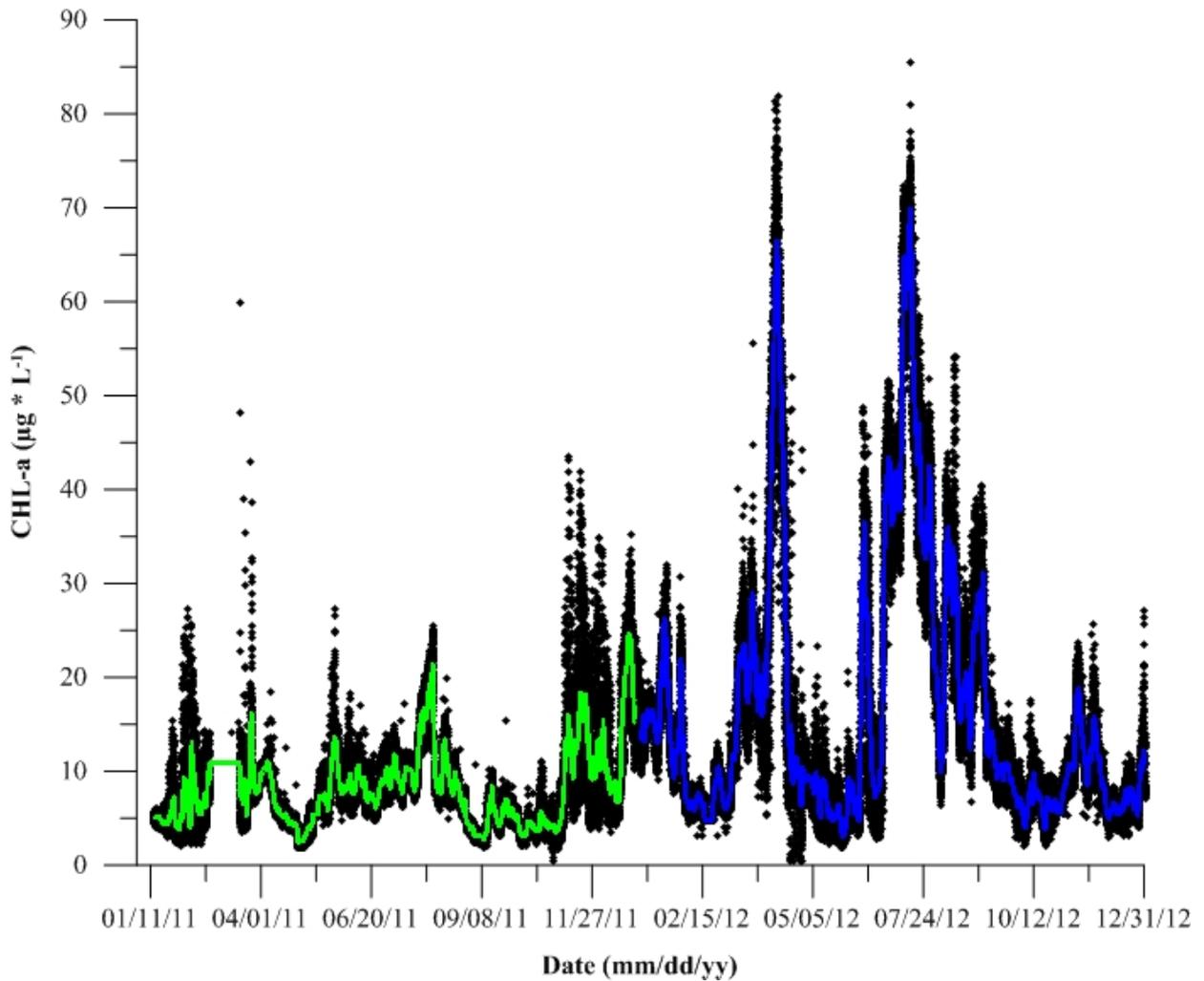


Figure 22. Temporal plots of Chl in 2011 and 2012 at Old River at Delta Mendota Canal (ODM) with a daily running average in green (for 2011) or blue (for 2012).

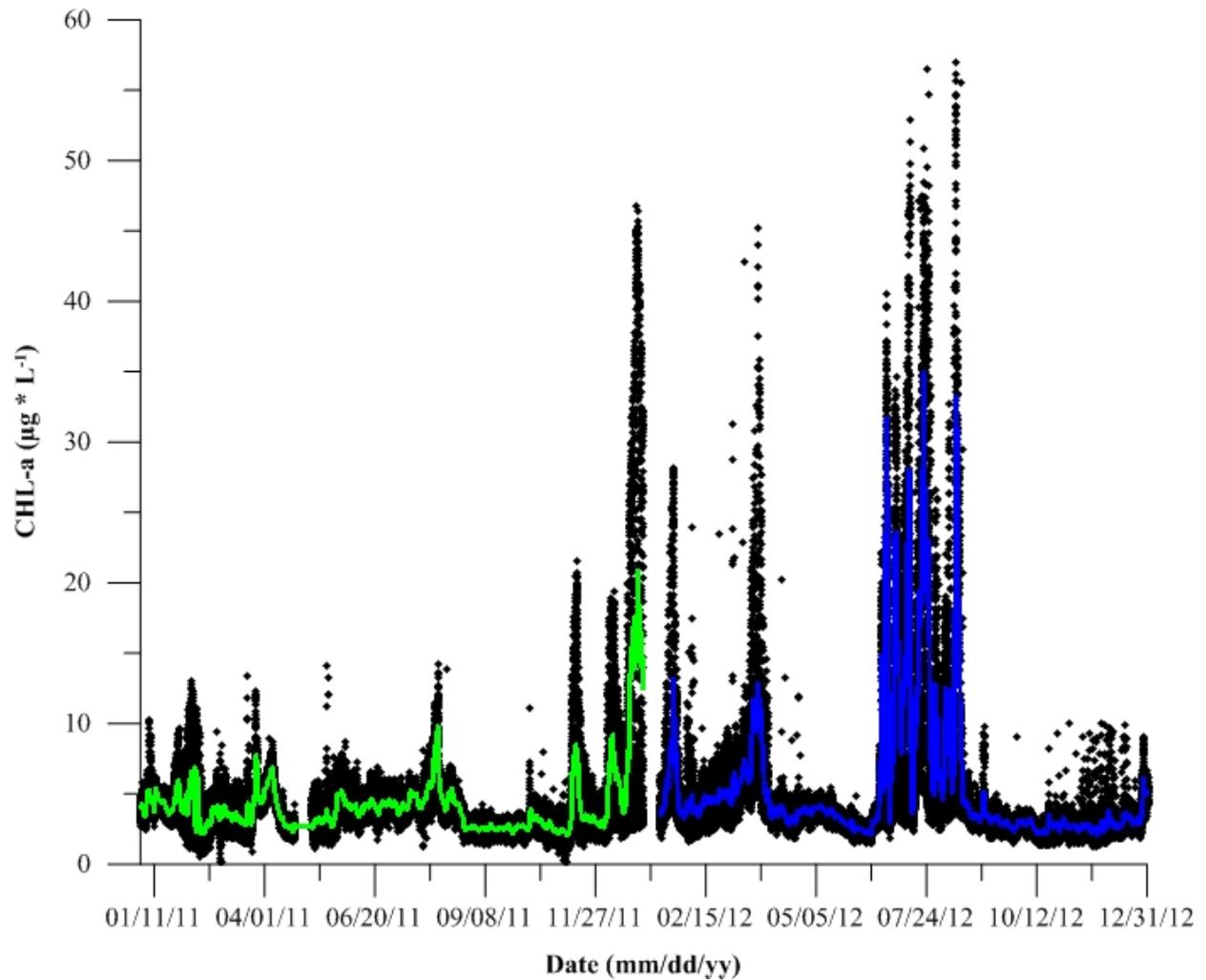


Figure 23. Temporal plots of Chl in 2011 and 2012 at Old River at DMC above dam (OAD) with a daily running average in green (for 2011) or blue (for 2012).

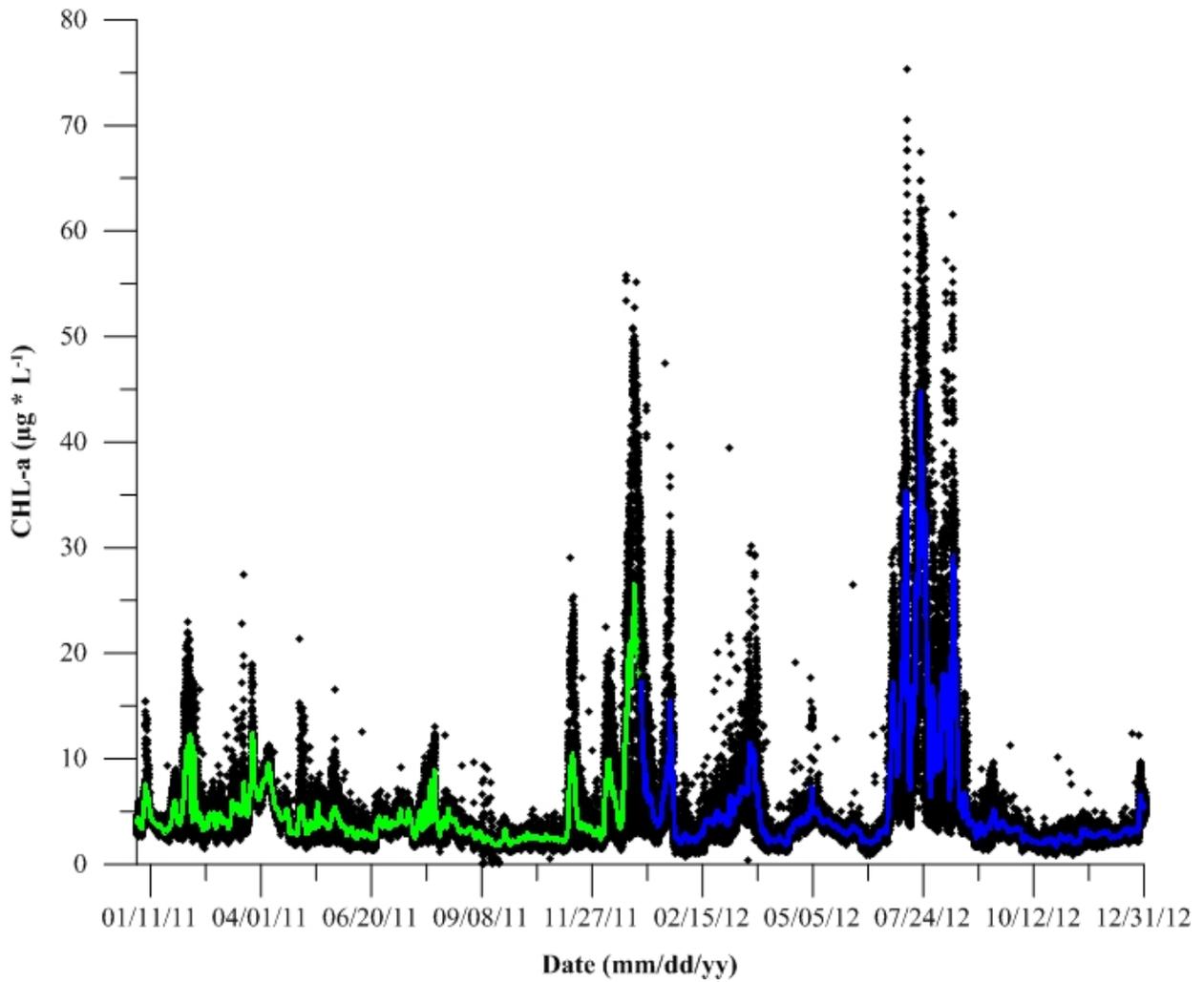


Figure 24. Temporal plots of Chl in 2011 and 2012 at Grantline Canal at Tracy Rd. Bridge (GCT) with a daily running average in green (for 2011) or blue (for 2012).

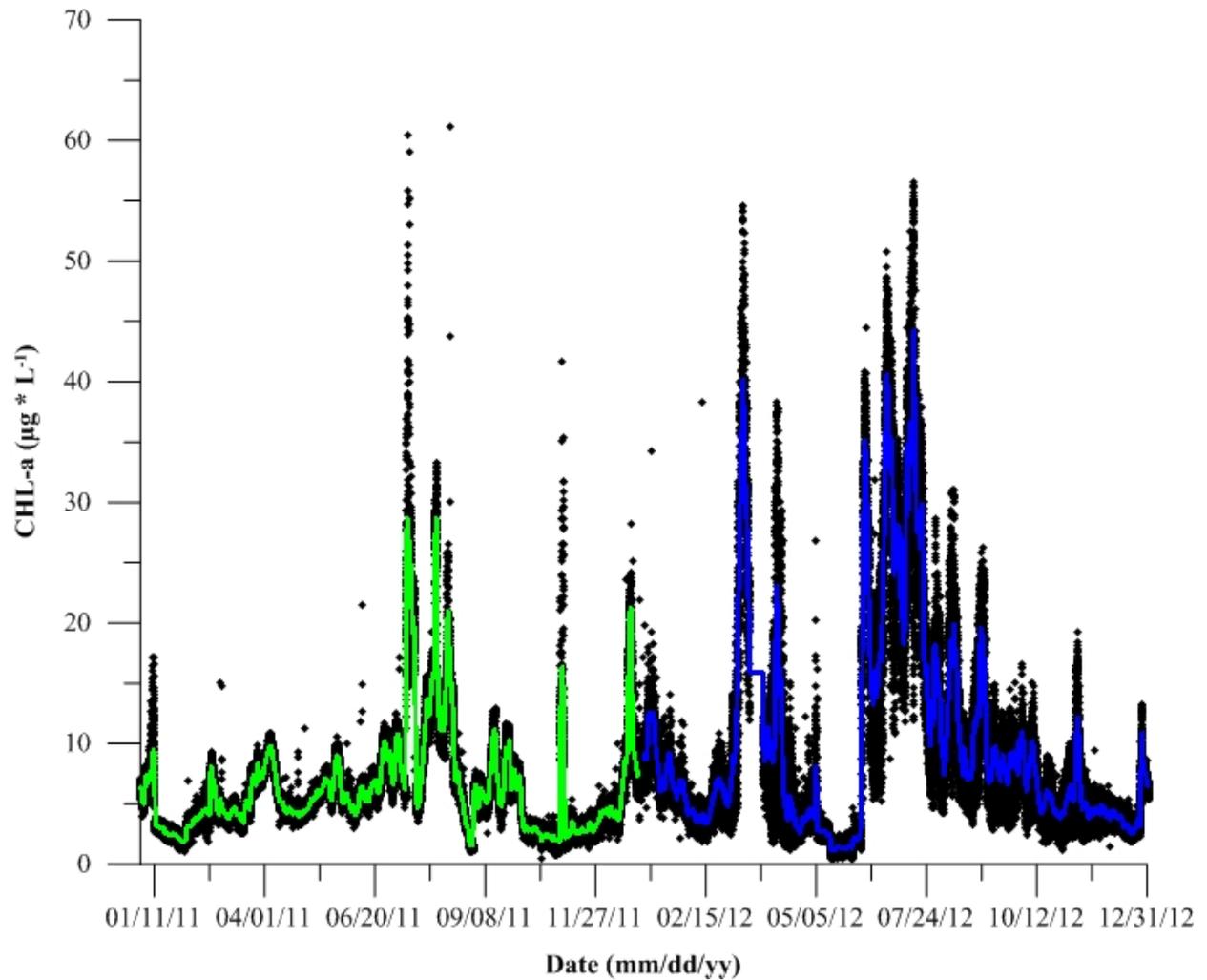


Figure 25. Temporal plots of Chl in 2011 and 2012 at Grantline Canal (GLC) with a daily running average in green (for 2011) or blue (for 2012).

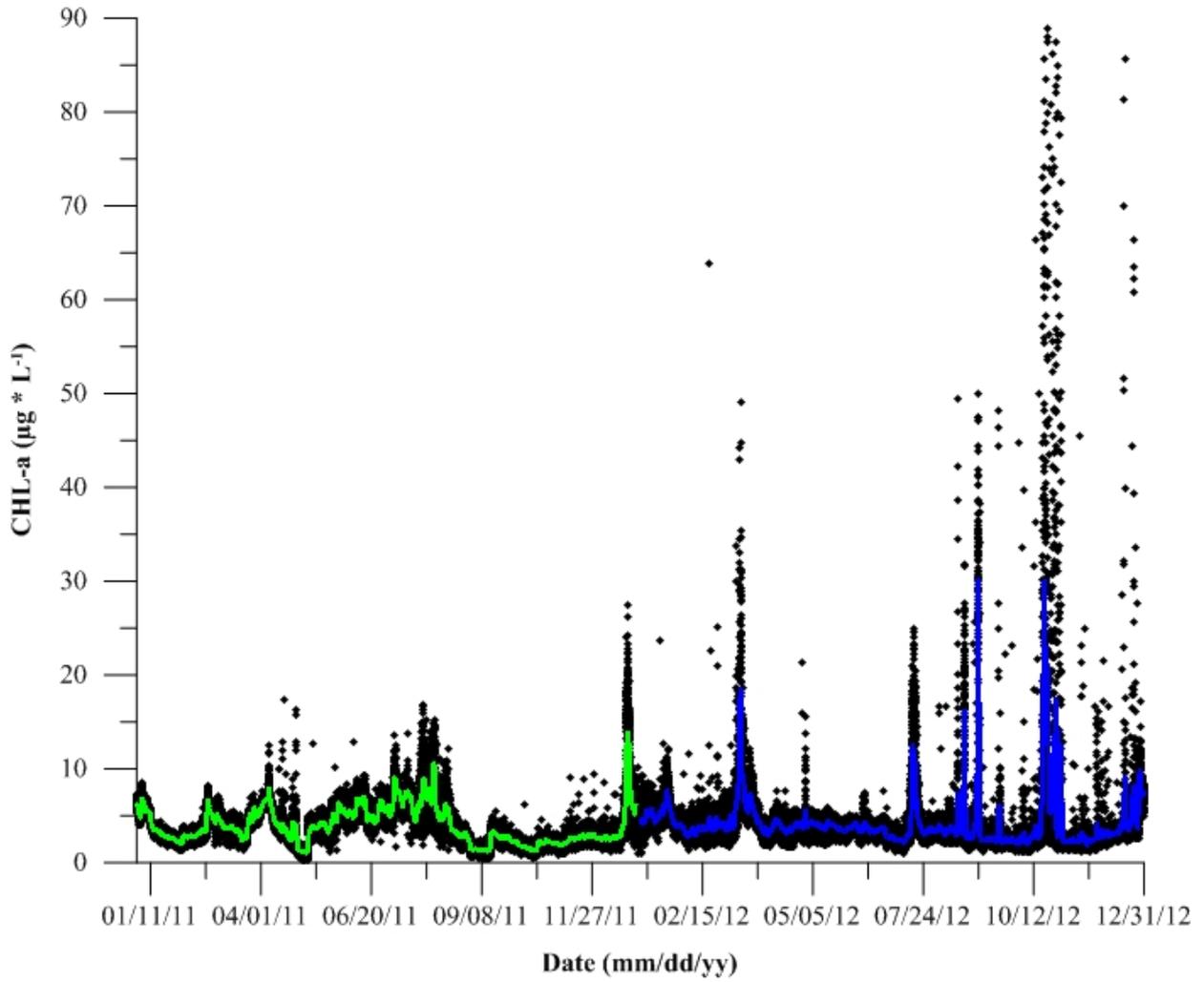


Figure 26. Temporal plots of Chl in 2011 and 2012 at Middle River near Howard Road Bridge (MHO) with a daily running average in green (for 2011) or blue (for 2012).

