Morro Bay National Estuary Program

Habitat Protection and Restoration Strategy

Prepared for: United States Environmental Protection Agency, Region IX
75 Hawthorne Street San Francisco, CA 94105

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List of Acronyms

Please refer to this list as you read through the Habitat Strategy:

ACOE Army Corps of Engineers

BMP Best Management Practice

Cal Poly California Polytechnic University

Camp SLO Camp San Luis Obispo, California National Guard

CCC California Conservation Corps

CCER Chorro Creek Ecological Reserve

CCMP Comprehensive Conservation and Management Plan

CDFW California Department of Fish and Wildlife

CEDEN California Environmental Data Exchange Network

CEQA California Environmental Quality Act

cfs Cubic feet per second

CLIM Climate Change

CMC California Men's Colony

CNPS California Native Plant Society

CPI Conservation Planning Initiative

CVA Climate Vulnerability Assessment

CSLRCD Coastal San Luis Resource Conservation District

CSP California State Parks

DO Dissolved oxygen

ECR Ecosystem Conservation and Restoration

EIR Environmental Impact Report

ESA Endangered Species Act

ESHA Environmental Sensitive Habitat Areas

ESRI Environmental Systems Research Institute, Inc.

EO Education and Outreach

EWD Environmental Water Demand

FEMEF Friends of the El Morro Elfin Forest

FWR Freshwater Flow

GIS Geographic Information System

HCP Habitat Conservation Plan

LCP Local Coastal Programs

LID Low Impact Development

LP Land Protection

LOCSD Los Osos Community Services District

MBNEP Morro Bay National Estuary Program

MCAS Morro Coast Audubon Society

METI/NASA Ministry of Economy, Trade, and Industry/National Aeronautics and Space Administration

MON Water Quality Standards and Monitoring

MWMT Maximum weekly maximum temperature

NGA National Geospatial-Intelligence Agency

NRCS Natural Resources Conservation Service

RWQCB State Regional Water Quality Control Board

SOD Sudden Oak Death

SLR Sea level rise

SRA Sensitive Resource Areas

TMDL Total Maximum Daily Loads

USDA United States Department of Agriculture

USE Environmentally Sound Estuarine Resource Use

USEPA U.S. Environmental Protection Agency

USFS United States Forest Service

USFWS United States Fish and Wildlife Service

USGS United States Geological Survey

VMP Volunteer Monitoring Program

WWTP Wastewater Treatment Plant

Executive Summary

The Morro Bay National Estuary Program (MBNEP) works to protect and restore the Morro Bay estuary and watershed for people and wildlife. The MBNEP is a collaborative, non-regulatory, nonprofit organization that brings community members, local governments, nonprofit organizations, state and federal agencies, and landowners together to support a healthy environment and vibrant local communities.

This Habitat Protection and Restoration Strategy was developed to guide protection, restoration, research, monitoring, educational, and resiliency efforts in the face of climate change throughout the Morro Bay estuary and watershed. It is intended to provide measurable objectives and targets to inform future management planning and projects within the Morro Bay watershed, including MBNEP's next Comprehensive Conservation & Management Plan (CCMP) update. The strategy describes the health, extent, and key species within the Morro Bay watershed's habitats and connect habitats to the following:

- 2022 CCMP Action Plans
- Past and current protection and restoration efforts
- Stressors and climate vulnerabilities from the 2021 Climate Vulnerability Assessment
- Measurable objectives and targets for the next five to ten years
- Ongoing and potential projects to achieve those objectives
- Climate resiliency

The strategy focuses on five habitat areas—estuarine; freshwater; sandy shores and dunes; upland; and urban and irrigated agriculture. For each habitat area, an example of a higher-level objective statement is provided below:

Estuarine: Understand and maintain the mosaic of functioning estuarine habitats with the impacts of climate change and sea level rise.

Freshwater: Monitor ambient conditions, implement projects, and track project effectiveness to promote and enhance healthy in-stream, riparian, and freshwater wetland habitat.

Sandy Shores and Dunes: Support and enhance dune ecosystem function and resilience through restoration efforts.

Upland: Maintain and enhance a healthy diversity of upland habitats including oak woodland, maritime chaparral, coastal scrub, and native grassland through habitat protection and restoration.

Urban and Irrigated Agriculture: Support projects that enhance native habitat and climate resiliency.

The MBNEP and its partners aim to improve climate resiliency for the Morro Bay watershed habitats and interconnected coastal communities through the implementation of this strategy.

Acknowledgements
The MBNEP would like to thank all the participants for the Conservation Planning Initiative process that helped develop some of the objectives in this document, particularly in freshwater and estuarine habitat areas. Thank you to MBNEP staff who contributed and provided feedback on this habitat strategy.

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INTRODUCTION

Morro Bay has long been recognized as one the most environmentally significant estuaries in California with its coastal dunes and wetlands relatively intact and a watershed that has remained largely undeveloped. Preservation of these natural areas was a prime impetus for efforts to protect Morro Bay and for its recognition as both a State and National Estuary.

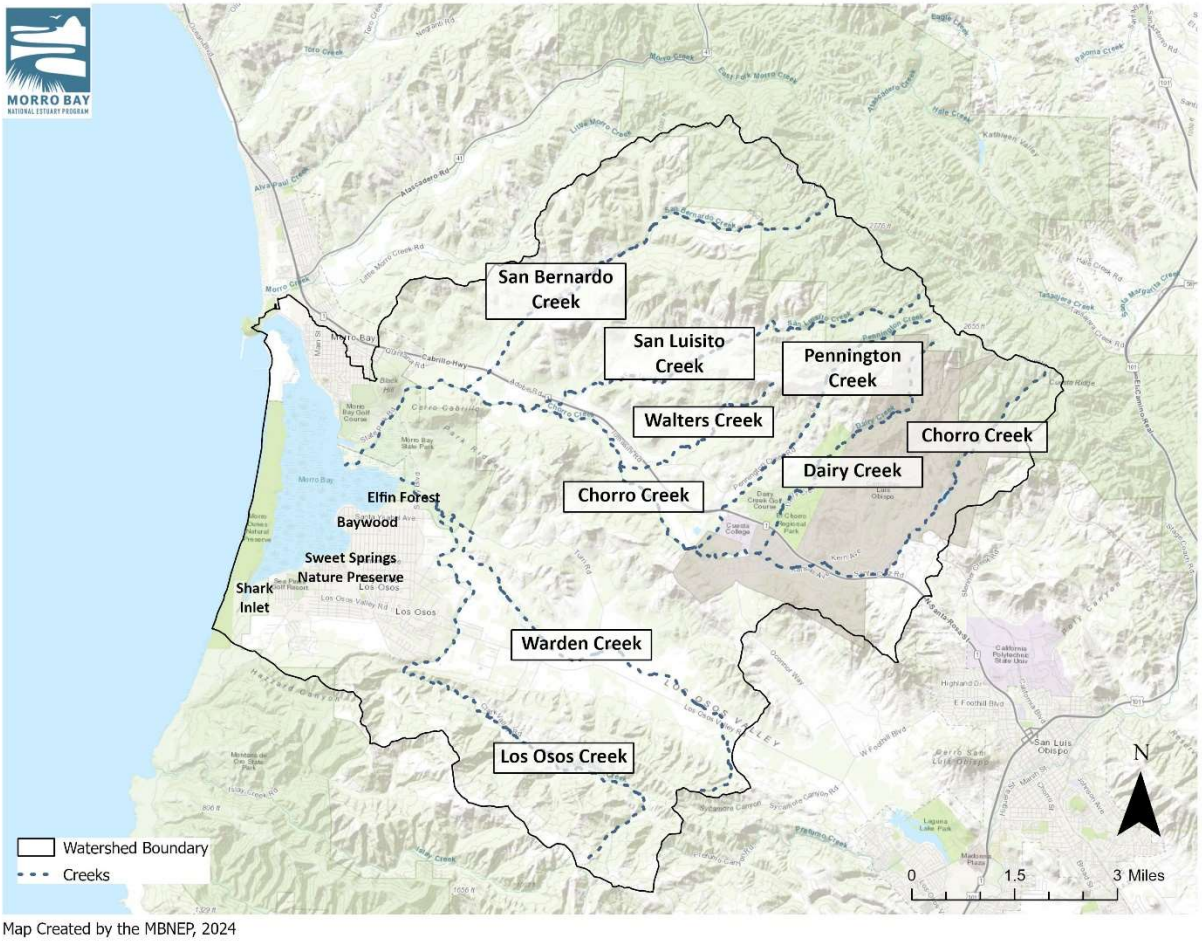


Figure 1. Watershed map and points of interest of the Morro Bay watershed

Habitats of the Morro Bay estuary and its watershed: An Overview

Like most estuaries, the interface of freshwater systems with ocean water in the Morro Bay estuary creates a diverse system of habitats including estuarine, freshwater creeks and wetlands, dunes and beaches, and a variety of upland communities.

The harbor mouth connects with the open ocean allowing access into the bay for nearshore fish, marine mammals and birds, as well as plankton, jellies, and other pelagic invertebrates carried by incoming tides.

A long jetty extending south from Morro Rock protects the harbor mouth from most wave action. Another jetty to the south that runs perpendicular to the shore and a smaller groin near

the main entry channel captures much of the sand from littoral drift in a forebay area. This sand build-up has resulted in the formation of a large area of mostly unvegetated dunes at the north end of the sandspit and some sandy beach areas in this part of the bay. Unlike the sandy shoreline to the north and south, these beaches are generally protected from the most severe wave action.

Subtidal channels, some dredged and others naturally created by stream flow and tidal erosion, cut through intertidal mudflats extending the underwater habitat into the back bay. In shallow reaches of the bay, tidal exchange is less complete, creating conditions that can adversely affect water quality and impact estuarine communities.

The bay bottom substrate is sandy in the front of the bay and transitions to fine silty mud in the back bay. Eelgrass grows in this substrate, forming the most significant seagrass beds in Central and Southern California. Eelgrass enhances biological functions in the bay's waters and is an important habitat for many fish and invertebrates as well as a food source for migrating brant geese (*Branta bernicla*).

At low tides, much of the bay is exposed, mostly as mudflats that provide a rich habitat for invertebrates and abundant food resources for shorebirds. Toward the back bay, the mudflats give way to the salt marsh, a very rare habitat in California where most coastal wetlands have been filled or otherwise altered by development. The largest extent of salt marsh lies at the confluence of Chorro and Los Osos Creeks where sediment has built up a delta interlaced with tidal channels.

The creek system that drains into the estuary supports substantial freshwater communities and species including South-Central California Coast steelhead trout (*Oncorhynchus mykiss*), a threatened anadromous fish, and federally endangered tidewater goby (*Eucyclogobius newberryi*). In most places, the creeks are lined by riparian vegetation, and together they form water-dependent biological communities that are especially critical during the dry, warm summer season typical of the area's Mediterranean climate. The floodplains of the creeks were altered in many places for farming and flood control, but where they have been restored, flourishing vegetation communities have returned along with the fauna that inhabit them.

In addition to stream corridors and floodplains, a few other noteworthy habitats occur in the Morro Bay area, the most well-known being Sweet Springs Nature Preserve in Los Osos/Baywood where a stable brackish marsh supports species such as the western pond turtle (*Actinemys marmorata*) just a short distance from the bay shoreline.

The watershed extends many miles inland and varies in elevation from sea level to over 2,500 feet. Near to the shore, dune communities dominate the sandspit and the relic dunes near Shark Inlet. Farther inland, maritime chaparral, a rare habitat, intergrades with coastal dune and other scrub species creating a mosaic of vegetative systems that support diverse plants and animals, including the threatened Morro manzanita (*Arctostaphylos morrensis*) and the

threatened Morro shoulderband snail (*Helmithoglypta walkeriana*). Much of this habitat has been lost or highly fragmented and is the subject of a Habitat Conservation Plan for Los Osos.

Other upland habitats include live oak woodlands, coastal and valley scrub, and grasslands. Given the strong seasonality of wet and dry weather in combination with the watershed's topography, plant communities within these broad habitat types can vary noticeably, such as those on north-facing versus south-facing hillsides or from valley floor versus ridges where orographic effects can enhance rainfall on the higher peaks and ridges. The prevalence or absence of coastal fog during warm, dry summers also affects plant communities.

There are other more specialized habitats within the watershed. Of particular interest are the serpentine outcroppings and soils whose chemical composition inhibits many common plant species and supports a high level of endemism. In sum, Morro Bay and its watershed encompass a suite of rich and highly diverse habitats. Each is described in more detail in later sections.

Morro Bay Habitat Mapping Overview

Several mapping efforts have occurred to determine vegetation types of the Morro Bay watershed and surrounding areas (Table 1). MBNEP used 2013 vegetation layers from San Luis Obispo (SLO) County based on 2007 imagery and habitat type layers from the Atlas of Sensitive Species (Sims, 2010) to create habitat maps in ArcGIS of the watershed. More in-depth and high-resolution mapping will be available by 2026 from the Coastal San Luis Resource Conservation District (CSLRCD), and habitat maps can be updated and compared to past habitat mapping efforts.

Table 1. Crosswalk of current vegetation mapping data sources.

Data Source	Year	Description and Methodology	Min. mapping unit
Atlas (Sims, 2010) with National Agriculture Imagery Program (NAIP) aerial imagery	1999 vegetation data in addition to 2005 aerial imagery	Selected habitats were produced by using NAIP 2005 aerial imagery, State Park inventories, ground truthing where access was allowed, and comparison of data with a pre-existing vegetation layer of the Estero Bay area created by San Luis Obispo (SLO) County and the Landscape Architecture GIS Lab of California Polytechnic State University in 1999.	Not specified

Data Source	Year	Description and Methodology	Min. mapping unit
SLO County	2013 using June 2007 imagery	The SLO County contracted Aerial Information Systems, Inc. in 2008 to create a baseline structural vegetation map and oak survey for the entire county based on 2007 imagery, encompassing roughly 2.2 million acres, adhering to the 2008 National Vegetation Classification System and the Manual of California Vegetation. Data was released in 2013 and is available here.	2 acres; 1 acre for critical wetland areas and land use
Fine Scale Mapping of SLO County from CSLRCD	Estimated 2026	This mapping effort will use most recent lidar data as well as California Native Plant Society (CNPS) surveys, calibration field work, machine learning, and expert human image interpretation to create a fine scale map of vegetation within SLO County.	¼ to 1 acre

Habitat types and areas were determined from existing from MBNEP documents (e.g. Comprehensive Conservation Management Plan; CCMP), state agency databases (e.g. California Department of Fish and Wildlife; CDFW), the Atlas of Sensitive Species (Sims, 2010), and from similar documents from other National Estuary Programs. The watershed is broken up into five habitat areas and 15 habitat types (Table 2). Habitat types were strategically grouped into habitat areas that align with management efforts and program goals for the watershed. Each habitat was mapped using existing data (SLO County, 2013 and Sims, 2010) to determine acreage extent and distribution throughout the watershed. Maps throughout this report were developed using ArcGIS Pro® mapping software. ArcGIS Pro® is the intellectual property of Esri and is used by MBNEP under a maintained license. Service layer credits for maps used throughout this report are as follows: San Luis Obispo County, Bureau of Land Management, Esri, HERE, Garmin, GeoTechnologies Inc., USGS, METI/NASA, NGA, EPA, USDA, and Maxar.

Table 2. Habitat areas and habitat types of Morro Bay Watershed

Habitat Areas	Habitat Types
Estuarine	Estuary (Open Water and Subtidal Channels, Eelgrass Beds, and Mudflats)
	Salt Marsh
Freshwater	Riparian and In-Stream

Habitat Areas	Habitat Types
	Freshwater Wetlands
Sandy Shores	Beaches
	Coastal Dunes (Foredunes and Backdunes)
Upland	Coast Oak Woodlands
	Maritime Chaparral
	Coastal Scrub
	Grasslands
	Other Chaparral and Scrub
	Other Habitats (Serpentine Outcrops and Soils, Dacite Outcrops, Sargent Cypress, Non-Native Woodlands: Monterey Pine/Cypress and Eucalyptus)
Urban Development and Irrigated Agricultural	Urban
	Irrigated Agricultural

Mapping Results

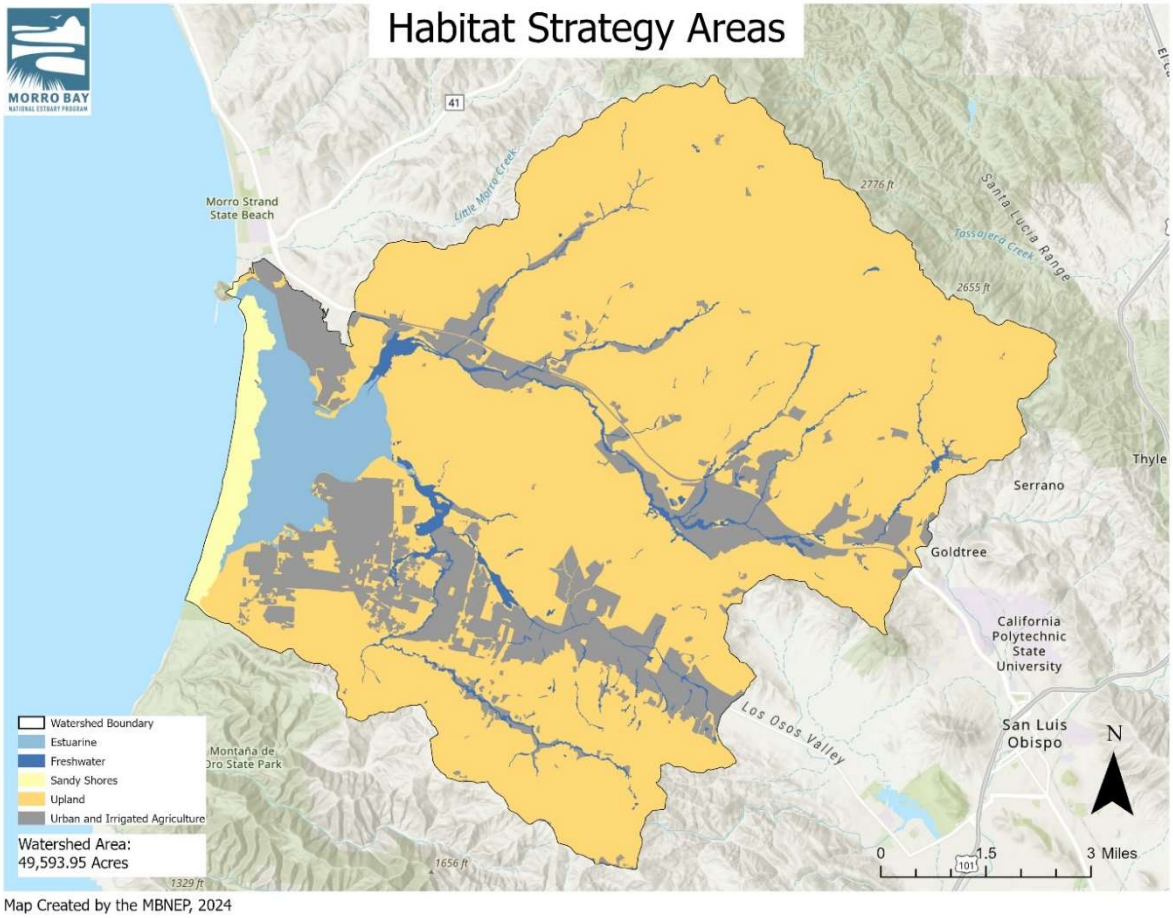


Figure 2. Habitat areas within the Morro Bay watershed, San Luis Obispo County, CA, USA.

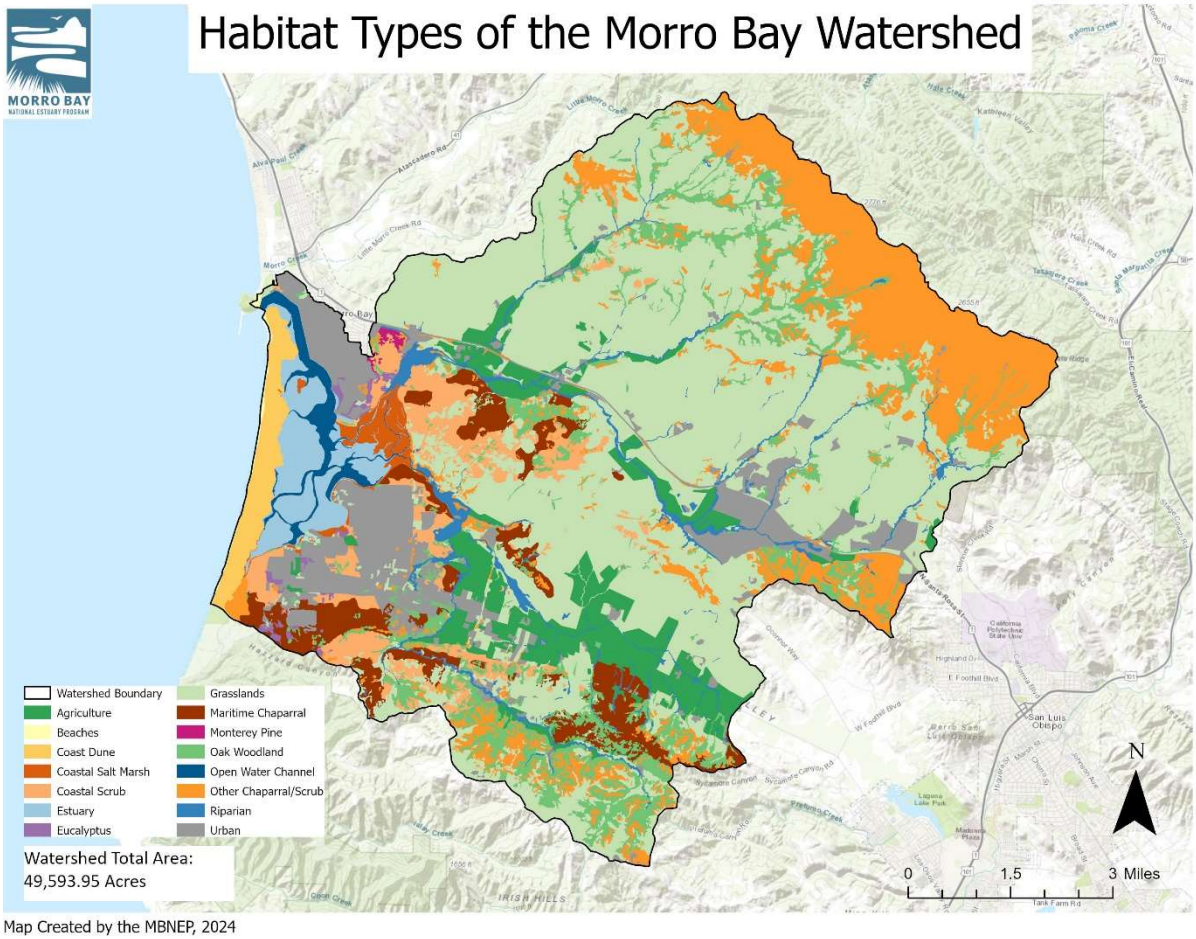


Figure 3. Habitat types of Morro Bay watershed.

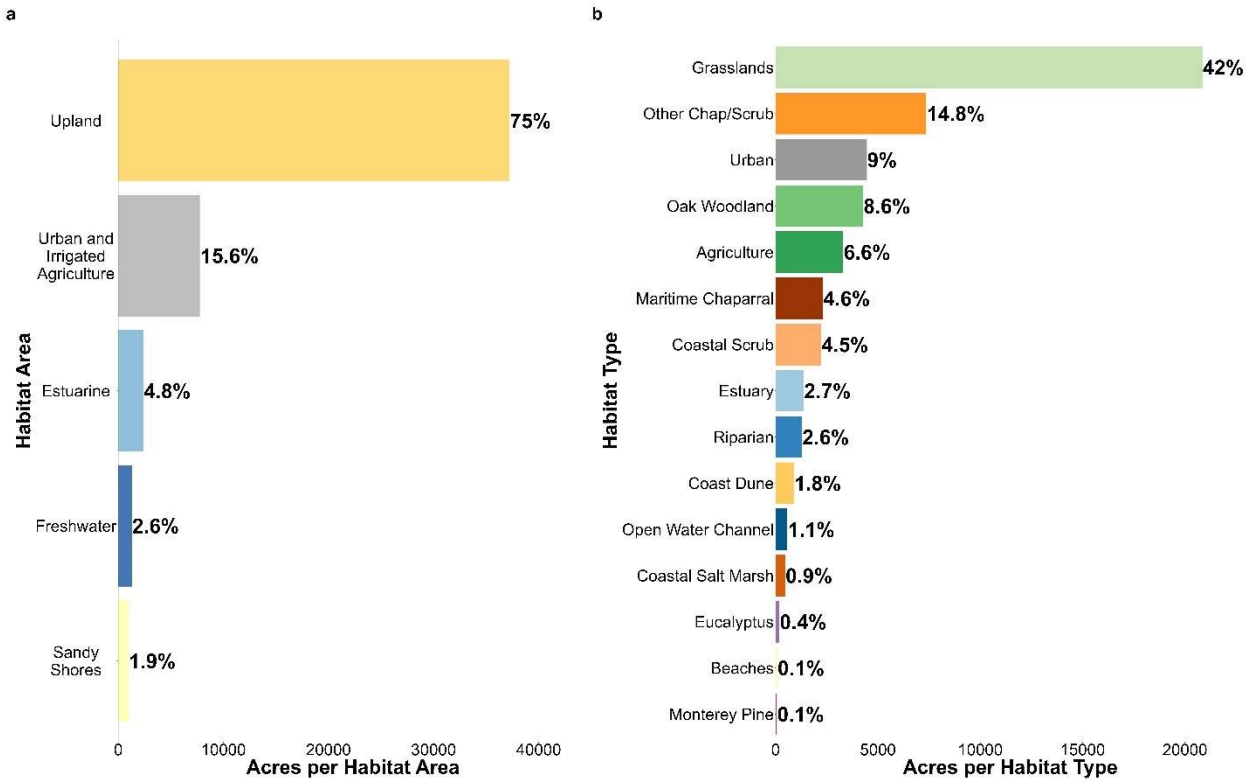


Figure 4. Acres and overall percentage of total watershed acreage within the Morro Bay watershed for each (a) habitat area and (b) habitat type.

Within the over 49,000-acre watershed, 37,216 acres or 75% of the watershed falls within upland habitat area (Figure 2; Figure 4). Irrigated agriculture and urban development cover 7,755 acres of the watershed, approximately 16% of the total watershed area. Estuarine habitat covers 2,391 acres, around 5% of the watershed area. Freshwater covers 1,275 acres, around 3% of the watershed, and sandy shores covers 957 acres, around 2% of the watershed. Grasslands are the most dominant habitat type within of the watershed with 20,854 acres or 42% of the watershed area (Figure 3; Figure 4).

Special Status Species

In 2010, the MBNEP and the California Department of Parks and Recreation (CSP) created a comprehensive *Atlas of Sensitive Species of the Morro Bay Area*. Authored by Aaron Sims, the *Atlas* includes accounts of habitat types and a catalog of the status, range, threats, and related data for over 90 plant, animal, and lichen species recognized as having some level of special concern by the federal or state governments as well as by nonprofits such as the California Native Plant Society. The *Atlas* provided a solid foundation for this Habitat Protection and Restoration Strategy ('Strategy'). For this Strategy, special status species is defined as any species designated as threatened or endangered by the federal and/or state of California governments (Table 3). Special status species identified in MBNEP's 2022 CCMP ECR-14: Support Recovery Plans were also included if they were not present in the *Atlas*.

Table 3. Names of special status species (state and/or federally threatened and endangered) in the Morro Bay watershed based on Atlas of Sensitive Species and MBNEP's 2022 CCMP ECR-14. Bolded or ***** species are of most concern for restoration and protection based on known current efforts in the watershed by MBNEP and partners. Bolded species have active focus in MBNEP projects. The ***** indicates species that partner organizations (e.g., Sea Otter Savvy, CSP, or CSLRCD) work more directly with.

State and/or Federal Threatened and Endangered Species	Status
Morro shoulderband snail, *Helmithoglypta walkeriana**	FT
Southern sea otter, *Enhydra lutris nereis**	FT
California red-legged frog, *Rana draytonii**	FT
Western snowy plover, *Charadrius nivosus nivosus**	FT
California black rail, *Iaterallus jamaicensis ssp. Coturniculus*	ST
Willow flycatcher, *Empidonax traillii*	SE
Morro Bay kangaroo rat, *Dipodomys heermanni*	SE/FE
South-Central California Coast steelhead trout, *Oncorhynchus mykiss**	FT
Tidewater goby, *Eucyclogobius newberryi**	FE
Morro manzanita, *Arctostaphylos morrensis**	FT
Salt marsh bird's beak, *Chloropyron maritimum ssp. maritimum**	SE/FE
Indian Knob mountainbalm, *Eriodictyon altissimum*	SE/FE
California seablite, *Suaeda californica*	FE
Beach spectacle pod, *Dithyrea maritima**	ST
Marsh sandwort, *Arenaria paludicola**	SE/FE
Chorro Creek bog thistle, *Cirsium fontinales var. obispoense**	SE/FE
Least Bell's vireo, *Viero bellii pusillus**	SE/FE
Marbled murrelet, *Brachyramphus marmoratus*	SE/FT

SE=state-listed endangered; ST= state-listed threatened; FT=federal-listed threatened; FE=federal-listed endangered. A full list of all biota with other sensitive status can be found in Atlas of Sensitive Species in Appendix A.

CDFW Natural Communities of Special Concern

CDFW has designated certain habitats as natural communities of special concern whose rarity and vulnerability warrant high priority for their protection and restoration. Projects affecting these communities must be evaluated pursuant to the California Environmental Quality Act (CEQA). Eelgrass beds are included on the list. The recent Los Osos Community Plan Update Environmental Impact Report (EIR) (SLO County, 2023) also noted the following natural communities of special concern in the Morro Bay area:

- Dune scrub
- Maritime chaparral
- Saltwater marsh

- Freshwater wetlands
- Riparian corridors

These habitats were included as habitat types within the strategy. Note, dune scrub is included in the coastal dune habitat type and riparian corridors are grouped with in-stream habitat type. Later sections discuss the locations, extent, and status of these habitats in more detail.

Relation to the CCMP and the Conservation Planning Initiative

The MBNEP's Comprehensive Conservation and Management Plan (CCMP) provides the overarching guidance for the program's goals, priorities and actions. The CCMP recognizes that the Morro Bay estuary and watershed "…sustain a resilient community with high habitat connectivity, ample biological integrity, and proper ecosystem functions…" and that "…water quality in the estuary and watershed support diverse habitats and wildlife populations."

Preserving biodiversity is an MBNEP priority issue aimed to "focus conservation efforts that provide critical habitat for sensitive species, high biodiversity patterns, essential ecosystem services and functions, and provide the greatest opportunity for biodiversity naturally in a changing and variable environment."

The CCMP called for the development of a Conservation Planning Initiative (CPI) that would identify effective indicators of ecosystem health that would also be practical to monitor. From 2017 to 2020, the MBNEP engaged a technical advisory committee comprised of local experts among state and federal agencies, academia, and nonprofits to determine measurable targets within Morro Bay's estuarine and freshwater habitats. The committee correlated CCMP goals with vital signs of habitat health and assessed a wide range of possible indicators. They recommended a subset for creek and estuary systems that included both "interim" and "ideal" measurable targets. The ideal targets represent long-term goals, and the interim targets are measures of the progress toward those goals. These indicators and targets have been incorporated where appropriate into the measurable objectives and targets in this Habitat Protection and Restoration Strategy. An excerpt from the CPI that shows the full range of potential indicators, and the ones selected for tracking purposes is included in Appendix A.

The CCMP spells out Action Plans, most of which are related to habitat protection and enhancement, either explicitly or indirectly. For each Action Plan, there is a timeframe for its implementation, measurable objectives, a list of partner agencies and other entities involved in the implementation, estimated costs and potential funding sources, and ways that the progress of the Action Plan can be assessed. The following table lists the CCMP Action Plans relevant to the different habitats in the Morro Bay watershed.

Table 4. CCMP Action Plans relevant to the Morro Bay watershed habitats

		Habitat Areas				
CCMP Code	CCMP	Estuarine	Freshwater	Sandy Shores and Dunes	Upland	Urban and Irrigated Agricultural
LP-1	Protect Special Habitats/Species	X	X		X	X
LP-3	Direct Urban Development				X	X
MON-1	Support Development of TMDLS	X	X			X
MON-2	Monitor Environmental Indicators	X	X			X
MON-3	Monitor Project Effectiveness	X	X	X		X
MON-4	Maintain VMP	X	X			X
MON-5	Support Partners	X	X	X	X	X
MON-6	Support Research Activities	X	X	X	X	X
BMP-1	Agricultural and Grazing BMPs		X		X	X
BMP-2	Rural Roads Erosion		X		X	X
BMP-5	BMPs by Private Landowners and Municipalities		X		X	X
BMP-6	Reduce Pet Waste	X	X	X	X	X
BMP-7	Support Stormwater BMPs	X	X		X	X
BMP-8	Harbor Operations BMPs	X				
BMP-9	Boating BMPs	X				
BMP-11	CMC Wastewater	X	X			X
BMP-12	MB Wastewater	X	X			X
ECR-1	In-stream Habitat		X			
ECR-3	Wetlands Protection and Enhancement		X			
ECR-4	Wetlands Habitat Assessment		X			
ECR-5	Sediment Traps	X	X			
ECR-6	Hydrology and Bathymetry	X	X			
ECR-7	Eelgrass Data and Research	X				
ECR-8	Eelgrass Restoration	X				
ECR-9	Regional and National Collaboration	X	X	X	X	X
ECR-10	Nutrients and Bacteria Dynamics	X	X			X
ECR-11	Conserve Ecosystem Functions	X	X	X	X	X
ECR-12	Upland Habitats				X	
ECR-13	Population Dynamics	X	X	X	X	X
ECR-14	Support Recovery Plans	X	X	X	X	X
ECR-15	Steelhead Barriers and Habitat	X	X			
ECR-16	Invasive Species Action Plan	X	X	X	X	X
FWR-1	Manage Freshwater Resources		X			X
FWR-3	Understand Flow for Public Trust Resources	X	X			X
FWR-4	Chorro Valley Water Users Group		X		X	X
FWR-5	Water Conservation		X		X	X
FWR-6	Groundwater Re-charge		X		X	X
CLIM-1	Improve Understanding of Climate Change Impacts	X	X	X	X	X
CLIM-2	Assist in the Implementation of Local Government Climate Action Plans	X	X	X	X	X
CLIM-3	Climate and Adaptation Education	X	X	X	X	X
USE-1	Recreational Uses	X	X	X	X	X
USE-2	Shellfish Farming	X				X
USE-3	Commercial Fishing Port Uses	X				X
USE-4	Morro Bay Power Plant	X				X
EO-1	Public Education and Outreach	X	X	X	X	X
EO-2	State of the Bay	X	X	X	X	X
EO-3	Nature Center	X	X	X	X	X
EO-4	Formal Education Programs	X	X	X	X	X

Past and current efforts at habitat protection

Widespread and substantial protection of the estuary and watershed natural habitats has been undertaken for decades by the MBNEP and its many partners. These partners have included local, state, and federal agencies; California Polytechnic State University, San Luis Obispo (Cal Poly); Cuesta College; numerous local and national nonprofits; and private property owners.

The main driver of most of these efforts has been to improve the water quality of the creeks and bay. One focus has been on reducing rates of sedimentation to the bay that has been accelerated due to alterations in the watershed. Examples of projects to address sedimentation include grazing best management practices (BMPs) such as riparian fencing and the use of rotational pastures; grade controls on unpaved ranch roads and riparian setbacks on agricultural lands; repair of scars from old mining operations; the installation of check dams; and revegetation of channels prone to erosion. Other significant efforts involve floodplain restorations, notably at Chorro Flats and the Chorro Creek Ecological Reserve (CCER) where large amounts of sediment have been captured upstream of the estuary and natural riparian communities are returning. On-going sediment monitoring and bathymetry surveys are being used to evaluate the efficacy of these efforts.

Other water quality projects have addressed toxic and bacterial contamination, nutrients, heavy metals, and low dissolved oxygen in the creeks and bay. In addition to work in the watershed, important elements of these efforts have been the use of BMPs for the harbor operations and municipalities around the bay. The MBNEP has a long-standing water quality monitoring program in place to track changes in these and other related parameters.

Another emphasis has been on the habitat value of the creek system, especially its importance to the threatened South-Central California Coast steelhead. Numerous projects have involved restoring in-creek and riparian habitat, removing barriers to fish migration and spawning, and controlling invasive fish species. The MBNEP conducts extensive on-going monitoring related to the health of the creeks.

The MBNEP also plays a pivotal role in tracking the health and extent of eelgrass habitat in the bay. Recently, a dramatic reduction in acreage occurred as documented by the MBNEP's ongoing eelgrass mapping and monitoring efforts. This triggered both a concerted effort among the MBNEP's partners to understand the causes of the decline, as well as efforts at restoration that involved hundreds of community volunteers. More recently, the eelgrass has rebounded beyond historic high levels. These events are discussed in more detail later in this report.

In one of the most significant efforts, the MBNEP supported and in some cases helped finance acquisition and protection of lands to create large green belts separating the community of Los Osos and the city of Morro Bay from the upper watershed, helping to protect most of the watershed open space. Environmentally significant habitats in private ownership have been acquired in-fee and turned over to public and nonprofit organizations for management. From 2000 to 2020, approximately 16,674 acres (33.6% of the total watershed) of undeveloped and

vulnerable open space was protected as public land. Other valuable habitat has been protected across 4,240 acres (8.55% of the total watershed) of conservation easements, some of which are monitored by the MBNEP. Currently, approximately half of the Chorro Creek watershed is under public ownership or conservation easements (Figure 5). Sandy shores and estuarine habitat areas have the most coverage of public ownership under management by the California Coastal Commission, CSP, State Lands Commission, and CDFW. The entire estuary is a protected and managed Marine Protected Area through its State Marine Reserve and Recreation Management Area designations (Figure 5). The majority of land that is protected is within the upland habitat area (Figure 6).

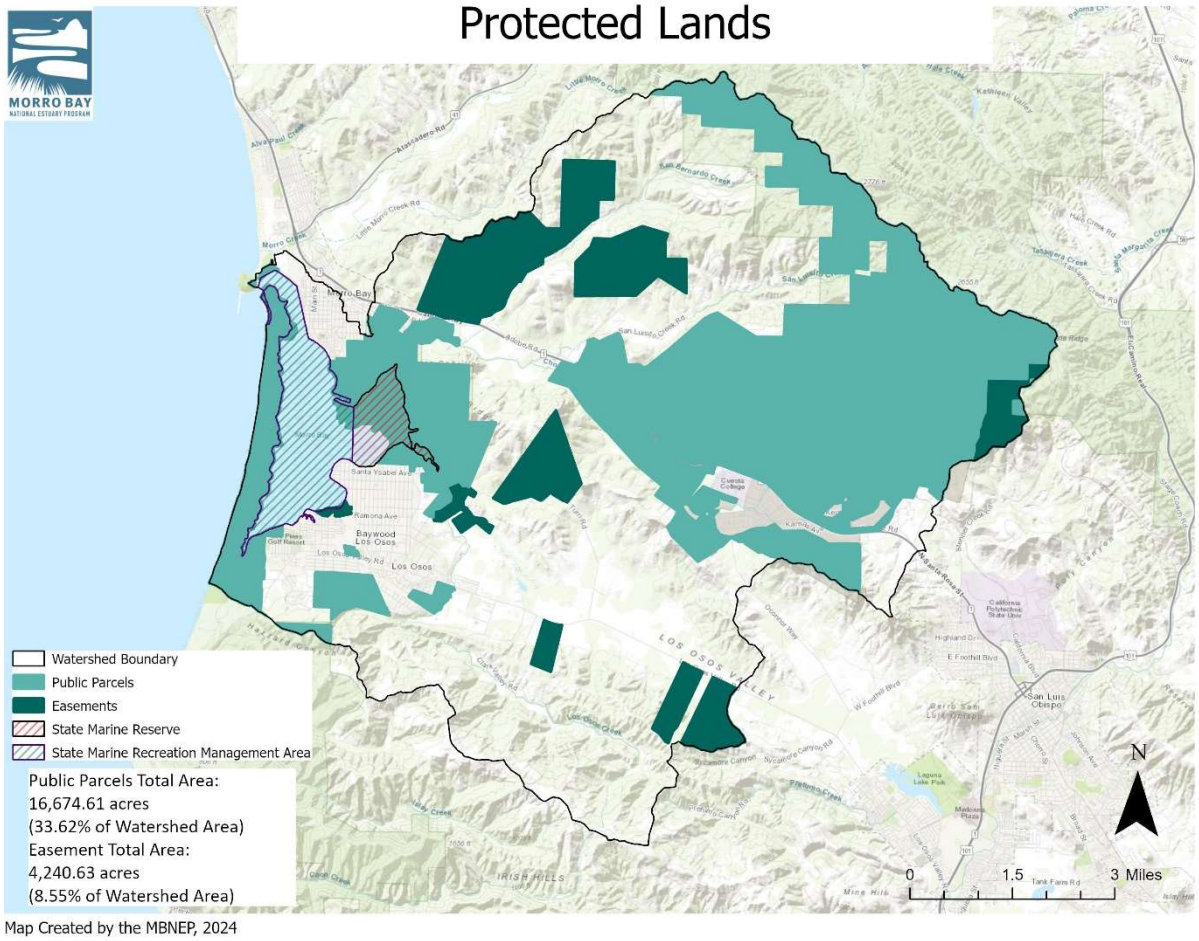


Figure 5. Protected lands via public ownership or conservation easements within the Morro Bay watershed. The Morro Bay estuary is protected under State Marine Reserve and Recreation Management Areas.

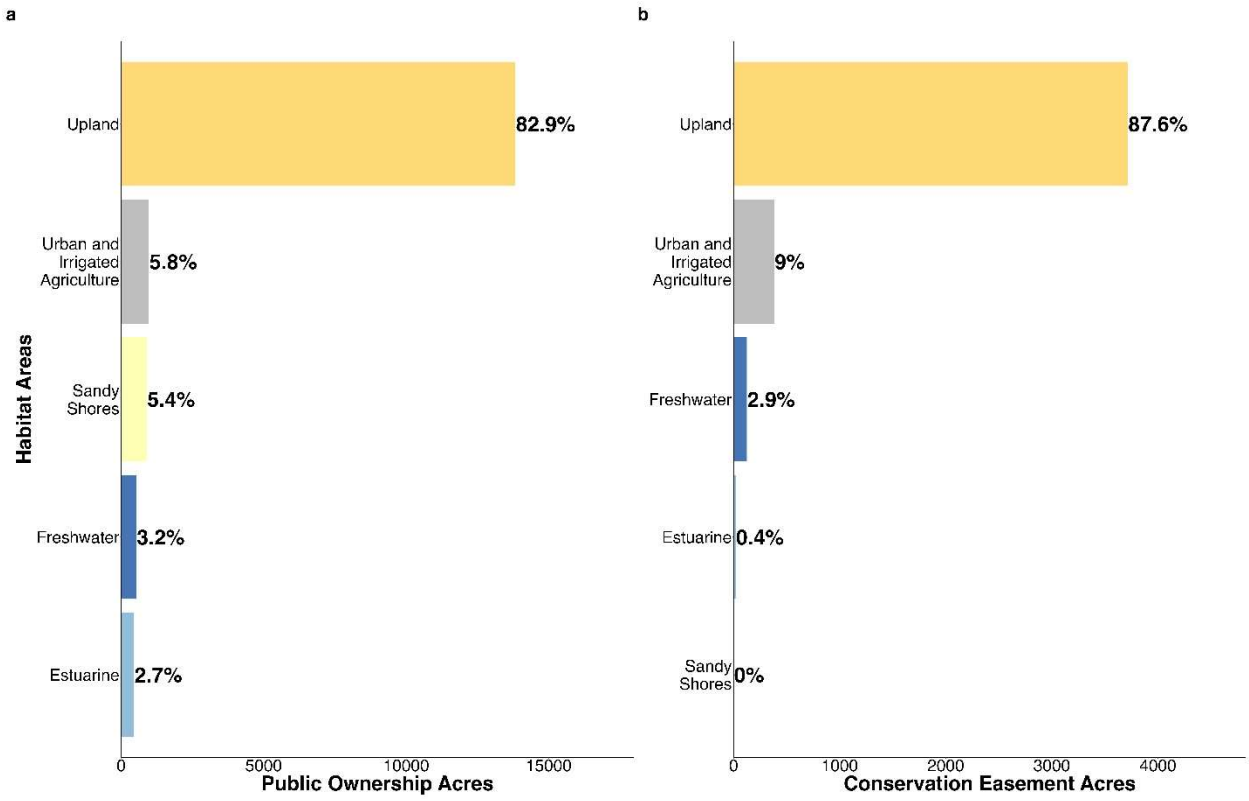


Figure 6. Acres and percentage of total protected land acres within (a) public ownership and (b) conservation easements within the Morro Bay watershed.

Environmentally sensitive habitat areas (ESHAs) in the estuary, dunes, and watershed have been explicitly recognized by the local governments and California Coastal Commission, who have adopted plans and regulations to ensure their protection from adverse impacts of development. A recent example is the updated Los Osos Community Plan, adopted by the County of San Luis Obispo, that explicitly addresses sensitive habitat in that area. A related layer of protection and habitat restoration is in the Los Osos Habitat Conservation Plan (HCP) that was developed concurrently with the Community Plan. Both the City of Morro Bay and the County of San Luis Obispo have adopted Local Coastal Programs (LCP) approved by the California Coastal Commission that cover the entire estuary and watershed. In addition to ESHA designation, certain features of the watershed are designated as Sensitive Resource Areas (SRA) by the County of San Luis Obispo. This designation overlays important habitats in the Morro Bay watershed, restricts activities in those areas, and requires a special level of analysis and permitting for land use proposals in such areas. ESHA and SRA designations are applied to many areas of the watershed including creeks, floodplains, riparian corridors, wetlands, woodlands, maritime chaparral, dunes, and dune scrubland, among others.

Another component of the MBNEP's habitat protection efforts has been its outreach and educational programs such as its State of the Bay reports, Bayside Living Guide, beach clean-ups and other volunteer opportunities, community events, and partnerships with local and regional

schools. The main purpose of these efforts is to increase awareness of the value of Morro Bay habitats and encourage stewardship.

Connectivity and Transitions

Maps of the different habitat types can give the impression that they are circumscribed by clear boundaries (Figure 3). However, especially among the upland habitats, vegetative communities often intergrade with one another on the edges and across jurisdictions. In many places, especially around Los Osos, the proximity of different plant suites can be characterized as forming "mosaics," for example with maritime chaparral, dune and valley scrub, and even oak woodlands sometimes transitioning from one to another with indistinct boundaries. In addition, some relatively distinct habitat types, such as riparian corridors and oak woodlands, cross others, such as scrub and grasslands, such that vegetative suites may intergrade at the edges.

Furthermore, while some faunal species are tied essentially to certain habitats and ecological conditions, others may utilize multiple ones and/or may traverse them from one preferred area to another. For those species, the preservation of wildlife corridors that provide connections to allow essential movement between habitat areas is an important component of management and preservation.

Climate Change Vulnerabilities

The MBNEP developed a detailed Climate Vulnerability Assessment (CVA) that projected how climate change will affect the Morro Bay estuary and watershed. The CVA found that in the Morro Bay area the following changes are expected to create new environmental stressors and/or exacerbate existing vulnerabilities:

- **Increasing Storminess**: Global climate modeling projecting out to 2100 suggests a wide range of precipitation outcomes for Morro Bay, but all models indicate that the frequency of large storm events will increase.
- **Warmer Annual Temperatures**: Climate models agree that temperatures will increase through the end of the century and that there will be greater instances of hot weather extremes and fewer of cold ones, with longer and more intense heat waves and prolonged summer-like seasons. Ocean temperatures are likewise expected to increase.
- **Increasing Droughts**: Modeling focused on the Morro Bay region suggests a less stable precipitation regime with wider variations from the annual average. This will not only result in periodically more intense storms and wet rainy seasons but also longer and more intense dry seasons. The resultant droughts will compound impacts from warmer temperatures.
- **Sea Level Rise**: Modeling also suggests that sea levels will rise as global temperatures increase. Locally, this will result in the inundation of low-lying areas around the estuary and the intrusion of sea water into nearshore freshwater regimes.
- **Ocean Acidification**: Ocean water is expected to become more acidic with increasing uptake of anthropogenic carbon dioxide from the atmosphere. Specifically, ocean pH is

expected to decrease by 0.3 to 0.4 by the year 2100 from 8.0 (Raven et al., 2005). Ocean acidification lowers the amount of carbonate ions available to calcifying organisms to build and maintain their shells. If the pH gets too low, shells and skeletons can even begin to dissolve, which would be significantly harmful to native and commercial shellfish, like in Morro Bay.

For each of these stressors, the CVA also identified a range of potential impacts which were then classified as "likely," "possible," and "not likely." This habitat strategy focuses on the likely impacts from climate change stressors in the Morro Bay area. The full range of impacts in the CVA, including those with greater degrees of uncertainty, are available on pages 47 to 84 in the 2021 CVA.

Report Organization

Descriptions of each of the principal habitat types in the estuary and watershed are accompanied by a list of some of **the most common plant species that typify the communities**.

For each habitat a summary of the most relevant **CCMP Action Plans** is included. The relationship of all the CCMP Action Plans to each of the habitat types is provided in Table 4.

Federally-threatened and endangered species found in each habitat are listed under individual habitat descriptions. Other sensitive species within habitats are included in the Atlas of Sensitive Species Appendix A.

The **location and extent of each habitat type** is described and mapped. Indicators of a habitat's health follow.

Some of the most important past and current **protection and restoration efforts** are highlighted.

Stressors on each habitat, emphasizing those likely to occur due to **climate change**, are discussed.

For each habitat, specific **measurable objectives and targets** for the next five to ten years are set with a summary of **implementation projects** that are currently underway or planned to help achieve those objectives.

A short discussion of how a particular habitat contributes to **climate change resiliency** follows.

Appendices A provides more information regarding the evaluation and selection process for habitat objectives and targets of the CPI process.

Overarching Objectives

There are three topics that intersect with all habitat types and areas that warrant more high-level overarching objectives: education and outreach, tribal engagement, and climate resiliency.

Community Engagement and Education: The MBNEP engages with community members in various forms to inspire human connections to the habitats of Morro Bay and its watershed, encourage behavior that benefits the environment, foster wider community participation in protecting and enhancing watershed resources, and communicate scientific research about changing conditions of the bay and watershed. The main community engagement and education initiatives listed below cover all habitat areas and types:

- Communications: This can include social media, newsletters, blogs, webpages, brochures, and annual reports. The MBNEP regularly communicates with the public via these methods about the habitats of the watershed and the work that the MBNEP does in these habitats.
- Outreach: The MBNEP provides outreach events that expand partners and community members' knowledge of the Morro Bay habitats, climate change, and climate adaptation. The MBNEP hosts and attends events throughout the year. Topics from any of the habitat objectives could be presented at these outreach events.
- Education: The MBNEP hosts field trips, conducts teacher training workshops, and works with local education partners to provide education on all habitats of the Morro Bay watershed. Specific curriculum and activities can be created to address any key issues for each habitat type.
    - Education Partners: The MBNEP works with many local environmental education groups to expand reach including Camp Ocean Pines, One Cool Earth, Cal Poly, Creek Lands Conservation, CSP, and local summer programs. In these partnerships, the MBNEP creates new curriculum, develops programs addressing key watershed education objectives, and expands teachings about the Morro Bay watershed.
- Estuary Program Nature Center: The MBNEP has a free public Nature Center near the MBNEP office. This Nature Center includes interactive exhibits, activities, and signage on Morro Bay's habitats and has over 20,000 visitors a year. Included in this space are two virtual kiosks that are regularly updated with new information, posters, and activities. The MBNEP also provides educational programming and outreach events in this space.
- Mutts for the Bay: This MBNEP effort provides eco-friendly pet ownership resources and educational information throughout the Morro Bay watershed and impacts all habitats

in the watershed. This program maintains 36 pet waste bag dispensers along beaches, trails, parks, open spaces, and urban spaces to encourage picking up after pets.

- Stewardship: The MBNEP hosts quarterly cleanups in the watershed and opportunistically hosts various restoration volunteer events. In addition to these events, the MBNEP strives to provide community science opportunities to expand stewardship actions in the Morro Bay watershed.

Tribal Engagement: The MBNEP recognizes the rich cultural history of the Morro Bay watershed that existed prior to the violent dispossession of land from Indigenous peoples by settler colonialism. All habitats within the Morro Bay watershed have ties to the ancestral, traditional, and contemporary lands of the yak titᵛu titᵛu yak tiłhini (ytt) Northern Chumash Tribe of San Luis Obispo County and Region, the Northern Chumash Tribal Council, and the Salinan Tribe, also known as T'epot'aha'l, "People of the Oaks". All tribal groups within the Morro Bay watershed are recognized by the State of California but are not federally-recognized. The MBNEP will engage with tribes who are traditionally and culturally affiliated to the project area as early as possible in any ground-disturbing project development to protect archaeological and cultural resources. The MBNEP will support work with tribes to enable traditional stewardship and cultural practices on ancestral land and co-management of their ancestral lands and natural resources, including regaining access to ancestral lands. The MBNEP will make efforts to incorporate Indigenous voices, leadership, and perspectives in planning and educational programs. The MBNEP will respect tribal knowledge and concerns in project and program development.

Climate Resiliency: Climate change impacts will affect all habitats within the Morro Bay watershed. The MBNEP will support local and regional research, planning, and partnerships that focus on improving climate resilience of human and ecological communities. Conservation of habitats and their ecological functions must incorporate and consider climate change impacts, fire management, and current and future land uses. Some additional example adaptation actions conducted by the MBNEP and partners can be found on pages 107 to 109 of the MBNEP's 2021 Climate Vulnerability Assessment and are summarized below in Table 5.

Table 5. 2021 CVA climate adaptation actions applied to CCMP action plans and habitat areas. Bolded actions are a focus of current/past MBNEP projects. The * indicates partners' focus.

2021 CVA Climate Adaptation Action	CCMP Codes Associated	Estuarine	Freshwater	Sandy Shores	Upland	Urban and Irrigated Ag
Bioswale creation	ECR-5, BMP-5, BMP-7, FWR-6					X
Dune stabilization	ECR-11, ECR-12			X		
Eelgrass planting	ECR-8, ECR-11	X				
Education on herbicide and pesticide alternatives	ECR-10, EO-1, EO-2, EO-3, EO-4	X	X		X	X
Erosion control measures	MON-1, ECR-5, BMP-5, BMP-7, ECR-15	X	X	X	X	X
Plant migration faciliation	ECR-11, CLIM-1	X	X	X	X	X
Floodplain restoration	LP-1, MON-2, MON-3, ECR-1, ECR-3, ECR-5, ECR-6, ECR-15, FWR-6		X			
Upland area grading to prevent wetland loss *	ECR-3, ECR-4	X	X			
Invasive plant species removal	ECR-9, ECR-14, ECR-16	X	X	X	X	X
Maintenance of physical conditions that support eelgrass habitat	ECR-7, ECR-8	X				
Levee removal projects	MON-2, ECR-3, ECR-6, ECR-15		X			
Large woody debris installation	ECR-1, ECR-15		X			
Riparian corridor maintenance	ECR-3, ECR-4, ECR-14, ECR-15		X			
On-farm BMPs	BMP-1, BMP-2, BMP-5, ECR-12				X	X
Percolation projects *	FWR-6					X
Drought tolerant and native plant use	BMP-1, ECR-12	X	X	X	X	X
Evergreen, resilient shade tree planting in upland tributaries	BMP-1, ECR-12		X		X	
Fire tolerant native plant use	BMP-1, ECR-12	X	X	X	X	X
Drought tolerant plant species use to maintain soil moisture	BMP-1, ECR-12	X	X	X	X	X
Prescribed grazing/fires *	ECR-12		X	X	X	X
Rainwater harvesting	BMP-11, FWR-5, FWR-6		X			X
Fuel load reduction work w/ CalFire *	ECR-12		X	X	X	X
Riparian fencing	MON-3, BMP-1, BMP-2, BMP-5, ECR-1, ECR-12		X			
Road erosion repairs	BMP-1, BMP-2		X		X	X
Sediment augmentation to tidal marsh for SLR	ECR-3, ECR-11	X				
Stormwater management	LP-3, BMP-5, BMP-7, ECR-10, FWR-6					X
Stream shading	ECR-1, ECR-3, ECR-14, ECR-15		X			
Local planning effort support to protect migration areas from development and encourage climate-smart growth	LP-1, LP-2, BMP-11, BMP 12, ECR-9, CLIM-2, USE-4	X	X	X	X	X
Collaboration with CDFW and CSP on mitigation efforts	MON-5, MON-6, ECR-9	X	X	X	X	X
Water conservation	FWR-1, FWR-4, FWR-5, FWR-6					X
Stream buffer widening	BMP-1, ECR-1, ECR-3		X			

THE HABITATS OF MORRO BAY ESTUARY AND WATERSHED

Estuarine

Estuarine communities occur where the ocean mixes with fresh water from the streams within a partially enclosed bay. Estuaries are characterized as having brackish waters with varying degrees of salinity, protection from ocean wave action and winds, and bay bottom sediments that often form thick mud (Holland and Keil, 1995). The Morro Bay estuary is a classic example as it is heavily influenced by stream inputs and tides (Gleason et al., 2011).

Salinity in the Morro Bay estuary's habitats varies significantly due to regular fluctuations of high and low tides and with seasonal changes in precipitation and streamflow. Rainy winter months generally dilute the salt content as fresh water drains from land, and in summer months decreased stream flow results in salinity increases (Holland and Keil, 1995). Consequently, many of the biota that thrive in the estuary are species that can tolerate this variation in salinity, as well as periods of both prolonged inundation and intermittent exposure.

Water temperature, salinity, dissolved oxygen, and pH vary spatially throughout the estuary. On average, these parameters exhibit gradients of change with increasing distance from the mouth of the estuary, although pockets of biological activity and small-scale physical processes create a high degree of spatial heterogeneity. For the majority of the year, temperature increases and salinity decreases from the mouth to the back of the estuary. However, the back bay experiences hypersaline conditions in summer due to longer flushing times (time it takes to exchange water masses in the bay with the ocean) and increased evaporation (Bartoloni et al., 2023; Taherkhani et al., 2023). The pH and dissolved oxygen concentrations follow similar seasonal trends, with the highest values in the winter and lowest values in the summer. Generally, the back of the estuary displays higher intra-monthly variability indicative of stronger biological modification due to photosynthesis and respiration (Bartoloni et al., 2023; State of the Bay, 2023; Bockmon and Walter, 2022). This variability affects the habitat suitability for different plant communities and associated fauna in different parts of the bay.

Coastal estuarine habitats cover the entirety of the Morro Bay estuary and can be categorized as open water and subtidal channels, eelgrass beds, intertidal mud flats, and salt marsh. While each of these habitats has unique characteristics, they are interconnected and changing over time. Open water areas receive sediment and eventually become mudflats, while mudflats gradually accumulate sediment and transition to salt marsh. Ongoing monitoring of eelgrass beds in Morro Bay has revealed a remarkable degree of variation in coverage, at times thriving on hundreds of acres and at other times declining to yield extensive mudflats.

Expanding Views on Sediment Management: In Morro Bay, sediment naturally washes from the uplands, down the creeks, and into the bay. Human activities can greatly increase erosion, sending an excess of sediment into the bay. The MBNEP works with landowners in the watershed on projects to reduce erosion and trap sediment before it can degrade downstream habitats.

However, climate change and sea level rise pose a paradigm shift for salt marsh habitats. While large sediment inputs can directly smother eelgrass and degrade habitats, climate models indicate that tidal marsh elevation gains will not keep pace with future projected sea level rise. This could mean that higher water levels will swamp the low marsh habitat, converting it to mudflats by the end of the century (Thorne et al., 2018). To maintain the existing estuarine habitat complex over time with sea level rise, more research and monitoring is needed to address the vulnerability of estuarine habitats and inform management actions. In similar systems, sediment augmentation is a management tool to maintain salt marsh habitat extent.

CCMP Action Plans

The CCMP specifically calls for the conservation and restoration of estuarine habitats through the following Action Plans:

- (ECR-3) Wetlands Protection and Enhancement
- (ECR-4) Wetlands Habitat Assessment
- (ECR-5) Sediment Traps
- (ECR-6) Hydrology and Bathymetry
- (ECR-7 Eelgrass Data and Research
- (ECR-8) Eelgrass Restoration
- (ECR-9) Regional and National Collaboration
- (ECR-10) Nutrient and Bacteria Dynamics
- (ECR-11) Conserve Ecosystem Functions

In addition, several other CCMP action plans are relevant to estuarine habitats:

CCMP Action Plan Number	CCMP Action Plan
LP-1	Protect Special Habitats/Species
MON-1	Support Development of TMDLS
MON-2	Monitor Environmental Indicators
MON-3	Monitor Project Effectiveness
MON-4	Maintain VMP
MON-5	Support Partners
MON-6	Support Research Activities
BMP-6	Reduce Pet Waste
BMP-7	Support Stormwater BMPs
BMP-8	Harbor Operations BMPs
BMP-9	Boating BMPs
BMP-11	CMC Wastewater
BMP-12	MB Wastewater

CCMP Action Plan Number	CCMP Action Plan
ECR-13	Population Dynamics
ECR-14	Support Recovery Plans
ECR-15	Steelhead Barriers and Habitat
ECR-16	Invasive Species Action Plan
FWR-3	Understand Flow for Public Trust Resources
CLIM-1	Improve Understanding of Climate Change Impacts
CLIM-2	Assist in the Implementation of Local Government Climate Action Plans
CLIM-3	Climate and Adaptation Education
USE-1	Recreational Uses
USE-2	Shellfish Farming
USE-3	Commercial Fishing Port Uses
USE-4	Morro Bay Power Plant
EO-1	Public Education and Outreach
EO-2	State of the Bay
EO-3	Nature Center
EO-4	Formal Education Programs

Habitat Description: Subtidal and Open Water Environments and Eelgrass Beds

During high tides, Morro Bay receives large volumes of ocean water, inundating much of the estuary. As tides recede, the bay bottom is exposed in many areas as intertidal mudflats. Relatively deep channels are naturally created by stream inflow, tidal action, and regular dredging for navigability. These provide an underwater habitat that is subject to both changing salinity and strong tidal flows. A rich array of biota inhabits this environment including several species of fish (e.g., perch, smelt, and rays) and invertebrates (e.g., sea hares, snails, and crabs). The bay is also home to three species of marine mammals: harbor seals, California sea lions, and southern sea otters.

Numerous avian species use the waters of the bay for food, resting, and over-wintering. Brant geese are known grazers of eelgrass within the estuary, and terns, gulls, kingfishers, ospreys, pelicans, cormorants, grebes, and loons forage the bay. Many duck species are commonly seen on the bay including buffleheads, teals, shovelers, mergansers, and scoters. Morro Bay is a critical stop on the Pacific Flyway, and many types of shorebirds and waterfowl as well as some passerine species overwinter here.

A small area of giant kelp (*Macrocystis pyrifera*) grows on the north side of the main harbor channel near Morro Rock. These algae are often used by sea otters who entwine themselves in

the floating fronds when sleeping. The kelp itself forms a habitat for crabs and other invertebrates.

One of the most notable estuarine habitats in Morro Bay is its eelgrass beds. Eelgrass (*Zostera marina*) grows in the bay's intertidal and subtidal areas to a depth of approximately -6 feet mean high tide and can tolerate short-term exposure above the water line during receding tides. Morro Bay's eelgrass beds are among the most significant in Central and Southern California, and they are considered an indicator of the health of the bay.

Eelgrass is a flowering plant that roots in the bay floor, serving many important ecological functions. Eelgrass stabilizes the bay floor which decreases turbidity from tidal action, contributes oxygen into the water column, and provides shelter and foraging habitat for a wide variety of aquatic life. Eelgrass serves as nurseries for rockfish and flatfish among many other animals. Some of the larger fish common in eelgrass beds are different species of rays, leopard sharks, and pipefish.

The bay's eelgrass beds were thought to be relatively stable from 1970 to the mid-1990s with about 400 to 500 acres. But in the 1994 to 1995 season there was a dramatic loss in acreage attributed to an extraordinary pulse of sediment entering the bay. That year the "Highway 41" wildfire that burned over one-third of the Chorro Creek watershed was followed by heavy spring rains. The resultant sediment delivered from Chorro Creek literally buried many of the eelgrass beds. Over time, eelgrass beds largely recovered with total acreage fluctuating from year to year. In 2007, the MBNEP mapped approximately 344 acres of eelgrass. But over the next decade, the beds dwindled drastically. The biggest decline occurred between 2010 and 2013, where 90% of eelgrass was lost within the bay. Four years later in 2017, only 13 acres of eelgrass could be found. It is not clear the exact cause(s) that lead to the collapse of eelgrass acreage given the lack of comprehensive baseline monitoring prior and during the decline (Walter et al., 2018).

The MBNEP worked with Cal Poly researchers to expand water quality monitoring in the estuary to better understand the lack of eelgrass recovery following the 2010 collapse. The results showed that gradients in environmental conditions driven by bay hydrodynamics may have prevented eelgrass recovery within the mid and back bay (Walter et al., 2018). Specifically, during summer and early fall of 2016, water quality sensors deployed in the mid and back bay indicated warmer, less oxygenated, more turbid, less circulation, and higher saline conditions (Walter et al., 2018). These conditions are less conducive to eelgrass recovery. In addition, temperature increases from 2014 to 2016 with the Northeast Pacific Marine Heatwave, nicknamed 'the Blob,' coupled with El Niño conditions could have exacerbated local effects that further prevented eelgrass recovery.

At the nadir of the die-off, various restoration efforts were undertaken by the MBNEP and many volunteers. Over a five-year period (2017 to 2022), nearly 15,000 plants were harvested from healthy beds and transplanted throughout the bay. Through this experience, considerable

data were gathered regarding the optimal time of year, depth and location of source beds, location of receiver beds, and anchoring methods. In total, 83% of restoration sites saw an increase in eelgrass growth (MBNEP, 2023). These restoration efforts created nodes of healthy eelgrass from which beds could expand via root growth and seed dispersal.

From 2017 to 2023, the beds experienced a rapid and robust regeneration so that by 2021, there were 500 acres of eelgrass and by 2023 approximately 750 acres were mapped. While restoration work certainly contributed to the recovery, its extent and rapidity suggested that other factors were also critical. The MBNEP, Cal Poly, and other partners studied the potential causes of the eelgrass recovery and developed several hypotheses. One is the widespread erosion that occurred after eelgrass loss created ideal conditions for eelgrass to re-establish at more optimal tidal ranges (Walter et al., 2020). In addition, cooler air and water temperatures associated with La Niña conditions from 2020 to 2023 (California Department of Water Resources, 2023) may have allowed for eelgrass to expand at tidal ranges that are usually not suitable for eelgrass. High seeding rates of restored beds were also observed, which is a sign of eelgrass resilience (Vercaemer et al., 2021) that may have contributed to the rapid increase in eelgrass beds within a short period. However, the correlation between estuarine-specific eelgrass genetics (e.g., seed production) and recovery capacity due to environmental stressors like climate change is not definitive.

Currently the estuary is supporting more eelgrass acreage than in recorded history and is likely approaching a maximum spatial extent in the bay (Merkel and Associates, 2024). It is predicted that eelgrass habitat will fluctuate with changing climatic conditions (e.g., warmer temperatures). The MBNEP is continuing to map eelgrass extent and monitor eelgrass health (e.g., density, signs of disease, eelgrass flowering, and seed production) at long-term monitoring sites to help inform future management of eelgrass habitat. Major deviations from current conditions can be indicators of a stress response. By tracking eelgrass health and mapping eelgrass extent for an impending decline, the MBNEP and its partners are better situated to respond with monitoring, research, and restoration efforts.

Habitat Description: Mudflats and Salt Marsh

Much of the bay below the mean high tide line and outside the subtidal channels is comprised of mudflats, an important habitat for numerous invertebrate species such as ghost shrimp, moon snails, worms, crabs, and clams. Mudflats intergrade with the saltwater marsh of the delta and Grassy Island, as well as along portions of the sandspit shoreline.

Wetland habitats are increasingly rare around the world, and particularly in coastal California. More than 90 percent of California's historic coastal wetlands have been lost or highly altered. Morro Bay represents one of the largest relatively pristine and intact coastal wetlands complexes in the southern portion of the state. In Morro Bay both coastal salt marsh and freshwater marsh wetland habitats occur.

Coastal salt marshes occur throughout fringes of the Morro Bay estuary, notably at locations along the shore of the sandspit and Shark Inlet, in Sweet Springs Nature Preserve, and in the upper portion of the salt marsh delta formed by the confluence of Chorro and Los Osos Creeks. At Sweet Springs and in the upper delta, salt marsh intergrades with freshwater marsh and riparian habitats. Plant diversity within coastal salt marsh tends to be lower than other communities because few species can tolerate the high amounts and fluctuations of salinity. Plants of coastal salt marsh are mostly herbaceous perennials that are halophytic (adapted to growing in saline conditions), and generally short statured with reduced leaves. In addition, many species of this community type have aerenchyma (tissues with many air cavities), which allow plants to respire in environments with low oxygen. Some species have salt glands that allow excess salts to be excreted. Other species have cells that contain high concentrations of dissolved solutes, allowing them to absorb water without osmotic imbalances (Holland and Keil, 1995). Common native plants in the Morro Bay salt marsh include widespread pickleweed, saltbush, sedges, rushes, and salt grass.

The mudflat/salt marsh complex in Morro Bay is a critical feeding and resting habitat for numerous migratory birds that travel the Pacific Flyway each year, as well as year-round habitat for resident shorebird species. The Pacific Flyway is one of four major migratory routes in North America, and Morro Bay is an important stop for birds traveling south along the West Coast. The protected wetlands of Morro Bay are used by nearly two hundred different bird species every winter, some of them threatened or endangered (National Audubon Society, 2010). Some sensitive species that use Morro Bay include the brown pelican, American peregrine falcon, and black brant geese (Sims, 2010). Salt marsh extent has changed over time and in general has expanded further into the estuary and along Los Osos Creek. A current historical ecology study is analyzing the past salt marsh extent and impacts of watershed land use changes on salt marsh habitat to inform future management.

Vegetation Species Typifying Salt Marsh Habitat

Common Name	Scientific Name
Arrowgrass	*Triglochin concinna*
California sea lavender	*Limonium californicum*
Fleshy jaumea	*Jaumea carnosa*
Pickleweed	*Salicornia pacifica*
Rush	*Juncas* spp.
Salt grass	*Distichlis spicata*
Saltbush	*Atriplex* spp.
Sea heather	*Frankenia salina*

State and Federal Threatened and Endangered Species of the Estuarine Habitats

- Southern sea otter (FT)
- California black rail (ST)
- South-Central California Coast steelhead trout (FT)
- Tidewater goby (FE)
- Salt marsh bird's beak (SE/FE)
- Indian Knob mountainbalm (SE/FE)
- California seablite (FE)
- Marsh sandwort (SE/FE)
- Marbled murrelet (SE/FT)

Habitat Extent: Figure 7 illustrates the estuary, open channel, and salt marsh habitats of the Morro Bay watershed. Estuary and open water channels account for 1,933 acres and coastal salt marsh accounts for 458 acres for a total of 2,391 acres (4.8 %) of the watershed.

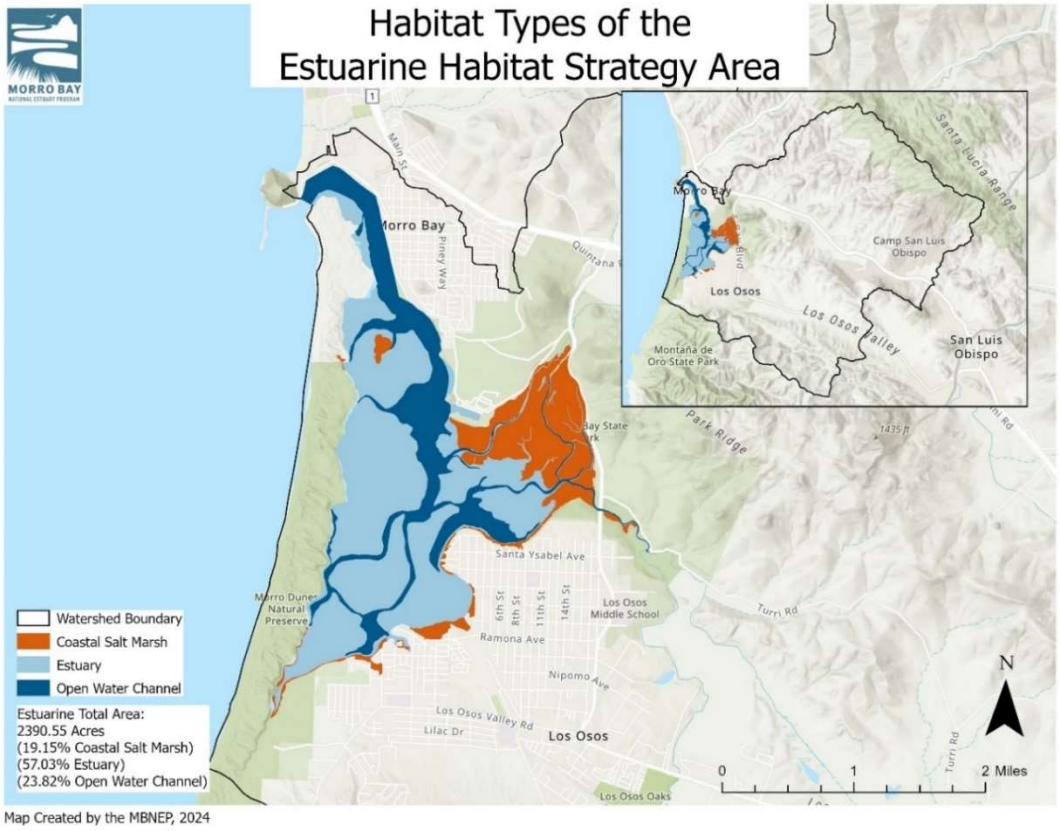


Figure 7. Estuarine habitat type of coastal salt marsh, estuary (subtidal and eelgrass habitat), and open water channel location and cover within the Morro Bay watershed. Percentages are relative to the estuarine habitat area.

As discussed above, eelgrass acreage has been widely variable, with a recorded low of only 13 acres in 2017 and a strong rebound more recently to 750 acres (Figure 8). Historical eelgrass acreage has widely fluctuated since initial surveys were completed in 1960. From 1960-2000,

eelgrass ranged from 98-335 acres and from 2001-2023 ranged from 13 to 750 acres (mapping methods have varied overtime). While many conditions determine suitability for eelgrass habitat (e.g., water quality), MBNEP and partners have focused on suitable depth being a key factor. In 2021, the eelgrass restoration target was determined based on multiplying the percent of eelgrass coverage during the most recent peak (observed in 2007 at 344 acres) and total available area from the 2019 bathymetry and within the -6 to 1.5' typical occurrence depth range (Tetra Tech, 2021, Table 4). This resulted in an ideal restoration target of 313 acres (Tetra Tech, 2021). Since 2021, eelgrass acreage has exceeded the target and recovered beyond any other known mapping effort since 1960. Ongoing monitoring is conducted to better understand conditions in the bay as it relates to eelgrass health. If acreage falls to 50% of 313 target (156 acres), restoration work may be considered again, in consultation with various partners and current research about causes and effectiveness of restoration.

Figure 8. Changes in relative eelgrass acreage in Morro Bay from 2007 to 2023. Note that the eelgrass extent for 2007 and 2017 was analyzed with multispectral imagery, and the extent for 2023 was analyzed using a combination of sonar and drone surveys.

Habitat Health: The CPI task force evaluated the "vital signs" of Morro Bay's estuarine system health linked specifically to the rate of sedimentation, eelgrass acreage, and tidal marsh coverage. For these vital signs, a range of indicators was discussed, and a subset was identified that would be most meaningful and practical to monitor over time. These have been incorporated into the objectives listed in a later section.

Protection and Restoration Efforts

The most important protection and restoration efforts of Morro Bay's estuarine habitats have been the various actions to reduce sedimentation and improve water quality, many of which

have occurred upstream of the bay. The primary purpose of the CCMP is to address these priority issues and direct the implementation of action plans. Many action plans have been accomplished and many others are ongoing. With future sea level rise and climate change, more research is needed to make management decisions on sediment dynamics to maintain estuarine habitats over time.

In the early 2000s, the MBNEP partnered with U.S. Army Corps of Engineers (ACOE) to investigate the possibility of in-bay habitat restoration projects, including dredging portions of the back bay, creating salt marsh "islands," and deepening tidal channels to increase tidal flushing. The ACOE study found that the estuarine habitats are inextricably linked such that expanding one could only occur at the loss of another and that disrupting that balance did not have clear ecological benefits. After detailed analysis, the study concluded that the potential benefits did not outweigh the significant and unavoidable adverse environmental impacts and that efforts to improve the estuary's habitat potential would be better spent on work in the watershed, such as reducing erosion and re-creating sediment trapping floodplains. Some highlights of this approach include floodplain restoration projects at Chorro Flats, Chorro Creek Ecological Reserve, and Los Osos Creek Wetland Preserve. The CSLRCD has estimated that the Chorro Flats project alone, implemented in 2001, has up to 610,000 tons of sediment capture potential over a 35-year period by trapping sediment that would otherwise have entered the bay.

The MBNEP and partners monitor changes to the habitat regime in the estuary. Parameters include the areal extent, surface elevation, and accretion rates in the salt marsh, bay bathymetry, tidal flushing, and retention rates for different parts of the bay, and water quality conditions including *Enterococcus* concentrations, temperature, salinity, chlorophyll, conductivity, pH, depth, turbidity, and dissolved oxygen (DO) levels.

As noted earlier, the MBNEP has conducted extensive eelgrass monitoring and restoration efforts. If another significant decline occurs, restoration work may be re-initiated using the methods found to be most effective during the last restoration experience. Meanwhile, the MBNEP has supported research by Cal Poly and others to better understand the underlying reasons for eelgrass bed fluctuations in Morro Bay.

Examples of ongoing in-bay and near-bay water quality projects include the distribution of pet waste bags to reduce bacterial pollution, the facilitation of harbor management BMPs, work with the local municipalities on storm water pollution reduction, and the MBNEP's many public outreach and educational programs to encourage residents and visitors to minimize their impact on the bay.

Other recent projects include updated fish surveys to see how the eelgrass loss and recovery may have affected populations, phytoplankton diversity and concentrations monitoring, and macroalgae monitoring to track extent on the mudflats and eelgrass beds.

Within the salt marsh, recent efforts with CSP and the Land Conservancy of San Luis Obispo County have reduced the presence of invasive European sea lavender (*Limonium durisusculum*) that can outcompete native marsh plants like California sea lavender (*Limonium californicum*) and endangered salt marsh bird's beak.

Over the past 20 years, University of San Francisco and USGS have tracked sediment accretion rates of the tidal marsh near Chorro Creek using surface elevation tables and marker horizon plots. USGS sediment monitoring has occurred every five years or more frequently as funding allows. A current project with USGS is modeling habitat vulnerability under a range of sea level rise and sediment scenarios. This study will inform the feasibility and future targets for adaptive management, such as sediment augmentation, to maintain tidal marsh habitat overtime with increasing climate change.

Stressors and Climate Vulnerabilities

Morro Bay's estuarine habitats will continue to be impacted by changes in sediment supply to the estuary. Sediment supply is crucial to maintaining salt marsh elevation with sea level rise, but too much sediment at once can negatively impact eelgrass and steelhead.

Other stressors will be water quality degradation, mostly from nearshore and upstream land uses that include urban runoff, bacteria and nutrients in the creeks from grazing land and agricultural operations, and sewage spills from wastewater treatment and boats.

Invasive species can negatively impact native salt marsh vegetation. Iceplant and European sea lavender can threaten native plant species and sensitive species habitat like salt marsh bird's beak and California seablite. In addition, invasive feral pigs can be significantly destructive to the salt marsh habitat.

These impacts from land use may be exacerbated by climate change in the coming decades:

- **Increasing storminess (more frequent, larger precipitation events)** will likely increase sedimentation rates, with excess sediment negatively impacting sensitive habitats like eelgrass and steelhead habitat. These larger events cause peaks in pollution carried by runoff from upland areas, especially from agriculture and urban areas. Increased storm surge can also increase erosion and quickly alter shoreline and coastal habitat edges.
- **Warmer temperatures** will likely increase algal blooms, provide favorable conditions for bacteria, and possibly diminish the viability of eelgrass as it does better in cooler waters. Increased harmful algal blooms fueled by warmer temperatures have wide-reaching impacts on marine mammals, seabirds, and coastal economic systems, especially commercial fisheries and tourism (Moore et al., 2020). A warming climate is expected to alter migration cycles or mistime food supplies for some avian species, resulting in lower survival rates. Hotter and more frequent terrestrial heat waves may increase intertidal organism mortality when timed with low tides (Raymond et al., 2022).

- **Increasing drought** is likely to adversely affect salt marsh habitat and increase moisture and temperature stresses on salt marsh species. In addition, increased drought conditions will reduce the amount of sediment input to the estuary. Without the sediment input, salt marsh elevation would not increase to keep pace with sea level rise. Drought can also alter foraging patterns of feral pigs and increase their use of the tidal marsh, leading to habitat degradation.
- **Sea level rise** will likely increase the inundation frequency of the salt marsh, pushing this habitat farther upstream and inland. The salinity throughout the estuary will be altered, affecting various species sensitive to such changes. Initially as sea levels rise, areas suitable for eelgrass may increase and back bay water circulation may improve. But if, as predicted by the end of the century, ocean levels rise beyond ideal tidal range for eelgrass, some of these benefits may be lost. Some negative effects of sedimentation in the estuary may be alleviated by raising the water levels, but the current sediment inputs are not expected to be enough for estuary habitats to keep pace without adaptation efforts (e.g., sediment augmentation). Tidal marsh habitat is expected to transition towards more mudflat habitat by the end of the century with three feet of sea level rise (Thorne et al., 2018).
- **Ocean acidification** will impact pH-sensitive species like shellfish that rely on calcium carbonate for their growth.
- **Marine heat waves**, defined as prolonged anomalously warm ocean temperatures (Hobday et al., 2016; Hobday et al., 2018), are likely to increase in frequency and intensity with climate change (Xu et al., 2022). This could lead to increased temperature stress, disease, and mortality with subtidal and intertidal organisms and wide-reaching impacts on Morro Bay's coastal communities and economies (Jacox et al., 2019).

Adaptation Actions: Adaptation actions relevant to estuarine habitats from the Climate Vulnerability Assessment (MBNEP, 2021) include education on herbicide and pesticide alternatives, erosion control measures, upland area grading to prevent wetland loss, maintenance of physical conditions that support eelgrass habitat, eelgrass planting, plant migration facilitation, invasive plant species removal, drought tolerant and native plants use, fire tolerant natives use, drought tolerant plant species use to maintain soil moisture, sediment augmentation to tidal marsh, local planning effort support to protect migration areas from development and encourage climate-smart growth, collaboration with CDFW and CSP on mitigation efforts. Partner adaptation actions include:

- The MBNEP will continue to work with CDFW and CSP in the management of natural resources within the watershed. Many species habitat enhancement and invasive species management projects are led by these agencies and will be important to the resilience of the watershed in the future.
- The Morro Coast Audubon Society (MCAS), manager of the Sweet Springs Nature Preserve, has worked collaboratively with California Native Plants Society (CNPS) to

increase the expansion of salt marsh plants. Past projects have proven to be successful, and more are likely needed to address future sea level rise (SLR). The MBNEP will consult with CNPS on similar efforts within the estuary in areas that will be most affected by SLR to reduce the risk of losing specialized species.

Climate Resiliency

Both eelgrass and tidal marsh habitats are important blue carbon sinks that uptake carbon dioxide from the atmosphere and incorporate it into plant biomass and soil carbon. They also act as a natural buffer for coastal communities from storm surge, flooding, and sea level rise. Maintaining the proportion of these habitats over time in Morro Bay increases resilience through carbon sequestration and addresses the climate vulnerability of the estuary to sea level rise and storminess.

Objectives and Targets

Understand and maintain the mosaic of functioning estuarine habitats with the impacts of climate change and sea level rise.

- Maintain a tidal prism volume of at least 4,200 acre-feet as defined by the Morro Bay Sediment TMDL.
- Monitor and support research to track eelgrass health and extent over time.
- If eelgrass coverage falls below 156 acres within a depth range of -6 ft to 1.5 ft mean high tide, consider re-initiating restoration measures, in consultation with various partners and current research on eelgrass restoration effectiveness.
- Support eelgrass monitoring, research, and restoration to help understand eelgrass changes over time.
- No net loss of salt marsh habitat. This target may change with additional studies and future climate change.
- Conduct and support projects to allow salt marsh/mudflat elevations to keep pace with sea level rise.
- Maintain 75% or more of enterococci indicator bacteria results meeting the regulatory statistical threshold value (STV) criteria (110 MPN/100 mL) for safe recreational contact.

Ongoing and potential projects. * Indicates ongoing projects

- ***Eelgrass Mapping:** Continue eelgrass mapping, typically on a biennial basis. Our current mapping approach uses drone imagery and sonar mapping as funding allows. Mapping methods may be adjusted as new technologies and/or guidelines are developed.
- ***Tidal Marsh Monitoring:** Continue to use a combination of sampling methods to measure accretion rates in the salt marsh. Evaluate vegetation communities to understand and observe potential changes with sea level rise.
- ***Habitat Sea Level Rise Modeling:** Support SLR modeling of estuarine habitats and transition zones to identify vulnerable areas and create adaptive management actions. These efforts will be used to create restoration targets and timelines for management actions.

- **Tidal Marsh Enhancement:** Evaluate and potentially implement sediment augmentation efforts or other management actions in tidal marsh habitat to help keep pace with sea level rise.
- ***Bathymetry Mapping:** Continue to map bay bathymetry at least once every ten years, potentially more frequently with large storm events.
- ***Research and monitoring:** Support research and monitoring efforts to understand physical, biological, and ecological function of estuarine habitats.
- ***Estuarine BMPs:**
    - Support educational efforts to reduce non-point source pollution runoff
    - Support BMPs for harbor operations and stormwater runoff to reduce impacts from nutrients, bacteria, and toxics to the estuary
    - Educate boaters on BMPs to reduce waste discharge to the bay
    - Perform regular monitoring and repairs on the boat pumpout stations in the bay

Example Projects

Eelgrass Restoration and Monitoring: The MBNEP has been monitoring eelgrass in the estuary for over twenty years. With the eelgrass decline in the 2010s, the MBNEP and partners put in a significant effort to restore eelgrass. The most successful eelgrass restoration occurred from 2017 to 2022 with nearly 15,000 plants harvested and transplanted at 39 restoration sites. Eelgrass is monitored annually for eelgrass condition, density, and cover at various sites throughout the estuary. In addition, eelgrass acreage has been mapped typically on a biennial basis to track eelgrass extent over time.

Bay Water Quality Monitoring: Over the past twenty years, the MBNEP has monitored bay water to track long-term conditions. Staff and volunteers collect and analyze water samples for bacteria at bay shoreline sites popular for recreation in partnership with Cuesta College. The MBNEP volunteers measure dissolved oxygen at various locations around the bay. The data is shared in the triennial State of Bay Report as well as through an annual bay health memo. The data is also submitted to the State Water Resources Control Board's California Environmental Data Exchange Network (CEDEN) for use by the state for assessments and progress tracking. The MBNEP has supported Cal Poly water quality stations in the front and back of the bay since 2016 and 2019, respectively.

Estuary-based Field Trips: The MBNEP staff led field trips and events for schools, community groups, education partners, and other organizations to expand knowledge of estuarine habitats and environmental stewardship. From 2023 to 2024, there have been eleven estuary-focused field trips that reached over 230 people. Field trips have focused on experiential education of estuarine habitats through kayaking, observational science, and nature journaling.

Freshwater

Freshwater habitats, including riparian, in-stream, and freshwater wetlands, play a vital role in watershed health and function. They are also home to several special status species, including the California red-legged frog and South-Central California Coast steelhead trout.

CCMP Action Plans

The CCMP specifically calls for the conservation and restoration of freshwater habitats through the following Action Plans:

- (LP-1) Protect Special Habitats/Species
- (MON-1) Support Development of TMDLs
- (MON-2) Monitor Environmental Indicators
- (MON-5) Support Partners
- (MON-6) Support Research Activities
- (BMP-1) Agricultural and Grazing BMPs
- (BMP-2) Rural Road Erosion
- (ECR-1) In-stream habitat
- (ECR-3) Wetlands Protection and Enhancement
- (ECR-4) Wetlands Habitat Assessment
- (ECR-13) Population Dynamics
- (ECR-14) Support Recovery Plans
- (ECR-15) Steelhead Barriers and Habitat
- (ECR-16) Invasive Species Action Plan
- (FWR-1) Manage Freshwater Resources
- (FWR-3) Understand Flow for Public Trust Resources
- (FWR-4) Chorro Valley Water Users Group

In addition, several other CCMP action plans are relevant to freshwater habitats:

CCMP Action Plan Number	CCMP Action Plan
MON-3	Monitor Project Effectiveness
MON-4	Maintain VMP
BMP-5	BMPs by Private Landowners and Municipalities
BMP-6	Reduce Pet Waste
BMP-7	Support Stormwater BMPs
BMP-11	CMC Wastewater
BMP-12	MB Wastewater

CCMP Action Plan Number	CCMP Action Plan
ECR-5	Sediment Traps
ECR-6	Hydrology and Bathymetry
ECR-9	Regional and National Collaboration
ECR-10	Nutrients and Bacteria Dynamics
ECR-11	Conserve Ecosystem Functions
FWR-5	Water Conservation
FWR-6	Groundwater Re-charge
CLIM-1	Improve Understanding of Climate Change Impacts
CLIM-2	Assist in the Implementation of Local Government Climate Action Plans
CLIM-3	Climate and Adaptation Education
USE-1	Recreational Uses
EO-1	Public Education and Outreach
EO-2	State of the Bay
EO-3	Nature Center
EO-4	Formal Education Programs

Habitat Description: Riparian and In-Stream

Riparian and in-stream habitats are comprised of the vegetation and physical features of stream channels, beds, banks, and floodplains. In the Morro Bay watershed, there are two primary riparian systems. The larger is composed of Chorro Creek and its tributaries, including San Bernardo, San Luisito, Walters, Pennington, and Dairy Creeks. The Chorro Creek sub-watershed accounts for about two-thirds of the freshwater inflow into the estuary. The smaller sub-watershed is drained by Los Osos Creek and its main tributary Warden Creek (Figure 1; Figure 9).

Morro Bay's creek flows are highly seasonal with the largest volumes of water during the winter and spring rainy season and much reduced flows in summer and fall. Many of the minor tributaries do not flow year-round. Chorro Creek is supplemented by treated effluent from the California Men's Colony wastewater treatment plant (CMC WWTP). Minimum flow and water quality requirements for their discharge of treated effluent to Chorro Creek are established by Regional Water Quality Control Board (RWQCB) operating permits. Competition for groundwater, mostly from irrigated agriculture, can affect flow levels, tapping into the shallow aquifers that connect with the streams and riparian corridors.

The creeks flowing into Morro Bay provide important spawning habitat for South-Central California Coast steelhead trout, an anadromous fish on the federal threatened species list. These fish need cool, clean water with shady pools and refugia from predators. Gravel bottoms free of silt are essential to their reproductive success. While local populations have evolved to be more tolerant of warmer water and can survive in deep pools during low flows, the conditions for this species in the watershed are challenging. Pollutants from the land uses in the watershed adversely impact this habitat. In some places, barriers block fish migration, limiting access to some tributaries. Other threats to steelhead are invasive fish species, especially the Sacramento pikeminnow, which is a known predator of juvenile trout and competes with adults for food and habitat. Considerable effort has been devoted to improving freshwater habitat for steelhead.

Throughout Morro Bay, the riparian corridors are best categorized as valley and foothill riparian scrub and woodland vegetative communities that are dominated by willows (*Salix* spp.) and other hydrophilic plants. Other native trees species found in some of the Morro Bay riparian corridors, especially higher up in the watershed, are sycamores, cottonwoods, bay laurel, and live oak.

The lateral extent of these riparian communities depends on the size and nature of floodplains and banks, the amount of water carried by the stream, and on the extent and depth of subterranean aquifers. Moreover, these habitats traverse areas of grassland, scrub, and chaparral communities intergrade with more water-dependent riparian cover (Holland and Keil, 1995) as streams work their way towards the coast. In many places, creek corridors have been straightened and leveed to provide bottomland for agriculture. These alterations have reduced natural floodplains and have contributed to incised creek beds, bank erosion, and the loss of riparian vegetation.

Streams and associated riparian vegetation provide cover and connectivity for in-stream organisms, such as fish and many types of invertebrates, and for a variety of birds and other wildlife species. Several resident and migratory passerine birds use these communities for breeding and foraging grounds. Healthy riparian vegetation is critical to habitat quality, water quality, bird nesting areas, and viable steelhead spawning grounds.

Vegetation Species Typifying Riparian Habitat

Common Name	Scientific Name
American Dogwood	*Cornus sericea*
Box Elder	*Acer negundo*
CA Mugwort	*Artemisia douglasiana*
CA wild rose	*Rosa californica*
Elderberry	*Sambucus mexicana*
Poison Oak	*Toxicodendron diversilobum*
Western Sycamore	*Platanus racemosa*
Willow	*Salix s*pp.

Habitat Description: Freshwater Wetlands and Other Smaller Water Sources

Freshwater wetlands are characterized by nutrient-rich mineral soils that are saturated through most or all of the year by slow moving or stagnant shallow water (Sims, 2010). These communities occur along margins of streams and ponds, in floodplains, and along hillsides where seepage from springs occur (Holland and Keil, 1995). In the Morro Bay watershed, this habitat type exists in Chorro Flats just east of Black Hill, in Los Osos Creek Wetland Preserve adjacent to southeastern Morro Bay State Park, at Warden Lake, at Sweet Springs Nature Preserve, and at many other scattered locations throughout the area (Figure 10). Wetlands contain mostly perennial monocots that can reproduce with underground rhizomes (Holland and Keil, 1995) due to their anaerobic or nearly anaerobic soils (Sims, 2010).

In addition to providing indispensable habitat, wetlands serve important ecological functions by filtering nitrogen, phosphorous, and other pollutants from the streams entering the estuary, by storing carbon, and by providing flood protection. These functions can be reduced or eliminated entirely when wetlands are significantly altered by development, hydrologic changes, increased sedimentation, and high pollutant levels.

Vegetation Species Typifying Freshwater Wetland Habitat

Common Name	Scientific Name
Broadleaf cattail	*Typha latifolia*
Marsh pennywort	*Hydrocotyle vulgaris*
Rush	*Juncas* spp.
Sedge	*Carex* spp.
Seep monkeyflower	*Erythranthe guttata*
Watercress	*Rorippa nasturtium-aquaticum*
Yerba mansa	*Anemopsis californica*

Other Freshwater Sources: Throughout the watershed there are numerous other small sources of fresh water including springs, stock ponds, and spring boxes. Especially during the dry season, these scattered features provide valuable water sources for numerous avian and wildlife species (Figure 10).

State and Federal Threatened and Endangered Species in Freshwater Habitats

- California red-legged frog (FT)
- California black rail (ST)
- Willow flycatcher (SE)
- South-Central California Coast steelhead trout (FT)
- Marsh sandwort (SE/FE)
- Chorro Creek bog thistle (SE/FE)
- Least Bell's vireo (SE/FE)

Habitat Extent: Figure 9 shows the streams and riparian corridors that total approximately 1,275 acres in the Morro Bay watershed.

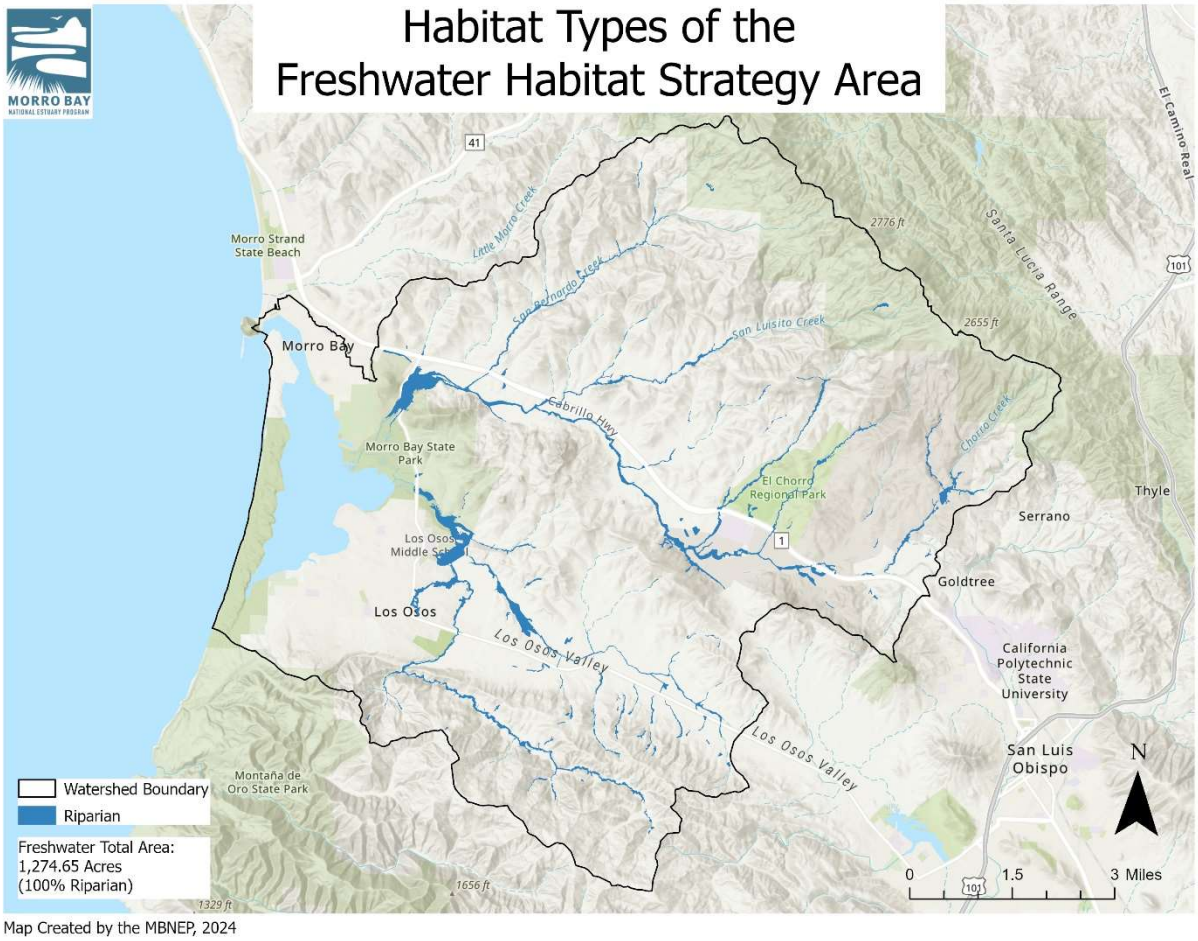


Figure 9. Riparian and in-stream habitat extent and location in Morro Bay watershed.

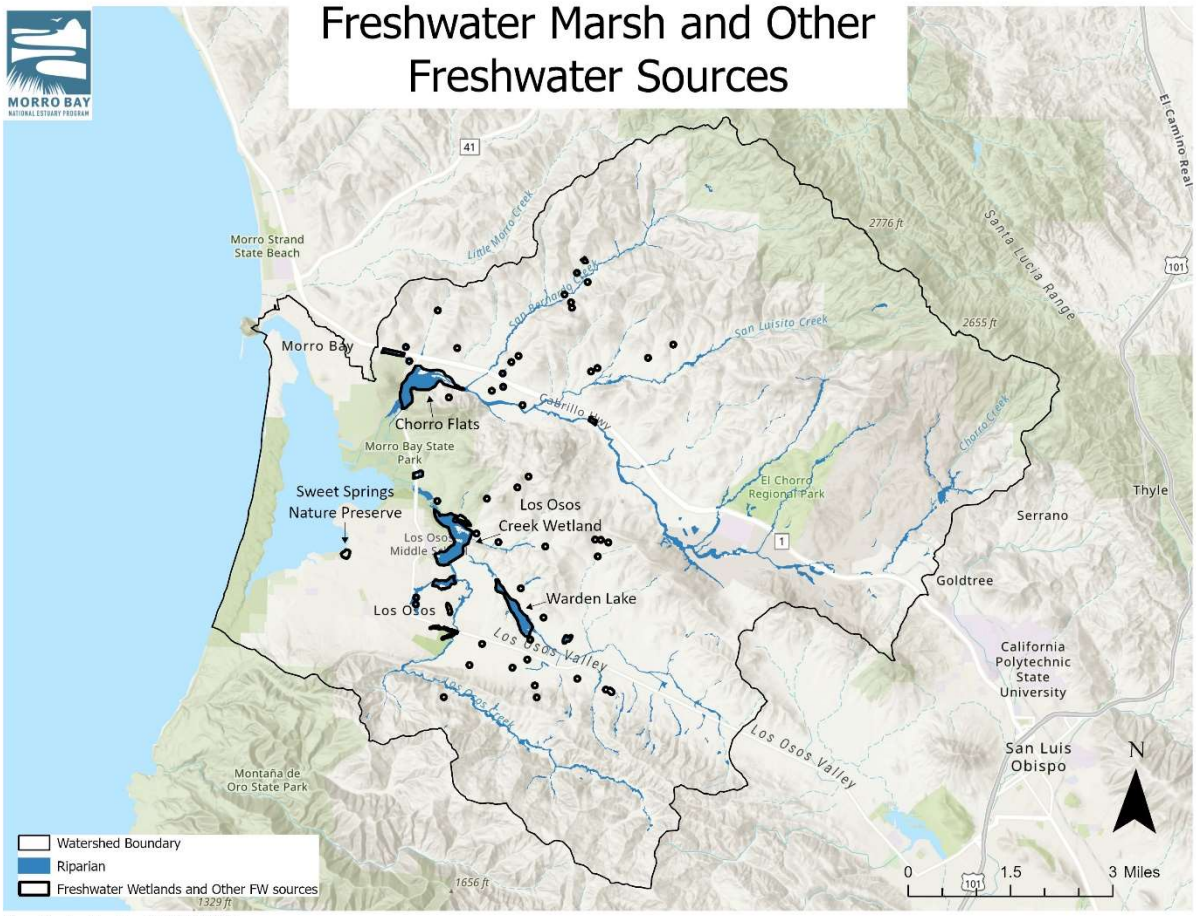


Figure 10. Freshwater marsh and other freshwater sources located within the Morro Bay watershed.

Habitat Health: The MBNEP has tracked various parameters of creek system health in the watershed. Based on index scores related to macroinvertebrates, the upper reaches of Los Osos Creek, as well as the major tributaries of Chorro Creek (San Bernardo, San Luisito, Pennington, and Dairy Creeks), all have good habitat health ratings. Both the upper and lower reaches of Chorro Creek enjoy fair levels of health, the middle reach (from Pennington to San Luisito Creeks) has been rated poor in terms of habitat health.

Morro Bay's creeks have experienced negative impacts from water quality degradation from nutrient runoff, toxics, and increased sedimentation. Nitrate levels are one measure of creek health in the watershed. Nitrate scores for upper Los Osos Creek, upper Chorro Creek, and the tributaries of Chorro Creek all show healthy conditions. However, middle and lower Chorro and Warden Creeks have very poor nitrate levels that can adversely affect aquatic life.

Competition for fresh water, especially from irrigated agriculture in the Chorro, Los Osos, and Clark Valleys, reduces flow and results in stress on instream fish and fauna, as well as on the adjacent riparian cover. The loss of shade further exacerbates stress from higher in-stream

water temperatures. In many places, floodplains have been significantly altered to accommodate agriculture and other land uses resulting in degradation of the affiliated habitats.

In some parts of the watershed, steelhead reproduction is inhibited by poor in-stream conditions and by barriers to fish passage for spawning. Especially in the Chorro Creek mainstem, the non-native Sacramento pikeminnow competes with the native steelhead and reduce the native fish viability.

The CPI task force evaluated the "vital signs" of Morro Bay's creek system health linked specifically to sediment carried in by the creeks, nutrient pollutants, reduced spring and summer stream flows, macroinvertebrate diversity, water temperature, steelhead spawning populations, and the presence of invasive pikeminnow. For these vital signs, a range of indicators was discussed, and a subset was identified that would be most meaningful and practical to monitor over time. These have been incorporated into the objectives listed below.

Protection and Restoration Efforts

The major creeks draining into Morro Bay, their named tributaries, and smaller seasonal drainages are all considered Environmentally Significant Habitat Areas (ESHA) by the local governments and California Coastal Commission and thus are subject to special regulatory protections. Freshwater wetlands are also considered ESHA and are subject to similar rigorous regulations that help protect them from encroachment and degradation from nearby land uses.

The CCMP has targeted Action Plans to enhance the habitat values of Morro Bay's freshwater resources. These include extensive and ongoing monitoring of several parameters of creek health including seasonal flow, temperature, abundance of macroinvertebrates, DO, nutrients, and bacteria. Monitoring provides data needed for science-based evaluations of changes in creek habitat health and for guiding water quality improvement efforts.

Work to improve water quality has included numerous projects in the watershed through pollution source controls like riparian fencing and rangeland BMPs on grazing lands, agricultural BMPs, and erosion control and repair work.

The importance of maintaining and enhancing stream flows have led to communication and collaboration with local agencies and landowners.

Steelhead habitat has been a focus of the MBNEP's work in the creeks. Several projects have been directed at creating the preferred conditions for steelhead including protecting and revegetating riparian corridors, providing in-stream refugia, removing fish passage barriers, repairing bank erosion, restoring floodplains, and restoring stream substrates for spawning.

Other major efforts have focused on understanding and controlling the impacts of invasive pikeminnow. Ongoing electrofishing efforts to remove pikeminnow has proved to increase steelhead populations in sections of Chorro Creek in subsequent years.

The MBNEP and its partners have also worked to manage invasive plants in the riparian areas that degrade the native vegetation communities and impact stream hydrology.

Stressors and Climate Vulnerabilities

Morro Bay's creek systems continue to be subject to significant and ongoing stressors, including impacts from nutrients, toxics, and sediment carried by runoff from adjacent lands. The discharge of treated effluent from the CMC WWTP contains elevated concentrations of nitrates and water that is warmer than ambient levels in the receiving waters. While the discharge meets the plant's permit requirements and provides much needed water to the creek, the discharged water might have negative impacts on the habitat in Chorro Creek.

Freshwater flow in the watershed has a direct impact on a wide variety of beneficial uses. Reduced flows can impede the migration and spawning of steelhead as low flows that contribute to higher water temperatures can directly affect the viability of steelhead. Fresh water is essential to other special-status species found in the watershed, including the red-legged frog and southwestern pond turtle. Competition for limited freshwater resources will continue to be a challenge.

Invasive species continue to diminish the habitat value of the creeks and wetlands. Invasive pikeminnow pose a particular challenge to the viability of steelhead. Pikeminnow tend to inhabit warmer waters of the mainstem of Chorro Creek and have the potential to expand into tributaries with increased water temperatures due to climate change. Barriers to steelhead migration into the upper reaches of the watershed also prevent pikeminnow from possibly expanding into tributaries. Improving fish passage for steelhead while keeping the invasive species from those relatively uncompromised reaches may pose a dilemma in the face of climate change.

Climate change is expected to exacerbate all of these current and projected stressors, including:

- **Increasing storminess (more frequent, larger precipitation events)** will likely increase sedimentation rates and result in more pollution from runoff. High peak flows may exacerbate stream incision and bank erosion while threatening communities living near or on the 100-year floodplain. Excess sediment may degrade habitat for fish and insects. On the other hand, periodic high flows may enhance floodplain habitat and ground water recharge.
- **Warmer temperatures** will likely increase algal blooms, increase favorable conditions for bacteria, and decrease dissolved oxygen critical for in-stream biota. Higher water temperatures will likely decrease viable habitat for steelhead, especially rearing habitat. A warming climate is expected to alter migration cycles or mistime food supplies for some avian species, resulting in lower survival rates.
- **Increasing drought** is likely to adversely affect all freshwater habitats leading to their early dry-out or complete loss due to moisture/temperature stresses. Specialized wetland species may be lost from current wetland habitats due to reduced water supply

or early dry-outs. Droughts will likely increase demand for irrigation and other water uses, affecting groundwater levels and stream flows. Certain invasive species better adapted to drier conditions will likely be able to outcompete native plants and animals. Reduced flows further exacerbate low dissolved oxygen levels.

- **Sea level rise** will likely change the location of the fresh water and saltwater interface as brackish water habitat migrates farther inland at the expense of current freshwater regimes. As sea levels rise, inland storm flooding that can negatively impact low-lying communities and infrastructure may be exacerbated due to the higher tides.

Adaptation Actions: Adaptation actions relevant to freshwater habitats from the MBNEP 2021 Climate Vulnerability Assessment include education on herbicide and pesticide alternatives, erosion control measures, plant migration facilitation, floodplain restoration, upland area grading to prevent wetland loss, invasive plant species removal, levee removal, large woody debris installation, riparian corridor maintenance, drought tolerant and native plants use, fire tolerant native plant use, evergreen, resilient shade tree planting in upland tributaries, drought tolerant plant species use to maintain soil moisture, prescribed grazing/fires, rainwater harvesting, fuel load reduction work with CalFire, riparian fencing, road erosion repairs, stream shading, local planning effort support to protect migration areas from development and encourage climate-smart growth, collaboration with CDFW and CSP on mitigation efforts, and stream buffer widening. Partner adaptation actions include:

- The CSLRCD completes projects like floodplain restoration, widening stream buffers, percolation projects, and education on herbicide and pesticide alternatives.
- Land Conservancy of San Luis Obispo County conducts invasive species management.
- The MBNEP will continue to work with CDFW and CSP on management of natural resources within the watershed. Many species habitat enhancement and invasive species management projects are led by these agencies and will be important to the resilience of the watershed in the future.
- MCAS, the manager of the Sweet Springs Nature Preserve, has worked collaboratively with CNPS to increase the expansion of salt marsh plants. Past projects have proven to be successful, and more are likely needed to address future SLR. The MBNEP will consult with CNPS on similar efforts within the estuary in areas that will be most affected by SLR in order to reduce the risk of losing specialized species.
- The City of Morro Bay changed the location of their new wastewater treatment plan to address concerns about future flooding due to climate change-related events, SLR, and tsunami flood risk. While the old plant was located outside the Morro Bay watershed boundary, the new site is within the Chorro Creek sub-watershed.

Climate Resiliency

The Morro Bay watershed's creek system and freshwater wetlands are essential elements of the area's "green infrastructure" drainage system. More intense precipitation events are expected as the climate warms and storms increase in size. Floodplains and marshes all help

retain water and slow flows, reducing downstream flooding impacts. Riparian corridors cool stream water which will be increasingly important as temperatures rise with climate change. During droughts, which are likely to be more intense and frequent with climate change, deep pools provide important water sources for wildlife and refugia for steelhead and other aquatic species. The plants within freshwater wetlands provide carbon storage, which reduces carbon dioxide in the atmosphere, and protect shorelines from erosion. Given their increasing importance in mitigating climate-related impacts, continued protection and restoration of the freshwater habitats will be critical in the watershed.

Objectives and Targets:
Monitor ambient conditions, implement projects, and track project effectiveness to promote and enhance healthy in-stream, riparian, and freshwater wetland habitat.

- Maintain a "yellow" status for all stream-monitoring sites using the Herbst-method of sediment impairment.
- 90% of creek samples have nitrate concentrations less than 3 mg/L NO_3-N to support human health standards at all monitoring sites (except Warden Creek).
- At least 60% of creek samples have less than 0.12 mg/L PO_4-P concentrations at ten monitoring stations.
- Spring and Summer Environmental Water Demand (EWD) flow objectives for the watershed will be met per criteria in Appendix A.
- Stream Condition Monitoring: For tributary systems, all ten bioassessment monitoring sites will have a score of "fair" ("Possibly altered stream conditions") or better using the California Stream Condition Index method.
- Maximum weekly maximum temperature (MWMT) from April to October is less than 20 °Celsius (C) on two monitoring sites on Chorro Creek downstream of the CMC WWTP.
- MWMT from April to May less than 20 °C for one site each on San Bernardo, San Luisito, Dairy, and Pennington Creeks.
- Conduct and support studies to understand sensitive species abundance (e.g., steelhead trout) and distribution in creek systems.
- Monitor, enhance, and restore native riparian, in-stream, and floodplain connectivity and conditions to improve habitat for native biodiversity and special status species.
- Monitor and manage targeted invasive species that have a significant impact on native biodiversity and hydrological processes.

Ongoing and potential projects. * Indicates ongoing projects

- ***Water Quality Monitoring:**
    - Continue long-term ambient monitoring dataset to track water quality and habitat health with MBNEP staff, MBNEP's Volunteer Monitoring Program, and partners.
    - Conduct continuous in-situ water quality measurements to assess changes in water quality.

    - Track flow to assess if EWD flow targets met in critical timeframes (e.g., spring and summer) to better understand baseline ecological water needs.
- ***Creek Health Monitoring:** Continue long-term monitoring to assess creek health through macroinvertebrate, habitat, and flow surveys.
- ***Water and Sediment Toxicity Monitoring:** Continue monitoring toxicity in water and sediment samples and submit information to CEDEN for broad distribution and use for assessments.
- ***Floodplain Enhancement/Restoration:**
    - Continue adaptative management at the Chorro Creek Ecological Reserve (CCER) following heavy storms of 2023 and ensure fish passage at the site.
    - Enhance floodplain connectivity on Walters Creek with Cal Poly process-based restoration techniques, such as through-levee removal and log-assisted structures.
    - Evaluate floodplain expansion in lower Chorro Creek watershed to increase floodwater storage and reduce current and future climate change flood and sea level rise impacts.
- ***Fish Passage Barrier Removal:** Support planning and implementation of fish passage barrier improvements and removal for special status species.
- ***Invasive Pikeminnow Reduction:** Continue to manage the Sacramento pikeminnow population in Chorro Creek to support improved habitat for steelhead.
- ***Steelhead Studies:** Continue to track steelhead through PIT tagging and spawner surveys to determine steelhead use and presence in freshwater systems.
- ***BMPs on Private Property:** Work with partners to implement BMPs (e.g., cover crops, riparian fencing, bioswales) on private property to reduce sediment and nutrient runoff to waterways.
- ***Road Erosion:** Work with partners, including private property owners, to stabilize roads and capture sediment runoff to reduce sedimentation to nearby streams.
- **Stream Flow Augmentation:** Develop projects (e.g., water storage) to address intermittent flows to improve steelhead habitat quality during the critical spring and summer seasons, increase groundwater recharge, etc.
- ***Low-tech Process-based Restoration:** Support planning, permitting, and implementation of low-tech process-based restoration techniques to enhance riparian habitat.
- ***Invasive Plant Species Management:** Continue to monitor and manage invasive plant species to support improved riparian habitat.
- **Bioreactors:** Consider water quality improvement projects such as bioreactors to treat elevated nutrients in runoff.

Example Projects

Bioassessment Monitoring: The MBNEP has conducted annual bioassessment monitoring for the past two decades to evaluate creek health and changing conditions in the watershed. Each survey involves gathering around 1,500 measurements to assess stream conditions. Each measurement helps determine if the creek can support sensitive aquatic species. The surveys are completed with the help of volunteers, Watershed Stewards Program Corpsmembers, and more recently with students from Cal Poly's Natural Resources Management and Environmental Sciences Department. Results are posted annually to CEDEN.

Floodplain Enhancement: The MBNEP has supported three major floodplain enhancement projects within the watershed. The MBNEP partnered with CSLRCD to support restoration of Chorro Flats and Los Osos Creek Wetlands Preserve. Overall, the projects improved 170 acres of floodplain and wetland habitat for sensitive species and improved groundwater recharge and sediment capture. CCER Floodplain Restoration Project reconnected over four acres of floodplain habitat along Chorro Creek and planted over 1,000 native plants to improve native riparian vegetation. These projects continue to be monitored and additional native plantings and adaptive management are being developed with site and climatic changes.

Watershed Stewards Program Corpsmembers: Since 2011, MBNEP has been a co-host for the San Luis Obispo Steelhead Initiative placement site of the Watershed Stewards Program (WSP). WSP is a program of the California Conservation Corps (CCC), in partnership with AmeriCorps. WSP is a professional development program for young scientists beginning their natural resource and environmental careers. All WSP corpsmembers teach watershed education curriculum in local schools, and each member is responsible for planning and organizing a restoration event for volunteers.

Sandy Shores and Dunes

Morro Bay is formed by a four-mile long sandspit that extends from Shark Inlet in Montaña de Oro State Park to the mouth of the harbor to the north. The ocean side of the spit is a sandy beach that does not directly connect with the estuary except near the harbor entrance between the south jetty and a rock groin. On the estuary side of the sandspit, a few sandy beaches are found south of Morro Rock behind the main harbor jetty at Coleman Beach, around the north end of the sandspit, and at a few locations where dune blow outs have reached the bay shore. In some places the active dunes are quite large and tower over the bay to an average maximum elevation of 59 feet. The remainder of the sandspit is vegetated with a dunes scrub complex (see below).

CCMP Action Plans

The CCMP specifically calls for the conservation and restoration of dune and sandy shore habitats through the following Action Plans:

- (LP-1) Protect Special Habitats/Species
- (ECR-12) Upland Habitats
- (ECR-14) Support Recovery Plans
- (ECR-16) Invasive Species Action Plan
- (USE-1) Recreational Uses

In addition, several other CCMP action plans are relevant to dune and sandy shore habitats:

CCMP Action Plan Number	CCMP Action Plan
MON-5	Support Partners
MON-6	Support Research Activities
BMP-6	Reduce Pet Waste
ECR-9	Regional and National Collaboration
ECR-11	Conserve Ecosystem Functions
ECR-13	Population Dynamics
ECR-14	Support Recovery Plans
CLIM-1	Improve Understanding of Climate Change Impacts
CLIM-2	Assist in the Implementation of Local Government Climate Action Plans
CLIM-3	Climate and Adaptation Education
EO-1	Public Education and Outreach
EO-2	State of the Bay
EO-3	Nature Center
EO-4	Formal Education Programs

Habitat Description: Sandy Beaches

The intertidal zone along the beaches is used by numerous shorebird species that feed on small invertebrates and insects below and at the wrack line. Sand depressions are also used as refuge by plovers and other shorebirds from the frequent ocean winds.

Morro Bay's beaches and dunes are critical breeding grounds for the western snowy plover that nest on the open sand. To help control human impacts, potential nesting habitat on the beaches and dunes is cordoned off with symbolic fencing and signage from February through October by CSP. Five vertical access corridors for recreationalists within the watershed have been demarcated between the bay and ocean beach to minimize impacts from visitors.

Habitat Description: Foredunes including Active Dunes

The foredune habitat is made up of coastal-facing active dunes, also called unstable or mobile dunes, which are vulnerable to strong coastal winds, salt sprays, and sand blowouts that change their form. Soils on active dunes are sandy and highly porous, meaning they are incapable of supporting most plants that rely on stable root systems. Fauna found on the dunes inland of the beach is limited generally to some invertebrate species although numerous animals and birds traverse the open dunes between scrub cover.

Vegetation Species Typifying Foredune Habitat

While most of this habitat is by definition unvegetated, some plants have evolved to survive above the high tide line and in more protected areas of the dunes. These plants occur most frequently at the transition zones adjacent to the more vegetated coastal dune scrub complex.

Common Name	Scientific Name
Beach bur	*Ambrosia chamissonis*
Beach saltbush	*Atriplex leucophylla*
Croton	*Croton californica*
Dune evening primrose	*Camissonia cheiranthifoia*
Dunedelion	*Malacothrics incanna*
Iceplant*	(*Carprobrotus* spp.)*
Sand verbena	*Abronia* spp.
Yarrow	*Achillea millefolium*

**Invasive species that is dominant in the habitat.*

Habitat Description: Backdunes (Coastal Dune Scrub)

The vegetated backdune community (sometimes referred to as coastal dune scrub in literature) is found on stabilized dunes that are typically just inland of and adjacent to the foredunes and active dunes. In contrast to active dunes, the backdune vegetative communities occur where plants have stabilized the sands so that soils can hold more water and have a lower salt content. Many plants on these stabilized dunes have extensive root systems that are further formed as the wind blows and pushes sand over the plants, forcing the plants to grow taller and to deepen their roots. In turn, these extensive root systems continue to stabilize the dune. In several areas where the dunes have stabilized, invasive species, including grasses and iceplant, have displaced native species. Backdune scrub vegetation covers much of the sandspit as well as a substantial area south and east of Shark Inlet which is underlaid with highly porous sandy soils from now stable, relic dunes. “Dune scrub” is classified as a habitat of special concern by CDFW.

Vegetation Species Matrix Typifying Morro Bay’s Backdune Habitat

Common Name	Scientific Name
California sagebrush	*Artemisia californica*
Coast dudleya	*Dudleya caespitosa*
Coastal buckwheat	*Eriogonum parvilfolium*

Common Name	Scientific Name
Coastal silver lupine	*Lupinus chamissonis*
Coyote bush	*Baccharis pilularis*
Deerweed	*Acmispon glaber*
Iceplant*	*Carprobrotus* spp.*
Mock heather	*Ericameria ericoides*

**Invasive species that is dominant in the habitat.*

State and Federal Threatened and Endangered Species in Sandy Shores Habitat

- Morro shoulderband snail (FT)
- California red-legged frog (FT)
- Western snowy plover (FT)
- California black rail (ST)
- Morro Bay kangaroo rat (SE/FE)
- Morro manzanita (FT)
- Salt marsh bird's beak (SE/FE)
- Indian Knob mountainbalm (SE/FE)
- California seablite (FE)
- Beach spectacle pod (ST)
- Marsh sandwort (SE/FE)

Habitat Extent: Figure 11 illustrates the beaches, foredunes, and backdune (coastal dune) habitats of Morro Bay. Beaches account for 69 acres and coastal dune accounts for 888 acres for a total of 957 acres (1.9%) of the watershed.

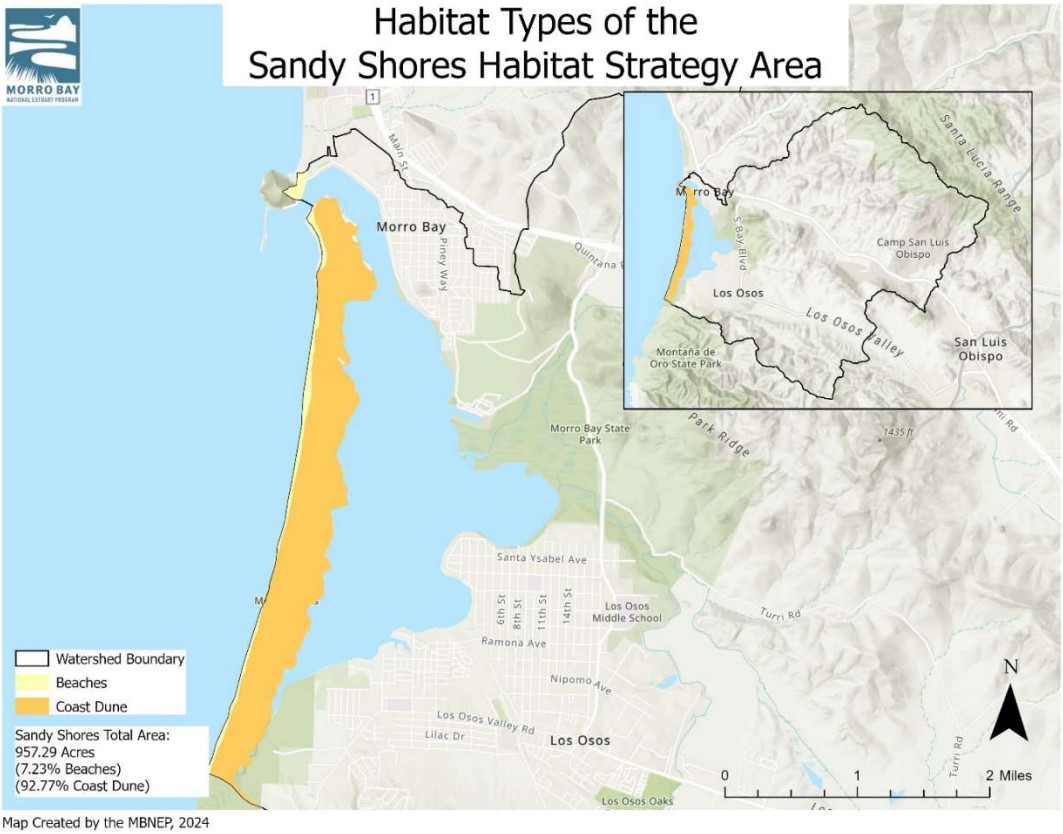


Figure 11. Beaches and coastal dune extent and location within the Morro Bay watershed. Percentages are relative to the sandy shores habitat area.

Habitat Health: Indicators of coastal dune habitat are a robust mix of native scrub species and the lack of invasive species, particularly non-native beach grasses and iceplant, within the stabilized dune areas. Also important is the absence of human-caused erosion and vegetation losses and the resultant fragmentation of the habitat. Sandy beach areas suitable for plover nesting are periodically reduced by strong storms and high tides. While typically these areas are replenished by littoral drift and prevailing winds, this pattern may be more frequently disrupted with climate change (see below).

Protection and Restoration Efforts

The entire dunes and beach complex is under public ownership and managed by public agencies. Specific management efforts have focused on protecting the western snowy plover nesting success. Other projects aim to remove invasive plant species, restore natural dune system function, and manage public access and recreation.

CSP manages western snowy plover habitat and outreach efforts on how to protect the species. To protect plover breeding habitat, much of the sandspit is closed to public access during the nesting season (February through October) with a “symbolic” barrier (a rope line suspended on poles) and signage. Despite these measures, the nests are vulnerable to predators, dogs, and

human intrusions that can destroy the eggs, kill nestlings, or drive off the parents from the nests, all of which reduce the success of a breeding season. When undisturbed nests are discovered, CSP will sometimes install nest enclosures that allow passage of the plovers but keep out predators and people.

Since 2018, there has been extensive efforts by CSP, with some monitoring support from the MBNEP and CSLRCD, to restore dune function and eradicate invasive species. CSP installed 275 straw bales on eight acres of the sandspit near Shark Inlet to the south of the sandspit to improve dune natural function. In addition, CSP eradicated 140 acres of iceplant on their Morro Dunes Natural Preserve property, and CSLRCD monitored project success from 2020 to 2022. In 2023, the MBNEP expanded monitoring and iceplant management in the northern, City of Morro Bay owned, section of the sandspit. This initial effort targeted 33 acres of iceplant. Both CSP and MBNEP efforts to manage iceplant on the sandspit are ongoing.

Stressors and Climate Vulnerabilities

The primary threats to dune and sandy shore habitat in the Morro Bay area are human use impacts and established invasive plants (e.g., iceplant) that outcompete native species and alter dune geomorphology.

Iceplant (*Carpobrotus* spp.) is the most abundant and widespread invasive plant found on the sandspit. In the foredunes, iceplant can rapidly spread and cover the bare sandy areas used as nesting habitat for western snowy plover. In the backdune, iceplant can displace the native dune scrub vegetation as well as "stabilize" the dunes, which alters the naturally shifting and changing geomorphology. A number of listed species that occur within the dunes are directly threatened by the further spread of iceplant, including the Morro shoulderband snail, California seablite, and others.

As the bay has become more popular as a recreational area, many people explore the bay by small watercraft, kayaks, and SUPs and often disembark on the sandspit. Despite signage and symbolic barriers (rope lines), public access is largely uncontrolled, and people and their dogs often traverse the dunes, frequently wandering into the scrub areas.

Recent monitoring by CSP during the COVID-19 pandemic has noted an increase in recreation and visitors entering areas fenced off for snowy plover habitat on the sandspit as compared to data from 2019. Increased human presence may contribute to loss of plover nesting habitat and cause nest abandonment due to disturbance. Once nests are established, predation (e.g., by coyotes, skunks, crows) is the leading factor in plover mortality and nest failure.

Habitats associated with the dunes and sandy beach complex are especially vulnerable to the effects of climate change, including:

- **Increasing storminess (more frequent, larger precipitation events)** will likely result in more severe beach erosion from increased wave action and consequent disruption of western snowy plover breeding areas. The preferred nesting habitat of plovers is

between the wrack line and the dunes scrub. Severe storms can erode the sandy beach and foredunes, greatly reducing nesting areas for these birds. After the winter of 2023 to 2024, much of the beach sand was lost, leaving the shore covered in cobble in many places. The impacts from storms will be compounded by sea level rise (see below). Dune blow-outs may be larger and more common, resulting in loss of scrubland as well as greater sand deposition in the bay which reduces tidal volume.

- **Warmer temperatures** will likely increase stress on plants in an already stressful environment. There is some indication that coastal fog patterns may be disrupted, affecting plant species that have evolved in foggy conditions. However, some studies suggest near shore fog may increase with warmer inland temperatures.
- **Increasing drought** is likely to exacerbate moisture and temperature stresses on dunes and dunes scrub plant species, leading to an expansion of sand dunes and blow outs.
- **Sea level rise** will likely result in greater shoreline erosion causing at least temporary loss of plover breeding habitat and its eventual migration farther to the east (if possible and at the expense of dunes scrub habitat). Near shore dune scrub areas near Shark Inlet and the bay side sandspit shore may be inundated.

Adaptation Actions: Adaptation actions relevant to sandy shore habitats from the MBNEP 2021 Climate Vulnerability Assessment include: dune stabilization, erosion control measures, plant migration facilitation, invasive plant species removal, drought tolerant and native plant use, fire tolerant natives use, drought tolerant plant species use to maintain soil moisture, prescribed grazing/fires, fuel loads reduction with CalFire, local planning effort support to protect migration areas from development and encourage climate-smart growth, and collaboration with CDFW and CSP on mitigation efforts. Partner adaptation actions include:

- Land Conservancy of San Luis Obispo County conducts invasive species management.
- The MBNEP will continue to work with CDFW and CSP to manage natural resources within the watershed. Many species habitat enhancement and invasive species management projects are led by these agencies and will be important to the resilience of the watershed in the future.

Climate Resiliency

Dune systems are considered a nature-based solution for protecting coastal communities from storms and sea level rise. As climate change increases storminess and sea level rise, erosion on the shoreline will become more pronounced. The vegetated dune system is critical to maintaining the physical barrier between the ocean and bay for the coastal communities of Los Osos and Morro Bay as well as ecological communities. Dune vegetation helps control blow outs and deposition of sand into the bay which can affect the estuary's area, depth, and tidal circulation. The role of backdune habitat in stabilizing the sandspit will be even more important with sea level rise and if storm events become more intense and frequent.

Objectives and Targets:

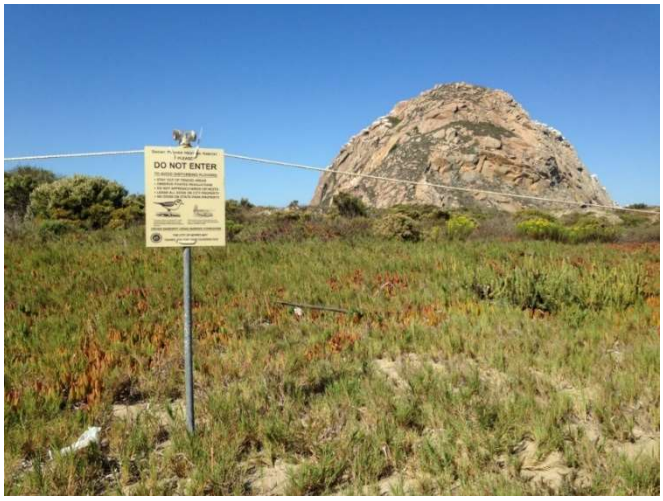
- Support research and partnerships to understand the impacts of climate change and sea level rise on sandy shores habitat.
- Support plans and management actions to monitor sensitive species habitat (e.g., snowy plover) habitat over time.
- Support and implement 100 acres of invasive vegetation removal within dune habitats.
- Support and enhance dune ecosystem function and resilience through restoration efforts.
- Support and promote environmental stewardship to reduce direct and indirect human impacts.

Ongoing and potential projects. * Indicates ongoing projects

- ***Western Snowy Plover Monitoring:** Support western snowy plover monitoring and public education efforts.
- ***Invasive Species Management:**
    - *Support CSP efforts to remove iceplant on Morro Dunes Ecological Reserve area of the sandspit.
    - *Work with partners to implement removal efforts on City of Morro Bay's sandspit property and conduct vegetation monitoring during restoration (annually for five years).
    - *Map iceplant along the sandspit as funding and capacity allows to track restoration success.
    - *Conduct targeted removal of invasive species near species status species (e.g., salt marsh bird's beak and California seablite).
    - If needed, complete native plantings on the sandspit.
- ***Community Cleanups:** Conduct beach cleanups at high-use areas on a biannual basis to increase education on sandy shores habitat and reduce trash pollution.

Example Projects

Invasive Species Management: The MBNEP has supported CSP iceplant management by funding the CSLRCD project monitoring within CSP's 700-acre Morro Dunes Natural Preserve. Over the course of five years, approximately 140 acres of iceplant was eradicated, and four out of the nine (56%) of monitoring sites saw an increase in native species richness. The MBNEP is currently working to manage iceplant within the City of Morro Bay's sandspit property. The project includes iceplant removal and annual vegetation monitoring with occasional aerial mapping to track ecosystem recovery and project success over the next five years. The project created an opportunity to collaborate with scientists at UC Santa Barbara and others as part of a statewide dune resilience grant. The project will track site changes and determine climate vulnerability of Morro Bay's sandspit.



Snowy Plover Monitoring and Education: The MBNEP has supported CSP efforts to monitor western snowy plover populations and nesting habitat and increase educational outreach efforts. Information on plover population trends is shared in the State of Bay Report every three years in collaboration with CSP.

Community Beach Clean-ups: The MBNEP and partners have led community beach and shoreline clean-ups since 2017 to help maintain the health and beauty of Morro Bay. Typically, the events occur around high-use days such as the July 4th holiday. The goal of these events is to remove litter from local beaches, roads, and trails before it enters the estuary or ocean and becomes marine debris.

Upland Habitats

The upland watershed that drains into the Morro Bay estuary includes ecologically-significant habitats as well as areas largely modified by grazing, agriculture, development, and other human activities. In these latter cases habitat values have been compromised to different degrees.

Beyond the dunes, the Morro Bay watershed upland habitats are primarily composed of oak woodlands, maritime chaparral, coastal scrub, and grasslands.

Transition zones and mosaics: Upland habitat types are generally characterized by assemblages of plant species found in the literature (e.g., Holland and Keil, 1995; Sims, 2010; Ritter, 2018). In these transition zones, plants that characterize one habitat type can be found intermixed with species that predominate another habitat type. In many parts of the upland areas, especially around Los Osos, the habitats can be better described as “mosaics” in which small areas of different habitat types are interspersed within larger open spaces.

CCMP Action Plans

The CCMP specifically calls for the conservation and restoration of upland habitats through the following Action Plans:

- (LP-1) Protect Special Habitats and Species
- (BMP-7) Support Stormwater BMPs
- (ECR-12) Upland Habitats
- (ECR-13) Population Dynamics

- (ECR-14) Support Recovery Plans

In addition, several other CCMP action plans are relevant to upland habitats:

CCMP Action Plan Number	CCMP Action Plan
LP-3	Direct Urban Development
MON-5	Support Partners
MON-6	Support Research Activities
BMP-1	Agricultural and Grazing BMPs
BMP-2	Rural Roads Erosion
BMP-5	BMPs by Private Landowners and Municipalities
BMP-6	Reduce Pet Waste
ECR-9	Regional and National Collaboration
ECR-11	Conserve Ecosystem Functions
ECR-16	Invasive Species Action Plan
FWR-4	Chorro Valley Water Users Group
FWR-5	Water Conservation
FWR-6	Groundwater Re-charge
CLIM-1	Improve Understanding of Climate Change Impacts
CLIM-2	Assist in the Implementation of Local Government Climate Action Plans
CLIM-3	Climate and Adaptation Education
USE-1	Recreational Uses
EO-1	Public Education and Outreach
EO-2	State of the Bay
EO-3	Nature Center
EO-4	Formal Education Programs

Habitat Description: Coast Live Oak Woodlands

Coast live oak woodlands are among California's most iconic landscapes (Ritter,2018). Although much more widespread farther inland, these woodlands still comprise important habitat within the Morro Bay watershed.

The woodlands endemic to the Morro Bay watershed are dominated by coast live oak (*Quercus agrifolia*), and these large trees form dense, closed canopies with shade tolerant shrubs in the understory. Oak woodlands are commonly found on the coastal slopes and foothills where groundwater is available at depth (Rundel and Gustafson, 2005). In the Morro Bay watershed,

coast live oak woodlands can be found primarily near the northern and southern portions of the watershed boundary and on the flanks of the Morros and higher hillsides. They prefer north-facing slopes and often merge with maritime chaparral, coastal scrub, and riparian communities. The types of plants found in the understory vary, often associated with plant communities neighboring the oak woodland. Although they are not considered true riparian trees that rely on root systems that tap into adjacent streams, fingers of oak canopy are frequently found in ephemeral drainages on hillsides.

As coast live oak trees generally do not tolerate harsh winds and salt spray, they are not typically found near the ocean shore. However, adjacent to the Morro Bay estuary is an unusual and noteworthy forest of low-growing live oaks that have been stunted and shaped by persistent ocean winds and other environmental factors. Located above the southern shore of the delta, the "Elfin Forest" has been preserved in public ownership by the County of San Luis Obispo and CSP) and is maintained by the local chapter of Friends of the El Morro Elfin Forest (FEMEF). This unusually intact "pygmy" oak forest shares many of the characteristics of maritime chaparral and coastal scrub communities.

Oak woodlands provide shade, shelter, and food sources for a wide variety of animal species. Numerous bird and bat species use the woodlands for roosting and foraging. Mammals that frequent oak woodlands include black-tailed deer, coyote, raccoon, Virginia opossum, striped skunk, and several rodent species including big-eared woodrat. Other representative animal species in the Morro Bay area's oak woodlands include arboreal salamander, black-bellied slender salamander, western skink, and common kingsnake.

Vegetation Species Matrix Typifying Oak Woodland Habitat

Common Name	Scientific Name
Bed straw	*Galium* spp.
Bracken fern	*Pteridium aquilinium*
Coast live oak	*Quercus agrifolia*
Gooseberries and currents	*Ribes* spp.
Hummingbird sage	*Salvia spathacea*
Miner's lettuce	*Claytonia perfoliata*
Poison oak	*Toxicodendron diversilobum*
Toyon	*Heteromeles arbutifolia*

Habitat Description: Maritime Chaparral

Maritime chaparral communities occur along the coast of California on sands, sandstones, marine sediments, and stabilized dunes. Within the Morro Bay watershed, this plant community inhabits the sandy soils of old stabilized sand dunes, primarily near Los Osos, forming a mosaic of related habitats with oak woodlands and coastal scrub. The Morro Bay area plays an integral role in maintaining maritime chaparral communities as they are among the most threatened in the state. Maritime chaparral is considered a habitat of special concern by CDFW.

In the areas around Los Osos this habitat type is primarily located in the summer coastal fog invasion zone, on well-drained and nutrient poor soils dominated by manzanita (*Arctostraphylos* spp.) and *Ceanothus* spp. including the federally endangered Morro manzanita (*Arctostraphylos morroensis*) (LOCP FEIR, 2020). Other typical plants found in this community include chamise, buck brush, deer weed, toyon, poison oak, and black sage. This rare habitat is home to common wildflowers including monkey flower, penstemon, poppies and lupine.

Animals that utilize this habitat include many common mammals and reptiles including raccoons, opossums, wood rats, coyotes, bobcats, grey foxes, rattlesnakes, gopher snakes, garter snakes, and fence lizards. Less common are legless lizards and coast horned lizards. The Morro Bay kangaroo rat, a federally-endangered endemic species, has not been observed since 1986 and may be extinct. The Morro shoulderband snail is a federally-threatened gastropod endemic to the Morro Bay area that is found primarily in this habitat type. It is the subject of a Habitat Conservation Plan (HCP) described further below.

Vegetation Species Typifying Maritime Chaparral Habitat

Common Name	Scientific Name
California coffeeberry	*Rhamnus californica*
Chamise	*Adenostoma fasciculatum*
Hollyleaf cherry	*Prunus ilicifolia*
Mock heather	*Ericaameria ericoides*
Morro manzanita	*Arctostaphylos morroensis*
Pygmy coast live oak	*Quercus agrifolia*
Toyon	*Heteromeles arbutifolia*

Habitat Description: Coastal Scrub and Chaparral

Southern coastal scrub communities are characterized by drought-tolerant shrubs that favor drier conditions. These communities appear along the coast or inland on coastal hills in semi-arid habitats (Rundel and Gustafson, 2005). Shrubs and subshrubs in these communities are

soft stemmed, usually about three-to-four feet in height, and have smaller, less-dense canopies compared to chaparral communities. They are found in areas with coarse, shallow soil and fine clays and tend to be dormant in the summer.

In the Morro Bay watershed, scrub land is common and covers large areas, especially on steeper slopes above grasslands where it often borders on oak woodlands and riparian areas. California sage and coyote bush are among the primary plant species in the southern coastal scrub communities, and deerweed, chamise, golden yarrow, everlastings, and California buckwheat also commonly occur. In shaded draws, north-facing hillsides, and on higher elevations of the watershed prone to greater rainfall totals due to orographic effects, manzanita, buck brush, and other chaparral species may intermix with the scrub species that are more typical of drier conditions. In these moister areas, larger woody species such as toyon, hollyleaf cherry, and mountain mahogany may occur. Numerous wildflowers are found in scrub habitat including bush lupine, sticky monkey flower, paint brush, penstemon, peony, and bush poppies.

Several animal species utilize this widespread habitat including coyote, brush rabbit, wood rats, gopher snakes, rattlesnakes, fence lizards, and alligator lizards as well as common birds such as jays, thrashers, and towhees. Several raptor species of special concern hunt in the scrublands of the watershed including northern harriers, white shouldered kites, and golden eagles.

One of the most important values of large stretches of intact scrub is its role in preserving wildlife corridors within the watershed. This habitat connects open spaces that are protected through public ownership or conservation easements and between other important habitats such as chaparral, riparian areas, and woodlands.

Vegetation Species Typifying Coastal Scrub Habitat

Common Name	Scientific Name
Black sage	Salvia mellifera
Buckbrush	*Ceanothus cuneatus*
CA poppy	*Eschscholzia californica*
California buckwheat	*Eriogonum fasciculatum*
California sagebrush	*Artemesia californica*
Coyote bush	*Baccharis pilularis*
Deerweed	*Acmispon glaber*
Lupine	*Lupinus* spp.
Yarrow	*Achillea millefolium*

Habitat Description: Grasslands

Like most of California's grasslands, those in the Morro Bay watershed are dominated by non-native species brought from Europe at least 200 years ago. The almost complete replacement of native grasses with non-native species is "one of the most dramatic examples of ecological invasion in recent history" (Ritter, 2018). Despite this, grasslands, which are used today primarily for livestock grazing, still have significant natural value as habitat for rodents and other small prey animals for a wide range of raptors and other vertebrate predators. Many species of bats are known to hunt insects in the watershed grasslands (Sims, 2010).

Interspersed within these grazing lands are some small but ecologically-specialized habitats, notably serpentine outcroppings and associated soils and relic areas of native bunch grasses. Serpentine soils are discussed in a later section.

Common introduced grasses in the Morro Bay area include wild oats, bromes, foxtail barley, and ryegrass. In addition to these grasses of European origin, numerous non-native weedy plants such as mustard, fennel, and thistle have spread into grazing areas that are not well managed and, once established, are very difficult to eradicate.

Properly managed grazing helps control weeds and other noxious invasive species, reduces wildfire intensity, and promotes retention of soils that are susceptible to erosion. The MBNEP has devoted considerable efforts to promote grazing BMPs in the watershed. Grassland adaptive management can also include controlled burns and removal of noxious invasives either mechanically or by chemical applications.

Native bunch grasslands are much diminished throughout California and in the watershed. In the vicinity of Morro Bay itself, they exist only as patches of needlegrass in Morro Bay State Park and a few other locations (Sims, 2010). The extent of relic native grasslands in the upper watershed is not well mapped.

Grasslands are inhabited by large numbers of rodents (e.g., ground squirrels, gophers, voles, and mice) that are the primary prey of many predator species. In the Morro Bay watershed several raptors on the CDFW Watch List including white-tailed kite, golden eagle, merlin, prairie falcon, northern harrier, sharp-shinned hawk, and Cooper's hawk occur. Burrowing owls have been observed seasonally. Resident faunal predator species include gopher snake, rattlesnake, bobcat, grey fox, coyote, mountain lion, and American badger, among others.

Grasslands also include many of much-loved spring-time native wildflowers including California poppy, fiddleneck, blue-eyed grass, buttercups, blue dicks, and several species of lupine including *Clarkia*, *Castilleja*, and *Calochortus*.

Freshwater springs and stock ponds are scattered throughout grassland habitat and provide water sources for animals and habitat for the Southwestern pond turtle and the threatened California red-legged frog. These freshwater sources are discussed in an earlier section.

Vegetation Species Matrix Typifying Grassland Habitat

Common Name	Scientific Name
California poppy	*Eschscholzia californica*
Fennel*	*Foeniculum vulgare**
Fiddleneck	*Amsinkcia* spp.
Foxtail barley*	*Hordeum murinum**
Lupine	*Lupinus* spp.
Purple needle grass	*Stipa pulcra*
Rip-gut brome*	*Bromus diandrus**
Sahara mustard*	*Brassica tournefortii**
Wild oat*	*Avena* spp.*

**Invasive species that are dominant in the habitat.*

State and Federal Threatened and Endangered Species

- Willow flycatcher (SE)
- Morro shoulderband snail (FT)
- Morro Bay kangaroo rat (SE/FE)
- Morro manzanita (FT)
- Indian Knob mountainbalm (SE/FE)

Habitat Extent: Upland habitat comprises approximately 37,216 acres, about 75% of total watershed area, within the Morro Bay watershed (Figure 12). Oak woodlands comprise approximately 4,268 acres within the Morro Bay watershed, about 9% of the watershed land area. Maritime chaparral comprises approximately 2,300 acres within the Morro Bay watershed, about 5% of the watershed land area. Coastal scrub comprises approximately 2,218 acres within the Morro Bay watershed, about 4.5% of the watershed land area. Other chaparral and scrub habitat accounts for approximately 7,350 acres of the watershed with about 15% of watershed land area. Grasslands comprise approximately 20,854 acres within the Morro Bay watershed, about 42% percent of the land area.

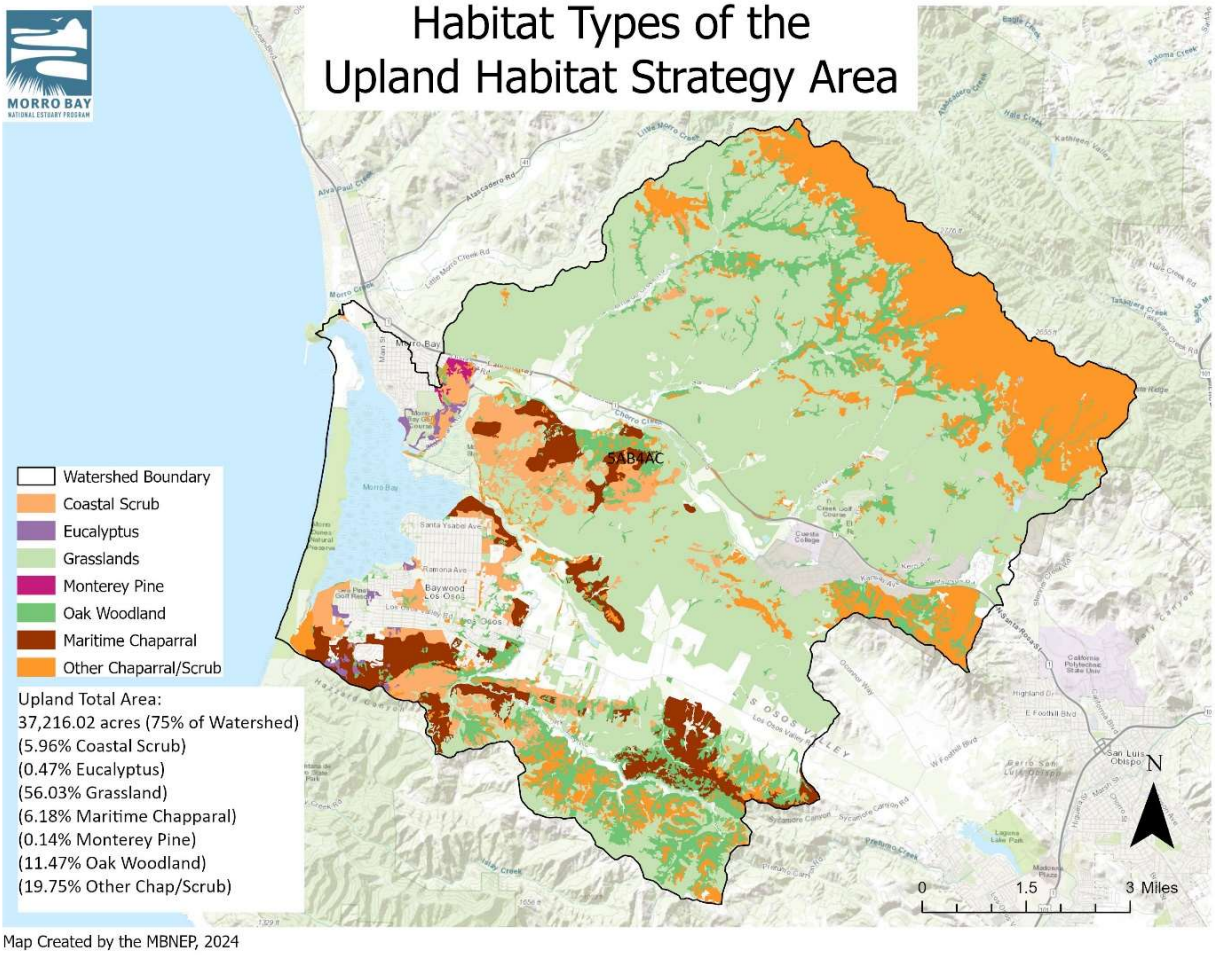


Figure 12. Upland habitat area and habitat types extent and location within the Morro Bay watershed. Percentages displayed are relative to total upland habitat acreage.

Habitat Health: Overall, upland habitats benefit from reduced habitat fragmentation with healthy native species cover and reduced invasive species presence.

- Oak woodland: Indicators of oak woodland health include the density of canopy, a good mix of trees of different ages within the woodland, and evidence of current reproduction. An important and critical health variable is the absence of sudden oak death (SOD) infections.
- Maritime chaparral: The most important indicator of maritime chaparral habitat health is its presence in a larger scale and continuous vegetative community that is not highly fragmented by development. The HCP designates areas in Los Osos as “preserves” for the Morro manzanita and Morro shoulderband snail. County regulations require the preservation of this habitat on existing parcels of 20,000 square feet or larger. On smaller parcels and in cases where preservation is not possible, landowners must contribute to the maintenance and management of the nearby preserves as a condition of development permits.

- Coastal scrub and chaparral: Healthy coastal scrub and chaparral include indicators like reduced invasive species within the habitat and along the habitat edge.
- Grasslands: Healthy grassland habitat is usually associated with the application of grazing BMPs (adaptive rangeland management) to reduce erosion, invasive weeds, and risk of intensive wildfire.

Protection and Restoration Efforts

Most of the protection and restoration efforts within upland habitat have been focused on minimizing development and habitat fragmentation. The MBNEP has also funded a wildfire management study to help reduce impacts from intense fires. Specific efforts within each habitat type are highlighted below.

Oak woodlands: Protecting surviving oak woodlands in the Morro Bay watershed from development and large-scale removal for grazing is the key to retaining this habitat. Large areas of woodlands (29% of oak woodland habitat) have already been preserved on public-owned and managed lands including Morro Bay State Park, Montaña de Oro State Park, Los Osos Oaks State Preserve, and Elfin Forest. Other oak woodlands are located on land managed by public entities including Cal Poly, County Parks, CDFW, U.S. Forest Service (USFS), and California Department of the Military. Woodlands outside these protected areas are generally located on higher elevations and steep slopes, reducing their vulnerability to large scale development and conversion to grazing and agriculture.

The MBNEP, with funding assistance from the California State Coastal Conservancy and The Nature Conservancy, obtained and now oversees a conservation easement along the southeastern edge of the city of Morro Bay. This easement includes provisions to protect the oak woodlands on the property.

The County of San Luis Obispo has adopted a native tree protection ordinance that specifically prohibits large scale clear cutting without special review and permissions. Development on steep slopes including parcels containing live oaks are also subject to special review requirements.

Maritime chaparral: Approximately 32.6% of maritime chaparral in the Morro Bay watershed is in publicly-owned and managed properties or under conservation easements, primarily in Morro Bay and Montaña de Oro State Parks and in open space preserves managed by the Los Osos Community Services District (CSD).

Areas outside these protected areas tend to be highly fragmented, making them vulnerable to development. The County of San Luis Obispo and the California Coastal Commission recognize the importance of this rare habitat for the endangered Morro manzanita and Morro shoulderband snail. As noted above, they have adopted land use requirements to avoid its loss where possible and its replacement into designated, managed reserves when not. The Los Osos Community Plan was updated in 2023 and includes detailed regulations on how future development will be permitted on parcels where Morro manzanita may exist. Concurrently, the

County along with USFWS and CDFW have developed an HCP that details how this critical habitat will be preserved. Outside publicly-managed properties, the County requires avoidance of the loss of maritime chaparral where Morro manzanita exists, including its replacement if encroachment is unavoidable in certain cases as well as financial contributions toward managing the preserves. Where practical, removal of invasive plants and replacement with native species will continue in targeted locations such as the Elfin Forest.

Coastal scrub and chaparral: Approximately 50.3% coastal scrub habitat in the Morro Bay watershed is already in publicly-owned and managed properties or under conservation easements, primarily in Morro Bay and Montaña de Oro State Parks and in property managed by Cal Poly, CDFW, County of San Luis Obispo, and the California Department of the Military.

Publicly-owned lands and conservation easements on private properties, many of which have been facilitated by the MBNEP with its many partners, form greenbelts around the Los Osos community and southern boundary of the city of Morro Bay. These greenbelts inhibit the incursion of urban type land uses into the upper watershed, preserving open space including scrub lands. Large areas of intact scrub habitat form important wildlife corridors allowing for the movement of many wide-ranging species such as mule deer, coyotes, and mountain lions. Continuity between existing open spaces is considered a priority for future acquisitions.

Much of the coastal scrub outside already protected areas is on relatively steeply sloping hillsides not threatened by future large-scale development. Furthermore, County and Coastal Commission regulations generally require avoidance of scrub habitat with new development.

Grasslands: Approximately 32.5% grasslands in the Morro Bay watershed are already in publicly-owned and managed properties by CSP, CDFW, Cal Poly, County Parks, USFWS, and California Department of the Military. In addition, conservation easements on private lands encompass an additional approximately 63 acres or 13% of the grassland habitat.

The MBNEP, with funding assistance from the California State Coastal Conservancy and The Nature Conservancy, obtained and oversees a conservation easement along the eastern edge of the city of Morro Bay. This easement includes provisions to protect the grassland on the property, limiting conversion to development and to irrigated agriculture. Grazing BMPs are practiced by the landowner and regularly monitored by the MBNEP. This large easement also formed a substantial greenbelt inhibiting potential future sprawl into the watershed. The MBNEP will continue to facilitate grazing BMPs. In some instances, grazing land may be suitable for restoration to native habitats, particularly restoring bunchgrasses and oak woodlands.

Stressors and Climate Vulnerabilities

The primary threats to upland habitats in Morro Bay watershed have been encroachment of development and habitat loss due to land use conversion to grazing or agriculture. The principal responses to those threats have been protection and management in public ownership or in conservation easements on private property, land use regulations administered by the County

of San Luis Obispo, and implementation of best management practices of working lands. In addition, habitat types have specific stressors and vulnerabilities:

Oak woodlands: Although not yet documented in the Morro Bay watershed (Sudden Oak Death Map Project) there are concerns that climate change will increase oak vulnerabilities to diseases and specifically to sudden oak death. Sudden oak death is caused by a plant pathogen, *Phytophthora ramorum*, that targets and kills primarily coast live oak. The disease has killed millions of trees along the Northern California coast and is present in bay laurel trees within San Luis Obispo County. The rate of SOD increases with normal to above-normal rainfall (Lione et al., 2017), which is predicted to occur with climate change paired with increased periods of drought.

Maritime chaparral: In some places, maritime chaparral has been successfully protected from development, but certain public access and recreational uses are allowed. Despite signage and symbolic fencing, irresponsible use of open spaces has damaged this habitat, diminishing its natural value. Balancing public access with habitat protection is a challenge for many public open spaces in the estuary and watershed, especially given the sensitive nature of many of the habitat types.

Maritime chaparral is also vulnerable to several invasive plant species. Efforts to cull invasives and restore the habitat to native mixes have been undertaken, notably in the Elfin Forest area of Los Osos, but these efforts are very labor intensive and require ongoing monitoring. In addition to invasive plant species, non-native animals also diminish habitat values. Domestic pets almost certainly contributed to the extirpation of the Morro Bay kangaroo rat (last observed in 1986). More recently, feral pigs have done considerable damage to maritime chaparral areas near the estuary.

Coastal scrub and chaparral: This habitat evolved to withstand occasional wildfires but when fire intervals are extended, the older, densely-vegetated communities can be subject to especially intense fires from which regeneration time can be lengthy. During that time, the habitat can suffer from erosion and soil depletion and can be especially vulnerable to invasive plant species.

Grasslands: Changes in precipitation and fire regimes can also affect grasslands. Unmanaged grazing land suffers reduced habitat value by the spread of invasive weeds. The accumulation of dense thatch from invasive weeds that inhibits native species, further aggravates weed encroachment, and increases fire fuel loads (Taylor, 2006).

Climate change is expected to exacerbate all these current and projected stressors including:

- **Increased storminess** will likely result in more erosion within upland systems, especially on steeper slopes and near ephemeral drainages, exposing roots systems. Especially when combined with high winds, mature oak trees are susceptible to uprooting or limb failure.

- **Warmer temperatures and increased drought** are likely to increase variability in precipitation and will have varying impacts on upland habitats. Live oak trees can be stressed by prolonged droughts and periods of high temperatures, both of which are expected to increase with climate change. Stressed trees are more vulnerable to disease and winds. They may "self-prune" by dropping large branches from the main stem. The demise of individual trees lessens the woodland canopy, making the habitat more vulnerable to conversion to scrub or grassland. Reduced canopy also makes certain invasive species more viable, reducing habitat value in the understory. Overall, grasslands tend to be adaptable to changing precipitation regimes, but shifts in the plant species mix in response to temperature and precipitation changes can affect rodent populations differently and thus the predators that have particular prey preferences.
- **Increased wildfire** is predicted to increase in frequency and intensity in California. Native plant communities within upland habitats have long evolved to survive and be enhanced by less frequent, low-intensity wildfire (Holmes et al., 2008), often stewarded by Indigenous peoples and cultural burning (Anderson, 2013). In fact, controlled fire via prescribed or cultural burning can be a tool in managing the spread of invasive weedy plants into the grasslands and can improve native plant biodiversity. However, climate change driven high intensity fires, especially when coupled with drought conditions, can kill native upland species, inhibit regeneration of native species, and encourage invasive weedy species regrowth. For example, high intensity wildfires that reach the canopies can kill mature oak trees, making post-fire regeneration of woodlands slower and more difficult. Coast live oaks can survive for hundreds of years, so the loss of mature specimens and their associated woodland canopy is especially impactful on ongoing habitat values. In addition, century-long fire suppression practices and removal of Indigenous fire stewardship has forever changed the composition of upland landscape. Less frequent wildfires accelerate the transition from grassland to scrub, and scrubs to woody types such as coast live oaks. Native plant communities may also be more vulnerable to climate change-fueled fire versus invasive species better adapted to hotter, drier conditions.

Adaptation Actions: Adaptation actions relevant to estuarine habitats from the Climate Vulnerability Assessment (MBNEP, 2021) include education on herbicide and pesticide alternatives, erosion control measures, upland area grading to prevent wetland loss, maintenance of physical conditions that support eelgrass habitat, eelgrass planting, plant migration facilitation, invasive plant species removal, drought tolerant and native plants use, fire tolerant natives use, drought tolerant plant species use to maintain soil moisture, sediment augmentation to tidal marsh, local planning effort support to protect migration areas from development and encourage climate-smart growth, collaboration with CDFW and CSP on mitigation efforts. Partner adaptation actions include:

- The CSLRCD has completed Climate Ready Rangeland projects in the Morro Bay watershed to prepare for climate change. These projects implemented multiple water conservation and soil building methods and improved grassland ecosystem health. CSLRCD has had demonstration workshops on climate-ready management of rangelands for cattle ranchers in the area. The project is considered an example of carbon farming, a method of building resiliency and capturing carbon through on-farm BMPs (Carbon Farm Plan, 2020).
- The CSLRCD also conducts projects like floodplain restoration, stream buffers widening, percolation projects, and education on herbicide and pesticide alternatives.
- The CSLRCD continues to be involved in facilitating best management agricultural practices throughout the Morro Bay watershed. Their efforts in soil conservation, biodiversity, and water stewardship continue to prepare agriculture in the area for climate change. The MBNEP will continue to collaborate with the CSLRCD on soil building and carbon farming projects in the future.
- Land Conservancy of San Luis Obispo County conducts invasive species management.
- Camp SLO, Cal Poly, and USFS partnered with the MBNEP to complete a roads improvement project to reduce erosion from ranch roads.
- The MBNEP will continue to work with CDFW and CSP in the management of natural resources within the watershed. Many species habitat enhancement and invasive species management projects are led by these agencies and will be important to the resilience of the watershed in the future.

Climate Resiliency

Native trees, shrubs, and grasses within upland habitats sequester carbon and provide soil stabilization during high precipitation events. Tree and shrub canopies provide shade and temperature relief from high temperatures. Native vegetation within upland habitats in general reduces wildfire risk compared to invasive species, especially within grasslands (Fusco et al. 2019). Upland habitats managed with low-intensity fire and managed grazing by livestock (e.g., goats, sheep, and cows) can reduce overall wildfire risk and improve native biodiversity.

Objectives and Targets:

- Maintain and enhance a healthy diversity of upland habitats including oak woodland, maritime chaparral, coastal scrub, and native grassland through habitat protection and restoration.
- Support monitoring, research, and management efforts to better understand climate resiliency, ecosystem function, and restoration opportunities.
- Collaborate with partners to support upland habitat protection through acquisitions and easements. Most of the upland habitat within the watershed is already protected via public ownership or private conservation easements. Future protection will be

opportunistic depending primarily on the willingness of landowners and the availability of funding.

- Collaborate with partners to support open space improvements that protect or enhance upland habitats and promote balanced human uses.
- Support partners and implement invasive species management within 100 acres of upland habitat.
- Support projects and planning efforts that conserve or enhance special status habitats and species, increase habitat connectivity, and improve overall resilience.
- Support invasive species monitoring, planning, and management efforts that enhance priority upland habitats.
- Collaborate with partners and landowners to implement best management practices (BMPs) that improve habitat value and resiliency of working lands.

Ongoing and potential projects. * Indicates ongoing projects

- ***Land Protection:** Continued work with partners in the watershed, including private property owners, to maintain current upland habitat through public ownership or conservation easements.
- **Oak Woodland Restoration:** Oak woodland restoration at CCER and continued restoration within suitable habitat of the watershed as funding allows.
- ***Invasive Species Management:**
    - Support continued targeted removal of invasive species from forest margins and understory in the Elfin Forest and Sweet Springs Nature Preserve.
    - Support partners to improve upland habitat through fire and invasive species management.
- ***Regional Collaboration:** Participate in and support local and regional efforts to restore and maintain protected species within upland habitats, such as Morro manzanita.
- ***Upland BMPs:** Continued work with partners to implement BMPs on grazing lands such as road improvements, gully erosion improvements, stormwater/groundwater catchment improvement (e.g., peak flow capture), riparian and rotational grazing fencing, bioswales, riparian fencing, off-channel livestock water, fire management, irrigation water and nutrient management plans, headcut repairs, and streambank stabilization.

Example Projects

Conservation Easements: Over the past twenty years, the MBNEP has supported the establishment of ten conservation easements within the watershed. These easements have protected over 3,700 acres of upland habitat mostly within grassland habitat types.

Monitoring of Grazing BMPs: The MBNEP monitors water quality parameters following implementation of grazing best management practices. After riparian fencing was installed along San Luisito Creek, monitoring program tracked bacterial levels in the creek and tracked resulting water quality improvements.

Cuesta College Ranch Education Program: The MBNEP funded water infrastructure to help establish a ranch education program at Cuesta College. The 75-acre site is heavily invaded by invasive grass and upland species. The program's goals are to provide work education and training for students interested in management of grazing and invasive species. The program trains and educates around 30 students per semester in farm maintenance and land use grazing. The site will be monitored pre- and post-livestock grazing to determine grazer effectiveness on soil remediation and invasive species control.

Other Smaller Habitats of Note

Interspersed among the more widespread upland habitat types are occurrences of other, smaller scale habitats of note.

Serpentine outcroppings and soils

Within the Morro Bay watershed upstream from the delta and bay are areas of serpentine outcroppings and associated soils. Serpentine, the state rock of California, is greenish grey in appearance and is common in the area. Soils that are formed from weathered serpentine are characterized by low levels of calcium and the presence of heavy metals, notably chromium in the Morro Bay region which was once mined in upper watershed.

Many plants cannot thrive in these soils, but several species tolerant of such conditions have evolved including several endemics. Plants that are associated with serpentine outcroppings include species of dudleya, chia, and gilia. Many lichen species are also found on the exposed rock surfaces in this habitat.

Because of the high level of endemism, these habitats are considered sensitive and warrant regulatory protection. Local land use regulations require assessment of the presence of this habitat prior to permitting development. For the most part, these soils are unsuitable for grazing and agriculture and are often associated with steep, rocky slopes that have limited intensive urban development. Furthermore, in the Morro Bay watershed serpentine soils often include naturally-occurring asbestos. Dust from grading is considered a potential health hazard

by the Air Pollution Control District that requires special protections for workers, which further inhibits development in these areas.

Dacite outcroppings

The well-known "Morros" are among the most beloved landscape features in the Morro Bay watershed. These large, exposed peaks are composed of dacite, a relatively hard, igneous rock. Its resistance to weathering accounts for the familiar rocky peaks that rise above the Chorro and Los Osos Valleys and includes Morro Rock near the mouth of the estuary. There are also some smaller dacitic outcroppings scattered around the bay and in the watershed.

The naturally-exposed outcroppings of dacite and other steep cliff faces formed by quarrying in the past have special habitat value, mostly related to bird roosting and nesting. Morro Rock is home to numerous seabird species including brown pelicans, cormorants, and gulls. Certain raptor species, notably the peregrine falcon, use these largely inaccessible rocks and quarried cliffs for nesting.

Morro Rock, Black Hill, Cerro Cabrillo, and Cerro Romaldo are under public ownership. Hiking access is permitted only on Black Hill and Cerro Cabrillo, both located in Morro Bay State Park. Morro Rock is designated as an environmentally-sensitive habitat and a state-managed ecological preserve. It is also a sacred site important to Indigenous peoples. Apart from occasional ceremonial visits, public access is strictly prohibited. Cerro Romualdo is on property managed by the California Military Department and is likewise unavailable to the public.

The other two Morros in the watershed, Chumash Peak and Hollister Peak, are under private ownership but are not open to the public and are protected from future development. The County of San Luis Obispo has designated these areas as Sensitive Resource Areas, and they are not considered threatened.

Sargent's cypress forest

The extreme northeast section of the watershed extends into the Cuesta Ridge Botanical Special Interest Area of the Los Padres National Forest. This botanical reserve includes 1,300 acres, most of which is outside the Morro Bay watershed. The principal feature of this reserve is a Sargent's cypress (*Hesperocyparis sargentii*) forest, a relatively rare vegetation community. The botanical area is managed by the USFS.

Non-native woodlands

Eucalyptus: In several areas of the watershed, stands of non-native eucalyptus trees dominate the landscape. Examples include several areas in Los Osos and Baywood Park, parts of Morro Bay and Montaña de Oro State Parks, Cal Poly lands, along Highway One near the California National Guard Base and the California Men's Colony, and on properties along Los Osos Valley Road and in Clark Valley where they have been planted as wind breaks and boundary markers.

The habitat value of these woodlands is mixed. Certain bird species, notably herons, egrets, and cormorants, use the eucalyptus trees near Morro Bay for roosting and nesting. A portion of Morro Bay State Park contains a long-established rookery where public access is limited.

Some eucalyptus groves in California's Central Coast are important Monarch butterfly habitat where large numbers of these insects over winter during their migrations. A substantial eucalyptus grove in Los Osos within the Montaña de Oro State Park and adjacent to the Sea Pines golf course has been designated as a Monarch Butterfly Preserve. Overwintering monarch butterflies throughout the United States have dramatically declined recently and have been designated by the federal government as a species of concern.

While they offer some value as habitat, the eucalyptus is prolifically invasive and its understory is usually barren of most native plants due to the oils in the bark and leaves that often create a thick duff that inhibits other plants from germinating. Those eucalyptus oils make these trees highly flammable, increasing wildfire risks when located near developed areas.

There has been significant debate (and controversy) about efforts to remove eucalyptus and restore native trees in places such as the State Parks and the Sweet Springs Nature Preserve.

Monterey pine: A species not native to Morro Bay that is found farther north along the coast, Monterey pines (*Pinus radiata*) have been introduced in many parts of the watershed, notably on Black Hill in Morro Bay State Park but also in several other locations for landscaping purposes. This species is vulnerable to a fungal disease, pine pitch canker, which killed large populations of Monterey pine in the Morro Bay area. Once thought likely to be exterminated by the fungus, disease resistant populations have emerged, and areas once characterized by dead and dying specimens have recovered to some degree.

The understory of the larger Monterey Pine woodlands in the Morro Bay area contains mostly non-native plants and poison oak, with patches of native scrub and chaparral species where the canopy is open.

As with eucalyptus, the habitat value of Monterey pine woodlands is mixed. The trees are used by many avian species for roosting and nesting. Dead limbs and trees harbor insects, a food source for many species. Largely for their scenic value rather than habitat importance, these woodlands are considered areas warranting special protection by the local governments, and large-scale removal is generally prohibited.

Monterey cypress: Another tree species familiar to the Morro Bay area is the Monterey cypress (*Cupressus macrocarpa)*. Like the Monterey pine, this species is not native to Morro Bay but occurs naturally farther north along the coast. However, the picturesque cypress has been planted in many locations near the estuary and in the watershed as landscaping features and wind breaks. In several locations the cypress trees have been interspersed with blue gum eucalyptus where they provide, in combination, roosting and sometimes nesting habitat for avian species. Of special note are the cypress trees intermixed with eucalyptus along Los Osos

Valley Road and near the heron rookery in Morro Bay State Park. As with Monterey pines, these trees are highly valued for their scenic qualities and are not considered vulnerable to widespread removal.

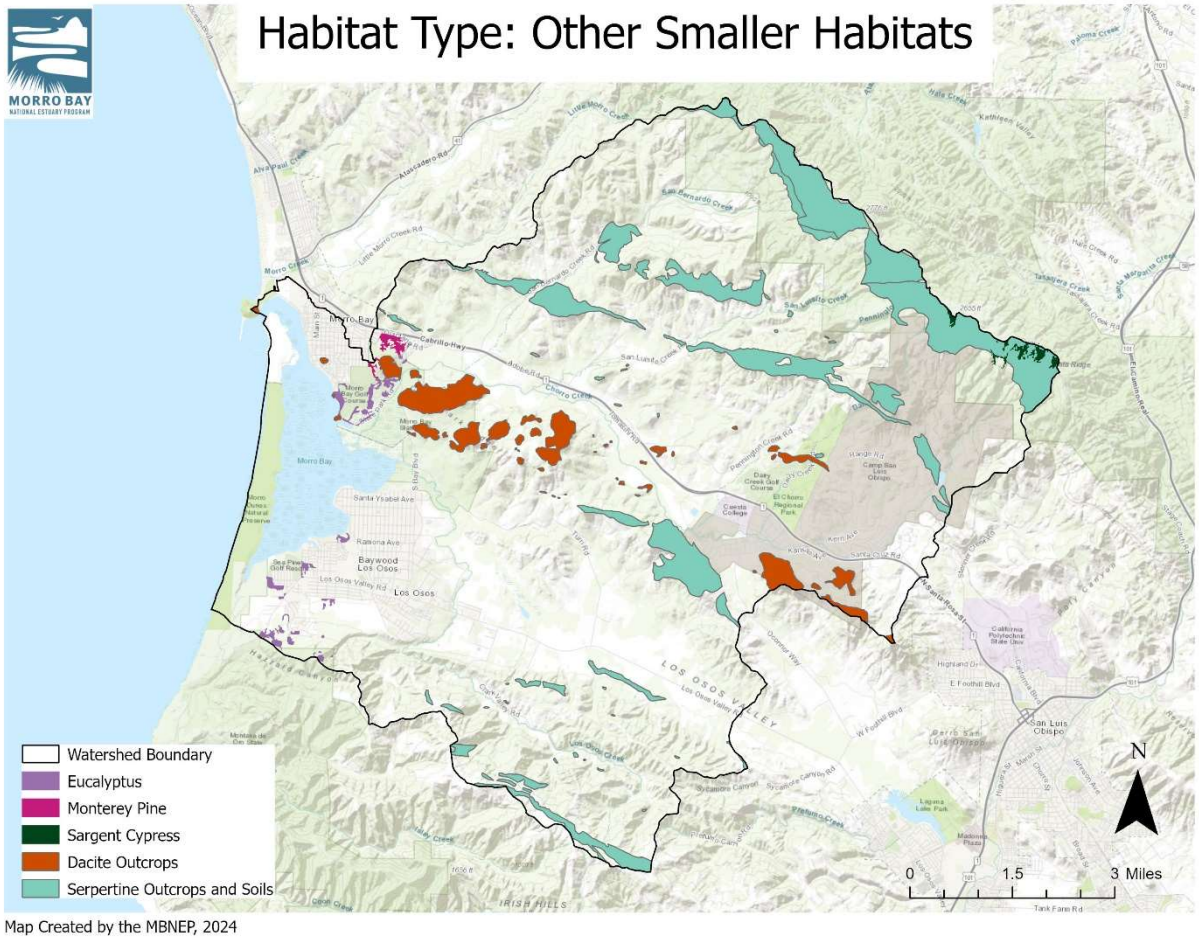


Figure 13. Extent and locations of other smaller habitats of note within the Morro Bay watershed including non-native woodlands (eucalyptus and Monterey pine), Sargent's cypress, and unique geologic outcrops (dacite and serpentine).

Urban Development and Irrigated Agriculture

Towns and agriculture are important elements of the Morro Bay estuary and watershed. The Morro Bay watershed is home to over 26,000 residents and is a significant contributor to San Luis Obispo County crop yields. From a natural habitat protection perspective, these landscapes may have some limited value for some native species. More importantly from a perspective of habitat protection and restoration, activities in urban and irrigated agriculture should be conducted in ways that minimize adverse impacts on nearby natural systems.

The MBNEP encourages this through the promotion of municipal and agricultural BMPs and through public information and education programs. The MBNEP's CCMP through its action plans has also facilitated projects that aim to ameliorate potential impacts from urban and

agricultural uses. A few examples include stormwater controls and capture, Los Osos sewage treatment, pet waste management, and the employment of agricultural setbacks/buffers, among many others.

CCMP Action Plans

- (LP-3) Direct Urban Development
- (MON-2) Monitor Environmental Indicators
- (BMP-1) Agricultural and Grazing BMPs
- (BMP-2) Rural Road Erosion
- (BMP-5) BMPs by Private Landowners and Municipalities
- (BMP-6) Reduce Pet Waste
- (BMP 7) Support Stormwater BMPs
- (BMP-8) Harbor Operations BMPS
- (BMP-9) Boating BMPs
- (USE-2) Shellfish Farming
- (USE-3) Commercial Fishing Port Uses

In addition, several other CCMP action plans are relevant to urban and irrigated agriculture:

CCMP Action Plan Number	CCMP Action Plan
LP-1	Protect Special Habitats/Species
MON-1	Support Development of TMDLS
MON-3	Monitor Project Effectiveness
MON-4	Maintain VMP
MON-5	Support Partners
MON-6	Support Research Activities
BMP-11	CMC Wastewater
BMP-12	MB Wastewater
ECR-9	Regional and National Collaboration
ECR-10	Nutrients and Bacteria Dynamics
ECR-11	Conserve Ecosystem Functions
ECR-13	Population Dynamics
ECR-14	Support Recovery Plans
ECR-16	Invasive Species Action Plan
FWR-1	Manage Freshwater Resources
FWR-3	Understand Flow for Public Trust Resources
FWR-4	Chorro Valley Water Users Group

CCMP Action Plan Number	CCMP Action Plan
FWR-5	Water Conservation
FWR-6	Groundwater Re-charge
CLIM-1	Improve Understanding of Climate Change Impacts
CLIM-2	Assist in the Implementation of Local Government Climate Action Plans
CLIM-3	Climate and Adaptation Education
USE-1	Recreational Uses
USE-4	Morro Bay Power Plant
EO-1	Public Education and Outreach
EO-2	State of the Bay
EO-3	Nature Center
EO-4	Formal Education Programs

Urbanized Areas

Urbanized areas make up approximately 9% of area within the watershed and include the City of Morro Bay and the unincorporated community of Baywood/Los Osos, both located adjacent to the estuary. Farther upstream in the watershed, built-up areas include Cuesta College, various San Luis Obispo County facilities, Camp San Luis Obispo National Guard Base, and the California Men's Colony (CMC) all of which are located on relatively flat or moderately sloping topography. Much of the developed land includes a large percentage of impervious surfaces with "gray" infrastructure.

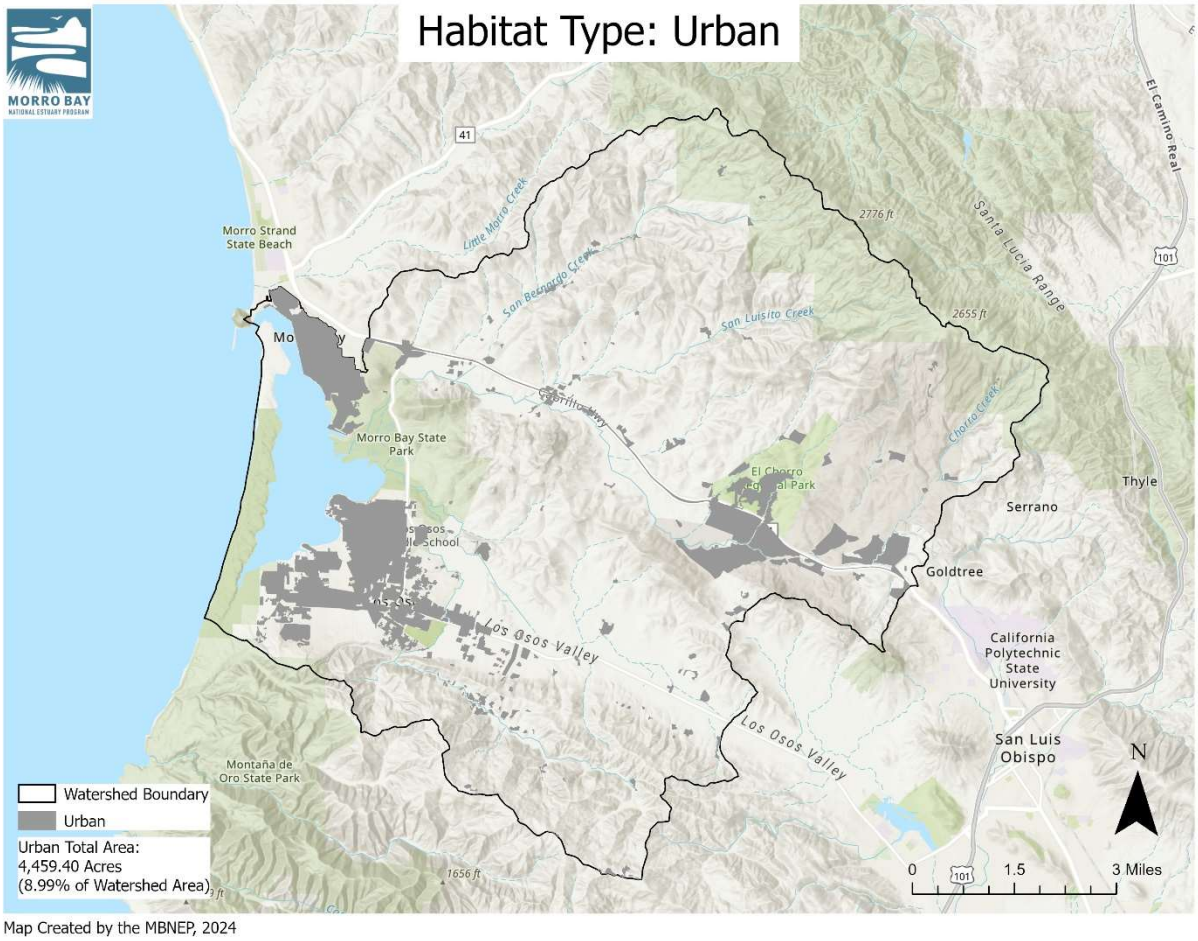


Figure 14. Urban development extent and location within the Morro Bay watershed.

The most significant potential impacts on the Morro Bay habitats would result from further encroachment of built-up areas into existing open spaces. As noted earlier, much of the estuary and watershed are protected and managed through public ownership or easements. Work by the MBNEP and many public agencies and nonprofits have contributed toward the creation of "green belts" around the boundaries of the City of Morro Bay and the community of Los Osos to encourage new urban expansion away from open spaces and into already built-up areas. The CCMP explicitly includes Action Plans to encourage the purchase of additional land or easements that protect vulnerable areas as opportunities arise.

In addition, the County, City, and California Coastal Commission have adopted plans, zoning, and development standards that limit the location and intensity of future development in the watershed. While such land use regulations can be amended, there has been long-standing strong support for protection of the estuary and watershed's habitat values. Furthermore, the entire estuary and watershed is within the boundaries of the California Coastal Zone, providing a significant additional layer of review and protection to these areas.

Urbanized areas as habitats: Generally, urbanization diminishes the habitat value of natural communities in many ways: by eliminating or intruding into those areas, generating pollutants, introducing invasive species, competing for resources such as freshwater, and disrupting wildlife corridors. However, urban areas do also provide habitats for many native species. This is especially true in small communities such as Morro Bay and Los Osos where the interfaces between developed and natural areas are extensive and intimate.

A good example of this mixed interface occurs in Los Osos where the approval of subdivisions early in the last century resulted in development within sensitive maritime chaparral habitat. This has severely impacted the threatened Morro shoulderband snail and Morro manzanita and likely contributed to the extirpation of the Morro Bay kangaroo rat. As noted earlier, an HCP has been prepared along with the County's recently adopted Los Osos Community Plan and Local Coastal Program update. These plans require new buildings to preserve maritime chaparral habitat where possible or to contribute to the management of consolidated habitat preserves nearby when on-site preservation is not possible.

Examples of how the built-up areas continue to contribute to natural fauna include the creation of an "urban forest" of landscape trees and other plants. The City of Morro Bay has developed an Urban Forest Management Plan (2012) that identified almost 700 trees just within the city's commercial zones. The majority of this urban forest is composed of eucalyptus trees. Other tree species commonly found within developed areas of Morro Bay and Los Osos include Monterey pine and Monterey cypress along with a great variety of decorative species.

Trees in developed areas combined with other landscape plants, especially when native types are used, provide habitat for birds and wildlife. Trees and gardens provide shelter, roosting, nesting areas, and food sources for many avian species. Several wildlife species inhabit the developed areas around the Morro Bay estuary including several types of bats, salamanders, tree frogs, legless lizards, and other reptiles. Migrating birds and insects including Monarch butterflies also utilize developed areas for shelter and food. In addition to providing wildlife habitat, the urban tree canopy lowers air temperatures, reduces heating/cooling costs, reduces air pollution, and provides aesthetic and community benefits.

The MBNEP and its partners such as the County of San Luis Obispo, the City of Morro Bay, LOCSD, and the California Coastal Commission actively work to strengthen the links to the natural environment and to minimize impacts from urban areas. Examples include the *Bayside Living Guide* and other education programs, local government tree protection regulations, wastewater treatment projects, improved storm runoff infrastructure, and BMPs for other municipal practices such as water conservation. The *Bayside Living Guide* provides information to homeowners and businesses regarding proper waste disposal and recycling, energy and water conservation, low impact gardening, and eco-sensitive pet ownership, among other topics.

The intent of these efforts is to increase awareness of peoples' relationship to the environment, to modify practices and behaviors to reduce adverse impacts on natural habitats, and to improve native habitat within the urban landscape where possible.

Stressors and Climate Vulnerabilities

Like people, vegetation and wildlife in urban areas are vulnerable to increased heat and flooding from climate change. Extreme temperature days in the Morro Bay area are projected to occur more frequently (Cal-Adapt, 2018; Thomas et al., 2018), which is especially problematic for areas dominated by gray infrastructure and the lack sufficient tree canopy coverage to absorb heat and provide shade. Increased storminess will generate a greater incidence of precipitation events with high run-off, increasing flood potential.

The two most significant potential impacts affecting habitat protection in the estuary and watershed are the intrusion of urban uses onto open spaces and water quality impacts from urban runoff. As noted earlier, strategic land acquisitions, in fee and by easement, in conjunction with local government plans and regulations have limited the likelihood of significant urban expansion. The MBNEP and its partners, especially the County of San Luis Obispo, LOCSD, and City of Morro Bay have identified a suite of BMPs for built up areas around the estuary to reduce impacts from urban runoff. Increasingly, local governments, long aware of environmental impacts from developed areas, have created plans and regulations that are more protective of nearby and downstream natural habitats.

Public access and coastal infrastructure will be impacted by sea level rise and increased storm surge with climate change. Local agencies have taken the lead on sea level rise considerations in the watershed's urban environment. For example, the City of Morro Bay has incorporated a sea level rise element into their Local Coastal Program, and the County of San Luis Obispo incorporates sea level rise into any coastal infrastructure project. The MBNEP will work with project partners to plan and implement projects that balance both coastal access and nature-based solutions to the impacts of climate change.

Adaptation Actions: Adaptation actions relevant to estuarine habitats from the Climate Vulnerability Assessment (MBNEP, 2021) include education on herbicide and pesticide alternatives, erosion control measures, upland area grading to prevent wetland loss, maintenance of physical conditions that support eelgrass habitat, eelgrass planting, plant migration facilitation, invasive plant species removal, drought tolerant and native plants use, fire tolerant natives use, drought tolerant plant species use to maintain soil moisture, sediment augmentation to tidal marsh, local planning effort support to protect migration areas from development and encourage climate-smart growth, collaboration with CDFW and CSP on mitigation efforts. Partner adaptation actions include:

- The County of San Luis Obispo encouraged Los Osos residents to reuse and repurpose their septic systems after decommissioning them when the Los Osos Water Reclamation Facility came online (Beneficial Reuse, 2015). The document they created provided

guidance to homeowners on converting septic systems into stormwater and grey water reuse systems. These conversions would help provide groundwater recharge to the area while also reducing stormwater runoff.

- Land Conservancy of San Luis Obispo County conducts invasive species management.
- The MBNEP will continue to work with CDFW and CSP in the management of natural resources within the watershed. Many species habitat enhancement and invasive species management projects are led by these agencies and will be important to the resilience of the watershed in the future.
- The City of Morro Bay changed the location of their new wastewater treatment plan to address concerns about future flooding due to climate change-related events, SLR, and tsunami flood risk. While the old plant was located outside the Morro Bay watershed boundary, the new site is within the Chorro Creek sub-watershed.
- Cal Poly completed a rainwater capture project in partnership with the MBNEP, Cal Poly, and the CCC.
- The CCC has completed stormwater/swale projects at their campus and throughout the watershed.

Climate Resiliency

Trees within the urban environment, especially trees mentioned within this strategy (e.g., eucalyptus, oak), help lower temperatures, sequester carbon, improve air quality, provide habitat, encourage groundwater retention, and reduce stormwater runoff. Native vegetation located on schools, greenways, or on private properties can act as important migratory pathways and microhabitats for native and sensitive species. Most people interact and impact with the Morro Bay watershed through living and working within or visiting the urban environment. Connecting visitors and community members to stewardship and climate resiliency awareness within the urban development space may have the greatest long-term impact.

Objectives and Targets:

- Improve and maintain partnerships to expand educational programming on watershed health, climate change solutions, special status species, and environmental stewardship within the urban environment.
- Support projects that enhance native habitat and climate resiliency within the urban environment.
- Partner at a local and regional level to improve stormwater/groundwater catchment and water conservation projects.
- Work with partners to implement projects that improve accessibility, public access, and recreation while considering nature-based solutions to sea level rise and climate change.

- Support municipalities and local planning departments to address the direct impacts of sea level rise and climate change on communities (e.g., saltwater intrusion in groundwater wells).

Ongoing and Potential Projects. * Indicates ongoing projects

- ***Stormwater Projects:** Funded and planned stormwater capture improvements at the Morro Bay State Park Marina and Camp SLO. Potential future project at San Luis Obispo County El Chorro Regional Park.
- ***Education and Outreach:** Educational programming with partner organizations and schools on watershed health curriculum. This includes creating targeted curriculum and activities to address urban impacts on watershed health and the estuary.
- ***Bay-friendly Gardening:** Provide education, resources, and funding for installations of native plant gardens at schools, local parks, and green spaces.
- ***Wastewater Management:** Participation in efforts to create a wastewater treatment plant in Los Osos by the County of San Luis Obispo and Los Osos Community Services District and move thousands of residents off septic systems.
- ***Water Conservation:**
    - Collaborate with partners and landowners to better coordinate reasonable groundwater extraction for all uses, including the function of natural systems.
    - Participate in regional efforts to study and implement innovative water conservation practices with climate change and sea level rise.
- ***Adopt-a-Spot Program:** Create a volunteer stewardship program in Morro Bay and Los Osos for community members to host their own cleanups, record what they find, and responsibly dispose of litter.

Irrigated Agriculture

Agriculture is a critical activity in the Central Coast region. Land with soils suitable for high agricultural productivity are recognized by State and local governments as an important natural resource to conserve. Farms and orchards cover 3,296 acres (6.7%) in the Morro Bay watershed mostly along the Chorro Creek and Los Oso Creek watershed valleys (Figure 15).

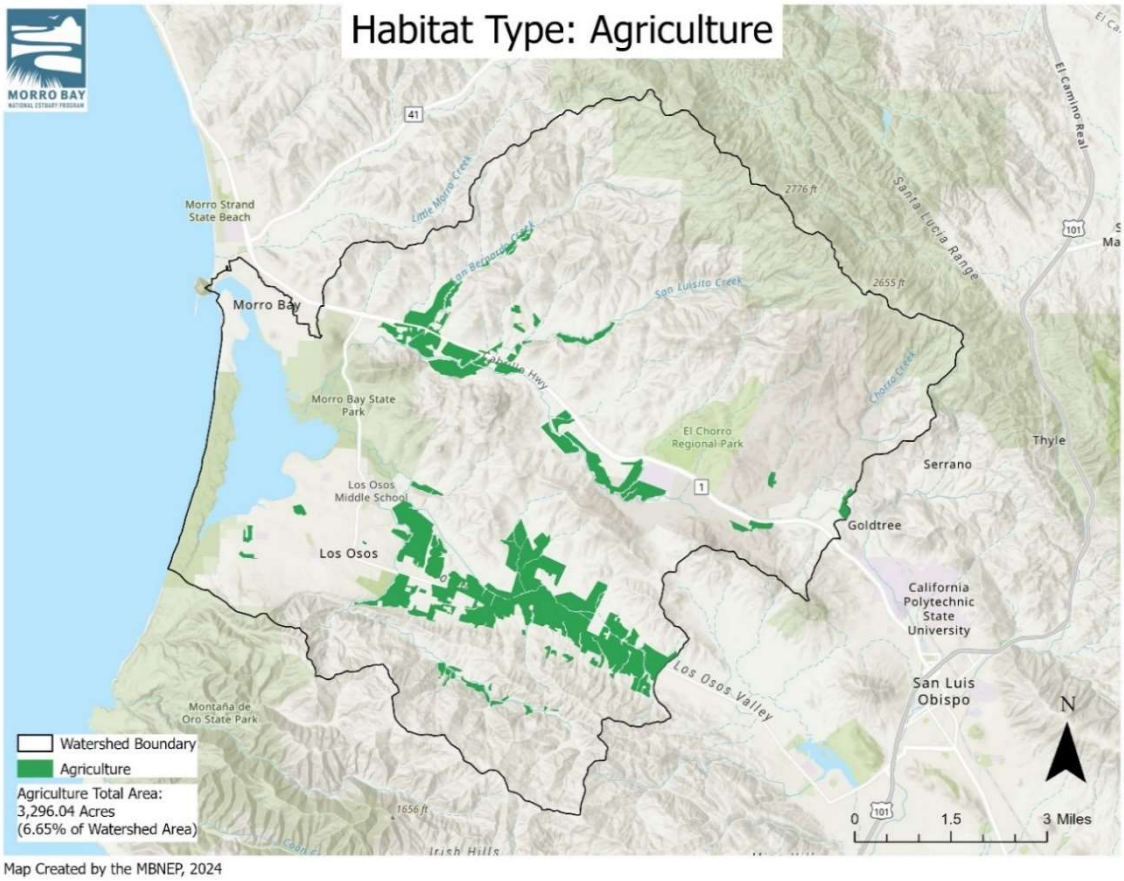


Figure 15. Irrigated agricultural extent and location within the Morro Bay watershed.

While well-managed grazing land can provide substantial natural habitat, the value for native biota of irrigated agriculture in the form of row crops and orchards is much less. Certain field and orchard crops may benefit from pollinators, and thus those birds and insects may benefit from such crops. Some bat species hunt prey above and around farming areas. But agriculture of necessity eliminates native species, replacing more diverse vegetation with domesticated food crops. Additionally, fallow agricultural fields can be invaded by non-native weedy species that then spread to nearby natural habitats.

Food production provides societal and economic benefits to the Morro Bay region and beyond. But farming practices often require groundwater for irrigation and fertilizers and pest control chemicals that could negatively impact overall watershed health. The MBNEP recognizes the importance of farming in the watershed and encourages BMP use to minimize impacts from nutrients and pesticides. Another protective measure is establishing buffers between

agricultural fields and creeks. Importantly, the MBNEP has encouraged all water users in the watershed to conserve water and to reasonably balance the needs of all uses including those of natural communities.

Stressors and Climate Vulnerabilities

Climate change will likely impact the area's agriculture. Higher temperatures and extended periods of drought will likely increase the need for groundwater withdrawals, increasing competition with natural systems for freshwater. More intense precipitation events may increase flooding which not only complicates agricultural practices but can also result in more nutrients making their way to the creeks. On the other hand, warmer temperatures could extend the time when crops are viable, perhaps leading to more double and even triple cropping practices. This could lead to higher water demand and increased use of fertilizers and pesticides in the watershed. The MBNEP has worked with landowners to encourage agricultural BMPs, including efficient water use, to minimize impacts on the estuary while supporting this vital industry.

Adaptation Actions: Adaptation actions relevant to irrigated agriculture from the MBNEP 2021 Climate Vulnerability Assessment include bioswale creation, education on herbicide and pesticide alternatives, erosion control measures, plant migration facilitation, invasive plant species removal, on-farm BMPs, percolation projects, drought tolerant and native plant use, fire tolerant natives use, drought tolerant species that maintain soil moisture, prescribed grazing/fires, rainwater harvesting, fuel loads reduction with CalFire, road erosion repairs, stormwater management, local planning efforts support to protect migration areas from development and encourage climate-smart growth, collaboration with CDFW and CSP on mitigation efforts, and water conservation. Partner adaptation actions include:

- The CSLRCD has completed Climate Ready Rangeland projects in the Morro Bay watershed to prepare for climate change. These projects implemented multiple water conservation and soil building methods and improved grassland ecosystem health. Implementation demonstrated climate-ready management of rangelands for the many other cattle ranchers in the area. The project is considered an example of carbon farming, a method of building resiliency and capturing carbon through on-farm BMPs (Carbon Farm Plan, 2020)
- The CSLRCD also completes projects like floodplain restoration, widening stream buffers, percolation projects, and education on herbicide and pesticide alternatives.
- The CSLRCD continues to be involved in facilitating best management agricultural practices throughout the Morro Bay watershed. Their efforts in soil conservation, biodiversity, and water stewardship continue to prepare agriculture in the area for climate change. The MBNEP will continue to collaborate with the CSLRCD on soil building and carbon farming projects in the future.
- Land Conservancy of San Luis Obispo County conducts invasive species management.

- The MBNEP will continue to work with CDFW and CSP in the management of natural resources within the watershed. Many species habitat enhancement and invasive species management projects are led by these agencies and will be important to the resilience of the watershed in the future.

Climate Resiliency

Irrigated agriculture can be a part of the climate solution and improve climate resiliency through alternative land management practices that help store carbon in the soil, also known as carbon farming. Some carbon farming and BMP activities include compost and mulch addition, cover crops use, no-till or reduced till farming, reduced fertilizer and pesticide use, and rotational grazing. Carbon farming not only sequesters carbon within the soil, but it also can increase crop yields and soil water holding capacity leading to improved water efficiency. Currently CSLRCD and Natural Resources Conservation Science (NCRS) provide assistance to local farms and ranches with their carbon farm plans and implementation within the Morro Bay watershed.

Objectives and Targets:

- Support local partners and landowners to implement and monitor BMPs on agricultural lands, including water conservation and carbon farming projects.
- Support agricultural and conservation easement efforts, especially when they enhance floodplain capacity during increased storminess with climate change.
- Support innovative sustainable farming practices that increase habitat value, connectivity, and climate resiliency.

Ongoing and Potential Projects. * Indicates ongoing projects

- ***Conservation Easements:** The MBNEP facilitated the purchase of 320 acres of irrigated avocado orchard and fallowed farmland to create the CCER.
- ***Agricultural BMPs:** Support implementation by the CSLRCD and NRCS to improve water conservation and climate resiliency practices.
- ***Monitoring:** Monitor habitat and water quality before and after implementation of agricultural BMPs.
- **Diversion of Peak Flows:** Consider necessary permitting and feasibility to complete pilot project(s) to divert and store large winter peak flows to reduce water needs during summer months.

Example Projects

Stormwater Improvement Projects: MBNEP has conducted stormwater improvement projects to improve water quality entering both the estuary and creeks. MBNEP worked with CSP and the California Marine Sanctuary Foundation to obtain grant funding from the Ocean Protection Council to design and construct an improved parking lot and BMP structures, including bioswale and a sediment trap structure, to improve water quality of parking lot runoff. Construction was completed in the spring of 2022. The project also involved monitoring the runoff during storms before and after the project installation to track the changes in the water quality. Three additional stormwater improvement projects have also occurred at Camp SLO with MBNEP and partner organizations.

Watershed Education Programming: The MBNEP provides watershed education to schools and organizations focusing on nonpoint source pollution and other anthropogenic impacts on watershed health. Over the past two years (2023 to 2024), the MBNEP has hosted 13 events focused on watershed education to teach over 280 people more about watershed health and stewardship. In addition, the MBNEP helps train and purchase materials for partner organizations to support their watershed education programming.

Groundwater Monitoring Wells: The LOCSD provides safe drinking water to parts of the Los Osos community. The basin faces challenges from saltwater intrusion, which necessitates the movement of monitoring and municipal supply wells inland away from the coast. The MBNEP funded the installation of a new groundwater monitoring wells and rehabilitation of two existing wells to support the groundwater management efforts of LOCSD and the County of San Luis Obispo from 2023 to 2024.

CONCLUSION

This Habitat Protection and Restoration Strategy ('strategy') provides a comprehensive, watershed-wide management approach to the health and climate resilience of habitats and communities of the Morro Bay watershed that will inform future planning and project efforts. The MBNEP will leverage program base funding from the USEPA through the Clean Water Action Section 320 and Bipartisan Infrastructure Law to accelerate efforts highlighted within this strategy and strengthen partnerships that are critical to long-term efforts. The MBNEP and its partners aim to improve climate resiliency for the Morro Bay watershed habitats and interconnected coastal communities through the implementation of this strategy. A summary of CCMP Actions/CVA Adaptation Action projects currently underway or planned to help achieve those can also be found below in Table 6.

Table 6. MBNEP projects highlighted within the strategy related to 2022 CCMP and 2021 CVA Adaptation Actions

Habitat	Project	CCMP Codes	CVA Adaptation Action
Estuarine	Eelgrass Mapping	LP-1, ECR-6, ECR-5, ECR-7	Maintenance of physical conditions that support eelgrass habitat
	Tidal Marsh Monitoring	ECR-4, ECR-11, CLIM-1	Sediment augmentation to tidal marsh for SLR
	Habitat Sea Level Rise Modeling	ECR-4, ECR-11, CLIM-1	Sediment augmentation to tidal marsh for SLR
	Bathymetry Mapping	MON-1, MON-3, CLIM-1	Maintenance of physical conditions that support eelgrass habitat
	Research and monitoring	MON-2, MON-5, MON-6, CLIM-1	Maintenance of physical conditions that support eelgrass habitat; Eelgrass planting
	Estuarine BMPs	BMP-8, BMP-9, USE-1, USE-2	Maintenance of physical conditions that support eelgrass habitat
Freshwater	Water Quality Monitoring	MON-1, MON-2, MON-3, MON-5, MON-6	N/A

Habitat	Project	CCMP Codes	CVA Adaptation Action
Freshwater	Creek Health Monitoring	MON-1, MON-2, MON-3, MON-5, MON-6	N/A
	Water and Sediment Toxicity Monitoring	MON-2, MON-5, MON-6, ECR-10, CLIM-1, USE-2, USE-1	Riparian corridor maintenance; Education on herbicide and pesticide alternatives
	Floodplain Enhancement/Restoration	LP-1, ECR-3, ECR-4, ECR-5, ECR-11, CLIM-1	Floodplain restoration; Large woody debris installation; Evergreen, resilient shade tree planting in upland tributaries; Levee removal projects; Stream shading; Stream buffer widening
	Fish Passage Barrier Removal	ECR-3, ECR-13, ECR-14, ECR-15, MON-3, MON-5	Riparian corridor maintenance
	Invasive Pikeminnow Reduction	LP-1, ECR-1, ECR-13, ECR-14, ECR-15, ECR-16	Riparian corridor maintenance
	Steelhead Studies	ECR-1, ECR-13, ECR-14, ECR-15	N/A
	BMPs on Private Property	BMP-1, BMP-5, ECR-9	Riparian fencing; Erosion control measures
	Road Erosion	BMP-2, BMP-5	Erosion control measures; Road erosion repairs
	Low-tech Process-based Restoration	ECR-3, ECR-4, ECR-11, CLIM-1, CLIM-2	Erosion control measures; Riparian corridor maintenance; Large woody debris installation; Stream buffer widening
Sandy Shores	Western Snowy Plover Monitoring	MON-5, ECR-9, ECR-13, ECR-14	N/A
	Community Cleanups	USE-1, EO-1, EO-4	N/A
Upland	Land Protection	LP-1	Collaboration with CDFW and CSP on mitigation efforts
	Regional Collaboration	ECR-9, CLIM-2	Collaboration with CDFW and CSP on mitigation efforts
	Upland BMPs	BMP-1, BMP-2, BMP-5, ECR-9	Riparian fencing

Habitat	Project	CCMP Codes	CVA Adaptation Action
Urbanized Areas	Stormwater Management	MON-3, BMP-5, BMP-7	Bioswale creation; Stormwater management
	Bay-friendly gardening	USE-1, EO-1, EO-4	Drought tolerant plant species use to maintain soil moisture; Fire tolerant native plant use; Drought tolerant and native plant use
	Wastewater Management	BMP-11, BMP-12, MON-3, ECR-10	N/A
	Water Conservation	FWR-1, FWR-3, FWR-4, FWR-5	Water conservation; Rainwater harvesting
	Adopt-a-Spot Program	USE-1, EO-1, EO-4	N/A
Irrigated Agriculture	Conservation Easements	LP-1, LP-2, BMP-5, ECR-12	Local planning effort support to protect migration areas from development and encourage climate-smart growth
	Agricultural BMPs	BMP-1, BMP-5, ECR-9	On-farm BMPs; Erosion control measures
	Agricultural Monitoring	MON-3	N/A
Freshwater, Sandy Shores, Upland	Invasive Plant Species Management	ECR-9, ECR-14, CR-16	Invasive plant species removal
Estuarine, Freshwater, Sandy Shores, Upland, Urban/Irrigated Agriculture	Education Programming	EO-1, EO-4, USE-1, CLIM-3	Education on herbicide and pesticide alternatives
	Mutts for the Bay	BMP-6	N/A

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APPENDIX A.

Morro Bay National Estuary Program Conservation Planning Initiative Excerpt

Goals	Vital Signs	Creek Target Indicators	Estuary Target Indicators
Healthy Water Quality	*Reduced Sedimentation*	**Herbst method- Sediment indicators**	**Tidal prism volume** **Mudflat/tidal marsh accretion rates**
	Reduced Bacteria and Pathogens	***E. coli* concentrations**	***Enterococci* concentrations**
	Reduced Nutrients	**Phosphorus** **Nitrogen**	
Abundant Water Quantity	*Increased Freshwater Resources*	**Spring stream flows** **Summer stream flows**	
Healthy Habitat and Ecosystems	*Improved Estuary Habitats*		**Eelgrass area** **Tidal marsh area**
	Improved Instream Habitat/Floodplain Function	**Macroinvertebrate biodiversity** **Stream temperatures**	
Thriving Species	*Improved Fish Populations*	**Steelhead spawning surveys** **Non-native pikeminnow management**	

Part 2: Measurable Target Development

The MBNEP also worked with TAC members to develop measurable targets for a sub-set of priority issues or vital signs in the watershed. Measurable targets will be used to help track success of collective watershed improvements by MBNEP and other partner agencies. These targets are not meant to replace existing goals and actions in the existing CCMP (2012) but rather to supplement and complement them. Achieving each of the measurable targets has a variety of assumptions such as availability of sufficient resources and landowner interest. Measurable targets will be used as a tool for adaptive management and will be revisited and

adjusted as additional scientific information is available or as major changes occur in the watershed. Progress toward these goals will be assessed approximately every 6 years, unless otherwise noted. The MBNEP currently tracks a sub-set of these targets through a State of the Bay report every three years. The next State of the Bay report will be completed in 2023.

Within the CCMP at the time of the CPI process (2012) that has since been updated in 2022, general parameters for tracking completed projects are referenced (e.g., number of projects completed, number of stream miles improved). However, measurable targets for individual priorities had yet to be developed. Regrouping watershed issues in the CCMP into overarching goals made it easier to assess and determine the targets. Vital signs were categorized into four overarching goals including: a) healthy water quality, b) abundant water quantity, c) healthy habitat and ecosystems, and d) thriving species. For each of these goals, various vital signs (e.g., reduced sedimentation) were reviewed by TAC members and MBNEP staff. For example, reduced sedimentation, reduced bacteria and pathogens, reduced nutrients, and reduced toxic pollutants are the vital signs chosen to track 'healthy water quality' in the watershed (Table 2). Additionally, some of the vital signs are direct priorities listed in the CCMP and others were added for developing targets more clearly.

Goals	**Vital Signs**
Healthy Water Quality	*Reduced Sedimentation*
	Reduced Bacteria and Pathogens
	Reduced Nutrients
	Reduced Toxic Pollutants
Abundant Water Quantity	*Increased Freshwater Resources*
Healthy Habitat and Ecosystems	*Improved Estuary Habitats*
	Improved Instream Habitat/Floodplain Function
Thriving Species	*Improved Fish Populations*
	Improved Bird Populations

Table 2: Goals and vital signs that were discussed during the CPI process.

Each vital sign had multiple indicators that were reviewed (Table 3). For example, to track sediment reduction in creek systems (vital sign), a range of sediment indicators could be monitored including suspended sediment concentrations, percentage of fine sediment in creek substrate, depth of pools at key locations, etc. TAC members and MBNEP staff discussed a range of questions related to these indicators including: Which indicators are most informative

and/or feasible?, What are the challenges to using this indicator?, What frequency of monitoring is needed to track this target?, Are there any factors outside of the watershed that impact this parameter?, among other questions. For some indicators chosen, further TAC discussions and potential studies are needed to determine the measurable target.

Goals	**Vital Signs**	**Range of Creek System Indicators Discussed**	**Range of Estuary System Indicators Discussed**
Healthy Water Quality	*Reduced Sedimentation*	**Herbst method- Sediment indicators** Suspended sediment loads Water turbidity % Fines in creek substrate Cross-sectional surveys Pool volume	**Tidal prism volume** **Mudflat/tidal marsh accretion rates** Mudflat/tidal marsh expansion rates
	Reduced Bacteria and Pathogens	***E. coli* concentrations**	**Enterococci concentrations**
	Reduced Nutrients	**Phosphorus** **Nitrogen** Dissolved oxygen Macroinvertebrates Algal coverage	Not evaluated
	Reduced Toxic Pollutants	Not evaluated	Not evaluated
Abundant Water Quantity	*Increased Freshwater Resources*	**Spring stream flows** **Summer stream flows**	Not evaluated
Healthy Habitat and Ecosystems	*Improved Estuary Habitats*	NA	**Eelgrass area** **Tidal marsh area** Eelgrass density

	Improved Instream Habitat/Floodplain Function	**Macroinvertebrate biodiversity** **Stream temperatures** Floodplain area	NA
Thriving Species	*Improved Fish Populations*	Steelhead population numbers **Steelhead spawning surveys** **Non-native pikeminnow management** Habitat improvement projects	Not evaluated
	Improved Bird Populations	Not evaluated	Not evaluated

Table 3: Indicators that were discussed between TAC members and MBNEP staff to help develop measurable targets for a sub-set of vital signs. Chosen indicators are shown in bold.

Goal: Healthy Water Quality

I. **REDUCED SEDIMENT**

Vital Sign	Possible Indicators	Discussion
Reduced Sedimentation in Creek Systems	**Herbst method-Sediment indicators**	**Chosen as indicator.** Part of the Herbst method captures a range of sediment indicators including percent fines, percent sand, percent gravel, D50 median particle size, and percent cover of fines and sands. It also utilizes various biotic metrics. This method is used by the Water Board to determine sediment impairment in Region 3 waterways.

	Suspended sediment (SSC) loads	Not chosen as indicator. SSC is not the best indicator because it is labor intensive to collect. If SSC is used in the future, a watershed model should be used to look at sinks and sources of sediment to better target monitoring efforts.
	Water turbidity	Not chosen as an indicator. Not considered by the Water Board to be a reliable metric for tracking sediment loading.
	% Fines in creek substrate	Not directly chosen as indicator. Percent fine sediment is integrated into the Herbst method.
	Cross-sectional surveys	Not chosen as indicator. Due to the variability among sites and effort involved, creek cross-section surveys weren't considered to be the best metric. Cross-section surveys will still be used to help track sediment dynamics for completed projects (e.g., sediment accumulation for floodplain projects).
	Pool volume	Not chosen as indicator. This is listed in the Chorro Creek Sediment TMDL (Water Board 2013) but is not currently used by the Water Board to track sediment accumulation.

Vital Sign	**Possible Indicators**	**Discussion**
Reduced Sedimentation in Estuary	**Tidal prism volume**	**Chosen as indicator.** Tidal prism volume will help assess if or how fast Morro Bay is filling with sediment and track whether the TMDL for sediment is reduced. The Morro Bay Sediment TMDL (Water Board 2003) uses tidal prism volume as the indicator to track improvements. Tidal prism volume will be calculated through bathymetry mapping.
	Mudflat and tidal marsh accretion rates	**Chosen as an indicator.** Sampling of tidal marsh/mudflat elevations using a combination of methods (e.g., SET tables, feldspar marker horizon plots). This is a well-documented method and not that expensive or time intensive. This method could potentially miss areas since it doesn't capture full bathymetry of the bay and potentially only captures what is happening at fixed

		stations. In the future, a mix of fixed and random rotational sampling could be considered to track bay-wide changes as sediment accumulation likely changes greatly across different parts of the bay.		
	Mudflat and tidal marsh expansion rates	Not chosen as indicator. The expansion of the Chorro Creek delta could be tracked over time. This could be monitored opportunistically when aerial images are captured for tracking other habitat types (e.g., eelgrass).		
Healthy Water Quality				
Sediment in Watershed	**Herbst method- Sediment indicators**	**Interim Measurable Target:** Yellow status for all monitoring sites using Herbst method- Sediment indicators. This denotes some signs of sediment impairment but does not require a 303(d) listing. **Ideal Target:** Green status for all sites using Herbst method- Sediment indicators. This denotes a lack of impairment by sediment.	**Status:** While Herbst monitoring data has occurred in the past, the method needs to be calibrated to the Morro Bay watershed before a status is defined. Analysis cannot be conducted until the optimal rain year occurs (between 25th to 75th percentile of average). **Evaluation:** Approximately every 10 years. Herbst method can only be conducted on average precipitation years.	**Management Discussion:** Will continue to work in the watershed to identify and reduce excess sedimentation (e.g., gullying, stormwater BMPs).
Sediment in Estuary	**Tidal prism volume**	**Interim Measurable Target:** Will be defined at a future date. A full bay bathymetry survey was completed in 2019. MBNEP is convening a TAC to discuss next steps since the tidal prism calculation	**Status:** The tidal prism increased from 1998 to 2019 by 4.9% based on 2020 Tetra Tech study. **Evaluation Frequency:** Due to the cost of a	**Management Discussion:** Will continue to work in the watershed to identify and reduce excess sedimentation

		results needed further discussion before determining a target. **Ideal Target:** Maintain a tidal prism volume of at least 4,200 acre-feet, as defined in the Morro Bay Sediment TMDL (Water Board 2003). May be altered based on TAC discussion of 2019 bathymetry results.	bathymetry survey (approximately $90k in 2019), evaluating sediment reduction through bathymetry mapping may occur at a longer time scale (10-15 years) compared to other parameters. Could occur more frequently if large sedimentation event occurs.	(e.g., gullying, stormwater BMPs).
	Mudflat and tidal marsh accretion rates	**Interim Measurable Target:** Will be defined at a future date. Existing data is available through USGS and the SFSU but discussions with TAC members is still ongoing for this target on the best approach **Ideal Target:** Tidal marsh/mudflat elevations that keep pace with accelerated sea level rise.	**Status:** From 2013-2021, the average cumulative elevation change for four SETs locations (two high marsh, two low marsh near Chorro Creek) is 8.8 mm based on USGS study. **Evaluation:** Every 6 years. Monitoring is completed annually.	**Management Discussion:** Will consider if sediment augmentation is feasible to keep elevations on track with sea level rise.

II. REDUCED BACTERIA AND PATHOGENS

Vital Sign	Possible Indicators	Discussion

Reduced Bacteria and Pathogens in Creek Systems	***E. coli* concentration**	**Chosen as indicator**. *E.coli* is considered by EPA as the best parameter for tracking bacteria concentrations. Due to high bacteria levels in the watershed, it is difficult to determine a reasonable target. No other parameters were evaluated.

Vital Sign	Possible Indicators	Discussion
Reduced Bacteria and Pathogens in Estuary	**Enterocci concentration**	**Chosen as indicator.** Enterococcus is considered by EPA as the preferred indicator for marine waters.

Only one parameter was considered for tracking reductions in bacteria/pathogens.

Healthy Water Quality				
Reduced Bacteria and Pathogens in Creek Systems	***E. coli* concentration**	**Interim Measurable Target:** Needs further study to develop target. Difficult to develop reasonable targets due to high bacteria levels in the watershed. Different targets would likely be set based on individual creeks given their differences. **Ideal Target:** All samples will meet recreational use standards of less than 126 MPN/100mL during baseflows (EPA 2012).	**Status:** Two of seven sites meet a rolling 30-sample geomean criteria established by the Water Board to be protective of human health. **Evaluation Frequency:** Every 10 years. Monitored monthly.	**Management Discussion:** Continue to assess sources and reduction of bacteria in watershed.
Reduced Bacteria and	**Enterococci concentration**	**Interim Measurable Target:** 75% of samples meet the STV criteria (110 MPN/100 mL)	**Status:** All 8 sites meet the 30-sample geomean	**Management Discussion:** Continue to

Pathogens in Estuary		**Ideal Target:** 90% of samples meet the STV criteria (110 MPN/100 mL)	criteria from 2005 to 2020. Interim and ideal target are met. **Evaluation Frequency:** Every 6 years. Monitored monthly.	assess sources and reduction of bacteria in watershed (e.g., bioreactors).

Maps are updated annually and can also be found at www.mbnep/qapp.

III. REDUCED NUTRIENTS

Vital Sign	Possible Indicators	Discussion
Reduced Nutrients in Creek Systems	**Nitrogen**	**Chosen as indicator.** Collecting water samples for nitrate analysis on a bi-monthly basis was determined to be the best metric to track nitrogen impairment. A two-part target was chosen. There will be one target specifically for Warden Creek, which has yet to be developed. Warden Creek has particularly high nitrate levels given land use and is a flashy system. Additional BMPs for Warden Creek will be prioritized before developing a numeric target for Warden Creek.
	Phosphorus	**Chosen as indicator.** Collecting water samples on a bi-monthly basis for orthophosphate analysis was determined to be the best metric to track phosphorus impairment.
	Dissolved oxygen	Not chosen as indicator. The Water Board considers it to be anecdotal evidence to support nutrient impairment.
	Algal coverage	Not chosen as indicator. This parameter is collected with bioassessment surveys but was not chosen because the Water Board considers it to be anecdotal evidence that supports nutrient impairment.

Reduced Nutrients in Creek Systems			
Nitrogen	**Interim Target:** 90% of nitrate as N in creek samples < 3 mg/L NO3-N to support human health standards at all sites other than Warden Creek. Warden Creek is TBD. **Ideal Target:** At least 90% of all nitrate samples collected in creek systems will be 1mg/L NO3-N or less to support standards for supporting aquatic life (Water Board).	**Status:** From 2002-2020, ten sites met the interim target but not on Warden Creek. Data too limited to report regarding lower Los Osos Creek. **Evaluation Frequency:** Every 6 years. Monitored bi-monthly.	**Management Discussion:** Ideal target will only be met below the California Mens Colony WWTP if additional management changes are made at the plant. Additional monitoring and analysis of Warden Creek (e.g., BMP effectiveness, flashy conditions) will be assessed to develop a target in the future.
Phosphorus	**Interim Target:** At least 60% of samples < 0.12 mg/L PO4-P to protect aquatic life. **Ideal Target:** At least 90% of all orthophosphate samples collected in creek systems will be < 0.12 mg/L to protect aquatic life.	**Status:** 70% of samples from 2002-2020 meet the interim target at five of the ten sites monitored and two of ten sites meet the ideal target. **Evaluation Frequency:** Every 6 years. Monitored bi-monthly.	**Management Discussion:** Interim and ideal targets would not be attainable in Los Osos Creek without substantial efforts to address agricultural runoff in the Los Osos Valley. Modifications to the California Mens Colony WWTP would also need to be made for obtaining lower phosphorus concentrations in Chorro Creek. There are also potential considerations to geology given high values at sites thought to have better conditions.

Maps are updated annually and can also be found at www.mbnep/qapp. At this time, there is no long-term monitoring of nutrient levels in the estuary. Therefore, levels of estuary nutrient concentrations were not evaluated as part of the CPI but may be re-evaluated as part of future TAC working groups.

IV. REDUCED TOXIC POLLUTANTS

Currently, there is limited knowledge of potential toxic pollutants in the watershed and for measuring them as compared with other priority issues (e.g., sediment, bacteria). While toxic pollutants are still likely an issue in the watershed, defining measurable targets for toxins were not evaluated as part of the study. Existing studies have been gathered related to toxic pollutants but further expertise is needed to develop a target.

To date, toxicity analysis has been limited. In reviewing available data from 2004 through 2019, testing indicates sediment toxicity in the following waterbodies: Chorro Creek, Los Osos Creek, Warden Creek, and Morro Bay. The bay data comes from monitoring by EPA's National Coastal Condition Assessment (NCCA), and the creek data is from Central Coast Water Quality Preservation, Inc. and California's Surface Water Ambient Monitoring Program (SWAMP). Results from the bay can be compared to criteria established by EPA for their NCCA effort. Monitoring in the creeks can be compared to the great lakes freshwater standards. Results for sediment analysis from this time period show approximately three-quarters of the results were classified as Good while the remaining quarter had Fair and Poor toxicity results in these four water bodies.

Abundant Water Quantity

I. INCREASED FRESHWATER RESOURCES

Vital Sign	Possible Indicators	Discussion
Increased Freshwater Resources in Creek Systems	**Spring stream flows**	**Chosen as indicator.** Spring flows from May-June are ecologically critical for steelhead. Stillwater Sciences (2014) completed a regional instream flow assessment that has provided guidance on this target, which was further refined by them using rainfall and creek flow data from 2006 to 2020. Based on precipitation data, each water year will be categorized as very dry, dry, average, wet, or very wet based on prior water year conditions. See Stillwater Sciences report (2021) for further details.

	Summer stream flows	**Chosen as indicator.** Creek flows from August-September are generally when flows are at their lowest and are critical for maintaining steelhead habitat and other aquatic life. Stillwater Sciences (2014) completed a regional instream flow assessment that has provided guidance on this target, which was further refined by them using precipitation and creek flow data from 2006 to 2020. Based on precipitation data, each water year will be categorized as very dry, dry, average, wet, or very wet based on prior water conditions. See Stillwater Sciences report (2021) for further details.

Description	Gage ID	Spring EWD (cfs)	Interim Target	Future Target
Chorro Creek Mainstem				
Upper Chorro Flats	CCC	2.29	EWD maintained 100% of the season during Very Wet, Wet, and 75% of the season in Average water years, and 25% of the season in Dry and Very Dry water years.	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and 50% of the season in Dry and Very Dry water years.
Canet Rd (CAN)	CAN	1.38	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and 75% of the season in Dry and Very Dry water years.	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and 90% of the season in Dry and Very Dry water years.
Ecological Reserve	UCR	1.18	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and 75% of the season in Dry and Very Dry water years.	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and 90% of the season in Dry and Very Dry water years.
Upper Chorro Creek at	CHO	0.71	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and

Highway 1 bridge			75% of the season in Dry and Very Dry water years.	90% of the season in Dry and Very Dry water years.
Chorro Creek Tributaries				
San Bernardo Creek, private property	SBC	0.64	EWD maintained 100% of the season during Very Wet and Wet water years, and 25% of the season in Average and Dry water years, and 10% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years, and 50% of the season in Average water years, and 25% of the season in Dry and Very Dry water years.
San Luisito Creek at Adobe Creek Rd	SLU	0.71	EWD maintained 100% of the season during Very Wet and Wet water years, and 25% of the season in Average and Dry water years, and 10% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years, and 50% of the season in Average water years, and 25% of the season in Dry and Very Dry water years.
Pennington Creek	CPN	0.4	EWD maintained 100% of the season during Very Wet and Wet water years, and 25% of the season in Average and Dry water years, and 10% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years, and 50% of the season in Average water years, and 25% of the season in Dry and Very Dry water years.
Dairy Creek	DAM	0.42	EWD maintained 100% of the season during Very Wet and Wet water years, and 25% of the season in Average and Dry water years, and 10% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years, and 50% of the season in Average water years, and 25% of the season in Dry and Very Dry water years.
Los Osos Mainstem				

Upper Los Osos Creek	CLV	0.54	EWD maintained 100% of the season during Very Wet and Wet water years, and 25% of the season in Average and Dry water years, and 10% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years, and 50% of the season in Average water years, and 25% of the season in Dry and Very Dry water years.

	Gage ID	**Summer EWD (cfs)**	**Interim Target**	**Future Target**
Chorro Creek Mainstem				
Upper Chorro Flats	CCC	0.69	EWD maintained 100% of the season during Very Wet, Wet and 75% of the season in Average water years, and 25% of the season in Dry and Very Dry water years.	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, and 50% of the season in Dry and Very Dry water years.
Canet Rd (CAN)	CAN	0.46	EWD maintained 100% of the season during Very Wet and Wet water years, 90% of the season in Average water years, and 50% of the season in Dry water years, and 30% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, 75% of the season in Dry water years, and 50% of the season in Very Dry water years.
Ecological Reserve	UCR	0.41	EWD maintained 100% of the season during Very Wet and Wet water years, 90% of the season in Average water years, and 50% of the season in Dry water years, and 30% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, 75% of the season in Dry water years, and 50% of the season in Very Dry water years.

Upper Chorro Creek at Highway 1 bridge	CHO	0.3	EWD maintained 100% of the season during Very Wet and Wet water years, 90% of the season in Average water years, and 50% of the season in Dry water years, and 30% of the season in Very Dry water years.	EWD maintained 100% of the season during Very Wet, Wet, and Average water years, 75% of the season in Dry water years, and 50% of the season in Very Dry water years.
Chorro Creek Tributaries				
San Bernardo Creek, private property	SBC	0.28	EWD maintained 100% of the season during Very Wet water years, 90% in Wet, 20% in Average water years, 10% in Dry water years, and 1% in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years, 40% in Average water years, and 10% in Dry and Very Dry water years.
San Luisito Creek at Adobe Creek Rd	SLU	0.3	EWD maintained 100% of the season during Very Wet water years, 90% in Wet, 20% in Average water years, 10% in Dry water years, and 1% in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years; 40% in Average water years, and 10% in Dry and Very Dry water years.
Pennington Creek	CPN	0.22	EWD maintained 100% of the season during Very Wet water years, 90% in Wet, 20% in Average water years, 10% in Dry water years, and 1% in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years; 40% in Average water years, and 10% in Dry and Very Dry water years.
Dairy Creek	DAM	0.23	EWD maintained 100% of the season during Very Wet water years, 90% in Wet, 20% in Average water years, 10% in Dry water years, and 1% in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years; 40% in Average water years, and 10% in Dry and Very Dry water years.
Los Osos Mainstem				

Upper Los Osos Creek	CLV	0.26	EWD maintained 100% of the season during Very Wet water years, 90% in Wet, 20% in Average water years, 10% in Dry water years, and 1% in Very Dry water years.	EWD maintained 100% of the season during Very Wet and Wet water years; 40% in Average water years, and 10% in Dry and Very Dry water years.

Instream flow will be monitored at bi-monthly (some sites have continuous measurements) at each of these sites during spring (April/May) and summer (August-September). Maps are updated annually and can also be found at www.mbnep/qapp. MBNEP will continue to access possible projects to increase flows including off-stream watering for livestock, stormwater management, land-use, irrigation improvements, among others.

Healthy Habitat and Ecosystems

I. IMPROVED ESTUARY HABITATS

Vital Sign	Possible Indicators	Discussion
Improved Estuary Habitats	**Eelgrass habitat area**	**Chosen as indicator.** Tracking eelgrass habitat area through aerial flights, UAV, or sonar is the most feasible and cost effective way to track eelgrass health overtime. A variety of methods have been used over the years to track acreage and the specific method moving forward is still under consideration. Total acreage targets were based on analysis of historic and current eelgrass coverage and suitable depth range utilizing 2019 bathymetry mapping. See 2021 Tetra Tech report for more details. Future analysis will take sea level rise into consideration for suitable available habitat.
	Tidal marsh habitat area	**Chosen as indicator.** Area will be evaluated using imagery collected via aerial flights or UAV.
	Intertidal eelgrass density	Not chosen as indicator. Density is helpful to track health of eelgrass beds. However, the range of densities in remaining eelgrass beds is high and this

		variability could complicate using density as an overall indicator of eelgrass habitat.

Improved Estuary Habitats			
Eelgrass Habitat	**Interim Target:** 156 acres of eelgrass within a depth range of -6ft to 1.5 ft. **Ideal Target:** 313 acres of eelgrass within a depth range of -6ft to 1.5 ft.	**Status:** In 2019, there were 42 acres of eelgrass. In 2020, there were an estimated 146 acres of eelgrass. **Evaluation Frequency:** Every 6 years.	**Management Discussion:** Continue restoration efforts and assess any negative conditions impacting eelgrass habitat.
Tidal Marsh Habitat	**Interim Target:** Will be further studied given impacts to sea level rise. **Ideal Target:** Will be further studied given impacts to sea level rise.	**Status:** In 2013 there were 393 acres and in 2019 there were 401 acres based on Ocean Imaging surveys. **Evaluation Frequency:** Every 6 years.	**Management Discussion:** Funding will be sought for tracking leading indicators of vegetation change in tidal marsh habitat and modeling of passive sediment augmentation to maintain tidal marsh elevations with sea level rise.

II. IMPROVED INSTREAM HABITAT AND FLOODPLAIN FUNCTION

Vital Sign	**Possible Indicators**	**Discussion**
Improved Creek Habitats	**Macroinvertebrates**	**Chosen as indicator**. For the last 19 years, MBNEP has tracked spring macroinvertebrate biodiversity in a range of tributary and mainstem creeks based on the SWAMP method. Targets were chosen separately for mainstem

		Chorro Creek and tributaries. Bioassessment data is used to calculate the Southern California Index of Biotic Integrity for each creek.
	Stream water temperature	**Chosen as indicator**. Targets were chosen separately for mainstem Chorro Creek and tributaries. Water temperatures in mainstem Chorro Creek are often more than 20°C during summer, while water temperatures in the tributaries are generally less than 19°C. Temperature targets were referenced from the Chorro Creek Pikeminnow Management Report (2017) and discussions with local fisheries biologists. Water temperatures in the mainstem of Chorro Creek are also affected by CMC WWTP discharge (permit allows increase up to 5°F of receiving waters) (Water Board, 1972). Cool water temperatures may limit pikeminnow distribution and reduce competition between juvenile steelhead and pikeminnow. In summer 2018, new temperature loggers were placed in Chorro Creek mainstem and tributaries to better track differences between habitats and possible implications for fish populations.
	Floodplain area	Not chosen as indicator. There has not been a watershed assessment that identifies disconnected floodplains to support a measurable target at this time. Restoring additional floodplain area in the watershed is still key to many of MBNEP's priorities including reduced sedimentation and increased instream flow. Other vital signs (e.g., sediment, stream temperature) may improve with additional floodplain habitat.

Improved Creek Habitats			
Macro-invertebrates	**Interim Measurable Target:** For tributary systems, all 10 sites will have a score of 'Fair', 'Good', or 'Very Good' based on So California IBI method. A	**Status:** Mainstem Chorro Creek sites currently score as Fair or Poor. In 2019: LVR, BTP, TWB were Poor and CER was Very Poor. DAM and CLK were Fair.	**Management Discussion:** Ideal target will not be able to be met unless the California Mens Colony WWTP makes changes to the

	target for mainstem Chorro Creek is TBD. **Ideal Target:** So CA IBI > 39 (Poor and Very Poor scores)	UPN, MNO, DAU, LSL were Good or Very Good. **Evaluation Frequency:** Every 6 years.	water treatment plant.
Stream Water Temperature	**Interim Measurable Target:** Maximum weekly maximum temperature (MWMT) from April through October is less than 20°C for two sites on Chorro Creek downstream from the CMC WWTP. MWMT is less than 20°C for one site on each San Bernardo Creek, San Luisito Creek, Dairy Creek, and Pennington Creek tributaries. **Ideal Target:** Maximum weekly maximum temperature (MWMT) from April through October is less than 15°C for two sites on Chorro Creek downstream from the CMC WWTP. MWMT is less than 15°C for one site on each San Bernardo Creek, San Luisito Creek, Dairy Creek, and Pennington Creek tributaries.	**Status:** In water year 2020, the interim target was met from April-July for all sites but exceeds the interim target at Chorro Creek at UCR in August and September, Chorro Creek at CHO in August, and Pennington Creek (UPN) in August. Ideal target was not met at any sites. **Evaluation Frequency:** Every 6 years.	**Management Discussion:** Ideal target will likely not be met unless CMC reduces temperatures to the WWTP outflow.

Thriving Species

I. IMPROVED FISH POPULATIONS

Vital Sign	Possible Indicators	Discussion
Improved Fish Populations	**Steelhead spawning surveys**	**Chosen as indicator.** Spawning surveys are an indirect measurement of steelhead populations. Completing yearly or bi-yearly spawning surveys is considered to be more affordable and therefore more sustainable in the long-term for tracking steelhead populations. California Conservation Corps members are currently trained for completing surveys and could potentially assist with this monitoring (if funding available). Spawning surveys are also being completed in other nearby coastal watershed by CDFW. Steelhead populations are affected by a range of factors outside of the watershed, which will impact tracking this target overtime but was still chosen as the preferred primary target to track fish populations in the watershed.
	Non-native pikeminnow management	**Chosen as indicator.** Removal of non-native pikeminnow is thought to help bolster juvenile steelhead and subsequent adult populations. It's estimated that roughly 450 adult pikeminnow are in Chorro Creek (Stillwater Sciences, 2017). Removing non-native pikeminnow however, isn't a direct target to the overall steelhead population. Pikeminnow diet analysis (via eDNA testing) was completed in fall 2017 and spring 2018, which showed that approximately 20% of pikeminnow stomachs sampled had eaten a steelhead within the last 12-24 hours. It is not realistic to expect complete eradication of pikeminnow in the Chorro Creek watershed due to the inability to remove all individuals (especially smaller size classes), but it is likely possible to control the population sufficiently to decrease the impact exerted by pikeminnow on the native steelhead population. This target is contingent on funding.
	Steelhead populations surveys	Not chosen as indicator. Current management efforts call for annual electrofishing of specific habitat units to estimate steelhead abundance and density overtime. However, no systematic and ongoing monitoring of steelhead in the watershed is currently funded and underway. Population estimates are based on 1) snorkel surveys of 20 pools in 2001, 2)

		management efforts to removal pikeminnow, 3) annual CDFW electrofishing surveys near the CMC WWTP, and 4) CCC snorkel surveys in 2012, 2016, and 2017.
	Diversity of native fish species in creek systems	Not chosen as indicator. There is no robust monitoring of the diversity of fish species in Chorro Creek. Some species identification is collected as a by-product of the pikeminnow removal efforts. This indicator would need sustained funding to pursue. The MBNEP is concerned about all native fish in the watershed, not just steelhead species. However, steelhead are currently designated as threatened under the Endangered Species Act and were chosen as a preferred target.
	Fish barrier removal	Not chosen as indicator. At this point, fish barrier removal has been on hold until adequate pikeminnow management has occurred in the Chorro Creek watershed but this will hopefully change in the future.

Improved Fish Populations			
Steelhead Spawning Surveys	**Interim Measurable Target:** TBD once more baseline information is collected. **Ideal Target:** TBD once more baseline information is collected.	**Status:** No data collected yet. **Evaluation Frequency:** Every 6 years.	**Management Discussion:** Working to develop monitoring protocol with CDFW. Limited sites monitored in fall 2020.
Non-native pikeminnow management	**Interim Measurable Target:** No more than two adult pikeminnow observed in Chorro Creek Reservoir. **Ideal Target:** No adult pikeminnow observed in	**Status:** In 2018, there was one pikeminnow observed in Chorro Creek Reservoir. Additional sampling in reservoir will occur in spring 2022. Ratio of steelhead to pikeminnow was 1:10 in 2017, 10:8 in 2018, 10:8 in 2019 and 5:1 in 2020.	**Management Discussion:** Continue management actions as reported in Stillwater Sciences Chorro Creek Pikeminnow Management Plan (2017).

	Chorro Creek Reservoir. Ratio of steelhead (all ages) to pikeminnow (all ages) of >1:1 in habitat units sampled with multiple pass electrofishing.	**Evaluation Frequency:** Every 6 years.	

II. IMPROVED BIRD POPULATIONS

At this time, a measurable target for tracking bird populations has not been evaluated as part of the study.