Appendix 6C
SCHISM Model Results

6C.1 Introduction: Study Objective

This appendix section summarizes 3D hydrodynamics modeling and analysis performed by the Modeling Support Office of the California Department of Water Resources (DWR) to investigate the Suisun Marsh Salinity Control Gate (SMSCG) reoperation and flow augmentation components of the Proposed Project.

The focus of 3D circulation modeling is to identify the habitat benefits of SMSCG operation and flow augmentation by mapping and computing the low-salinity zone (LSZ) in various hydrologic and operational scenarios. Long-term water supply impacts of the proposed reoperation are incorporated in the CalSim and Delta Simulation Model 2 (DSM2) modeling work described elsewhere.

6C.2 SCHISM and Bay-Delta SCHISM Background

The model used in this study is Bay-Delta SCHISM, which is based on the Semi-Implicit Cross-Scale Hydroscience Integrated System Model (SCHISM) (Zhang et al. 2016), which in turn is derived from the semi-implicit Eulerian-Lagrangian finite-element (SELFE) model (Zhang and Baptista 2008). SCHISM is an open-source community-supported modeling system, whose origins were to serve as a second-generation model (following ELCIRC, a Eulerian–Lagrangian algorithm used to solve shallow water equations) for use in the Columbia River estuary by the Center for Coastal Margin Observation and Prediction. The model has subsequently been enhanced by the Virginia Institute of Marine Sciences and used in basins throughout the world in applications as diverse as reservoir temperature, estuarine transport of salinity, morphology, and near-coast tsunami response. The model has participated in numerous regional benchmark projects. A list of peer-reviewed papers is maintained on the model website (http://ccrm.vims.edu/schismweb). The larger SCHISM suite includes modules for water age, sediment transport, ecology/biology, wind-wave interaction, ice, oil spill, and marsh evolution.

The formulation of the core SCHISM hydrodynamic module is based on the 3D hydrostatic Reynolds-averaged shallow water equations, including mass conservation, horizontal momentum conservation, and salinity transport. The SCHISM hydrodynamic algorithm is based on mixed triangular-quadrangular unstructured grids in the horizontal and a flexible coordinate system in the vertical (localized sigma coordinates with shaved cells, or LSC^2) (Zhang et al. 2015). The modeling system utilizes a semi-implicit finite-element/finite-volume method together with a Eulerian-Lagrangian method for momentum advection to solve the Reynolds-averaged Navier-Stokes and transport equations at ocean to creek scales. It has both a hydrostatic and non-hydrostatic option, but non-hydrostatic modeling is not feasible at field scale in the Sacramento-San Joaquin Delta (Delta) because of the resolution required (MacWilliams et al. 2016).

The DWR application of SCHISM to the Delta as well as a regional description of performance is described in Ateljevich et al. (2014). The mesh for the present model version v110 is shown in Figure 6C-1 with model boundaries for key hydraulic structures. The mesh contains 328,232 elements and 305,834 nodes, with length scales of the elements ranging from 1 kilometer (km) on the coast to 5 meters (m) inland. The LSC^2 vertical grid is terrain-conforming, but tapers in the number of vertical layers from 23 at the Farallon Islands to a single layer (2D horizontal) in the upstream reaches of the Sacramento River, Yolo Bypass, and San Joaquin River. Near Suisun Bay and Marsh the mesh has 10–12 vertical layers, resulting in vertical resolution of 1 m in the main ship channel and finer than 0.6 m in Suisun Bay and Montezuma Slough.

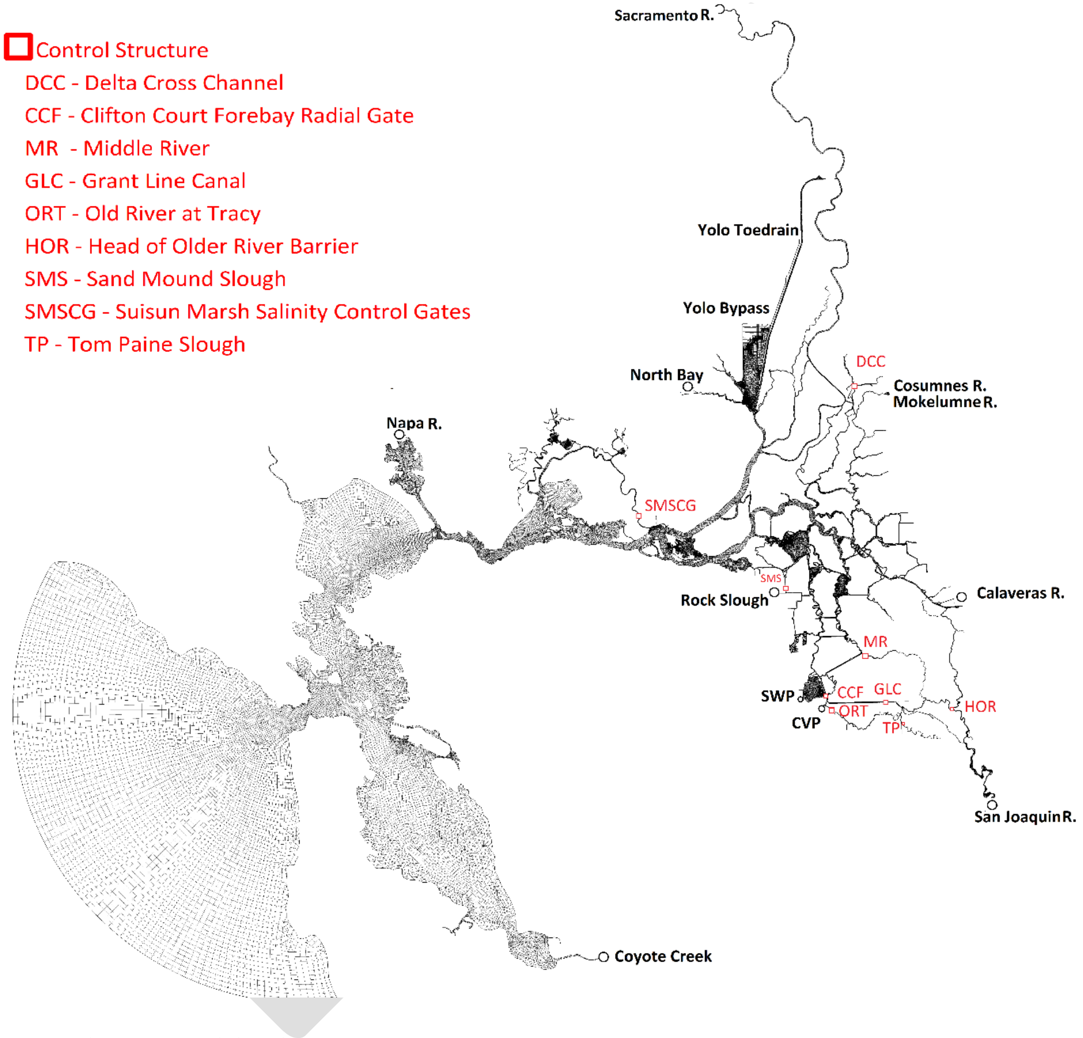


Figure 6C-1. Delta SCHISM mesh, boundary condition location and hydraulic structure locations. In addition, channel depletion sources from the Delta DCD model or similar methods are imposed throughout.

The Delta SCHISM model has been applied to study the performance of numerous operational and planning scenarios in the Delta, including the emergency drought barrier (DWR efficacy report, in press), restoration of Franks Tract (Ateljevich 2018), and hydrodynamic transit time through Clifton Court (Shu 2018). The Franks Tract restoration study includes validation of performance in the western and middle Delta A Bay-only portion of SCHISM extended to Rio Vista is described and validated in Chao et al. (2017a) for temperature as well as salinity and used to study a sea surface temperature anomaly in the Bay and near the coast in Chao et al. (2017b). The work of Cai (2018) focused on the effects of submerged aquatic vegetation on flow physics and biogeochemistry in the Cache Slough Complex.

Modeling assumptions and boundary conditions for the present study generally conform to the methods described by Ateljevich et al. (2014). The mesh has been developed generally as part of the studies cited above and in response to improvements in bathymetry. For the Proposed Project, the mesh was modified to incorporate more marsh channels and marsh plains than previous versions of the Bay-Delta SCHISM mesh. Existing Montezuma Slough bathymetry was found to be insufficiently accurate for a focused study of the region and was resurveyed by the Bathymetry and Technical Support Group at DWR. This work, as well as single beam soundings upstream by the University of California at Davis, were incorporated into the latest (v4.2) modeling bathymetry map for modeling produced by DWR's Delta Modeling Section and were used in the current modeling. The production of the elevation model described by Wang et al. (2019) and the elevations are available online in GeoTiff format in the Resources Agency Open Data Portal (California Department of Water Resources 2018).

The standard Bay-Delta SCHISM configuration incorporates approximations of numerous hydraulic structures in the Delta, including SMSCG, Delta Cross Channel, and Clifton Court Forebay. All of these are modeled as radial gates using standard parameterizations based on stage difference across the gate. See the SCHISM Hydraulic Structure Guide (http://ccrm.vims.edu/yinglong/wiki_files/structs_main.pdf) and open source input templates for details on values used (https://github.com/CADWRDeltaModeling/BayDeltaSCHISM). No special configuration or recalibration was undertaken for the present work, but new periods of tidal operation were incorporated for SMSCG for some scenarios.

DWR consumptive use models for the Delta traditionally did not account for evaporation and consumptive use in Suisun Marsh (including pond up of duck clubs and managed wetlands), and results in Grizzly Bay and the Marsh appear to be sensitive to this assumption. An estimate of evaporation from Suisun Bay and the marsh was included in the model, using a methodology similar to the Delta Evapotranspiration of Applied Water/Delta Channel Depletion (DCD) land water balance technique (Liang 2017). Some tuning was performed relative to these estimates. Managed exports for duck clubs and wetlands were estimated by scaling the volumes used by Research Management Associates for the Bay Delta Conservation Program Draft Environmental Impact Report/Environmental Impact Statement down by 60 percent, which gives a good balance between mean flow and tidal transport and leads to diversions that agree at the one site in which short-term monitoring and gate ratings were available at Roaring River intake. The assumption produces a peak pond-up flow in September that is similar in magnitude to the peak evapotranspiration in June, consistent with the relatively constant rate of salinity intrusion across this transition.

6C.3 Scenarios

DWR studied the impact of reoperating Montezuma Slough gate on habitat in Suisun Marsh. The scenarios composed of no operation, 30 or 60 days of continuous tidal operation, and alternating seven-day tidal, seven-day open schedule. The seven-day length of the alternating pattern was determined through two batches of numerical experiments as part of Delta Coordination Group decision-making process in 2021–2022 using various cycles of operation and opening.

The operations were applied to 2010, 2016, and 2020 hydrology to represent different hydrologic, regulatory, and antecedent salinity conditions. The 30-day operational patterns were only tested in 2020, the Dry year example. A total of 11 scenarios are presented here and are summarized in Table 6C-1.

Two types of flow modification appear on this table and represent departures from the historical river and export flows. *X2 Flow* refers to an added flow action to drive the 2 practical salinity unit (psu) isohaline westward and provide habitat. This augmentation was required to use 2010 as a surrogate for an Above Normal year, a category to which it is otherwise well suited and for which there is no historical example under modern regulatory conditions.

The second flow modification appearing on Table 6C-1 is *Compensating Flow*, which refers to supplemental flow used during gate operation to maintain salinity at peripheral stations at or below the level of the corresponding no operation case. This is the water cost of the action. The reference site for calculating compensating flow depends on the prevailing regulatory or salinity management concern upstream, which will either be a D-1641 objective or Fall X2. During alternating (7d-7d) operations, compensating flow is only during the days when the gate is operated. Compensating flow was calculated offline of the present study by DWR’s Operations Control Office using results from the 1D model DSM2. Based on time series plots (see Figures 6C-6 and 6C-7) SCHISM results corroborate the estimates.

As shown in Table 6C-1, the compensating flow needed to support gate operations is greater during wetter year types when the objective being maintained is more stringent. For instance it requires two to three times more water to maintain an Fall X2 action or 450 microSiemens per centimeter (µS/cm) D-1641 electrical conductivity objective at Jersey Point in an Above Normal year, than it does with the 1350 µS/cm D-1641 objective at Jersey Point in a Dry year.

Table 6C-1. Scenario Descriptions for SCHISM Modeling of Proposed Operations for Suisun Marsh Habitat

Label	Year Type	Adjustment To Scenario	SMSCG Gate Operation	Start	Days	Compensating flow (cfs)
2010 No Operation	AN*	X2=80km (+)	None	NA	0	650/850**
2010 60d	AN*	X2=80km (+)	Tidal	01 Jul	60	650/850**
2010 7d-7d	AN*	X2=80km (+)	Tidal, 7 d alt	01 Jul	60	650/850**
2016 No Operation	BN		None	NA	0	450
2016 60d	BN		Tidal	13 Jun	60	450
2016 7d-7d	BN		Tidal, 7d alt	13 Jun	60	450
2020 No Operation	D		None	NA	0	300
2020 30d	D		Tidal	18 Jun	30	300
2020 30d 7d-7d	D		Tidal, 7d alt	18 Jun	30	300
2020 60d	D		Tidal	18 Jun	60	300
2020 7d-7d	D		Tidal, 7d alt	18 Jun	60	300

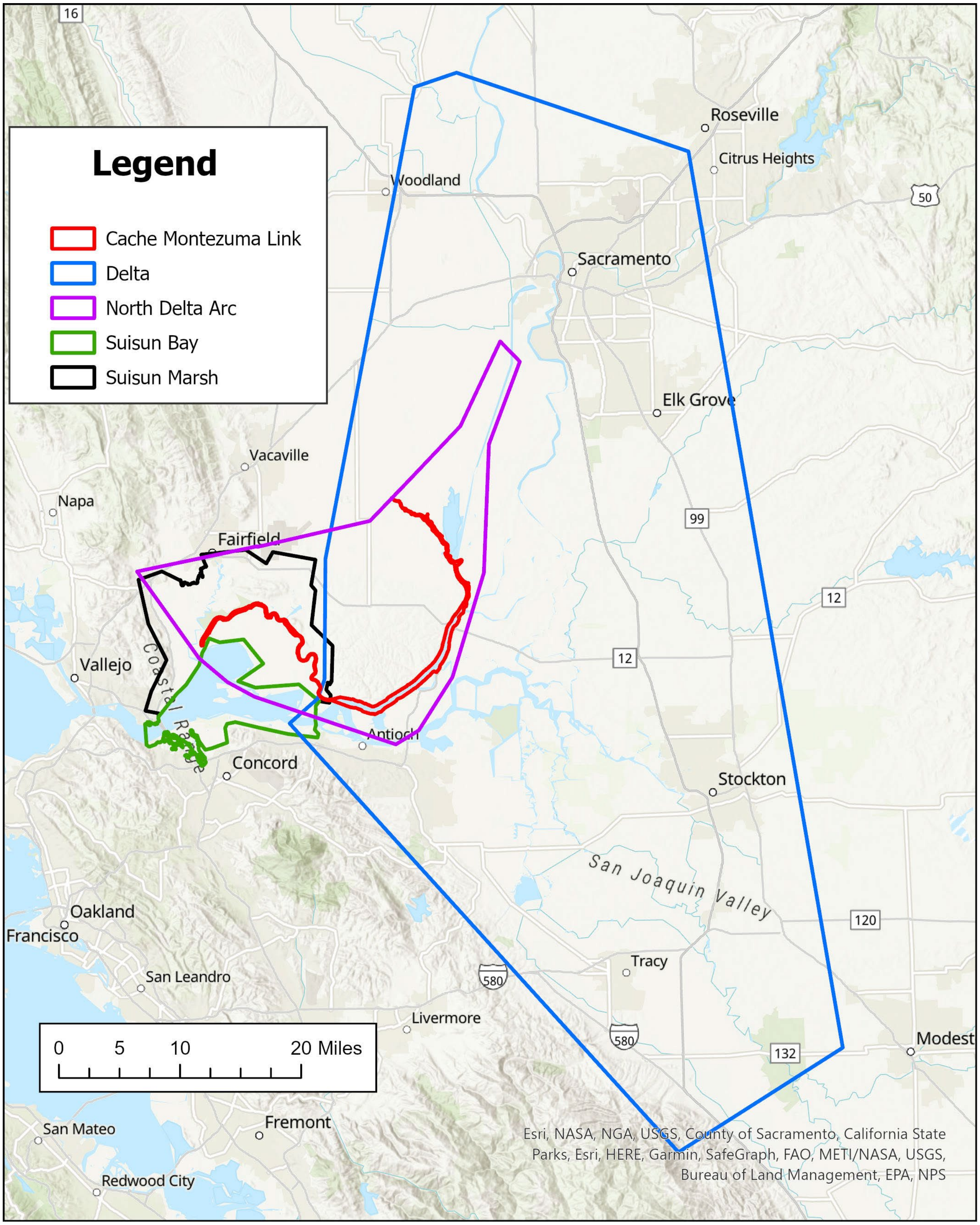
Notes:
AN = Above Normal; BN = Below Normal; cfs = cubic feet per second; D = Dry
* 2010 was modified to represent an Above Normal (AN) year.
** 650 cfs used through July, 850 cfs starting August 1.

6C.4 Habitat Metrics

The main metric of habitat produced in this model study was acreage of habitat that met an LSZ threshold of 6 psu as a time series over the summer-fall season. SCHISM model elements were queried based on their daily and depth averaged salinity and the spatial area of each element included if the area met the 6 psu criterion. Elements are not included if they were dry for more than two hours per day. LSZ acreage was summarized by aggregating within the zones shown in Figure 6C-2. The different zones overlap and though the acres of benefit are redundant, they are presented because they give a perspective on scale, not because they represent independent habitat.

Other metrics have been attempted in the literature. For instance, in the 2019 ITP Application (California Department of Water Resources 2019), a three-factor metric was constructed using a simultaneous target Secchi disk depth of 0.5 m or less (higher turbidity) and water temperature of 25 degrees Celsius (°C) or lower. The work of Bever et al. (2016), modified by RMA (2021) to incorporate temperature, suggests a more complicated formula that incorporates current speed, water temperature, salinity, and turbidity. The Bever et al. criteria were derived from correlation with smelt catch.

The current study does not consider multi-factor metrics. Work from 2020 to 2022 with the Delta Coordination Group suggested the calculations become speculative in a planning context because maximum water temperature and turbidity are highly driven by local air temperature and wind respectively. These are difficult-to-forecast atmospheric inputs that are poorly related to either flow management or gate operations; their effects would be poorly represented by anecdotal annual examples. A second issue with these metrics is thresholding and quantification of acreage. The modified Bever et al. (2016) metric produces many intermediate scores, in part because favorable current speed and temperature offset high salinity. The authors are unaware of methods that resolve the resulting ambiguities in habitat quantification when this type of substitutability arises. Because of these difficulties, and because the SMSCG action's main effect is on salinity, LSZ habitat is the major focus of study here.



Esri, NASA, NGA, USGS, County of Sacramento, California State Parks, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, Bureau of Land Management, EPA, NPS

The category "All" represents the spatial union of areas in the legal Delta, Suisun Marsh and Suisun Bay.

Figure 6C-2. Regions Used to Aggregate Low-Salinity Zone and Habitat Suitability Indexes

6C.5 Key Results

The SMSCG effectively freshen the marsh area. Figures 6C-3 through 6C-5 show change in modeled salinity averaged over a 14-day period in 2010, 2016, and 2020 during August, September, and October. Tidal operations freshen the marsh with little change along the mainstem of the estuary and Suisun Bay and slight change along a thin margin of Suisun Bay.

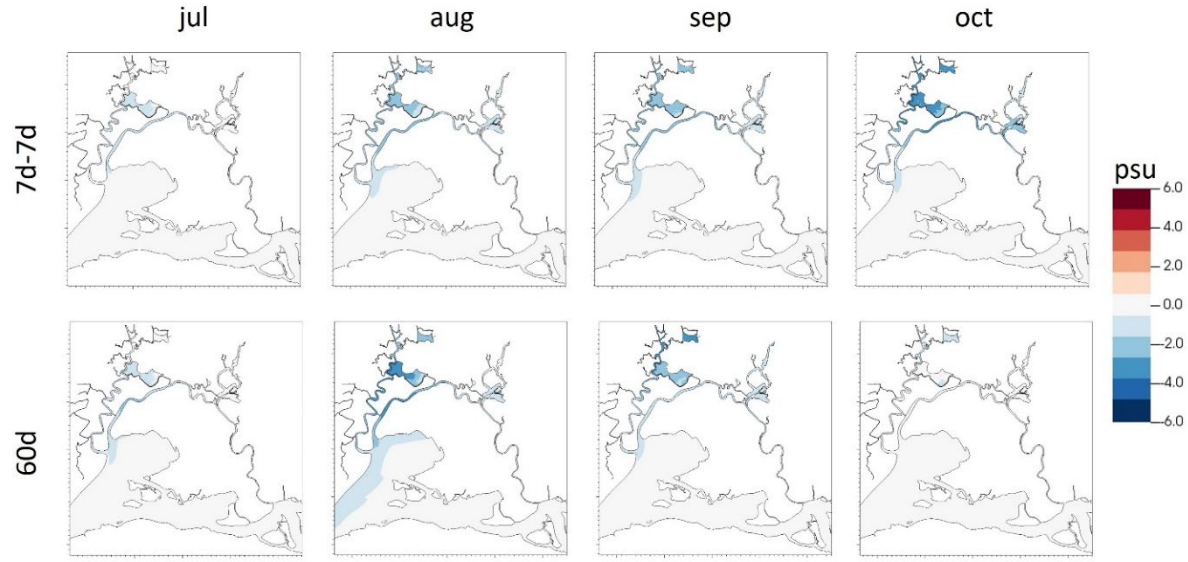


Figure 6C-3. 2010 Salinity Difference Maps Showing the Influence of the Operation Relative to No Operation

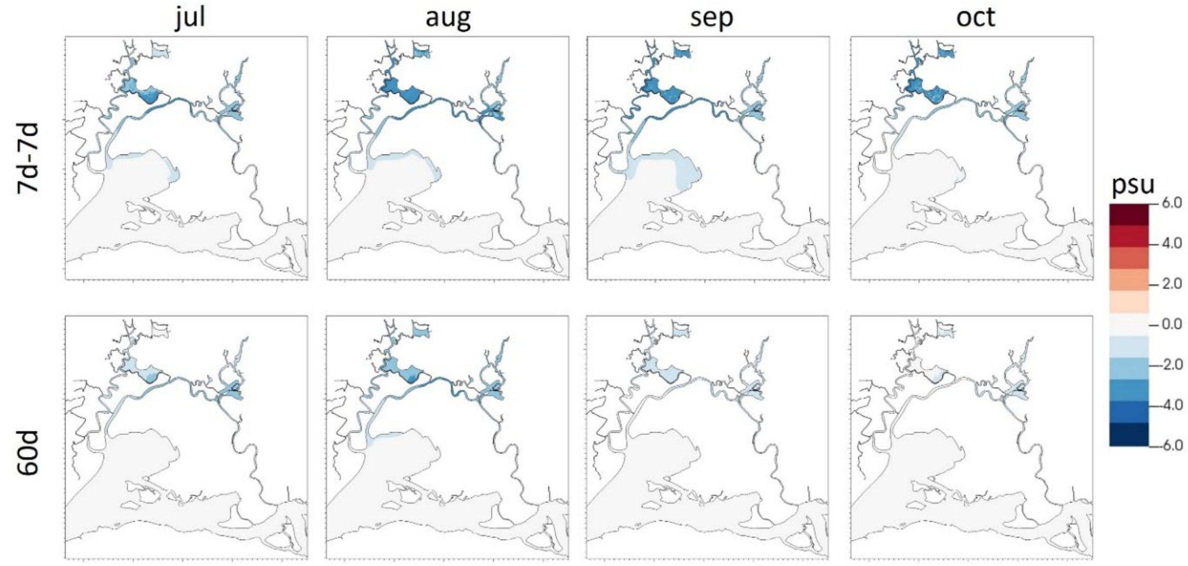


Figure 6C-4. 2016 Salinity Difference Maps Showing the Influence of the Operation Relative to No Operation

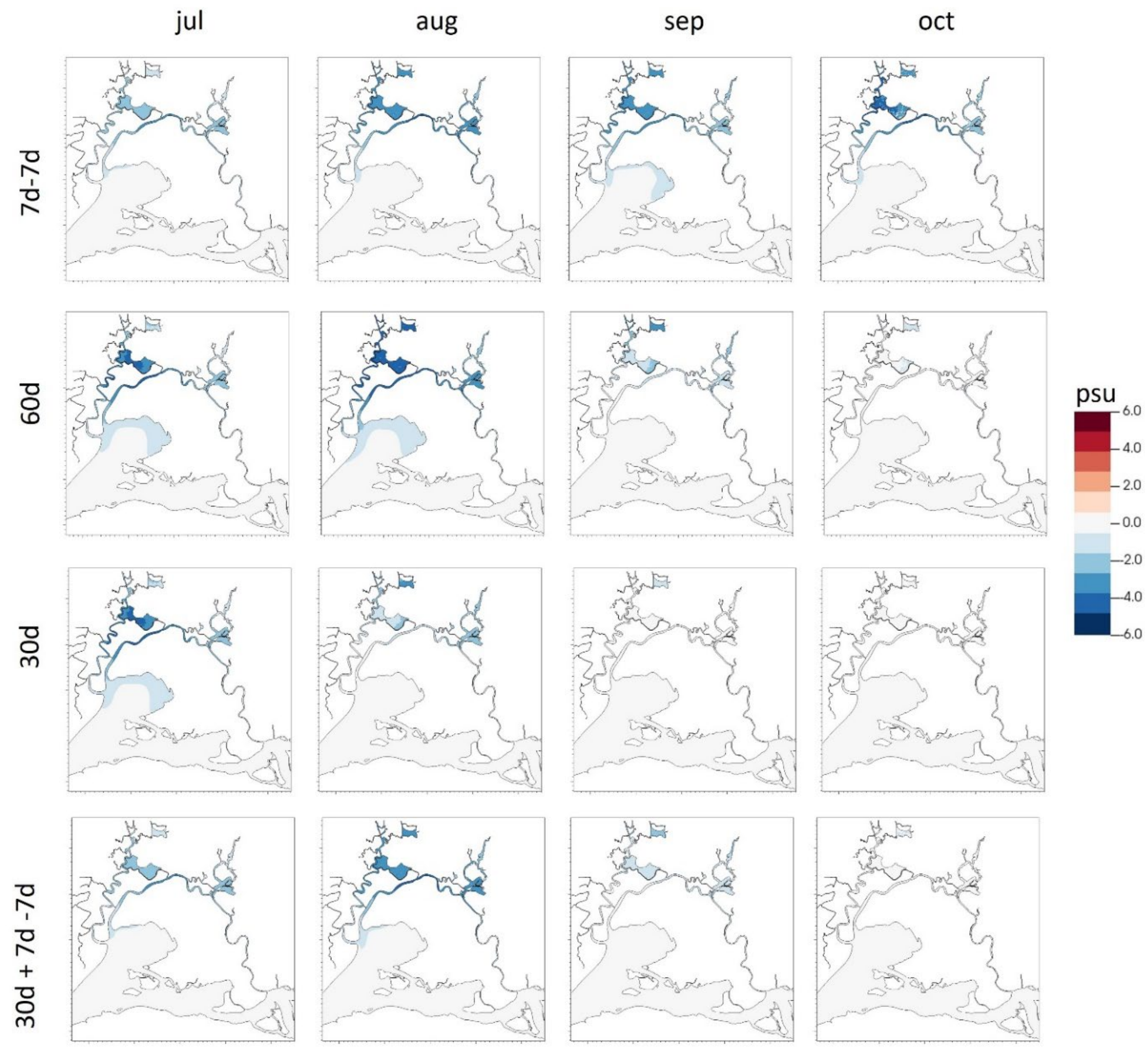


Figure 6C-5. 2020 Salinity Difference Maps Showing the Influence of the Operation Relative to No Operation

Figures 6C-6 through 6C-8 show time series of tidally filtered salinity at Collinsville (CLL), Beldon's Landing (BDL), National Steel (NSL), and Jersey Point (JER) for each of the year types and operational patterns considered in the study. Tidal operations were initiated based either on a predetermined date or on a triggering salinity condition of 4 psu, in either case focusing on conditions at BDL or on likely habitat improvement.

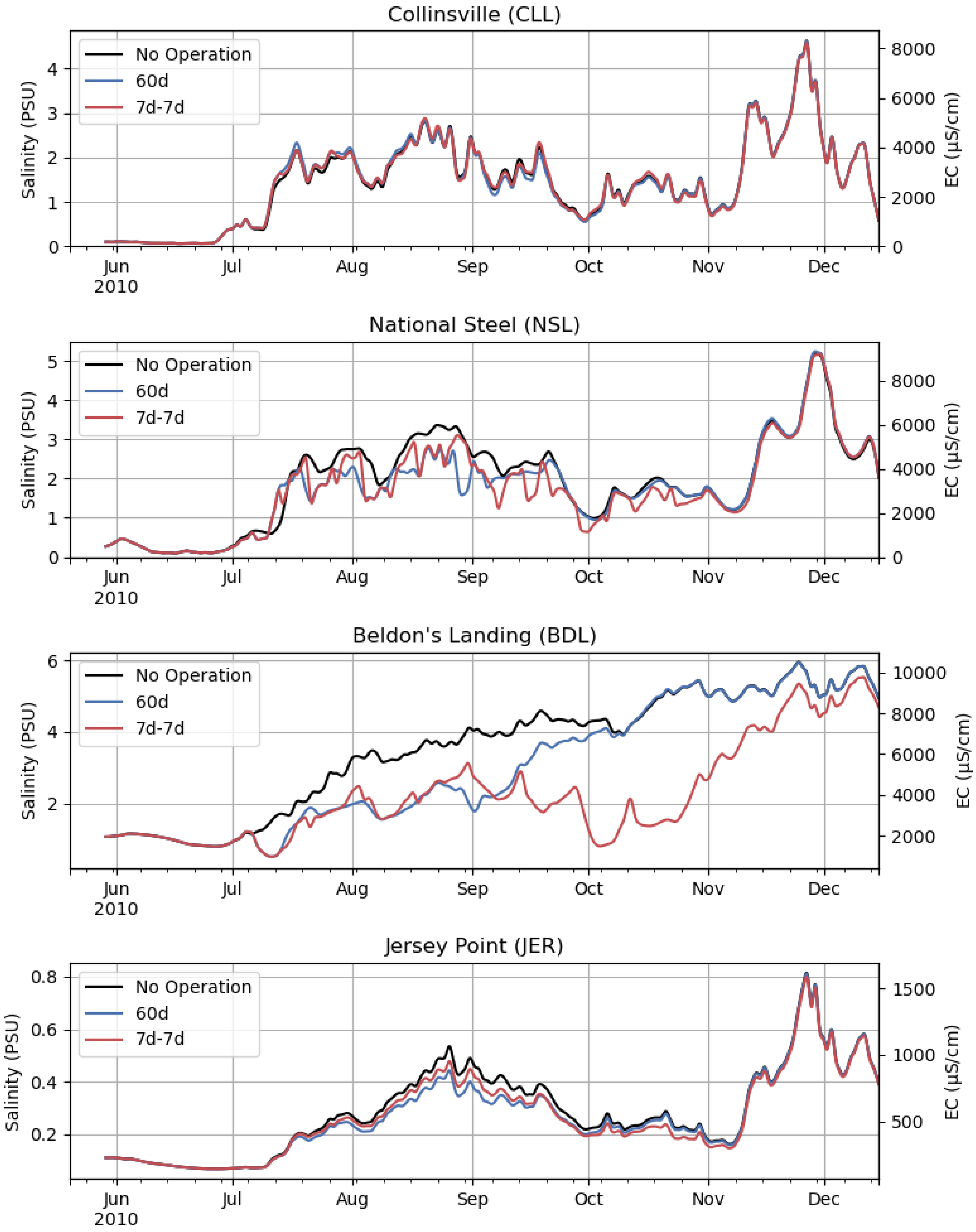


Figure 6C-6. Time Series of Salinity at Four Marsh and Compliance Locations in 2010

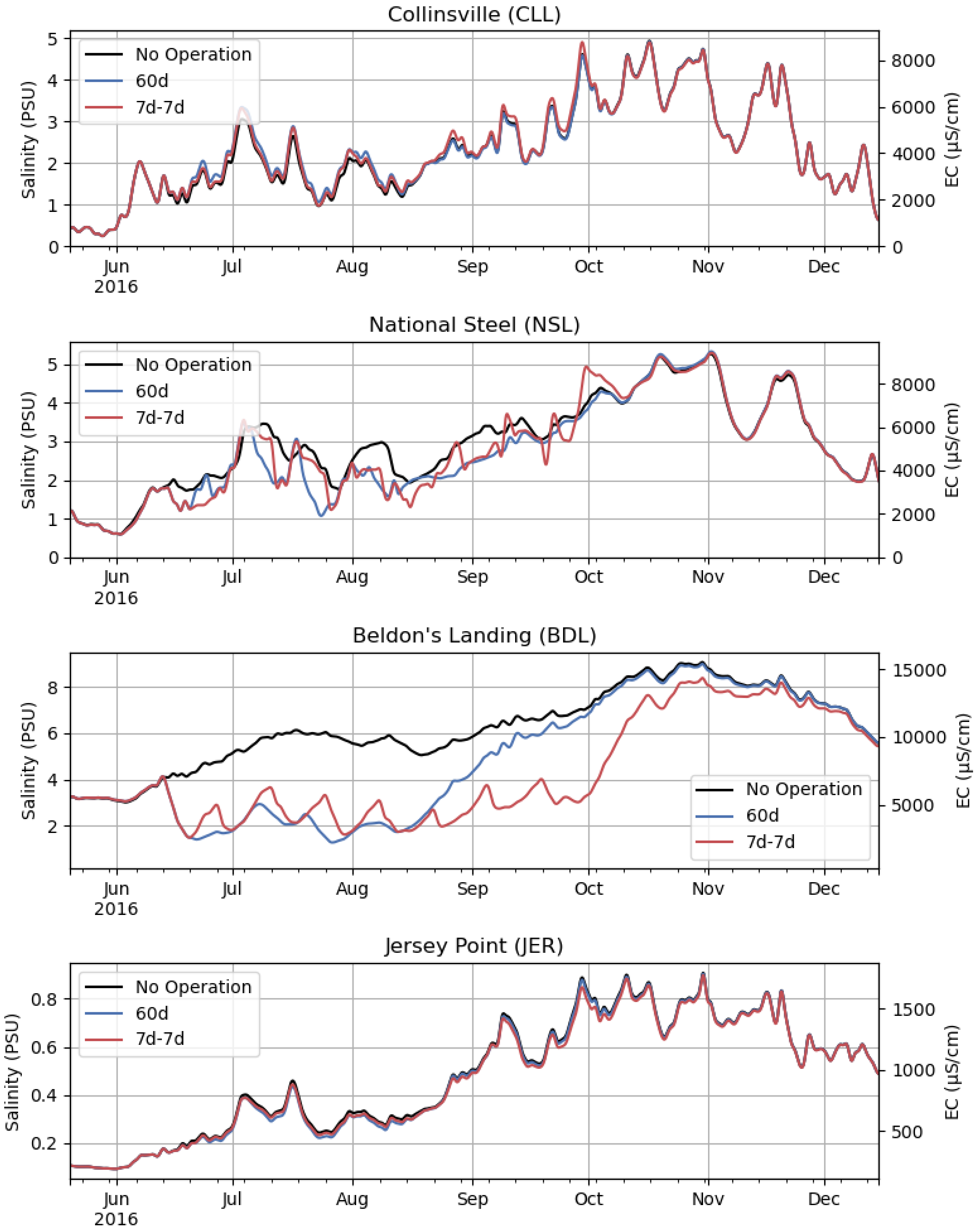


Figure 6C-7. Time Series of Salinity at Four Marsh and Compliance Locations in 2016

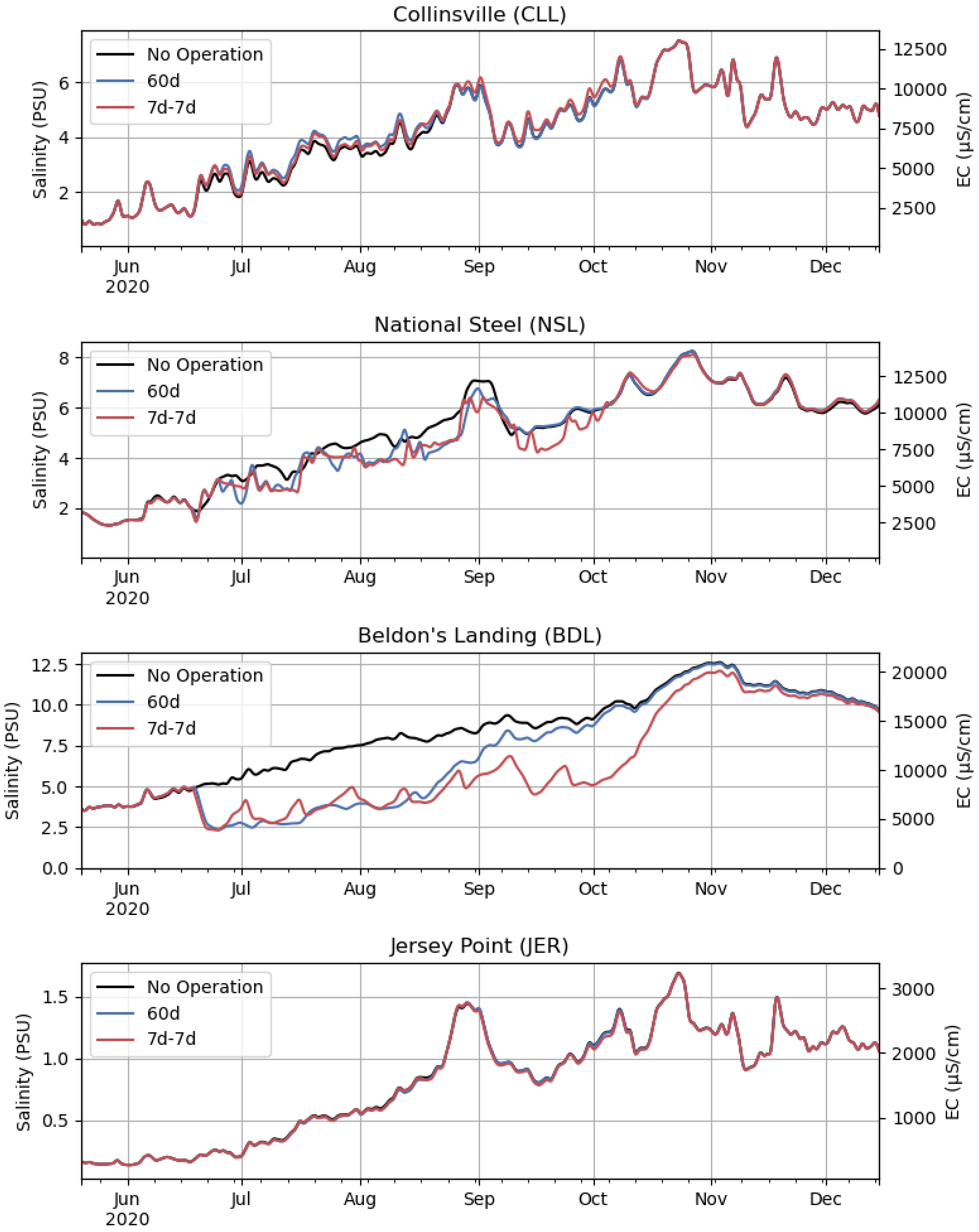


Figure 6C-8. Time Series of Salinity at Four Marsh and Compliance Locations in 2020

Figures 6C-9 through 6C-11 show time series of LSZ within the regions shown in Figure 6C-2 for each of the representative years. LSZ acreage is the main habitat statistic reported here. In each case the top plot is Suisun Marsh. SMSCG freshens the Suisun Marsh and has the potential to improve marsh habitat under suitable conditions. Those conditions determining efficacy are dominated by two bracketing considerations:

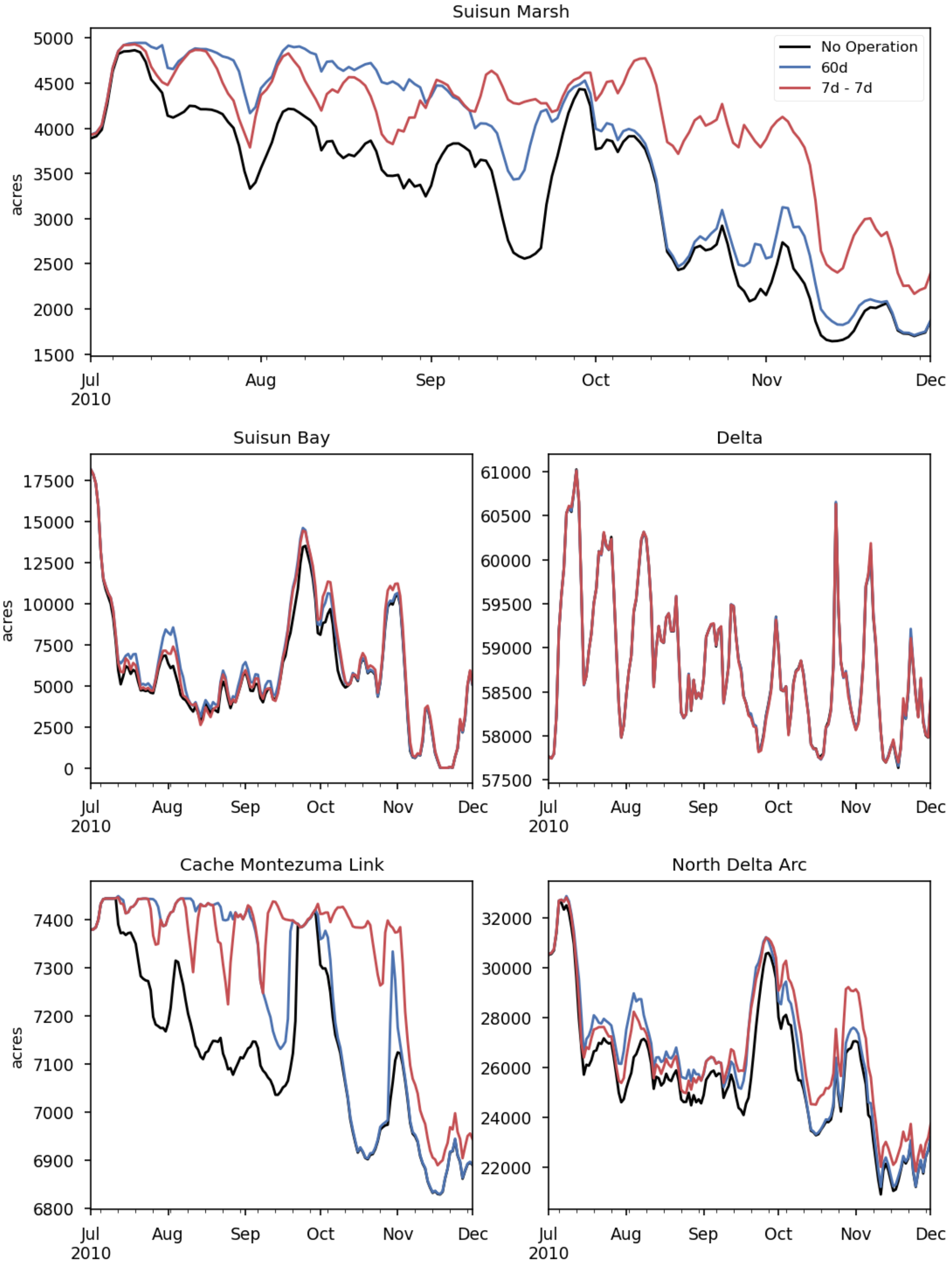
- Ambient salinity in Suisun Bay and upstream must be high enough to pressure the system towards conditions requiring improvement. In some wetter year types or in the early season when external considerations such as the 450 µS/cm D-1641 agricultural standards or Fall X2 standard freshens the surrounding region, there is less potential to increase habitat. For instance, low efficacy is seen in 2017 for this reason.
- Salinity at Collinsville may also be so high that the action of the gate is no longer beneficial. The water that is injected into the marsh by Suisun gate operations must itself be under the LSZ threshold and ideally should be obviously fresh compared to water in the marsh. This consideration limited efficacy in late summer in 2020. Compare, for instance, the forays above 6 psu at Collinsville in September–October 2020 in Figure 6C-8 and the dips in acreage in Figure 6C-11.

As is evident in Figures 6C-9 through 6C-11, scenarios based on a seven-day alternation between tidal operations and gate openings are often effective in sustaining LSZ habitat longer in summer by lowering the fraction of time when the gates are operating and thus the rate of compensating flow. The benefit of the alternating operations is greater in drier water years because salinity encroaches earlier.

Besides Suisun Marsh, several regional aggregations of LSZ are shown in Figures 6C-9 through 6C-11. Apparent improvement in other regions is due to their overlap with the marsh. The main reason for presenting the results in this way is to provide perspective relevant to past work in fish ecology. No appreciable habitat or connectivity is produced upstream of Collinsville.

LSZ habitat improvement is modest in Grizzly Bay and occurs near the margin of the Bay. Prior results by AnchorQEA (2019) suggested freshening of 1–2 psu over a substantial acreage in Grizzly Bay during a 2018 operational experiment. Neither SCHISM nor observation supports the idea that tidal operation produce a benefit of that magnitude or a substantial increase in acreage of LSZ habitat, although improvement does occur at the margins of the bay.

The influence of the gates can also be gleaned from field data. Figure 6C-12 shows tidally averaged salinity as a scatter between Collinsville and the Grizzly Bay or Hunter Cut stations. The latter two stations lie only 4.5 km apart, but Grizzly Bay station is in the bay and Hunter Cut is inside the marsh on Montezuma Slough. The points have been tidally averaged, resampled at 12-hour spacing and filtered to eliminate dynamic periods with large flow transitions or Delta filling extremes. Black dots are used to represent transitional days from tidal operations to open. The scatter between Grizzly Bay and Collinsville is tight and does not change appreciably depending on whether SMSCG is tidally operating or open. By contrast, the relationship between Collinsville and Hunter Cut experiences a large shift between two distinct regimes based on gate operations.



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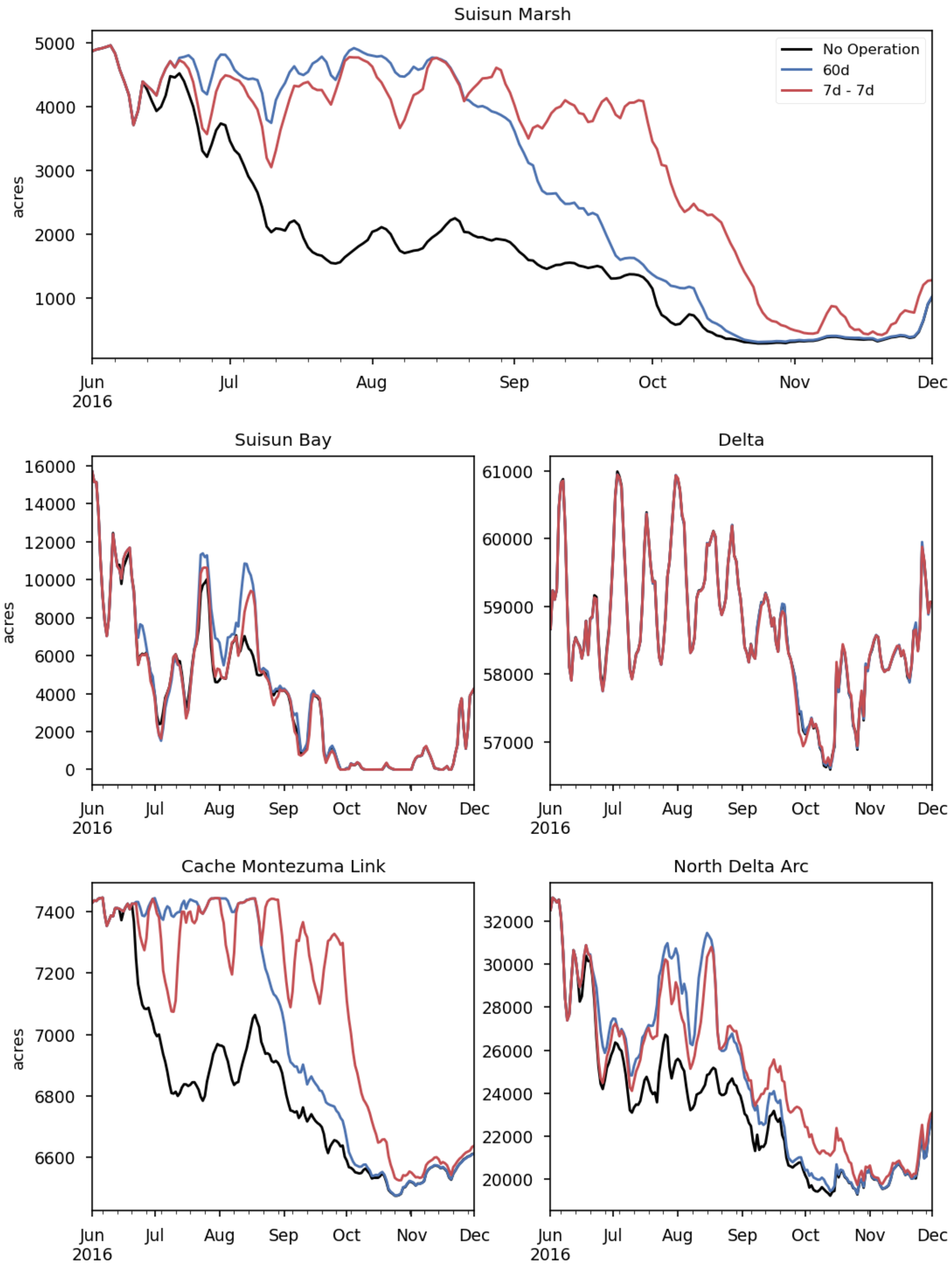


Figure 6C-10. Habitat Acreage Time Series in 2016 under the Study Alternatives for that Year

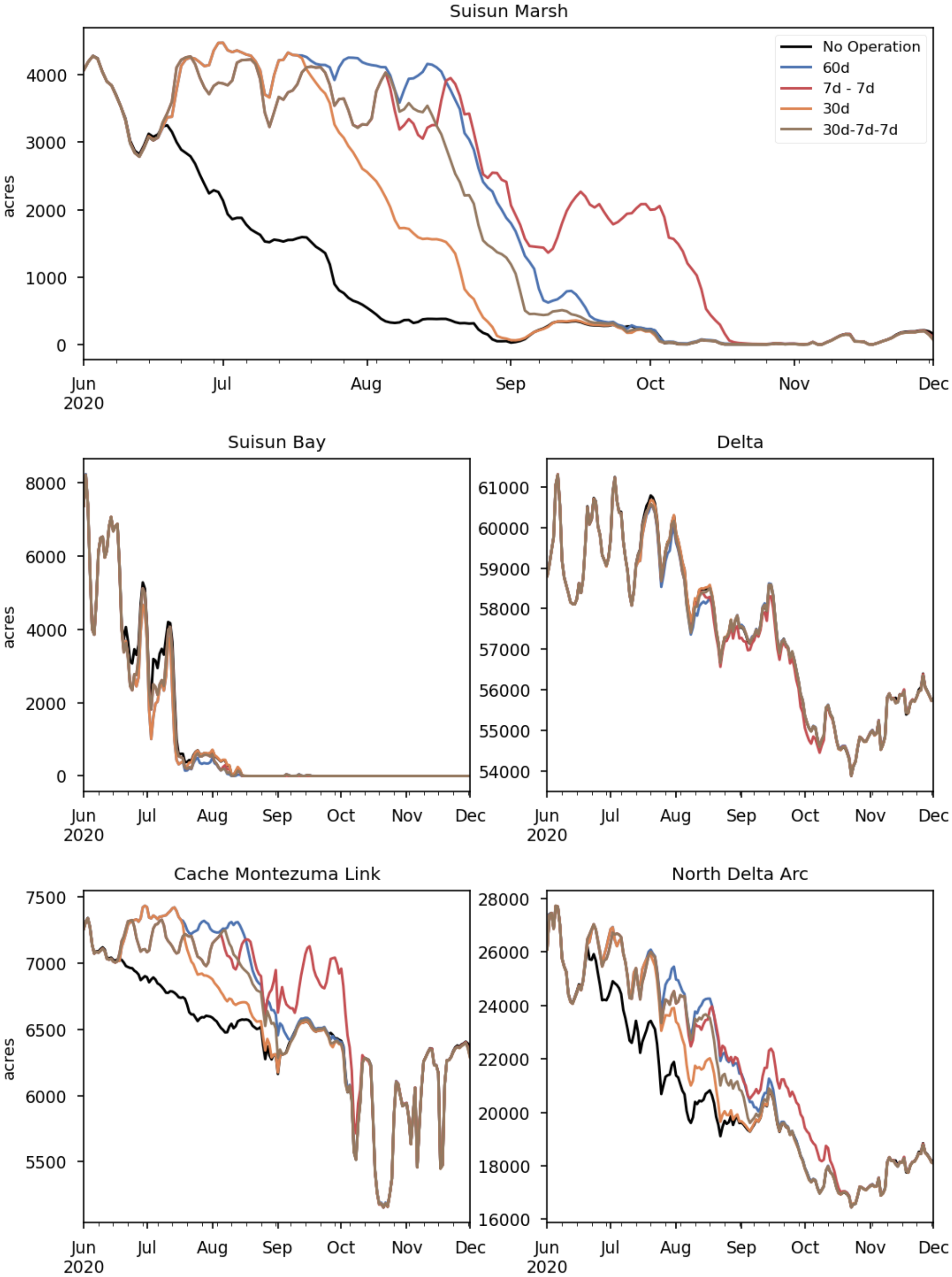
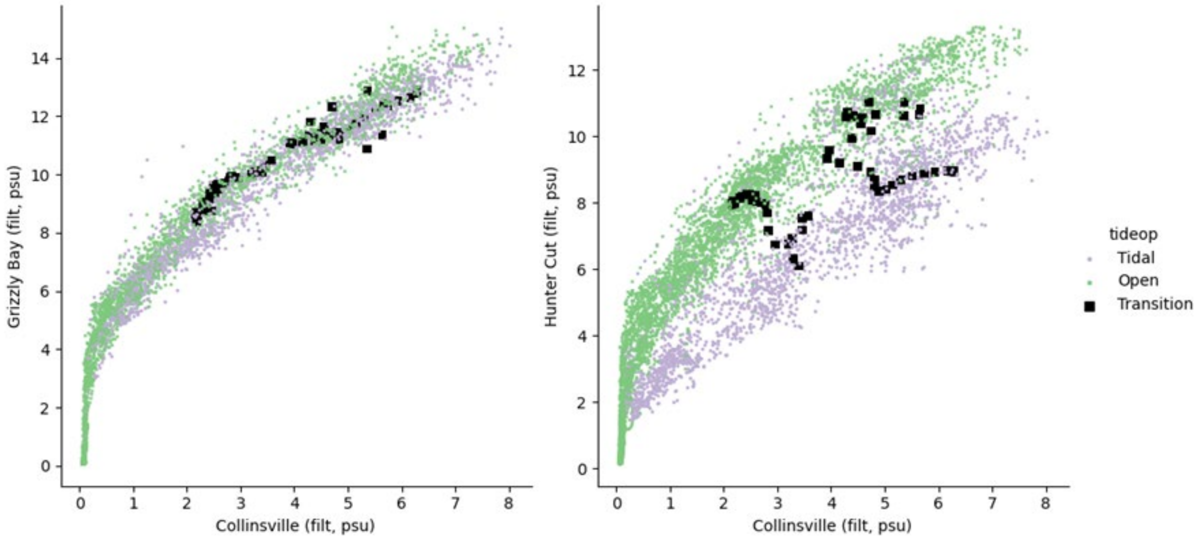


Figure 6C-11. Habitat Acreage Time Series in 2020 under the Study Alternatives for that Year



Black points are transitional weeks when SMSCG operations changed from tidal to open.

Figure 6C-12. Scatter in Observed Data Showing the Relationship between Collinsville and Grizzly Bay in Non-dynamic Periods

The black dots in Figure 6C-12 are also indicative of the time scale of transition between the two gate regimes at Hunter Cut. There are two transitions of 14 days, starting three days before the cessation of tidal operations on September 4, 2018 and October 5, 2020 and extending 11 days after opening the gates. The dots are resampled at a spacing of 12 hours. The transition is very direct and the bulk of the changeover takes five to seven days in both examples.

6C.6 Conclusions

The study affirms the effectiveness of the SMSCG in reducing salinity and increasing LSZ habitat under suitable conditions. In absolute terms, the water cost of operating the gate is lower in Below Normal and Dry water year types and the LSZ habitat benefit is greater. These considerations must be balanced against the relative scarcity of water resources in those years.

In numerous scenarios, an alternating seven-day tidal, seven-day open operation achieved nearly the same habitat acreage at a 50 percent lower rate of operational days and compensating flow. In principle this would allow a longer period of habitat creation given a fixed budget of days (30 or 60 days). This extension is particularly useful in Dry and Below Normal year types because the season starts earlier. An alternating operation also draws out the otherwise brief period of benefit under a 30-day Dry year action.

6C.7 References

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