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Forbs from seasonal managed wetlands boost plankton production more than emergent graminoids by supplying novel labile detritus

Kyle A. Phillips[1] | Alice M. Tung[1] | Rachel M. McConnell[1,2] | Teejay A. O'Rear[1] | Eliška Rejmánková[3] | Sharon P. Lawler[4] | John R. Durand[1]

[1]Center for Watershed Sciences, University of California, Davis, California, USA

[2]California Department of Fish and Wildlife, Davis, California, USA

[3]Department of Environmental Science and Policy, University of California, Davis, California, USA

[4]Department of Entomology and Nematology, University of California, Davis, California, USA

Correspondence
Kyle A. Phillips, Center for Watershed Sciences, University of California, Davis, CA, USA.
Email: kapphillips@ucdavis.edu

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Abstract

1. Opportunities to enhance ecosystem functions exist in human-dominated working landscapes, but understanding of key drivers is often lacking in these novel environments. In Suisun Marsh, California, USA, impounded managed wetlands designed to promote waterfowl incidentally support higher plankton densities—a key resource for imperilled pelagic fishes—than adjacent tidal habitats. Managed wetland operations could produce plankton at critical periods for fish and the aquatic food-web more broadly, but drivers of plankton production in managed wetlands are poorly understood.
2. We proposed that decaying vegetation resulting from controlled flooding in managed wetlands is important for stimulating plankton blooms, but that the effect varies by plant species and functional type. We conducted a mesocosm experiment to test the effects of different inundated plants on plankton production, including three forb species, three emergent graminoid species and a control treatment without added plant material.
3. Forbs promoted larger phytoplankton blooms and higher zooplankton production—by an order of magnitude—than both emergent graminoids and the control treatment. Emergent graminoids supported larger phytoplankton blooms, but not higher zooplankton production, than the control treatment. Phytoplankton blooms exhibited pulse dynamics in all treatments, with densities increasing initially and crashing by the end of the experiment. Phytoplankton blooms in forb and emergent treatments lasted similar durations, counter to the expectation that emergent graminoids would support diminished production over a relatively prolonged period. Among zooplankton taxa, *Daphnia magna* and rotifers were strongly associated with all three forbs species while the nonnative cyclopoid copepod *Limnothoina tetraspina* were associated with cattails (*Typha domingensis*) and the control. Forbs temporarily depleted dissolved oxygen concentrations during the first week of the experiment, suggesting a tradeoff by which decaying forbs boost plankton production at risk of initial hypoxia.

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4. Our results suggest that seasonal drying and flooding operations in managed wetlands are likely to enhance plankton production because dry periods promote forb growth and subsequent flooding introduces labile forb material to the aquatic food web. Results also suggest that seasonal managed-wetlands act as novel floodplain-analogues, by which flood pulses drive productivity. Further research is needed to quantify production benefits and tradeoffs to the aquatic ecosystem at the landscape scale and to identify optimal management regimes that will help conserve imperilled species.

KEYWORDS
estuaries, flood pulse, novel ecosystems, plant functional types, working lands

1 | INTRODUCTION

Novel ecosystems can generate beneficial functions that support wildlife conservation and provide ecosystem services even though they are departures from historic states (Evers et al., 2018; Hobbs et al., 2009). Novel ecosystems often include actively managed working lands (such as agriculture, grazing rangelands and managed forests) whose role in conservation has only recently been considered beyond their negative effects on ecosystems (Eastburn et al., 2017; Hobbs et al., 2014). Managed wetlands are an aquatic variant of working lands which have been shown to produce food and habitat for wild fish, waterbirds and other taxa including many that are not directly targeted by managers (Agha et al., 2020; Aha et al., 2021; Deichmann et al., 2019; Gray et al., 2013; Katz et al., 2017; Sloan et al., 2007; Smith et al., 2020; Williamshen et al., 2021). While many studies link management regimes to the productivity of directly harvested taxa in managed wetlands, relatively little is known about how wetland operations like flooding and vegetation management influence other ecological functions, such as plankton production.

Managed wetlands—also referred to as diked wetlands, dike ponds, fishponds, irrigated ponds or managed floodplains—exist globally along coasts, estuaries or inland basins and are typically operated to promote human interests such as waterfowl hunting, fishing, aquaculture, agriculture (especially rice fields) or industry (Costa-Pierce, 1987; Wood & Barker, 2000; Pokorný & Hauser, 2002; Gray et al., 2013; Li et al., 2011; Katz et al., 2017). Managed wetlands consist of artificially impounded shallow waterbodies with the ability to control hydroperiod or water exchange via culverts, pumps, or water control structures. By manipulating hydrology, managed wetlands can mimic different natural water bodies (including lagoons, marshes, perennial ponds and seasonal floodplains) and can often promote similar ecological functions, although these functions are poorly studied compared to natural counterparts (Alminagorta et al., 2016; Corline et al., 2017; Lewis & Granek, 2021; Potužák et al., 2007).

Suisun Marsh—a 470-km^2 brackish marsh within the anthropized San Francisco Estuary (SFE), California, USA—is a representative ecosystem fit for the study of managed wetlands as novel habitat. Composed of tidal sloughs and seasonally flooded managed wetlands, Suisun Marsh provides habitat for a variety of fauna including migratory and resident waterfowl, endangered salt marsh harvest mice (*Reithrodontomys raviventris*), tule elk (*Cervus canadensis nannodes)*, western pond turtles (*Actinemys marmorata*) and a suite of native fishes (Agha et al., 2020; Moyle et al., 2014; O'Rear et al., 2021; Smith et al., 2020). While principally operated to attract migratory waterfowl for recreational hunting, the managed wetlands incidentally support high plankton production when flooded, providing vital food for resident and migratory fishes in the otherwise plankton-sparse SFE (Jassby, 2008; Tung et al., 2021; Williamshen et al., 2021). However, it is not yet clear what mechanisms drive plankton production in managed wetlands, nor how managed wetlands could be optimized to support the aquatic food web of the SFE.

Zooplankton are a key trophic link in lentic food webs and are the principal food of estuarine larval fish and many pelagic fishes (Winder & Jassby, 2011). Within the SFE, several pelagic species have declined due to habitat loss and decreasing zooplankton, including the endangered Delta smelt (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), Chinook salmon (*Oncorhynchus tshawytscha*), Threadfin shad (*Dorosoma petenense*), American Shad (*Alosa sapidissima*) and the prized-sportfish striped bass (*Morone saxatilis*) (Sommer et al., 2007; Stompe et al., 2022). Zooplankton, in turn, rely on phytoplankton as a major source of essential polyunsaturated fatty acids (PUFAs) and long-chain essential fatty acids (LCEFAs), although they can also subsist on nutritionally inferior microbes from detrital food webs (Harfmann et al., 2019; Hixson et al., 2015; Winder et al., 2017). Phytoplankton too have declined throughout much of the SFE due to the loss of upstream floodplains, to water diversions for agricultural and municipal needs and to introduced filter-feeding clams (Barros et al., 2024; Greene et al., 2011; Hammock, 2019; Lehman et al., 2008; Winder & Jassby, 2011). As a result, few areas in the SFE currently provide sufficient support for pelagic food webs (Jassby, 2008; Kimmerer et al., 2014; Moyle et al., 2016).

Plants associated with seasonal drying and flooding in managed wetlands may be important for stimulating phytoplankton and zooplankton production. During dry months, managed wetlands in Suisun Marsh support a novel assemblage of halophytic terrestrial forbs and emergent graminoids of native and non-native origins (Grewell et al., 2014; Figure 1). Material from both plant types

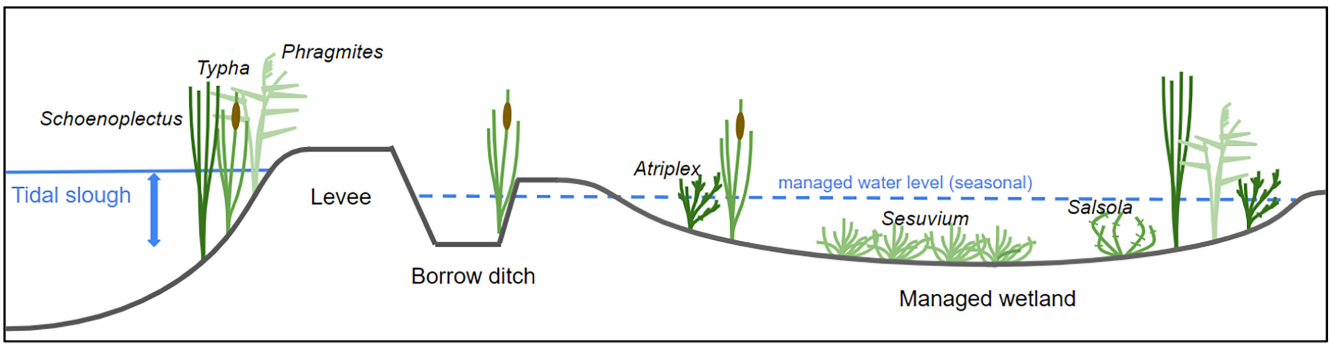


FIGURE 1 Profile diagram of a seasonal managed wetland and tidal slough interface in Suisun Marsh (adapted from Barthman-Thompson et al., 2007). Typical growth locations of different plant species shown (dry period) in addition to target water levels in managed wetlands (wet period). Typical target depths in managed wetlands may vary from 0.4 to 2 m. Interconnecting sloughs flood tidally year-round.

senesce and decompose in autumn and winter when wetlands are flooded, releasing carbon and nutrients that can fuel the aquatic food web, but the relative effect of the two plant types on plankton production has remained untested.

Many forb species are annuals that can complete their life cycle within summer and produce free-floating seeds prior to flooding in autumn (Ackerman et al., 2014). Some forbs, such as sea purslane (*Sesuvium portulacastrum*) and fat hen (*Atriplex triangularis*), are actively promoted by land managers because their seeds provide valuable food for wintering waterfowl (Barthman-Thompson et al., 2007). Other forb species, such as Russian thistle (*Salsola soda*), are considered pests as they choke up canals, outcompete other halophytes and do not produce palatable seeds for waterfowl (Wang, 2015). Forbs are generally restricted to managed wetlands during summer dry periods or in upland areas of Suisun Marsh because they are intolerant of tidal flooding.

Emergent graminoids such as California bulrush (*Schoenoplectus californicus*), cattails (*Typha domingensis*) and common reed (*Phragmites australis*) are flood-tolerant perennials that occur in both managed wetlands and tidal marsh habitats (Grewell et al., 2014). Managers often promote stands of *Schoenoplectus* and *Typha* within wetlands to provide cover for waterfowl. *Phragmites* can also be used by waterfowl and shorebirds for cover, but it is often considered a pest because it outcompetes other vegetation by releasing allelopathic chemicals in wetland soils and can quickly choke up waterways (Uddin & Robinson, 2017). All three emergent species produce deciduous leaves or stems which senesce in late summer and drop in autumn, often into waterways where they can be accessed by the aquatic food web. Under nutrient-limiting conditions, perennial emergent graminoids can resorb nitrogen and phosphorus from leaf or stem material for storage in their rhizomes prior to leaf shed, generating relatively recalcitrant leaf litter (Rejmánková, 2005).

We conducted an aquatic mesocosm experiment to test the effect of decomposing plant material from terrestrial forbs and emergent graminoids on plankton growth and community composition. We expected that detritus from inundated forbs would be relatively labile and generate a nutrient pulse, which could support large phytoplankton blooms for a brief period and, in turn, stimulate increased zooplankton production. Meanwhile, we expected detritus from emergent graminoids would be relatively recalcitrant and generate a nutrient press which could support smaller phytoplankton blooms over an extended period and provide diminished, but stable, support for zooplankton (Zhao et al., 2022). We also considered a possible trade-off by which excessively rapid decomposition of forbs could deplete dissolved oxygen concentrations and create lethal conditions for zooplankton and other aquatic organisms, while the relatively recalcitrant material shed by emergent plants could mitigate the risk of oxygen depletion (Siegel et al., 2011). Quantifying effects of plant functional types on pelagic productivity will inform wetland management practices and help identify trade-offs and synergies in vegetation management. Managers could apply this information to target vegetation types that benefit aquatic food webs in addition to wintering waterfowl and other species of interest.

2 | METHODS

2.1 | Study design

In late autumn 2019 (November 22, 2019, to December 14, 2019), we conducted a mesocosm experiment in an unshaded greenhouse heated to 20°C at the University of California, Davis to test the effect of detritus from different wetland plant species on plankton production. We collected all field materials and organisms from Suisun Marsh, California. To best represent plant conditions prior to typical autumn flooding in managed wetlands—and to natural leaf shed of emergent graminoids—we collected above-ground plant material from three emergent species (*Schoenoplectus californicus*, *Typha domingensis* and *Phragmites australis*) and three forb species (*Sesuvium portulacastrum*, *Atriplex triangularis* and *Salsola soda*) at Potrero Pond and Meins Landing in September of 2019 (Figure 2). Emergent graminoids were mostly senescent during plant tissue collections, while forbs were either flowering or seeding. To standardize biomass to be introduced in experimental treatments, we oven-dried collected plant material for 2 weeks at 60°C and divided material into 3.00-g portions (a quantity determined from pilot mesocosms that allowed plankton growth for all litter types) which we then stored

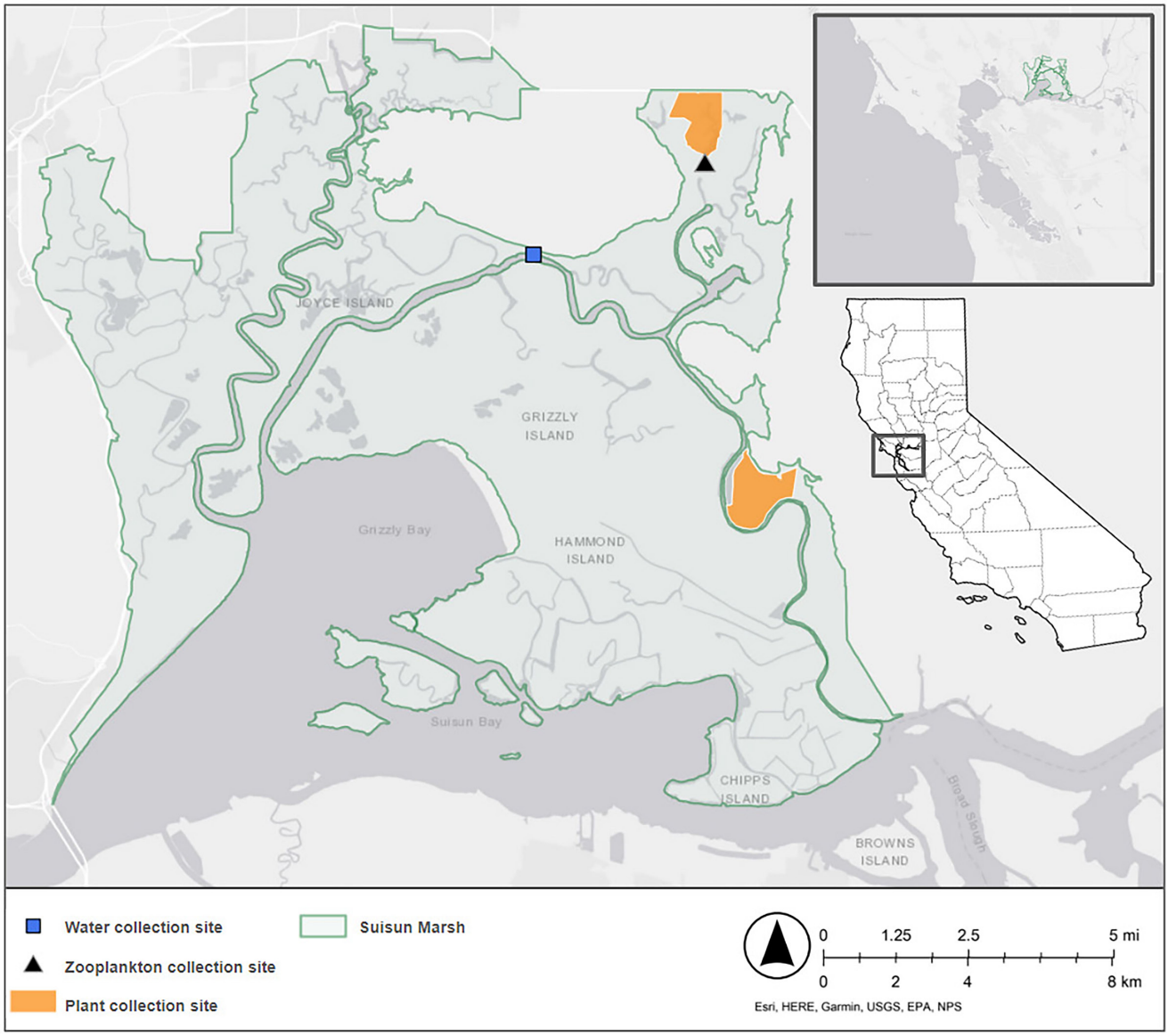


FIGURE 2 Map of materials collection locations within Suisun Marsh, CA, USA, for a study of how detritus from various wetland plants fuels aquatic food webs. Suisun Marsh boundary depicted in green along with location within the San Francisco Estuary (upper right) and California (middle right). Plant material was collected within Potrero Pond and Meins Landing (orange areas). Water was collected in Montezuma Slough at Beldens Landing (blue square). Zooplankton were sampled from Luco Slough (black triangle).

freeze-dried until the start of the experiment. We collected field water from Montezuma Slough at Belden's Landing 1 day prior to starting the experiment.

We filled 35 mesocosms (21-cm diameter, 24-cm height, high-density polyethylene buckets) with 7 L of water collected at Belden's Landing and filtered through 50-μm mesh to remove zooplankton. We placed mesocosms in a greenhouse at UC Davis campus, arranged them in pools (114-cm diameter, 15-cm depth) to buffer water temperature and assigned one of 7 plant-substrate treatments (Table 1), amounting to 5 replicates per treatment. We placed plant material in 1-cm mesh LaMotte® Leaf Pack nylon bags which we submerged in assigned mesocosms and allowed to incubate for 11 days prior to zooplankton addition. For control treatments, we submerged empty leaf pack bags to mediate any effects driven by added material structure. We used an EXO2 multiparameter sonde from Yellow Springs Instruments to record spot measurements of water temperature, daytime dissolved-oxygen, salinity, turbidity, pH, chlorophyll a concentration and fluorescent dissolved organic-carbon (FDOM) in all mesocosms three times per week. We subsampled 250 mL of water from each mesocosm once per week, of which three subsamples per species treatment (21 total per week) were examined in the laboratory for dissolved organic carbon, ammonium, nitrate, total dissolved nitrogen, total nitrogen, phosphate, total dissolved phosphorus and total phosphorus concentrations using standardized practices of water-quality analysis (Baird et al., 2017). We replaced all water collections from mesocosms with equal volumes of reverse osmosis (RO) water and Instant Ocean® solution in order to maintain volume and salinity. We added RO water three times per week to counteract evaporative water loss and maintain initial water volumes.

TABLE 1 Experimental plant species used in a study on litter contributions to plankton production, including associated plant functional type and origins.

Species treatment	Common name	Functional type	Origin
Sesuvium portulacastrum	Sea purslane	Forb	Native in California
Atriplex triangularis	Fat hen	Forb	Nonnative
Salsola soda	Russian thistle	Forb	Nonnative, invasive
Schoenoplectus californicus	California bulrush (tules)	Emergent graminoid	Native to Suisun Marsh
Typha domingensis	Cattails	Emergent graminoid	Native in California
Phragmites australis	Common reed	Emergent graminoid	Nonnative, invasive
Control	No added plant material	–	–

To create zooplankton inoculum, we towed a 30 cm-diameter conical zooplankton net with 150-μm mesh through an estimated 1060 L of water in Luco Slough that we then concentrated into 18 L of water, filtered through 1-mm mesh to remove macroinvertebrates and transported to the greenhouse. On day 11, we took 250 mL well-mixed aliquots from the concentrated zooplankton and introduced them into each mesocosm. We preserved five additional aliquots in a 5% formaldehyde solution for analysis of the initial zooplankton species composition. We then incubated the mesocosms for an additional 12 days and continued to monitor water quality through this period. We subsampled zooplankton 5 days and 11 days after introduction by filtering 250 mL of mesocosm water through 50-μm mesh and preserving retrieved zooplankton in 5% formaldehyde solution.

To quantify zooplankton biomass and composition trends, we used a counting wheel and dissection microscope to identify and count specimens and eggs from preserved samples. We counted all specimens in each sample except for rotifers, which we volumetrically subsampled with Hensel-Stempel pipettes when their numbers exceeded 1000 individuals. As *Daphnia magna* was the largest zooplankter present (hereafter '*Daphnia*'), we measured carapace lengths and identified the sex of a subsample of specimens (80 per sample, or all available specimens if there were less than 80 present).

2.2 | Data analysis

We used the equation $W = 0.008^{L} - 0.009$ (where L = carapace length in mm; W = dry weight in mg) to estimate the mass of subsampled *Daphnia* within samples and calculated total *Daphnia* biomass in each sample by multiplying average mass estimates by the total number of *Daphnia* in respective samples (Ku et al., 2022). We used values from existing literature to estimate dry weights of remaining zooplankton taxa based on species and life stage (Table S1) and combined the summed totals with *Daphnia* biomass estimates to calculate total zooplankton biomass for each sample. Initial densities of all zooplankton taxa were scarce, with *Daphnia* being the dominant zooplankter present in the initial community at a median density of 3.6 individuals^{-L} (Figure S5). *Acartiella sinensis*, *L. tetraspina* and Rotifera were not detected in inoculum samples, despite being present later in the experiment, although these taxa may have been present in inocula as nauplii or eggs. We imputed initial biomass estimates for each mesocosm by randomly sampling estimates from the normal distribution (mean = 0.0488, SD = 0.0159) of the 5 initial aliquots collected on the day of introduction. We calculated average zooplankton growth rates (mg/L/day) for each mesocosm by subtracting initial biomass estimates from final biomass estimates and dividing the difference by 11 days.

To estimate the effects of time and plant functional type on chlorophyll-a concentrations, we constructed linear mixed models using the lme4 package (R lme4). To account for repeated measurements obtained from each mesocosm, we included mesocosm ID as a random intercept while including time (in days) and plant functional type (forb, emergent, or control) as fixed effects. We checked that model assumptions were met, including normality and homoscedasticity of model residuals, and we used AIC, BIC and R^2 to guide model selection. Our selected chlorophyll-a model used a log-transformed dependent variable, due to violations of homoscedasticity detected in our non-transformed models. Our model also incorporated a quadratic regression equation to fit a parabolic relationship between time and chlorophyll-a concentration, which improved model fit and could be expected when initial phytoplankton growth is followed by decline due to consumption by zooplankton and a lack of resource renewal. Our selected model also incorporated interactive terms between plant functional type and time (Equation 1).

Quadratic linear mixed model, where Chlor_{ij} is the jth observation in MesocosmID_i, $i = 1, \ldots, 35$ and MesocosmID_i is the random intercept which is assumed to be normally distributed around 0 with variance σ^2.

$$\log(\text{Chlor}_{ij}) \sim N(\mu_{ij})$$

$$\begin{aligned}\log(\text{Chlor}_{ij}) = {} & \text{PlantFunctionalType}_{ij} + \text{Days}_{ij} + \text{Days}_{ij}^2 \\ & + \text{PlantFunctionalType}_{ij} \times \text{Days}ij + \text{PlantFunctionalType}_{ij} \\ & \times \text{Days}_{ij}^2 + \text{MesocosmID}_i\end{aligned}$$

$$\text{MesocosmID}_i \sim N(0, \sigma^2) \quad (1)$$

When testing the effects of plant functional type on dissolved oxygen or on zooplankton biomass, random effects prescribed to mesocosm ID caused linear mixed models to fail due to regression singularities, meaning that repeat measurements from mesocosms could not be factored into linear models predicting these two parameters. In place of linear mixed models, we used the ez package (R ez) to conduct RANOVAs to test the effect of plant functional type over time on daytime dissolved-oxygen and on zooplankton biomass, using Greenhouse–Geisser corrected estimates to account for violations of sphericity. For the dissolved-oxygen model, we used weekly average oxygen values to reduce the number of time steps and preserve degrees of freedom. To assess pairwise comparisons of plant functional type effects for both RANOVA models, we conducted paired *t* tests within time steps with Bonferroni corrections and used the papaja package (R papaja) to compute within-subject 95% confidence intervals for species-level and functional-type-level effects (Cousineau-Morey method). To compare the effect of plant functional type and nested plant species treatments on zooplankton growth rates (mg/L/day), we performed a nested two-way ANOVA and then used Tukey's HSD test for multiple comparisons to describe differences within paired groups for variables that turned out to be significant in the growth rate model. We also performed ANOVAs—accompanied by Tukey's HSD tests—to estimate the effect (averaged over time) of plant functional type on remaining water-quality variables (temperature, salinity, pH, turbidity, FDOM, dissolved organic carbon, ammonium, nitrate, total dissolved nitrogen, total nitrogen, phosphate, total dissolved phosphorus and total phosphorus concentrations). To evaluate the relative contributions of macronutrients released from detritus on phytoplankton production, we constructed a linear model using average chlorophyll-a measurements for each mesocosm as the response variable and the average concentrations of total nitrogen, total phosphorus and dissolved organic carbon as predictor variables (Equation 2).

Multiple linear model where AvgChlor_i is the *i*th observation representing an independent mesocosm.

$$\begin{aligned} \text{AvgChlor}_i &\sim N\left(\mu_i\right) \\ \text{AvgChlor}_i &= \text{avgTN}_i + \text{avgTP}_i + \text{avgDOC}_i \end{aligned} \tag{2}$$

To assess differences in zooplankton composition, we used ANOSIM and constructed nonmetric dimensional scaling (NMDS) ordination plots using the vegan package (R vegan) with 95% confidence ellipses grouped by treatment and mapped vectors for each species and for water-quality variables associated with changes in community structure. We used the indicspecies package (R indicspecies) to perform an indicator species analysis that identified which among possible groups of treatments had the strongest effect on the densities of individual zooplankton taxa. We conducted pairwise Mantel tests to estimate how water quality variables within mesocosms related to changes in zooplankton community structure (De Cáceres et al., 2010; Mantel, 1967).

3 | RESULTS

3.1 | Chlorophyll-a and water quality

Chlorophyll-a concentration was tightly associated with plant functional types, with forbs producing larger phytoplankton blooms than control or emergent graminoid treatments (Figure S1a). The control treatment supported moderately elevated phytoplankton concentrations within the first 5 days followed by an abrupt decline back to initial concentrations for the remainder of the experiment. Emergent graminoids supported moderate concentrations which peaked at 25 μg/L on day 9 and gradually declined. Forbs supported relatively low chlorophyll-a concentrations for the first 4 days, followed by abrupt growth which peaked at 120 μg/L on day 9 and a gradual decline back to initial levels by day 23. Our quadratic mixed-model reflected these trends, outlining a strong interactive effect between time (in days) and plant functional type and predicting higher chlorophyll-a concentrations in the presence of forbs through most of the experiment, with exception of the first few days (Table 2, Figure 3).

Initial daytime dissolved-oxygen (DO) concentrations were similar in all mesocosms, after which DO concentrations varied over time among prescribed plant functional types (RANOVA[Greenhouse–Geisser estimates]: $F_{4.76,\ 76.16} = 23.930$; $p < 0.0001$). Daytime DO in the forb treatments decreased to hypoxic levels during the first week, increased to supersaturated concentrations by the third week and returned to initial concentrations by the fourth week (Table 3, Figure 4). Daytime DO in the emergent graminoid treatments also decreased in the first week (though less severely than forb treatments) and then returned to near saturation levels for the remainder of the experiment. Daytime DO in the control treatment climbed slightly in the first 2 weeks of incubation then returned to initial concentrations for the remainder of the experiment.

Aside from temperature, sonde-measured water quality trends varied either by plant functional type or by nested plant species (Table 4; Figure S1d–h). Mesocosm water temperatures ranged from 17 to 23°C during the experiment but did not vary among treatments. Water salinities gradually declined over the course of the experiment, ranging from 2.6 to 3.1 parts per thousand with higher average salinities in forb treatments than in emergent graminoid or control treatments. pH ranged between 6.5 and 9.5 over the course of the experiment and trends among treatments closely tracked DO concentrations. Initial turbidity ranged from 4 to 12 NTUs and declined in all treatments over the course of the experiment, after which turbidity remained higher in forb treatments than in control or emergent graminoid treatments. FDOM levels increased in all treatments over time, except for the control treatment which decreased from initial levels. *Typha* promoted the highest FDOM

levels, followed by *Sesuvium*, *Salsola*, *Atriplex*, *Schoenoplectus* and *Phragmites*.

Nutrient trends differed between plant functional types for all measured constituents, except for NO_3 concentrations which were low in all mesocosms (Table 4; Figure S2a–h). Forbs released higher concentrations of NH_4, total nitrogen (TN), total dissolved nitrogen (TDN), PO_4, total phosphorus (TP) and total dissolved phosphorus (TDP) than emergent graminoids or control treatments. Emergent plants increased TN concentrations compared to the control but did not significantly increase other nutrient constituents. Dissolved organic carbon (DOC) trends reflected FDOM trends and varied by plant species. As with FDOM trends, *Typha* promoted the highest DOC concentrations, followed by the three forb species, *Schoenoplectus*, then *Phragmites*. Released dissolved nutrients were depleted in most treatments by day 16 but increased again in forb treatments by the end of the experiment. When averaged over time, all macronutrients (TN, TP and DOC) produced in the mesocosms were positively correlated with average chlorophyll-a concentrations, but when combined into our linear model only the effect of TN was significant (Table 5; Figures S3 and S4).

TABLE 2 Summary of estimates in selected quadratic mixed-model describing the effects of plant litter from different plant functional types (PFT) and time (in days) on chlorophyll-a concentration.

Dependent variable: Log(chlorophyll-a)			
Predictors	**Estimates**	**CI**	***p***
Intercept	2.06	1.77 to 2.34	**<0.001**
PFT [control]	Reference		
PFT [emergent]	0.53	0.20 to 0.86	**<0.002**
PFT [forb]	1.28	0.95 to 1.61	**0.001**
Days	−5.43	−8.66 to −2.21	**<0.001**
Days^2	−0.47	0.33 to 0.41	0.770
PFT [control] × days	Reference		
PFT [emergent] × days	5.84	2.12 to 9.57	**0.002**
PFT [forb] × days	14.53	10.80 to 18.25	**<0.001**
PFT [control] × days^2	Reference		
PFT [emergent] × days^2	−11.74	−15.43 to −8.05	**<0.001**
PFT [forb] × days^2	−19.58	−23.28 to −15.89	**<0.001**
Random effects			
σ^2		0.38	
τ [mesocosm ID]		0.07	
ICC		0.16	
N [mesocosm ID]		35	
Observations		400	
Marginal R^2		0.664	
Conditional R^2		0.718	

Significant *p* values ($\alpha < 0.05$) presented in bold.

3.2 | Zooplankton response

Zooplankton biomass increased in all mesocosms over the course of the study but at different rates between prescribed plant functional types (RANOVA[Greenhouse–Geisser estimates]: $F_{2.376, 38.016} = 4.161$; $p < 0.018$). Zooplankton biomass increased faster in the three forb species treatments than in emergent graminoid and control treatments (Figure 5, Table 6). Zooplankton biomass trends in emergent graminoid treatments closely resembled trends in the control treatment over the entire incubation period.

Zooplankton growth rates differed between plant functional types (nested two-way ANOVA: $F_{2,28} = 28.324$, $p < 0.0001$) but not among plant species within functional types ($F_{4,28} = 0.455$, $p = 0.768$; Figure 6). Growth rates were higher in forb treatments than emergent graminoid and control treatments (Tukey's HSD, $p < 0.001$) but did not differ between emergent graminoid and control treatments (Table 7).

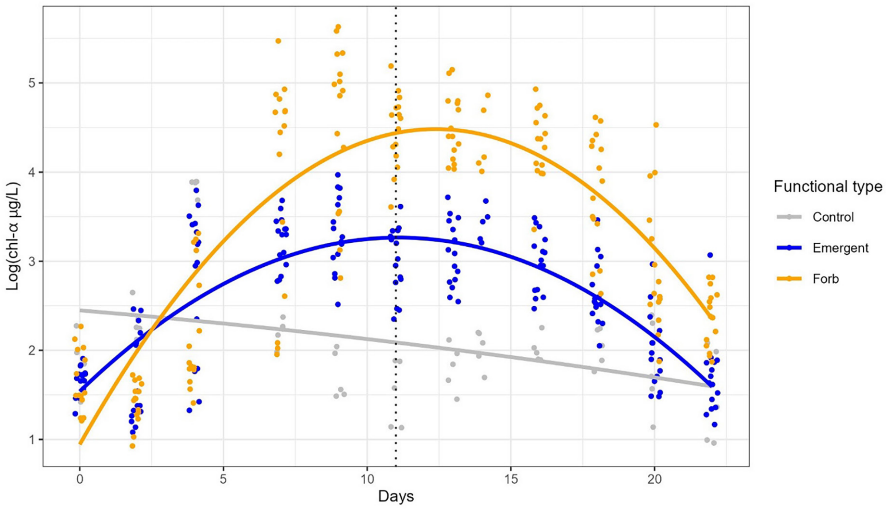


FIGURE 3 Fitted quadratic mixed-model depicting interactive effects of plant functional types and time (in days) on chlorophyll-a concentrations in a mesocosm experiment on how plant litter type affects wetland plankton. Curves represent fitted model per plant functional type. Points represent log-transformed chlorophyll-a observations used to fit the model. Vertical dotted line depicts time of zooplankton introduction.

TABLE 3 Results of post-hoc paired *t*-tests evaluating the effect of submerged litter from different plant functional types on average dissolved oxygen concentrations over time (in weeks).

Week	Group 1	Group 2	N1	N2	*t* stat	*p* adjusted
	Control	Emergent	5	15	−0.124	0.904
Initial	Control	Forb	5	15	0.525	0.611
	Emergent	Forb	15	15	0.756	0.456
	Control	Emergent	5	15	11.2	**<0.001**
First	Control	Forb	5	15	31.7	**<0.001**
	Emergent	Forb	15	15	5.77	**<0.001**
	Control	Emergent	5	15	7.27	**<0.001**
Second	Control	Forb	5	15	3.74	**0.006**
	Emergent	Forb	15	15	1.28	0.654
	Control	Emergent	5	15	1.86	0.238
Third	Control	Forb	5	15	−6.15	**<0.001**
	Emergent	Forb	15	15	−6.50	**<0.001**
	Control	Emergent	5	15	11.4	**<0.001**
Fourth	Control	Forb	5	15	2.19	0.126
	Emergent	Forb	15	15	−5.32	0.747

Note: Pairwise comparisons conducted within sampling weeks (including an initial period prior to the addition of plant litter) and tested using Bonferroni adjusted *p*-values.
Significant *p* values ($\alpha < 0.05$) presented in bold.

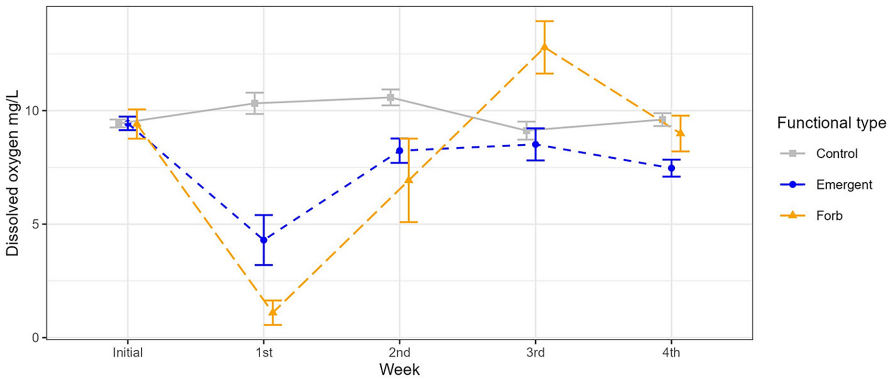


FIGURE 4 Dissolved-oxygen trends for a mesocosm experiment testing the effects of plant litter on plankton communities and water quality. Treatments grouped by plant functional type. Points depict estimated weekly mean dissolved-oxygen values. Error bars depict within-mesocosm 95% confidence intervals (Cousineau-Morey method).

When averaged over time, zooplankton community compositions were different among plant functional types (ANOSIM: $R = 0.437$, $p = 0.0001$; Figure 7) and four of the eight analysed zooplankton taxa were associated with one or more treatments, according to indicator species analysis (Table 8, Figure S6). Rotifers and *Daphnia magna* were associated with all three forb treatments (*Daphnia*: $t = 0.825$, $p = 0.001$; Rotifera: $t = 0.599$, $p = 0.018$). *Limnothoina tetraspina* was associated with *Typha* and the control treatment ($t = 0.581$, $p = 0.03$) while calanoid nauplii were associated with *Schoenoplectus* ($t = 0.518$, $p = 0.039$).

According to Mantel tests, pairwise differences in zooplankton community composition (Spearman's rank Bray–Curtis dissimilarity) were correlated with pairwise differences in several continuous variables (Euclidean distance). Significant correlations included mean chlorophyll-a concentrations ($R = 0.479$, $p = 0.001$), mean turbidity measurements ($R = 0.431$, $p = 0.001$), mean dissolved oxygen concentrations ($R = 0.284$, $p = 0.001$), mean pH values ($R = 0.256$, $p = 0.001$), mean salinities ($R = 0.139$, $p = 0.013$) and mean FDOM values ($R = 0.103$, $p = 0.036$). Zooplankton community structure did not correlate with differences in mean temperature, as temperature differences between mesocosms were very small.

4 | DISCUSSION

4.1 | Phytoplankton and water quality

Decaying forbs supported larger phytoplankton blooms than decaying emergent graminoids—by an order of magnitude—which was likely driven by higher nutrient loads released from labile forb material. Forbs released the highest concentrations of nitrogen and phosphorus, especially ammonium and phosphate, which are preferentially taken up by algae over other forms of macronutrients

TABLE 4 Results of nested ANOVAs and Tukey's HSD tests for multiple comparisons describing the effects of litter from different plant functional types and nested plant species on water quality variables (averaged over a 23-day incubation period) in a mesocosm experiment.

	PFT			PFT: plant species			Tukey's HSD results and (*p*-values)		
Response variable	df	*F*-value	*p*	df	*F*-value	*p*	Emergent-control	Forb-control	Forb-emergent
Temperature C	2, 28	0.163	0.851	4, 28	1.165	0.347	0.08 (0.926)	0.12 (0.84)	0.04 (0.961)
Salinity (PPT)	2, 28	25.54	**<0.001**	4, 28	3.12	**0.031**	0.02 (0.164)	0.08 (**<0.001**)	0.05 (**<0.001**)
pH	2, 28	84.18	**<0.001**	4, 28	14.22	**<0.001**	−0.51 (**<0.001**)	−0.19 (**<0.001**)	0.32 (**<0.001**)
Turbidity (NTU)	2, 28	48.747	**<0.001**	4, 28	1.079	0.385	−0.27 (0.694)	1.93 (**<0.001**)	2.19 (**<0.001**)
FDOM	2, 28	167.26	**<0.001**	4, 28	45.01	**<0.001**	8.81 (**<0.001**)	9.11 (**<0.001**)	0.29 (0.704)
DOC	2, 14	74.07	**<0.001**	4, 14	28.16	**<0.001**	4.66 (**<0.001**)	4.75 (**<0.001**)	0.09 (0.941)
NH_4	2, 14	5.465	**0.018**	4, 14	0.494	0.74	0.02 (0.983)	0.25 (0.086)	0.23 (**0.023**)
NO_3	2, 14	2.02	0.17	4, 14	2.067	0.14	0.001 (0.965)	0.007 (0.317)	0.006 (0.214)
TN	2, 14	309.63	**<0.001**	4, 14	16.12	**<0.001**	0.24 (**0.018**)	1.42 (**<0.001**)	1.18 (**<0.001**)
TDN	2, 14	28.924	**<0.001**	4, 14	4.742	**0.0125**	0.16 (0.403)	0.71 (**<0.001**)	0.55 (**<0.001**)
TP	2, 14	36.68	**<0.001**	4, 14	7.14	**0.002**	0.06 (0.258)	0.23 (**<0.001**)	0.18 (**<0.001**)
TDP	2, 14	7.496	**<0.006**	4, 14	3.586	**0.033**	0.02 (0.849)	0.08 (**0.027**)	0.07 (**0.011**)
PO_4	2, 14	5.743	**0.0151**	4, 14	3.583	**0.0326**	0.01 (0.916)	0.07 (0.059)	0.06 (**0.024**)

Note: Significant *p* values presented in bold.

TABLE 5 Results of a multiple linear model describing the effects of macronutrients (TN, TP and DOC) on chlorophyll-a concentrations averaged over a 23-day incubation period in a mesocosm experiment.

Dependent variable	Average chlorophyll-a		
Predictors	Estimates	CI	*p*
Intercept	0.35	(−34.28 to 34.98)	0.983
Avg TN	32.28	(11.92 to 52.64)	**0.004**
Avg TP	6.21	(−103.50 to 115.91)	0.906
Avg DOC	0.50	(−3.93 to 4.92)	0.815
Observations	21		
Multiple R^2	0.597		
Adjusted R^2	0.526		

Note: Significant *p* values presented in bold.

(Domingues et al., 2011). Chlorophyll-a production was more strongly correlated with nitrogen than phosphorus, suggesting that nitrogen was the more limiting macronutrient for phytoplankton growth. However, without a way to isolate singular additions of N or P in this experiment, it is impossible to rule out the co-limitation of both N and P (see Bratt et al., 2020). An initial lag in forb treatments was associated with extreme hypoxia likely driven by heterotrophic microbes that can deplete dissolved oxygen and can competitively exclude phytoplankton from released nutrients when there is a sufficient source of carbon (Hulot et al., 2001). Heterotrophic conditions in forb treatments were short-lived, possibly because microbes became carbon-limited after the first few days, allowing phytoplankton to bloom in the second week of the experiment and photosynthetically restoring dissolved-oxygen concentrations. As our experiment did not incorporate physical water mixing, aeration, or water exchange, we assumed that oxygen trends in the mesocosms were largely driven by photosynthesis and respiration with only limited gas exchange at the water surface.

In contrast to forbs, phytoplankton blooms in control treatments were immediate but short-lived. Confining Suisun Marsh water within mesocosms effectively removed grazing pressures (prior to reintroduction of zooplankton) and prevented any loss through advection, allowing phytoplankton to exploit—and soon deplete—the limited pool of nitrogen and phosphorus present in ambient Suisun Marsh water (Lucas & Thompson, 2012). Without an additional source of released nutrients, phytoplankton in control treatments crashed after the first week, likely due to nutrient limitation.

Emergent graminoids generated intermediate phytoplankton trends between control and forb treatments. Emergent graminoids promoted mildly heterotrophic conditions early in the experiment—diminishing but not depleting dissolved oxygen—before supporting a moderate phytoplankton bloom. Phytoplankton in emergent graminoid treatments were limited by low nitrogen and phosphorus concentrations, which may have been largely resorbed from emergent leaf material during leaf senescence (Rejmánková, 2005). Microbe and phytoplankton production may have been further impacted by leached humic compounds, such as lignins and tannins, which can inhibit microbial and algal growth (Chen et al., 2012; Kang et al., 2020). Among plants used in the experiment, *Typha* promoted the highest concentrations of dissolved organic carbon (and stained mesocosm water a reddish hue) but supported relatively low phytoplankton production, indicating possible leaching of humic substances

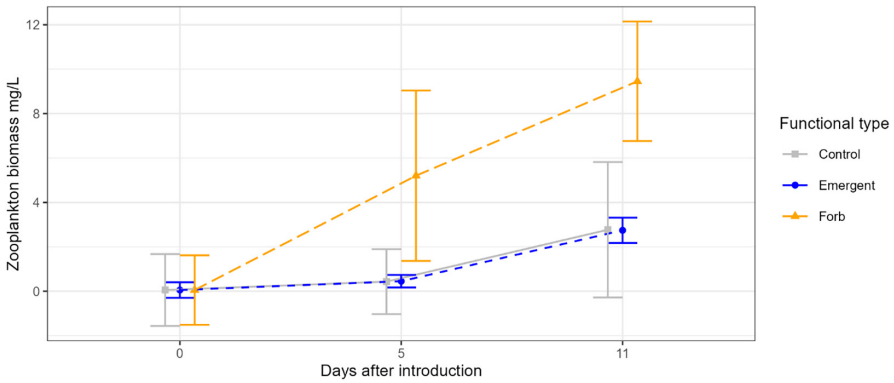


FIGURE 5 Estimated zooplankton biomass trends in an experiment testing the effects of litter from different plant functional types on plankton production. Error bars depict within-subject 95% confidence intervals (Cousineau-Morey method).

TABLE 6 Results of post-hoc paired *t*-tests evaluating the effect of submerged litter from different plant functional types on zooplankton biomass concentration over time.

Day	Group 1	Group 2	N1	N2	*t* stat	*p* adjusted
	Control	Emergent	5	15	−0.11	1
5	Control	Forb	5	15	−2.40	0.092
	Emergent	Forb	15	15	−2.39	0.094
	Control	Emergent	5	15	0.09	1
11	Control	Forb	5	15	−4.21	**0.011**
	Emergent	Forb	15	15	−7.57	**<0.001**

Note: Pairwise comparisons conducted within sampling periods and tested using Bonferroni adjusted *p*-values.
Significant *p* values ($\alpha < 0.05$) presented in bold.

(Oliveira et al., 2016). Overall, these trends implicate a trade-off whereby flooded forbs can promote large phytoplankton blooms at increased risk of water hypoxia while leaves or stems shed from emergent graminoids support limited phytoplankton production with decreased risk of hypoxia.

In real wetlands, phytoplankton production could be driven by a variety of other factors that were not adequately captured in this experiment but could be considered in subsequent studies. Wetlands often support a multitude of plants of varying functional types rather than monocultures of single species. Combinations of detritus from different plant species and functional types may further augment phytoplankton production by providing a broader range of nutrient compositions and nutrient release rates (Kominoski et al., 2007). Seasonally flooded soils can release large amounts of dissolved nutrients as they switch between anaerobic and aerobic conditions, although the contents of soil nutrients are often linked to the cycling of local plant assemblages (Baldwin & Mitchell, 2000). Phytoplankton production can become light limited by turbid conditions, especially in tidally mixed channels such as in Suisun Marsh (Cloern, 1999). Contrary to findings in Suisun Marsh, average turbidity concentrations were positively correlated with phytoplankton growth in the experiment, but also with plant functional type, indicating that any light limitation effects were insubstantial compared to the effect of plant detritus in our experiment. The phytoplankton blooms themselves may have increased turbidity, as cells can scatter light at higher concentrations (Schroeder, 2003). However, measured turbidity values in the experiment were much lower than turbidity values typically found in Suisun Marsh, as suspended particles likely settled in the mesocosms (O'Rear et al., 2021). It is possible at the landscape scale and at extreme detrital loads that forbs could induce light limitation and at times suppress phytoplankton production.

Phytoplankton blooms in emergent graminoid treatments lasted longer than the control treatment but peaked and declined at similar times as forb treatments, suggesting that emergent graminoids do not support more sustained blooms than forbs, contrary to our hypothesis. For both plant functional types, peak phytoplankton concentrations aligned with relatively depleted nitrogen and phosphorus concentrations but also with the introduction of grazing zooplankton. As densities of grazers increased, phytoplankton concentrations decreased in all treatments despite zooplankton excretion replenishing nutrient concentrations at this point, suggesting that bottom-up processes were circumvented by strong top-down effects regardless of plant litter inputs (Sommer & Sommer, 2006; Strong, 1992). Therefore, we cannot rule out the possibility that emergent graminoids may support relatively prolonged phytoplankton blooms, though only in the absence of grazing zooplankton (especially filter-feeding cladocerans).

4.2 | Zooplankton

Zooplankton studies in oligotrophic lakes have considered the effect of terrestrial particulate organic carbon (t-POC) on pelagic food webs compared to autochthonous sources, concluding that t-POC contributes little to zooplankton production (Brett et al., 2017; Taipale et al., 2014). Little consideration has yet been given to the plant functional type from which t-POC was sourced (as leaves from deciduous trees or emergent graminoids have been used to broadly represent t-POC)—although these studies do acknowledge that the biochemical composition of terrestrial inputs is key to their effects on productivity. These studies primarily emphasized direct consumption of detritus by zooplankton but did not evaluate indirect consumption mediated by phytoplankton which can assimilate nutrients released from t-POC. Our study found that plant functional type is important when considering the effects of terrestrial inputs on zooplankton

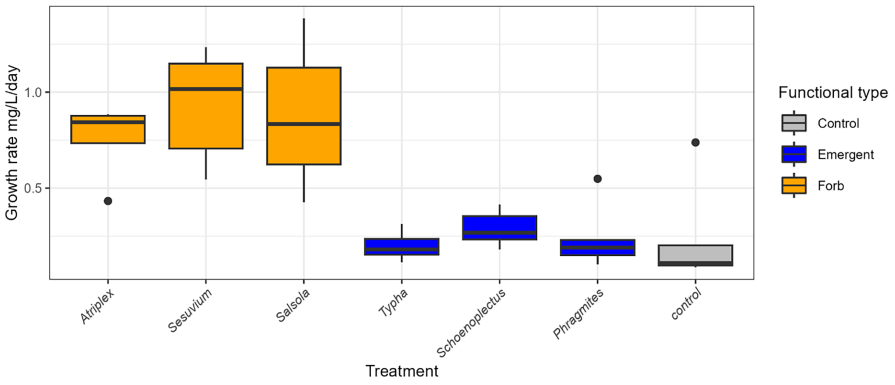


FIGURE 6 Boxplot depicting zooplankton growth rate estimates ($n = 5$) in mesocosms prescribed with litter from different plant species. Boxes indicate inner quartile range with midline depicting median estimates. Whiskers indicate outer quartile range and points refer to outliers outside of the outer quartile range.

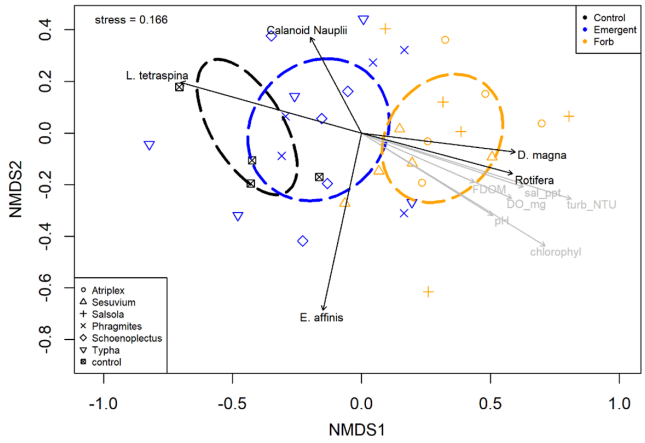


FIGURE 7 NMDS ordination plot depicting differences in zooplankton community composition among mesocosms treated with plant detritus from different species (shapes) and plant functional types (colour). Standard error ellipses highlight differences between plant functional types. Black vectors indicate significant zooplankton taxa driving ordination outcomes (intrinsic variables). Grey vectors indicate associations of significant water quality variables with ordination outcomes (extrinsic variables).

production. Decaying forbs promoted higher zooplankton production than emergent graminoids on an equal per-mass basis, due to increased food resources in the form of phytoplankton and possibly microbes (as indicated by extreme heterotrophic conditions early on in our experiment). Phytoplankton provide crucial proteins and lipids for growth and reproduction while microbes may supplement zooplankton diets, especially in relatively eutrophic systems (Harfmann et al., 2019; Hixson et al., 2015; Müller-Solger et al., 2002; Tang et al., 2023). Emergent graminoids provided no additional support compared to unamended ambient Suisun Marsh water despite increased phytoplankton production in emergent graminoid treatments compared to the control, although this result was possibly due to limited power attributed to small sample size in the control group ($n = 5$). We found no significant differences in zooplankton growth rates among plant species treatments within respective plant functional types, indicating—as with our water quality results—that forbs and emergent graminoids are useful classifications when estimating effects on the aquatic food web.

Daphnia and rotifers were numerically dominant in all treatments, although forbs supported the highest densities of both taxa. *Daphnia* are valuable prey for juvenile fish, planktivorous fish and macroinvertebrates while rotifers can provide an important trophic link between the microbial loop and the classic aquatic food web (Corline et al., 2017; Kalinowska et al., 2015; Porter, 1996). Rotifer populations exhibited explosive growth within the first week of introduction but crashed in the second week while *Daphnia* populations continually grew through the end of the experiment. Increasing *Daphnia* densities was a likely cause of the rotifer decline, as filter-feeding *Daphnia* can competitively exclude rotifers via more efficient grazing (Gilbert, 1985). Copepods were relatively sparse in all treatments and most taxa were not strongly associated with any treatment, except for calanoid nauplii which were associated with *Schoenoplectus*, and the small cyclopoid *L. tetraspina* which was associated with *Typha* and the control treatment. As with rotifers, *Daphnia* can competitively limit the growth and survival of copepod nauplii through the depletion of shared food resources (Toscano et al., 2016). It is possible that the apparent benefit of emergent graminoid and control treatments for calanoid nauplii and *L. tetraspina* may instead be driven by a negative association with competing cladocerans. Ongoing field observations indicate that managed wetlands, which are dominated by forbs prior to flooding, support high densities of copepods within the first few weeks of flooding, but densities decrease when cladocerans become abundant (Tung et al., 2021). Future experiments excluding *Daphnia* could confirm the effect of plant litter types on copepod production free of competition.

Chlorophyll-a, turbidity, dissolved oxygen, pH, salinity and FDOM were all correlated with changes in zooplankton community composition, but, of these constituents, chlorophyll-a was the strongest predictor of zooplankton abundance and composition ($R = 0.4792$), likely because it is a direct measurement of food abundance. Turbidity and salinity were likely driven by plant functional type but were unlikely to affect zooplankton composition directly because the ranges of both variables were narrow and within thresholds that could support the growth of present taxa (Ghazy et al., 2009; Kimmerer et al., 1998). Dissolved oxygen and pH were correlated with chlorophyll-a, as these constituents are often driven by primary production, and were within ranges that could support

TABLE 7 Results of a Tukey's HSD post-hoc test for multiple comparisons estimating the effects of litter from different plant functional types on zooplankton growth rates (95% confidence interval).

Groups	Difference	Lower CI	Upper CI	*p* adjusted
Emergent-control	−0.0022	−0.3052	0.3007	0.9998
Forb-control	0.6079	0.3049	0.9109	**0.0001**
Forb-emergent	0.6102	0.3959	0.8244	**<0.0001**

Significant *p* values ($\alpha < 0.05$) presented in bold.

TABLE 8 Results of an indicator species analysis identifying the strongest associations between each zooplankton taxa and detritus from different wetland plant species (or groups of plant species) in a mesocosm experiment.

Taxa	Number of associated treatments	Associated plant treatments	*t*	*p* value
Cyclopoid nauplii	1	*Sesuvium*	0.514	0.102
Calanoid nauplii	1	*Schoenoplectus*	0.518*	0.039*
A. vernalis	2	*Salsola* *Schoenoplectus*	0.337	0.619
A. sinensis	2	*Salsola* *Typha*	0.389	1
L. tetraspina	2	*Typha* Control	0.581*	0.03*
D. magna	3	*Atriplex* *Sesuvium* *Salsola*	0.825*	0.001*
Rotifera	3	*Atriplex* *Sesuvium* *Salsola*	0.599*	0.018*
E. affinis	3	*Sesuvium* *Schoenoplectus* Control	0.351	0.508

Note: Significant results marked with an asterisk.
Significant *p* values ($\alpha < 0.05$) presented in bold.

zooplankton growth in all treatments at the time of zooplankton introduction. Forb treatments were briefly hypoxic for the first few days after submerging plant material, which would likely have been lethal to most taxa had they been introduced at the beginning of the experiment (Karpowicz et al., 2020). While we found that decaying forbs increased zooplankton production by an order of magnitude, this outcome may be dependent on the ability of zooplankton to diapause during stressful periods of anoxia or to recolonize through advection after conditions improve.

4.3 | Management implications

Wetlands operated by duck clubs or fish and wildlife agencies are principally managed to attract migratory waterfowl for recreational hunting, yet management practices incidentally support pelagic food webs. In Suisun Marsh and adjacent Sacramento-San Joaquin Delta, managers use tidal-powered water control structures and pumps to flood, circulate water, or dry their wetlands. When wetlands are dry, managers control vegetation by mowing, applying herbicides, or administering control burns. Wetlands are typically managed to promote growth of target forbs (such as *Atriplex*) and emergent graminoids (such as *Typha*) to provide food and cover, respectively, for wintering waterfowl (Barthman-Thompson et al., 2007; Grewell et al., 2014). Our experimental findings indicate that, when flooded, decomposing forbs stimulate a large pulse of primary and secondary production while decomposing emergent graminoids stimulate limited production. We assert that management actions that promote forb growth (such as seasonal wetting and drying) are likely to increase aquatic production in nutrient-limited aquatic ecosystems, in a manner reminiscent of floodplains. In natural floodplains, aquatic production is driven by flood pulses which release high concentrations of nutrients from wetted soil and decomposing terrestrial plants that can be used by primary and secondary producers (Junk et al., 1989). As observed in natural floodplains, pulses of productivity in managed wetlands are likely to benefit higher trophic levels of the aquatic food web, especially fish, although risk of anoxia may present a trade-off at initial flooding.

Until recently, it was presumed that managed wetlands in Suisun Marsh harmed native and desirable fishes because of fish entrainment risk, and seasonal hypoxic events following flood-up (Culberson et al., 2004; Siegel et al., 2011). However, mark-recapture studies

monitoring salmonid entrainment in managed wetlands (Fishery Monitoring Program: A Component of the Suisun Marsh Diversion Screening Program., 1996) found poor evidence of entrainment risk. A recent cage study found that juvenile chinook salmon grew faster within and adjacent to managed wetlands—even with hypoxia—than in tidal habitats, suggesting that managed wetlands can benefit fisheries (Aha et al., 2021). In an ongoing field study, we observed low dissolved-oxygen events only in a few managed wetlands, while many retain adequate oxygen concentrations to support primary and secondary productivity, possibly due to mitigating effects of wind and water circulation (Tung et al., 2021). To minimize the risk of low dissolved oxygen over a wide area from wetland outflows, land managers in Suisun Marsh currently alternate wetland flood timing among wetlands under the co-management of the Suisun Resource Conservation District. Given disparities between our findings and preconceptions about managed wetlands, as well as actions already implemented to reduce harm to fisheries, managed wetlands warrant reconsideration for their role in estuarine conservation, and further study to assess their effects on estuarine ecosystems.

In contrast, tidal wetlands are dominated by emergent graminoids and do not support forbs, except on marsh uplands (Grewell et al., 2014). Our results suggest that tidal habitats provide limited support for primary and secondary production compared to managed wetlands, although overland flow from floods or from king tides along estuarine-terrestrial gradients may occasionally import labile carbon from upland vegetation (Colombano et al., 2020). The Suisun Marsh Habitat Management, Preservation and Restoration plan from 2013 mandates the restoration of 8000 acres of managed wetlands to tidal marsh over 30 years to increase habitat and food production for native fishes (DOI et al. 2013). Our results—though limited by the spatial–temporal scale of mesocosms—suggest that tidal restoration of managed wetlands is more likely to decrease primary and secondary production in Suisun Marsh by eliminating forb growth and beneficial flood-pulses. Recent and ongoing field studies found that tidally restored wetlands support lower zooplankton densities and promote nonnative fishes over native fishes (Williamshen et al., 2021). Collectively, this emerging research suggests that tidal restoration is not a panacea and may not achieve intended outcomes without consideration of novel ecosystem functioning. It is possible, however, that future tidal restoration efforts could be designed to better incorporate resource subsidies from adjacent managed wetlands to both increase habitat for pelagic fish and provide pelagic food at key periods.

AUTHOR CONTRIBUTIONS

Conceptualisation: Kyle A. Phillips, Alice M. Tung, Eliška Rejmánková, Sharon P. Lawler, John R. Durand. Developing methods: Kyle A. Phillips, Rachel M. McConnell, Sharon P. Lawler, John R. Durand. Data analysis, preparation of figures and tables: Kyle A. Phillips. Conducting the research: Kyle A. Phillips, Alice M. Tung, Rachel M. McConnell. Data interpretation, writing: Kyle A. Phillips, Alice M. Tung, Rachel M. McConnell, Teejay A. O'Rear, Eliška Rejmánková, Sharon P. Lawler, John R. Durand.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest related to this publication.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, KP, upon reasonable request.

ORCID

Kyle A. Phillips https://orcid.org/0009-0004-9694-0722
Eliška Rejmánková https://orcid.org/0000-0001-7539-0232

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