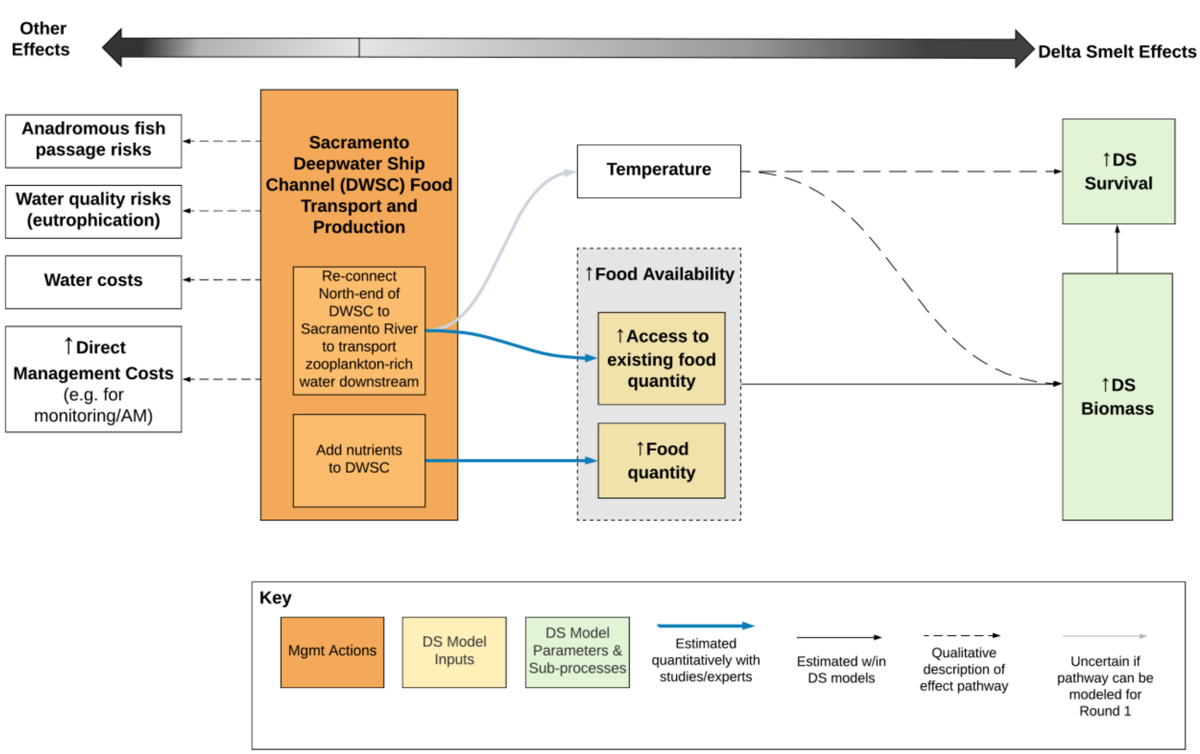
Action Specification Sheet:

Sacramento Deepwater Ship Channel Food Subsidy Action

1 Short Description and Hypothesized Bottleneck

The primary goal of this action is to subsidize the food supply for Delta Smelt occupying the Turbidity Maximum Zone (TMZ) of the Sacramento Deepwater Ship Channel (DWSC) by enhancing the production and export of food resources from the upper ship channel (see Influence Diagram). Boosting food supply could result in faster smelt growth and improved survival. Production in the upper channel would be enhanced by applying fertilizer when phytoplankton growth becomes nitrogen-limited and export to the TMZ would be increased by diverting net flow from the Sacramento River via the Stone Lock barge canal. Conducting this action in spring could benefit larval Delta Smelt, while summer and fall actions could benefit juveniles. An ancillary goal is to export food from the ship channel to Cache Slough.

2 Influence Diagram



3 Action Evaluation

#	Effect Hypothesis	Effect Characterization for Round 1 SDM
1	**Re-connect North-end of DWSC to Sacramento River to transport zooplankton-rich water downstream → increase zooplankton**	Used results from the RMA (2021) modeling study of this action (see further description in Evidence section below).

#	Effect Hypothesis	Effect Characterization for Round 1 SDM
2	**Add nutrients to DWSC → increase zooplankton**	Erwin Van Nieuwenhuyse (Bureau lead for this action) provided a coarse estimate for this pathway based on available data and expert judgement from the research team working on the action (See Appendix 1 for details on the calculations).
3	**Re-connect North-end of DWSC to Sacramento River to transport zooplankton-rich water downstream → temperature**	Round 1 analysis did not capture this effect pathway. Note that RMA (2021) did model this pathway and that study could inform future analysis.
Financial and water resources		
	Financial resource costs	We used a best estimate from Luke Loken (USGS) that includes annual operating costs of nutrient application and monitoring. See Section 14 for details. **Final financial resource estimate: $900,000 per year**

4 Action Specification

- This action was included in the 2020 Record of Decision for the Long-term Operation of the Projects
- Erwin Van Neiuwenhuyse provided inputs to this Action Specification Sheet in Summer 2022.

5 Location(s)

Liquid fertilizer (N and P) would be applied using a boat (or tanks on shore) to the uppermost ~350 acres of the ship channel near the City and Port of West Sacramento (between NL76 and the locks). Phytoplankton growth in this area becomes nitrogen-limited in the late spring and remains so through summer and fall. Much of this area is oriented perpendicular to the prevailing winds and thus has lower dispersion and a higher probability of remaining thermally stratified than rest of the channel, which is roughly parallel to the prevailing winds (Figure 1). The Stone Lock facility (WSP) is at the terminus of the ship channel in downtown West Sacramento and is equipped with two sets of sector gates that are currently inoperable. The TMZ encompasses the area between NL62 and NL66.

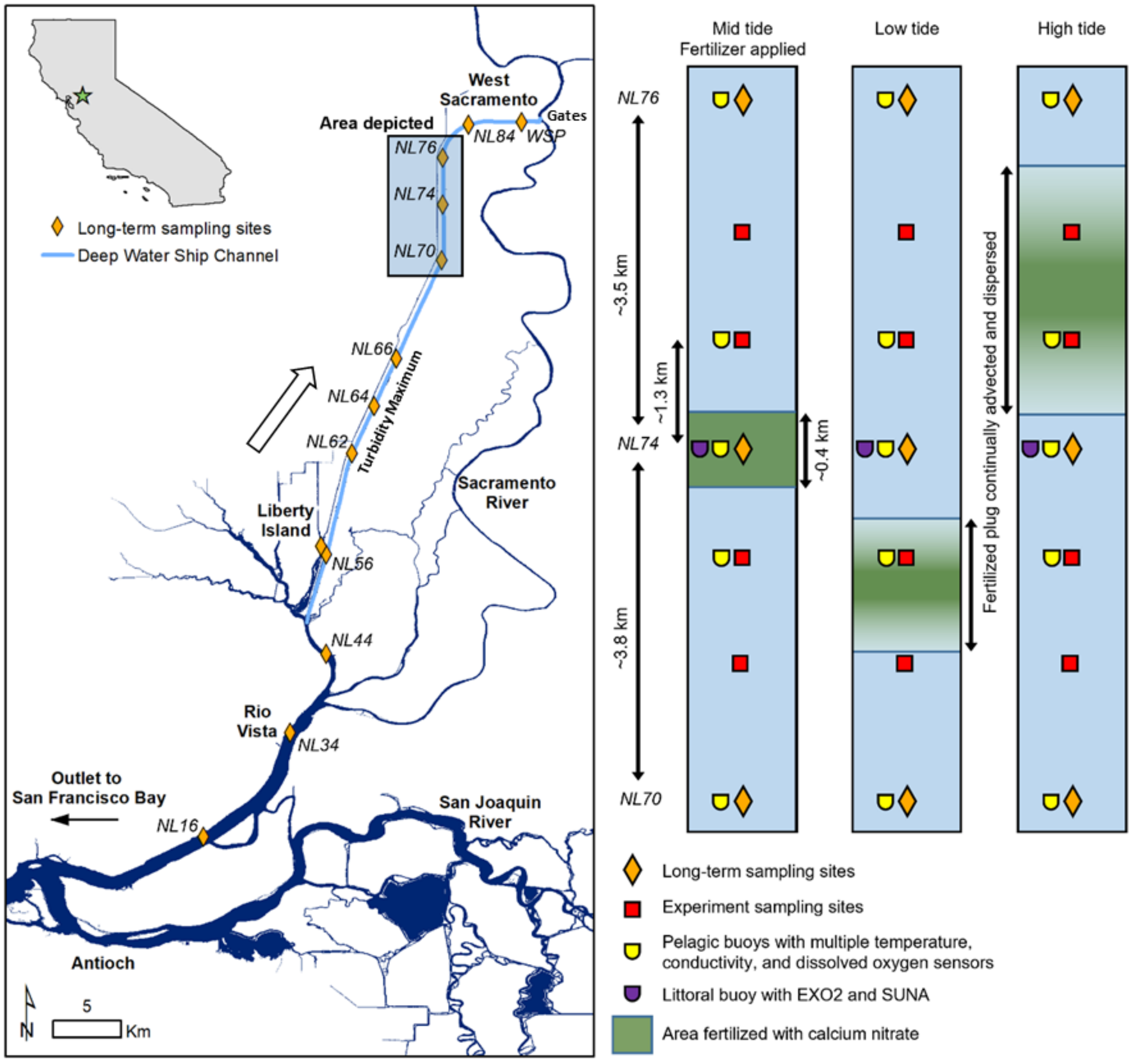


Figure 1. Sacramento Deep Water Ship Channel long-term (2012 - 2019) sampling sites (left), and sampling design for 2019 nitrate-addition experiment (right). Turbidity Maximum Zone is between NL62 and NL66. Area where fertilized would be applied is between NL76 and the barge canal (WSP). During the 2019 experiment, fertilizer was applied to a 0.4 km-long, ~15-acre reach (green polygon) centered at NL74. The fertilized water mass moved seaward or landward of NL74, moving up to 4 km daily due to tides (excursion length). Sensor buoys and moorings (half-ovals) were deployed ~30 m from the western shore. Synoptic sampling occurred in the center of the channel at 7 sites (orange diamonds and red squares) evenly spaced longitudinally. Arrow shows direction of prevailing wind. Inset not drawn to scale.

6 Timing and Intensity

6.1 Bureau of Reclamation

The precise timing, magnitude and duration of fertilizer application and flow diversion would vary with flow and water quality conditions in the Sacramento River and the upper ship channel and with other considerations such as flood control requirements, ship traffic and juvenile and adult anadromous fish passage. These decisions would presumably be made by a technical advisory group/steering committee consisting of representatives from the West Sacramento Area Flood Control Agency, City and Port of West Sacramento, the Army Corps of Engineers, U.S. Fish and Wildlife Service, National Marine Fisheries Service, the California Department of Fish and Wildlife, Central Valley Regional Board, the California

Department of Water Resources, the Bureau of Reclamation and others. The decisions of this group would be informed by a calibrated and validated model using an adaptive management approach.

Fertilizer could be applied up to three times per year, in spring, summer and fall. In each case, after ~2-3 weeks (enough time for phytoplankton and zooplankton to process the added nutrients), net flow would be diverted from the river to accelerate plankton export to the TMZ and, depending on the magnitude of the net flow, perhaps further downstream to Cache Slough.

For purposes of modeling the effect of this action on the Delta Smelt population (using the IBMR), the following assumptions are made:

- Action occurs in summer (June-July) and fall (September-October) in all water year types to benefit juvenile delta smelt
- Action occurs in spring (March-April) in below normal, dry, and critical water year types to benefit larval delta smelt

6.2 RMA (2021)

In the scenario modeled by RMA (2021), 700 cfs of Sacramento River flow was diverted into the DWSC for three weeks in July when the system is typically N-limited and phytoplankton production and zooplankton standing stocks are relatively low.

7 Evidence / Examples

7.1 Nitrogen addition experiment

In 2019, a Reclamation-UC-Davis-US Geological Survey team conducted a field experiment to test the hypothesis that phytoplankton production in the upper ship channel would respond positively to an increase in nitrogen concentration. Monthly sampling conducted by Reclamation and UC-Davis during 2012-2019 had indicated that phytoplankton growth rate in the upper ship channel might be constrained by nitrogen, particularly during summer and fall. Low N:P ratio (<5 by mass) and the drawdown of nitrate after the spring phytoplankton bloom suggested chronic nitrogen limitation (Figure 2). This hypothesis was further supported by laboratory experiments indicating little or no response to added nutrients in the lower Sacramento River (NL34) but substantial positive responses in samples collected in the ship channel (Figure 3).

Using a crop-dusting airplane, 1360 kg of calcium nitrate fertilizer (equivalent to 211 kg of nitrate-N) were applied on 8 occasions to a ~15-acre reach of the upper ship channel centered at the USGS continuous biogeochemistry monitoring station at NL74 (Loken et al. in press). Although daily variability in near-surface phytoplankton abundance (chlorophyll concentration) was controlled primarily by processes regulating thermal stratification, especially wind shear (Lenoch et al. 2021), the results indicated a significant positive interaction with nitrate concentration, i.e., under strongly stratified conditions, fertilized water produced ~3-times more phytoplankton than unfertilized water (Figure 4).

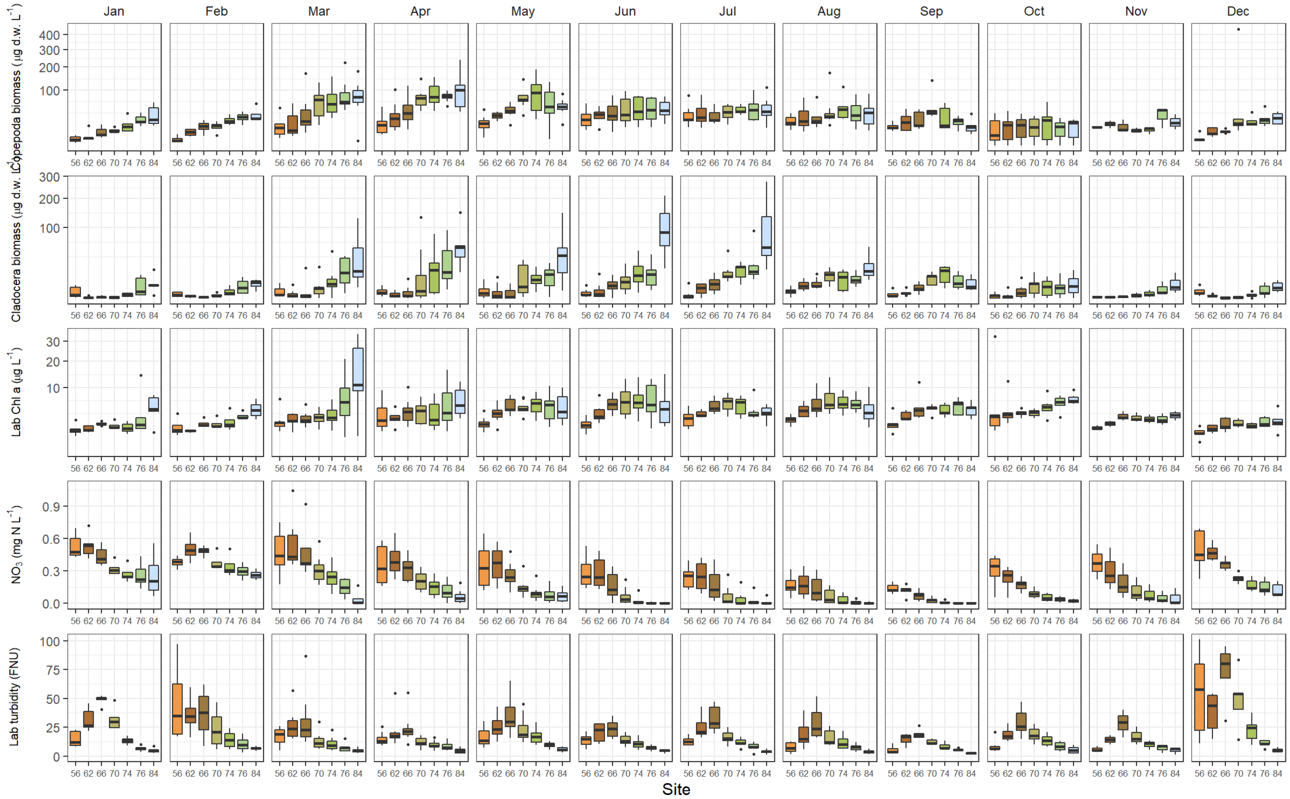


Figure 2. Monthly spatial patterns in turbidity, nitrate-N, chlorophyll concentration and biomass of Cladocera and Copepods at long-term monitoring stations (2012-2019). Stations are arranged from seaward to landward. Y-axes are square-root-transformed. Each boxplot is the distribution of concentrations for each station and month and includes between 3 and 8 unique observations (i.e., years). The upper and lower edges are the 25th and 75th percentiles, whiskers are drawn up to 1.5 times the interquartile range, and points are plotted if beyond the whiskers. Copepod biomass is dominated by *Sinocalanus doerri* and *Pseudodiaptomus forbesii* and Cladocera biomass by *Bosmina longirostris, Diaphanosoma brachyurum* and *Daphnia parvula*. Source: Loken et al. in press.

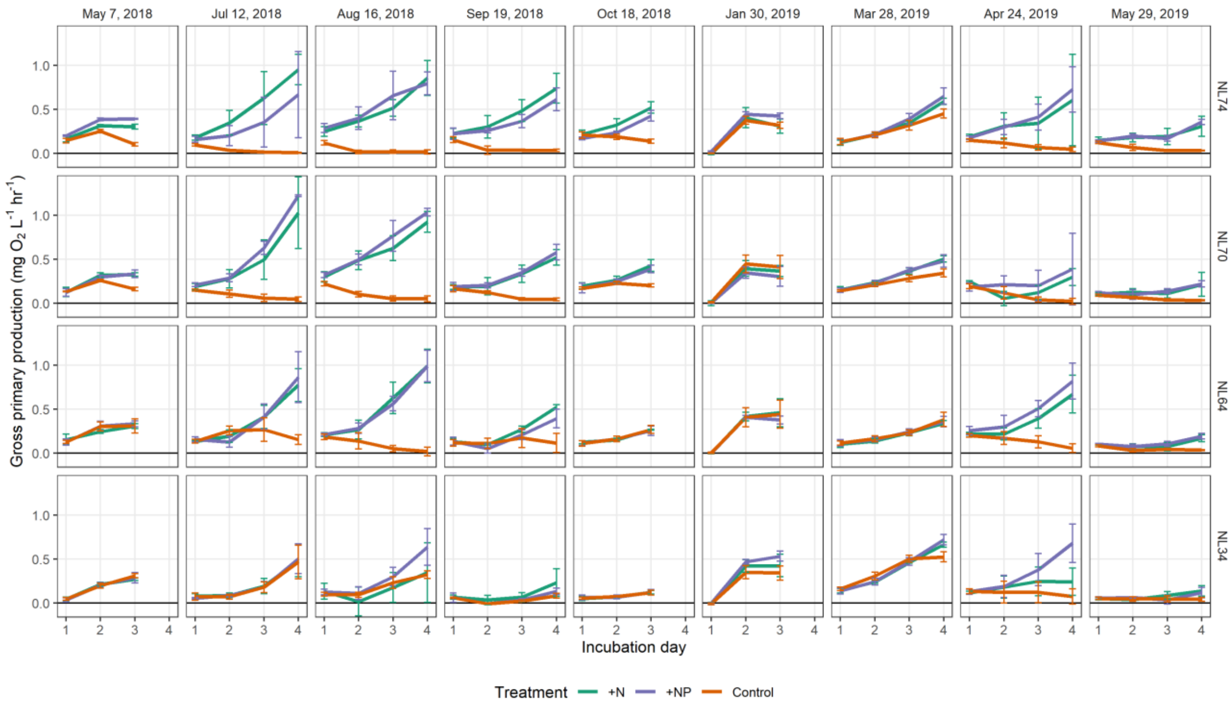


Figure 3. Laboratory-based rates of gross primary production (GPP) among nutrient treatments. Each panel is a 3–4-day incubation. Water was collected at four sites (rows) on nine dates (columns). The seaward site (NL34; bottom row) did not show signs of nitrogen (N) limitation as the control (brown) and nutrient-amended (green and purple) incubations had similar rates. Moving landward (up), the potential for N limitation increased shown as a divergence between the control and nutrient-amended treatments. Maximum N-limitation potential occurred in the uppermost stations during the mid to late summer (Jul–Sept). Error bars show the standard deviation among replicates. Source: Loken et al. in press.

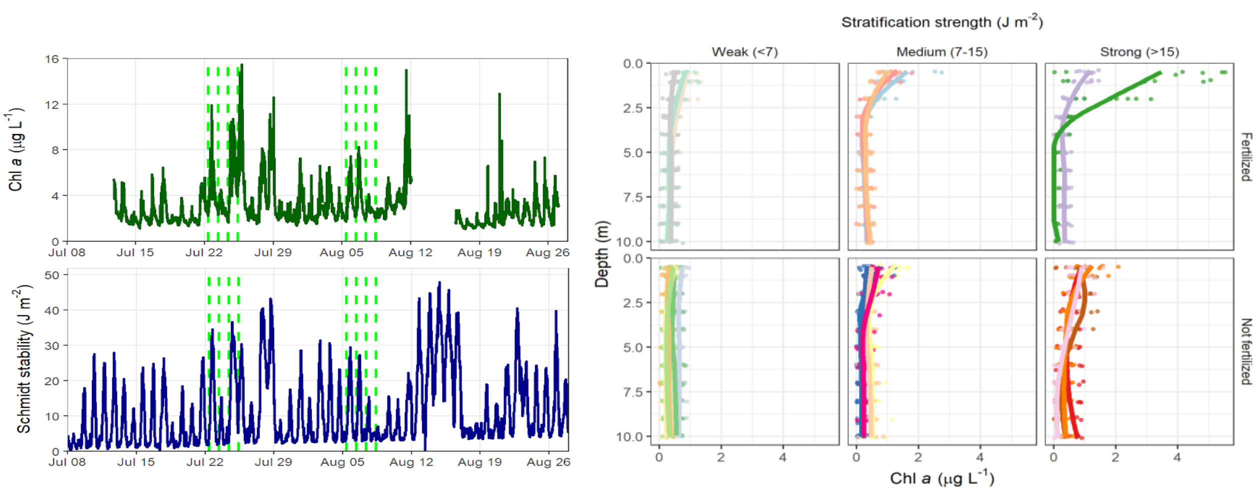


Figure 4. (left) Chlorophyll concentration and stratification strength (Schmidt stability index) at NL74 during nitrate addition experiment (dashed vertical lines mark mornings when fertilizer was applied) (right) Vertical profiles of chlorophyll concentration collected on each sampling event during the experiment (n = 27). Each color is a different date and represents the average profile among the 7 sampling sites. Profiles were grouped based on whether fertilizer was added that day (top row) and strength of stratification (columns). Weak (<7 J m^{-2}), medium (7–15 J m^{-2}), and strong (>15 J m^{-2}) stratification was based on concurrent temperature vertical profiles and calculated Schmidt stability. Source: Loken et al. in press.

7.2 RMA (2021)

RMA (2021) defined the DWSC action as diverting 700 cfs of water from the Sacramento River into the DWSC in July and examined changes in water temperature, salinity, current speed, and a metric of copepod catch-per-unit effort. Turbidity was estimated from observations. RMA (2021) only modeled the flow component of this action and did not include the fertilization component.

Four water year types were simulated: Dry, Below Normal, Above Normal and Wet. For these water year types, scenarios used inflows generated with CalSim II by Reclamation. During above normal and wet years, an X2 action (X2 at 80 km) was included in flow estimates from the CalSim II model for all management scenarios. The model results were analyzed to provide monthly maps of variables and habitat suitability metrics. The modeled effects of the action included: (i) reduction of surface water temperature in the upper ship channel and an increase in surface water temperature in the TMZ and lower ship channel; (ii) reduction in salinity; (iii) minimal zooplankton growth in the ship channel owing to low initial chlorophyll concentration; and (iv) only modest export of zooplankton biomass to the Cache Slough Complex and other downstream areas (Figure 5).

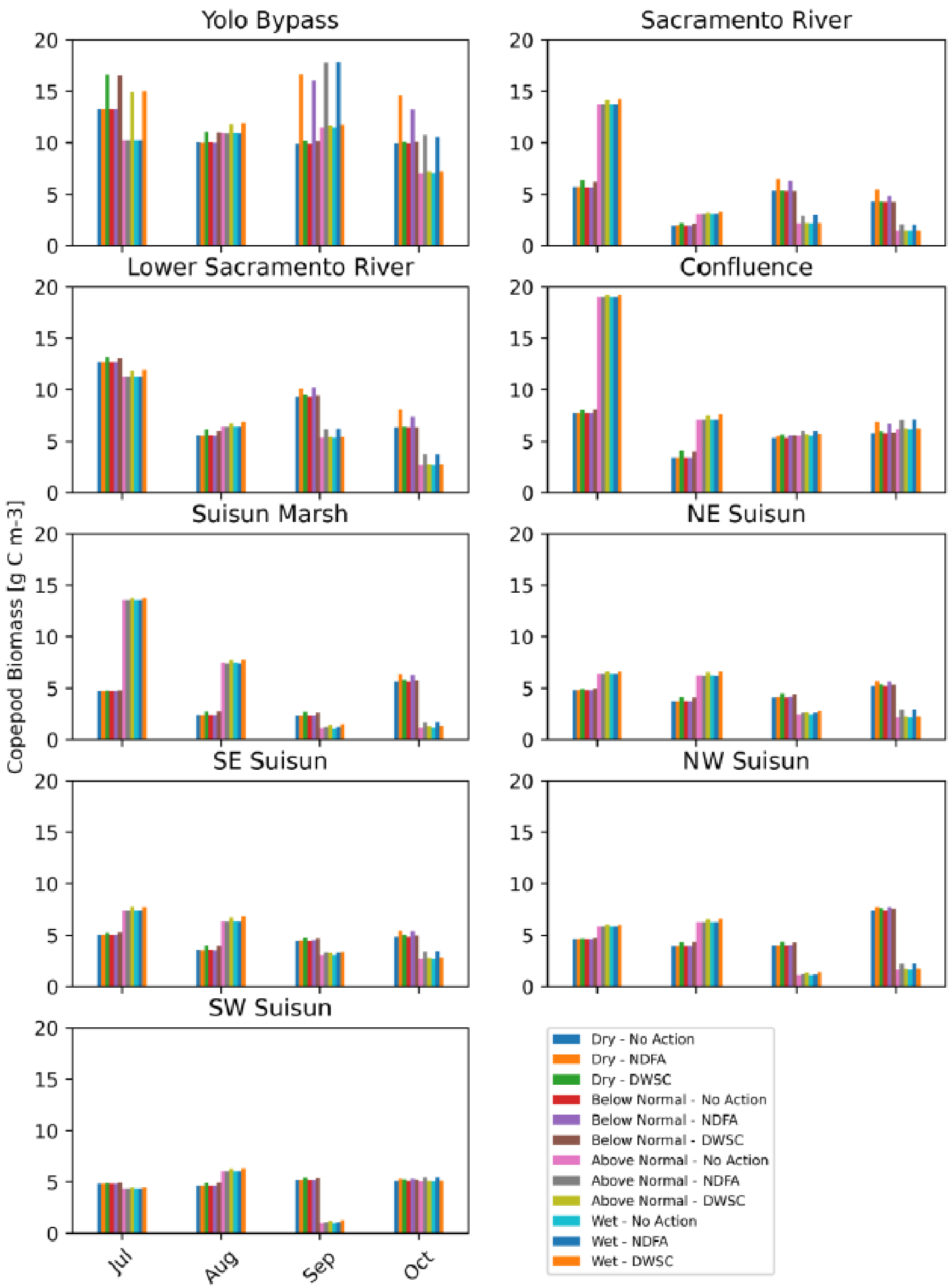


Figure 9 Regionally-averaged monthly calanoid copepod BPUE (Rose et al. 2013 IBM regions), for 4 water years types and 3 different management scenarios.

Figure 5. Results of RMA modeling (Figure 9 in RMA 2021).

8 Relationships with other actions

Increasing zooplankton production in the upper ship channel would have a positive effect on food supply for Delta Smelt even if there were no mechanism for diverting water from the Sacramento River. Delta Smelt use the whole ship channel but are mostly concentrated in the TMZ and some fraction of the extra food produced in the upper channel would be dispersed into the TMZ through tidal exchange (Cloern 2007). Delta Smelt feed most effectively in turbid water however and may also be less susceptible to predation than in the much clearer water of the upper ship channel (Figure 2). Thus, maximizing the benefits of this action would require the ability to export zooplankton from the upper ship channel to the TMZ using net flow diverted from the Sacramento River. This ability could be restored by repairing the sector gates of the Stone Lock facility. Ownership of the Stone Lock facility and adjacent lands was transferred from the Corps of Engineers to the City of West Sacramento in 2015.

West Sacramento and the West Sacramento Area Flood Control Agency (WSAFC) are interested in pursuing an alternative to the currently authorized Corps of Engineers plan for achieving 200-year flood protection for the city and surrounding lands (COE 2015). This plan calls for construction of a sheet-piled earthen levee that would permanently disconnect the ship channel from the river. The alternatives to a levee that have been evaluated so far include repairing the Stone Lock sector gates, which if fully opened could divert up to ~40% of Sacramento River flow down the ship channel, and construction of a permanent barrier outfitted with flap-gated culverts whose combined capacity would be 700 cfs. Currently, the ship channel is separated from the river by a vegetated sediment bar and bulkhead structure which does not provide 200-year protection. Implementation of the Corps-authorized plan began in 2017 with construction of the Southport set back levee project and is slated for completion by 2027. Between now and then, the WSAFC and COE, in consultation with the FWS and NMFS and the participation of other stakeholders, must determine which alternative to implement.

This action also depends on action by the State Board. Neither West Sacramento, WSAFC nor the Corps currently possesses a water right to divert water from the Sacramento River to the ship channel. The water used for the North Delta Food Subsidy Action is Reclamation water. Reclamation water could presumably also be used to implement the DWSC Food Subsidy Action.

9 Delta Smelt Model Results

The table below shows predicted population outcomes across the 20-year model timeframe for several versions of the action that were tested with the IBMR and LF models.

		Population Growth Rate		% Change in Population Growth Rate from Baseline	
		IBMR	LF	IBMR	LF
Action run ID	Scenario name	Average lambda (1995-2014)	Average lambda (1995-2014)	% change in average lambda (1995-2014)	% change in average lambda (1995-2014)
2.1	DWSC transport	0.98	-	0%	-
2.2	DWSC NutrientAdd	0.98	0.92	0%	7%

- Multiple runs were used to explore different food effects assumptions and methods.
- Action run 2.1 used RMA (2021) simulation modeling results of the transport effect only.
- Action run 2.2 used coarse estimates based on data and expert knowledge from Erwin Van Nieuwenhuyse (previous USBR lead for this action, now retired), who was involved in a pilot

application of nutrients in the Sacramento DWSC in 2019. See Appendix 1 for details on Erwin's methods, which considered both the RMA (2021) results of the transport effect and the nutrient addition effect.

- **Action run 2.2 was used as the "primary" model run for Round 1 portfolio evaluation.**

10 Discussion and Next Steps

Next steps for this action identified by Erwin Van Neiwenhuyse in July 2022:

- Continue fixed station monitoring of flow, specific conductance, temperature, turbidity, nitrate-N and chlorophyll in the upper channel and TMZ (US Geological Survey)
- Expand scope of ecosystem metabolism measurements (UC-Davis)
- Quantify denitrification and other nutrient fluxes (UC-Davis)
- Improve understanding of TMZ dynamics (USGS, UC-Davis)
- Assess bioavailability of hydrophobic organic compounds in sediment and zooplankton using Tenax method (Southern Illinois University/UC-Davis)
- Improve estimates of zooplankton and clam grazing rates (UC-Davis)
- Continue non-invasive monitoring of fish community (Cramer Fish Sciences)
- Calibrate and validate a nutrient-phytoplankton-zooplankton-fish-clam ecosystem model (Reclamation/Department of Water Resources)

11 Key Contacts

- Erwin Van Nieuwenhuyse (evannieuwenhuyse@usbr.gov) – USBR lead for this action.
- Steve Sadro, UC-Davis (ssadro@ucdavis.edu) – lead for biogeochemical-food web investigations.
- Luke Loken, US Geological Survey (lloken@usgs.gov) – lead for 2019 nitrogen addition experiment.
- Joe Merz, Cramer Fish Science (jmerz@fishsciences.net) – lead for fish community monitoring.
- Paul Stumpner, US Geological Survey (pstump@usgs.gov) – ship channel hydrodynamics and thermal stratification.
- Leah Lenoch, US Geological Survey (llenoch@usgs.gov) – ship channel hydrodynamics and thermal stratification.
- Jon Burau, US Geological Survey (jrburau@usgs.gov) – turbidity maximum zone dynamics.

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13 Appendix 1 – Initial estimates of zooplankton response to action

Prepared by: Erwin Van Nieuwenhuyse (2022)

The 2019 experiment suggests that phytoplankton production in the upper ship channel would respond positively to an increase in its nutrient supply, particularly during summer and fall when nitrate-N declines to growth rate-limiting concentrations. The experiment took place in an area subject to vigorous tidal dispersion and parallel to the prevailing winds (Lenoch et al. 2021). Had the experiment been conducted further landward, where tides are more muted and the orientation is perpendicular to the wind fetch, it is likely that the response to fertilizer addition would have been more marked (Loken et al. in press). Thus, it is not unrealistic to assume that enough fertilizer (N and P) could be applied to the roughly 350 acres of the uppermost ship channel landward of NL76 **to produce a 3-fold increase in Chl, e.g., from 5 ug/L to 15 ug/L.** Assuming the lake-like upper ship channel responds to this increase in primary food supply in a manner parallel to northern hemisphere lakes (McCauley and Kalff 1981; Bernat et al. 2020), an increase in chlorophyll concentration of this magnitude could be expected **to roughly double the standing stock of zooplankton (Figure 6)**. Such a response would also be consistent with the positive relationship between chlorophyll and copepod abundance documented by Orsi and Mecum (1986) for the Delta during the 1970s (Figure 7).

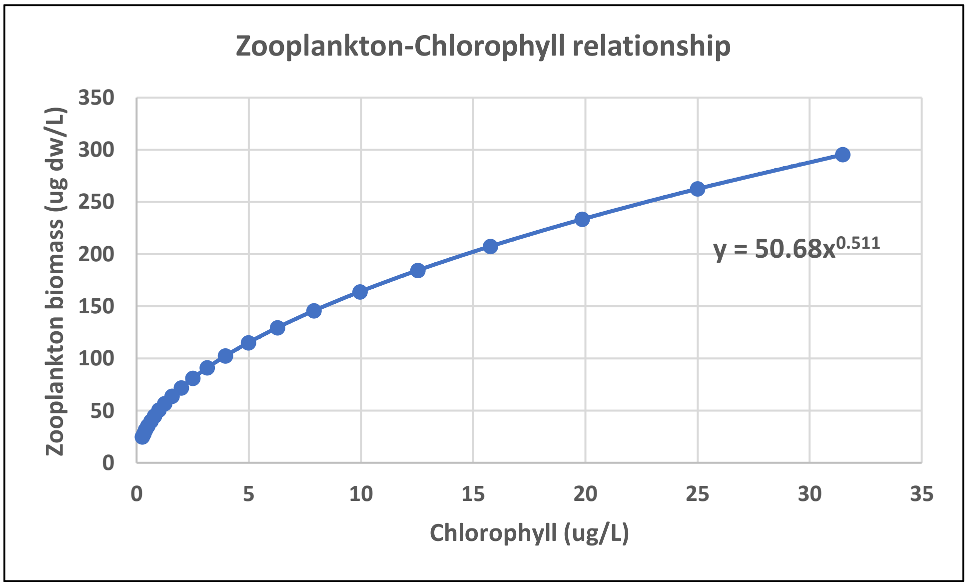

Figure 6. Empirical relationship between mean chlorophyll concentration and crustacean zooplankton biomass in 17 northern hemisphere lakes (McCauley and Kalff 1981). The original model used fresh weight for zooplankton and phytoplankton standing stock. Zooplankton biomass was converted to dry weight assuming a dry-to-fresh weight ratio of 0.12 (McCauley and Kalff 1981) and phytoplankton biomass was converted to chlorophyll concentration assuming a chlorophyll-to-fresh weight ratio of 0.025 (Evans et al. 1995).

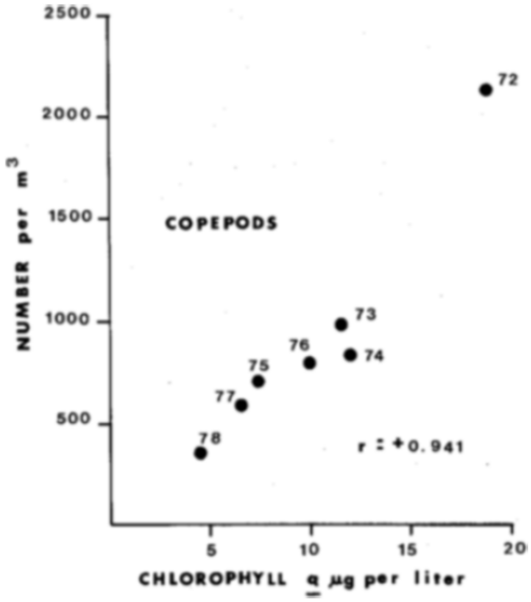

Fig. 17. Mean annual abundance of freshwater copepods vs. mean annual chlorophyll *a* at all delta stations from 1972 to 1978. Numbers next to the points signify the years.

Figure 7. Copepod-chlorophyll relationship in the Delta during the 1970s (Orsi and Mecum 19xx).

Zooplankton biomass in the uppermost ship channel (NL76 and NL84) during March-April averages about 120 ug dw/L (Table 1). Doubling this value provides an estimate of the zooplankton biomass to expect if chlorophyll concentration in the upper channel were tripled. The RMA modeling suggests that a net flow of 700 cfs would be able to transport this upper channel biomass to the TMZ within about a week. Assuming that any growth in transit is offset by losses to predation and that pre-action zooplankton biomass in the TMZ during March-April averages ~35 ug dw/L (Table 2), **the action could result in a nearly 7-fold, i.e., 240/35, increase in the potential food supply for Delta Smelt in the TMZ.** Relative increases for June-July (230/35) and September-October (44/6) actions would similar. Thus, a combination of fertilizer addition and net flow (as opposed to just adding net flow) could be expected to result in a substantial increase in Delta Smelt food supply.

Table 1. Monthly mean EC (uS/cm), turbidity (NTU), nitrate-N (mg/L), chlorophyll (ug/L), cladocera, copepod and total zooplankton biomass (ug dw/L) at long-term monitoring stations in the upper ship channel. n = number of observations (years).

Station	Month	n	EC	Tubidity	NO_3-N	Chl	Cladocera	Copepoda	Zooplankton
WSP	Jan	5	896	6.4	0.20	41.1	11.0	27.9	39.0
WSP	Feb	4	542	24.1	0.26	10.6	0.7	21.4	22.2
WSP	Mar	8	724	9.0	0.12	39.4	89.5	104.6	196.6
WSP	Apr	8	699	6.2	0.00	18.9	70.8	85.6	187.7
WSP	May	8	941	4.9	0.03	14.2	269.0	81.7	352.6
WSP	Jun	8	961	4.2	0.01	12.1	118.7	15.2	134.1
WSP	Jul	7	983	3.7	0.00	11.9	52.4	26.2	85.8
WSP	Aug	8	851	3.7	0.00	17.4	30.7	3.5	34.9
WSP	Sep	5	850	2.2	0.00	11.6	59.5	17.0	86.4
WSP	Oct	8	936	4.0	0.01	19.4	29.4	32.1	61.7
WSP	Nov	3	1049	5.5	0.02	12.3	7.1	23.2	30.4
WSP	Dec	5	701	26.5	0.21	4.2	65.5	20.7	87.2
NL84	Jan	5	1073	5.0	0.26	6.6	5.4	31.0	36.4
NL84	Feb	4	871	6.6	0.26	6.0	4.3	31.4	35.7
NL84	Mar	8	984	4.7	0.03	21.5	37.9	82.0	119.9
NL84	Apr	8	913	4.6	0.05	9.1	54.1	101.7	155.7
NL84	May	8	1066	5.7	0.06	6.6	43.8	49.4	93.4
NL84	Jun	8	1019	4.4	0.00	6.6	100.7	44.3	145.1
NL84	Jul	7	1018	3.9	0.01	5.3	98.7	46.3	177.9
NL84	Aug	8	1011	3.6	0.00	6.4	20.9	35.1	56.3
NL84	Sep	5	974	2.5	0.00	5.6	4.7	13.3	21.2
NL84	Oct	8	1009	5.3	0.02	9.4	5.2	11.9	17.2
NL84	Nov	3	1063	4.7	0.05	5.2	5.2	19.0	24.2
NL84	Dec	5	1049	5.1	0.12	4.2	3.0	25.0	28.0
NL76	Jan	5	1059	6.5	0.26	5.7	4.1	21.4	25.6
NL76	Feb	4	945	10.5	0.30	4.8	3.7	26.0	30.3
NL76	Mar	8	995	7.3	0.14	10.7	17.5	89.1	106.7
NL76	Apr	8	980	8.4	0.11	7.5	29.9	78.0	107.8
NL76	May	8	1085	9.5	0.08	7.4	11.3	60.0	71.4
NL76	Jun	8	1000	7.2	0.00	8.9	12.7	45.0	57.7
NL76	Jul	7	985	8.0	0.03	6.2	25.3	45.1	90.1
NL76	Aug	8	993	7.6	0.01	7.6	7.6	38.1	46.1
NL76	Sep	5	965	5.6	0.00	6.4	6.6	17.9	24.5
NL76	Oct	8	973	8.4	0.03	7.2	3.2	11.1	14.4
NL76	Nov	3	1002	6.9	0.05	3.7	2.2	31.3	33.5
NL76	Dec	5	985	10.8	0.15	3.6	1.8	24.2	26.0

Table 2. Monthly mean EC (uS/cm), turbidity (NTU), nitrate-N (mg/L), chlorophyll (ug/L), cladocera, copepod and total zooplankton biomass (ug dw/L) at long-term monitoring stations in the TMZ (NL62-NL66) and lower ship channel (NL56). n = number of observations (years).

Station	Month	n	EC	Tubidity	NO_3-N	Chl	Cladocera	Copepoda	Zooplankton
NL66	Jan	5	613	48.3	0.44	3.2	0.0	6.1	6.1
NL66	Feb	4	662	36.5	0.48	3.3	0.0	12.0	12.0
NL66	Mar	8	724	31.3	0.46	4.3	2.7	43.3	46.0
NL66	Apr	8	727	24.2	0.32	5.3	1.3	43.8	45.2
NL66	May	8	790	34.5	0.27	7.2	1.1	40.0	41.1
NL66	Jun	8	678	23.5	0.16	7.9	4.2	37.9	42.1
NL66	Jul	7	635	32.5	0.17	7.5	4.8	28.2	33.1
NL66	Aug	8	625	28.5	0.13	7.9	4.7	25.9	30.6
NL66	Sep	5	624	19.3	0.07	8.0	2.4	22.5	24.9
NL66	Oct	8	543	29.5	0.17	5.6	1.8	13.9	15.8
NL66	Nov	3	592	28.5	0.19	4.9	0.0	12.0	12.1
NL66	Dec	5	516	72.3	0.37	5.3	0.0	6.5	6.6
NL62	Jan	5	432	31.4	0.54	2.7	0.0	3.7	3.8
NL62	Feb	4	445	36.0	0.50	2.6	0.1	5.8	5.9
NL62	Mar	8	551	26.9	0.54	4.0	0.7	19.2	20.0
NL62	Apr	8	592	21.4	0.40	4.5	0.3	32.3	32.6
NL62	May	8	551	25.6	0.36	5.3	1.8	28.7	30.5
NL62	Jun	8	437	20.6	0.28	5.8	2.1	30.2	32.3
NL62	Jul	7	415	25.1	0.25	5.6	2.2	35.6	37.9
NL62	Aug	8	407	19.2	0.17	5.9	3.5	27.4	30.9
NL62	Sep	5	431	14.6	0.12	4.8	0.7	20.3	21.1
NL62	Oct	8	375	18.2	0.24	6.6	0.4	13.2	13.5
NL62	Nov	3	412	14.0	0.30	3.7	0.0	14.9	15.0
NL62	Dec	5	347	37.9	0.47	3.9	0.2	6.3	6.5
NL56	Jan	5	315	14.7	0.53	2.7	1.2	1.5	2.7
NL56	Feb	4	266	46.0	0.38	3.8	0.4	1.4	1.8
NL56	Mar	8	373	17.2	0.48	4.1	1.4	13.7	15.1
NL56	Apr	8	330	14.7	0.35	5.1	1.0	16.2	17.3
NL56	May	8	293	16.4	0.34	3.3	2.0	17.3	19.4
NL56	Jun	8	222	13.9	0.28	3.1	0.8	24.5	25.4
NL56	Jul	7	226	12.6	0.24	4.3	0.7	32.1	32.9
NL56	Aug	8	231	7.4	0.17	3.5	1.0	18.8	22.4
NL56	Sep	5	272	5.2	0.14	3.0	0.5	11.7	14.6
NL56	Oct	8	231	8.3	0.31	8.5	0.2	11.4	11.7
NL56	Nov	3	267	5.9	0.38	2.2	0.0	11.1	11.1
NL56	Dec	5	240	54.3	0.49	3.8	1.2	2.2	3.6

14 Appendix 2 – Financial Resource Cost Calculations

The table below provides cost estimates and assumptions used for the action. It shows the calculation for performing the action in all years, which was applied to Portfolios 2b, 2c, and 3d in the Round 1 evaluation. The orange cell indicates the annualized cost used for this action in those portfolios.

Deep Water Ship Channel Food Production and Transport

Portfolio(s) **2b, 2c, 3d**

Source: See table notes

Component		Notes	Unit Cost		Frequency		Total	
Initial Costs								
	High	[a]						
	Low	[b]						
Annual Operating Costs								
	Best	[c]	300000	/nutrient application	100%	of years	900,000	/yr
	Best	[d]	300000	/yr	100%	of years		/yr
Undiscounted average annual costs								
High								/yr
Average of high and low							900,000	/yr
Low								/yr

Notes

[c], [d] For nutrients, crop-duster (estimate from Luke Loken, pers. comm., Jan. 26, 2023)

[d] Monitoring cost (estimate from Luke Loken, pers. comm., Jan. 26, 2023)