Elk Valley Water Quality Plan

Annex G

Evaluation of Potential Ecological Effects Associated with Cadmium in the Elk and Fording Rivers

Teck

Prepared for Teck Coal Limited

Evaluation of Potential Ecological Effects Associated with Cadmium in the Elk and Fording Rivers

Prepared by Robert Santore and Adam Ryan

HDR, Inc. Syracuse, NY.

Robert C. Santore

Adam C. Ryan

HDR

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Executive Summary

HDR developed a methodology to evaluate the potential effects of cadmium in the Elk Valley and Fording River Valley waters, as a basis for establishing water quality concentration targets. Target cadmium concentrations for use in developing effects matrices were established considering monitoring data of cadmium concentrations at the site. Each of the effects matrices includes an upper target and an intermediate target concentration. For all stations the upper target was defined as the 95th percentile of all detected dissolved cadmium concentrations in water samples taken from all monitoring locations within the site, inclusive of tributaries. This upper target is considerably higher than cadmium concentrations measured in any samples collected at the order stations, and therefore represents a conservative upper bound for developing the effects matrices.

Estimates of the toxicological effects from cadmium were based on an extensive review of the scientific literature regarding the toxicity of cadmium in chronic exposures. Cadmium toxicity data from these literature sources was compiled into an database that considered effects to 42 biological species, including 22 species of invertebrates, 16 species of fish, 3 species of aquatic plants and algae, and 1 amphibian species. For each of these species, the reported toxicological data were screened to select low-effects endpoints, for non-lethal toxicological responses, using sensitive life-stages in accordance with procedures for developing water quality guidelines developed by the British Columbia Ministry of Environment (BCMOE). Normalization of toxicity data was conducted using the Biotic Ligand Model, which considers numerous water quality factors such as the presence of organic matter, the pH of the water, and other constituents such as hardness and alkalinity. A parallel analysis similar to the more traditional methodology used in development of water quality guidelines by BCMOE, which considers only hardness, was also conducted. Both analyses identified *Daphnia magna* (*D. magna*) as the most sensitive species to cadmium toxicity.

A cadmium benchmark was defined to protect the lowest toxicity endpoint for *D. magna*. Cadmium concentrations at order stations were consistently below the cadmium benchmark values, indicating that no effects to aquatic life from cadmium are expected at order stations. This conclusion was further supported by toxicity tests using site waters. BLM predicted effect concentrations for samples used in the site-specific testing indicate that ambient cadmium concentrations would need to increase by an order of magnitude (10×) before reaching a potential effect concentration.

1.0 Introduction

Water quality in the Elk Valley is a recognized concern for regulators, community stakeholders and Teck Coal Limited (Teck). Chemical constituents of potential concern as identified within Ministerial Order No. M113 (hereafter referred to as "the Order") are cadmium (Cd), selenium (Se), nitrate (NO_3) and sulphate (SO_4). The Order, issued by the Minister of Environment on April 15, 2013, directed Teck to develop an area-based management plan for the Elk Valley, herein referred to as "the Plan". Under the Plan, Teck will establish short-, medium- and long-term water quality concentration targets for cadmium, selenium, nitrate and sulphate at the following seven locations known as order stations:

- Fording River, downstream of Greenhills Creek, FR4 (Environmental Monitoring System No. [EMS#] 0200378)
- Fording River, at the mouth, FR5 (EMS# 0200028)
- Elk River, downstream of Greenhills Operations, ER1 (EMS# E206661)
- Elk River, downstream of the Fording River, ER2 (EMS# 0200027)
- Elk River, downstream of Michel Creek, ER3 (EMS# 0200393)
- Elk River, at Elko Reservoir, ER4 (EMS# E294312)
- Lake Koocanusa, south of the mouth of the Elk River, LK2 (EMS# E294311).

Outcomes to be achieved through implementation of the Plan include protection of aquatic health, management of contaminant bioaccumulation in the receiving environment, protection of human health, and protection of groundwater.

The objectives of this report are as follows:

- Summarize cadmium concentrations in waters at each of the order stations as a first step in assessing cadmium exposure to aquatic biota in the Elk and Fording rivers.
- Summarize generic information from the scientific literature on the toxicity of cadmium to aquatic biota.
- Develop an effects matrix at each of the order stations, to evaluate potential ecological effects on aquatic biota from chronic exposure to a range of cadmium concentrations.

This information will aid the development of medium- and long-term target concentrations for cadmium at the order stations.

2.0 Problem Definition

Under certain circumstances, cadmium toxicity has been observed for a variety of freshwater organisms. The mechanism of toxicity has been associated with disruption of calcium homeostasis by inhibition of calcium uptake (Wood et al., 1997; McGeer et al., 2012). Cadmium toxicity has also been related to interactions of dissolved cadmium with gill tissue, and the uptake of cadmium on gills has been shown to be affected both by the presence of dissolved organic carbon (DOC) and elevated calcium concentrations (Playle et al, 1993). Chemical factors in water can alter speciation of cadmium, and can reduce its bioavailability[1] by forming complexes, thereby reducing its chemical activity and interaction with gill surfaces. Alternatively, the presence of competing cations, and especially calcium (Ca), can reduce the binding of cadmium to the gill surface, reducing bioavailability and toxicity . This combination of factors related to chemical activity of the metal and competition at binding sites is accounted for within the Biotic Ligand Model (BLM; Figure 1). The BLM is a generalized bioavailability approach that has been used for a number of metals (Paquin et al., 2002), and has been applied to cadmium in both acute and chronic exposure settings (Hollis et al., 1999; 2000a; 2000b). Versions of the BLM have been developed for a number of metals in addition to cadmium, including aluminum (Al), cobalt (Co), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) (DiToro et al., 2001; Santore et al., 2001; Santore et al., 2002). One of the benefits of the BLM framework is that the conceptual model can be applied consistently to explain and predict effects of metals on aquatic organisms including fish and invertebrates.

Consideration of toxicity modifying factors (TMFs) is important and can be used to help explain variation in observed cadmium toxicity in the toxicological literature. Bioavailability and toxicity of cadmium has been observed to vary with changes in cations associated with hardness (such as Ca), alkalinity, and DOC (Niyogi et al., 2004; Niyogi et al., 2008). For example, DOC can bind cadmium, thereby reducing bioavailability and toxicity (Figure 2). A reduction in cadmium bioavailability and toxicity with increasing DOC concentrations has been observed for rainbow trout (*Oncorhynchus mykiss*), and the measured effect of DOC on cadmium toxicity closely matches the effect predicted by the BLM (Figure 2). Elevated calcium concentrations have a similar protective effect for *O. mykiss* and the freshwater flea (*Daphnia magna),* and the observed effects for these organisms also closely match the effect predicted by the BLM (Figure 3).

[1] The term "bioavailability" refers to changes in the toxicity of a metal to aquatic organisms that result from changes in the composition of the exposure water. These bioavailability effects may be caused by factors that affect the chemical speciation of the metal (such as organic matter), or they may result from factors that inhibit the interaction of metal ions with biological surfaces (such as elevated Ca, which is associated with harder water).

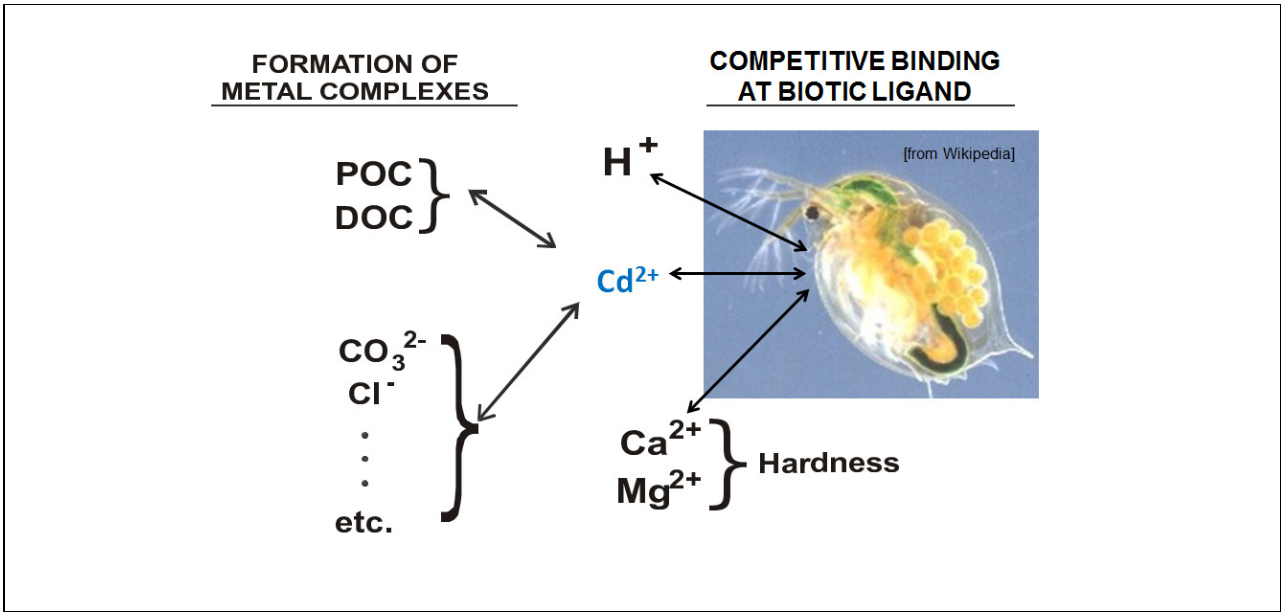

Figure 1: Model of Water Quality Factors That Affect Cadmium Bioavailability

Cadmium can exist in numerous forms, depending on chemical speciation reactions with dissolved or particulate organic carbon, or with anionic ligands such as carbonate (CO_3^{2-}) or chloride (Cl^-) ions. The overall chemical speciation that results from these simultaneous reactions determines the chemical activity of the free cadmium ion (Cd^{2+}), which also determines the extent to which it binds to biotic ligand sites in aquatic organisms. Biotic ligand sites can also bind other cations, such as calcium, magnesium and hydrogen ions (H^+). These competitive cations can reduce the extent to which cadmium binds to biotic ligand sites, thereby reducing cadmium bioavailability and toxicity.

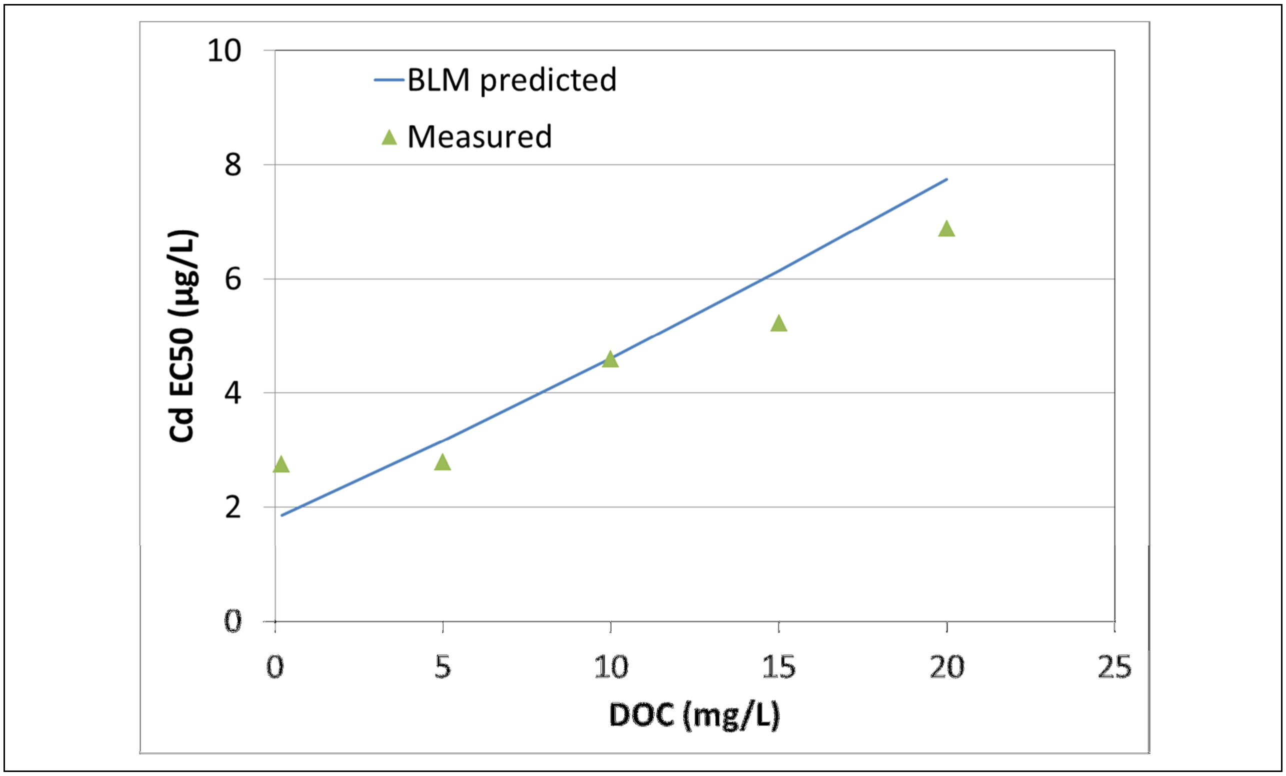

Figure 2: Effect of DOC Concentration on Cadmium Toxicity to Rainbow Trout (*O. mykiss*)

The effects of DOC on cadmium toxicity to rainbow trout (*O. mykiss*) reported by Niyogi et al. (2008) shown as the green triangles. The predicted effect of DOC based on the calculated change in cadmium speciation using the BLM is shown as the blue line.

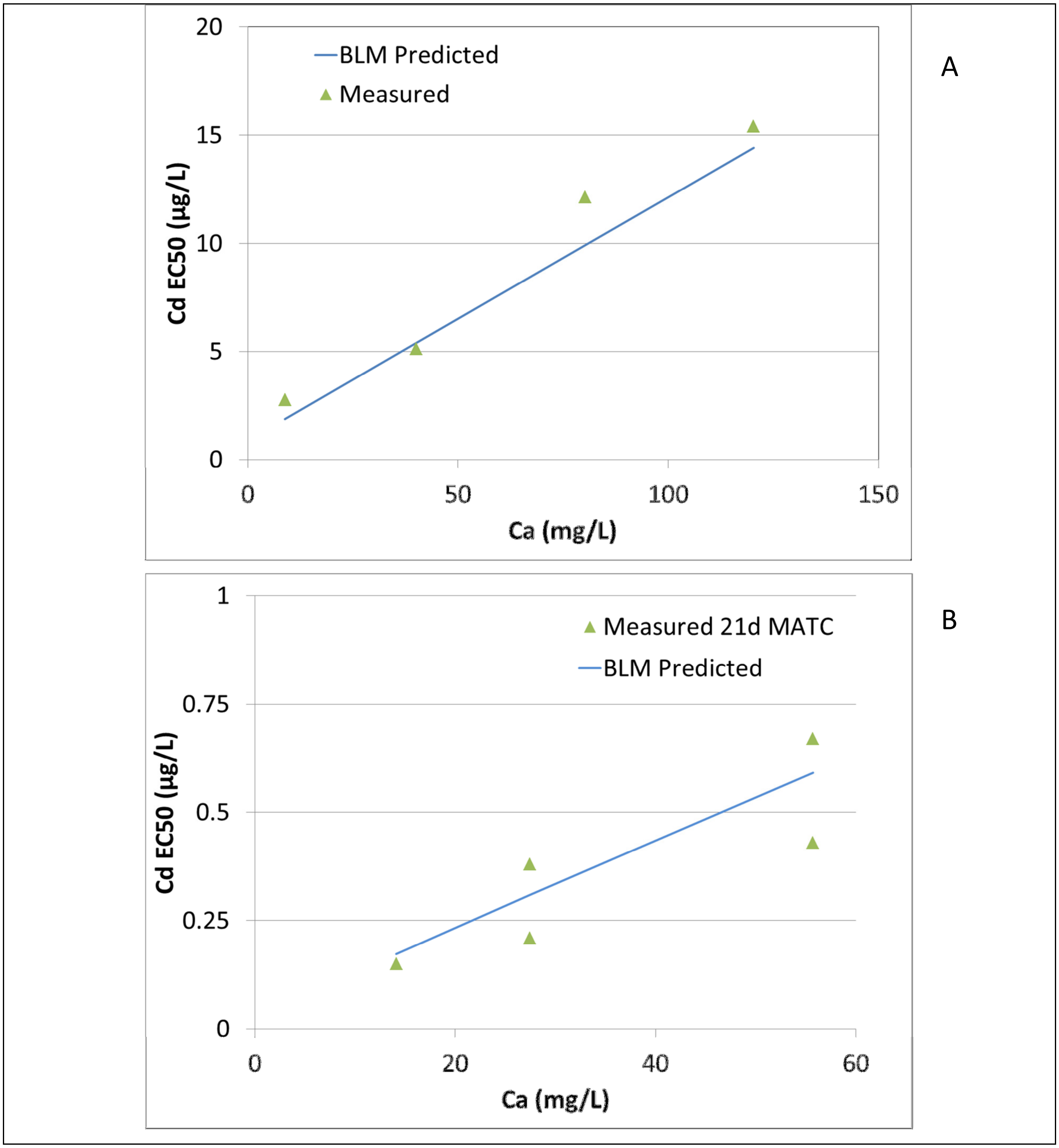

Figure 3: Effect of Calcium Concentrations on Cadmium Toxicity to Rainbow Trout (*O. mykiss*) and the Freshwater Flea (*D. magna*)

The effects of calcium on cadmium toxicity to rainbow trout (*O. mykiss*; panel A, Niyogi et al. 2008) and the freshwater flea (*D. magna;* panel B, Chapman 1980) are shown as green triangles. For each organism, the predicted effect of calcium using the BLM is shown as the blue line.

The BLM has been used to consider TMFs for other metals, and it is used by the United States Environmental Protection Agency (USEPA) in a revision to the water quality criteria for Cu (USEPA, 2007). Development of a BLM-based approach for copper effects on marine organisms is currently in review by USEPA. The BLM has been adopted as part of the overall metal risk assessment framework in the European Union for a number of metals including Cu (EURAR, 2008), and is being considered as a regulatory tool in other jurisdictions around the world.

The BLM is used herein to consider the impact of TMFs on the observed toxicity of cadmium and to normalize observed effects from laboratory conditions to conditions based on measured chemistry in the field. In addition to using the BLM for normalization of laboratory toxicity data to field conditions, the hardness equation (CCME 2014) will also be used to normalize toxicity data. Consistency of the two approaches will be evaluated, and it is anticipated that both approaches will contribute to the evaluation of potential effects of cadmium at order stations.

3.0 Approach

This analysis compares a range of potential cadmium exposure concentrations in the Elk and Fording rivers with cadmium effect concentrations in the published literature for other waters. To quantify potential cadmium exposure concentrations, monitoring data from the order stations and all surface water samples (including tributaries) collected by Teck have been analyzed to determine the geometric mean and range of cadmium concentrations. Statistical methods considered data quality and the presence of values that were below analytical detection limits when necessary.

To quantify cadmium effects, a comprehensive review of the toxicological literature was conducted to determine the range in cadmium toxicity observed to a wide variety of freshwater aquatic organisms. These results were summarized and ranked to determine the most sensitive biological receptors, and by default to identify those organisms most likely to be at risk as a result of exposure to cadmium. As noted in the problem definition, a number of TMFs are expected to influence cadmium bioavailability and toxicity, and the influence of these TMFs are considered in both the exposure and the effects assessment.

4.0 Overview of Technical Methods

TMFs expected to affect cadmium bioavailability include factors that bind cadmium in complexes or that affect chemical speciation, such as pH, DOC and bicarbonate (HCO_3^-), as well as hardness cations that can inhibit cadmium uptake by competitive interactions at binding sites. To assessment cadmium effects, quantification of TMFs was considered as part of the overall review of cadmium toxicity in a wide variety of aquatic organisms. The BLM was used to help assess the extent to which TMFs have contributed to the variability in observed cadmium toxicity and can explain, for example, why cadmium toxicity changes with changes in hardness, alkalinity, or DOC concentrations. For the assessment of cadmium exposure, influence of TMFs can also be accounted for by normalizing the effects database to the chemical conditions in waters at each of the order stations. In addition, the effects data for the three most sensitive species were normalized to historical chemical conditions at each site on a weekly basis. This additional analysis permitted the evaluation of potential effects due to cadmium over the range of conditions at the order stations.

5.0 Overview of Results

Possible effects of cadmium on aquatic life in the Elk and Fording rivers was assessed by comparing a range of cadmium concentrations to effects, based on published literature documenting the levels at which cadmium toxicity occurs. Section 5.1 includes a description of the assembled effect concentration dataset and the normalization process, and Section 5.2 is an evaluation of potential cadmium exposure concentrations. Information in Sections 5.1 and 5.2 is used in Section 6 to determine whether any potential effects from cadmium are anticipated under exposure conditions at the order stations.

5.1 Effect Concentration Data and Normalization

A survey of the published literature was conducted to determine the range of toxicological effects that chronic exposure to cadmium has on freshwater aquatic organisms. Compilations of cadmium toxicity established in recent reviews by others (such as Mebane, 2010) were considered and supplemented with additional citations wherever possible by online databases using services such as Web of Science. From these sources, a database of cadmium effects from chronic exposure of aquatic organisms was compiled (Appendix A). Information compiled from each published source included:

- species tested
- life stage tested
- toxicological endpoints measured
- effect size
- exposure duration
- source water used in the exposure
- nature of the exposure apparatus (e.g., static, flow-through, etc.).

Information on relevant TMFs (Figure 1) was concomitantly compiled as part of this review. All documented endpoints were recorded and, wherever possible, endpoints preferred for use in British Columbia Ministry of Environment (BC MOE) water quality guidelines (WQGs) were selected. Preference for toxicity data included selection of a low-effect threshold for a non-lethal effect (Meays, 2012).

If available, regression-based estimates (i.e., effect concentration [ECx]) are preferable to hypothesis-based estimates such as no observable effect concentrations (NOECs) or lowest observable effect concentrations (LOECs). The hierarchical preference for endpoints considered for this work as specified in Meays 2012 was as follows:

1. an ECx or inhibition concentration (ICx) calculated for a non-lethal effect, in which the magnitude of the effect is less than 15% of the tested population (e.g., an EC10)
2. an ECx or ICx calculated for a non-lethal effect, in which the magnitude of the effect ranges from 15 to 25% of the tested population (e.g., an EC20)
3. an LOEC;
4. a maximum acceptable toxicant concentration (MATC)
5. an ECx or ICx calculated for a non-lethal effect, in which the magnitude of the effect ranges from 26 to 49% of the tested population (e.g., an EC30)
6. an EC50 or IC50 calculated for a non-lethal effect
7. a median lethal concentration (LC50).

One of the goals of this review was to include effects data for fish, invertebrates and plants. Information about cadmium toxicity to amphibians was also highly desirable. The guidelines included the following requirements:

- Data for fish should include at least three long-term studies on three or more species, including two cold-water species (e.g., trout).
- Data for invertebrates should include at least two long-term studies on two or more species from different classes, one of which should be a planktonic species resident in British Columbia (e.g., daphnids).
- Data for plants should include at least one study on a freshwater vascular plant or freshwater algal species resident in British Columbia.

In addition to these minimum data requirements, the guidelines recommend that "flexibility and the use of scientific judgment as well as innovative new approaches are recognized as necessary and important components of the derivation process." (Meays, 2012). As identified in the problem definition, consideration of important TMFs using the BLM is consistent with the desire for scientific innovation.

The toxicological database assembled in this review meets the data requirements, and individual observations have been prioritized according to the specified endpoint preference. The assembled database includes 16 fish species (including several cold-water species, e.g., *O. mykiss,* brown trout *(Salmo trutta),* brook trout *(Salvelinus fontinalis),* Atlantic salmon *(Salmo* *salar)*, etc.), 22 species of invertebrates, 2 species of algae, and 1 species of aquatic plant. Data were further screened to preferentially consider longer-duration tests using a sensitive lifestage. From this list of preferences, one or more observations were selected to represent each of the 42 species reviewed. When multiple data for a single species were considered to be equivalent according to these preferences, a geometric mean of the selected observations (after normalization) was used to represent cadmium effects for that species. All data obtained for the review are listed in Appendix A, and data selected for characterizing organism effects are identified.

The conceptual model for cadmium effects on aquatic organisms suggests that any factor affecting cadmium bioavailability, such as pH, the presence of DOC, or major ion concentrations, may be important for understanding documented toxicological effects. Much of this information was missing from the published documentation on cadmium effects. Most studies reported pH and hardness at a minimum, but few studies reported detailed chemistry including ion composition and DOC. Despite the lack of reports, the chemistry for many of the reported studies could be elucidated and estimated based on details included in the study descriptions. For example, many studies used deionized water, and/or well-defined USEPA and ASTM International recipes based on salt additions. For such studies, these recipes were used to estimate the chemical composition of the exposure water.

Several studies used source water that was chemically characterized in previous or subsequent studies. For example, Lake Superior water was commonly used as a test water, and the chemistry of Lake Superior has been well-described by the USEPA laboratory in Duluth (e.g., Erickson et al., 1997). When no documentation of source-water chemistry could be found, chemistry was estimated based on hardness and pH.

Roughly half of the records in the entire toxicity database required estimates of major ions. Of the 508 records collected, the following number of estimates were required for total concentrations of the specified major ion: 235 for calcium (Ca^{2+}), 241 for magnesium (Mg^{2+}), 255 for sodium (Na), 268 for potassium (K), 261 for sulphate, 264 for chloride (Cl^{-}), and 62 for alkalinity. For these estimates, the average ratio of ions in waters from across North America was determined from monitoring data from the USEPA STORET (Storage and Retrieval) database (http://www.epa.gov/storet/dbtop.html). Over 23,000 individual observations in which all BLM parameters were measured were considered. Major ion ratios were determined from the STORET data and used to estimate cation concentrations that match the reported hardness chemistry. The variation in ion ratios was low for calcium to magnesium (less than 1.8× from the 25th to the 75th percentile; Table 1).

Table 1: Variations in Ion Ratios for Water Samples Retrieved from the STORET Database

Summary Statistic	Ca:Mg mol:mol	Ca:Na mol:mol	Ca:K mol:mol	SO_4:Cl mol:mol
25th Percentile	1.54	0.59	6.45	0.30
Median	1.99	1.08	11.96	0.57
75th Percentile	2.77	2.57	20.52	1.20

The balance of calcium and magnesium is among the most important considerations in determining cadmium bioavailability at a given hardness. Therefore, the relative lack of variation in calcium to magnesium ratios suggested that a consistent approach based on median ion ratios could be used to estimate major ion concentrations for studies that did not report detailed water chemistry. Considerably more variation was seen in ratios of calcium to sodium, and especially calcium to potassium, but these cations have almost no effect on cadmium bioavailability, and so uncertainty in these parameters was unimportant to the overall analysis.

If alkalinity was reported, soluble carbonate species were estimated directly from alkalinity and pH. When alkalinity was not reported, concentrations of carbonate and bicarbonate ions were estimated from pH and atmospheric carbon dioxide [$CO_{2(g)}$] solubility. Once estimates for major cations and carbonates were determined, concentrations of sulphate and chloride were determined by charge balance, while also considering median anion ratios calculated from STORET data.

Very few studies measured DOC concentrations, and since DOC is one of the more important TMFs for cadmium, this lack had to be addressed before application of the BLM. This uncertainty was, however, mitigated by the fact that most of the source waters used in toxicity testing were synthesized according to USEPA or ASTM recipes, which recommend using ultrapure deionized water and reagent-grade salts. Other frequently used sources included well waters, which also tend to be low in organic matter (Santore et al., 2002). Since such source waters are expected to have little or no organic matter, low concentrations of DOC can be assumed. Similar assumptions have been accepted in other BLM applications for normalizing metal toxicity (Santore et al., 2001; USEPA 2007).

For synthetic waters, a default DOC concentration of 0.5 mg/L was used, and for de-chlorinated tap water a DOC value of 1.0 mg/L was employed. These default values were used only in cases where the DOC was not otherwise measured or reported. Default DOC values were used for 359 of the 508 records in the assembled toxicity database. To evaluate the impact of these DOC assumptions on BLM normalizations, a sensitivity analysis was conducted over a range of DOC concentrations that may be expected to occur in laboratory waters that likely have low DOC concentrations. The DOC range selected for this analysis was 0.5 mg/L to 3 mg/L, and these values were used only when DOC concentrations were not reported in the original study.

In an sample application, toxicity data were normalized using the hardness equation (equation 1 or 2) and the BLM to conditions reflecting waters upstream of the order stations, with a hardness of 160 mg/L as calcium carbonate, pH of 8.3, alkalinity of 130 mg/L as calcium carbonate, and a DOC of 1.0 mg/L[2]. A comparison of cadmium toxicity data for all 42 species in the data review, using the hardness equation and the BLM normalization approaches, is shown in Panels A and B of Figure 4, respectively.

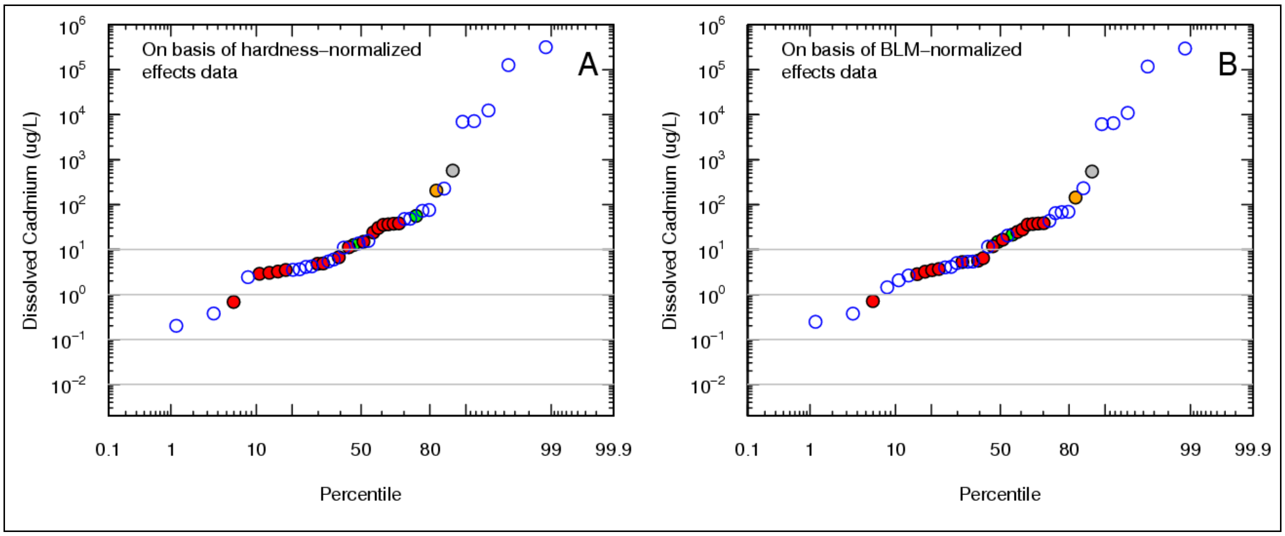

Figure 4: Distribution of Effect Concentrations for Chronic Cadmium Toxicity Observed for Freshwater Aquatic Organisms

The literature-based cadmium toxicity data selected and detailed in Appendix A were normalized to a reference condition within the Elk Valley (i.e., hardness of 160 mg/L as calcium carbonate, pH of 8.3, alkalinity of 130 mg/L as calcium carbonate, and a DOC of 1.0 mg/L) using the hardness equation approach (panel A), and the BLM (panel B). Normalized, low-level effect concentrations for invertebrates are shown using a blue symbol (n = 22), fish are shown in red (n = 16), algae are shown in green (n = 2), aquatic plants are shown in orange (n = 1), and amphibians are in grey (n = 1).

[2] For this normalization, median concentrations of pH, DOC, hardness, calcium, magnesium, sodium, potassium, sulphate, chloride, and alkalinity at the upstream Fording River station (i.e., FR_UFR1) were used.

The normalization with hardness uses an empirical relationship similar to that used in WQGs, such as equation 1, which is a log-linear equation using a slope (parameter a) and an intercept (parameter b). The slope in the BC MOE working guideline for cadmium[3] is 0.86, but a slope of 0.83 was used because it is the slope used by the more recently revised Canadian Council of Ministers of the Environment guideline (CCME 2014). The reported effect concentration (EC_R) at the hardness in the original study ($Hardness_R$) can be adjusted to a normalized value (EC_N) for a hardness concentration that corresponds to the normalized condition ($Hardness_N$) using equation 2.

$$WQG = 10^{(a*log_{10}(Hardness)-b)} \qquad \text{Equation 1}$$

$$EC_N = 10^{\left[\left((log_{10}(Hardness_N)-log_{10}(Hardness_R))*a\right)+log_{10}(EC_R)\right]} \qquad \text{Equation 2}$$

BLM normalization uses the procedure outlined by the USEPA (2007).

Both approaches show similar distributions, and with either approach a wide range in organism sensitivity is evident. Normalized values for chronic effect concentrations range from 0.2 µg/L for the most sensitive species to over 100,000 µg/L for the least sensitive species. Both approaches identified *D. magna* as the most sensitive species, with *Hyalella azteca* and *O. mykiss* as the second and third most sensitive species, respectively. The normalized effect concentration for *D. magna* is similar for both approaches, but for other species the BLM-normalized values may be higher or lower than the hardness-normalized values, due to differences in the chemistry of the exposure conditions in the original studies. A direct comparison of the effect of water hardness on the two normalization approaches is shown in Appendix B1, where the toxicity database is normalized to three different hardness conditions. Generally, the two approaches produce similar normalized effect concentrations, but the effect of hardness is slightly more pronounced with the BLM. In addition to evaluating sensitivity and response to hardness conditions, the sensitivity of DOC assumptions for studies that failed to report DOC concentrations is shown in Appendix B2. This sensitivity analysis suggests that over a range of low DOC concentrations (0.5 to 3.0 mg/L), the magnitude of normalized effect concentrations is minimally affected.

[3] http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

The BLM and the effects database (Appendix A) can be used to consider variation in organism sensitivity and responses to TMFs. This allows prediction of the potential effects of cadmium for selected organisms from chronic exposures. As an illustration, the BLM can be used to assess the likelihood that toxicity from cadmium would have been observed in recent site-specific toxicity studies using water samples taken from the order stations (Nautilus, 2013a; 2013b).

As outlined in Nautilus (2013a; 2013b), site-specific toxicity testing was recently conducted to evaluate potential toxicity of sulphate and nitrate. Because water samples for the Nautilus studies were collected directly from the Elk and Fording rivers, the samples represent an ambient mixture of potential constituents of interest, including cadmium. Therefore, the BLM was used to evaluate the likelihood that ambient cadmium concentrations in these water samples could cause any toxic effect. The BLM was used to estimate low-effect concentrations for each of the test organisms examined by Nautilus (2013a; 2013b): two invertebrates (*Ceriodaphnia dubia* [7d EC20] and *H. azteca* [28d IC25]), and two fish (*O. mykiss* [62d LOEC] and *Pimephales promelas* [32d EC20]). The endpoints chosen for the purposes of BLM predictions were based upon the endpoints and specific study results selected, which were in turn based upon the preferences described above and the rationale provided in Appendix A. Results for these predictions are shown in Figure 5.

As indicated by the literature review, *H. azteca* and *O. mykiss* were the species that were second- and third-most sensitive to chronic cadmium effects. For these organisms, the predicted effect concentrations were between 0.3 and 2 μg/L (Figure 5). Predicted effect concentrations for *C. dubia* were between 1 and 3 μg/L, and for *P. promelas* they were between 20 and 80 μg/L (Figure 5). All measured dissolved cadmium concentrations in these samples were below the analytical detection limit of 0.05 μg/L and most (all except one observation [i.e., 0.098 μg/L]) of the measured total cadmium concentrations were below the analytical detection limit of 0.05 μg/L (Nautilus, 2013a; 2013b). As a result of this large margin of safety between measured total and dissolved cadmium concentrations and predicted effect concentrations, no toxicity would be expected from ambient concentrations of cadmium in these samples. It should be noted that toxicity tests for unspiked samples in both studies confirmed the absence of toxicity at ambient concentrations (Nautilus, 2013a; 2013b).

Figure 5 shows predicted effect concentrations for chronic cadmium toxicity for samples collected as part of the recent Elk Valley toxicity studies. These studies used *H. azteca* 28d IC25 (panel A), *O. mykiss* 62d LOEC (panel B), *C. dubia* 7d EC20 (panel C), and *P. promelas* 32d EC20 (panel D). Predicted chronic cadmium toxicity based on the BLM applied to the cadmium effects database (refer to Figure 4 and Appendix A) are shown as green (Nautilus, 2013a), or blue (Nautilus, 2013b) symbols. Measured dissolved cadmium concentrations for these samples were near or below the analytical detection limit of 0.05 μg/L, shown on each panel by the horizontal grey line. One sample had a measured total concentration above detection at 0.098 µg/L, which is shown on each panel by the horizontal black line. Based on site-specific toxicity data, ambient cadmium concentrations would need to increase by an order of magnitude (10×) before reaching a potential effect concentration.

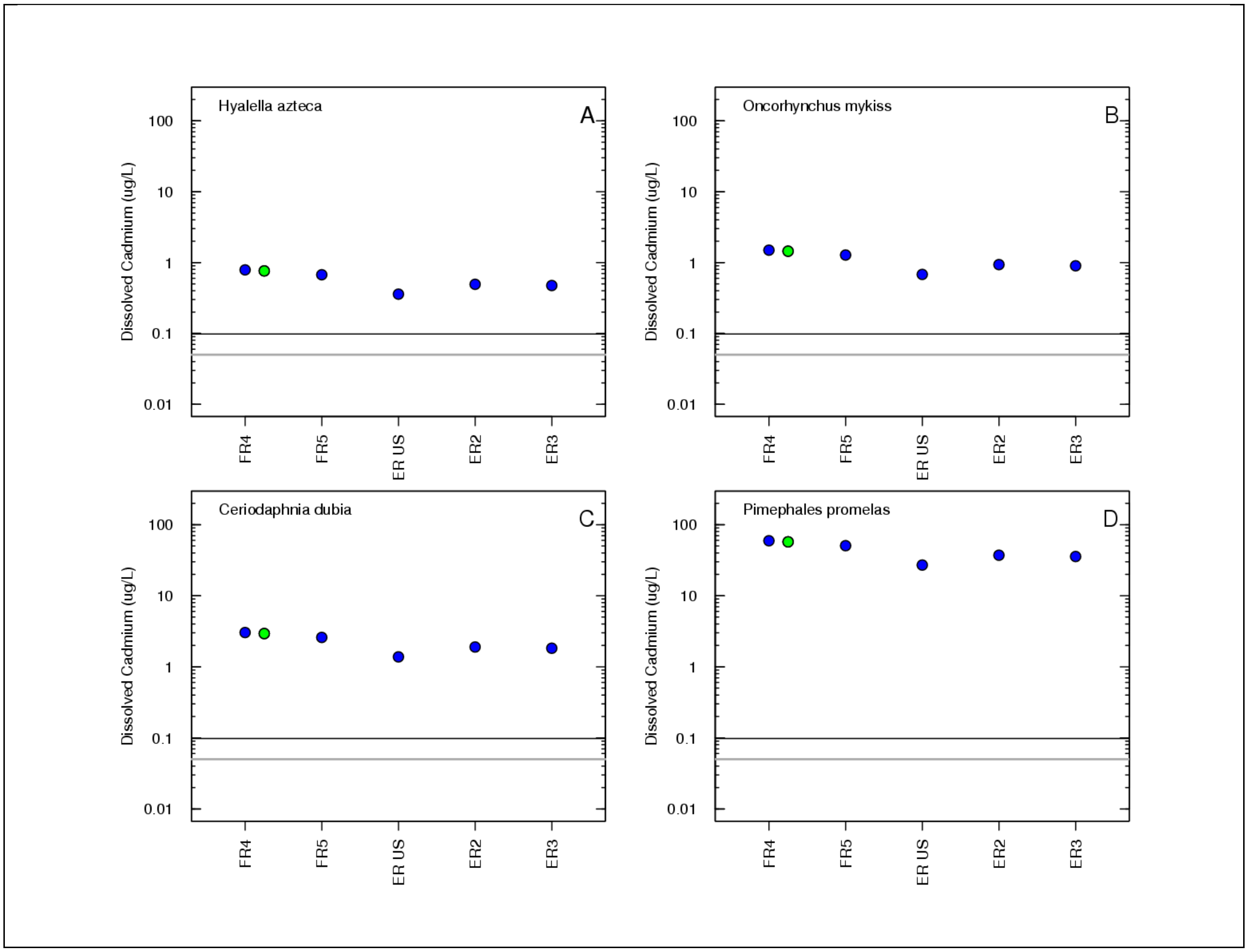

Figure 5: BLM-Predicted Cadmium Toxicity to Fish and Invertebrates in Samples Collected Within the Fording and Elk Rivers

5.2 Exposure Considerations

A considerable amount of water chemistry information is maintained in Teck's EQuIS database. This information includes cadmium measurements for the past 20 years, although the data ultimately used for this analysis were collected after April 28, 2010. This time period was selected because it was believed to be representative of recent and current conditions. In addition, the data before 2010 is frequently affected by high analytical detection limits.

Values below detection limits can create challenges for determining the overall distribution of measured values (Helsel, 1990). For these observations, the true concentration is somewhere between zero and the analytical detection limit. Fortunately, numerical approaches such as maximum likelihood estimation (MLE) can be used for estimating statistical distributions for data that include values below detection limits (Helsel, 1990; Shumway et al., 2002). The MLE approach was used in this analysis to account for cadmium concentrations that are below detection. Details of the overall approach and application to cadmium concentrations are included in Appendix C.

As indicated by Figures 6 through 14, monitoring data suggest spatial and seasonal patterns in both total and dissolved cadmium concentrations. Concentrations tend to be highest at order stations FR5 in the Fording River and ER3 in the Elk River, where exceedances of the interim BC MOE water quality guideline for cadmium are noted. For order stations where a sufficient number of observations were at detectable concentrations, a seasonal pattern was evident, with concentrations of total and dissolved cadmium higher in summer than in winter.

Each figure shows time series for total (A) and dissolved (B) cadmium concentrations at the corresponding upstream station in water samples collected from 2000 to mid-2013. Individual measurements of cadmium concentrations are shown as a circle for values above the analytical detection limit or as a less-than sign (<) for values below the analytical detection limit. The orange line shows the BC MOE water quality guideline for cadmium using the time variable upstream hardness concentration. .

Figure 6: Total and Dissolved Cadmium Concentrations in the Fording River Upstream of Operations (FR_UFR1)

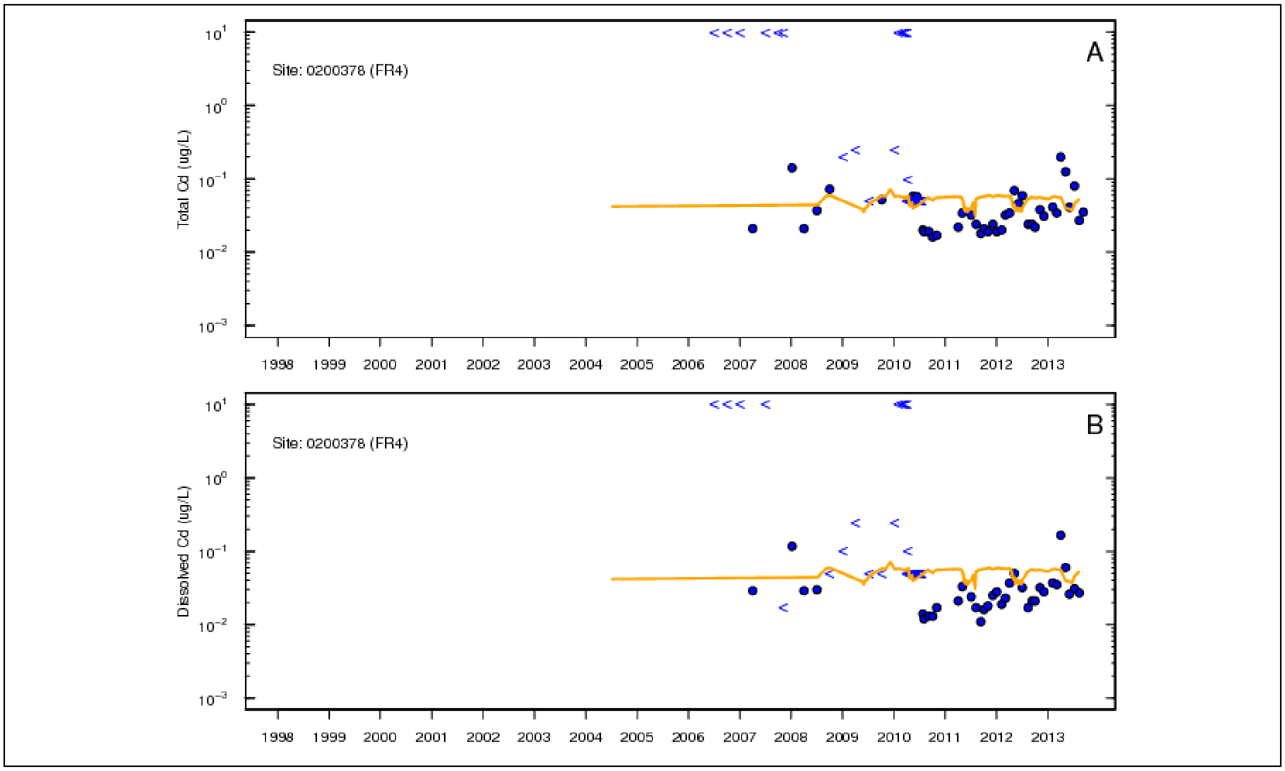

Figure 7 : Total and Dissolved Cadmium Concentrations for FR4 (EMS #0200378)

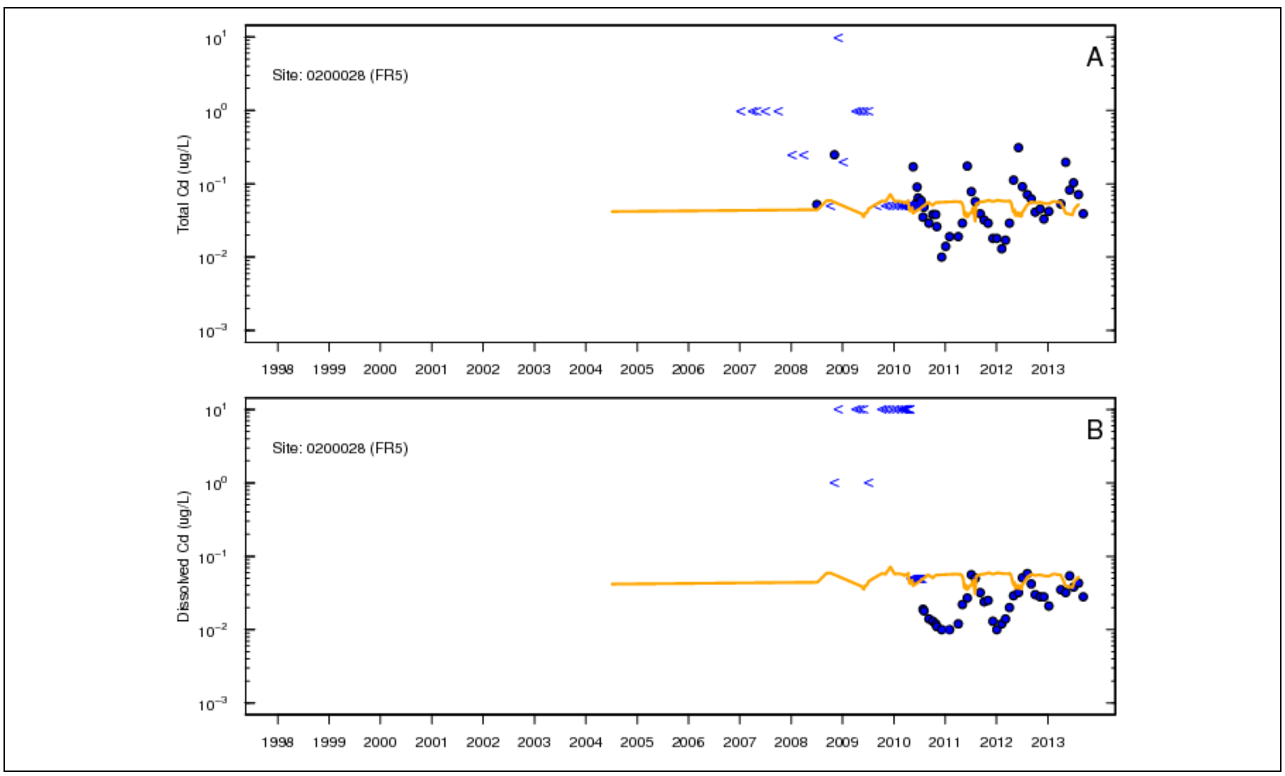

Figure 8: Total and Dissolved Cadmium Concentrations for FR5 (EMS #0200028)

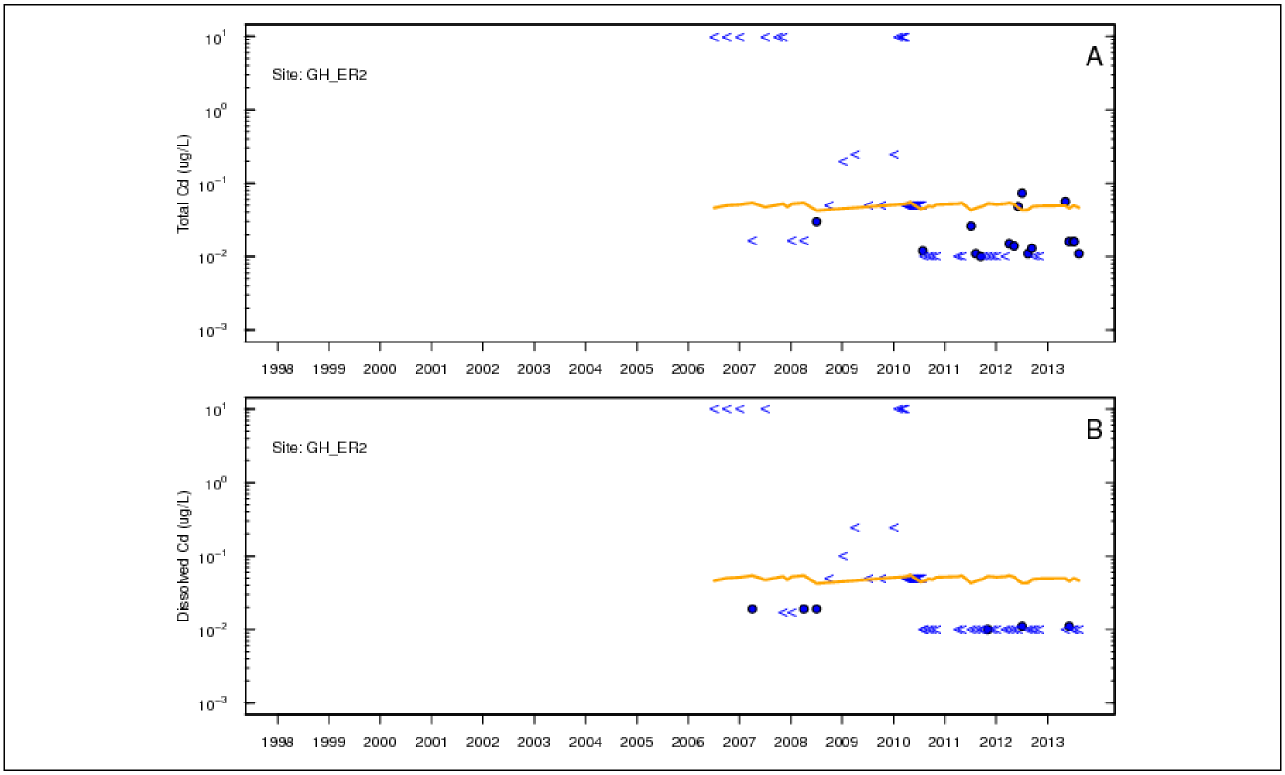

Figure 9: Total and Dissolved Cadmium Concentrations in the Elk River Upstream of Operations (GH_ER2)

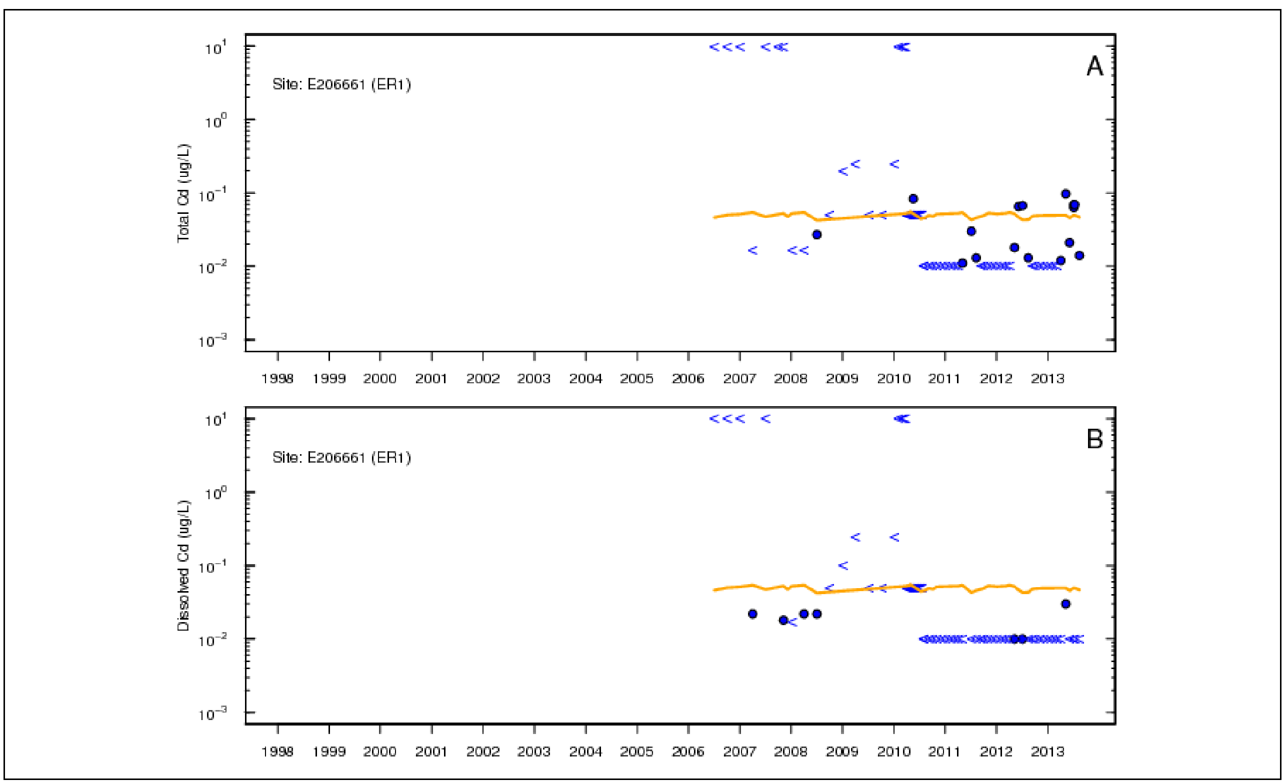

Figure 10: Total and Dissolved Cadmium Concentrations at ER1 (EMS #E2006661)

Figure 11: Total and Dissolved Cadmium Concentrations at ER2 (EMS #0200027)

Figure 12: Total and Dissolved Cadmium Concentrations at ER3 (EMS #0200393)

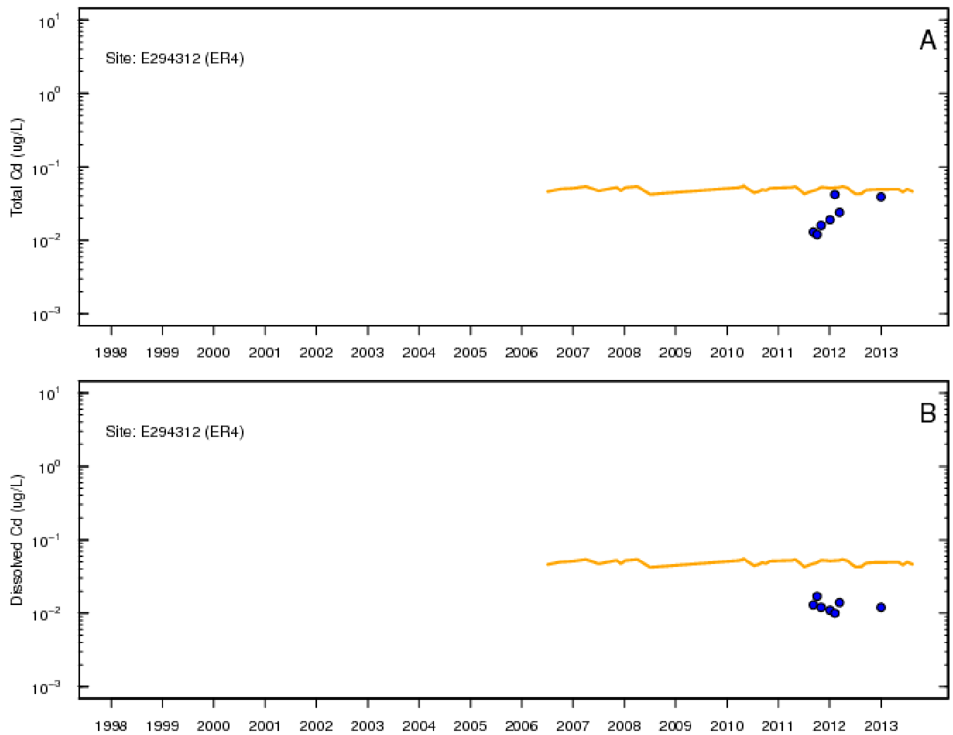

Figure 13: Total and Dissolved Cadmium Concentrations at ER4 (EMS #E294312)

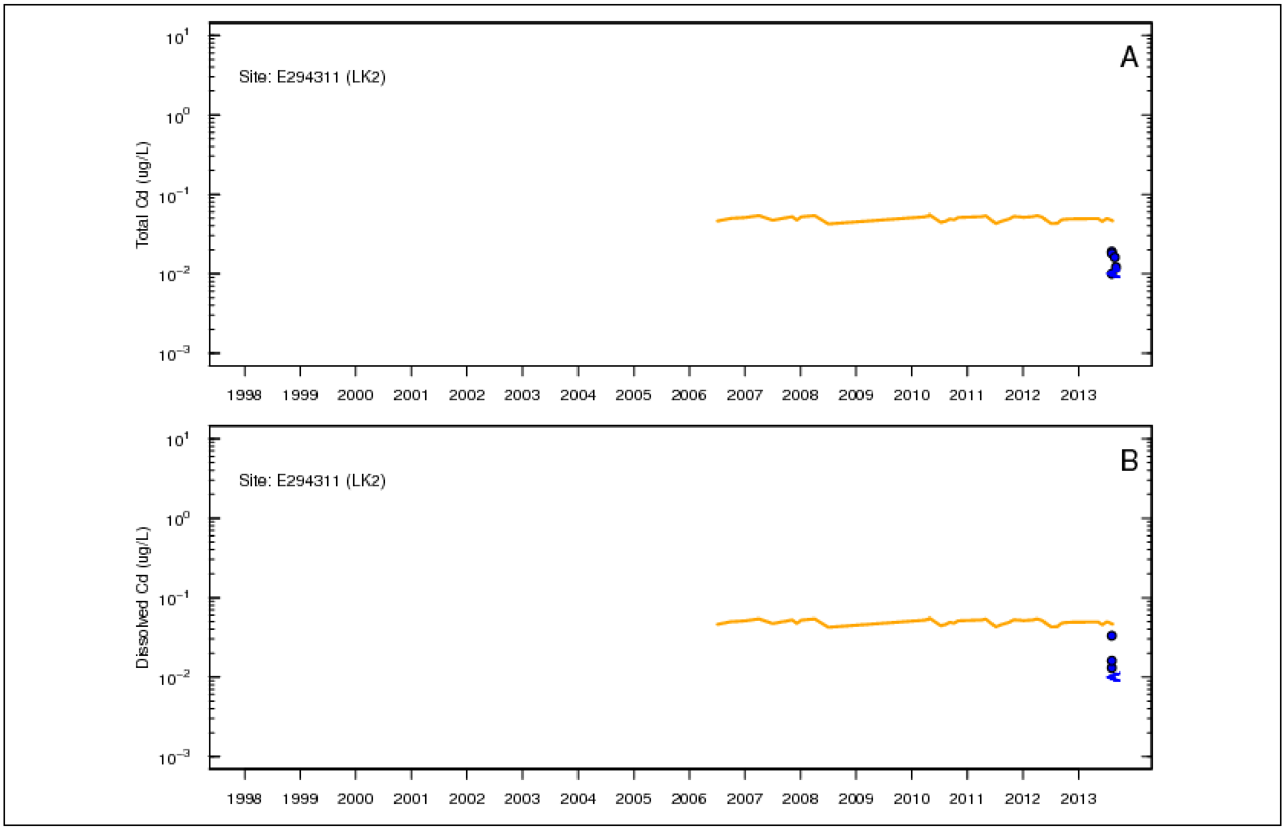

Figure 14: Total and Dissolved Cadmium Concentrations at LK2 (EMS #E294311)

5.3 Seasonal Patterns in Cadmium and Selected Toxicity Modifying Factors

As noted in Section 5.2 and Figures 6 to 14, a seasonal pattern is evident in total and dissolved cadmium concentrations, with higher values routinely observed in summer than in winter. These patterns are better illustrated by Figure 15, in which concentrations from 2010 to 2013 at Order Station FR5 are shown. As illustrated in Figures 15A (total fraction) and 15B (dissolved fraction), cadmium concentrations are relatively elevated during the summer months (peaking in June), which coincides with the freshet.

Concentrations of several TMFs also show strong seasonal patterns. For example, hardness concentrations at FR5 are lower during summer months (Figure 16A), while DOC concentrations are elevated during summer months (Figure 16B). The contrast in the annual patterns of hardness and DOC concentrations has implications for bioavailability modeling because both hardness and DOC are important TMFs for cadmium. The importance of these two TMFs and the contrasting seasonal patterns also highlights the difference between a guideline based only on hardness and the BLM-based approach, which considers multiple factors. If hardness were the only TMF considered (as would be the case with hardness-based WQGs), the expectation would be for cadmium bioavailability to be greatest in the summer when hardness is low. However, consideration of DOC and hardness cations together using the BLM dampens this seasonal trend to some extent, depending on the order station and the seasonal variation of TMFs. The effect of seasonal trends on cadmium bioavailability was evaluated as part of the effort to characterize the potential effects of a range of cadmium concentrations on aquatic organisms. Appendix D shows the seasonal patterns of cadmium and potential TMFs, and includes hardness-normalized and BLM-normalized effect concentrations for *D. magna*.

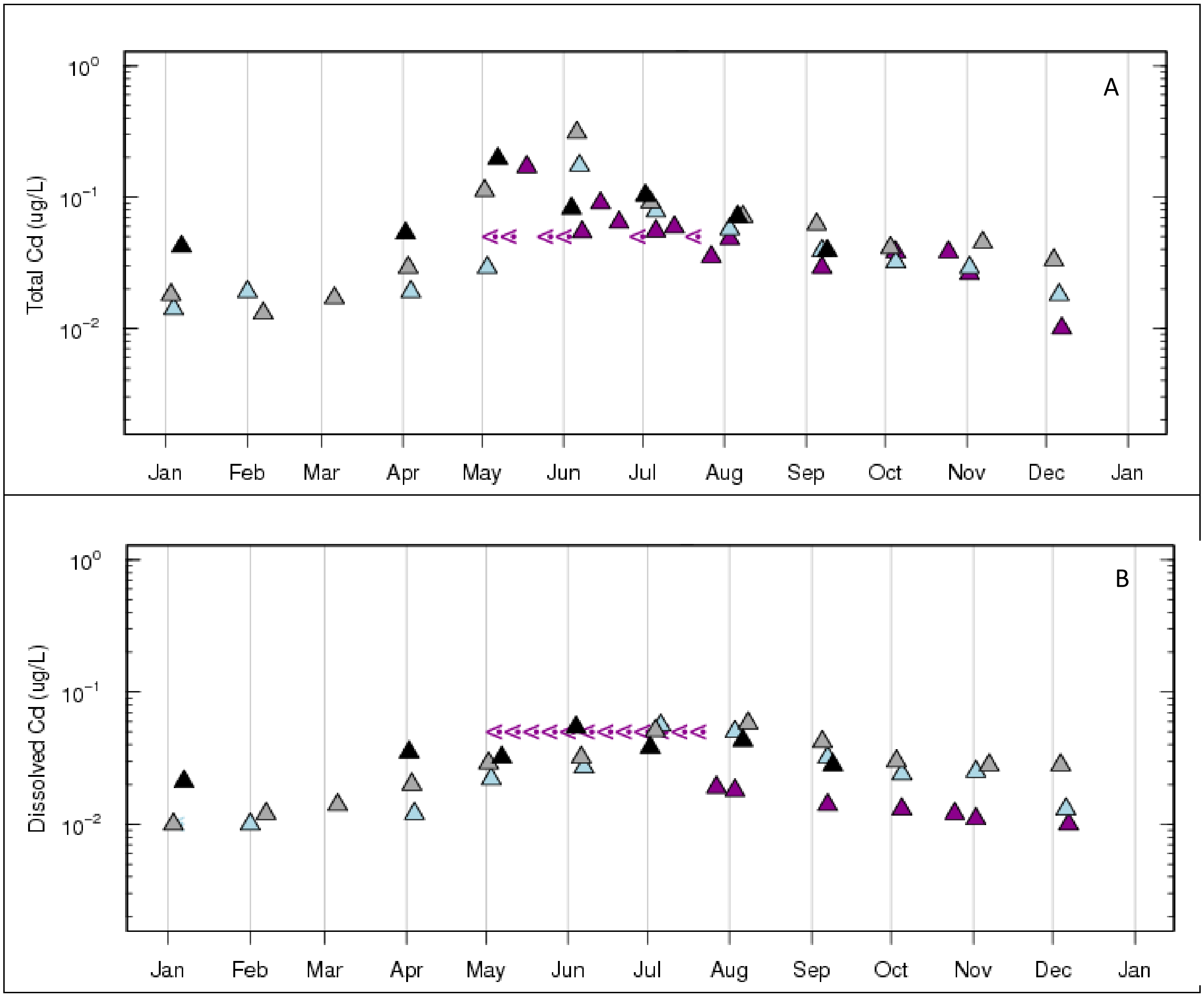

Figure 15: Seasonal Patterns in Total and Dissolved Cadmium Concentrations at FR5

Figure 15 shows total (A) and dissolved (B) cadmium concentrations for samples collected at Order Station FR5 from April 2010 to December 2013 based on the day of the year samples were collected. Different coloured symbols correspond to the year samples were collected as follows: 2010 = purple; 2011 = blue; 2012 = grey; and 2013 = black. Individual measurements of Cd concentrations are shown as a less-than sign (<) for values below the analytical detection limit.

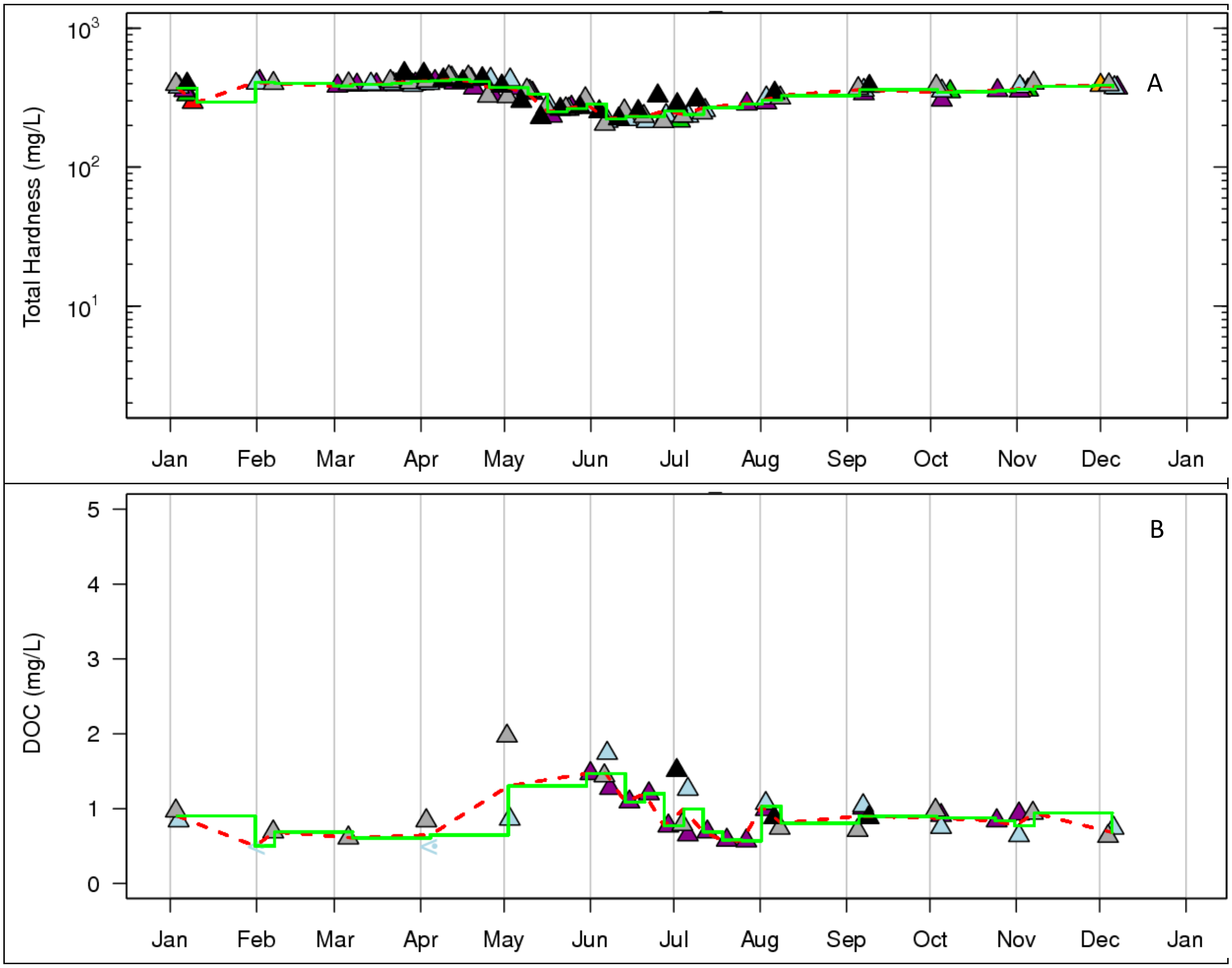

Figure 16: Seasonal Patterns in Hardness and DOC Concentrations at FR5

Figure 16 shows hardness (A) and DOC (B) concentrations for samples collected at Order Station FR5 from April 2010 to December 2013 based on the day of the year samples were collected. Different coloured symbols correspond to the year samples were collected as follows: 2010 = purple; 2011 = blue; 2012 = grey; and 2013 = black. Individual measurements of Cd concentrations are shown as a less-than sign (<) for values below the analytical detection limit. Data were aggregated based on sampling frequency, which could be as frequent as weekly. The annual trend is shown as a segmented linear series based on the geometric mean of each time interval (dashed red line) or as a step function connecting each bin (solid green line).

6.0 Effects Matrices

To assess the potential for cadmium effects at each order station, a comparison was made between the range of concentrations observed at each station, and normalized cadmium effect concentrations. Other locations were considered for context only. Effect concentrations were normalized using both the hardness equation and the BLM, and normalizations were performed using median site chemistry. To evaluate the effects of seasonally variable water chemistry on normalization of cadmium effect concentrations, normalizations were also performed on the basis of the variable chemistry conditions observed over the course of a yearly cycle (Appendix D). If an exposure concentration exceeds a normalized effect concentration for a given species, then toxic effects are possible for that species, as well as any others with effects at or below the exposure concentrations.

To prepare the cadmium effects matrices, an upper-bound concentration was determined as the 95th percentile of all detected cadmium concentrations in surface water samples collected from the receiving environment (i.e., mainstems and tributaries) within the Elk Valley. As a result, a total of 3,361 cadmium concentrations were used to calculate a 95th percentile dissolved cadmium concentration of 0.51 µg/L. For comparison, the 95th percentile of total cadmium was 0.61 µg/L. The dissolved concentration is preferable for the purpose of estimating effects, as it better represents the exposure concentration to aquatic receptors. Comparisons between total and dissolved cadmium are provided in Appendix E. Given that the 95th percentile of all detected cadmium concentrations is considerably higher than cadmium concentrations measured in any samples collected at the order stations, it represents a reasonable upper bound in developing the effects matrices.

The cadmium effects data considered in the development of the effects matrices included prioritized data from the toxicity literature review (Appendix A), normalized to conditions at each of the order stations using both the BLM and the hardness equation. In Figures 17 to 25, dissolved cadmium exposure concentrations in the referenced order station are compared to cadmium effects data normalized for average chemical conditions. Panel A shows a probability plot of the range in dissolved cadmium concentrations. Individual measurements of cadmium concentrations are shown as a circle for values above the analytical detection limit or as a less-than sign for values below the analytical detection limit. The cadmium toxicity data in panel B are normalized to conditions at this station using the BLM and cadmium toxicity data in panel C are normalized to conditions at this station using the hardness equation. For each panel, the solid green horizontal line represents the upper-bound cadmium concentration, and the dashed green line represents the maximum observed cadmium concentration at this station. The horizontal orange line shows the BC MOE WQG for cadmium using the average upstream hardness concentration, and the orange dashed line shows the CCME WQG. For effects data shown in panels B and C, data for invertebrates are shown using a blue symbol, fish are shown in red, algae and plants are shown in orange, and amphibians are shown in grey. Ranges shown in panels B and C for the three most sensitive organisms represent the magnitude of change associated with normalizing the toxicity data to seasonally variable conditions (Appendix D).. Normalization results for both approaches are similar, with the hardness equation being slightly more conservative.

Because the BLM approach considers multiple TMFs, it may be considered the definitive evaluation of potential effects due to cadmium. However, a conservative cadmium benchmark (CB) may be defined using a hardness equation with a form and slope identical to the Canadian Council of Ministers of the Environment (CCME) WQG (CCME 2014):

$$CB = 10^{(0.83*log_{10}(Hardness)-2.529)} \qquad \text{Equation 3}$$

The intercept in equation 3 represents the sensitivity of the most sensitive organism and endpoint in the effects database (i.e., for *D. magna* reproduction), and the hardness used in equation 3 is the lowest weekly average observed for the site, which is consistent with the lower "whisker" in Figures 17 through 25.

As indicated in Figure 17, actual cadmium concentrations observed in the Fording River upstream of mining operations are much lower than the upper-bound value. Most cadmium measurements correspond to values that are below detection limits and are therefore plotted with a less-than sign (Figure 17). With the high percentage of values below detection at this site, a reliable MLE analysis could not be performed to estimate the 95th percentile. As an alternative, the upper-bound cadmium concentration is shown in Figure 17 as a horizontal green line. Comparison of this value to either the BLM-normalized effects data in Figure 17B, or to the hardness-normalized effects data in Figure 17C, shows that no effects would be expected at cadmium concentrations at or below this value at this site. Similar analyses were conducted at the other order stations.

Where sufficient cadmium measurements at values above analytical detection limits were available, the distribution of cadmium concentrations was estimated using MLE, indicated by the blue line shown in Figure 18, panel A. For sites where MLE was possible, the 95th percentile of the fitted distribution of cadmium concentrations is shown as a black line (Figures 18, 19, 22, 23 and 24). These were the only order stations where a sufficiently high percentage of dissolved cadmium concentrations were detectable to support the estimation of a 95th percentile. At all stations, cadmium concentrations recorded to date are sufficiently low that no toxic effects are expected for any aquatic organisms. These results are summarized in the effects matrices presented in Tables 2 to 10.

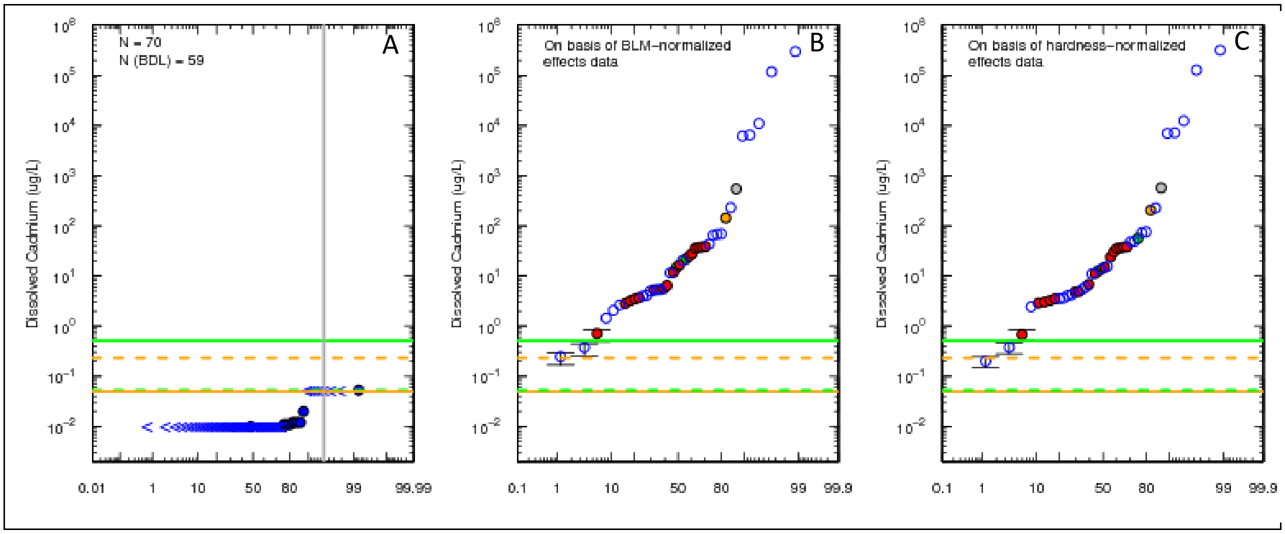

Figure 17: Exposure and Effects Comparison for FR_UFR1

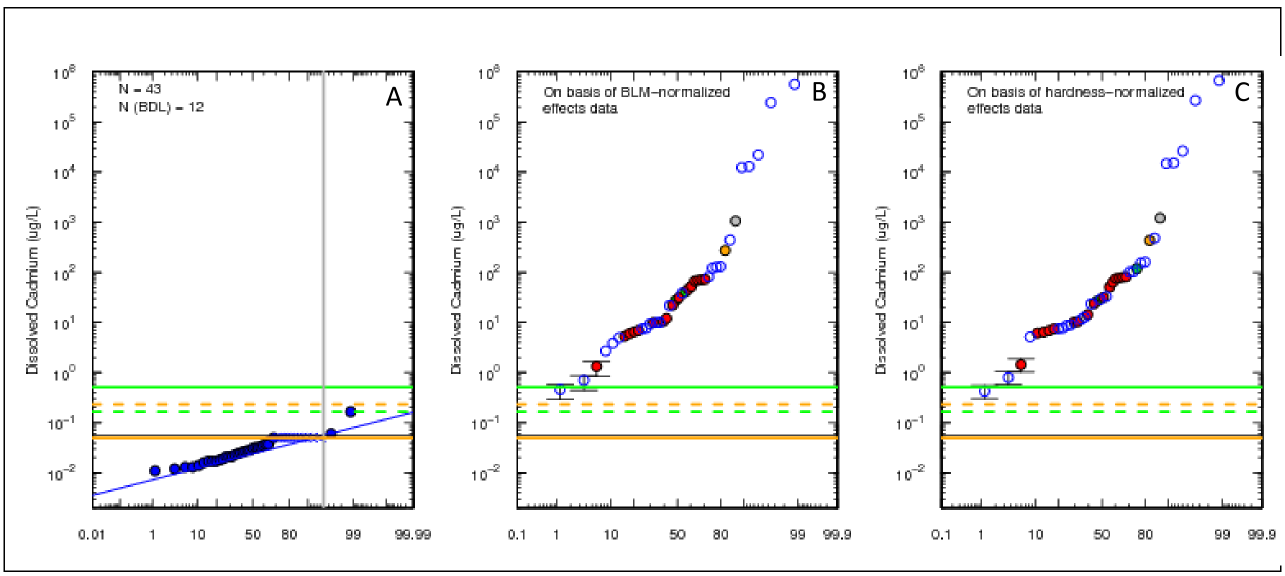

Figure 18: Exposure and Effects Comparison for Order Station FR4

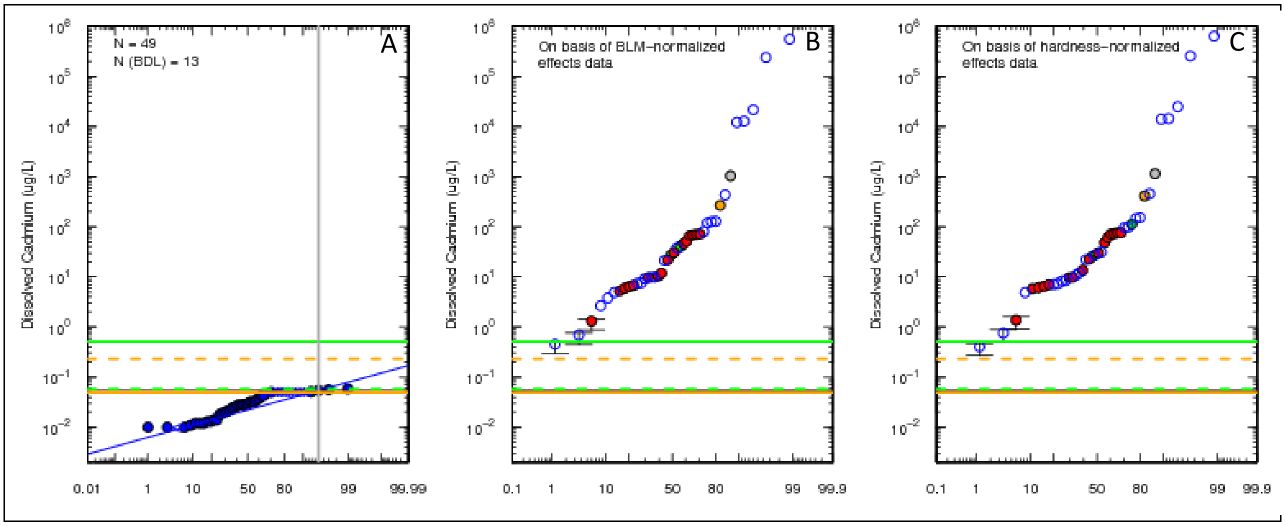

Figure 19: Exposure and Effects Comparison for Order Station FR5

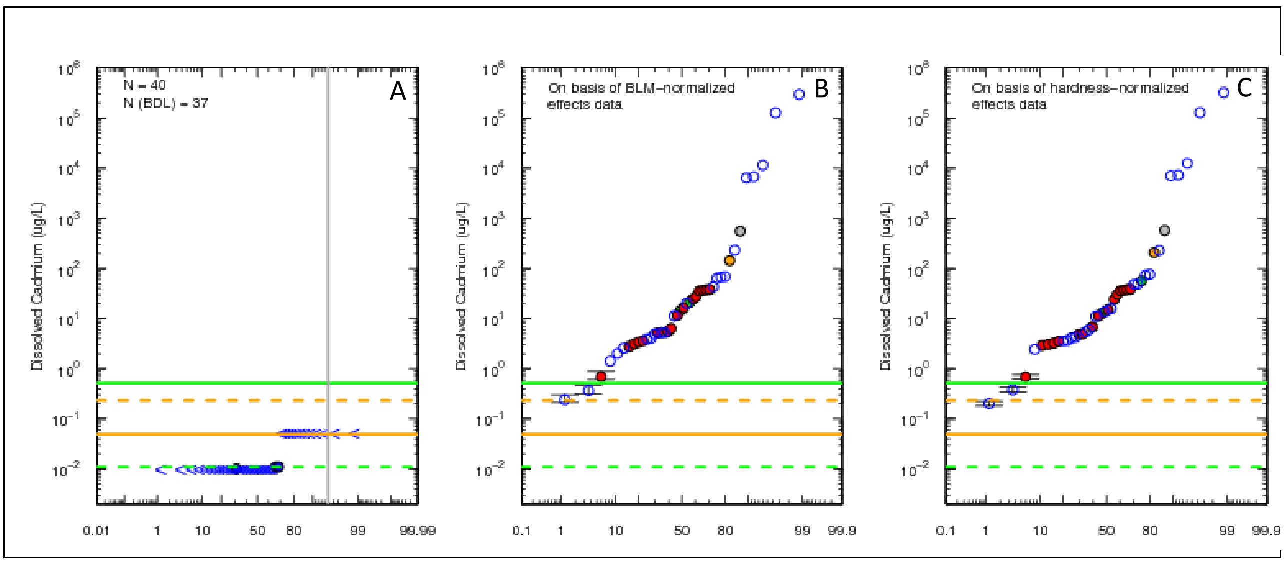

Figure 20: Exposure and Effects Comparison for GH_ER2

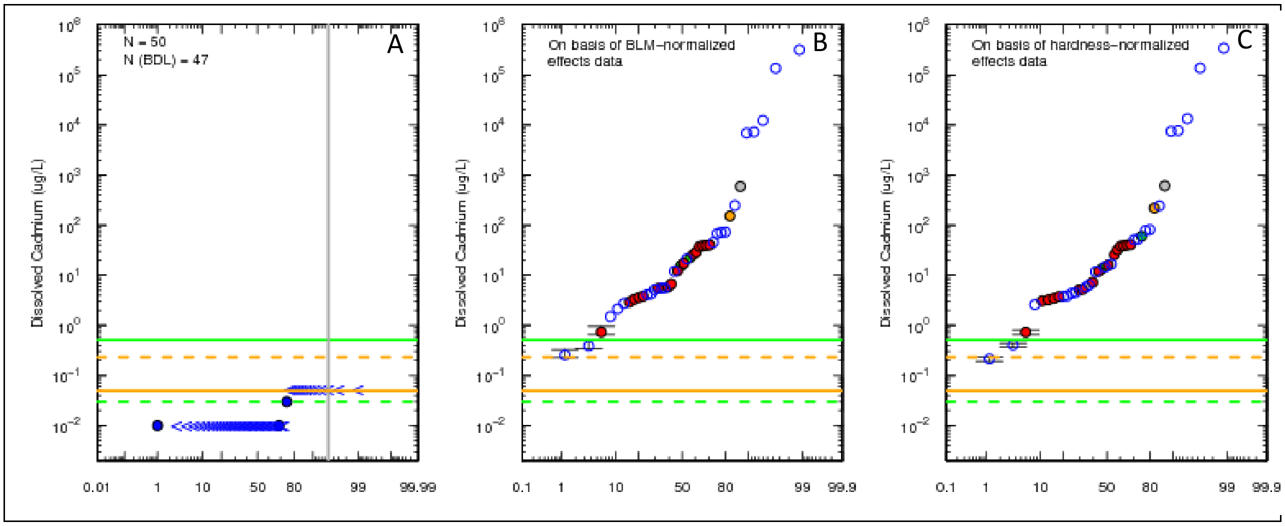

Figure 21: Exposure and Effects Comparison for ER1 (GH_ER1)

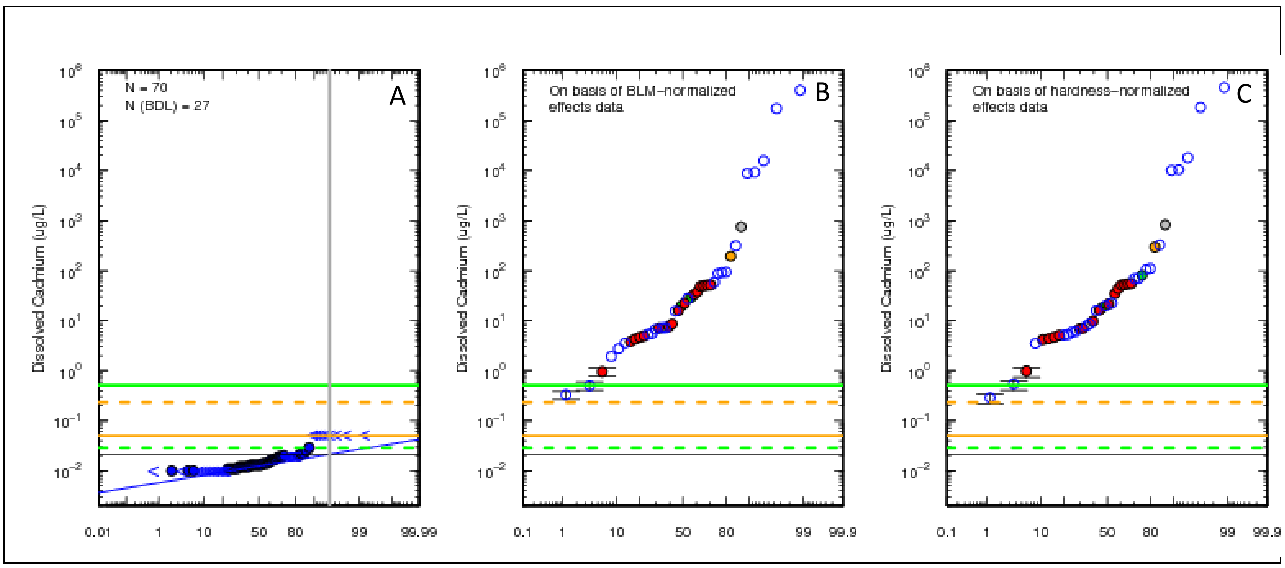

Figure 22: Exposure and Effects Comparison for ER2 (EV_ER4)

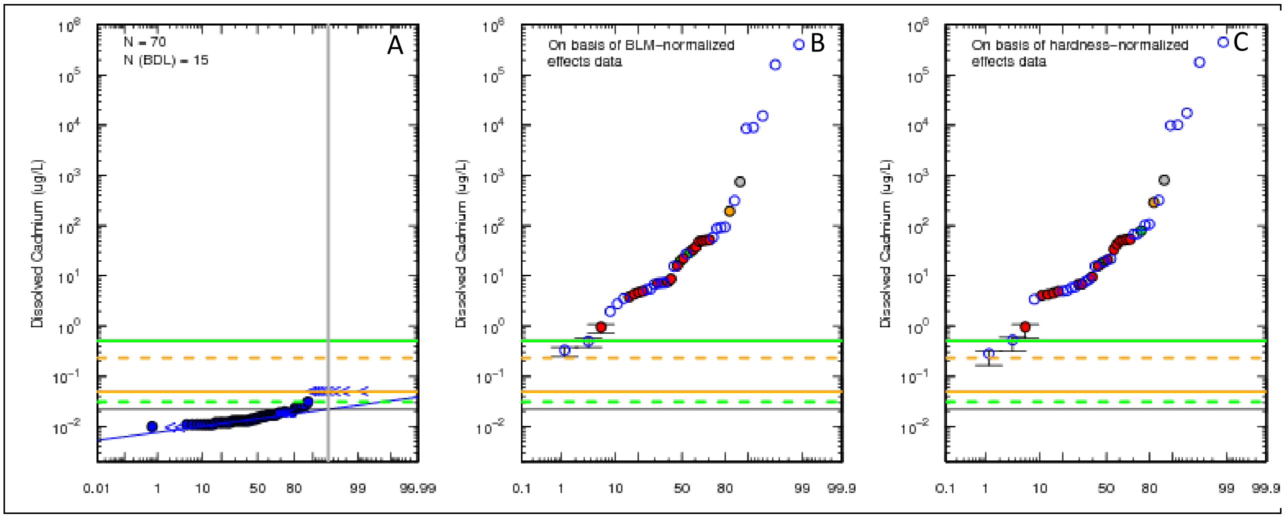

Figure 23: Exposure and Effects Comparison for ER3 (EV_ER1)

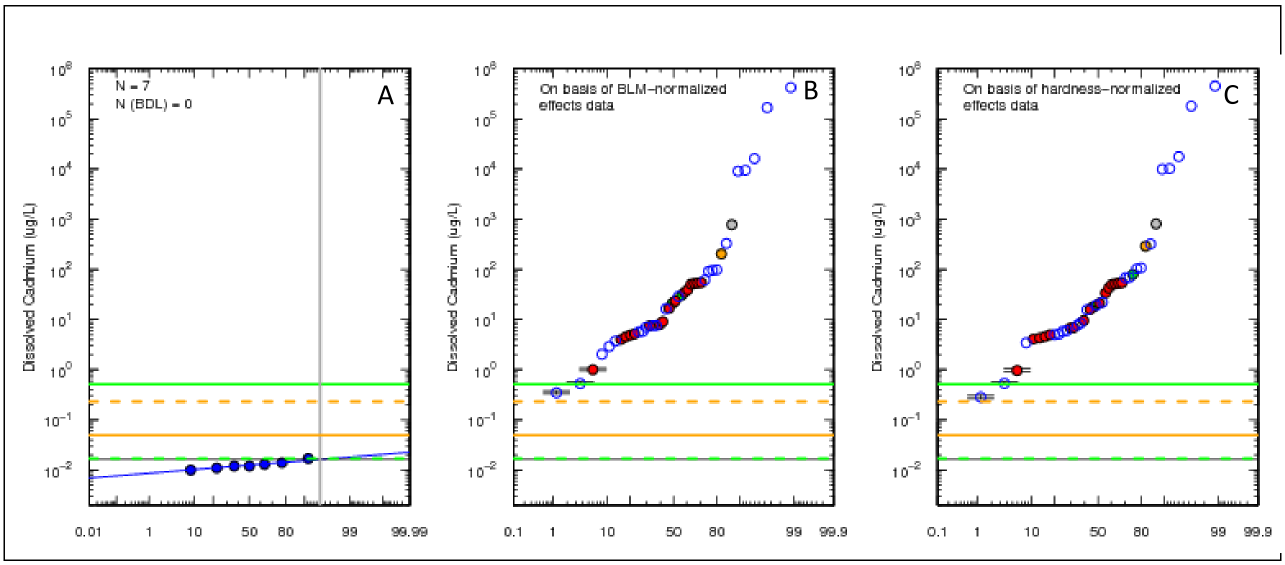

Figure 24: Exposure and Effects Comparison for ER4 (RG_ELKORES)

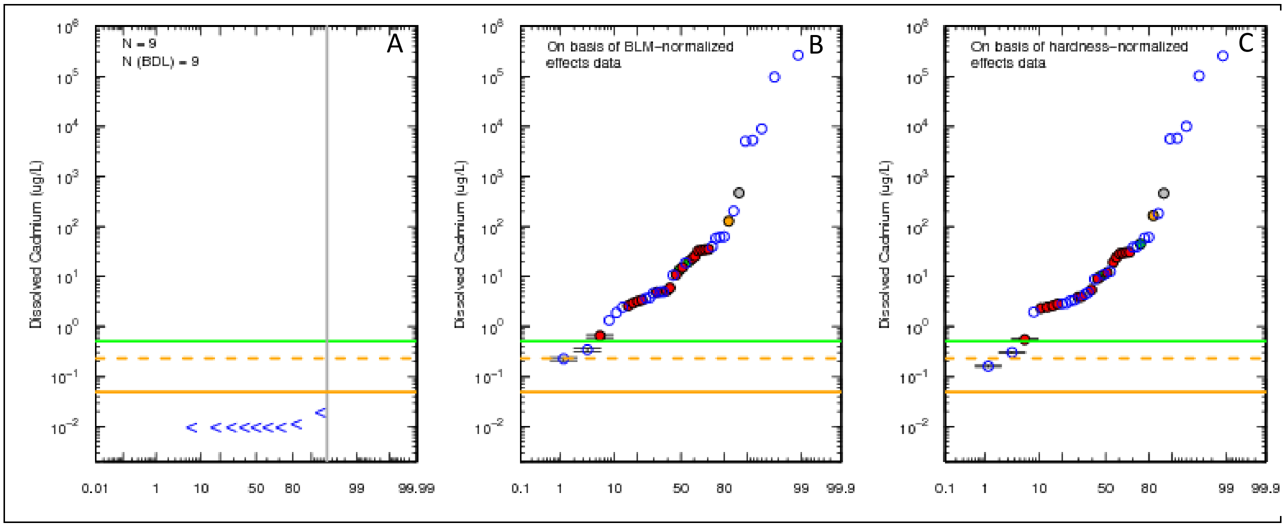

Figure 25: Exposure and Effects Comparison for LK2

Table 2: Water Concentration Effects Matrix for Order Station FR4

Concentration in Water Column	Level of Protection and Potential Effects		
	Fish	**Aquatic Invertebrates**	**Amphibians**
Upper Bound: 0.51 µg/L (for context only)[(a)]	No effect	No effects on 21 of 22 documented species Possible reproduction effects on *D. magna*	No effect
CBs: 0.29 µg/L (BLM) and 0.30 µg/L (hardness equation)	No effect	Low level reproduction effects (~10%) on *D. magna* if concentration held constant when cadmium is most bioavailable	No effect
BC WQG: 0.05 µg/L	No effect	No effect	No effect

(a) Effects for an upper-bound concentration are included to provide context for the effects of a range of concentrations from the BC MOE WQG to an upper bound based upon the 95th percentile of cadmium concentrations in water samples collected from the Fording and Elk Rivers (inclusive of tributaries).

Table 3: Water Concentration Effects Matrix for Order Station FR5

Concentration in Water Column	Level of Protection and Potential Effects		
	Fish	**Aquatic Invertebrates**	**Amphibians**
Upper Bound: 0.51 µg/L (for context only)[(a)]	No effect	No effects on 21 of 22 documented species. Possible reproduction effects on *D. magna.*	No effect
CBs: 0.30 µg/L (BLM) 0.26 µg/L (hardness equation)	No effect	Low level reproduction effects (~10%) on *D. magna* if concentration held constant when cadmium is most bioavailable	No effect
BC WQG: 0.05 µg/L	No effect	No effect	No effect

(a) Effects for an upper-bound concentration are included to provide context for the effects of a range of concentrations from the BC MOE WQG to an upper bound based upon the 95th percentile of cadmium concentrations in water samples collected from the Fording and Elk Rivers (inclusive of tributaries).

Table 4: Water Concentration Effects Matrix for Order Station ER1

Concentration in Water Column	Level of Protection and Potential Effects		
	Fish	**Aquatic Invertebrates**	**Amphibians**
Upper Bound: 0.51 µg/L (for context only)[(a)]	No effect	No effects on 20 of 22 documented species Possible reproduction effects on *D. magna* Possible biomass, growth, and reproduction effects on *H. azteca*	No effect
CBs: 0.23 µg/L (BLM) 0.19 µg/L (hardness equation)	No effect	Low level reproduction effects (~10%) on *D. magna* if concentration held constant when cadmium is most bioavailable	No effect
BC WQ G: 0.05 µg/L	No effect	No effect	No effect

[(a)] Effects for an upper-bound concentration are included to provide context for the effects of a range of concentrations from the BC MOE WQG to an upper bound based upon the 95th percentile of cadmium concentrations in water samples collected from the Fording and Elk Rivers (inclusive of tributaries).

Table 5: Water Concentration Effects Matrix for Order Station ER2

Concentration in Water Column	Level of Protection and Potential Effects		
	Fish	**Aquatic Invertebrates**	**Amphibians**
Upper Bound: 0.51 µg/L (for context only)[(a)]	No effect	No effects on 20 of 22 documented species Possible reproduction effects on *D. magna* Possible biomass, growth, and reproduction effects on *H. azteca*	No effect
CBs: 0.27 µg/L (BLM) 0.22 µg/L (hardness equation)	No effect	Low level reproduction effects (~10%) on *D. magna* if concentration held constant when cadmium is most bioavailable	No effect
BC WQG: 0.05 µg/L	No effect	No effect	No effect

[(a)] Effects for an upper-bound concentration are included to provide context for the effects of a range of concentrations from the BC MOE WQG to an upper bound based upon the 95th percentile of cadmium concentrations in water samples collected from the Fording and Elk Rivers (inclusive of tributaries).

Table 6: Water Concentration Effects Matrix for Order Station ER3

Concentration in Water Column	Level of Protection and Potential Effects		
	Fish	**Aquatic Invertebrates**	**Amphibians**
Upper Bound: 0.51 µg/L (for context only)[(a)]	No effect	No effects on 20 of 22 documented species Possible reproduction effects on *D. magna* Possible biomass, growth, and reproduction effects on *H. azteca*	No effect
CBs: 0.25 µg/L (BLM) 0.17 µg/L (hardness equation)	No effect	Low level reproduction effects (~10%) on *D. magna* if concentration held constant when cadmium is most bioavailable	No effect
BC WQG: 0.05 µg/L	No effect	No effect	No effect

[(a)] Effects for an upper-bound concentration are included to provide context for the effects of a range of concentrations from the BC MOE WQG to an upper bound based upon the 95th percentile of cadmium concentrations in water samples collected from the Fording and Elk Rivers (inclusive of tributaries).

Table 7: Water Concentration Effects Matrix for Order Station ER4

Concentration in Water Column	Level of Protection and Potential Effects		
	Fish	**Aquatic Invertebrates**	**Amphibians**
Upper Bound: 0.51 µg/L (for context only)[(a)]	No effect	No effects on 20 of 22 documented species Possible reproduction effects on *D. magna* Possible biomass, growth, and reproduction effects on *H. azteca*	No effect
CBs: 0.33 µg/L (BLM) 0.26 µg/L (hardness equation)	No effect	Low level reproduction effects (~10%) on *D. magna* if concentration held constant when cadmium is most bioavailable	No effect
BC WQ G: 0.05 µg/L	No effect	No effect	No effect

(a) Effects for an upper-bound concentration are included to provide context for the effects of a range of concentrations from the BC MOE WQG to an upper bound based upon the 95th percentile of cadmium concentrations in water samples collected from the Fording and Elk Rivers (inclusive of tributaries).

Table 8: Water Concentration Effects Matrix for Lake Koocanusa Within the Designated Area (LK2)

Concentration in Water Column	Level of Protection and Potential Effects		
	Fish	**Aquatic Invertebrates**	**Amphibians**
Upper Bound: 0.51 µg/L (for context only)[(a)]	No effect	No effects on 20 of 22 documented species Possible reproduction effects on *D. magna* Possible biomass, growth, and reproduction effects on *H. azteca*	No effect
CBs: 0.21 µg/L (BLM) 0.16 µg/L (hardness equation)	No effect	Low level reproduction effects (~10%) on *D. magna* if concentration held constant when cadmium is most bioavailable	No effect
BC Water Quality Guideline – 0.05 µg/L	No effect	No effect	No effect

(a) Effects for an upper-bound concentration are included to provide context for the effects of a range of concentrations from the BC MOE WQG to an upper bound based upon the 95th percentile of cadmium concentrations in water samples collected from the Fording and Elk Rivers (inclusive of tributaries).

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Appendix A: Data Considered for Chronic Cadmium Effects Assessment

Taxonomic groups, scientific and common species names, and summary details of the exposure are shown for toxicity data identified in the review of chronic cadmium toxicity data for aquatic organisms. Observations that were used in the effects assessment are indicated with a Yes in the Selected column. The rationale for selection of an individual observation is given in the Rationale column. All references for the studies cited in this appendix can be found in the “References” section of the main body of the report.

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Algae	*Ankistrodesmus falcatus*	Green algae	NOEC	Growth	Population	10	(Baer et al. 1999)	0.5	121	Yes	No other available data
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC10	Growth	Population	2.8	(Kallqvist 2009)	1.8	3	Yes	Longest duration EC10
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC10	Growth	Population	6	(Kallqvist 2009)	4.1	46	Yes	Longest duration EC10
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC10	Growth	Population	7.5	(Kallqvist 2009)	4.1	6	Yes	Longest duration EC10
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC10	Growth	Population	8.5	(Kallqvist 2009)	4.1	16	Yes	Longest duration EC10
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC20	Growth	Population	4.3	(Kallqvist 2009)	1.8	3		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC20	Growth	Population	12.8	(Kallqvist 2009)	4.1	6		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC20	Growth	Population	16.2	(Kallqvist 2009)	4.1	16		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC20	Growth	Population	22	(Kallqvist 2009)	4.1	46		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	NOEC	Growth	Population	5	(Baer et al. 1999)	0.5	121		Not used due to only nominal concentrations reported, while measured concentrations are available in other studies
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC50	Growth	Population	9.4	(Kallqvist 2009)	1.8	3		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC50	Growth	Population	29	(Kallqvist 2009)	4.1	6		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC50	Growth	Population	43	(Kallqvist 2009)	4.1	16		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC50	Growth	Population	43.5	(Benhra et al. 1997)	1	18		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Algae	*Pseudokirchneriella subcapitata*	Green algae	EC50	Growth	Population	199	(Kallqvist 2009)	4.1	46		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Amphibian	*Ambystoma gracile*	Northwestern salamander	LOEC	Weight	Larva	193.1	(Nebeker et al. 1995)	1	45	Yes	LOEC preferred over NOEC or MATC
Amphibian	*Ambystoma gracile*	Northwestern salamander	LOEC	Weight	Larva	227.3	(Nebeker et al. 1995)	1	45		Not used due to availability of longer duration exposures
Amphibian	*Ambystoma gracile*	Northwestern salamander	MATC	Weight	Larva	97.2	(Nebeker et al. 1995)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Amphibian	*Ambystoma gracile*	Northwestern salamander	MATC	Weight	Larva	155.4	(Nebeker et al. 1995)	1	45		Not used due to availability of longer duration exposures
Amphibian	*Ambystoma gracile*	Northwestern salamander	NOEC	Weight	Larva	48.9	(Nebeker et al. 1995)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Amphibian	*Ambystoma gracile*	Northwestern salamander	NOEC	Weight	Larva	106.3	(Nebeker et al. 1995)	1	45		Not used due to availability of longer duration exposures
Aquatic Plant	*Lemna minor*	Duckweed	EC50	Growth	Not reported	214	(Drost et al. 2007)	0.5	167	Yes	Longest duration exposure
Aquatic Plant	*Lemna minor*	Duckweed	EC50	Growth	Not reported	214	(Drost et al. 2007)	0.5	167		Not used due to availability of longer duration exposures
Aquatic Plant	*Lemna minor*	Duckweed	EC50	Growth	Not reported	315	(Drost et al. 2007)	0.5	167		Not used due to availability of longer duration exposures

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Aquatic Plant	*Lemna minor*	Duckweed	EC50	Growth	NR	337	(Drost et al. 2007)	0.5	167		Not used due to availability of longer duration exposures
Aquatic Plant	*Lemna minor*	Duckweed	EC50	Growth	NR	393	(Drost et al. 2007)	0.5	167		Not used due to availability of longer duration exposures
Fish	*Acipenser transmontanus*	sturgeon	LC20	Mortality	Fry	1.5	(Vardy et al. 2011)	2.5	70	Yes	Low effect threshold preferred over LOEC, MATC, LC50
Fish	*Acipenser transmontanus*	sturgeon	LC20	Mortality	Fry	8.7	(Vardy et al. 2011)	2.5	70		Not used due to availability of longer duration exposures
Fish	*Acipenser transmontanus*	sturgeon	LOEC	Mortality	Fry	8.3	(Vardy et al. 2011)	2.5	70		Not used because a preferred endpoint (LC20) is available for otherwise equivalent exposure conditions
Fish	*Acipenser transmontanus*	sturgeon	MATC	Mortality	Fry	3.022	(Vardy et al. 2011)	2.5	70		Not used because a preferred endpoint (LC20) is available for otherwise equivalent exposure conditions
Fish	*Acipenser transmontanus*	sturgeon	NOEC	Mortality	Fry	1.1	(Vardy et al. 2011)	2.5	70		Not used because a preferred endpoint (LC20) is available for otherwise equivalent exposure conditions
Fish	*Acipenser transmontanus*	sturgeon	LC50	Mortality	Fry	5.6	(Vardy et al. 2011)	2.5	70		Not used because a preferred endpoint (LC20) is available for otherwise equivalent exposure conditions
Fish	*Acipenser transmontanus*	sturgeon	LC50	Mortality	Fry	21.4	(Vardy et al. 2011)	2.5	70		Not used due to availability of longer duration exposures
Fish	*Catostomus commersoni*	White Sucker	LOEC	Biomass, decrease in	Embryo	12	(Eaton et al. 1978)	1	45	Yes	LOEC preferred over NOEC or MATC
Fish	*Catostomus commersoni*	White Sucker	MATC	Biomass, decrease in	Embryo	7.1	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Catostomus commersoni*	White Sucker	NOEC	Biomass, decrease in	Embryo	4.2	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Cottus bairdi*	Mottled sculpin	MATC	Biomass, decrease in	Swim-up fry	0.88	(Besser et al. 2007)	0.9	92	Yes	MATC for non-lethal effect preferred over EC50 or other lethal effects
Fish	*Cottus bairdi*	Mottled sculpin	MATC	Biomass, decrease in	Swim-up fry	3.7	(Besser et al. 2007)	0.9	92	Yes	MATC for non-lethal effect preferred over EC50 or other lethal effects
Fish	*Cottus bairdi*	Mottled sculpin	EC50	Biomass, decrease in	Swim-up fry	1.77	(Besser et al. 2007)	0.9	92		Not used because a preferred endpoint (MATC) is available for otherwise equivalent exposure conditions
Fish	*Cottus bairdi*	Mottled sculpin	EC50	Biomass, decrease in	Swim-up fry	2.4	(Besser et al. 2007)	0.9	92		Not used because a preferred endpoint (MATC) is available for otherwise equivalent exposure conditions
Fish	*Cottus bairdi*	Mottled sculpin	MATC	Mortality	Swim-up fry	0.88	(Besser et al. 2007)	0.9	92		Not used because non-lethal effects have been characterized in other studies
Fish	*Cottus bairdi*	Mottled sculpin	MATC	Mortality	Swim-up fry	1.9	(Besser et al. 2007)	0.9	92		Not used because non-lethal effects have been characterized in other studies
Fish	*Cottus bairdi*	Mottled sculpin	MATC	Mortality	Swim-up fry	1.9	(Besser et al. 2007)	0.9	92		Not used because non-lethal effects have been characterized in other studies
Fish	*Cottus bairdi*	Mottled sculpin	LC50	Mortality	Swim-up fry	1.73	(Besser et al. 2007)	0.9	92		Not used because non-lethal effects have been characterized in other studies
Fish	*Cottus bairdi*	Mottled sculpin	LC50	Mortality	Swim-up fry	2.02	(Besser et al. 2007)	0.9	92		Not used because non-lethal effects have been characterized in other studies
Fish	*Cottus bairdi*	Mottled sculpin	LC50	Mortality	Swim-up fry	2.9	(Besser et al. 2007)	0.9	92		Not used because non-lethal effects have been characterized in other studies
Fish	*Esox lucius*	Northern pike	LOEC	Biomass, decrease in	Embryo	12.9	(Eaton et al. 1978)	1	45	Yes	LOEC preferred over NOEC or MATC
Fish	*Esox lucius*	Northern pike	MATC	Biomass, decrease in	Embryo	7.4	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Esox lucius*	Northern pike	NOEC	Biomass, decrease in	Embryo	4.2	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Ictalurus punctatus*	Channel Catfish	LOEC	Weight	Fry	17	(Sauter et al. 1976)	1	185	Yes	LOEC preferred over NOEC or MATC
Fish	*Ictalurus punctatus*	Channel Catfish	MATC	Weight	Fry	14.283	(Sauter et al. 1976)	1	185		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Ictalurus punctatus*	Channel Catfish	NOEC	Weight	Fry	12	(Sauter et al. 1976)	1	185		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Ictalurus punctatus*	Channel Catfish	LOEC	Mortality	Fry	17	(Sauter et al. 1976)	1	37		Not used because non-lethal effects have been characterized in other studies
Fish	*Ictalurus punctatus*	Channel Catfish	MATC	Mortality	Fry	13.675	(Sauter et al. 1976)	1	37		Not used because non-lethal effects have been characterized in other studies
Fish	*Ictalurus punctatus*	Channel Catfish	NOEC	Mortality	Fry	11	(Sauter et al. 1976)	1	37		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Fish	*Micropterus dolomieui*	Smallmouth bass	LOEC	Biomass, decrease in	Embryo	12.7	(Eaton et al. 1978)	1	45	Yes	LOEC preferred over NOEC or MATC
Fish	*Micropterus dolomieui*	Smallmouth bass	MATC	Biomass, decrease in	Embryo	7.4	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Micropterus dolomieui*	Smallmouth bass	NOEC	Biomass, decrease in	Embryo	4.3	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus kisutch*	Coho salmon	LOEC	Biomass, decrease in	Embryo	3.4	(Eaton et al. 1978)	1	45	Yes	LOEC preferred over NOEC or MATC
Fish	*Oncorhynchus kisutch*	Coho salmon	LOEC	Biomass, decrease in	Embryo	12.5	(Eaton et al. 1978)	1	45	Yes	LOEC preferred over NOEC or MATC
Fish	*Oncorhynchus kisutch*	Coho salmon	LOEC	Biomass, decrease in	Larva	12.5	(Eaton et al. 1978)	1	45	Yes	LOEC preferred over NOEC or MATC
Fish	*Oncorhynchus kisutch*	Coho salmon	MATC	Biomass, decrease in	Embryo	2.1	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus kisutch*	Coho salmon	MATC	Biomass, decrease in	Embryo	7.2	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus kisutch*	Coho salmon	MATC	Biomass, decrease in	Larva	7.2	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus kisutch*	Coho salmon	NOEC	Biomass, decrease in	Embryo	1.3	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus kisutch*	Coho salmon	NOEC	Biomass, decrease in	Embryo	4.1	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus kisutch*	Coho salmon	NOEC	Biomass, decrease in	Larva	4.1	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Weight	Early life stage	0.16	(Mebane et al. 2008)	2	29	Yes	Long duration exposure, sensitive life stage, non-lethal LOEC preferred over NOEC or MATC. EC10 for this study is unbounded.
Fish	*Oncorhynchus mykiss*	Rainbow trout	EC10	Weight	Early life stage	0.15	(Mebane et al. 2008)	2	29		Although an EC10 has been reported in this study, this is actually an unbounded value. The study shows almost no dose response. As an example, the reported LOEC, although significantly different from control, is below a 10% effect. Higher exposure concentrations were not significantly different from control. Since using this study places RBT as the most sensitive fish, a lot of impact comes from this one study and there is not much evidence of a dose-response relationship to back it up. Nevertheless, we will use the LOEC value in preference to this unbounded EC10.
Fish	*Oncorhynchus mykiss*	Rainbow trout	EC10	Length	Early life stage	2.5	(Mebane et al. 2008)	2	29		Not used because effects on weight appear to be more sensitive
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Length	Early life stage	0.16	(Mebane et al. 2008)	2	29		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Reproduction , delay in oogenesis	Adult	1.77	(Brown et al. 1994)	1	250		Not used because effects on weight appear to be more sensitive
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Length	Early life stage	0.16	(Mebane et al. 2008)	2	29		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Weight	Early life stage	0.16	(Mebane et al. 2008)	2	29		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Reproduction , delay in oogenesis	Adult	0.91	(Brown et al. 1994)	1	250		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Length	Early life stage	0.16	(Mebane et al. 2008)	2	29		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Weight	Early life stage	0.16	(Mebane et al. 2008)	2	29		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Reproduction , delay in oogenesis	Adult	0.47	(Brown et al. 1994)	1	250		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC10	Mortality	parr	0.7	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC10	Mortality	smolt	0.8	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	EC10	Mortality	Early life stage	0.82	(Mebane et al. 2008)	1	20		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC10	Mortality	Swim-up fry	1	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC1	Mortality	Unknown	1.58	(Davies et al. 1993)	1	46		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	EC10	Mortality	Early life stage	1.6	(Mebane et al. 2008)	2	29		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC1	Mortality	Unknown	2.39	(Davies et al. 1993)	1	414		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC1	Mortality	Unknown	2.43	(Davies et al. 1993)	1	217		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC10	Mortality	Alevin	6	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Mortality	Early life stage	1.3	(Mebane et al. 2008)	1	20		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Mortality	Unknown	1.74	(Davies et al. 1993)	1	46		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Mortality	Early life stage	2.5	(Mebane et al. 2008)	2	29		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Mortality	Unknown	5.03	(Davies et al. 1993)	1	217		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LOEC	Mortality	Unknown	5.16	(Davies et al. 1993)	1	414		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Mortality	Early life stage	0.88	(Mebane et al. 2008)	1	20		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Mortality	Unknown	1.47	(Davies et al. 1993)	1	46		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Mortality	Early life stage	1.6	(Mebane et al. 2008)	2	29		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Mortality	Unknown	3.58	(Davies et al. 1993)	1	217		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	MATC	Mortality	Unknown	3.64	(Davies et al. 1993)	1	414		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Mortality	Early life stage	0.6	(Mebane et al. 2008)	1	20		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Mortality	Early life stage	1	(Mebane et al. 2008)	2	29		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Mortality	Unknown	1.25	(Davies et al. 1993)	1	46		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Mortality	Unknown	2.55	(Davies et al. 1993)	1	217		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	NOEC	Mortality	Unknown	2.57	(Davies et al. 1993)	1	414		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Stealhead trout	LC50	Mortality	Unknown	0.5	(Cusimano et al. 1986	1	9		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Stealhead trout	LC50	Mortality	Unknown	0.7	(Cusimano et al. 1986	1	9		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC50	Mortality	parr	0.9	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC50	Mortality	Swim-up fry	1.3	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC50	Mortality	smolt	1.6	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus mykiss*	Stealhead trout	LC50	Mortality	Unknown	6.3	(Cusimano et al. 1986	1	9		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Fish	*Oncorhynchus mykiss*	Rainbow trout	LC50	Mortality	Alevin	27	(Chapman 1978)	1.4	24		Not used because non-lethal effects have been characterized in other studies
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC10	Mortality	Swim-up fry	1.2	(Chapman 1978)	1.4	24	Yes	Low effect threshold preferred over LC50
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC10	Mortality	parr	1.3	(Chapman 1978)	1.4	24	Yes	Low effect threshold preferred over LC50
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC10	Mortality	smolt	1.5	(Chapman 1978)	1.4	24	Yes	Low effect threshold preferred over LC50
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC10	Mortality	Alevin	22	(Chapman 1978)	1.4	24		Not used because other tests use more sensitive life-stages
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC50	Mortality	Swim-up fry	1.6	(Chapman 1978)	1.4	24		Not used because a preferred endpoint (LC10) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC50	Mortality	parr	2	(Chapman 1978)	1.4	24		Not used because a preferred endpoint (LC10) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC50	Mortality	smolt	2.3	(Chapman 1978)	1.4	24		Not used because a preferred endpoint (LC10) is available for otherwise equivalent exposure conditions
Fish	*Oncorhynchus tshawytscha*	Chinook salmon	LC50	Mortality	Alevin	26	(Chapman 1978)	1.4	24		Not used because a preferred endpoint (LC10) is available for otherwise equivalent exposure conditions
Fish	*Pimephales promelas*	Fathead minnow	EC20	Growth	NR	10	(Spehar and Fiandt 1986)	2	44	Yes	Long duration low effect threshold for non-lethal effect
Fish	*Pimephales promelas*	Fathead minnow	LOEC	Growth	Other	16.5	(Castillo, III and Longley 2001)	1	278		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Pimephales promelas*	Fathead minnow	MATC	Growth	NR	10	(Spehar and Fiandt 1986)	2	44		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Growth	Larva	2	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Growth	Larva	3	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Growth	4 to 6 days old	11.3	(Castillo, III and Longley 2001)	1	278		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Pimephales promelas*	Fathead minnow	LOEC	Mortality	4 to 6 days old	12.2	(Castillo, III and Longley 2001)	1	267		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	LOEC	Mortality	Juvenile	26.7	(Spehar and Carlson 1984)	20.2	65		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	LOEC	Mortality	Fry	57	(Pickering and Gast 1972)	1	204		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	LOEC	Mortality	Adult	110	(Pickering and Gast 1972)	1	201		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	MATC	Mortality	Larva	1.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	MATC	Mortality	Larva	2.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	MATC	Mortality	Larva	4.9	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	MATC	Mortality	Juvenile	18.9	(Spehar and Carlson 1984)	20.2	65		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	MATC	Mortality	Fry	39.2	(Pickering and Gast 1972)	1	204		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	MATC	Mortality	Adult	60.83	(Pickering and Gast 1972)	1	201		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Mortality	4 to 6 days old	8.5	(Castillo, III and Longley 2001)	1	278		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Mortality	4 to 6 days old	9.6	(Castillo, III and Longley 2001)	1	267		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Mortality	4 to 6 days old	11.3	(Castillo, III and Longley 2001)	1	278		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Mortality	Juvenile	13.4	(Spehar and Carlson 1984)	20.2	65		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Mortality	Fry	27	(Pickering and Gast 1972)	1	204		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	NOEC	Mortality	Adult	37	(Pickering and Gast 1972)	1	201		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	LC50	Mortality	Larva	1.6	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	LC50	Mortality	Larva	2.3	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Fish	*Pimephales promelas*	Fathead minnow	LC50	Mortality	Larva	4.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Fish	*Prosopium williamsoni*	Mountain Whitefish	IC10	Biomass, decrease in	Embryo	1.25	(Brinkman and Vieira 2008)	1.9	48	Yes	Longest duration exposure
Fish	*Prosopium williamsoni*	Mountain Whitefish	IC20	Biomass and Weight	Embryo	1.29	(Brinkman and Vieira 2008)	1.9	48		Not used because a preferred endpoint (IC10) is available for otherwise equivalent exposure conditions
Fish	*Prosopium williamsoni*	Mountain Whitefish	IC20	Biomass and Weight	Embryo	3.02	(Brinkman and Vieira 2008)	1.9	48		Not used due to availability of longer duration exposures
Fish	*Salmo salar*	Atlantic salmon	LOEC	Weight	Egg	0.47	(Rombough and Garside 1982)	1	28	Yes	Long duration LOEC for non-lethal effect
Fish	*Salmo salar*	Atlantic salmon	LOEC	Weight	Egg	2.5	(Rombough and Garside 1982)	1	28	Yes	Long duration LOEC for non-lethal effect
Fish	*Salmo salar*	Atlantic salmon	LOEC	Length	Egg	0.47	(Rombough and Garside 1982)	1	28		Long duration LOEC for non-lethal effect
Fish	*Salmo salar*	Atlantic salmon	LOEC	Biomass, decrease in	Egg	2.5	(Rombough and Garside 1982)	1	28		Long duration LOEC for non-lethal effect
Fish	*Salmo salar*	Atlantic salmon	MATC	Biomass, decrease in	Egg	0.61	(Rombough and Garside 1982)	1	28		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Salmo salar*	Atlantic salmon	MATC	Biomass, decrease in	Egg	5.5	(Rombough and Garside 1982)	1	19		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Salmo salar*	Atlantic salmon	MATC	Weight	Egg	5.5	(Rombough and Garside 1982)	1	19		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Salmo salar*	Atlantic salmon	MATC	Hatching success	Early gastrulati	88	(Rombough and Garside 1982)	1	19		Not used due to availability of longer duration exposures
Fish	*Salmo salar*	Atlantic salmon	MATC	Hatching success	Eyed egg stage	156	(Rombough and Garside 1982)	1	19		Not used due to availability of longer duration exposures
Fish	*Salmo salar*	Atlantic salmon	MATC	Hatching success	Egg	156	(Rombough and Garside 1982)	1	19		Not used due to availability of longer duration exposures
Fish	*Salmo salar*	Atlantic salmon	MATC	Hatching success	Egg	490	(Rombough and Garside 1982)	1	28		Not used due to availability of longer duration exposures
Fish	*Salmo salar*	Atlantic salmon	MATC	Hatching success	Egg	490	(Rombough and Garside 1982)	1	28		Not used due to availability of longer duration exposures
Fish	*Salmo salar*	Atlantic salmon	MATC	Mortality	Egg	4.5	(Rombough and Garside 1982)	1	28		Not used due to availability of longer duration exposures
Fish	*Salmo salar*	Atlantic salmon	MATC	Mortality	Egg	156	(Rombough and Garside 1982)	1	19		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Salmo salar*	Atlantic salmon	MATC	Mortality	Egg	490	(Rombough and Garside 1982)	1	28		Not used due to availability of longer duration exposures
Fish	*Salmo trutta*	Brown trout	IC20	Biomass, decrease in	Swim-up fry	0.87	(Brinkman and Hansen 2007)	1	29	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage
Fish	*Salmo trutta*	Brown trout	IC20	Biomass, decrease in	Swim-up fry	2.18	(Brinkman and Hansen 2007)	1	68	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage
Fish	*Salmo trutta*	Brown trout	IC20	Biomass, decrease in	Swim-up fry	6.62	(Brinkman and Hansen 2007)	1	151	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage
Fish	*Salmo trutta*	Brown trout	IC20	Biomass, decrease in	Egg	2.22	(Brinkman and Hansen 2007)	1	31		Not used because other tests use more sensitive life-stages
Fish	*Salmo trutta*	Brown trout	IC20	Biomass, decrease in	Egg	4.71	(Brinkman and Hansen 2007)	1	71		Not used because other tests use more sensitive life-stages
Fish	*Salmo trutta*	Brown trout	LOEC	Weight	Swim-up fry	2.72	(Brinkman and Hansen 2007)	1	29		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Fish	*Salmo trutta*	Brown trout	LOEC	Biomass, decrease in	Larva	3.7	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	LOEC	Weight	Swim-up fry	4.49	(Brinkman and Hansen 2007)	1	68		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	LOEC	Biomass, decrease in	Embryo	11.2	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	LOEC	Biomass, decrease in	Larva	11.7	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	LOEC	Biomass, decrease in	Embryo	11.7	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	MATC	Biomass, decrease in	Larva	2	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	MATC	Biomass, decrease in	Embryo	6.4	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	MATC	Biomass, decrease in	Larva	6.7	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	MATC	Biomass, decrease in	Embryo	6.7	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	NOEC	Biomass, decrease in	Larva	1.1	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	NOEC	Weight	Swim-up fry	1.4	(Brinkman and Hansen 2007)	1	29		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	NOEC	Weight	Swim-up fry	2.58	(Brinkman and Hansen 2007)	1	68		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	NOEC	Biomass, decrease in	Embryo	3.7	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	NOEC	Biomass, decrease in	Larva	3.8	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	NOEC	Biomass, decrease in	Embryo	3.8	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Fish	*Salmo trutta*	Brown trout	IC20	Mortality	Egg	13.6	(Brinkman and Hansen 2007)	1	149		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	LOEC	Mortality	Swim-up fry	1.4	(Brinkman and Hansen 2007)	1	29		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	LOEC	Mortality	Swim-up fry	2.58	(Brinkman and Hansen 2007)	1	38		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	LOEC	Mortality	Egg	4.87	(Brinkman and Hansen 2007)	1	31		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	LOEC	Mortality	Egg	8.64	(Brinkman and Hansen 2007)	1	71		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	LOEC	Mortality	Swim-up fry	8.88	(Brinkman and Hansen 2007)	1	151		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	LOEC	Mortality	Egg	19.1	(Brinkman and Hansen 2007)	1	149		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	NOEC	Mortality	Swim-up fry	0.74	(Brinkman and Hansen 2007)	1	29		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	NOEC	Mortality	Swim-up fry	1.3	(Brinkman and Hansen 2007)	1	68		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	NOEC	Mortality	Egg	2.54	(Brinkman and Hansen 2007)	1	31		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	NOEC	Mortality	Egg	4.68	(Brinkman and Hansen 2007)	1	71		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	NOEC	Mortality	Swim-up fry	4.81	(Brinkman and Hansen 2007)	1	151		Not used because non-lethal effects have been characterized in other studies
Fish	*Salmo trutta*	Brown trout	NOEC	Mortality	Egg	9.62	(Brinkman and Hansen 2007)	1	149		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus confluentus*	Bull trout	LOEC	Growth	Juvenile	0.786	(Hansen et al. 2002b)	1	31	Yes	LOEC preferred over NOEC or MATC
Fish	*Salvelinus confluentus*	Bull trout	MATC	Growth	Juvenile	0.549	(Hansen et al. 2002b)	1	31		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Fish	*Salvelinus confluentus*	Bull trout	NOEC	Growth	Juvenile	0.383	(Hansen et al. 2002b)	1	31		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Salvelinus confluentus*	Bull trout	LOEC	Mortality	Juvenile	0.786	(Hansen et al. 2002b)	1	31		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus confluentus*	Bull trout	MATC	Mortality	Juvenile	0.549	(Hansen et al. 2002b)	1	31		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus confluentus*	Bull trout	NOEC	Mortality	Juvenile	0.383	(Hansen et al. 2002b)	1	31		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Biomass, decrease in	Larva	3.8	(Eaton et al. 1978)	1	45	Yes	Long duration LOEC for non-lethal effect
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Biomass, decrease in	Embryo	0.48	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Biomass, decrease in	Larva	0.48	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Weight	Fry	3	(Sauter et al. 1976)	1	37		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Biomass, decrease in	Larva	3.8	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Biomass, decrease in	Embryo	11.7	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Weight	Fry	12	(Sauter et al. 1976)	1	188		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	MATC	Weight	Fry	1.7	(Sauter et al. 1976)	1	37		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	MATC	Biomass, decrease in	Larva	2	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Salvelinus fontinalis*	Brook Trout	MATC	Weight	Fry	9.17	(Sauter et al. 1976)	1	188		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Weight	Fry	1	(Sauter et al. 1976)	1	37		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Biomass, decrease in	Larva	1.1	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Biomass, decrease in	Larva	1.1	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Biomass, decrease in	Embryo	3.8	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Weight	Fry	7	(Sauter et al. 1976)	1	188		Not used due to availability of longer duration exposures
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Mortality	Mixed	3.4	(Benoit et al. 1976)	1	44		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Mortality	Fry	6	(Sauter et al. 1976)	1	37		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	LOEC	Mortality	Fry	7	(Sauter et al. 1976)	1	188		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	MATC	Mortality	Mixed	2.4	(Benoit et al. 1976)	1	44		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	MATC	Mortality	Fry	4.24	(Sauter et al. 1976)	1	37		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	MATC	Mortality	Fry	9.17	(Sauter et al. 1976)	1	188		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Mortality	Mixed	1.7	(Benoit et al. 1976)	1	44		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Mortality	Fry	3	(Sauter et al. 1976)	1	37		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus fontinalis*	Brook Trout	NOEC	Mortality	Fry	12	(Sauter et al. 1976)	1	188		Not used because non-lethal effects have been characterized in other studies
Fish	*Salvelinus namaycush*	Lake Trout	LOEC	Biomass, decrease in	Larva	12.3	(Eaton et al. 1978)	1	45	Yes	Long duration LOEC preferred over NOEC, MATC
Fish	*Salvelinus namaycush*	Lake Trout	LOEC	Biomass, decrease in	Embryo	12.3	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus namaycush*	Lake Trout	MATC	Biomass, decrease in	Embryo	7.4	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus namaycush*	Lake Trout	MATC	Biomass, decrease in	Larva	7.4	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Fish	*Salvelinus namaycush*	Lake Trout	NOEC	Biomass, decrease in	Embryo	4.4	(Eaton et al. 1978)	1	45		Not used due to availability of longer duration exposures
Fish	*Salvelinus namaycush*	Lake Trout	NOEC	Biomass, decrease in	Larva	4.4	(Eaton et al. 1978)	1	45		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Aeolosoma headleyi*	Oligochaete	LOEC	Population growth	Young worms	50.2	(Niederlehner et al. 1984)	0.5	168	Yes	Long duration LOEC preferred over NOEC, MATC
Invertebrates	*Aeolosoma headleyi*	Oligochaete	LOEC	Population growth	Young worms	36.9	(Niederlehner et al. 1984)	1	60		Not used due to availability of longer duration exposures
Invertebrates	*Aeolosoma headleyi*	Oligochaete	LOEC	Population growth	Young worms	92	(Niederlehner et al. 1984)	0.5	189		Not used due to availability of longer duration exposures
Invertebrates	*Aeolosoma headleyi*	Oligochaete	MATC	Population growth	Young worms	25.2	(Niederlehner et al. 1984)	1	60		Not used due to availability of longer duration exposures
Invertebrates	*Aeolosoma headleyi*	Oligochaete	MATC	Population growth	Young worms	40.1	(Niederlehner et al. 1984)	0.5	168		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Aeolosoma headleyi*	Oligochaete	MATC	Population growth	Young worms	70.2	(Niederlehner et al. 1984)	0.5	189		Not used due to availability of longer duration exposures
Invertebrates	*Aeolosoma headleyi*	Oligochaete	NOEC	Population growth	Young worms	17.2	(Niederlehner et al. 1984)	1	60		Not used due to availability of longer duration exposures
Invertebrates	*Aeolosoma headleyi*	Oligochaete	NOEC	Population growth	Young worms	32	(Niederlehner et al. 1984)	0.5	168		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Aeolosoma headleyi*	Oligochaete	NOEC	Population growth	Young worms	53.6	(Niederlehner et al. 1984)	0.5	189		Not used due to availability of longer duration exposures
Invertebrates	*Atyaephyra desmarestii*	European shrimp	LOEC	Feeding inhibition	Adult	6.53	(Pestana et al. 2007)	1	263	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Atyaephyra desmarestii*	European shrimp	NOEC	Feeding inhibition	Adult	4.2	(Pestana et al. 2007)	1	263		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Baetis rhodani*	Mayfly	LC50	Mortality	Unknown	2300	(Gerhardt 1992)	1	50	Yes	No non-lethal effect data available
Invertebrates	*Baetis rhodani*	Mayfly	LC50	Mortality	Unknown	2500	(Gerhardt 1992)	1	50	Yes	No non-lethal effect data available
Invertebrates	*Baetis rhodani*	Mayfly	LC50	Mortality	Unknown	3000	(Gerhardt 1992)	1	50	Yes	No non-lethal effect data available
Invertebrates	*Ceriodaphnia dubia*	Water flea	EC20	Reproduction - number of neonates	NR	2.38	(Spehar and Fiandt 1986)	7.1	100	Yes	EC20 preferred over LOEC, NOEC, or MATC
Invertebrates	*Ceriodaphnia dubia*	Water flea	LOEC	Reproduction (brood size)	Neonate	1	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	LOEC	Reproduction (total young/female)	Neonate	1	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	LOEC	Reproduction (total young/female)	Neonate	1	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	LOEC	Reproduction (brood size)	Neonate	2	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Reproduction (brood size)	Neonate	1.4	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Reproduction - number of neonates	NR	2.2	(Spehar and Fiandt 1986)	7.1	100		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	NOEC	Reproduction (brood size)	Neonate	1	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Reproduction	Not reported	2	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Reproduction	Not reported	2	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Reproduction	Not reported	2	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (EC20) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Mortality	Not reported	11.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Mortality	Not reported	11.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Ceriodaphnia dubia*	Water flea	MATC	Mortality	Not reported	11.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia dubia*	Water flea	LC50	Mortality	Not reported	10.1	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia dubia*	Water flea	LC50	Mortality	Not reported	10.6	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia dubia*	Water flea	LC50	Mortality	Not reported	11.6	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia reticulata*	Cladocerans	LOEC	Reproduction	Less than 24hrs	7.2	(Spehar and Carlson 1984)	20.2	65	Yes	LOEC for non-lethal endpoint preferred over NOEC, MATC, or lethal endpoints
Invertebrates	*Ceriodaphnia reticulata*	Water flea	MATC	Reproduction , number of young per adult	Less than 24hrs	0.43	(Elnabarawy et al. 1986	1	240		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia reticulata*	Cladocerans	MATC	Reproduction	Less than 24hrs	4.9	(Spehar and Carlson 1984)	20.2	65		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia reticulata*	Cladocerans	NOEC	Reproduction	Less than 24hrs	3.4	(Spehar and Carlson 1984)	20.2	65		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia reticulata*	Water flea	EC50	Reproduction , number of young per adult	Less than 24hrs	15.3	(Elnabarawy et al. 1986	1	240		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Ceriodaphnia reticulata*	Cladocerans	LOEC	Mortality	Less than 24hrs	15.2	(Spehar and Carlson 1984)	20.2	65		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia reticulata*	Cladocerans	MATC	Mortality	Less than 24hrs	10.5	(Spehar and Carlson 1984)	20.2	65		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia reticulata*	Cladocerans	NOEC	Mortality	Less than 24hrs	7.2	(Spehar and Carlson 1984)	20.2	65		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Ceriodaphnia reticulata*	Water flea	LC50	Mortality	Less than 24hrs	15.3	(Elnabarawy et al. 1986	1	240		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Chironomus riparius*	Midge	LOEC	Mortality	1st instar	150	(Pascoe et al. 1989)	1	98	Yes	LOEC preferred over NOEC or MATC, no non-lethal effects available
Invertebrates	*Chironomus riparius*	Midge	MATC	Mortality	1st instar	47.4	(Pascoe et al. 1989)	1	98		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Chironomus riparius*	Midge	NOEC	Mortality	1st instar	15	(Pascoe et al. 1989)	1	98		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Chironomus tentans*	Midge	IC25	Hatching success	Less than 24hrs	4	(Ingersoll and Kemble 2001)	1	280	Yes	Long duration low effect threshold for non-lethal effect
Invertebrates	*Chironomus tentans*	Midge	IC25	Percent emergence	Less than 24hrs	8.1	(Ingersoll and Kemble 2001)	1	280	Yes	Long duration low effect threshold for non-lethal effect
Invertebrates	*Chironomus tentans*	Midge	IC25	Weight	Less than 24hrs	9.9	(Ingersoll and Kemble 2001)	1	280	Yes	Long duration low effect threshold for non-lethal effect
Invertebrates	*Chironomus tentans*	Midge	IC25	Biomass, decrease in	Less than 24hrs	10.3	(Ingersoll and Kemble 2001)	1	280	Yes	Long duration low effect threshold for non-lethal effect
Invertebrates	*Chironomus tentans*	Midge	IC25	Repro - No. eggs per individual	Less than 24hrs	16.4	(Ingersoll and Kemble 2001)	1	280	Yes	Long duration low effect threshold for non-lethal effect
Invertebrates	*Chironomus tentans*	Midge	LOEC	Growth	2nd instar	100	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (IC25) is available for otherwise equivalent exposure conditions
Invertebrates	*Chironomus tentans*	Midge	LOEC	Growth	2nd instar	500	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (IC25) is available for otherwise equivalent exposure conditions
Invertebrates	*Chironomus tentans*	Midge	LOEC	Growth	2nd instar	500	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (IC25) is available for otherwise equivalent exposure conditions
Invertebrates	*Chironomus tentans*	Midge	IC25	Mortality	Less than 24hrs	16.4	(Ingersoll and Kemble 2001)	1	280		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Chironomus tentans*	Midge	MATC	Mortality	2nd instar	707	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Chironomus tentans*	Midge	MATC	Mortality	2nd instar	707	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Chironomus tentans*	Midge	MATC	Mortality	2nd instar	707	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Chironomus tentans*	Midge	LC50	Mortality	2nd instar	635	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Chironomus tentans*	Midge	LC50	Mortality	2nd instar	963	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Chironomus tentans*	Midge	LC50	Mortality	2nd instar	1700	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	EC10	Repro - brood mass	Adult	0.13	(Barata and Baird 2000	0.5	170	Yes	Long duration low effect threshold for non-lethal effect
Invertebrates	*Daphnia magna*	Water flea	EC10	Reproduction , brood size	Adult	0.14	(Barata and Baird 2000	0.5	170	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage
Invertebrates	*Daphnia magna*	Water flea	EC16	Reproduction	Less than 24hrs	0.17	(Biesinger and Christensen 1972)	1	45	Yes	Long duration low effect threshold for non-lethal effect
Invertebrates	*Daphnia magna*	Water flea	EC10	Feeding inhibition	Adult	0.13	(Barata and Baird 2000	0.5	170		Not used because more sensitive endpoints (Reproduction) have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	EC10	Weight	Adult	1.65	(Barata and Baird 2000	0.5	170		Not used because other tests use more sensitive life-stages
Invertebrates	*Daphnia magna*	Water flea	LOEC	Growth	Neonate	1.5	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LOEC	Reproduction , number of young per adult	Not reported	1.86	(Borgmann et al. 1989)	1	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LOEC	Reproduction	24h	1.94	(Kuhn et al. 1989)	0.5	250		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LOEC	Growth	Neonate	2	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LOEC	Growth	Neonate	2	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LOEC	Reproduction (brood size)	Neonate	3	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LOEC	Reproduction (total young/female)	Neonate	3	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LOEC	Reproduction	Less than 24hrs	10	(Bodar et al. 1988)	1	150		Not used because a preferred endpoint (EC16) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction , number of young per adult	Less than 24hrs	0.15	(Chapman et al. 1980)	1	53		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Repro - Number of young per survivor	Less than 24hrs	0.21	(Chapman et al. 1980)	1	103		Not used because a preferred endpoint (EC16) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction , number of young per adult	Less than 24hrs	0.38	(Chapman et al. 1980)	1	103		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction , number of young per adult	Less than 24hrs	0.43	(Chapman et al. 1980)	1	209		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction , number of young per adult	Not reported	0.64	(Borgmann et al. 1989)	1	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Repro - Number of young per survivor	Less than 24hrs	0.67	(Chapman et al. 1980)	1	209		Not used because a preferred endpoint (EC16) is available for otherwise equivalent exposure conditions

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction	24h	1.09	(Kuhn et al. 1989)	0.5	250		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Growth	Neonate	1.2	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Growth	Neonate	1.4	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Growth	Neonate	1.4	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Repro - Number of young per survivor	Less than 24hrs	1.52	(Chapman et al. 1980)	1	53		Not used because a preferred endpoint (EC16) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Reproduction (brood size)	Neonate	2	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction (total young/female)	Neonate	2.45	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction , number of young per adult	Less than 24hrs	4.3	(Elnabarawy et al. 1986	1	240		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction	Less than 24hrs	7.07	(Bodar et al. 1988)	1	150		Not used because a preferred endpoint (EC16) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Reproduction , number of young per adult	Not reported	0.22	(Borgmann et al. 1989)	1	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Reproduction	24h	0.6	(Kuhn et al. 1989)	0.5	250		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Growth	Neonate	1	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Growth	Neonate	1	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Growth	Neonate	1	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Reproduction (total young/female)	Neonate	2	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	MATC	Reproduction (brood size)	Neonate	2.45	(Winner 1988)	0.5	90		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	NOEC	Reproduction	Less than 24hrs	5	(Bodar et al. 1988)	1	150		Not used because a preferred endpoint (EC16) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	EC50	Reproduction	Less than 24hrs	0.7	(Biesinger and Christensen 1972)	1	45		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	EC50	Reproduction , number of young per adult	Less than 24hrs	3.5	(Elnabarawy et al. 1986	1	240		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia magna*	Water flea	LC10	Mortality	Adult	1.15	(Barata and Baird 2000	0.5	170		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	MATC	Mortality	Not reported	7.1	(Suedel et al. 1997)	1	78		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	MATC	Mortality	Not reported	7.1	(Suedel et al. 1997)	1	78		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	MATC	Mortality	Not reported	7.1	(Suedel et al. 1997)	1	78		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	LC50	Mortality	Adult	2.47	(Barata and Baird 2000	0.5	170		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Daphnia magna*	Water flea	LC50	Mortality	Less than 24hrs	5	(Biesinger and Christensen 1972)	1	45		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	LC50	Mortality	Not reported	8.6	(Suedel et al. 1997)	1	78		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	LC50	Mortality	Not reported	9	(Suedel et al. 1997)	1	78		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	LC50	Mortality	Not reported	9.9	(Suedel et al. 1997)	1	78		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia magna*	Water flea	LC50	Mortality	Less than 24hrs	15.3	(Elnabarawy et al. 1986	1	240		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Repro - Number of young per survivor	Less than 24hrs	0.3	(Roux et al. 1993)	0.5	85	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	4.8	(Winner 1986)	0.1	58	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	9.9	(Winner 1986)	0.72	115	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	9.9	(Winner 1986)	0.36	115	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction (day of first reproduction)	Less than 24hrs	10	(Ingersoll and Winner 1982)	0.5	106	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	10	(Winner 1986)	0.72	58	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	10	(Winner 1986)	0.36	58	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	10	(Ingersoll and Winner 1982)	0.5	106	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	10.1	(Winner 1986)	0.72	230	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	10.1	(Winner 1986)	0.36	230	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	10.4	(Winner 1986)	0.1	230	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	10.8	(Winner 1986)	0.1	115	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	15	(Ingersoll and Winner 1982)	0.5	106	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	LOEC	Reproduction , brood size	Less than 24hrs	20	(Ingersoll and Winner 1982)	0.5	106	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Daphnia pulex*	Water flea	MATC	Repro - Number of young per survivor	Less than 24hrs	0.095	(Roux et al. 1993)	0.5	85		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction , brood size	Less than 24hrs	3.6	(Winner 1986)	0.1	58		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction , brood size	Less than 24hrs	7.04	(Winner 1986)	0.72	115		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction , brood size	Less than 24hrs	7.04	(Winner 1986)	0.36	115		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction (day of first reproduction)	Less than 24hrs	7.07	(Ingersoll and Winner 1982)	0.5	106		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction , brood size	Less than 24hrs	7.14	(Winner 1986)	0.72	58		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction , brood size	Less than 24hrs	7.14	(Winner 1986)	0.36	58		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction, brood size	Less than 24hrs	7.35	(Winner 1986)	0.1	230		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction, brood size	Less than 24hrs	7.39	(Winner 1986)	0.72	230		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction, brood size	Less than 24hrs	7.39	(Winner 1986)	0.36	230		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction , brood size	Less than 24hrs	7.78	(Winner 1986)	0.1	115		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	MATC	Reproduction , number of young per adult	Less than 24hrs	13.7	(Elnabarawy et al. 1986	1	240		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Repro - Number of young per survivor	Less than 24hrs	0.03	(Roux et al. 1993)	0.5	85		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	2.7	(Winner 1986)	0.1	58		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction (day of first reproduction)	Less than 24hrs	5	(Ingersoll and Winner 1982)	0.5	106		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5	(Winner 1986)	0.72	115		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5	(Winner 1986)	0.36	115		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5	(Ingersoll and Winner 1982)	0.5	106		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5.1	(Winner 1986)	0.72	58		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5.1	(Winner 1986)	0.36	58		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5.2	(Winner 1986)	0.1	230		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5.4	(Winner 1986)	0.72	230		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5.4	(Winner 1986)	0.36	230		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	5.6	(Winner 1986)	0.1	115		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	10	(Ingersoll and Winner 1982)	0.5	106		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	NOEC	Reproduction , brood size	Less than 24hrs	15	(Ingersoll and Winner 1982)	0.5	106		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	EC50	Reproduction , brood size young per adult	Less than 24hrs	15.3	(Elnabarawy et al. 1986	1	240		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Daphnia pulex*	Water flea	LC50	Mortality	Less than 24hrs	15.3	(Elnabarawy et al. 1986	1	240		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Echinogammarus meridionalis*	Gammarid amphipod	LOEC	Feeding inhibition	Adult	6.35	(Pestana et al. 2007)	1	263	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Echinogammarus meridionalis*	Gammarid amphipod	NOEC	Feeding inhibition	Adult	4.2	(Pestana et al. 2007)	1	263		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Erythemis simplicicollis*	Dragonfly	NOEC	Mortality	Larva	1.00E+05	(Tollett et al. 2009)	0.5	120	Yes	No other available data
Invertebrates	*Gammarus fasciatus*	Amphipod	LOEC	Mortality	0 - 7 d old	2.23	(Borgmann et al. 1989)	1	90	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Gammarus fasciatus*	Amphipod	MATC	Mortality	0 - 7 d old	1.82	(Borgmann et al. 1989)	1	90		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Gammarus fasciatus*	Amphipod	NOEC	Mortality	0 - 7 d old	1.49	(Borgmann et al. 1989)	1	90		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	LOEC	Behaviour - Inhibition of swimming ability	Adult	7.5	(Felten et al. 2008)	1	269	Yes	Long duration LOEC preferred over NOEC, MATC
Invertebrates	*Gammarus pulex*	Amphipod	LOEC	Respiration	Adult	7.5	(Felten et al. 2008)	1	269	Yes	Long duration LOEC preferred over NOEC, MATC
Invertebrates	*Gammarus pulex*	Amphipod	LOEC	Feeding inhibition	Adult	15	(Felten et al. 2008)	1	269	Yes	Long duration LOEC preferred over NOEC, MATC
Invertebrates	*Gammarus pulex*	Amphipod	LOEC	Behaviour - Inhibition of swimming ability	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	LOEC	Respiration	Adult	15	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	MATC	Behaviour - Inhibition of swimming ability	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	MATC	Behaviour - Inhibition of swimming ability	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	MATC	Respiration	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	MATC	Feeding inhibition	Adult	10.6	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	MATC	Respiration	Adult	10.6	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	NOEC	Behaviour - Inhibition of swimming ability	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	NOEC	Feeding inhibition	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	NOEC	Respiration	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	NOEC	Respiration	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Gammarus pulex*	Amphipod	LOEC	Mortality	Adult	7.5	(Felten et al. 2008)	1	269		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Gammarus pulex*	Amphipod	LOEC	Mortality	Adult	15	(Felten et al. 2008)	1	269		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Gammarus pulex*	Amphipod	MATC	Mortality	Adult	7.5	(Felten et al. 2008)	1	269		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Gammarus pulex*	Amphipod	MATC	Mortality	Adult	10.6	(Felten et al. 2008)	1	269		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Gammarus pulex*	Amphipod	NOEC	Mortality	Adult	7.5	(Felten et al. 2008)	1	269		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Gammarus pulex*	Amphipod	NOEC	Mortality	Adult	7.5	(Felten et al. 2008)	1	269		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Gammarus pulex*	Amphipod	NOEC	Behaviour - Inhibition of swimming ability	Adult	7.5	(Felten et al. 2008)	1	269		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Hyalella azteca*	Amphipod	IC25	Biomass, decrease in	7-8 d old	0.51	(Ingersoll and Kemble 2001)	1	280	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage
Invertebrates	*Hyalella azteca*	Amphipod	IC25	Weight	7-8 d old	0.74	(Ingersoll and Kemble 2001)	1	280	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Hyalella azteca*	Amphipod	IC25	Reproduction	7-8 d old	1.4	(Ingersoll and Kemble 2001)	1	280		Not used because more sensitive endpoints (Biomass) have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	IC25	Mortality	7-8 d old	1.9	(Ingersoll and Kemble 2001)	1	280		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	IC25	Length	7-8 d old	2.6	(Ingersoll and Kemble 2001)	1	280		Not used because more sensitive endpoints (Biomass) have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	NOEC	Growth	Juvenile	2	(Suedel et al. 1997)	1	17		Not used because a preferred endpoint (IC25) is available for otherwise equivalent exposure conditions
Invertebrates	*Hyalella azteca*	Amphipod	LOEC	Mortality	0 - 7 d old	0.92	(Borgmann et al. 1989)	1	90		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LOEC	Mortality	Unknown	0.94	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	LOEC	Mortality	7-8 d old	1.9	(Ingersoll and Kemble 2001)	1	280		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LOEC	Mortality	Unknown	4.53	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LOEC	Mortality	Unknown	4.53	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LOEC	Mortality	7-8 d old	5.09	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LOEC	Mortality	Unknown	5.09	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LOEC	Mortality	7-8 d old	22.97	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LOEC	Mortality	Unknown	22.97	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LOEC	Mortality	7-8 d old	22.97	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LOEC	Mortality	Unknown	22.97	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	MATC	Mortality	Juvenile	0.16	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	MATC	Mortality	Unknown	0.67	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	MATC	Mortality	0 - 7 d old	0.72	(Borgmann et al. 1989)	1	90		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	MATC	Mortality	7-8 d old	0.98	(Ingersoll and Kemble 2001)	1	280		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	MATC	Mortality	Juvenile	1.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	MATC	Mortality	Juvenile	1.4	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	MATC	Mortality	Unknown	2.63	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	MATC	Mortality	Unknown	2.63	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	MATC	Mortality	7-8 d old	3.56	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	MATC	Mortality	Unknown	3.56	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	MATC	Mortality	7-8 d old	12.52	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	MATC	Mortality	7-8 d old	12.52	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	MATC	Mortality	Unknown	12.52	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	MATC	Mortality	Unknown	12.52	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Hyalella azteca*	Midge	NOEC	Mortality	Unknown	0.48	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	NOEC	Mortality	7-8 d old	0.51	(Ingersoll and Kemble 2001)	1	280		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	NOEC	Mortality	0 - 7 d old	0.57	(Borgmann et al. 1989)	1	90		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	NOEC	Mortality	7-8 d old	2.49	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	NOEC	Mortality	Unknown	2.49	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	NOEC	Mortality	Unknown	4.53	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	NOEC	Mortality	Unknown	4.53	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	NOEC	Mortality	7-8 d old	6.82	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	NOEC	Mortality	7-8 d old	6.82	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	NOEC	Mortality	Unknown	6.82	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	NOEC	Mortality	Unknown	6.82	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	LC50	Mortality	Juvenile	0.15	(Borgmann et al. 2005)	0.28	18		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	LC50	Mortality	0 - 7 d old	0.53	(Borgmann et al. 1991)	2	130		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	Juvenile	0.65	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	LC50	Mortality	0 - 7 d old	0.72	(Borgmann et al. 1991)	0.2	13		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LC50	Mortality	Unknown	1.12	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	Juvenile	1.2	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	Juvenile	1.6	(Borgmann et al. 2005)	1.1	124		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	Juvenile	1.7	(Suedel et al. 1997)	1	17		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LC50	Mortality	Unknown	4.53	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Amphipod	LC50	Mortality	0 - 7 d old	4.6	(Borgmann et al. 1991)	11.4	130		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LC50	Mortality	Unknown	5.09	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	7-8 d old	5.37	(Stanley et al. 2005)	1	163		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	7-8 d old	14.1	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LC50	Mortality	Unknown	14.1	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	7-8 d old	14.22	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LC50	Mortality	Unknown	14.22	(Stanley et al. 2005)	3	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Scud	LC50	Mortality	7-8 d old	18.77	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Hyalella azteca*	Midge	LC50	Mortality	Unknown	18.77	(Stanley et al. 2005)	8.96	140		Not used because non-lethal effects have been characterized in other studies

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Hydra viridissima*	Green hydra	NOEC	Population growth inhibition		0.4	(Holdway et al. 2001)	1	20	Yes	No other available data
Invertebrates	*Hydra vulgaris*	Pink hydra	NOEC	Population growth inhibition		12.5	(Holdway et al. 2001)	1	20	Yes	No other available data
Invertebrates	*Lampsilis siliquoidea*	fatmucket	IC10	Length	Juvenile	4.6	(Wang et al. 2010)	0.3	47	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage
Invertebrates	*Lampsilis siliquoidea*	fatmucket	IC20	Length	Juvenile	5	(Wang et al. 2010)	0.3	47	Yes	Low effect threshold for non-lethal endpoint in sensitive life stage
Invertebrates	*Lampsilis siliquoidea*	fatmucket	LOEC	Length	Juvenile	8.2	(Wang et al. 2010)	0.3	47		Not used because a preferred endpoint (IC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Lampsilis siliquoidea*	fatmucket	MATC	Length	Juvenile	6	(Wang et al. 2010)	0.3	47		Not used because a preferred endpoint (IC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Lampsilis siliquoidea*	fatmucket	NOEC	Length	Juvenile	4.4	(Wang et al. 2010)	0.3	47		Not used because a preferred endpoint (IC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Lampsilis siliquoidea*	fatmucket	EC50	Mortality	Juvenile	8.1	(Wang et al. 2010)	0.3	47		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lampsilis siliquoidea*	fatmucket	EC50	Mortality	Juvenile	12	(Wang et al. 2010)	0.3	47		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lampsilis siliquoidea*	fatmucket	IC10	Mortality	Juvenile	4.8	(Wang et al. 2010)	0.3	47		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lampsilis siliquoidea*	fatmucket	IC20	Mortality	Juvenile	5.7	(Wang et al. 2010)	0.3	47		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lampsilis siliquoidea*	fatmucket	LOEC	Mortality	Juvenile	8.2	(Wang et al. 2010)	0.3	47		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lampsilis siliquoidea*	fatmucket	MATC	Mortality	Juvenile	6	(Wang et al. 2010)	0.3	47		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lampsilis siliquoidea*	fatmucket	NOEC	Mortality	Juvenile	4.4	(Wang et al. 2010)	0.3	47		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Leptophlebia marginata*	Mayfly	LC50	Mortality	Unknown	3600	(Gerhardt 1992)	1	50	Yes	No non-lethal effect data available
Invertebrates	*Leptophlebia marginata*	Mayfly	LC50	Mortality	Unknown	5000	(Gerhardt 1992)	1	50	Yes	No non-lethal effect data available
Invertebrates	*Leptophlebia marginata*	Mayfly	LC50	Mortality	Unknown	5000	(Gerhardt 1992)	1	50	Yes	No non-lethal effect data available
Invertebrates	*Leptophlebia marginata*	Mayfly	LC50	Mortality	Unknown	5000	(Gerhardt 1992)	1	50	Yes	No non-lethal effect data available
Invertebrates	*Lymnaea palustris*	Marsh snail	LOEC	Growth	Adult	80	(Coeurdassier et al. 2003	0.5	284	Yes	LOEC for non-lethal endpoint preferred over NOEC, MATC, EC50, or lethal endpoints
Invertebrates	*Lymnaea palustris*	Marsh snail	LOEC	Repro - No. egg masses per individual	Adult	80	(Coeurdassier et al. 2003	0.5	284	Yes	LOEC for non-lethal endpoint preferred over NOEC, MATC, or lethal endpoints
Invertebrates	*Lymnaea palustris*	Marsh snail	LOEC	Repro - No. eggs per individual	Adult	80	(Coeurdassier et al. 2003	0.5	284	Yes	LOEC for non-lethal endpoint preferred over NOEC, MATC, EC50, or lethal endpoints
Invertebrates	*Lymnaea palustris*	Marsh snail	MATC	Growth	Adult	56.6	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	MATC	Repro - No. egg masses per individual	Adult	56.6	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	MATC	Repro - No. eggs per individual	Adult	56.6	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	NOEC	Growth	Adult	40	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	NOEC	Repro - No. egg masses per individual	Adult	40	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions

Taxonomic group	Species name	Common name	Endpoint	Effect	Lifestage	Effect Conc µg/L	Reference	DOC	Hardness	Selected	Rationale
Invertebrates	*Lymnaea palustris*	Marsh snail	NOEC	Repro - No. eggs per individual	Adult	40	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	EC50	Growth	Adult	58.2	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	EC50	Repro - No. egg masses per individual	Adult	60.9	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	EC50	Repro - No. eggs per individual	Adult	64.7	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	EC50	Repro - No. eggs per egg mass	Adult	124	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea palustris*	Marsh snail	NOEC	Mortality	Adult	320	(Coeurdassier et al. 2003	0.5	284		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lymnaea palustris*	Marsh snail	LC50	Mortality	Adult	320	(Coeurdassier et al. 2003	0.5	284		Not used because non-lethal effects have been characterized in other studies
Invertebrates	*Lymnaea stagnalis*	Great pond snail	LOEC	Growth	Adult	120	(Coeurdassier et al. 2003	0.5	284	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Lymnaea stagnalis*	Great pond snail	MATC	Growth	Adult	98	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea stagnalis*	Great pond snail	NOEC	Growth	Adult	80	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Lymnaea stagnalis*	Great pond snail	EC50	Growth	Adult	142.2	(Coeurdassier et al. 2003	0.5	284		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Pachydiplax longipennis*	Dragonfly	LOEC	Mortality	Larva	250000	(Tollett et al. 2009)	0.5	120	Yes	LOEC preferred over NOEC or MATC
Invertebrates	*Pachydiplax longipennis*	Dragonfly	MATC	Mortality	Larva	160000	(Tollett et al. 2009)	0.5	120		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Pachydiplax longipennis*	Dragonfly	NOEC	Mortality	Larva	1.00E+05	(Tollett et al. 2009)	0.5	120		Not used because a preferred endpoint (LOEC) is available for otherwise equivalent exposure conditions
Invertebrates	*Rhithrogena hageni*	Mayfly	EC10	Mortality	nymph	2571	(Brinkman and Johnston 2008)	1	48	Yes	EC10 preferred over LOEC, NOEC, or MATC
Invertebrates	*Rhithrogena hageni*	Mayfly	LOEC	Mortality	nymph	3520	(Brinkman and Johnston 2008)	1	48		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions
Invertebrates	*Rhithrogena hageni*	Mayfly	NOEC	Mortality	nymph	1880	(Brinkman and Johnston 2008)	1	48		Not used because a preferred endpoint (EC10) is available for otherwise equivalent exposure conditions

Appendix B: Additional Hardness and Dissolved Organic Carbon Evaluations

All references for the studies cited in this appendix can be found in the "References" section of the main body of the report.

Appendix B1: Hardness-Normalized and BLM-Normalized Effect Concentrations Used to Evaluate Potential Effects of Cadmium When the Toxicity Database Is Normalized to a Hardness of 160 mg/L Carbonate

The normalization with hardness uses an empirical relationship similar to that used in the BC MOE WQGs (e.g., Equation B-1). This relationship is described by a log-linear equation with slope parameter a and intercept parameter b. The slope in the BC MOE working guideline for cadmium[4] is 0.86. The reported effect concentration (EC_R) at the hardness in the original study ($Hardness_R$) can be adjusted to a normalized value (EC_N) for a hardness concentration that corresponds to the normalized condition ($Hardness_N$; 160 mg/L $CaCO_3$) using Equation B-2.

$$WQG = 10^{(a*log_{10}(Hardness)-b)} \qquad \text{Equation B-1.}$$

$$EC_N = 10^{\left[\left((log_{10}(Hardness_N)-log_{10}(Hardness_R))*a\right)+log_{10}(EC_R)\right]} \qquad \text{Equation B-2.}$$

Normalization of the toxicity database with the BLM used the procedure outlined by the US EPA (2007). Inputs to the BLM were consistent with a hardness of 160 mg/L $CaCO_3$. A DOC concentration of 1 mg/L, a pH of 8.25, and an alkalinity of 160 mg/L $CaCO_3$ was used for the analysis. Inputs for major ions were calculated from ratios with calcium consistent with those observed in the upper Fording River.

Results presented in the following table (Table B1-1) used 160 mg/L $CaCO_3$ as the hardness to which toxicity data were normalized.

The sensitivity of the hardness- and BLM-normalization approaches to varying hardness is compared with similar normalizations performed for hardness values of 80 and 320 mg/L $CaCO_3$. In Figure B1-1:

- the condition associated with a hardness of 160 mg/L $CaCO_3$, pH 8.25, alkalinity of 160 mg/L $CaCO_3$, and 1 mg/L DOC is shown with circles as symbols;
- the condition associated with a hardness of 80 mg/L $CaCO_3$, pH 8.0, alkalinity of 80 mg/L $CaCO_3$, and 1 mg/L DOC is shown with downward pointing triangles; and
- the condition associated with a hardness of 320 mg/L $CaCO_3$, pH 8.5, alkalinity of 320 mg/L $CaCO_3$, and 1 mg/L DOC is shown with upward pointing triangles.

[4] http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

Table B1-1. Hardness- and BLM-normalized effect concentrations used in the evaluation of potential effects of cadmium (Cd) to aquatic life.

				mg/L		BLM (µg/L)		Hardness Equation (µg/L)		
Species genus	Endpoint	Effect	Cd (µg/L)	DOC	Hardness	Normalized ECx	Geomean	Normalized ECx	Geomean	Reference
Daphnia magna	7 d EC10	Reproduction	0.13	0.5	170	0.18	0.25	0.12	0.20	Barata and Baird 2000
Daphnia magna	7 d EC10	Reproduction	0.14	0.5	170	0.19		0.13		Barata and Baird 2000
Daphnia magna	21 d EC16	Reproduction	0.17	1	45.3	0.50		0.48		Biesinger and Christensen 1972
Hyalella azteca	28 d IC25	Biomass	0.51	1	280	0.32	0.39	0.32	0.39	Ingersoll and Kemble 2001
Hyalella azteca	28 d IC25	Weight	0.74	1	280	0.47		0.47		Ingersoll and Kemble 2001
Oncorhynchus mykiss	62 d LOEC	Weight	0.16	2	29.4	0.74	0.74	0.65	0.65	Mebane et al. 2008
Ceriodaphnia dubia	7 d EC20	Reproduction	2.38	7.1	100	1.49	1.49	3.52	3.52	Spehar and Fiandt 1986
Gammarus fasciatus	42 d LOEC	Mortality	2.23	1	90	2.14	2.14	3.60	3.60	Borgmann et al. 1989
Hydra viridissima	7 d NOEC	Growth	0.4	1	19.5	2.73	2.73	2.29	2.29	Holdway et al. 2001
Cottus bairdi	28 d MATC	Biomass	3.7	0.9	92	6.00	2.93	5.86	2.86	Besser et al. 2007
Cottus bairdi	21 d MATC	Biomass	0.88	0.9	92	1.43		1.39		Besser et al. 2007
Acipenser transmontanus	58 d LC20	Mortality	1.5	2.5	70	3.32	3.32	2.98	2.98	Vardy et al. 2011
Prosopium williamsoni	90 d IC10	Biomass	1.25	1.9	47.8	3.59	3.59	3.41	3.41	Brinkman and Vieira 2008
Salvelinus confluentus	55 d LOEC	Growth	0.786	1	30.6	3.81	3.81	3.10	3.10	Hansen et al. 2002b
Echinogammarus meridionalis	6 d LOEC	Feeding inhibition	6.35	1	263	4.13	4.13	4.20	4.20	Pestana et al. 2007
Atyaephyra desmarestii	6 d LOEC	Feeding inhibition	6.53	1	263	4.25	4.25	4.32	4.32	Pestana et al. 2007
Ceriodaphnia reticulata	9 d LOEC	Reproduction	7.2	20.2	65	5.17	5.17	15.25	15.25	Spehar and Carlson 1984
Salmo trutta	30 d IC20	Biomass	0.87	1	29.2	3.72	5.46	3.57	4.80	Brinkman and Hansen 2007
Salmo trutta	30 d IC20	Biomass	2.18	1	67.6	5.29		4.46		Brinkman and Hansen 2007
Salmo trutta	30 d IC20	Biomass	6.62	1	151	8.28		6.95		Brinkman and Hansen 2007
Gammarus pulex	7 d LOEC	Behaviour	7.5	1	269	4.39	5.53	4.87	6.14	Felten et al. 2007
Gammarus pulex	7 d LOEC	Respiration	7.5	1	269	4.39		4.87		Felten et al. 2007
Gammarus pulex	7 d LOEC	Feeding inhibition	15	1	269	8.77		9.75		Felten et al. 2007
Chironomus tentans	60 d IC25	Hatching success	4	1	280	2.52	5.57	2.51	5.56	Ingersoll and Kemble 2001
Chironomus tentans	60 d IC25	Emergence	8.1	1	280	5.10		5.09		Ingersoll and Kemble 2001
Chironomus tentans	20 d IC25	Weight	9.9	1	280	6.23		6.22		Ingersoll and Kemble 2001
Chironomus tentans	20 d IC25	Biomass	10.3	1	280	6.48		6.47		Ingersoll and Kemble 2001
Chironomus tentans	60 d IC25	Reproduction	16.4	1	280	10.30		10.31		Ingersoll and Kemble 2001
Salmo salar	496 d LOEC	Weight	0.47	1	28	2.56	5.83	2.00	4.61	Rombough and Garside 1982
Salmo salar	470 d LOEC	Weight	2.5	1	28	13.28		10.62		Rombough and Garside 1982
Oncorhynchus tshawytscha	8 d LC10	Mortality	1.2	1.4	24	6.02	6.65	5.79	6.41	Chapman 1978
Oncorhynchus tshawytscha	8 d LC10	Mortality	1.3	1.4	24	6.51		6.28		Chapman 1978
Oncorhynchus tshawytscha	8 d LC10	Mortality	1.5	1.4	24	7.50		7.24		Chapman 1978
Daphnia pulex	42 d LOEC	Reproduction	10.4	0.1	230	8.87	11.98	7.70	10.98	Winner 1986
Daphnia pulex	42 d LOEC	Reproduction	4.8	0.1	58	11.90		11.14		Winner 1986
Daphnia pulex	58 d LOEC	Reproduction	10	0.5	106	15.14		14.07		Ingersoll and Winner 1982
Daphnia pulex	42 d LOEC	Reproduction	10.8	0.1	115	17.26		14.21		Winner 1986
Daphnia pulex	58 d LOEC	Reproduction	10	0.5	106	15.14		14.07		Ingersoll and Winner 1982
Daphnia pulex	58 d LOEC	Reproduction	15	0.5	106	22.74		21.11		Ingersoll and Winner 1982
Daphnia pulex	58 d LOEC	Reproduction	20	0.5	106	30.36		28.15		Ingersoll and Winner 1982
Daphnia pulex	21 d LOEC	Reproduction	0.3	0.5	85	0.84		0.51		Roux et al. 1993
Daphnia pulex	42 d LOEC	Reproduction	10.1	0.36	230	8.20		7.47		Winner 1986
Daphnia pulex	42 d LOEC	Reproduction	10	0.36	58	22.11		23.22		Winner 1986

Table B1-1. Hardness- and BLM-normalized effect concentrations used in the evaluation of potential effects of cadmium (Cd) to aquatic life.

Species genus	Endpoint	Effect	Cd (µg/L)	mg/L		BLM (µg/L)		Hardness Equation (µg/L)		Reference
				DOC	Hardness	Normalized ECx	Geomean	Normalized ECx	Geomean	
Daphnia pulex	42 d LOEC	Reproduction	9.9	0.36	115	14.61		13.02		Winner 1986
Daphnia pulex	42 d LOEC	Reproduction	10.1	0.72	230	7.70		7.47		Winner 1986
Daphnia pulex	42 d LOEC	Reproduction	10	0.72	58	19.22		23.22		Winner 1986
Daphnia pulex	42 d LOEC	Reproduction	9.9	0.72	115	13.22		13.02		Winner 1986
Salvelinus fontinalis	126 d LOEC	Biomass	3.8	1	45	12.21	12.21	10.89	10.89	Eaton et al. 1978
Ankistrodesmus falcatus	96 h NOEC	Growth	10	0.5	121	15.24	15.24	12.59	12.59	Baer et al. 1999
Ictalurus punctatus	60 d LOEC	Weight	17	1	185	17.17	17.17	15.07	15.07	Sauter et al. 1976
Lampsilis siliquoidea	28 d IC10	Length	4.6	0.3	47	20.31	21.16	12.72	13.26	Wang et al. 2010
Lampsilis siliquoidea	28 d IC20	Length	5	0.3	47	22.03		13.82		Wang et al. 2010
Pseudokirchneriella subcapitata	72 h EC10	Growth rate	2.8	1.8	3.4	18.78	22.28	68.46	51.97	Kallqvist 2009
Pseudokirchneriella subcapitata	72 h EC10	Growth rate	6	4.1	46.2	13.82		16.82		Kallqvist 2009
Pseudokirchneriella subcapitata	72 h EC10	Growth rate	7.5	4.1	6.2	30.34		111.38		Kallqvist 2009
Pseudokirchneriella subcapitata	72 h EC10	Growth rate	8.5	4.1	16.2	31.30		56.88		Kallqvist 2009
Oncorhynchus kisutch	27 d LOEC	Biomass	3.4	1	45	10.94	25.51	9.74	23.21	Eaton et al. 1978
Oncorhynchus kisutch	47 d LOEC	Biomass	12.5	1	45	38.95		35.82		Eaton et al. 1978
Oncorhynchus kisutch	62 d LOEC	Biomass	12.5	1	45	38.95		35.82		Eaton et al. 1978
Pimephales promelas	32 d EC20	Growth	10	2	43.9	28.90	28.90	29.25	29.25	Spehar and Fiandt 1986
Catostomus commersoni	40 d LOEC	Biomass	12	1	45	37.25	37.25	34.39	34.39	Eaton et al. 1978
Salvelinus namaycush	64 d LOEC	Biomass	12.3	1	45	38.34	38.34	35.25	35.25	Eaton et al. 1978
Micropterus dolomieui	33 d LOEC	Biomass	12.7	1	45	39.24	39.24	36.40	36.40	Eaton et al. 1978
Esox lucius	35 d LOEC	Biomass	12.9	1	45	39.96	39.96	36.97	36.97	Eaton et al. 1978
Lymnaea palustris	28 d LOEC	Growth	80	0.5	284	45.00	45.00	49.66	49.66	Coeurdassier et al. 2003
Lymnaea palustris	28 d LOEC	Reproduction	80	0.5	284	45.00		49.66		Coeurdassier et al. 2003
Lymnaea palustris	28 d LOEC	Reproduction	80	0.5	284	45.00		49.66		Coeurdassier et al. 2003
Lymnaea stagnalis	28 d LOEC	Growth	120	0.5	284	67.03	67.03	74.50	74.50	Coeurdassier et al. 2003
Aeolosoma headleyi	14 d LOEC	Population growth	50.2	0.5	168	70.58	70.58	48.21	48.21	Niederlehner et al. 1984
Hydra vulgaris	7 d NOEC	Population growth	12.5	1	19.5	71.91	71.91	71.71	71.71	Holdway et al. 2001
Lemna minor	7 d EC50	Growth rate	214	0.5	166.8	149.5	149.5	206.8	206.8	Drost et al. 2007
Chironomus riparius	17 d LOEC	Mortality	150	1	98	241.7	241.7	225.3	225.3	Pascoe et al. 1989
Ambystoma gracile	24 d LOEC	Weight	193.1	1	45	570.9	570.9	553.4	553.4	Nebeker et al. 1995
Baetis rhodani	5 d LC50	Mortality	2300	1	50	5795	6513	6039	6784	Gerhardt 1992
Baetis rhodani	5 d LC50	Mortality	2500	1	50	6317		6564		Gerhardt 1992
Baetis rhodani	5 d LC50	Mortality	3000	1	50	7547		7877		Gerhardt 1992
Rhithrogena hageni	10 d EC10	Mortality	2571	1	48	6874	6874	6983	6983	Brinkman and Johnston 2008
Leptophlebia marginata	5 d LC50	Mortality	5000	1	50	12523	11609	13129	12094	Gerhardt 1992
Leptophlebia marginata	5 d LC50	Mortality	5000	1	50	12646		13129		Gerhardt 1992
Leptophlebia marginata	5 d LC50	Mortality	3600	1	50	9022		9453		Gerhardt 1992
Leptophlebia marginata	5 d LC50	Mortality	5000	1	50	12714		13129		Gerhardt 1992
Erythemis simplicicollis	7 d NOEC	Mortality	1.00E+05	0.5	120	122416	122416	126969	126969	Tollett et al. 2009
Pachydiplax longipennis	7 d LOEC	Mortality	250000	0.5	120	309243	309243	317424	317424	Tollett et al. 2009

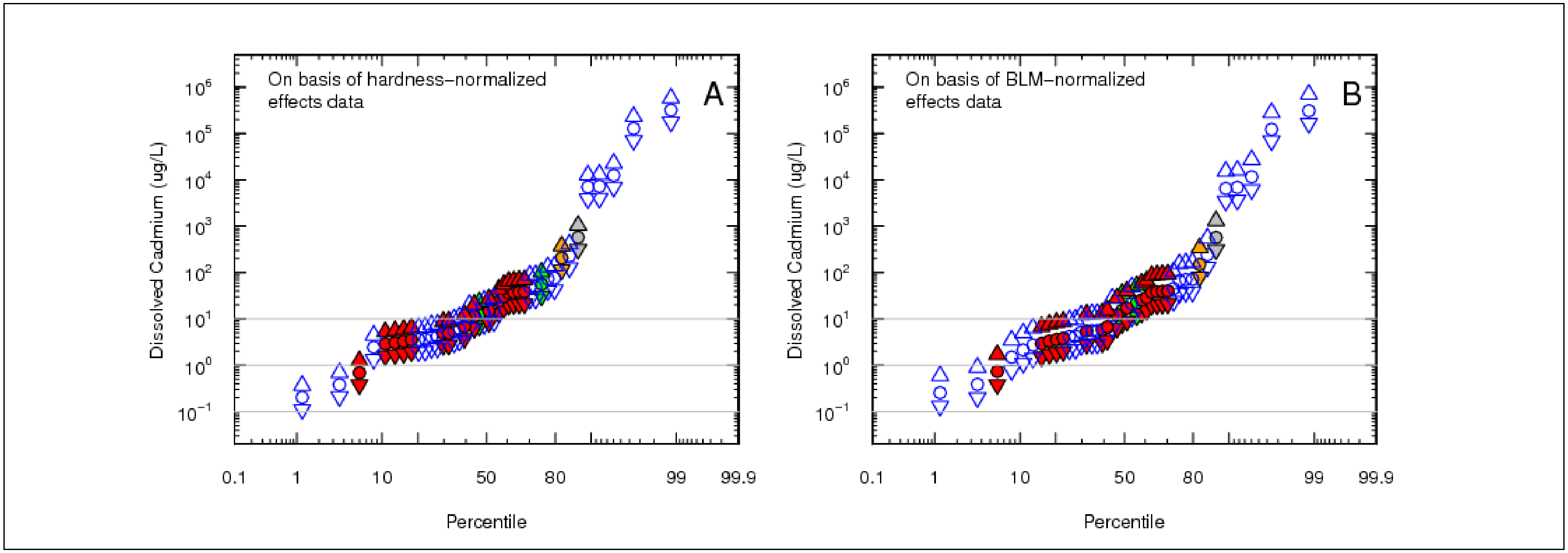

Figure B1-1. Comparison of Hardness-Normalization and BLM-Normalization Approaches for a Range of Hardness Conditions

In panel A, the toxicity data used in the effects characterization were normalized with the hardness equation; in panel B, the toxicity data used in the effects characterization were normalized with the BLM. Upward pointing triangles represent a hardness condition with 320 mg/L $CaCO_3$, circles represent a hardness of 160 mg/L $CaCO_3$, and downward pointing triangles represent a hardness of 80 mg/L $CaCO_3$.

Appendix B2: Evaluation of Dissolved Organic Carbon Concentration Assumptions for Cadmium Toxicity Data That Did Not Report DOC Concentrations

In the assembled toxicity database, several studies did not report the DOC concentration in the exposure water. To perform BLM normalizations with these data, it was necessary to assume DOC concentrations for those exposures. For synthetic waters, a default DOC concentration of 0.5 mg/L was used, and for dechlorinated tap water a DOC value of 1.0 mg/L was employed. These DOC assumptions were used for 359 of the 508 records in the assembled cadmium toxicity database.

To evaluate the impact of these DOC assumptions on BLM normalizations, a sensitivity analysis was conducted over a range of DOC concentrations that may be expected to occur in laboratory waters that likely have low DOC concentrations (i.e., reconstituted waters made from laboratory waters). The DOC range selected for this analysis was 0.5 mg/L to 3 mg/L, and these values were used only when DOC concentrations were not reported in the original study.

The effect of these DOC assumptions is shown for the three most sensitive species in the toxicity database (Table B2-1). Values in the table represent the normalized effect concentration and the percent change in the value under the specified DOC assumption (i.e., in parentheses). The DOC concentration for the rainbow trout (*Oncorhynchus mykiss)* test was specified in the original study, so modification was necessary in this sensitivity analysis. This analysis demonstrates that the assumptions used for DOC concentrations do not appreciably affect the results and therefore do not change the conclusions or the comparisons used to develop the effect matrices (e.g., Figure 17-25).

Table B2-1. Evaluation of DOC Assumptions on BLM-Normalized Effect Concentrations for the Three Most Sensitive Species in the Cadmium Toxicity Database

Species	Normalized Effect Concentration (µg/L)			
	0.5x DOC assumption	1x DOC assumption	2x DOC assumption	3x DOC assumption
Daphnia magna	0.263 (+6.47%)	0.247	0.220 (-10.6%)	0.200 (-19.0%)
Hyalella azteca	0.389 (+3.70%)	0.375	0.350 (-6.68%)	0.328 (-12.5%)
Oncorhynchus mykiss	0.712	0.712	0.712	0.712

Appendix C: Estimating Summary Statistics for Datasets That Include Values Below the Detection Limit

In the analysis of water quality data that were collected at various monitoring stations within the Elk Valley, reported analyte (e.g., cadmium [Cd]) concentrations were frequently below analytical detection limits (BDLs). As a result, the true concentrations for chemicals of potential concern (e.g., dissolved metals) lay somewhere between zero and the analytical method detection limit (MDL) or method reporting limit (MRL). To enable the use of these data (i.e., censored data) in evaluating summary statistics such as arithmetic and geometric means, and standard deviations, maximum likelihood estimation (MLE) procedures were used. Procedures such as MLE provide better estimates of summary statistics for censored data (e.g., BDLs) than simple blind calculations that treat BDLs as detected measurements or 'fabricate' values with the use of archaic substitution (e.g., one-half the value of the detection limit) methods (Helsel 1990). The following appendix outlines the application and subsequent evaluation (via Monte Carlo methodology) of several methods based on MLE or alternative procedures applied to data containing BDLs. Four methods were tested in this comparison and include the censored MLE (CENMLE) and regression on order statistics (ROS) procedures built into the R-statistical package (Helsel 2005), the MLE procedure built into the Biotic Ligand Model (BLM; HydroQual 2009), and a blind calculation method that treats the BDL values as regular measurements.

To evaluate these methods, a Monte Carlo procedure was used to generate a sample dataset from a known distribution. Estimates of the geometric mean and standard deviation from each of the methods could then be compared to the known answer to evaluate the accuracy and precision of each method. Sample datasets generated by Monte Carlo were intended to resemble the types of metal concentration data encountered in the Elk Valley dataset. Values for geometric mean, standard deviation, number of data points, and fraction of data that were BDL were all chosen to resemble the actual data. For a given distribution with specified geometric mean and standard deviation, individual data points were randomly generated, some noise representing plus or minus 10 percent of the value was introduced to represent analytical variability, and a detection limit was then chosen so that a specified fraction of the available data were BDL. To test these methods over a range of conditions representative of metal concentration data in the Elk Valley dataset, different values of the fraction BDL were used, ranging from 20 to 80 percent of the total number of data. An example dataset is shown in Figure C-1. For these example data, there are 10 data points and 70 percent of them are BDL. The "true" lognormal distribution used to generate the data is shown as the black diagonal line and represents a dataset with a geometric mean of 0.017, and a standard deviation of 0.75.

For this example, the ten data points were then supplied to four different estimation procedures to evaluate how well these methods could estimate summary statistics. Values that were BDL were replaced by the detection limit (Figure C-1).

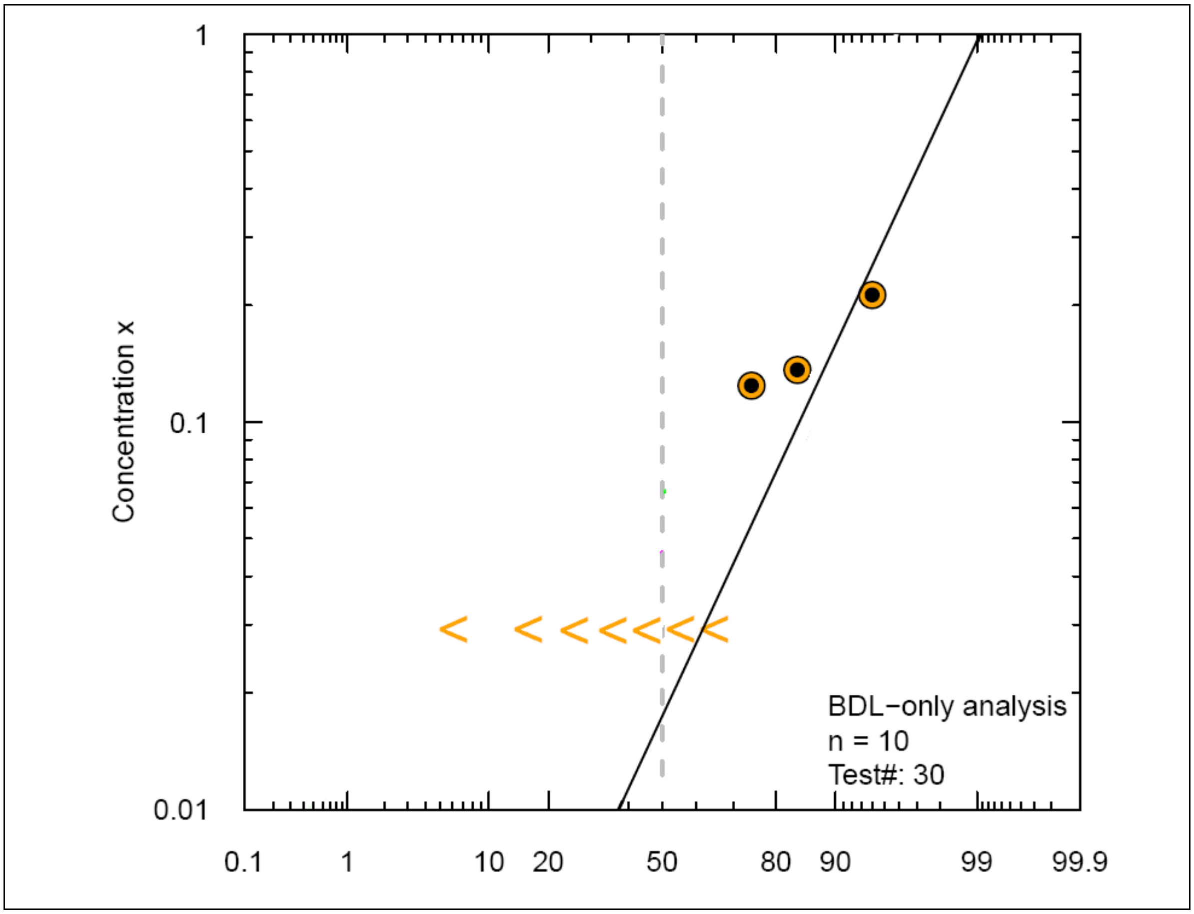

Figure C-1. An Example Test Dataset Generated for a Monte Carlo Evaluation of Numerical Procedures to Estimate Statistical Distributions for Datasets That Include Values Below an Analytical Detection Limit.

Note:

The true distribution is a lognormal distribution with a geometric mean of 0.017, and standard deviation of 0.75 and is shown with the solid black line. Ten random sample points were generated from this distribution. To each data some random noise was added. A detection limit was selected and any points with values below the detection limit were replaced with the detection limit. Observations that remain above the detection limit are shown as circles and those below the detection limit are shown as less-than (<) signs plotted at the value of the detection limit. The geometric mean, standard deviation, number of points, and proportion of data below the detection limit were all selected to be similar to actual analyte concentrations reported in the Elk Valley dataset.

The MLE procedures are based on optimization of a likelihood function (Shumway et al. 2002). For a given dataset with n observations, the likelihood function is based on the following equation:

$$L = \prod_{i=1}^{n} P(x_i)^{1-\delta_i} \times C(x_i)^{\delta_i} \qquad \text{C-1}$$

Where, for the likelihood function L across n observations, P(x) is the probability density function for a normal distribution used for non-BDL values of x, and C(x) is the cumulative density function used for BDL values of x.

For a given mean (μ) and standard deviation (σ), the probability density function is:

$$P(x) = \frac{exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right]}{\sigma\sqrt{2\pi}} \qquad \text{C-2}$$

For the same distribution, a cumulative density function is defined as:

$$C(x) = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\mu}{\sqrt{2\sigma^2}}\right)\right] \qquad \text{C-3}$$

Where erf is the Gauss error function (Andrews 1997). For detected observations, the censored flag δ is 0, so only the term for P(x) is used in the likelihood function, and the C(x) term will drop out. For BDL observations, the censored flag δ is 1 and the P(x) term will drop out. The goal of the MLE procedure is to find a mean (μ) and standard deviation (σ) that maximizes L (Equation C-1) for a given dataset that includes both detected and BDL observations. For a log-normally distributed dataset, a geometric mean can be found by applying the MLE to log-transformed values of x.

The blind calculation was included to allow comparison of MLE methods that consider BDL values against a simple alternative and so demonstrate the benefit of incorporating these methods into the overall analysis. As shown in the pink line in Figure C-2, if the BDL data are treated the same as other measurements, calculation of the geometric mean tends to produce a value that is higher than the true value, and the estimate of the standard deviation is lower than the true value. For this example, the resulting blind estimate of the geometric mean is 0.047, compared to an actual value of 0.017; while the estimate of the standard deviation is 0.36, compared to an actual value of 0.75.

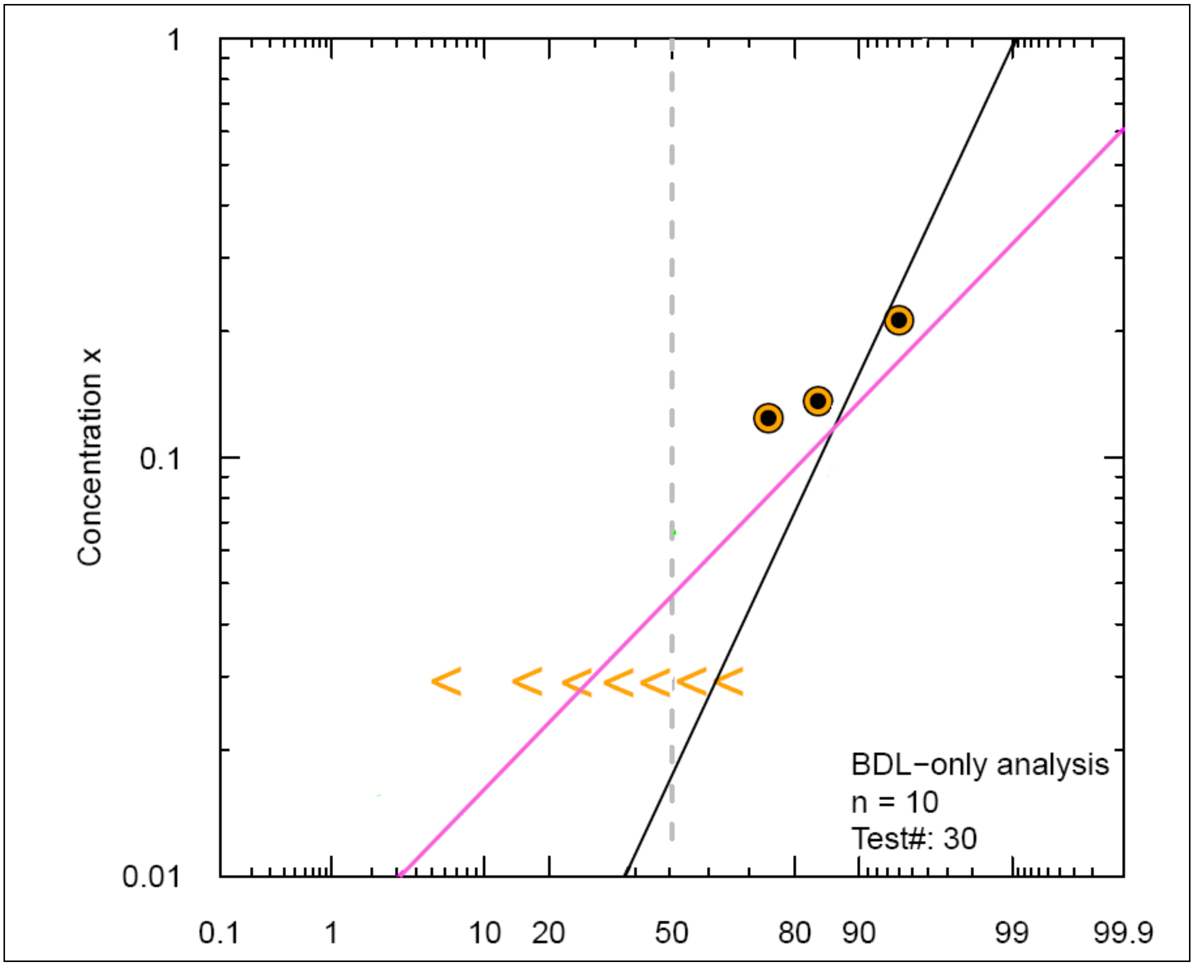

Figure C-2. An Example Blind Calculation Permitting Comparison of MLE Methods That Consider BDL Values Against a Simple Alternative

Note:

If below detection limit values shown in Figure C-1 are treated as actual measured values, the resulting geometric mean and standard deviation are biased from the true values. This blind characterization of the distribution (shown as the solid pink line) tends to overestimate the geometric mean (estimate 0.047, actual value 0.017) and underestimate the standard deviation (estimate 0.36, actual value 0.75) relative to the true distribution (shown as the solid black line).

Consideration of BDL values using an MLE procedure results in estimated summary statistics that are much closer to the true values (Figure C-3) (estimated geometric mean of 0.011 and standard deviation of 0.48). This type of comparison was repeated with a Monte Carlo procedure to generate 4000 independent datasets. Results for all 4000 comparisons of the geometric mean are shown in Figure C-4. For each estimate, the ratio of the estimated value of the geometric mean to the true value is shown as a histogram. Results from the CENMLE procedure produce a histogram that is nearly centered around a ratio of 1.0 (Figure C-4, Panel A). Results from the ROS procedure (Helsel 2005) are shown in Figure C-4 Panel B for comparison. A second MLE method incorporated in the BLM (HydroQual 2009) differs from the

CENMLE procedure in that it only assumes that the fraction of the data that are BDL are normally distributed. This method was included in this comparison since the general use of the BLM in the analysis of cadmium effects data makes this built-in procedure an attractive alternative in subsequent data analyses. For these data, the BLM-based MLE produced results that were comparable to CENMLE (Figure C-4 Panel C). The ROS procedure typically produced estimates that were somewhat more variable compared to the true value than either of the MLE procedures (i.e., the histogram in Panel B is broader, indicating that there was a higher proportion of ROS estimates with larger deviations from the true value). The blind calculation that treats BDL data the same as detected observations shows a consistent tendency to overestimate the geometric mean (Figure C-4 Panel D).

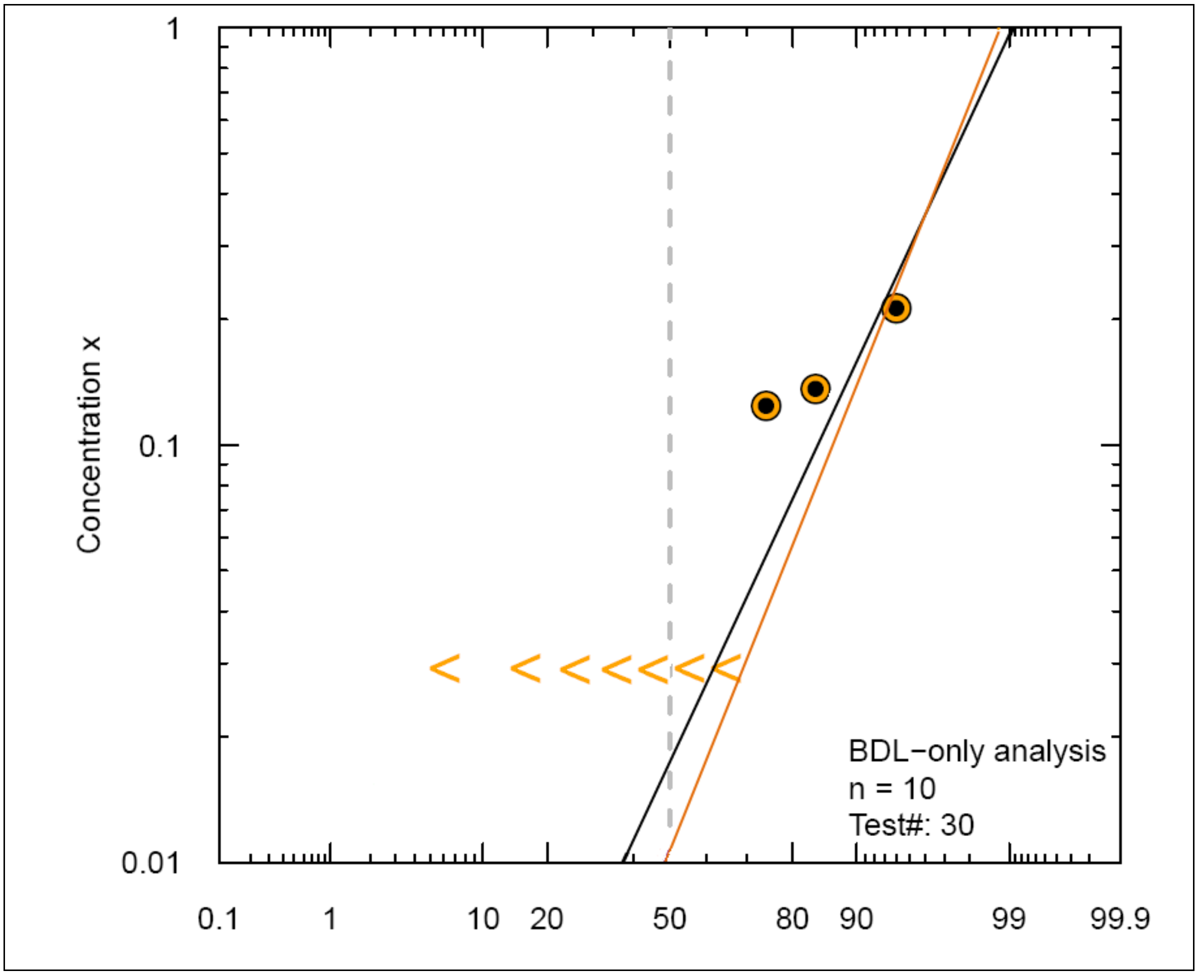

Figure C-3. An Example Calculation Incorporating BDL Values Using MLE Methods.

Note:

Summary statistics for datasets that include values below analytical detection limits can be estimated using MLE techniques. An estimate of the distribution using MLE is shown for the sample data described in Figure C-1 (brown line). The MLE estimates of the geometric mean (0.011) and standard deviation (0.48) are closer to the true distribution (shown in black) than a blind calculation that does not consider BDL values (shown in Figure C-2).

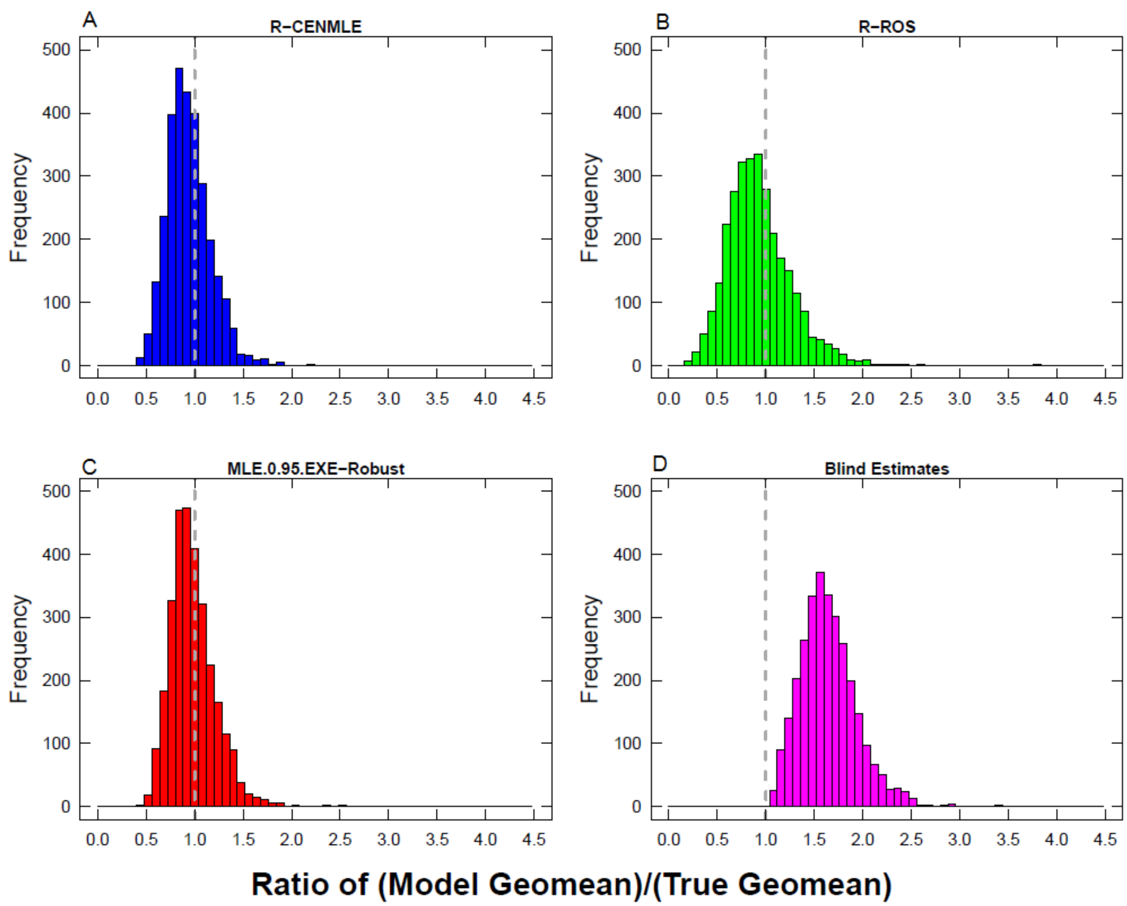

Figure C-4. Frequency Histograms for 4000 Estimates of the Geometric Mean from 4000 Different Synthetic Datasets Generated as Part of the Monte Carlo Evaluation

Note:

Results for four estimation methods are shown, including the CENMLE and ROS procedures in the R-statistical package (Panels A and B; Helsel 2005), the MLE procedure built into the BLM (Panel C) and a blind calculation that treats BDL as normal measurements (Panel D). Estimated values are shown as a ratio to the actual geomean. For this comparison, 40 percent of the synthetic data were replaced by a detection limit value.

Similar conclusions are reached from comparisons of the estimates of the standard deviation (Figure C-5). Both MLE methods and ROS produce histograms centered around a value of 1, indicating that there is no systematic bias in these methods. However, estimates from the ROS method tend to deviate from the true values more frequently (and hence a broader histogram in Figure C-5 Panel B). The blind calculation shows a systematic bias with estimates of standard deviation consistently lower than the true values.

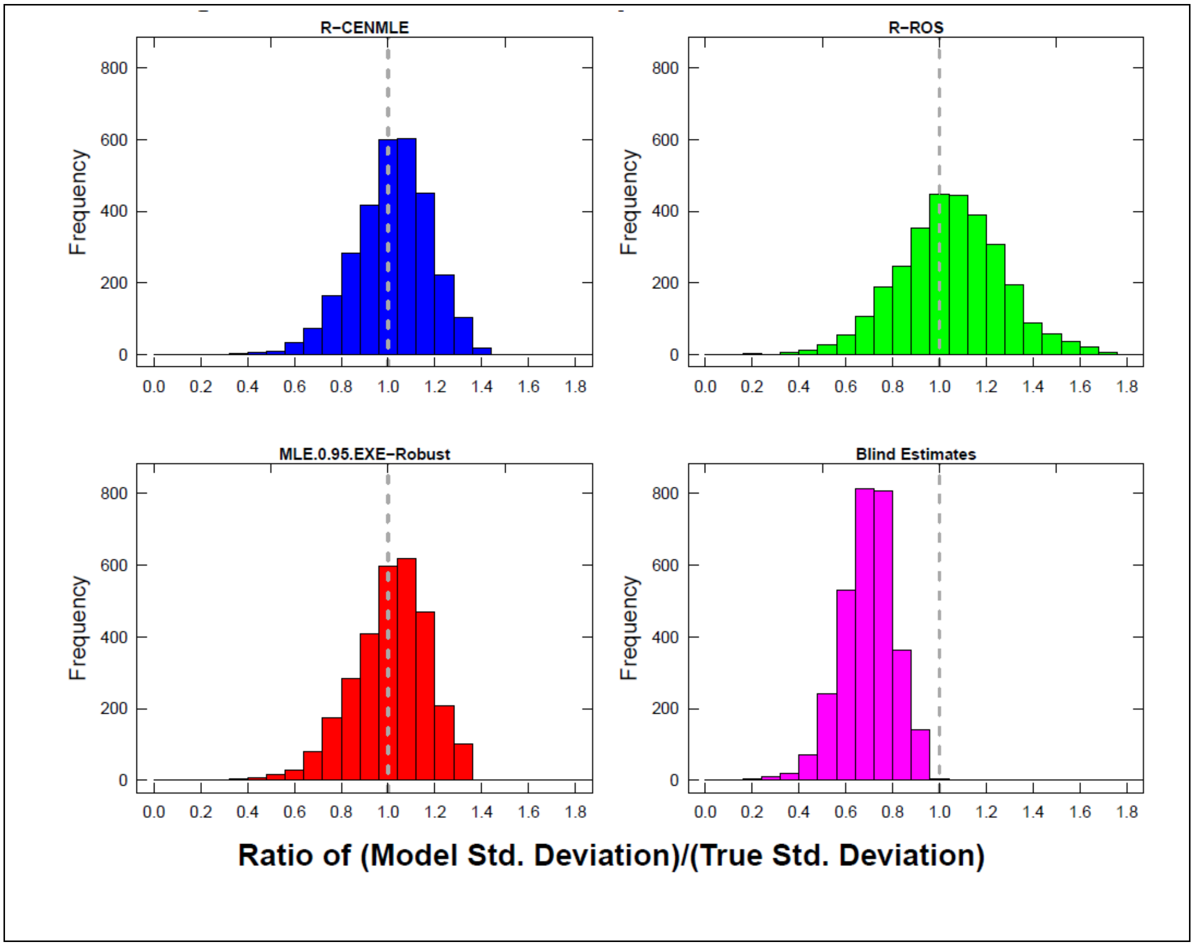

Figure C-5. Frequency Histograms for 4000 Estimates of the Standard Deviation from 4000 Different Synthetic Datasets Generated as Part of the Monte Carlo Evaluation

Note:

Results for four estimation methods are shown, including the CENMLE and ROS procedures in the R-statistical package (Panels A and B; Helsel 2005), the MLE procedure built into the BLM (Panel C) and a blind calculation that treats BDL as normal measurements (Panel D). Estimated values are shown as a ratio to the actual standard deviation. For this comparison 40 percent of the synthetic data were replaced by a detection limit value.

The Monte Carlo evaluation shown in Figures C-4 and C-5 were repeated with percentages of data from 20 to 80 percent assigned as BDL and number of data points from 10 to 30. Results from all cases were comparable to the 40 percent BDL dataset shown in Figures C-4 and C-5. The MLE methods consistently performed marginally better than ROS and considerably better than a blind estimate that did not consider BDLs. As a result and given that the R-statistical software package was used extensively in the evaluation and graphing of analyte data from the Elk and Fording rivers, the CENMLE procedure (an internal function in the R software) was chosen for the analysis of metal concentration data. Application of the CENMLE procedure was limited to datasets which had BDL values ≤ 80 percent of the total number of observations, as the procedure has been noted by others to be unreliable when more than 80 percent of the data correspond to BDL values (Helsel 2005). For datasets with greater than 80 percent BDLs, an upper bound to the geometric mean was estimated by using the detection limit values in the averaging procedure. Monte Carlo analysis shows that this result is always greater than the actual geometric mean, and values estimated this way are therefore shown with a less-than sign to indicate that the result is known to be lower than the estimated value.

The results from this comparison are consistent with recommendations by Helsel (2005, p. 78) that either MLE or ROS would be appropriate for small datasets with censored values that are 80 percent or fewer of the total data. The demonstrated performance of these methods in this Monte Carlo analysis is particularly relevant to the Elk Valley dataset, since parameters such as number of data points, geometric mean, and standard deviation were all chosen to be representative of metal concentration data from this study. The performance summarized in Figures C-4 and C-5 is therefore representative of the expected performance of the MLE procedure used in the analysis of the analyte (e.g., cadmium) concentration data in the Elk Valley dataset. For datasets where BDL values represent more than 80 percent of the total data available, MLE and ROS procedures are less reliable, and in these cases a blind estimate of the geometric mean can be used, with the acknowledgment that it is a conservative estimate shown to be biased to values greater than the actual value (as in Figure C-4 Panel D).

The MLE procedure was also used to develop box-and-whisker plots for data that included BDL values. An example of this application is shown in Figure C-6. The box in the box and whisker plot is defined such that the upper edge of the box corresponds to the 75th percentile of the original data, and the bottom edge of the box corresponds to the 25th percentile. The whiskers extend to maximum and minimum values exclusive of extreme values. Application of the box and whisker format to the true distribution from the aforementioned example is shown as the gray box in Figure C-6 Panel A. Vertical lines show where the true distribution (black line) intersects the 25th and 75th percentile. At these intersections, horizontal lines read across to the lower and upper edges of the box. The geometric mean for this distribution is equivalent to the median (50th percentile) because it is log-normally distributed, and this value is shown as a horizontal line in the middle of the box.

If BDL values are not considered and are treated the same as detected values, the result will overestimate the geometric mean, and underestimate the standard deviation, as is shown in the pink box in Figure C-6 Panel B. These graphical discrepancies are consistent with the numerical discrepancies seen in Figures C-4 and C-5.

If MLE methods are used to consider BDL values, a much better estimate of the true distribution results, such that the red box in Figure C-6 Panel C is nearly identical to the gray box that results from the true distribution. It is important to note, however, that the resulting box and whisker plot that results from the MLE analysis appears to produce a geometric mean that is lower than all of the observed data (i.e., measured values and detection limits for samples that are BDL). This apparent discrepancy results from the fact that a high proportion of the observed data are actually BDL values plotted at the detection limit. The real values that correspond to these BDL values are, by definition, lower than the detection limit. The MLE procedure considers this fact and produces an estimate of the geometric mean accordingly. Similar box and whisker plots that correspond to analyte concentrations in the Elk Valley dataset frequently exhibit similar behavior. The comparably low geometric means evident in those figures are likewise an understandable and expected consequence that results from a high proportion of BDL values in the metals datasets.

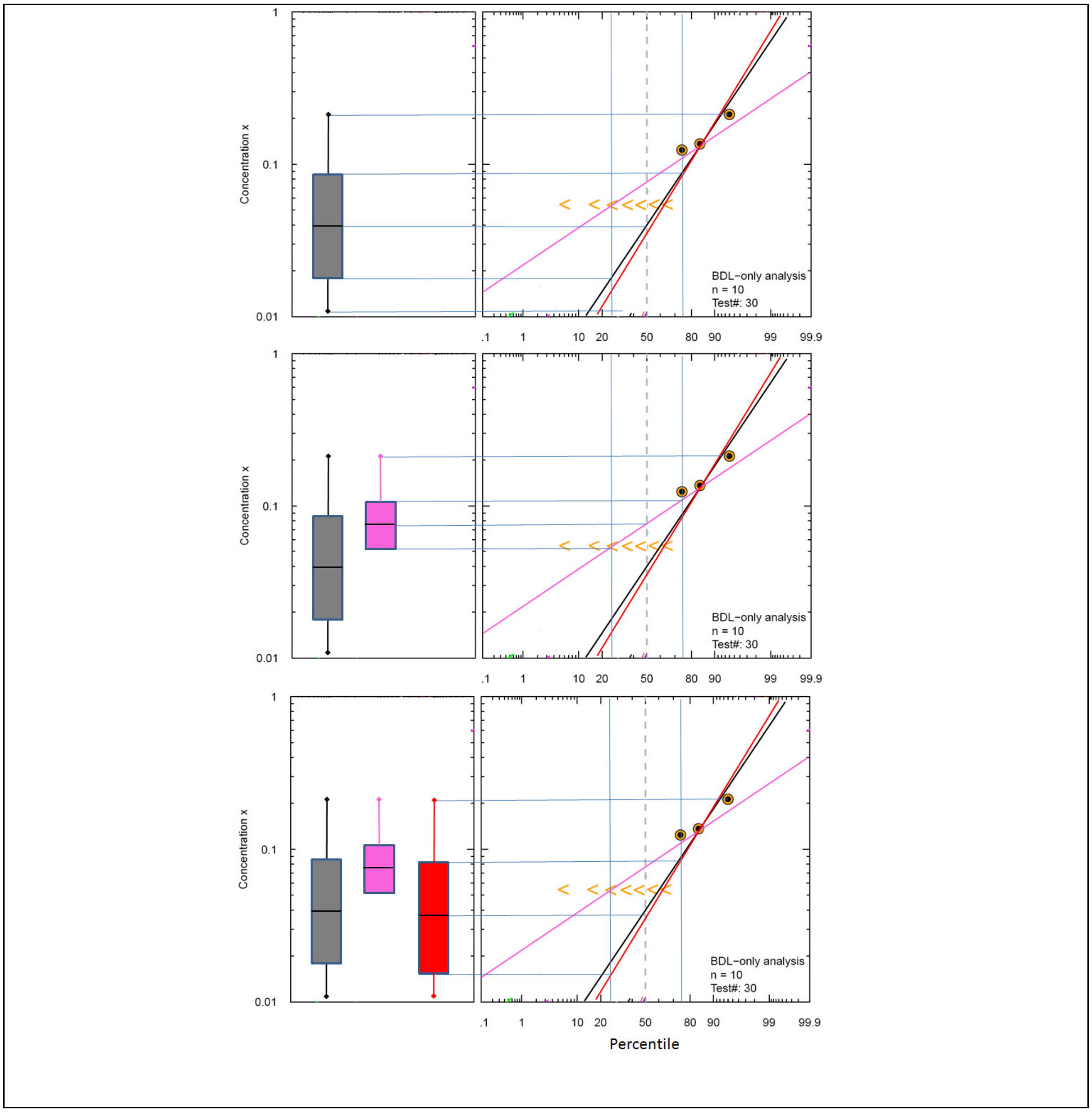

Figure C-6. Box Plots of MLE Results for Datasets That Include BDL Values

Note:

Data are the same in Figure C-1 and are drawn at random from a distribution (black line). For each box plot, the upper edge of the box represents the 75th percentile, the lower edge the 25th percentile, and the horizontal line in the middle of the figure represents the geometric mean. Whiskers above and below the box extend to minimum and maximum values. In Panel A the box plot (grey) is developed from the true distribution. In Panel B the measurements are used to develop the box plot (pink) without considering that some values are BDL and show the typical overestimation of the mean and underestimation of the standard deviation. In Panel C the summary statistics for the box plot (red) were derived from the MLE estimate of the distribution, as characterized by the geometric mean and standard deviation.

SUMMARY

- Analyte concentrations in the Elk Valley dataset frequently include values that are BDLs.
- A Monte Carlo analysis showed that ignoring the presence of BDLs resulted in systematic errors in estimates of the mean and standard deviation and should be avoided.
- Consideration of BDLs using either MLE or ROS produced unbiased estimates of the mean and standard deviation, and of these two methods the MLE procedure produced an accurate result.
- The MLE procedure, and specifically the CENMLE procedure in the R-statistical software package, was chosen for the analysis of analyte concentrations in the Elk Valley dataset to produce summary statistics and summary graphics (e.g., box and whisker plots).
- Application of the MLE was limited to datasets which had 80 percent or fewer observations flagged as BDLs. For datasets with more than 80 percent BDLs, an upper bound on the geometric mean was calculated using the reported detection limit values.

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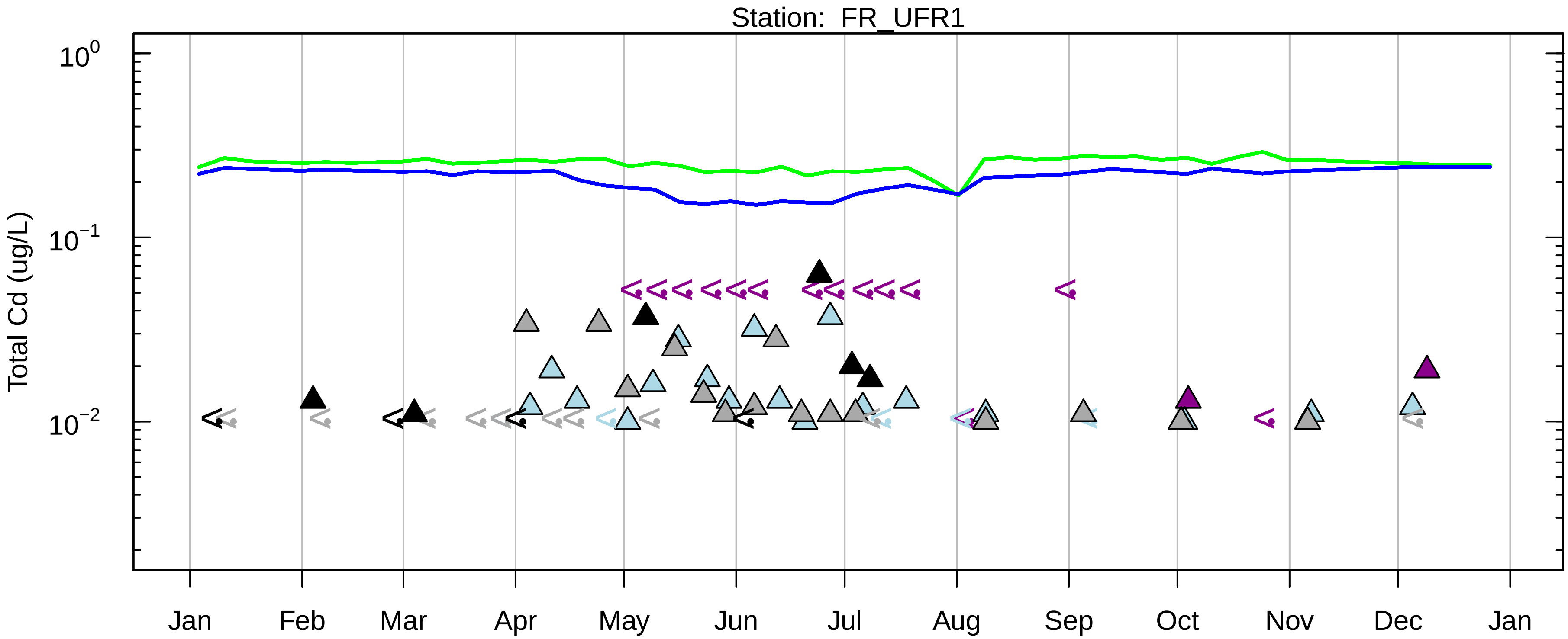
Appendix D: Seasonal Patterns in Measured Water Quality Characteristics

Selected analyte concentrations for samples collected at the order stations from 2000 to December 2013 are shown based on the day of the year samples were collected. Different colored symbols correspond to the year samples were collected as follows:

2000:
2001:
2002:
2003:
2004:
2005:
2006:
2007:
2008:
2009:
2010:
2011:
2012:
2013:

Concentration data were binned based on sampling frequency, which could be as frequent as weekly. The annual trend is shown as a segmented linear series based on the geometric mean of each bin, represented by a dashed red line, or as a step function connecting each bin, represented by a solid green line.

On plots for total and dissolved cadmium, hardness-normalized and BLM-normalized effect concentrations (EC; aggregation of 7-day EC10 values and 21-day EC16 values) for *D. magna* are demonstrate the effect of seasonal variation in water chemistry constituents on normalized effect concentrations at each station. For the hardness-normalized effect concentrations (solid blue line), the seasonal pattern reflects the variation in hardness observed through a yearly cycle. For the BLM-normalized effect concentrations, represented by a solid green line, the seasonal pattern reflects the variation in pH, alkalinity, DOC, calcium, magnesium, sodium, potassium, sulphate, and chloride concentrations observed through a yearly cycle. For the yearly patterns of these water chemistry constituents, refer to the appropriate page in this appendix. The range in the normalized effect concentrations shown for each order station within a yearly cycle is depicted as bars on the figures showing the normalized effect concentrations in the main body of the report (Figures 17 to 25).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Total Cd (ug/L)
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10^{-1}
10^{-2}
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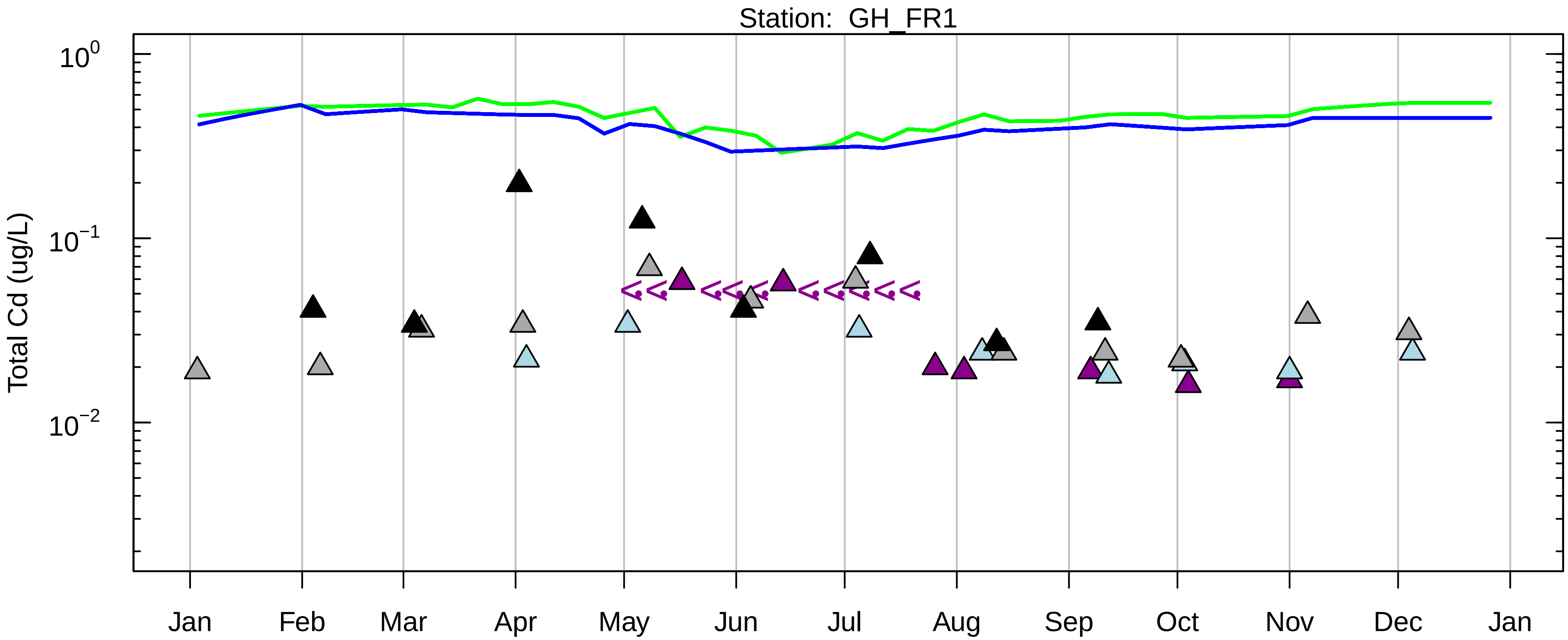
Jan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Total Cd (ug/L)
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10^{-2}
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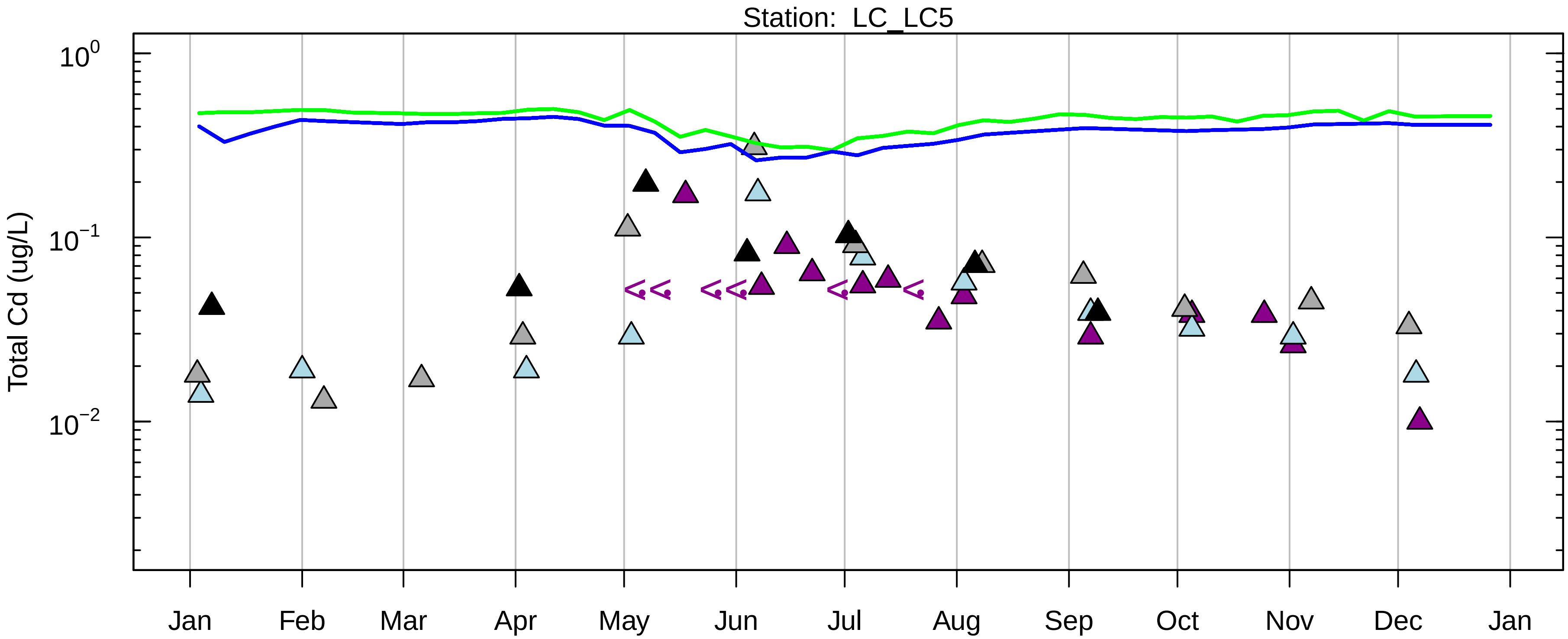

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Total Cd (ug/L)
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10^{-2}
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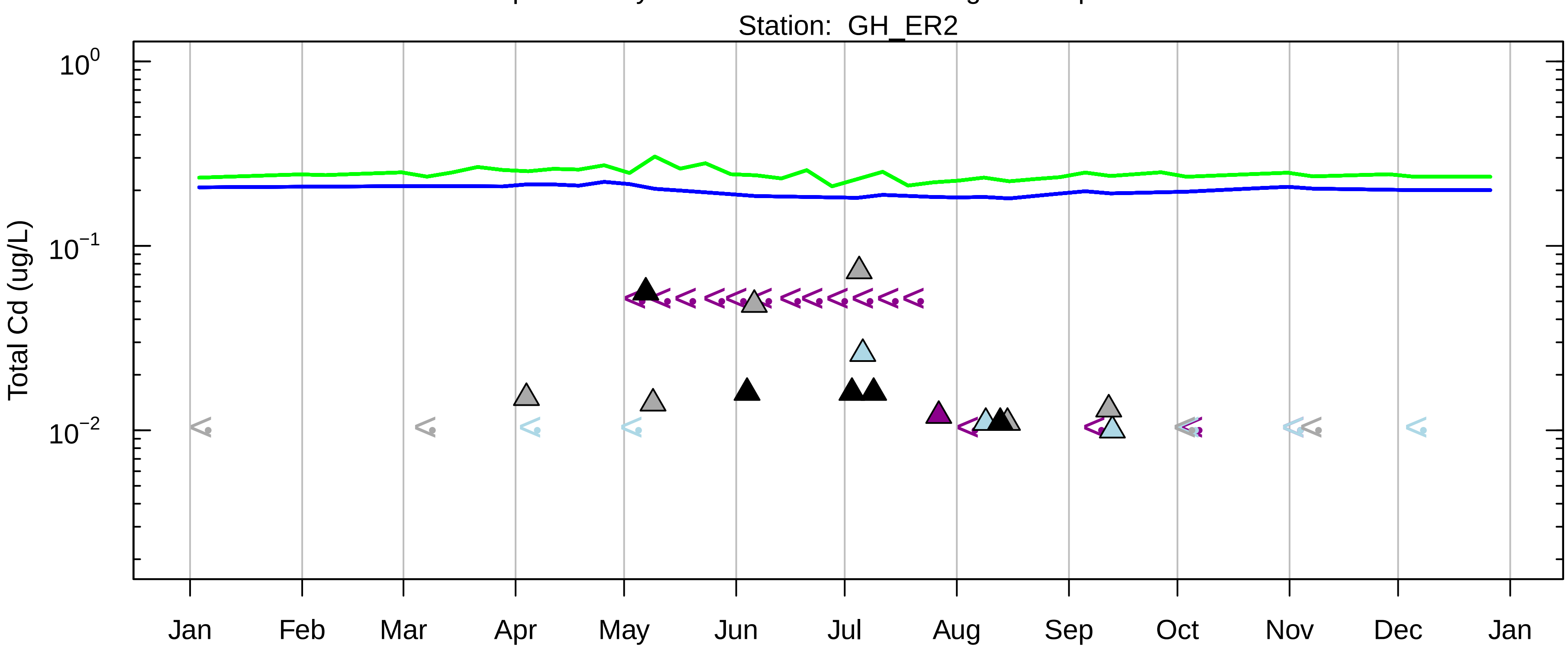

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Total Cd (ug/L)
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10^{-2}
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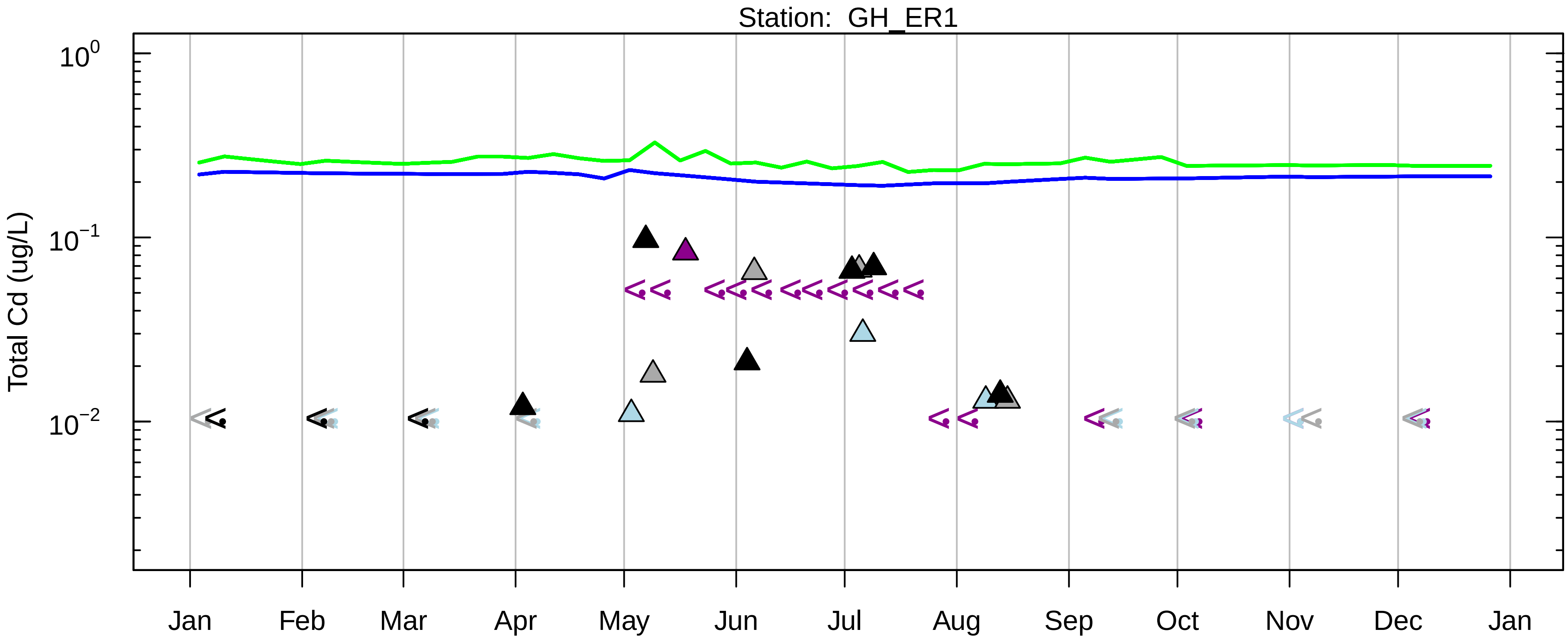
Jan



Station: GH_ER1
Total Cd (ug/L)
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10^{-2}
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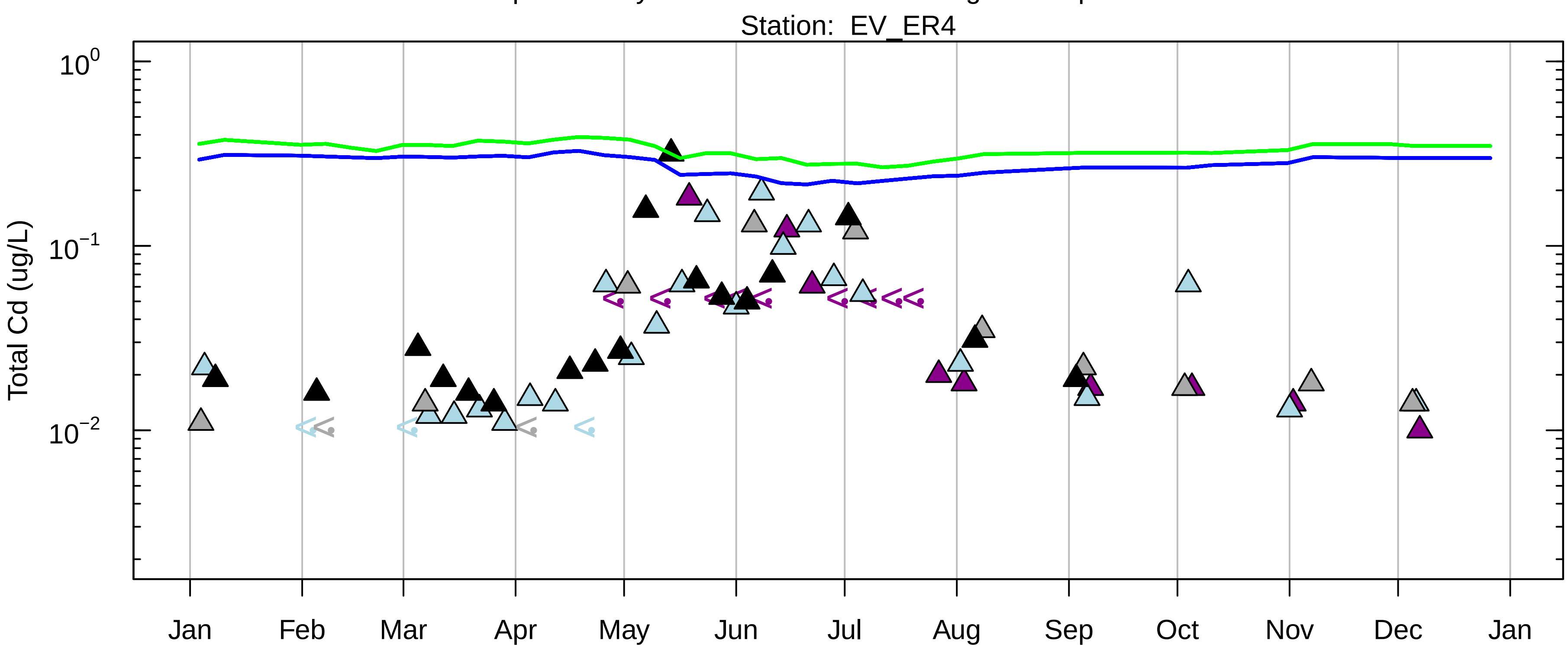

Station: EV_ER4
Total Cd (ug/L)
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10^{-2}
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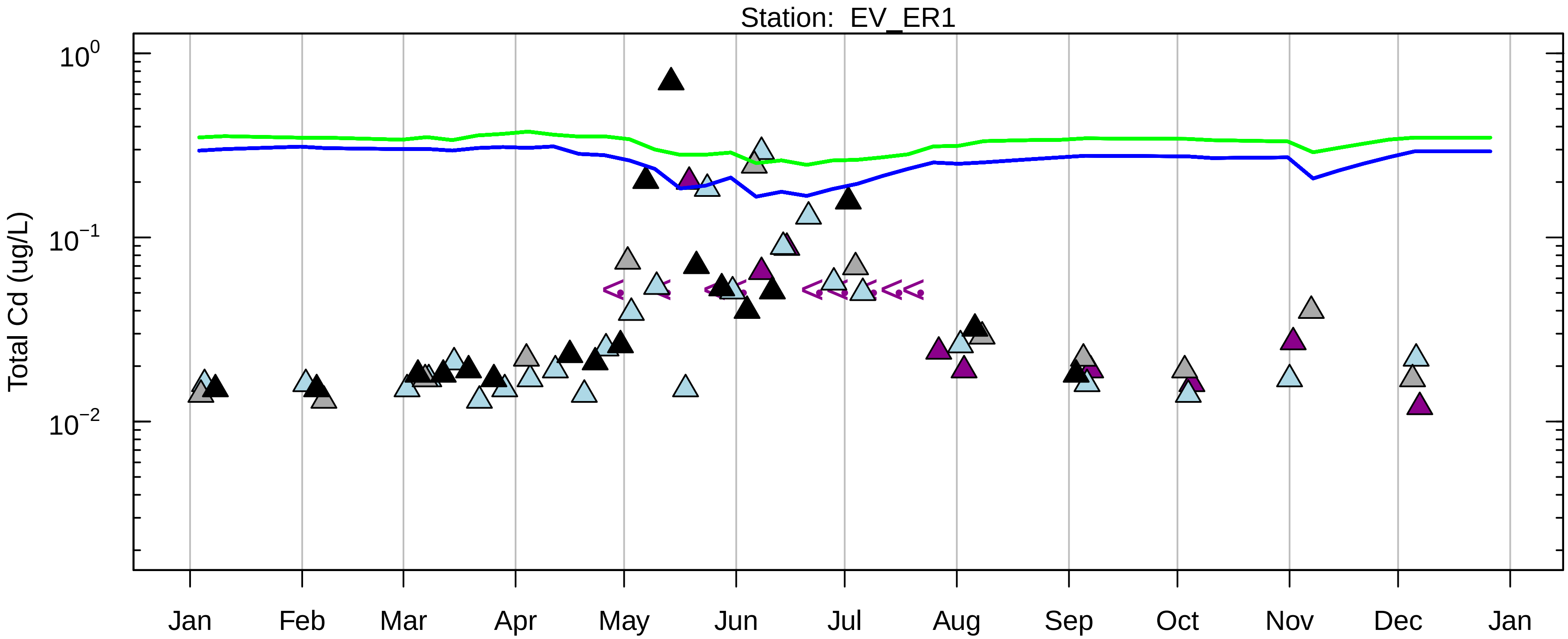
Jan



Station: EV_ER1
Total Cd (ug/L)
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10^{-1}
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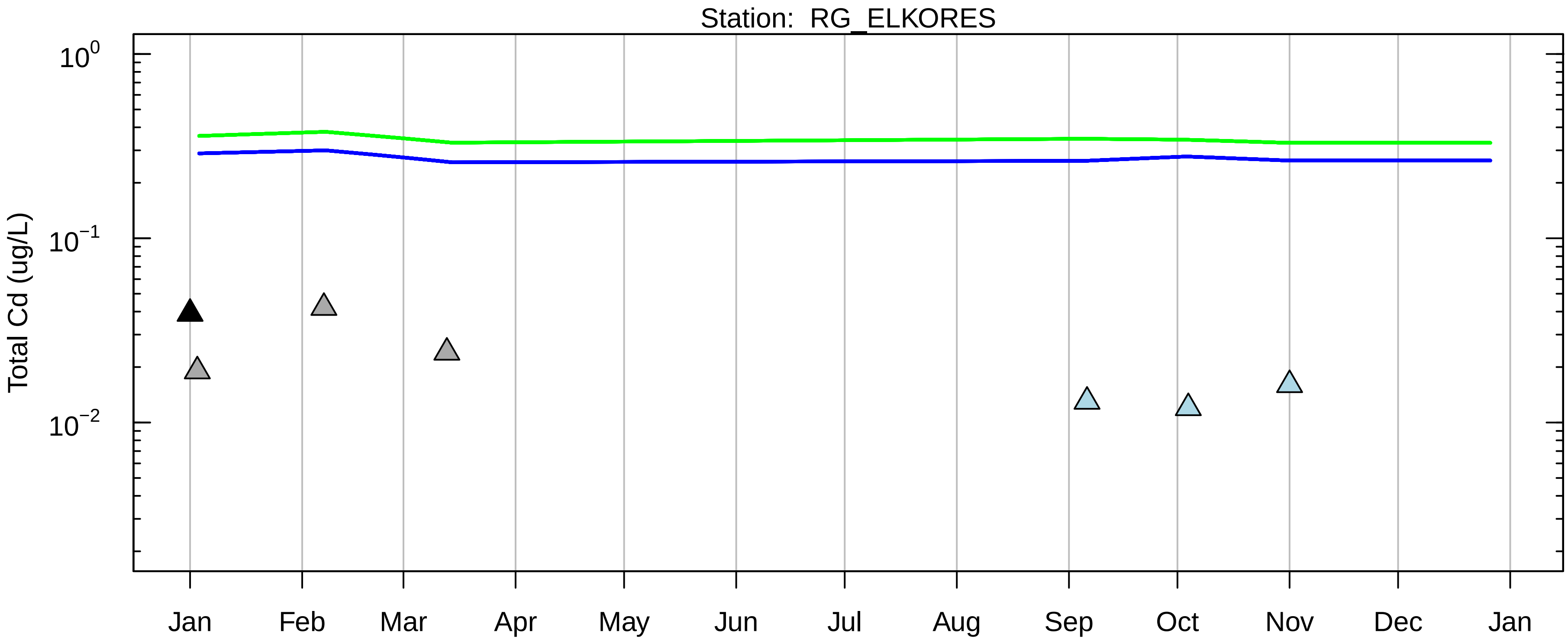
Jan



Station: RG_ELKORES
Total Cd (ug/L)
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10^{-2}
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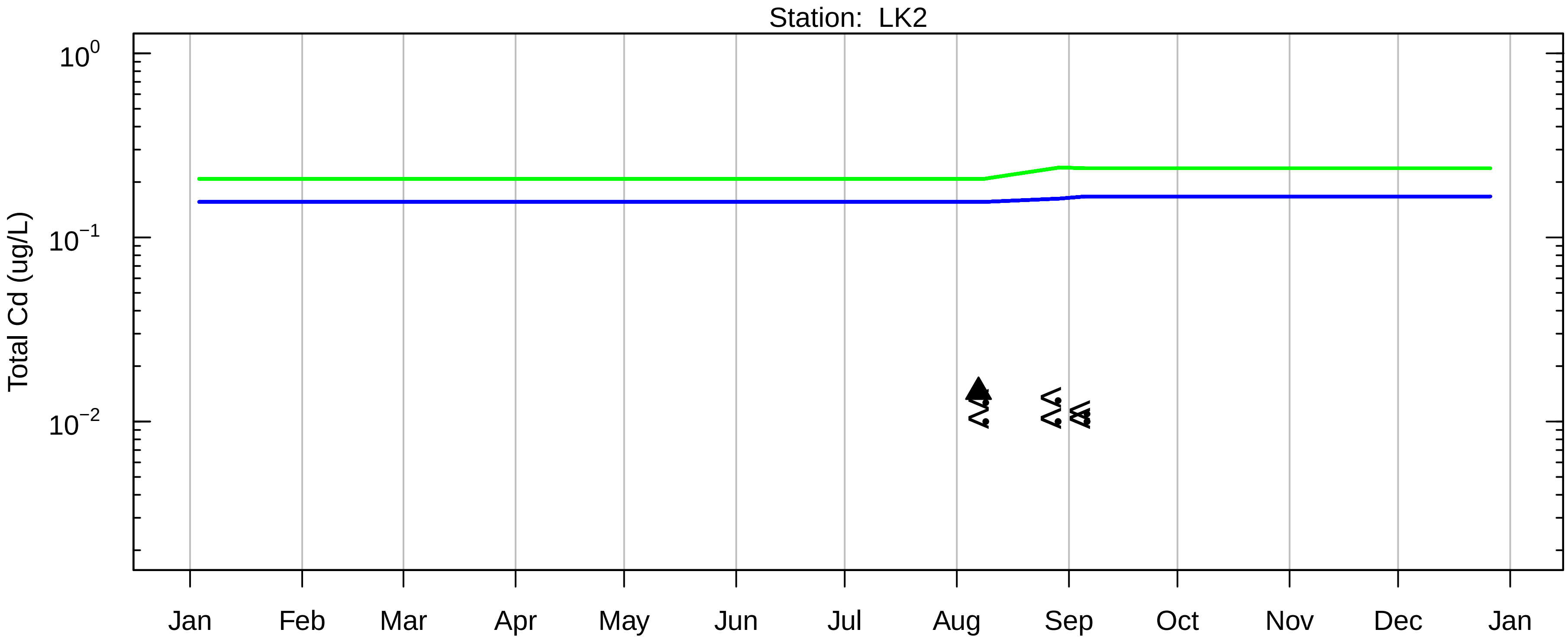
Jan



Station: LK2
Total Cd (ug/L)
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10^{-2}
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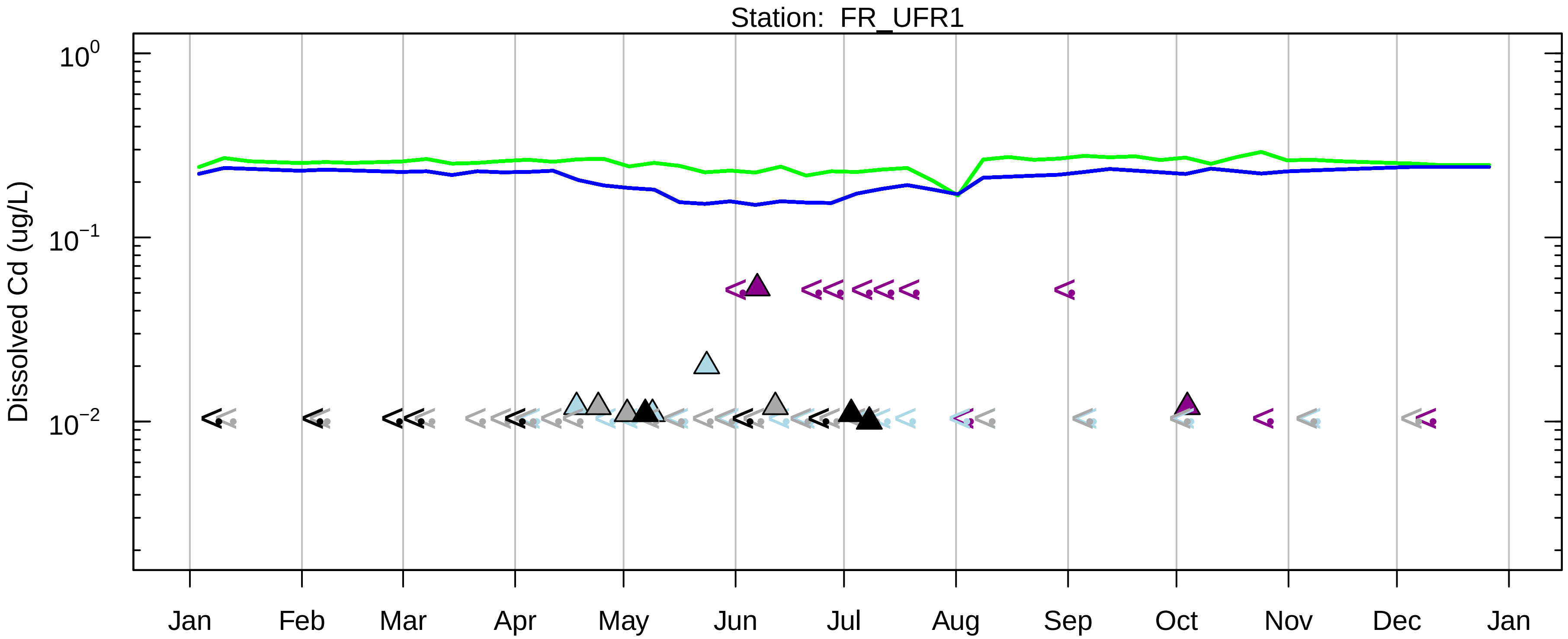
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Dissolved Cd (ug/L)
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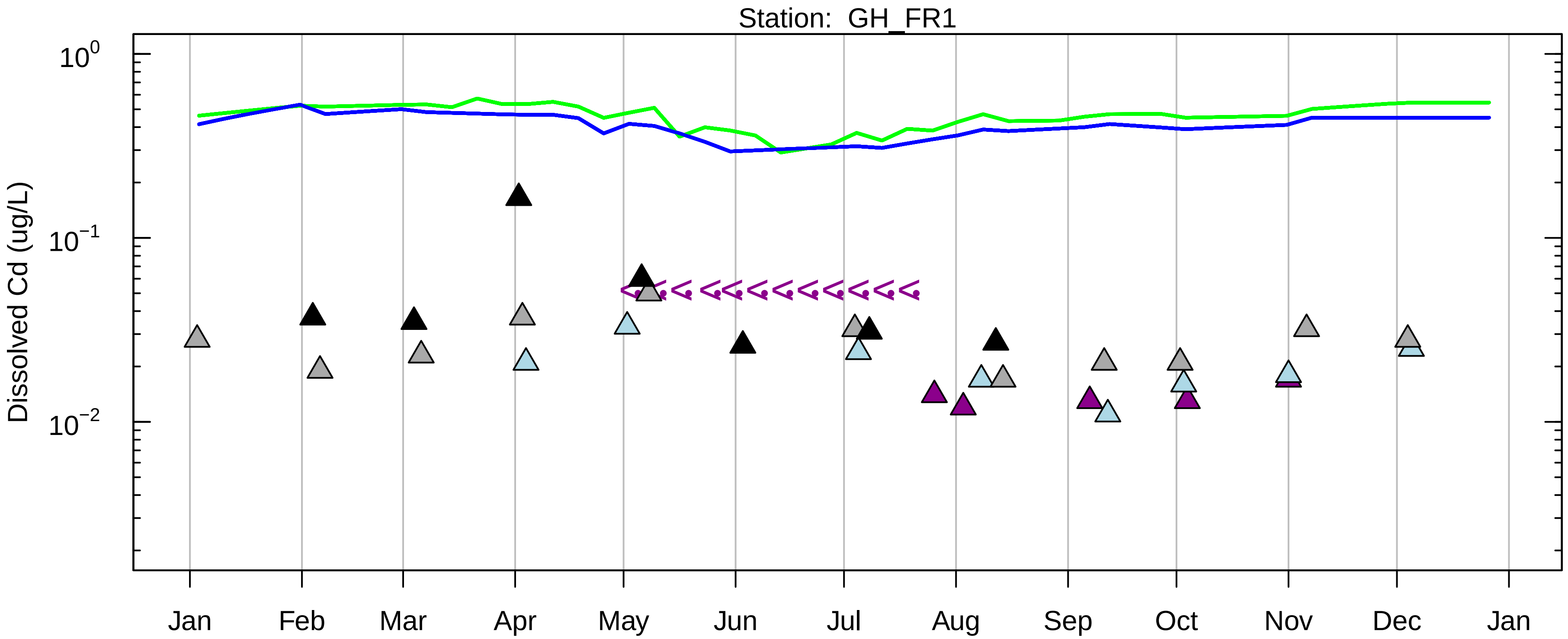
Station: GH_FR1
Dissolved Cd (ug/L)
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10^{-1}
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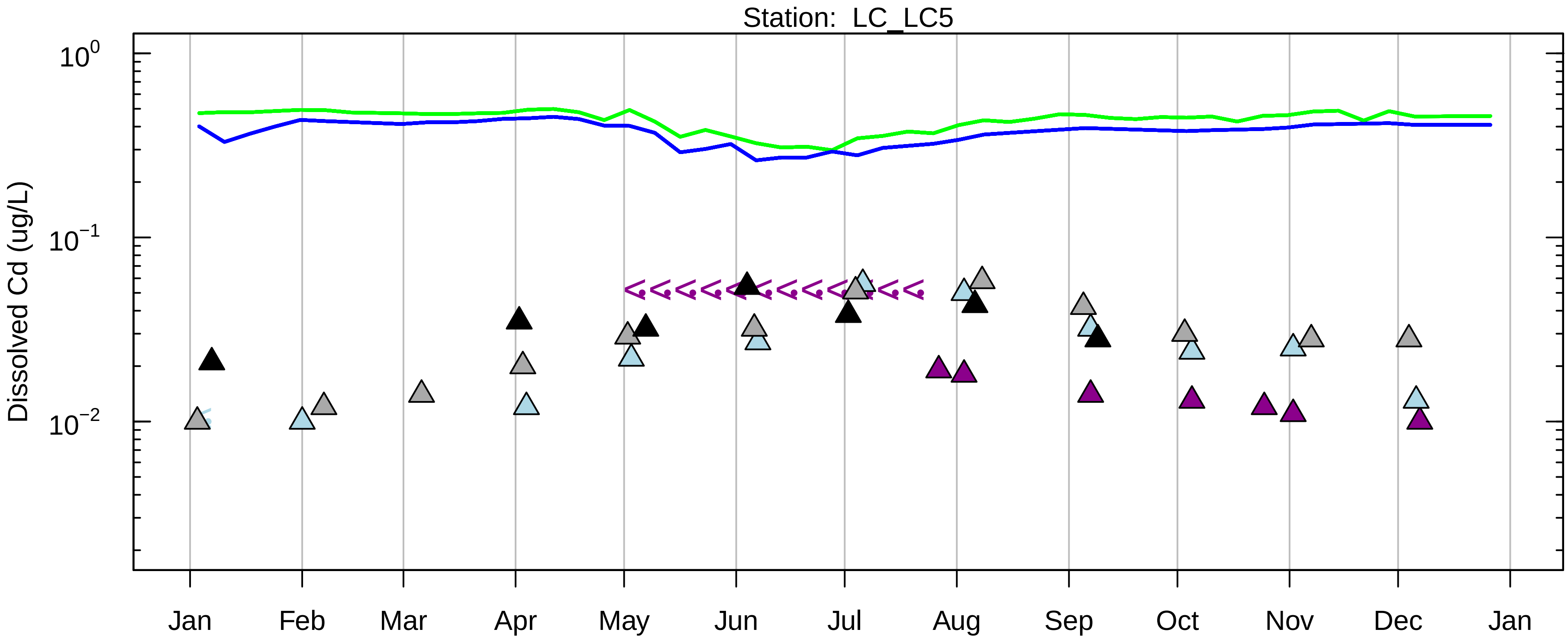
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10^{-2}
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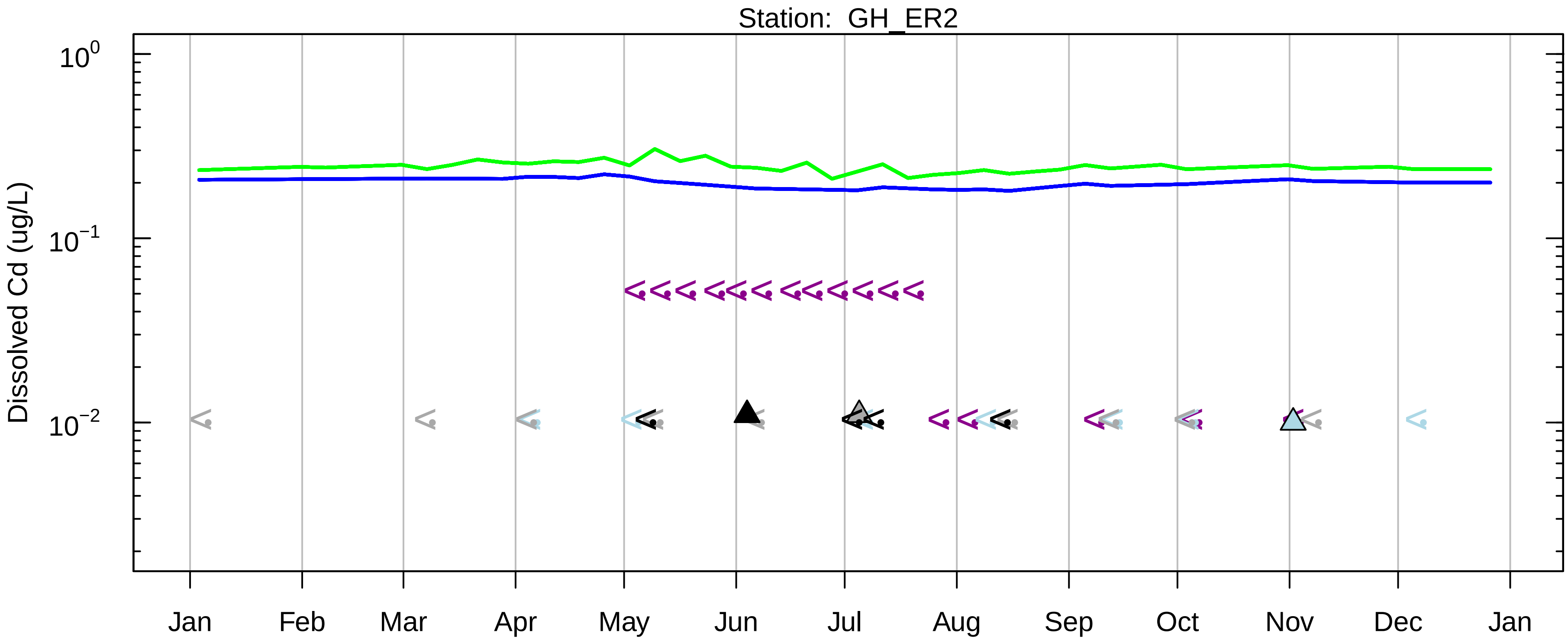
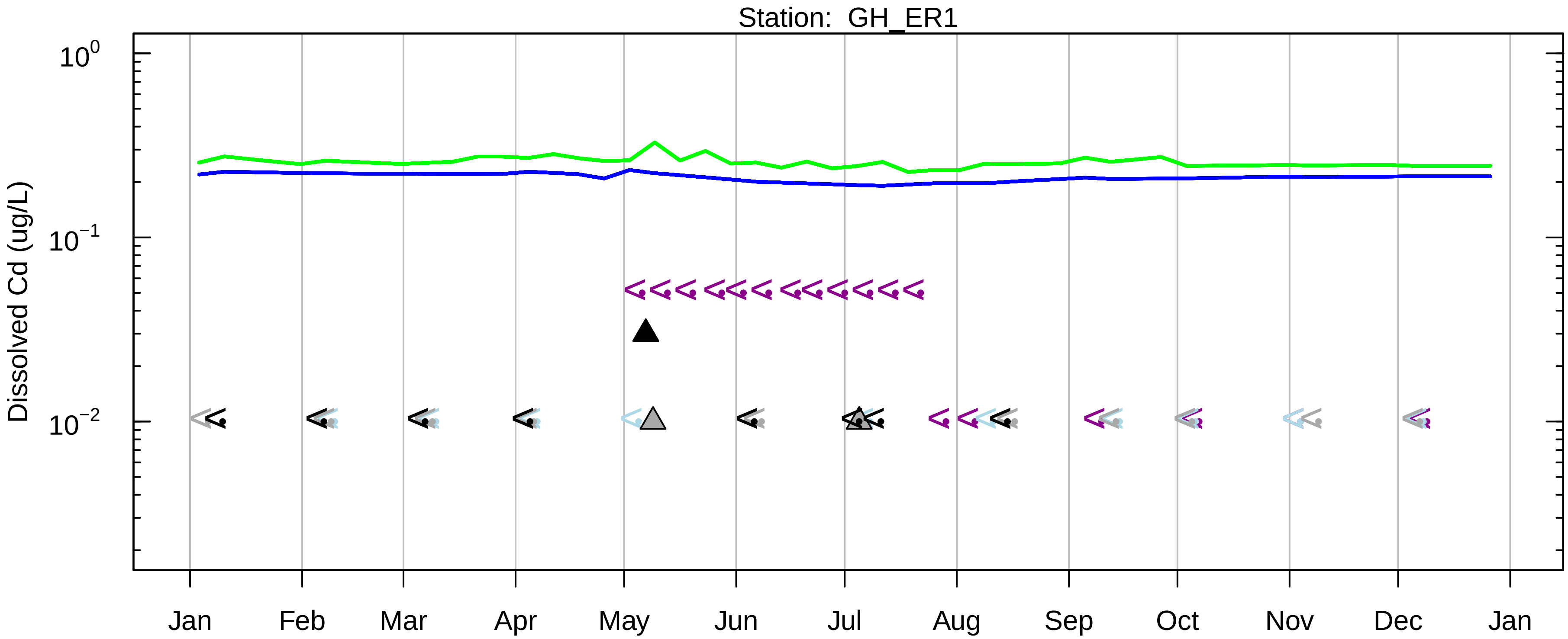
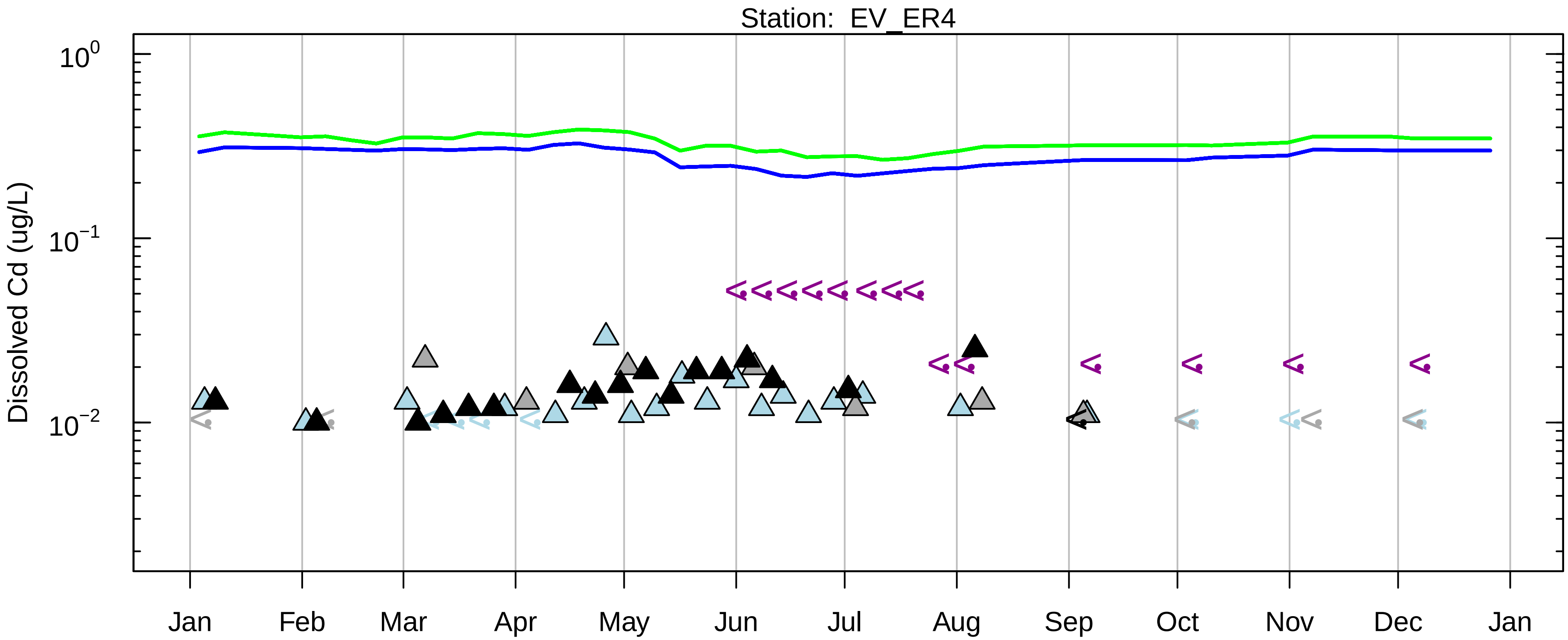
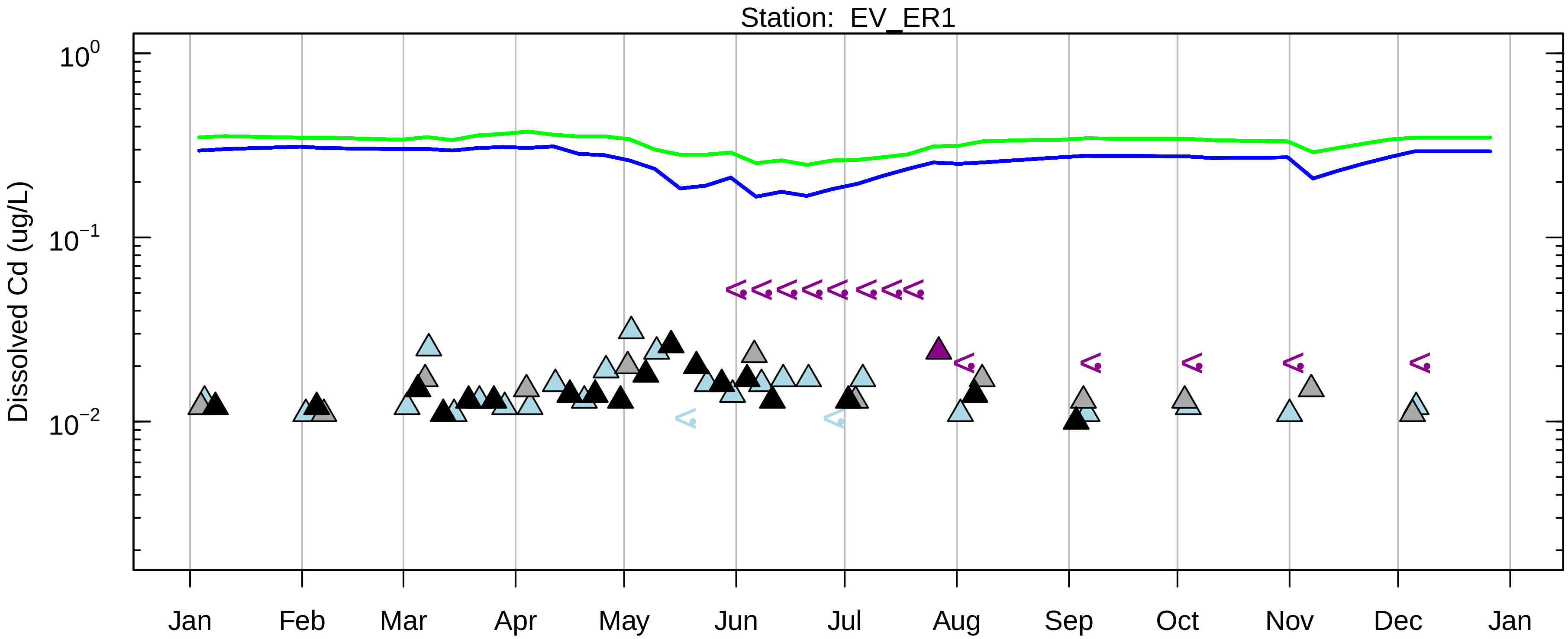
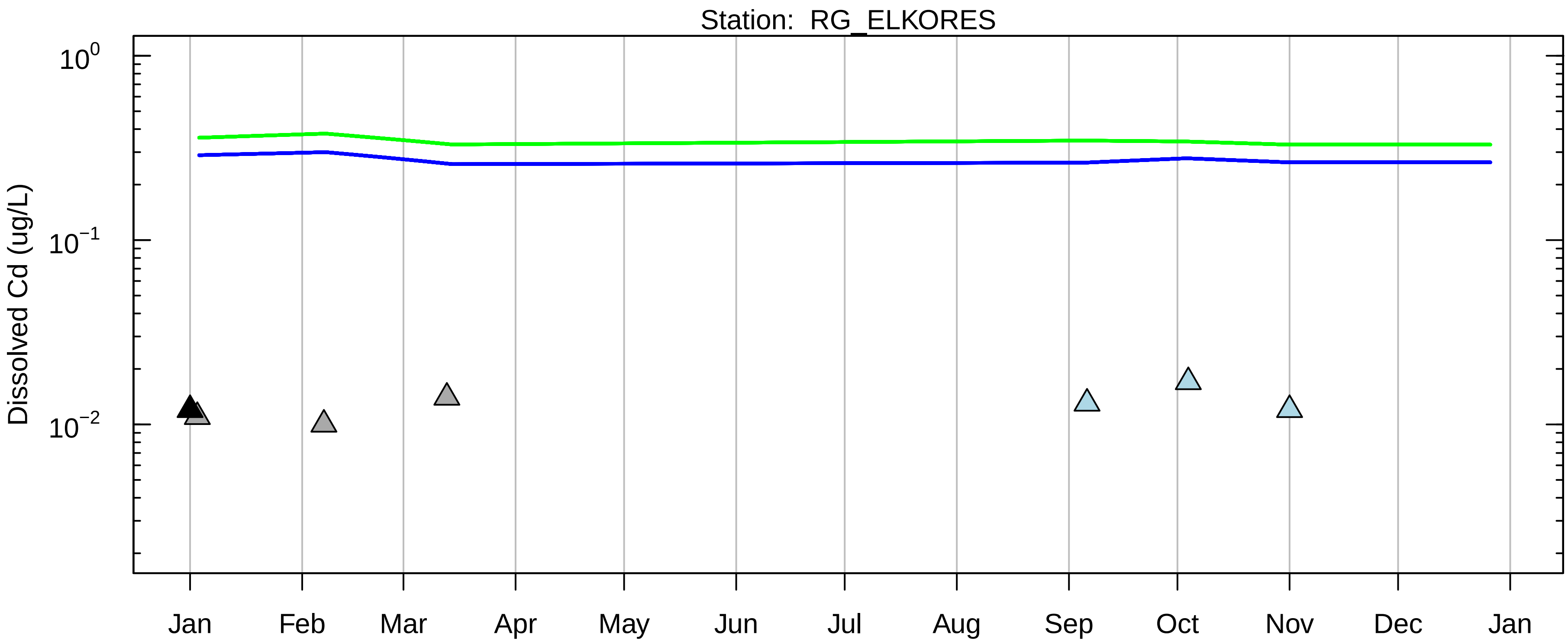
Dec
Jan

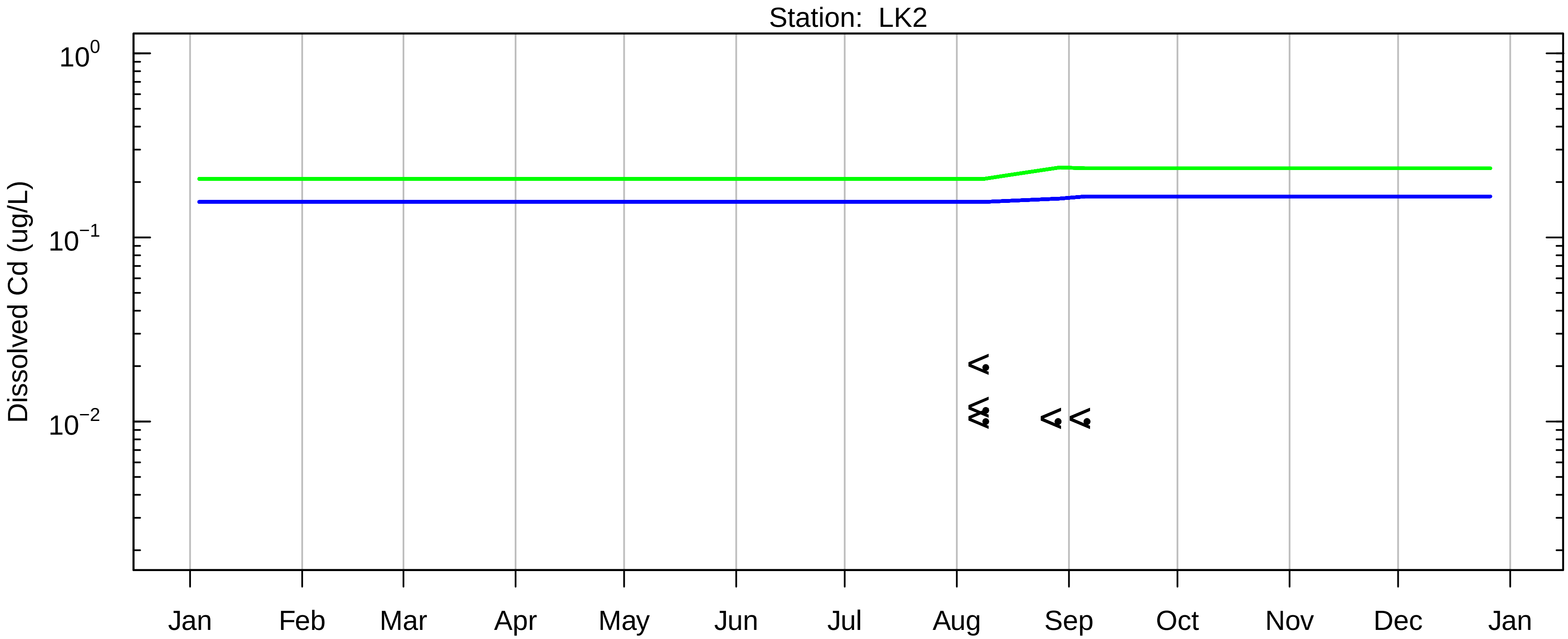

Station: GH_ER2
Dissolved Cd (ug/L)
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: GH_ER1
Dissolved Cd (ug/L)
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

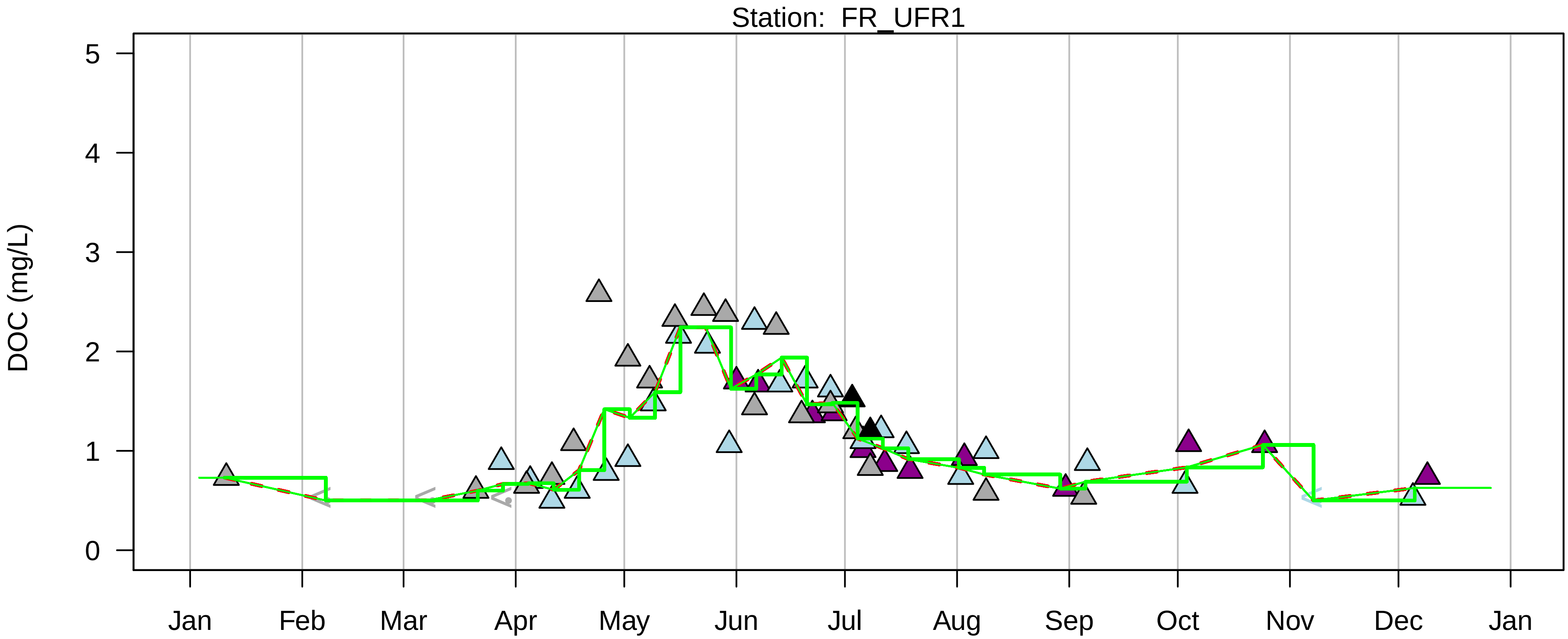

Station: EV_ER4
Dissolved Cd (ug/L)
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

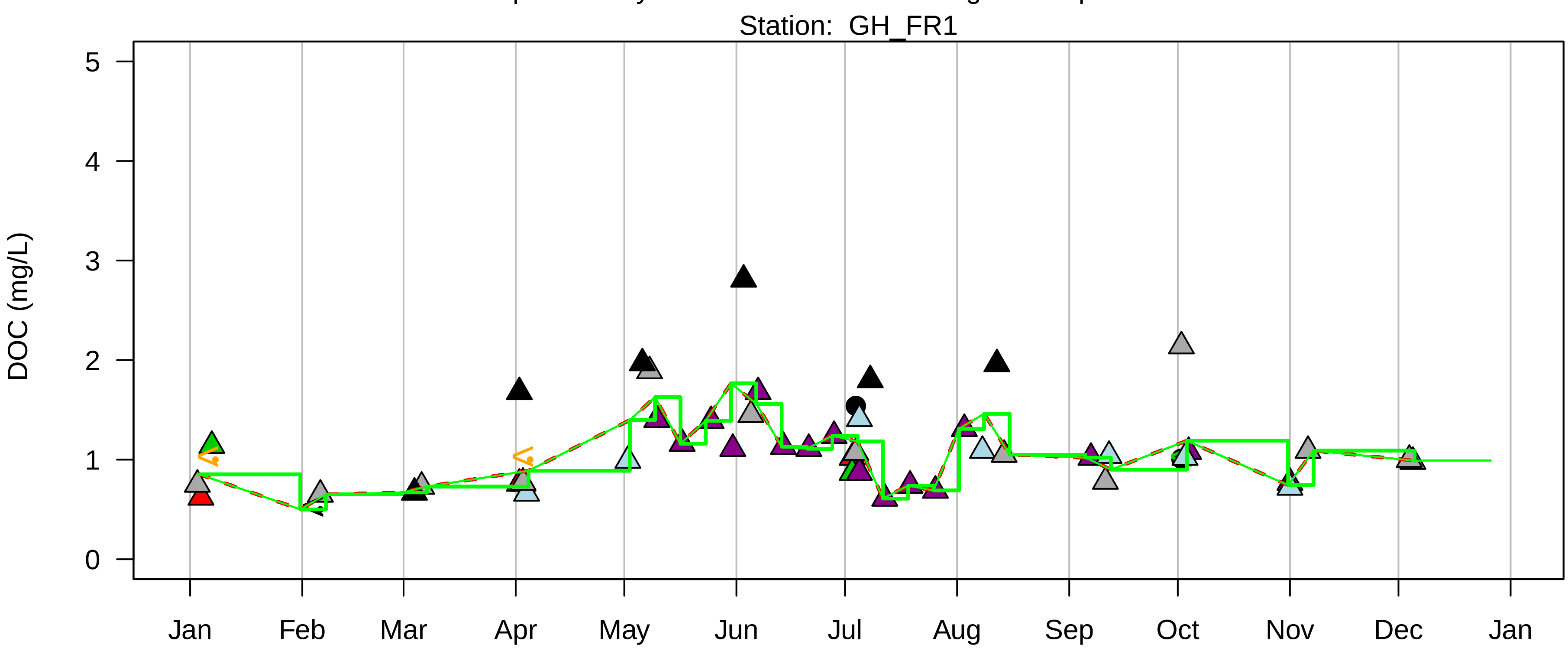

Station: EV_ER1
Dissolved Cd (ug/L)
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

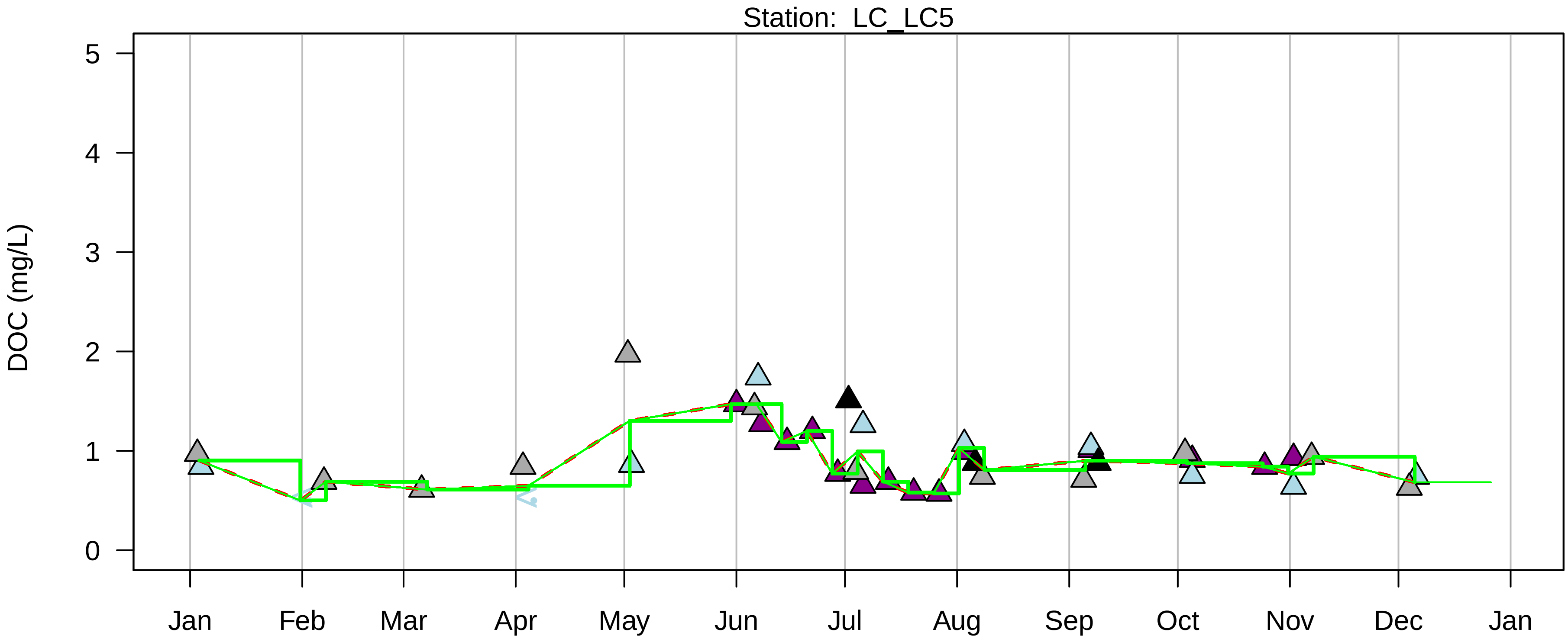

Station: RG_ELKORES
Dissolved Cd (ug/L)
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

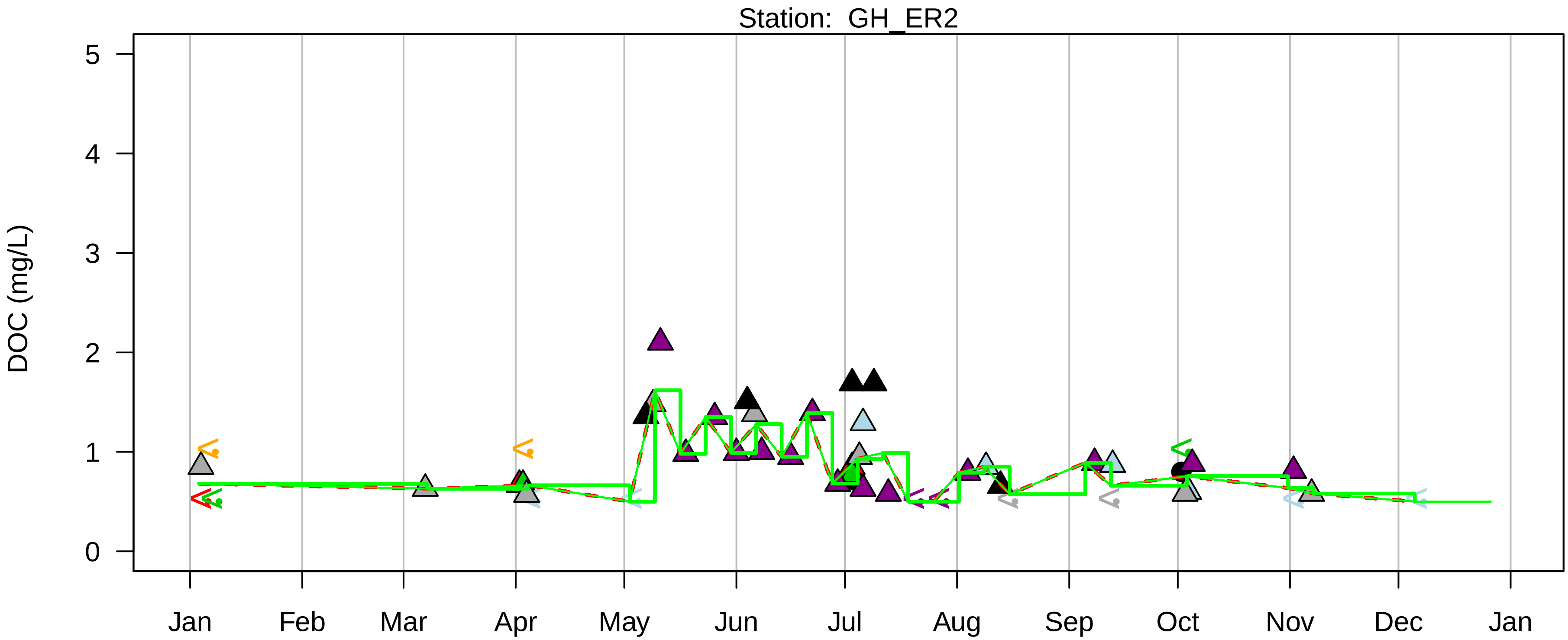


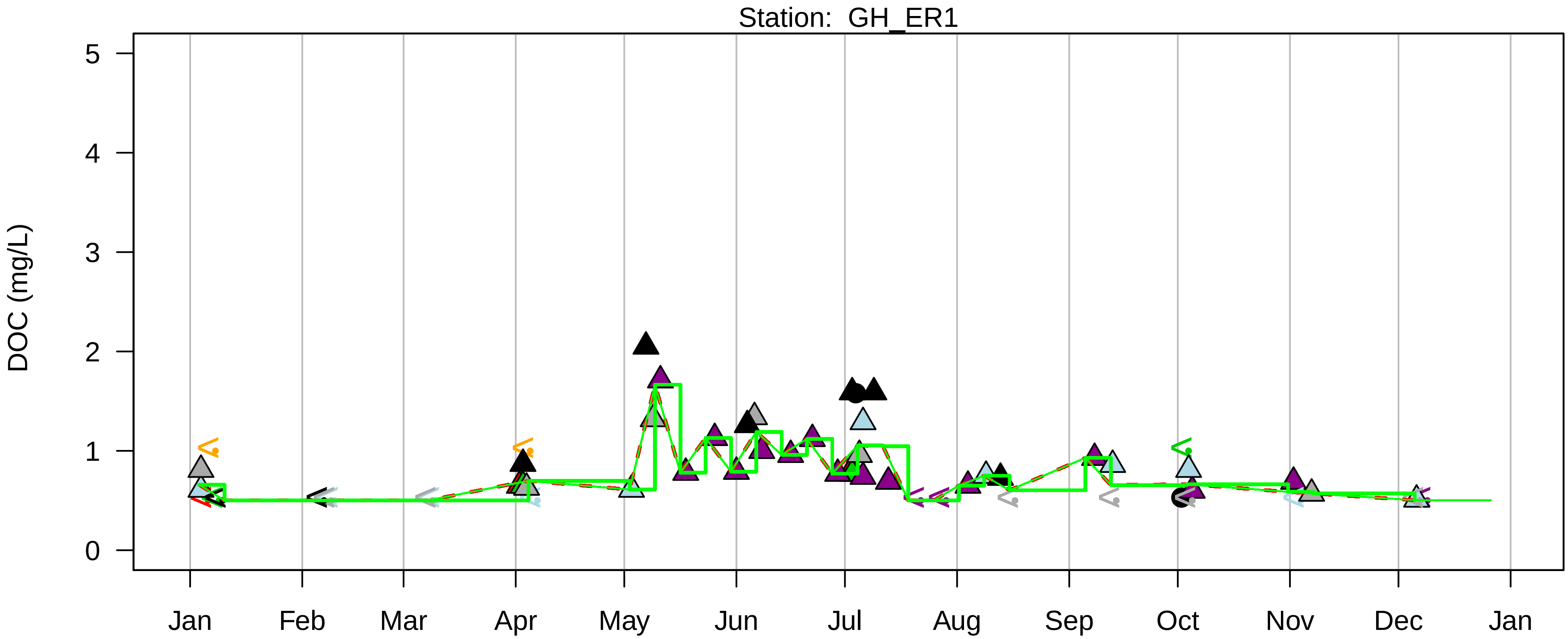
Station: LK2
Dissolved Cd (ug/L)
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: FR_UFR1
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

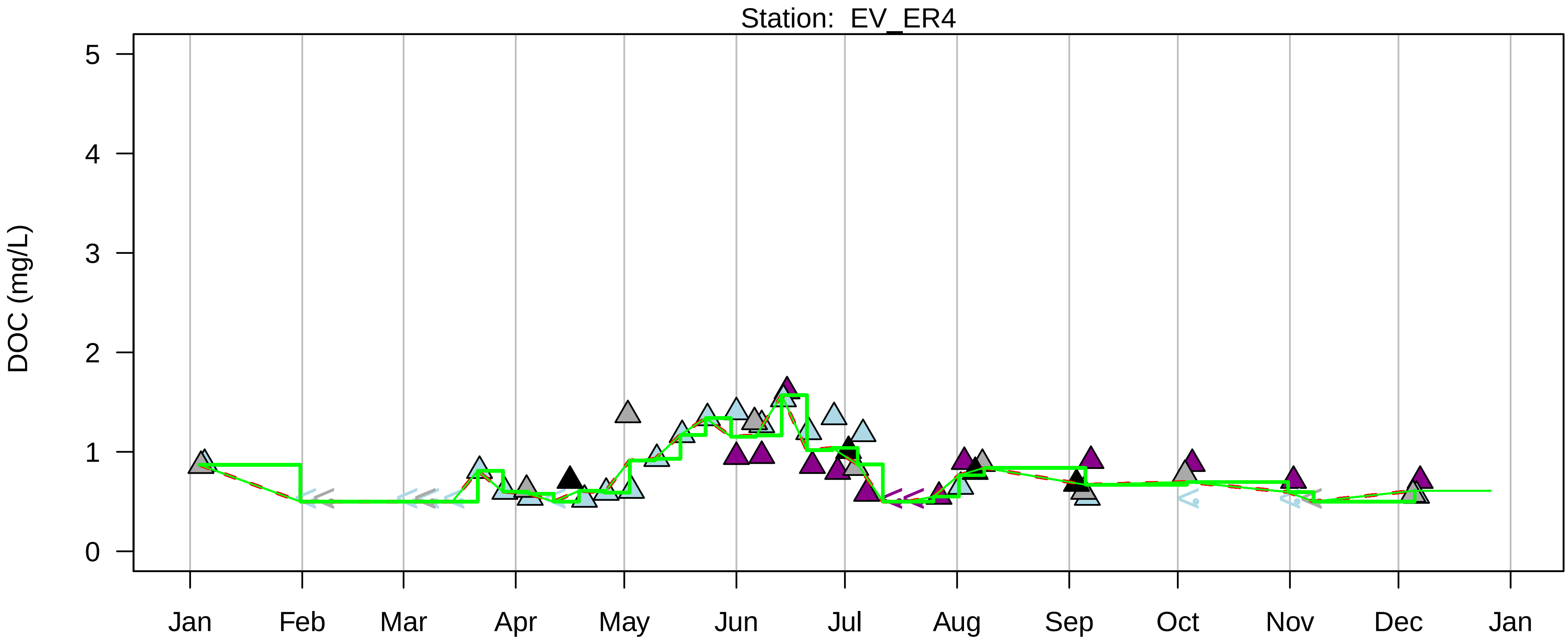

Station: GH_FR1
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: LC_LC5
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

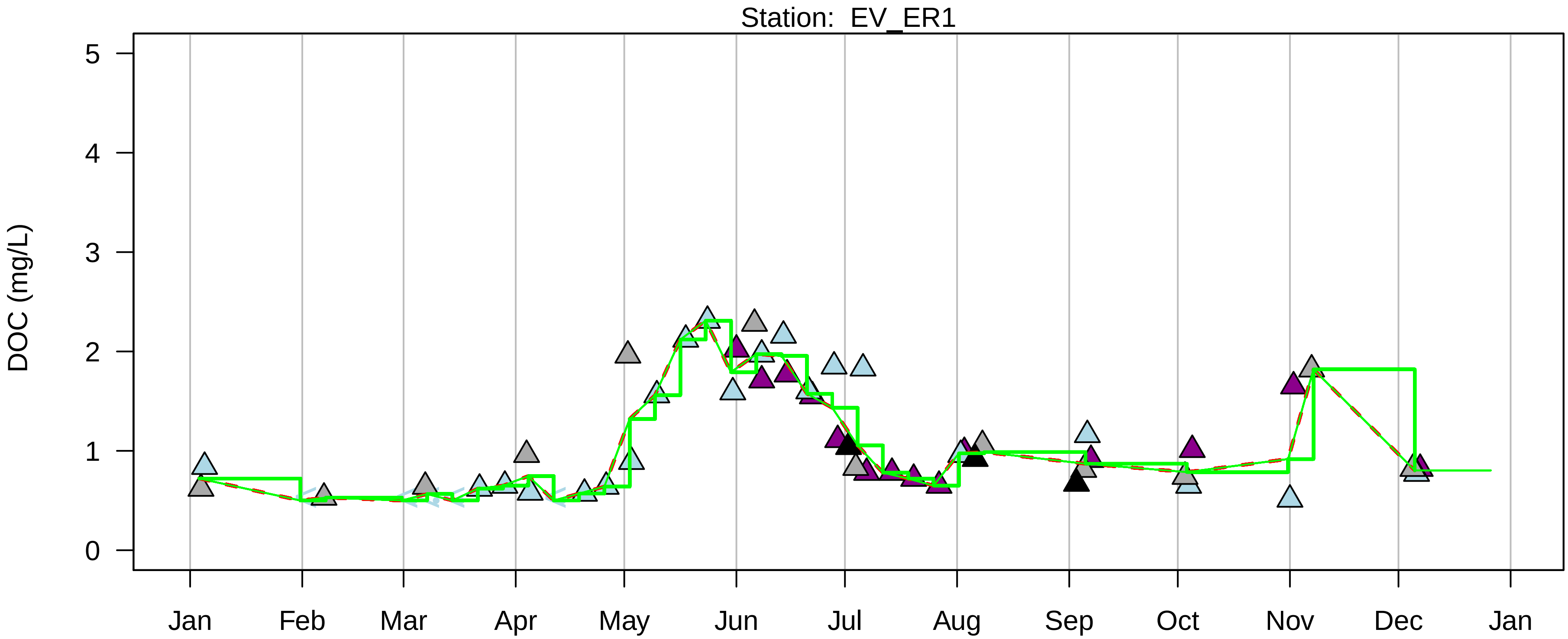

Station: GH_ER2
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

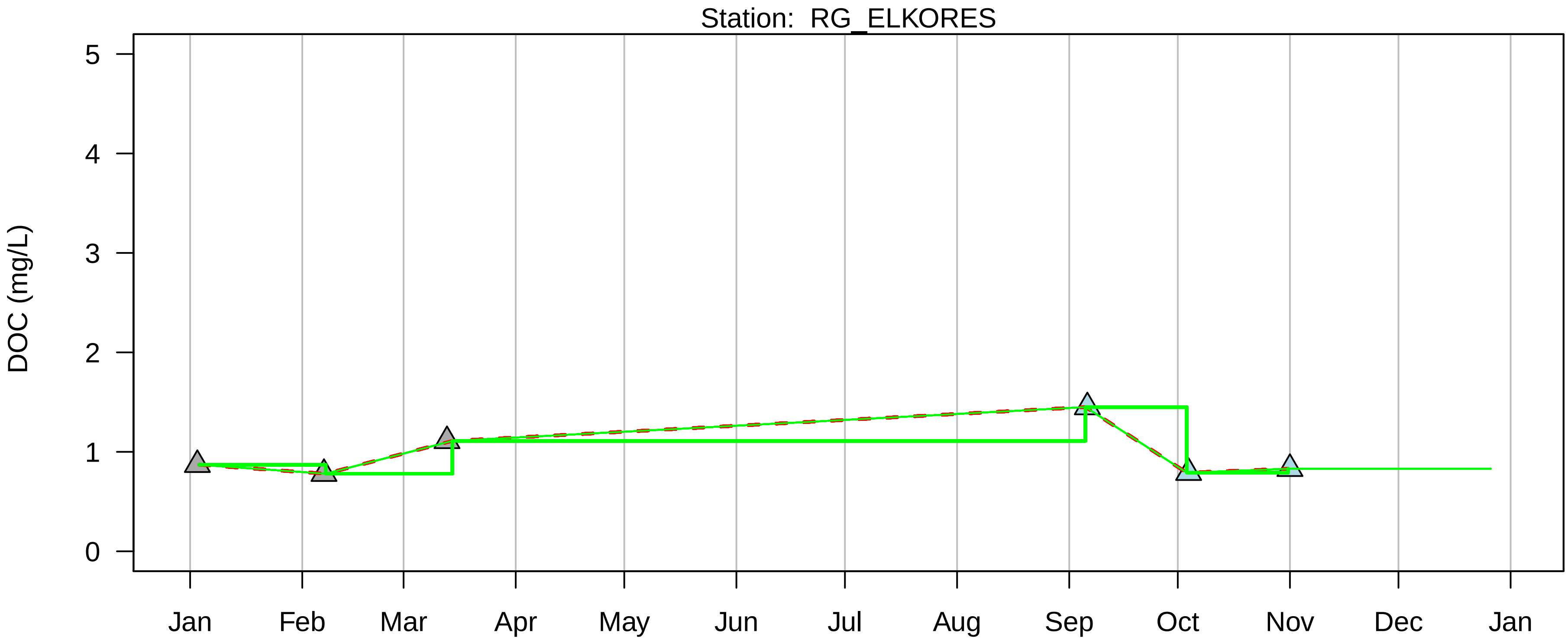


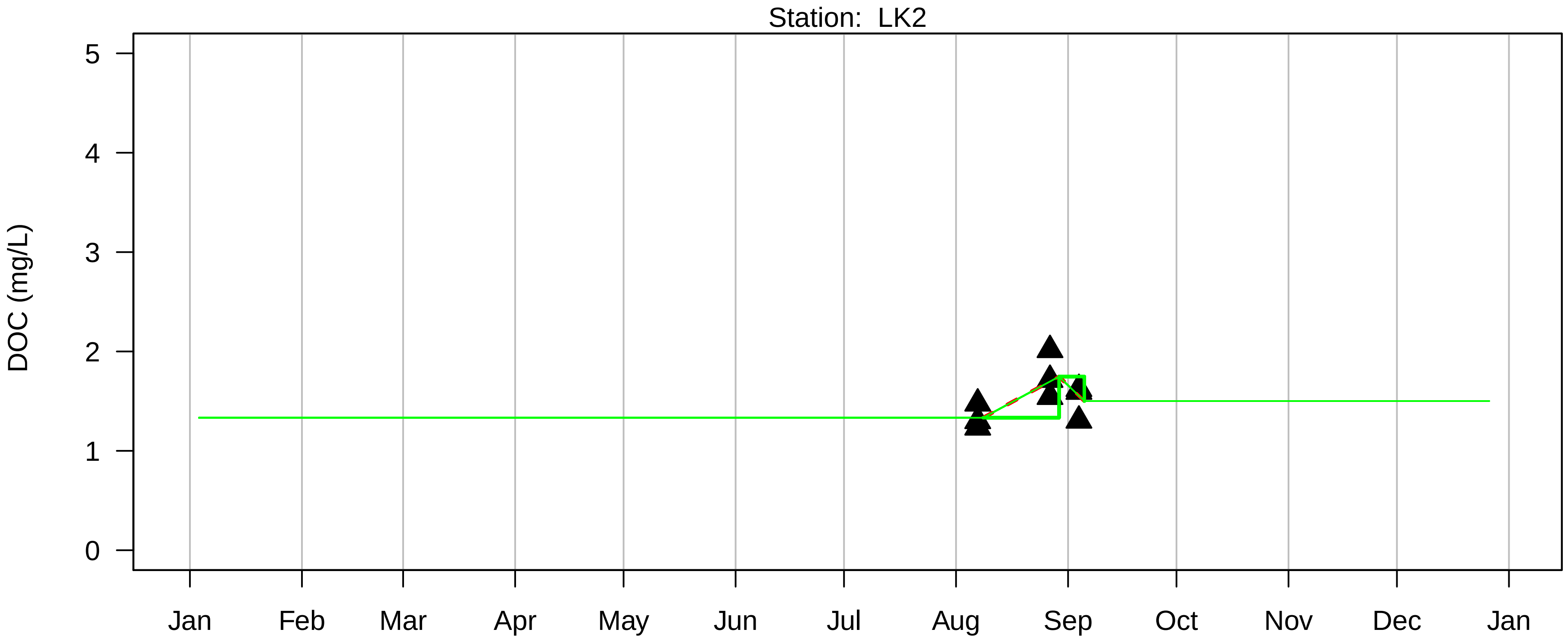
Station: GH_ER1
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan



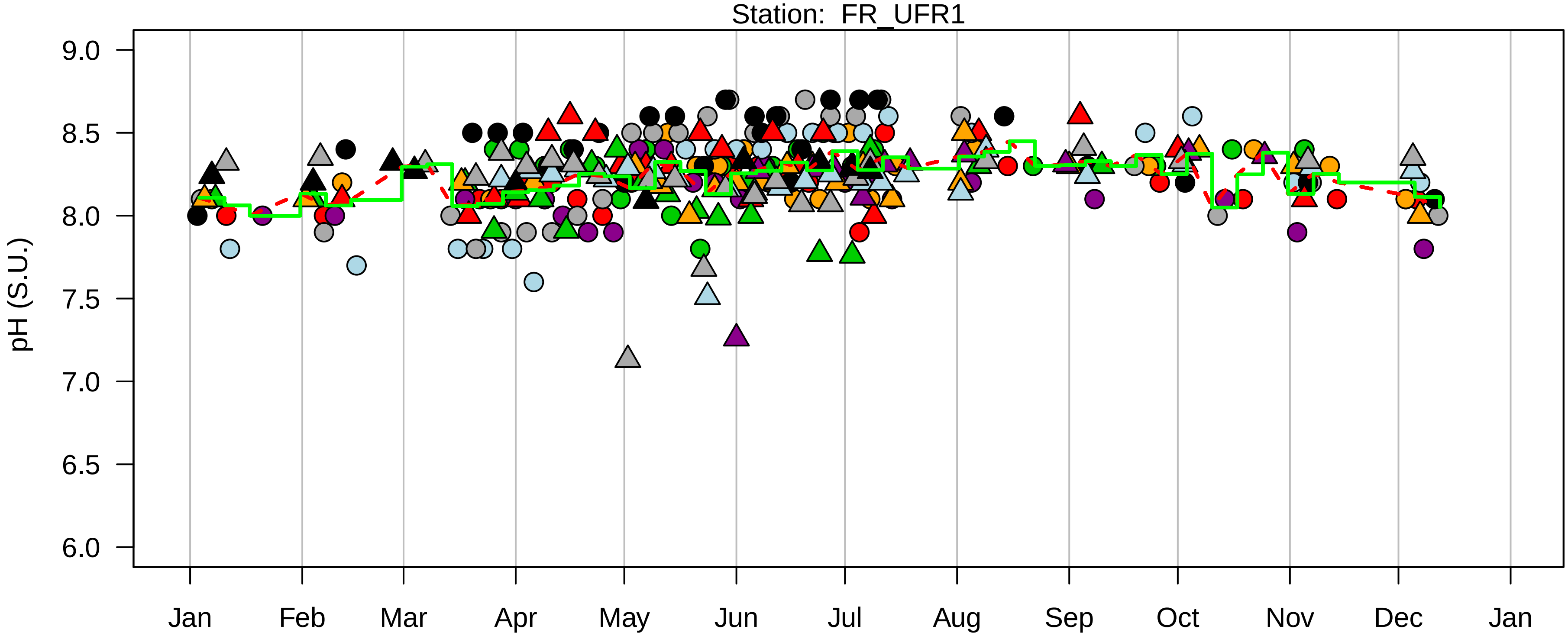
Station: EV_ER4
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

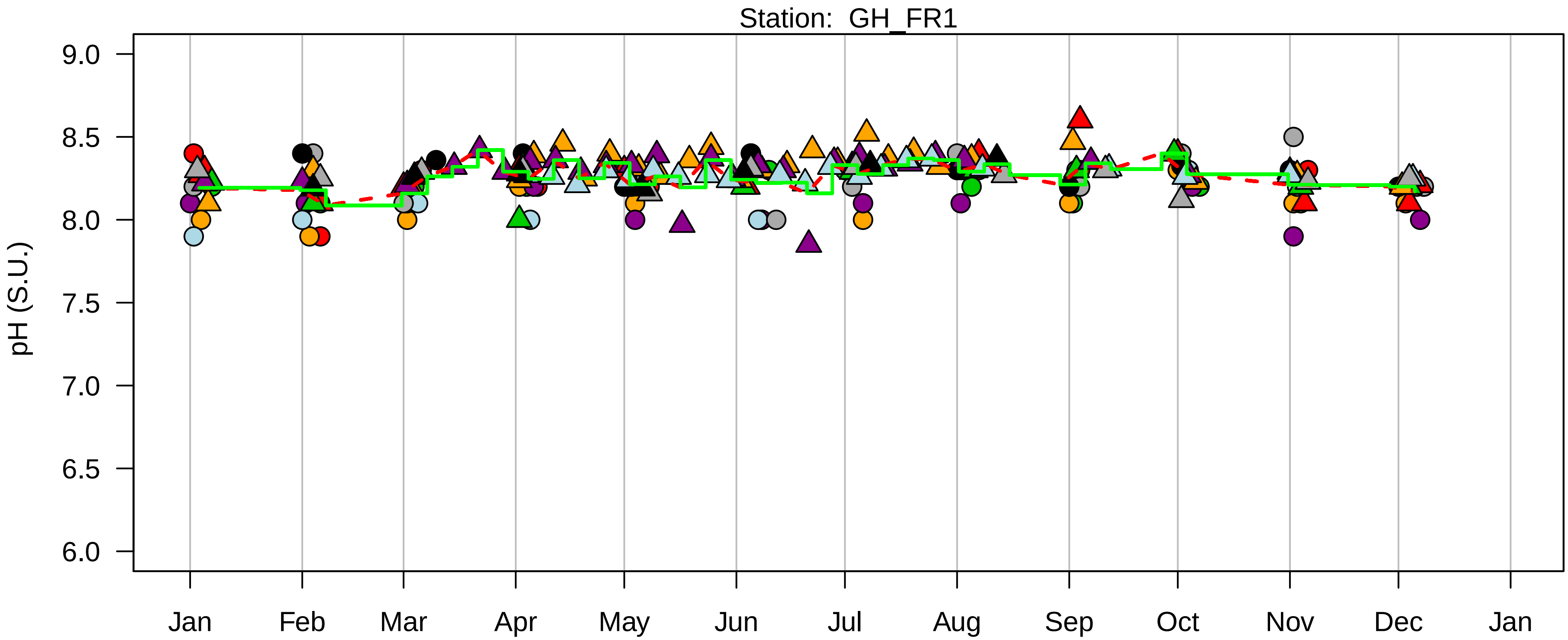

Station: EV_ER1
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

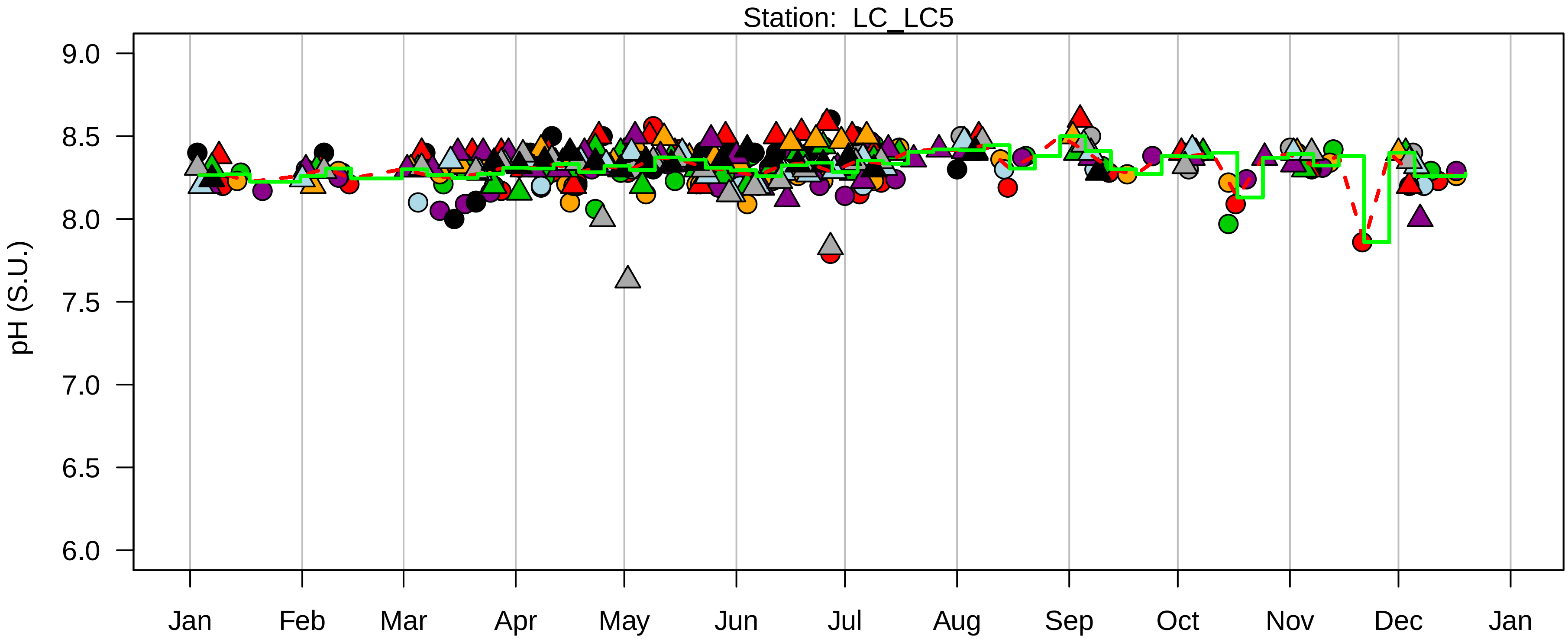

Station: RG_ELKORES
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

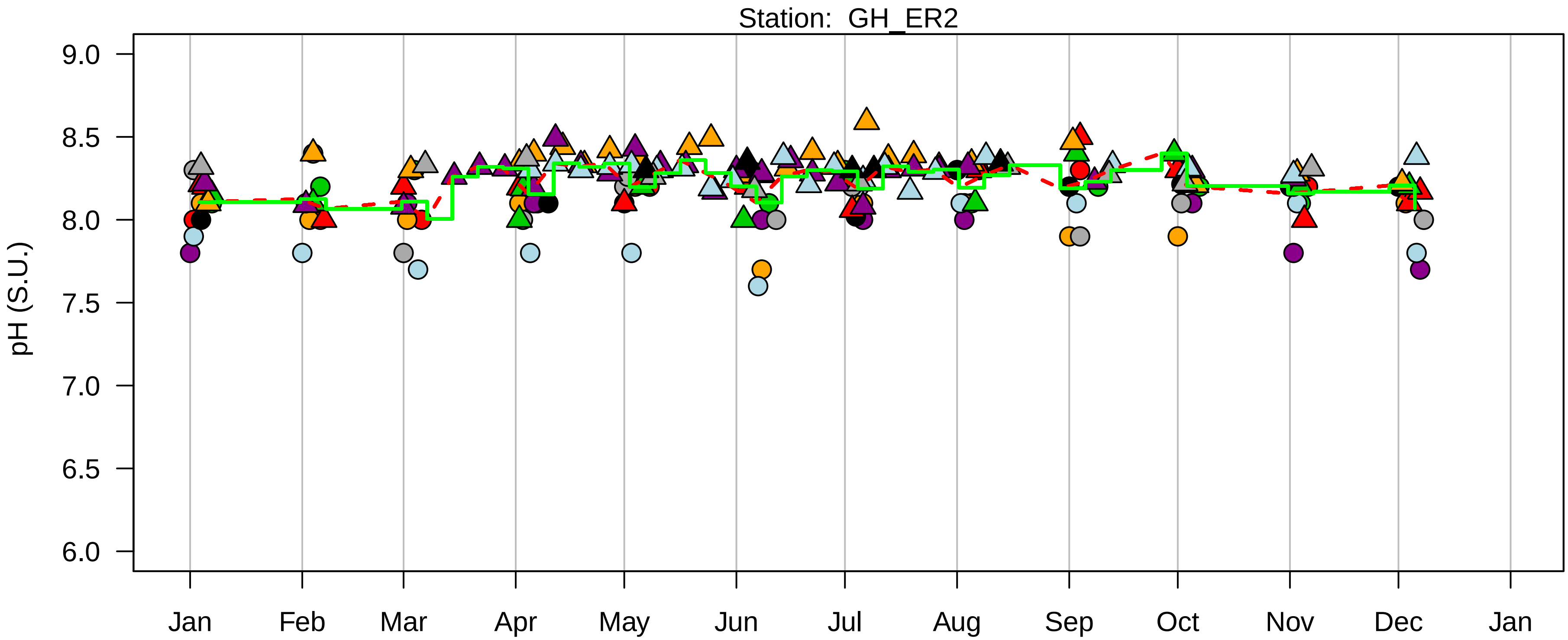


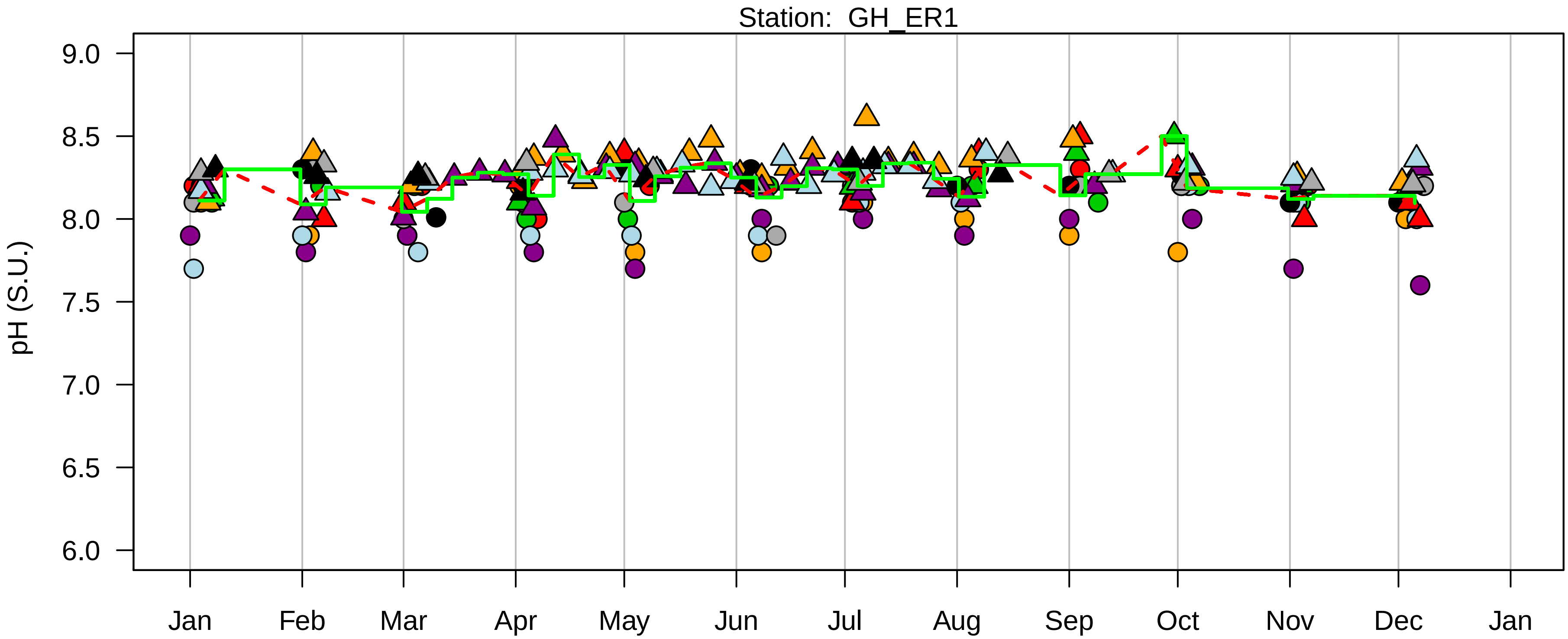
Station: LK2
DOC (mg/L)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

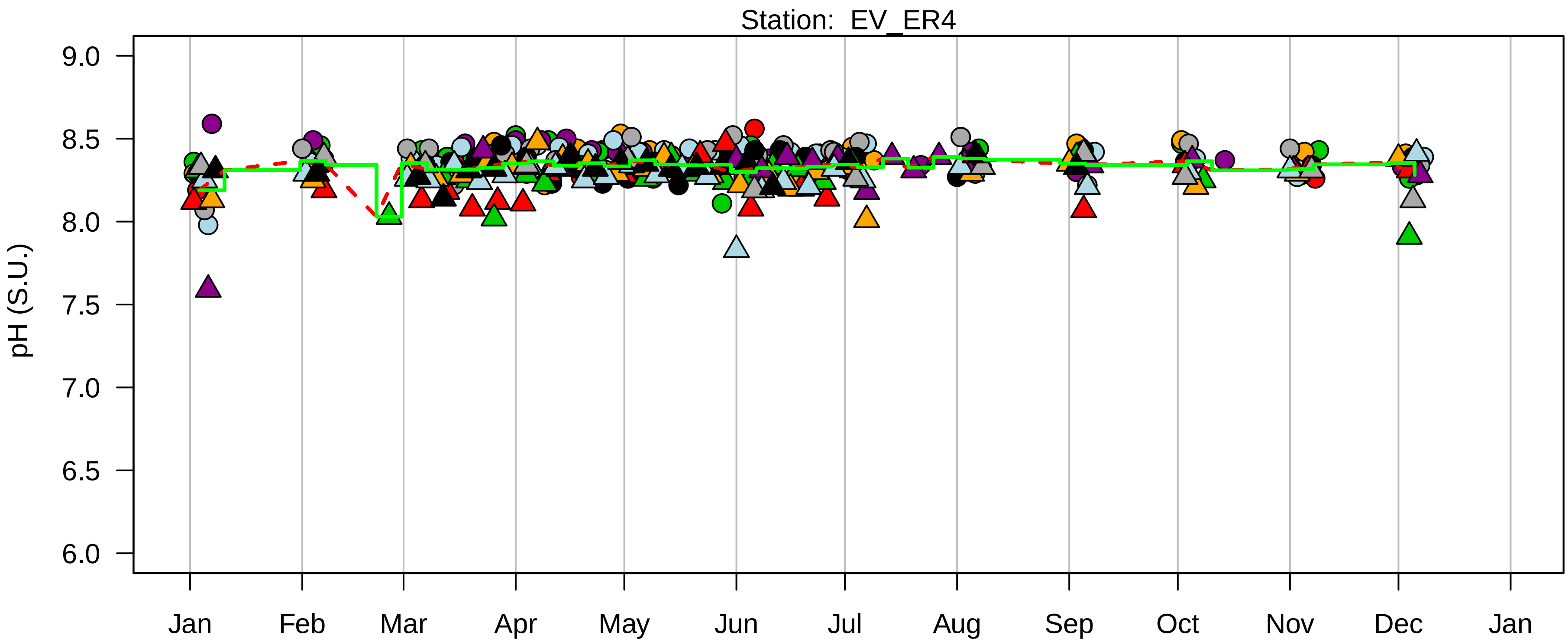

Station: FR_UFR1
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

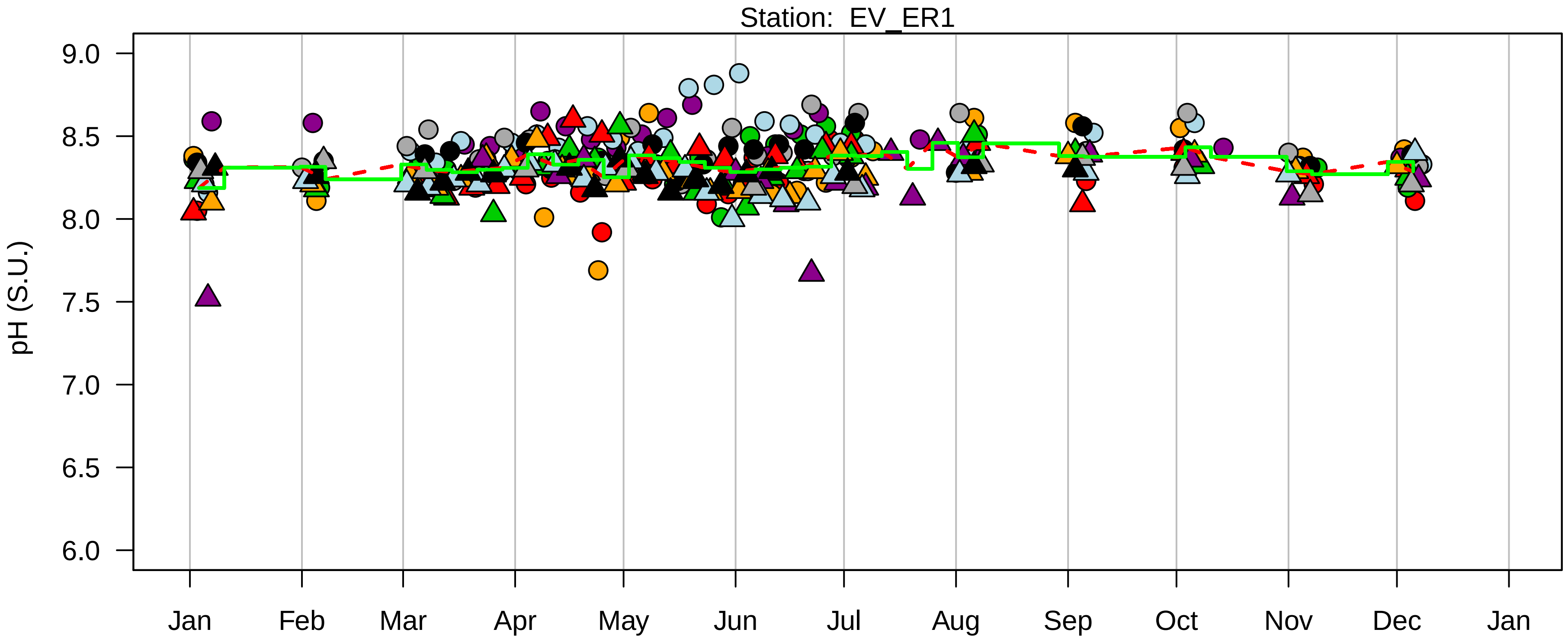

Station: GH_FR1
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

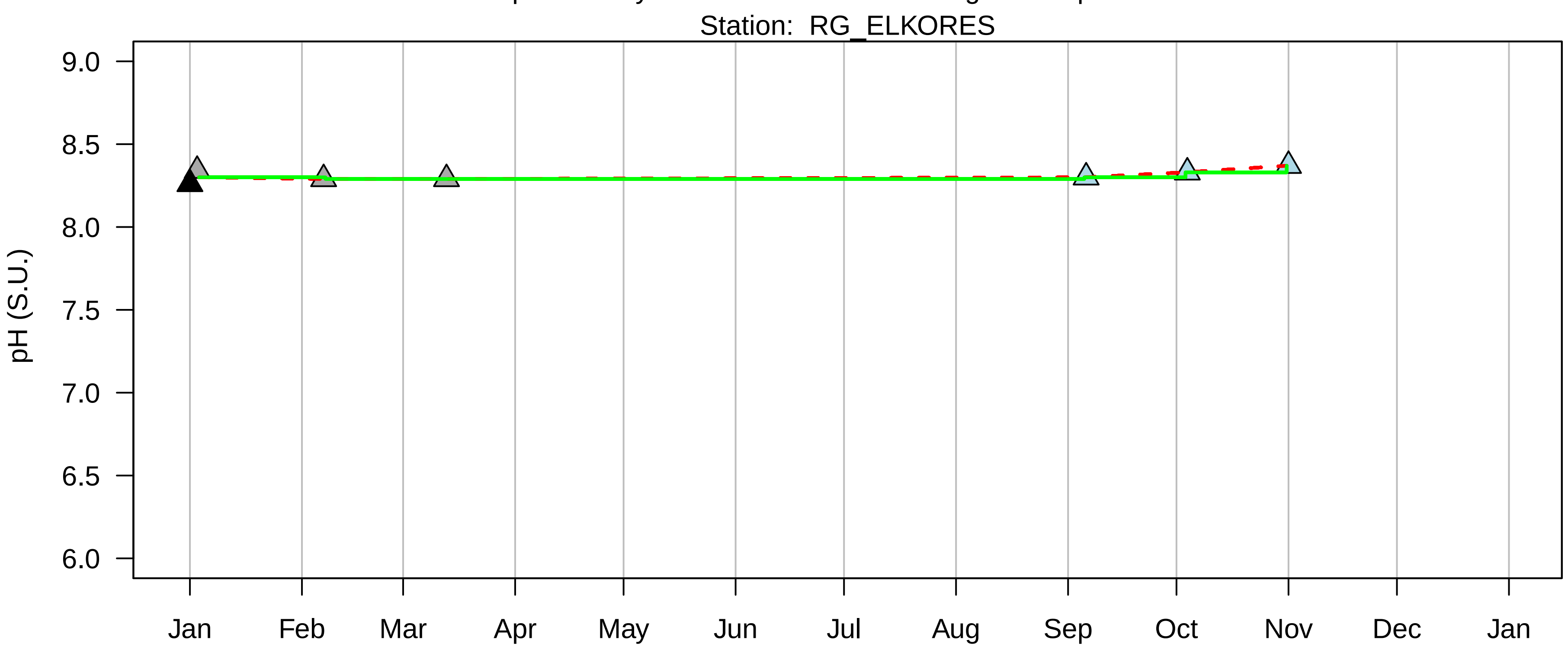

Station: LC_LC5
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

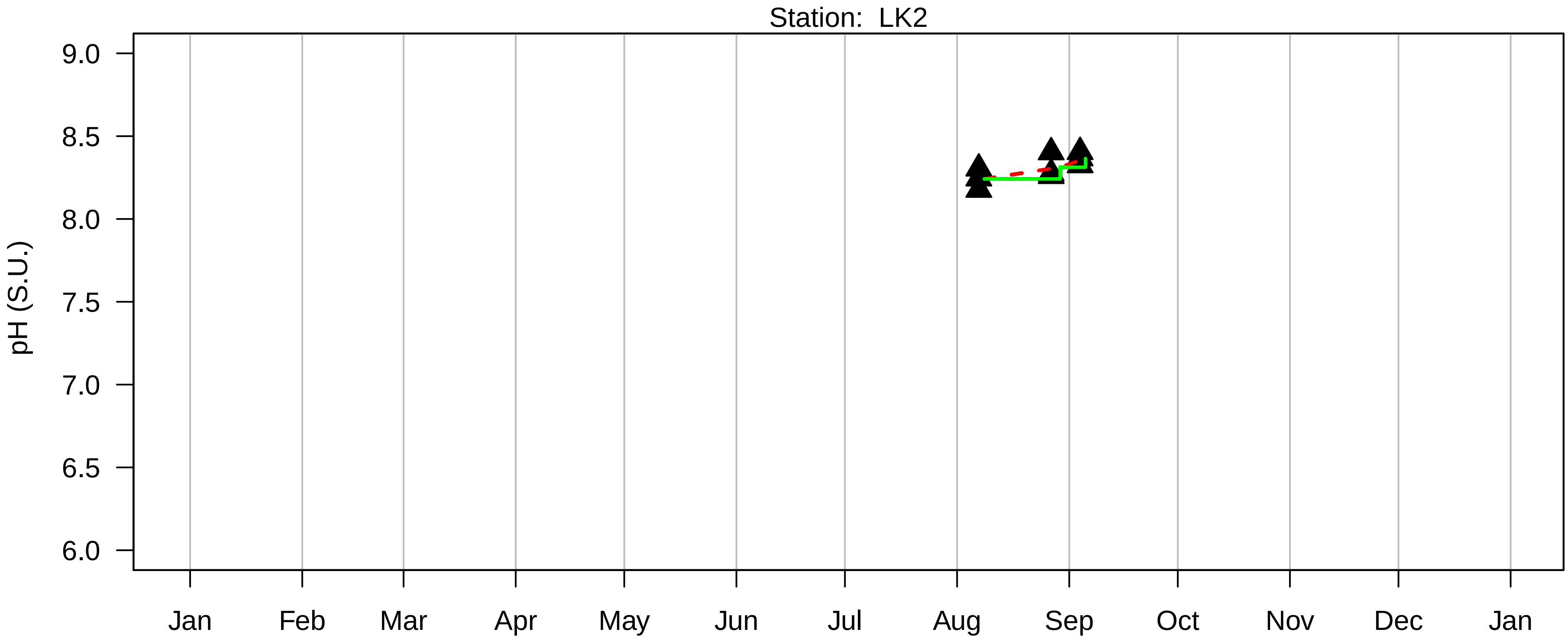

Station: GH_ER2
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

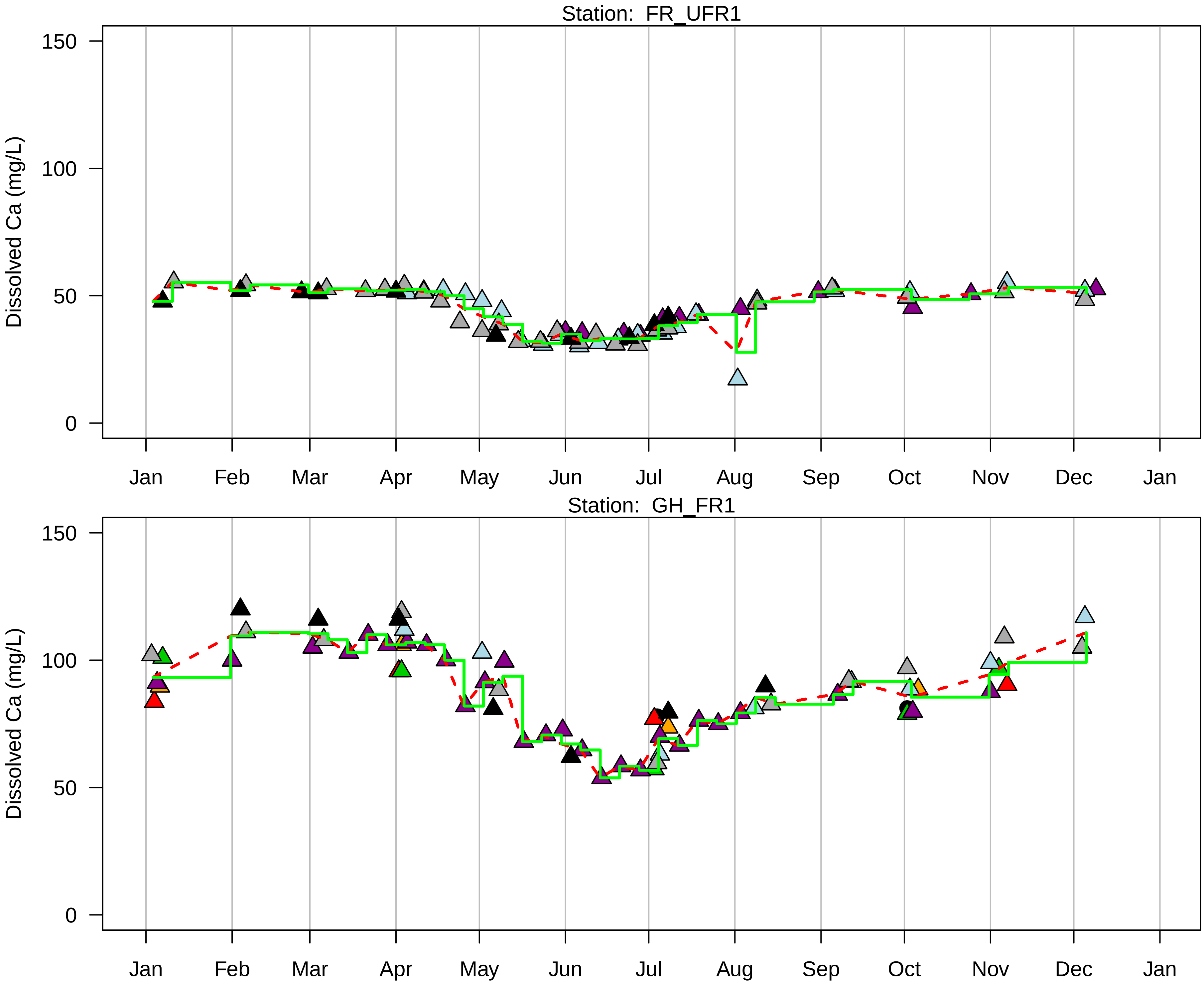

Station: GH_ER1
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

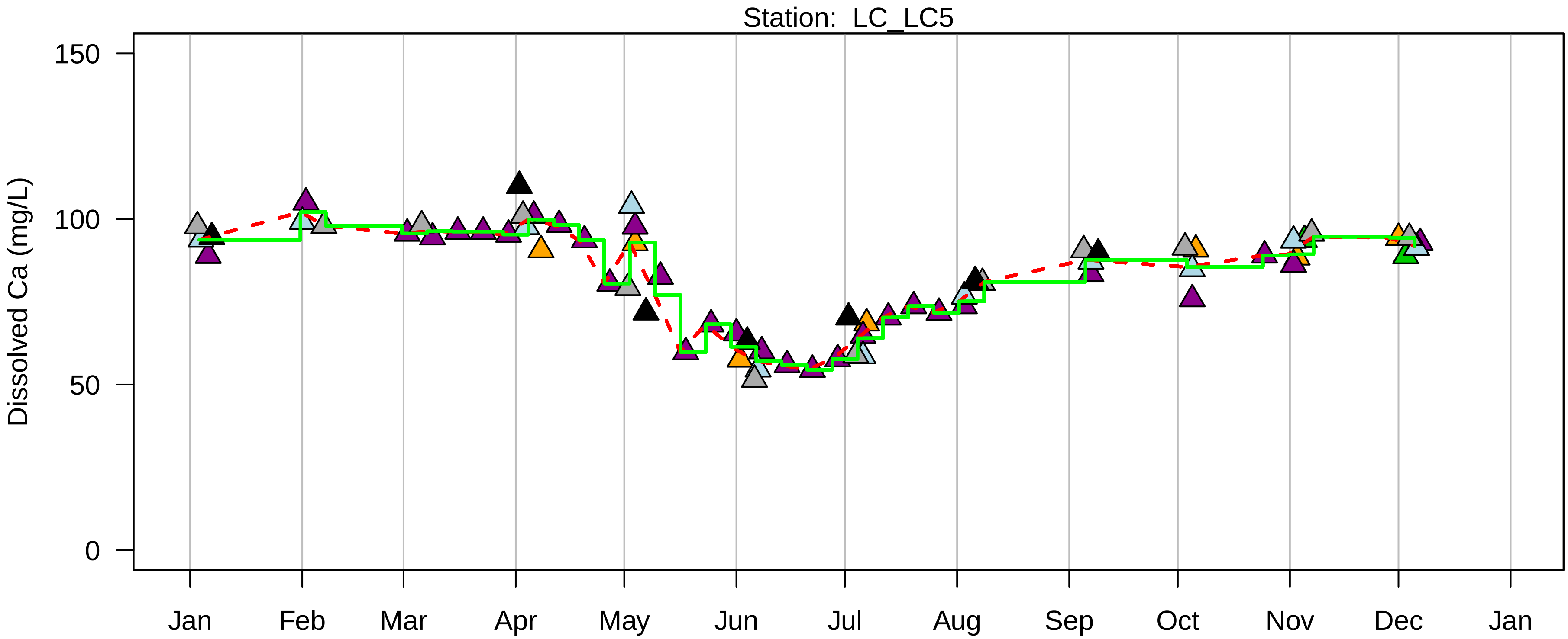

Station: EV_ER4
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

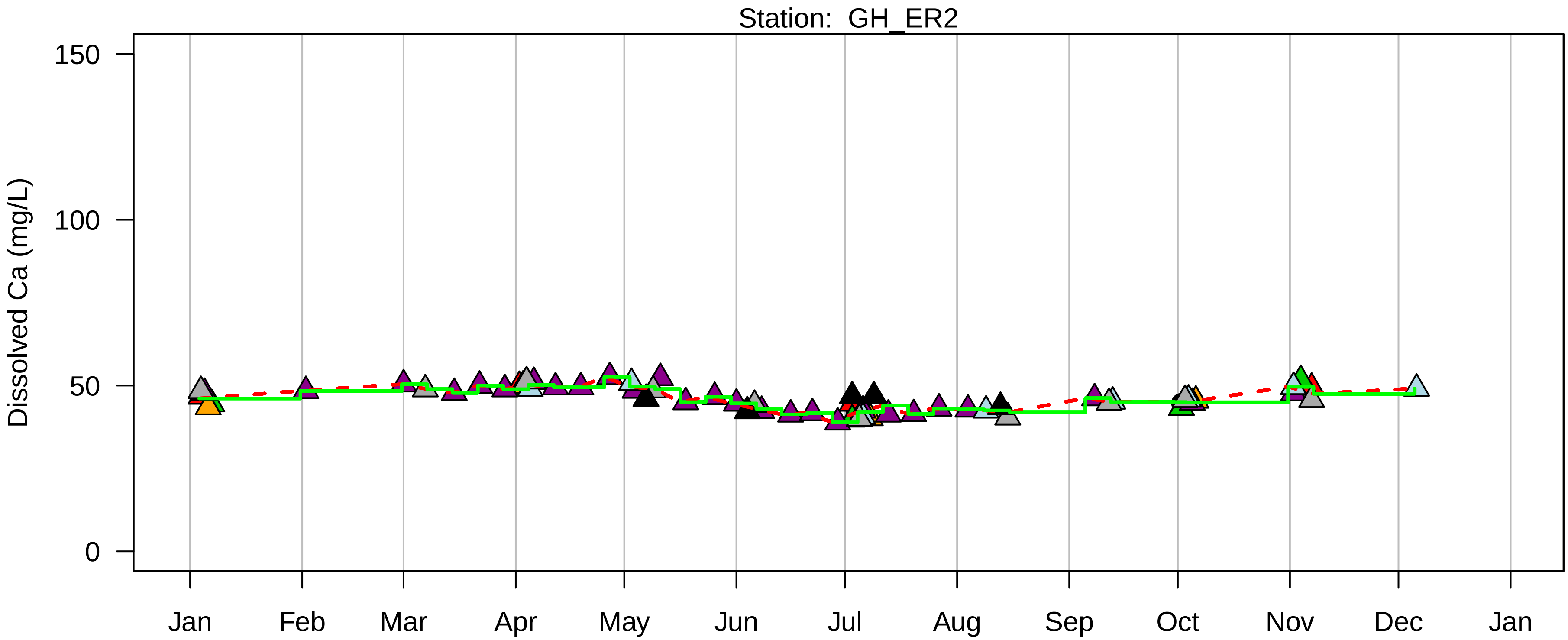

Station: EV_ER1
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

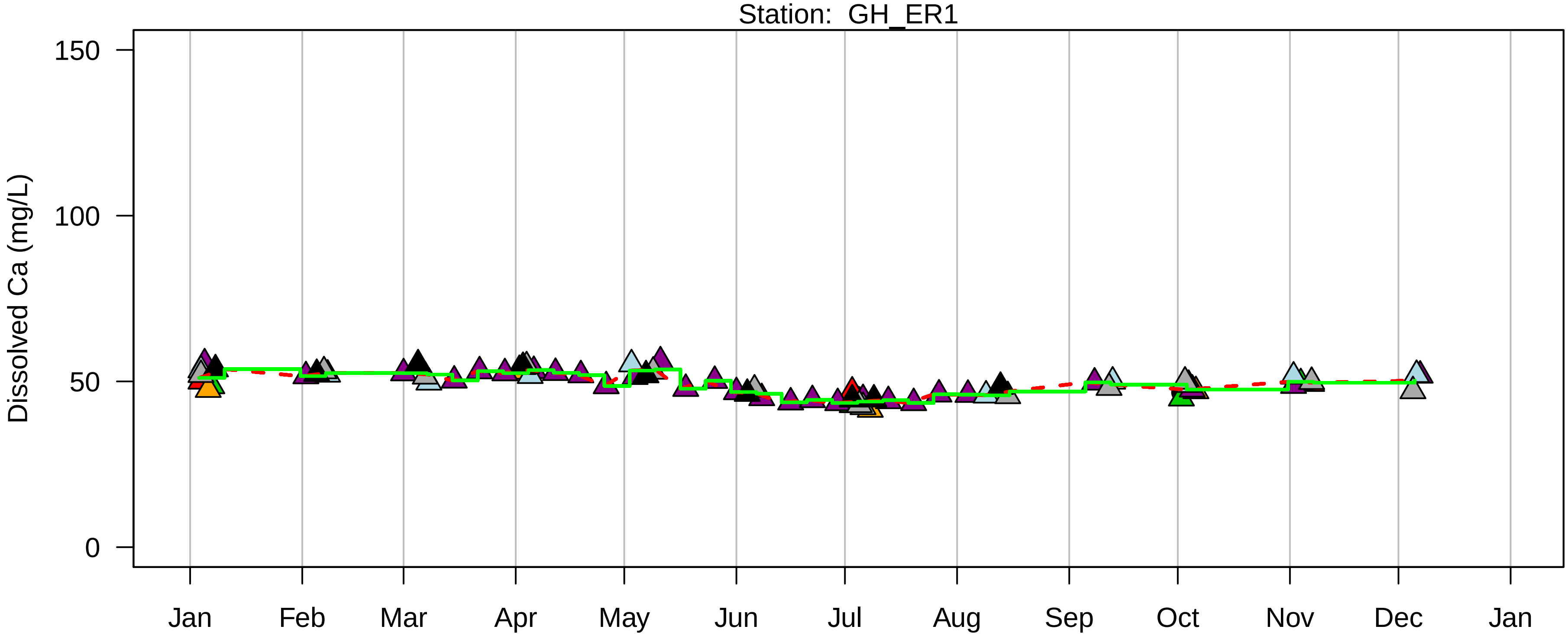

Station: RG_ELKORES
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

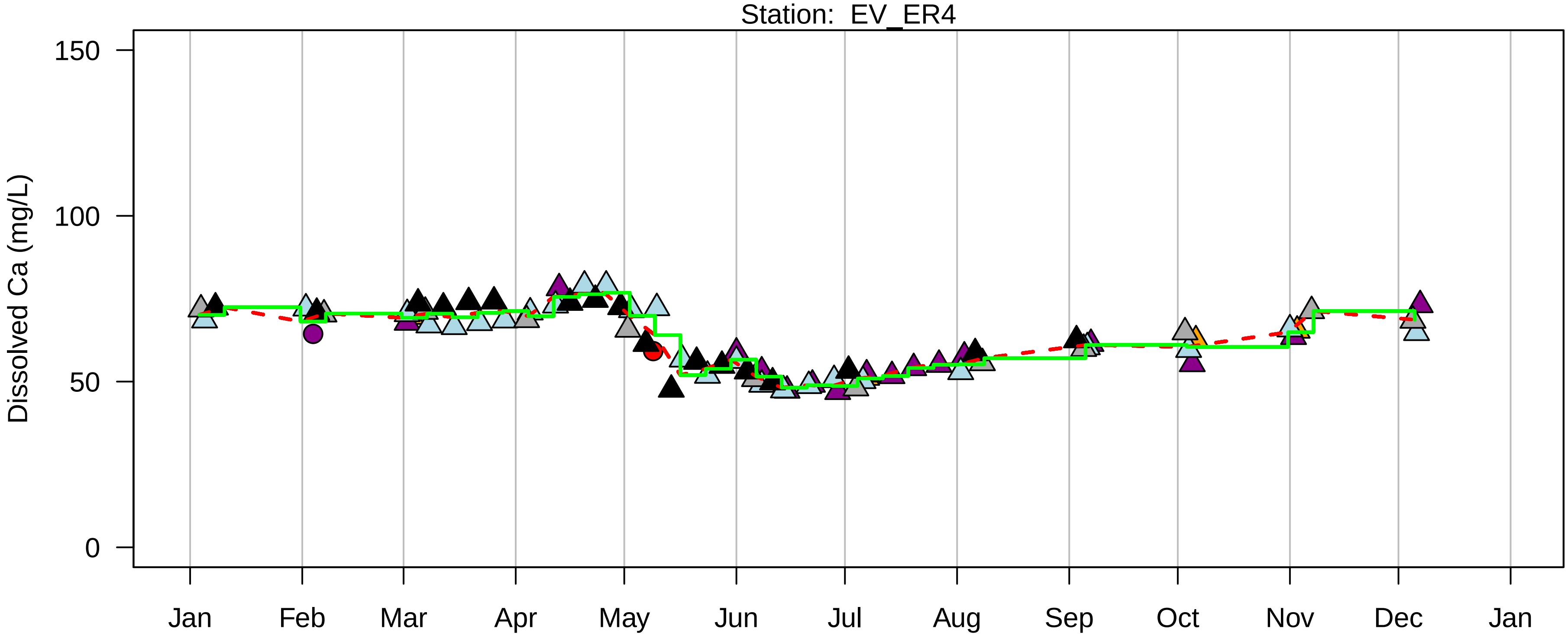

Station: LK2
pH (S.U.)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

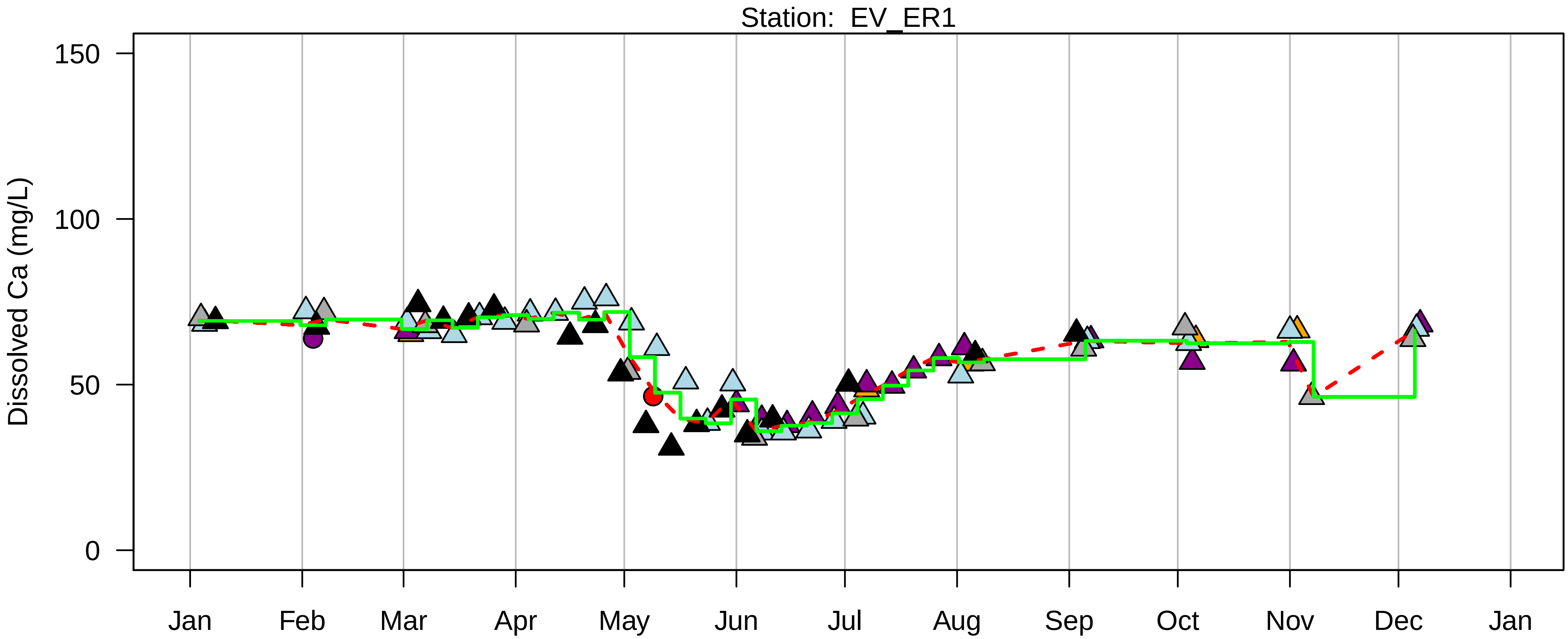

Station: FR_UFR1
Dissolved Ca (mg/L)
0
50
100
150
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Station: GH_FR1
Dissolved Ca (mg/L)
0
50
100
150
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

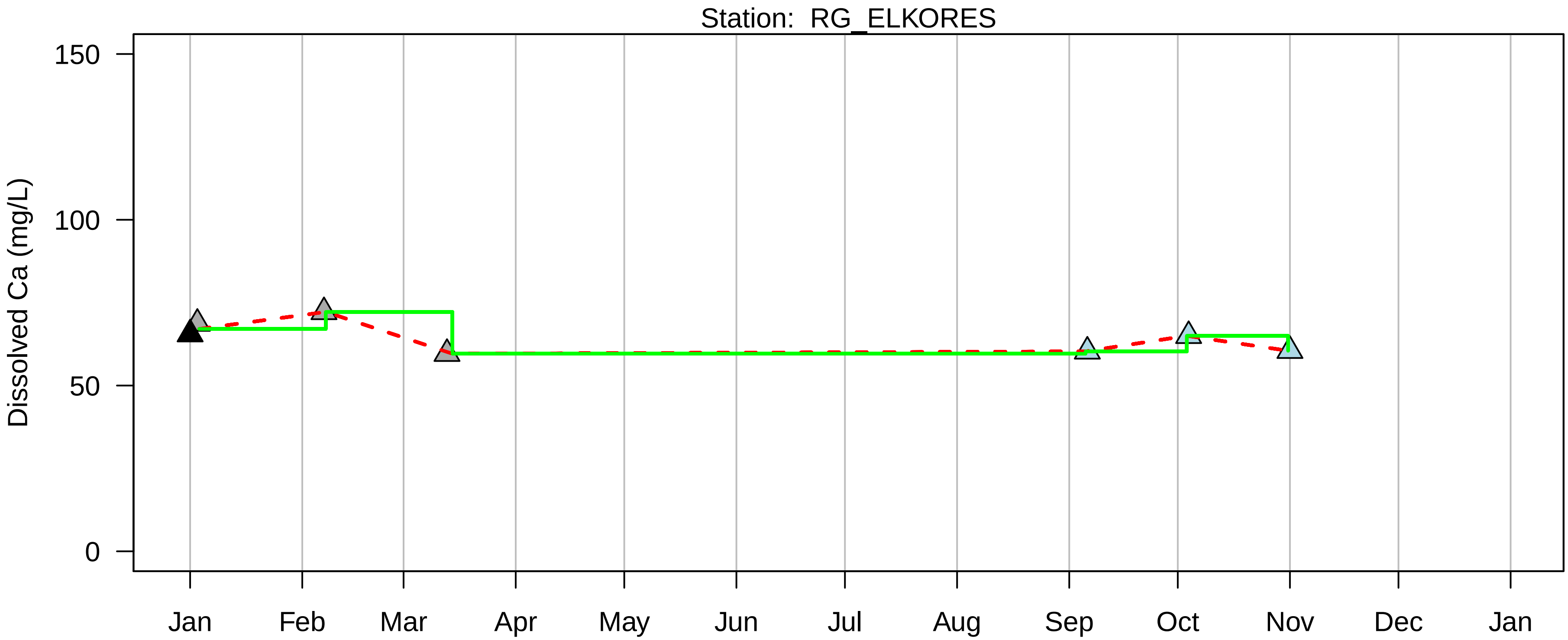

Station: LC_LC5
Dissolved Ca (mg/L)
0
50
100
150
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

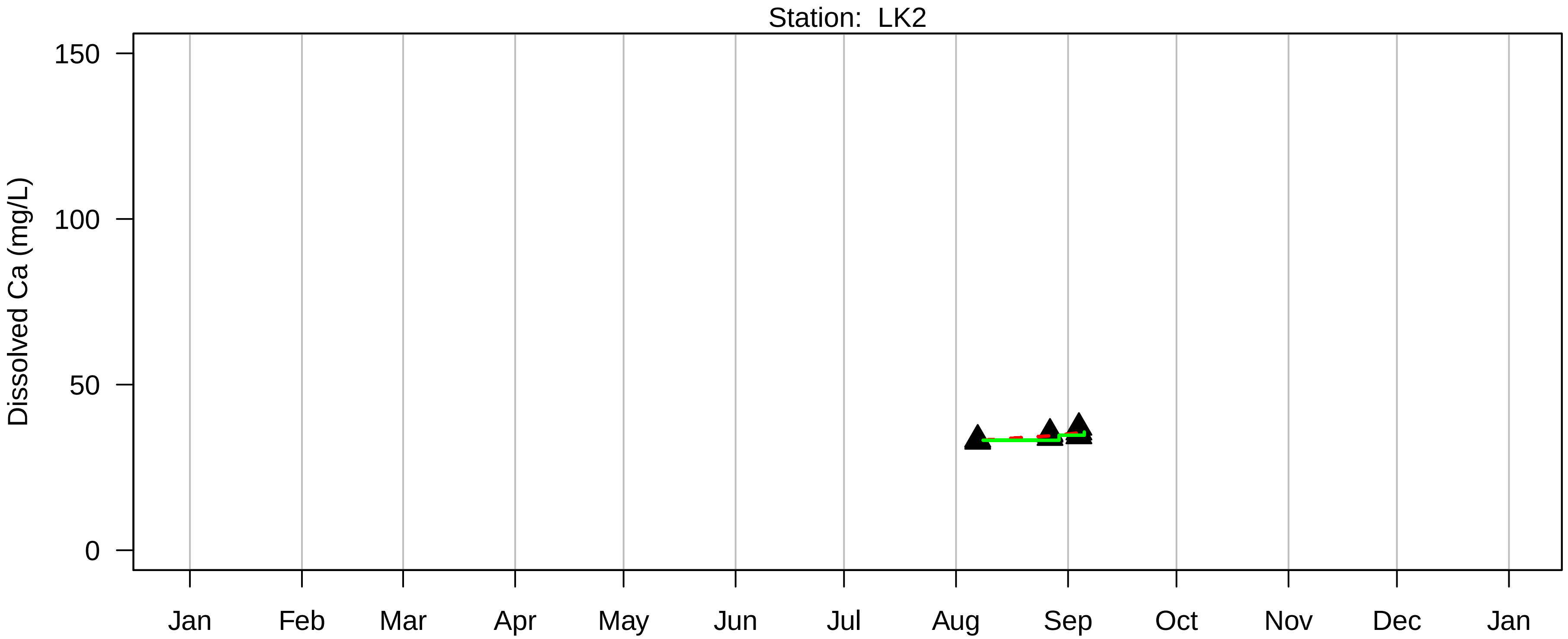

Station: GH_ER2
Dissolved Ca (mg/L)
0
50
100
150
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

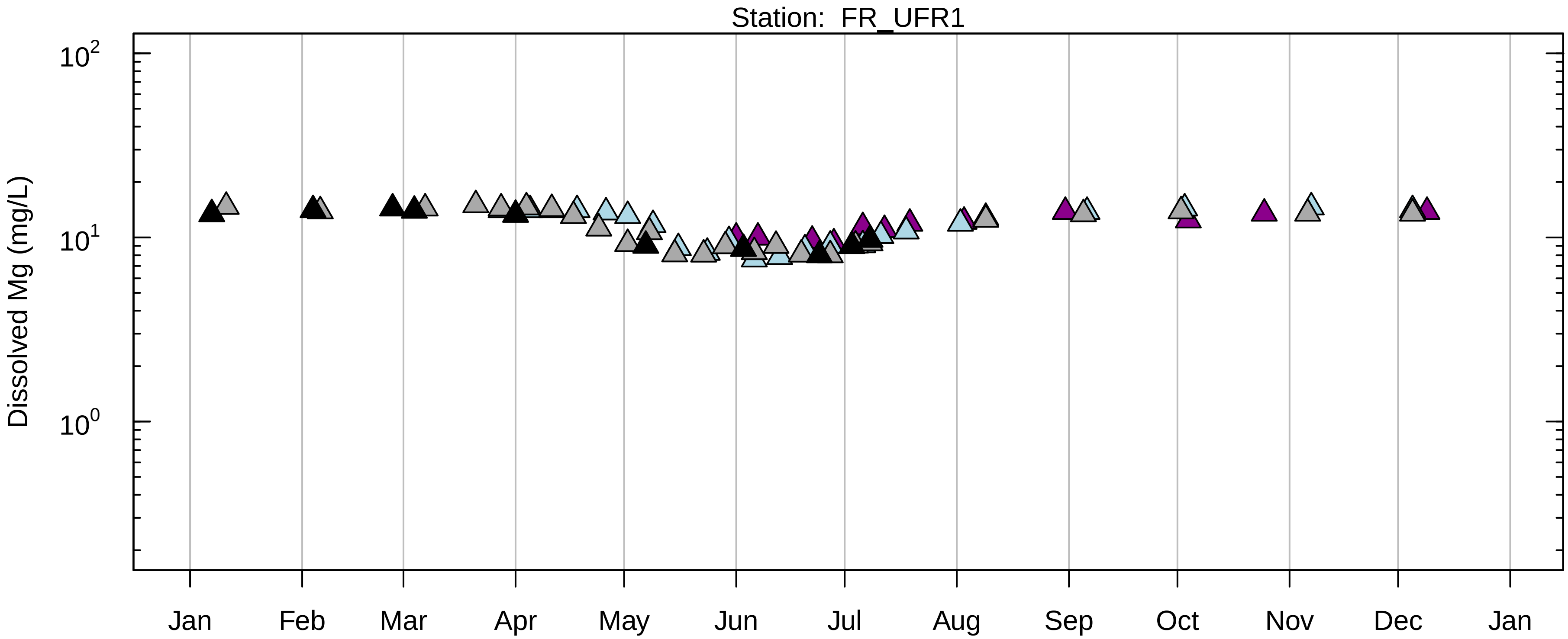

Station: GH_ER1
Dissolved Ca (mg/L)
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

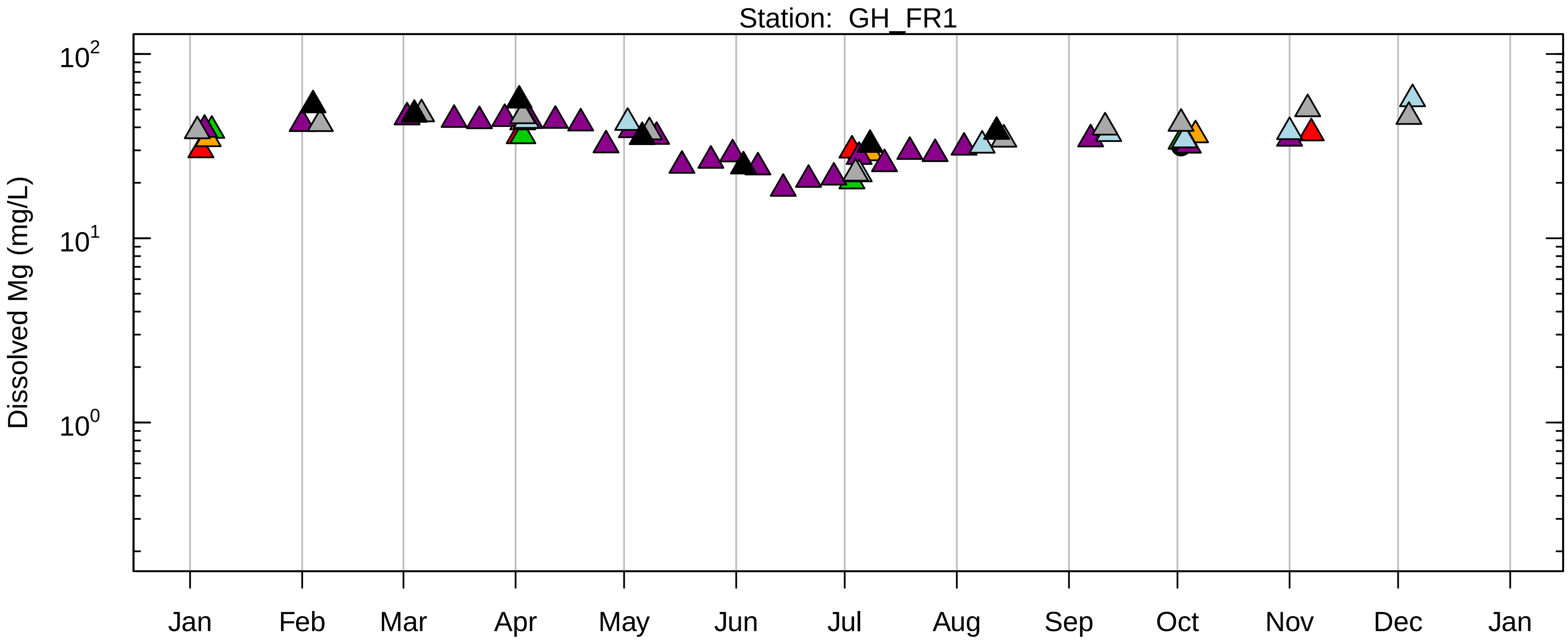

Station: EV_ER4
Dissolved Ca (mg/L)
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

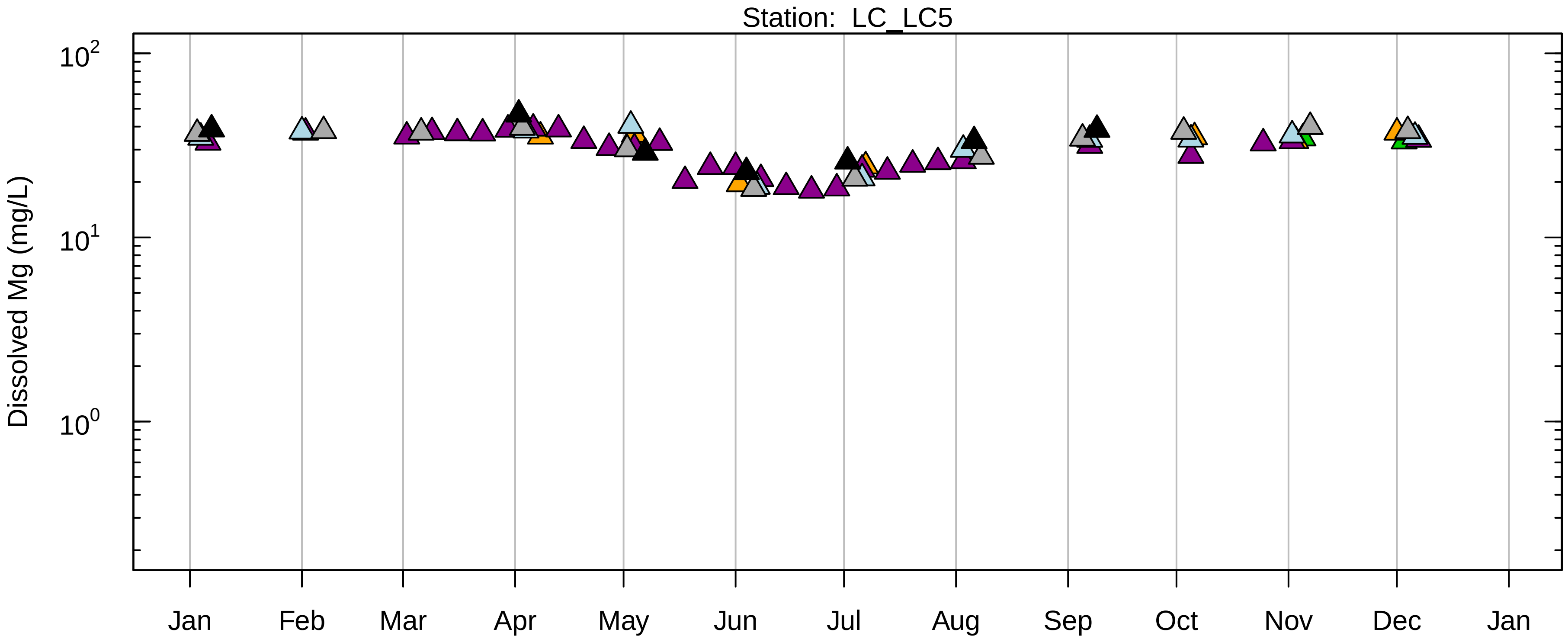

Station: EV_ER1
Dissolved Ca (mg/L)
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

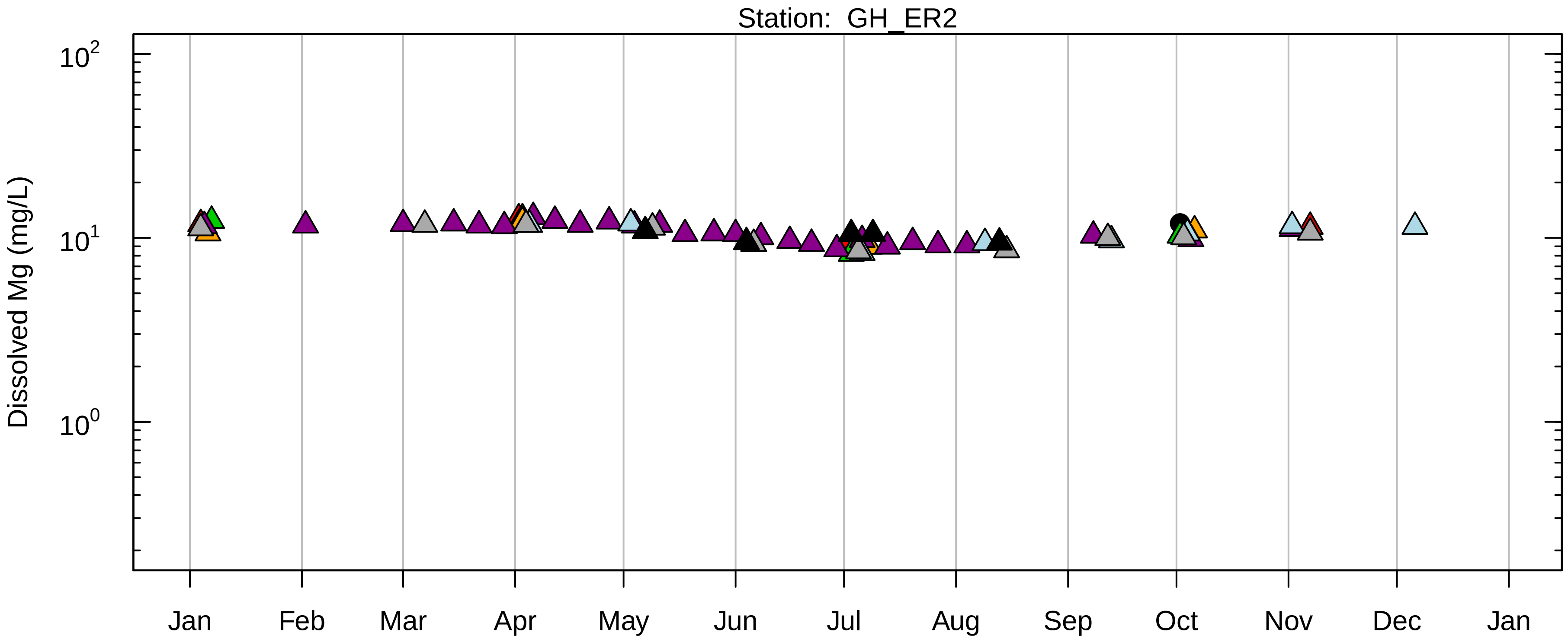

Station: RG_ELKORES
Dissolved Ca (mg/L)
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

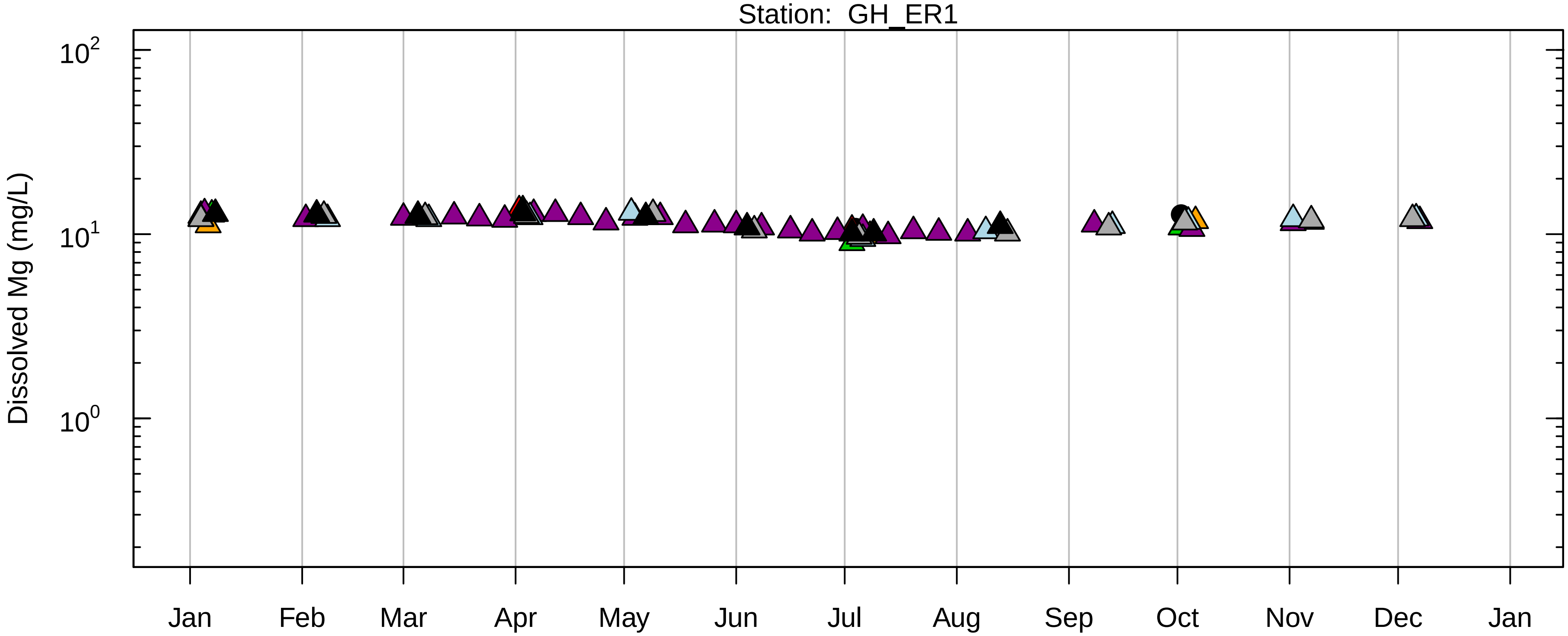

Station: LK2
Dissolved Ca (mg/L)
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: FR_UFR1
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

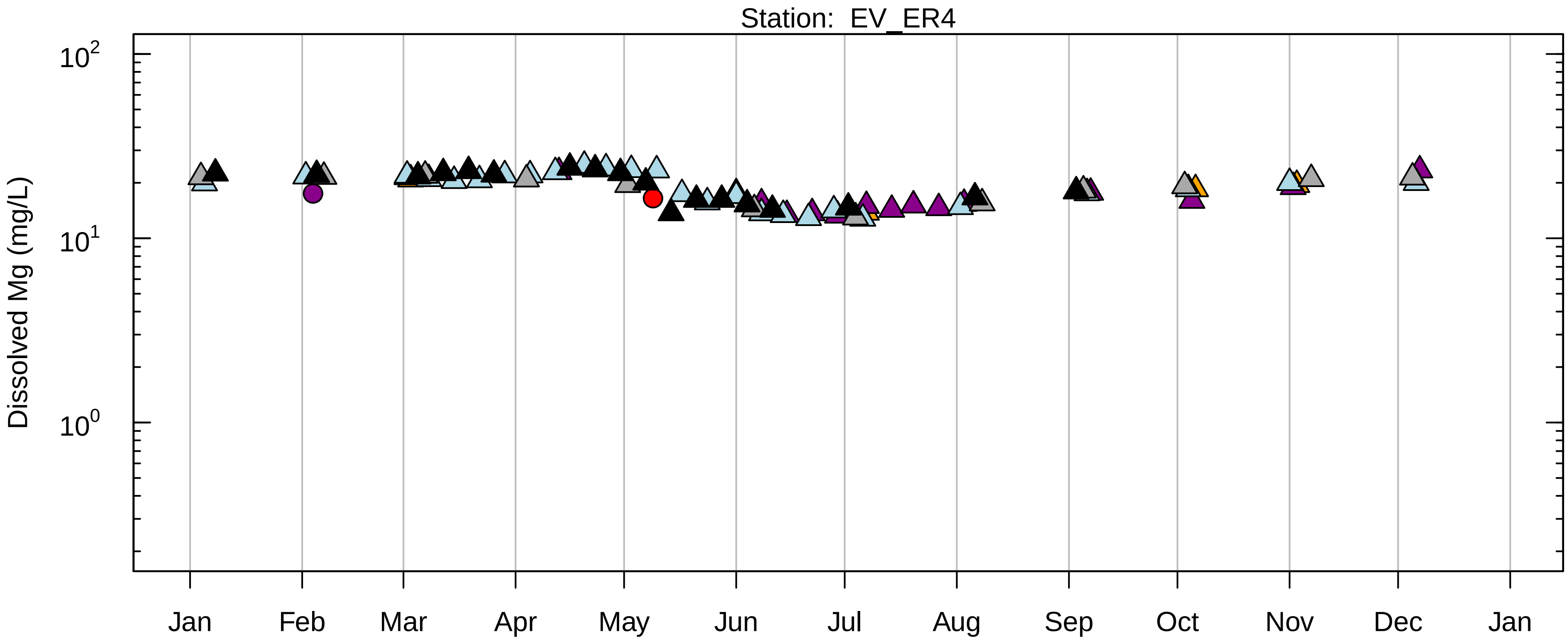

Station: GH_FR1
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: LC_LC5
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

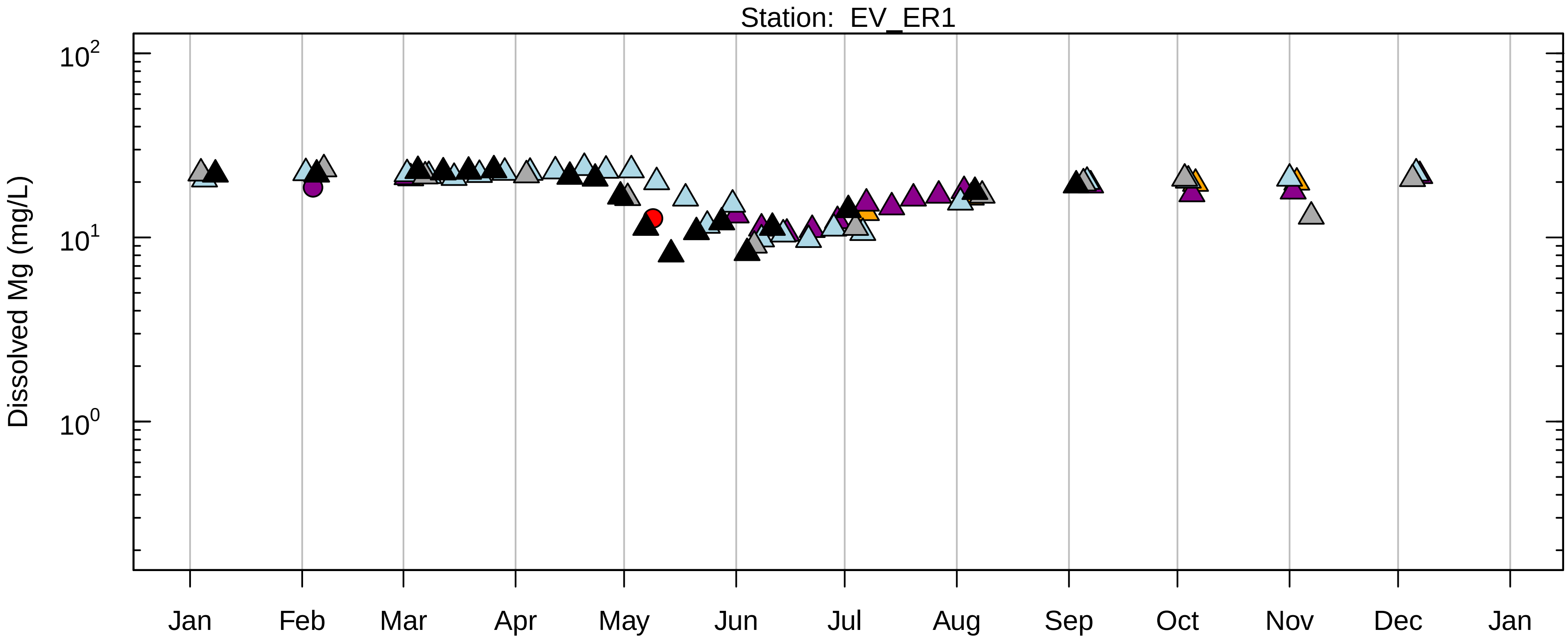

Station: GH_ER2
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan



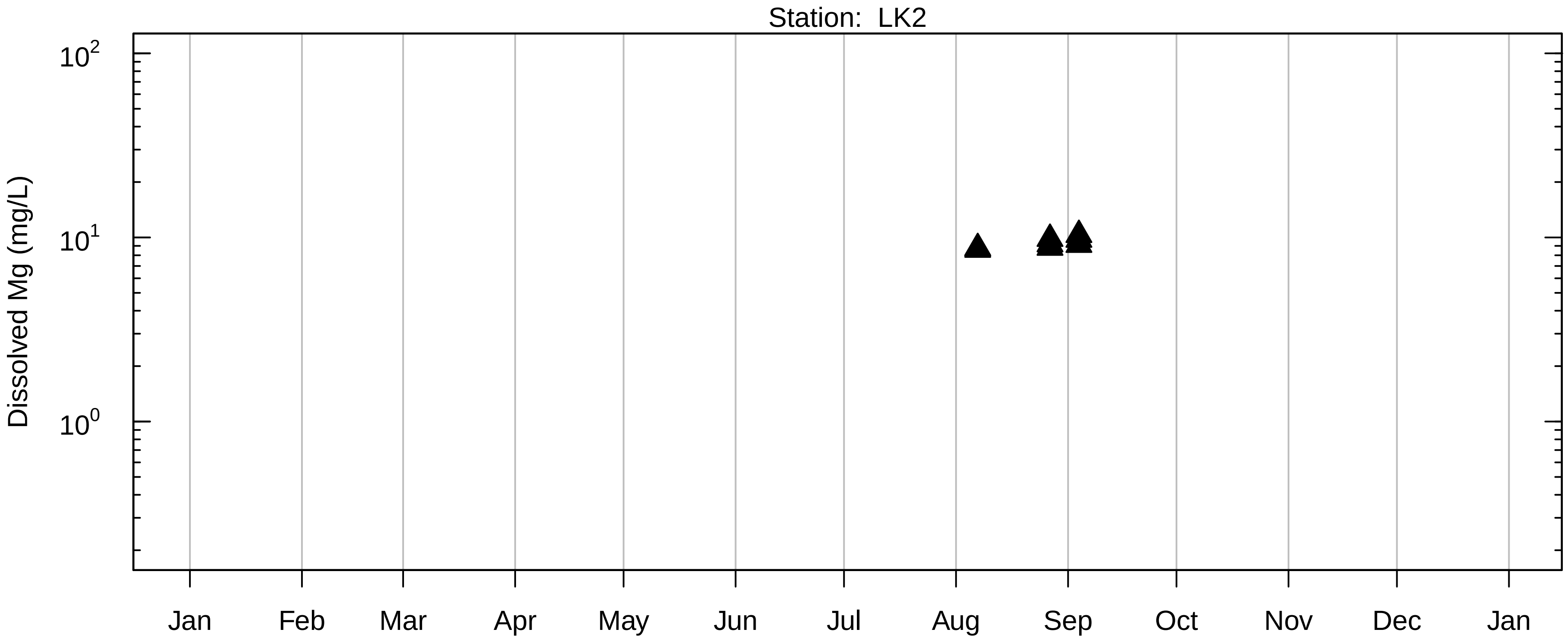
Station: GH_ER1
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

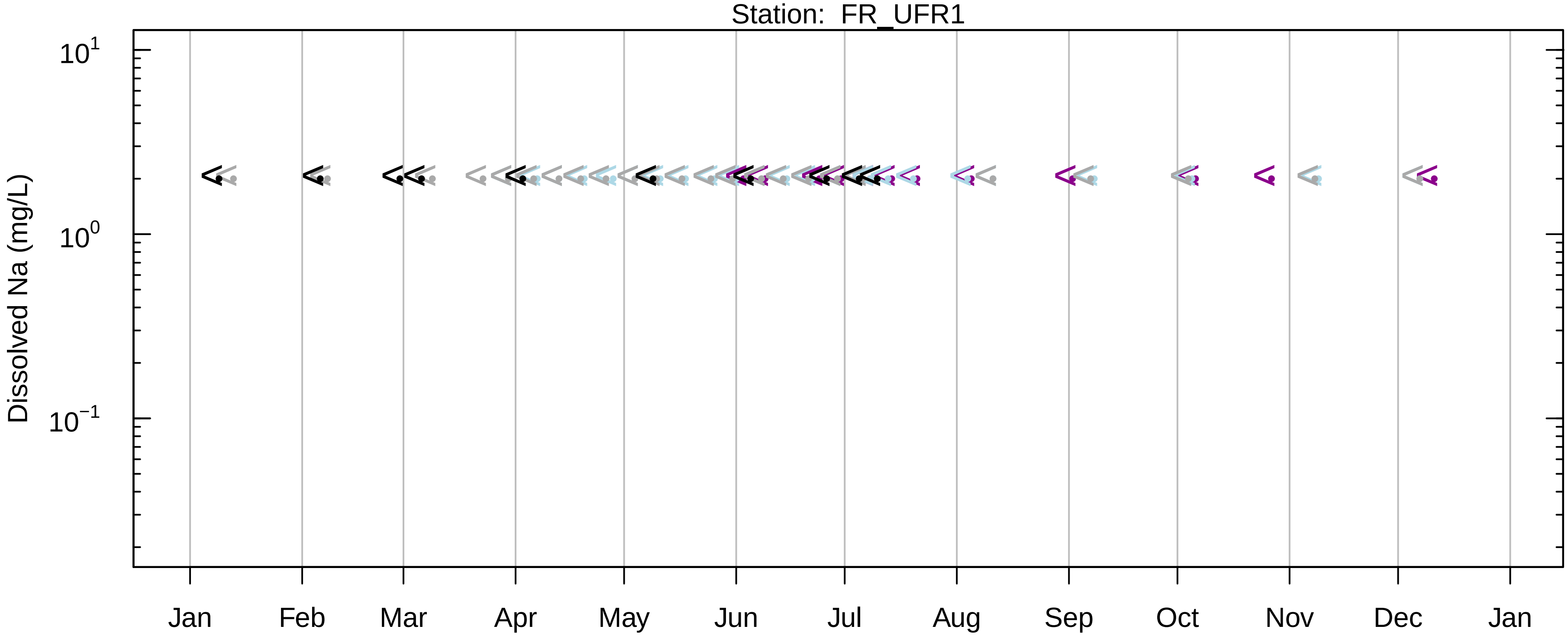


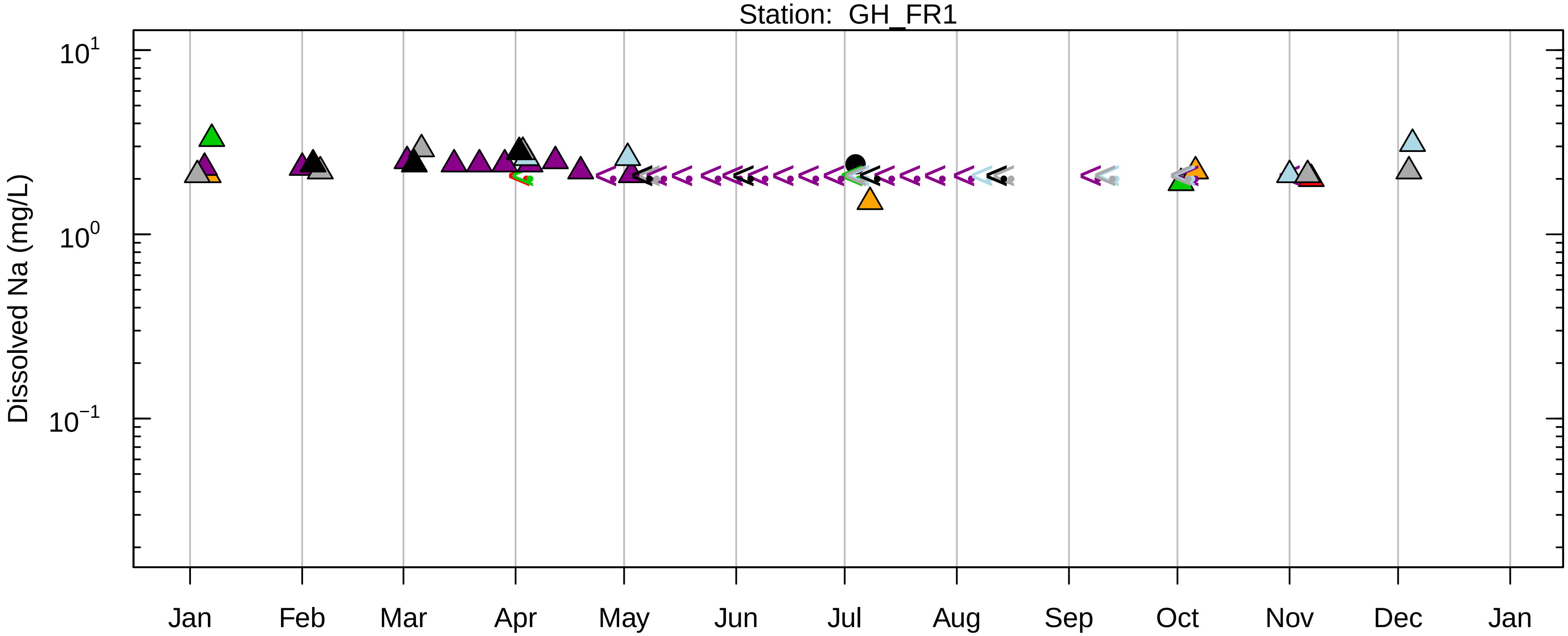
Station: EV_ER4
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

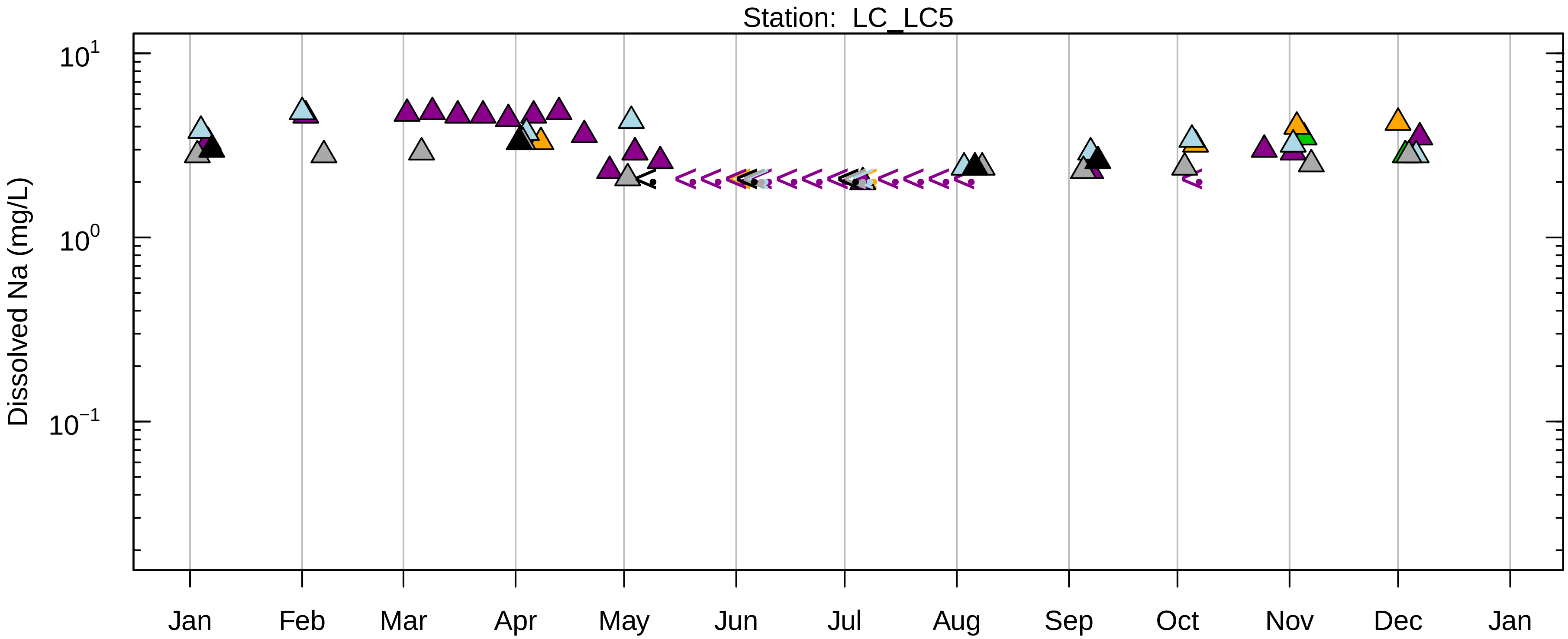

Station: EV_ER1
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

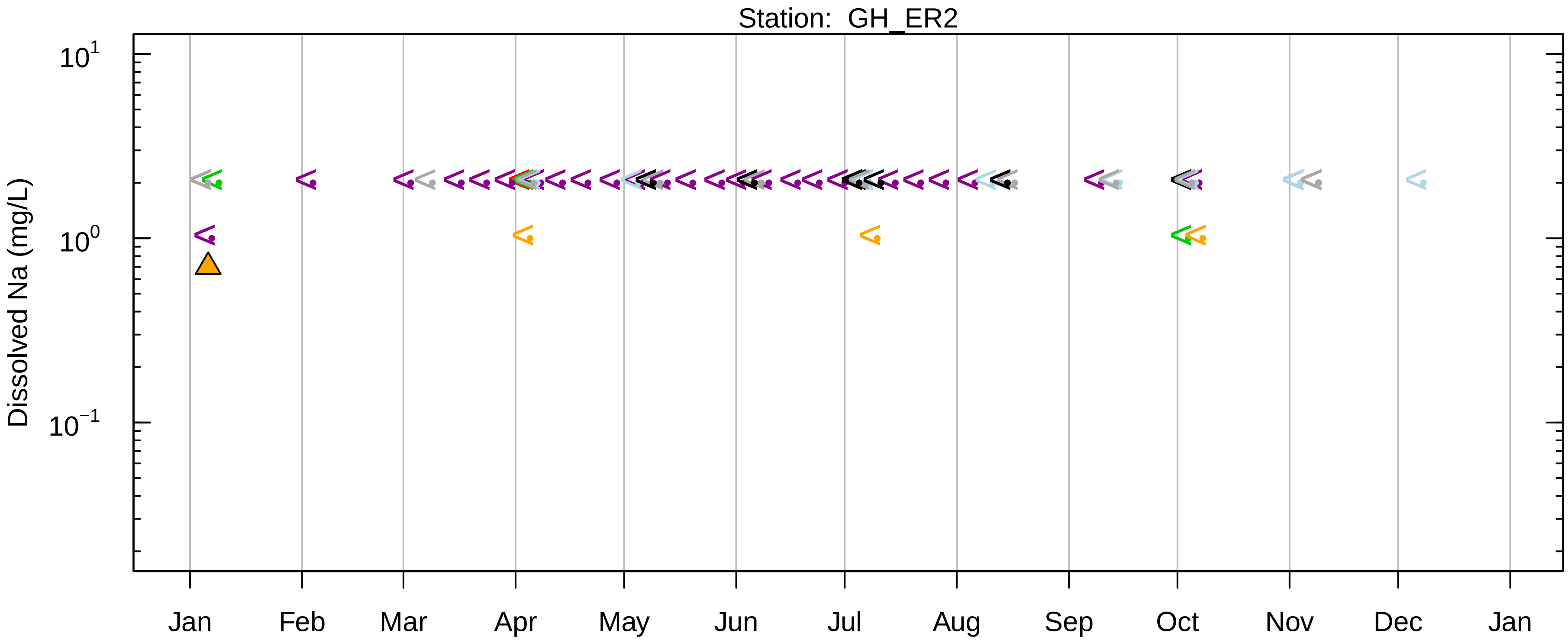

Station: RG_ELKORES
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

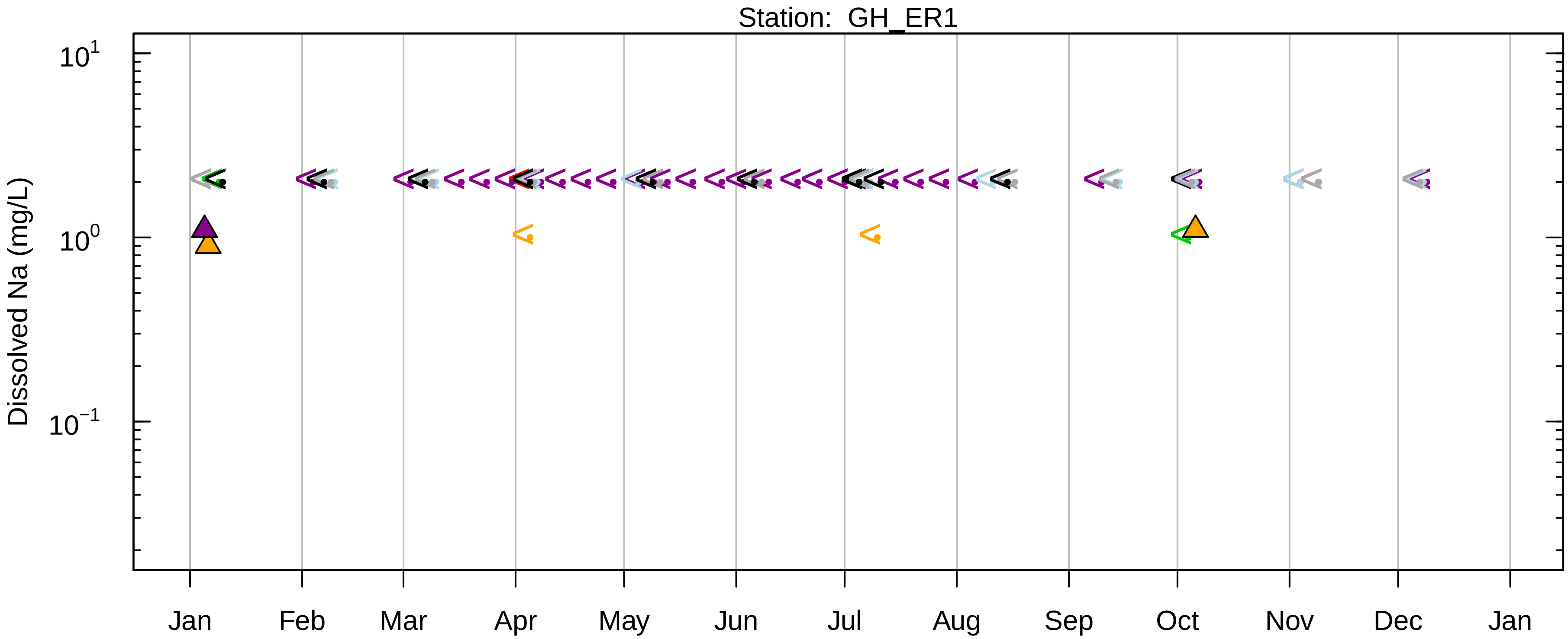

Station: LK2
Dissolved Mg (mg/L)
10^2
10^1
10^0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

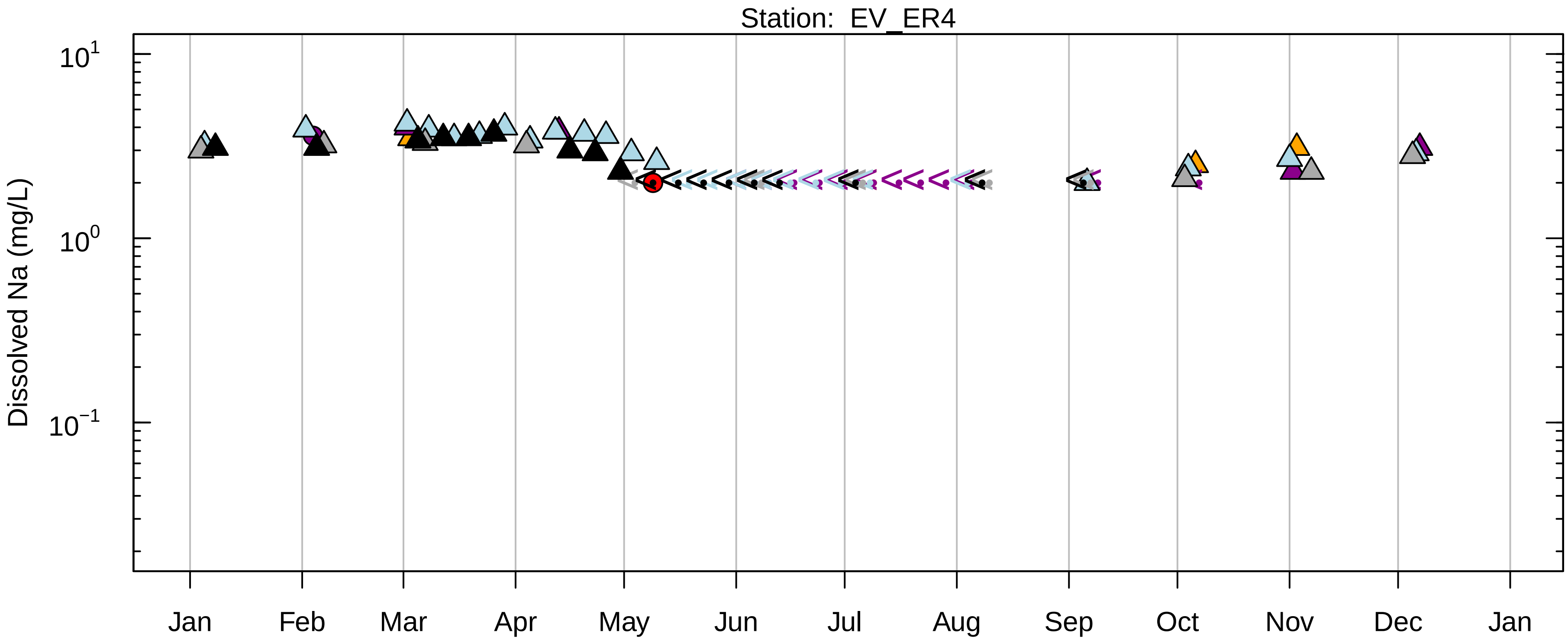

Station: FR_UFR1
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

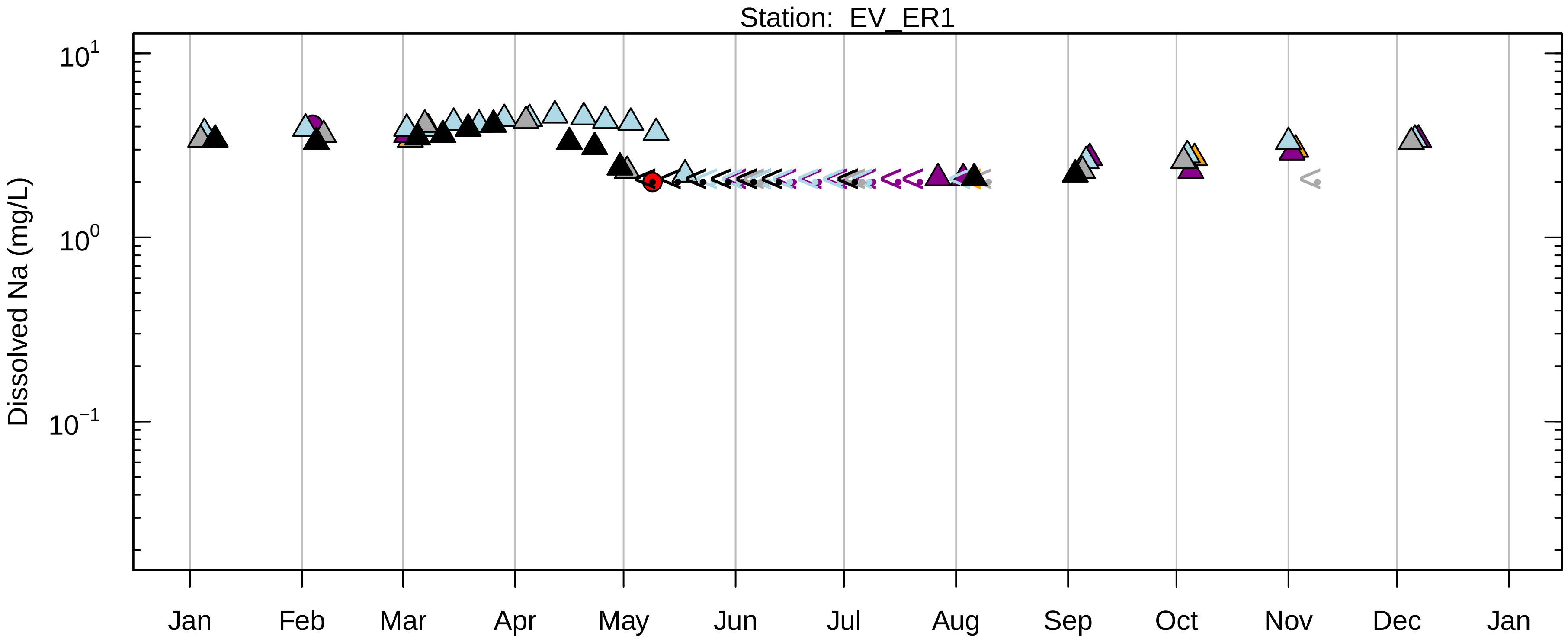

Station: GH_FR1
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

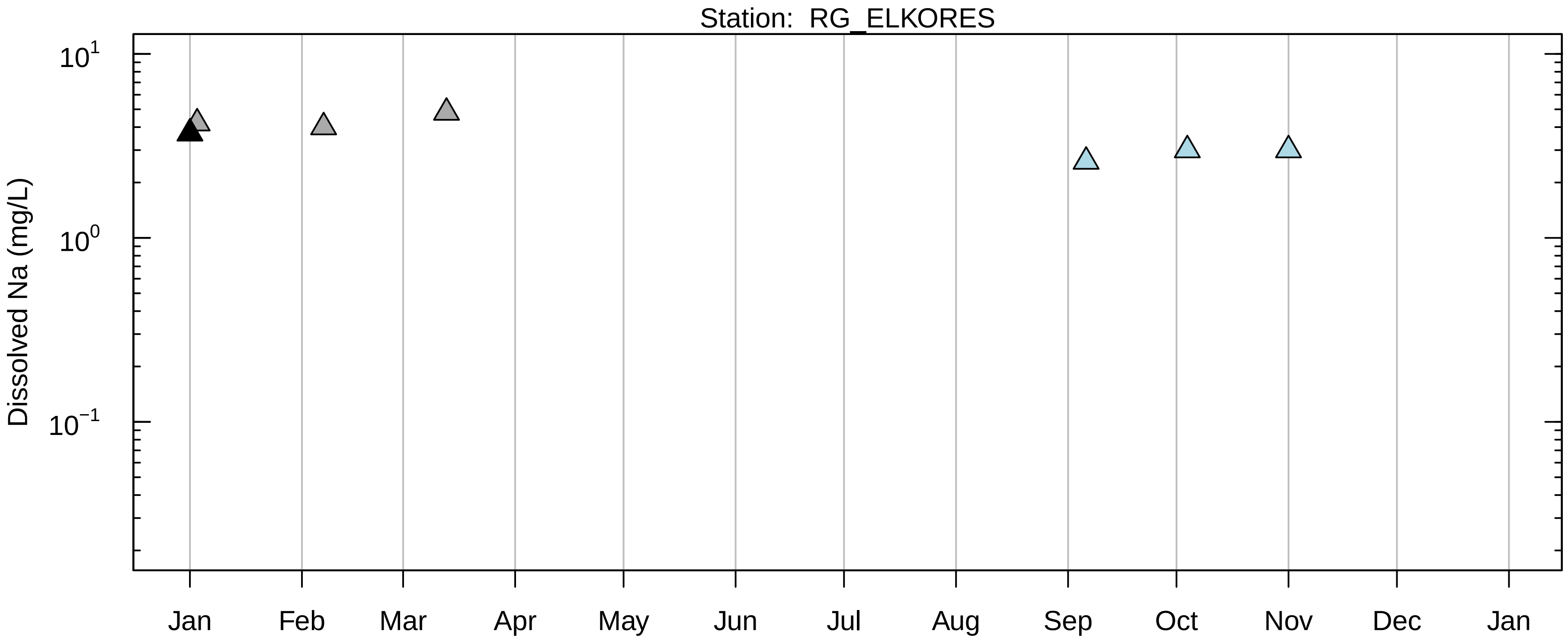

Station: LC_LC5
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

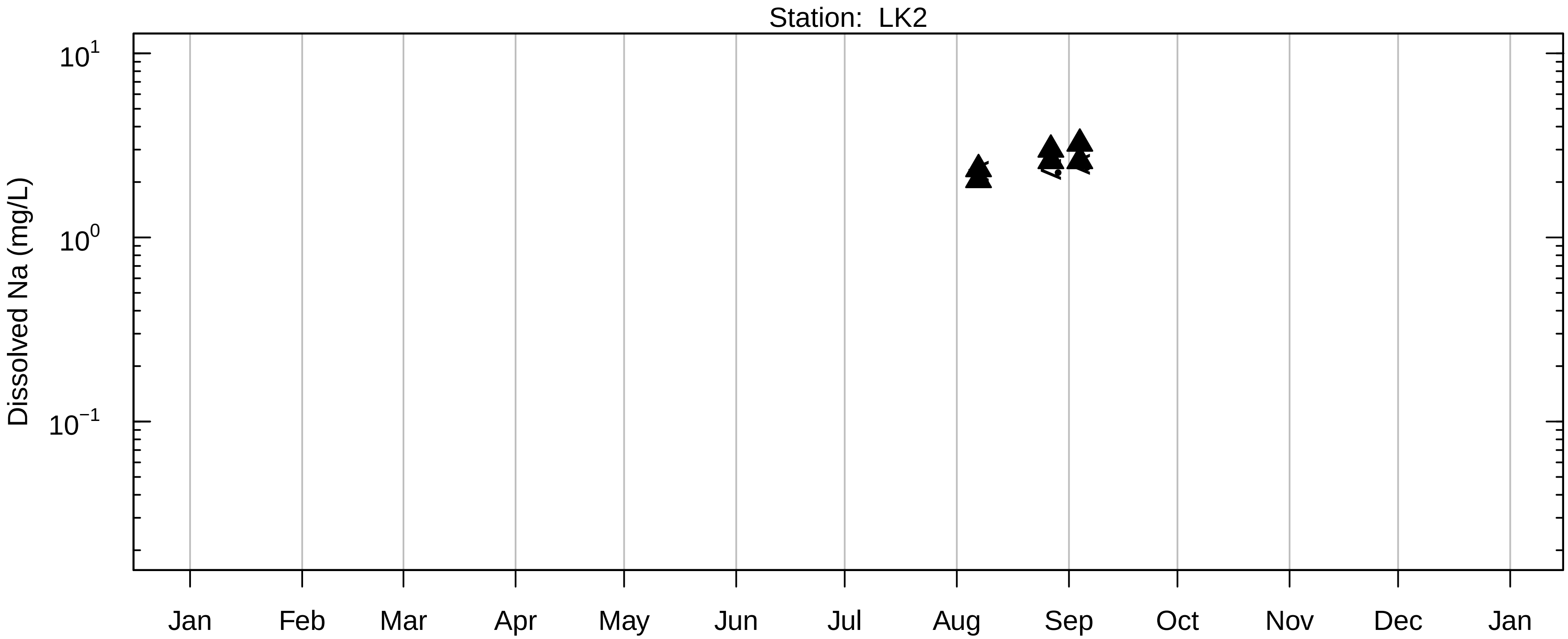

Station: GH_ER2
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: GH_ER1
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

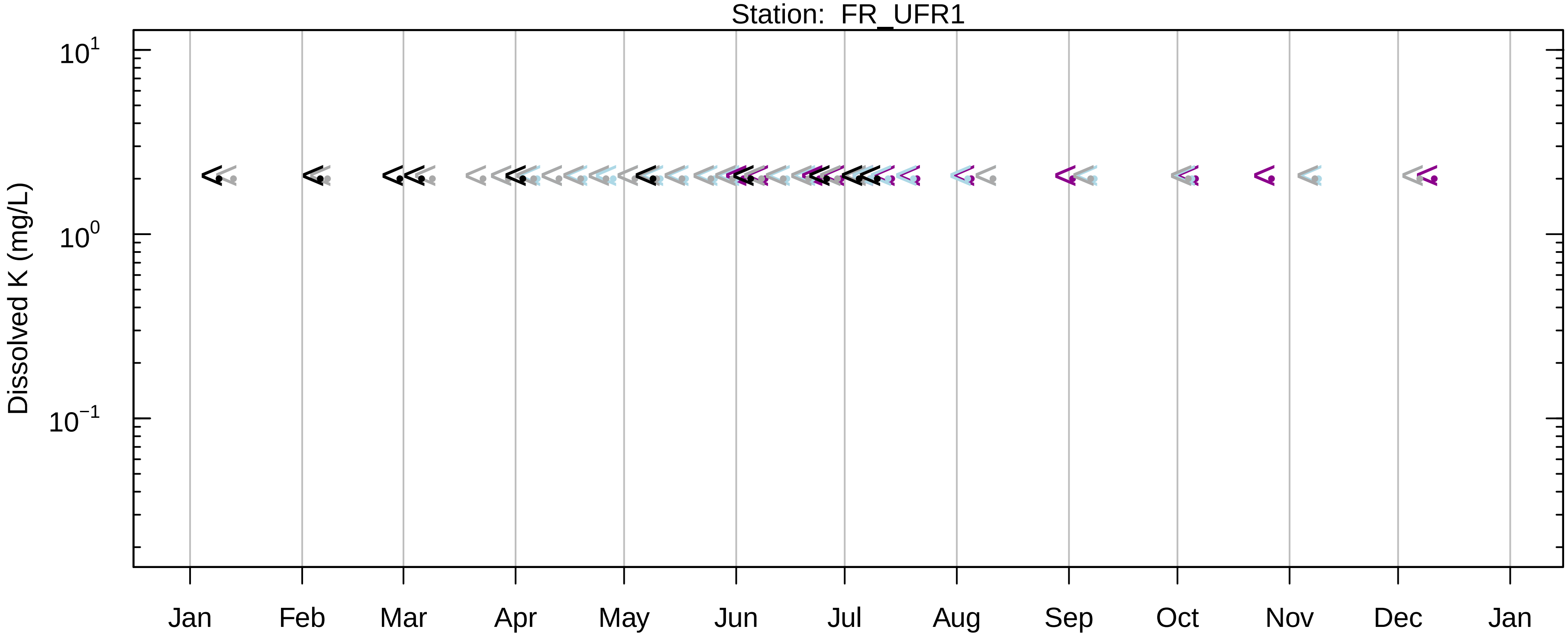

Station: EV_ER4
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

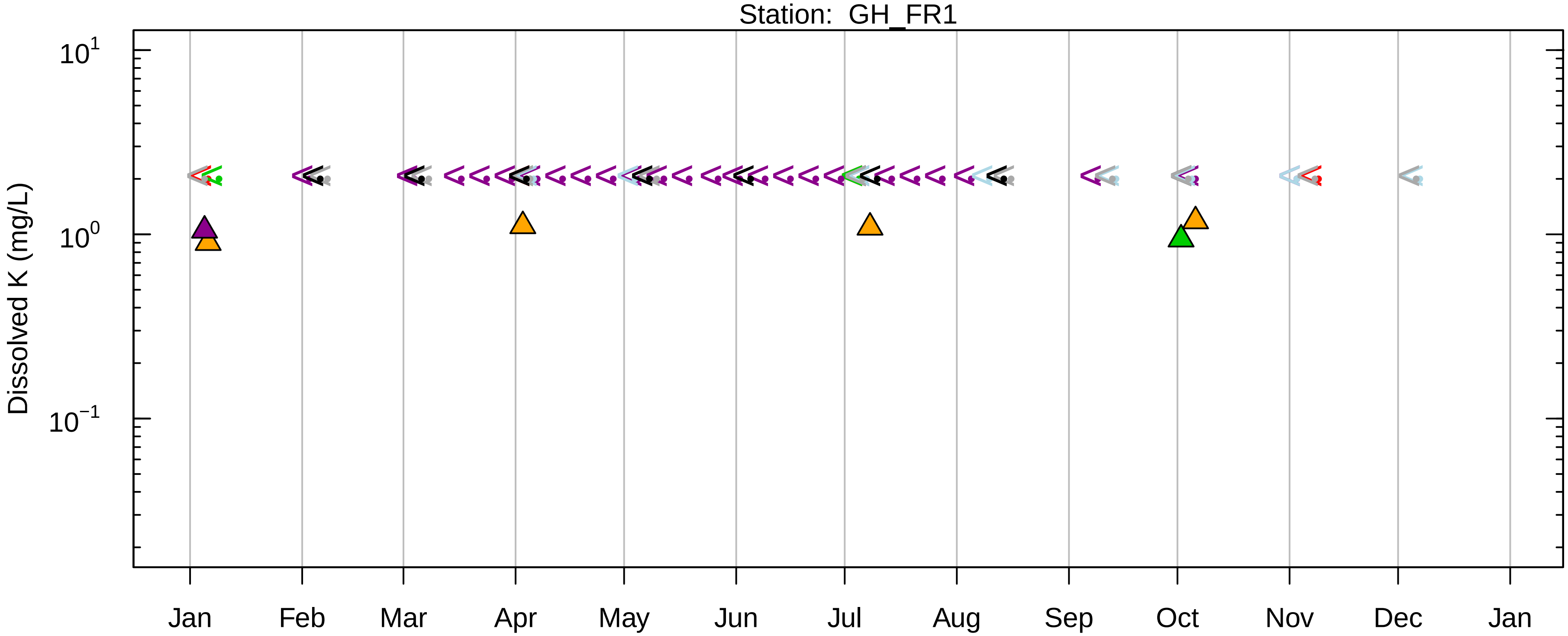

Station: EV_ER1
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

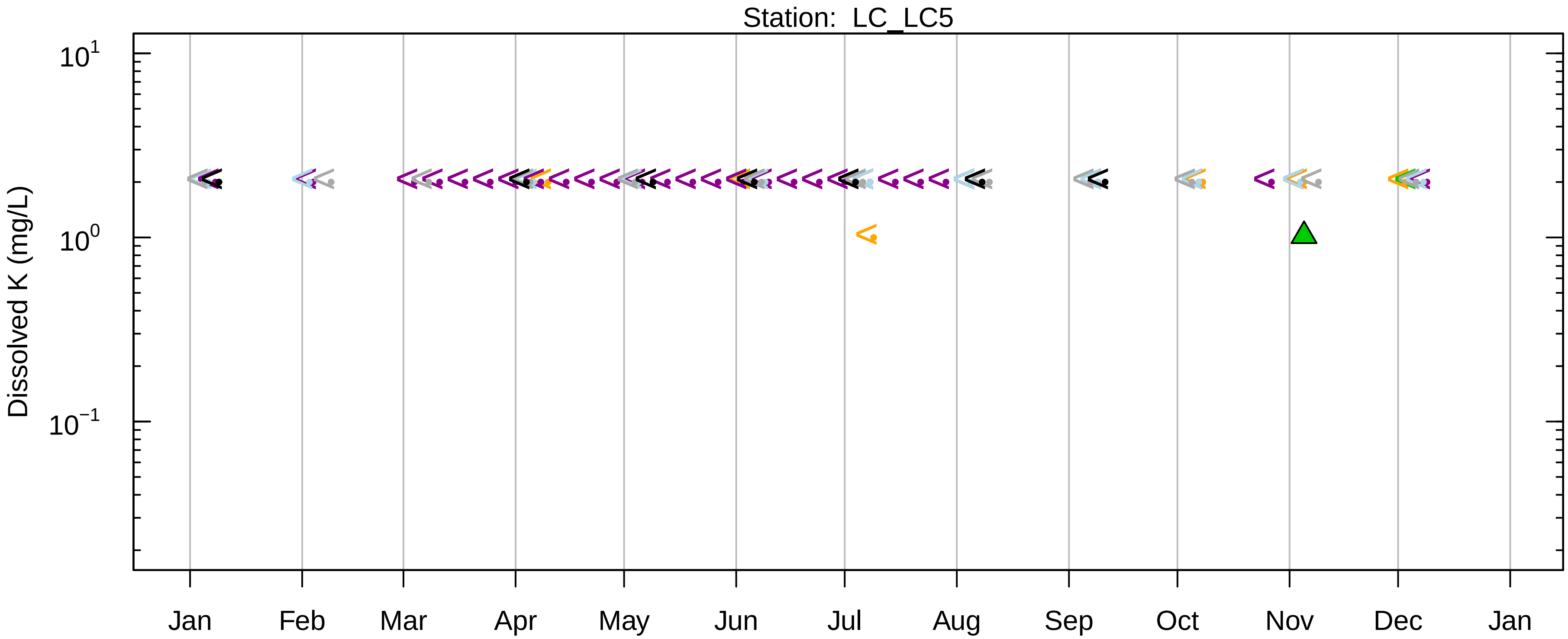

Station: RG_ELKORES
Dissolved Na (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

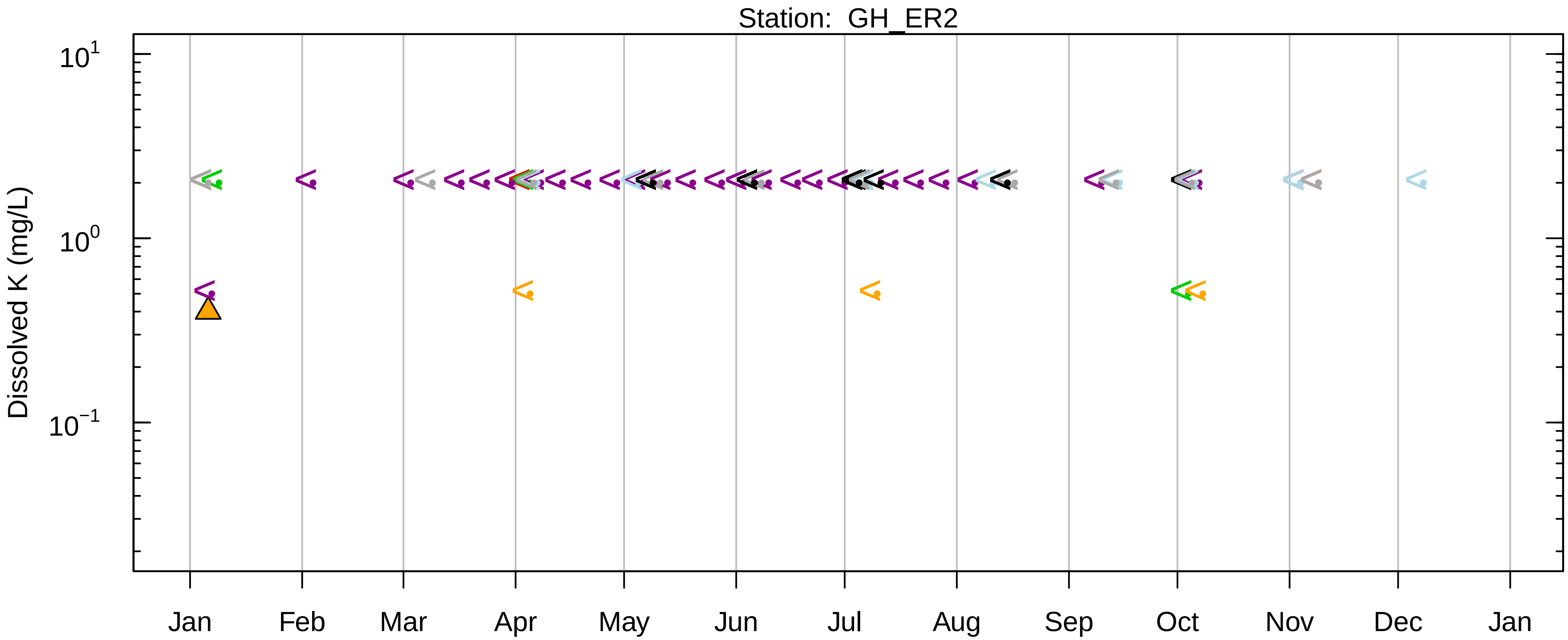


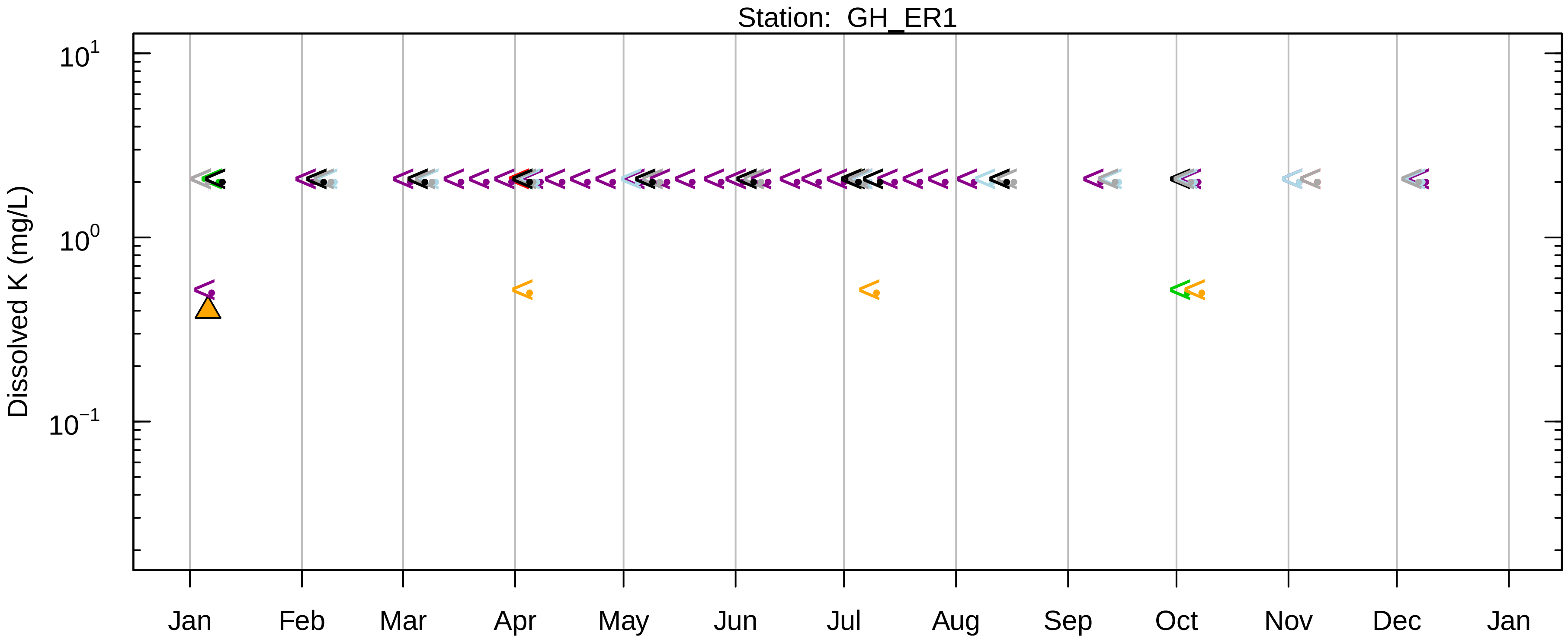
Station: LK2
Dissolved Na (mg/L)
10^{1}
10^{0}
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: FR_UFR1
Dissolved K (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

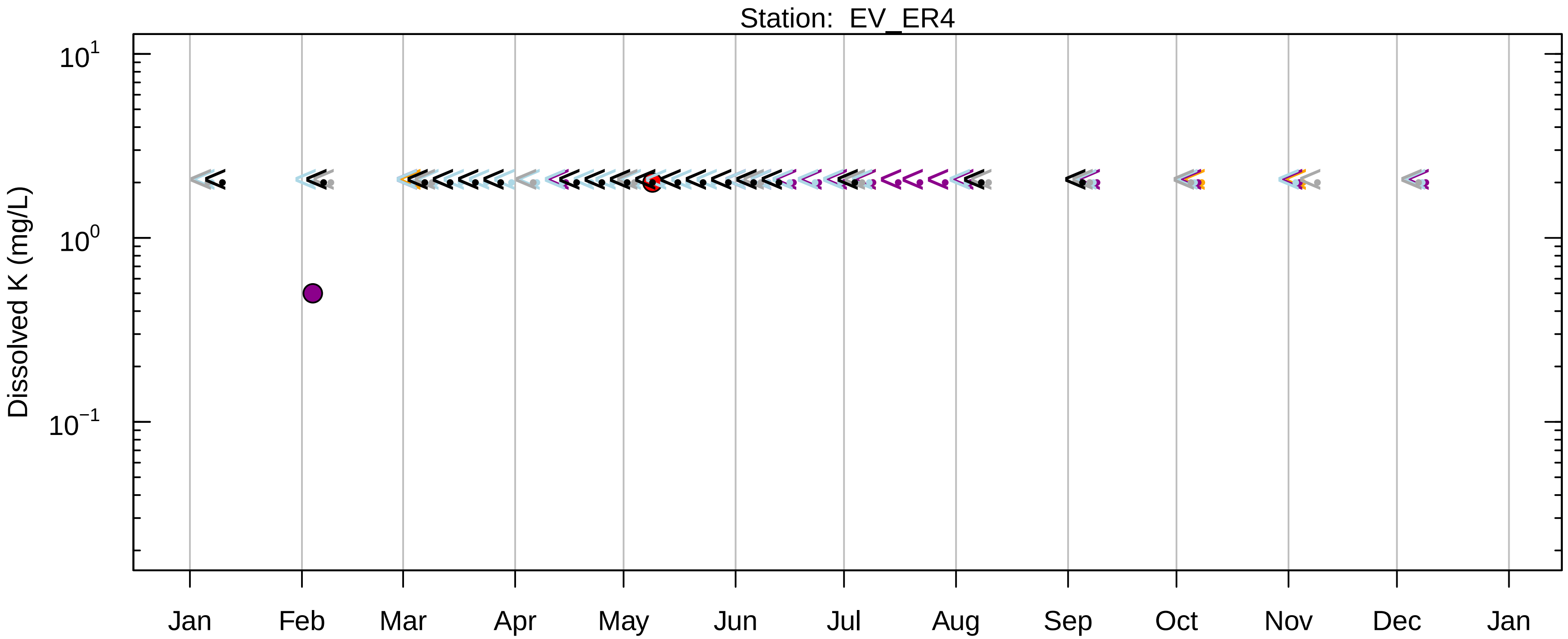

Station: GH_FR1
Dissolved K (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: LC_LC5
Dissolved K (mg/L)
10^1
10^0
10^{-1}
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

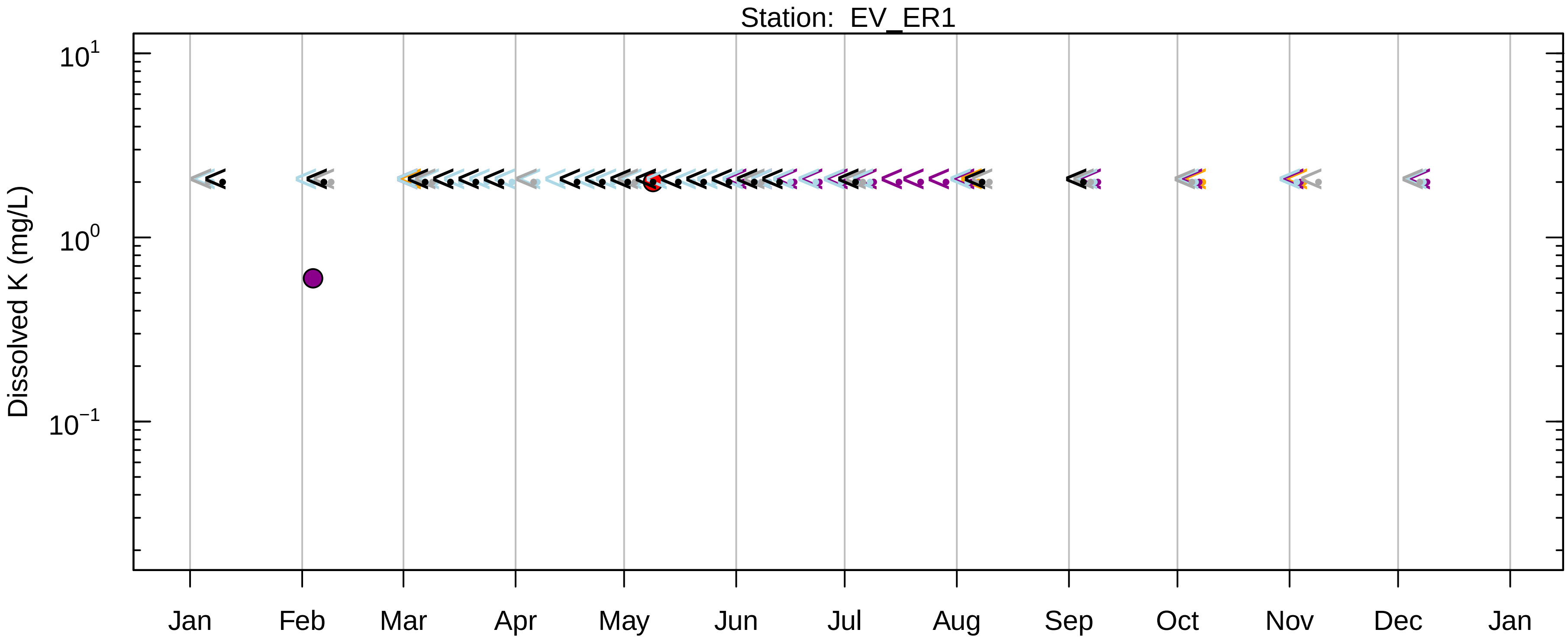

Station: GH_ER2
Dissolved K (mg/L)
10^1
10^0
10^{-1}
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan



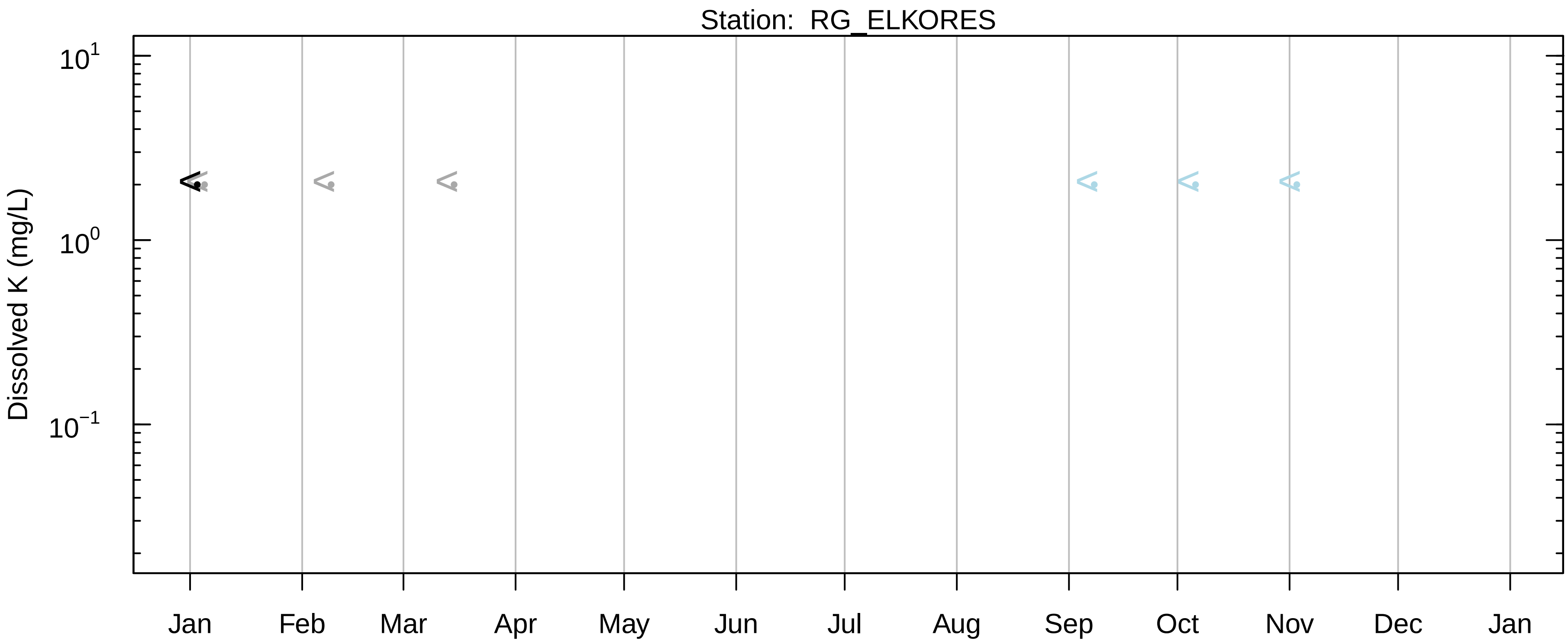
Station: GH_ER1
Dissolved K (mg/L)
10^1
10^0
10^-1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan



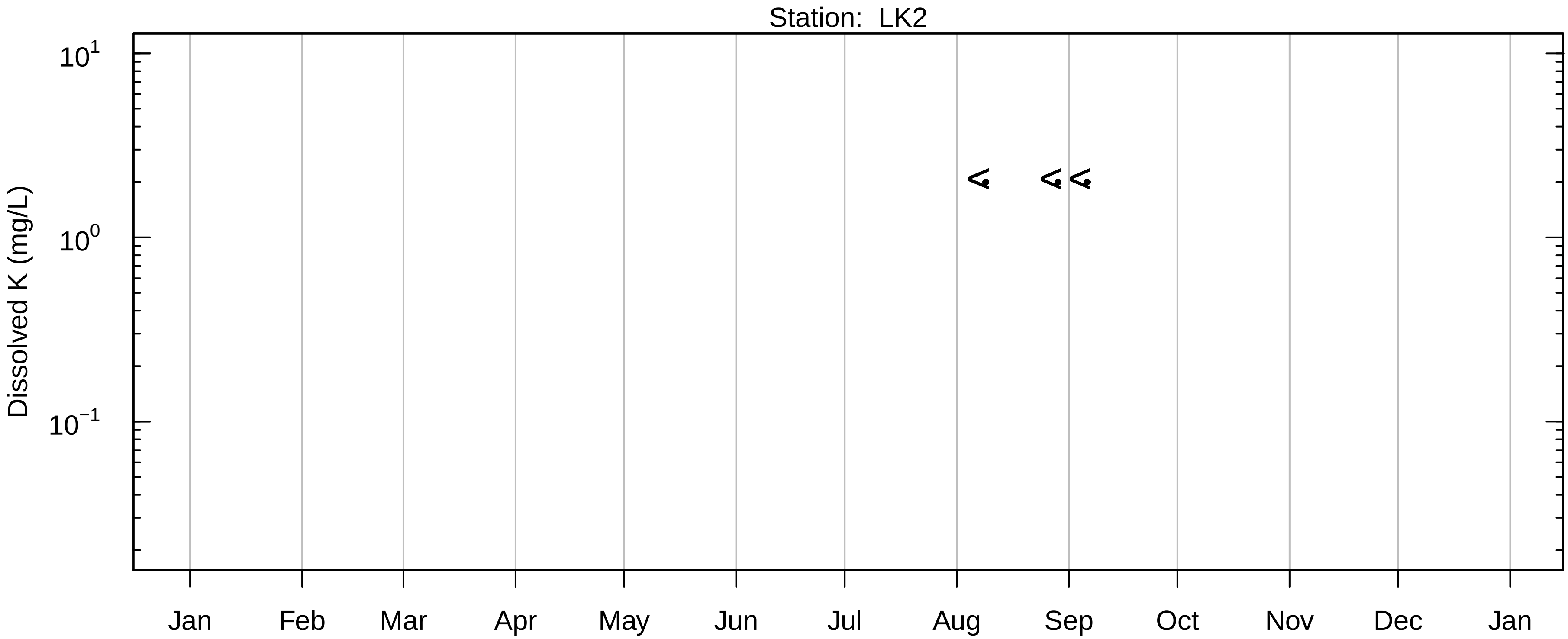
Station: EV_ER4
Dissolved K (mg/L)
10^1
10^0
10^-1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan



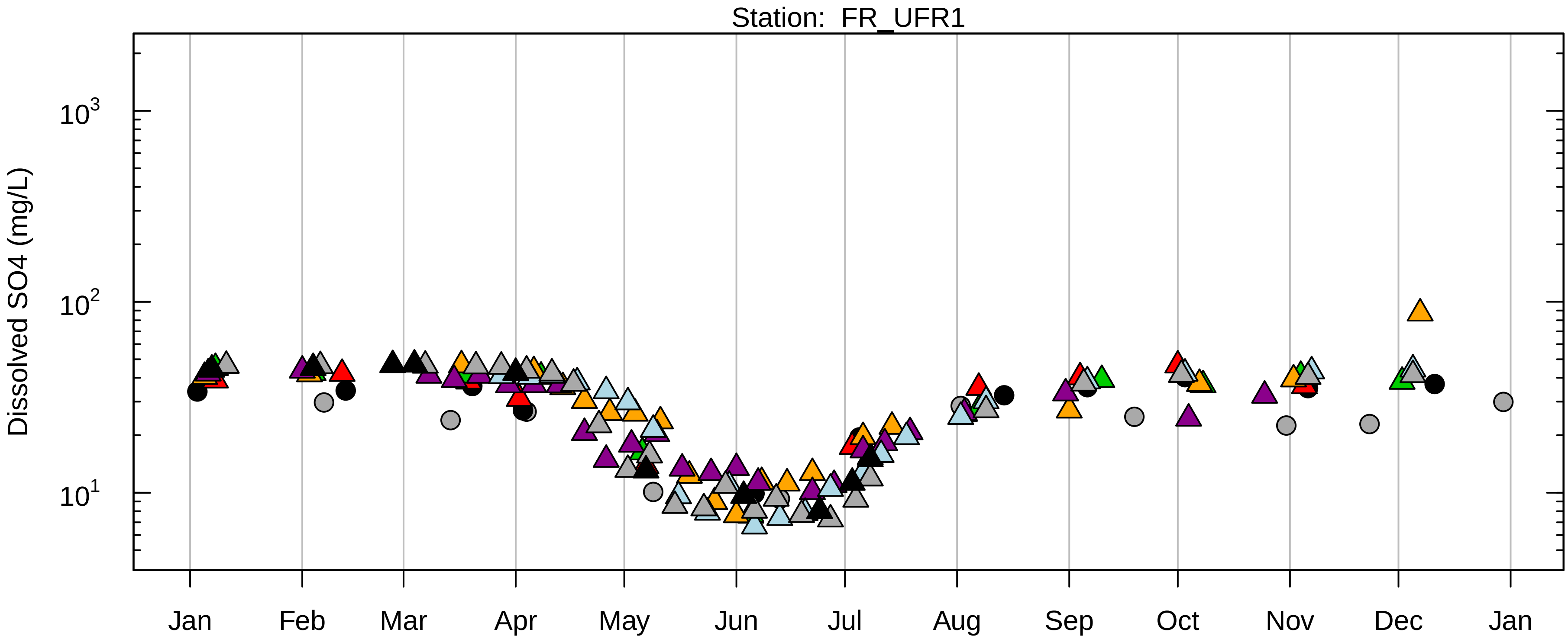
Station: EV_ER1
Dissolved K (mg/L)
10^{1}
10^{0}
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

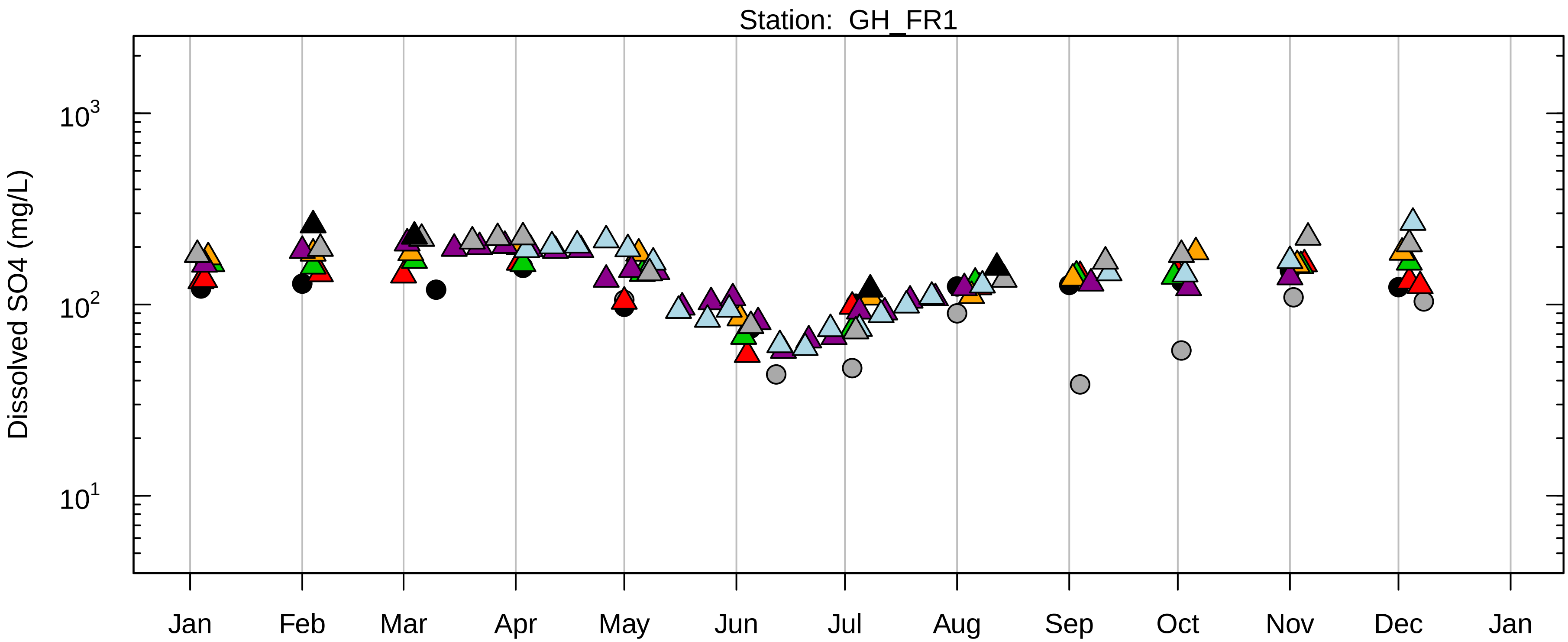


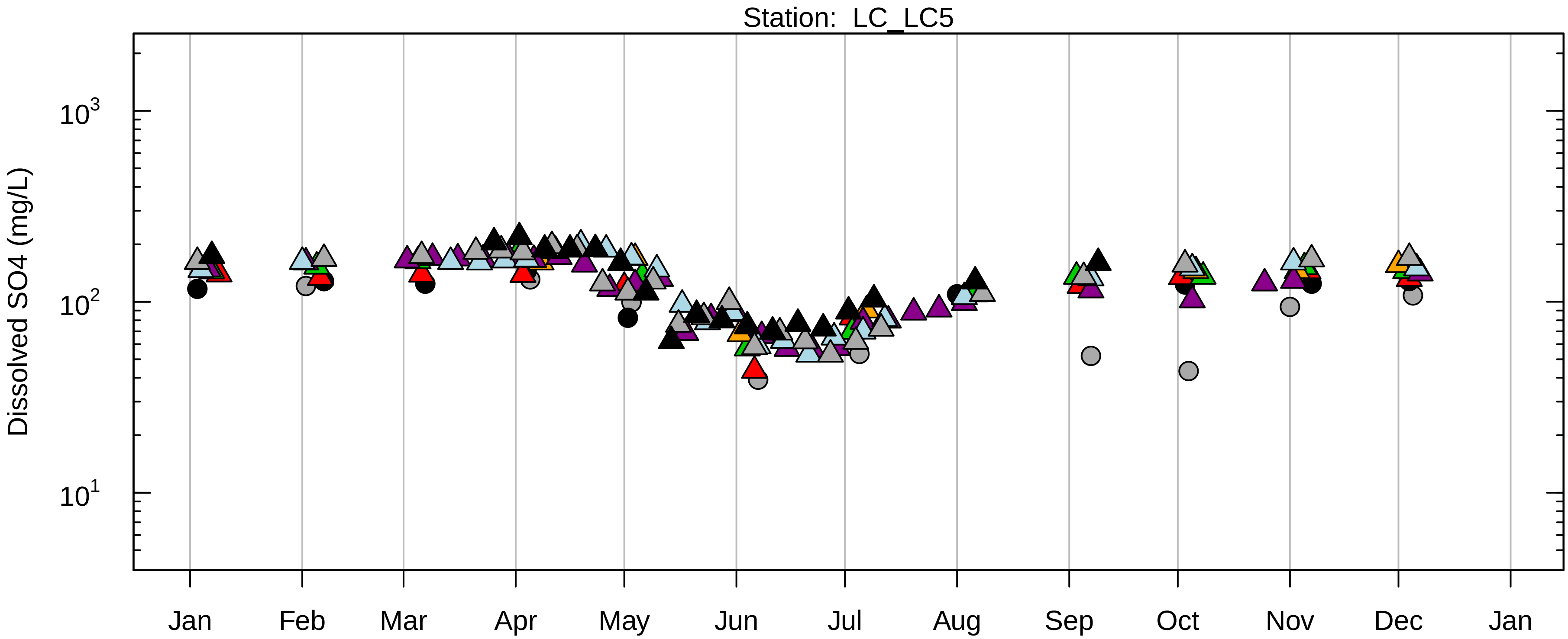
Station: RG_ELKORES
Dissolved K (mg/L)
10^{1}
10^{0}
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

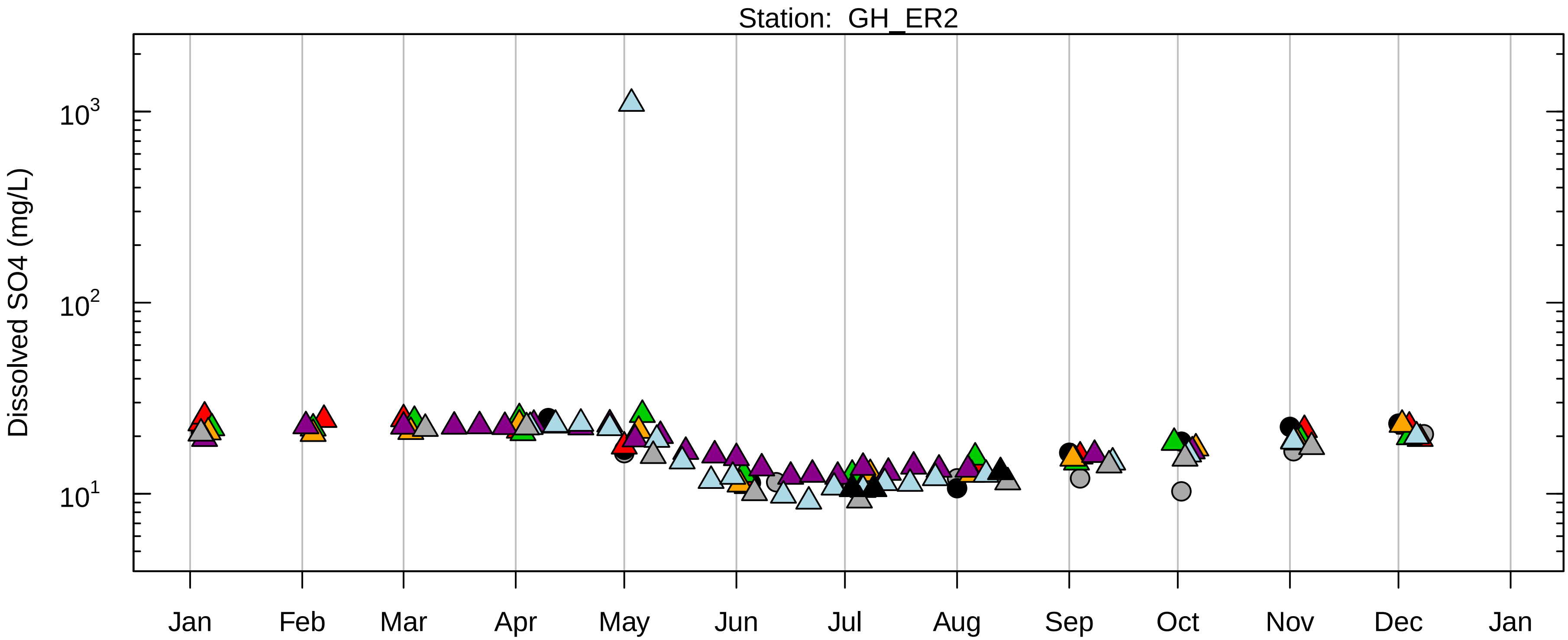


Station: LK2
Dissolved K (mg/L)
10^1
10^0
10^{-1}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

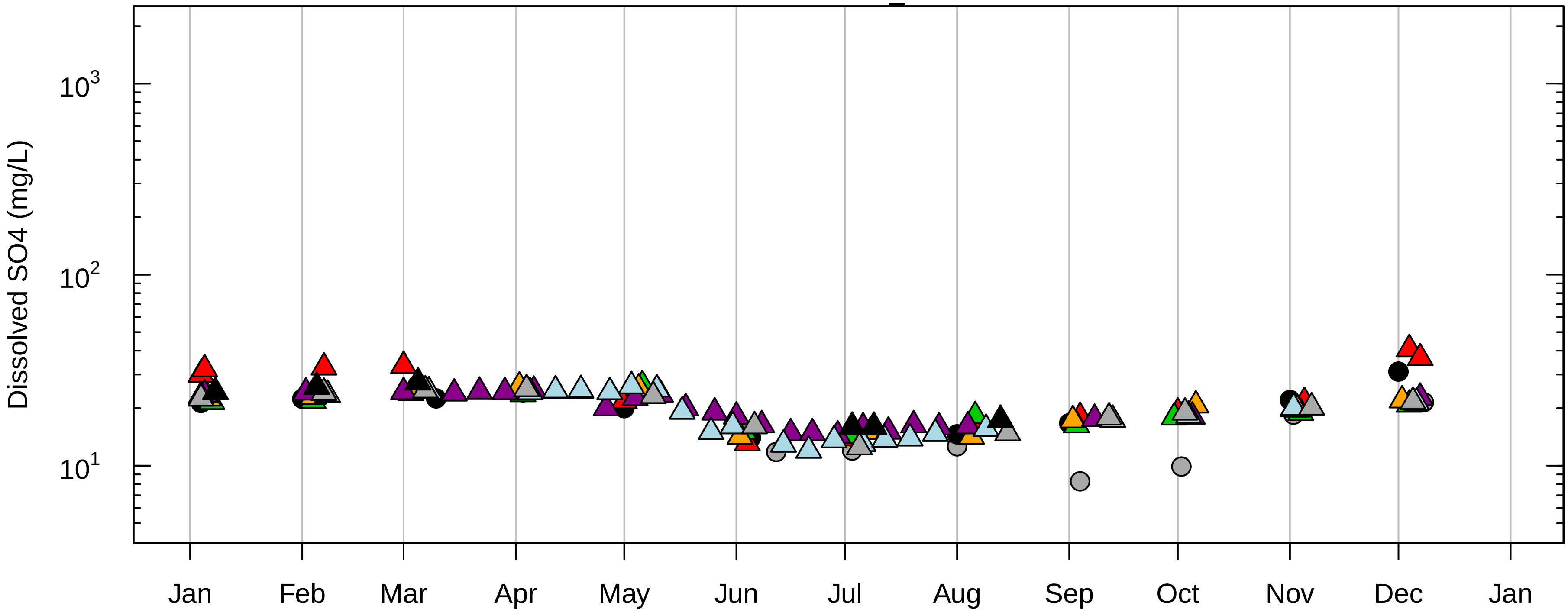

Station: FR_UFR1
Dissolved SO4 (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: GH_FR1
Dissolved SO4 (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

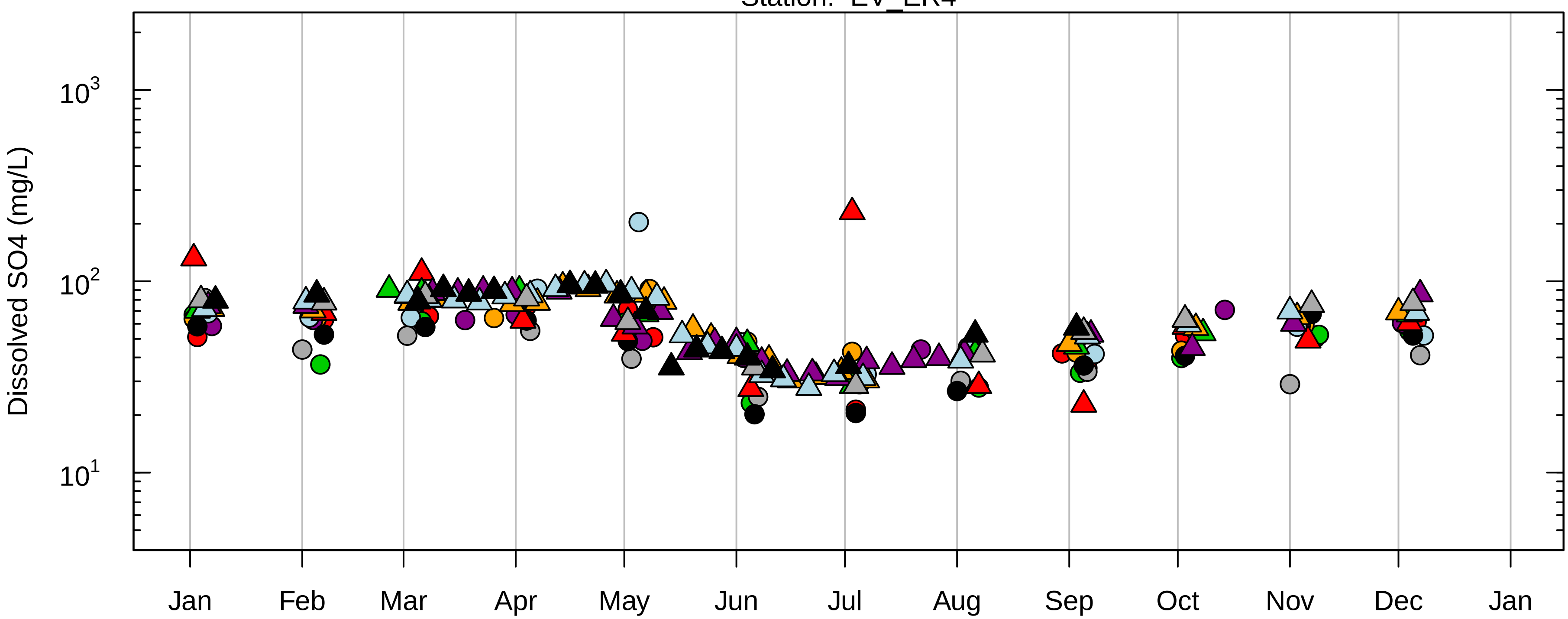

Station: LC_LC5
Dissolved SO4 (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

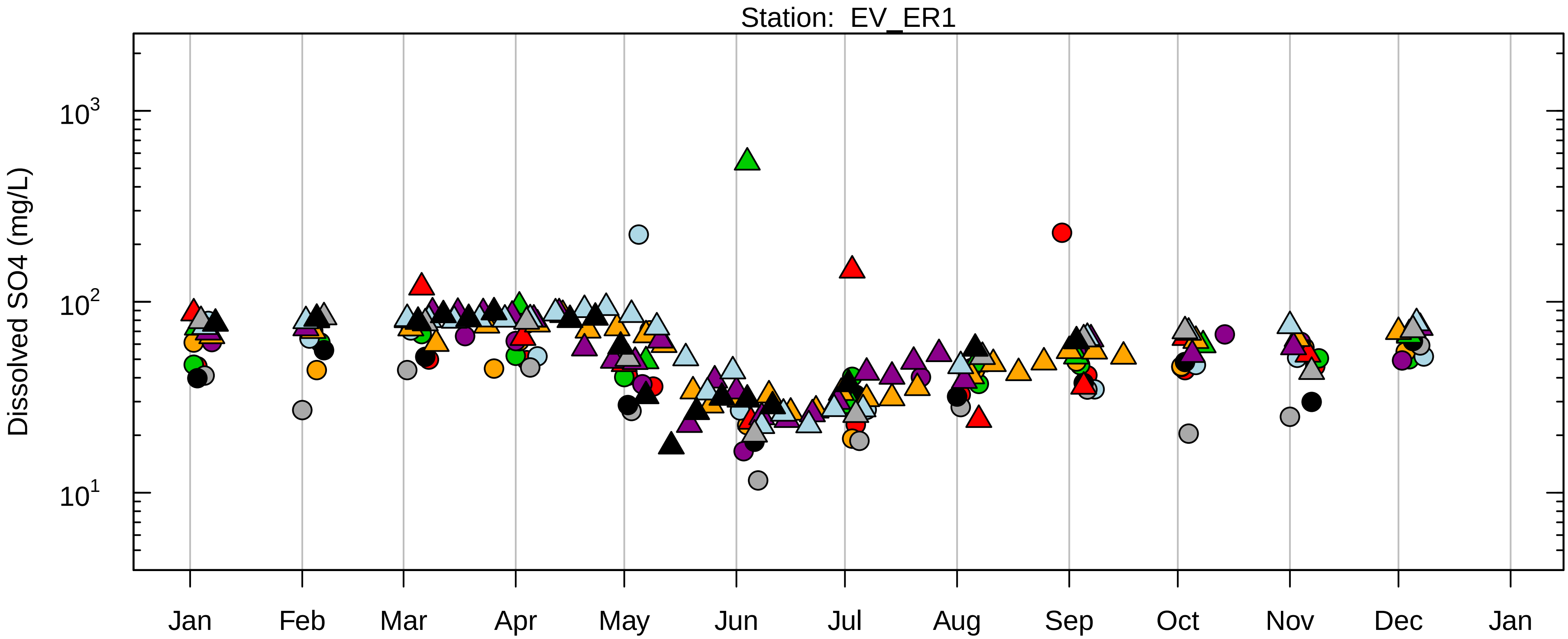

Station: GH_ER2
Dissolved SO4 (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

Station: GH_ER1

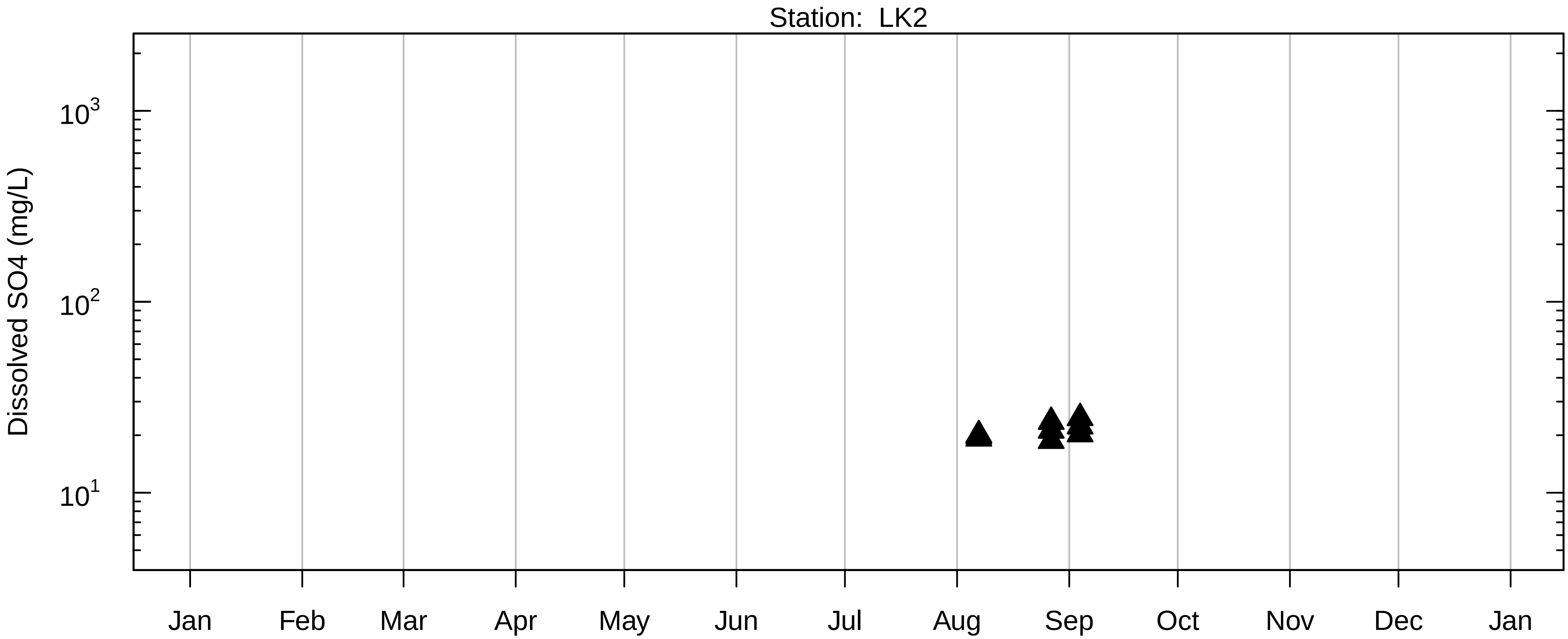


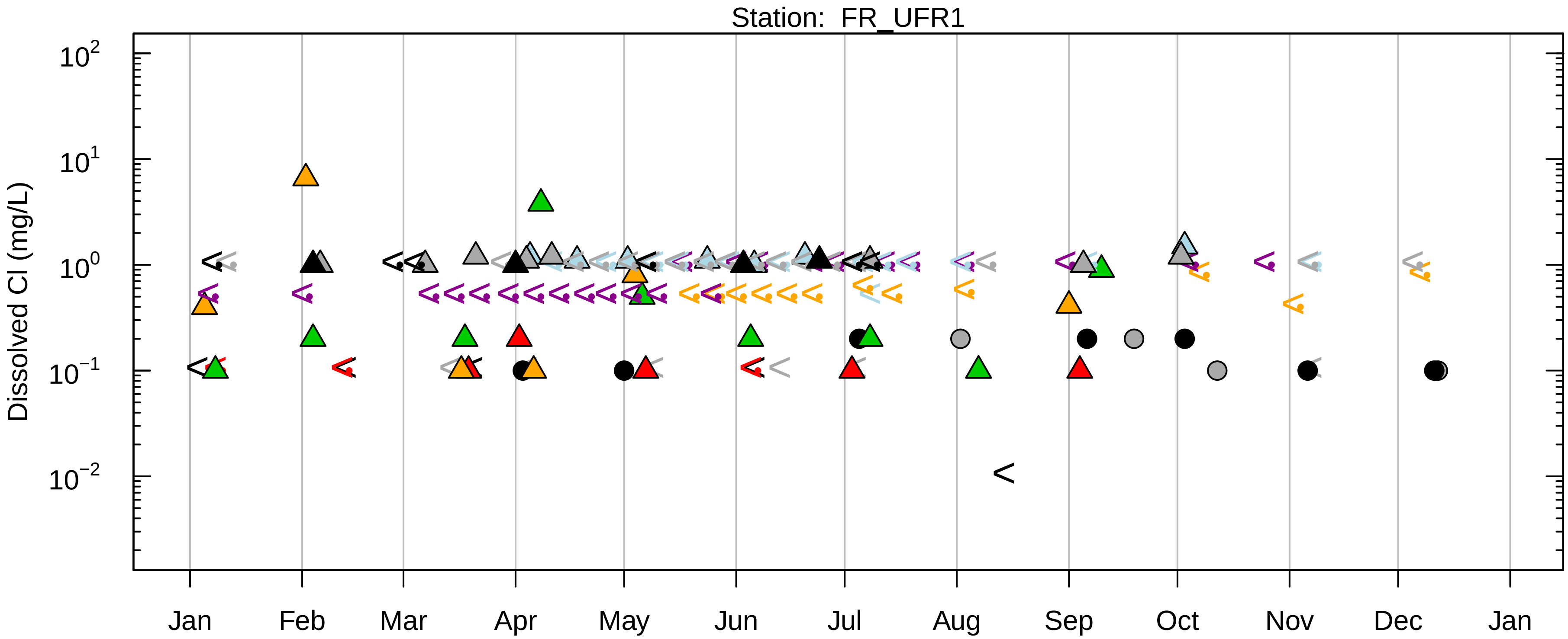
Station: EV_ER4



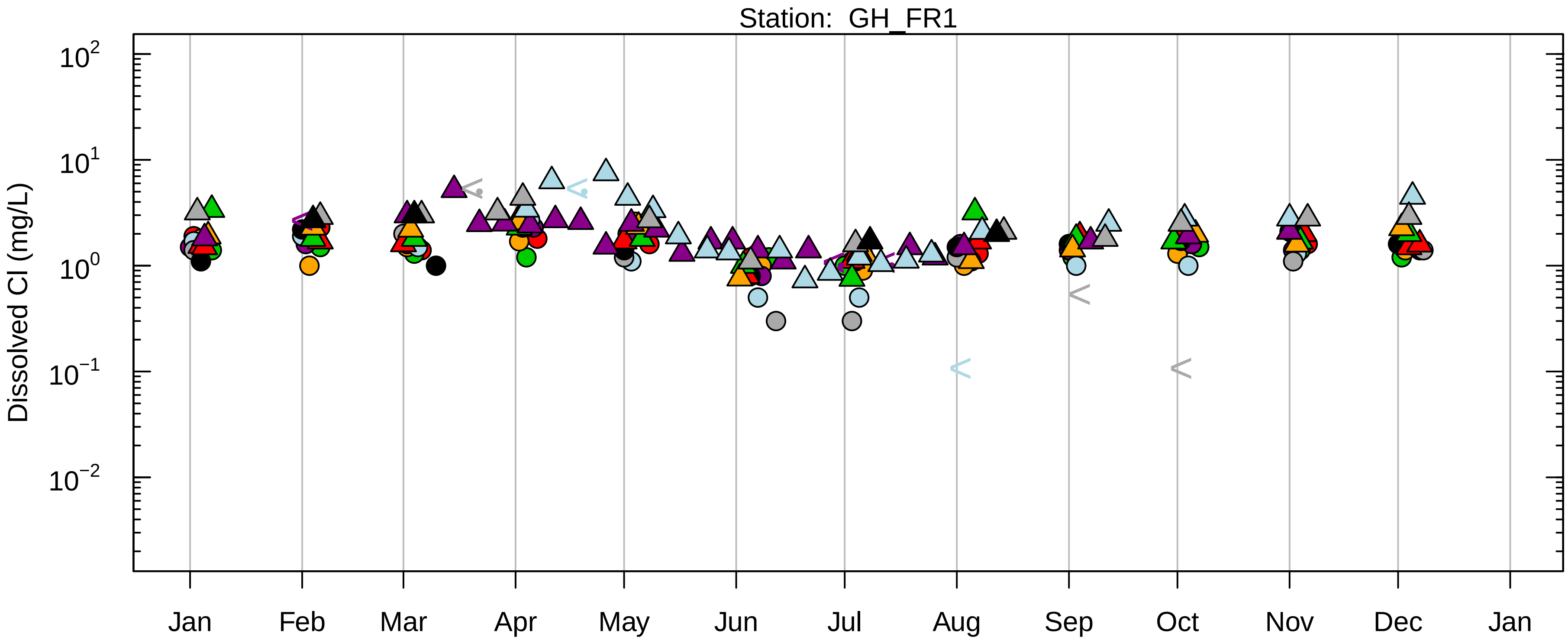

Station: EV_ER1
Dissolved SO4 (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: RG_ELKORES
Dissolved SO4 (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

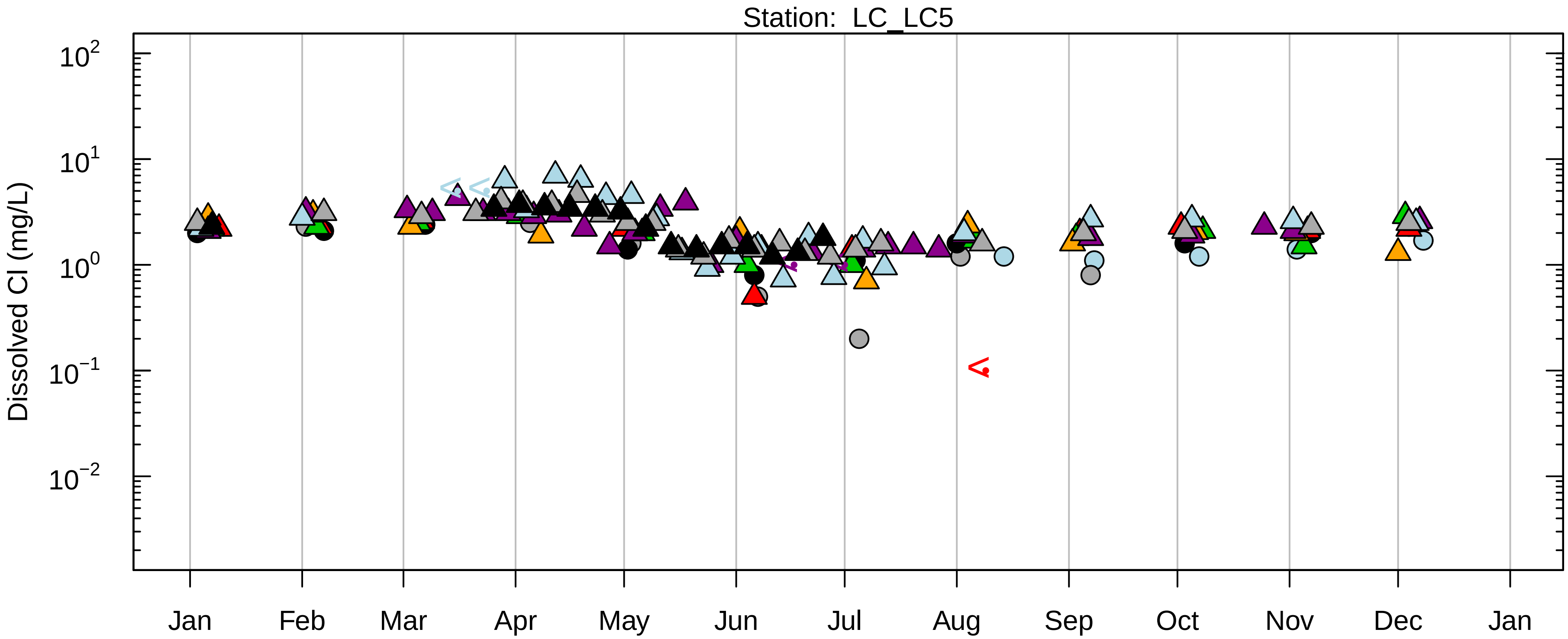

Station: LK2
Dissolved SO4 (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

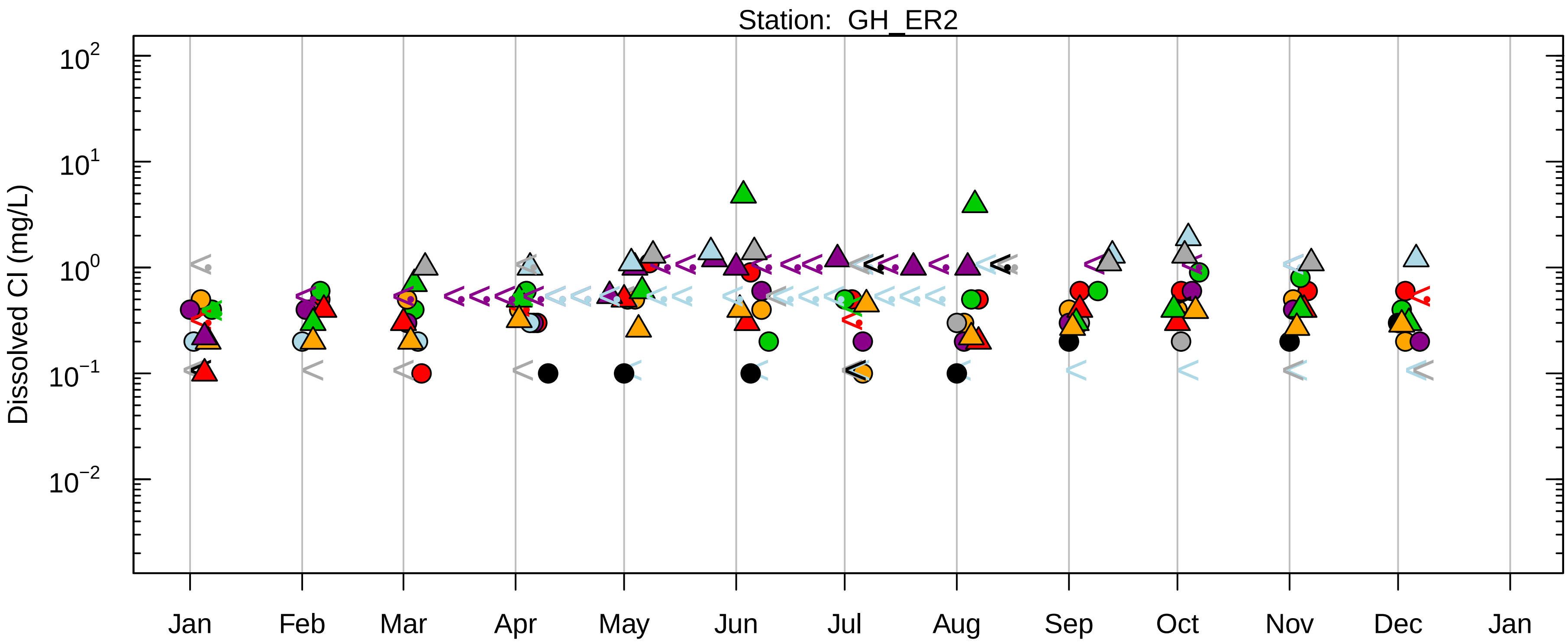


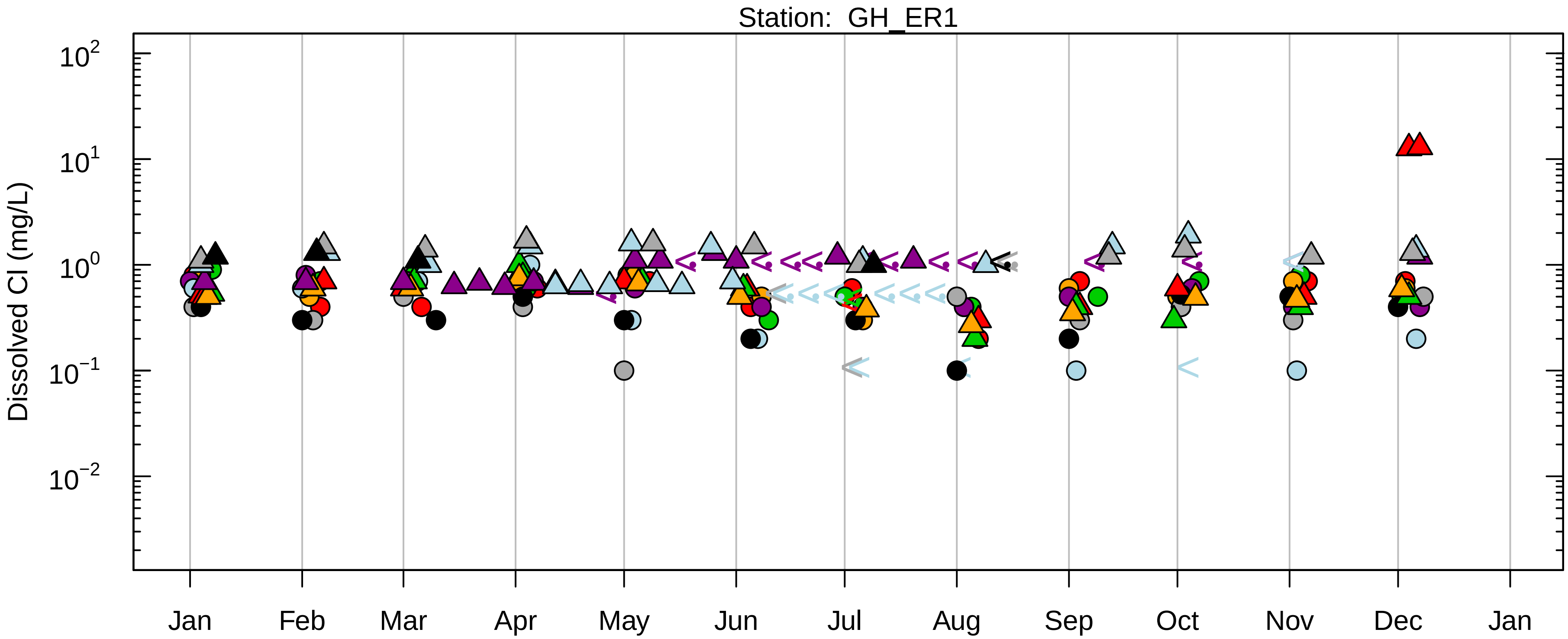
Station: FR_UFR1
Dissolved Cl (mg/L)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

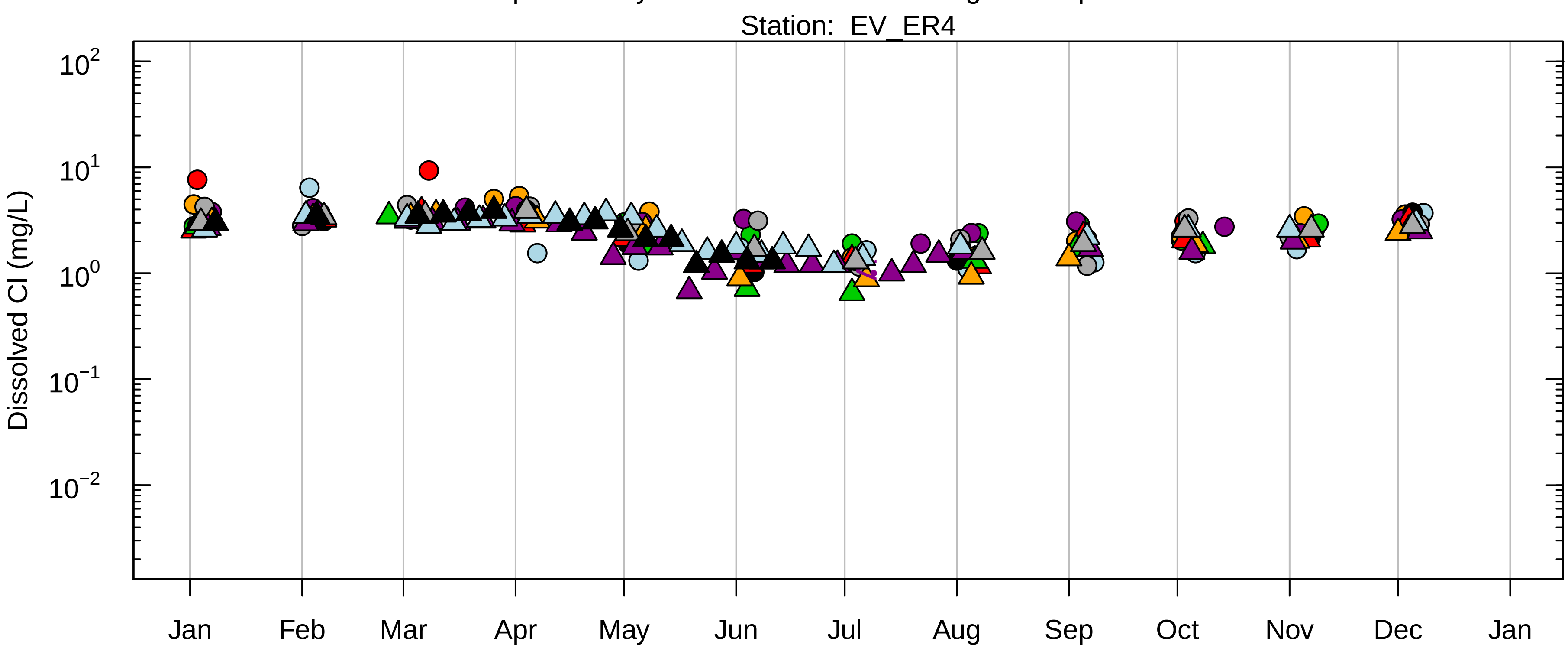


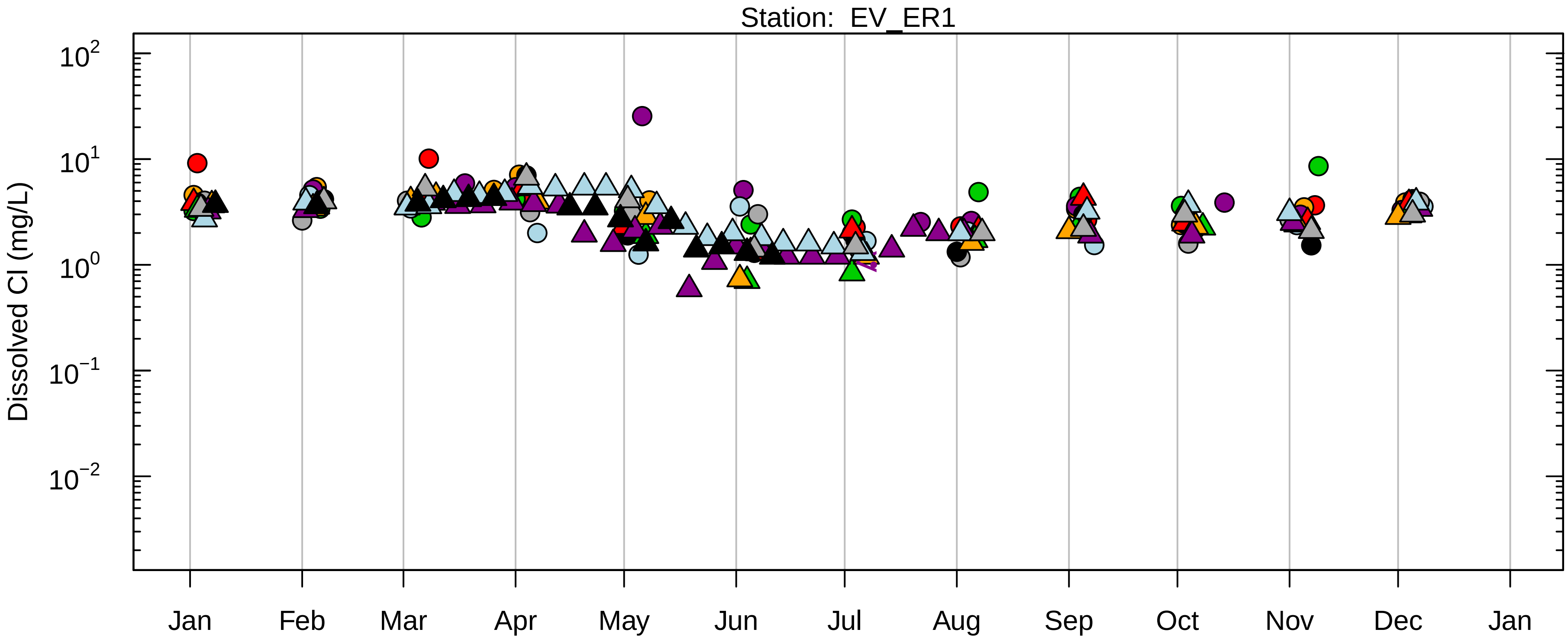
Station: GH_FR1
Dissolved Cl (mg/L)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: LC_LC5
Dissolved Cl (mg/L)
10^2
10^1
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

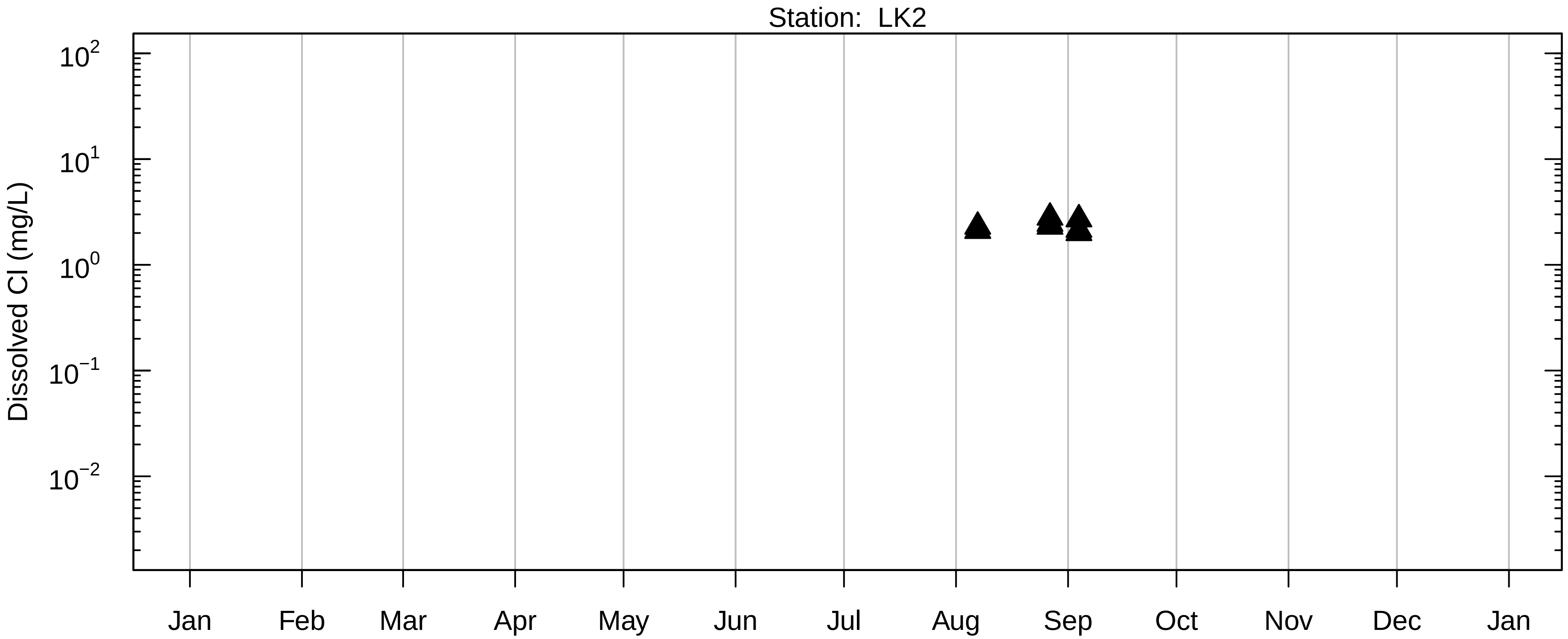

Station: GH_ER2
Dissolved Cl (mg/L)
10^2
10^1
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

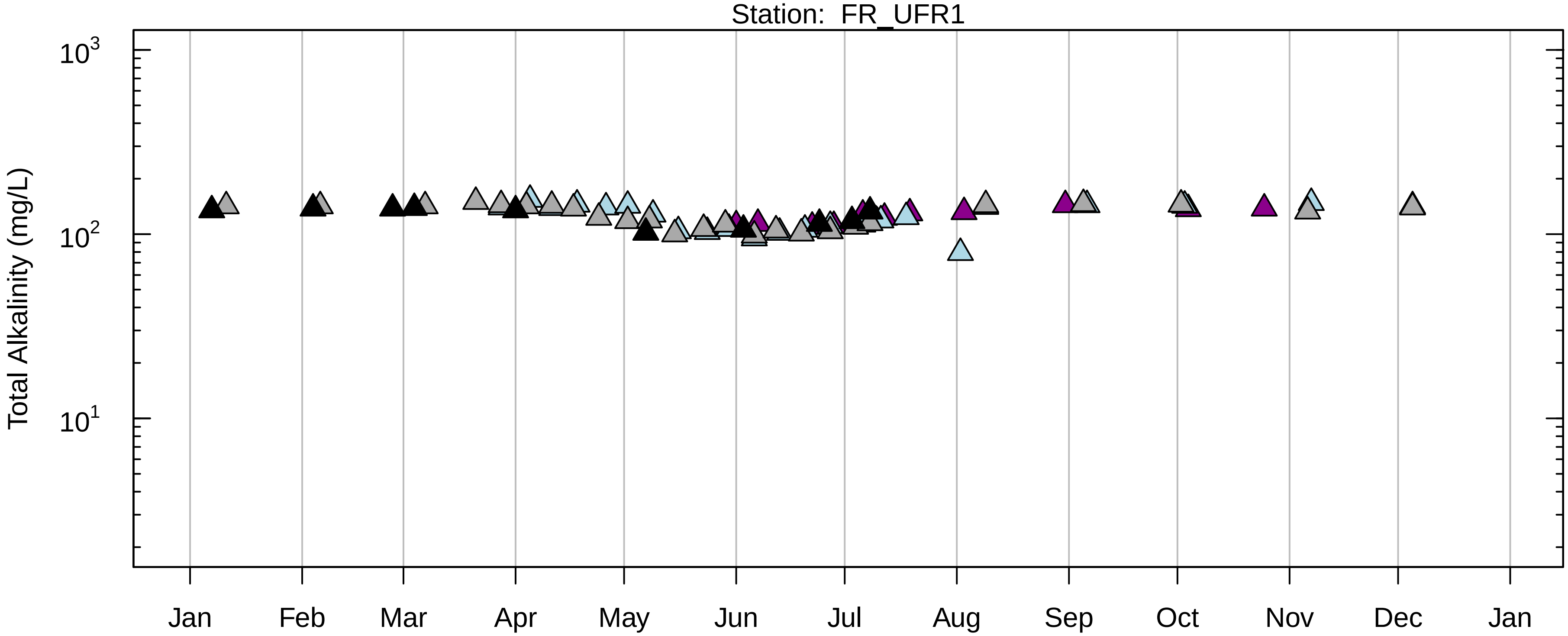

Station: GH_ER1
Dissolved Cl (mg/L)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

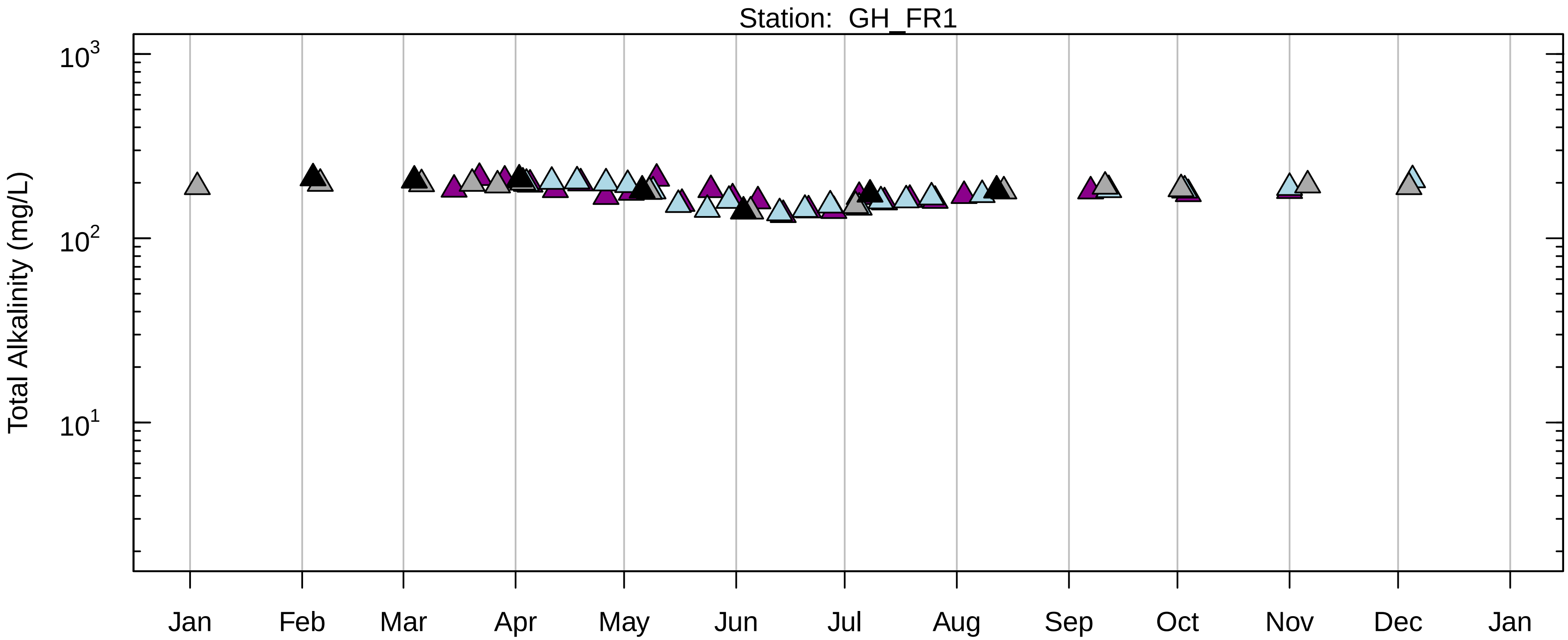

Station: EV_ER4
Dissolved Cl (mg/L)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

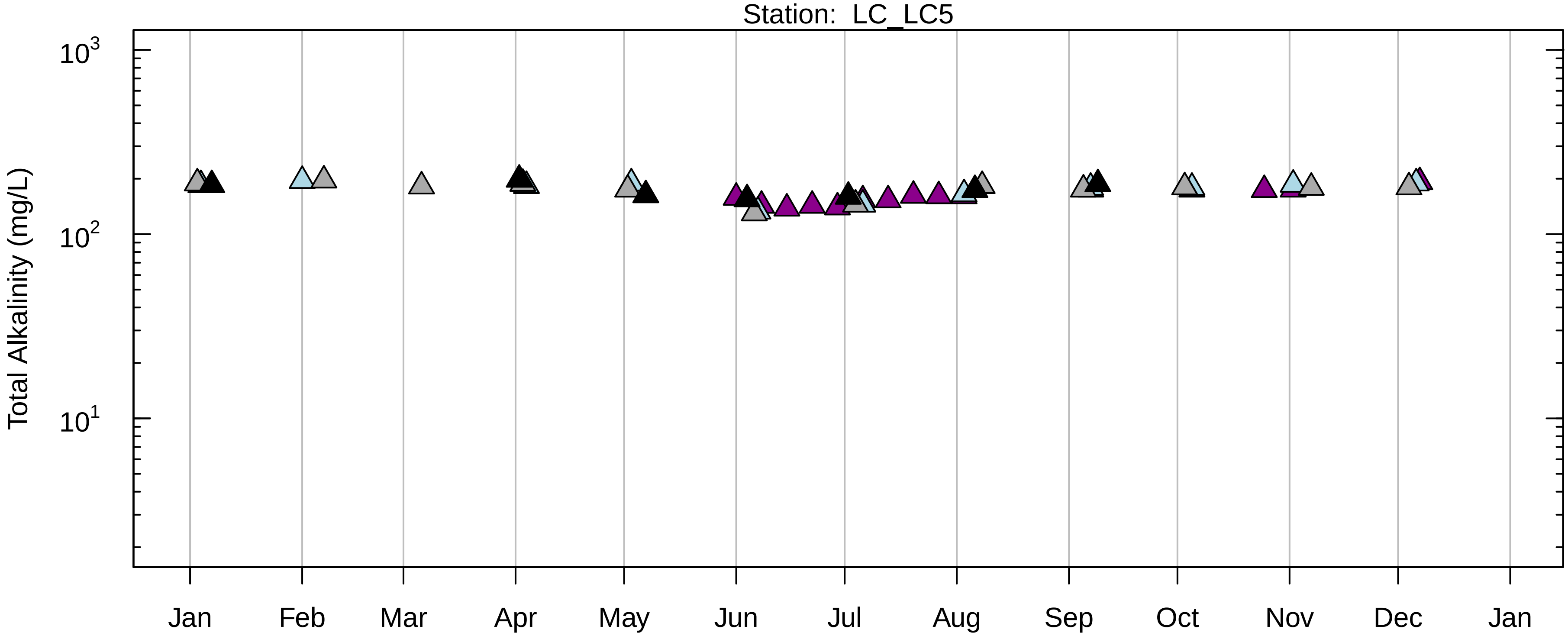

Station: EV_ER1
Dissolved Cl (mg/L)
10^2
10^1
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

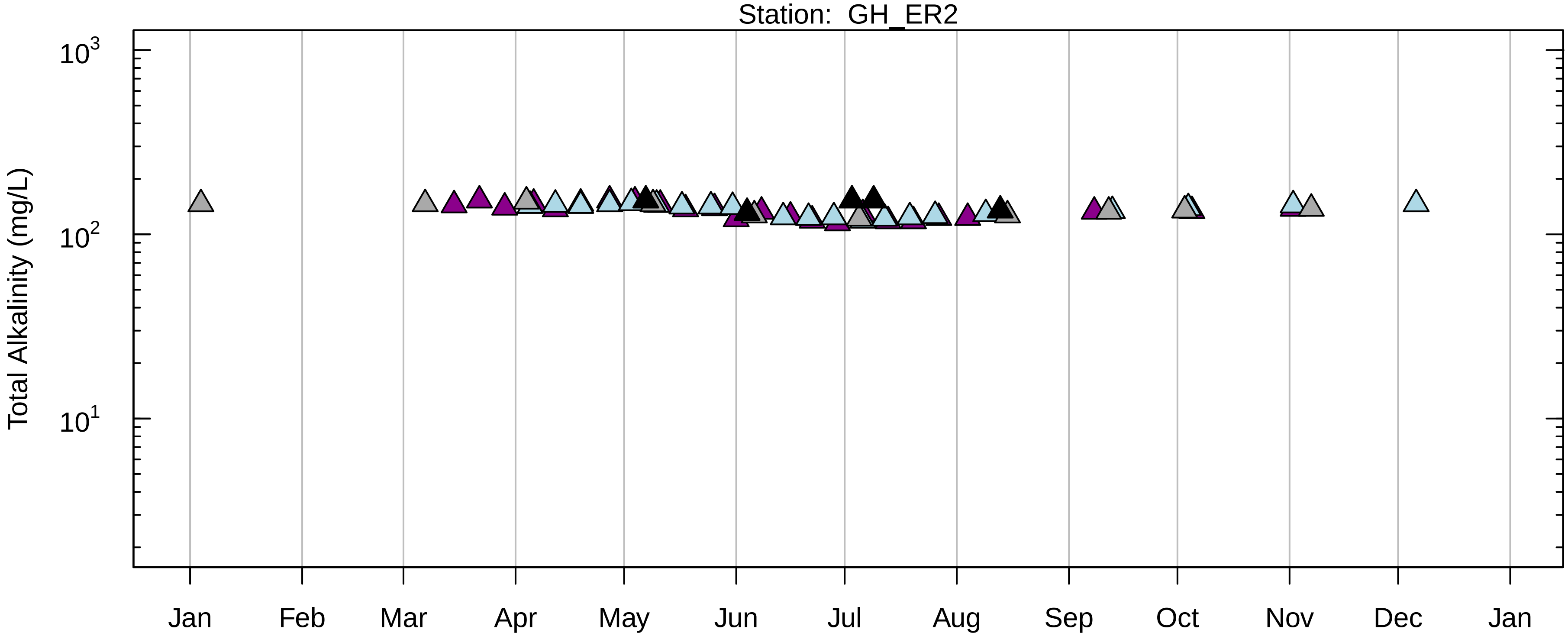

Station: RG_ELKORES
Dissolved Cl (mg/L)
10^2
10^1
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

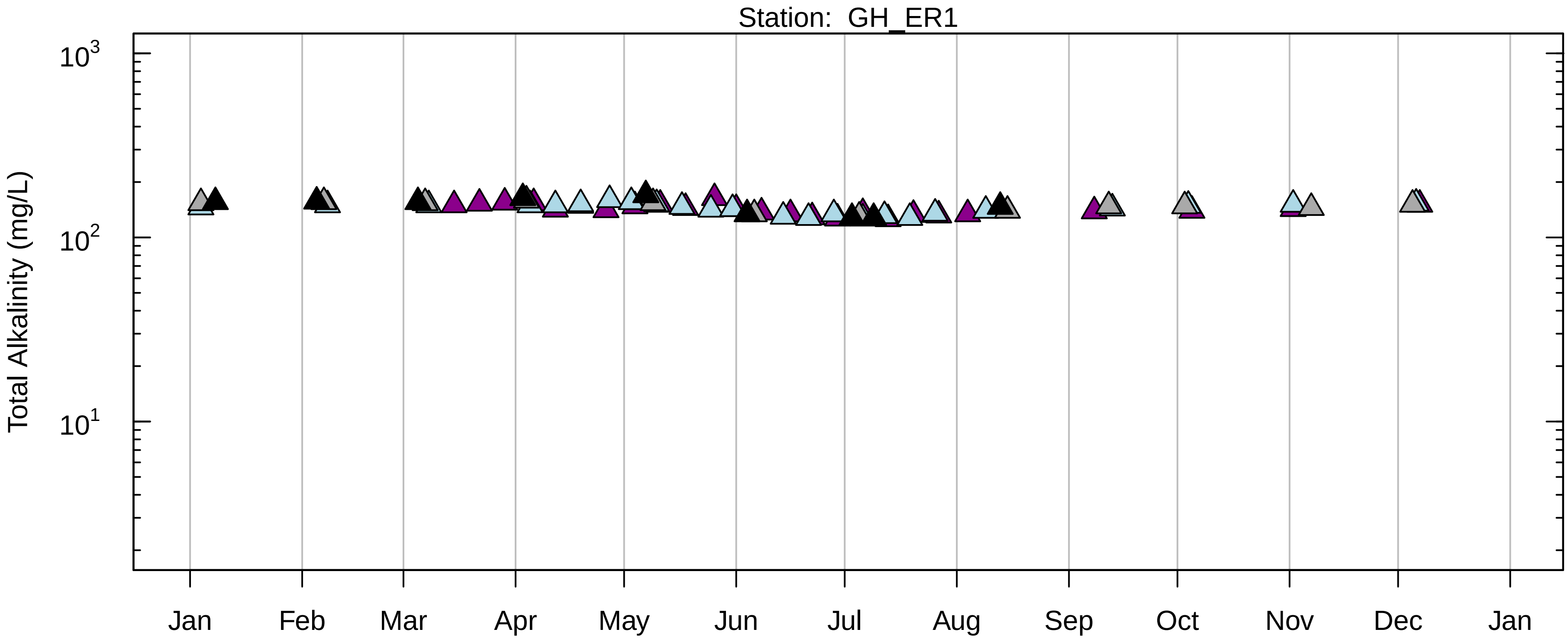

Station: LK2
Dissolved Cl (mg/L)
10^2
10^1
10^0
10^{-1}
10^{-2}
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

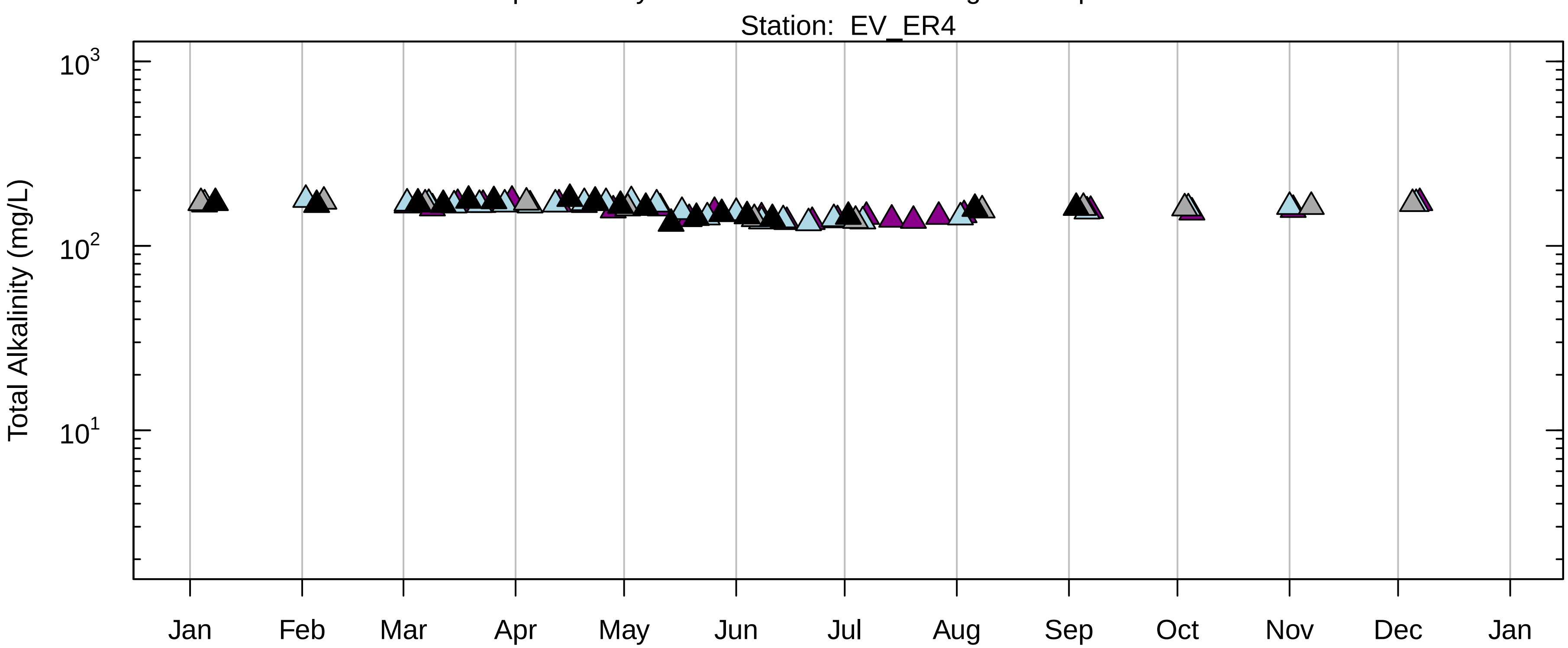

Station: FR_UFR1
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

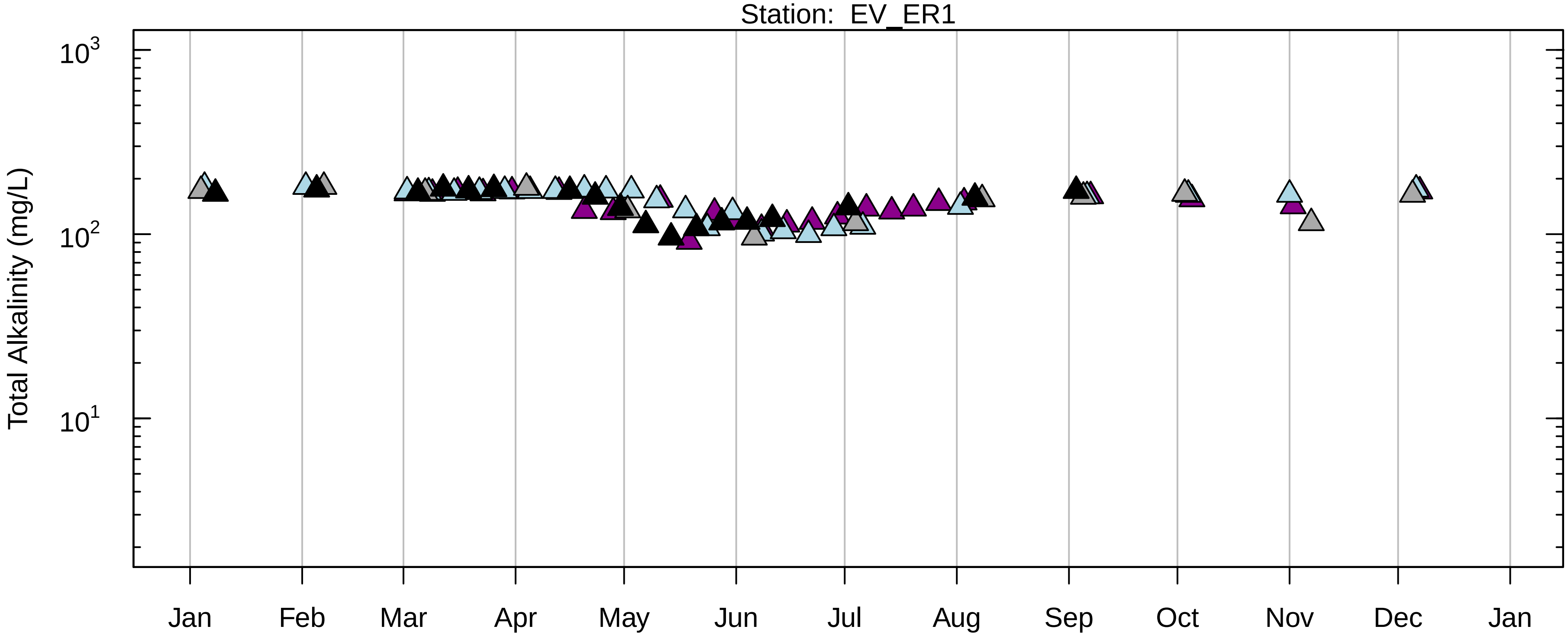

Station: GH_FR1
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

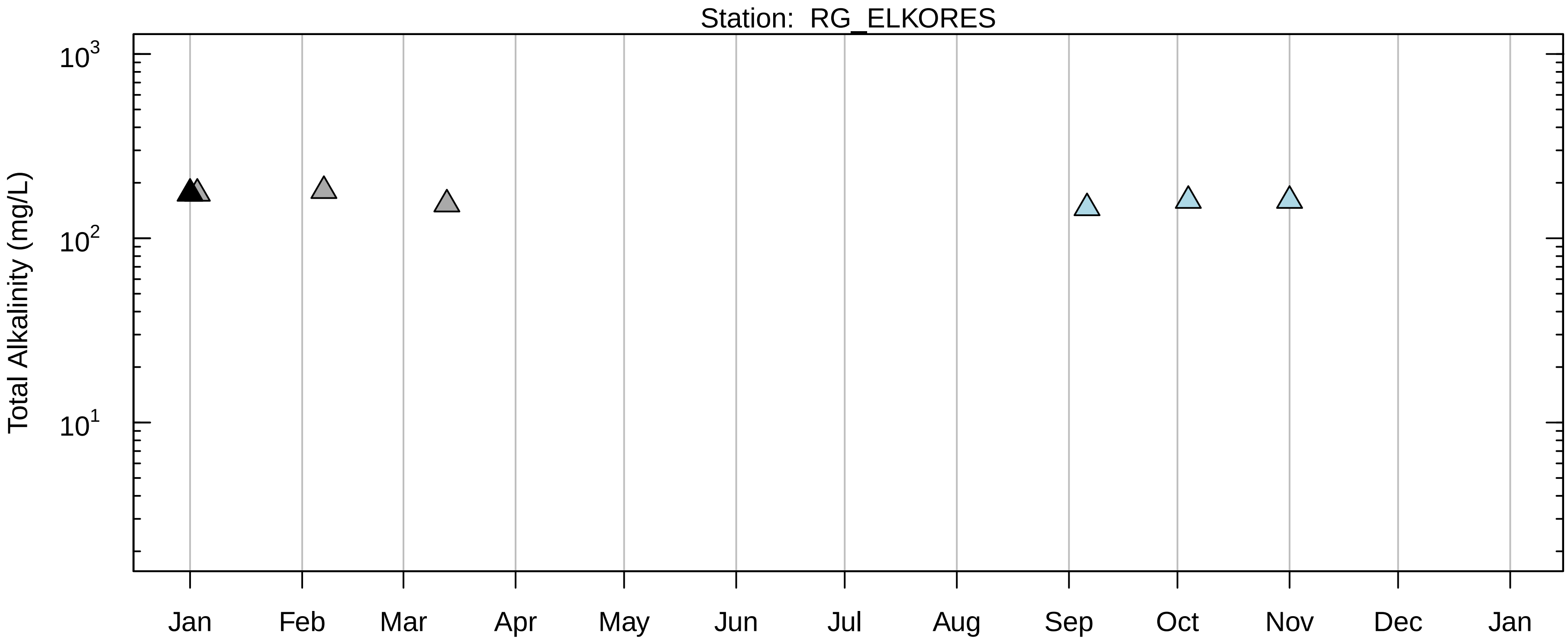

Station: LC_LC5
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

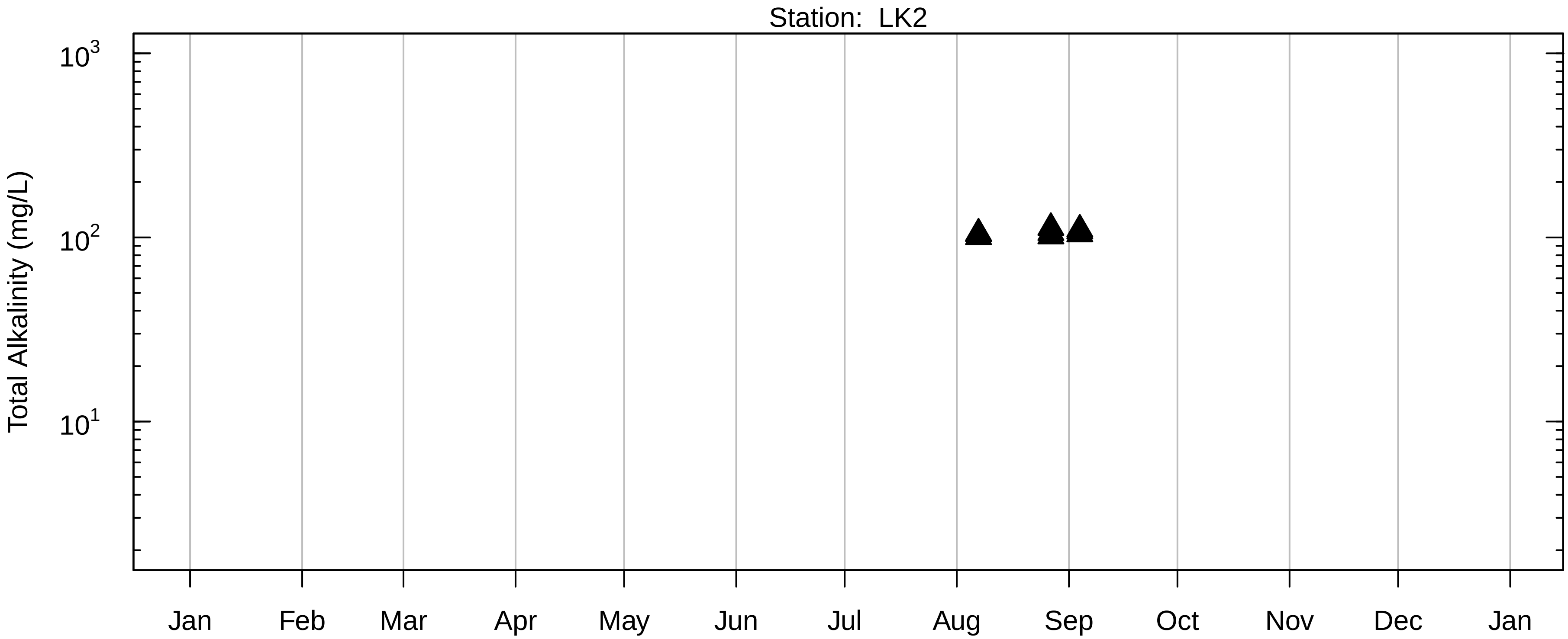

Station: GH_ER2
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: GH_ER1
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

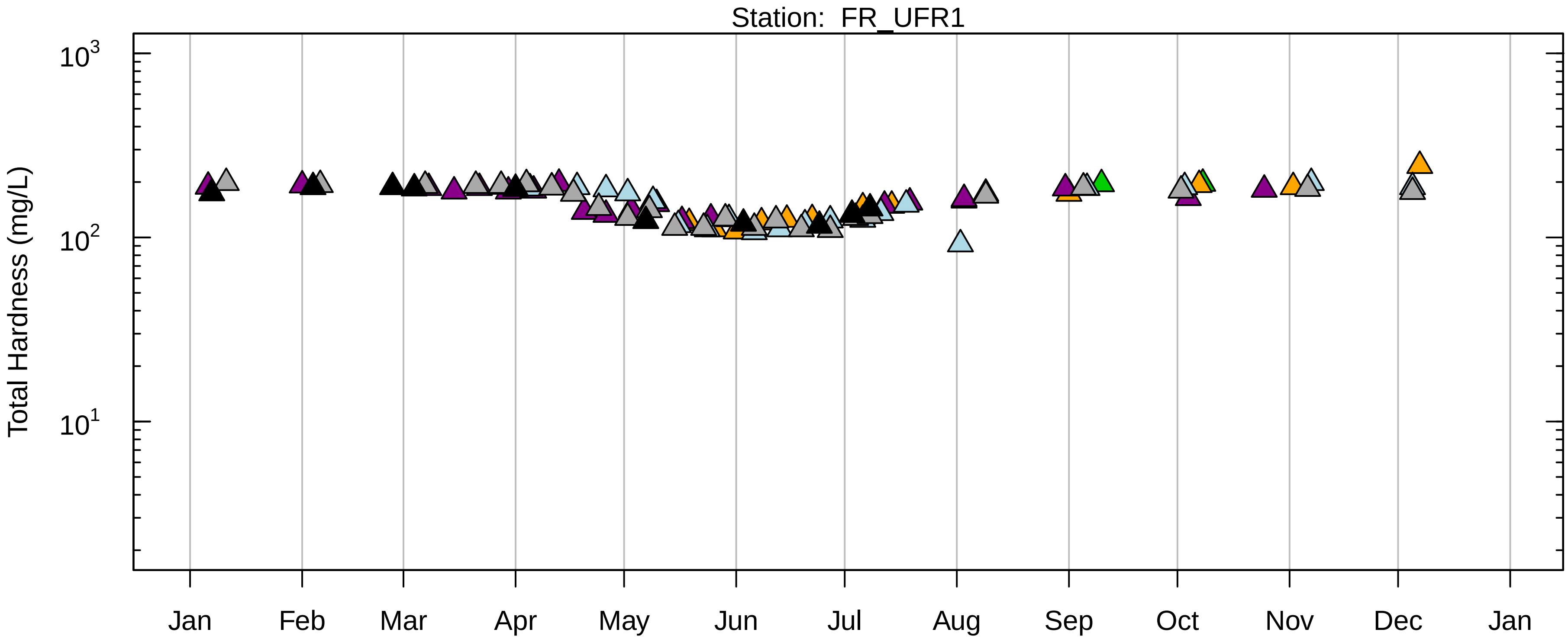

Station: EV_ER4
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

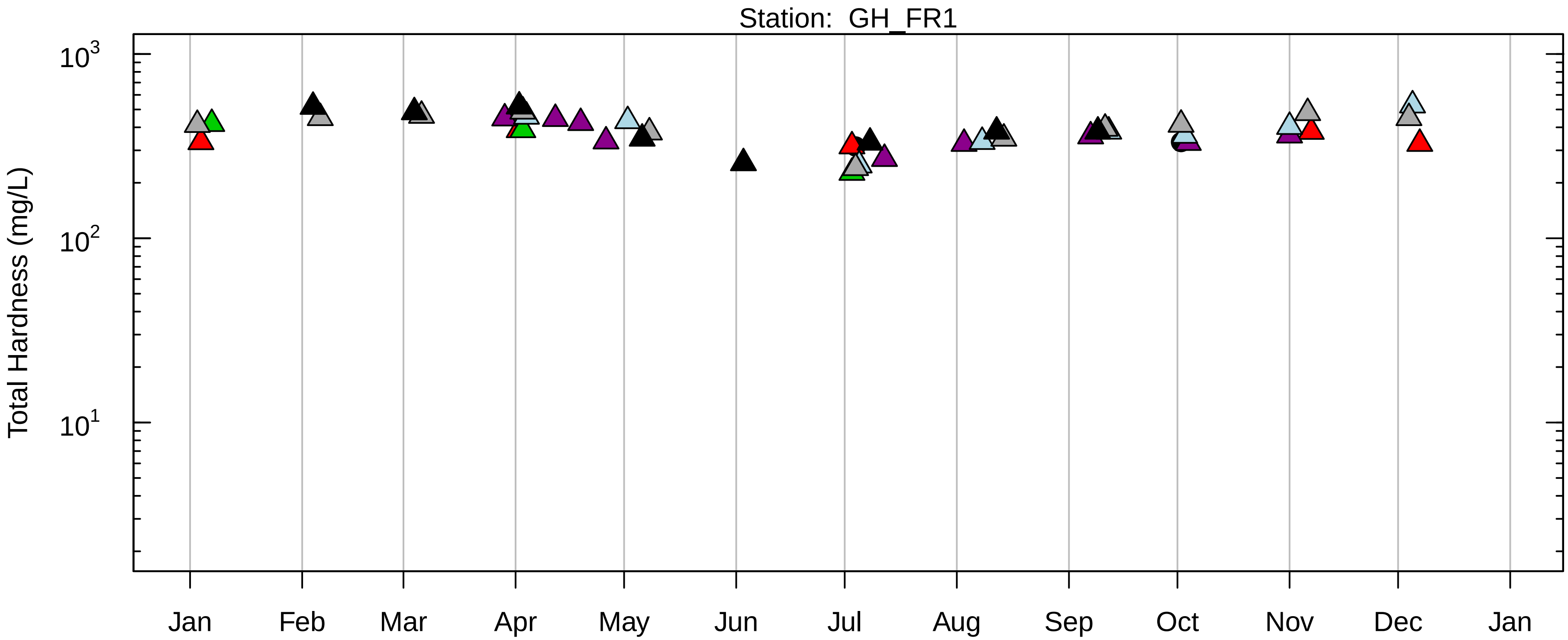

Station: EV_ER1
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

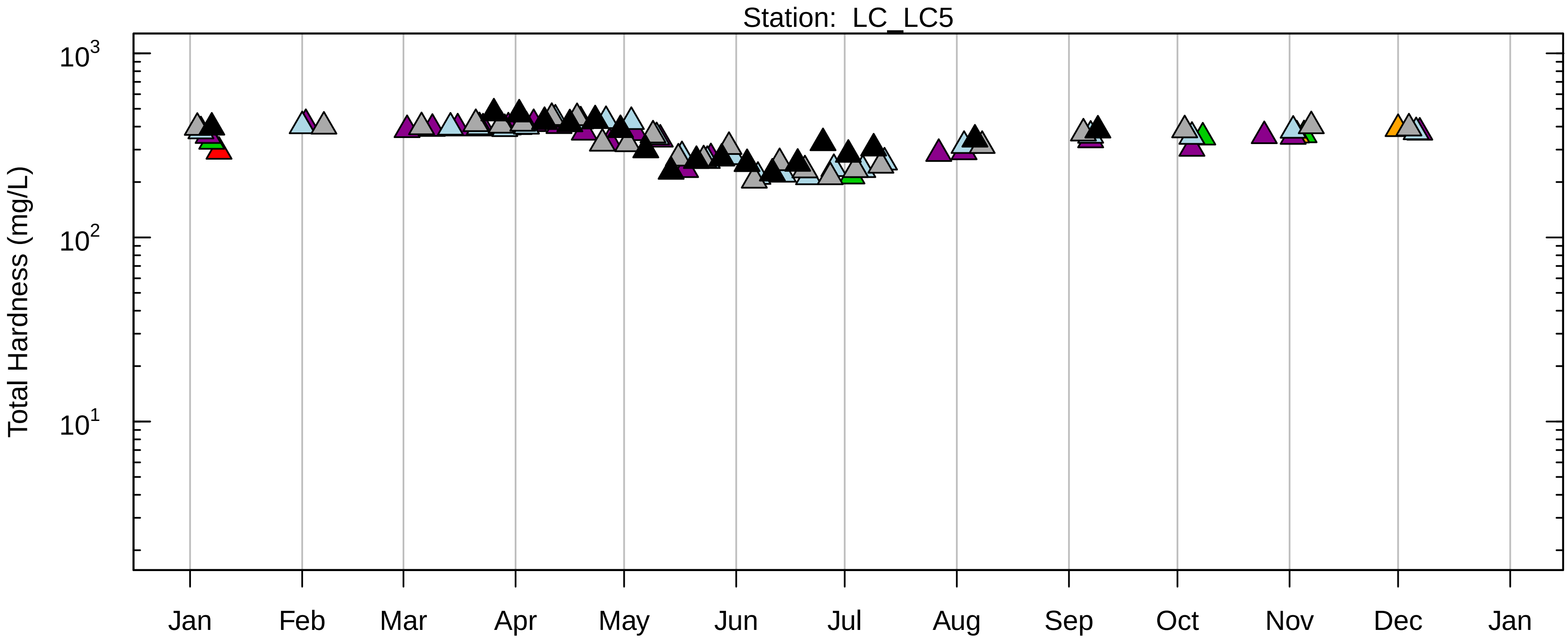

Station: RG_ELKORES
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

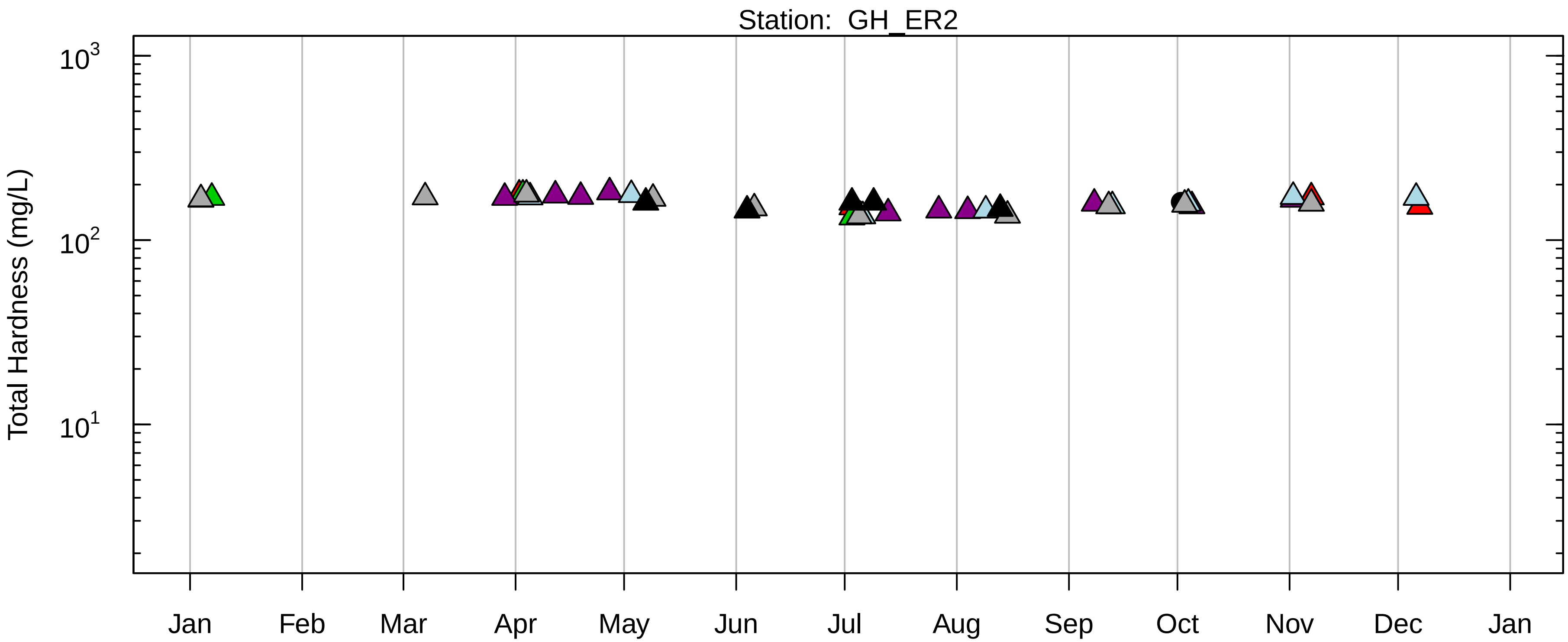


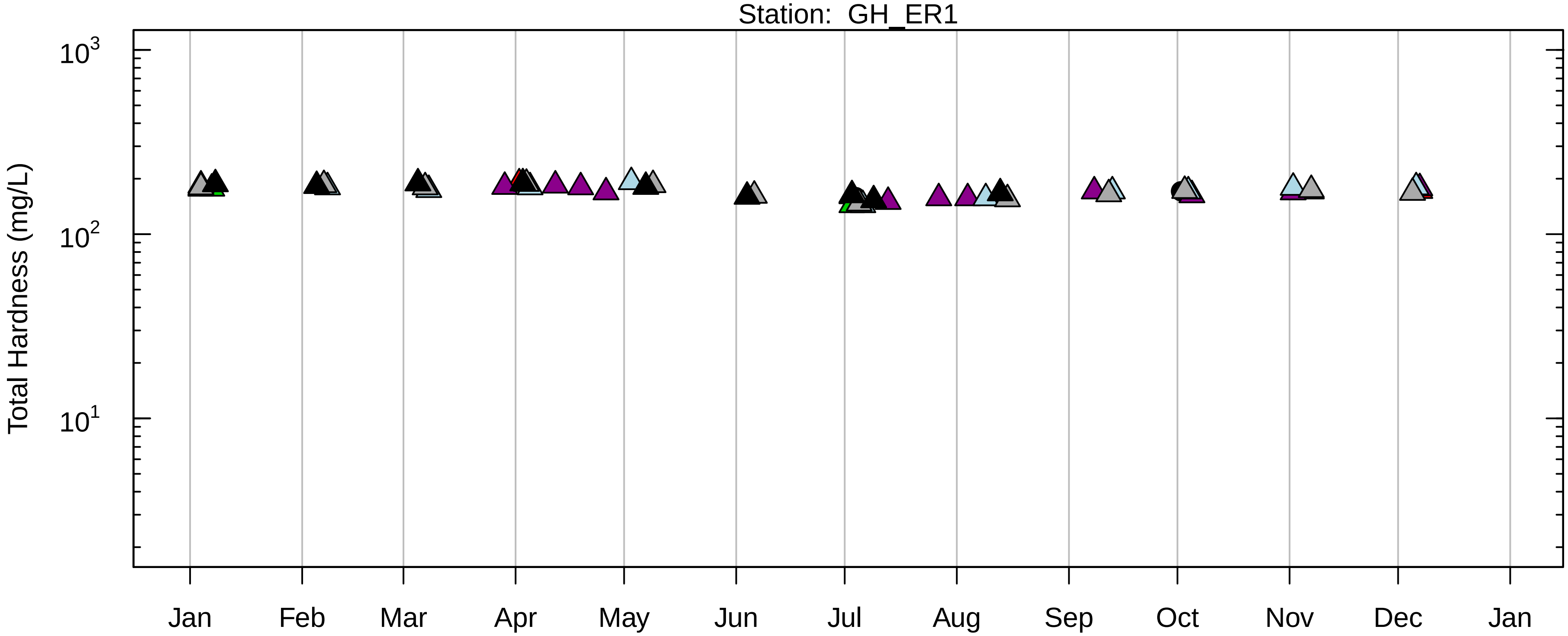
Station: LK2
Total Alkalinity (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

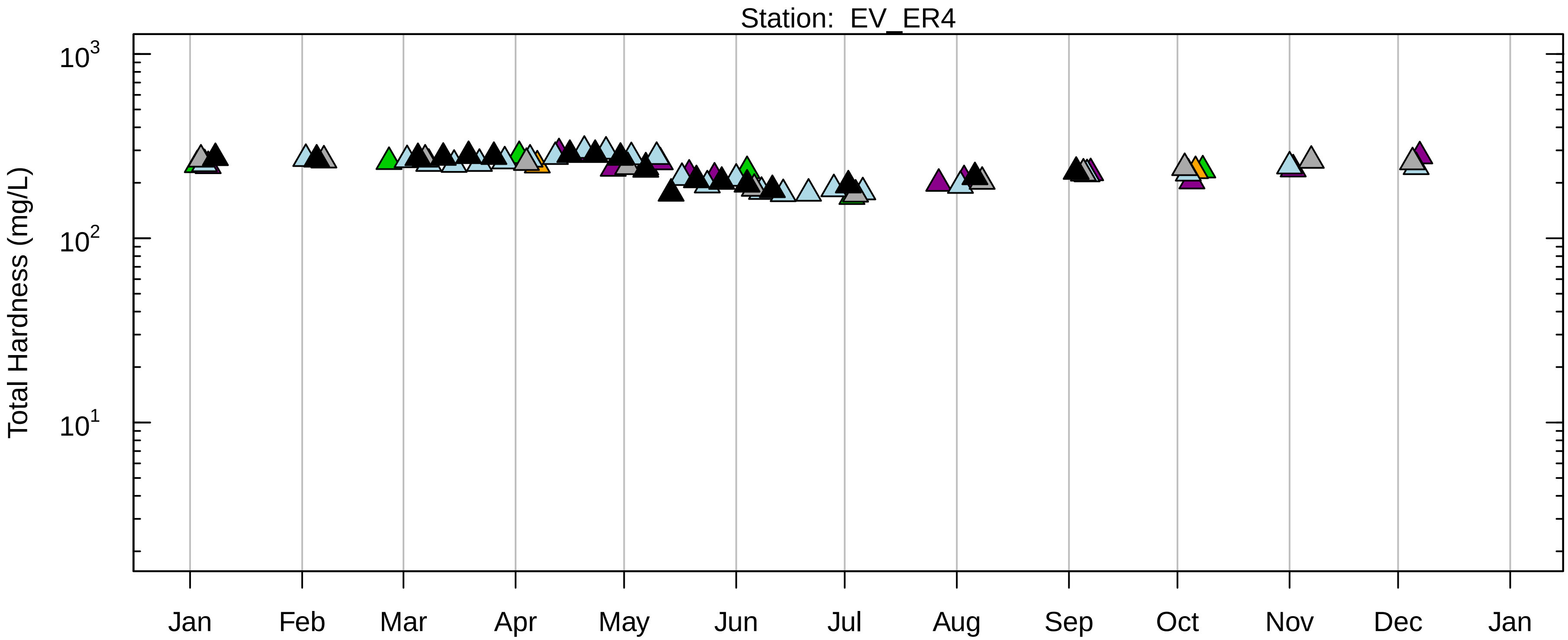

Station: FR_UFR1
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

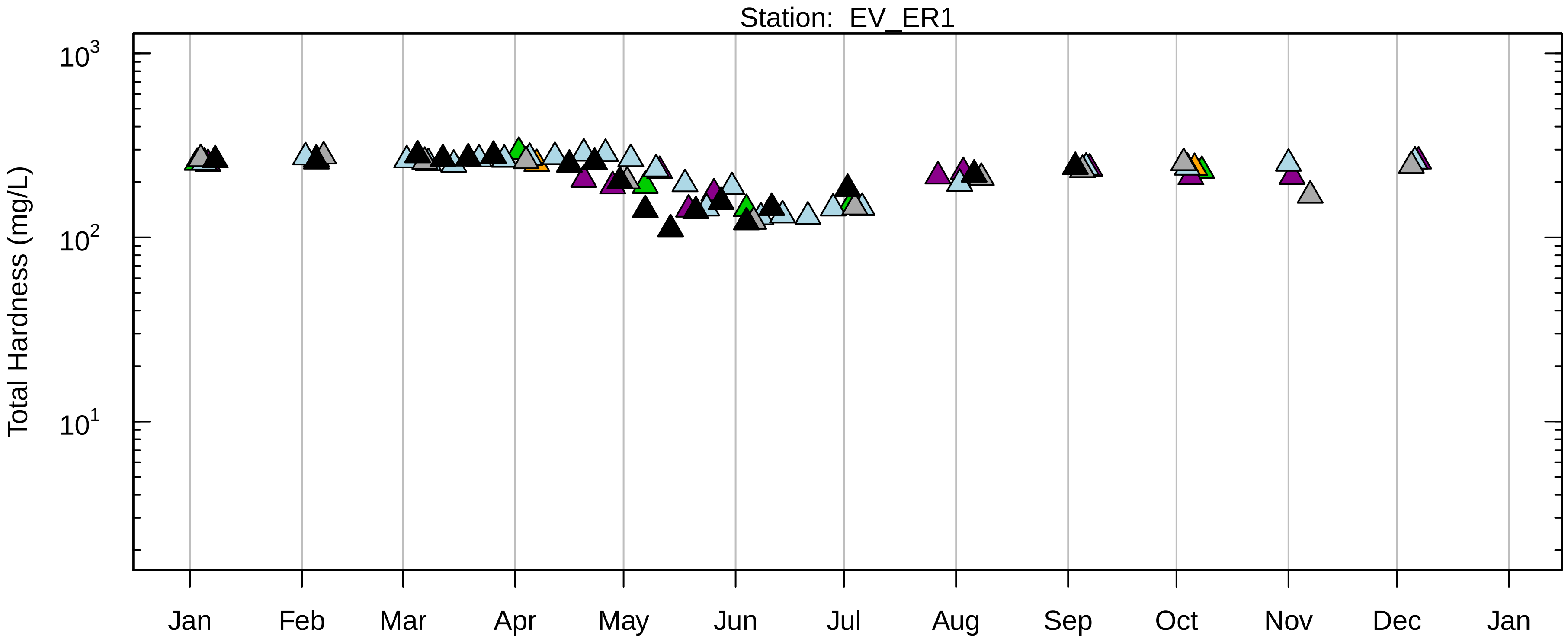

Station: GH_FR1
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

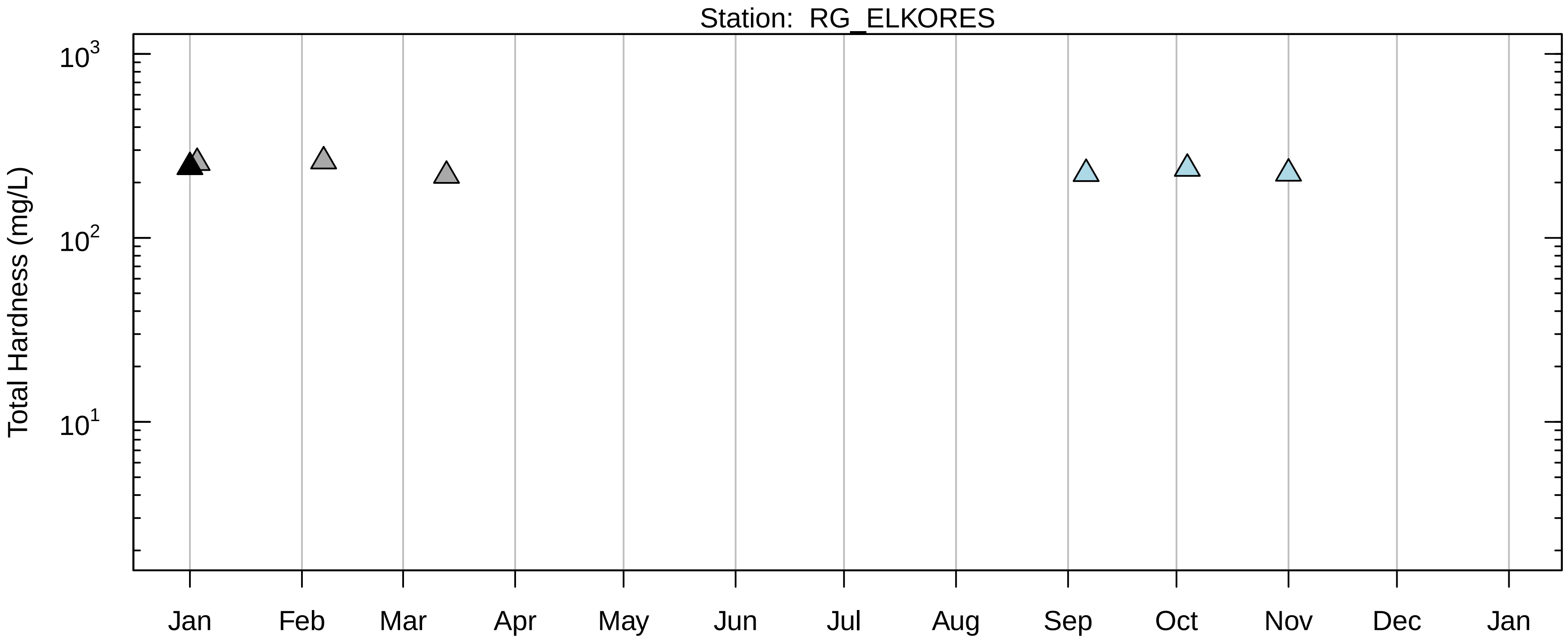

Station: LC_LC5
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

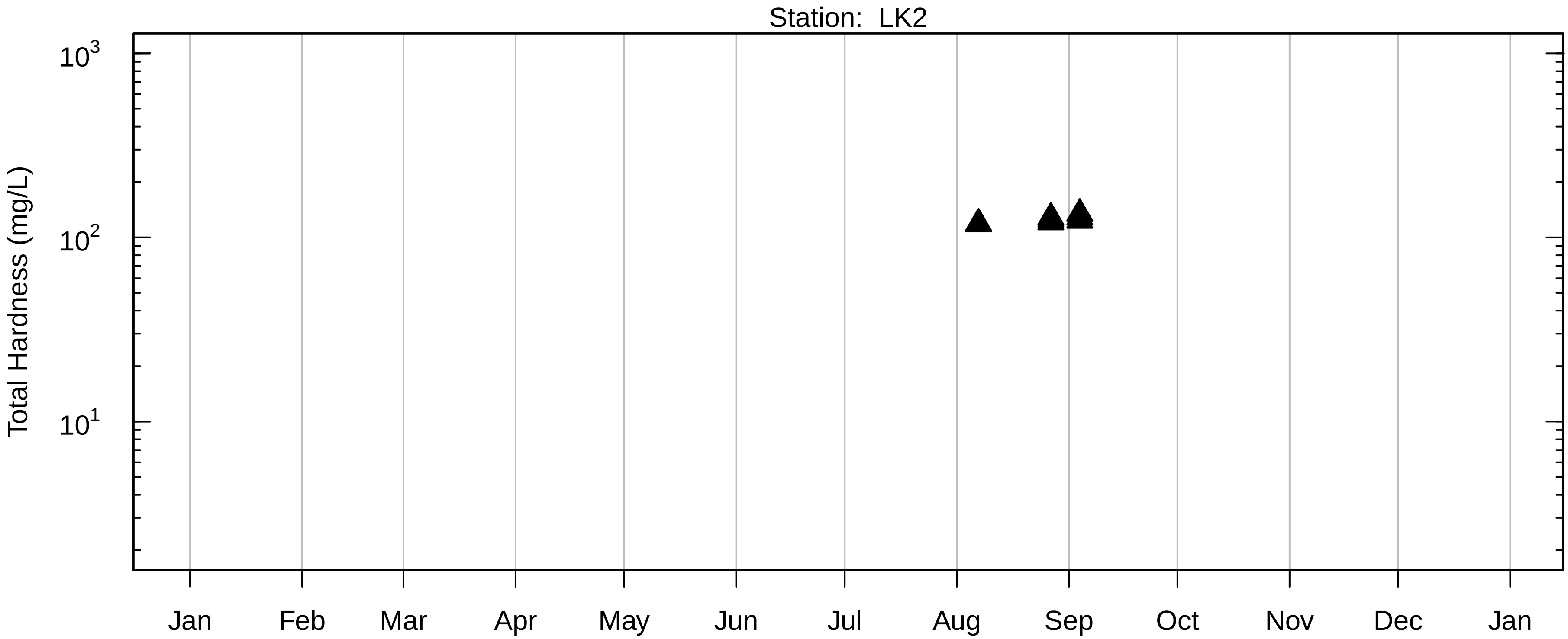

Station: GH_ER2
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: GH_ER1
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: EV_ER4
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: EV_ER1
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: RG_ELKORES
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Station: LK2
Total Hardness (mg/L)
10^3
10^2
10^1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

Appendix E: Comparison Between Total and Dissolved Cadmium Concentrations at Upstream and Order Stations

Total and dissolved cadmium concentrations for samples collected at the upstream and order stations from May 2000 to December 2013 are shown as probability plots:

- top left panel – total cadmium
- top right panel – dissolved cadmium
- bottom left panel – total vs. dissolved
- bottom right panel – total:dissolved vs. day of the year.

In the probability plots:

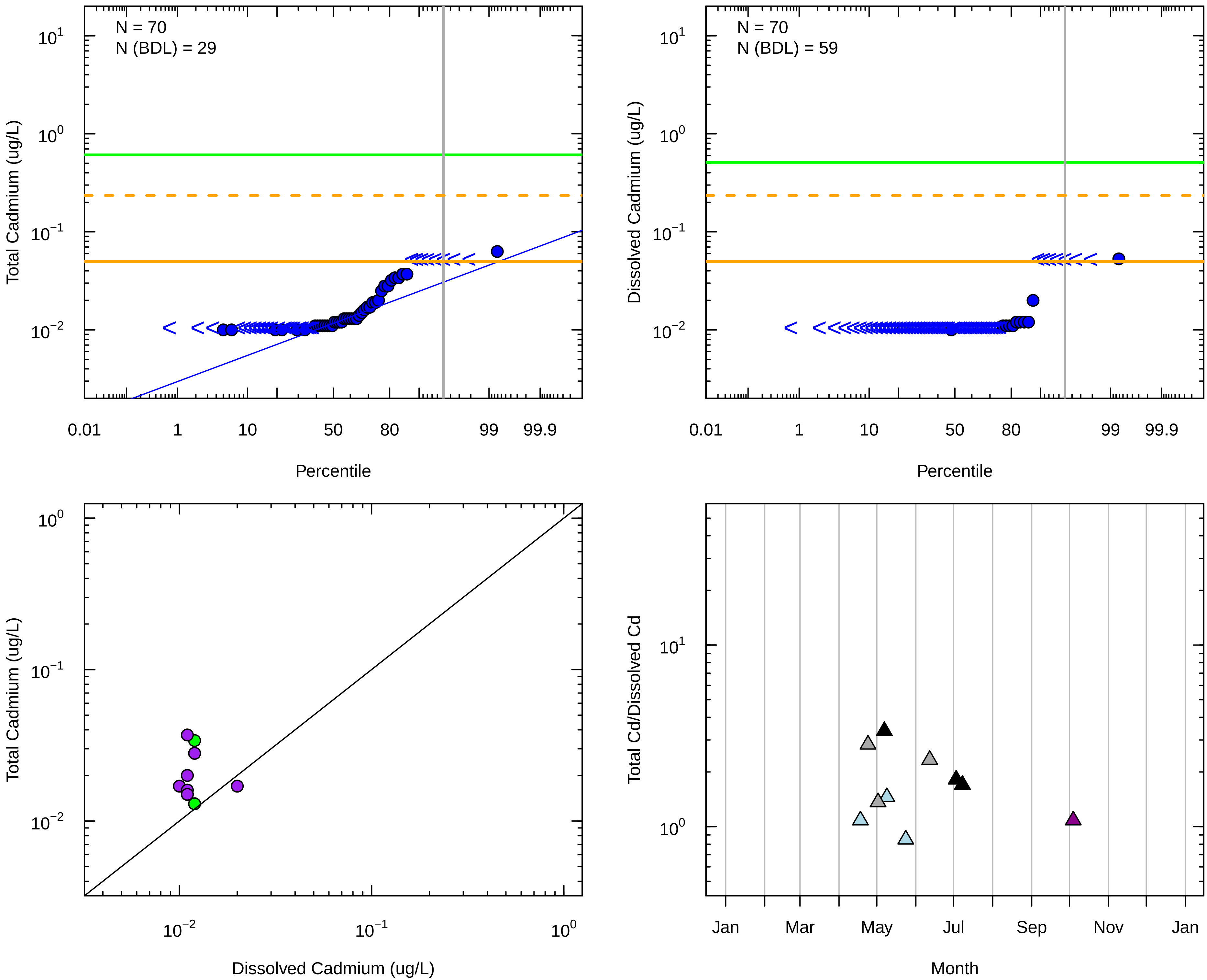
- green horizontal line represent 95th percentile of cadmium concentrations in all surface water samples recorded in Teck's EQuIS database
- orange dashed horizontal line represents CCME WQG
- solid orange horizontal line represents BC MOE WQG.

In the total cadmium vs. dissolved cadmium plots (bottom left panel), purple symbols represent samples collected between May and September and roughly correspond to the freshet period, while green symbols represent samples collected outside of this time range (i.e., not during the freshet).

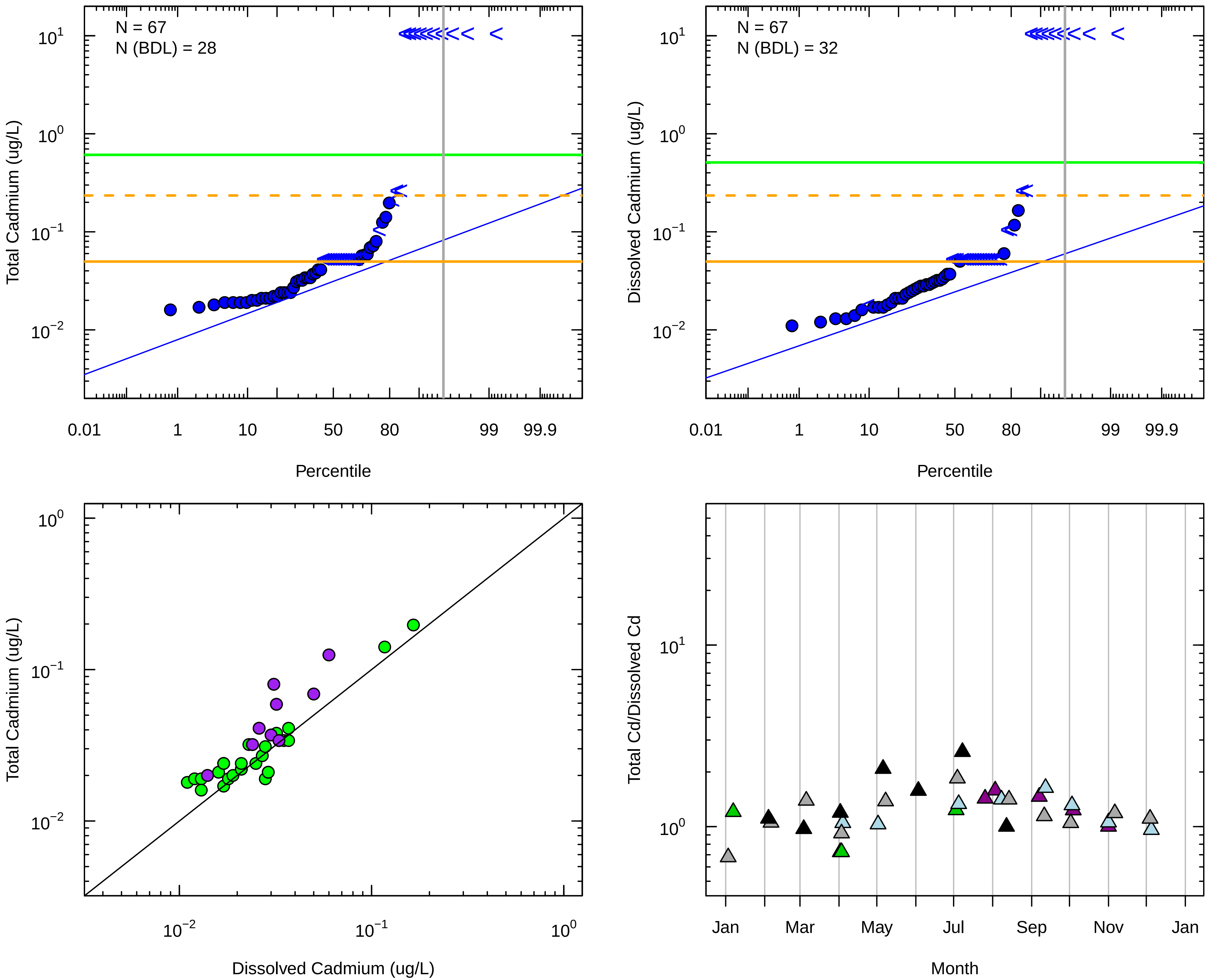
In the bottom right panel, different colored symbols correspond to the year samples were collected as follows:

2000:
2001:
2002:
2003:
2004:
2005:
2006:
2007:
2008:
2009:
2010:
2011:
2012:
2013:

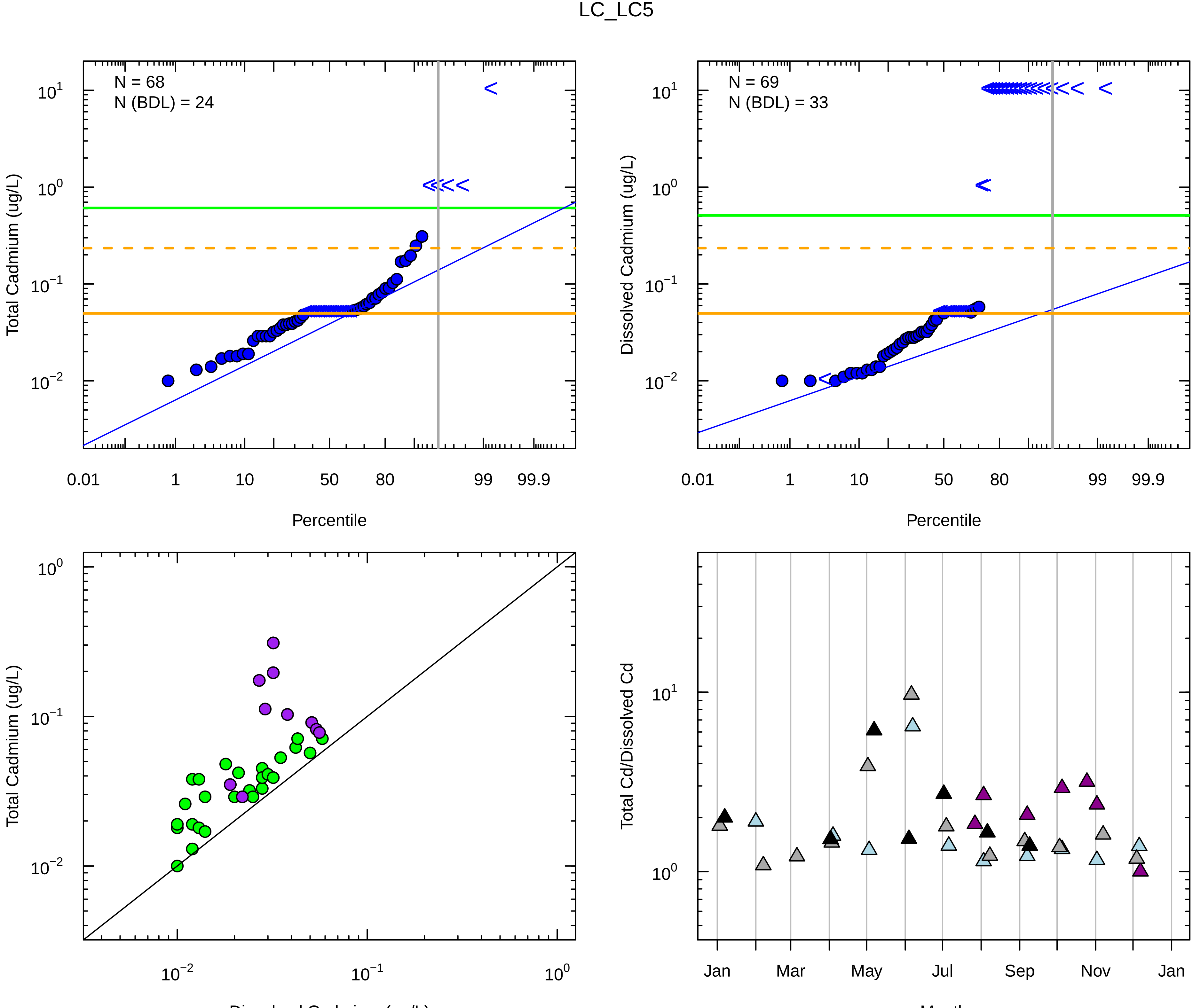
FR_UFR1


N = 70
N (BDL) = 29
Total Cadmium (ug/L)
Percentile
N = 70
N (BDL) = 59
Dissolved Cadmium (ug/L)
Percentile
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Month
Jan
Mar
May
Jul
Sep
Nov
Jan

GH_FR1

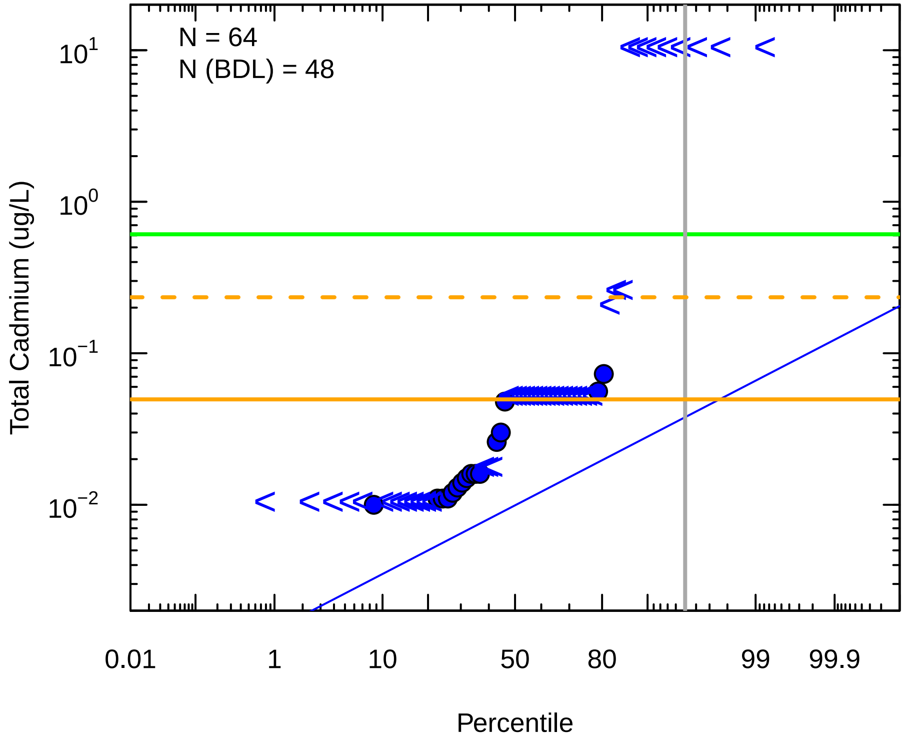


N = 67
N (BDL) = 28
Total Cadmium (ug/L)
Percentile
N = 67
N (BDL) = 32
Dissolved Cadmium (ug/L)
Percentile
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Month
Jan
Mar
May
Jul
Sep
Nov
Jan

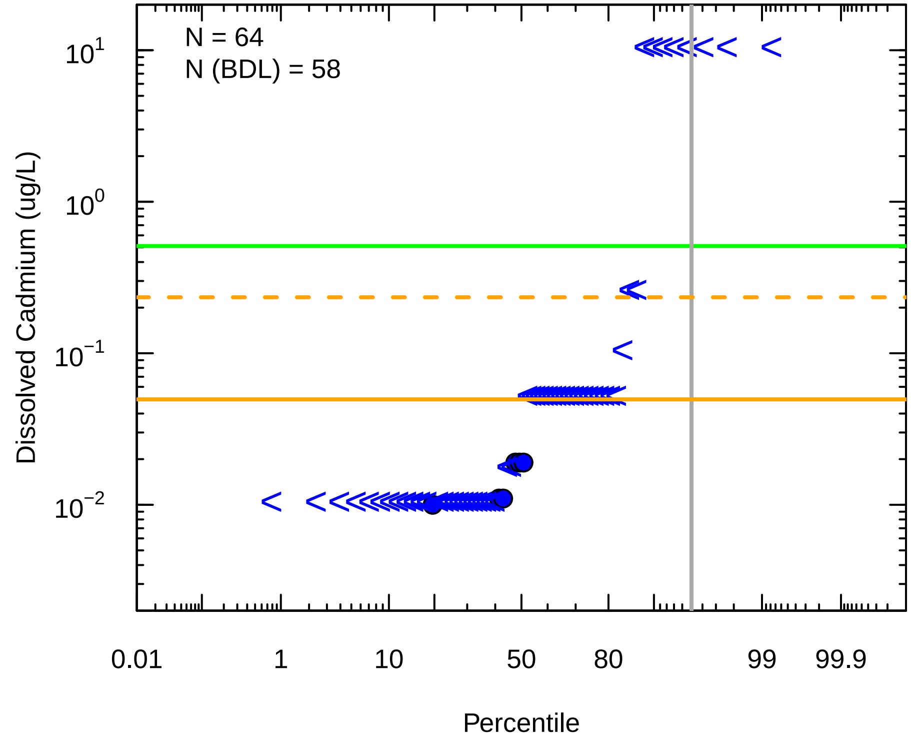


LC_LC5
N = 68
N (BDL) = 24
Total Cadmium (ug/L)
Percentile
0.01
1
10
50
80
99
99.9
N = 69
N (BDL) = 33
Dissolved Cadmium (ug/L)
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Month
Jan
Mar
May
Jul
Sep
Nov
Jan

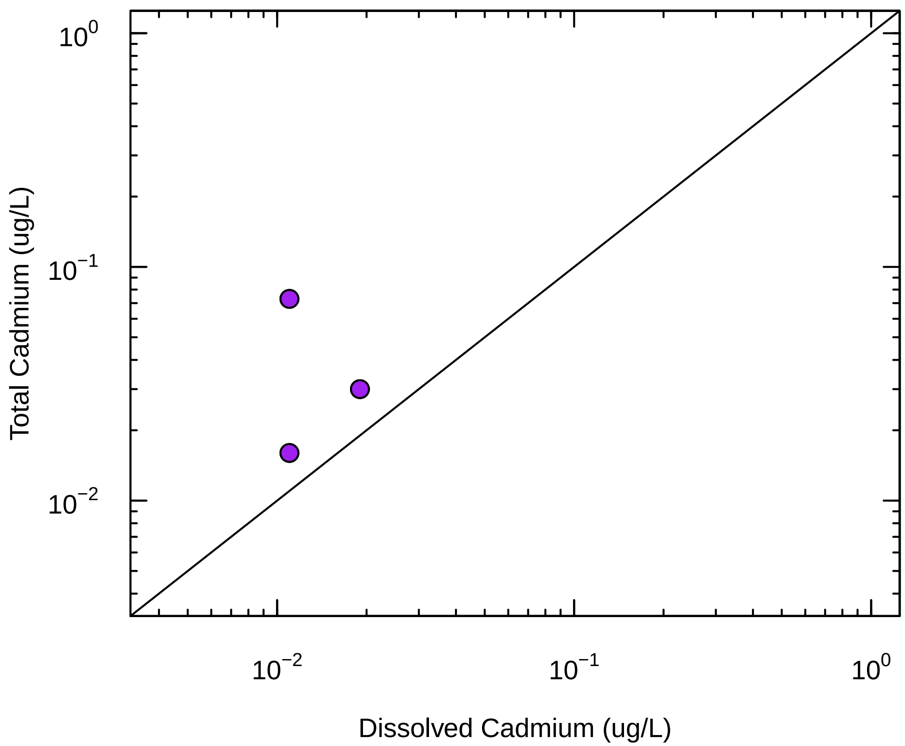
GH_ER2



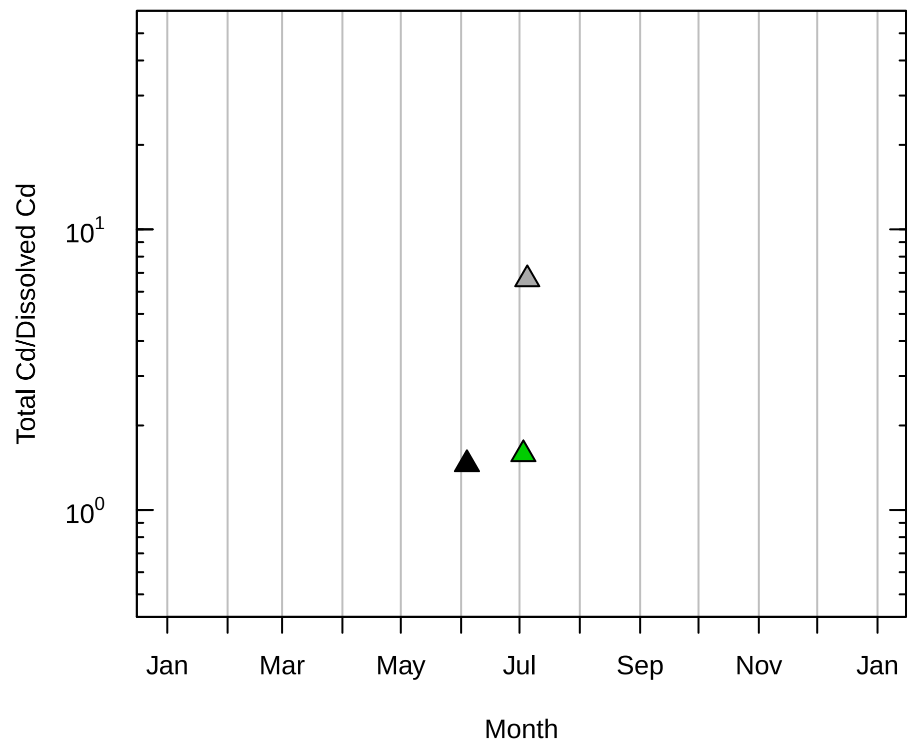
N = 64
N (BDL) = 48
Total Cadmium (ug/L)
Percentile
0.01
1
10
50
80
99
99.9



N = 64
N (BDL) = 58
Dissolved Cadmium (ug/L)
Percentile
0.01
1
10
50
80
99
99.9

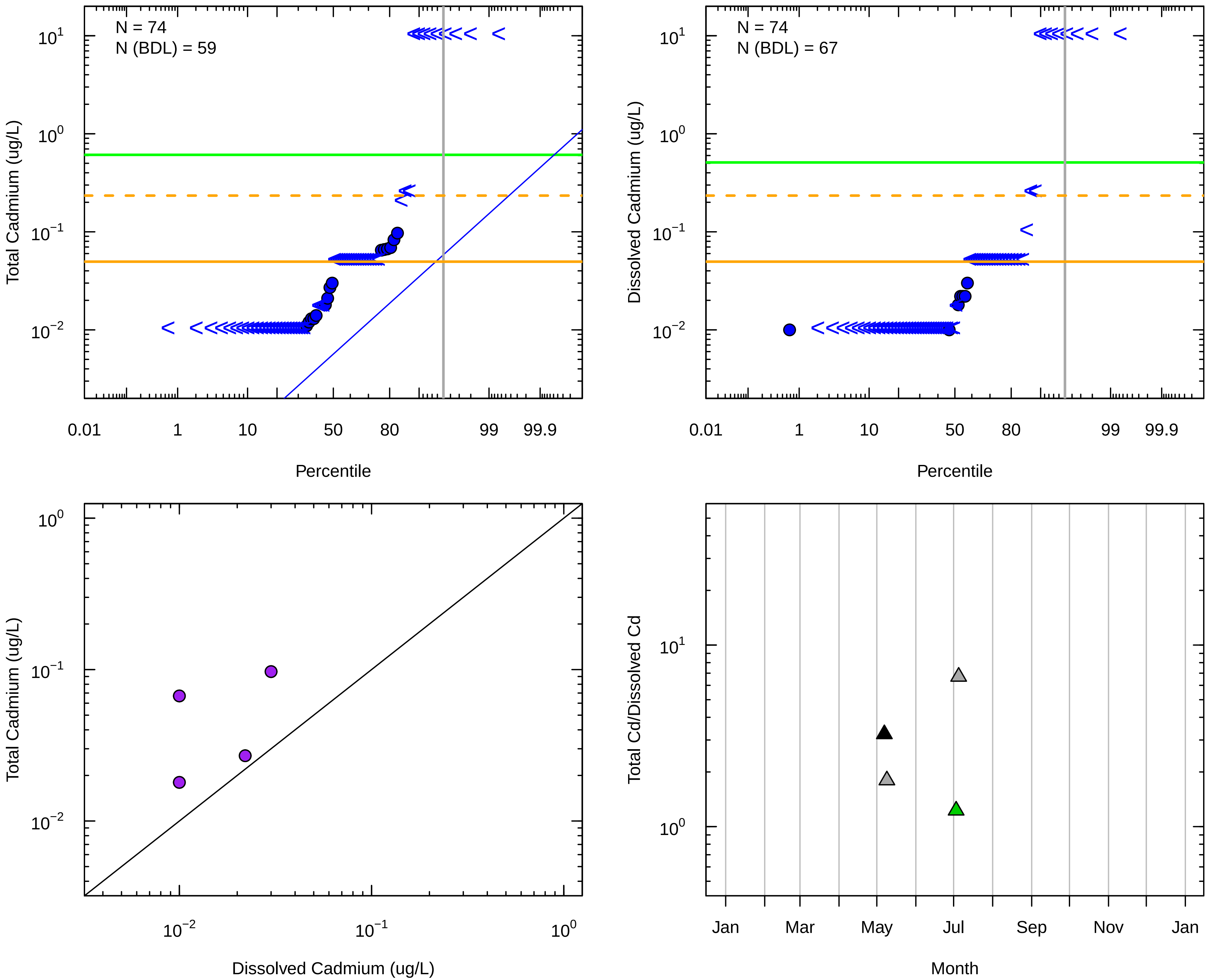


Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)

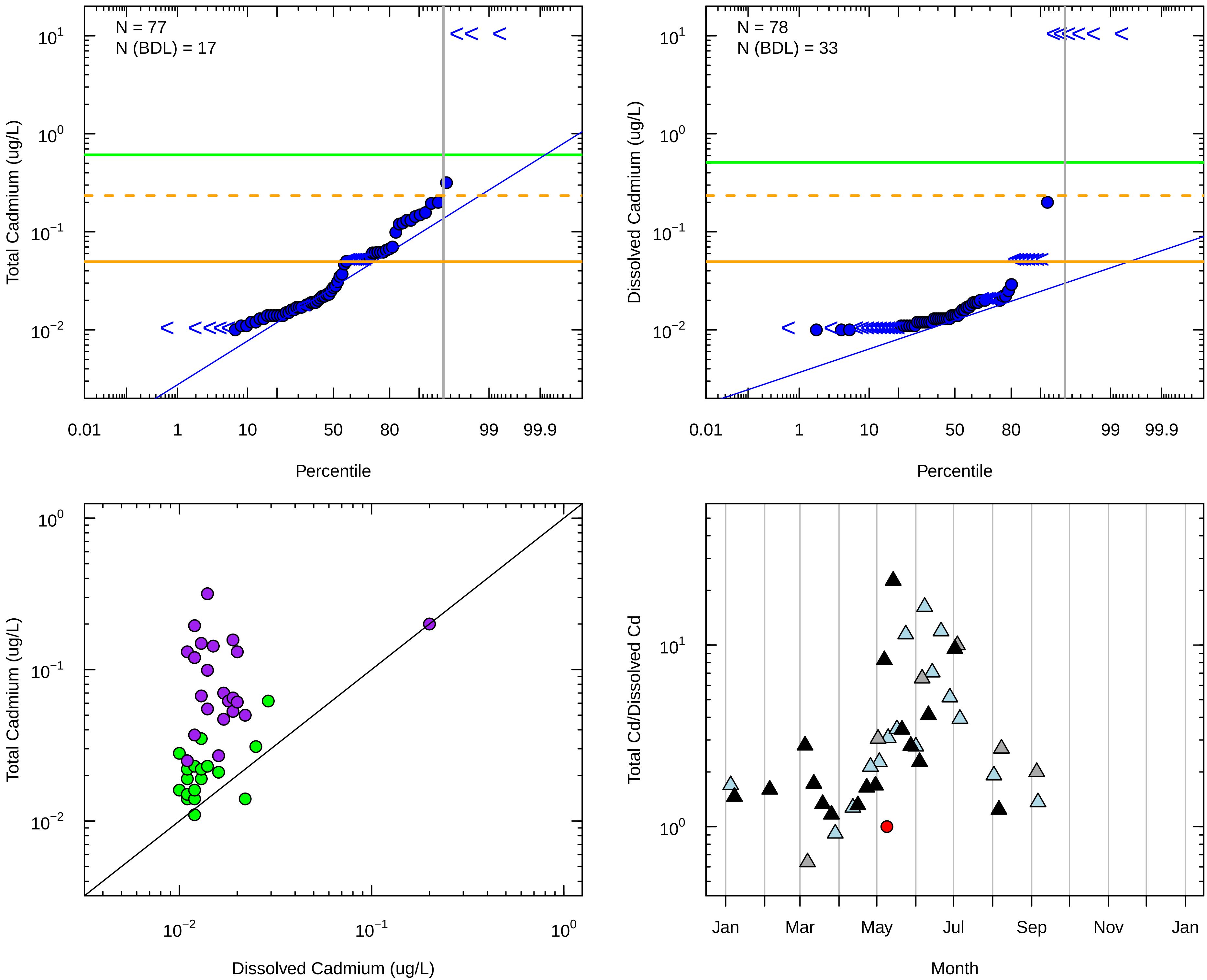


Total Cd/Dissolved Cd
Jan
Mar
May
Jul
Sep
Nov
Jan
Month

GH_ER1

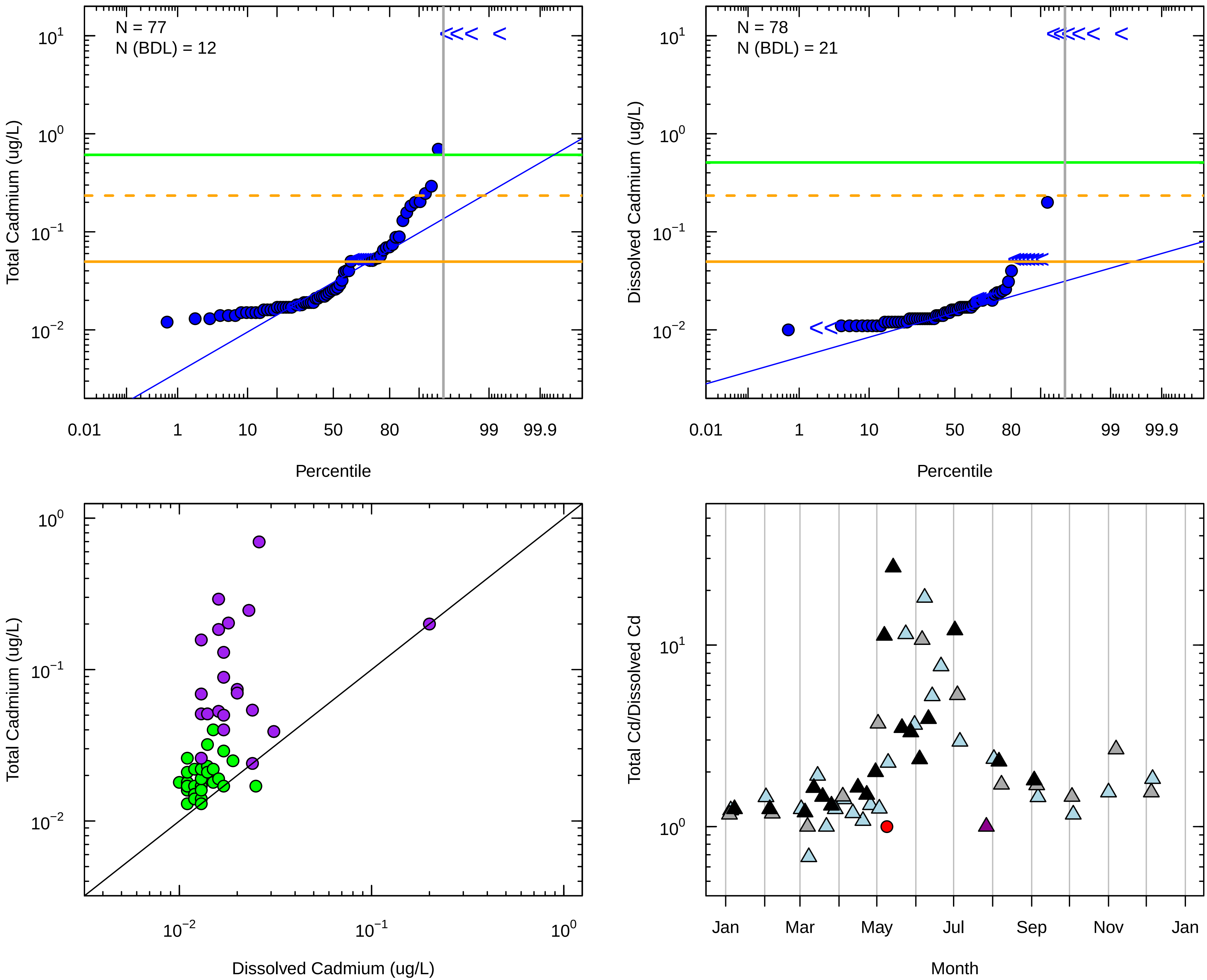

N = 74
N (BDL) = 59
Total Cadmium (ug/L)
Percentile
0.01
1
10
50
80
99
99.9
N = 74
N (BDL) = 67
Dissolved Cadmium (ug/L)
Percentile
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Month
Jan
Mar
May
Jul
Sep
Nov
Jan

EV_ER4



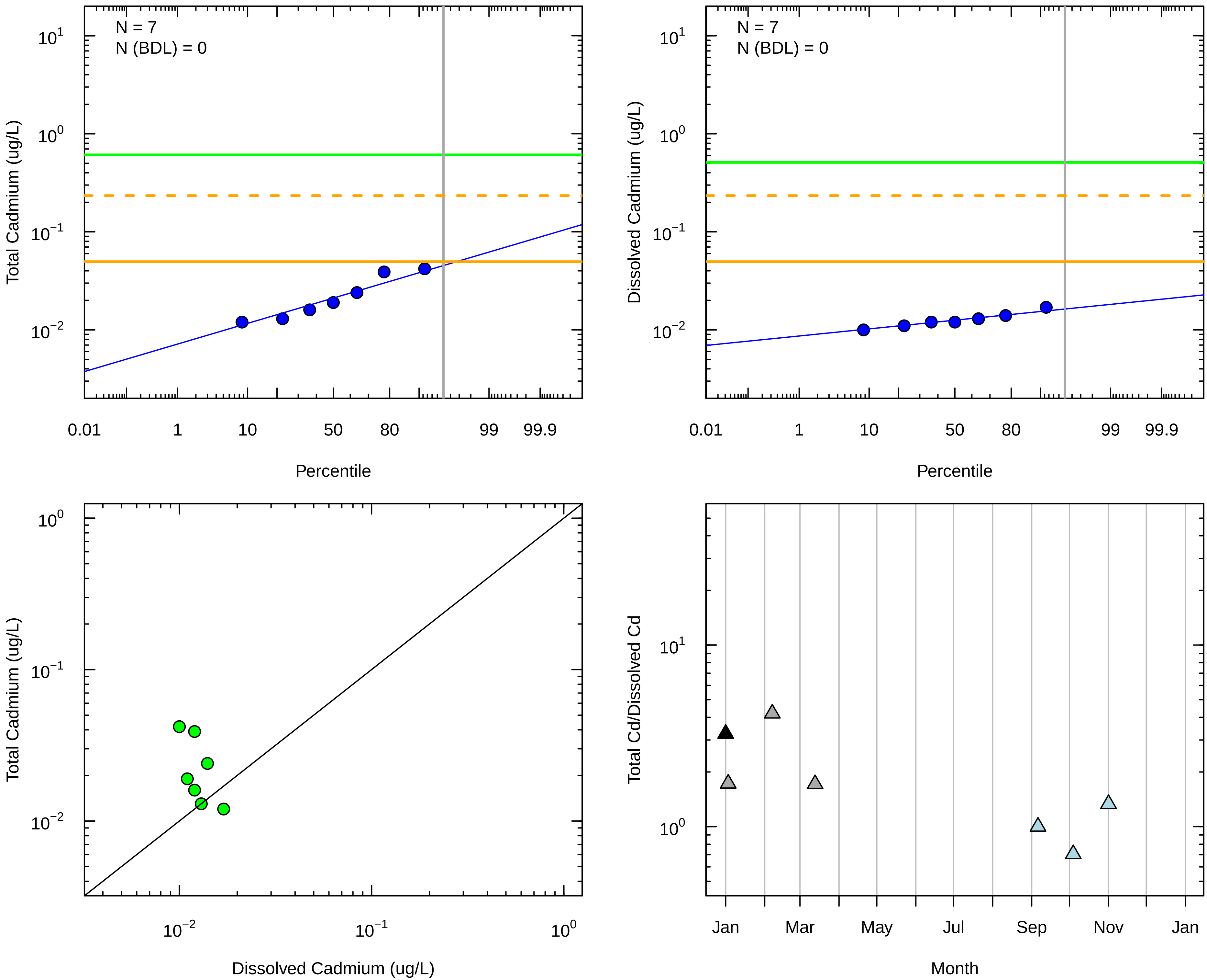
N = 77
N (BDL) = 17
Total Cadmium (ug/L)
Percentile
N = 78
N (BDL) = 33
Dissolved Cadmium (ug/L)
Percentile
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Month
Jan
Mar
May
Jul
Sep
Nov
Jan

EV_ER1

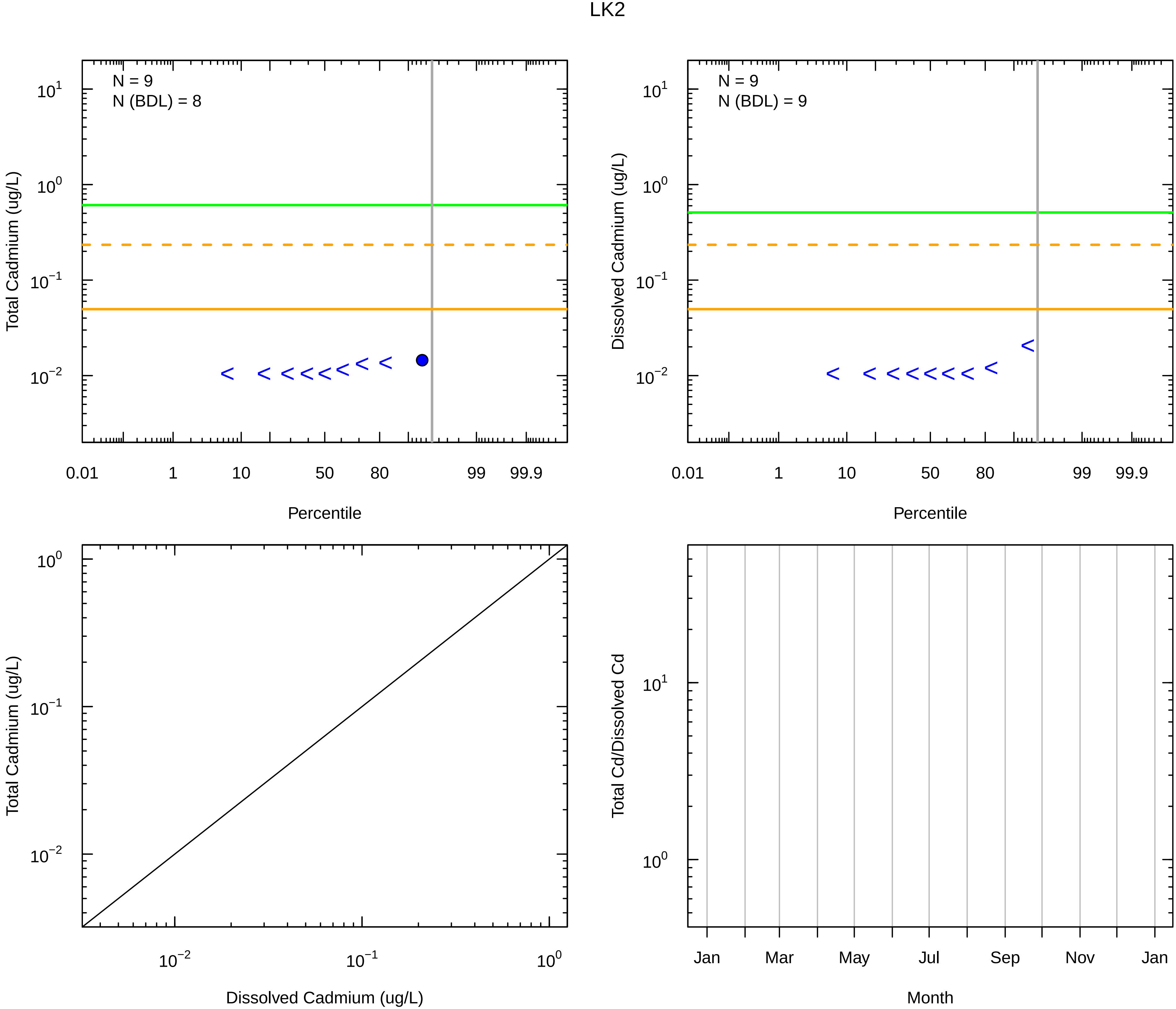


N = 77
N (BDL) = 12
Total Cadmium (ug/L)
Percentile
0.01
1
10
50
80
99
99.9
N = 78
N (BDL) = 21
Dissolved Cadmium (ug/L)
Percentile
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Month
Jan
Mar
May
Jul
Sep
Nov
Jan

RG_ELKORES



N = 7
N (BDL) = 0
Total Cadmium (ug/L)
10^{1}
10^{0}
10^{-1}
10^{-2}
0.01
1
10
50
80
99
99.9
Percentile
N = 7
N (BDL) = 0
Dissolved Cadmium (ug/L)
Percentile
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Jan
Mar
May
Jul
Sep
Nov
Jan
Month



LK2
N = 9
N (BDL) = 8
Total Cadmium (ug/L)
Percentile
N = 9
N (BDL) = 9
Dissolved Cadmium (ug/L)
Percentile
Total Cadmium (ug/L)
Dissolved Cadmium (ug/L)
Total Cd/Dissolved Cd
Month
Jan
Mar
May
Jul
Sep
Nov
Jan