LEVERAGING **WETLANDS** FOR A BETTER CLIMATE FUTURE

Incorporating Blue Carbon into California's Climate Planning

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PHOTO: WETLANDS AT CORTE MADERA SHORELINE EDGE • IMAGERY BY PETE KAUHANEN, SFEI

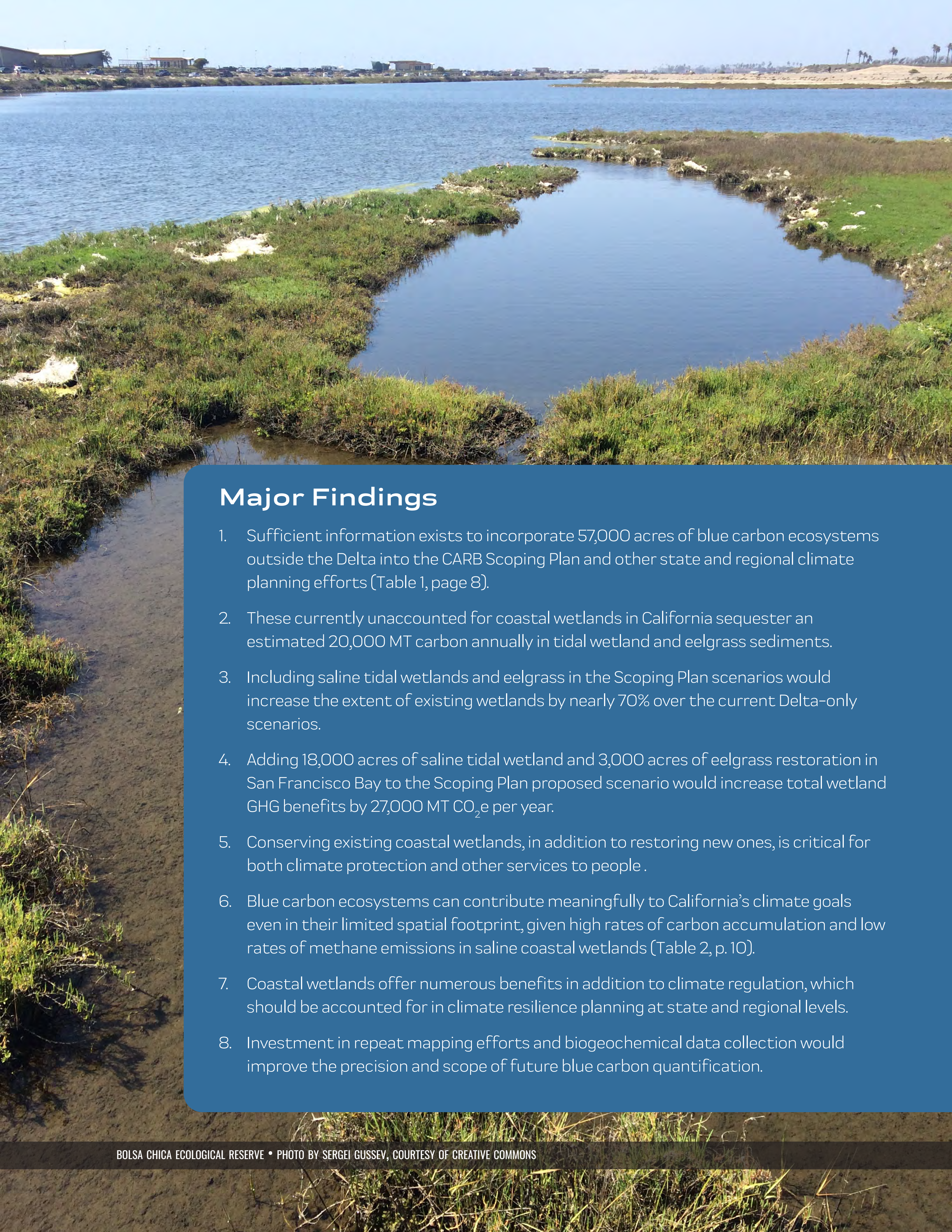
INTRODUCTION

Managing Natural and Working Lands (NWL) to enhance carbon sinks and limit greenhouse gas (GHG) emissions is a key component of California's ambitious strategy to achieve net carbon neutrality by 2045. The California Air Resources Board (CARB) Climate Change Scoping Plan includes 7 NWL categories in its GHG emission reduction scenarios, one of which is wetlands. Coastal wetlands in California are a high-leverage NWL type for GHG management relative to their small spatial footprint. These ecosystems have high rates of carbon sequestration and can accumulate large stocks of carbon, due to high productivity, efficient sediment trapping, and low decomposition rates (Chmura et al. 2003, Mcleod et al. 2011). In the absence of management interventions focused on wetland conservation, however, conversion of coastal wetlands to other land uses such as agriculture, grazing, development, impounded wetlands, or subtidal or upland habitat can halt or reverse carbon sequestration, and can shift these ecosystems from long-term GHG sinks to large GHG sources (Hatala et al. 2012, Tan et al. 2019). Filling of wetlands for infrastructure and development was a common practice throughout the early 20th century (Goals Project 1999), dramatically reducing the state's coastal wetland area and associated carbon sink.

The wetlands category in the most recent (May 2022) Scoping Plan draft is limited to wetlands and agricultural lands in Suisun Marsh and the Sacramento-San Joaquin Delta (the Delta). This represents only a portion of California's coastal wetlands, but is an important step forward in the state's climate planning, given the potential for high GHG benefits from wetland restoration in the Delta (Figure A1). The proposed scenario in the May 2022 draft Scoping Plan includes 60,000 acres of wetland restoration in the Delta, with a cumulative GHG benefit of 0.43 million metric tons (MMT) carbon dioxide equivalent (CO_2e) per year. As reported in the draft Scoping Plan, this wetland-specific reduction in GHG emissions is greater than the modeled benefits of scenario management interventions in forestland/shrubland/grassland and croplands combined.

The 2022 draft Scoping Plan identifies "blue carbon" as an 8th NWL type, which the Scoping Plan states may be included in future scenarios if sufficient methods and data become available for robust scenario analyses. This blue carbon category would expand on the wetlands in the Delta to add coastal wetlands elsewhere in the state, including tidally influenced estuarine wetlands and eelgrass meadows in San Francisco Bay (SF Bay) and the rest of the state. Outside of the Delta, California's blue carbon ecosystems cover over 57,000 acres, including roughly 43,000 acres of tidal marsh and tidal scrub/shrub wetlands and 13,000 acres of eelgrass. As in the Delta, these systems offer opportunities for efficient carbon sequestration and high GHG benefits, with the potential for long-term carbon storage in a durable carbon reservoir. In addition to their value for climate change mitigation, wetlands provide a variety of important co-benefits for water quality, flood risk management, wildlife habitat, and cultural uses.

To support broader inclusion of coastal wetlands in future Scoping Plan scenarios, this report provides an overview of available coastal wetland datasets, methods, and scenario considerations. The following sections of the report cover wetland mapping, GHG and carbon accumulation data, considerations regarding wetland vulnerability and resilience to sea-level rise, and specific suggestions for coastal wetlands scenarios. Together, this information is intended to (a) enable CARB to move forward with the 8th "blue carbon" NWL type given existing information and available methods, and (b) highlight key focus areas where additional science investment would meaningfully improve existing scenario analysis methods, offering a roadmap to broader inclusion of California's coastal wetlands in future NWL scenarios.



Major Findings

1. Sufficient information exists to incorporate 57,000 acres of blue carbon ecosystems outside the Delta into the CARB Scoping Plan and other state and regional climate planning efforts (Table 1, page 8).
2. These currently unaccounted for coastal wetlands in California sequester an estimated 20,000 MT carbon annually in tidal wetland and eelgrass sediments.
3. Including saline tidal wetlands and eelgrass in the Scoping Plan scenarios would increase the extent of existing wetlands by nearly 70% over the current Delta-only scenarios.
4. Adding 18,000 acres of saline tidal wetland and 3,000 acres of eelgrass restoration in San Francisco Bay to the Scoping Plan proposed scenario would increase total wetland GHG benefits by 27,000 MT CO_2e per year.
5. Conserving existing coastal wetlands, in addition to restoring new ones, is critical for both climate protection and other services to people .
6. Blue carbon ecosystems can contribute meaningfully to California's climate goals even in their limited spatial footprint, given high rates of carbon accumulation and low rates of methane emissions in saline coastal wetlands (Table 2, p. 10).
7. Coastal wetlands offer numerous benefits in addition to climate regulation, which should be accounted for in climate resilience planning at state and regional levels.
8. Investment in repeat mapping efforts and biogeochemical data collection would improve the precision and scope of future blue carbon quantification.

BOLSA CHICA ECOLOGICAL RESERVE • PHOTO BY SERGEI GUSSEV, COURTESY OF CREATIVE COMMONS

WETLAND MAPPING

Quantifying GHG emissions and removals from California's blue carbon ecosystems requires reliable mapping resources to determine the acreages of coastal wetland types in the state's bays and estuaries. Mapping is needed for the Climate Change Scoping Plan to determine current conditions, background rates of change, and progress over time toward scenario targets. Mapped wetland acreages can then be paired with best-available emission factors or more complex models to quantify current and future-scenario rates of carbon accumulation and GHG emissions. These data must be spatially explicit because rates of carbon accumulation and GHG emissions from wetlands depend on the specific wetland type and region. Consistent mapping over time is required to detect change in wetland extents and determine changes in GHG emissions.

A challenge for statewide blue carbon analysis is that no single dataset currently exists that offers statewide coverage with both a high level of detail/accuracy and the consistent re-mapping needed to detect change over time. Instead, a set of statewide and regional mapping datasets exists for California, with varying levels of detail in wetland type classification, spatial resolution, and ability to track change over time. This section provides an overview of how these existing mapping resources can be knit together to quantify current extents and rates of change in the area of California's blue carbon ecosystems.

Guide to mapping resources

Six statewide or regional mapping datasets are recommended for use with best-available emission factors or biogeochemical models to quantify blue carbon stocks and GHG emissions statewide. Together, these datasets offer statewide coverage of saline wetland and eelgrass extents, mapped acreages of brackish wetlands in Suisun Marsh, and additional wetland (and former wetland) types in the Delta where wetland restoration can sequester carbon and reduce baseline GHG emissions. Each of these datasets is briefly described below and in Appendix B.

- **C-CAP NOAA's Coastal Change Analysis Program (C-CAP) wetland potential layer** is a national wetland mapping product that uses existing wetland data from products such as National Wetlands Inventory, National Hydrography Dataset, Soil Survey Geographic Database, National Elevation Dataset, and Landsat imagery, along with modeling methods to determine the likelihood of an area to be a wetland. C-CAP is updated every five years based on updates to its source data products, which makes it the best statewide dataset for assessing change in coastal wetland habitats at the state level. C-CAP can be downloaded from NOAA at https://coast.noaa.gov/digitalcoast/data/ccapwetland.html

  Note that C-CAP does not include eelgrass as a unique category. Other local eelgrass datasets will be needed to supplement C-CAP (see description of the SF Bay Eelgrass Inventory below).

- **CARI The California Aquatic Resources Inventory (CARI)** is a statewide wetland mapping product based on the National Wetlands Inventory (NWI), National Hydrography Dataset (NHD), county aquatic resources surveys, and regional datasets. While not updated as frequently or comprehensively as C-CAP, CARI provides a finer level of detail in terms of wetland habitat mapping as it draws from detailed state-specific resources and mapping products. Version 0.3 of CARI is currently available through the San Francisco Estuary Institute data center (https://www.sfei.org/

sfeidata.htm). Version 0.3 was released in May 2016, and an updated version of CARI (version 1.0) will be released to the public in July 2022. The new version of CARI represents a significant advance over version 0.3, with the inclusion of the Delta Aquatic Resources Inventory, updated versions of the NHD and NWI, and eelgrass and coastal lagoon data.

Note that eelgrass data do not include SF Bay. For eelgrass extents, see SF Bay Eelgrass Inventory below.

- **BAARI The Bay Area Aquatic Resources Inventory (BAARI)** provides regional mapping information for SF Bay and Suisun Marsh. This dataset is nested within CARI, and incorporates additional county and watershed level mapping to provide finer-scale wetland delineation. BAARI includes a greater number of wetland categories than CARI, all of which have been crosswalked to the CARI wetland types. Version 2.1 of BAARI is available at https://www.sfei.org/data/baari-version-21-gis-data. An effort is underway to develop mapping protocols for BAARI that would enable repeat mapping for change detection. If this repeat mapping effort is funded, it will enable changes in wetland area to be tracked across SF Bay and Suisun Marsh at a finer level of detail than with C-CAP alone. For both the Scoping Plan GHG inventory, BAARI could replace C-CAP in SF Bay and Suisun Marsh as the means for tracking change over time.
- **LSPT The Landscape Scenario Planning Tool (LSPT)** incorporates detailed habitat type maps for the Sacramento-San Joaquin Delta and Suisun Marsh. Prepared by the San Francisco Estuary Institute, these habitat type maps are available in the LSPT for 2003 and 2015 for the Delta and 2004 and 2016 for Suisun Marsh. These layers can be downloaded as part of the LSPT package, which can be accessed at https://www.sfei.org/projects/landscape-scenario-planning-tool. In addition to mapping from the 2000s, this data package includes early-1800s habitat type mapping for the Delta and Suisun Marsh, and historical ecology data for many other coastal regions is also available on the SFEI data center page (https://www.sfei.org/sfeidata.htm). These historical maps can be used to track historical changes in wetland extents when evaluating restoration opportunities and priorities.
- **DARI The Delta Aquatic Resources Inventory (DARI)** provides regional mapping information for the Sacramento-San Joaquin Delta. Like BAARI, this dataset is nested within CARI and provides finer-scale wetland delineation and a greater number of wetland categories, all crosswalked to CARI wetland types. For wetlands in the Delta, DARI offers an alternative to the LSPT maps that offers greater compatibility (though lesser detail). Version 1.1 of DARI is available at https://www.sfei.org/data/delta-aquatic-resource-inventory-dari#sthash.hhizewQq.dpbs
- **San Francisco Bay Eelgrass Inventory** Comprehensive surveys of the eelgrass distribution in SF Bay were completed in 2003, 2009, and 2014 (Merkel & Associates 2015). Surveys were based on acoustic and aerial surveys combined with ground truthing, and can be used to track change in eelgrass extent over time. Comparisons between 2003, 2009, and 2014 show high variability in the Bay's eelgrass distribution, with mapped eelgrass extents measuring 2,628 acres in 2003, 3,707 acres in 2009, and 2,790 acres in 2014. In addition to repeated mapping, the report includes a predictive model for eelgrass distribution that suggests SF Bay has the potential to support greater eelgrass extents than currently exist.

Used together, the resources described above provide sufficient statewide coverage to determine the existing acreage of coastal wetland types (Fig. 1). CARI can be combined with more detailed regional mapping for the San Francisco Estuary, including BAARI, DARI, and/or the LSPT datasets, as well as local information on restoration acreages (e.g., Delta-specific restoration information from the Delta Stewardship council, DSC). Each of these mapping products is based on the best-available data for a given mapping region from a variety of data sources, offering a high level of detail and combined statewide coverage. A summary of coastal wetland acreages from these mapping resources is shown in Table 1. As shown in this example, adding statewide saline wetlands and eelgrass to the Delta wetlands included in the May 2022 Scoping Plan draft would increase the extent of existing wetlands evaluated in Scoping Plan NWL scenarios by 57,000 acres, or nearly 70%.

To project coastal wetland GHG emissions to 2045, it is necessary to apply background rates of change to existing wetland extents. The combination of datasets shown in Figure 1 and Table 1 offers the best available information on existing wetland extents, but these mapping products are not designed to track changes in wetland area over time. Repeating mapping with consistent underlying datasets and standard crosswalks for wetland categories is needed to quantify transitions between wetlands and other habitat types over the 2001-2014 time period (the period used to define baseline land management for the Scoping Plan reference scenario). For tidal wetlands outside the Delta, C-CAP is the best available dataset to quantify background rates of change for the reference scenario. C-CAP provides consistent repeat mapping every ~5 years since 1975, with mapping data available for 2001 and 2016 (Appendix B). An example of how C-CAP can be combined with CARI to track change over time in wetland extents can be found in the report produced by Silvestrum Climate Associates, *Coastal Wetland Greenhouse Gas Inventory for the San Francisco Bay Estuary* (Beers and Crooks 2022).

Whereas C-CAP can be used to track change in tidal wetlands statewide, no comparable dataset exists for seagrass. *Zostera marina* (eelgrass) is the dominant seagrass species in California (Gillett et al. 2018), and while a variety of other species are also present, eelgrass has been the subject of most monitoring, restoration, and carbon stock/sequestration research on the West Coast. For this reason, eelgrass is the only seagrass category covered in this report's mapping and emission factor tables. Eelgrass is mapped by C-CAP within the Estuarine Aquatic Bed class, but this class does not distinguish between eelgrass, algal mats and other aquatic vegetation, making C-CAP a poor resource for tracking change over time in eelgrass extents. No other statewide datasets exist to track change over time in California's eelgrass, but regional surveys are available for a limited set of time points, and additional data may be available in the future through regional monitoring efforts (Bernstein et al. 2011, Merkel & Associates 2016, Gilkerson and Merkel 2019). Over 80% of California's eelgrass is estimated to occur within five bays in California, Humboldt Bay, SF Bay, San Diego Bay, Tomales Bay, and Mission Bay (NOAA Fisheries 2014), so a combination of comprehensive regional monitoring covering these locations would offer relatively good statewide coverage for the purposes of change detection.

To use these mapping resources to develop NWL scenarios, relevant wetland types from each mapping dataset must be crosswalked to a common set of wetland categories that correspond to carbon accumulation rates and GHG emission factors. Appendix A provides a crosswalk from each of the recommended datasets to key wetland types for blue carbon analysis. To generate this crosswalk, all land cover classes from the wetland mapping resources were evaluated for characteristics such as tidal influence, salinity, presence of vegetation, and vegetation type. Habitat types that were unvegetated were not considered for inclusion because they lack significant carbon capture potential, and forested wetlands were excluded, as they are assumed to be included within the "Forest and other lands" NWL category. Agricultural lands and nontidal wetlands were included only for the Delta and Suisun Marsh, where placing managed wetlands on subsiding agricultural lands (that historically were tidal marsh) is a key wetland restoration strategy and sufficient data are available for GHG flux and carbon accumulation/loss rates.

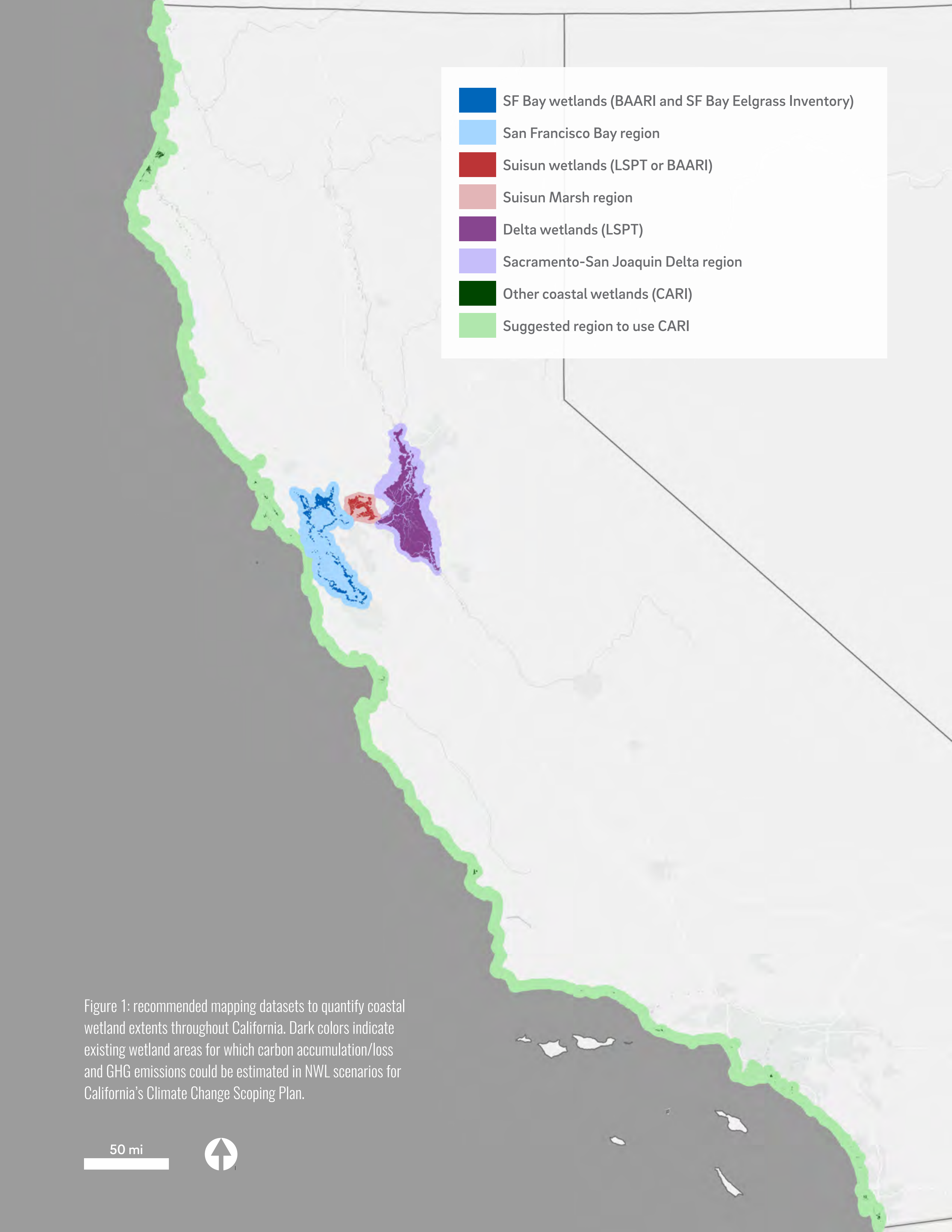


Figure 1: recommended mapping datasets to quantify coastal wetland extents throughout California. Dark colors indicate existing wetland areas for which carbon accumulation/loss and GHG emissions could be estimated in NWL scenarios for California's Climate Change Scoping Plan.

For each mapping region (Fig. 1), total area of each NWL wetland type is summarized in Table 1. This table reports total area in the mid-2010s.

Table 1. Coastal wetland extents within California mapping regions

Region*	Recommended resource for existing area	Recommended resources for change quantification	Scoping Plan NWL coastal wetland type	Existing area (acres)	Included in May 2022 Scoping Plan draft?
Delta	LSPT	LSPT	Drained wetlands used for agriculture	305,720	Yes
Delta	LSPT	LSPT	Rice	3,860	Yes
Delta	LSPT	LSPT	Freshwater tidal wetlands	9,319	Yes
Delta	DSC data	DSC data	Rewetted or restored wetlands (impounded marshes)	1,700	Yes
Delta	LSPT	LSPT	Seasonal wetlands (organic and mineral soils)	16,721	Yes
Suisun Marsh	LSPT or BAARI	LSPT or BAARI	Brackish tidal wetlands	9,169	Yes
Suisun Marsh	LSPT or BAARI	LSPT or BAARI	Brackish managed seasonal wetlands (organic and mineral soils)	43,159	Yes
SF Bay	BAARI	C-CAP or BAARI	Saline tidal wetlands	29,276	No
SF Bay	SF Bay Eelgrass Inventory	SF Bay Eelgrass Inventory	Eelgrass	2,790	No
Statewide (excluding SF Estuary)	CARI	C-CAP	Saline tidal wetlands	15,350	No
Statewide (excluding SF Estuary)	CARI	--	Eelgrass	9,791	No

Note: If future consistent remapping is funded for BAARI, it is recommended for future wetland extent estimates in SF Bay and Suisun Marsh.

*Acreage values for the Delta and Suisun Marsh from HydroFocus, Inc., et al. (2022)

GREENHOUSE GAS AND CARBON ACCUMULATION DATA

Carbon accumulation and GHG emission factors can be applied to wetland acreages to evaluate carbon sequestration and GHG emissions in reference and alternative Scoping Plan scenarios. This emission factor approach is compatible with IPCC guidelines for national GHG inventories (IPCC 2006, IPCC 2014), and has been used by CARB in the current draft Scoping Plan update (released May 2022) to evaluate the effect of wetland restoration in the Delta on GHG emissions and soil carbon accumulation/loss.

Emission factors for coastal wetland carbon accumulation/loss and GHG emissions are based on a variety of primary data types. In areas undergoing rapid subsidence or accretion such as subsiding agricultural lands or subsidence reversal wetlands in the Delta, repeat elevation surveys and peat core samples can be used to track change over time in soil carbon stocks (Miller et al. 2008, Arias-Ortiz et al 2021). However, for most of the state's tidal wetlands and eelgrass beds, repeated core sampling is a less effective way to quantify carbon accumulation or loss. Changes in carbon stocks over annual or decadal timescales are often far lower than background variability between replicate cores (Chmura et al. 2003), and surficial samples may not reflect changes in the total carbon content of the entire sediment profile (Ward et al. 2021). Instead of repeat core sampling, radiometric dating of individual layers in a sediment profile offers a window into historical carbon accumulation and a robust means to infer carbon sequestration rates from single time-point samples (Drexler et al. 2009).

In addition to sediment core data, CO_2 and CH_4 flux measurements from eddy covariance towers or soil chambers can be used to infer rates of change in carbon stocks and estimate net annual rates of CO_2 and CH_4 emissions. Continuous flux measurements from eddy covariance towers integrate carbon uptake and emissions over a large spatial footprint (Baldocchi 2014), and can be used to evaluate both interannual and short-term variability in carbon uptake and loss rates. When flux data are used to estimate carbon accumulation or GHG budgets, calculations must account for other carbon outputs and inputs, such as lateral losses of dissolved or particulate carbon in tidal marsh systems (Arias-Ortiz et al. 2021) or biomass harvested from agricultural fields (Hemes et al. 2019).

Table 2 presents suggested carbon accumulation and GHG emission factors for California's coastal wetlands that correspond to mapped regions identified above in Figure 1. For the San Francisco Estuary, where 87% of the state's tidal marshes are located (Heady et al. 2018), region-specific emission factors have been derived from local sediment cores, GHG flux measurements, and biogeochemical models. These emission factors are consistent with values provided to the California Air Resources board for use in the Scoping Plan and NWL Inventory by Hydrofocus, Inc. and Silvestrum Climate Associates. For coastal wetlands elsewhere in California, generalized emission factors can be used until more locally specific numbers become available. Palustrine wetland values are provided for the Delta only, due to limited data elsewhere in California.

Due to data limitations, IPCC tier 1 values are used for tidal wetland carbon accumulation in regions of California outside the San Francisco Estuary. Specific emission factors for regions within CA would enable more precise scenario evaluation, given the high variability in coastal wetland carbon sequestration rates (Chmura et al. 2003). Biogeochemical data from coastal wetlands are available through the Coastal Carbon Research Coordination Network (https://serc.si.edu/coastalcarbon), and an effort is currently underway by the Pacific Northwest Blue Carbon Working Group to calculate carbon accumulation rates for west coast wetlands as part of the PNW Carbon Stocks and Blue Carbon Database Project (https://www.pnwbluecarbon.org/clients; Janousek et al. 2022). This database is currently the best source of

Table 2. California region-specific emission factors for coastal wetlands

Region	NWL coastal wetland type	**Total emissions** MT CO_2-e/acre/yr	**Soil carbon accumulation** MT C/acre/yr	**CH_4 emissions** MT CO_2e/acre/yr
Delta	Drained wetlands used for agriculture	9.56 (7.77 to 11.3)	-2.51 (-3.00 to -2.03)(1)	0.6 (0.2 to 1.0)(1)
Delta	Rice	7.02 (3.63 to 10.4)	-1.46 (-2.38 to -0.54)(1)	1.8 (1.2 to 2.4)(1)
Delta	Freshwater tidal wetlands	0.10 (-1.03 to 2.01)	0.51 (0.41 to 0.61)(2)	2.2 (1.1 to 4.1)(3)
Delta	Rewetted or restored wetlands (impounded marshes)	1.35 (-0.48 to 3.17)	1.37 (0.94 to 1.81)(1)	7.1 (5.9 to 8.3)(1)
Delta	Seasonal wetlands (organic and highly organic mineral soils)	3.6 (1.7 to 5.5)	-0.98 (-1.5 to -0.46)(4)	0(5)
Delta	Seasonal wetlands (mineral soils)	Data unavailable		
Suisun Marsh	Brackish tidal wetlands	-1.83 (-2.18 to -1.48)	0.50 (0.41 to 0.60)(6)	0.015(7)
Suisun Marsh	Brackish managed seasonal wetlands (organic or highly organic mineral soils)	4.0 (2.2 to 5.4)	-1.1 (-1.5 to -0.6)(4)	0.2(8)
Suisun Marsh	Brackish managed seasonal wetlands (mineral soils)	Data unavailable		
SF Bay	Saline tidal wetlands	-1.39 (-1.68 to -1.08)	0.40 (0.32 to 0.48)(6)	0.1 (0.04 to 0.2)(9)
SF Bay	Eelgrass	-0.55 (-0.95 to -0.19)	0.17 (0.1 to 0.3)(10)	0.1 (0.04 to 0.2)(10)
Statewide	Saline tidal wetlands	-1.26 (-1.55 to -0.93)	0.37 (0.3 to 0.4)(9)	0.1 (0.04 to 0.2)(9
Statewide	Eelgrass	-0.55 (-0.95 to -0.19)	0.17 (0.1 to 0.3)(10)	0.1 (0.04 to 0.2)(10)

Note: CO_2e for methane calculated from GWP-28. Total emissions were calculated from soil carbon accumulation and CH_4 emission rates, except in the case of Hemes et al. (2019), where values were provided for total GHG emissions. Additional wetland types and regions could be included in future versions of the Scoping Plan as additional carbon accumulation and GHG emission data become available.

1. Hemes et al. (2019) summarized data for drained agriculture, rice, and impounded marshes on Twitchell and Sherman Islands.
2. Carbon accumulation rates were calculated from vertical accretion rates from Callaway et al. (2012) and peat carbon contents from remnant marsh cores (Drexler et al. 2009, Callaway et al. 2012)
3. IPCC tier 1 values for freshwater tidal marsh (IPCC 2014)
4. Values are based on SUBCALC^2 model runs (Deverel et al. 2016). Seasonal wetlands on organic or highly organic mineral soils are assumed to emit CO_2 similarly to agriculture (Deverel et al. 1998). Modeled fluxes for brackish sites are consistent with preliminary eddy covariance data provided by Dr. Dennis Baldocchi.
5. Deverel et al. (1998) reported minimal CH_4 fluxes from seasonal wetlands on Twitchell Island.
6. Callaway et al. (2012) presented peat carbon accumulation rates from brackish and saline sites in the San Francisco Estuary.
7. CH_4 emission rate based on Rush Ranch eddy covariance data provided to HydroFocus, Inc. by Lisamarie Windham-Myers at USGS.
8. Value was estimated from eddy covariance data provided to HydroFocus, Inc. by Dr. Dennis Baldocchi.
9. CH_4 emissions from Eden Landing (saline tidal wetland in SF Bay) reported in Arias-Ortiz et al. (2021).
10. IPCC tier 1 values for seagrass meadow (IPCC 2014). CH_4 emissions are assumed to equal saline tidal marsh.

for blue carbon data for the US West coast and includes soil carbon density and accretion rate data for California, with data from the San Francisco Estuary, Elkhorn Slough, Tijuana Estuary, Humboldt Bay, Bolinas and Bodega Bays, Morro Bay, and other estuaries in California's south coast (e.g., Weis et al. 2001, Drexler et al. 2009, Callaway et al. 2012, Brown 2019). The availability of additional data will allow values specific to California (statewide or regional values) to replace default IPCC values for use in future state-level GHG inventories and Scoping Plan projections.

In keeping with the methods in the current CARB Inventory and Scoping Plan, wetland emission factors reported in Table 2 include soil carbon only, and do not account for changes in biomass carbon. Gains or losses of biomass carbon stocks could be tracked where scenarios include conversions between vegetated and unvegetated wetland types (Beers and Crooks 2022). Aboveground stocks of emergent wetland vegetation biomass can be quantified from harvested field plots, and have been estimated for SF Bay using a combination of field plots and remote sensing data (Byrd et al. 2020). These can be combined with root:shoot ratios and carbon conversion factors and used to estimate changes in biomass carbon due to the creation, loss, or conversion of wetland habitat. However, the vast majority of carbon storage in tidal marsh and eelgrass is in the soil, so explicitly including biomass carbon in Scoping Plan coastal wetland scenarios is likely to be a low priority.

Emission factors for saline tidal wetlands in Table 2 correspond to mapped saline tidal wetlands in SF Bay and elsewhere in the state (Table 1). In both C-CAP and CARI, however, the saline or estuarine class includes a range of salinities encompassing both saline and brackish conditions. CARI documentation recognizes that it is often not possible to distinguish between saline and fresh or brackish sites using aerial imagery and elevation data, and notes that when additional vegetation information or other data are available, this information is used to define the boundary between fresh and saline wetland classes. Where the saline tidal wetland class includes low-salinity brackish wetlands (salinities < 18ppt), methane emissions are likely to be under-represented by the Table 2 emission factors, representing a source of potential bias in the proposed approach. However, a comparison between CARI and other salinity information including local mapping (Elkhorn Slough Tidal Wetland Project Team 2007) and data from the California Rapid Assessment Method (CRAM; https://www.cramwetlands.org/) that are available through EcoAtlas (ecoatlas.org) suggests that, in some regions at least, brackish sites with low salinity are commonly classified in the fresh, not saline, wetland categories. Additional mapping that distinguishes between wetlands with salinities above and below the 18ppt threshold for IPCC default emission factors would enable brackish wetlands to be explicitly included in Scoping Plan scenarios, and would improve the accuracy of GHG emission and carbon accumulation estimates from saline tidal wetlands.

The value for eelgrass carbon accumulation presented in Table 2 is the global IPCC tier 1 default value for seagrass meadows. Globally, eelgrass and other SAV species form substantial beds and can sequester carbon at high rates, but eelgrass beds local to California tend to be smaller and more variable in size from year to year than in other systems. Available datasets generally focus on carbon stocks within seagrass meadow sediments, while measured carbon accumulation rates are far less common. Accumulation data can be calculated from the change in stock if the age of the meadow is known, or by using radiometric dating of sediment cores. There are no reported accretion rate values from California eelgrass beds, but preliminary analyses of accretion rate data from Pacific Northwest eelgrass sediments indicate that the IPCC default value falls within the broad range of reported accretion rates (0.018 to 0.24 MT C/per acre per year) (Christopher Janousek, *pers. comm.*, Janousek et al. 2022). New measurements of eelgrass carbon accumulation in California sites are expected over the coming years (Dr. Kathy Boyer, *pers. comm.*), which

EEL GRASS, PINOLE REGIONAL SHORELINE • PHOTO BY SHIRA BEZALEL, SFEI

could be used to update IPCC default emission factors in future Scoping Plan updates. Additionally, non-native aquatic vegetation has been seen to accumulate carbon at roughly 10x the rate of Pacific Northwest eelgrass (Drexler et al. 2021, Janousek et al. 2022). Control of invasive aquatic vegetation has had little success, so it may merit inclusion in future updates to the Scoping Plan reference scenario or other statewide carbon accounting efforts.

SEA LEVEL RISE AND COASTAL WETLAND VULNERABILITY

The persistence of California's tidal wetlands is threatened by sea level rise (SLR) over the coming century. Tidal wetlands are resilient systems, adapted to dynamic environments and have historically been capable of responding to long term changes in sea level via biophysical feedback processes (Morris et al. 2002, Callaway et al. 2012, Kirwan and Megonigal 2013). However, if SLR rates exceed the capacity of wetland systems to respond, vegetated marshes will transition to unvegetated mudflats or subtidal habitats (Reed 1995, Kirwan et al. 2010, Kirwan and Guntenspergen 2012). Where this occurs, carbon accumulation rates will decline and a fraction of the sequestered carbon in sediments may be mobilized and returned to the atmosphere as CO_2 (Ward et al. 2018).

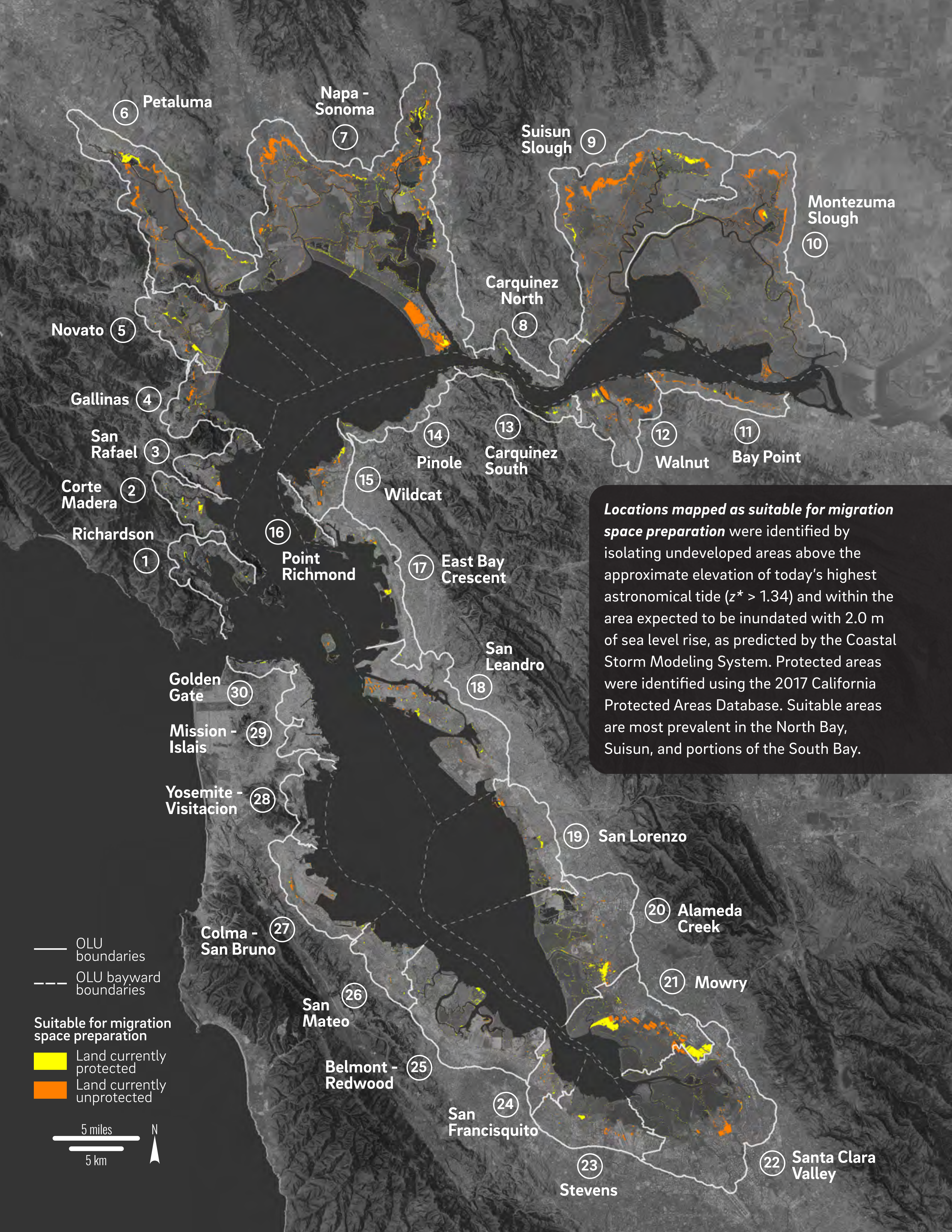
Vertical accretion is the fundamental mechanism through which coastal wetlands maintain elevation in place, and the key process by which carbon is sequestered. Wetlands build elevation by trapping sediment from the water column and building vegetation biomass. As water depths rise above the marsh plain, sedimentation and carbon accumulation rates increase due to the increased trapping of sediment suspended in the water column (Kirwan and Mudd 2012). However, there are limits to the ability of wetland accretion to keep pace with SLR, and the threshold SLR rate that wetlands can sustain depends on site-specific factors including available suspended sediment and plant productivity rates (Schile et al. 2014, Swanson et al. 2015, Morris et al. 2016). Sediment concentrations are controlled by the limited supply of sediment from watersheds (Dusterhoff et al. 2021), and vegetation productivity declines at low elevations in the tidal frame (Morris et al. 2012, 2021). When sedimentation and biomass growth cannot keep up with SLR, vegetated wetlands drown, transitioning to mudflats or subtidal habitats. Regional analyses of coastal wetland vulnerability have indicated that California's coastline may lose many of its wetlands without management interventions to promote their persistence (Stralberg 2011, Southern California Wetlands Recovery Project 2018, DSC 2021).

A range of management actions may be employed to increase the resilience of tidal wetlands to SLR. One of the most valuable of these tools is protection of wetland migration space. Coastal wetlands naturally migrate inland and upland as sea levels rise. At high rates of SLR, coastal wetlands will be better able to persist through inland migration than through vertical accretion. Opportunities for wetland migration, however, are often constrained by infrastructure and existing land uses (Orr and Sheehan 2012, Heady et al. 2018). A modeling study of the US Pacific Coast, for example, predicts that with existing migration opportunities (excluding hard infrastructure and other development constraints), 59% of existing tidal wetlands will be lost by 2110 under high SLR scenarios (56″ for Washington and Oregon, and 65″ for California) (Thorne et al. 2018). Underscoring the importance of migration opportunities, this same study predicts that without migration, 99% of existing vegetated tidal wetlands would drown.

Available opportunities for wetland migration vary by region, as does the vulnerability to SLR of existing coastal wetlands (Heady et al. 2018). Additionally, many of the areas suitable for wetland migration are not currently protected and could be developed or converted to other uses, limiting future wetland persistence via upland migration. Maps of land elevation and ownership/protection status can be used to determine suitable areas for future wetland migration. For example, the SF Bay Shoreline Adaptation Atlas (SFEI and Spur 2019) mapped migration space for SF Bay using elevation data and protection status, as reported in the California Protected Areas Database (Figure 2). Protection of these areas, which are currently upland habitat but could be tidal wetlands in the future, is a key aspect of coastal wetland conservation in the context of rapid SLR.

In addition to migration space conservation, management interventions exist to build and maintain wetland elevations. Restoration projects may incorporate elevation-building practices prior to restoring tidal flows, such as sediment placement, tule farming for subsidence reversal, and warping (Miller et al. 2008, Robinson et al. 2016). Other management actions can aid in maintaining elevation of existing tidal marshes, though these actions can often be expensive and complicated to implement. Options include direct placement of sediment (e.g.. thin layer placement or water column seeding) and enhancing connections between watersheds and marshes.

Although substantial wetland drowning is not expected by 2045, losses could be large by the end of the century without management intervention. For coastal wetland scenarios in the Scoping Plan to represent long-term, durable sinks for atmospheric CO_2, they should include management interventions to maintain existing and future (restored) tidal wetlands. In addition to sustaining coastal wetland carbon sequestration beyond 2045, increasing migration space adjacent to existing wetlands provides important co-benefits including high water refuge for native species, enhanced flood resilience, and water quality benefits (Heady et al. 2018).



Locations mapped as suitable for migration space preparation were identified by isolating undeveloped areas above the approximate elevation of today's highest astronomical tide ($z^* > 1.34$) and within the area expected to be inundated with 2.0 m of sea level rise, as predicted by the Coastal Storm Modeling System. Protected areas were identified using the 2017 California Protected Areas Database. Suitable areas are most prevalent in the North Bay, Suisun, and portions of the South Bay.

EXPANDING COVERAGE OF COASTAL WETLANDS IN THE SCOPING PLAN SCENARIOS

Wetland scenarios currently included in the May 2022 Scoping Plan draft include restoration of between 19,000 and 120,000 acres of coastal wetlands in the Delta and Suisun Marsh, with 60,000 acres of restoration in the proposed scenario (scenario 3). These added wetlands include freshwater wetlands managed for subsidence reversal, rice, and brackish tidal wetlands. The draft Scoping Plan reference scenario does not currently include wetland losses (drowning) due to SLR or restoration of saline wetlands.

This section presents examples of how CARB could expand existing Scoping Plan scenarios to include greater coverage of California's coastal wetland ecosystems. Three management actions are included in these suggestions: (1) expansion of the NWL wetland category to include saline tidal wetlands and eelgrass beds; (2) conservation of existing coastal wetlands; and (3) management interventions to limit tidal wetland vulnerability to SLR. The example scenarios below include saline tidal wetland and eelgrass restoration in SF Bay, based on regional restoration targets (Goals Project 1999, Subtidal Goals 2010, Goals Project 2015). The basis of these numbers is detailed in Appendix C.

Recommendations for updates to the reference scenario:

- **Add saline tidal wetlands to the NWL wetlands category**, using acreages from Table 1 and C-CAP 2001 and 2016 layers to estimate the baseline rate of change. An example of change quantification for SF Bay can be found in the report produced by Silvestrum Climate Associates, *Coastal Wetland Greenhouse Gas Inventory for the San Francisco Bay Estuary* (Beers and Crooks 2022).
- **Add eelgrass meadows to the NWL wetlands categories**, using acreages from Table 1. Due to highly variable eelgrass extents over the past 20 years and variable effects of SLR and other natural and anthropogenic influences, assume no net change over time in eelgrass extents.
- To account for projected losses of existing wetlands due to SLR (e.g. Thorne et al. 2018), **assume only 40% of the tidal wetland area will provide long-term GHG benefits** (only 40% will maintain carbon accumulation rates until and beyond 2110.)

Recommendations for updates to scenario 1, prioritize short-term carbon stocks, minimize disturbances:

- **Restore 27,000 acres of saline tidal wetland** in SF Bay.
- **Conserve 50% of the wetlands converted to other land cover types** in the reference scenario.
- **Restore an additional 6,000 acres of eelgrass** in SF Bay.
- **Add resilience interventions over 30,000 acres** to prevent losses of vegetated tidal wetlands due to SLR.

(left) Figure 2. Mapped protected and unprotected land suitable for marsh migration in SF Bay. From the SF Bay Shoreline Adaptation Atlas (SFEI and SPUR 2019).

Recommendations for updates to the proposed scenario (scenario 3), prioritize restoration and climate resilient carbon stocks (half the acreages of scenario 1, in keeping with the Delta scenarios currently included in the Scoping Plan):

- **Restore 17,000 acres of saline tidal wetland** in SF Bay.
- **Conserve 25% of the wetlands converted to other land cover types** in the reference scenario.
- **Restore 3,000 acres of eelgrass** in SF Bay.
- **Add resilience interventions over 15,000 acres to prevent losses of vegetated tidal wetlands** due to SLR.

The suggested additions of SF Bay restoration would reduce scenario GHG emissions by an estimated 53,000 MT CO_2e per year for scenario 1 or by 27,000 MT CO_2e per year for the proposed scenario (scenario 3), sequestering an additional 15,000 or 7,700 MT of carbon annually for scenarios 1 and 3 respectively. Wetland conservation would protect existing carbon stocks and reduce GHG emissions relative to the reference scenario. While resilience interventions may not directly affect GHG emissions or carbon sequestration in the timeframe of the Scoping Plan analysis, initiating such activities in the near term will be critical for maintaining coastal wetlands' long-term climate benefits. Explicitly including these activities in Scoping Plan scenarios would allow state-level planners to assume that rates of carbon accumulation and GHG uptake can be maintained beyond 2045.

Building on these suggestions for SF Bay, a more complete representation of coastal wetlands in future versions of the Scoping Plan scenarios would additionally incorporate saline tidal wetland and eelgrass restoration outside the San Francisco Estuary. Restoration targets comparable to those for the San Francisco Estuary (Goals Project 1999, DSC 2013) have not been developed for other regions of the state, but opportunities exist to increase the extent of coastal wetlands across the North, Central, and South Coast. Doubling California's current ~15,000 acres of saline tidal wetland outside SF Bay, for example, would sequester an additional ~6,000 MT carbon annually and reduce the state's GHG emissions by roughly 19,000 MT CO_2e per year. Additionally, information on current restoration commitments (planned or early-stage restoration projects) could be incorporated into the Scoping Plan scenarios 2 and 4. Information on planned and completed restoration projects can be found in EcoAtlas (https://www.ecoatlas.org/).

CONCLUSIONS AND FUTURE OPPORTUNITIES

With available mapping and emission factor data, blue carbon ecosystems can be added to the Scoping Plan reference scenario and alternative scenarios in accordance with IPCC methods. Adding coastal wetland ecosystems outside the Delta would increase the Scoping Plan's representation of existing wetlands by 57,000 acres, and expanding coastal wetland restoration would reduce scenario GHG emissions by an estimated 1 to 1.5 MT CO_2e per year for each acre of restored saline tidal wetland, or 0.5 MT CO_2e per year for each acre of eelgrass. Carbon stored in coastal wetland sediments is resistant to wildfire and other key disturbances that pose an increasing threat to carbon stocks in California's terrestrial ecosystems. If measures are taken to promote wetland resilience to SLR, blue carbon ecosystems offer a high-leverage and durable carbon sink with long-term, sustained climate benefits.

Restoring and conserving blue carbon ecosystems offers numerous co-benefits in addition to GHG emission reductions. Coastal wetlands also provide a wide variety of other ecosystem services, including improved water quality (Knox et al. 2008, Shapiro et al. 2010, Sherman and DeBruyckere 2018), enhanced shoreline resilience to flooding (Narayan et al. 2017, Thorne et al. 2018, SFEI and SPUR 2019), wildlife habitat (Perry et al. 2010, Barbier et al. 2011, Sherman and DeBruyckere 2018, Dybala et al 2020), support for fisheries and tourism (Barbier et al. 2011), and cultural services (Sherman and DeBruyckere 2018, Rouleau et al. 2021). Some of the ecosystem services provided by coastal wetlands contribute to reducing the direct impacts of climate change. For example, tidal salt marshes can attenuate waves, reduce shoreline erosion, and lessen the impacts of storm surges and flooding (California Natural Resources Agency and California Ocean Protection Council 2020), and seagrass beds mitigate ocean acidification (Ricart et al. 2021, Ward et al. 2021).

Focus areas for science investment

Investments in key science focus areas could improve the precision of future Scoping Plan updates (or other state or regional climate planning efforts) and expand the set of wetland types that could be included in scenario modeling.

FOCUS AREA 1: MAPPING

- Regular re-mapping efforts are needed to ensure consistent spatial data is available over time. Methods including change detection are particularly valuable for tracking change over time. These methods are already in the pipeline for SF Bay for future BAARI updates, but would be valuable on a statewide basis.
- Detailed salinity mapping is needed to more accurately quantify GHG and carbon accumulation and emission factors. Vegetation mapping from California Department of Fish and Wildlife's Vegetation Classification and Mapping Program (VegCAMP) or the US Forest Service's Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG) could be used with additional available data to delineate salinity zones.
- LiDAR-corrected elevation datasets can be employed as a supplement to vegetation mapping to aid in tracking the transition from high to low marsh as sea levels rise. This information is central to understanding wetland resilience to SLR and potential changes in carbon accumulation rates.

FOCUS AREA 2: BIOGEOCHEMICAL DATA

- Spatially distributed carbon sequestration and methane emission data from California's tidal wetlands would improve the accuracy of reference and alternative scenario estimates. These data would be greatly improved by the installation and operation of an increased number of eddy covariance towers in coastal wetlands statewide, across a range of salinities, along with soil carbon accumulation and lateral carbon flux measurements. Where better biogeochemical data are available, emission and sequestration factors can be updated, consistent with IPCC guidelines. Historical estimates can also be updated to maintain consistency when comparing over time.
- California-specific carbon sequestration rate measurements are needed for eelgrass, as well as other seagrasses and kelp.
- Methane flux and carbon sequestration data are needed for intermittent estuaries and nontidal wetlands outside the Delta that have the potential for tidal restoration.
- A portion of carbon exported laterally from tidal wetlands is thought to be sequestered long-term in

the oceans, potentially increasing the value of tidal wetlands as a carbon and GHG sink (Santos et al. 2021). Additional research into the rate of lateral carbon exports and the fate of this exported carbon is needed to better understand this process and incorporate it into models.

FOCUS AREA 3: STATEWIDE COORDINATION FOR COASTAL WETLAND PLANNING AND TRACKING

- To expand Scoping Plan scenarios for coastal wetland restoration beyond the San Francisco Estuary, clear restoration targets are needed for other regions in California. Although robust regional coordination efforts do exist elsewhere in the state, such as the Southern California Wetlands Recovery Project (2018), further coordination among scientists, agency leaders, restoration planners, environmental advocates, and local communities is needed to develop realistic acreage targets that are comparable to those that have been defined for SF Bay and the Delta (Goals Project 1999, DSC 2013). Such efforts are important not only for scenario planning efforts like the Scoping Plan, but also for prioritizing management actions needed to maintain coastal wetlands with increasing SLR.

- Once restoration targets are defined, additional coordination is needed to track and measure progress toward restoration goals. Coordinated reporting on restoration progress would enable regional targets to be updated over time and inform state-level processes such as the Climate Change Scoping Plan and Natural and Working Lands Inventory.

FOCUS AREA 4: MODELS

- As an alternative to emission factor approaches, process based biogeochemical models can be used to project future GHG emissions/uptake and carbon accumulation/loss associated with both changing wetland extents and changing process rates due to warming, SLR, and changing management practices.

- Process-based models have been developed for CA coastal wetlands, including SUBCALC[2] (Deverel et al. 2016), SEDCALC (Deverel et al. 2014), PEPRMT (Oikawa et al. 2017), CWEM, an updated version of MEM (Morris and Bowden 1986, Morris et al. 2021), and WARMER (Swanson et al. 2015), but will benefit from further development and validation in order to meet the needs of CARB.

- An investment in ongoing model development and the collection of validation data would better enable process-based models to be used for coastal wetlands in future Scoping Plan updates. Areas for investment include: development of vegetation-corrected LiDAR-derived digital elevation models statewide; ongoing biogeochemical data collection with a focus on underrepresented wetland types to better parameterize and validate models; and investments in model usability, such as development of an integrated platform to run models across the state or specific regions.

- It may not be necessary to commit solely to emission factors or process-based models. A hybrid approach could use emission factors for certain wetland categories and process-based models for others. As needed, outside experts could run models if specialized expertise is a barrier to CARB implementation.

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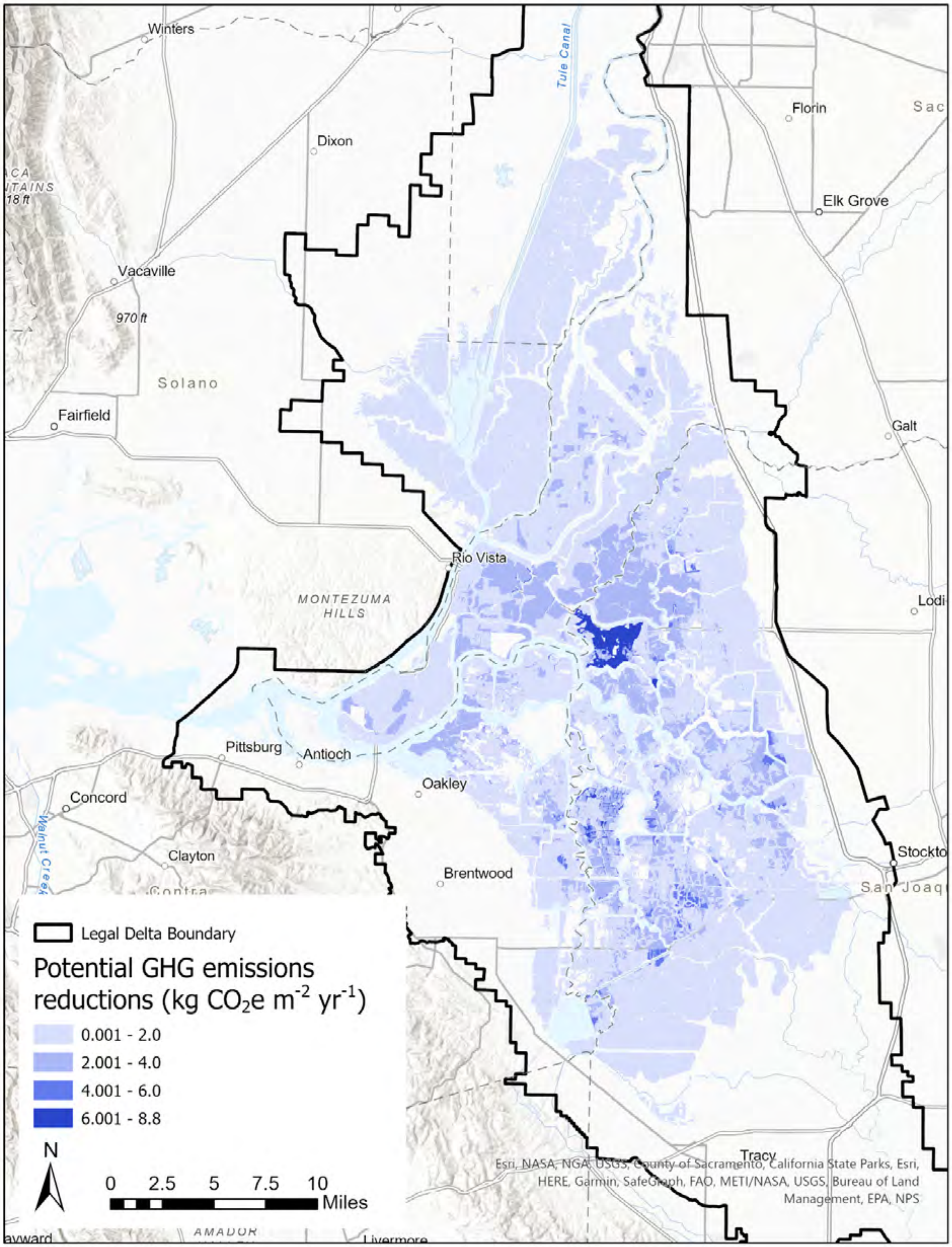
CARPINTERIA SALT MARSH PRESERVE • PHOTO BY LIZ IXER, COURTESY OF CREATIVE COMMONS

APPENDIX A

Map of potential blue carbon opportunities for the Delta. Blue shading indicates areas where replacement of existing land uses with managed or tidal wetlands offers a net GHG emissions reduction relative to baseline conditions (the current configuration of land uses). Values represent mean emission reductions over a 40-year period (2017-2057), as projected with the Landscape Scenario Planning Tool (LSPT; https://www.sfei.org/projects/landscape-scenario-planning-tool). Tool projections are based on a combination of process-based models and emission factors, as described in the LSPT user guide.



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

APPENDIX B

Table B1. Description of wetland mapping sources

Recommended Data Sources						
Product	**Housed within**	**Spatial coverage**	**Years available**	**Future remap frequency**	**Source data**	**Recommended Use**
C-CAP		United States	1975, 1985, 1992, 1996, 2001, 2006, 2010, 2016	Every 5 years	• National Wetland Inventory (NWI) • National Hydrography Dataset (NHD) • Soil Survey Geographic Database (SSURGO) • 30m National Elevation Dataset (NED) from USGS • Satellite imagery (Landsat)	Tidal wetland change detection
CARI		California	V 0.0 2013 V 0.1 2014 V 0.2 2016 V 0.3 2017 V 0.4 2022 (not yet released)	Unknown/ sporadic	• National Wetland Inventory (NWI) • National Hydrography Dataset (NHD) • County Aquatic Resources Inventories • Santa Clara Valley Creeks • BAARI, TARI, NCARI	California wetland habitat estimates for areas outside of SF Bay, Suisun Marsh, and the Delta
BAARI	CARI	SF Bay	V 1.0 2013 V 2.0 2015 V 2.1 2017	Unknown/ sporadic	• NAIP Imagery • CalWater • ArcHydro • National Wetland Inventory (NWI) • National Elevation Dataset (NED) • EcoAtlas • Wetland Tracker	Wetland habitat estimates within San Francisco Bay and Suisun Marsh

Product	Housed within	Spatial coverage	Years available	Future remap frequency	Source data	Recommended Use
DARI	CARI	Delta	V 1.0 Not Released V 1.1 2022	Unknown/ sporadic	• NAIP Imagery • USGS LiDAR • National Hydrography Dataset (NHD) • National Wetlands Inventory (NWI) • Modern Delta Habitats • 2012 DARI pilot Dataset • VegCamp 2016 • Landsat	Wetland habitat estimates within the Delta (alternative to SFEI Delta mapping)
LSPT		Delta & Suisun Marsh	V 0.1 (Delta Only) Mid 2000's V 0.2 Mid 2010s	Unknown/ sporadic	• CDFW VegCAMP • CDFW CVRMP • WWR CSCCA Natural Communities • SFEI 2013 Supplemental Mapping	Wetland habitat estimates within Suisun Marsh and the Delta
San Francisco Bay Eelgrass Inventory		SF Bay	2003, 2009, 2014	Unknown/ sporadic	• Aerial imagery • Acoustic surveys with ground-truthing	Eelgrass estimates within SF Bay

Additional Data Sources						
SCCWRP		Southern California	2005	One time mapping	• National Wetland Inventory (NWI) • Center for Geographical Studies (CGS)	
Coastal Topographic Sheets (T-Sheets)		Entire California Coastline	Mid 1800's	One time mapping		Determining areas of historical tidal wetland influence
The Humboldt Bay Inventory, Mapping, and Sea Level Rise Vulnerability Assessment Project		Humboldt Bay	2013	Unknown	• Aerial Photography • DEM	Wetland area estimates within Humboldt bay

Table B2. Crosswalk of map source habitat types to recommended CARB Scoping Plan classes

Scoping Plan	• CARI	• BAARI	• DARI	• LSPT	• C-CAP
Eelgrass	• Estuarine Natural Subtidal Eelgrass				• Estuarine Aquatic Bed
Freshwater Tidal Wetland	• Estuarine Non-saline Managed Intertidal Vegetated • Estuarine Non-saline Natural Intertidal Vegetated		• Tidal Vegetated Natural	• Tidal Emergent Wetland • Tidal Willow Thicket • Tidal Willow Riparian Scrub/ Shrub	• Palustrine Emergent • Palustrine shrub-scrub
Saline Tidal Wetland	• Estuarine Saline Natural Intertidal Emergent • Estuarine Saline Natural Intertidal Shrub-Scrub • Estuarine Saline Unnatural Intertidal Vegetated • Estuarine Saline Unnatural Intertidal Emergent • Estuarine Saline Unnatural Muted Tidal Shrub-Scrub	• Tidal Nascent Vegetation • Tidal Vegetation			• Estuarine Emergent • Estuarine Shrub/Scrub
Delta Habitat Types Only					
Rice			• Managed Wetland_Rice Field	• Rice	
Drained Wetlands used for Agriculture	• Depressional Seasonal Unnatural Farmed • Depressional Seasonal Managed Farmed		• Managed Wetland_ Flooded Agriculture	• Agriculture/ Ruderal	• Cultivated
Brackish Tidal Marsh		• Tidal Vegetation		• Tidal emergent wetland (Suisun Marsh) • Tidal willow riparian scrub/ shrub (Suisun Marsh)	• Estuarine Emergent

Scoping Plan	• CARI	• BAARI	• DARI	• LSPT	• C-CAP
Brackish managed seasonal wetlands (organic or highly organic mineral soils)		• Depressional Vegetated Unnatural		• Non-tidal emergent wetland (highly organic soils, Suisun Marsh) • Wet Meadow/ Seasonal Wetland (highly organic soils, Suisun Marsh)	• Palustrine Emergent • Estuarine Emergent
Brackish managed seasonal wetlands (mineral soils)		• Depressional Vegetated Unnatural		• Non-tidal emergent wetland (mineral soils, Suisun Marsh) • Wet Meadow/ Seasonal Wetland (mineral soils, Suisun Marsh)	• Palustrine Emergent • Estuarine Emergent
Freshwater seasonal wetlands (organic and highly organic mineral soils)				• Wet Meadow/ Seasonal Wetland (organic and highly organic mineral soils, Delta)	• Palustrine Emergent • Palustrine Scrub/Shrub
Freshwater seasonal wetlands (mineral soils)				• Wet Meadow/ Seasonal Wetland (mineral soils, Delta)	• Palustrine Emergent • Palustrine Scrub/Shrub
Rewetted or restored wetlands (impounded marshes)				• Non-tidal emergent wetland (subsided areas, Delta)	• Palustrine Emergent • Palustrine Scrub/Shrub

APPENDIX C

Basis of SF Bay restoration acreages included in scenario recommendations

Saline tidal wetland restoration targets for SF Bay are based on recommendations set by the San Francisco Bay Area Wetlands Ecosystem Goals Project in 1999 (Goals Project 1999), which call for increasing the extent of tidal marsh in SF Bay and Suisun Marsh from roughly 40,000 acres to between 95,000 and 105,000 acres. Within the San Francisco estuary, this goal of ~60,000 acres of tidal marsh restoration includes 22,000 acres in the North Bay, 16,000-21,000 acres in the South Bay, minimal acres in the Central Bay, and 17,000-22,000 acres in Suisun. Approximately 13,000 acres have been restored since 1999 (Goals Project 2015, The State of the Estuary 2015, The State of the Estuary 2019), leaving a remaining target of roughly 47,000 acres estuary-wide, ~27,000 of which are in the North and South Bay regions. The recommended addition of 27,000 acres of tidal marsh in SF Bay to Scoping Plan scenario 1 represents this ambitious goal, which if met would align with the overall Goals Project target of 100,000 acres of tidal marsh across SF Bay and Suisun. For Scoping Plan scenario 3, meeting a more modest goal of 75,000 acres of total tidal marsh in SF Bay and Suisun, or 75% of the Goals Project targets, would require restoring an additional 17,000 acres of tidal marsh in the North and South Bay regions.

The suggested scenarios include an increase of 3,000 acres (proposed scenario) or 6,000 acres (scenario 1) of eelgrass in SF Bay. The proposed scenario represents a doubling of the existing SF Bay eelgrass extent, and scenario 1 acreage is twice that of the proposed scenario. These proposed acreages are based loosely on the San Francisco Bay Subtidal Habitat Goals Report (Subtidal Goals 2010), which includes a target of 8,000 acres over which native eelgrass populations should be increased Bay-wide, and reports model predictions that as much as 23,000 acres of habitat potential habitat exists in SF Bay that may be suitable for eelgrass growth and survival. The suggested restoration extent of 6,000 acres for the more ambitions scenario 1 are only 75% of the 8,000-acre target, given that this 8,000 acres may include existing beds with sparse eelgrass populations, and a number of factors may impede eelgrass restoration success, such as light limitation, sediment texture, physical disturbance, disease, and herbivory.

Additional information on coastal wetland restoration elsewhere in California

In California's North Coast, Humboldt Bay historically contained roughly 9,000 acres of tidal marsh. Currently approximately 900 acres remain, with about 400 acres of tidal marsh restoration underway. This project did not identify acreages of ongoing restoration for the Eel River Estuary, but capacity for restoration in the Eel River is likely higher than Humboldt Bay, assuming that agricultural land can be purchased from willing sellers and converted from agricultural use. Additionally, information on in-progress restoration and total restoration capacity in Point Reyes and Tomales Bay, Bodega Bay, and Bolinas Lagoon could be incorporated into scenarios 2 and 4 (current commitments) as well as scenarios 1 and 3. Based on conversations with experts from the Central Coast Wetlands Group at Moss Landing Marine Labs, planned restoration on the Central Coast includes 104 acres of new salt marsh in Elkhorn Slough, and additional projects have been completed in Morro Bay, Elkhorn Slough, and Goleta. This information could be used to develop scenarios 2 and 4 (current commitments), and coordination with groups such as the Central Coast Joint Venture (CCJV) can help with additional target-setting for the region. In southern California, 14,380 acres of vegetated estuarine habitats have been lost since 1850, and additional losses are expected as SLR accelerates. The Southern California Wetland Recovery Project Regional Strategy (Southern California Wetlands Recovery Project 2018) provides an analysis of restoration and migration opportunities with 24 inches and 66 inches of SLR, which includes drained and diked areas that are currently undeveloped, adjacent uplands that could be restored to wetlands today, and areas that could be tidally inundated if hydrological connectivity were restored Similar analyses could be performed inorder to identify restoration opportunities within the timeframe of Scoping Plan analyses, and additional coordination with regional experts would be needed to set realistic restoration targets.

No eelgrass restoration is included in the suggested scenarios for regions of the state outside SF Bay. Published targets for eelgrass in Humboldt Bay focus on maintaining distributions and plant densities (Schlosser et al. 2009), and modeling efforts suggest that eelgrass is likely to expand in Humboldt Bay due to SLR (Gilkerson and Merkel 2019). Existing frameworks for eelgrass restoration elsewhere in the state focus primarily on mitigation projects (Merkel & Associates 2016).

Assumptions about prior GHG emissions in restored sites

Restored saline tidal wetlands may replace a variety of habitat types. In many cases, they will replace land currently maintained for agriculture, including agricultural lands that were historically tidal wetlands before they were diked and drained. Tidal wetlands may also replace existing managed ponds and other nontidal wetlands where tidal flows have been interrupted (Goals Project 2015). In other cases, particularly in Southern California, tidal wetlands restoration may take place on lands that were altered by urban development in California (Southern California Wetlands Recovery Project 2018).

In general, current GHG emissions from these existing (pre-restoration) habitat types are likely to be low, for example from former salt ponds in SF Bay or agricultural lands on mineral soil. Where emission factors are available for existing (pre-restoration) habitat types, they can be explicitly modeled in Scoping Plan scenarios. As in the case of subsiding agricultural lands in the Delta, these baseline emissions may be included in the reference scenario for the wetlands NWL type. Alternatively, they can be represented through a change in acreage of other NWL types. Without specific emission factors for existing (pre-restoration) habitat types, not explicitly accounting for these emissions results in a conservative estimate of scenario GHG benefits. For example, where tidal flows are restored to existing non-tidal wetlands, CH_4 emissions are expected to decrease relative to reference conditions (Kroeger et al. 2017).