Final Project Report

PROJECT INFORMATION

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Abstract

Temperatures are warming fastest at high latitudes and annual temperatures have increased by 2-3° C in the Arctic over the second half of the 20th century. Shorebirds respond to cues on their overwintering grounds to initiate long migrations to nesting sites throughout the Arctic. Climate-driven changes in snowmelt and temperature, which drive invertebrate emergence, may lead to a lack of synchrony between the timing of shorebird nesting and the availability of invertebrate prey essential for egg formation and subsequent chick survival. To explore the drivers and potential magnitude of climate-related shifts in the availability of invertebrate prey, we modeled the biomass of invertebrates captured in modified Malaise traps as a function of accumulated temperature and weather variables for nine North American research camps in the Arctic Shorebird Demographic Network over the years 2010-2012. Our results confirm the importance of both accumulated and daily temperatures as predictors of invertebrate availability, while also showing that wind negatively affected invertebrate availability at the majority of camps. Our analysis suggests that the seasonal timing of invertebrate availability over a geographic range spanning >3500 km is advancing due to warming temperatures coupled with earlier snowmelt.

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Introduction

Temperatures are warming fastest at high latitudes and annual temperatures have increased by 2-3˚ C in the Arctic over the second half of the 20th century (ACIA 2004). Observed environmental changes resulting from increasing temperatures include earlier snowmelt and later freeze-up, decline in the water balance (precipitation – potential evapotranspiration), warmer lake and pond temperatures, increased shrubbiness, and thermokarsting (Hinzman et al. 2005). Animal responses to these alterations include changes in distribution, advancing phenology, and decreased fitness due to mismatches with food resources (Post et al. 2009).

The effects of climate change appear to be greatest for long-distance migrants that breed in seasonally productive habitats, like Arctic-nesting shorebirds (Both et al. 2009). Climate-driven changes in seasonality may lead to asynchrony between Arctic-nesting shorebirds and their invertebrate prey because the timing of shorebird arrival on the breeding grounds, which is constrained to match long-term average conditions, has not advanced along with warming trends (Meltofte et al. 2007, Grabowski et al. 2013). The breeding success of Arctic shorebirds is sensitive to any resulting mismatches with prey availability because most species rely on breeding-ground food resources for egg formation (i.e., they are income breeders; Morrison and Hobson 2004, Meltofte et al. 2007) and because the survival of chicks, which begin foraging on their own soon after hatching, is dependent upon adequate food during the short Arctic summer (McKinnon et al. 2012).

The phenology of invertebrates is largely driven by local weather conditions on the Arctic breeding grounds. Invertebrates become available upon seasonal emergence, the timing of which is determined by snowmelt and the attainment of temperature thresholds required for development (Danks and Oliver 1972, Høye and Forchhammer 2008a). The prey biomass available to Arctic-breeding birds varies across the breeding season according to the density and activity level of invertebrate prey species. Density is best described by variables representing seasonal development, such as date or accumulated temperature, while activity is best described by weather conditions (Tulp and Schekkerman 2008, Høye and Forchhammer 2008b, Bolduc et al. 2013). Temperature is the most important determinant of activity, although wind speeds, precipitation, humidity, and radiation can also play a role (Tulp and Schekkerman 2008, Bolduc et al. 2013).

Patterns of invertebrate availability have yet to be examined at multiple sites during similar time periods across a broad geographic scale. The goal of the current project was to explore relationships between climatic predictors and the timing of invertebrate availability at nine sites extending from western Alaska to eastern Canada, a range of >3500 km. These nine sites are part of the Arctic Shorebird Demographic Network (ASDN) wherein biologists used standardized methods to collect invertebrate samples throughout the 2010-2012 summers.

Our objectives were to (1) describe differences in terrestrial invertebrate community composition among habitats, years, and sites; and (2) build models that relate the timing of invertebrate prey availability for shorebirds nesting at ASDN research camps as a function of seasonal and climatic variables. Our final objective is to use the models to quantify how the timing of prey availability has changed over the past 25 years, which will be included in a separate report.

Methods

Invertebrate sampling

Terrestrial invertebrate samples were collected from modified Malaise pitfall traps (Figure 1) during the summers of 2010 – 2012 at nine camps in the ASDN (Figure 2). The modified Malaise traps captured both crawling and low-flying invertebrates. Capture rates reflect the abundance and activity of invertebrates providing a good proxy of shorebird prey availability (Tulp and Schekkerman 2008). Abundances from similar trap designs have been linked to shorebird chick growth (Schekkerman et al. 2003). Each camp permanently established two line transects of five modified malaise pitfall traps spaced 15 meters apart. One transect was placed in a mesic habitat (pond edges and low-centered polygons) and one transect was placed in a dry habitat (frost boil tundra or dry lowland sites). Samples were collected every three days, preserved in 95% isopropyl alcohol or 70 to 100% ethanol, and shipped to the processing laboratory at the end of the field season. At each camp, sampling began at the day of snow out (end May to mid-June) and finished at the completion of shorebird hatching (early- to late-July).

Figure 1. Modified Malaise pitfall trap.

All insect samples were processed at Aquatic Biology Associates, Inc. in Corvallis, Oregon and identified by Robert Wisseman and James DeGiulio. Field samples were transferred to 95% ethanol upon receipt in the lab. All organisms were identified to order or family using a dissecting scope at 12X magnification. Length of invertebrates was measured with a stage micrometer gridded at 1 mm intervals to nearest 0.25 mm for individuals <2 mm long and to nearest 0.5 mm for individuals >2 mm long. Published length weight regressions were used to calculate biomass.

A total of 597 invertebrate samples were collected across the nine camps, three years, and two habitats (Table 1). Six camps had three years of data, two camps had two years of data, and Prudhoe Bay had one year. Generally, the Barrow, Nome, and Colville camps collected data over the longest portion of the summer season (≥ 13 samples each year).

Table 1. Total number of invertebrate sample events for each year at each camp, by habitat type.

Camp	Dry Habitat			Mesic Habitat		
	2010	2011	2012	2010	2011	2012
Barrow	16	18	19	14	19	17
Canning River Delta	9	11	12	9	11	11
Cape Krusenstern	0	11	14	0	11	12
Colville	0	16	18	0	14	15
East Bay	13	11	13	13	11	10
Ikpikpuk	11	13	12	11	13	12
Mackenzie River Delta	8	12	10	8	12	10
Nome	13	19	19	13	17	18
Prudhoe Bay	9	0	0	9	0	0

We calculated the mean biomass per trap for each taxon from the traps collected on each sampling event (the number of traps collected varied from two to five per sampling event, although five traps were collected on 97% of all sample dates). We further divided the mean biomass per trap by the number of days between sampling events (the number of days varied from one to 12, although 93% of samples were collected every three days). For the first sample collected each year, we divided by three days. The mean daily biomass per trap by taxon was used to compare invertebrate communities across the nine camps. Daily biomass per trap for each taxon was plotted separately for each camp, habitat, and year in descending order by their contribution to total biomass over the entire dataset (Appendix A). We summed the taxa biomasses to calculate the total daily invertebrate biomass per trap used for statistical modeling.

Weather data

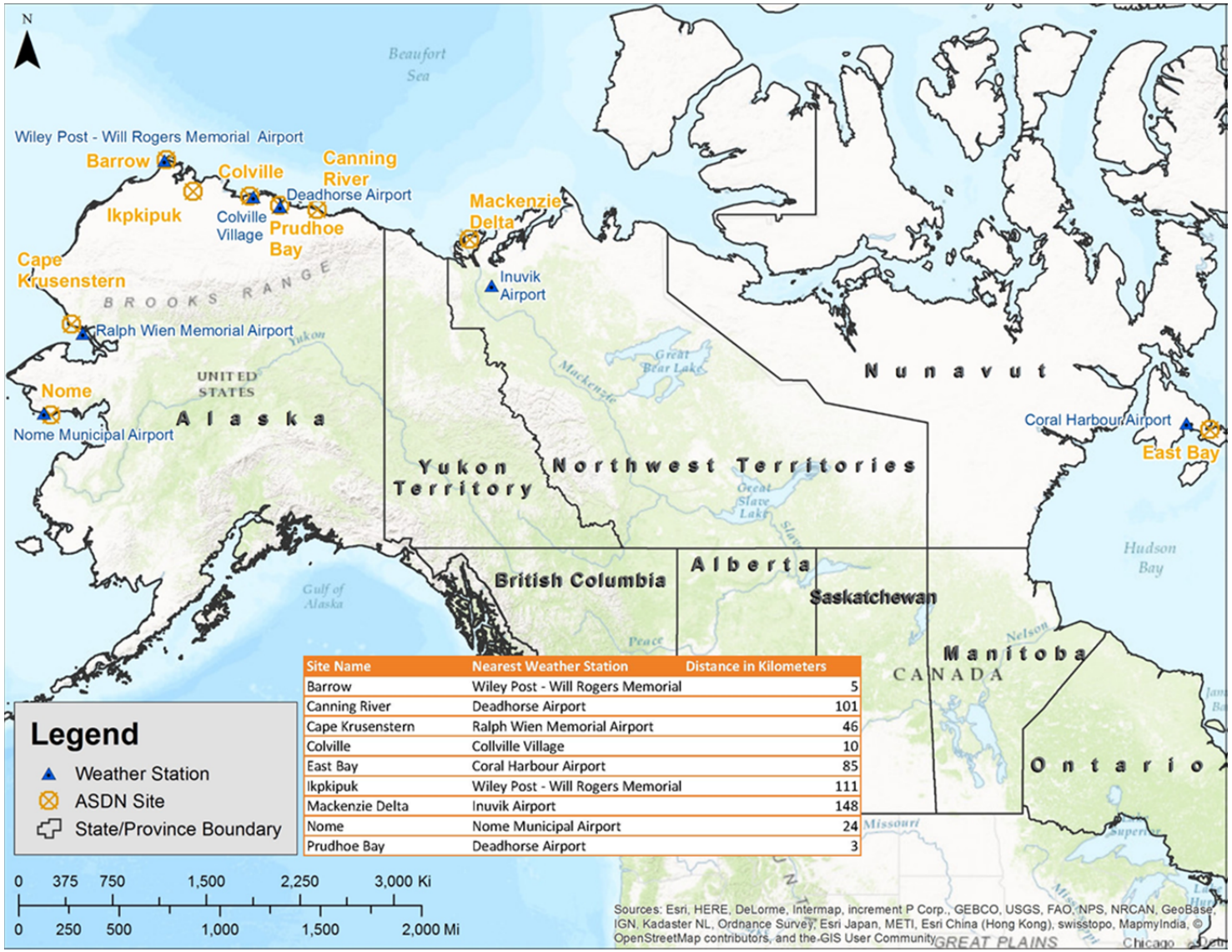
Hourly weather conditions (air temperature, relative humidity, wind speed, wind direction) were recorded by a weather station (HOBO U30 datalogger) at each camp, unless an established airport weather station was nearby. The Barrow and Prudhoe Bay camps used Barrow and Deadhorse airport data, respectively. These airports were five kilometers or less from the camps (Figure 2). Precipitation at camps was measured daily using a manual rain/snow gauge. Visual estimates of snow cover were made every other day from the beginning of the season until the snow melted (90% or more was gone). All weather measurements were converted to metric, time offsets were checked (based on daylight savings) for the HOBO weather stations, and hourly weather measurements were converted to daily averages. Days with less than 90% of hourly measurements were not used.

Weather data were not available for all sampling dates at all camps. For example, in 2011 Cape Krusenstern (CAKR) weather data were collected for less than two weeks, whereas invertebrate

data were collected for more than five weeks (Table 2). We dealt with incomplete weather data on a camp-by-camp basis by not modeling dates with incomplete weather data or by using weather data from a nearby weather station (National Climate Data Center: http://www.ncdc.noaa.gov/data-access, Table 2). Weather data sources for each camp are described in the statistical methods.

Daily air temperatures are an important factor affecting invertebrate activity in addition to cumulative temperatures. Cumulative degree-days were calculated as the sum of all mean daily temperatures from the day of snow melt. The timing of snow melt was unavailable for 11 of the 23 site-years in our dataset because field staff arrived after the snow was completely gone or because snow cover estimates were not recorded. To determine if remotely sensed products were suitable substitutes, we compared the observed day of snow out, defined as the date when snow cover was less than 50%, to the National Ice Center's IMS Daily Northern Hemisphere Snow and Ice Analysis at 4 km resolution (National Ice Center 2008) and the MODIS-derived snow metrics at 500 m resolution developed by the National Park Service and the Geographic Information Network of Alaska (Lindsay et al. 2015) (Table 3). We evaluated two MODIS-derived snow metrics: last snow day of the full snow season (LSD) and last day of the longest continuous snow season (LCLD). The continuous snow season does not include more than two consecutive days of no-snow. The mean differences between the observed day of snow out and the IMS 4 km product and the LCLD metric were 9 days and 4 days, respectively. We decided to use the LCLD metric because it matched the observed day of snow out better than the LSD metric or the IMS 4 km product and we felt it was biologically meaningful to capture days of no-snow in our calculation of cumulative degree days. The East Bay camp did not record the day of snow out in 2011 and the MODIS snow metrics are not available for this camp. We used recorded snow depth from the Coral Harbor Airport to determine day of snow out for East Bay in 2011.

We plotted each weather predictor over the season for each camp and year (Appendix B). The warmest summer for the three year dataset varied across the nine camps, although 2012 accumulated the most degree days during the sampling season for five of the nine camps.



Site Name	Nearest Weather Station	Distance in Kilometers
Barrow	Wiley Post - Will Rogers Memorial	5
Canning River	Deadhorse Airport	101
Cape Krusenstern	Ralph Wien Memorial Airport	46
Colville	Collville Village	10
East Bay	Coral Harbour Airport	85
Ikpkipuk	Wiley Post - Will Rogers Memorial	111
Mackenzie Delta	Inuvik Airport	148
Nome	Nome Municipal Airport	24
Prudhoe Bay	Deadhorse Airport	3

Figure 2. Location of nine camps in Arctic Shorebird Data Network that submitted data for this project. Locations of weather stations are also shown with distance to nearest camp in table.

Table 2. Summary of weather, snow, and invertebrate data available for each ASDN camp and year.

Camp[1]	Date of snow out-satellite imagery	Date of snow out-camp data	First day of weather collection	Last day of weather collection	First day of invertebrate collection	Last day of invertebrate collection	Weather Data Source	All weather predictors collected	Nearest airport weather station
BARR	6/19/2010	6/12/2010	5/20/2010	7/31/2010	6/14/2010	7/29/2010	Airport	Yes	Barrow
BARR	6/22/2011	6/14/2011	6/1/2011	8/31/2011	6/4/2011	7/28/2011	Airport	Yes	Barrow
BARR	6/16/2012	6/2/2012	5/1/2012	8/31/2012	6/7/2012	7/28/2012	Airport	Yes	Barrow
CAKR	5/29/2011	NA	6/4/2011	7/4/2011	6/3/2011	7/3/2011	HOBO	Yes	Kotzebue
CAKR	5/26/2012	5/29/2012	6/2/2012	6/13/2012	5/30/2012	7/8/2012	HOBO	No	Kotzebue
CARI	6/13/2010	6/8/2010	6/4/2010	7/12/2010	6/13/2010	7/7/2010	HOBO	Yes	Kaktovik-Barter Island
CARI	6/19/2011	6/11/2011	6/5/2011	7/13/2011	6/8/2011	7/8/2011	HOBO	No	Kaktovik-Barter Island
CARI	6/14/2012	NA	6/5/2012	7/16/2012	6/9/2012	7/12/2012	HOBO	Yes	Kaktovik-Barter Island
COLV	6/19/2011	5/30/2011	6/11/2011	8/8/2011	5/28/2011	7/13/2011	HOBO	No	Helmericks Homestead
COLV	6/14/2012	6/7/2012	5/20/2012	8/9/2012	5/28/2012	7/18/2012	HOBO	Yes	Helmericks Homestead
EABA	6/30/2010	6/9/2010	5/27/2010	7/30/2010	6/17/2010	7/25/2010	Davis Vantage Pro2	No	Coral Harbor Airport
EABA	6/25/2011	NA	6/16/2011	8/5/2011	6/18/2011	7/24/2011	Davis Vantage Pro2	Yes	Coral Harbor Airport
EABA	6/18/2012	6/15/2012	6/12/2012	7/27/2012	6/20/2012	7/22/2012	Davis Vantage Pro2	Yes	Coral Harbor Airport

Camp	Date of snow out-satellite imagery	Date of snow out-camp data	First day of weather collection	Last day of weather collection	First day of invertebrate collection	Last day of invertebrate collection	Airport weather summarized	All weather predictors collected	Nearest airport weather station
IKPI	6/18/2010	NA	6/10/2010	7/13/2010	6/13/2010	7/13/2010	HOBO	Yes	Barrow
IKPI	6/19/2011	NA	6/5/2011	7/16/2011	6/8/2011	7/14/2011	HOBO	Yes	Barrow
IKPI	6/14/2012	NA	6/12/2012	7/16/2012	6/10/2012	7/13/2012	HOBO	Yes	Barrow
MADE	6/13/2010	NA	6/11/2010	7/7/2010	6/15/2010	7/7/2010	HOBO	Yes	Aklavik
MADE	6/12/2011	NA	6/7/2011	7/11/2011	6/8/2011	7/11/2011	HOBO	Yes	Aklavik
MADE	6/14/2012	NA	6/5/2012	7/9/2012	6/10/2012	7/7/2012	HOBO	Yes	Aklavik
NOME	5/24/2010	NA	5/16/2010	7/12/2010	6/4/2010	7/10/2010	HOBO	Yes	Nome
NOME	5/28/2011	5/20/2011	5/18/2011	7/21/2011	5/25/2011	7/21/2011	HOBO	Yes	Nome
NOME	6/3/2012	5/21/2012	5/21/2012	7/21/2012	5/26/2012	7/19/2012	HOBO	Yes	Nome
PRBA	6/13/2010	NA	5/20/2010	7/31/2010	6/12/2010	7/11/2010	Airport	Yes	Prudhoe Bay

[1] BARR=Barrow, CAKR=Cape Krusenstern, CARI= Canning River, COLV=Colville River, EABA= East Bay, IKPI= Ikpikpuk, MADE=Mackenzie Delta, NOME= Nome, PRBA=Prudhoe Bay.

NA – data were not collected.

Table 3. Day of snow-out recorded at six ASDN camps compared to two satellite data sources.

Site	Year	Recorded day of snow-out	IMS 4 km[1]	MODIS LSD[2]	MODIS LCLD[2]	Difference from recorded day of snow out	
						IMS 4 km	MODIS LCLD
BARR	2010	6/12/2010	6/19/2010	6/15/2010	6/15/2010	7 days	3 days
BARR	2011	6/14/2011	6/22/2011	7/13/2011	6/1/2011	8 days	-13 days
BARR	2012	6/2/2012	6/16/2012	6/8/2012	6/8/2012	14 days	6 days
CAKR	2012	5/29/2012	5/26/2012	5/31/2012	5/25/2012	-3 days	-4 days
CARI	2010	6/8/2010	6/13/2010	5/27/2010	5/27/2010	5 days	-12 days
CARI	2011	6/11/2011	6/19/2011	6/2/2011	6/2/2011	8 days	-9 days
COLV	2011	5/30/2011	6/19/2011	5/30/2011	5/30/2011	20 days	0 days
COLV	2012	6/7/2012	6/14/2012	5/30/2012	5/30/2012	7 days	-8 days
EABA	2010	6/9/2010	6/30/2010	NA	NA	21 days	NA
EABA	2012	6/15/2012	6/18/2012	NA	NA	3 days	NA
NOME	2011	5/20/2011	5/28/2011	5/19/2011	5/19/2011	8 days	-1 day
NOME	2012	5/21/2012	6/3/2012	6/23/2012	5/20/2012	13 days	-1 day

[1] IMS 4 km is from the National Snow and Ice Data Center (http://nsidc.org/data/docs/noaa/g02156_ims_snow_ice_analysis/).

[2] MODIS LSD is the last day of the full snow season and MODIS LCLD is the last day of the longest continuous snow season. Both snow metrics are available at 500 m resolution from GINA (http://www.gina.alaska.edu/projects/modis-derived-snow-metrics).

NA - The MODIS snow metrics were not available for the East Bay camp.

Statistical analysis

We explored patterns of invertebrate community composition using non-metric multidimensional scaling (NMS) of mean daily biomass by taxon for each camp, year, and habitat (n = 46). The NMS was performed on a matrix of Bray-Curtis distances. Camp, year, habitat, latitude and longitude were evaluated as correlates of community composition by fitting environmental vectors or factors. The vectors point in the direction of maximum correlation to the ordination and are scaled by their correlation coefficient. Significant relationships between environmental variables and ordinations were assessed by randomly permuting the variable 1000 times and calculating the proportion of times the squared correlation coefficient was higher than the observed value. We further assessed differences in community composition by camp, year, and habitat using permutational multivariate analysis of variance on the Bray-Curtis distance matrix. Camps were used as groups within which to constrain the permutations for habitats and years.

Variables that explained significant variation in community composition (camp, year, habitat, latitude, and longitude) were used to evaluate how individual taxa responded to environmental gradients. Points in the ordination plot were sized according to taxa biomass and overlaid with environmental variables. We also used indicator species analysis to identify taxa that have high frequency and abundance at individual camps. All multivariate analyses were run using the vegan and labdsv packages in R (Oksanen et al. 2016, Roberts 2016).

We modeled daily invertebrate biomass per trap for each camp as a function of habitat type (dry vs. mesic) and five weather variables: temperature, relative humidity, wind, precipitation, and cumulative degree days (CDD, Table 4). Daily weather data were adjusted for the number of days between sample events by averaging temperature, relative humidity and wind, and by summing precipitation. Cumulative degree days was calculated by summing the positive daily temperatures since the day of snow out up to and including the day sampled.

Table 4. Weather variables used for predicting daily invertebrate biomass at each camp.

Variable	Units	Notes
Temperature	˚C	Mean over days between sample events
Relative humidity	%	Mean over days between sample events
Wind	km/h	Mean over days between sample events
Precipitation	mm	Sum over days between sample events
Cumulative degree days	˚C	Sum since day of snow out
Habitat	NA	Dry or mesic

We used linear mixed effects models with a random intercept for year because each camp was sampled over two or three years (except Prudhoe Bay where we have only one year of data, Table 1). For cumulative degree-days, we included a quadratic term to allow for a non-linear

relationship with biomass. We centered all of the continuous predictor variables by subtracting their mean because it made the intercept interpretable as the estimated biomass in the middle of the season (mean cumulative degree-days) during average weather conditions and it decreased the correlation between cumulative degree-days and its quadratic term. We tested for co-linearity in the weather variables using pairwise plots and variance inflation factors (VIF). The predictor with the highest VIF was removed in a stepwise procedure until all predictors had VIF < 5.

A suite of all possible models was built using the six weather variables and the habitat type as predictors; squared cumulative degree-days was only included in models that also had the linear term. Models were compared using Akaike's Information Criterion (AIC). We used all subsets modeling because we expected that all of our weather variables would affect invertebrate activity so constructing a smaller list of a priori models would not have been meaningful. In addition, one of our goals was to identify the most important predictors of daily invertebrate activity, and all subsets results in a balanced model set so that relative variable importance can be meaningfully calculated (Burnham and Anderson 2002).

We defined our confidence set as all models with $\Delta AIC \leq 4$ while removing any models with uninformative parameters (i.e., models added a parameter to a better model but were within 0 – 2 ΔAIC units of that model) (Arnold 2010). Parameter estimates were averaged over all models in the confidence set by substituting zero when a parameter was missing from a model (Anderson 2008, Grueber et al. 2011). Confidence intervals (85%) were estimated for each parameter using unconditional standard errors based on the final model set. Variable importance was calculated as the sum of the Akaike weights (Σw_i) over all the models in which a parameter occurred. Model assumptions were evaluated using a global model with all predictors and included normality of the residuals, normality of the random effects, homogeneity of variances (normalized residuals plotted against fitted values and each predictor), a check for outliers using Cook's distance, and a check of temporal autocorrelation using the autocorrelation function. All analyses were conducted in R using the nlme and MuMIn libraries (Pinheiro et al. 2014, R Core Team 2014, Barton 2016).

Model fit was quantified using the marginal and conditional R^2, which are equivalent to the variance explained by the fixed effects and the variance explained by the fixed and random effects, respectively (Nakagawa and Schielzeth 2013). The adjusted R^2 was used for the Prudhoe Bay camp since there was only one year of data. The observed versus predicted coefficient of determination, r^2, was also used to assess model performance for prediction (Piñeiro et al. 2008).

Analyses were run differently for each camp in order to address multicollinearity between predictors and missing weather data. Multicollinearity was assessed using variance inflation factors (VIF).

- At Barrow, weather data originated from the nearby airport so all predictors were available for modeling all sample dates. Temperature and CDD were moderately correlated ($r = 0.8$), but VIF were all below five.
- At the Canning River camp, two dates from 2012 were not included in the analysis due to missing weather data when the HOBO weather station blew over and became inoperable at the beginning of the season (per camp notes). Relative humidity was removed due to high collinearity with temperature.
- Due to missing weather data at the Cape Krusenstern camp (12 of the 25 invertebrate sampling dates could not be modeled), Kotzebue airport weather data were used for this camp. Relative humidity was not available for the Kotzebue airport so it was not included in the analysis. Temperature and precipitation were strongly correlated between the airport and the camp ($r = 0.97$ and $r = 0.81$, respectively). CDD was dropped due to high collinearity with temperature (CDD VIF > 8, CDD^2 was also dropped). No data were missing from the Kotzebue airport weather dataset so all dates were included in the analysis.
- The weather station at the Colville River camp was set up 12 days after the collection of the first invertebrate sample in 2011, resulting in five dates removed from the analysis. Precipitation data were not collected at the camp so precipitation data from Colville Village were used instead (~10 km away). Relative humidity was removed from the analysis due to collinearity with temperature.
- At the East Bay camp, the relative humidity sensor failed during the 2012 season so it was not included in the analysis for this camp. Temperature and CDD were moderately correlated ($r = 0.8$), but VIF were all below five.
- At the Ikpikpuk camp, two days were removed from the beginning of the 2012 field season because the HOBO weather station was not setup. Relative humidity was removed from the analysis due to collinearity with temperature.
- All weather data were available for the Mackenzie Delta camp. Temperature and CDD were moderately correlated ($r = 0.7$), but VIF were all below five.
- At the Nome camp, precipitation data were not collected consistently on all dates, which prevented the analysis of 11 dates (nine in 2011 and two in 2010). In order to include as many dates as possible in the analysis, precipitation data were replaced with data from the Nome airport, approximately 24 km away. Missing precipitation data from the Nome airport resulted in the removal of five days in 2012 from the analysis. All predictors had VIF less than five and none were strongly correlated ($r \leq 0.5$).
- At Prudhoe Bay, weather data originated from the Deadhorse airport so all predictors were available for modeling all sample dates. CDD and CDD^2 were not used to model Prudhoe Bay invertebrate biomass due to high collinearity with temperature and relative humidity.

Results

There were a total of 48 unique taxa identified to the family or higher taxonomic level across the nine camps (Table 5). Eighteen of the 48 taxa occurred at all nine camps. The Nome and Mackenzie Delta camps had the highest taxa richness (42 and 37, respectively). The lowest richness was found at Barrow and East Bay. There were 11 taxa with mean annual biomass across the dataset > 100 mg. Aranae (spiders) had the highest biomass across all of the camps, which was driven by exceptionally high biomasses at Nome and Cape Krusenstern. This was closely followed by several dipteran (true fly) taxa, which included Brachycera (a group of flies), Chironomidae (non-biting midges), Tipulidae (craneflies), Mycetophilidae (fungus gnats), and Sciaridae (dark-winged fungus gnats). Other taxa with high biomass included Carabidae (ground beetles), Hymenoptera (bees and wasps), Trichoptera (caddisflies), Lepidoptera (moths), and Hymenoptera (parasitic wasps).

The NMS ordination of annual mean daily biomass for each taxon resulted in a three dimensional solution with a stress of 16.7. Factor fitting between camp, year, habitat and the ordination scores indicated significant differences in community composition between camps, but not habitats or years (*p-value* for camp = 0.001, *p-value* for year = 0.5, and *p-value* for habitat = 0.5). Permutational multivariate analysis of variance on the distance matrix confirmed this result (*p-value* for camp = 0.001, *p-value* for year = 0.6, and *p-value* for habitat = 0.5). Geographic differences in community composition were correlated with both latitude and longitude (*p-value* = 0.001) with latitude explaining more variation in the ordination than longitude (R^2 = 0.55 for latitude and R^2 = 0.28 for longitude).

Geographic variation in invertebrate composition was visually assessed on the NMS ordination plots by scaling the points by taxa biomass, symbolizing the points by camp, and displaying the vectors for latitude and longitude (Appendix C). Of the taxa that had high biomass across the dataset, several showed geographic variation and some were indicator taxon (high fidelity and abundance) for individual camps. Both Aranae (spiders) and Lepidoptera (moths) had higher biomass at lower latitudes, specifically the Nome and Cape Krusenstern camps, and both were indicator taxa for the Cape Krusenstern camp. Carabidae (ground beetles) was also more common at camps further south, but its highest biomass was at the Ikpikpuk camp, where it was an indicator taxon. Brachycera (a group of flies), Tipulidae (craneflies), Hymenoptera (bees and wasps), and Trichoptera (caddisflies) were all indicator taxa for the Colville camp, where they had high biomass and occurred frequently across habitats and years. Tipulids were also common and had higher than average biomass at the Ikpikpuk camp. Chironomidae (non-biting midges), Sciaridae (dark-winged fungus gnats), and Hymenoptera (parasitic wasps) were well distributed across all of the camps. Mycetophilidae (fungus gnats) were most common at the Cape Krusenstern, Nome, and Barrow camps. There were a total of 24 indicator taxa and most of the

camps had from one to three indicator taxa, except for the Colville camp, which had nine indicator taxa (Table 6).

We summed across all taxa to get total daily invertebrate biomass per trap for each camp (Figure 3). Most camps had several peaks of biomass throughout the sampling season indicating synchronous emergence events for different taxa. There were very few sites or years where invertebrate biomass tailed off completely by the end of the sampling season, which is probably because sampling ended in July. The Barrow camp had the longest sampling season (end dates of July 28 or 29) and invertebrate biomass peaks occurred in mid to late July.

Cumulative biomass was plotted against cumulative degree days to compare total degree days, total biomass, and differences in slopes across camps (Figure 4). Steeper slopes indicate a larger invertebrate pool available for emergence for a given number of degree-days, while a decreasing slope at the end of the sampling season indicates a depletion of the invertebrate pool. The Nome, Colville, and Cape Krusenstern camps had the highest biomass over the season, while the Nome and Mackenzie Delta camps accumulated the most degree days. Colville produced the most invertebrate biomass per degree-day; it was the only camp with slopes greater than three for both years (daily biomass of 3 mg/trap for every degree-day, data not shown). Only some sites and years showed obvious depletion of the invertebrate pool by the end of the sampling season. At East Bay, invertebrate biomass started to decrease between 100 and 200 degree days. At Cape Krusenstern and East Bay, there were large differences in biomass between years, with 2012 producing low biomass at both camps. At Barrow, 2012 produced the largest invertebrate biomass across the three years sampled. Several camps had no change or very minor changes in slopes at the end of the sampling season.

Table 5. Mean annual biomass (mg dry mass) for each unique taxon by ASDN camp.

Taxon	Camps[1]									Total Biomass	Freq.
	BARR	CARI	CAKR	COLV	EABA	IKPI	MADE	NOME	PRBA		
Acari	0.15	0.02	0	0	0.01	0.02	0.24	0.01	0.22	0.67	7
Aphididae	0	0	0	0	0	0	0.02	0.4	0	0.42	3
Apidae	0	0	2.42	30.18	0	0	1.3	12.77	0	46.67	4
Araneae	28.19	41.78	620.35	25.21	93.71	327.32	127.99	599.47	93.88	1957.9	9
Brachycera	92.63	3.41	44.98	690.35	64.95	26.53	83.6	111.65	8.83	1126.93	9
Cantharidae	0	0	12.8	0	0	0	0	0	0	12.8	1
Carabidae	10.83	4.99	202.89	8.82	111.5	378.05	45.73	197.74	27.66	988.21	9
Cecidomyiidae	2.31	0.2	0.28	0.9	0.14	1.02	0.47	2.32	0.37	8.01	9
Ceratopogonidae	0.33	0.03	1.02	0.02	2.58	0.31	1.27	2.32	0.53	8.41	9
Chilopoda	0	0	0	0	0	0	0	0.18	0	0.18	1
Chironomidae	59.05	15.56	72.02	112.46	98.89	25.41	6.6	49.86	29.84	469.69	9
Chrysomelidae	0	4.79	0.68	0.46	0	1.68	0	0.03	0	7.64	5
Cicindelidae	0	0	1.88	0.1	4.51	0	1.44	0	0	7.93	4
Coccinellidae	0	0	1.24	2.77	0	0	0	2.65	0	6.66	3
Coleoptera	0	0.03	0	0	0	0.05	0.66	15.21	0.18	16.13	5
Collembola	1.85	0.43	1.7	0.66	0.28	4.28	0.98	3.57	0.38	14.13	9
Culicidae	2.11	0.75	2.23	3.52	2.94	1.55	7.25	1.72	1.31	23.38	9
Curculionidae	0	0	6.8	6.89	0.54	1.11	4.01	2.65	0	22	6
Dixidae	0	0	0	0	0	0	0	0	0	0	1
Dytiscidae	0	0.44	5.54	1.6	8.04	0.18	0	11.78	0	27.58	6
Elateridae	0	0	0	0	0	0	0	0.1	0	0.1	1
Ephemeroptera	0	0	0	0	0.05	0	0.02	0	0	0.07	2
Hemiptera: Auchenorrhyncha	0	1.28	0.02	3.91	0	6.15	0.19	2.74	1.04	15.33	7
Hemiptera: Heteroptera	0	0	0.32	0	0	0	0.21	0.13	0	0.66	3
Hemiptera: Sternorrhyncha	0	0	0	1.23	0	0	0	0.08	0	1.31	3

Taxon	Camps[1]									Total Biomass	Freq.
	BARR	CARI	CAKR	COLV	EABA	IKPI	MADE	NOME	PRBA		
Hydrophilidae	0	0	0	0	0	0	0	2.42	0	2.42	1
Hymenoptera bees and wasps	3.23	0.72	2.42	135.01	0.72	5.2	1.24	10.46	12.82	171.82	9
Hymenoptera parasitoid	22.72	2.25	7.02	28.08	12.95	3.65	5.13	25.57	1.83	109.2	9
Hymenoptera sawflies	5.81	0.92	0.5	13.85	0.63	1.61	4.14	3.37	0.2	31.03	9
Lepidoptera	6.15	1.44	52.3	11.26	7.16	11.1	5.72	35.23	5.61	135.97	9
Lymnaeidae	0	0	0	0	0	0.11	27.76	2.53	0	30.4	3
Mycetophilidae	69.45	2.3	65.16	2.29	5.77	8.59	13.28	83.71	0.25	250.8	9
Neuroptera	0	0	0.02	0	0	0	0	0.16	0	0.18	2
Oligochaeta	0	0	0	0	0	0	0	1.98	0.02	2	2
Physidae	0	0	0	0	0	0	0.01	0	0	0.01	1
Plecoptera	0.25	0.86	0	12.61	0	0	6.32	0.06	0	20.1	5
Psocoptera	0	0	0	0	0	0	0.19	0	0.73	0.92	2
Psychodidae	0.13	0.01	0.02	0.14	0	0.07	0.12	0.22	0.02	0.73	8
Psyllidae	0	0	0	0.92	0	0	0.26	0.02	0	1.2	3
Saldidae	9.9	2.04	0.02	1.84	25.91	1.52	0.15	0.04	0.48	41.9	9
Sciaridae	32.94	2.28	7.24	36.26	7.66	8.24	10.19	18.84	6.14	129.79	9
Silphidae	0	0	0	0	0	0	2.91	0	0	2.91	1
Simuliidae	0.02	0	0.02	0.04	0	0	0.78	0.01	0	0.87	5
Staphylinidae	1.49	1.09	1.26	0.36	0.44	1.69	4.45	3.06	2.02	15.86	9
Thysanoptera	0	0	0	0	0	0	0.01	0.01	0	0.02	3
Tipulidae	45.25	11.52	5.14	188.4	20.79	65.78	0.94	14.85	9.83	362.5	9
Trichocera	7.44	0.38	0.08	0.28	0.01	0.26	0.14	0.08	0.34	9.01	9
Trichoptera	4.63	4.09	0	118.44	7.16	7.59	1.45	4.97	6.09	154.42	8
Richness	24	27	31	31	24	27	37	42	25		

[1] BARR=Barrow, CAKR=Cape Krusenstern, CARI= Canning River, COLV=Colville River, EABA= East Bay, IKPI= Ikpikpuk, MADE=Mackenzie Delta, NOME= Nome, PRBA=Prudhoe Bay.

Table 6. Indicator taxa for each camp.

Camp	Indicator Taxa
Barrow	Trichocera
Canning	Chrysomelidae
Cape Krusenstern	Araneae, Cantharidae, Lepidoptera
Colville	Brachycera, Coccinellidae, Hemiptera: Sternorrhyncha, Hymenoptera bees and wasps, Hymenoptera sawflies, Plecoptera, Sciaridae, Tipulidae, Trichoptera
East Bay	Ceratopogonidae, Cicindelidae
Ikpikpuk	Carabidae, Hemiptera: Auchenorrhyncha
MacKenzie	Simuliidae, Staphylinidae
Nome	Coleoptera, Neuroptera, Oligochaeta
Prudhoe Bay	Psocoptera

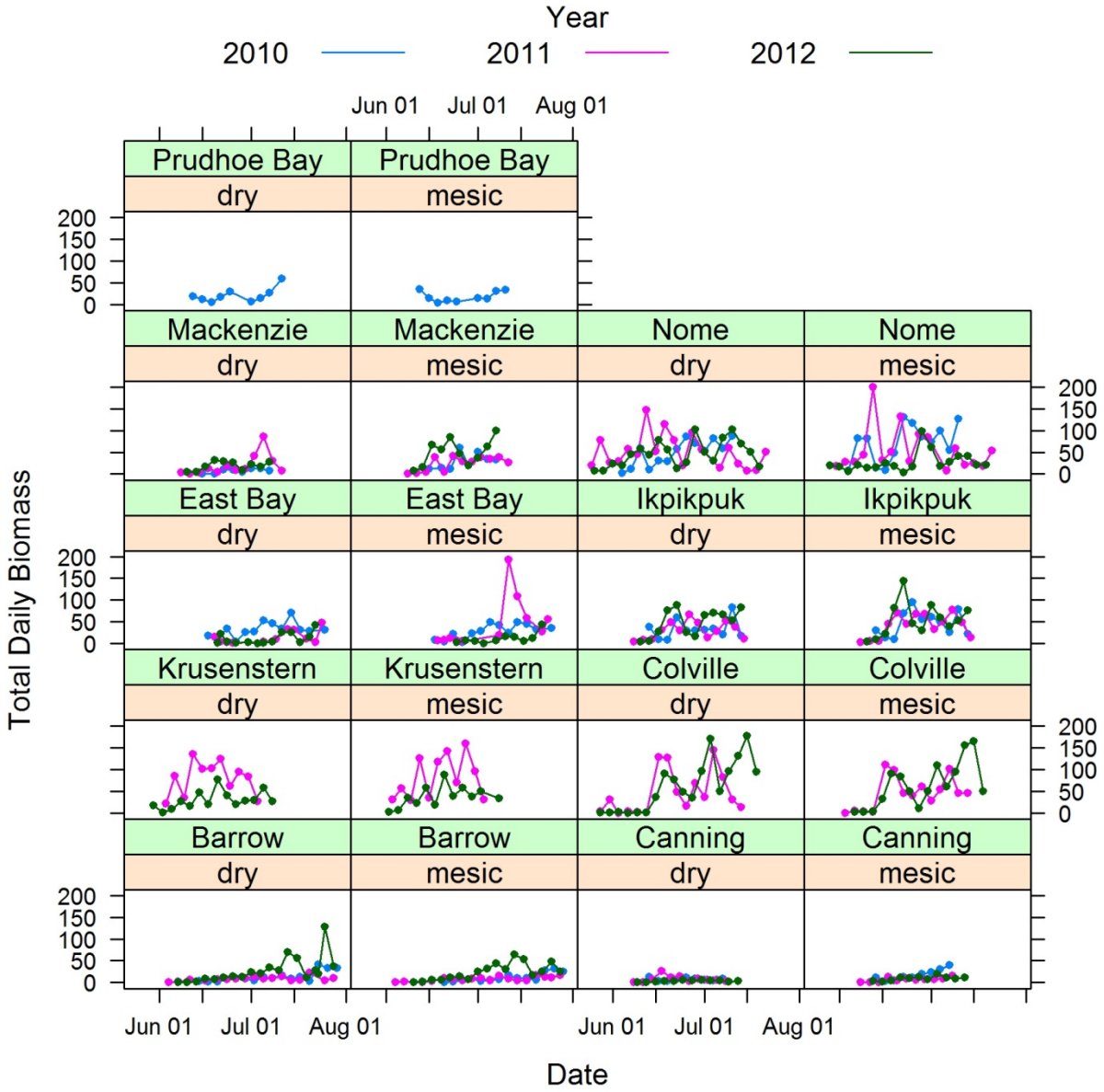


Figure 3. Daily invertebrate biomass per trap (mg) for each ASDN camp, habitat type, and year.

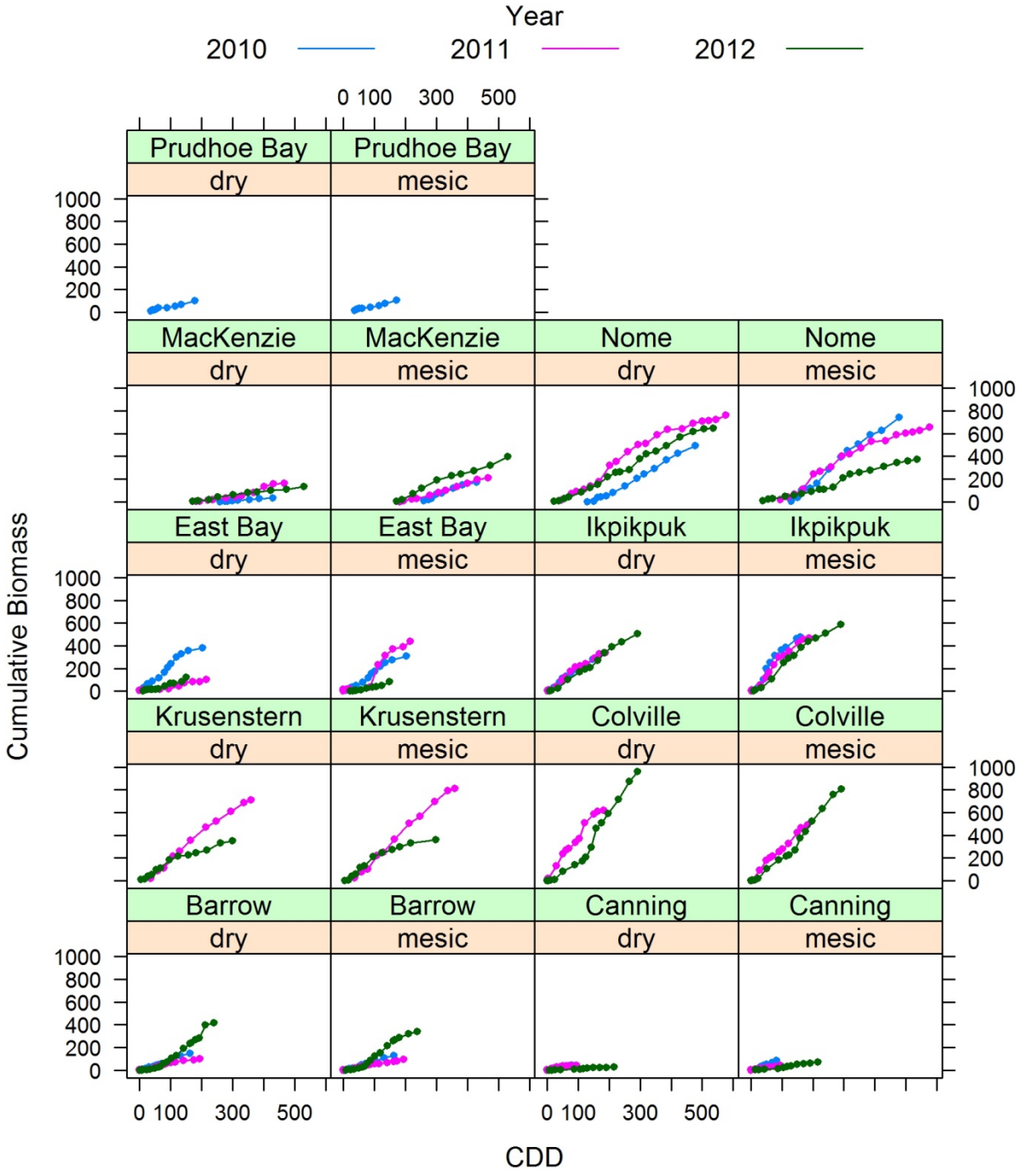


Figure 4. Cumulative biomass (mg/trap/day) versus cumulative degree-days (˚ C) at all nine ASDN camps by year and habitat.

Invertebrate biomass models

At many of the camps, there was multicollinearity between temperature, relative humidity, and cumulative degree days. Temperature and relative humidity have an inverse relationship because warmer air can hold more moisture causing relative humidity to decrease at higher temperatures when no moisture is added to the air. Temperature and CDD increased together as temperatures warmed over the sampling season, which ended in July. We decided to remove relative humidity first to attempt to address problems with multicollinearity because previous research has shown the importance of accumulated and daily temperature for predicting invertebrate activity, while the direction and effect size of humidity has been variable. At Canning River, Colville River, and Ikpikpuk; relative humidity was removed and variance inflation factors for the remaining variables were all below five. At Cape Krusenstern and Prudhoe Bay, removing relative humidity did not fix problems with multicollinearity, so CDD and its square term were removed (Table 7).

The final confidence sets across the nine camps included two to six models after removal of models with uninformative parameters (Appendix D). Most of the camps had substantial model uncertainty as only Cape Krusenstern and Nome had top models with model weights > 0.7.

Temperature and CDD had the highest relative variable importance across the camps (Table 7). Temperature's importance was 1.00 at six camps, but was much lower at Canning River, Barrow, and Prudhoe Bay (< 0.6). A one-unit change in any of the predictors can be interpreted as a percentage change in the response since biomass was log-transformed prior to modeling (Gelman and Hill 2007). At Colville River, Cape Krusenstern, East Bay, Ikpikpuk, Mackenzie Delta, and Nome; temperature had a positive effect on invertebrate biomass: a 1˚ C increase in temperature was associated with a 17-44% increase in biomass (Figure 5). Among these camps, temperature had the strongest effect at Nome and East Bay. The 85% confidence intervals for temperature at Canning River and Prudhoe Bay included zero, indicating uncertainty in its effect on invertebrate biomass (Figure 5). These were two of the coldest camps, with daily temperatures rarely above 10˚ C (Appendix B).

CDD's importance was ≥ 0.89 for six camps and 0.75 at East Bay (Table 7). At the Nome camp, the squared term for CDD was not in the final confidence set so the CDD parameter estimate can be interpreted on its own. CDD had a weak negative effect on invertebrate biomass at Nome; a 10˚ C increase in CDD was associated with a 3% decrease in biomass (Figure 5). For camps with confidence sets that included both CDD and CDD^2, the parameter estimate for CDD indicates the rate of change in invertebrate biomass at mean CDD and the parameter estimate for CDD^2 indicates the shape of the curve. The parameter estimate was negative for CDD^2 at all camps indicating a concave relationship between CDD and invertebrate biomass. CDD^2 was highly important at Ikpikpuk, Barrow, and Mackenzie Delta, indicating that the pool of invertebrates decreased over the sampling season (Figure 5).

Habitat and the remaining weather variables (relative humidity, precipitation, and wind) were all less important predictors for modeling invertebrate biomass (Table 7). The mesic habitat had much higher invertebrate biomass at the Canning River and Mackenzie Delta camps (53% and 105%, respectively, Figure 5). Relative humidity (which was only included in the analyses for four camps due to problems with multicollinearity and missing data) was negatively associated with invertebrate biomass at Prudhoe Bay and Barrow, positively associated with biomass at Nome, and inconclusive at Mackenzie Delta (Figure 5).

Precipitation had relative variable importance ≥ 0.89 at Colville River, Ikpikpuk, and Nome (Table 7). At these three camps, precipitation was negatively correlated with invertebrate biomass, although the effect sizes were highly variable with biomass decreasing from 5% (Nome) to 29% (Colville River) in association with a 1-mm increase in precipitation (Figure 5).

Relative variable importance for wind was greatest (≥ 0.81) at Barrow, Canning River, Colville River, and Nome (Table 7). A 1-km/hr increase was associated with a 6-7% decrease in invertebrate biomass at Barrow, Canning River, and Colville River (Figure 5). Wind was also negatively associated with biomass at Ikpikpuk and Cape Krusenstern, although the confidence intervals overlapped zero. At Nome, by contrast, a 1-km/hr increase in wind speed was associated with a 5% increase in biomass.

The conditional R^2 for the models in each camp's confidence set ranged from 0.55 to 0.85 (Appendix D) with models for the Barrow, Colville, Ikpikpuk, and Mackenzie Delta camps explaining the most variance in the data (conditional $R^2 \geq 0.70$). There were no differences between years (random effect) not explained by the weather variables (fixed effects) at the Barrow, Ikpikpuk, and Mackenzie Delta camps (marginal and conditional R^2 were the same). The accuracy of model predictions, as measured by the coefficient of determination between fitted and observed values, were greatest overall at the Barrow camp ($r^2 \geq 0.76$), but were also relatively high for Colville River in 2012 and Ikpikpuk in 2011 (Table 8). The Mackenzie Delta and Nome camps also had relatively high prediction accuracy ($r^2 > 0.7$) for one or more years. See figure 6-14 for plots of observed vs. fitted values.

Table 7. Relative variable importance by ASDN camp for each predictor.

	Predictors						
Camp	CDD	CDD^2	Habitat	Temperature	Humidity[1]	Wind	Precipitation
Barrow	1.00	1.00	0.26	0.34	0.91	1.00	0.61
Canning River	0.89	0.80	0.96	0.59	NA	0.97	0.29
Cape Krusenstern	NA	NA	0.29	1.00	NA	0.72	0.31
Colville River	1.00	0.71	0.24	1.00	NA	1.00	0.89
East Bay	0.75	0.64	0.50	1.00	NA	0.25	0.51
Ikpikpuk	0.99	0.99	0.70	1.00	NA	0.71	0.99
Mackenzie Delta	0.90	0.86	1.00	1.00	0.61	0.34	0.22
Nome	0.99	0.26	0.23	1.00	1.00	0.81	1.00
Prudhoe Bay	NA	NA	0.12	0.25	0.87	0.54	0.40

NA – Predictor(s) not included in analysis due to multicollinearity, except for relative humidity at East Bay and Cape Krusenstern.

[1] Relative humidity not included in the model for Cape Krusenstern and East Bay camps because it was not available at the Kotzebue Airport and was missing for 2012, respectively.

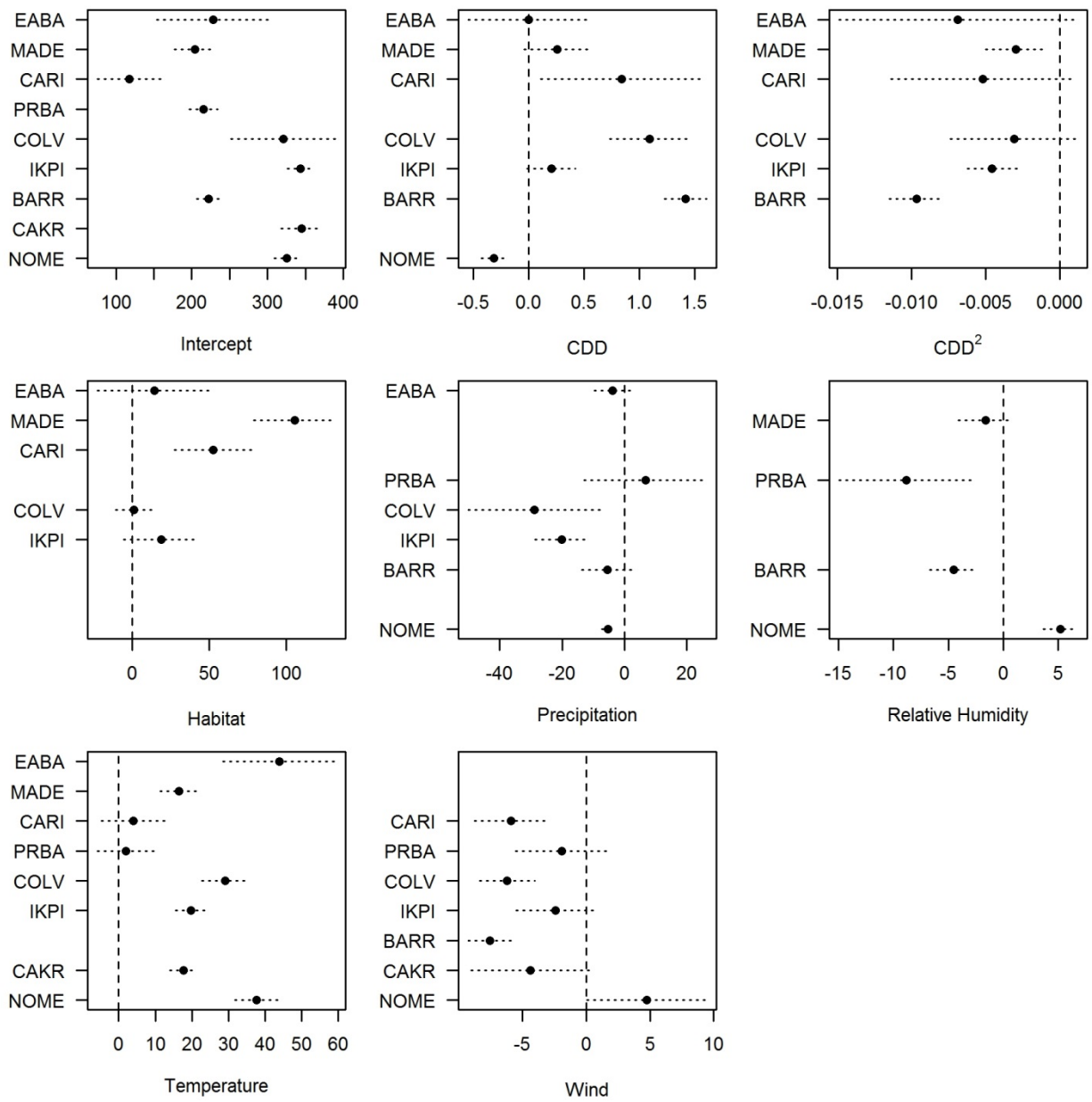


Figure 5. Parameter estimates and 85% confidence intervals for all ASDN camps. Camps are ordered from east to west.

Table 8. Coefficient of determination (r^2) of observed versus fitted values for all ASDN camps and years.

Camp	2010	2011	2012
Barrow	0.84	0.76	0.80
Canning River	0.52	0.41	0.69
Colville River	NA	0.70	0.87
East Bay	0.32	0.57	0.60
Ikpikpuk	0.45	0.88	0.48
Cape Krusenstern	NA	0.73	0.45
Mackenzie Delta	0.70	0.76	0.75
Nome	0.73	0.76	0.49
Prudhoe Bay	0.70	NA	NA

NA – data not collected for that year.

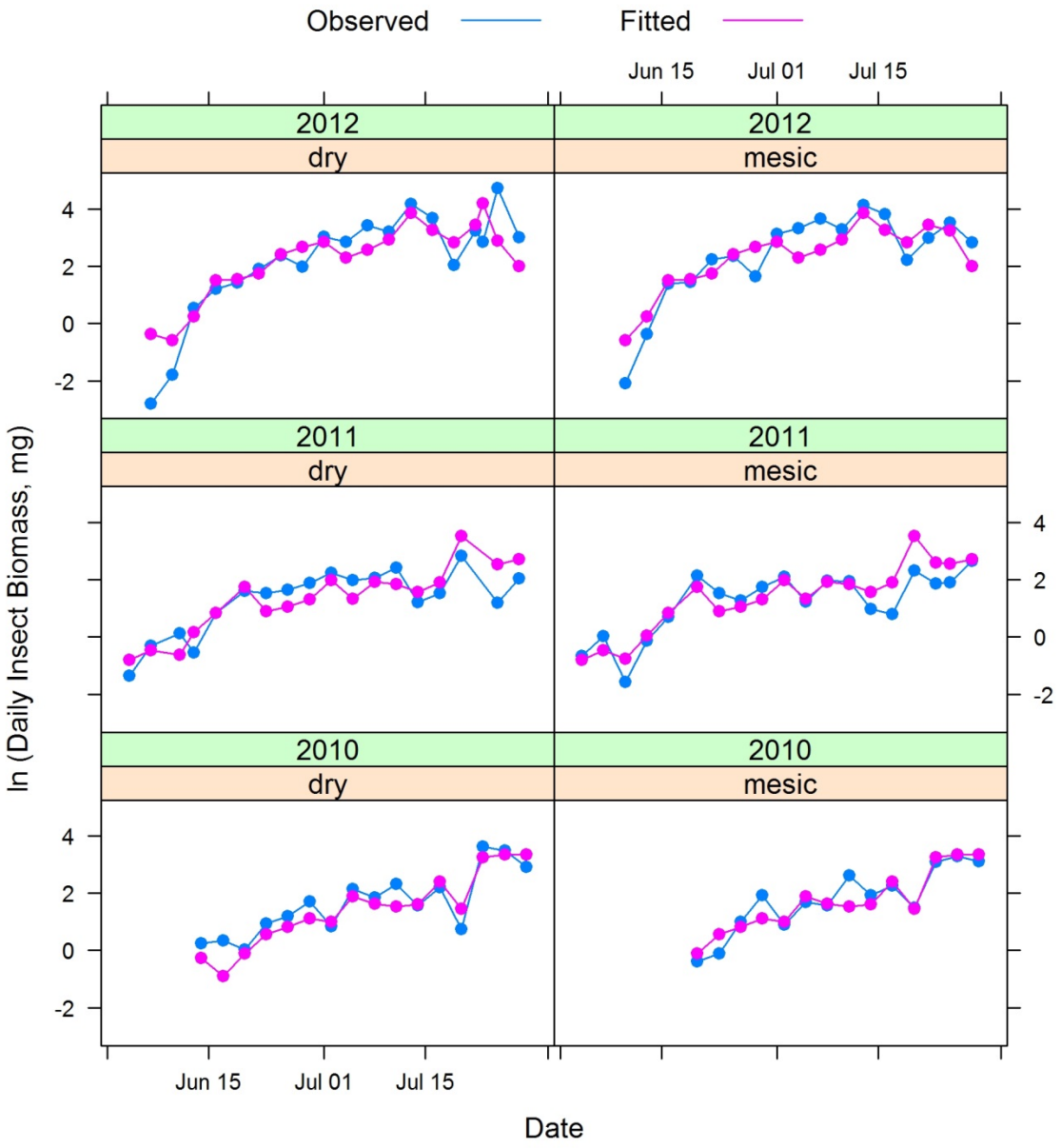


Figure 6. Barrow observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

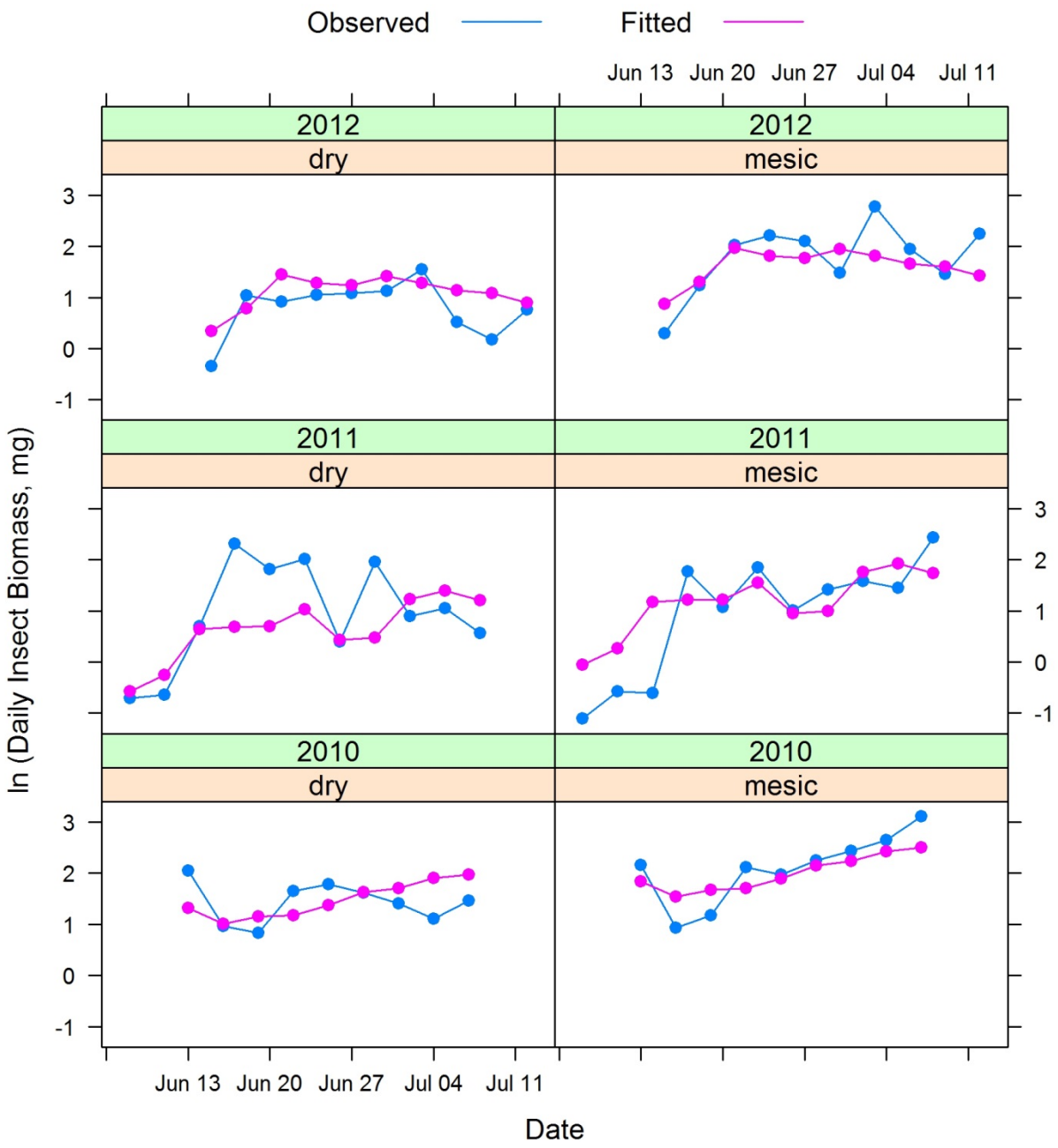


Figure 7. Canning River observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

Figure 8. Cape Krusenstern observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

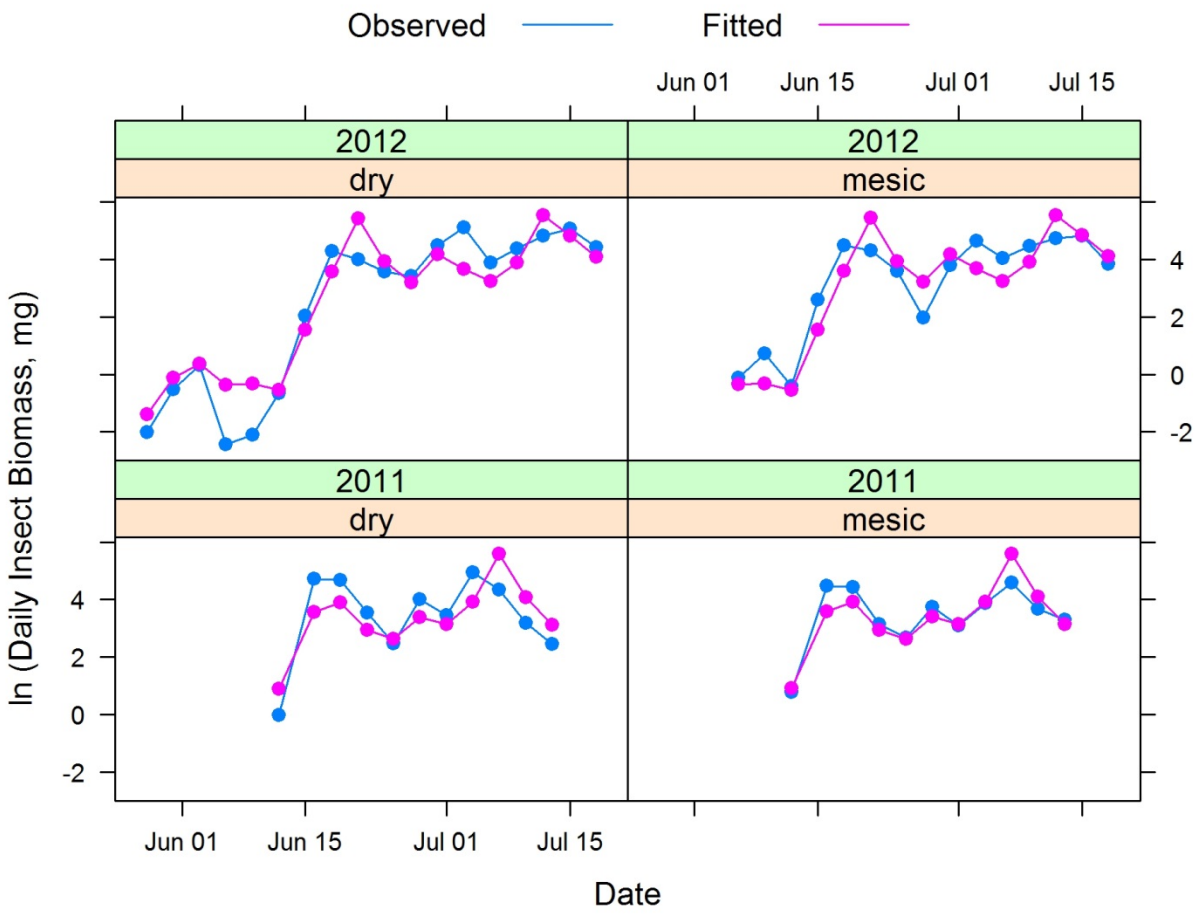


Figure 9. Colville River observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

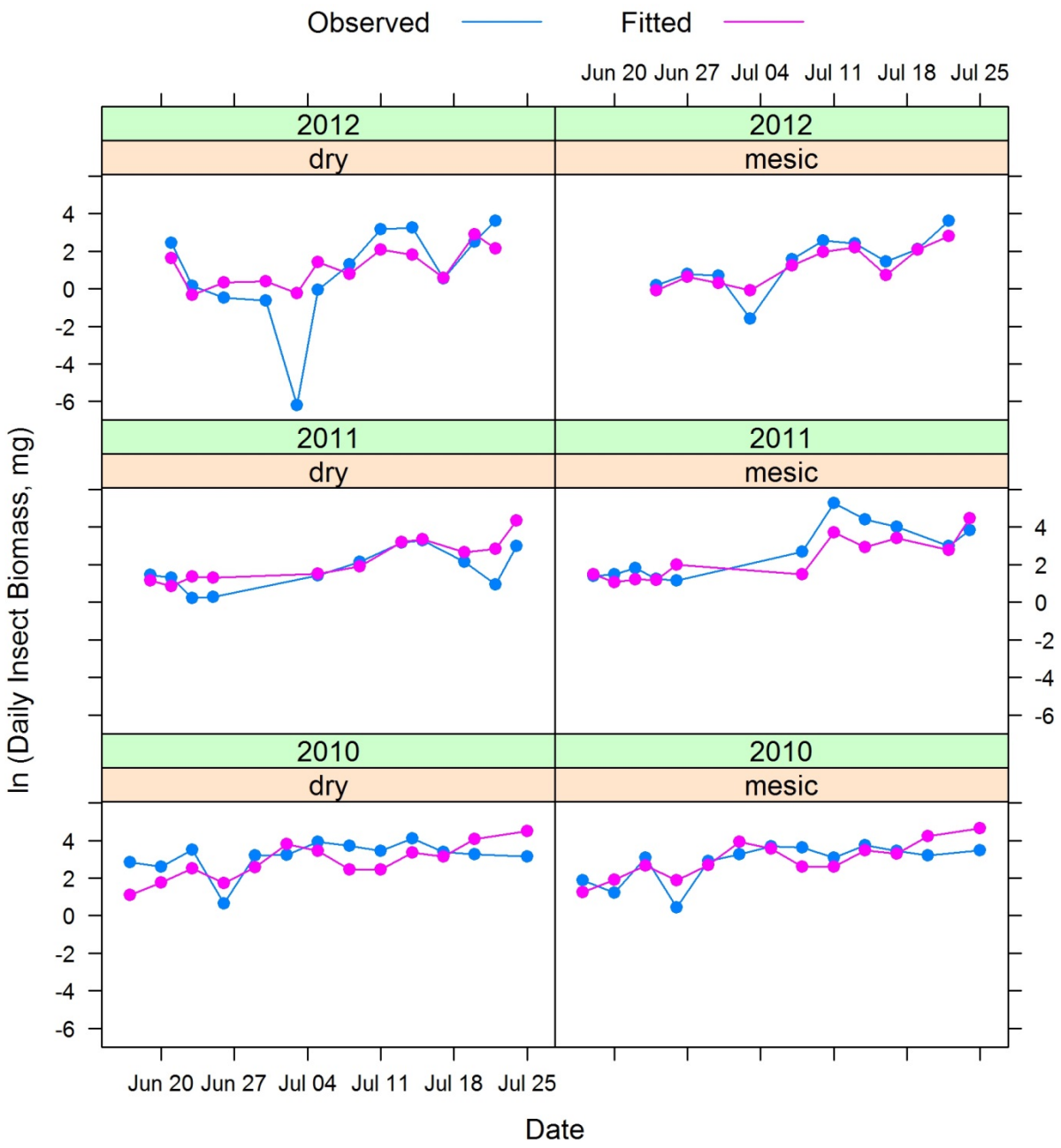


Figure 10. East Bay observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

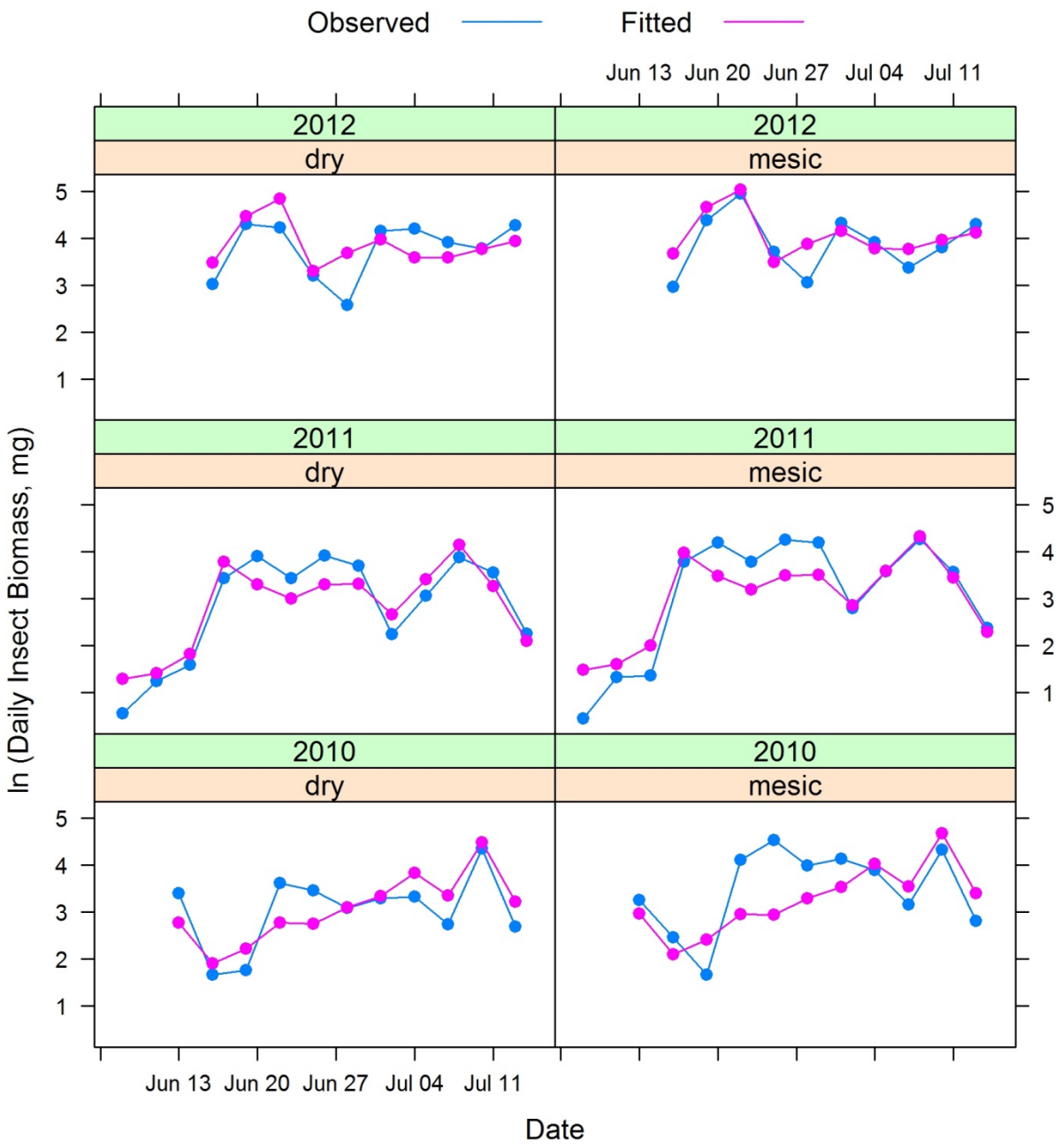


Figure 11. Ikpikpuk observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

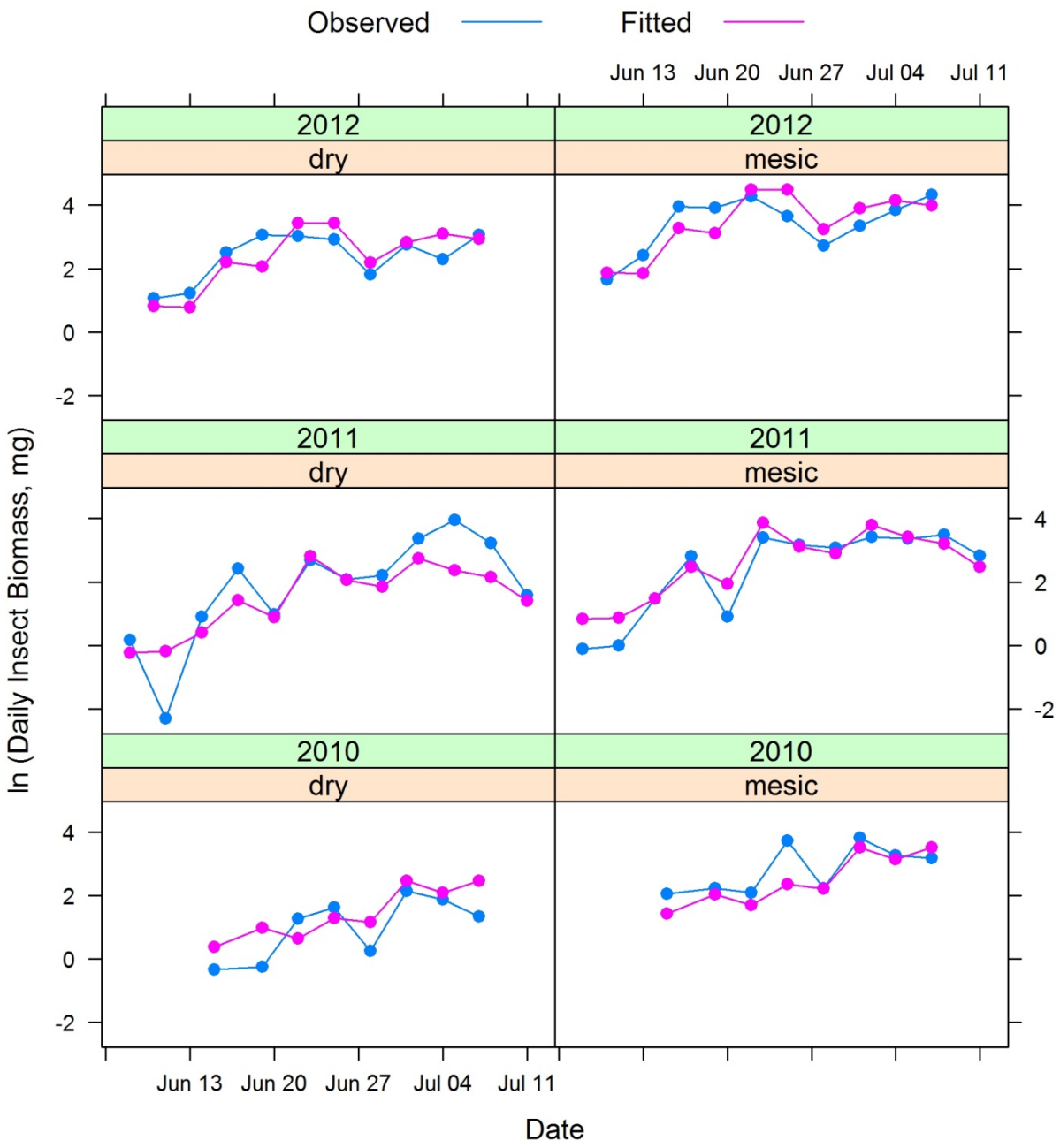


Figure 12. Mackenzie Delta observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

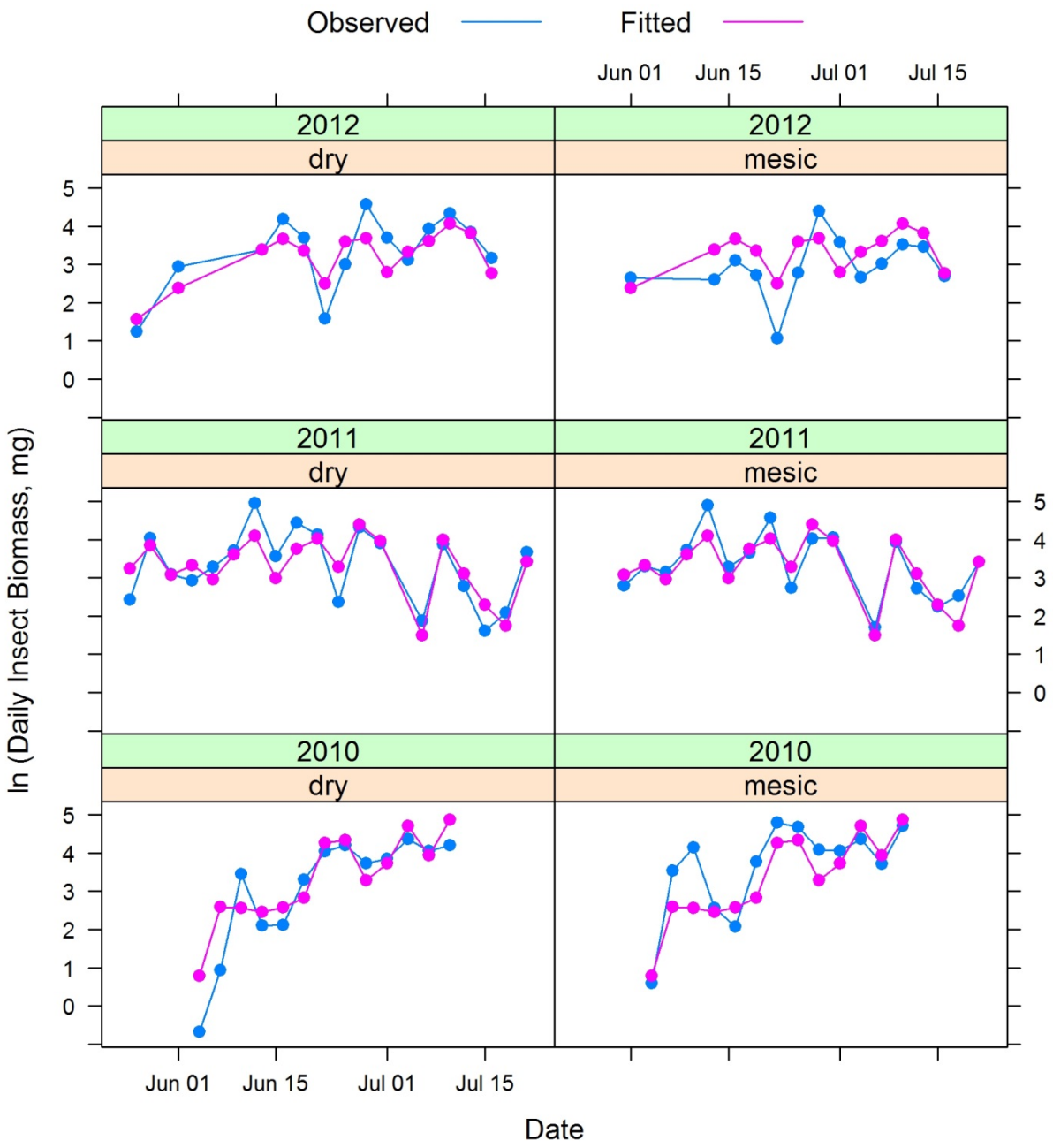


Figure 13. Nome observed and fitted daily invertebrate biomass in mg on log scale across habitats and years.

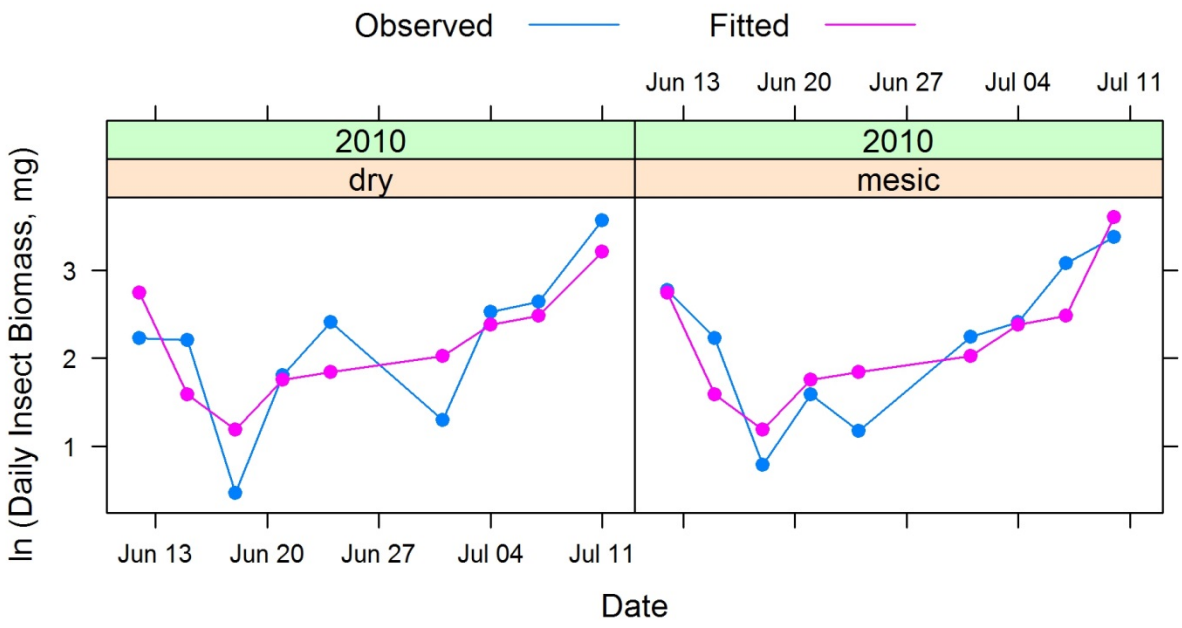


Figure 14. Prudhoe Bay observed and fitted daily invertebrate biomass in mg on log scale across habitats for 2010.

Discussion

The wide range in total invertebrate biomass across the nine camps is not easily explained. Colville River had the largest cumulative biomass even though it is cooler than many of the other camps (e.g., Nome). It is likely that unmeasured local habitat factors contributed to differences among camps, such as availability of nearby aquatic habitats, soil moisture, depth of the insulating layer (e.g., vegetation or snow), and nutrient availability.

Dipteran taxa composed the majority of biomass across all sites. The higher flies (Brachycera), midges (Chironomidae), crane flies (Tipulidae), and fungus gnats (Mycetophilidae) comprised roughly one third of the total invert biomass across sites. The dominant fly taxa generally were dominant in a few of the sites and less common elsewhere. For example, Brachycera were dominant at Barrow, Colville, and MacKenzie; while Mycetophilidae were dominant at Barrow, Nome, and Krusenstern. The dominance of dipteran taxa observed in this study (5 of the 11 dominant taxa) has been well documented in previous studies from northern latitudes. In Svalbard, for example, Diptera represent over half of the total insect species (Ávila-Jiménez et al. 2010) and flies also represent the most important guild of Arctic pollinators (Elberling and Olesen 1999, Tiusanen et al. 2016). Within Alaska, Diptera is the dominant insect order in rivers and streams (Oswood 1989).

Several of the other dominant taxa were large-bodied (mean individual biomass > 4 mg), which included Carabidae, Hymenoptera (bees and wasps), Trichoptera, and Lepidoptera. Large Hymenoptera and Trichoptera comprised a large amount of biomass at Colville, but were minor at all other sites. Carabidae and Lepidoptera were particularly dominant at the two Bering Sea sites, Nome and Krusenstern, and less common elsewhere. Overall there was not a clear pattern in the geographic distributions of the dominant taxa. None of the taxa appeared to be responding to the longitudinal gradient spanned by the nine camps. Half of the taxa (24) were indicators for one of the camps, which is surprising given the coarse taxonomic resolution of the dataset. The Colville camp was most distinctive with nine indicator taxa. This distinctiveness of this camp is possibly due to a high diversity of habitats, especially diverse substrates and flowing water, as both Trichoptera and Plecoptera include genera that require lotic habitats for larval development.

For all of the camps, there was model uncertainty, indicating a lack of evidence for a single model of daily invertebrate activity at any of the ASDN camps. The relative variable importance values showed the importance of CDD and temperature at most of the camps, but no predictor was highly important across all camps. Other studies that modeled invertebrate biomass at the family level have reported differences in the direction and effect size of both seasonal and daily weather predictors on activity between taxonomic groups (Høye and Forchhammer 2008b, Bolduc et al. 2013). The inclusion of up to 48 taxa in our invertebrate biomass models may be one source of the uncertainty in our models of invertebrate activity at each of the camps.

The effects of seasonal and weather predictors on invertebrate activity at the nine camps generally matched earlier findings. Several studies have found that date or cumulative temperature explained a large proportion of the variation in seasonal timing of insect emergence (Høye and Forchhammer 2008b, Bolduc et al. 2013). Models of insect abundance or biomass typically have a unimodal relationship over the summer, although this is complicated by the life histories of individual taxa and the taxonomic resolution of the response (Bolduc et al. 2013). We found that, at six camps, total invertebrate biomass increased over the summer before decreasing again. At the Nome camp, by contrast, biomass decreased slowly over the sampling season. Possibly, the dominant taxa at the Nome camp emerged directly after snow melt causing activity levels to decrease over the summer (Danks and Oliver 1972).

Temperature had a strong positive association with invertebrate biomass, except at three of the coldest camps. This positive association may be partly explained by the temperature cues used by many taxa, such as Chironomidae, for adult emergence (Danks 1999). Additionally, insects have minimum temperature thresholds for initiating flight (Taylor 1963).

Wind was negatively associated with invertebrate biomass at the majority of camps. We found little published information on wind thresholds, although oestrid flies, which are a nuisance to caribou, decrease flight at wind speeds of 6 m/s (~22 km/hr) (Weladji et al. 2003). Conversely, wind was positively associated with biomass at the Nome camp. Wind speeds there were generally below 20 km/hr, which may be below thresholds that limit flight behavior and air movement should increase the interception rate for weaker flying taxa.

Precipitation, relative humidity, and habitat were not important predictors of invertebrate biomass at the majority of camps (variable importance < 0.8). The higher biomass in the mesic habitats at two camps is consistent with other studies that have reported higher biomass at wet versus dry habitats (Tulp and Schekkerman 2008, Bolduc et al. 2013). Precipitation was negatively associated with invertebrate biomass at three camps, although the effect sizes varied widely. In other studies, precipitation had both positive and negative effects (Hodkinson et al. 1996, Tulp and Schekkerman 2008, Bolduc et al. 2013). The low amounts of precipitation in the Arctic and the variable thresholds that impede flight for each taxon probably make it a poor predictor of overall invertebrate biomass. Humidity was positively associated with biomass at Nome and negatively at Prudhoe Bay. We generally feel less confident in the results for the Prudhoe Bay camp as we only analyzed one year of data. Humidity had a positive effect on chironomid abundance in Svalbard (Hodkinson et al. 1996), while its effect varied by family across four sites in eastern Canada (Bolduc et al. 2013).

Snowmelt in northern Alaska has advanced by approximately two days per decade due to decreased snowfall and warmer spring temperatures (Stone et al. 2002, Grabowski et al. 2013). As our results show a positive relationship between accumulated temperature and invertebrate biomass, earlier snowmelt may result in earlier timing of invertebrate emergence and activity.

We plan to estimate the extent to which invertebrate phenology has advanced by using the models developed here to hindcast invertebrate biomass using historic weather data from nearby airports over the last 25 years.

Previous studies have concluded that the timing of invertebrate availability is advancing with climatic warming (Høye et al. 2007, Tulp and Schekkerman 2008), but they have focused on single research sites, leaving this phenomenon unquantified at broad spatial scales. Our results suggest that advances in spring snowmelt and warming temperatures are leading to changes in the timing of invertebrate availability at sites across Arctic Alaska and Canada, with potential implications for shorebirds and other consumers whose phenology is programmed to capitalize on brief periods of abundance characteristic of Arctic invertebrates.

Management Applications

The models developed in this study identify some of the environmental factors driving invertebrate biomass at sites across Arctic Alaska and Canada and can be used to predict biomass using weather data. Predicted invertebrate biomass may be a useful covariate in studies of Arctic animals like shorebirds or caribou, or it can be used to hindcast or forecast invertebrate activity to understand the effects of climate change. These models may also be useful to ASDN researchers for linking climatic conditions, shorebird phenology, and changes in food resources.

To estimate how climatic change over the last 25 years has affected invertebrate phenology across the ASDN camps, we will use the models to hindcast changes in the timing and duration of invertebrate availability, possibly incorporating biomass thresholds that can be linked to growth rates of chicks. If we are unable to find pertinent thresholds in the literature, we will use a threshold that allow for comparison across the camps (e.g., 50 mg/trap). Our expected responses include first day above a threshold, number of days above a threshold, and date of peak biomass; each regressed against year to assess trends. The hindcasting results will provide managers with a more accurate picture of how invertebrate phenology is changing in the Arctic, which can be used for management of other species dependent upon invertebrates.

Products

a. Publications, conference papers, and presentations: None at this time.
b. Education and outreach: None at this time.
c. Other products:
    a. Access database

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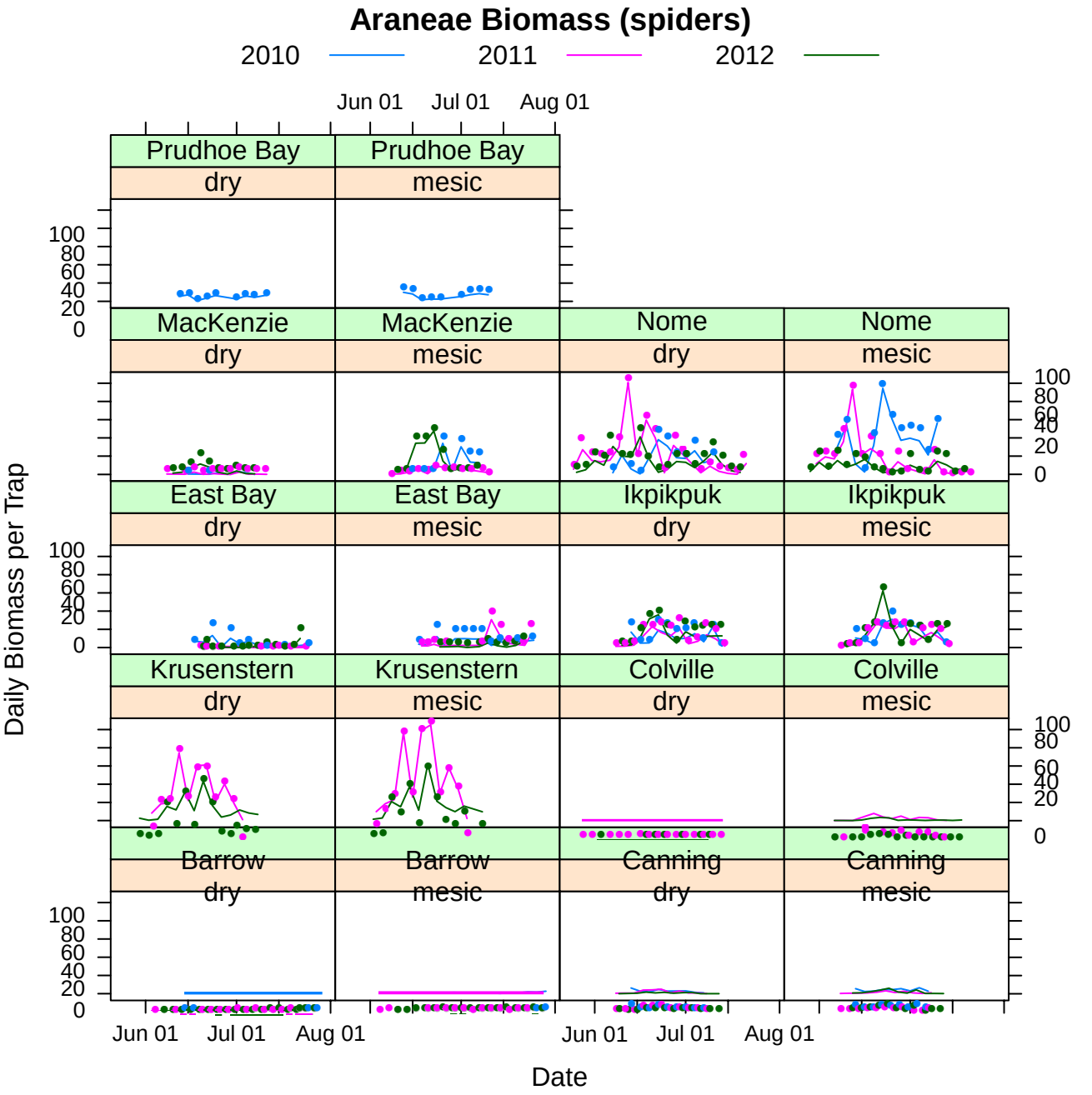
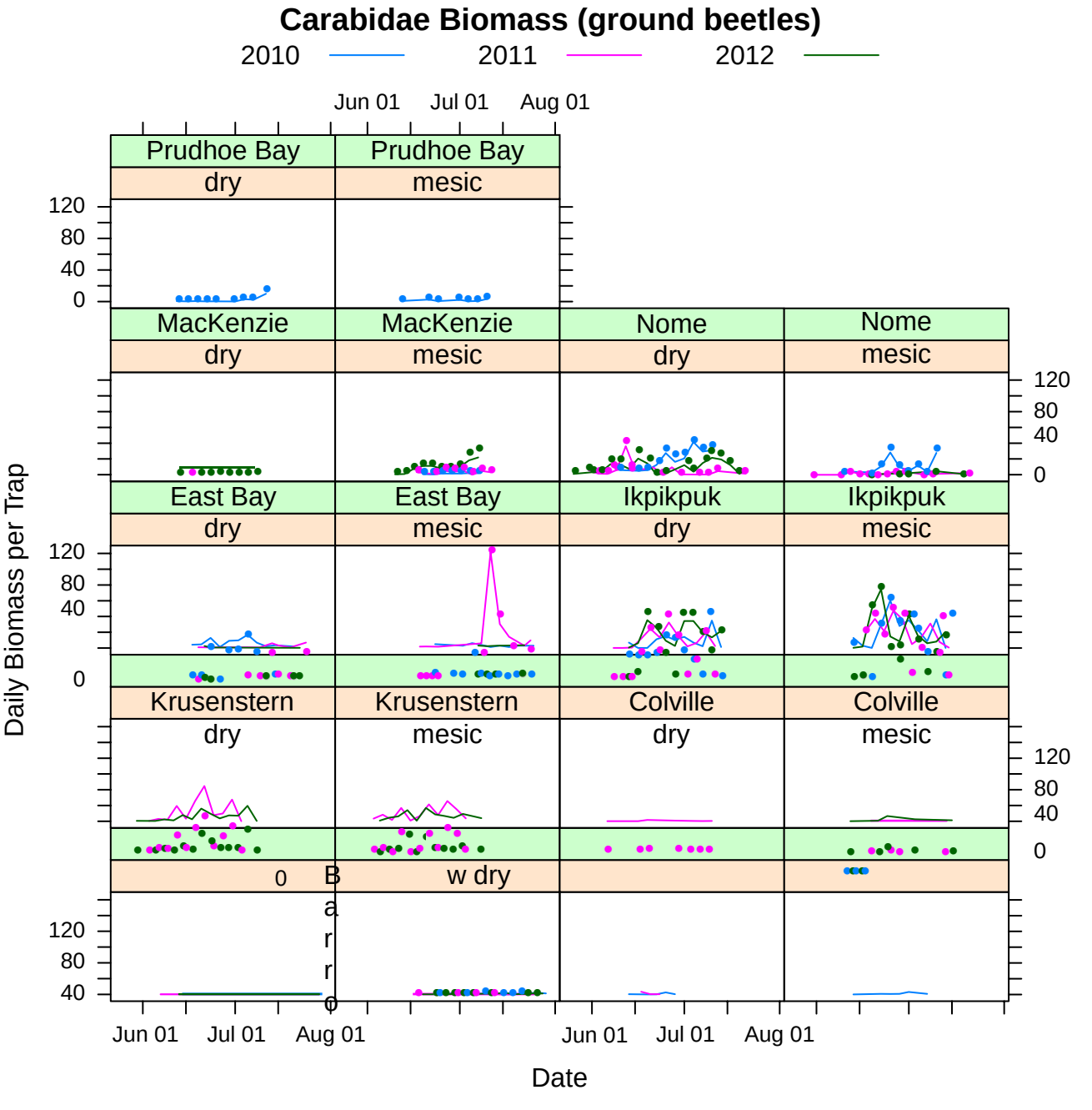
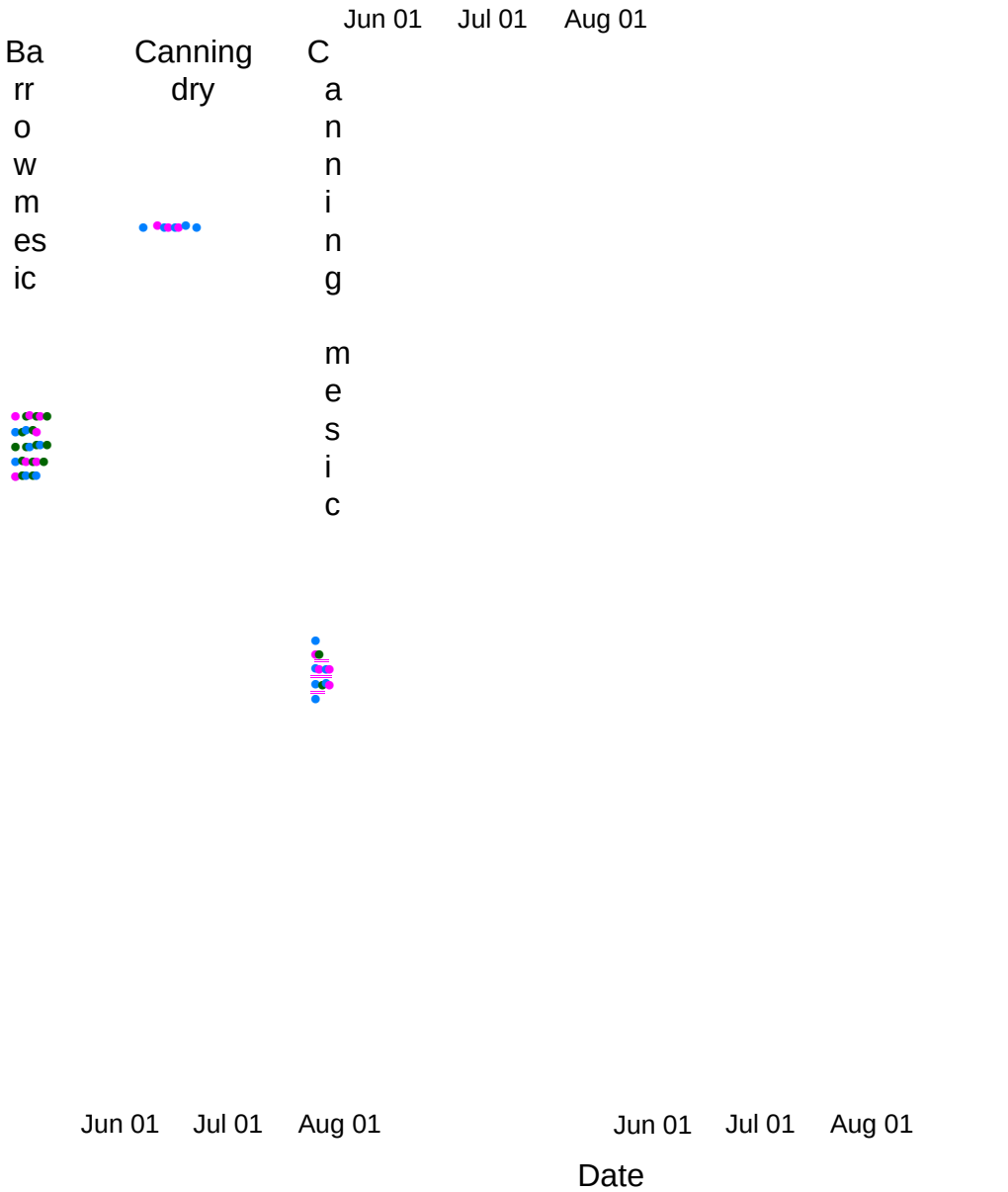
Appendix A

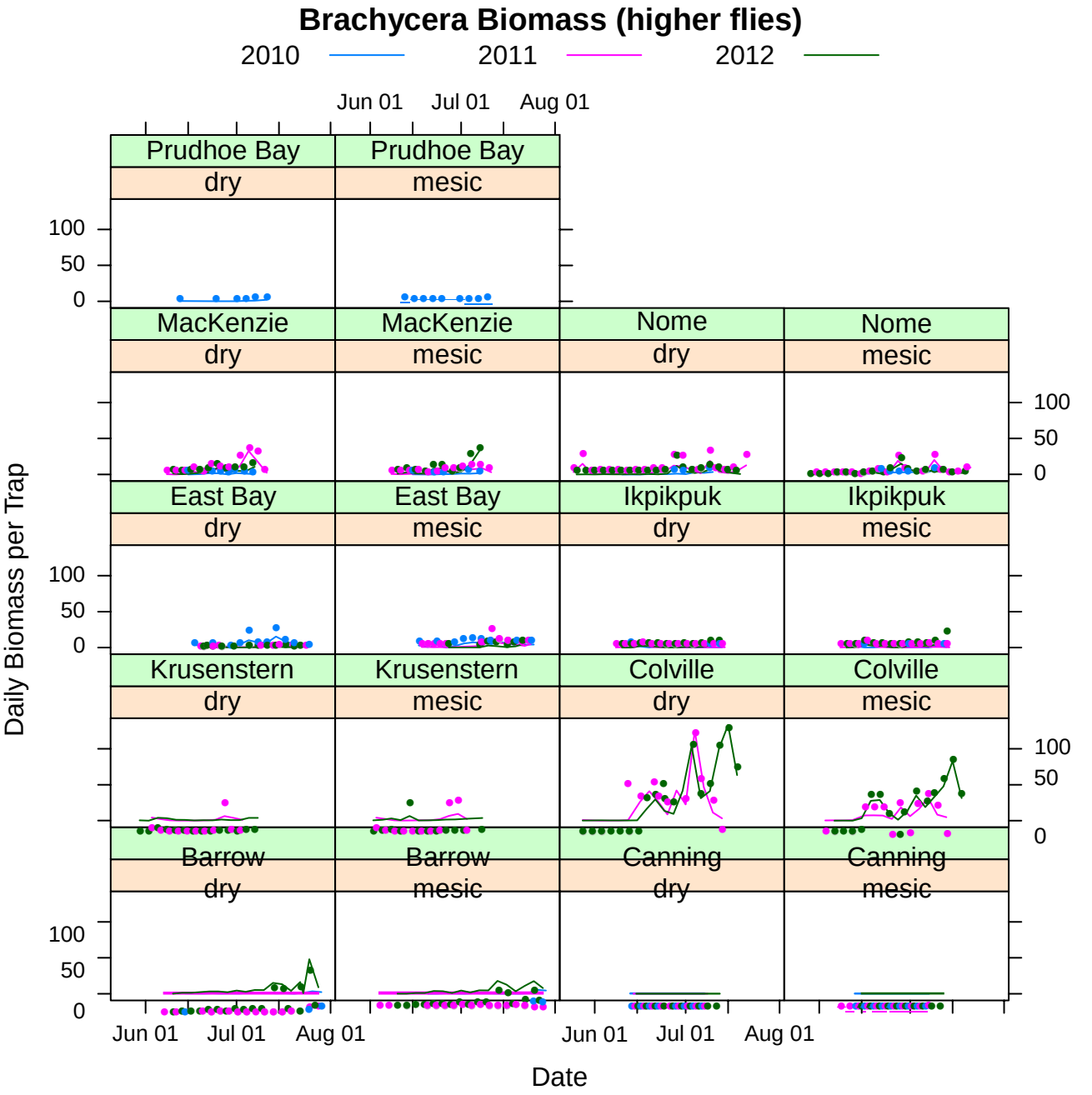

Araneae Biomass (spiders)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Jun 01
Jul 01
Aug 01
0
20
40
60
80
100
Daily Biomass per Trap
Date

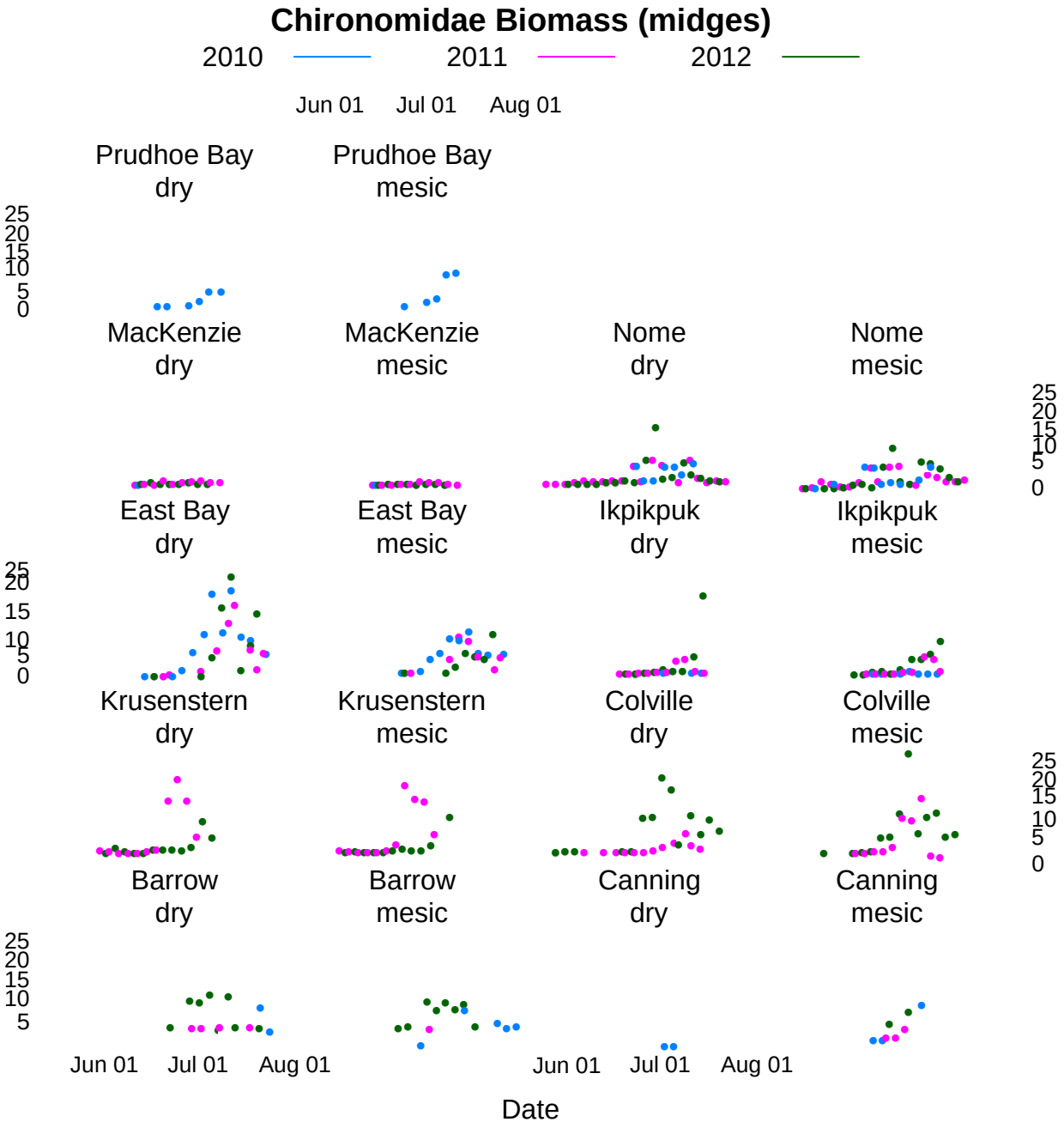

Carabidae Biomass (ground beetles)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow dry
Daily Biomass per Trap
Date
Jun 01
Jul 01
Aug 01
0
40
80
120

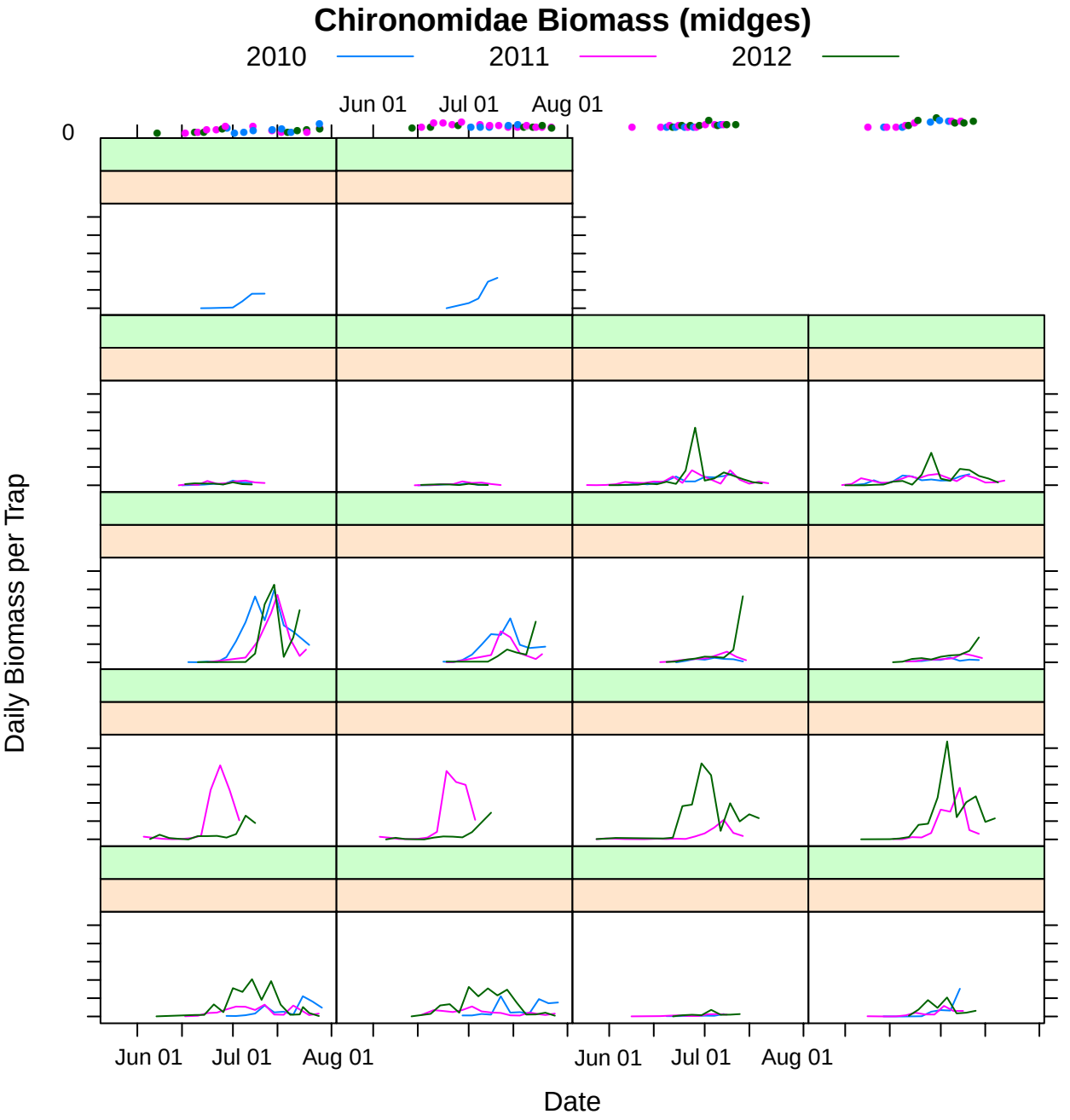
Carabidae Biomass (ground beetles)

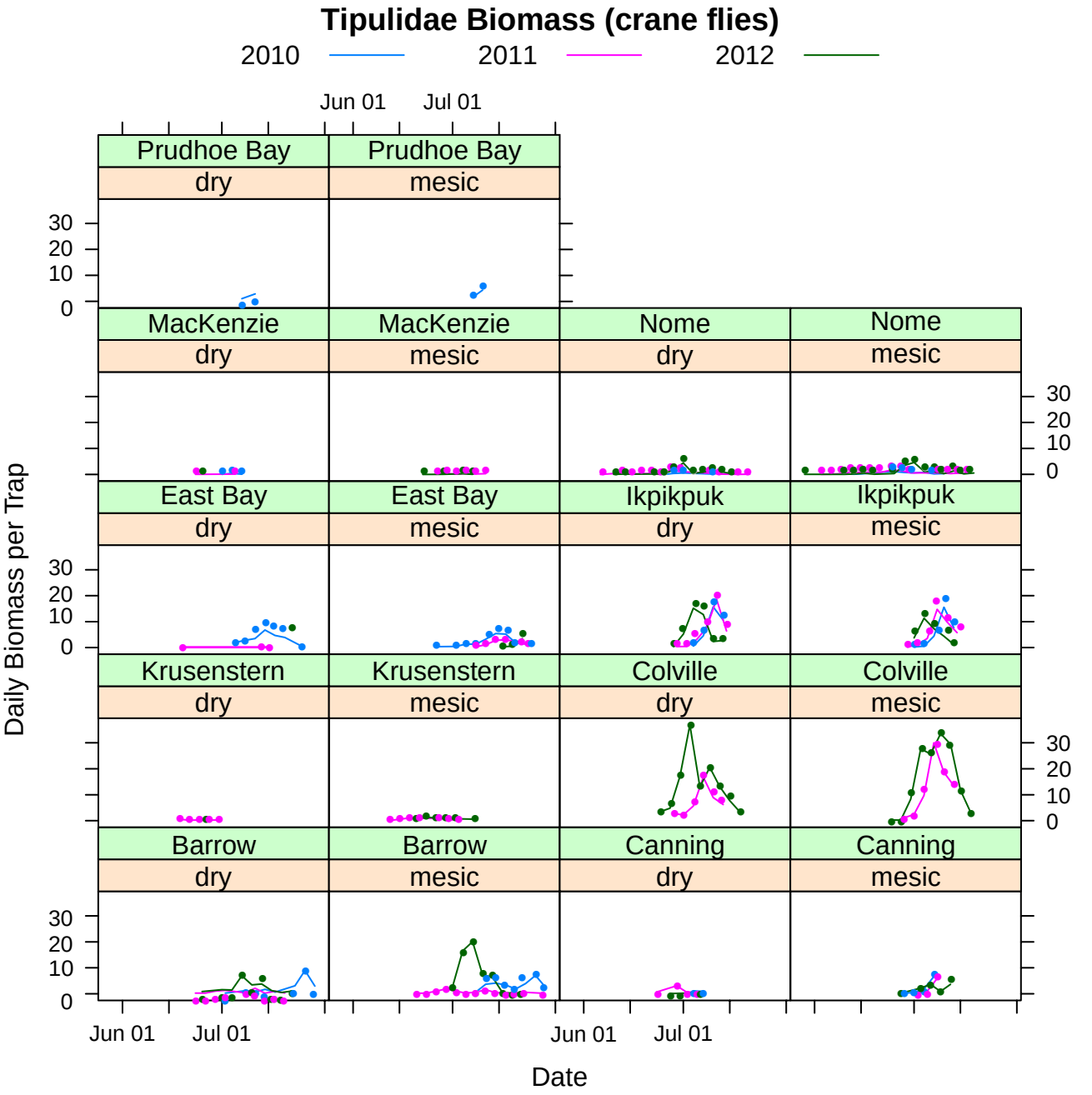
2010 2011 2012

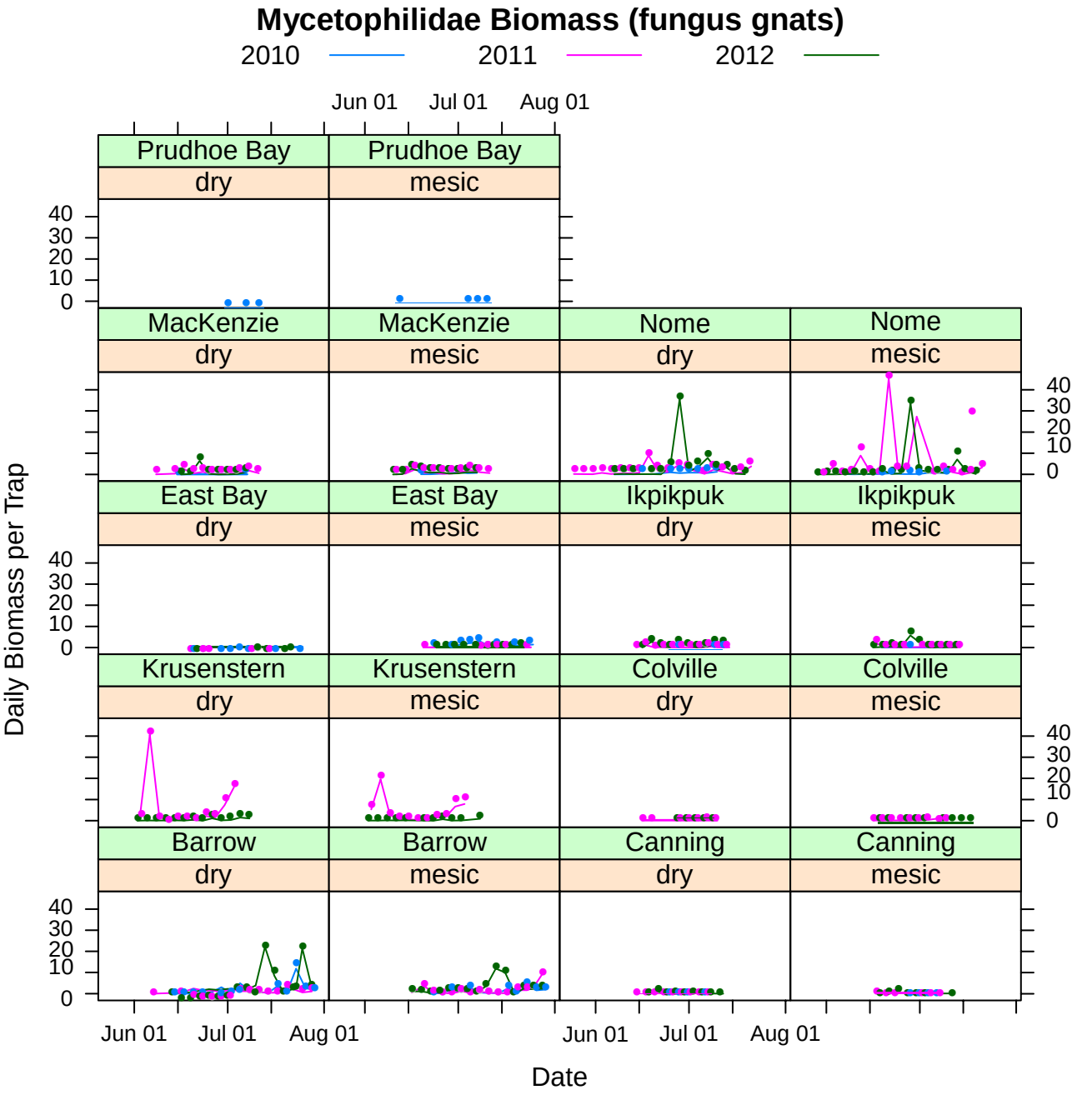


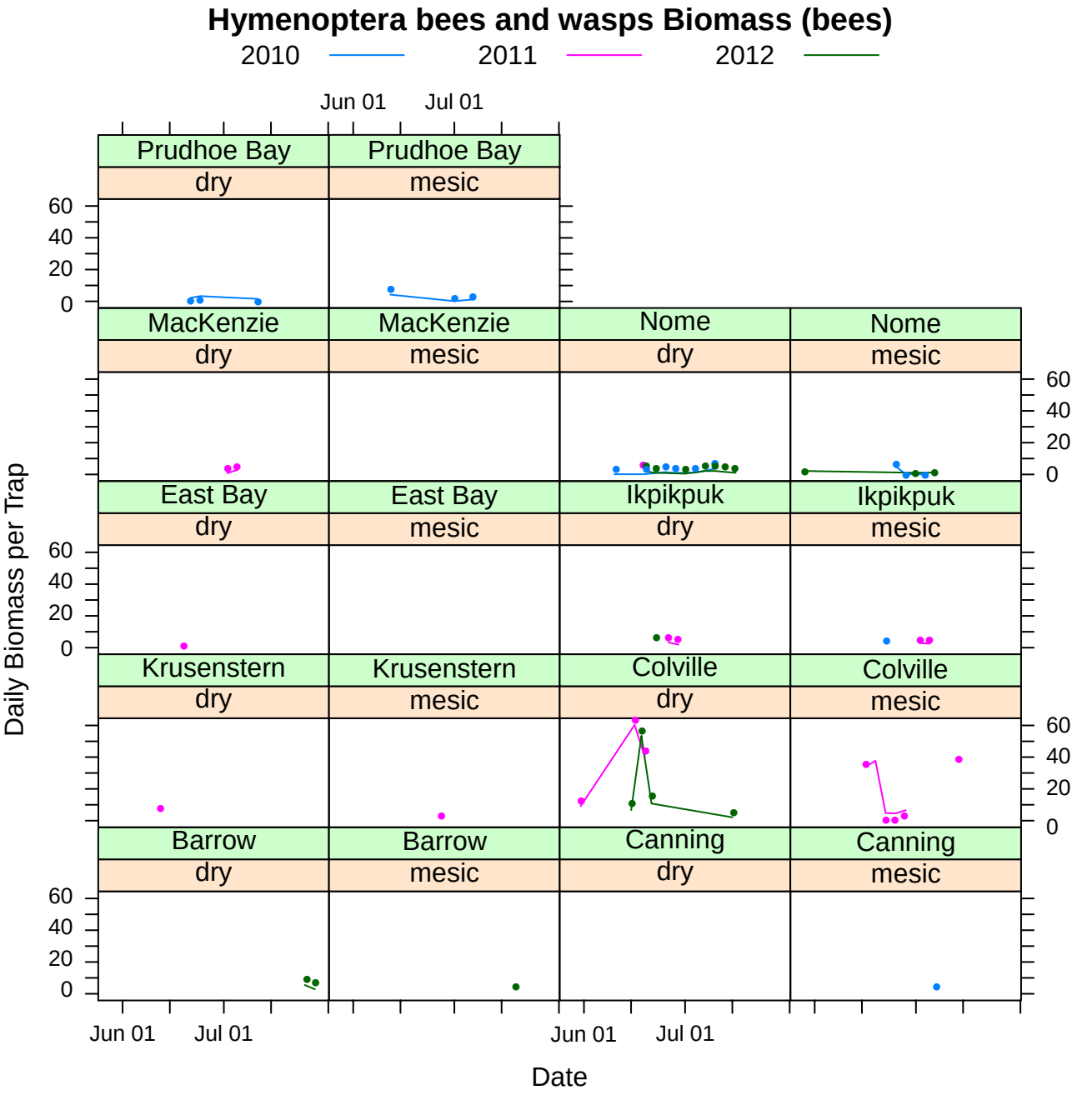

Brachycera Biomass (higher flies)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Jun 01
Jul 01
Aug 01
100
50
0
Daily Biomass per Trap
Date

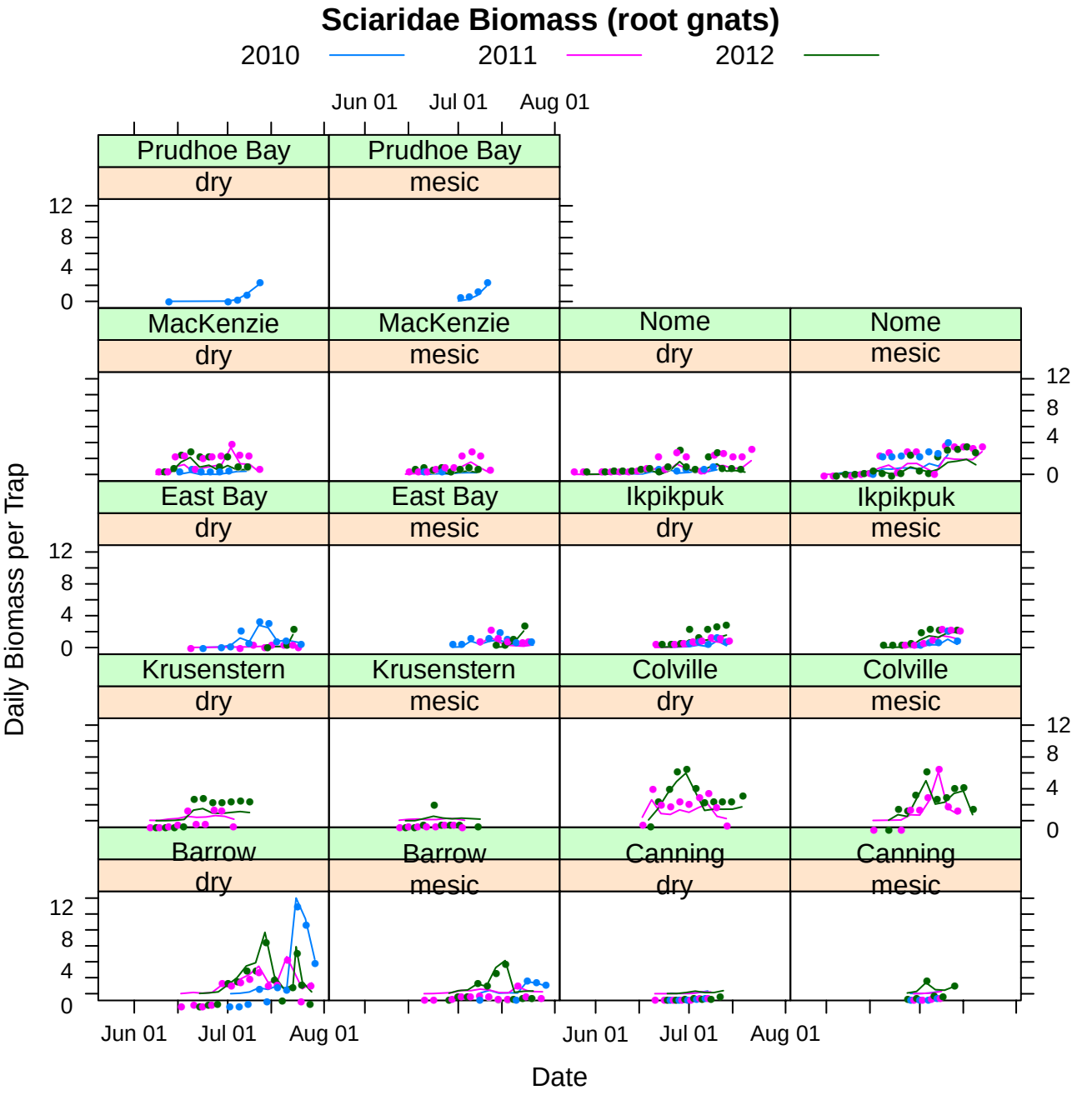

Chironomidae Biomass (midges)
2010
2011
2012
Jun 01
Jul 01
Aug 01
Prudhoe Bay dry
Prudhoe Bay mesic
MacKenzie dry
MacKenzie mesic
Nome dry
Nome mesic
East Bay dry
East Bay mesic
Ikpikpuk dry
Ikpikpuk mesic
Krusenstern dry
Krusenstern mesic
Colville dry
Colville mesic
Barrow dry
Barrow mesic
Canning dry
Canning mesic
0
5
10
15
20
25
Date

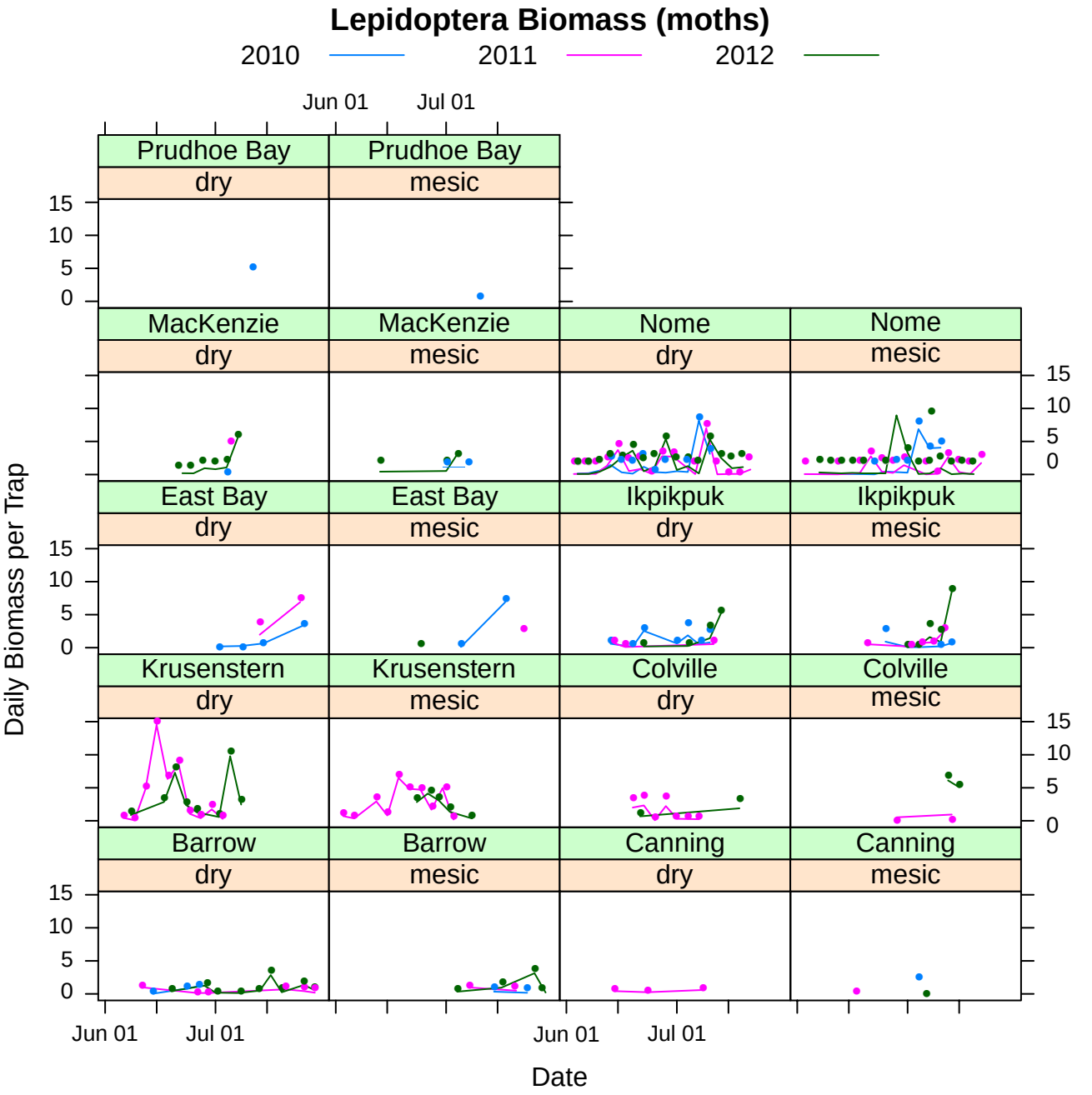

Chironomidae Biomass (midges)
2010
2011
2012
0
Jun 01
Jul 01
Aug 01
Daily Biomass per Trap
Date

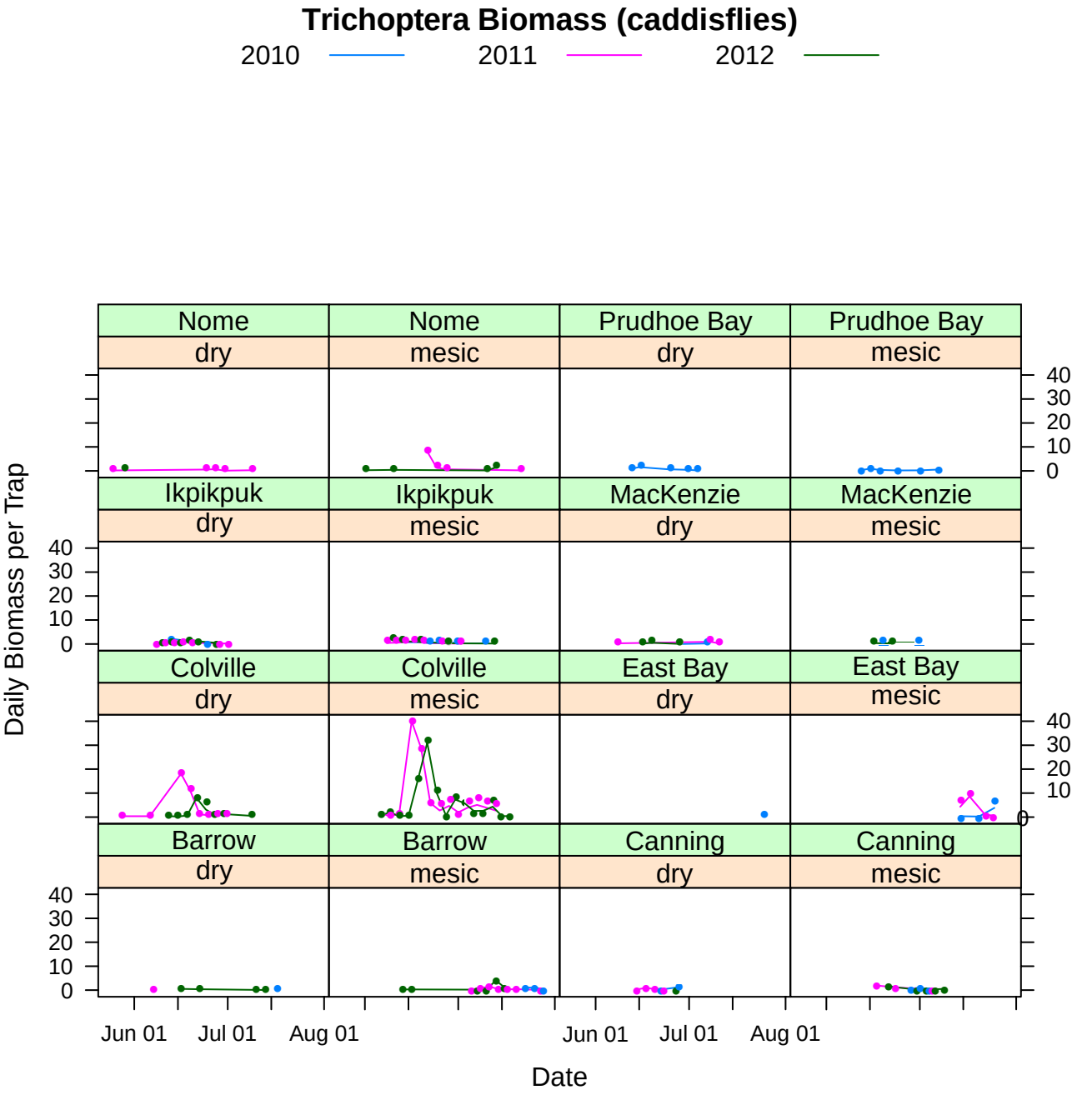

Tipulidae Biomass (crane flies)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Jun 01
Jul 01
0
10
20
30
Daily Biomass per Trap
Date

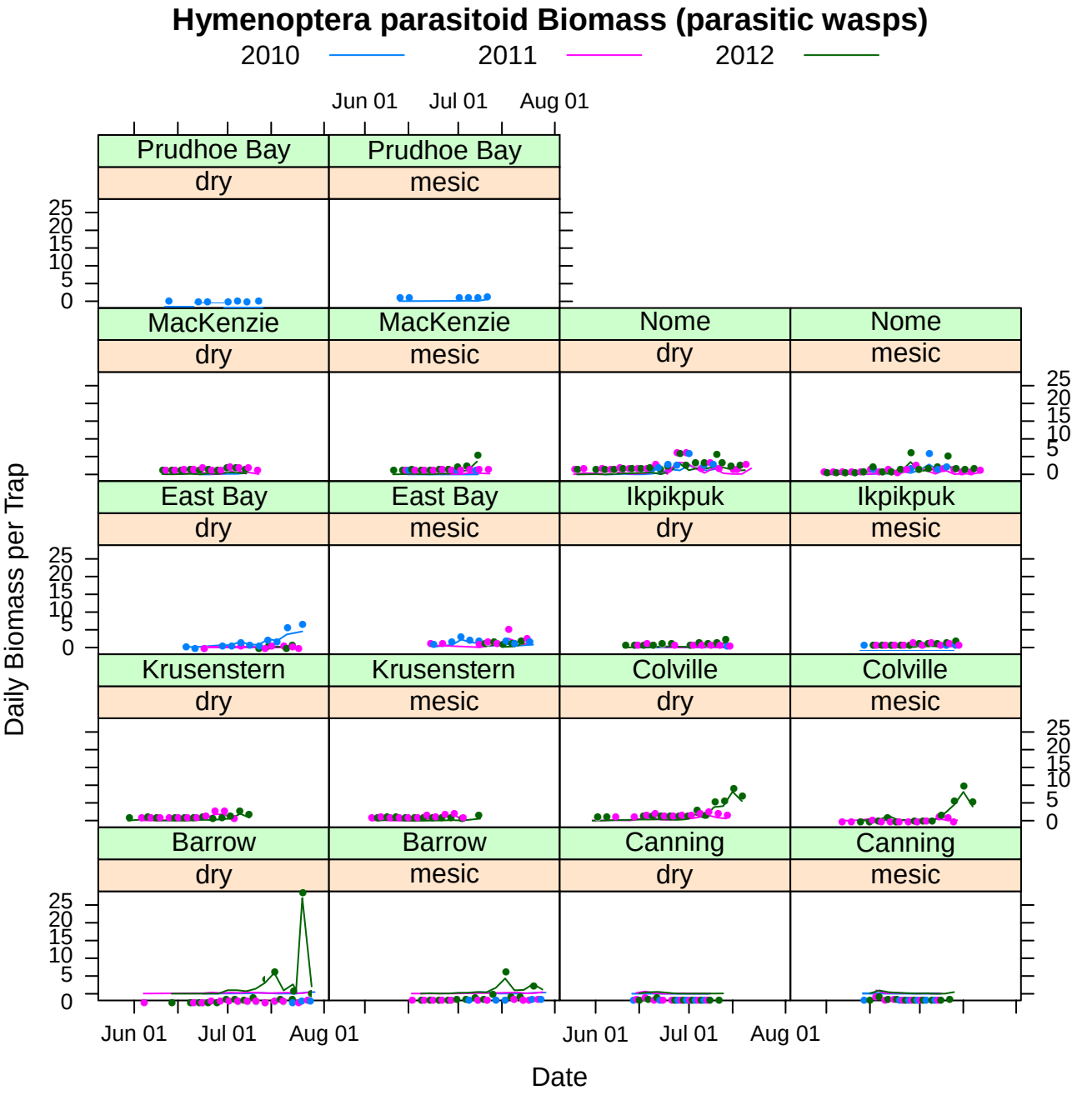

Mycetophilidae Biomass (fungus gnats)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
Aug 01
0
10
20
30
40


Hymenoptera bees and wasps Biomass (bees)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
0
20
40
60
Jun 01
Jul 01
Date


Sciaridae Biomass (root gnats)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
Aug 01
0
4
8
12


Lepidoptera Biomass (moths)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Jun 01
Jul 01
0
5
10
15
Daily Biomass per Trap
Date


Trichoptera Biomass (caddisflies)
2010
2011
2012
Nome
dry
Nome
mesic
Prudhoe Bay
dry
Prudhoe Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
MacKenzie
dry
MacKenzie
mesic
Colville
dry
Colville
mesic
East Bay
dry
East Bay
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
0
10
20
30
40
Jun 01
Jul 01
Aug 01
Date


Hymenoptera parasitoid Biomass (parasitic wasps)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
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Canning
mesic
Daily Biomass per Trap
Date
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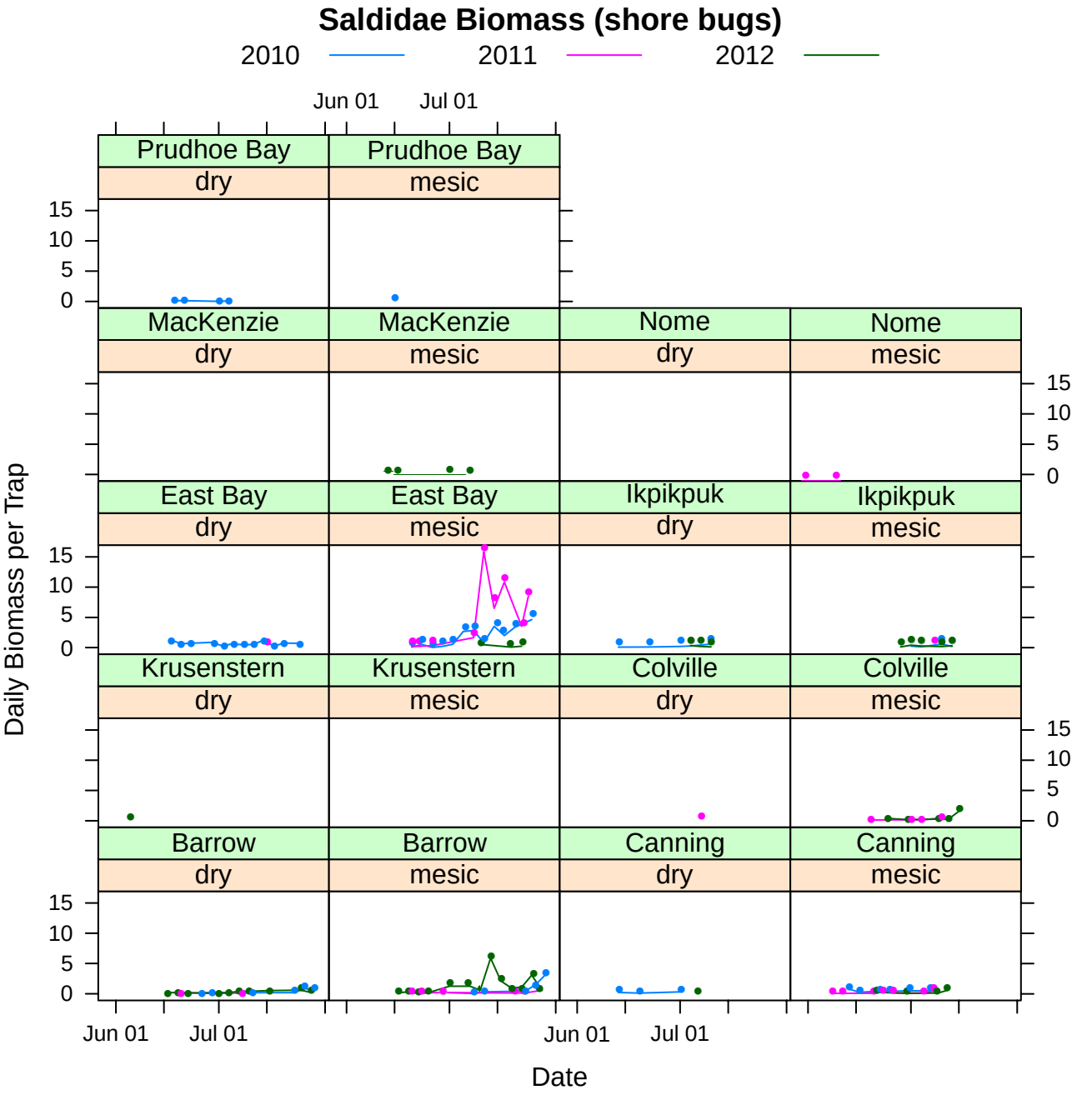
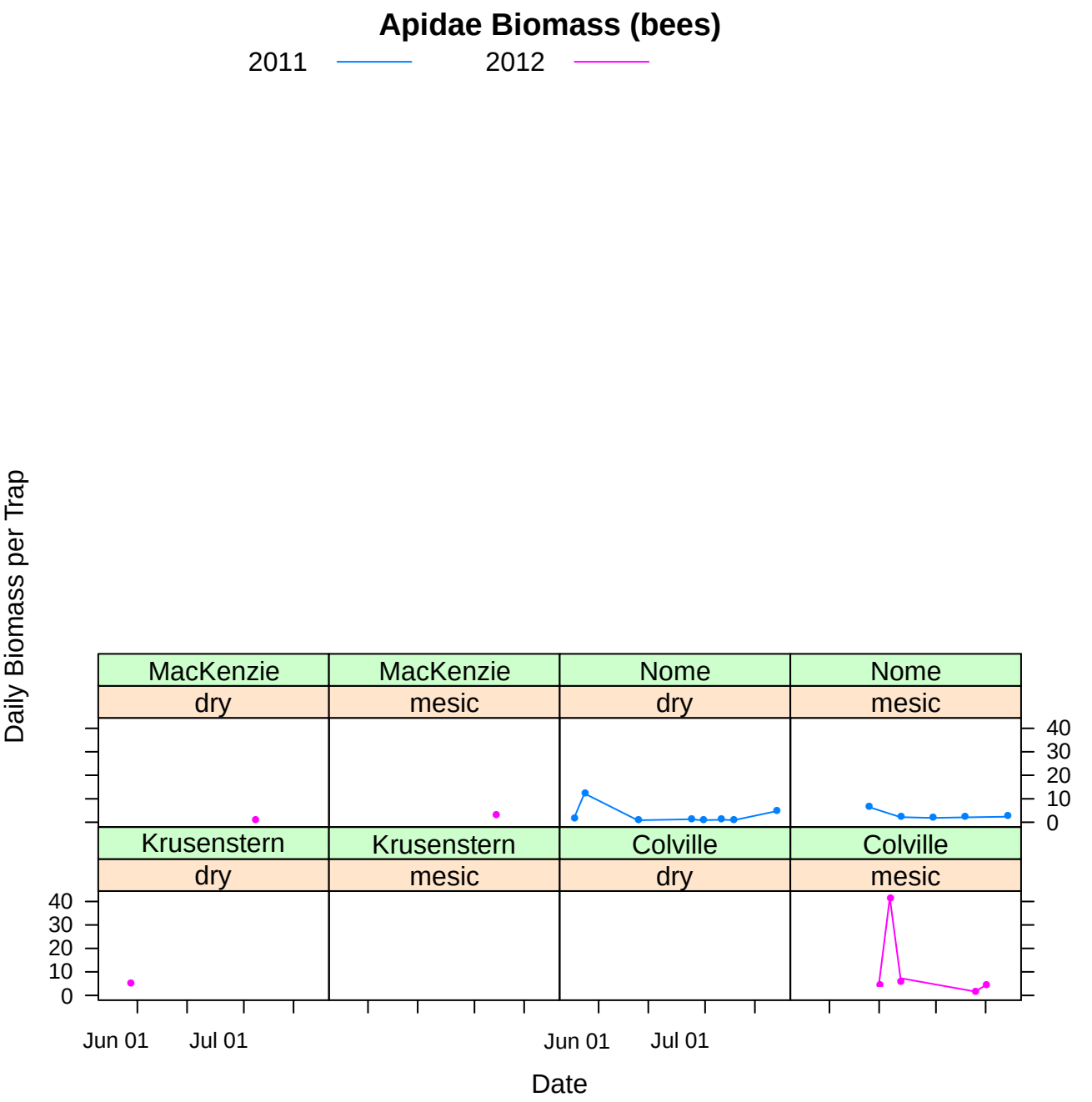
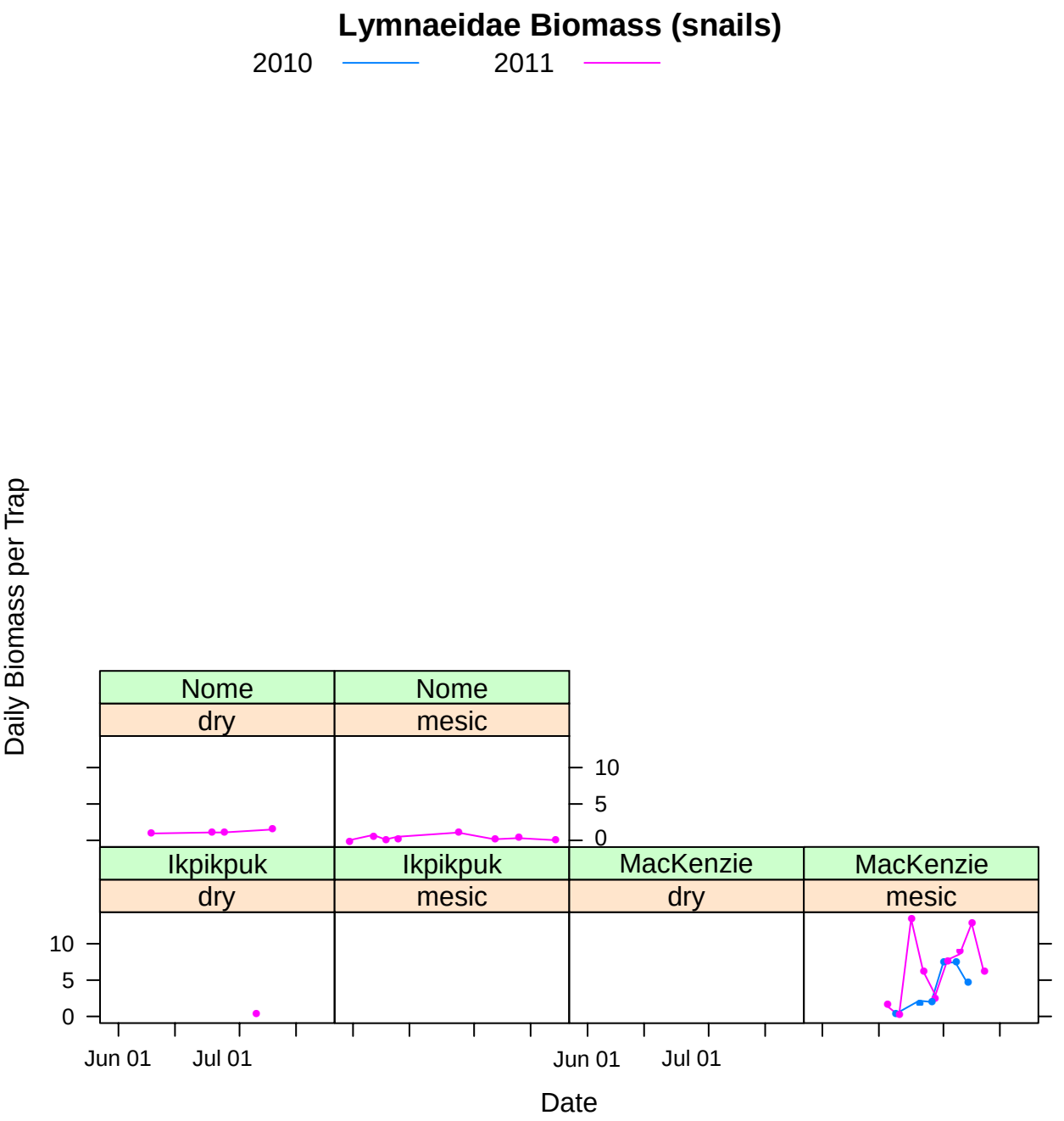
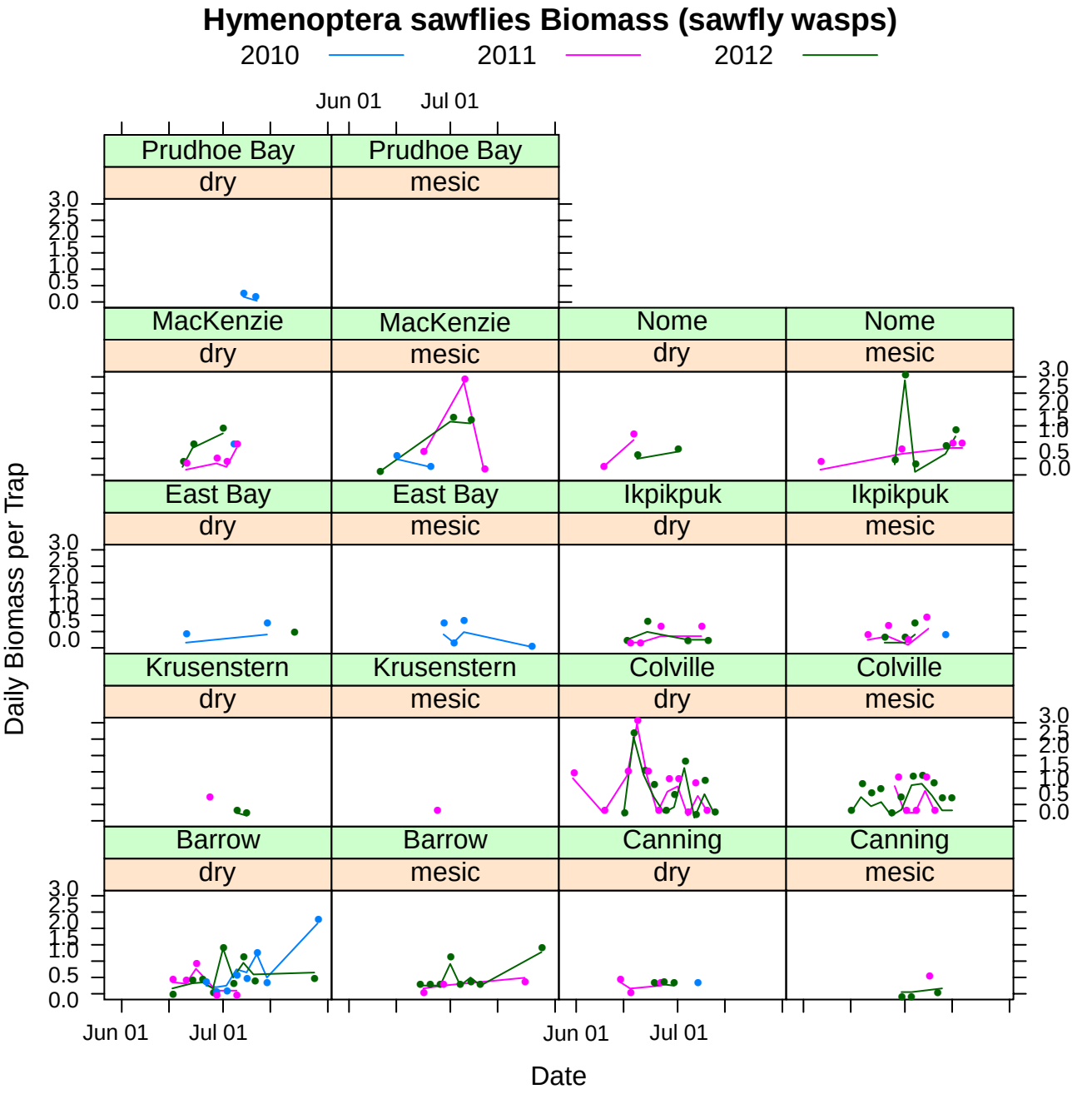
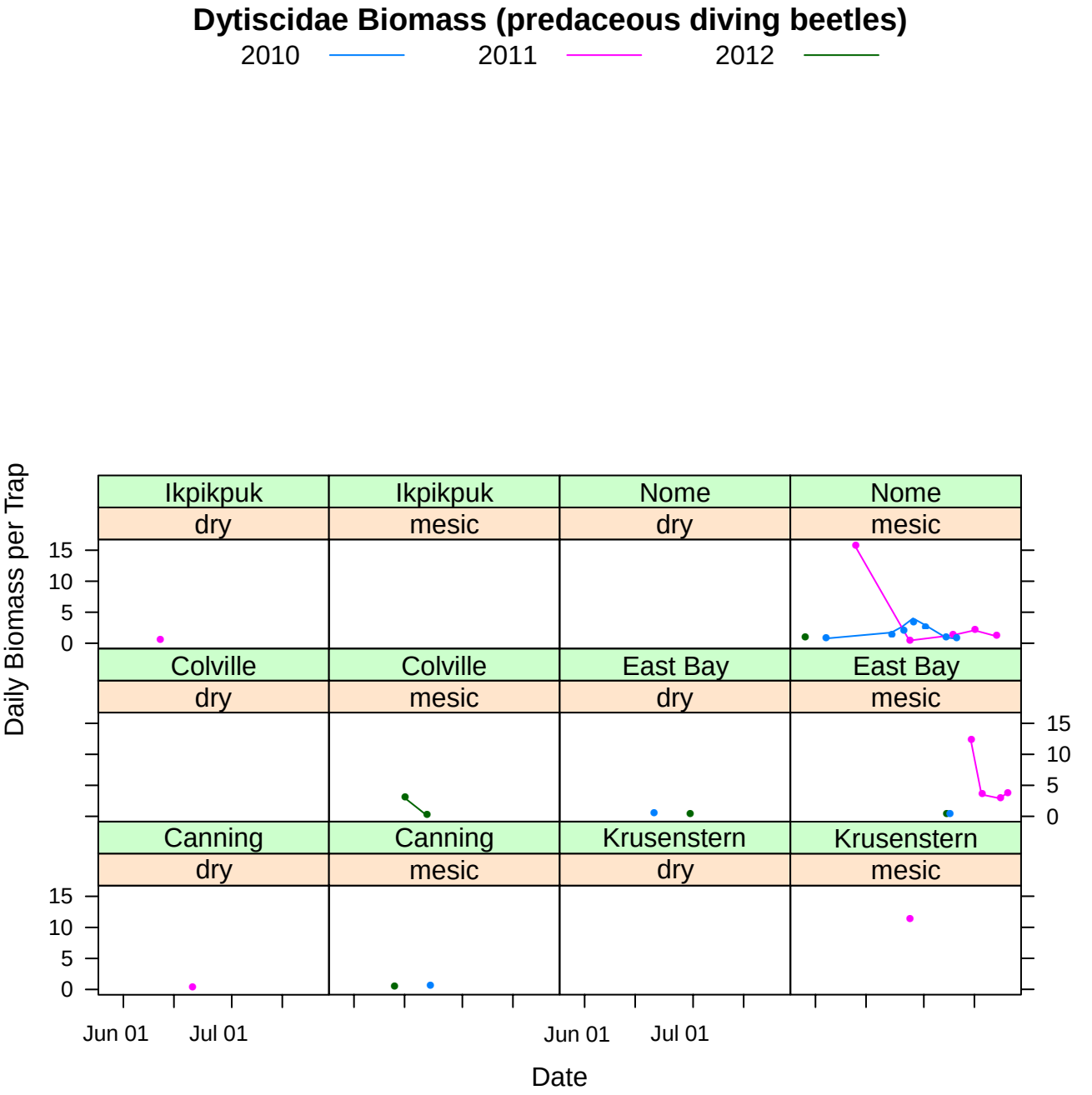
Jul 01
Aug 01
0
5
10
15
20
25

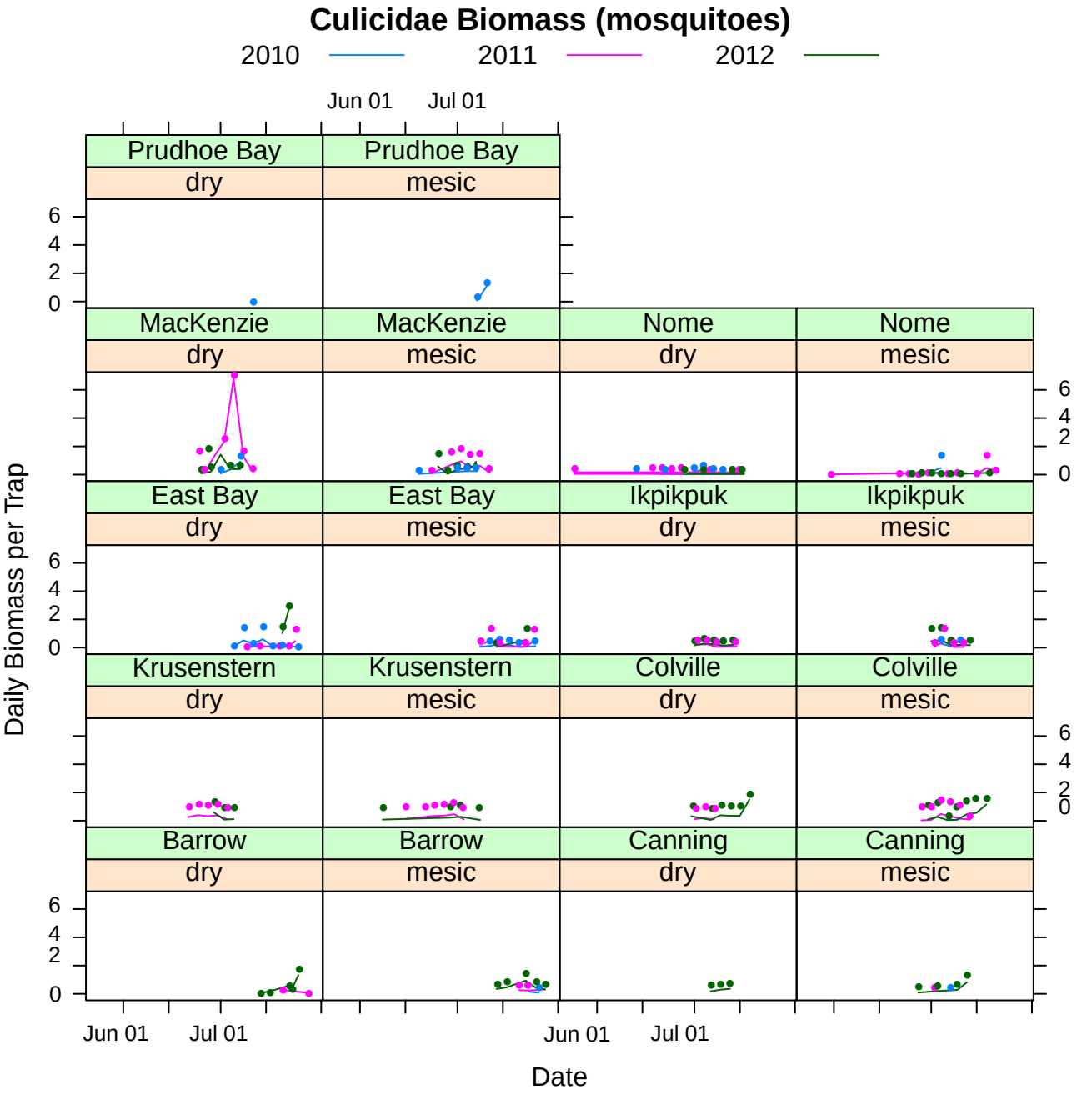

Saldidae Biomass (shore bugs)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
0
5
10
15

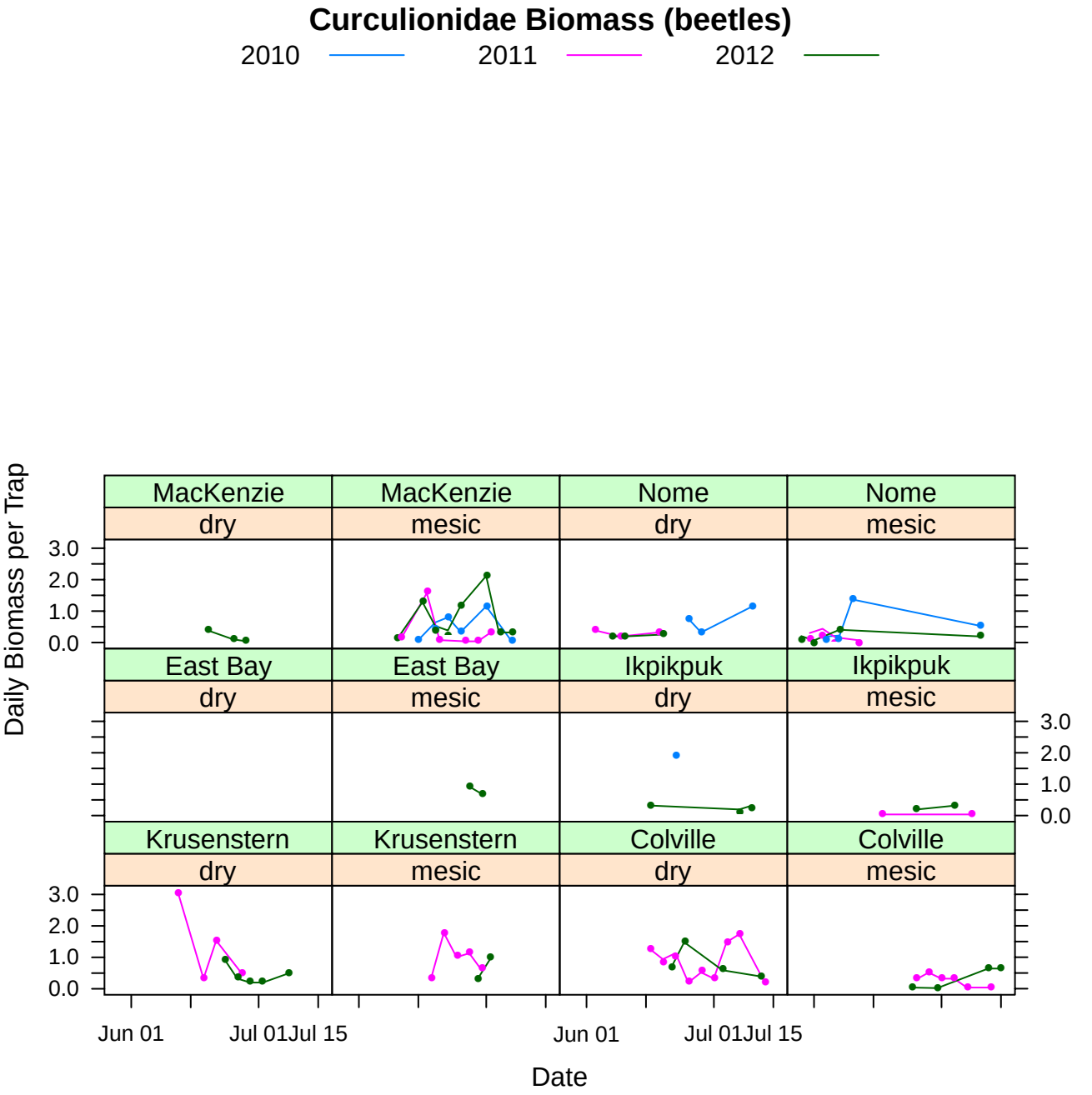

Apidae Biomass (bees)
2011
2012
Daily Biomass per Trap
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
0
10
20
30
40
Jun 01
Jul 01
Jun 01
Jul 01
Date

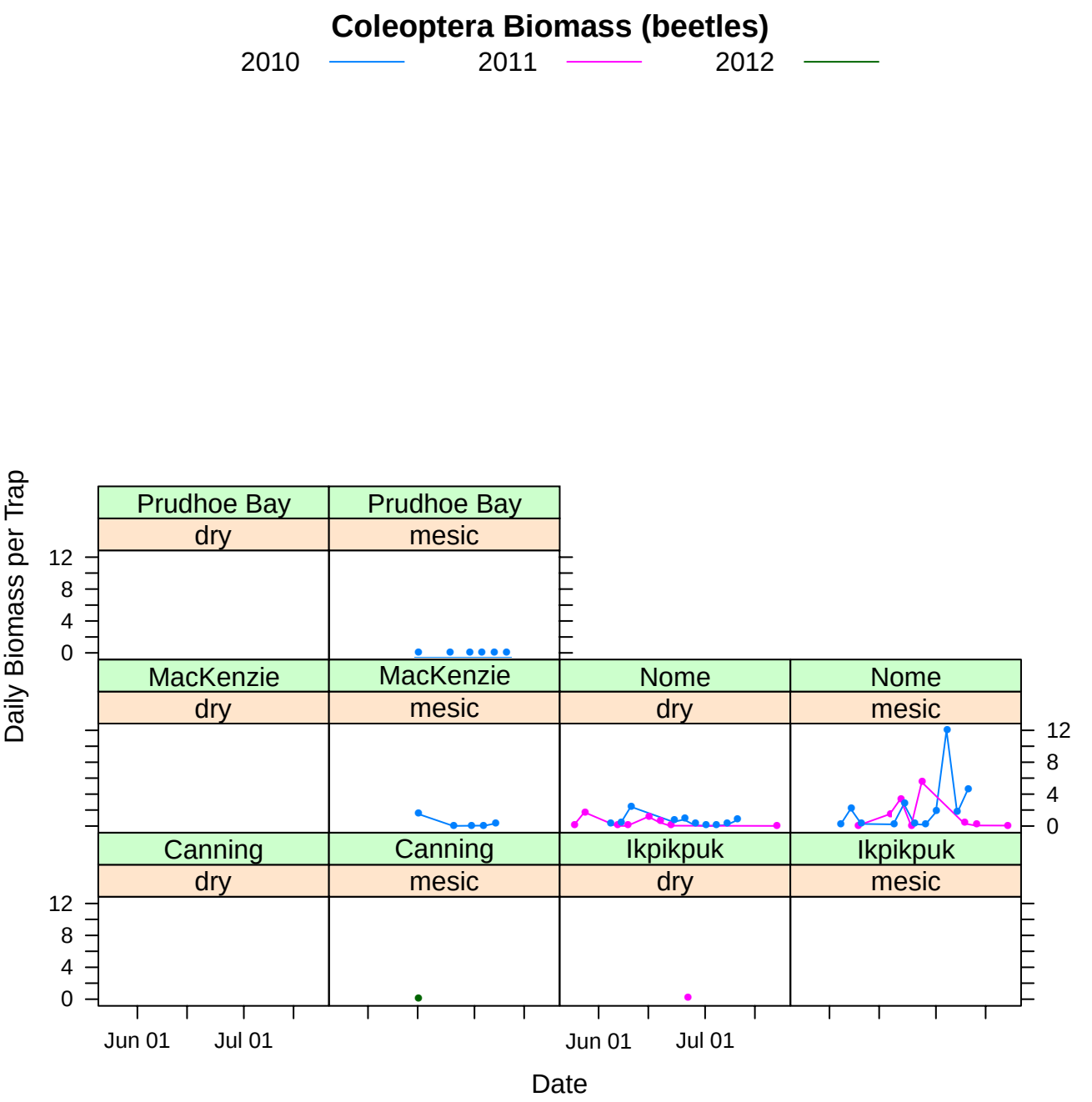

Lymnaeidae Biomass (snails)
2010
2011
Daily Biomass per Trap
Nome
dry
Nome
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
MacKenzie
dry
MacKenzie
mesic
10
5
0
Jun 01
Jul 01
Date

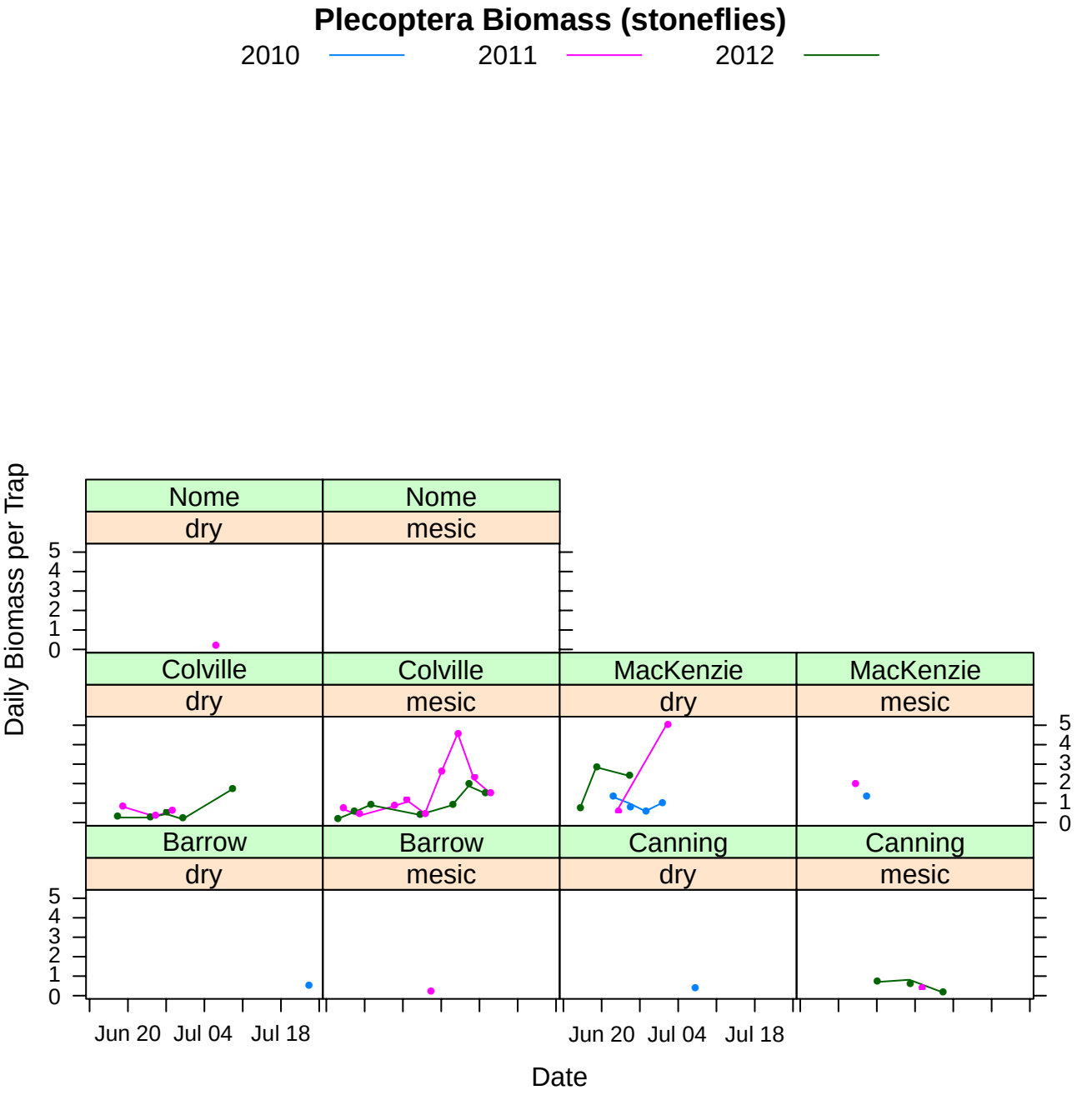

Hymenoptera sawflies Biomass (sawfly wasps)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
0.0
0.5
1.0
1.5
2.0
2.5
3.0

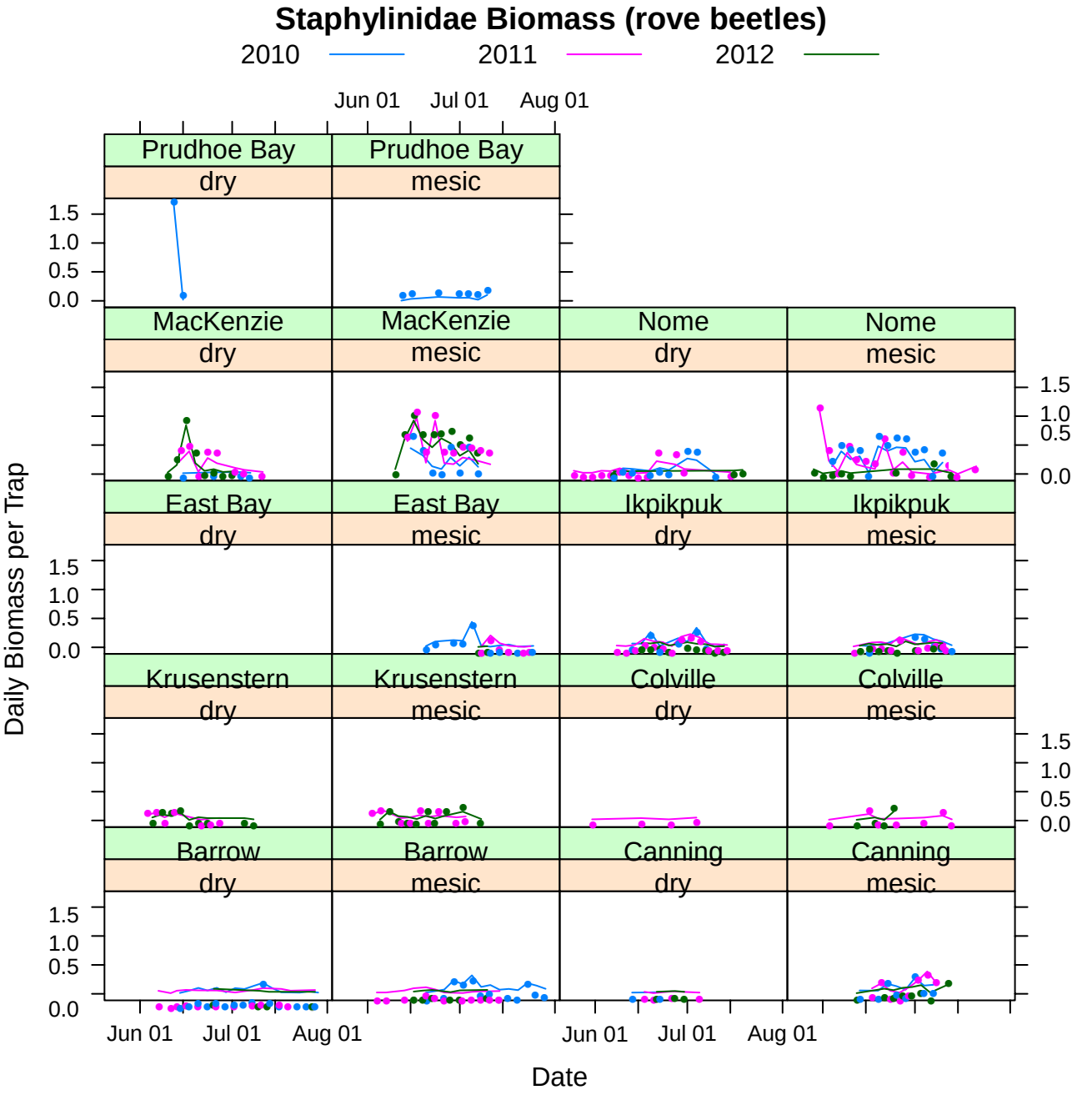

Dytiscidae Biomass (predaceous diving beetles)
2010
2011
2012
Daily Biomass per Trap
Ikpikpuk
dry
Ikpikpuk
mesic
Nome
dry
Nome
mesic
Colville
dry
Colville
mesic
East Bay
dry
East Bay
mesic
Canning
dry
Canning
mesic
Krusenstern
dry
Krusenstern
mesic
15
10
5
0
Jun 01
Jul 01
Date

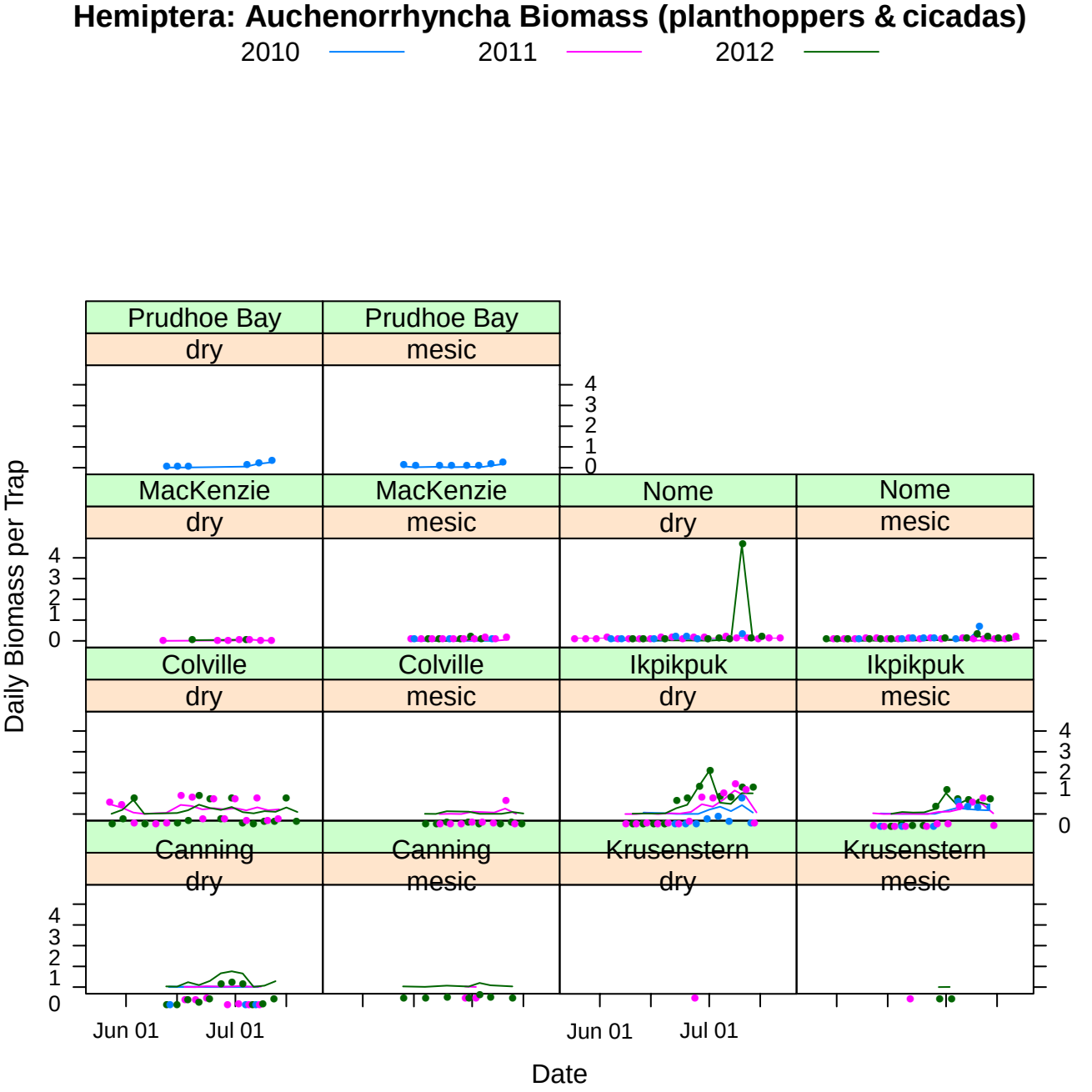

Culicidae Biomass (mosquitoes)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
0
2
4
6

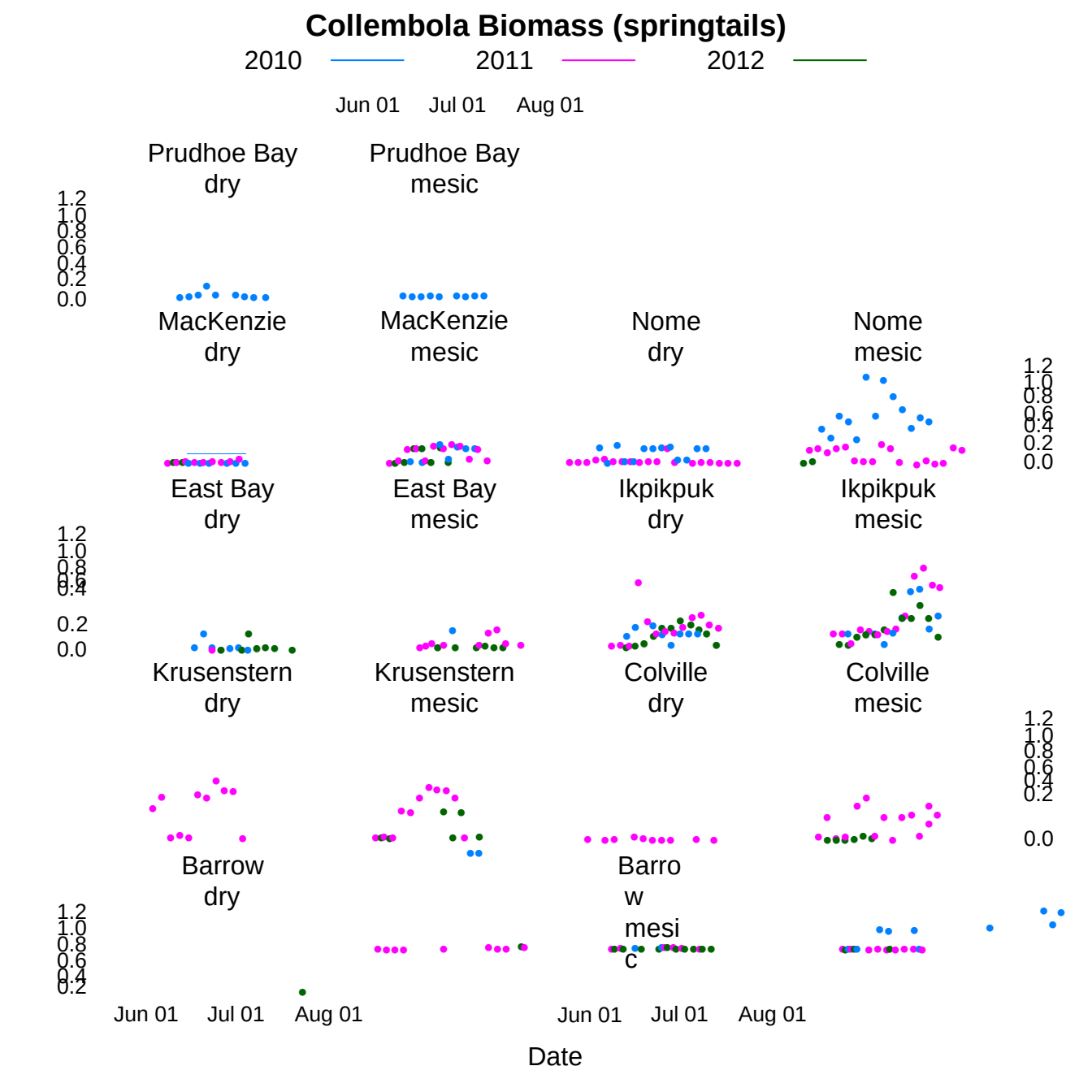

Curculionidae Biomass (beetles)
2010
2011
2012
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Daily Biomass per Trap
3.0
2.0
1.0
0.0
Jun 01
Jul 01
Jul 15
Date

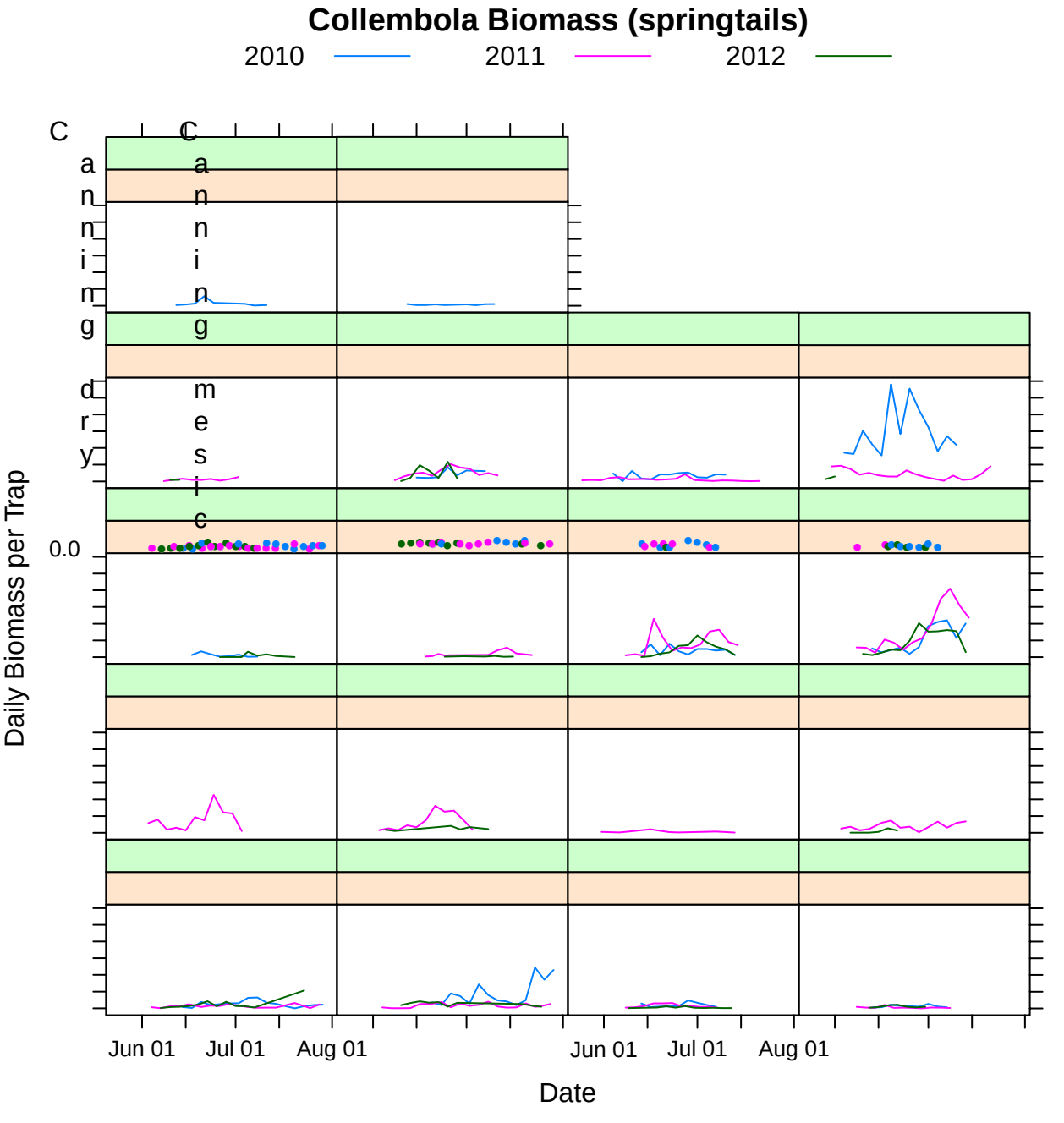

Coleoptera Biomass (beetles)
2010
2011
2012
Daily Biomass per Trap
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
Canning
dry
Canning
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
0
4
8
12
Jun 01
Jul 01
Date

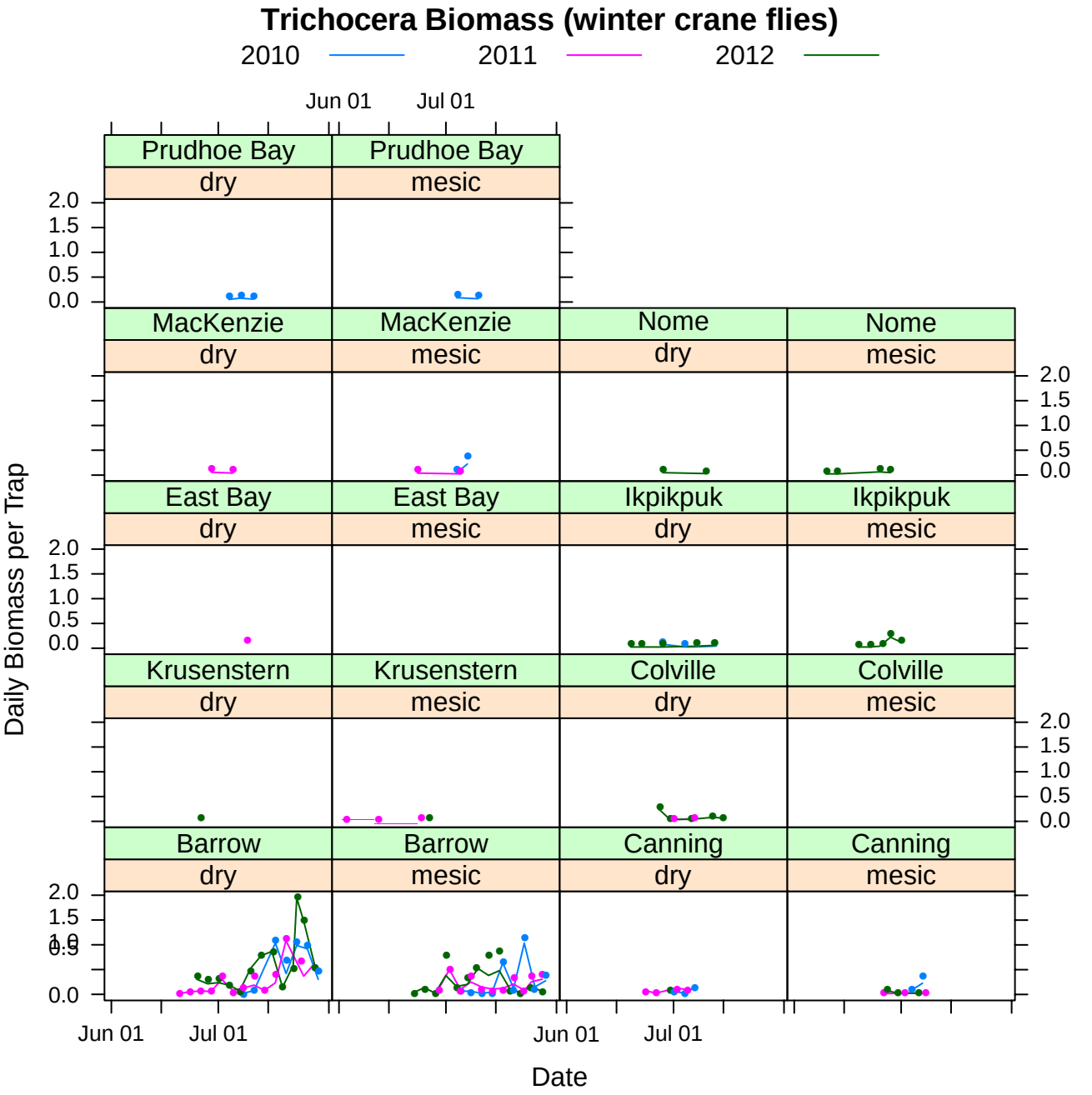

Plecoptera Biomass (stoneflies)
2010
2011
2012
Daily Biomass per Trap
Nome
dry
Nome
mesic
Colville
dry
Colville
mesic
MacKenzie
dry
MacKenzie
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
0
1
2
3
4
5
Jun 20
Jul 04
Jul 18
Date

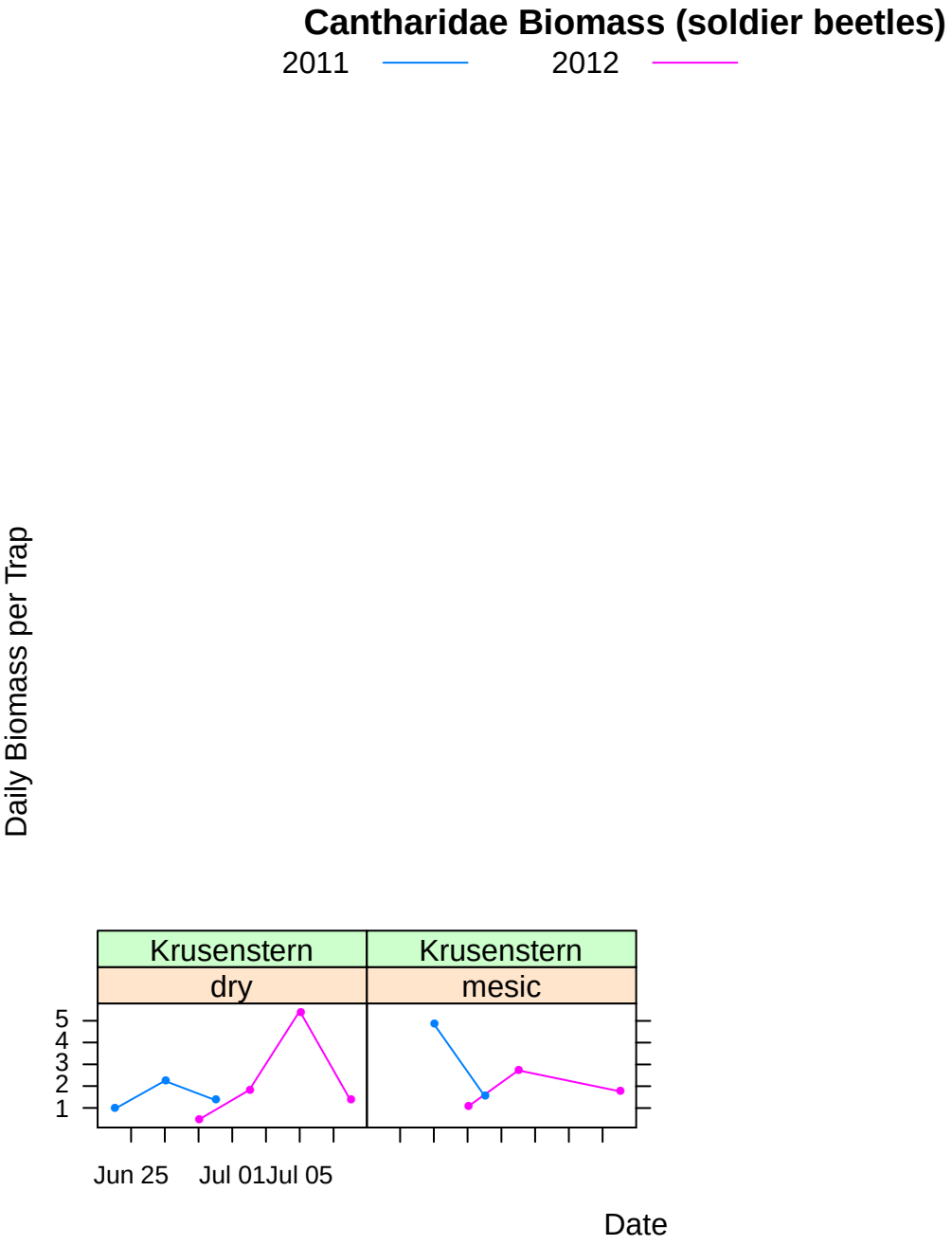

Staphylinidae Biomass (rove beetles)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Jun 01
Jul 01
Aug 01
0.0
0.5
1.0
1.5
Daily Biomass per Trap
Date

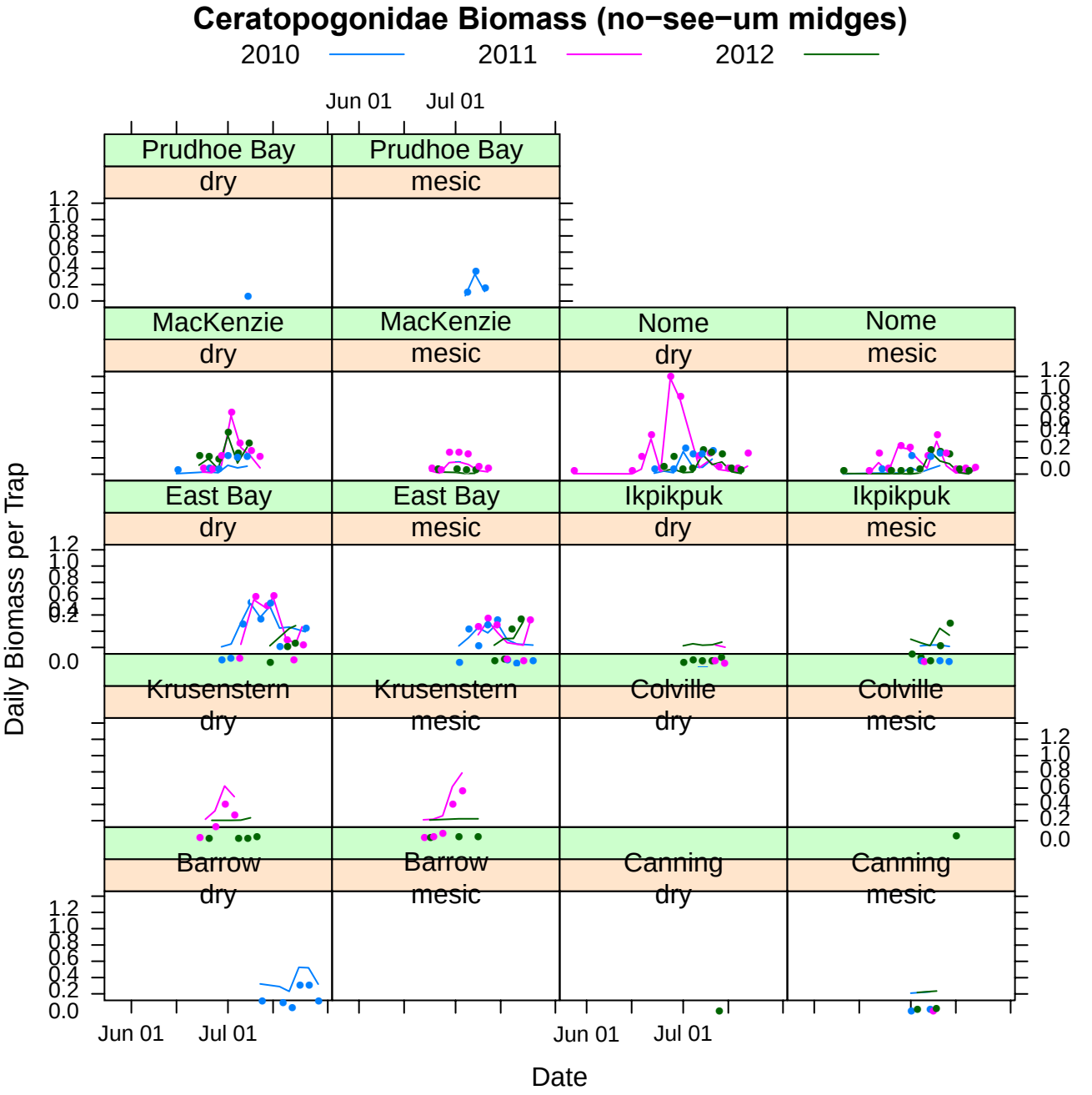

Hemiptera: Auchenorrhyncha Biomass (planthoppers & cicadas)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
Colville
dry
Colville
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Canning
dry
Canning
mesic
Krusenstern
dry
Krusenstern
mesic
Daily Biomass per Trap
0
1
2
3
4
Jun 01
Jul 01
Date

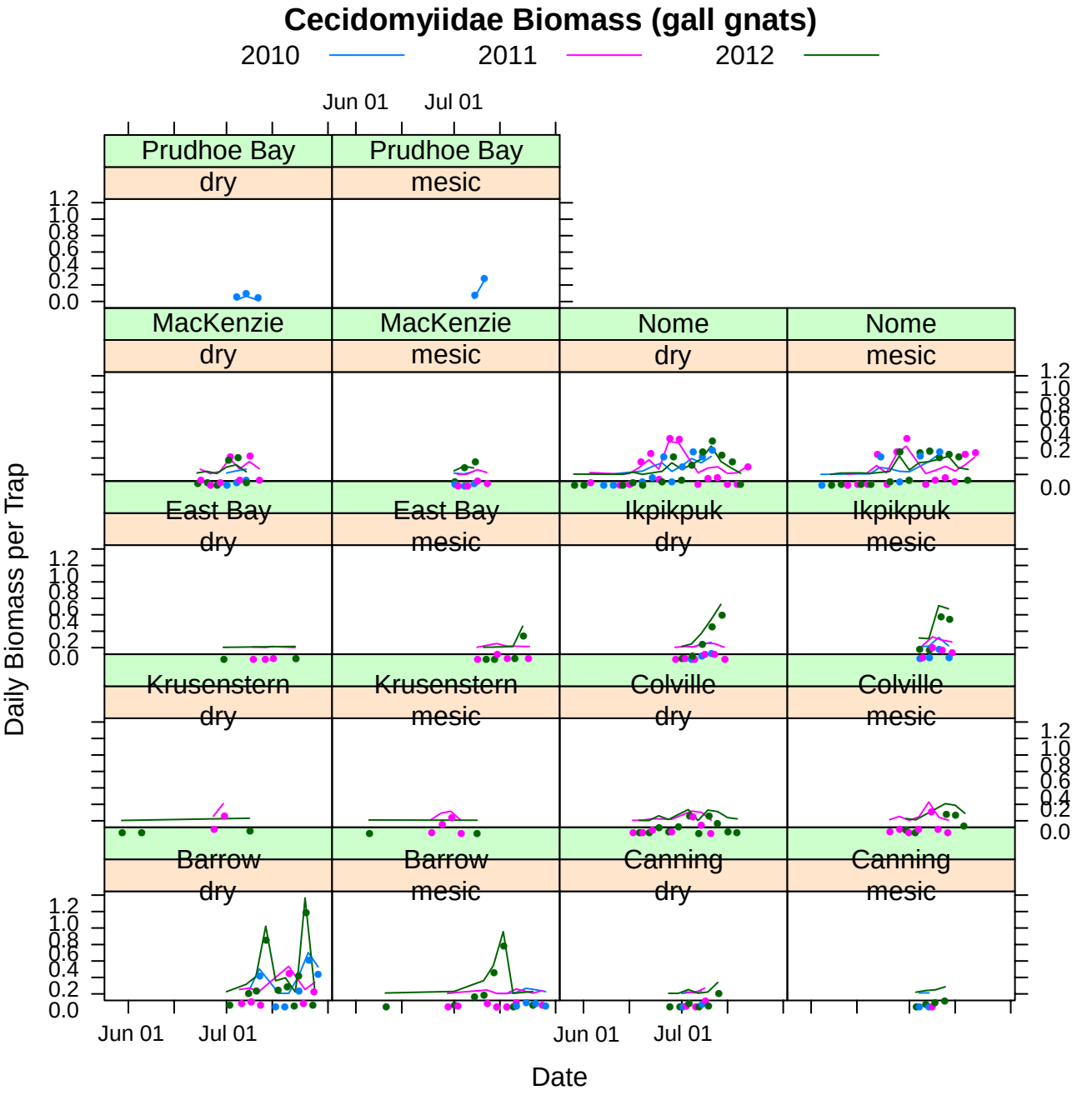

Collembola Biomass (springtails)
2010
2011
2012
Jun 01
Jul 01
Aug 01
Prudhoe Bay dry
Prudhoe Bay mesic
MacKenzie dry
MacKenzie mesic
Nome dry
Nome mesic
East Bay dry
East Bay mesic
Ikpikpuk dry
Ikpikpuk mesic
Krusenstern dry
Krusenstern mesic
Colville dry
Colville mesic
Barrow dry
Barrow mesic
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Date

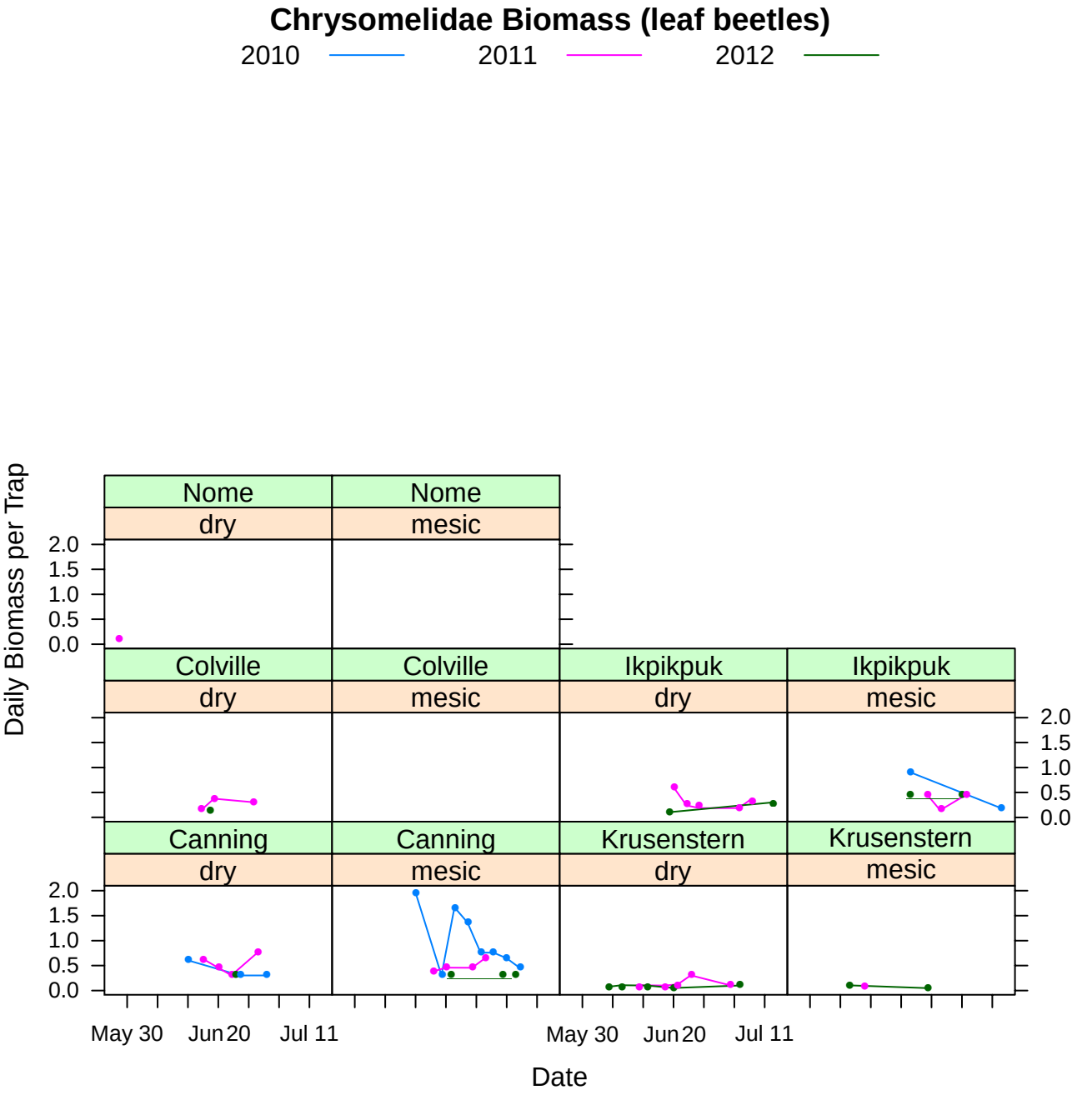

Collembola Biomass (springtails)
2010
2011
2012
Canning dry
Canning mesic
0.0
Daily Biomass per Trap
Jun 01
Jul 01
Aug 01
Jun 01
Jul 01
Aug 01
Date

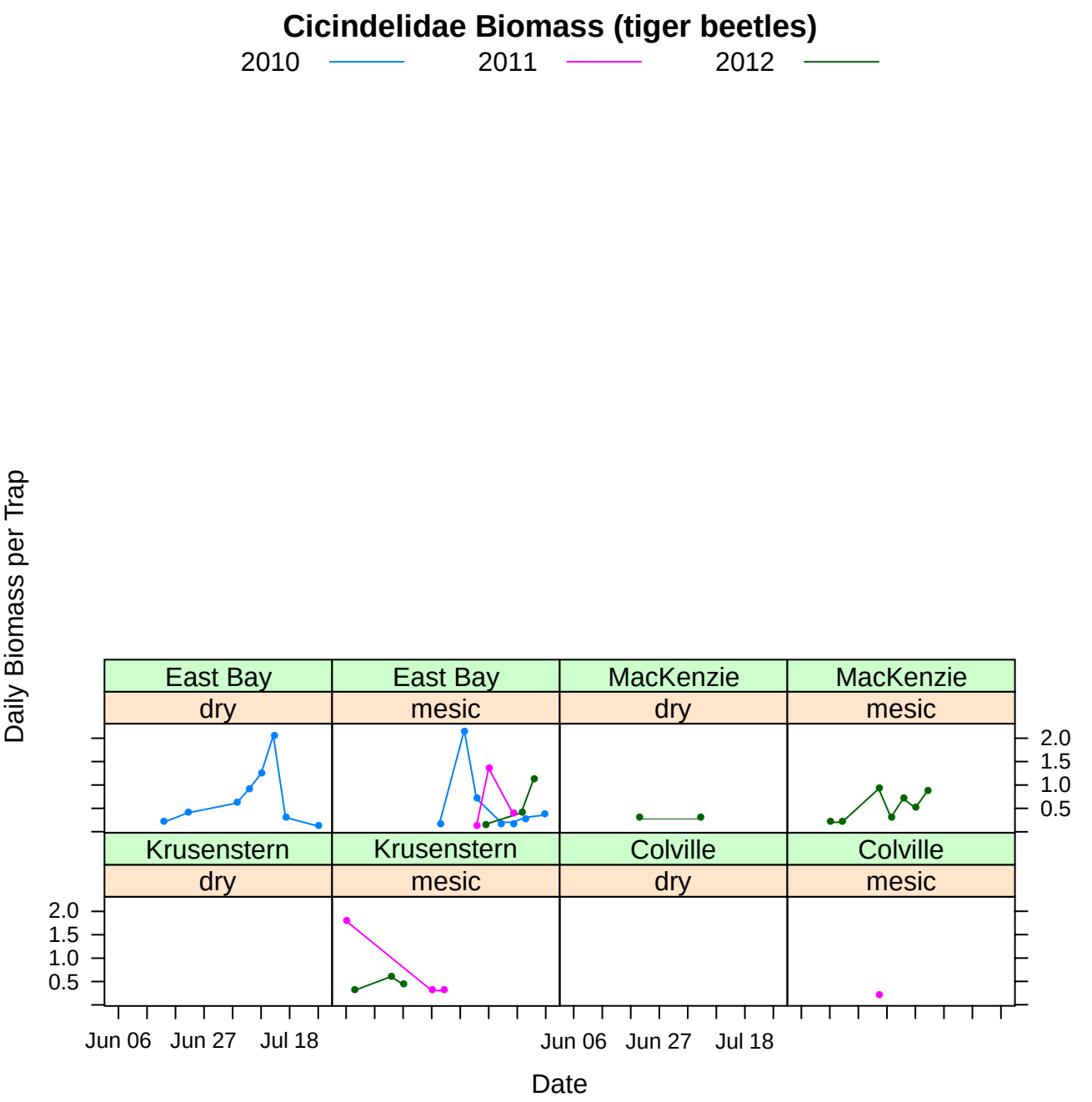

Trichocera Biomass (winter crane flies)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
0.0
0.5
1.0
1.5
2.0

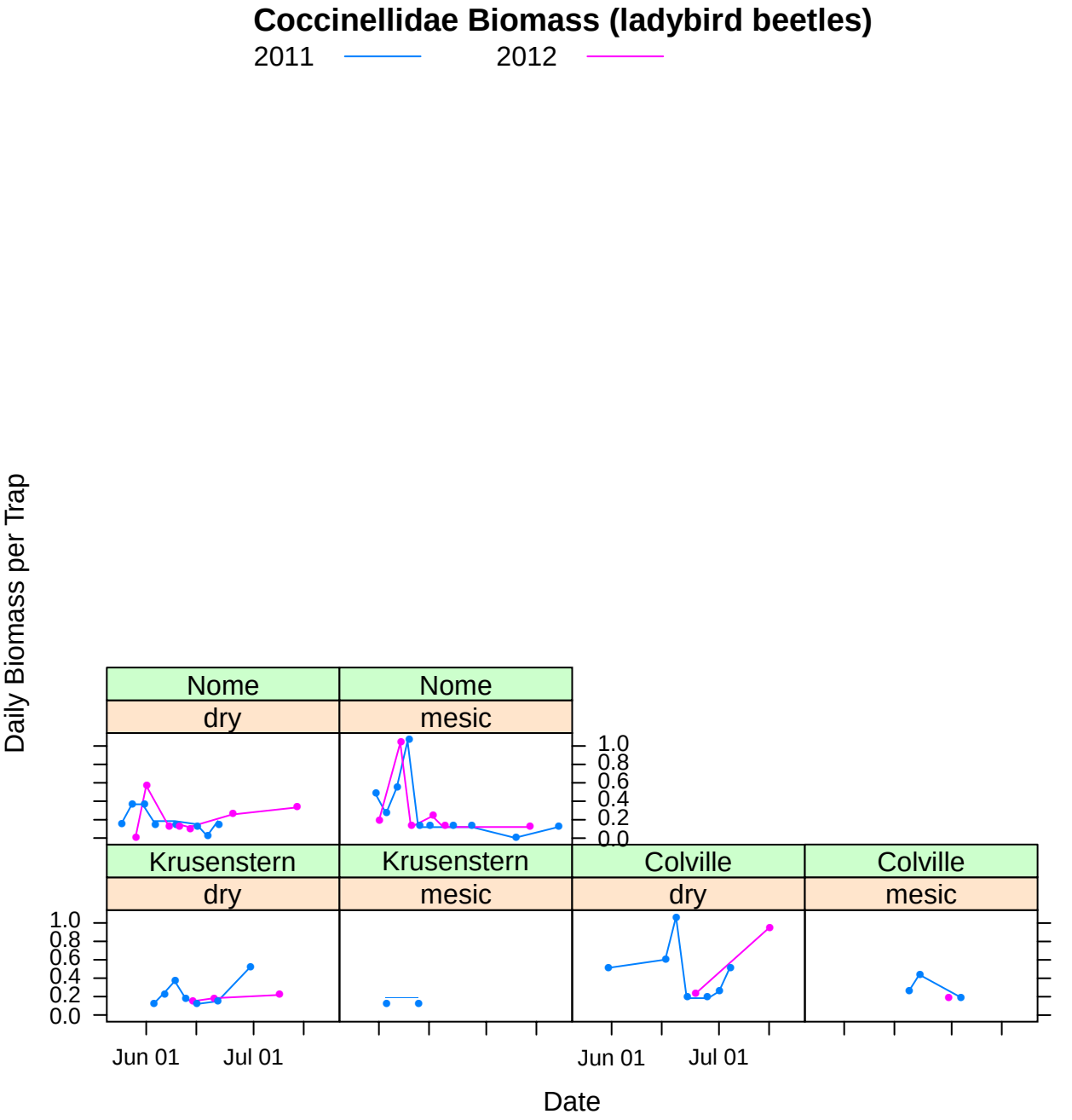

Cantharidae Biomass (soldier beetles)
2011
2012
Daily Biomass per Trap
Krusenstern
dry
Krusenstern
mesic
5
4
3
2
1
Jun 25
Jul 01
Jul 05
Date

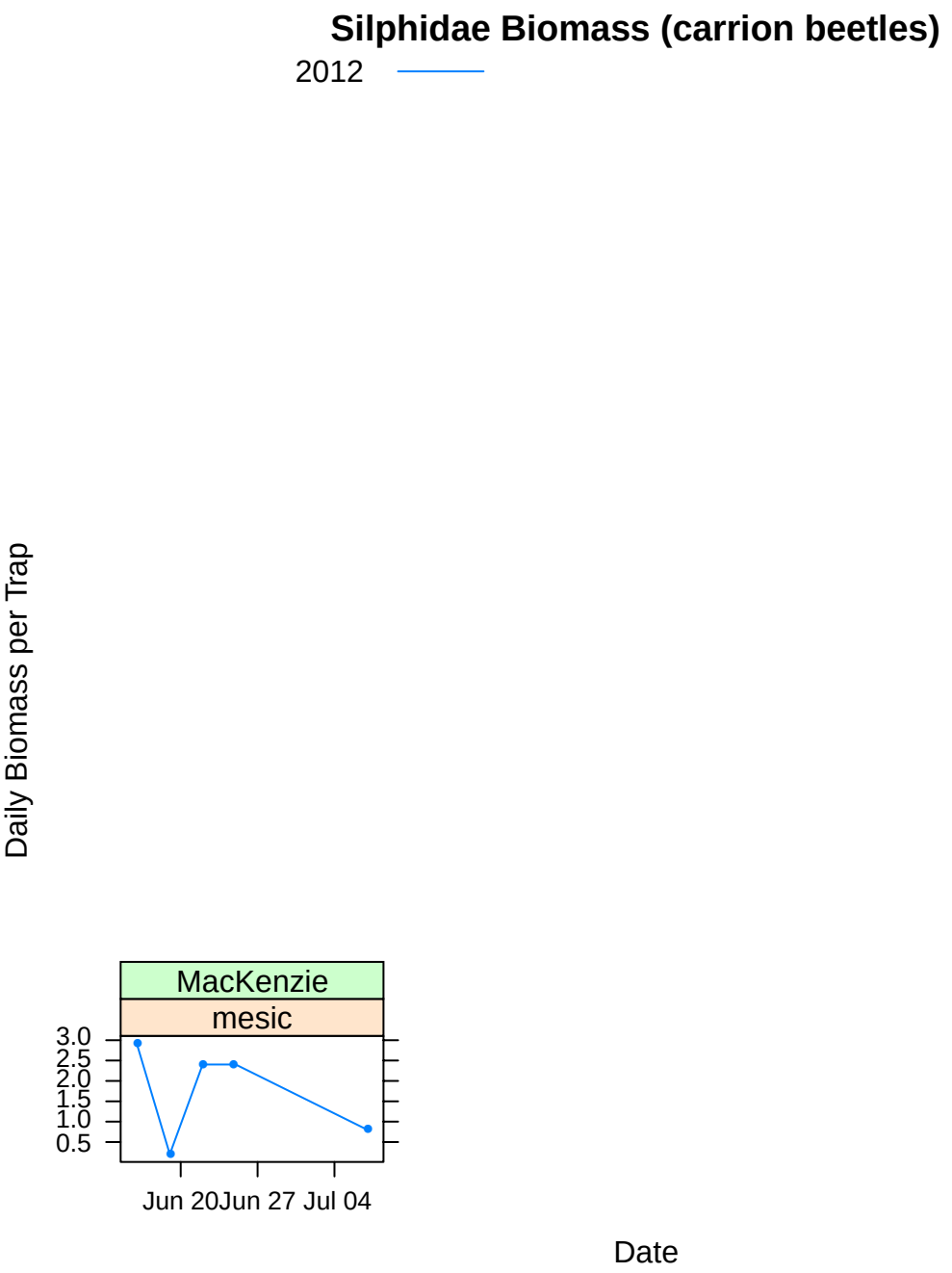

Ceratopogonidae Biomass (no−see−um midges)
2010
2011
2012
Prudhoe Bay dry
Prudhoe Bay mesic
MacKenzie dry
MacKenzie mesic
Nome dry
Nome mesic
East Bay dry
East Bay mesic
Ikpikpuk dry
Ikpikpuk mesic
Krusenstern dry
Krusenstern mesic
Colville dry
Colville mesic
Barrow dry
Barrow mesic
Canning dry
Canning mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
0.0
0.2
0.4
0.6
0.8
1.0
1.2

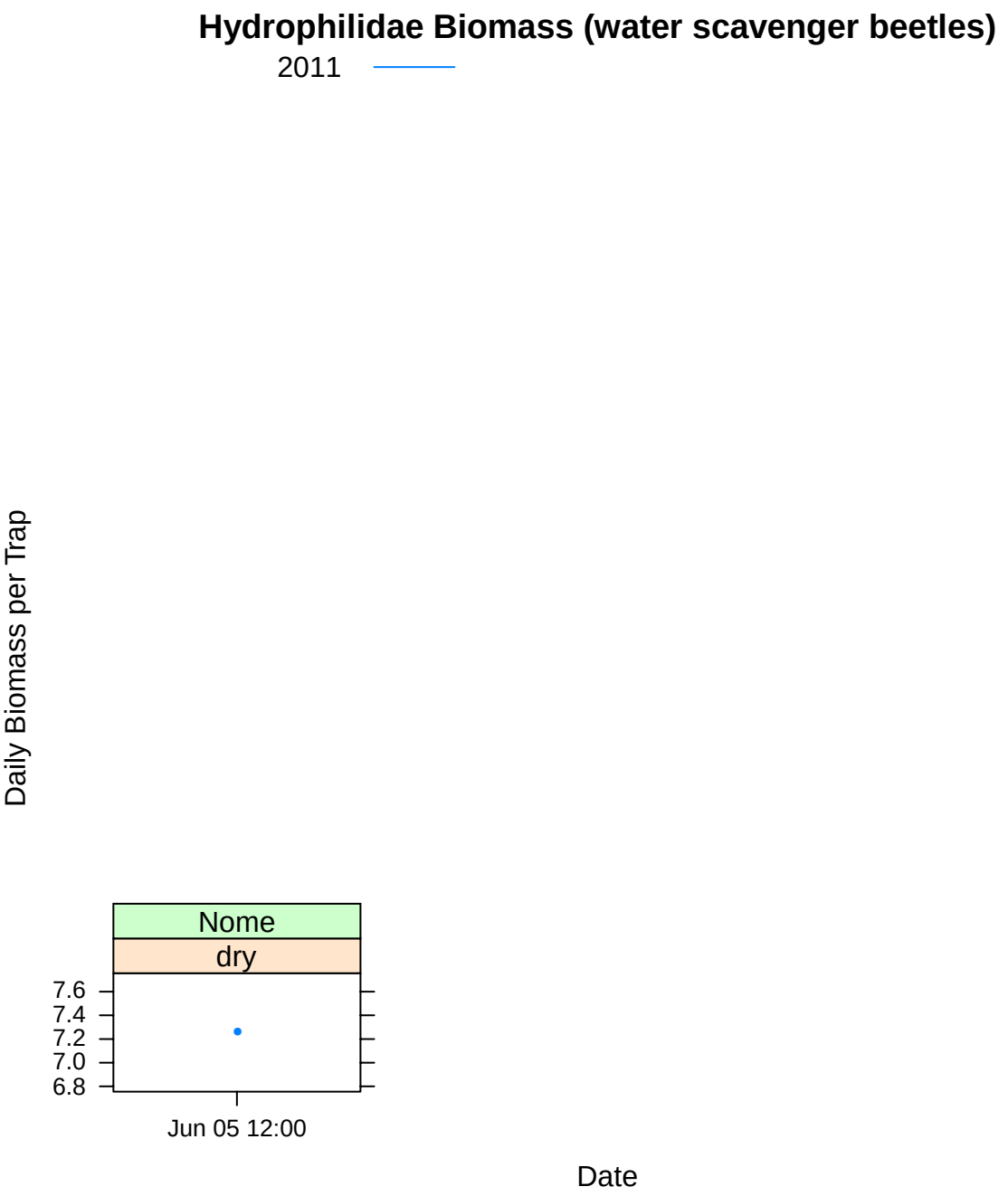

Cecidomyiidae Biomass (gall gnats)
2010
2011
2012
Prudhoe Bay dry
Prudhoe Bay mesic
MacKenzie dry
MacKenzie mesic
Nome dry
Nome mesic
East Bay dry
East Bay mesic
Ikpikpuk dry
Ikpikpuk mesic
Krusenstern dry
Krusenstern mesic
Colville dry
Colville mesic
Barrow dry
Barrow mesic
Canning dry
Canning mesic
Daily Biomass per Trap
Date
Jun 01
Jul 01
0.0
0.2
0.4
0.6
0.8
1.0
1.2

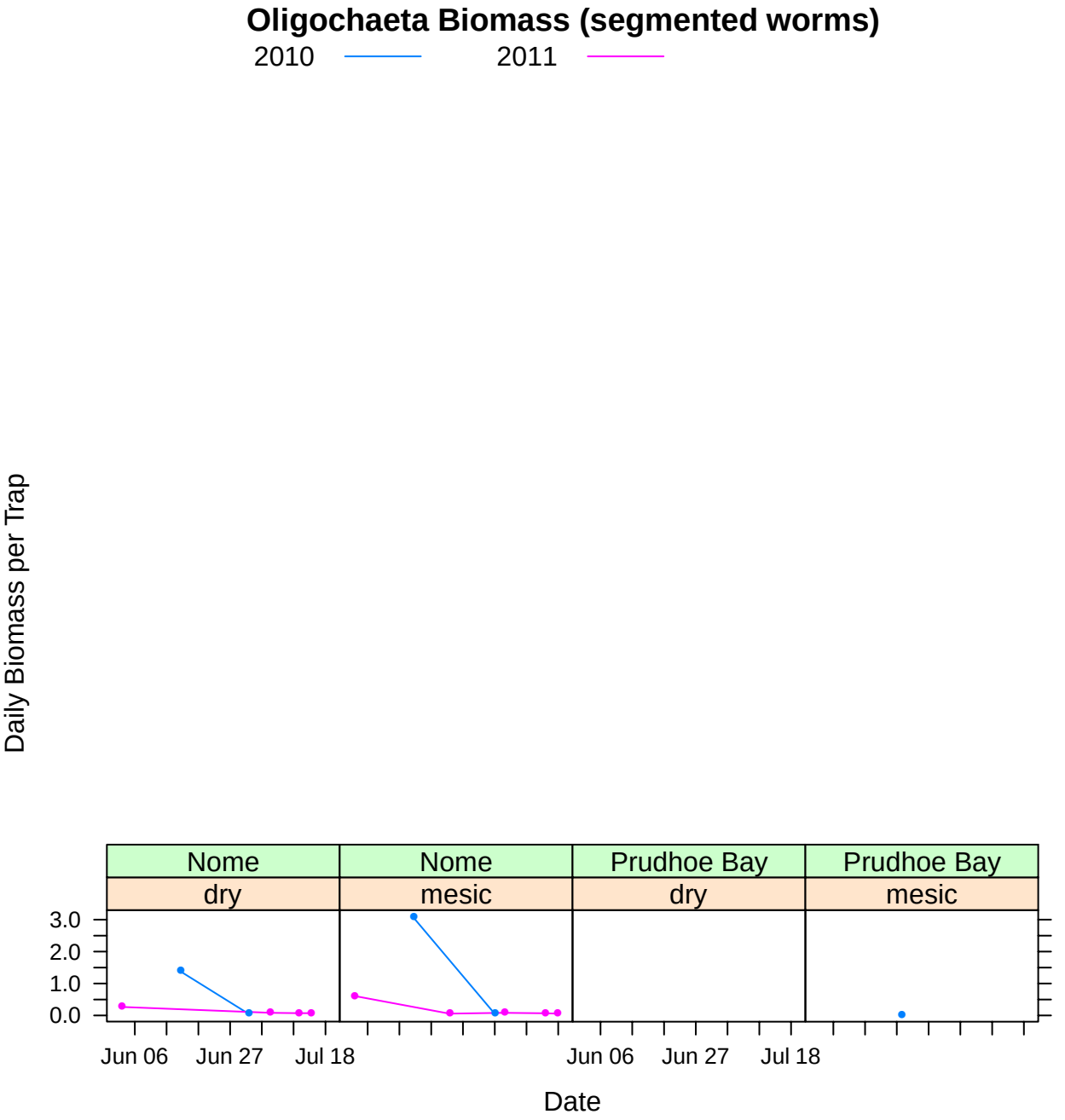

Chrysomelidae Biomass (leaf beetles)
2010
2011
2012
Nome
dry
Nome
mesic
Colville
dry
Colville
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Canning
dry
Canning
mesic
Krusenstern
dry
Krusenstern
mesic
Daily Biomass per Trap
2.0
1.5
1.0
0.5
0.0
May 30
Jun 20
Jul 11
Date

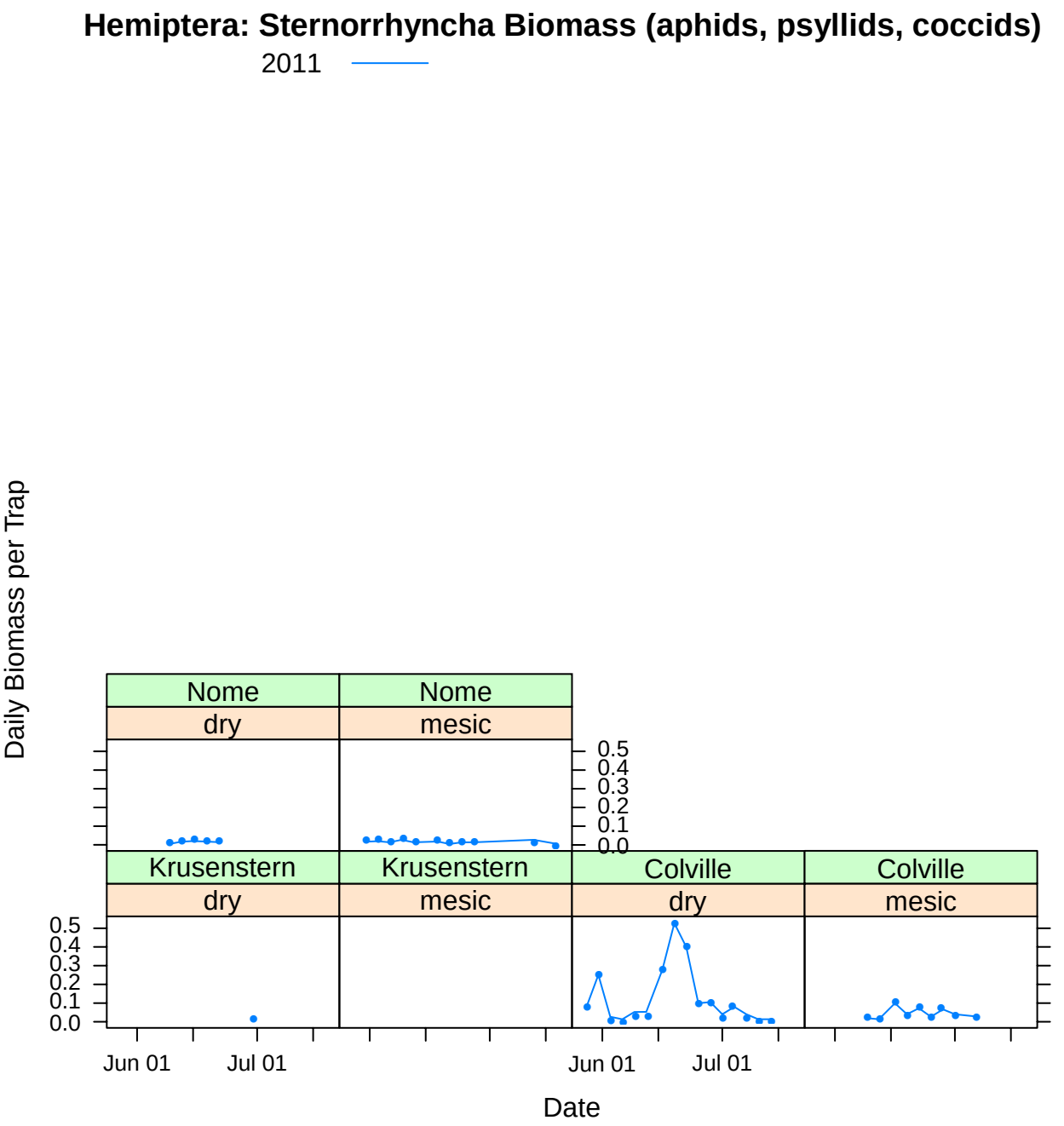

Cicindelidae Biomass (tiger beetles)
2010
2011
2012
Daily Biomass per Trap
East Bay
dry
East Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
2.0
1.5
1.0
0.5
Jun 06
Jun 27
Jul 18
Date

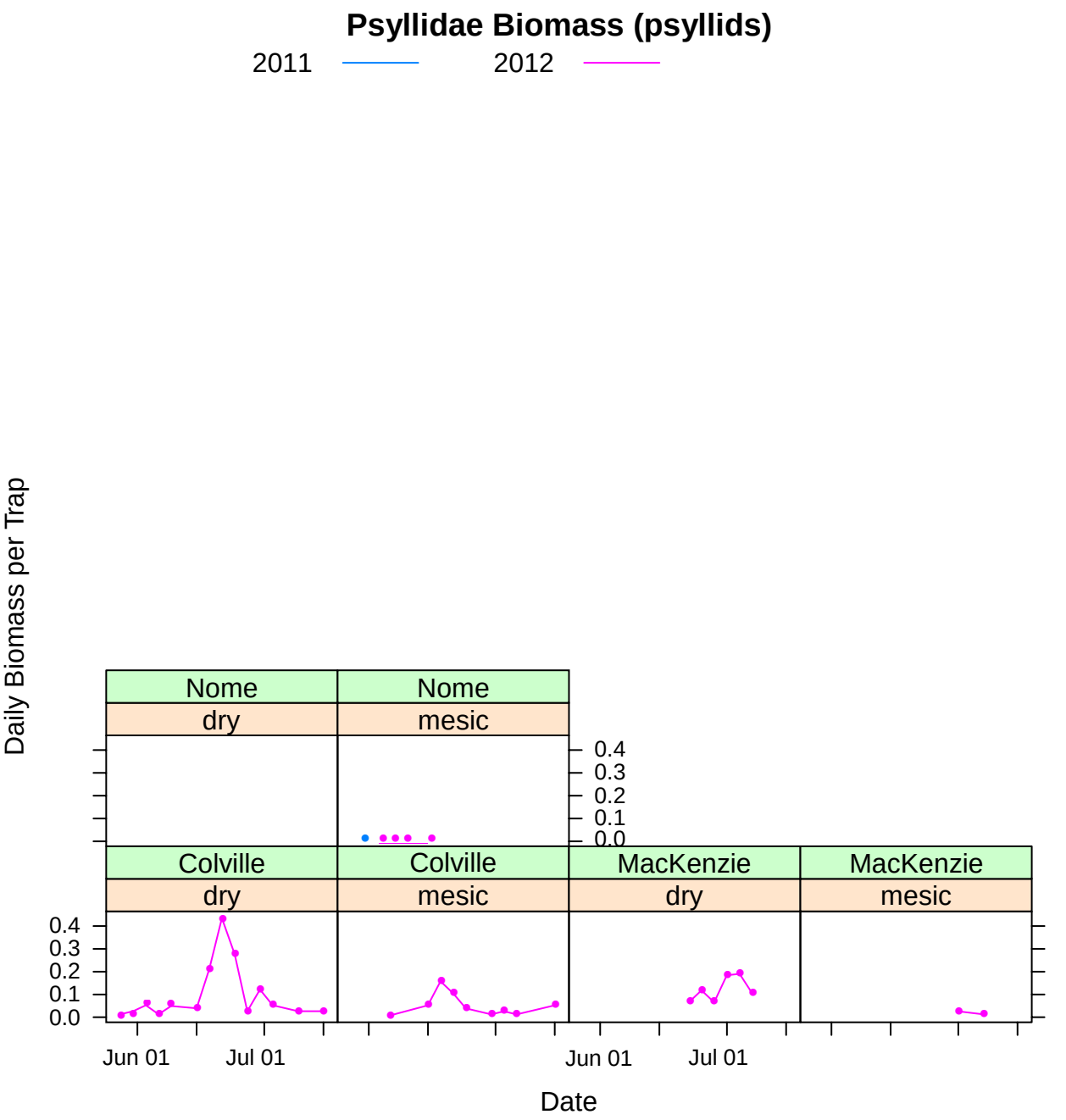

Coccinellidae Biomass (ladybird beetles)
2011
2012
Daily Biomass per Trap
Nome
dry
Nome
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
1.0
0.8
0.6
0.4
0.2
0.0
Jun 01
Jul 01
Date

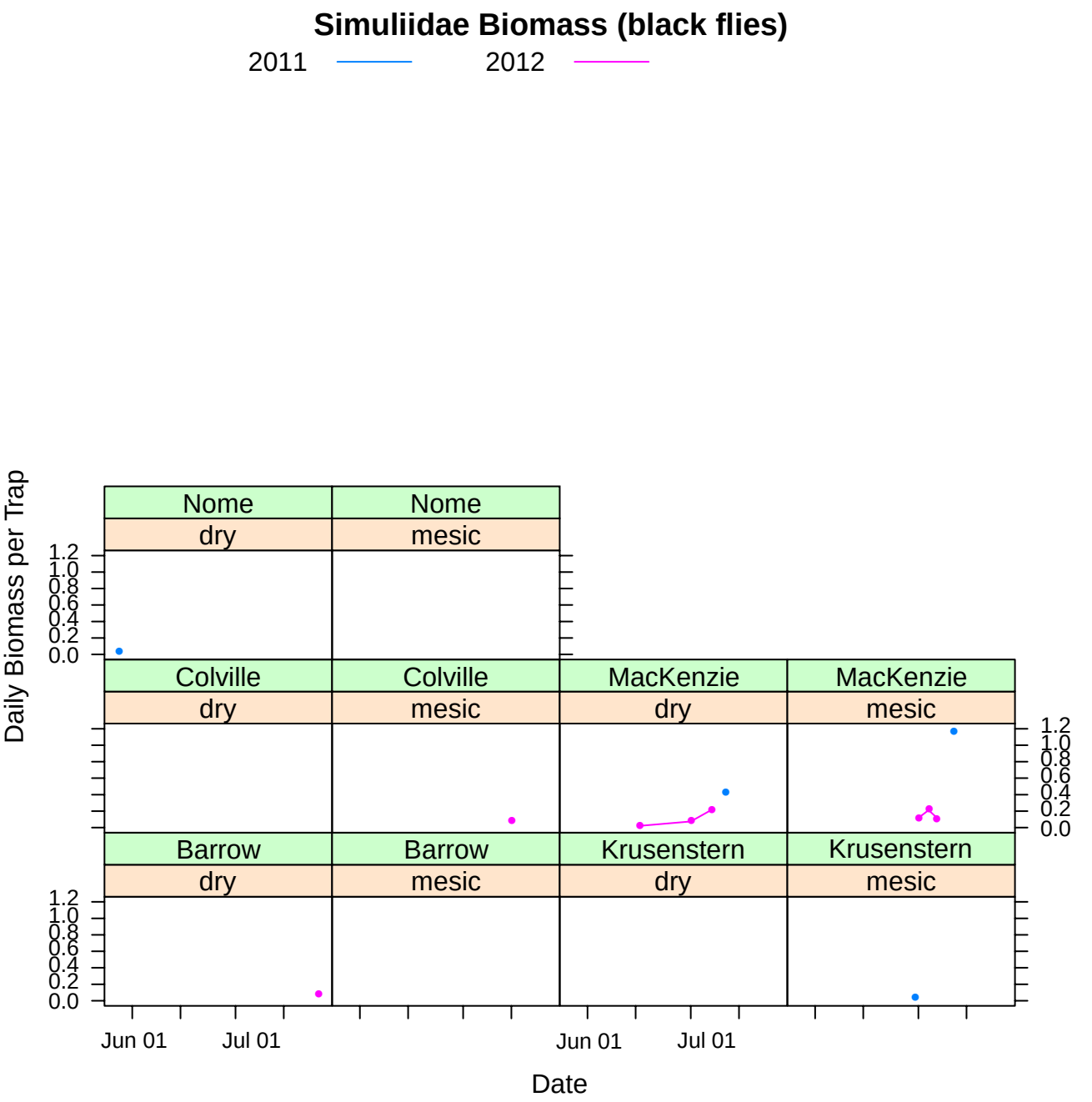

Silphidae Biomass (carrion beetles)
2012
Daily Biomass per Trap
MacKenzie
mesic
3.0
2.5
2.0
1.5
1.0
0.5
Jun 20
Jun 27
Jul 04
Date

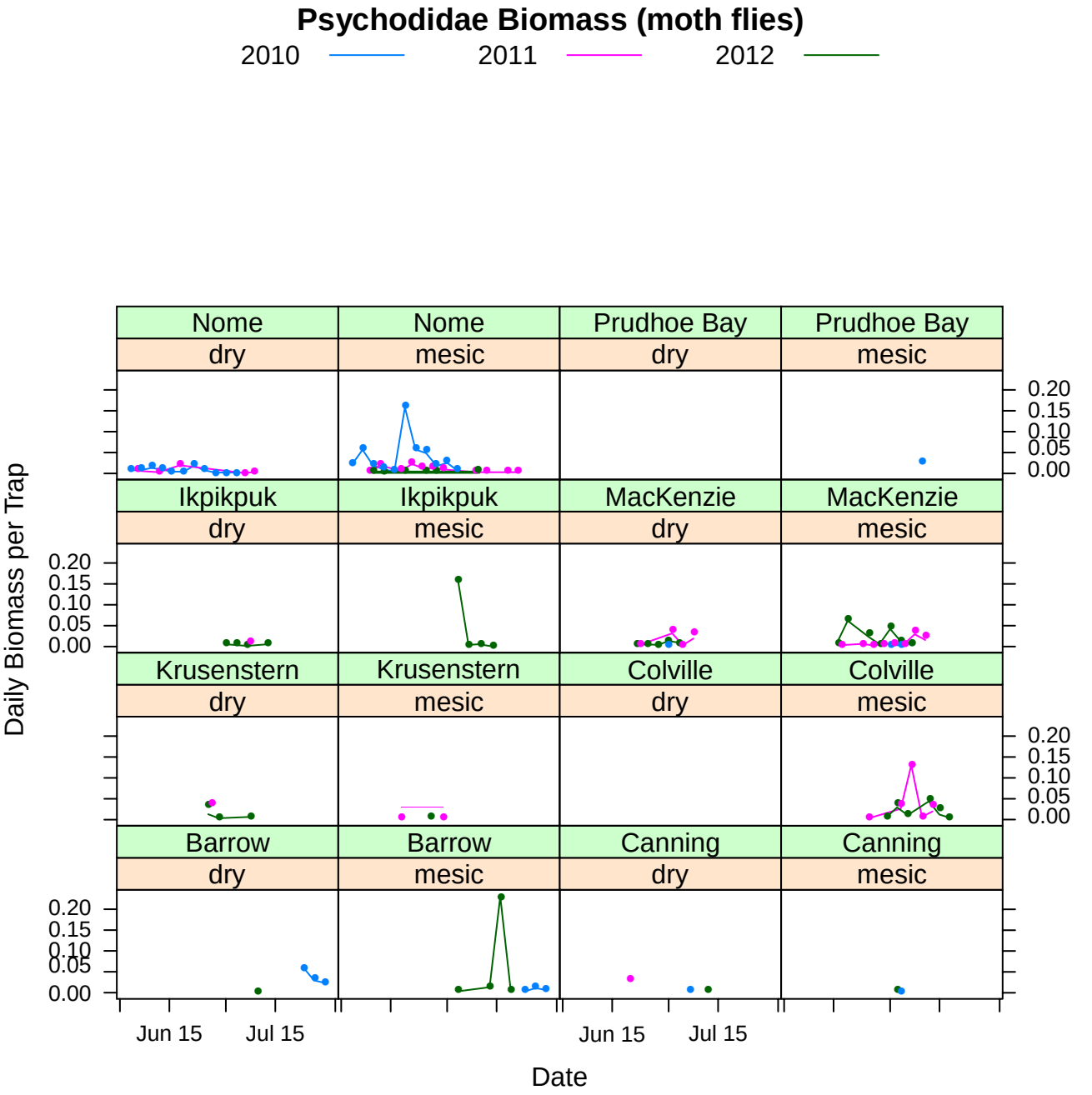

Hydrophilidae Biomass (water scavenger beetles)
2011
Daily Biomass per Trap
Nome
dry
7.6
7.4
7.2
7.0
6.8
Jun 05 12:00
Date

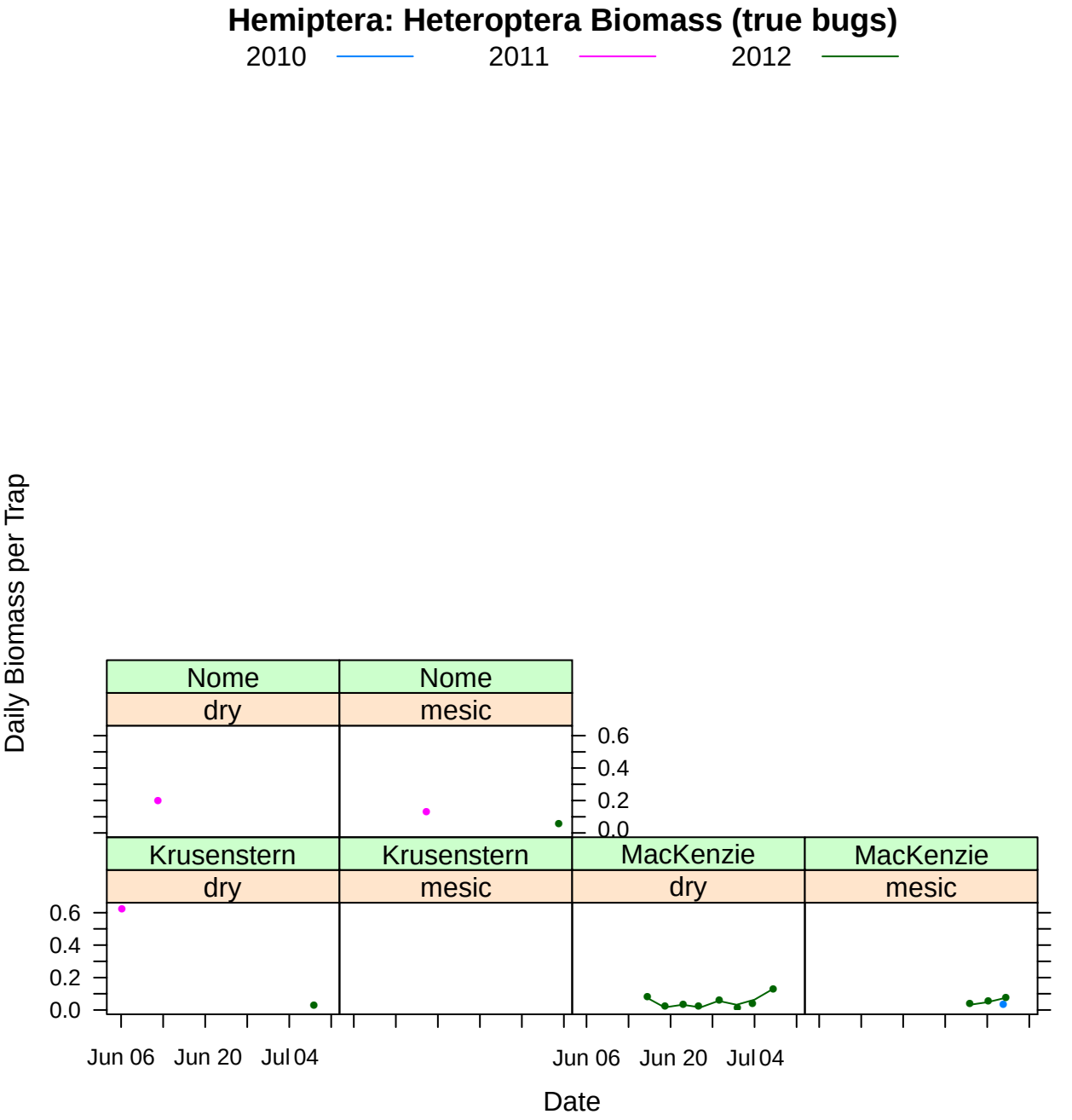

Oligochaeta Biomass (segmented worms)
2010
2011
Daily Biomass per Trap
Nome
dry
Nome
mesic
Prudhoe Bay
dry
Prudhoe Bay
mesic
3.0
2.0
1.0
0.0
Jun 06
Jun 27
Jul 18
Jun 06
Jun 27
Jul 18
Date

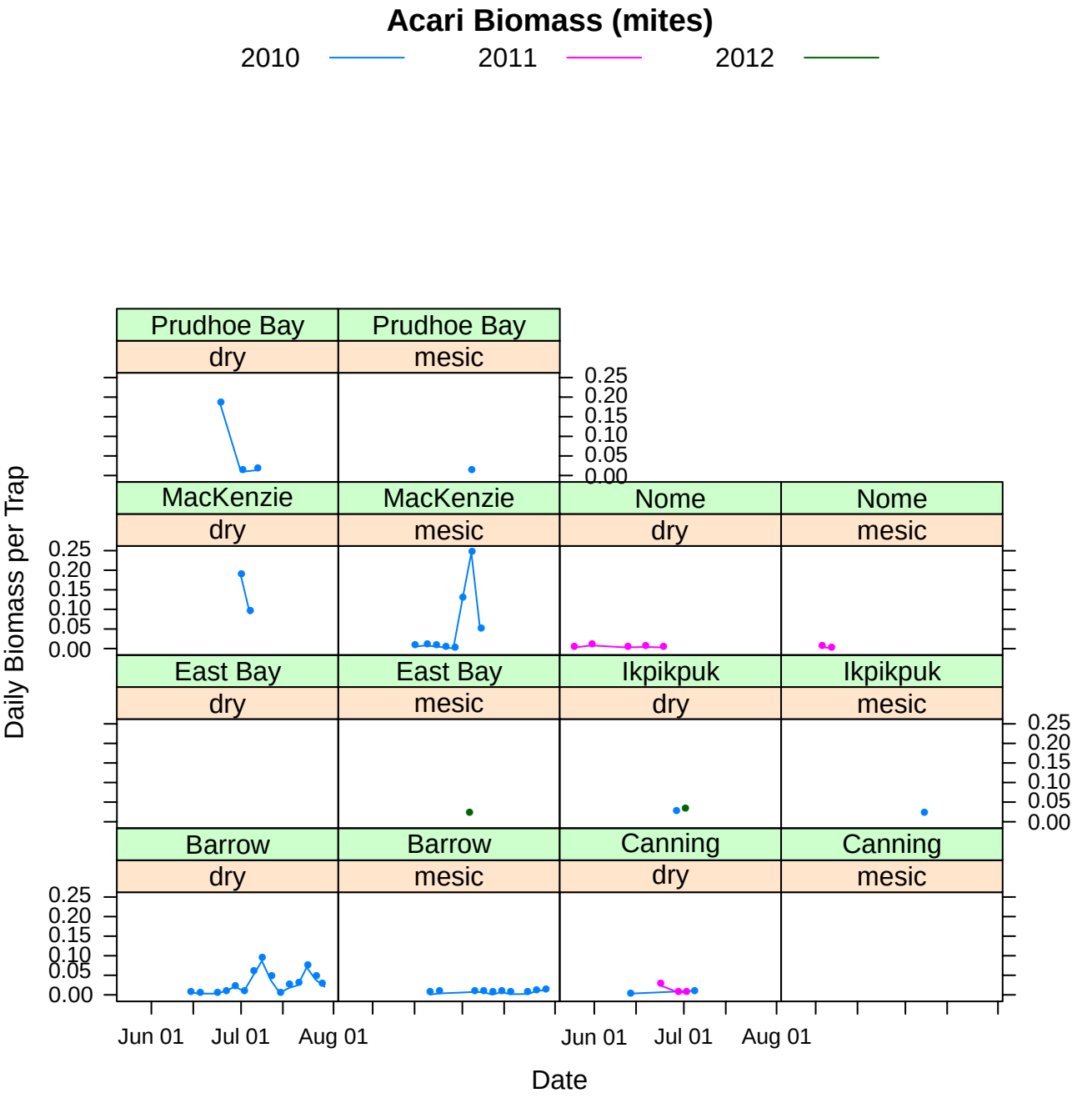

Hemiptera: Sternorrhyncha Biomass (aphids, psyllids, coccids)
2011
Daily Biomass per Trap
Nome
dry
Nome
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
0.5
0.4
0.3
0.2
0.1
0.0
Jun 01
Jul 01
Date


Psyllidae Biomass (psyllids)
2011
2012
Daily Biomass per Trap
Nome
dry
Nome
mesic
Colville
dry
Colville
mesic
MacKenzie
dry
MacKenzie
mesic
0.4
0.3
0.2
0.1
0.0
Jun 01
Jul 01
Date

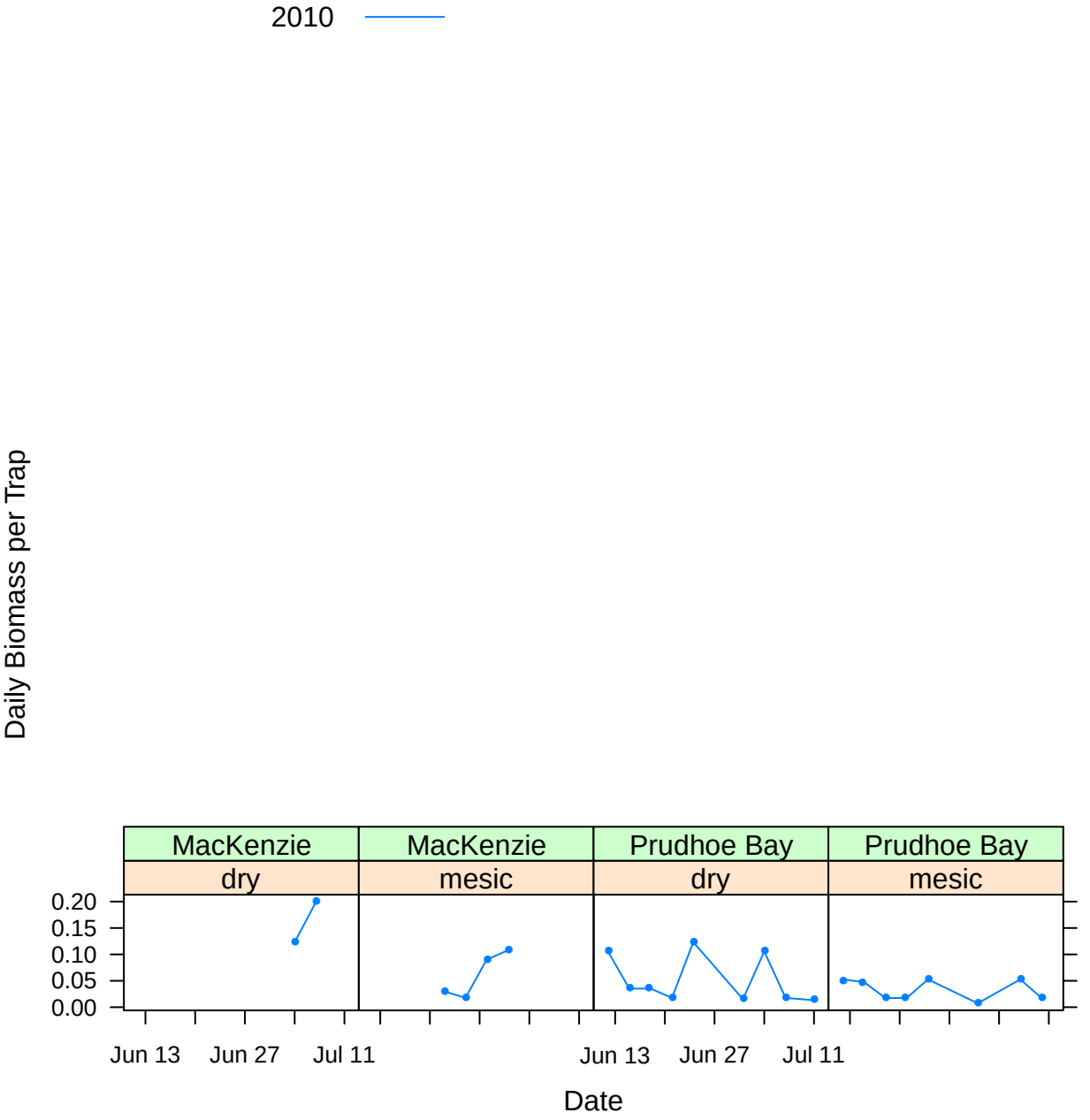

Simuliidae Biomass (black flies)
2011
2012
Daily Biomass per Trap
Nome
dry
Nome
mesic
Colville
dry
Colville
mesic
MacKenzie
dry
MacKenzie
mesic
Barrow
dry
Barrow
mesic
Krusenstern
dry
Krusenstern
mesic
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jun 01
Jul 01
Date

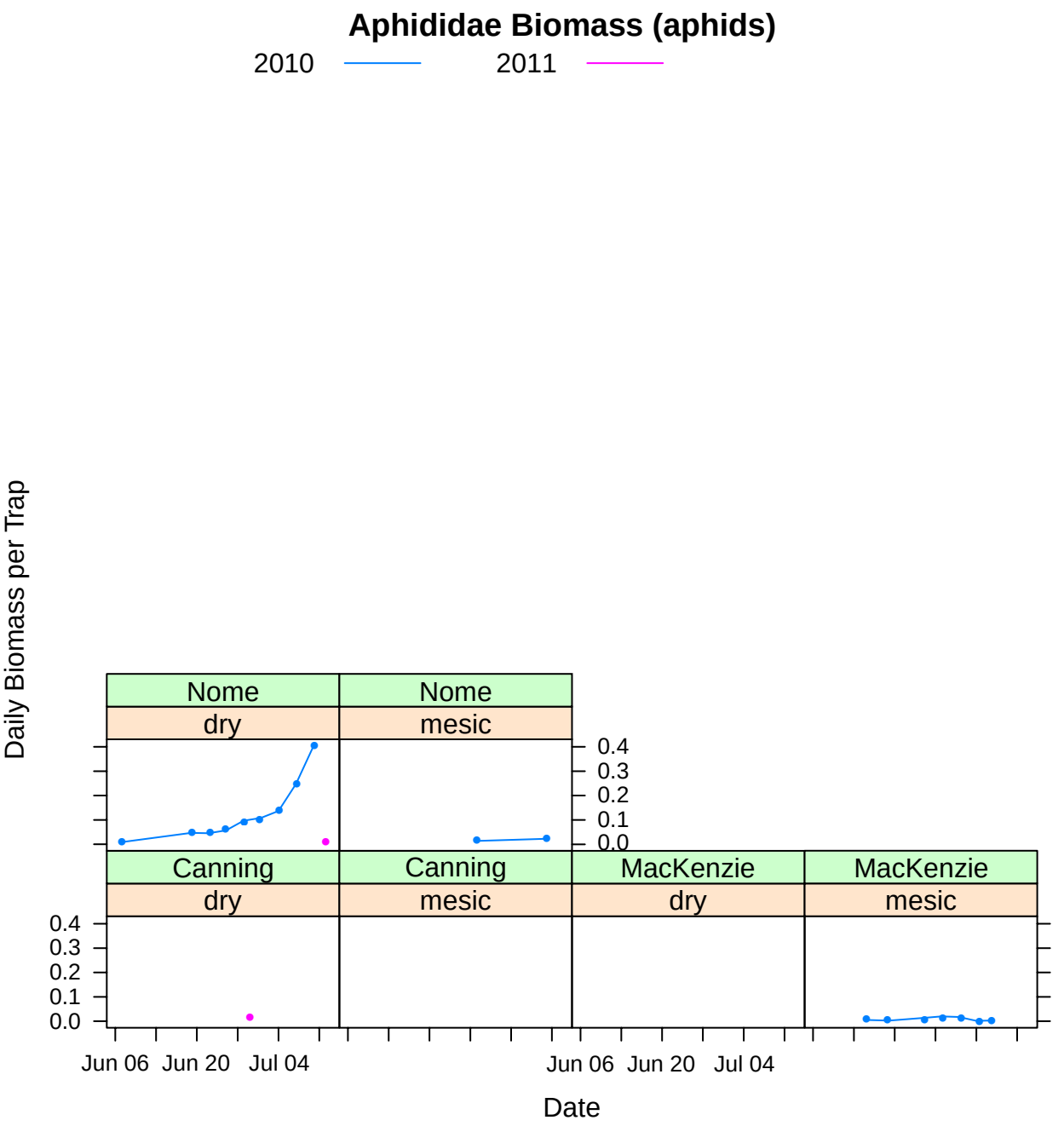

Psychodidae Biomass (moth flies)
2010
2011
2012
Nome
dry
Nome
mesic
Prudhoe Bay
dry
Prudhoe Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
MacKenzie
dry
MacKenzie
mesic
Krusenstern
dry
Krusenstern
mesic
Colville
dry
Colville
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
0.20
0.15
0.10
0.05
0.00
Daily Biomass per Trap
Jun 15
Jul 15
Date

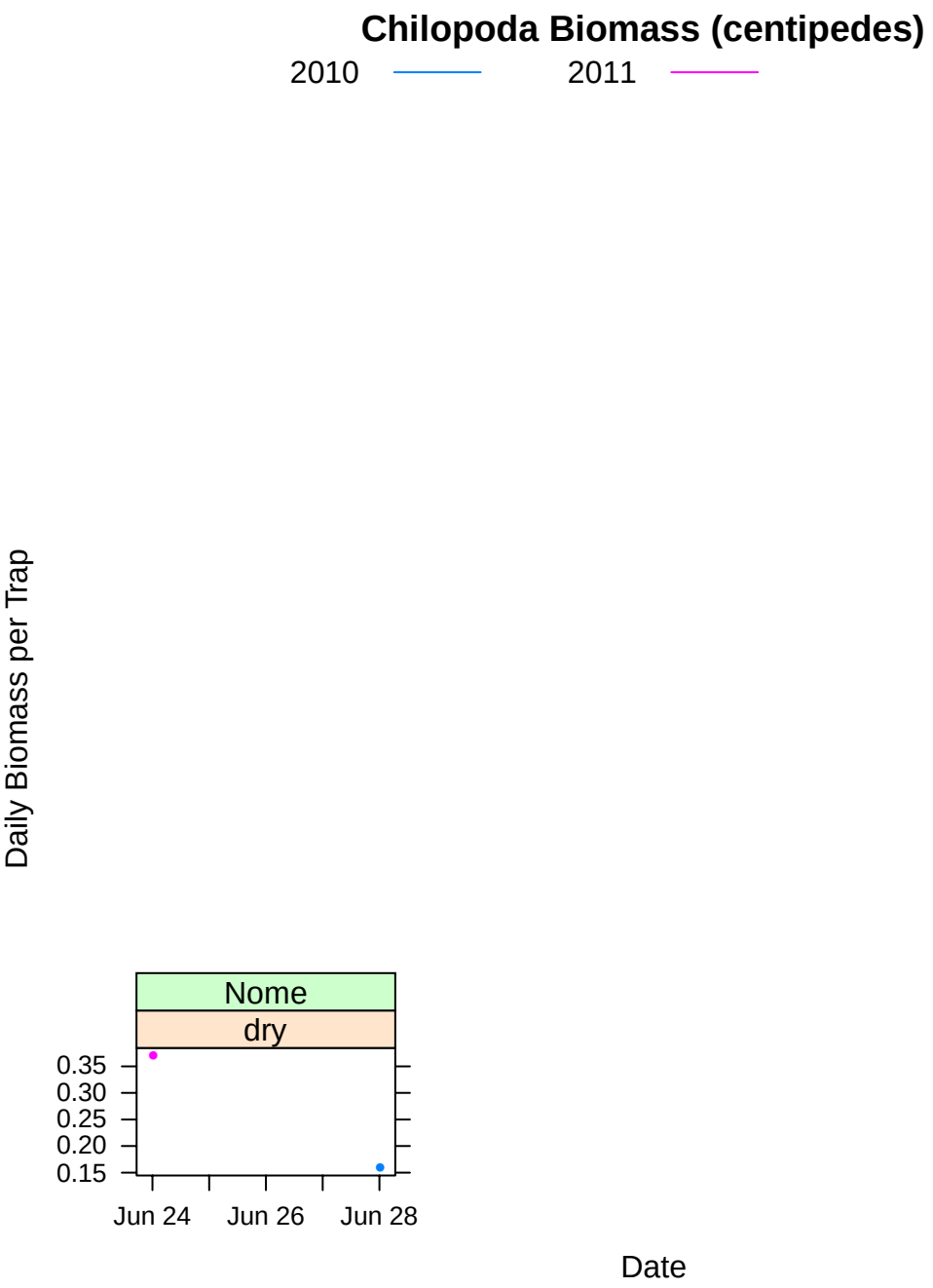

Hemiptera: Heteroptera Biomass (true bugs)
2010
2011
2012
Daily Biomass per Trap
Nome
dry
Nome
mesic
Krusenstern
dry
Krusenstern
mesic
MacKenzie
dry
MacKenzie
mesic
0.6
0.4
0.2
0.0
Jun 06
Jun 20
Jul 04
Date

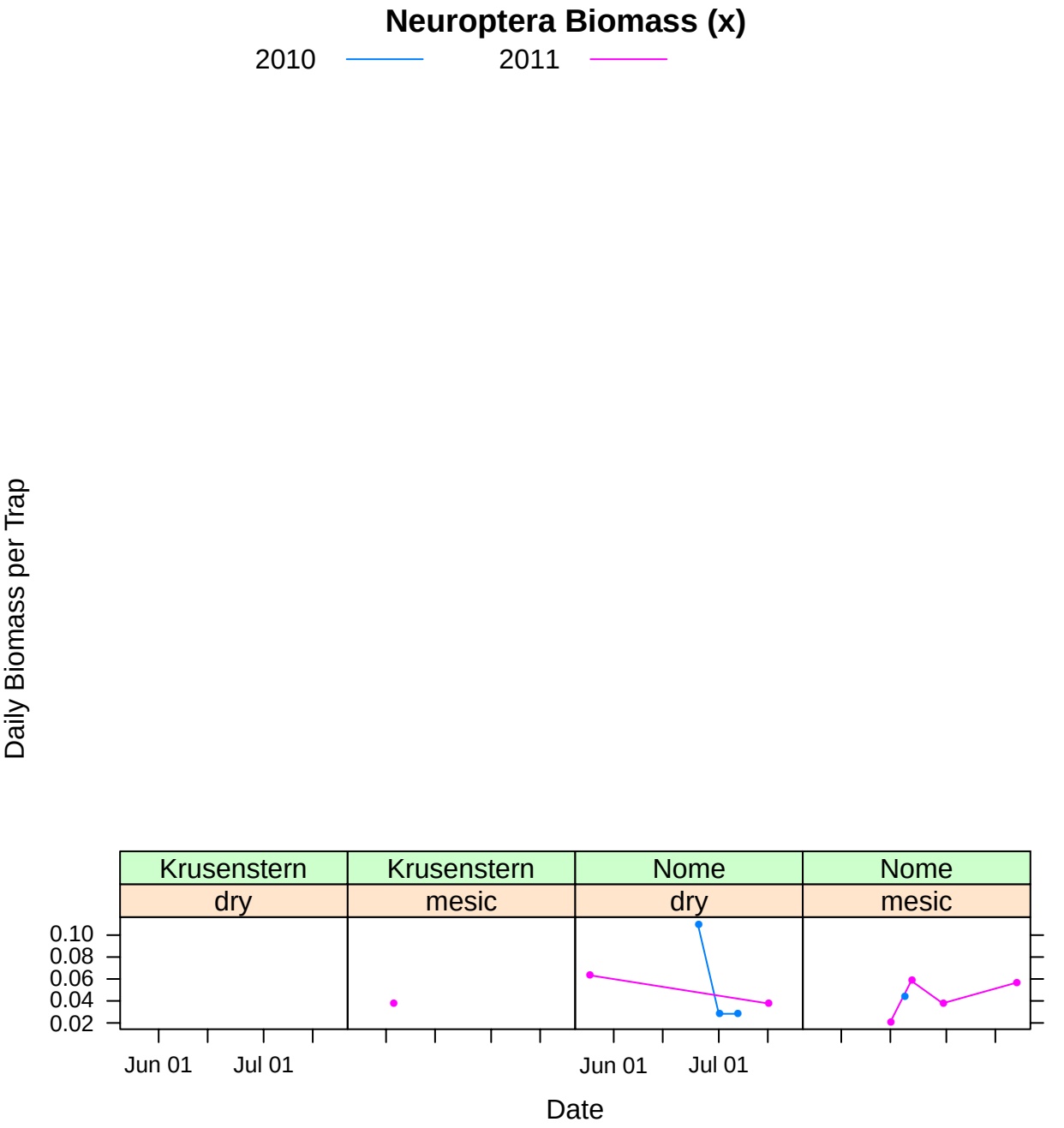

Acari Biomass (mites)
2010
2011
2012
Prudhoe Bay
dry
Prudhoe Bay
mesic
MacKenzie
dry
MacKenzie
mesic
Nome
dry
Nome
mesic
East Bay
dry
East Bay
mesic
Ikpikpuk
dry
Ikpikpuk
mesic
Barrow
dry
Barrow
mesic
Canning
dry
Canning
mesic
0.25
0.20
0.15
0.10
0.05
0.00
Daily Biomass per Trap
Jun 01
Jul 01
Aug 01
Date

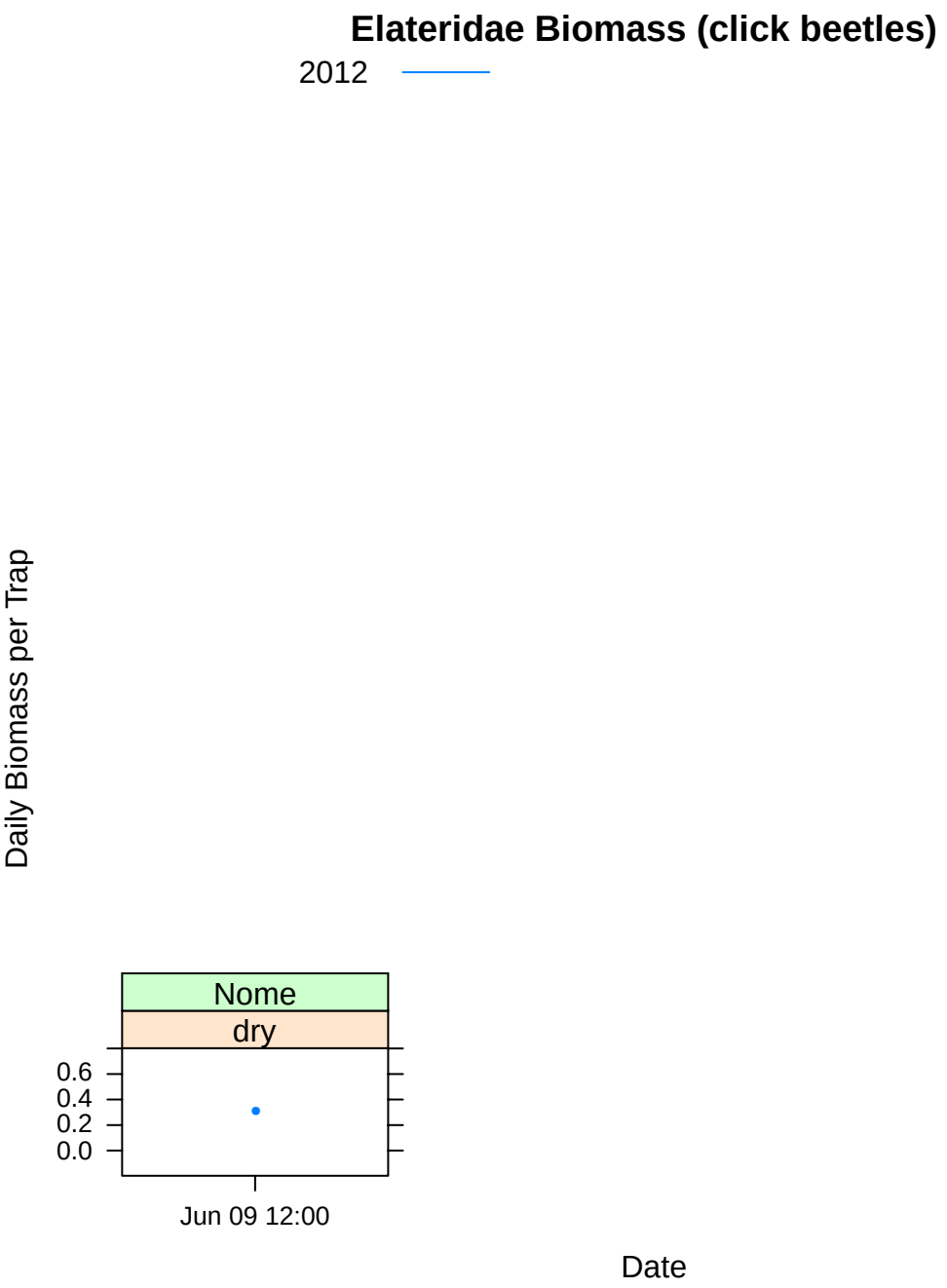
Psocoptera Biomass (psocids)

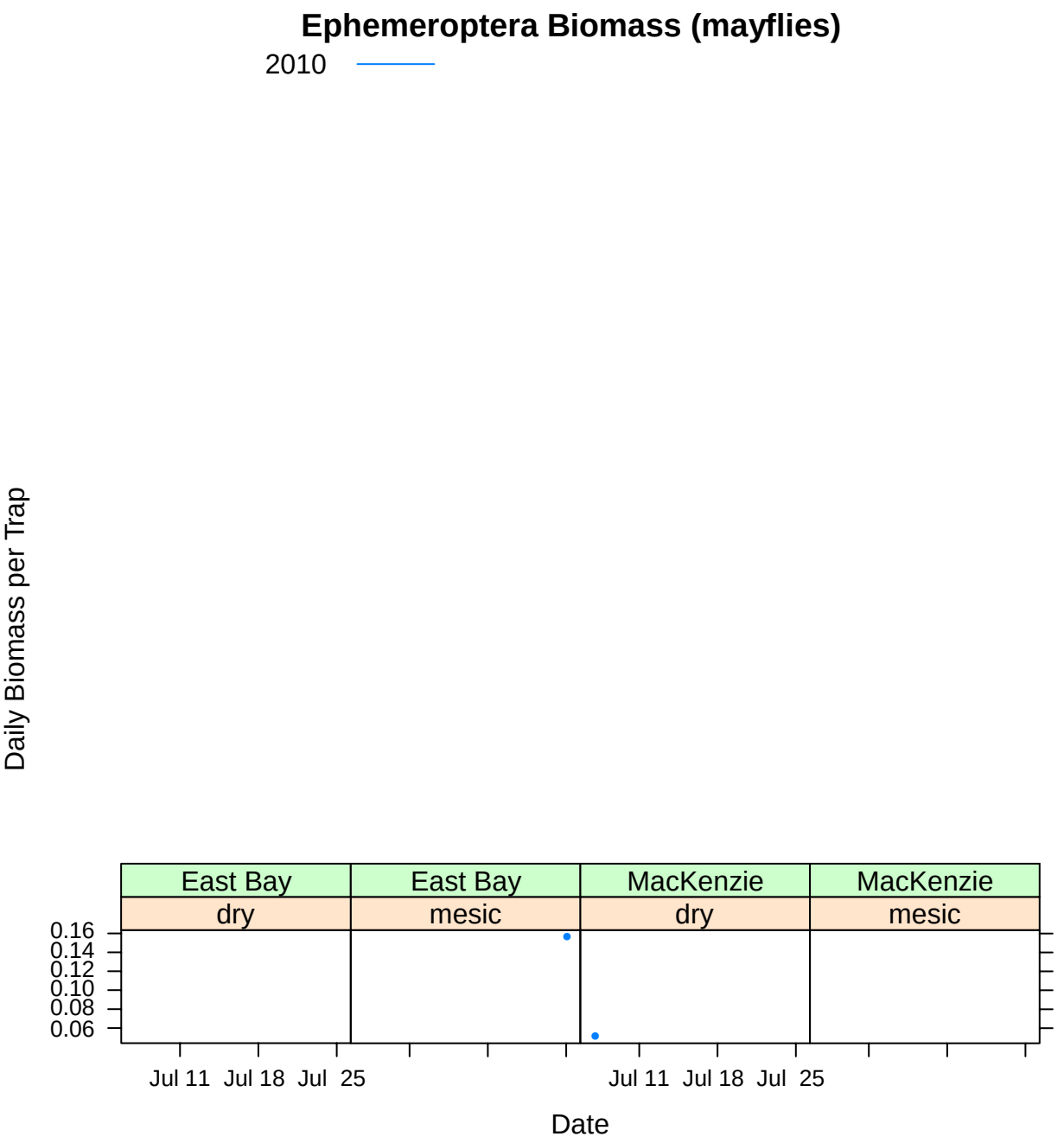


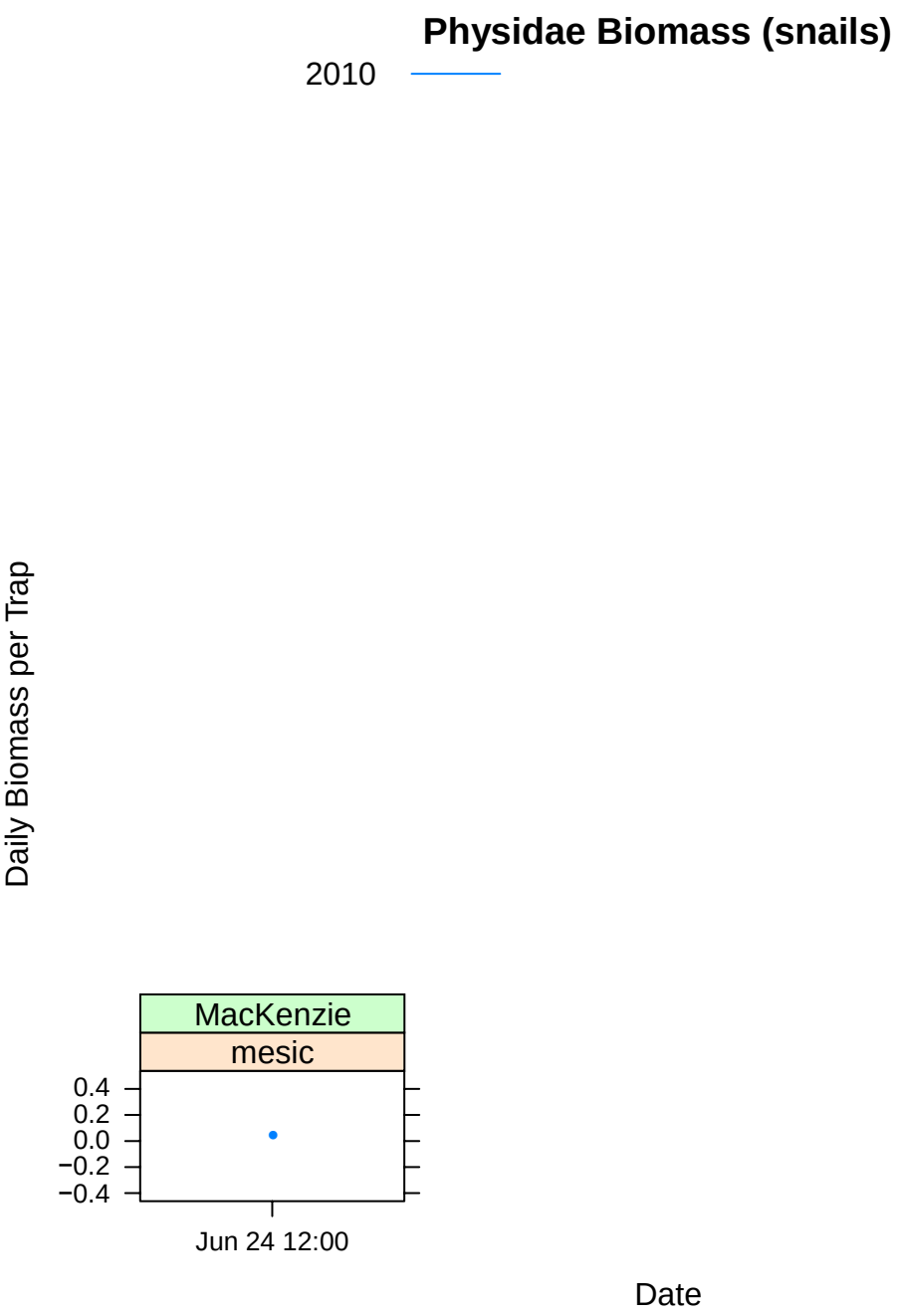

Aphididae Biomass (aphids)
2010
2011
Daily Biomass per Trap
Nome
dry
Nome
mesic
Canning
dry
Canning
mesic
MacKenzie
dry
MacKenzie
mesic
0.4
0.3
0.2
0.1
0.0
Jun 06
Jun 20
Jul 04
Date

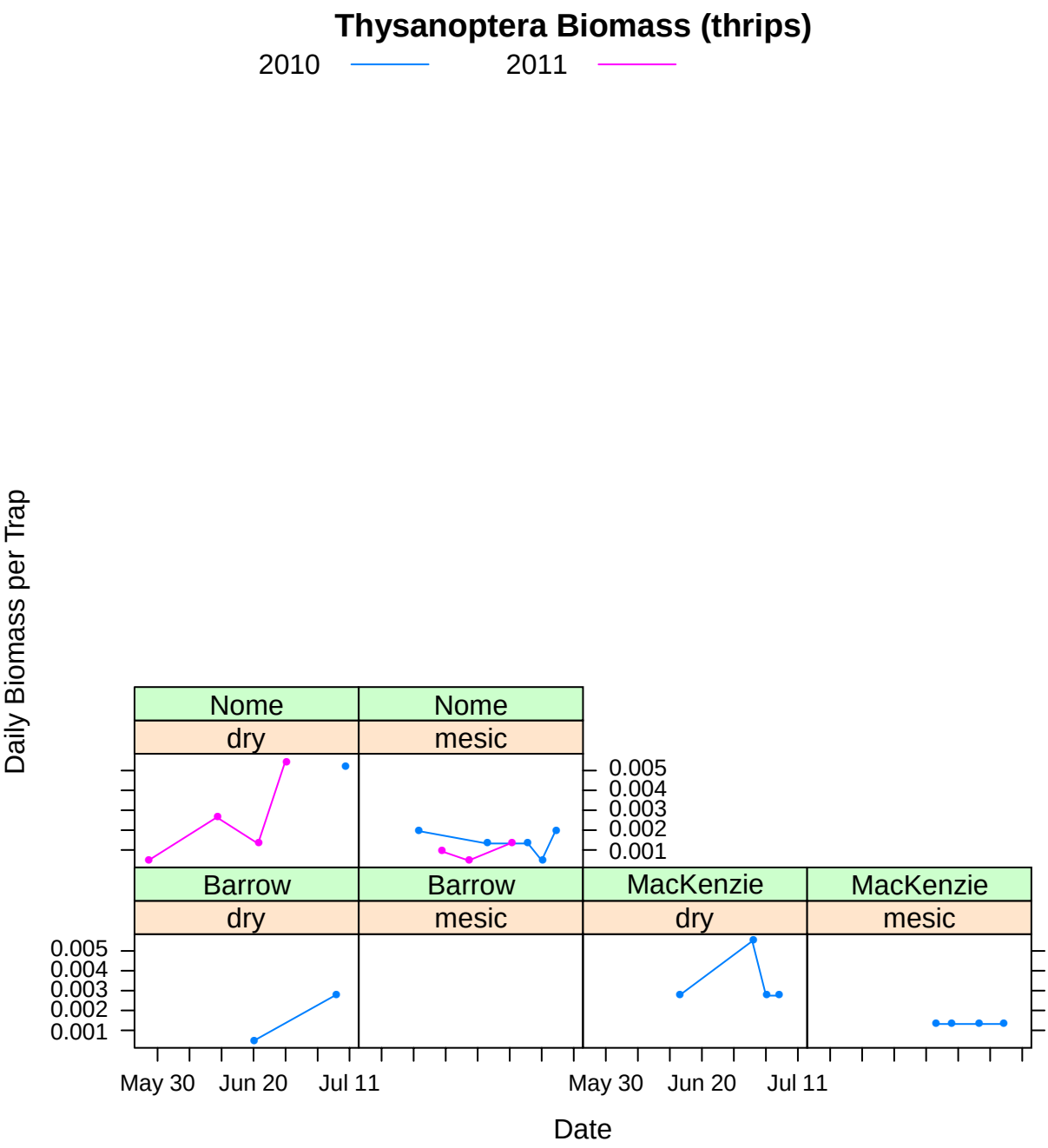

Chilopoda Biomass (centipedes)
2010
2011
Daily Biomass per Trap
Nome
dry
0.35
0.30
0.25
0.20
0.15
Jun 24
Jun 26
Jun 28
Date

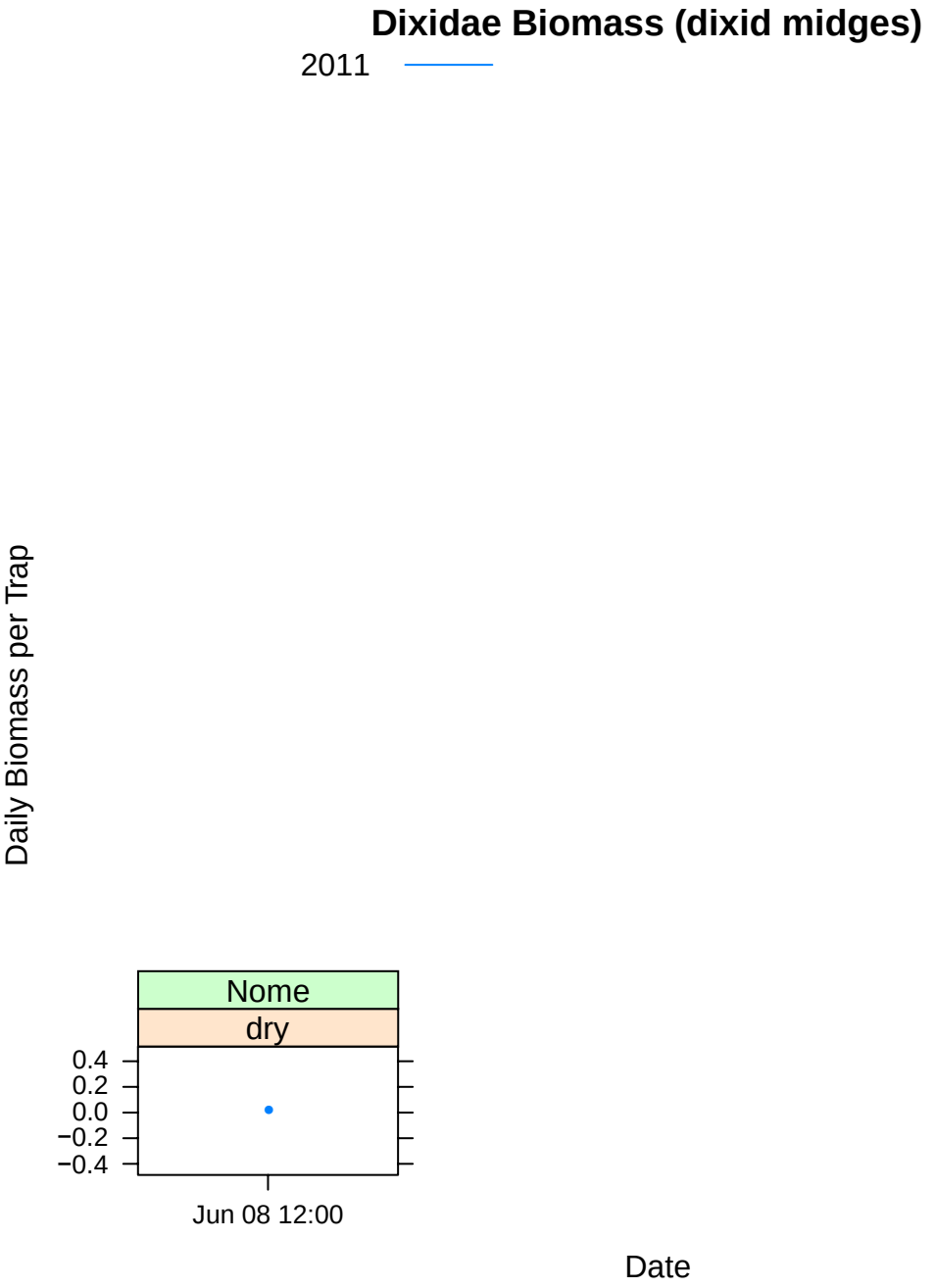

Neuroptera Biomass (x)
2010
2011
Daily Biomass per Trap
Krusenstern
dry
Krusenstern
mesic
Nome
dry
Nome
mesic
0.10
0.08
0.06
0.04
0.02
Jun 01
Jul 01
Jun 01
Jul 01
Date


Elateridae Biomass (click beetles)
2012
Daily Biomass per Trap
Nome
dry
0.6
0.4
0.2
0.0
Jun 09 12:00
Date

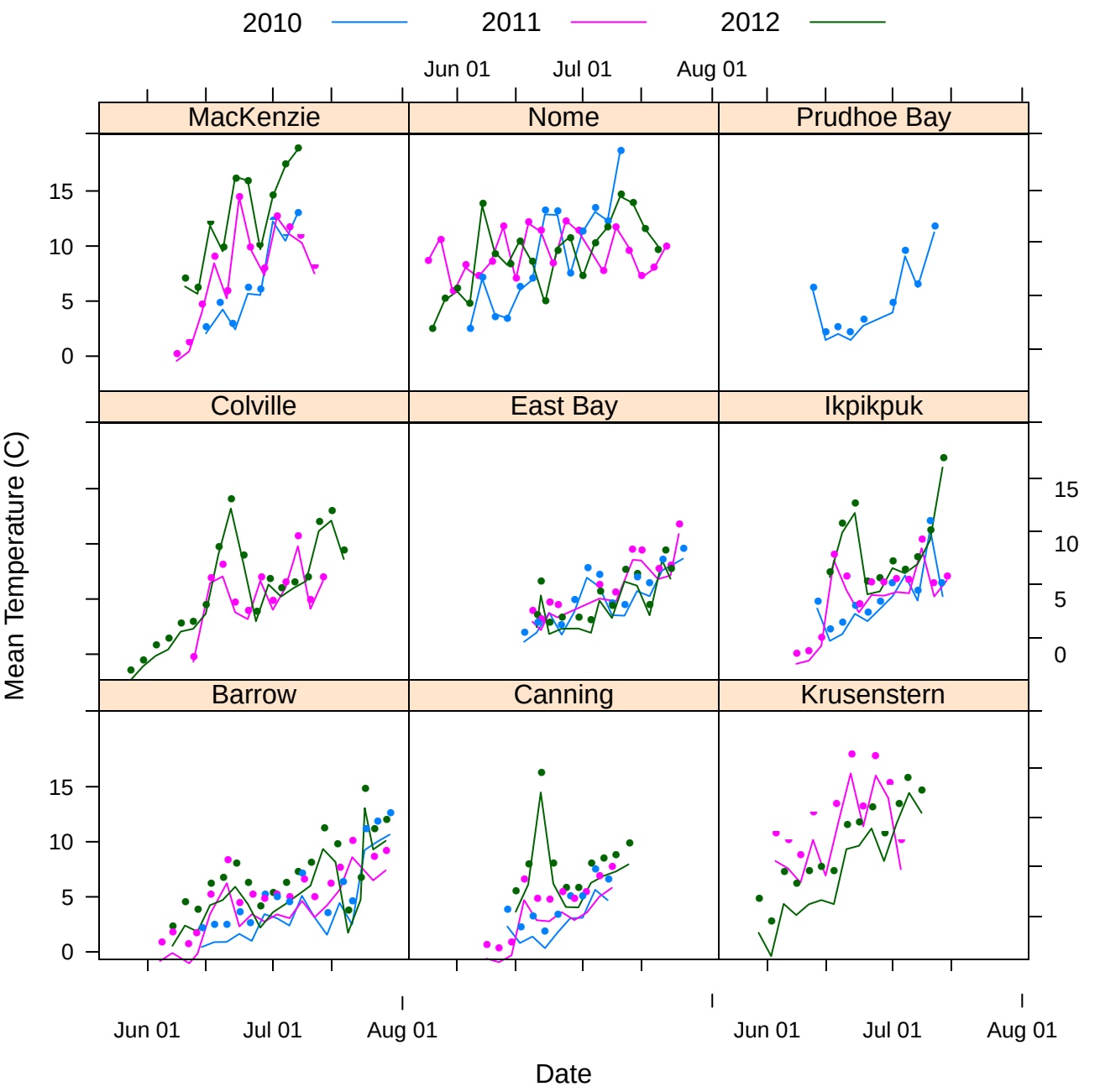

Ephemeroptera Biomass (mayflies)
2010
Daily Biomass per Trap
East Bay
dry
East Bay
mesic
MacKenzie
dry
MacKenzie
mesic
0.16
0.14
0.12
0.10
0.08
0.06
Jul 11
Jul 18
Jul 25
Jul 11
Jul 18
Jul 25
Date

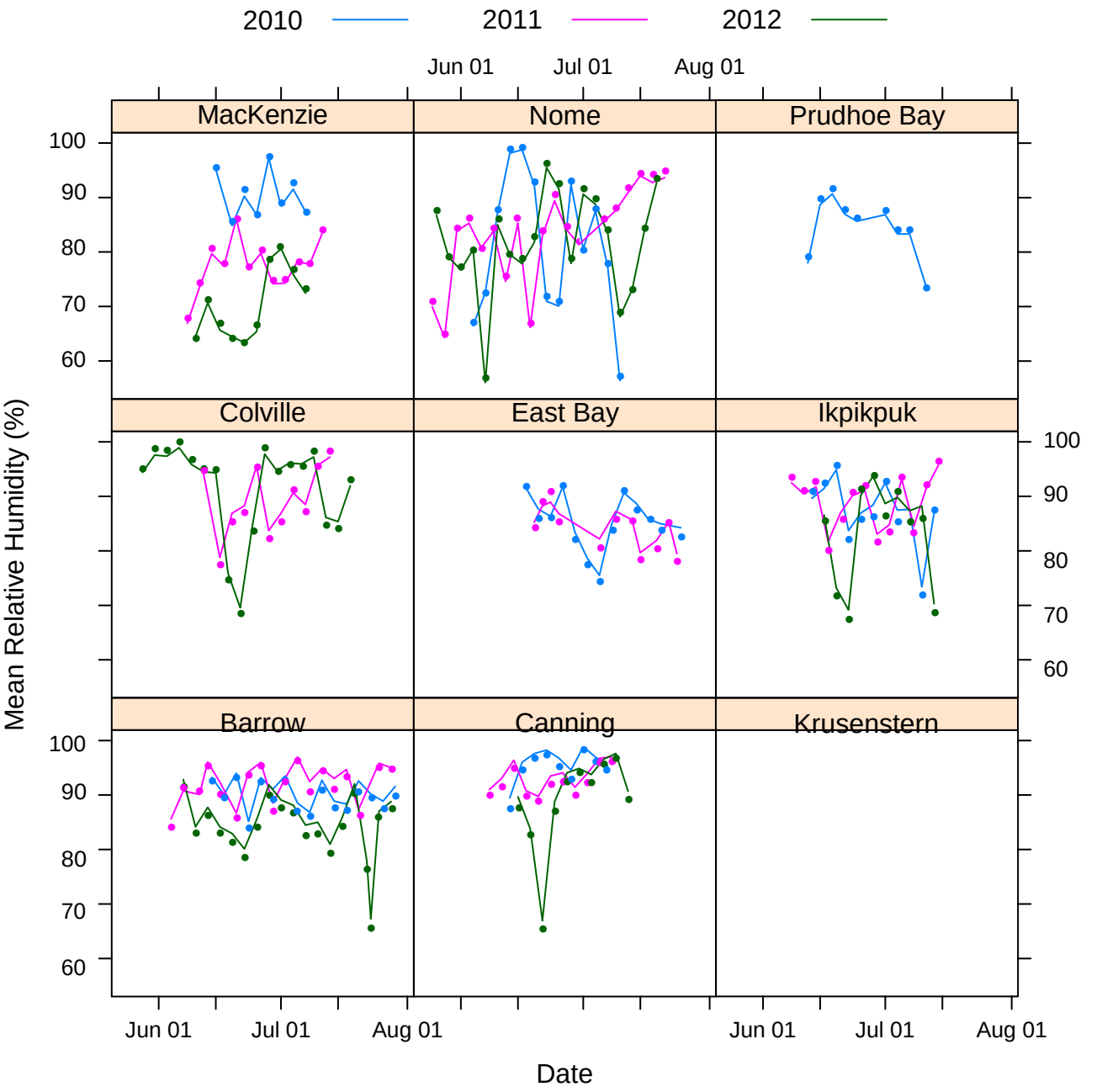

Physidae Biomass (snails)
2010
Daily Biomass per Trap
MacKenzie
mesic
0.4
0.2
0.0
−0.2
−0.4
Jun 24 12:00
Date

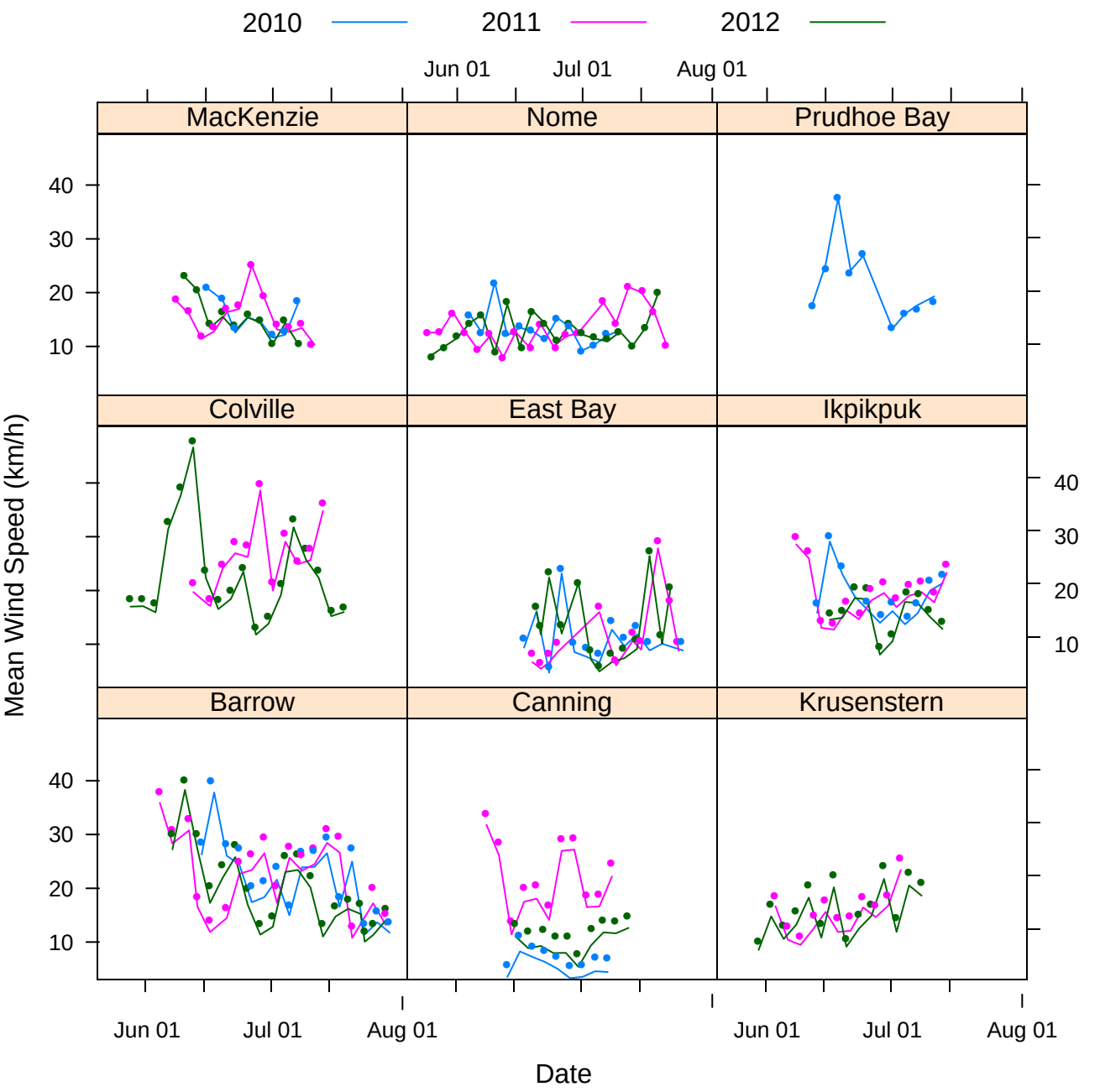

Thysanoptera Biomass (thrips)
2010
2011
Daily Biomass per Trap
Nome
dry
Nome
mesic
Barrow
dry
Barrow
mesic
MacKenzie
dry
MacKenzie
mesic
0.005
0.004
0.003
0.002
0.001
May 30
Jun 20
Jul 11
Date

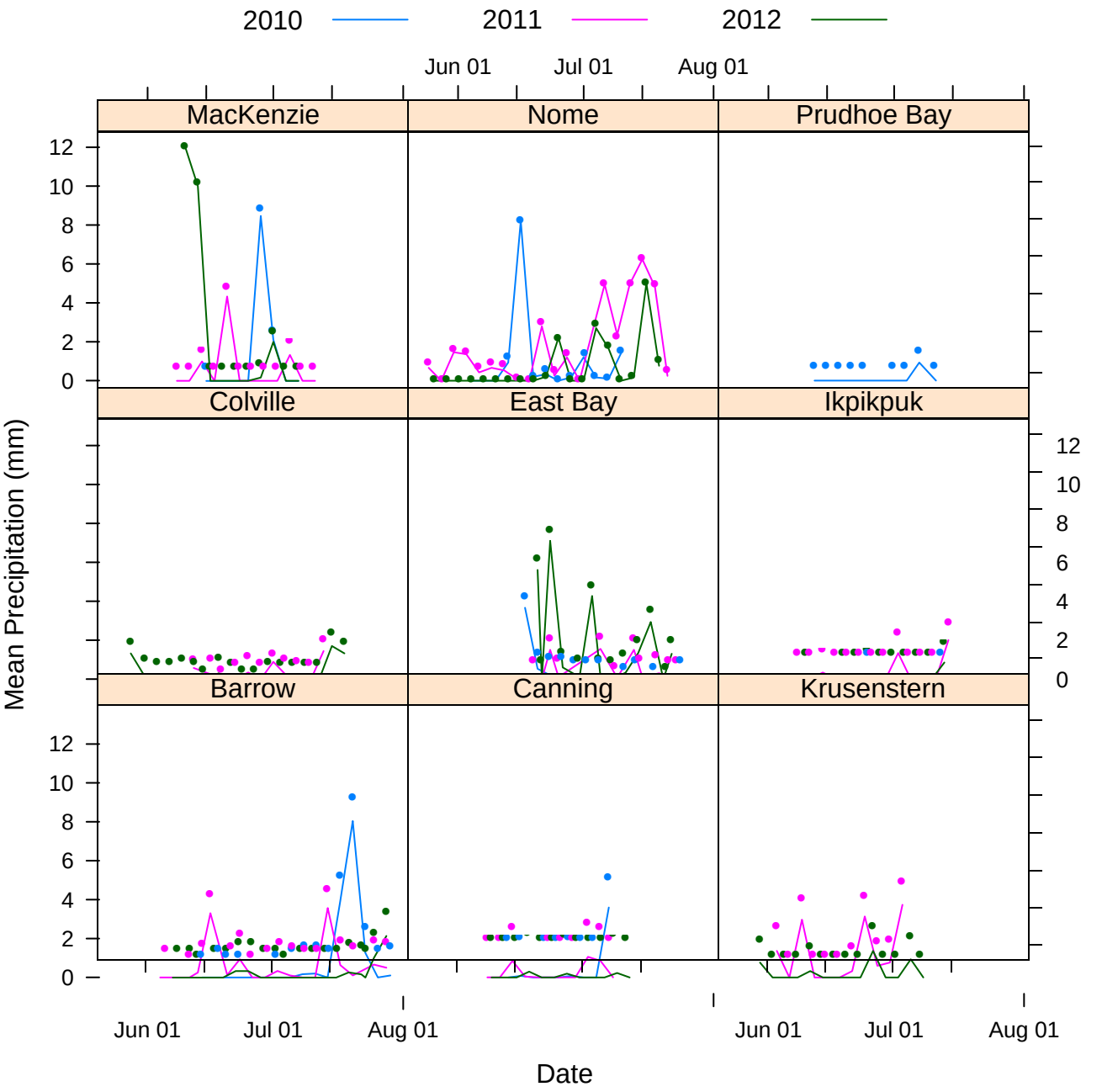

Dixidae Biomass (dixid midges)
2011
Daily Biomass per Trap
Nome
dry
0.4
0.2
0.0
−0.2
−0.4
Jun 08 12:00
Date

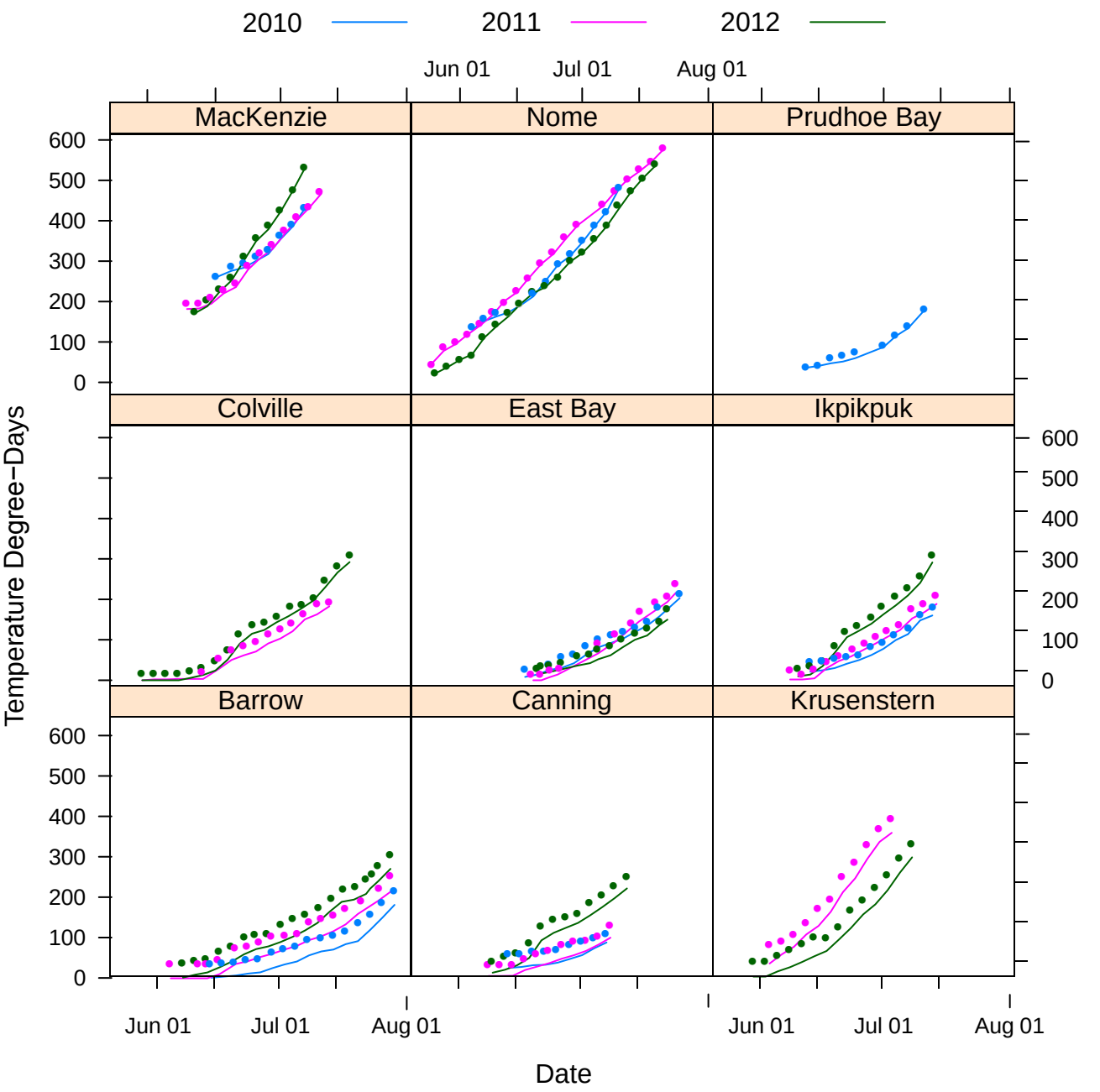
Appendix B

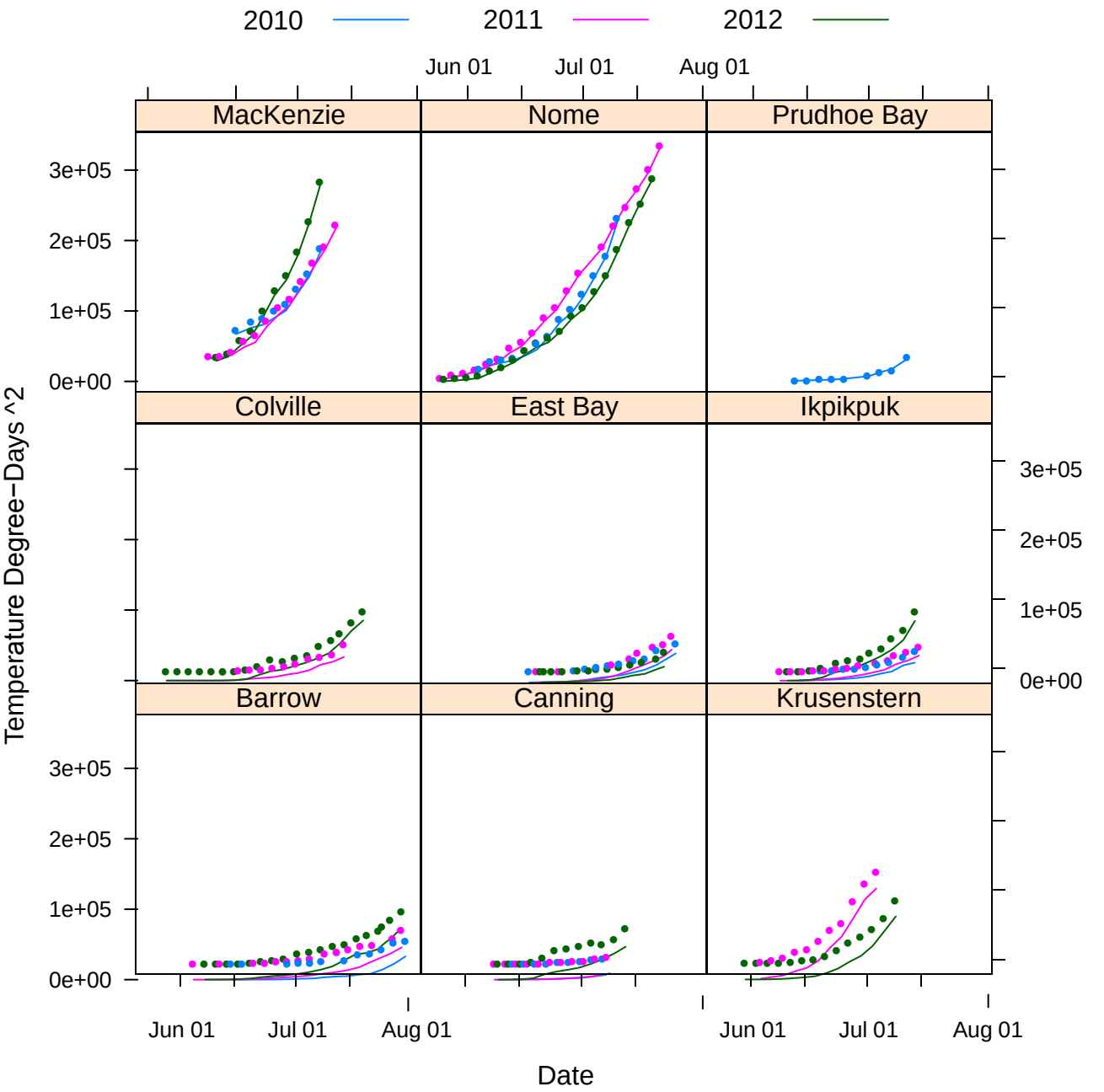

2010
2011
2012
Jun 01
Jul 01
Aug 01
MacKenzie
Nome
Prudhoe Bay
Colville
East Bay
Ikpikpuk
Barrow
Canning
Krusenstern
Mean Temperature (C)
Date
0
5
10
15


2010
2011
2012
MacKenzie
Nome
Prudhoe Bay
Colville
East Bay
Ikpikpuk
Barrow
Canning
Krusenstern
Mean Relative Humidity (%)
Date
Jun 01
Jul 01
Aug 01
100
90
80
70
60


2010
2011
2012
MacKenzie
Nome
Prudhoe Bay
Colville
East Bay
Ikpikpuk
Barrow
Canning
Krusenstern
Mean Wind Speed (km/h)
10
20
30
40
Jun 01
Jul 01
Aug 01
Date

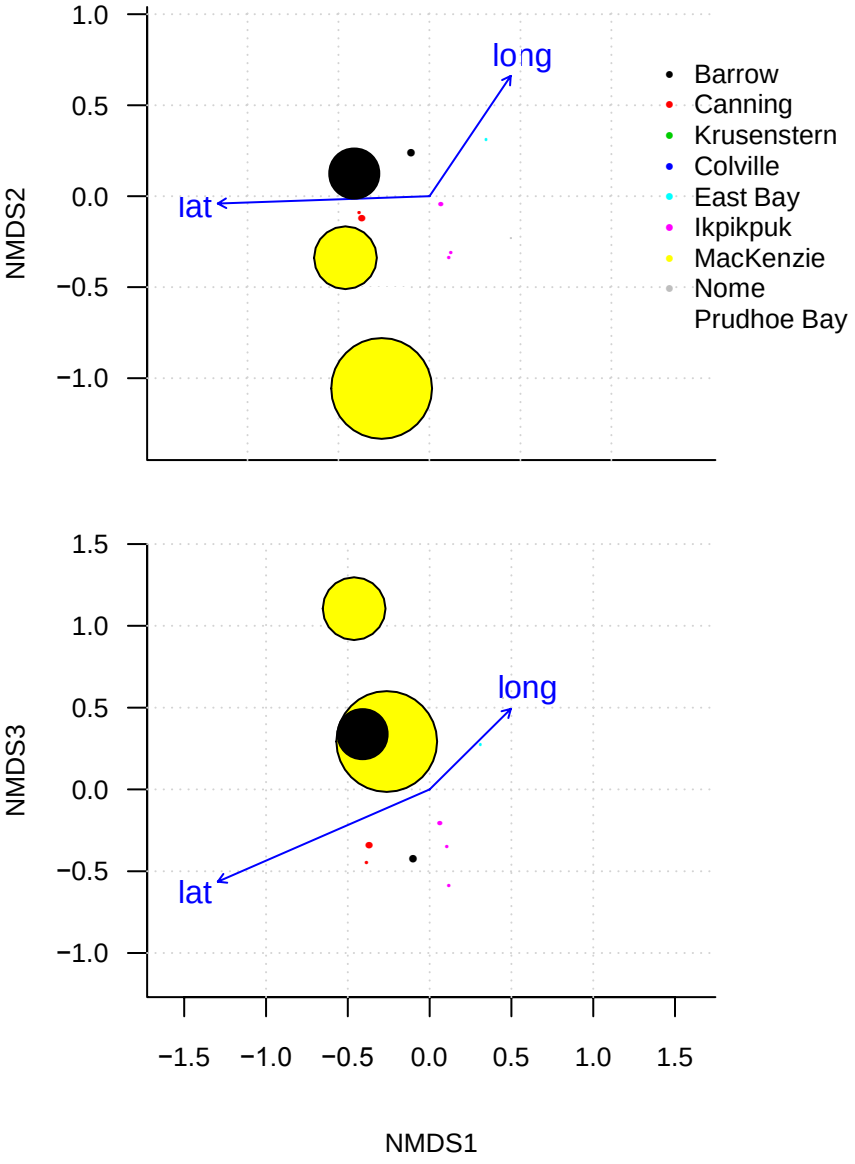

2010
2011
2012
MacKenzie
Nome
Prudhoe Bay
Colville
East Bay
Ikpikpuk
Barrow
Canning
Krusenstern
Jun 01
Jul 01
Aug 01
0
2
4
6
8
10
12
Mean Precipitation (mm)
Date


2010
2011
2012
MacKenzie
Nome
Prudhoe Bay
Colville
East Bay
Ikpikpuk
Barrow
Canning
Krusenstern
Jun 01
Jul 01
Aug 01
0
100
200
300
400
500
600
Temperature Degree−Days
Date

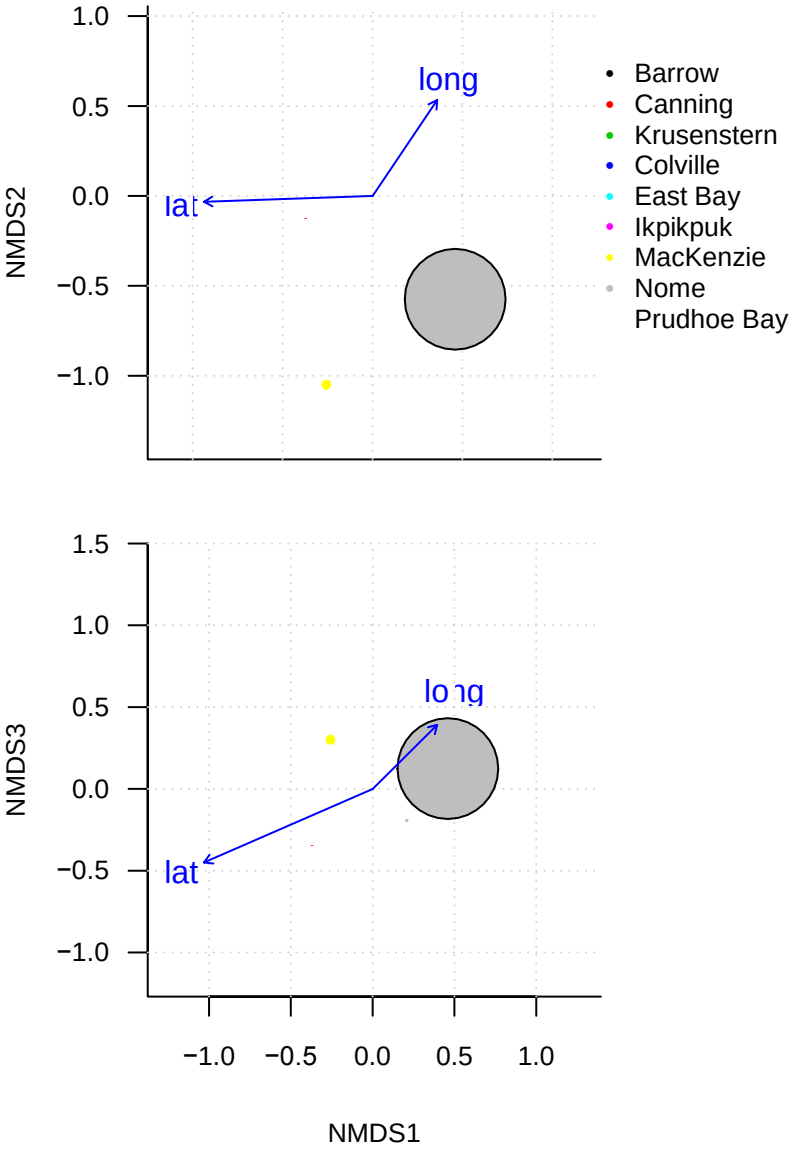

2010
2011
2012
MacKenzie
Nome
Prudhoe Bay
Colville
East Bay
Ikpikpuk
Barrow
Canning
Krusenstern
Jun 01
Jul 01
Aug 01
0e+00
1e+05
2e+05
3e+05
Temperature Degree−Days ^2
Date

Appendix C

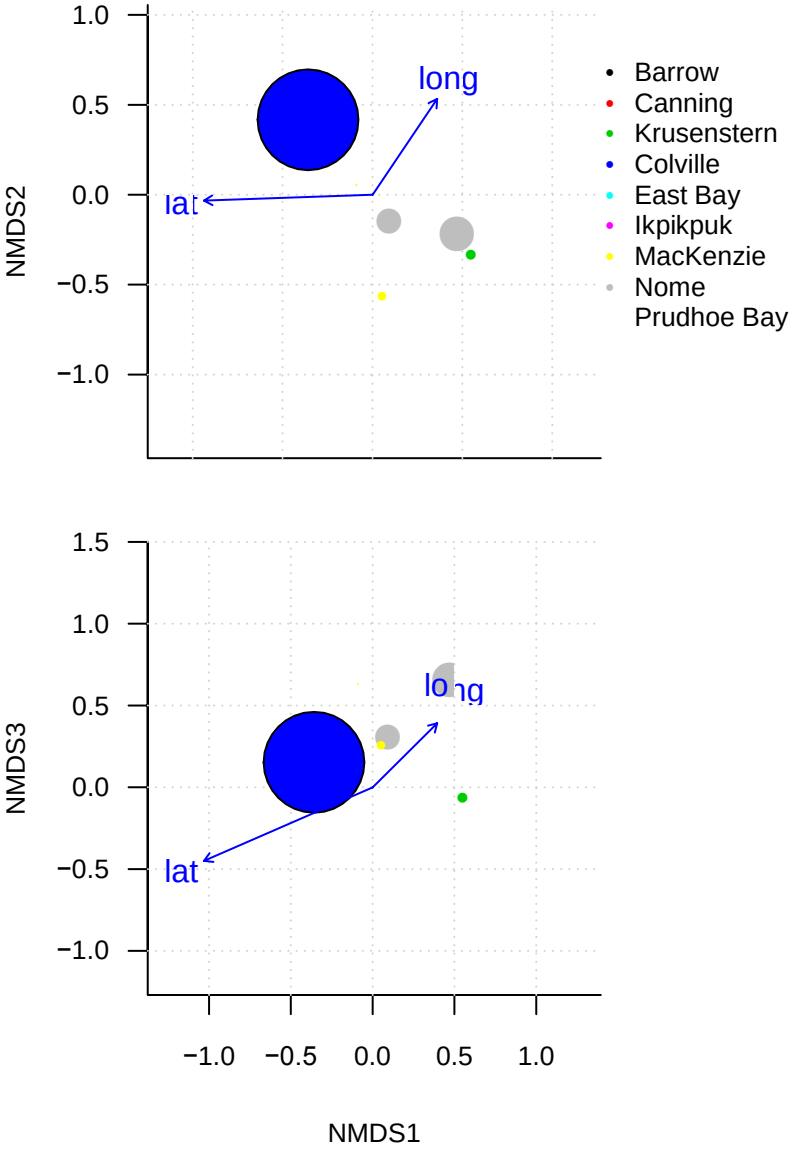
Acari (mites)


1.0
0.5
0.0
−0.5
−1.0
NMDS2
long
lat
Barrow
Canning
Krusenstern
Colville
East Bay
Ikpikpuk
MacKenzie
Nome
Prudhoe Bay
1.5
1.0
0.5
0.0
−0.5
−1.0
NMDS3
long
lat
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
NMDS1

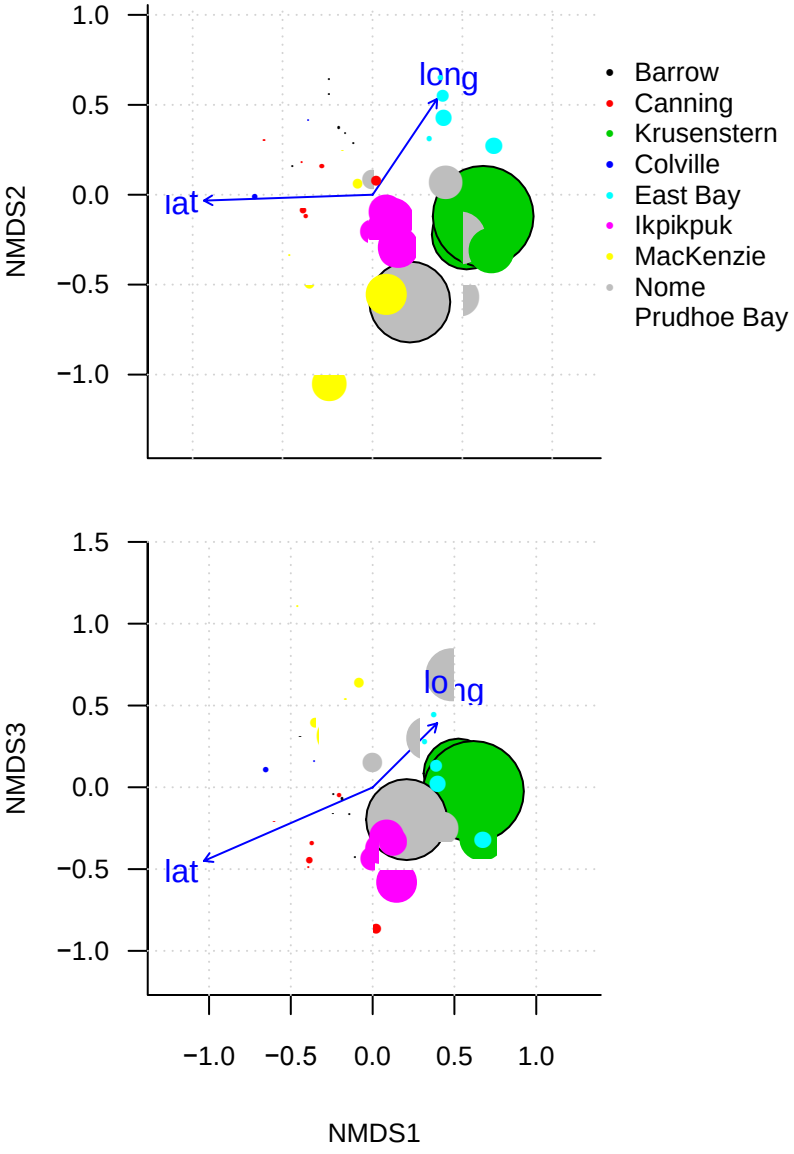
Aphididae (aphids)



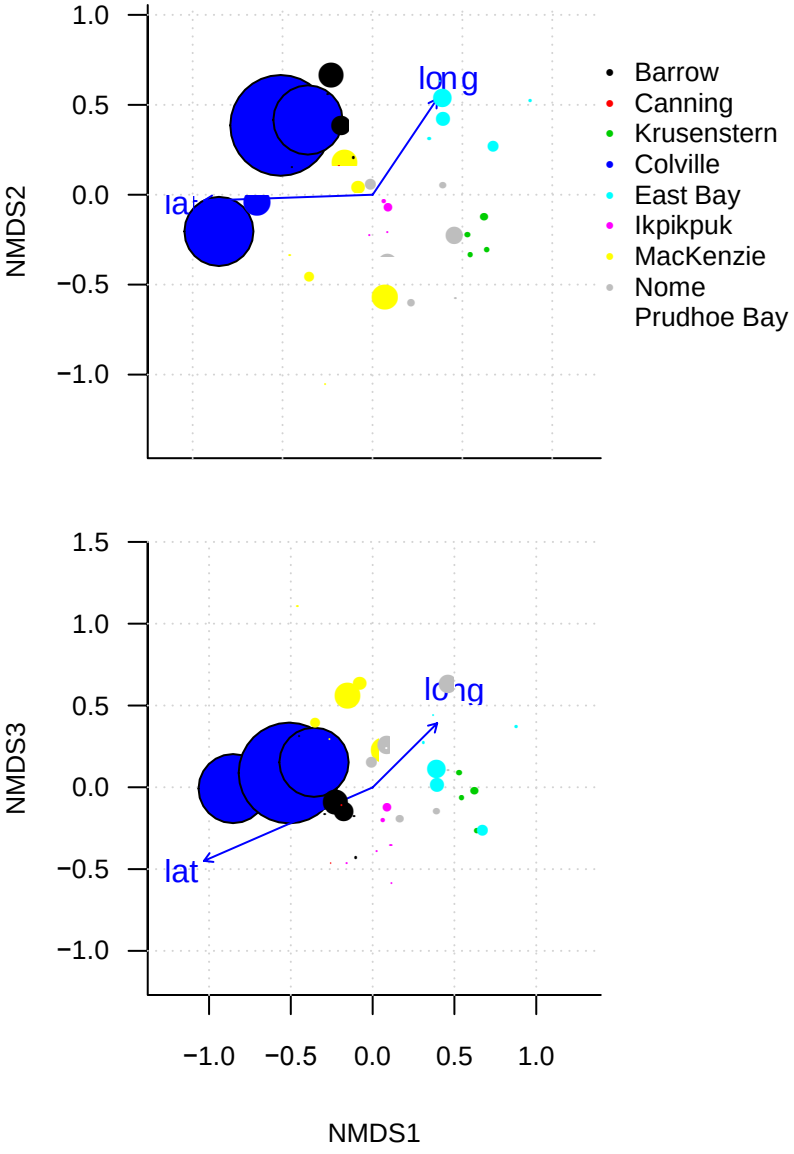
Apidae (bees)


1.0
0.5
0.0
−0.5
−1.0
NMDS2
long
lat
Barrow
Canning
Krusenstern
Colville
East Bay
Ikpikpuk
MacKenzie
Nome
Prudhoe Bay
1.5
1.0
0.5
0.0
−0.5
−1.0
NMDS3
long
lat
−1.0
−0.5
0.0
0.5
1.0
NMDS1

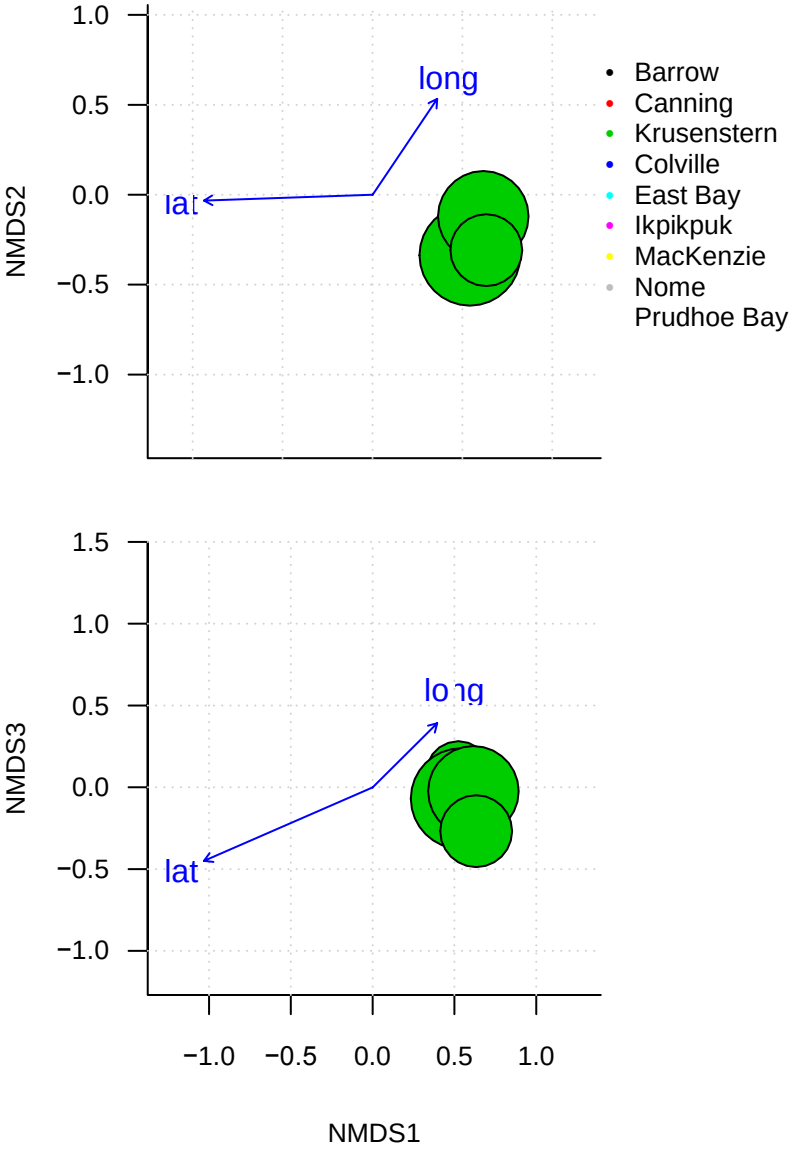
Araneae (spiders)



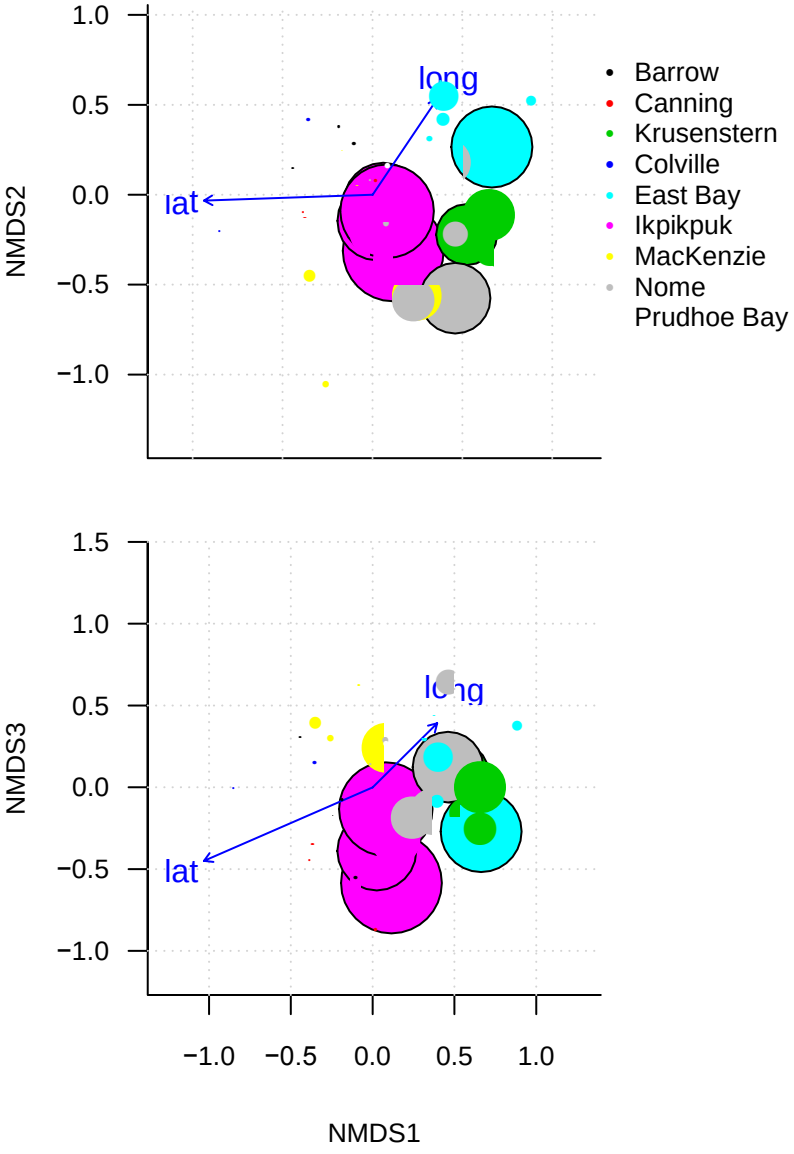
Brachycera (higher flies)



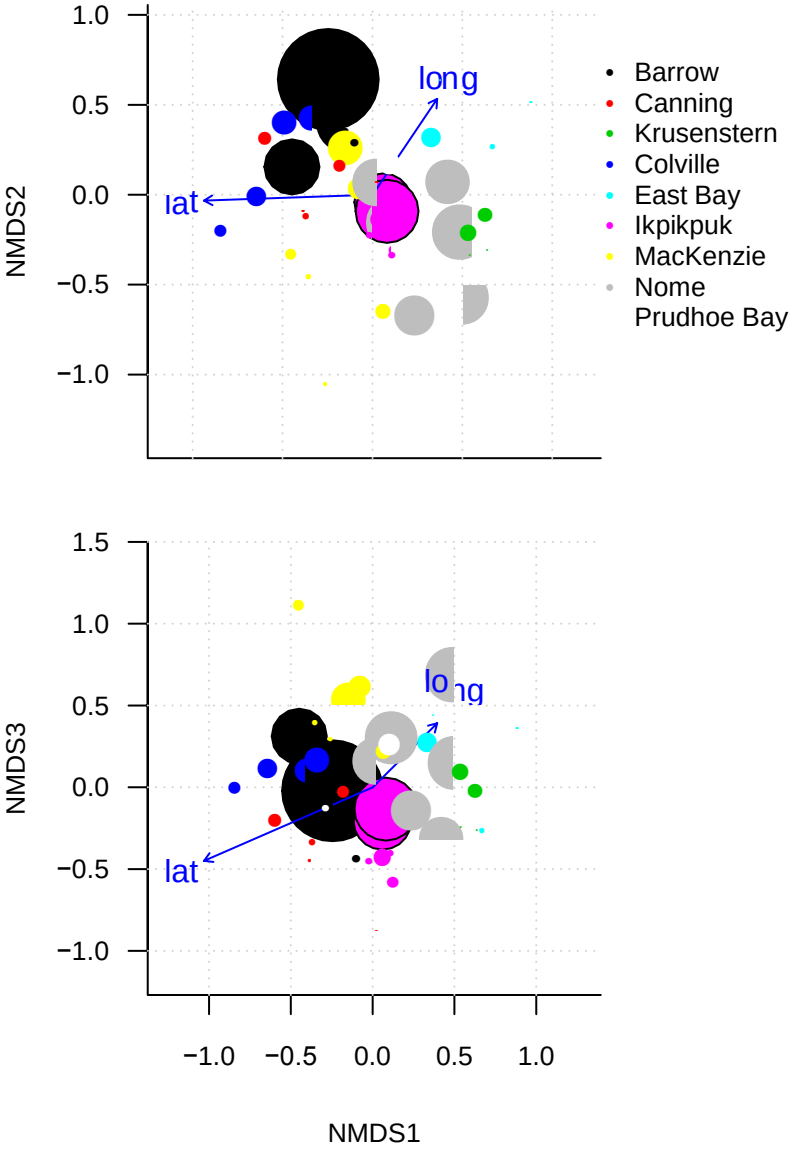
Cantharidae (soldier beetles)



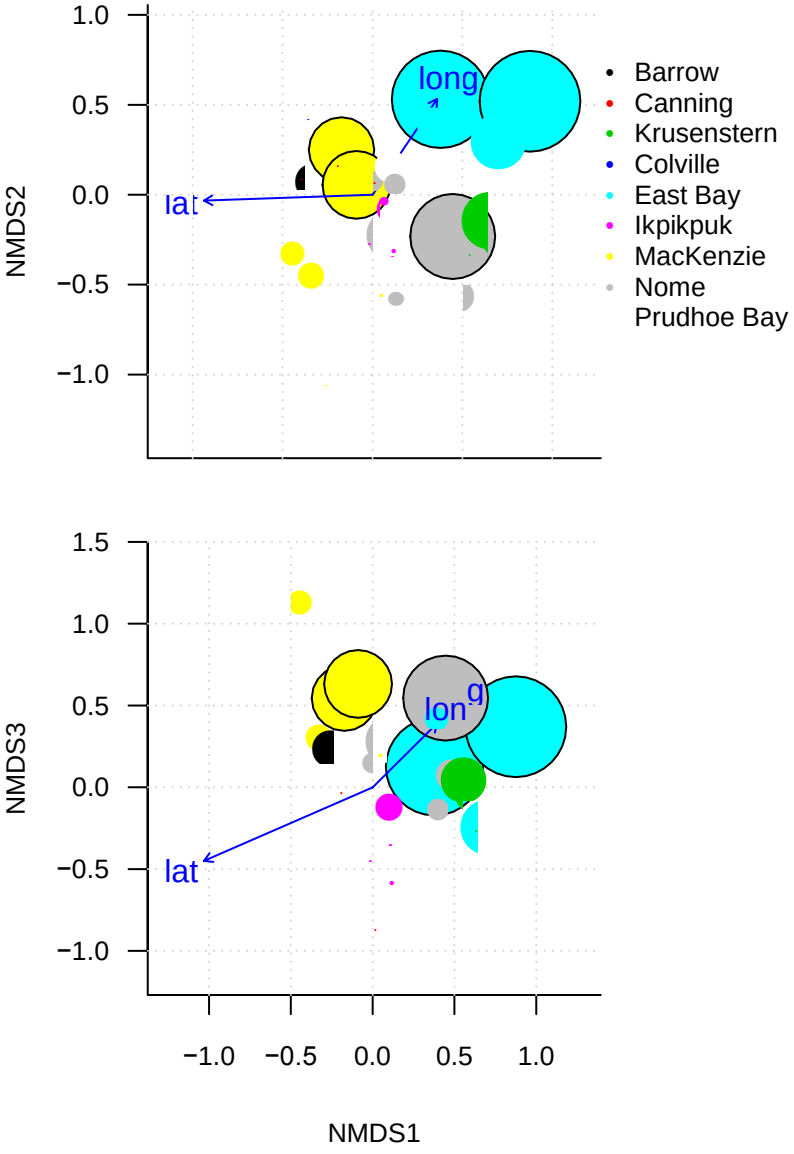
Carabidae (ground beetles)



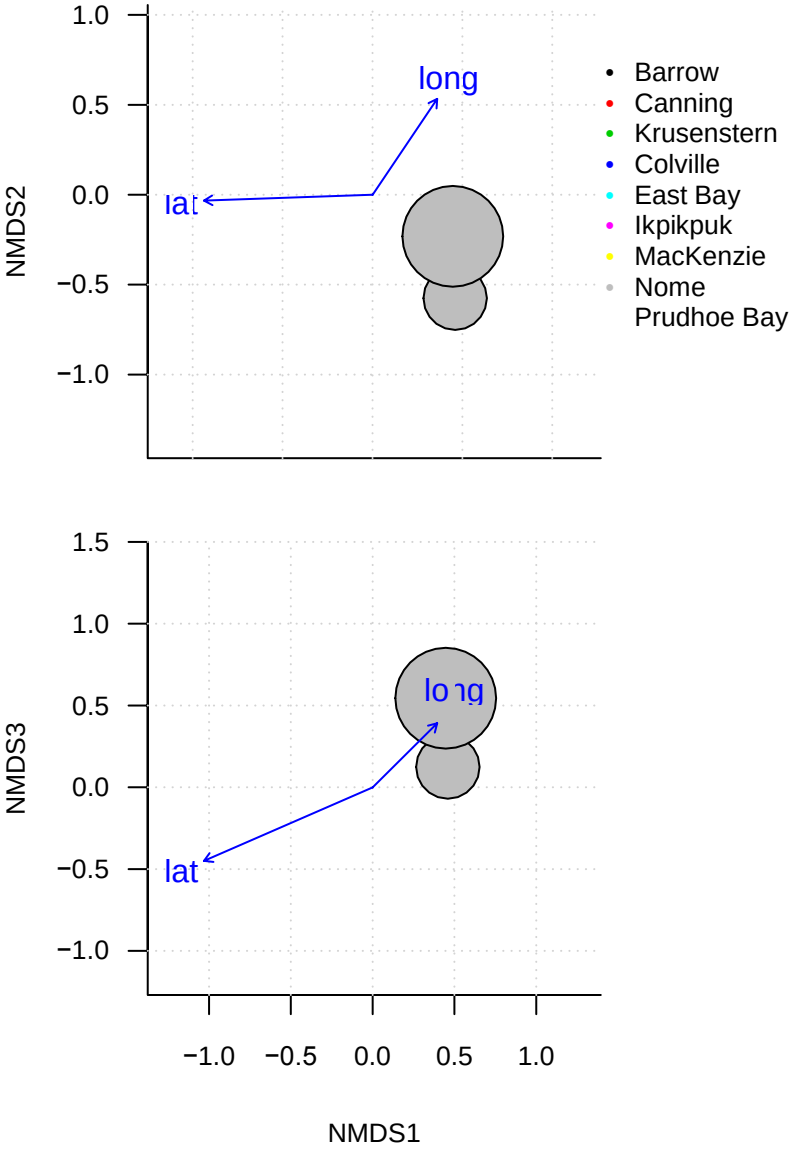
Cecidomyiidae (gall gnats)



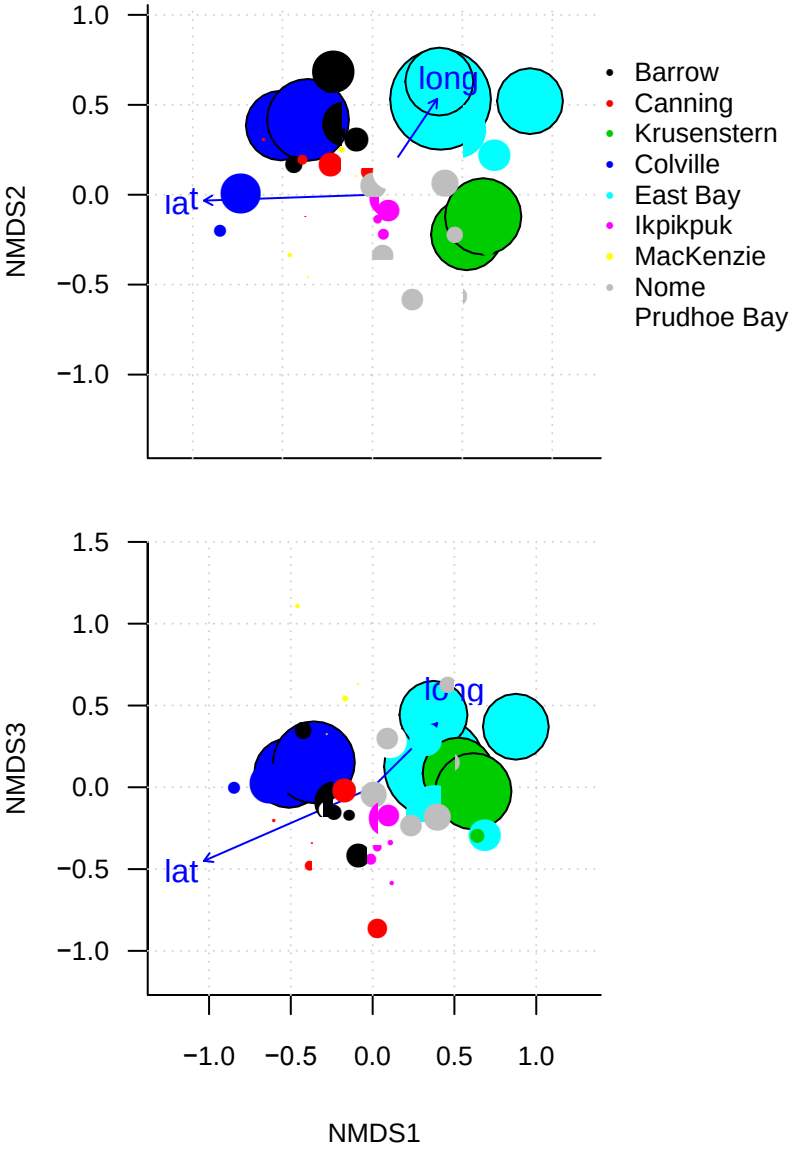
Ceratopogonidae (no−see−um midges)



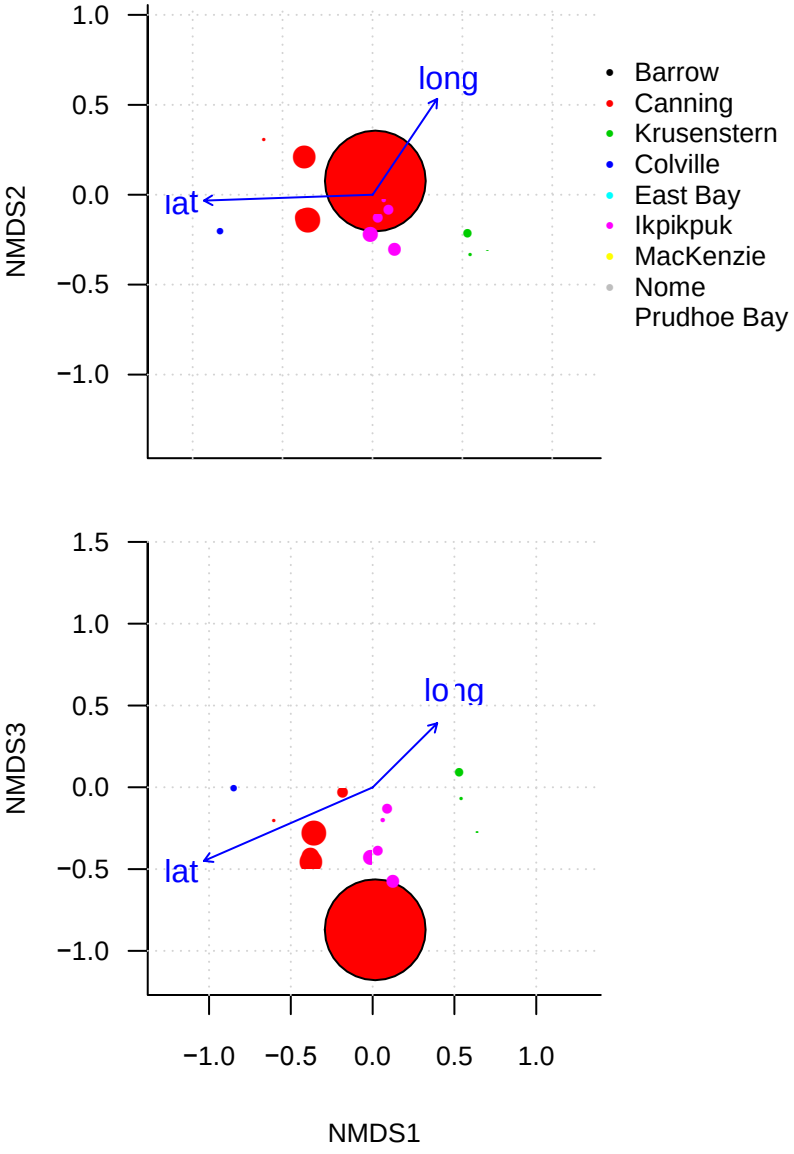
Chilopoda (centipedes)



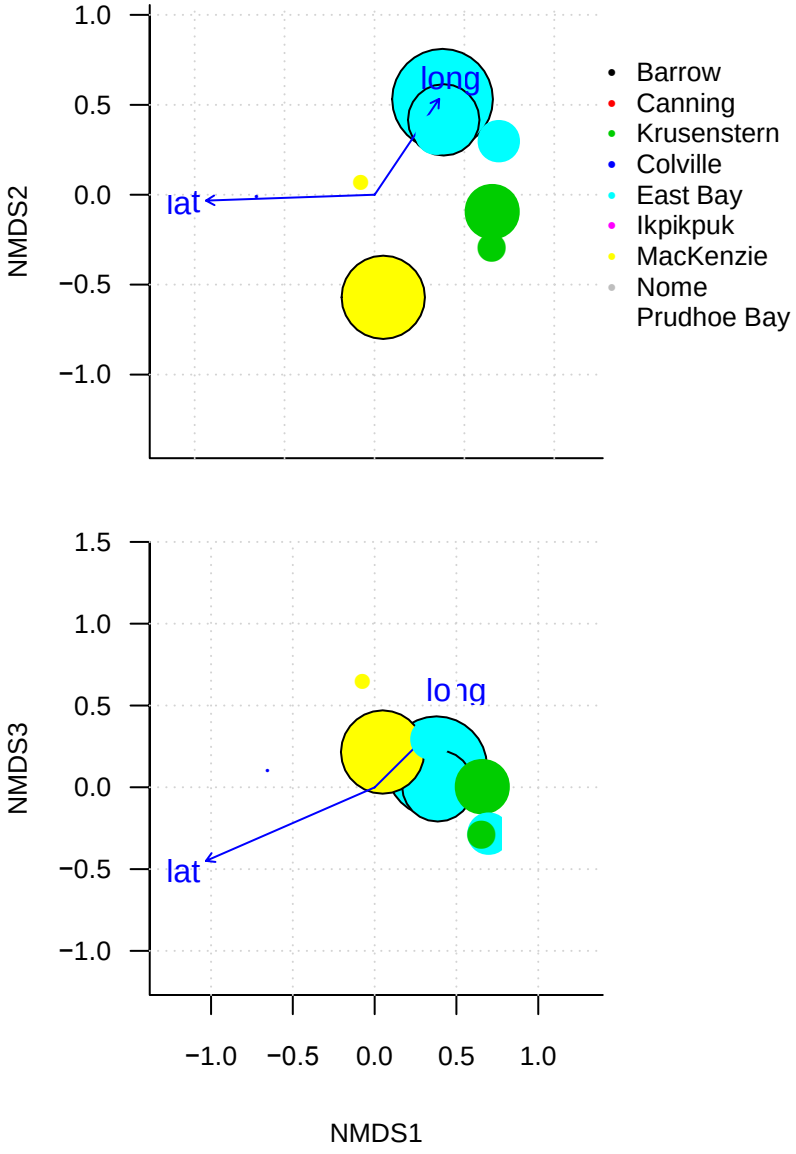
Chironomidae (midges)



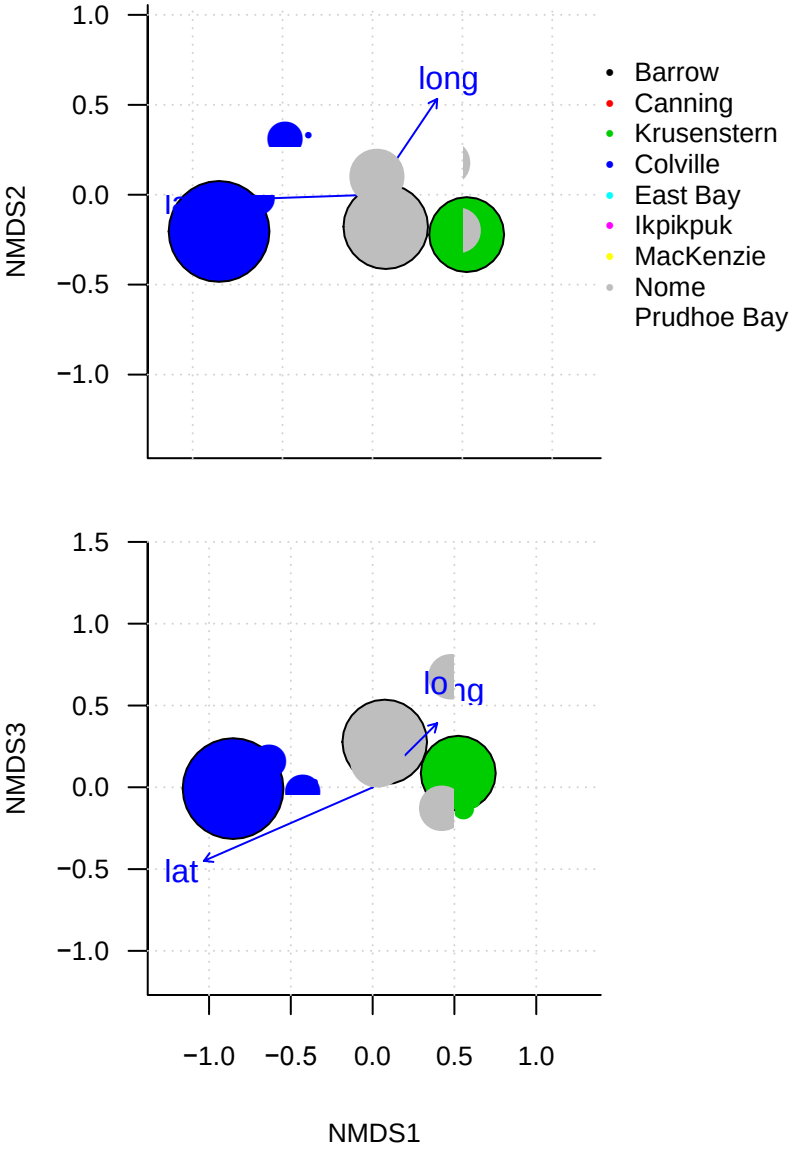
Chrysomelidae (leaf beetles)



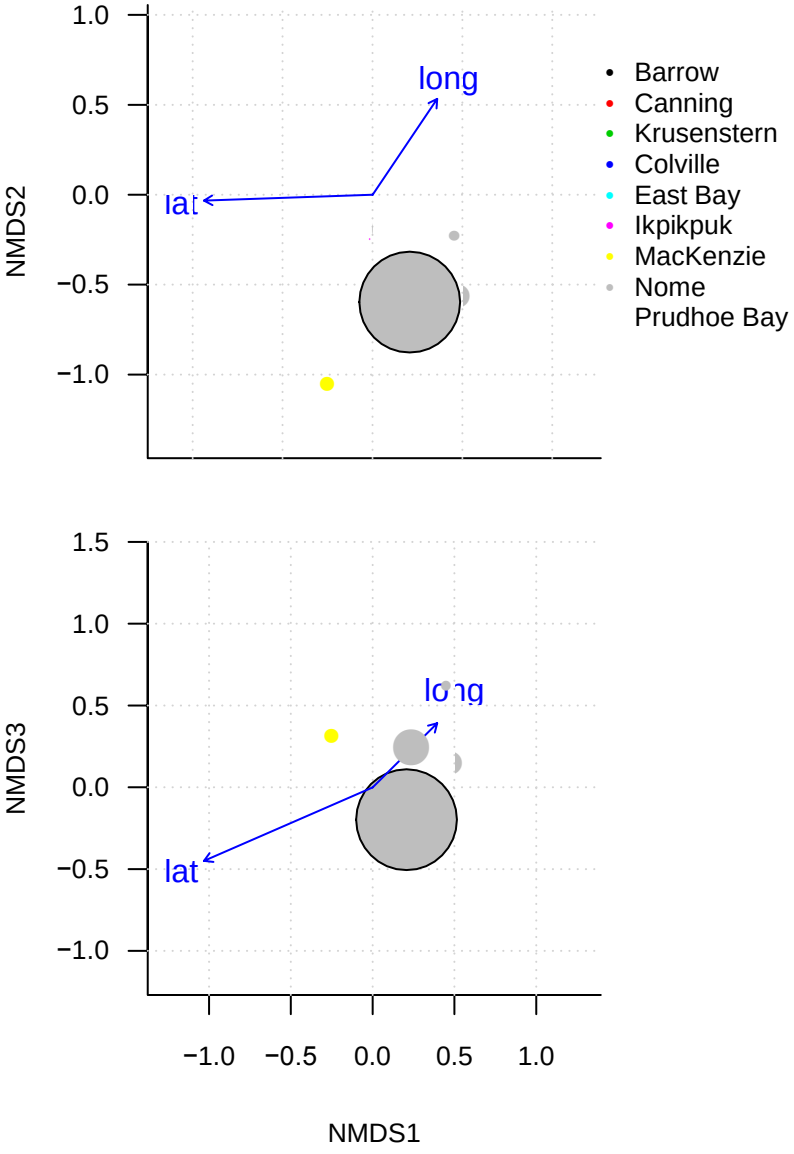
Cicindelidae (tiger beetles)



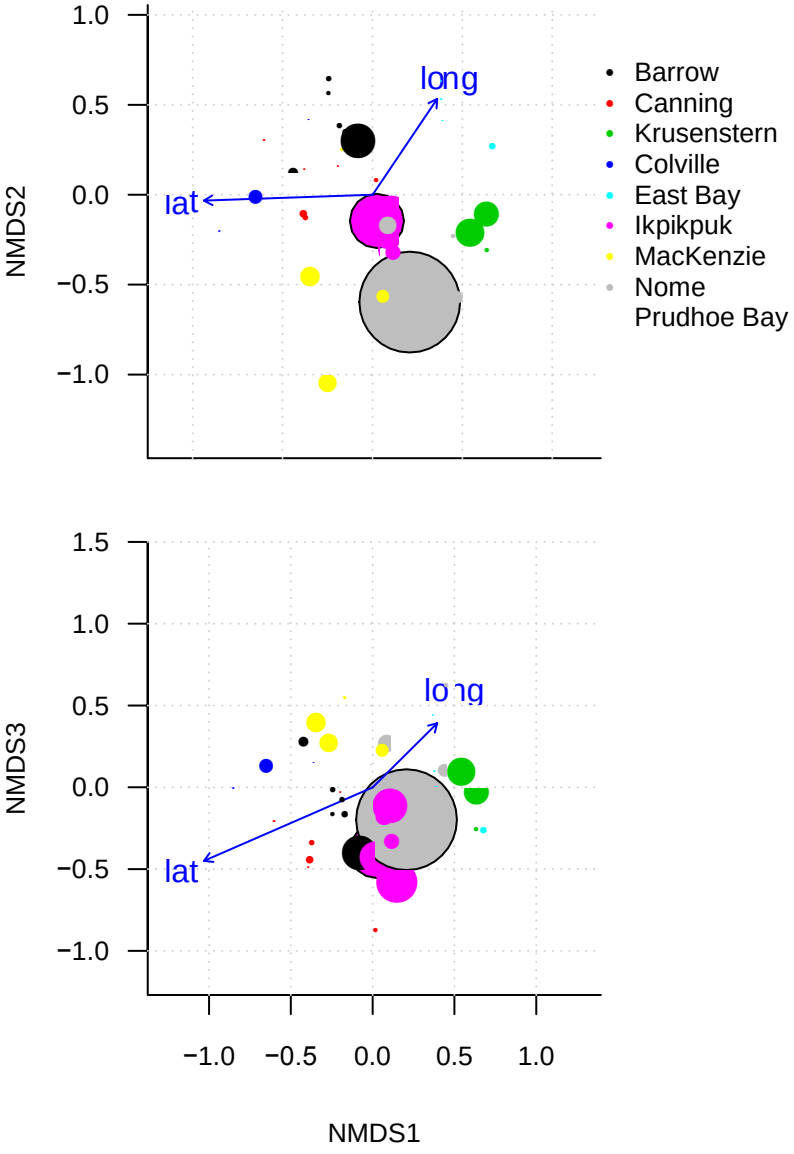
Coccinellidae (ladybird beetles)



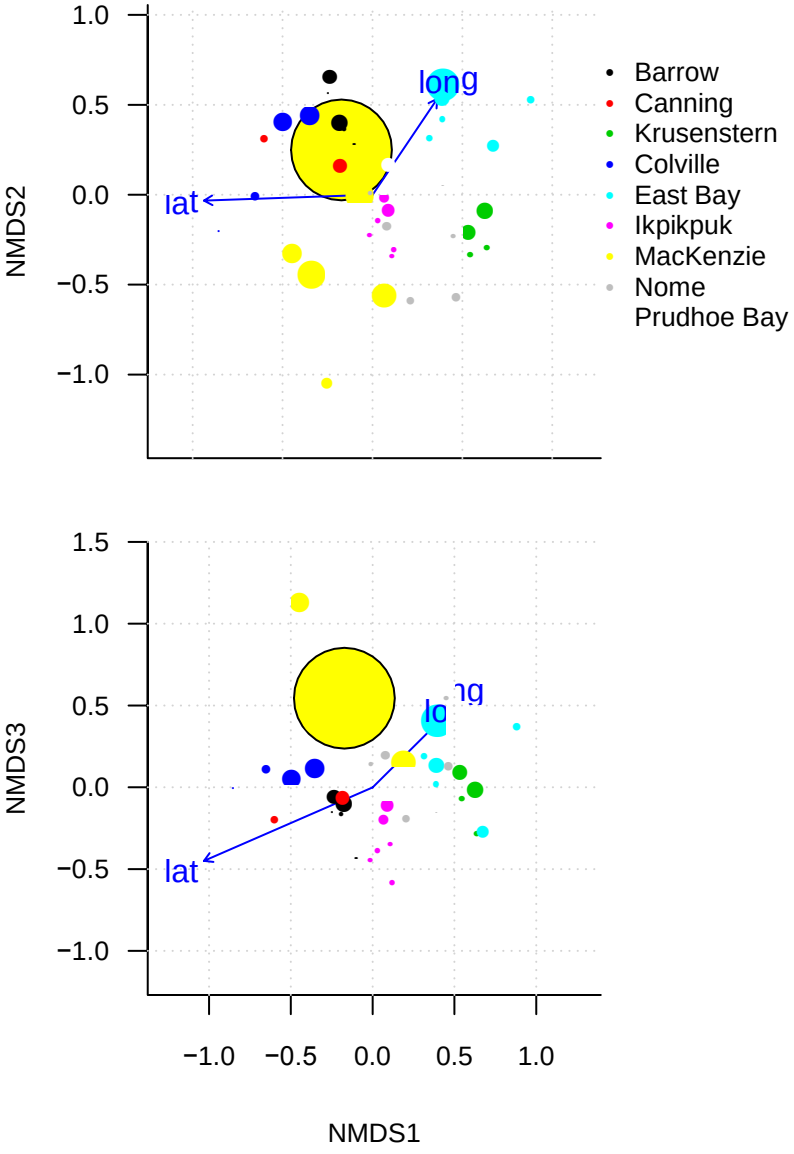
Coleoptera (beetles)



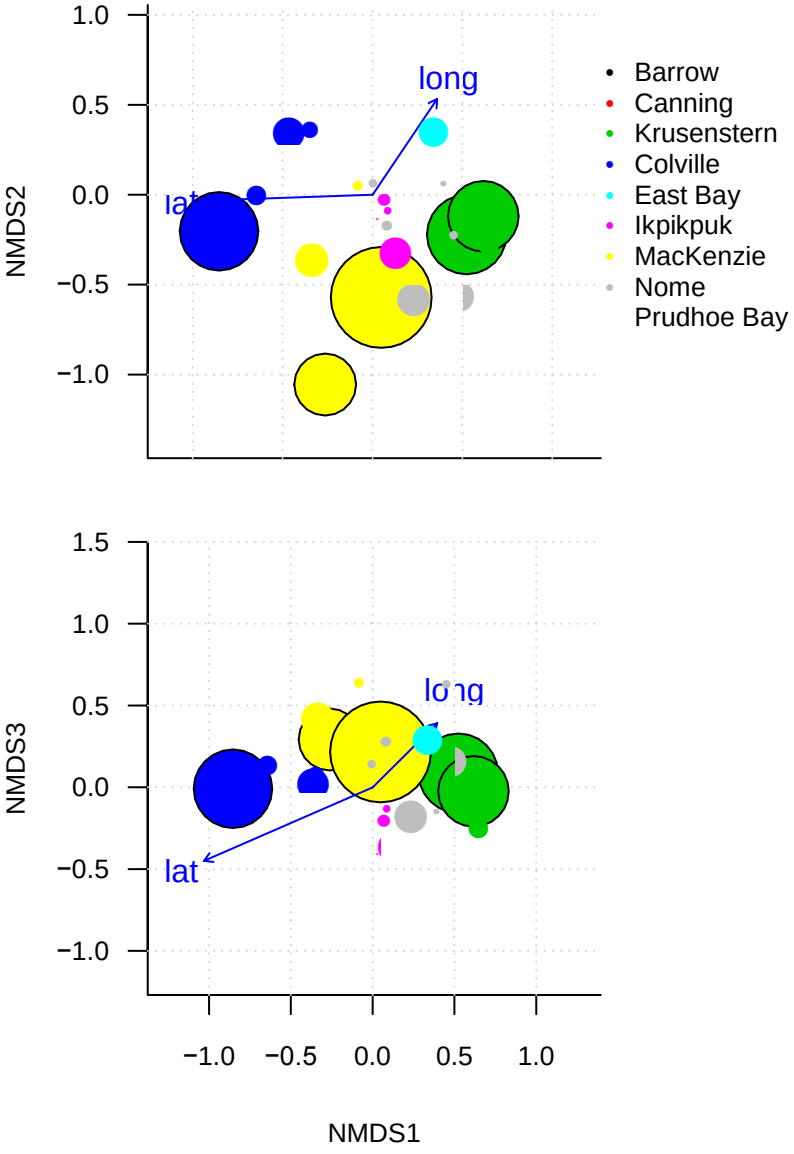
Collembola (springtails)



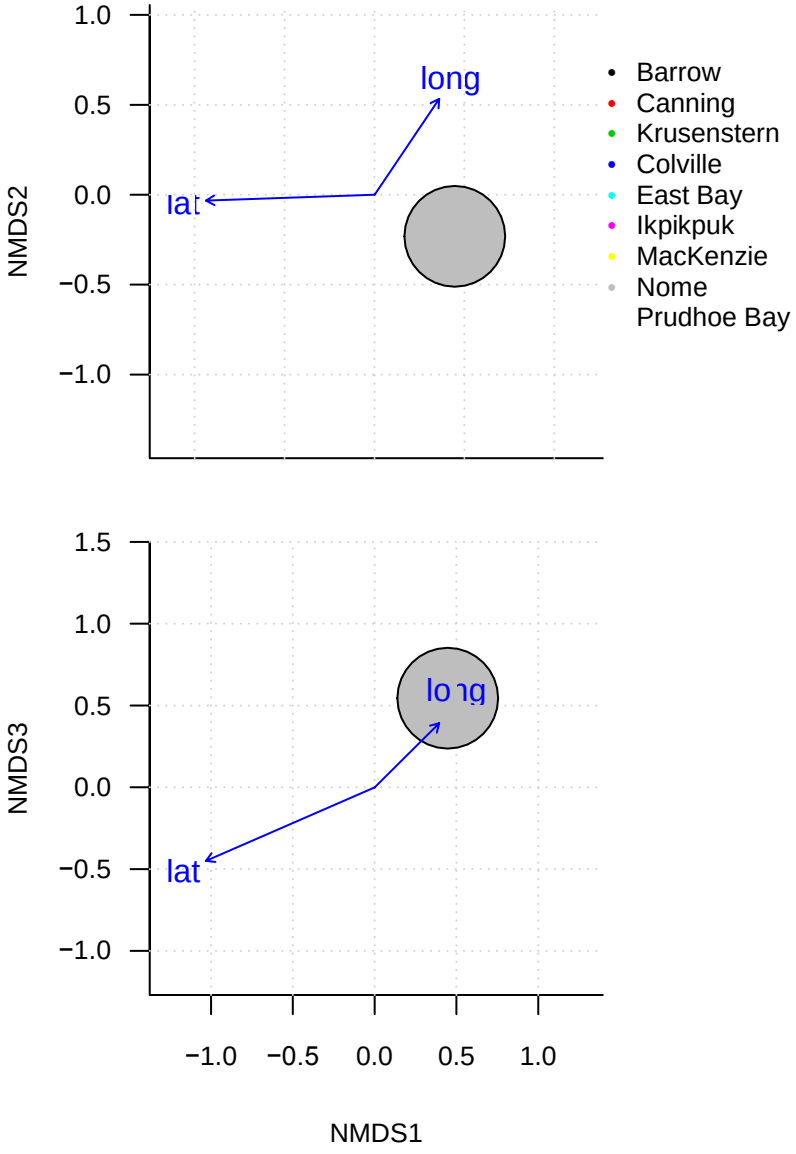
Culicidae (mosquitoes)



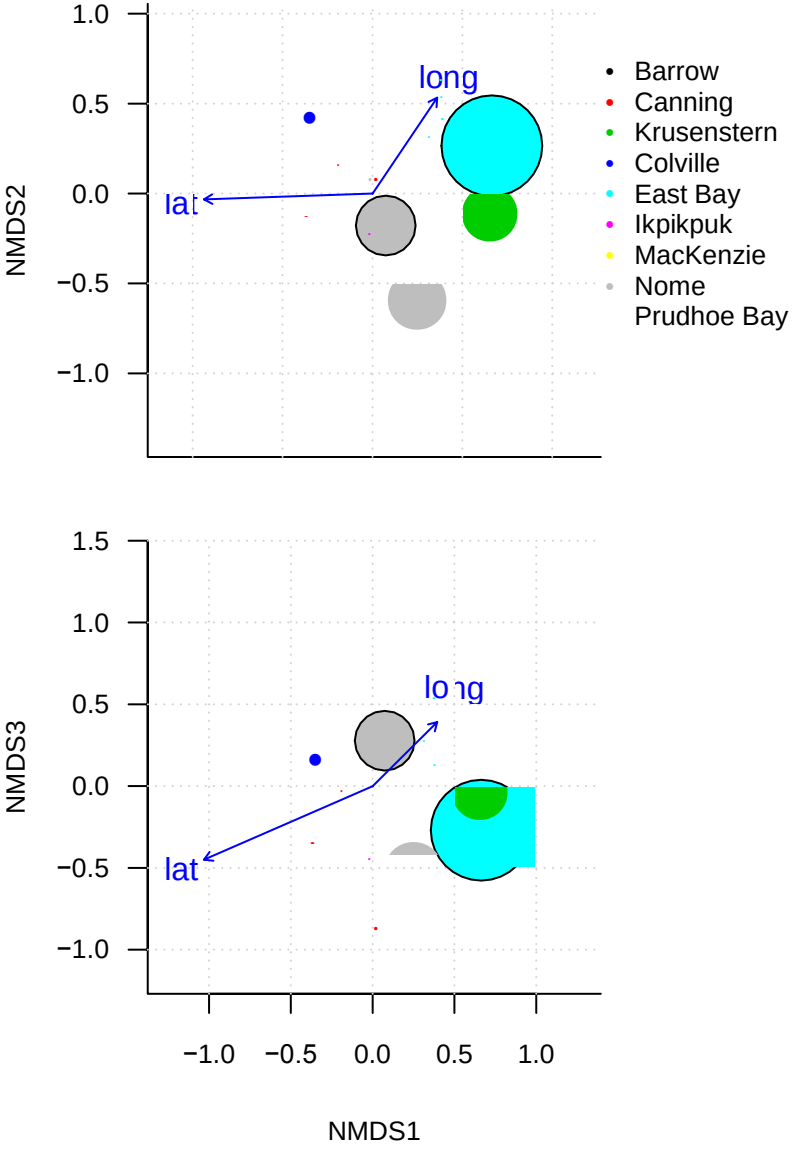
Curculionidae (beetles)



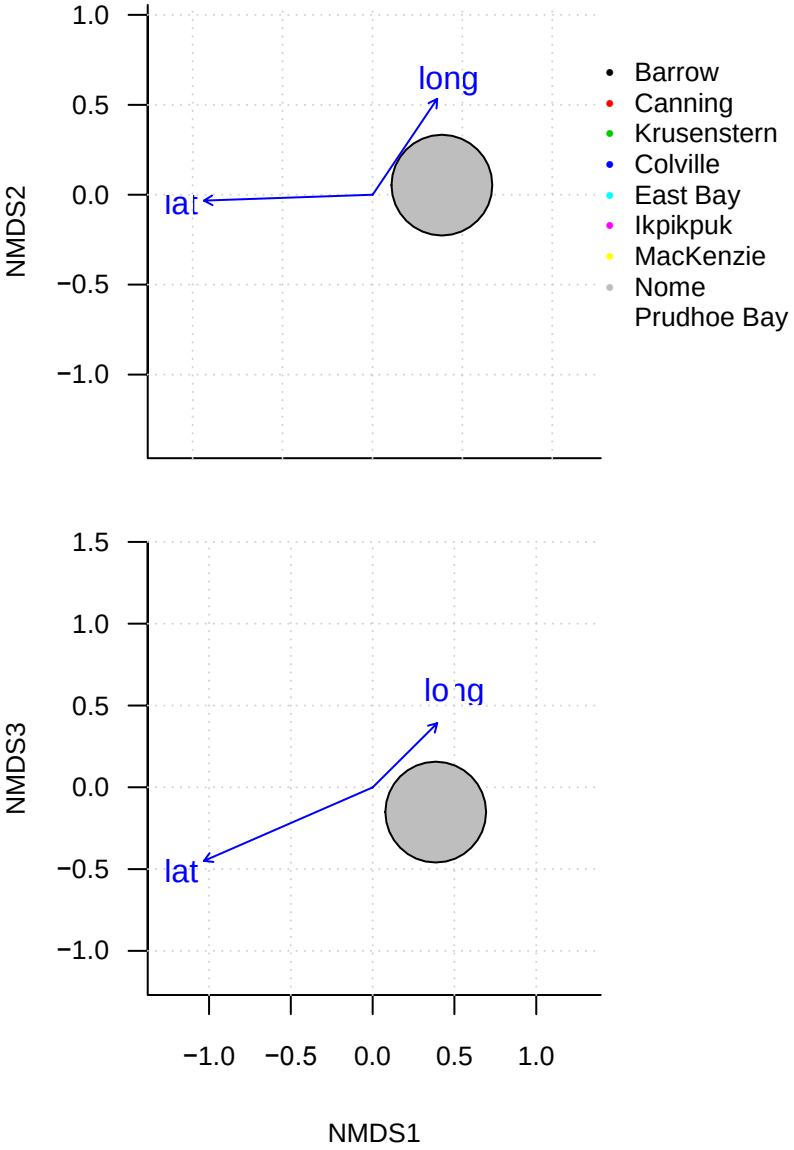
Dixidae (dixid midges)



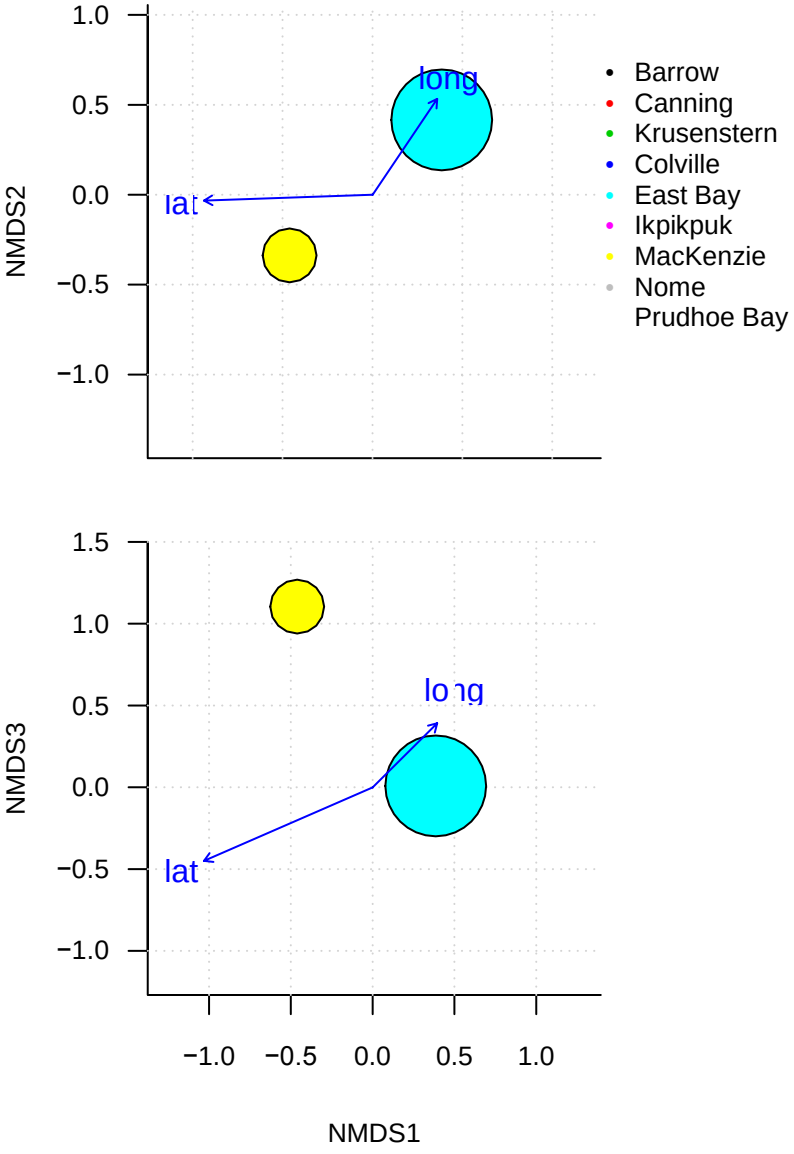
Dytiscidae (predaceous diving beetles)



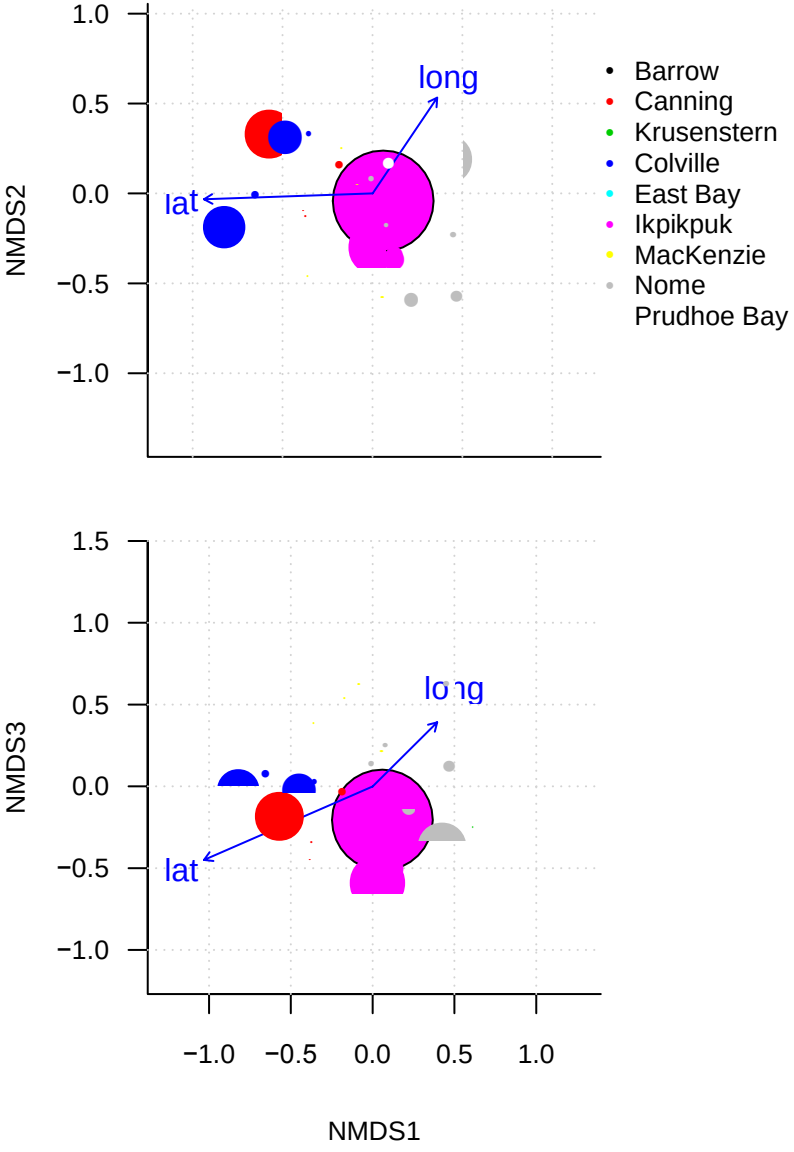
Elateridae (click beetles)



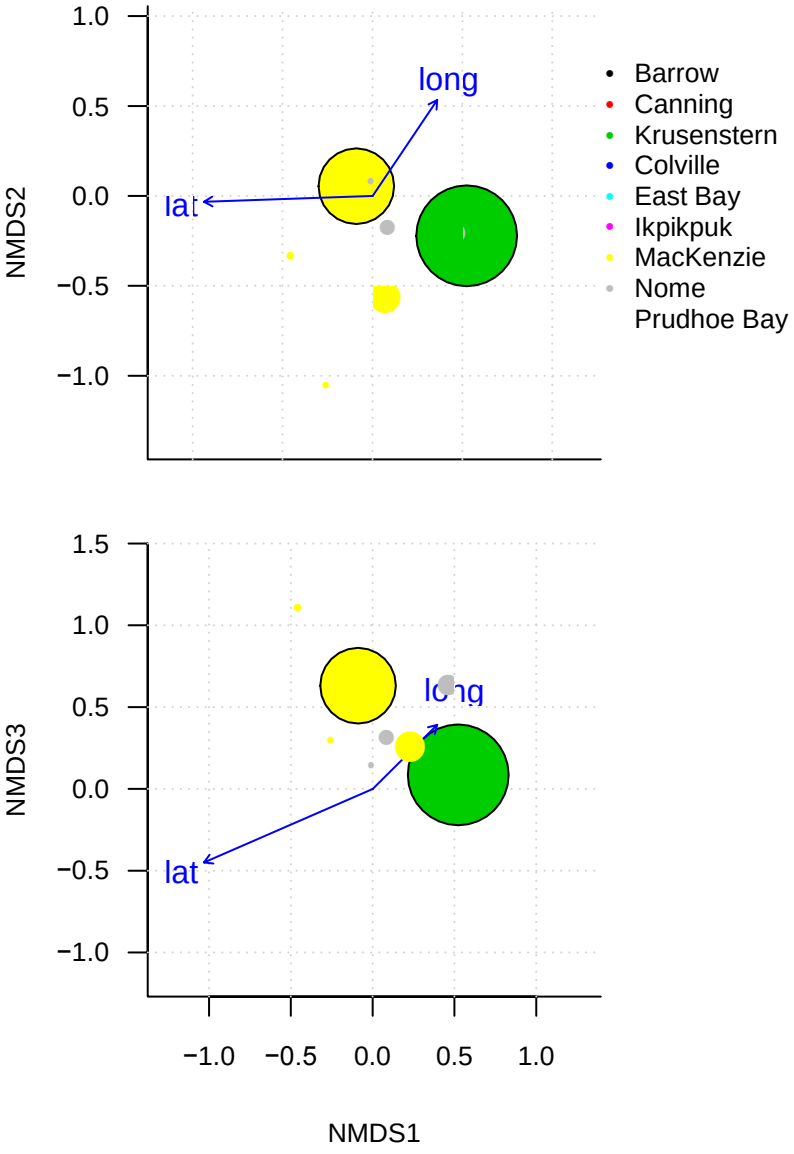
Ephemeroptera (mayflies)



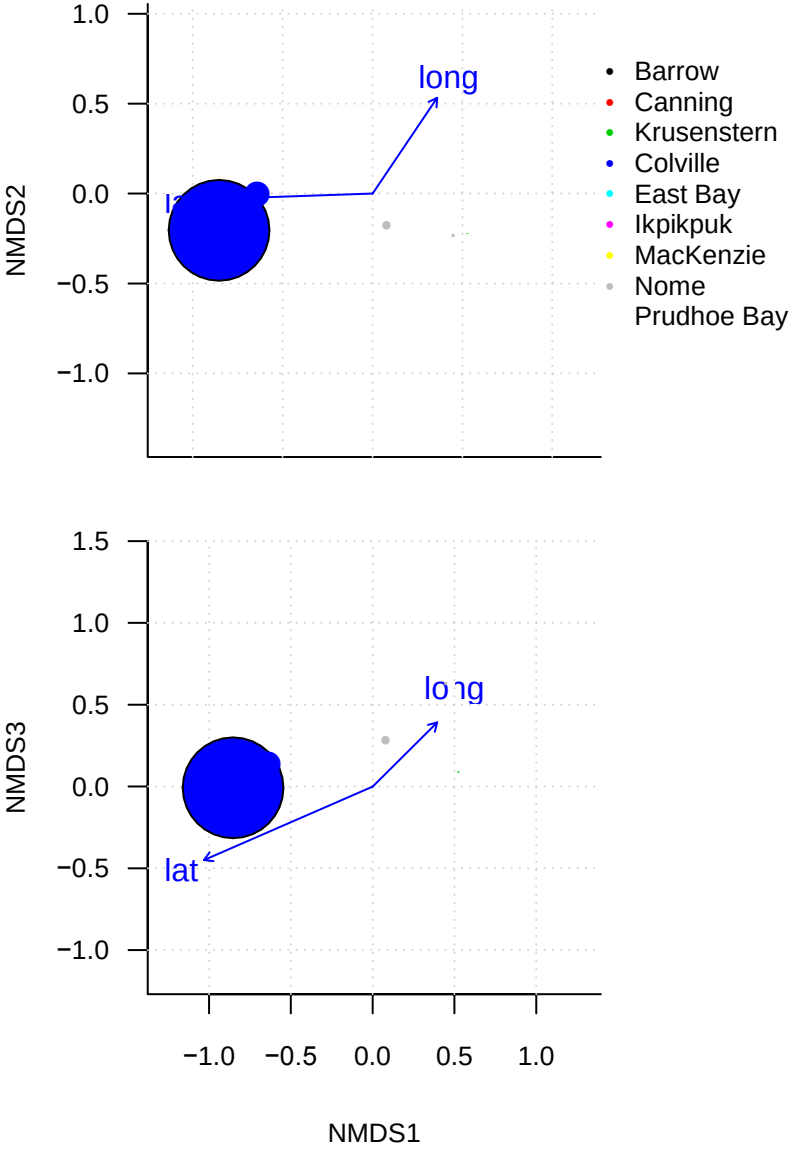
Hemiptera: Auchenorrhyncha (planthoppers & cicadas)



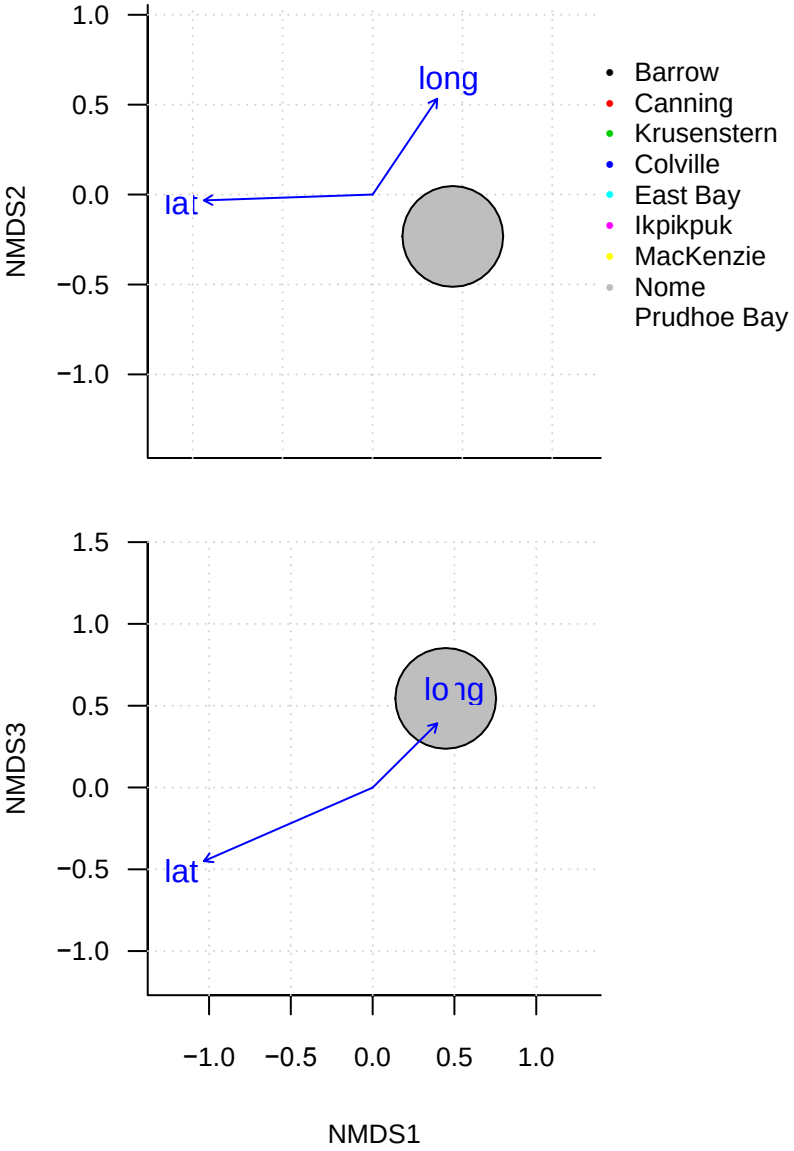
Hemiptera: Heteroptera (true bugs)



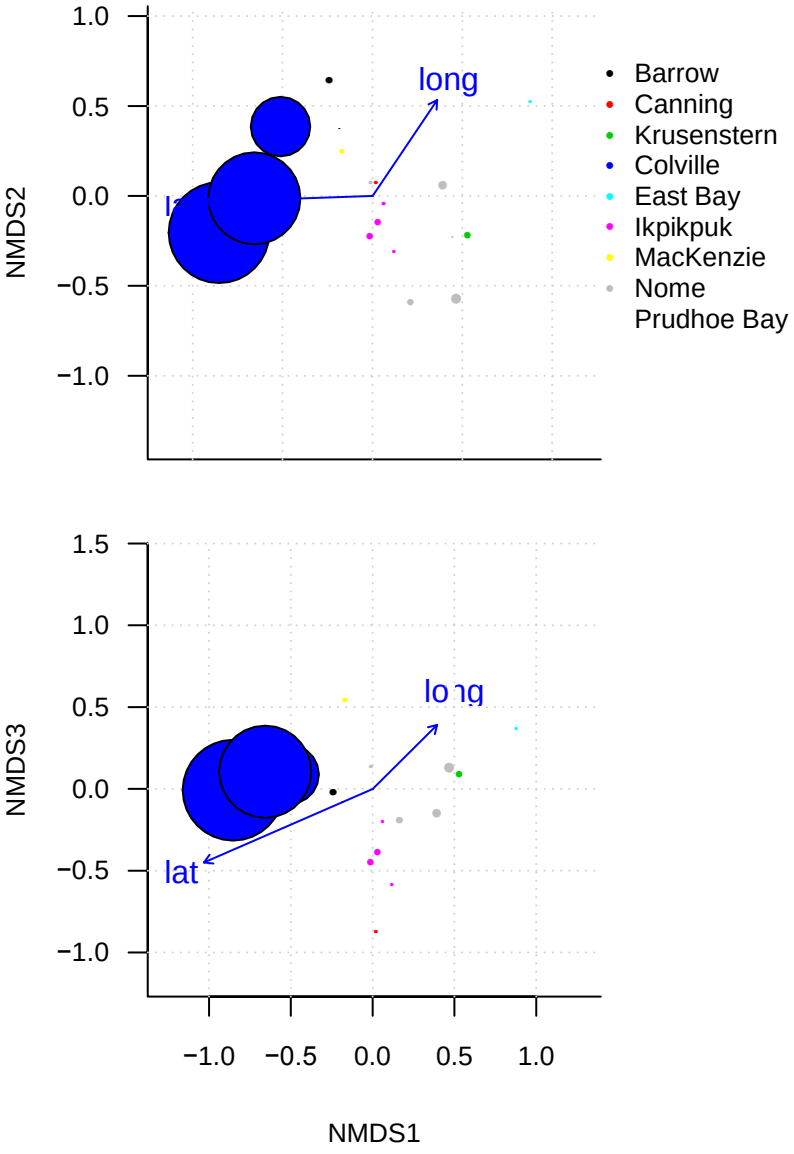
Hemiptera: Sternorrhyncha (aphids, psyllids, coccids)



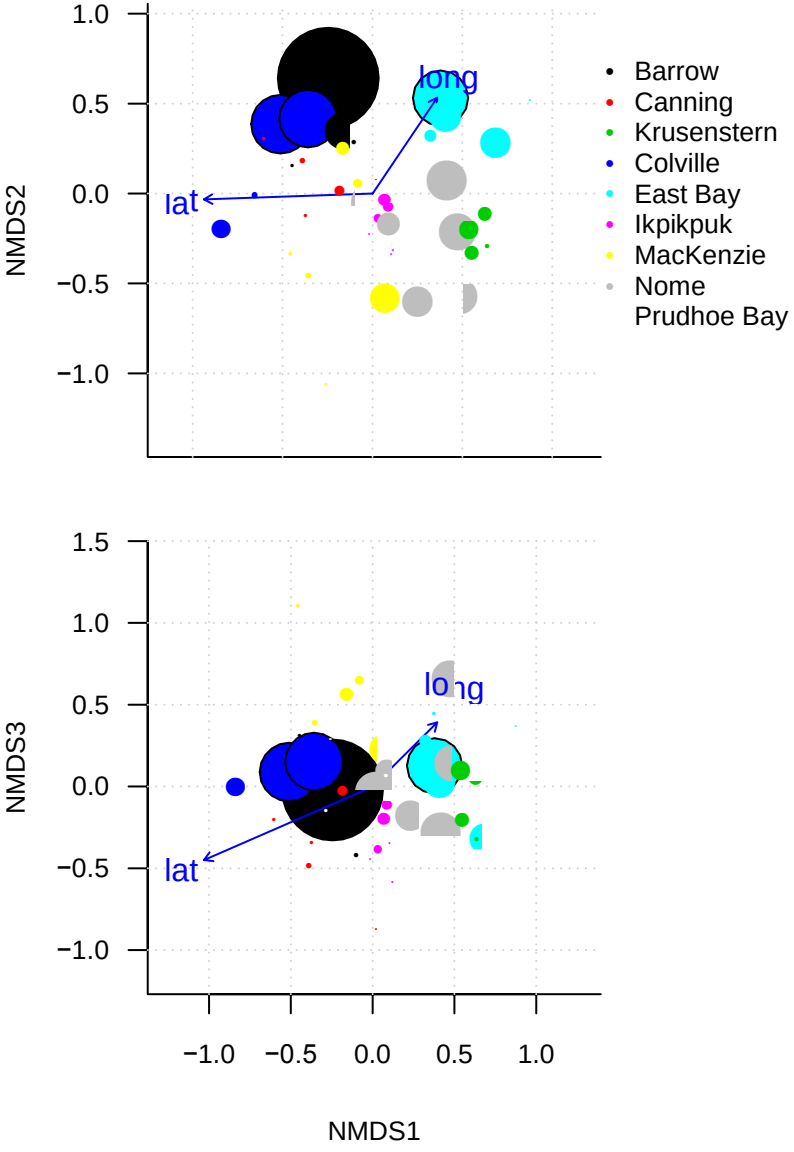
Hydrophilidae (water scavenger beetles)



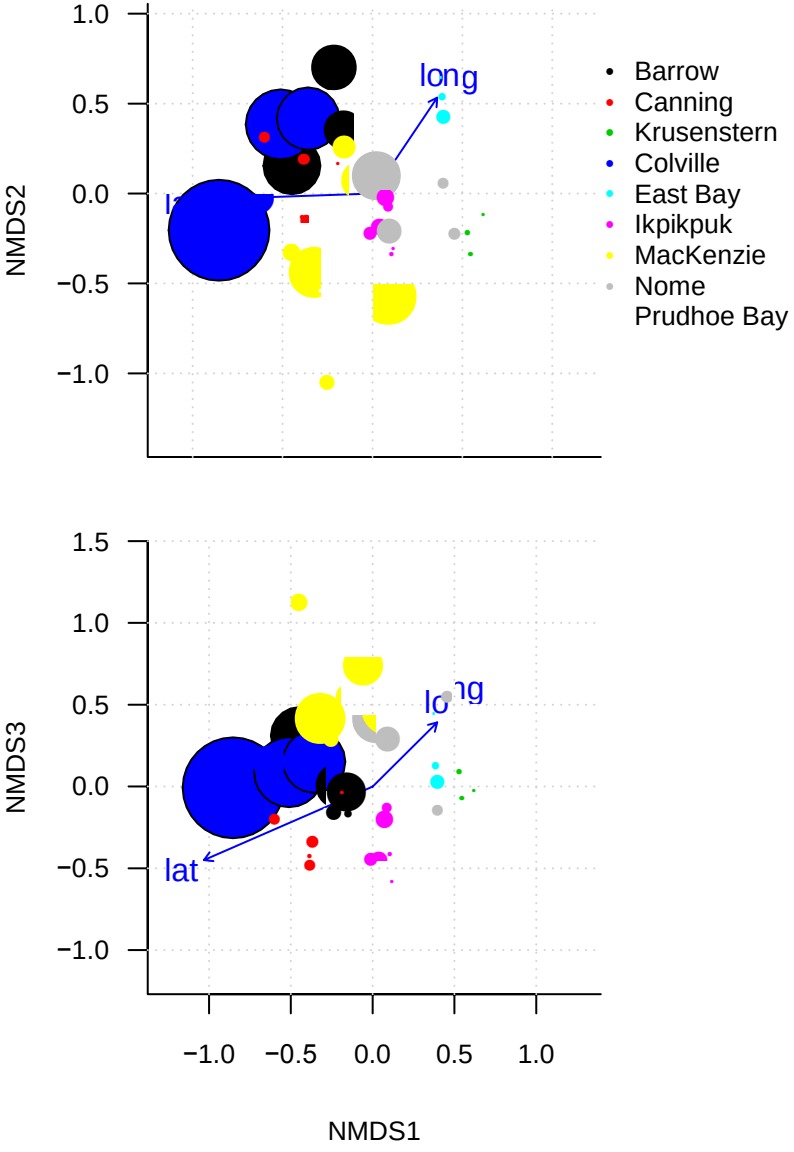
Hymenoptera bees and wasps (bees)



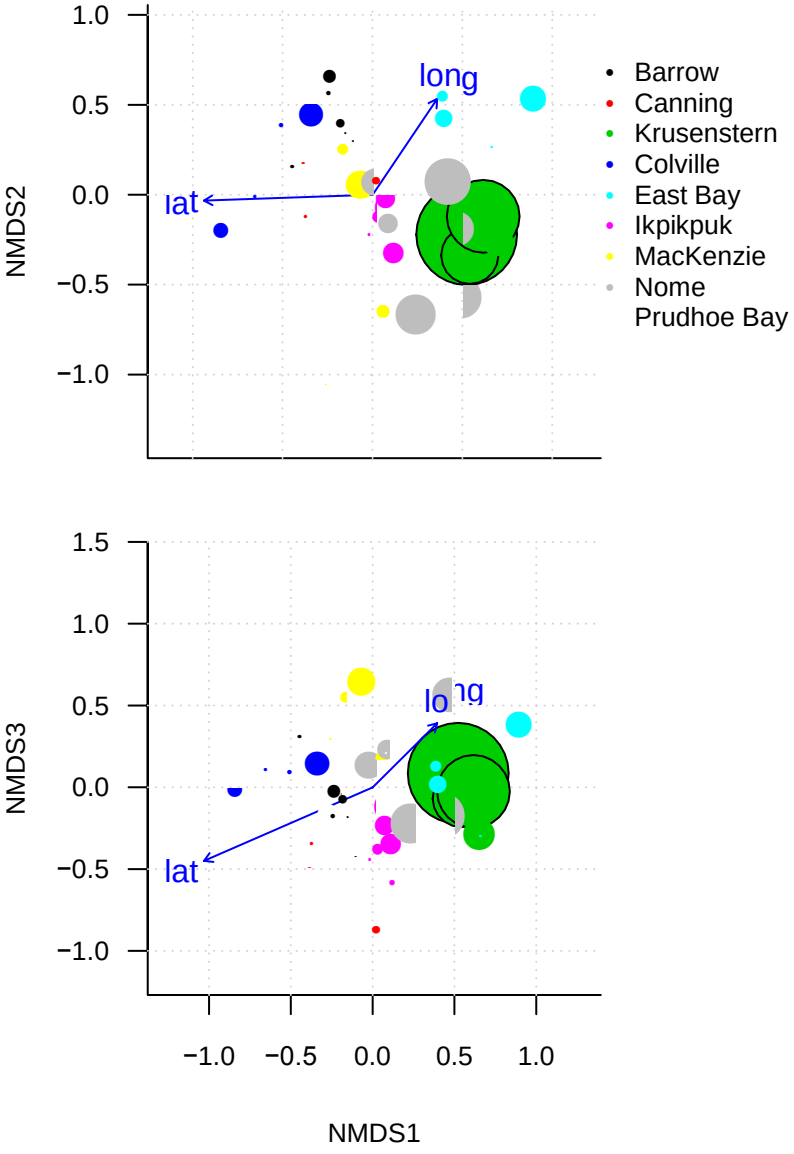
Hymenoptera parasitoid (parasitic wasps)



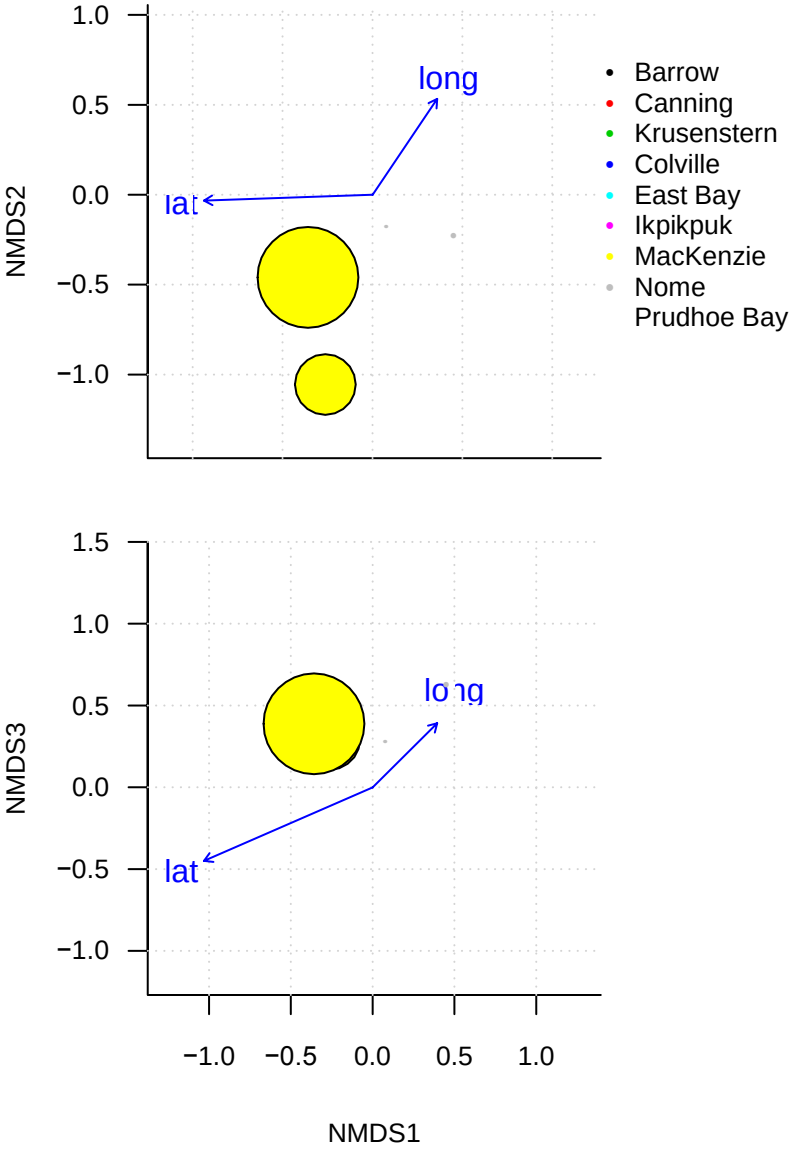
Hymenoptera sawflies (sawfly wasps)



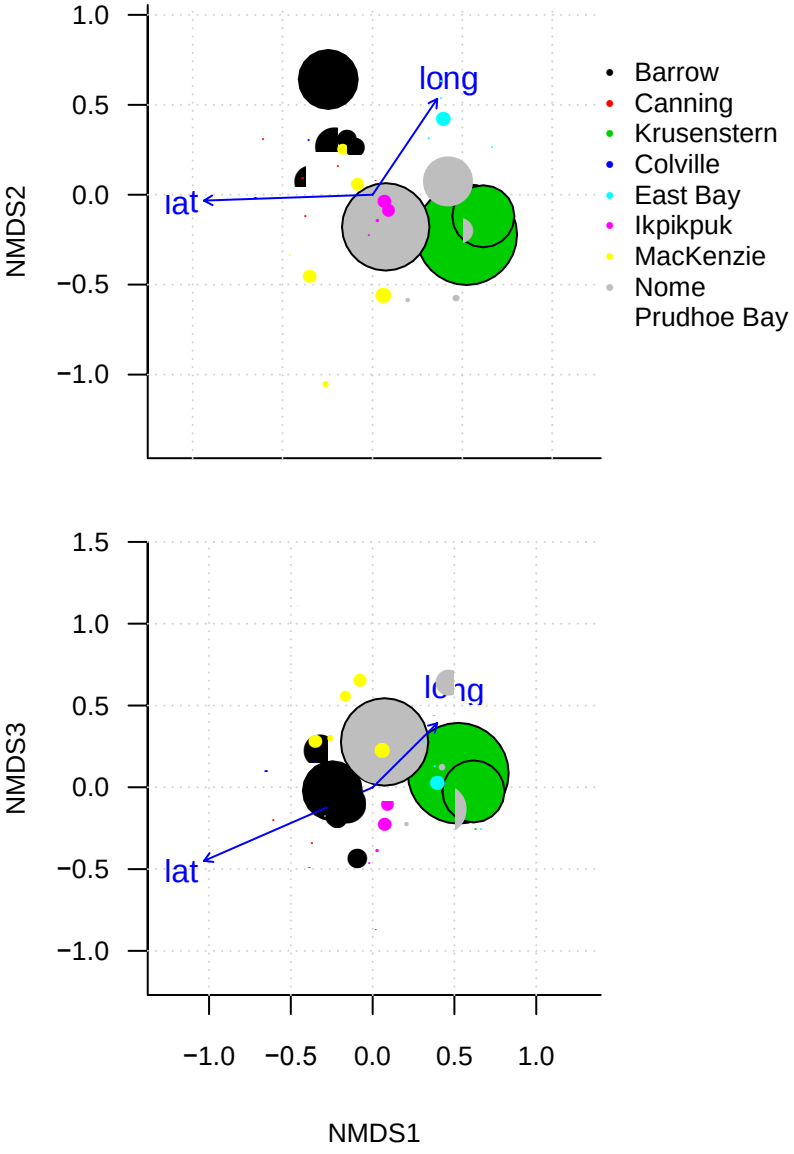
Lepidoptera (moths)



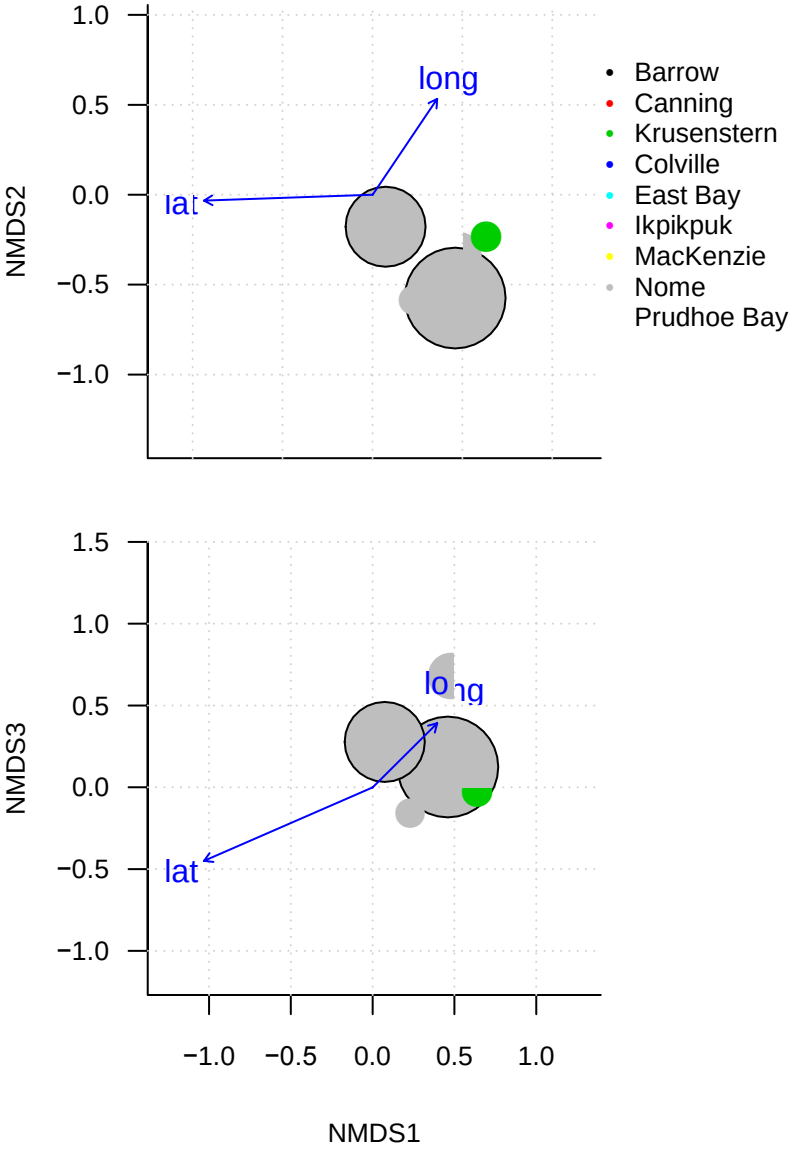
Lymnaeidae (snails)



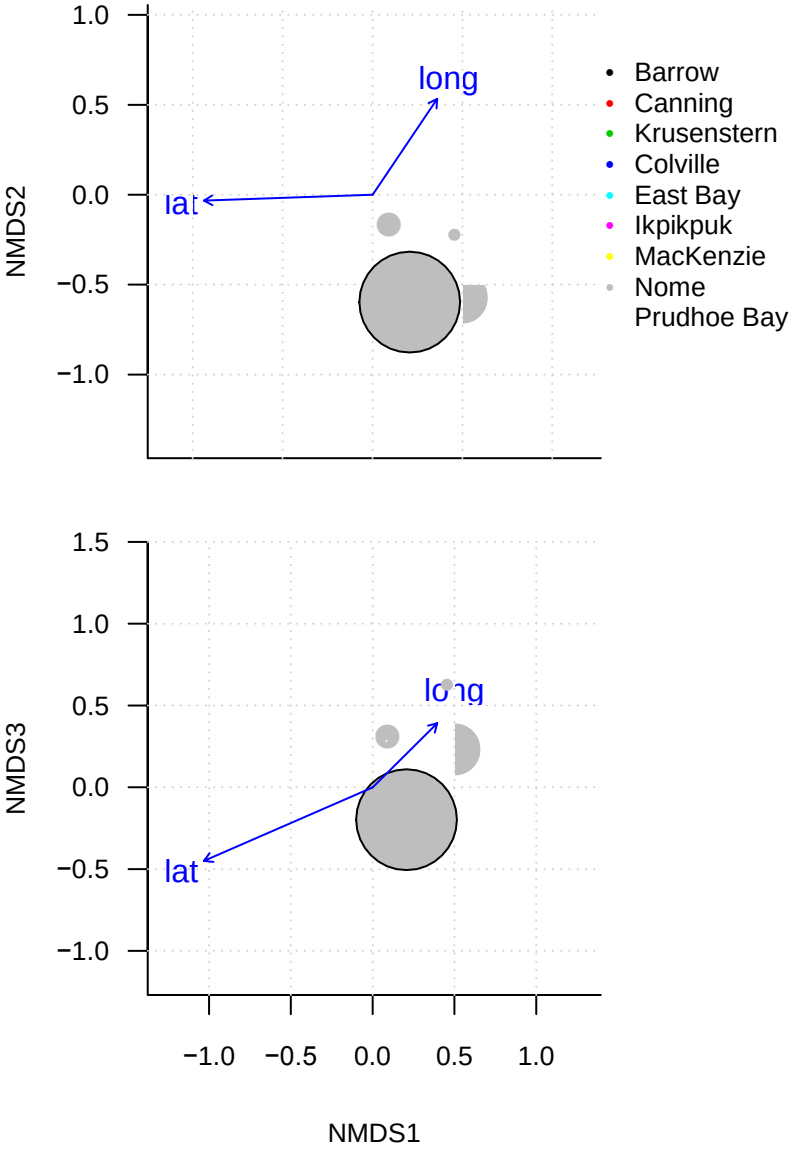
Mycetophilidae (fungus gnats)



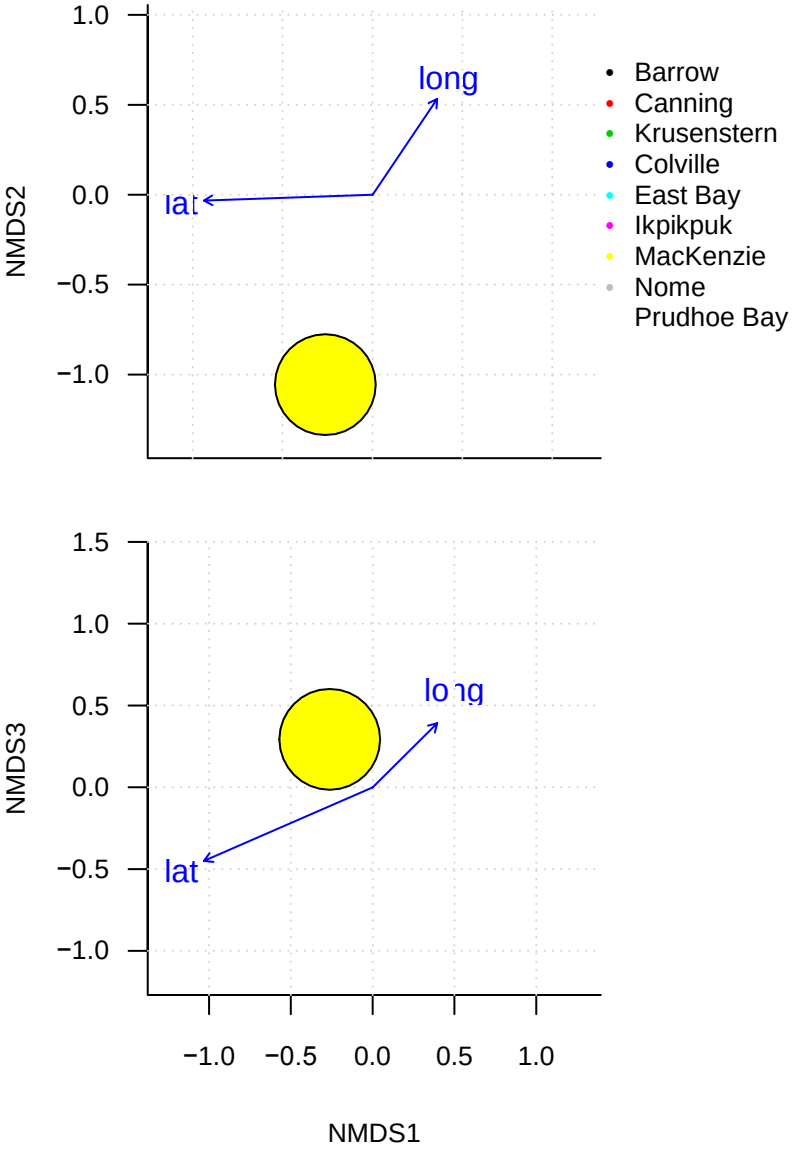
Neuroptera (x)



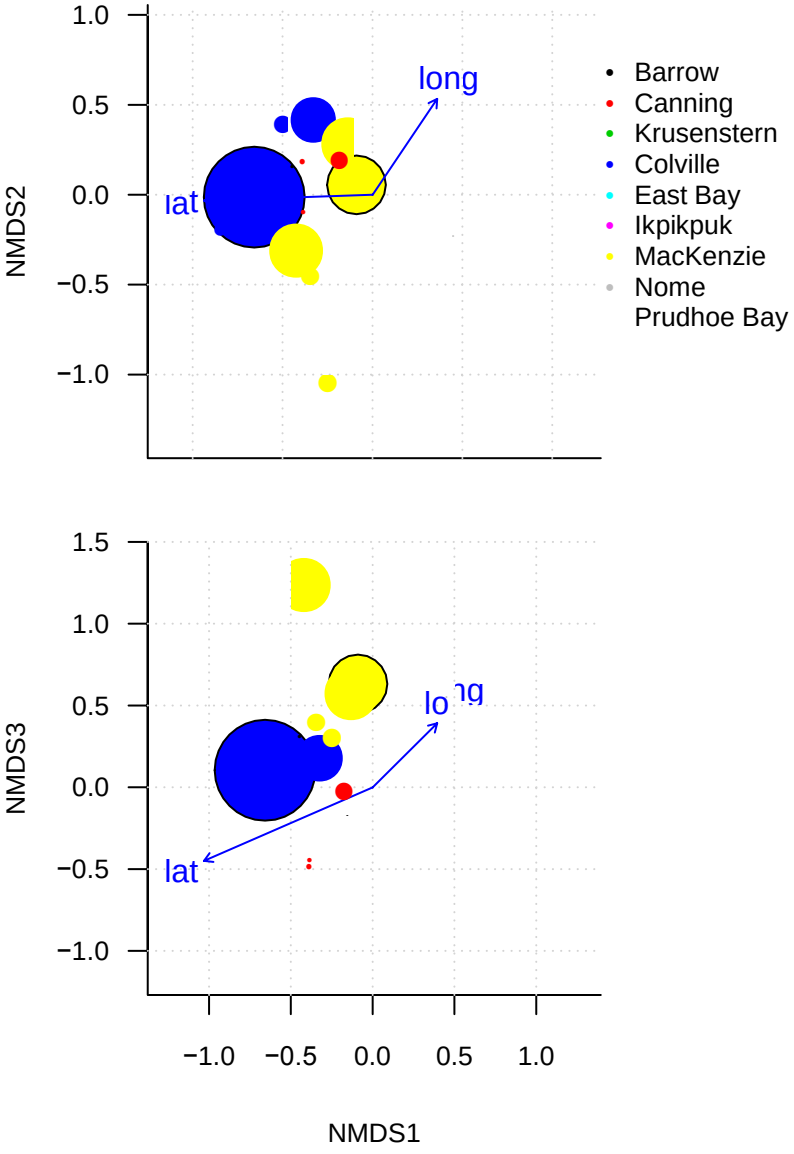
Oligochaeta (segmented worms)



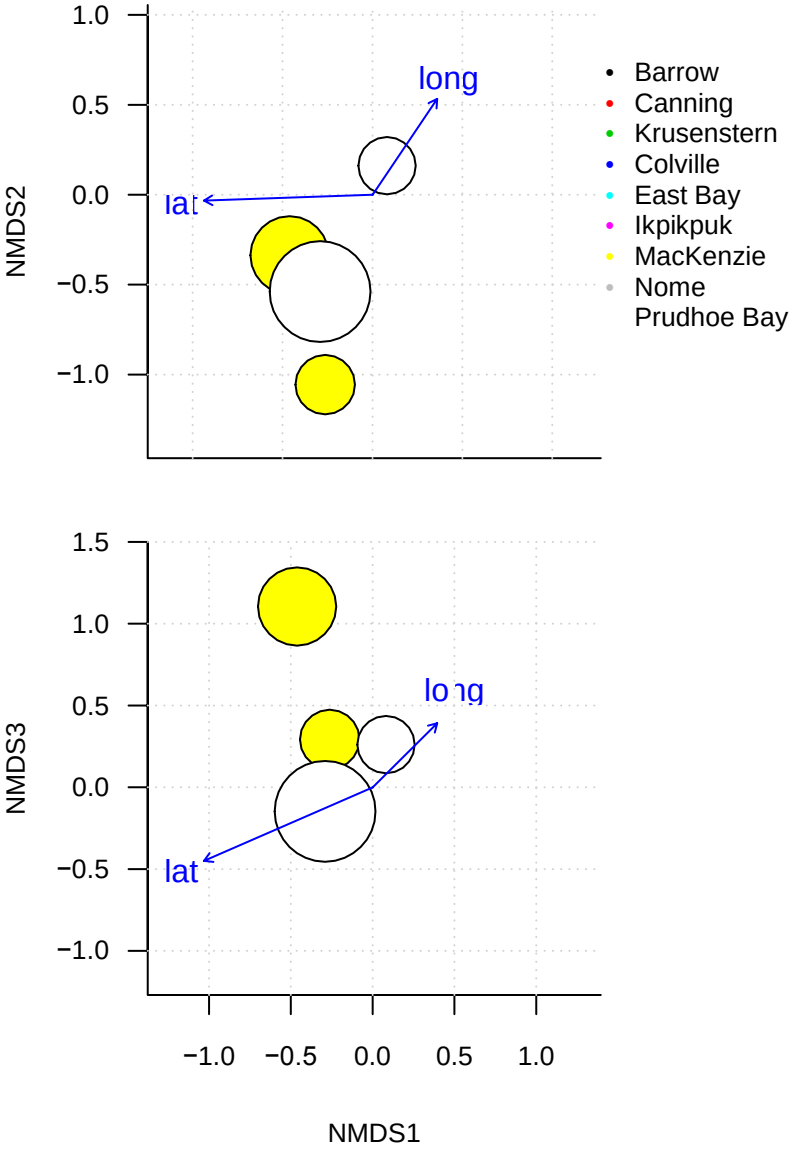
Physidae (snails)



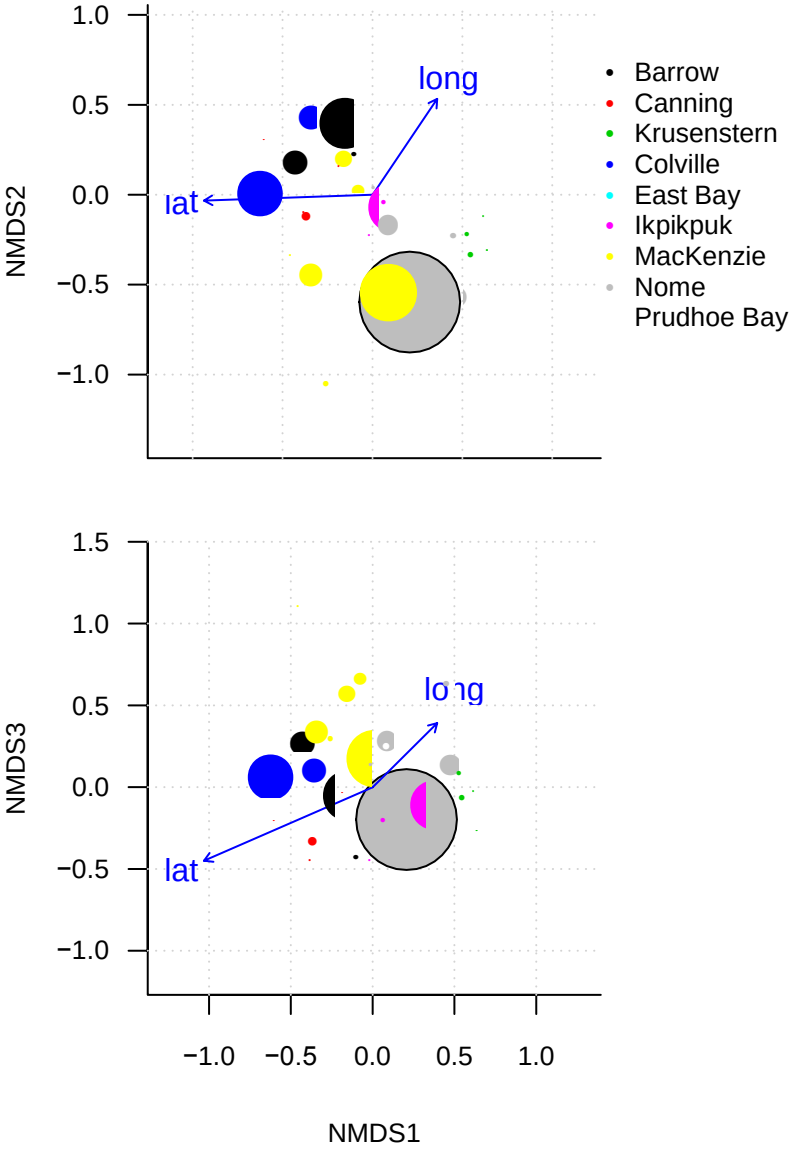
Plecoptera (stoneflies)



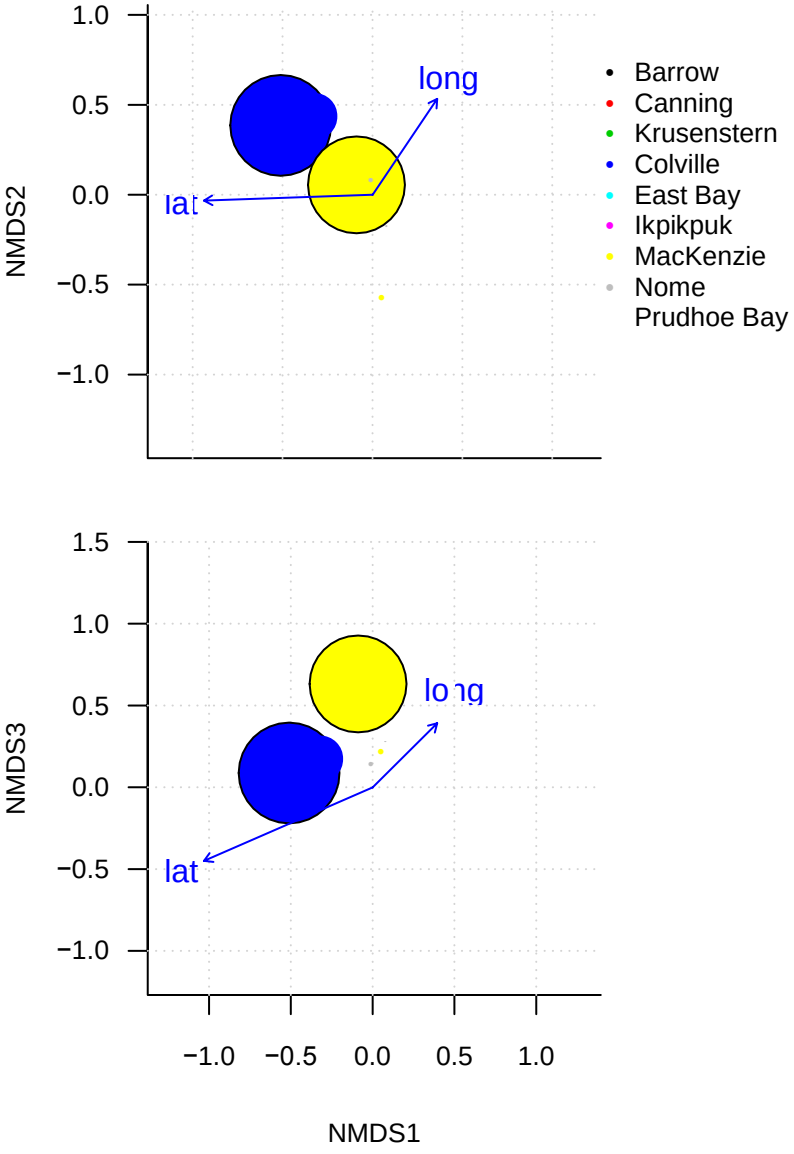
Psocoptera (psocids)



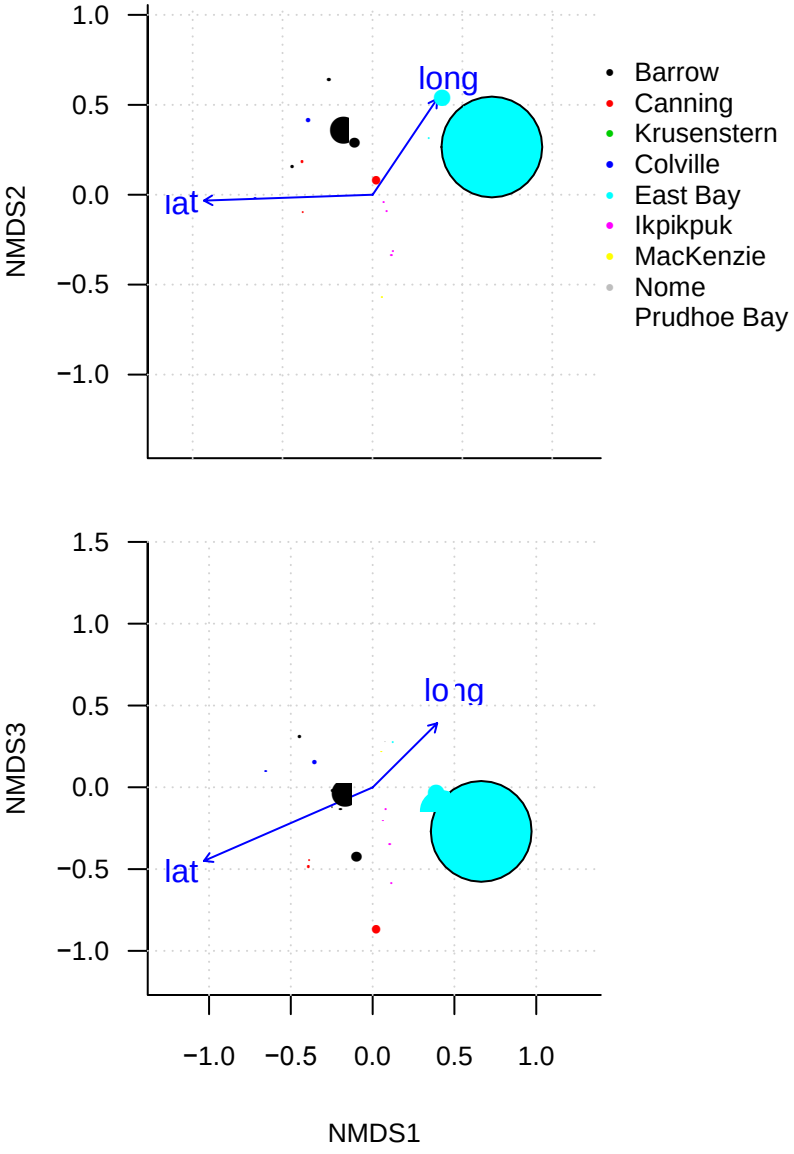
Psychodidae (moth flies)



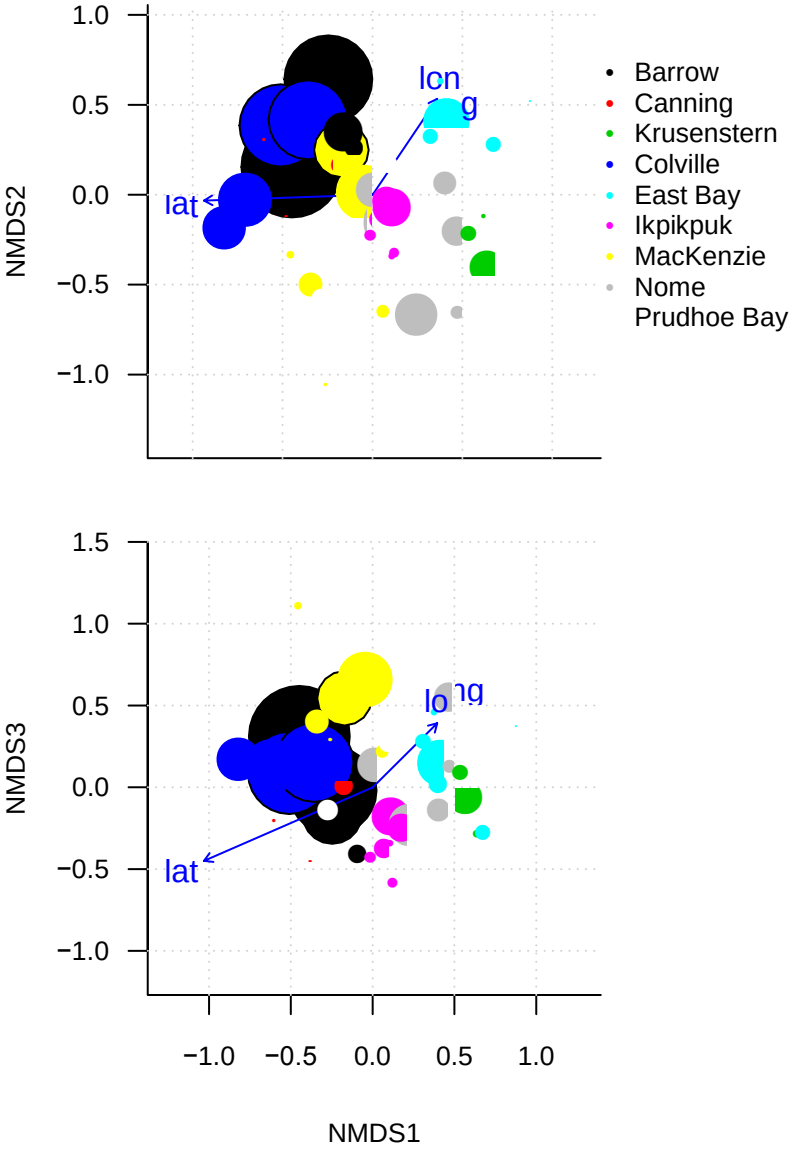
Psyllidae (psyllids)



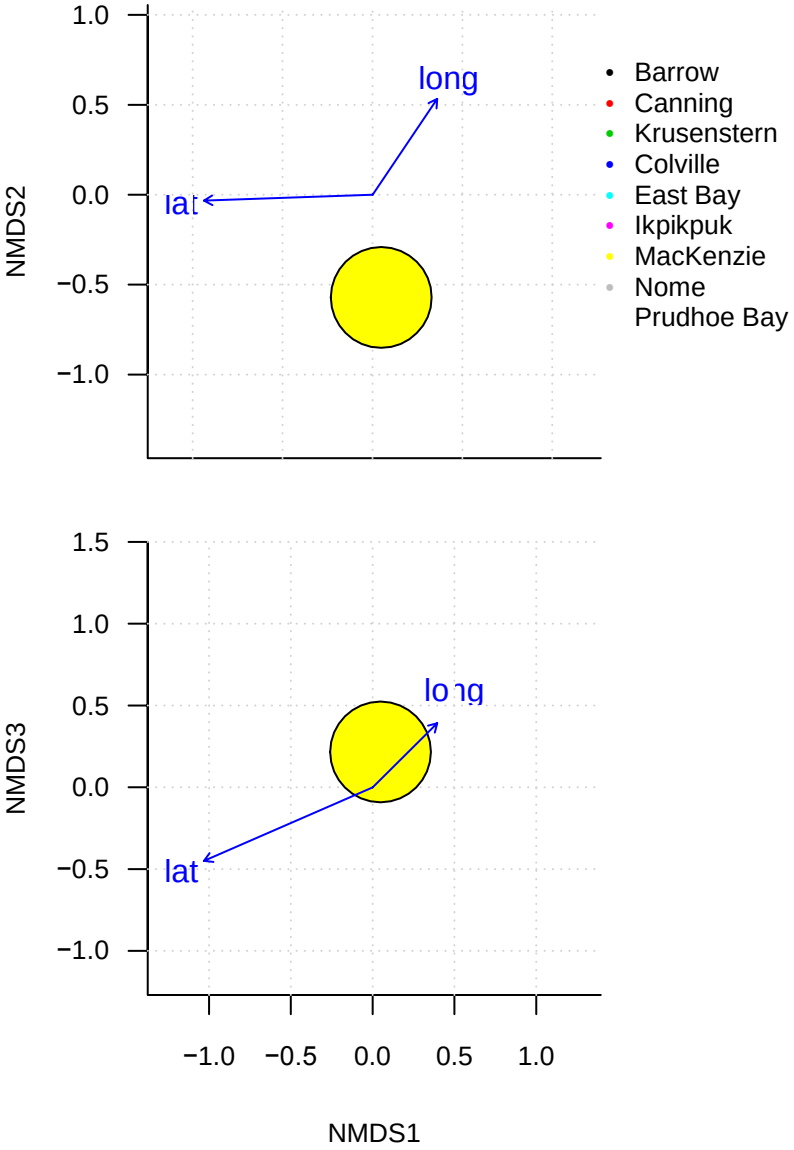
Saldidae (shore bugs)



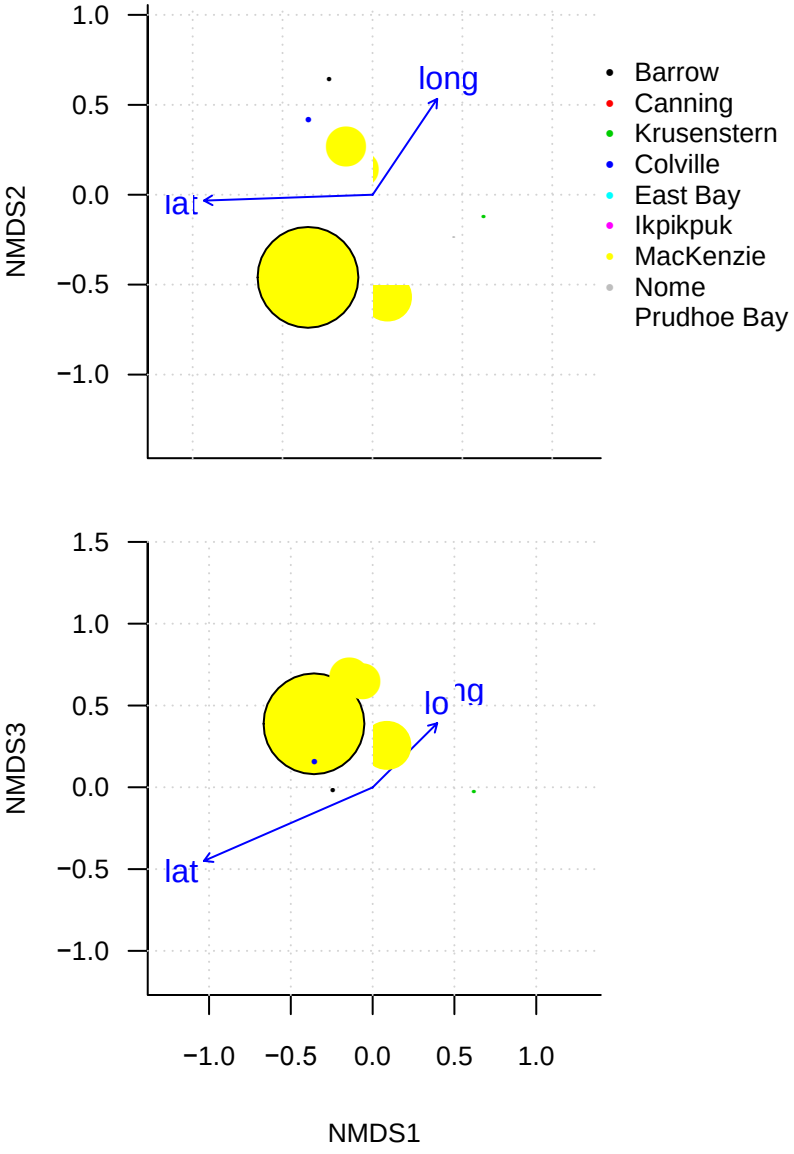
Sciaridae (root gnats)



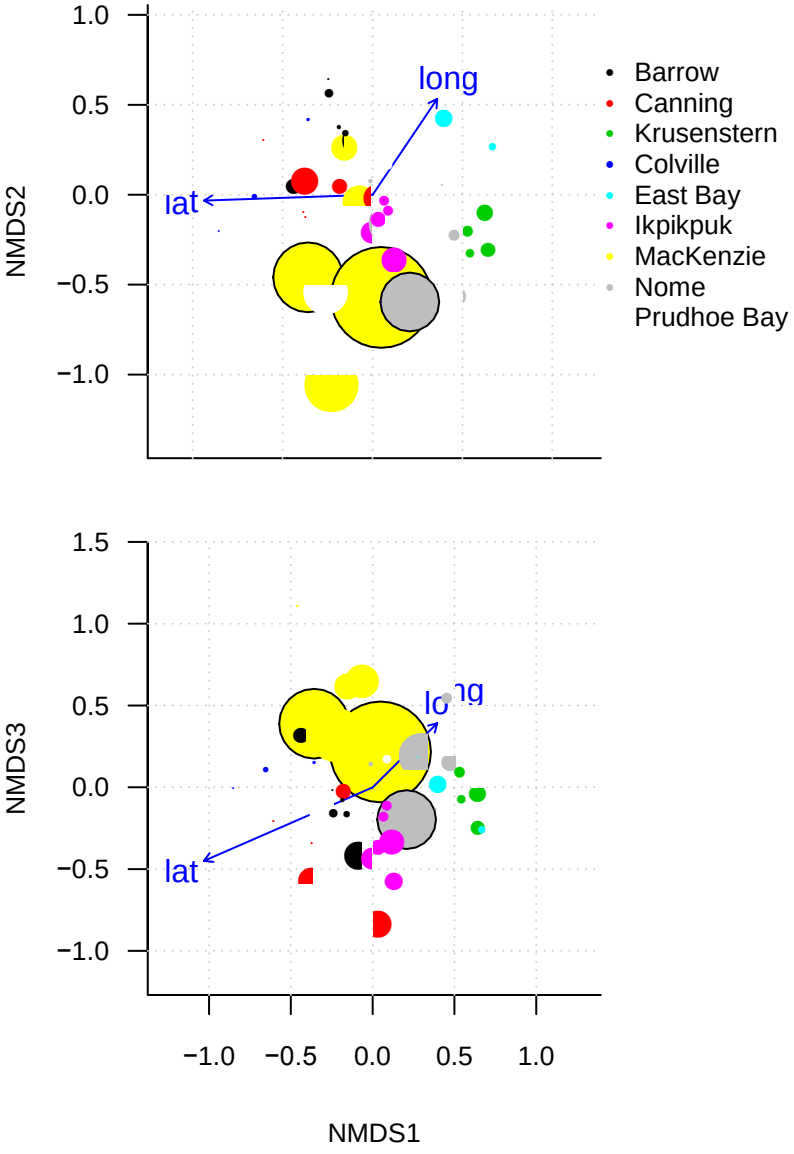
Silphidae (carrion beetles)



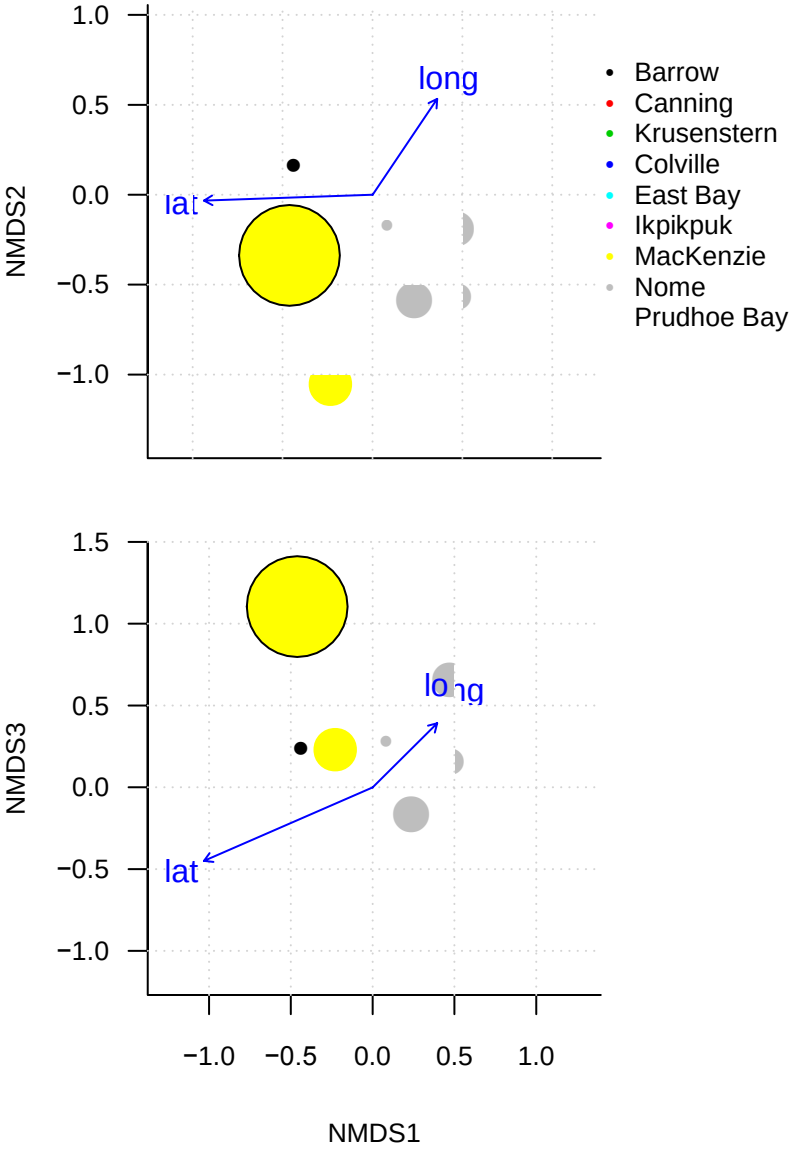
Simuliidae (black flies)



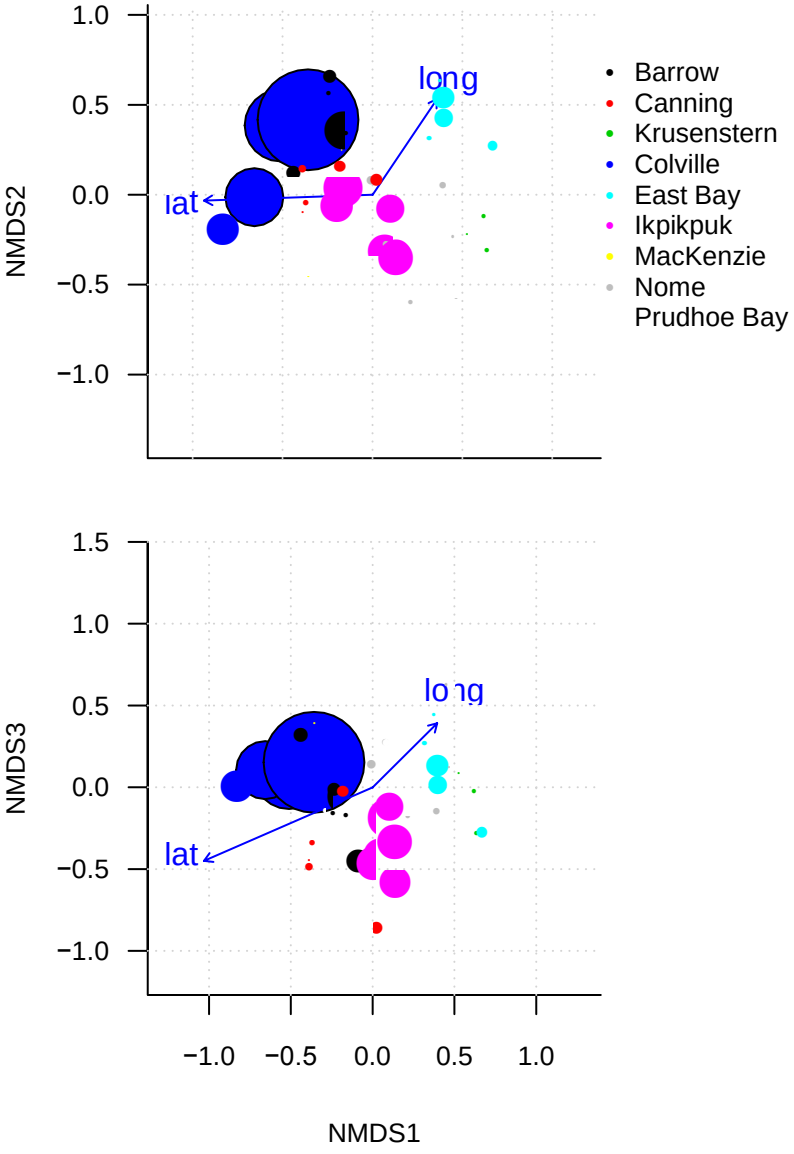
Staphylinidae (rove beetles)



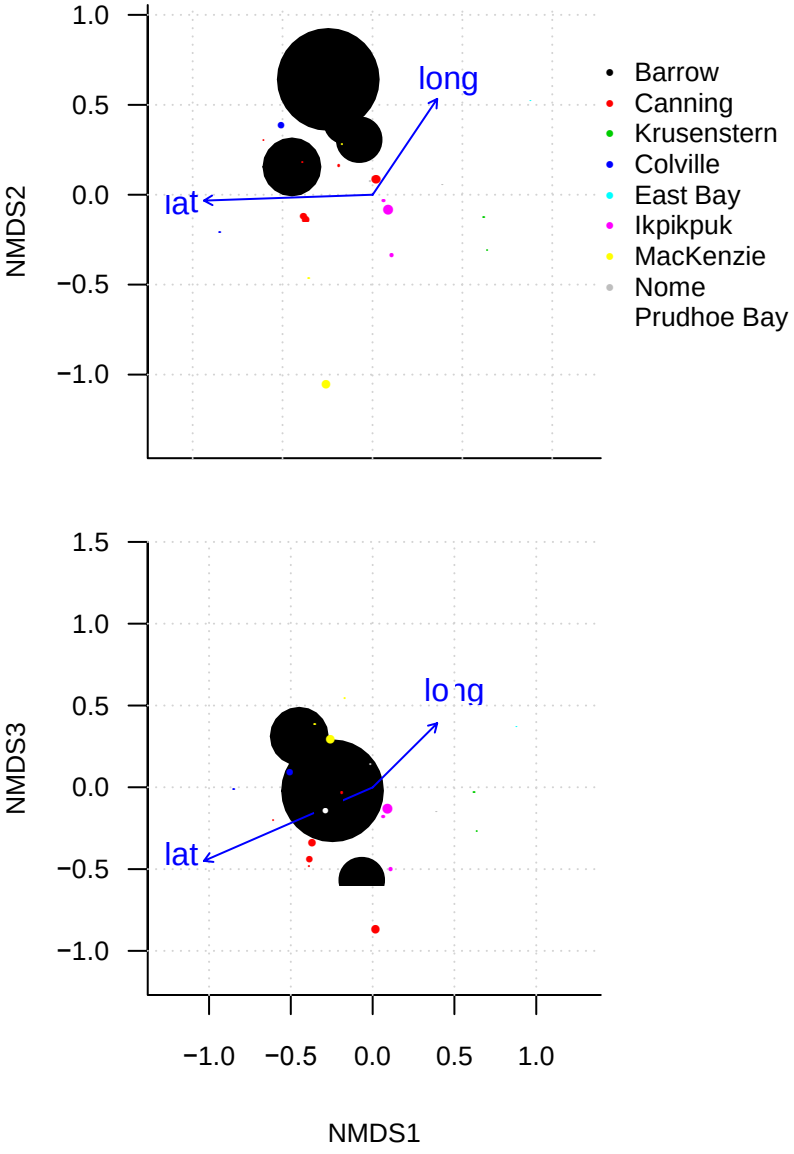
Thysanoptera (thrips)



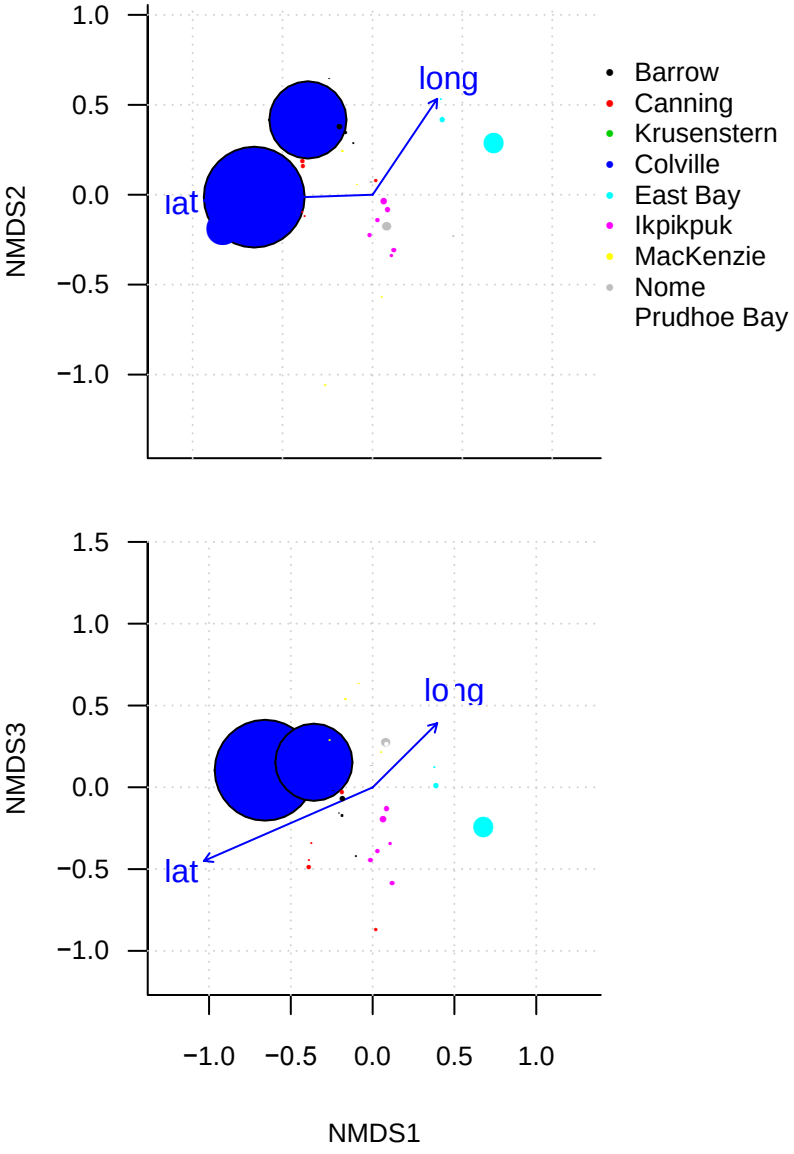
Tipulidae (crane flies)



Trichocera (winter crane flies)



Trichoptera (caddisflies)



Appendix D

Appendix D. Final confidence sets for each camp.

Camp	Intercept	CDD	CDD^2	Habitat	Precip.	Humidity	Temp.	Wind	AICc	ΔAICc	Model weight	Marginal R^2	Conditional $R^{2,1}$
Barrow	2.223	0.014	-0.00010		-0.089	-0.043		-0.075	222.1	0.00	0.61	0.76	0.76
Barrow	2.214	0.014	-0.00010			-0.048		-0.076	222.9	0.88	0.39	0.76	0.76
Canning	1.257	0.011	-0.00008	+				-0.055	137.7	0.00	0.66	0.53	0.64
Canning	1.018	0.004		+			0.107	-0.067	140.2	2.45	0.19	0.53	0.71
Canning	1.032			+			0.130	-0.062	140.7	2.99	0.15	0.49	0.60
Colville	3.277	0.012	-0.00004		-0.270		0.285	-0.062	154.5	0.00	0.55	0.79	0.85
Colville	3.056	0.01			-0.398		0.300	-0.064	156.0	1.48	0.26	0.75	0.85
Colville	3.439	0.012	-0.00008				0.288	-0.055	158.1	3.55	0.09	0.79	0.82
Colville	2.980	0.009		+	-0.395		0.298	-0.064	158.2	3.70	0.09	0.75	0.85
East Bay	2.256	0.001	-0.00010	+	-0.058		0.435		233.9	0.00	0.25	0.44	0.60
East Bay	2.461	0.001	-0.00010		-0.056		0.435		234.0	0.08	0.24	0.42	0.59
East Bay	2.447	-0.001	-0.00009				0.497		234.1	0.17	0.23	0.39	0.59
East Bay	1.881			+	-0.057		0.390		235.8	1.86	0.10	0.41	0.56
East Bay	2.087				-0.056		0.389		235.8	1.88	0.10	0.40	0.55
East Bay	2.092						0.421		235.8	1.90	0.10	0.36	0.55
Ikpikpuk	3.393	0.002	-0.00004	+	-0.197		0.191	-0.034	126.1	0.00	0.50	0.73	0.73
Ikpikpuk	3.528	0.002	-0.00004		-0.197		0.191	-0.034	127.8	1.73	0.21	0.71	0.71
Ikpikpuk	3.407	0.002	-0.00005	+	-0.211		0.212		127.9	1.81	0.20	0.71	0.71
Ikpikpuk	3.543	0.002	-0.00005		-0.211		0.212		129.4	3.36	0.09	0.69	0.69
Cape Krusenstern	3.447						0.178	-0.056	110.8	0.00	0.78	0.55	0.59
Cape Krusenstern	3.448						0.173		113.3	2.53	0.22	0.50	0.55
Mackenzie Delta	2.094	0.004	-0.00004	+		-0.027	0.148		139.5	0.00	0.60	0.76	0.76
Mackenzie Delta	2.004	0.001	-0.00003	+			0.189		140.8	1.29	0.32	0.74	0.74
Mackenzie Delta	1.765			+			0.197		143.5	3.93	0.08	0.70	0.70
Nome	3.257	-0.003			-0.055	0.053	0.384	0.058	179.6	0.00	0.82	0.66	0.69
Nome	3.253	-0.003			-0.046	0.046	0.343		182.6	2.98	0.18	0.64	0.67
Prudhoe Bay	2.157					-0.089		-0.041	34.3	0.00	0.40		0.64
Prudhoe Bay	2.157				0.261	-0.112			35.1	0.88	0.26		0.63
Prudhoe Bay	2.157					-0.113			35.6	1.29	0.21		0.57
Prudhoe Bay	2.157						0.132	-0.040	37.8	3.52	0.07		0.57
Prudhoe Bay	2.157						0.174		37.9	3.61	0.07		0.51

[1] Adjusted R^2 is shown for Prudhoe Bay because there was only one year of data.