Appendix J, Spring Delta Outflow

# Attachment J.3 Zooplankton-Delta Outflow Analysis

## J.3.1 Model Overview

Zooplankton are an important food source for many larval, juvenile and small pelagic fishes in the Bay-Delta. Delta smelt and longfin smelt are two species that rely on zooplankton. This analysis followed the general framework of similar, prior analyses (Kimmerer 2002; Hennessy and Burris 2017; Greenwood 2018; California Department of Water Resources and U.S. Bureau of Reclamation 2023:2-10) to examine the relationship between Sacramento–San Joaquin Delta (Delta) outflow and Delta smelt and longfin smelt zooplankton prey density (catch per cubic meter) in the low salinity zone (i.e., 0.5–6 parts per thousand salinity). The analyses related prey density to Delta outflow during spring (March–May), summer (June–August), and fall (September–November) for the period from 2000 to 2021. This period generally represents the onset of the Pelagic Organism Decline ecological regime (Thomson et al. 2010). Zooplankton examined in the analyses were based on taxa (species or species groupings, split by life stage where appropriate) included in recent modeling and diet studies of both Delta smelt and longfin smelt (Slater and Baxter 2014; Smith 2021:45; Barros et al. 2022; Smith and Nobriga 2023). Results demonstrate the relationship between abundance of smelt prey in the Delta and outflow, controlled by CVP and SWP seasonal operations.

## J.3.2 Model Development

### J.3.2.1 Methods

Historical zooplankton data were synthesized using the R (R Core Team 2023) statistical software package zooper (Bashevkin et al. 2022; Bashevkin et al. 2023a, b). Data was subset as follows. For mysids, surveys included ‘EMP’ (Environmental Monitoring Program) data, whereas for other taxa surveys included ‘EMP’ as well as ‘20mm’ (20-mm Survey in spring), ‘STN’ (Summer Townet) and ‘FMWT’ (Fall Midwater Trawl). The data type chosen was ‘Community’, with size class of ‘Macro’ for mysids and ‘Micro’, ‘Meso’, and ‘Macro’ for other taxa. Only samples within the low salinity zone (salinity = 0.5–6 parts per thousand) were selected. The mean catch per unit effort (number per cubic meter) was calculated by year and for each season.

Historical Delta outflow data by year for each seasonal period were obtained from Dayflow via the Drought Data R package’s dataset raw_hydro_1975_2022.

For each taxon, mean annual loge-transformed catch per unit effort + 1 for each taxon was regressed against mean annual loge-transformed Delta outflow for each seasonal period. Statistically significant regressions (Table J.3-1 through Table J.3-3) were then applied to the 1922-2021 CalSim 3-modeled data for Baseline Conditions and Proposed Action scenarios, with predictions back-transformed to the original measurement scale (catch per unit effort, number per cubic meter) for summary of results.

Table J.3-1. Spring (March–May) zooplankton regression summary.

| Taxon | Intercept | Slope | $R^2$ | P |
|---|---|---|---|---|
| *Acartiella sinensis* (copepod) adults | 8.134 | -0.506 | 0.125 | 0.107 |
| **Cladocerans except *Daphnia*** | **-3.746** | **0.730** | **0.365** | **0.003** |
| Copepod nauplii | 10.145 | 0.140 | 0.079 | 0.205 |
| Cyclopoid copepods except *Limnoithon* adults | 7.441 | 0.042 | 0.005 | 0.764 |
| *Daphnia* adults | -0.639 | 0.318 | 0.169 | 0.057 |
| ***Eurytemora affinis* (copepod) adults** | **0.234** | **0.528** | **0.255** | **0.016** |
| **Harpacticoid copepods** | **1.072** | **0.501** | **0.309** | **0.007** |
| *Limnoithona* adults | 7.973 | 0.135 | 0.030 | 0.439 |
| Mysids | 1.563 | 0.114 | 0.015 | 0.593 |
| **Other calanoid copepod adults** | **-1.593** | **0.669** | **0.210** | **0.032** |
| **Other calanoid copepod copepodites** | **2.296** | **0.469** | **0.357** | **0.003** |
| *Pseudodiaptomus* (copepod) adults | 4.496 | 0.053 | 0.001 | 0.874 |
| *Pseudodiaptomus* (copepod) copepodites | 0.882 | 0.476 | 0.149 | 0.076 |

Bolded text indicates statistically significant ($P<0.05$) regressions subsequently applied to CalSim 3-modeled data.
Note: regressions were loge(mean annual catch per meter+1) = loge(mean annual Delta outflow).

Table J.3-2. Summer (June–August) zooplankton regression summary.

| Taxon | Intercept | Slope | $R^2$ | P |
|---|---|---|---|---|
| *Acartiella sinensis* (copepod) adults | 3.779 | 0.196 | 0.006 | 0.732 |
| Cladocerans except *Daphnia* | 11.625 | -0.836 | 0.034 | 0.410 |
| Copepod nauplii | 10.883 | 0.163 | 0.038 | 0.385 |
| Cyclopoid copepods except *Limnoithona* adults | 9.204 | -0.021 | 0.000 | 0.922 |
| *Daphnia* adults | 13.713 | -1.316 | 0.104 | 0.143 |
| *Eurytemora affinis* (copepod) adults | -2.567 | 0.445 | 0.055 | 0.294 |
| Harpacticoid copepods | -2.539 | 0.788 | 0.119 | 0.117 |
| *Limnoithona* adults | 9.811 | 0.077 | 0.012 | 0.621 |
| Mysids | 0.065 | 0.364 | 0.031 | 0.211 |

| Taxon | Intercept | Slope | $R^2$ | P |
|---|---|---|---|---|
| Other calanoid copepod adults | 8.603 | -0.444 | 0.076 | 0.215 |
| Other calanoid copepod copepodites | 4.051 | 0.188 | 0.024 | 0.487 |
| *Pseudodiaptomus* (copepod) adults | 4.822 | 0.211 | 0.058 | 0.282 |
| *Pseudodiaptomus* (copepod) copepodites | 2.674 | 0.435 | 0.072 | 0.228 |

Regressions were loge(mean annual catch per meter+1) = loge(mean annual Delta outflow). None of the regressions were statistically significant ($P<0.05$).

Table J.3-3. Fall (September–November) zooplankton regression summary.

| Taxon | Intercept | Slope | $R^2$ | P |
|---|---|---|---|---|
| *Acartiella sinensis* (copepod) adults | 7.658 | -0.119 | 0.005 | 0.752 |
| Cladocerans except *Daphnia* | 14.953 | -1.375 | 0.053 | 0.300 |
| Copepod nauplii | 8.321 | 0.427 | 0.095 | 0.164 |
| Cyclopoid copepods except *Limnoithona* adults | 9.852 | -0.069 | 0.002 | 0.862 |
| *Daphnia* adults | 6.854 | -0.729 | 0.038 | 0.382 |
| ***Eurytemora affinis* (copepod) adults** | **-6.972** | **0.908** | **0.234** | **0.023** |
| Harpacticoid copepods | 4.114 | 0.054 | 0.000 | 0.960 |
| *Limnoithona* adults | 5.613 | 0.542 | 0.173 | 0.054 |
| **Mysids** | **-7.945** | **1.153** | **0.213** | **0.018** |
| Other calanoid copepod adults | 6.321 | -0.436 | 0.012 | 0.621 |
| Other calanoid copepod copepodites | 2.286 | 0.359 | 0.032 | 0.426 |
| *Pseudodiaptomus* (copepod) adults | 11.444 | -0.581 | 0.146 | 0.080 |
| *Pseudodiaptomus* (copepod) copepodites | 10.184 | -0.484 | 0.047 | 0.334 |

Bolded text indicates statistically significant ($P<0.05$) regressions subsequently applied to CalSim 3-modeled data. Regressions were loge(mean annual catch per meter+1) = loge(mean annual Delta outflow).

### J.3.2.2 Assumptions/Uncertainty

This analysis is meant as a tool to compare mean abundance of zooplankton prey across different operation scenarios and is not a predictive tool.

While Delta outflow explains some of the variance in zooplankton CPUE, the relatively low $R^2$ values suggest that other factors contribute as well. Both Delta outflow and inflow are highly correlated (Kimmerer 2004); outflow is used as the variable of interest because it is more readily available and more easily linked to the position of X2. There are various hypothesized mechanisms for how flow affects zooplankton abundance in the low salinity zone via subsidies of zooplankton from higher abundance regions into the low salinity zone to subsidies of nutrients or phytoplankton (Hassrick et al. 2023; Kimmerer et al. 2019; Kimmerer 2002). A historical regression of zooplankton CPUE with flow may be too simple and including other factors such as salinity, temperature, chlorophyll-*a*, residence time, etc. may have more explanatory power.

Historically, relationships between outflow and zooplankton abundance have changed over time (e.g., mysids in the summer) or relationships have become significant with increased outflow (e.g., *E. affinis* in the spring) or there is no relationship with outflow (e.g., rotifers and *E. affinis* in the summer) (Kimmerer 2009).

Zooplankton CPUE exhibits high variability, across regions, seasons, and years (Winder and Jassby 2011; Bollens et al. 2014; Lee et al. 2023) which may limit the statistical power to detect effects of flow alterations (Brandon et al. 2022).

### J.3.2.3 Code and Data Repository

Biological data can be found online at www.wildlife.ca.gov/Conservation/Delta/Zooplankton-Study and on the ICF SharePoint in the Data and Code folder (Data and Code).

Hydrologic data can be found online at http://www.water.ca.gov/dayflow/output/

R code and results can be found on the ICF SharePoint in the Data and Code folder (Data and Code).

## J.3.3 Results

Results are presented by taxon for statistically significant zooplankton regressions by water year type for each alternative in Table J.3-4 through Table J.3-17.

Tables include results from Explanatory 1 (EXP1), Explanatory 3 (EXP3), No Action Alternative (NAA), Alternative 2 with TUCPs (Alt2wTUCPwoVA), Alternative 2 without TUCPs (Alt2woTUCPwoVA), Alternative 2 with Delta VA (Alt2woTUCPDeltaVA), and Alternative 2 with systemwide VAs (Alt2woTUCPAllVA).

Another set of tables include results from No Action Alternative (NAA), Alternative 1 (Alt1), Alternative 2 with TUCPs (Alt2wTUCPwoVA), Alternative 2 without TUCPs (Alt2woTUCPwoVA), Alternative 2 with Delta VA (Alt2woTUCPDeltaVA), and Alternative 2 with systemwide VAs (Alt2woTUCPAllVA), Alternative 3 (Alt3), Alternative 4 (Alt4).

During spring months (March to May), the following taxa had a significant relationship with Delta outflow: Cladocerans (except *Daphnia*), *Eurytemora affinis* (copepod) adults, Harpacticoid copepods, Other calanoid copepod adults, and Other calanoid copepod copepodites (Table J.3-1).

### J.3.3.1 Taxons

#### *J.3.3.1.1 Cladocerans (except Daphnia)*

For Cladocerans (except *Daphnia*) in the spring, during the **wet year type**, Alt3 had the highest CPUE (76) which was a 10% increase compared to the NAA. Alt1, Alt2wTUCPwoVA, Alt2woTUCPwoVA, and Alt4 had the lowest CPUE (68) which was a 1% decrease compared to the NAA. Alt2woTUCPAllVA was no different from the NAA.

For **above normal year type**, Alt3 had the highest CPUE (54) which was a 12% increase compared to the NAA. Alt1 had the lowest CPUE (44) which was an 8% decrease compared to the NAA. Alt2wTUCPwoVA, Alt2woTUCPwoVA, and Alt4 all showed a 4% decrease compared to the NAA. Alt2woTUCPDeltaVA only showed a 2% decrease and Alt2woTUCPAllVA was no different from the NAA.

For the **below normal year type**, Alt3 had the highest CPUE (36) which was a 12% increase compared to the NAA. Alt1 had the lowest CPUE (30) which was a 6% decrease compared to the NAA. Alt2wTUCPwoVA, Alt2woTUCPwoVA, and Alt4 all showed a 3% decrease compared to the NAA. Alt2woTUCPDeltaVA was no different from the NAA and Alt2woTUCPAllVA showed a 6% increase.

For the **dry year type**, Alt3 had the highest CPUE (29) which was a 16% increase compared to the NAA. Alt1 had the lowest CPUE (24) which was a 4% decrease compared to the NAA. Alt2wTUCPwoVA, Alt2woTUCPwoVA, and Alt4 were no different than the NAA. Alt2woTUCPDeltaVA showed a 4% increase and Alt2woTUCPAllVA showed an 8% increase.

For the **critical year type**, Alt2woTUCPAllVA and Alt3 had the highest CPUE (18), which was a 20% increase compared to the NAA. Alt2woTUCPwoVA and Alt4 had the lowest CPUE (15) which was the same as the NAA. Alt1, Alt2woTUCPwoVA, and Alt2woTUCPDeltaVA showed a 13% increase.

Historically, in the low salinity zone (LSZ), CPUE of Cladocerans are lower when compared to more freshwater regions (Winder and Jassby 2011 Fig. 5, 7). While some marine and brackish water Cladocerans species are present in the San Francisco Estuary, freshwater Cladocerans tend to be more abundant in the Bay-Delta system. This could explain the lower CPUE observed during lower outflow scenarios and water year types.

Yet the mechanism for why CPUE increases in the low salinity zone during higher outflow has not been clearly and definitively established. Kimmerer (2002) found lower trophic level taxa (zooplankton) responded inconsistently with flow across seasons and historical periods. Kimmerer also found that chlorophyll showed little response to flow, suggesting a bottom up, “agricultural model” explanation for increased CPUE with higher flows is unlikely. Another possible mechanism is that increased flows also increase subsidies of zooplankton from higher abundance freshwater regions into the LSZ (Hassrick et al. 2023; Kimmerer et al. 2019).

Differences in operations during wet years appear to have little influence on the CPUE. Across all scenarios the CPUE remained unchanged or only decreased slightly (-1%) when compared to the NAA except for Alt3 which had increased outflow compared to all other scenarios.

As water year types became drier, the effect of scenarios on CPUE generally increased compared to the NAA. Alt1 generally had lower flows and lower CPUE for all year types, except for the critical year type. Similarly, Alt2wTUCPwoVA outflow and CPUE only increased for the critical year type. Alt2woTUCPwoVA outflow was only slightly less than the NAA for Wet, Above Normal and Below Normal years and almost the same for the Dry and Critical years. Alt2woTUCPDeltaVA only outflow increased compared to the NAA for Below Normal, Dry and Critical years. Alt2woTUCPAllVA, outflow increased for Above Normal, Dry and Critical years. For all year types, Alt3 generally had the highest outflow and the largest CPUE increase compared to the NAA. Alt4 generally was either slightly below or above the NAA in terms of both outflow and CPUE percent difference.

For the critical year type all scenarios showed an increase or no change in CPUE from the NAA.

#### *J.3.3.1.2 Adult Eurytemora affinis*

For adult *Eurytemora affinis* in the spring, during the **wet year type**, Alt3 had the highest CPUE (432) which was a 7% increase compared to the NAA. Alt1 had the lowest CPUE (396) which was a 2% decrease compared to the NAA. For **above normal year type**, Alt3 had the highest CPUE (340) which was a 9% increase compared to the NAA. Alt1 had the lowest CPUE (297) which was a 5% decrease compared to the NAA. For the **below normal year type**, Alt3 had the highest CPUE (258) which was a 10% increase compared to the NAA. Alt1 had the lowest CPUE (223) which was a 5% decrease compared to the NAA. For the **dry year type**, Alt3 had the highest CPUE (218) which was a 9% increase compared to the NAA. Alt1 had the lowest CPUE (192) which was a 4% decrease compared to the NAA. For the **critical year type**, Alt3 had the highest CPUE (158), which was an 9% increase compared to the NAA. Alt2woTUCPwoVA had the lowest CPUE (141) which was the same compared to the NAA.

Kimmerer (2002) found a significant relationship between adult *E. affinis* and outflow. However, this relationship was only present after 1987, the post *Potamocorbula amurensis* invasion period which also coincided with a seven-fold decline in *E. affinis*.

The mechanism for why CPUE increases in the low salinity zone during higher outflow has not been clearly and definitively established. Kimmerer (2002) found lower trophic level taxa (zooplankton) responded inconsistently with flow across seasons and historical periods. Kimmerer also found that chlorophyll showed little response to flow, suggesting a bottom up, “agricultural model” explanation for increased CPUE with higher flows is unlikely. Another possible mechanism is that increased flows also increase subsidies of zooplankton from higher abundance freshwater seasons into the LSZ as seen in *Pseudodiaptomus forbesi*, another calanoid copepod species (Hassrick et al. 2023; Kimmerer et al. 2019).

#### *J.3.3.1.3 Harpacticoids*

For harpacticoids in the spring, during the **wet year type**, Alt3 had the highest CPUE (736) which was a 7% increase compared to the NAA. Alt1 had the lowest CPUE (678) which was a 2% decrease compared to the NAA. For the **above normal year type**, Alt3 had the highest CPUE (587) which was a 9% increase compared to the NAA. Alt1 had the lowest CPUE (517) which was a 4% decrease compared to the NAA. For the **below normal year type**, Alt3 had the highest CPUE (452) which was a 10% increase compared to the NAA. Alt1 had the lowest CPUE (393) which was a 5% decrease compared to the NAA. For the **dry year type**, Alt3 had the highest CPUE (385) which was an 8% increase compared to the NAA. Alt1 had the lowest CPUE (342) which was a 4% decrease compared to the NAA. For the **critical year type**, Alt3 had the highest CPUE (284), which was an 11% increase compared to the NAA. Alt2woTUCPwoVA and Alt4 had the lowest CPUE (256) which was a less than 0.5% decrease compared to the NAA.

Harpacticoids are not well studied in the Bay-Delta system but do sporadically show up in Delta smelt and longfin smelt diets (Burris et al. 2022; Slater et al. 2019; Slater and Baxter 2014; Nobriga 2002) and are a primary prey for common carp, Sacramento sucker, splittail (Feyrer et al. 2003), and smaller fish species such as mosquitofish, inland silversides, gobies (Glibert et al. 2011). Harpacticoids are present throughout the Bay-Delta system year-round (Ambler et al. 1985). Harpacticoids tend to be associated with benthic environments and may not be as readily available for consumption by Delta smelt and longfin smelt. There has been no previous research that observed a relationship between harpacticoids and flow.

The mechanism for why CPUE increases in the low salinity zone during higher outflow has not been clearly and definitively established. Kimmerer (2002) found lower trophic level taxa (zooplankton) responded inconsistently with flow across seasons and historical periods. Kimmerer also found that chlorophyll showed little response to flow, suggesting a bottom up, “agricultural model” explanation for increased CPUE with higher flows is unlikely. Another possible mechanism is that increased flows also increase subsidies of zooplankton from higher abundance freshwater seasons into the LSZ (Hassrick et al. 2023; Kimmerer et al. 2019).

#### *J.3.3.1.4 Other adult calanoid copepods*

For other adult calanoid copepods in the spring, during the **wet year type**, Alt3 had the highest CPUE (333) which was a 9% increase compared to the NAA. Alt1 had the lowest CPUE (300) which was a 2% decrease compared to the NAA. For **above normal year type**, Alt3 had the highest CPUE (244) which was an 11% increase compared to the NAA. Alt1 had the lowest CPUE (206) which was a 6% decrease compared to the NAA. For the **below normal year type**, Alt3 had the highest CPUE (172) which was a 13% increase compared to the NAA. Alt1 had the lowest CPUE (143) which was a 6% decrease compared to the NAA. For the **dry year type**, Alt3 had the highest CPUE (138) which was an 11% increase compared to the NAA. Alt1 had the lowest CPUE (118) which was a 5% decrease compared to the NAA. For the **critical year type**, Alt3 had the highest CPUE (92), which was a 15% increase compared to the NAA. Alt2woTUCPwoVA and Alt4 had the lowest CPUE (80) which was the same as the NAA.

The other calanoid copepods species included as part of “other adult calanoid copepods” were: *Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae. These species have been found in larval Delta smelt and longfin smelt diets (Burris et al. 2022; Slater et al. 2019; Slater and Baxter 2014; Nobriga 2002). Historically, since its introduction in 1978, *S. doerrii* was most abundant in the Suisun Bay region, with peak abundance during the spring to summer season, though it was noted that flow during winter would advect individuals into San Pablo Bay (Ambler et al. 1985). Since then, the range of *S. doerrii* has shifted landwards, likely because of effects of *Potamcorbula amurensis* grazing (Kimmerer et al. 1998). Therefore, increased flow is possibly advecting more individuals from more freshwater regions into the LSZ.

The mechanism for why CPUE increases in the low salinity zone during higher outflow has not been clearly and definitively established. Kimmerer (2002) found lower trophic level taxa (zooplankton) responded inconsistently with flow across seasons and historical periods. Kimmerer also found that chlorophyll showed little response to flow, suggesting a bottom up, "agricultural model" explanation for increased CPUE with higher flows is unlikely. Another possible mechanism is that increased flows also increase subsidies of zooplankton from higher abundance freshwater seasons into the LSZ (Hassrick et al. 2023; Kimmerer et al. 2019).

#### *J.3.3.1.5 Other copepodite calanoid copepods*

The other calanoid copepods species included as part of "other copepodite calanoid copepods" were: *Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae. These species have been found in larval Delta smelt and longfin smelt diets (Burris et al. 2022; Slater et al. 2019; Slater and Baxter 2014; Nobriga 2002).

For other copepodite calanoid copepods in the spring, during the **wet year type**, scenario Alt3 had the highest CPUE (1757) which was a 6% increase compared to the NAA. Alt1 had the lowest CPUE (1626) which was a 2% decrease compared to the NAA. For **above normal year type**, scenario Alt3 had the highest CPUE (1423) which was an 8% increase compared to the NAA. Alt1 had the lowest CPUE (1264) which was a 4% decrease compared to the NAA. For the **below normal year type**, scenario Alt3 had the highest CPUE (1116) which was a 9% increase compared to the NAA. Alt1 had the lowest CPUE (978) which was a 4% decrease compared to the NAA. For the **dry year type**, scenario Alt3 had the highest CPUE (960) which was an 8% increase compared to the NAA. Alt1 had the lowest CPUE (860) which was a 3% decrease compared to the NAA. For the **critical year type**, scenario Alt3 had the highest CPUE (723), which was an 11% increase compared to the NAA. Alt2woTUCPwoVA had the lowest CPUE (656) which was a less than 0.5% increase compared to the NAA.

The mechanism for why CPUE increases in the low salinity zone during higher outflow has not been clearly and definitively established. Kimmerer (2002) found lower trophic level taxa (zooplankton) responded inconsistently with flow across seasons and historical periods. Kimmerer also found that chlorophyll showed little response to flow, suggesting a bottom up, "agricultural model" explanation for increased CPUE with higher flows is unlikely. Another possible mechanism is that increased flows also increase subsidies of zooplankton from higher abundance freshwater seasons into the LSZ (Hassrick et al. 2023; Kimmerer et al. 2019).

### J.3.3.2 Tables

Table J.3-4. Mean catch per unit effort (CPUE) for **Cladocerans (except *Daphnia*)** in **spring** by modeled scenario and water year type.

| **Water Year Type** | **EXP1** | **EXP3** | **NAA** | **Alt2wTUCPwoVA** | **Alt2woTUCPwoVA** | **Alt2woTUCPDeltaVA** | **Alt2woTUCPAllVA** |
|---|---|---|---|---|---|---|---|
| Wet | 88 | 78 | 69 | 68 | 68 | 68 | 69 |
| Above Normal | 65 | 54 | 48 | 46 | 46 | 47 | 48 |
| Below Normal | 47 | 38 | 32 | 31 | 31 | 32 | 34 |
| Dry | 38 | 30 | 25 | 25 | 25 | 26 | 27 |
| Critical | 22 | 19 | 15 | 17 | 15 | 17 | 18 |

Values are rounded to the nearest integer.

Table J.3-5. Mean catch per unit effort (CPUE) for **Cladocerans (except *Daphnia*)** in **spring** by modeled scenario and water year type.

| **Water Year Type** | **NAA** | **Alt1** | **Alt2wTUCPwoVA** | **Alt2woTUCPwoVA** | **Alt2woTUCPDeltaVA** | **Alt2woTUCPAllVA** | **Alt3** | **Alt4** |
|---|---|---|---|---|---|---|---|---|
| Wet | 69 | 68 (-1%) | 68 (-1%) | 68 (-1%) | 68 (-1%) | 69 (0%) | 76 (10%) | 68 (-1%) |
| Above Normal | 48 | 44 (-8%) | 46 (-4%) | 46 (-4%) | 47 (-2%) | 48 (0%) | 54 (12%) | 46 (-4%) |
| Below Normal | 32 | 30 (-6%) | 31 (-3%) | 31 (-3%) | 32 (0%) | 34 (6%) | 36 (12%) | 31 (-3%) |
| Dry | 25 | 24 (-4%) | 25 (0%) | 25 (0%) | 26 (4%) | 27 (8%) | 29 (16%) | 25 (0%) |
| Critical | 15 | 17 (13%) | 17 (13%) | 15 (0%) | 17 (13%) | 18 (20%) | 18 (20%) | 15 (0%) |

Percentage values in parentheses indicate the difference between NAA and each alternative. Values and percent difference are rounded to the nearest integer.

Table J.3-6. Mean catch per unit effort (CPUE) for ***E. affinis*** **adults** in **spring** by modeled scenario and water year type.

| **Water Year Type** | **EXP1** | **EXP3** | **NAA** | **Alt2wTUCPwoVA** | **Alt2woTUCPwoVA** | **Alt2woTUCPDeltaVA** | **Alt2woTUCPAllVA** |
|---|---|---|---|---|---|---|---|
| Wet | 480 | 438 | 404 | 399 | 399 | 400 | 401 |
| Above Normal | 388 | 343 | 312 | 304 | 306 | 311 | 316 |
| Below Normal | 307 | 264 | 234 | 229 | 230 | 235 | 243 |
| Dry | 264 | 226 | 200 | 198 | 198 | 202 | 209 |
| Critical | 180 | 163 | 141 | 153 | 141 | 153 | 157 |

Values are rounded to the nearest integer.

Table J.3-7. Mean CPUE for ***E. affinis*** **adults** in **spring** by modeled scenario and water year type.

| **Water Year Type** | **NAA** | **Alt1** | **Alt2wTUCPwoVA** | **Alt2woTUCPwoVA** | **Alt2woTUCPDeltaVA** | **Alt2woTUCPAllVA** | **Alt3** | **Alt4** |
|---|---|---|---|---|---|---|---|---|
| Wet | 404 | 396 (-2%) | 399 (-1%) | 399 (-1%) | 400 (-1%) | 401 (-1%) | 432 (7%) | 398 (-1%) |
| Above Normal | 312 | 297 (-5%) | 304 (-3%) | 306 (-2%) | 311 (0%) | 316 (1%) | 340 (9%) | 305 (-2%) |
| Below Normal | 234 | 223 (-5%) | 229 (-2%) | 230 (-2%) | 235 (0%) | 243 (4%) | 258 (10%) | 229 (-2%) |
| Dry | 200 | 192 (-4%) | 198 (-1%) | 198 (-1%) | 202 (1%) | 209 (4%) | 218 (9%) | 198 (-1%) |
| Critical | 141 | 150 (6%) | 153 (9%) | 141 (0%) | 153 (9%) | 157 (11%) | 158 (12%) | 142 (1%) |

Percentage values in parentheses indicate the difference between NAA and each alternative. Values and percent difference are rounded to the nearest integer.

Table J.3-8. Mean CPUE for **Harpacticoids** in **spring** by modeled scenario and water year type.

| Water Year Type | EXP1 | EXP3 | NAA | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA |
|---|---|---|---|---|---|---|---|
| Wet | 813 | 746 | 690 | 682 | 682 | 684 | 685 |
| Above Normal | 666 | 592 | 541 | 528 | 531 | 539 | 548 |
| Below Normal | 533 | 462 | 412 | 404 | 405 | 414 | 428 |
| Dry | 463 | 399 | 355 | 352 | 352 | 359 | 370 |
| Critical | 321 | 292 | 255 | 276 | 256 | 276 | 282 |

Values are rounded to the nearest integer.

Table J.3-9. Mean CPUE for **Harpacticoids** in **spring** by modeled scenario and water year type.

| Water Year Type | NAA | Alt1 | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|
| Wet | 690 | 678 (-2%) | 682 (-1%) | 682 (-1%) | 684 (-1%) | 685 (-1%) | 736 (7%) | 681 (-1%) |
| Above Normal | 541 | 517 (-4%) | 528 (-2%) | 531 (-2%) | 539 (0%) | 548 (1%) | 587 (9%) | 531 (-2%) |
| Below Normal | 412 | 393 (-5%) | 404 (-2%) | 405 (-2%) | 414 (0%) | 428 (4%) | 452 (10%) | 404 (-2%) |
| Dry | 355 | 342 (-4%) | 352 (-1%) | 352 (-1%) | 359 (1%) | 370 (4%) | 385 (8%) | 352 (-1%) |
| Critical | 255 | 270 (6%) | 276 (8%) | 256 (0%) | 276 (8%) | 282 (11%) | 284 (11%) | 256 (0%) |

Percentage values in parentheses indicate the difference between NAA and each alternative. Values and percent difference are rounded to the nearest integer.

Table J.3-10. Mean CPUE for **other calanoid copepod adults** in **spring** by modeled scenario and water year type.

| Water Year Type | EXP1 | EXP3 | NAA | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA |
|---|---|---|---|---|---|---|---|
| Wet | 380 | 340 | 306 | 302 | 302 | 303 | 304 |
| Above Normal | 289 | 247 | 219 | 212 | 214 | 218 | 223 |
| Below Normal | 216 | 178 | 152 | 148 | 149 | 153 | 160 |
| Dry | 178 | 146 | 124 | 123 | 123 | 126 | 131 |
| Critical | 109 | 96 | 80 | 89 | 80 | 89 | 91 |

Values are rounded to the nearest integer.

Table J.3-11. Mean CPUE for **other calanoid copepod adults** in **spring** by modeled scenario and water year type.

| Water Year Type | NAA | Alt1 | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|
| Wet | 306 | 300 (-2%) | 302 (-1%) | 302 (-1%) | 303 (-1%) | 304 (-1%) | 333 (9%) | 301 (-2%) |
| Above Normal | 219 | 206 (-6%) | 212 (-3%) | 214 (-2%) | 218 (0%) | 223 (2%) | 244 (11%) | 213 (-3%) |
| Below Normal | 152 | 143 (-6%) | 148 (-3%) | 149 (-2%) | 153 (1%) | 160 (5%) | 172 (13%) | 148 (-3%) |
| Dry | 124 | 118 (-5%) | 123 (-1%) | 123 (-1%) | 126 (2%) | 131 (6%) | 138 (11%) | 123 (-1%) |
| Critical | 80 | 86 (8%) | 89 (11%) | 80 (0%) | 89 (11%) | 91 (14%) | 92 (15%) | 80 (0%) |

Percentage values in parentheses indicate the difference between NAA and each alternative. Values and percent difference are rounded to the nearest integer.

Table J.3-12. Mean CPUE for **other calanoid copepod copepodites** in **spring** by modeled scenario and water year type.

| Water Year Type | EXP1 | EXP3 | NAA | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA |
|---|---|---|---|---|---|---|---|
| Wet | 1930 | 1780 | 1653 | 1635 | 1635 | 1641 | 1643 |
| Above Normal | 1602 | 1434 | 1319 | 1291 | 1297 | 1315 | 1336 |
| Below Normal | 1301 | 1138 | 1023 | 1005 | 1005 | 1027 | 1059 |
| Dry | 1139 | 991 | 890 | 883 | 883 | 900 | 925 |
| Critical | 808 | 742 | 653 | 704 | 656 | 704 | 719 |

Values are rounded to the nearest integer.

Table J.3-13. Mean CPUE for **other calanoid copepod copepodites** in **spring** by modeled scenario and water year type.

| Water Year Type | NAA | Alt1 | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|
| Wet | 1653 | 1626 (-2%) | 1635 (-1%) | 1635 (-1%) | 1641 (-1%) | 1643 (-1%) | 1757 (6%) | 1633 (-1%) |
| Above Normal | 1319 | 1264 (-4%) | 1291 (-2%) | 1297 (-2%) | 1315 (0%) | 1336 (1%) | 1423 (8%) | 1295 (-2%) |
| Below Normal | 1023 | 978 (-4%) | 1005 (-2%) | 1005 (-2%) | 1027 (0%) | 1059 (4%) | 1116 (9%) | 1004 (-2%) |
| Dry | 890 | 860 (-3%) | 883 (-1%) | 883 (-1%) | 900 (1%) | 925 (4%) | 960 (8%) | 882 (-1%) |
| Critical | 653 | 690 (6%) | 704 (8%) | 656 (0%) | 704 (8%) | 719 (10%) | 723 (11%) | 657 (1%) |

Percentage values in parentheses indicate the difference between NAA and each alternative. Values and percent difference are rounded to the nearest integer.

During fall months (September to November), the CPUE of following taxon was significantly related to Delta outflow: adult *Eurytemora affinis* and mysids (Table J.3-3).

For adult *Eurytemora affinis* in the fall, across all scenarios, CPUE was very low (≤ 5). When CPUE was rounded to the nearest integer there was often no change compared to the NAA. During the **wet year type**, scenario Alt3 had the highest CPUE (4) which was a 33% increase compared to the NAA. Alt1 had the lowest CPUE (2) which was a 33% decrease compared to the NAA. For the **above normal year type**, scenario Alt2wTUCPwoVA, Alt2woTUCPwoVA, Alt2woTUCPDeltaVA, Alt2woTUCPAllVA, Alt3 and Alt4 had the highest CPUE (3) which was no different compared to the NAA. Alt1 had the lowest CPUE (1) which was a 67% decrease compared to the NAA. For the **below normal year type**, all scenarios were no different from the NAA, the CPUE was 1. For the **dry year type**, scenarios Alt2wTUCPwoVA, Alt2woTUCPwoVA, Alt2woTUCPDeltaVA, Alt2woTUCPAllVA, Alt3, and Alt4 had the highest CPUE (2) which was no different from the NAA. Alt1 had the lowest CPUE (1) which was a 50% decrease compared to the NAA. For the **critical year type**, all scenarios were no different from the NAA, the CPUE was 1. (Provide biological, ecological, and operational explanation for the observations)

For mysids in the fall, during the **wet year type**, scenario Alt3 had the highest CPUE (18) which was a 20% increase compared to the NAA. Alt1 had the lowest CPUE (11) which was a 27% decrease compared to the NAA. For **above normal year type**, scenario Alt3 had the highest CPUE (15) which was a 25% increase compared to the NAA. Alt1 had the lowest CPUE (7) which was a 42% decrease compared to the NAA. For the **below normal year type**, scenario Alt3 had the highest CPUE (7) which was a 17% increase compared to the NAA. Alt1 had the lowest CPUE (5) which was a 17% decrease compared to the NAA. For the **dry year type**, scenarios Alt2woTUCPAllVA and Alt3 had the highest CPUE (8) which was a 14% increase compared to the NAA. All other scenarios showed no difference from the NAA, the CPUE was 7. For the **critical year type**, all scenarios were no different from the NAA, the CPUE was 4. (Provide biological, ecological, and operational explanation for the observations)

Table J.3-14. Mean CPUE for ***E. affinis* adults** in **fall** by modeled scenario and water year type.

| **Water Year Type** | **EXP1** | **EXP3** | **NAA** | **Alt2wTUCPwoVA** | **Alt2woTUCPwoVA** | **Alt2woTUCPDeltaVA** | **Alt2woTUCPAllVA** |
|---|---|---|---|---|---|---|---|
| Wet | 4 | 5 | 3 | 3 | 3 | 3 | 3 |
| Above Normal | 3 | 4 | 3 | 3 | 3 | 3 | 3 |
| Below Normal | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
| Dry | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| Critical | 0 | 2 | 1 | 1 | 1 | 1 | 1 |

Values are rounded to the nearest integer.

Table J.3-15. Mean CPUE for ***E. affinis* adults** in **fall** by modeled scenario and water year type.

| **Water Year Type** | **NAA** | **Alt1** | **Alt2wTUCPwoVA** | **Alt2woTUCPwoVA** | **Alt2woTUCPDeltaVA** | **Alt2woTUCPAllVA** | **Alt3** | **Alt4** |
|---|---|---|---|---|---|---|---|---|
| Wet | 3 | 2 (-33%) | 3 (0%) | 3 (0%) | 3 (0%) | 3 (0%) | 4 (33%) | 3 (0%) |
| Above Normal | 3 | 1 (-67%) | 3 (0%) | 3 (0%) | 3 (0%) | 3 (0%) | 3 (0%) | 3 (0%) |
| Below Normal | 1 | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) |
| Dry | 2 | 1 (-50%) | 2 (0%) | 2 (0%) | 2 (0%) | 2 (0%) | 2 (0%) | 2 (0%) |
| Critical | 1 | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) | 1 (0%) |

Percentage values in parentheses indicate the difference between NAA and each alternative. Values and percent difference are rounded to the nearest integer.

Table J.3-16. Mean CPUE for **mysids** in **fall** by modeled scenario and water year type.

| Water Year Type | EXP1 | EXP3 | NAA | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA |
|---|---|---|---|---|---|---|---|
| Wet | 19 | 22 | 15 | 15 | 15 | 15 | 15 |
| Above Normal | 15 | 16 | 12 | 13 | 13 | 13 | 13 |
| Below Normal | 11 | 14 | 6 | 6 | 6 | 6 | 6 |
| Dry | 13 | 15 | 7 | 7 | 7 | 7 | 8 |
| Critical | 3 | 8 | 4 | 4 | 4 | 4 | 4 |

Values are rounded to the nearest integer.

Table J.3-17. Mean CPUE for **mysids** in **fall** by modeled scenario and water year type.

| Water Year Type | NAA | Alt1 | Alt2wTUCPwoVA | Alt2woTUCPwoVA | Alt2woTUCPDeltaVA | Alt2woTUCPAllVA | Alt3 | Alt4 |
|---|---|---|---|---|---|---|---|---|
| Wet | 15 | 11 (-27%) | 15 (0%) | 15 (0%) | 15 (0%) | 15 (0%) | 18 (20%) | 15 (0%) |
| Above Normal | 12 | 7 (-42%) | 13 (8%) | 13 (8%) | 13 (8%) | 13 (8%) | 15 (25%) | 13 (8%) |
| Below Normal | 6 | 5 (-17%) | 6 (0%) | 6 (0%) | 6 (0%) | 6 (0%) | 7 (17%) | 6 (0%) |
| Dry | 7 | 7 (0%) | 7 (0%) | 7 (0%) | 7 (0%) | 8 (14%) | 8 (14%) | 7 (0%) |
| Critical | 4 | 4 (0%) | 4 (0%) | 4 (0%) | 4 (0%) | 4 (0%) | 4 (0%) | 4 (0%) |

Percentage values in parentheses indicate the difference between NAA and each alternative. Values and percent difference are rounded to the nearest integer.

### J.3.3.3 Figures

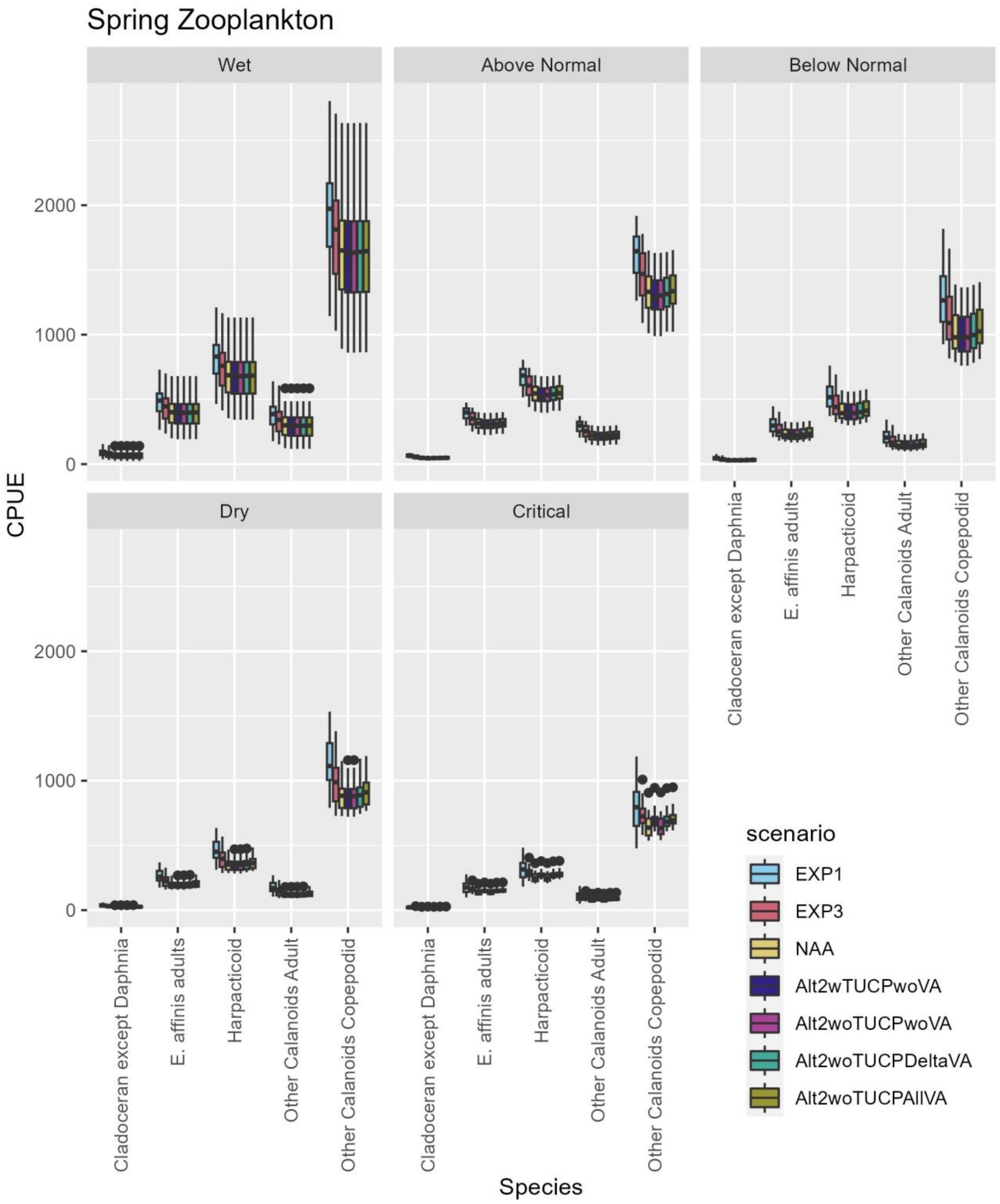

Figure J.3-1. Box Plots of CPUE of significant zooplankton species by scenario across different water year types for spring.

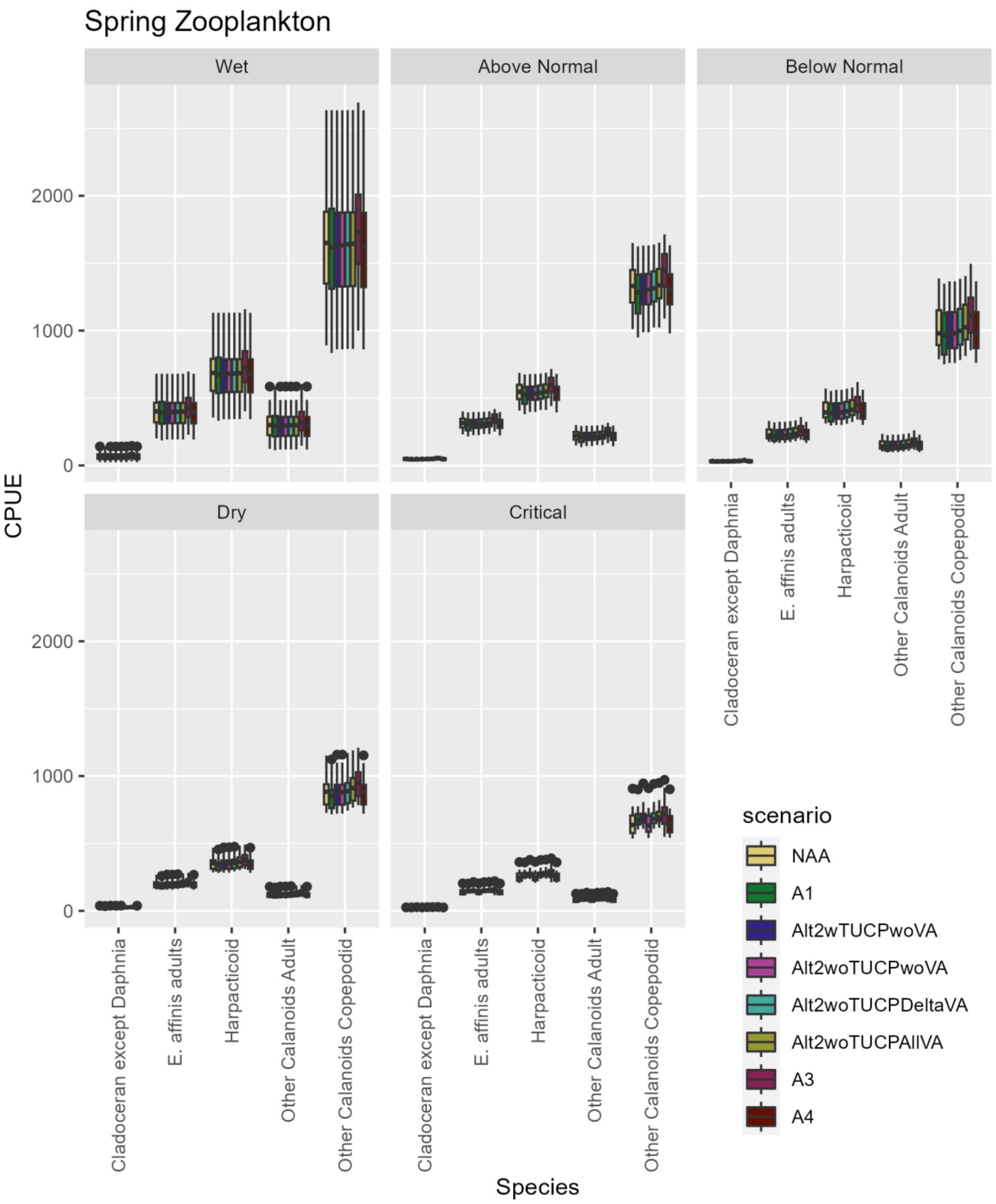

Figure J.3-2. Box Plots of CPUE of significant zooplankton species by scenario across different water year types for spring.

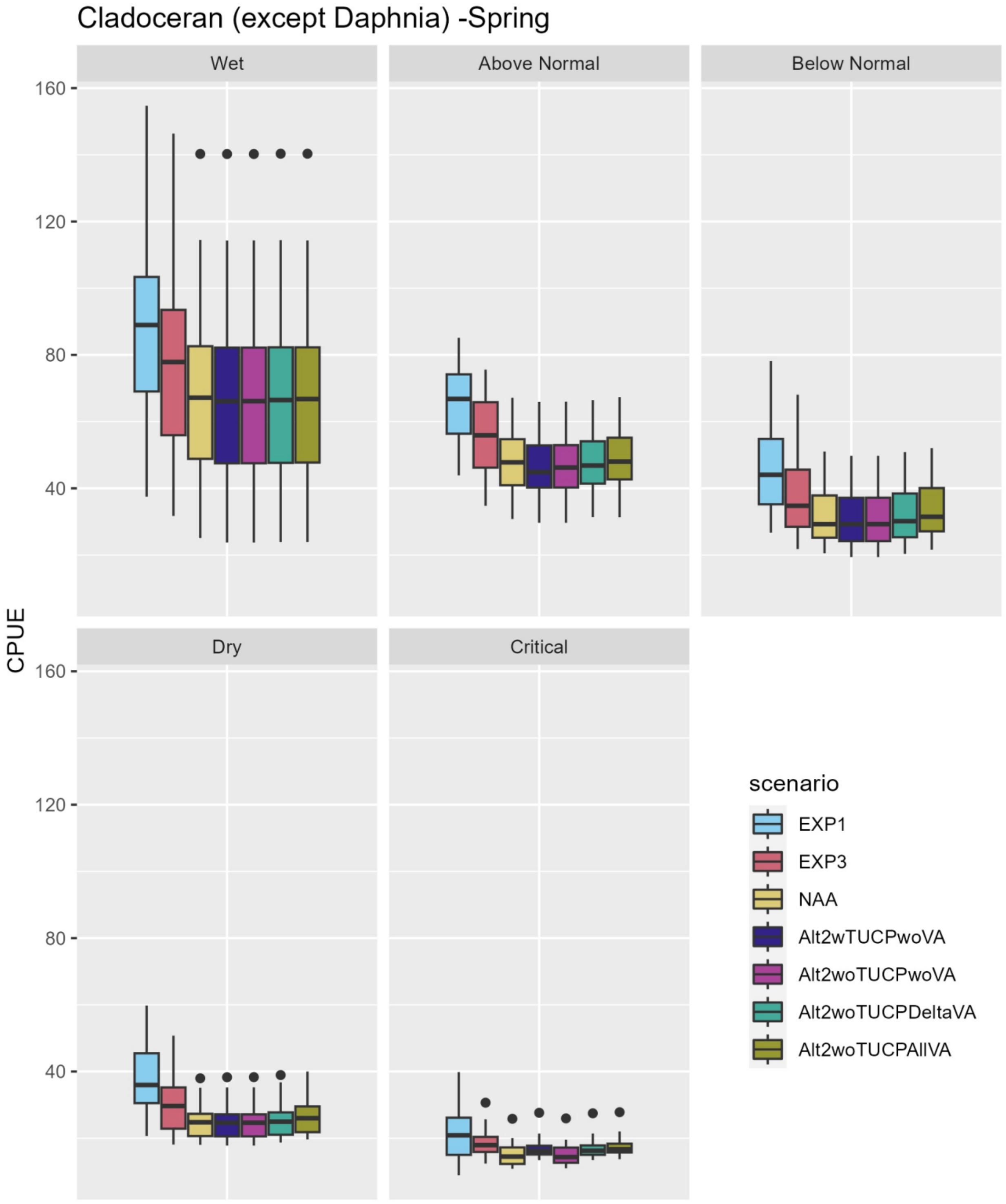

Figure J.3-3. Box Plots of CPUE of Cladocerans (except *Daphnia*) by scenario across different water year types for spring.

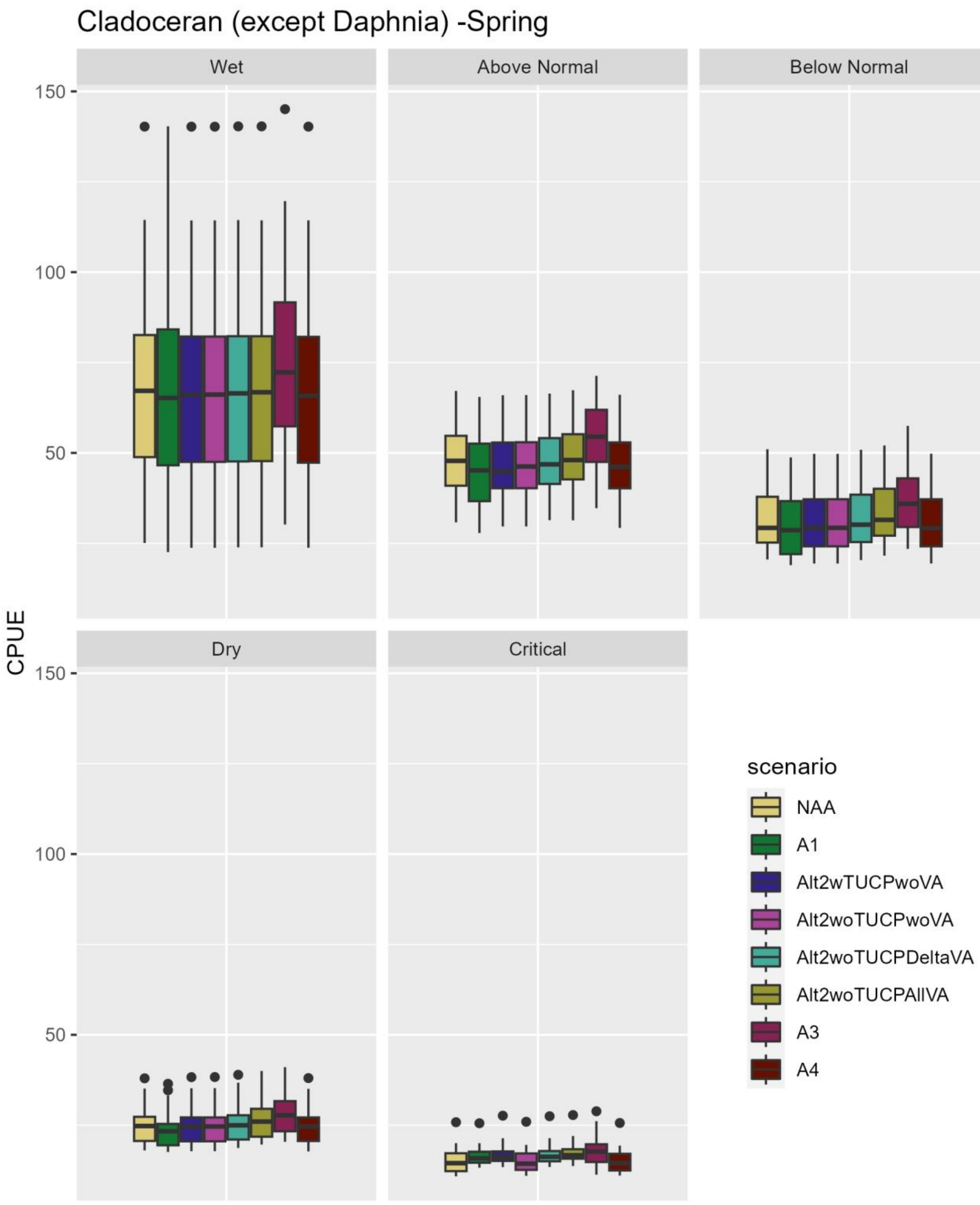

Figure J.3-4. Box Plots of CPUE of Cladocerans (except *Daphnia*) by scenario across different water year types for spring.

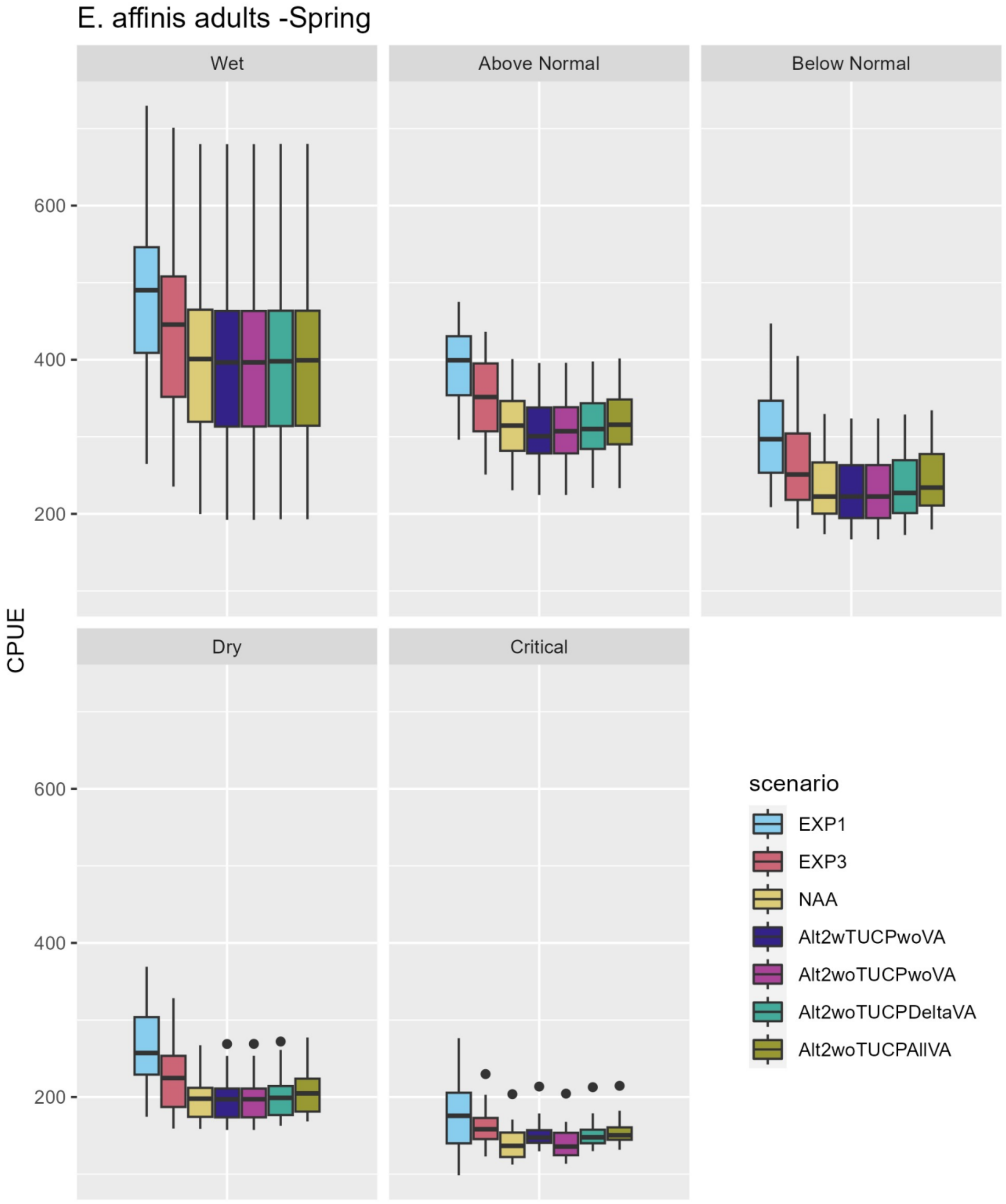

Figure J.3-5. Box Plots of CPUE of *E. affinis* adults by scenario across different water year types for spring.

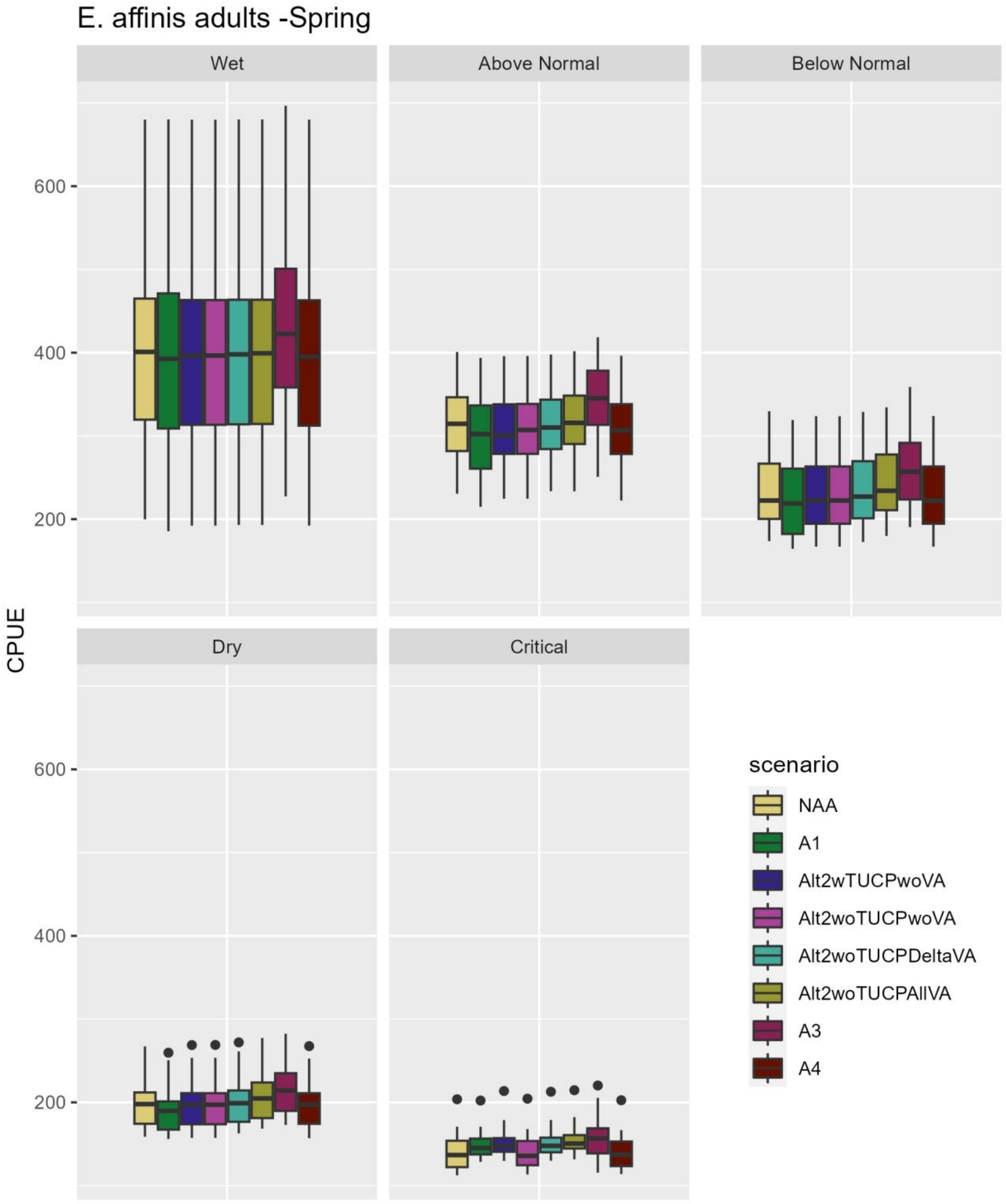

Figure J.3-6. Box Plots of CPUE of *E. affinis* adults by scenario across different water year types for spring.

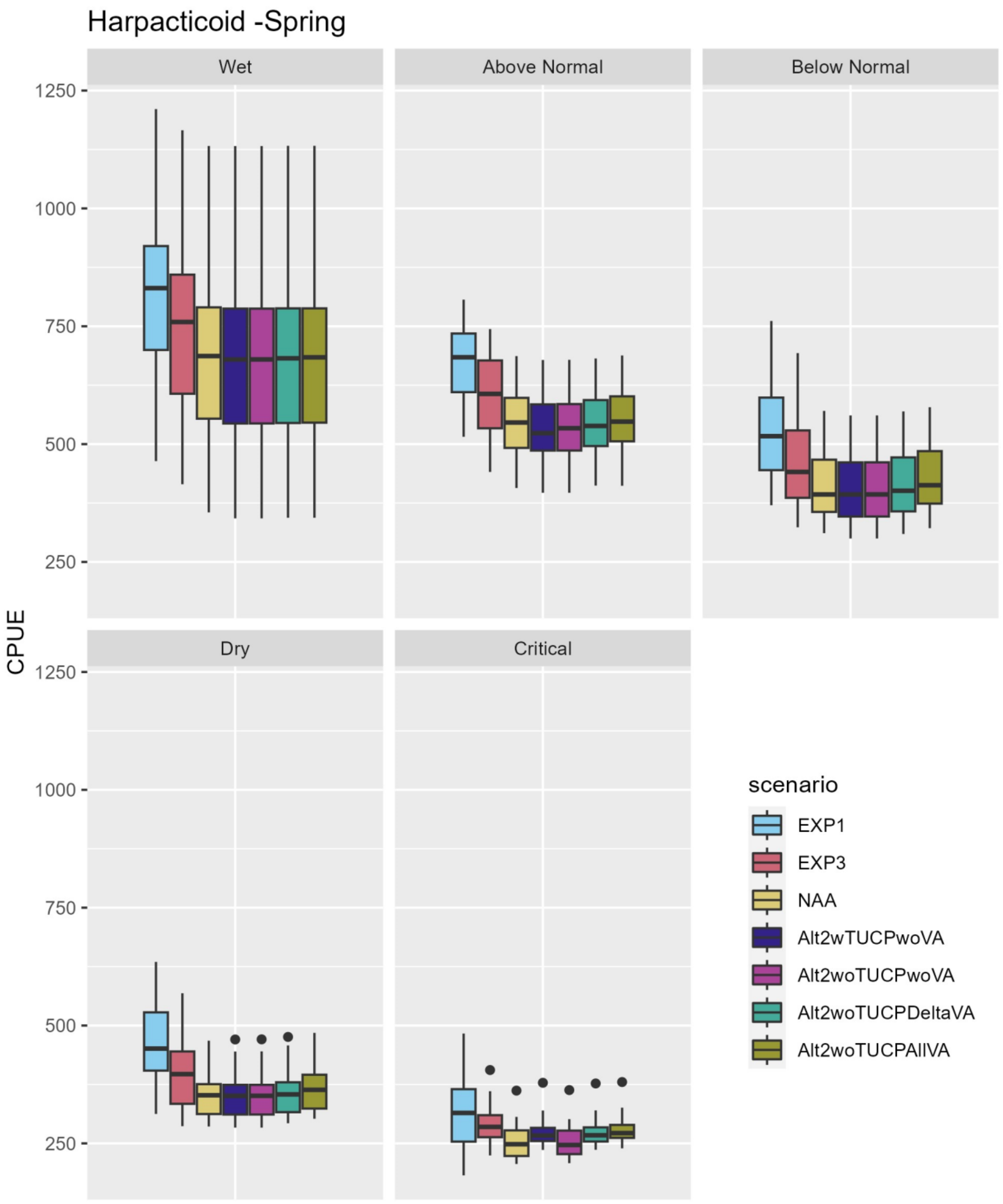

Figure J.3-7. Box Plots of CPUE of harpacticoids by scenario across different water year types for spring.

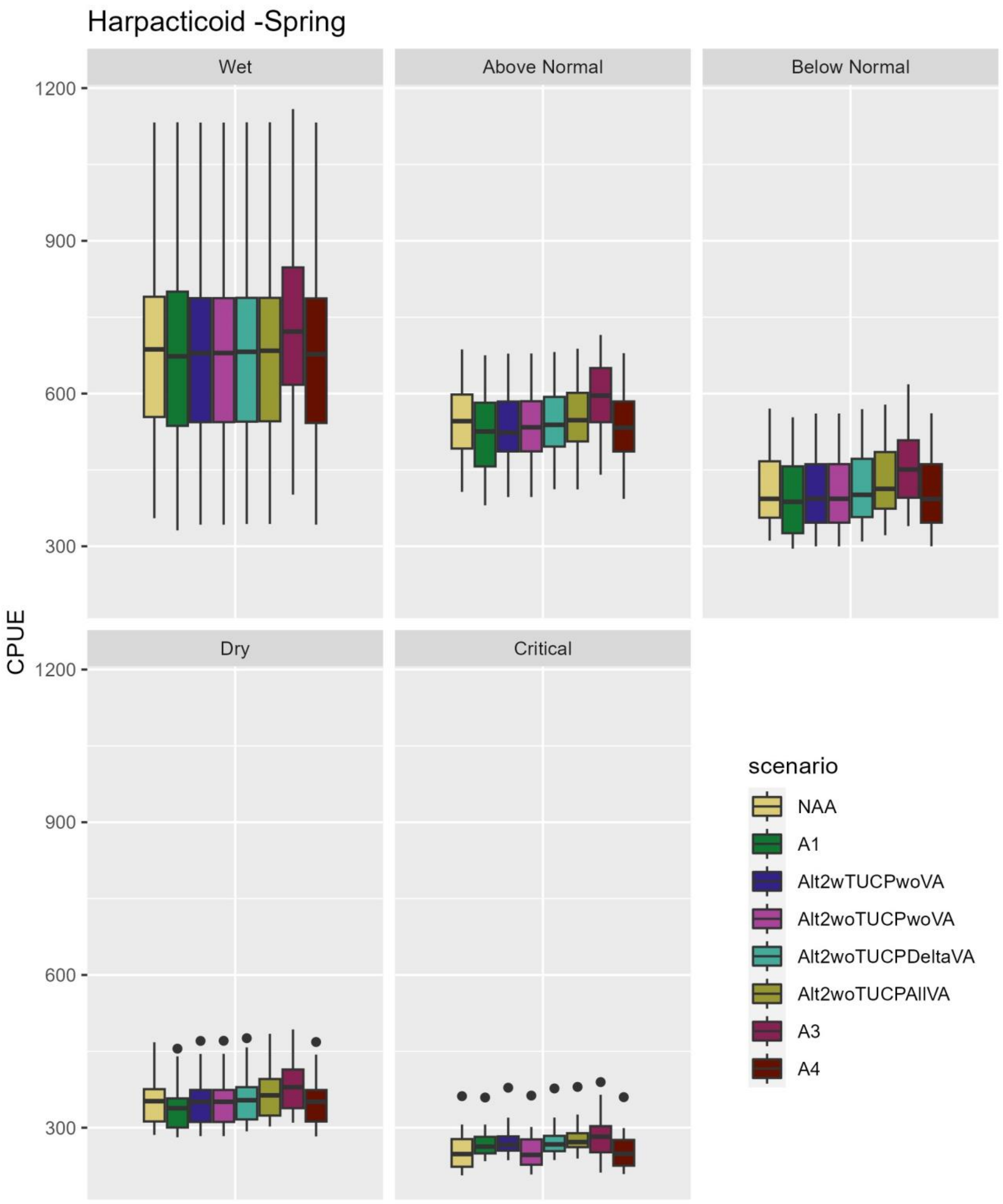

Figure J.3-8. Box Plots of CPUE of harpacticoids by scenario across different water year types for spring.

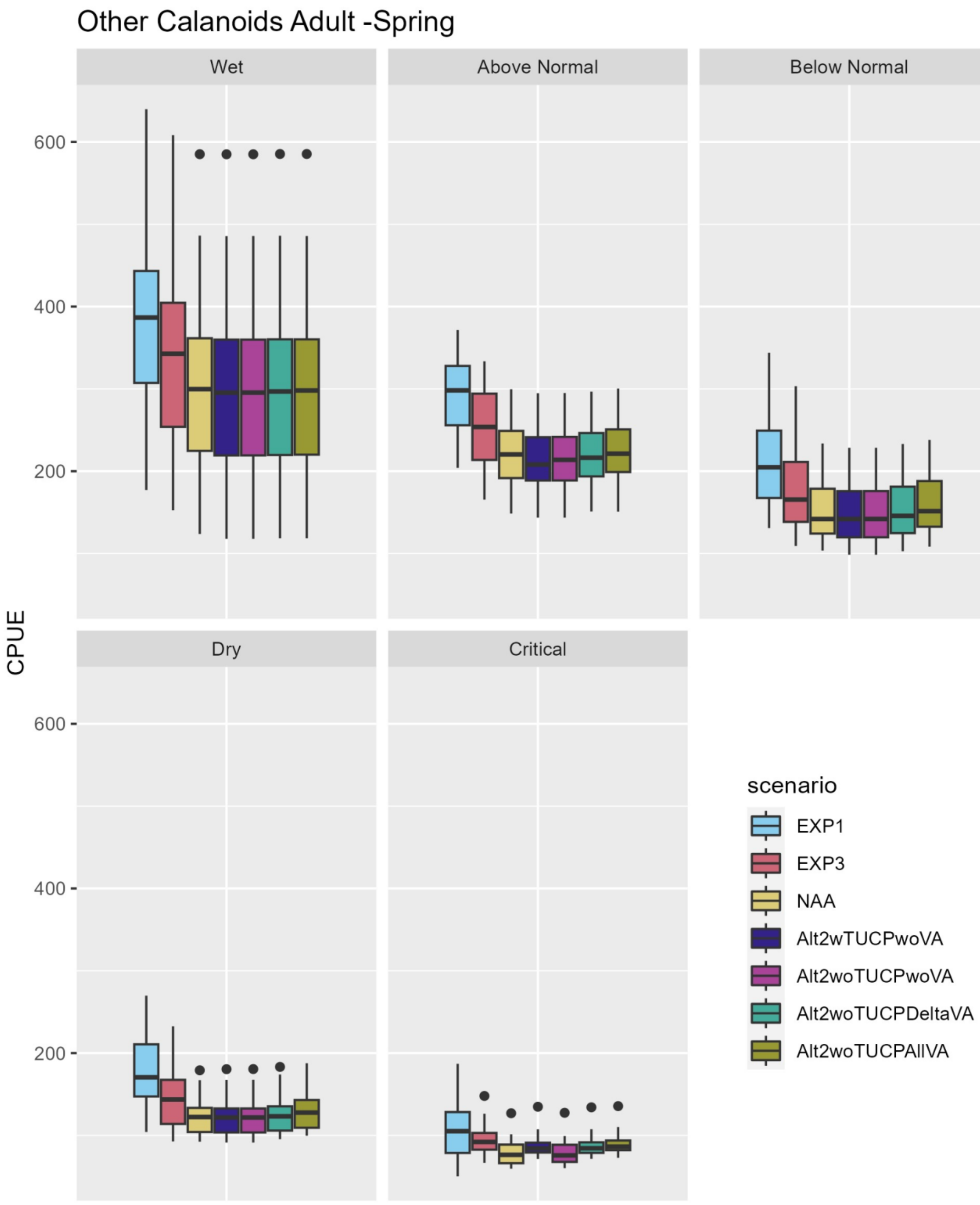

Figure J.3-9. Box Plots of CPUE of other calanoids adults by scenario across different water year types for spring.

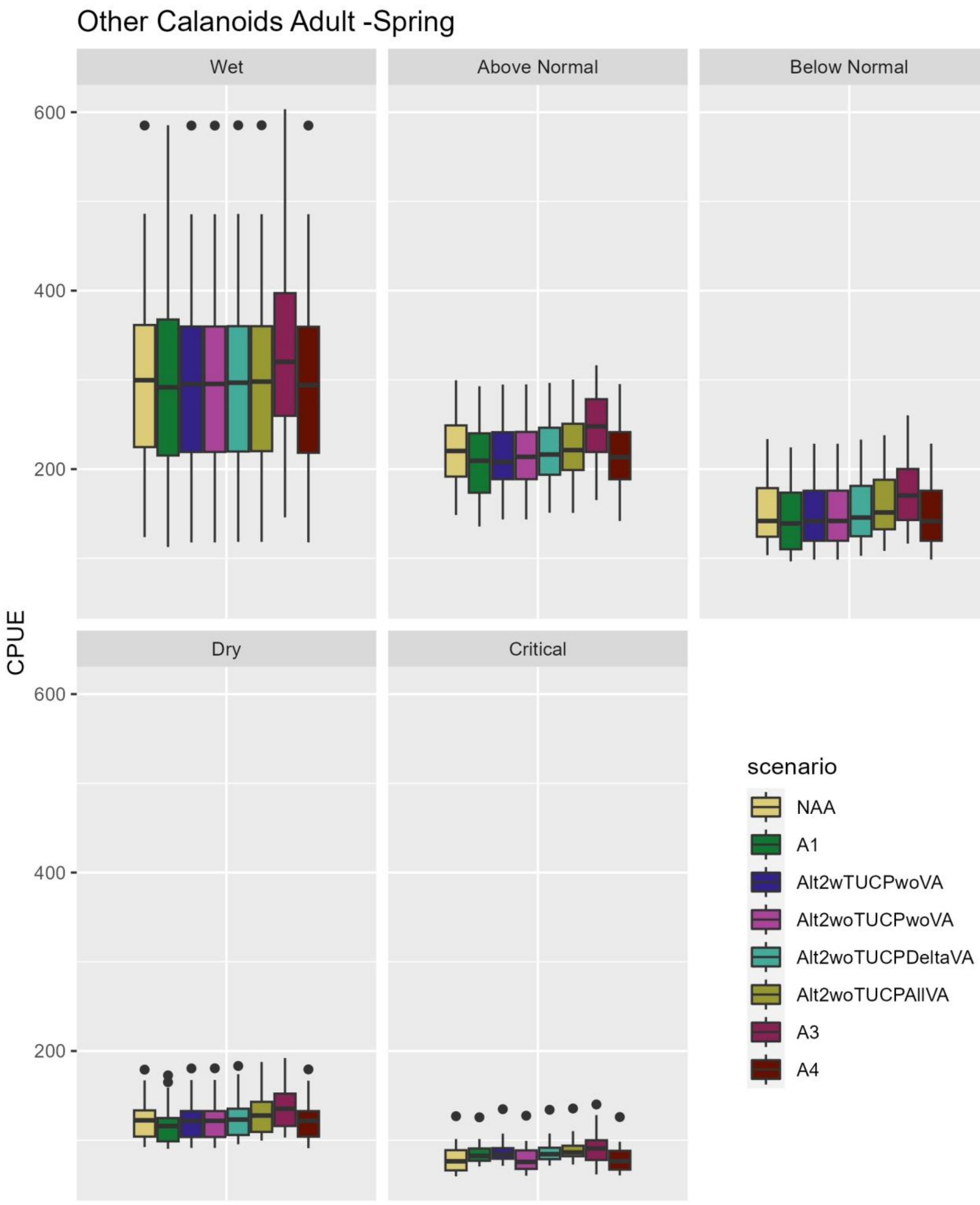

Figure J.3-10. Box Plots of CPUE of other calanoids adults by scenario across different water year types for spring.

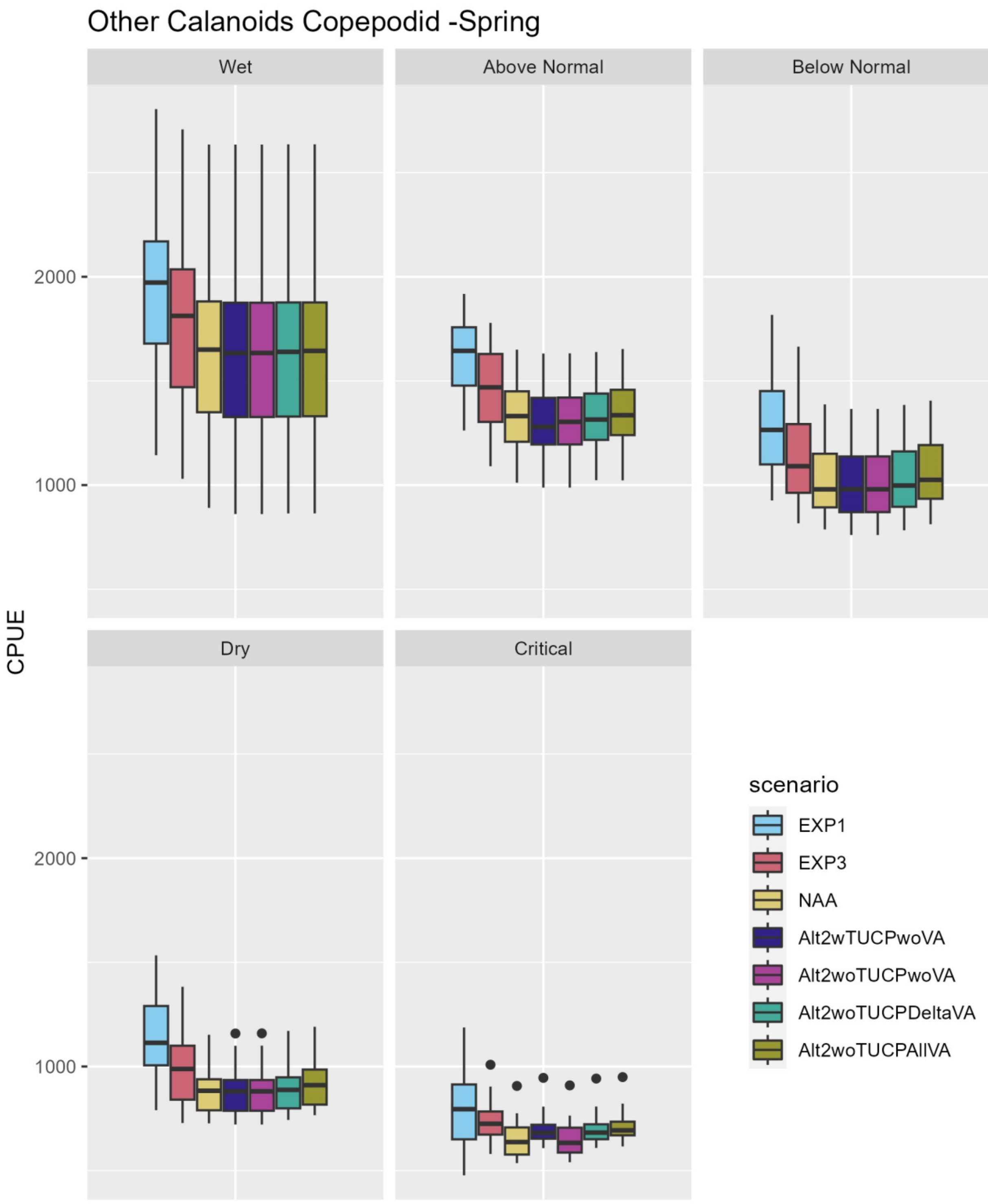

Figure J.3-11. Box Plots of CPUE of other calanoids copepodids by scenario across different water year types for spring.

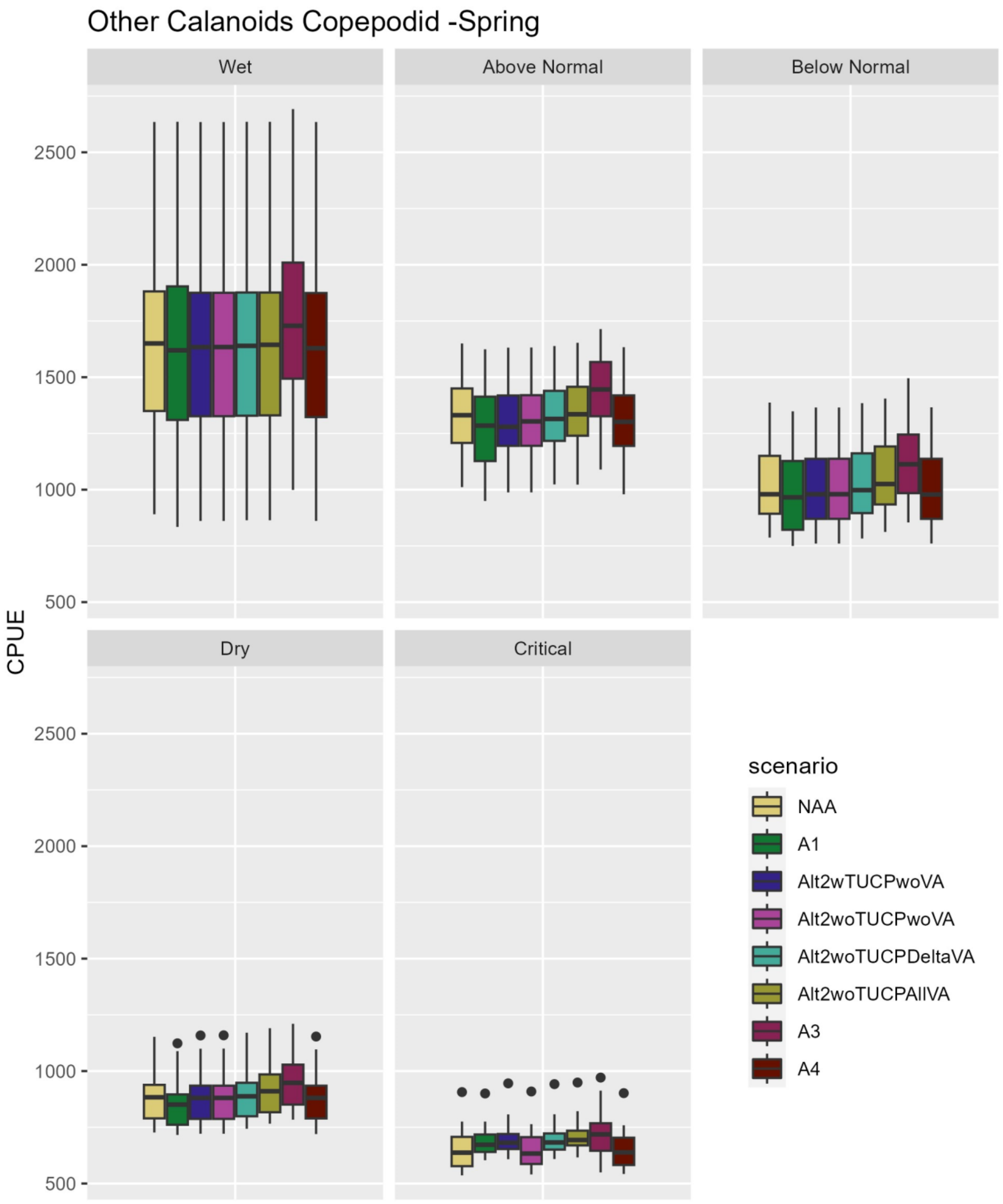

Figure J.3-12. Box Plots of CPUE of other calanoids copepodids by scenario across different water year types for spring.

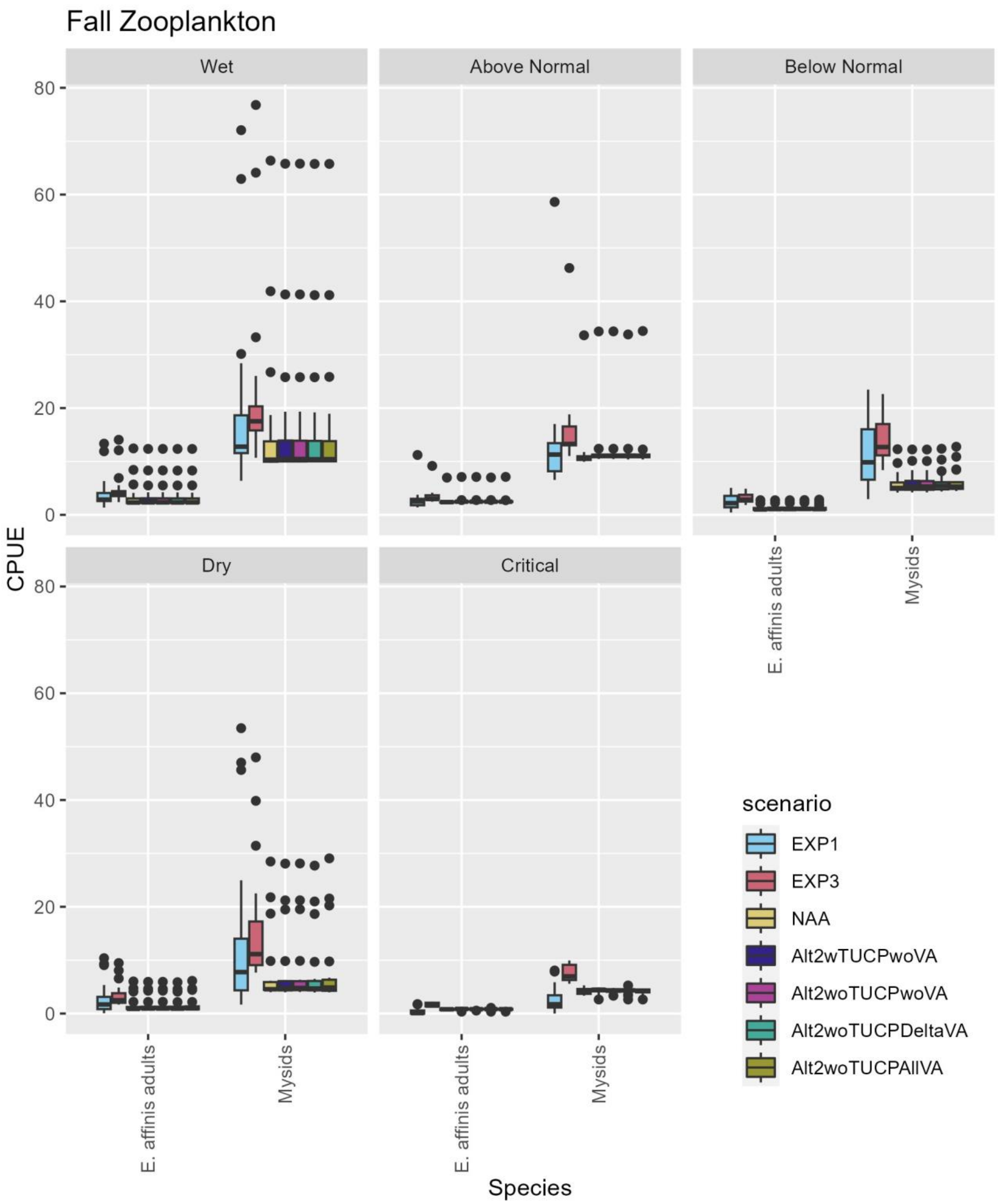

Figure J.3-13. Box Plots of CPUE of significant zooplankton species by scenario across different water year types for fall.

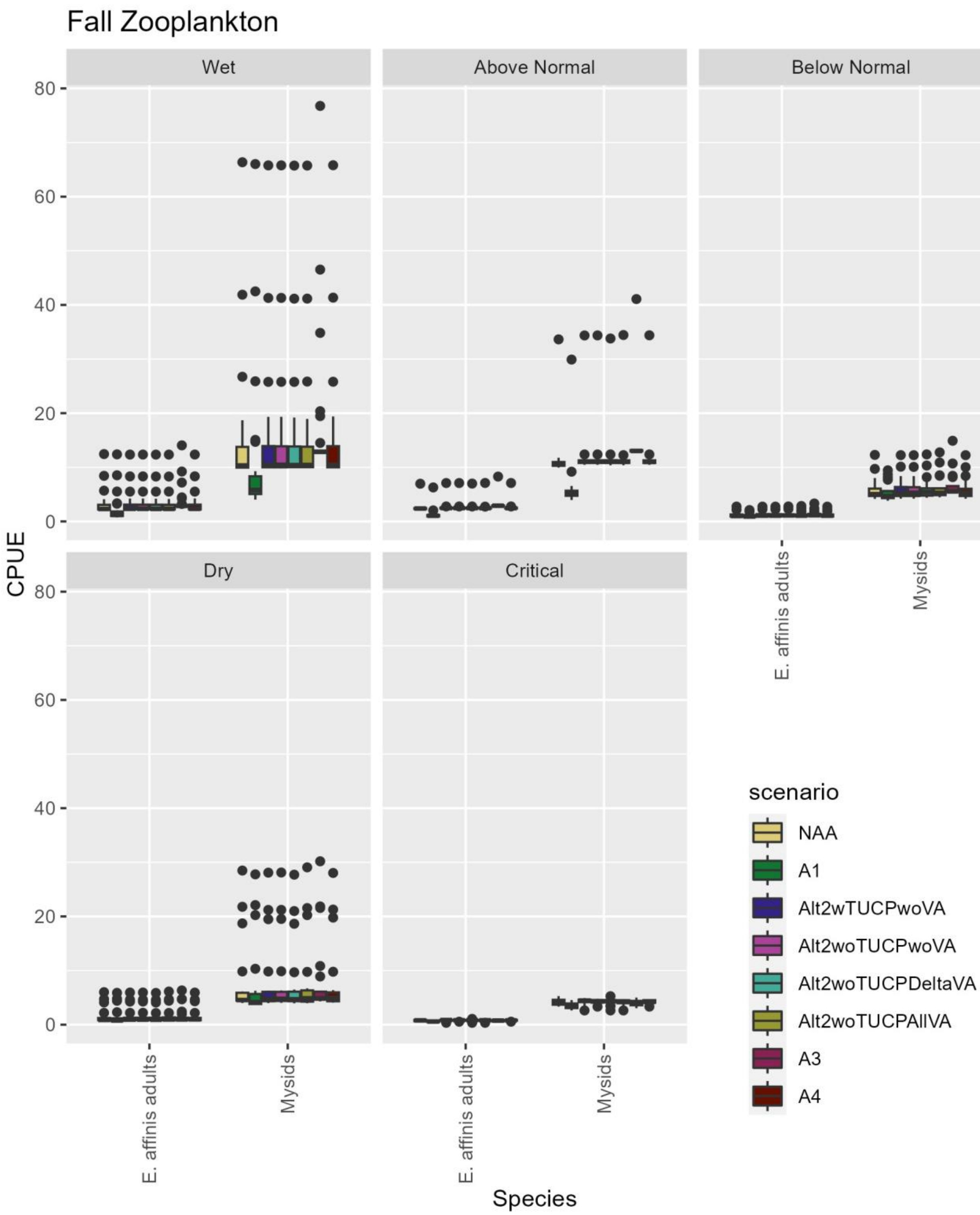

Figure J.3-14. Box Plots of CPUE of significant zooplankton species by scenario across different water year types for fall.

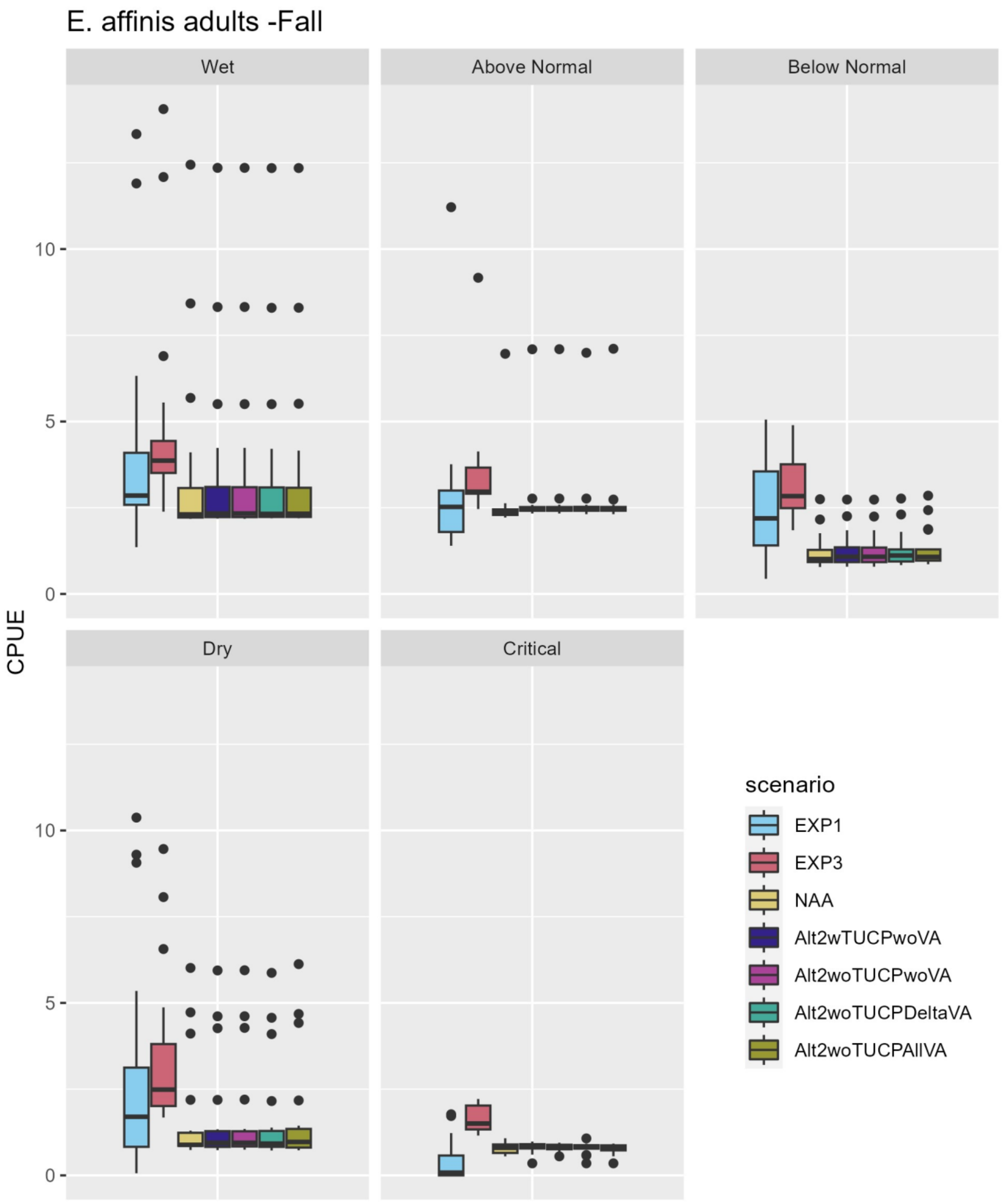

Figure J.3-15. Box Plots of CPUE of *E. affinis* adults by scenario across different water year types for fall.

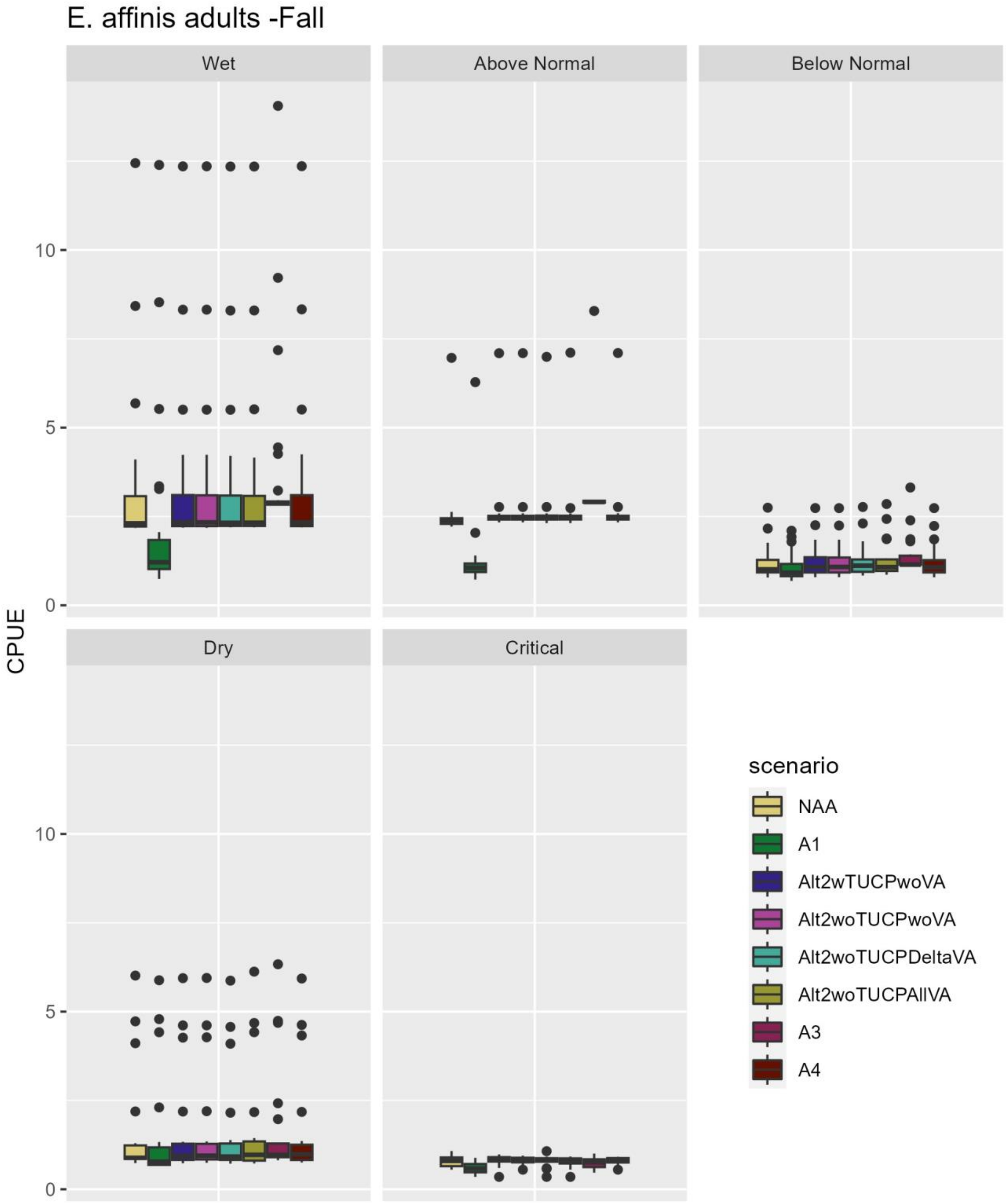

Figure J.3-16. Box Plots of CPUE of *E. affinis* adults by scenario across different water year types for fall.

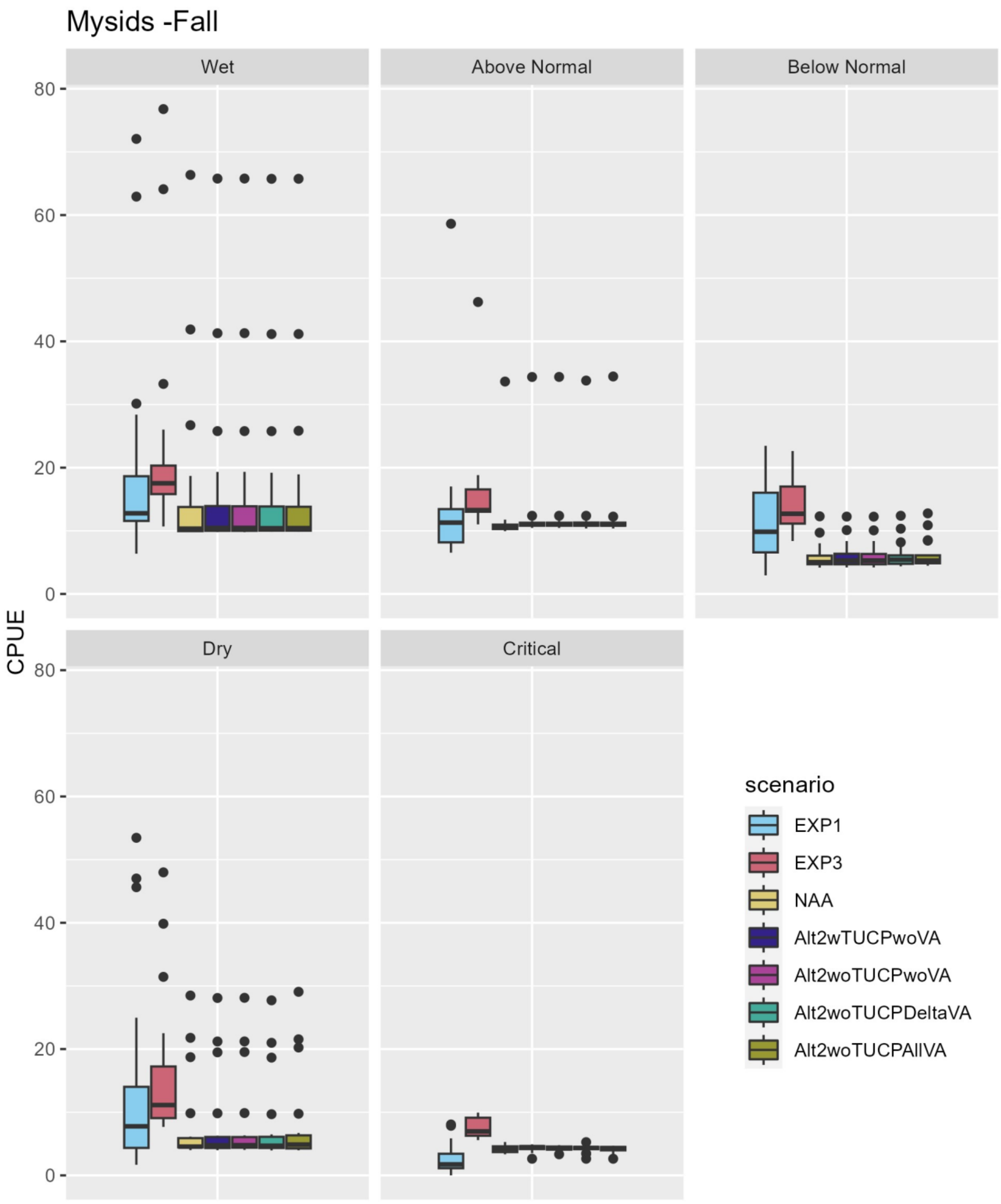

Figure J.3-17. Box Plots of CPUE of mysids by scenario across different water year types for fall.

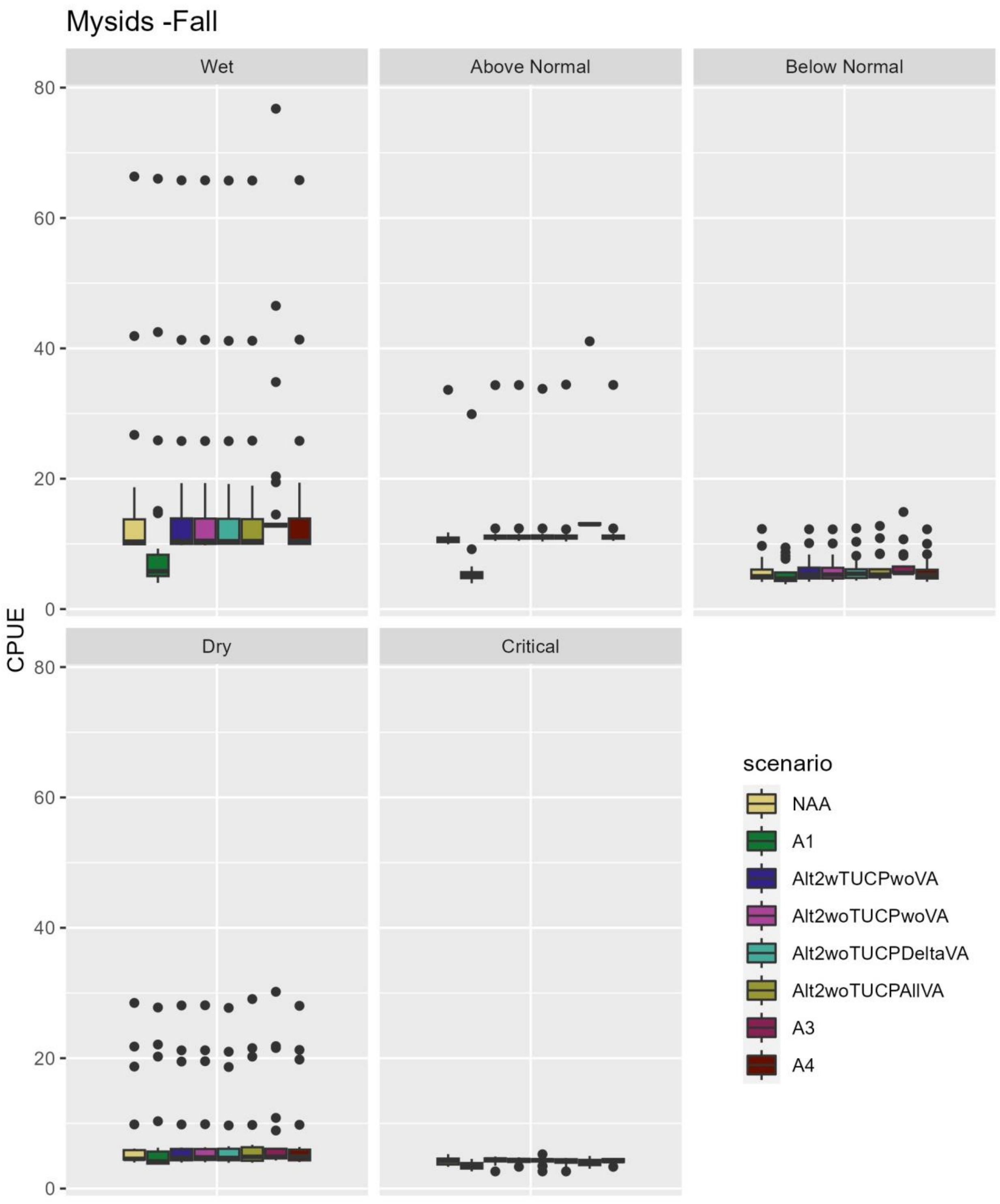

Figure J.3-18. Box Plots of CPUE of mysids by scenario across different water year types for fall.

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