North Central Coast MPA Baseline Report
LiMPETS 2013

Final Report

An Analysis of Citizen Science Data From LiMPETS

In Support of the North Central Coast Baseline Characterization Project

Prepared for:

CALIFORNIA SEA GRANT PROGRAM STATE COASTAL CONSERVANCY (SCC),

OCEAN PROTECTION COUNCIL (OPC), AND

CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE (CDFW)

LiMPETS Long-term Monitoring Program and Experiential Training for Students

LiMPETS Final Report

Prepared for:

California Sea Grant Program
State Coastal Conservancy (SCC)
Ocean Protection Council (OPC)
California Department of Fish and Wildlife (CDFW)

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1.0 Introduction

1.1 OVERVIEW: AN ANALYSIS OF CITIZEN SCIENCE DATA FROM LIMPETS

The 1999 Marine Life Protection Act directed the state of California to design a comprehensive network of marine protected areas to protect, sustain and conserve marine life populations and increase the health, productivity, and resilience of ocean ecosystems. The MLPA requires monitoring of marine protected areas (MPAs). Monitoring will facilitate adaptive management of MPAs and ensure that the MPA network meets the goals of the Act. The North Central Coast MPA Baseline Program is a collaborative effort among the State Coastal Conservancy, Ocean Protection Council (OPC), California Department of Fish and Wildlife, California Ocean Science Trust, MPA Monitoring Enterprise and California Sea Grant. "The program seeks to provide a summary description, assessment and understanding of ecological and socioeconomic conditions, inside and outside North Central Coast MPAs to be designated under the Marine Life Protection Act, at or near the time of MPA implementation" (NCC MPA Monitoring Plan, 2010). The North Central Coast MPA region consist of 25 MPAs and 6 special closure areas comprised of approximately 153 square miles (20.1%) of state waters within the region.

In this project, an existing citizen-science data set, collected through LiMPETS, Long-term Monitoring Program and Experiential Training for Students, will be analyzed and integrated into the baseline data being collected by the other research teams. The LiMPETS data include surveys of the Pacific mole crab (*Emerita analoga*), a denizen of sandy beaches, at 16 sites within the North Central Coast (NCC) study region. Pacific mole crabs are one of the most important and abundant invertebrates on exposed beaches of California. They can exceed 100,000 individuals m^{-1} on beaches of the central coast of California and elsewhere (Dugan et al., 2000). Pacific mole crabs are also a vital link in the sandy beach food web and are important prey for birds, mammals, and fishes, including threatened species such as the Western Snowy Plover. Despite their significance to sandy beaches in the study region, temporal variability in the abundance of *E. analoga* is poorly understood outside of central California. Moreover, long-term trends in abundance and recruitment over a period greater than 2-3 years are virtually absent from the literature.

LiMPETS data also include a more diverse and complex set of rocky intertidal data at four sites in the region, including areas in and around two of the new marine protected areas. The rocky intertidal survey data follow trends of 33 key invertebrate and algae species/groups. In addition to the existing long-term data set, we have conducted 2+ years of baseline monitoring (2010 – 2011/12) at LiMPETS sites in and around the new MPAs to further enhance the creation of a meaningful benchmark for the North Central Coast.

The rocky shores along the west coast of North America are some of the richest and most diverse places in the world (Stephenson and Stephenson, 1972; Ricketts et al., 1985). They provide services that contribute to our economy, including tourism, sport fishing, and the recreational (and commercial) collection of resources for food. Harvested resources include intertidal seaweeds, mussels, sea urchins,

abalone, limpets, crabs, snails and more (Denny and Gaines, 2007). On rocky shores throughout California, overharvesting has severely depleted stocks of some species (Harley and Rogers-Bennet, 2004) and has compromised biodiversity in these areas (Van De Werfhorst and Pearse, 2007). As a result, overharvested areas have become extremely vulnerable. Monitoring, research and the establishment of the North Central Coast MPAs can help to ensure that these valued areas are healthy, resilient and productive in the future.

Compilation and description of the existing LiMPETS data set will contribute to the assessment of population and community trends within North Central Coast sandy beach and rocky intertidal ecosystems both prior to and at the time of MPA implementation. The project reviewed in this report is primarily, but not exclusively, focused on long-term analyses of the existing data sets of the LiMPETS program. Project goals align with two main objectives of the baseline characterization objectives, as described in the North Central Coast MPA Baseline Program Request for Proposals: (1) provide initial data points and historical trend data for long-term tracking of condition and trends in North Central Coast sandy beach and rocky intertidal ecosystems, and (2) inform long-term monitoring recommendations. The following project will provide the following:

- Compilation and description of the historic LiMPETS data set to describe methods and data collected in areas currently surveyed within the North Central Coast region;
- Compilation and description of LiMPETS rocky intertidal and sandy beach data to describe methods and data collected at existing LiMPETS sites inside and outside of North Central Coast MPAs during the time of implementation (2010-2011);
- Spatial analysis of *Emerita analoga* populations at established LiMPETS sandy beach sites within the NCC region;
- Spatial analysis of species and communities at established LiMPETS rocky intertidal sites within the NCC region, including sites inside and outside of MPAs;
- Description and analysis of historical trends in species and communities with considerations of potential driving or causal factors;
- Identification of select monitored species, if possible, considered to be sensitive and rapid in responding to MPA implementation. Description of any changes observed that may seem likely due to MPA implementation; and
- Description of long-term monitoring recommendations including an analysis of methodological comparison study of *E. analoga* populations conducted between LiMPETS and the sandy beach project group (Dugan, Morgan, and Nielsen).
- Description of the unique role that citizen science can play in MPA monitoring, beyond providing scientific data.

As summarized in this report, the Farallones Marine Sanctuary Association (FMSA) has completed data collection, compilation and description of our historic data sets, data analyses, narrative descriptions and explanations, and long-term monitoring recommendations for the purposes of this project. Established in 1995, FMSA is the nonprofit partner that supports and assists the Gulf of the Farallones National Marine Sanctuary in education, outreach, stewardship, and citizen science. The Association also works as a funding partner, increasing resources available to the Sanctuary via a public-private partnership

approach to programs, initiatives, and facilities.

Since the inception of LiMPETS, FMSA has functioned as a leading and key partner in the statewide LiMPETS network. The LiMPETS network was created in 2002 when the National Marine Sanctuaries of the West Coast worked together to streamline their intertidal student monitoring programs. Student-friendly protocols for monitoring rocky intertidal and sandy beach ecosystems were developed with the expertise of Dr. John Pearse, Dr. Jennifer Salzman, and others. Serving mostly middle, high school and undergraduate students, it operates in California from Bodega Bay to San Diego, with three regional centers: San Francisco, Monterey Bay, and Santa Barbara. LiMPETS has approximately 4000 participants in California per year, approximately 60% of participants are high school aged students. To date, LiMPETS is the only regional student-based citizen science program that has a strong science foundation, a science advisory panel, a breadth and depth of educational resources, including a 5-unit curriculum, and an innovative website with data entry, query and graphing capabilities.

1.2 METHODS

LiMPETS Sandy Beach Methodology For Long-term Monitoring & NCC MPA 'Baseline' Surveys (2010 – 2011): The LiMPETS network uses the following methods to conduct monitoring of the Pacific mole crab at established sandy beach sites in the NCC MPA region (Figure 2) as well as throughout the entire LiMPETS study region in California.

The Pacific mole crab is surveyed along a 50-m segment of beach. Five randomly placed transects are run vertically into the upper 10-m of the swash zone, and ten cores (0.115m diameter x 0.1 m depth) are collected along each transect. In each core sample, *E. analoga* are enumerated and measured. Life stage/sex is categorized as recruit, male, female or fecund female. Recruits are classified as individuals < 0.1 m in length. During each survey, a total of 50 cores are processed. Survey abundance is reported as average number of individuals per core.

The *North Central Coast MPA Baseline Program RFP (request for proposals)* identified *E. analoga* as a potential metric of ecosystem health or change along sandy beaches in the region. Though it is unlikely that mole crab populations will respond (quickly or at all) to MPA protection, they may be used as a potential indicator of ecosystem condition. The LiMPETS long-term sandy beach data set can provide metrics for *E. analoga* distribution, population demographics, recruitment, as well as broad and fine-scale trends in abundance over time and space. In this report, we focus on the following: long-term trends in *E. analoga* abundance and recruitment over time and space as well as 'baseline' abundance and recruitment at Salmon Creek and Montara beaches, 2010-2011.



Analyses include all data from established LiMPETS monitoring sites within the MPA NCC region. In consideration of potential causal factors, a correlation of Multivariate ENSO Index (MEI) with sand crab abundance (linear regression analysis) was conducted. MEI is a composite index using a number of variables to measure ENSO events. MEI uses sea surface temperatures, surface air temperatures, sea-level pressure, zonal (i.e., east-west) surface wind, meridional (i.e., north-south) surface wind and total amount of cloudiness. Positive MEI values are related to warm phase or El Niño events and negative values with cool phase or La Niña events.

For this project's baseline assessment, LiMPETS monitoring was conducted seasonally (May, August, and October) at Montara State Beach and Salmon Creek State Beach during the first two years of implementation, 2010 and 2011 (Table 2). These beaches were also sampled seasonally during the first two years of implementation by the *Sandy Beach Baseline Project* team (Dugan, Morgan and Nielsen). Coordination of data collection efforts for *E. analoga* was planned at these sites so that data outputs could be compared between the LiMPETS citizen science team and the Dugan, Morgan and Nielsen team.

Methods Comparison For Sampling Emerita analoga Abundance: The *Sandy Beach Baseline Project* team (Dugan, Morgan and Nielsen) conducted a comparison of methods for sampling *E. analoga* abundance on sandy beaches along the North Central Coast in May 2011. Using the 'LiMPETS' method alongside the Nielsen's 'baseline' method, a paired sampling block (Figure 1) was repeated 2-3 times per site at 3 sites, Montara, Limantour, and Salmon Creek beaches. The Nielsen group designed the study, conducted the data collection, and performed statistical modeling and analyses. LiMPETS provided staff and trained students for the data collection at Montara and Salmon Creek beaches.

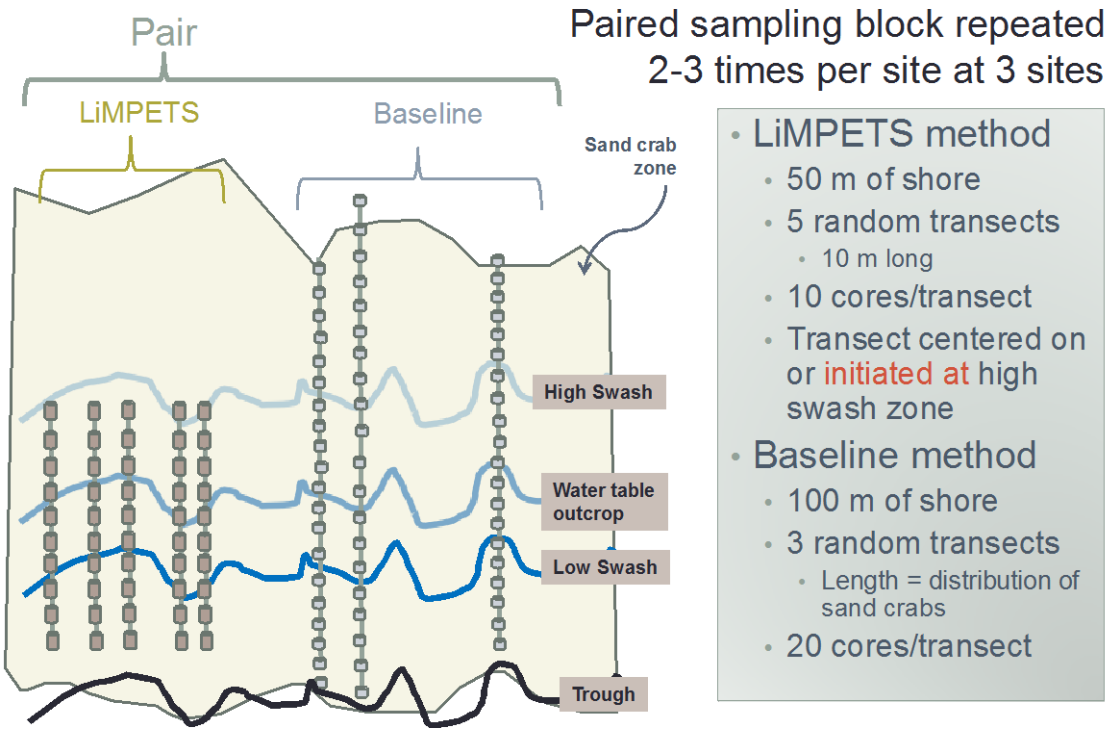


Figure 1. Methods comparison for sampling *E. analoga* abundance (schematic) – LiMPETS 50-m survey area

alongside of the Nielsen group's 'Baseline' 100-m survey area (figure provided by K. Nielsen).

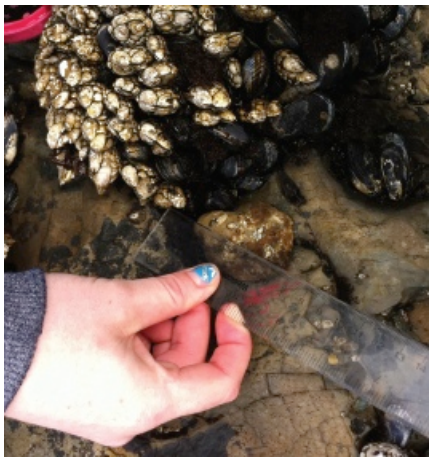
LiMPETS Rocky Intertidal Methodology For Long-term Monitoring & 'Baseline' Surveys (2010 – 2011/12): The LiMPETS network uses four sampling methods to collect intertidal data. Some or all of the four methods are used at each rocky intertidal site (Appendix). Brief overviews of each of the four methods are described here.

1. Vertical transect data are collected along a fixed line reaching from the high to the low intertidal. Data are collected at regular intervals along the line using gridded 0.25 m^2 quadrats.

2. LiMPETS 'random quadrat' protocol estimates density by counting each individual found within a gridded 0.25 m^2 quadrat. Quadrats are placed randomly in one or more permanent areas at a site. Typically, 10-20 replicates are conducted during each survey, depending on issues of available student time and tidal height.

3. LiMPETS 'total count' protocol estimates density of ochre sea stars (*Pisaster ochraceous*), giant green anemones (*Anthopleura xanthogrammica*) and sunburst anemones (*Anthopleura sola*) by counting the total number of individuals present in one or more defined areas at a site.

4. LiMPETS 'size measurements of owl limpets' protocol estimates density and size structure of owl limpets (*Lottia gigantea*) by counting and measuring the total number of individuals found in defined permanent areas at a site. Owl limpets that are greater than 2.0 cm are measured to the nearest 0.5 cm.



Student measuring an owl limpet at Montara SMR

The LiMPETS long-term rocky intertidal data set provides the following: densities and/or estimates of percent cover using a presence/absence approach of 33 invertebrate and algal species/groups (Appendix). It also provides density and size structure data for owl limpets. In this report, we focus on some of the candidate metrics for ecosystem feature assessment identified in the NCC Baseline Characterization RFP. These include: cover of fucoid algae (*Fucus gardneri*), cover of mussels (*Mytilus californianus*), sea star (*Pisaster ochraceus*) density, purple sea urchin (*Strongylocentrotus purpuratus*) density, and owl limpet (*Lottia gigantea*) density and size structure.

For this project's baseline assessment, monitoring was conducted within two MPAs (Duxbury Reef SMCA; Montara SMR) and at Pillar Point, a reference site for Montara SMR. LiMPETS monitoring surveys were conducted three times seasonally (May, August and November) in 2010. An additional four surveys were conducted in 2011 (January, May, August and November). One winter survey was conducted in January 2012. A total of eight surveys were completed at each site during the first two years of implementation (Table 2).

Standard Method For Training Citizen Scientists: LiMPETS is a student-based citizen science program that partners with schools and teachers, primarily, with a majority of participants being high school teachers and students. Teachers receive training by attending a mandatory 8-hour *Introductory LiMPETS Workshop*, students receive 1-3 hours of training in-class using standardized training materials, and finally students and teachers conduct monitoring surveys at one of our established field sites. All surveys are supervised by experienced LiMPETS personnel. A more detailed description of the educational opportunities and outcomes provided by this project can be found in section 3 – beyond the science.

1.3 OVERVIEW OF LIMPETS MONITORING SITES IN THE NORTH CENTRAL COAST STUDY REGION

Twenty-five MPAs and six special closure areas were designated in the North Central Coast region of California in 2010, between Alder Creek near Point Arena in the north and Pigeon Point in the south.

Sixteen established LiMPETS sandy beach sites are located in this region. LiMPETS sites are located on outer coast beaches between Salmon Creek to the north and Pescadero to the south with the exception of one beach site located just inside of the San Francisco Bay at Crissy Field (Figure 2). Montara and Salmon Creek are "reference" sites for the NCC *Sandy Beach Baseline Project* team (Dugan, Morgan and Nielsen). LiMPETS monitoring data was used from these two sites in a methodological comparison for estimating abundance of the Pacific mole crab.

Four established LiMPETS rocky intertidal sites are located in the NCC region: Duxbury Reef to the north, Fitzgerald Marine Reserve (Montara SMR), Pillar Point and Pigeon Point to the south. Two LiMPETS sites are located inside of MPAs in the NCC region: Duxbury Reef SMCA and Montara SMR (Figure 2).

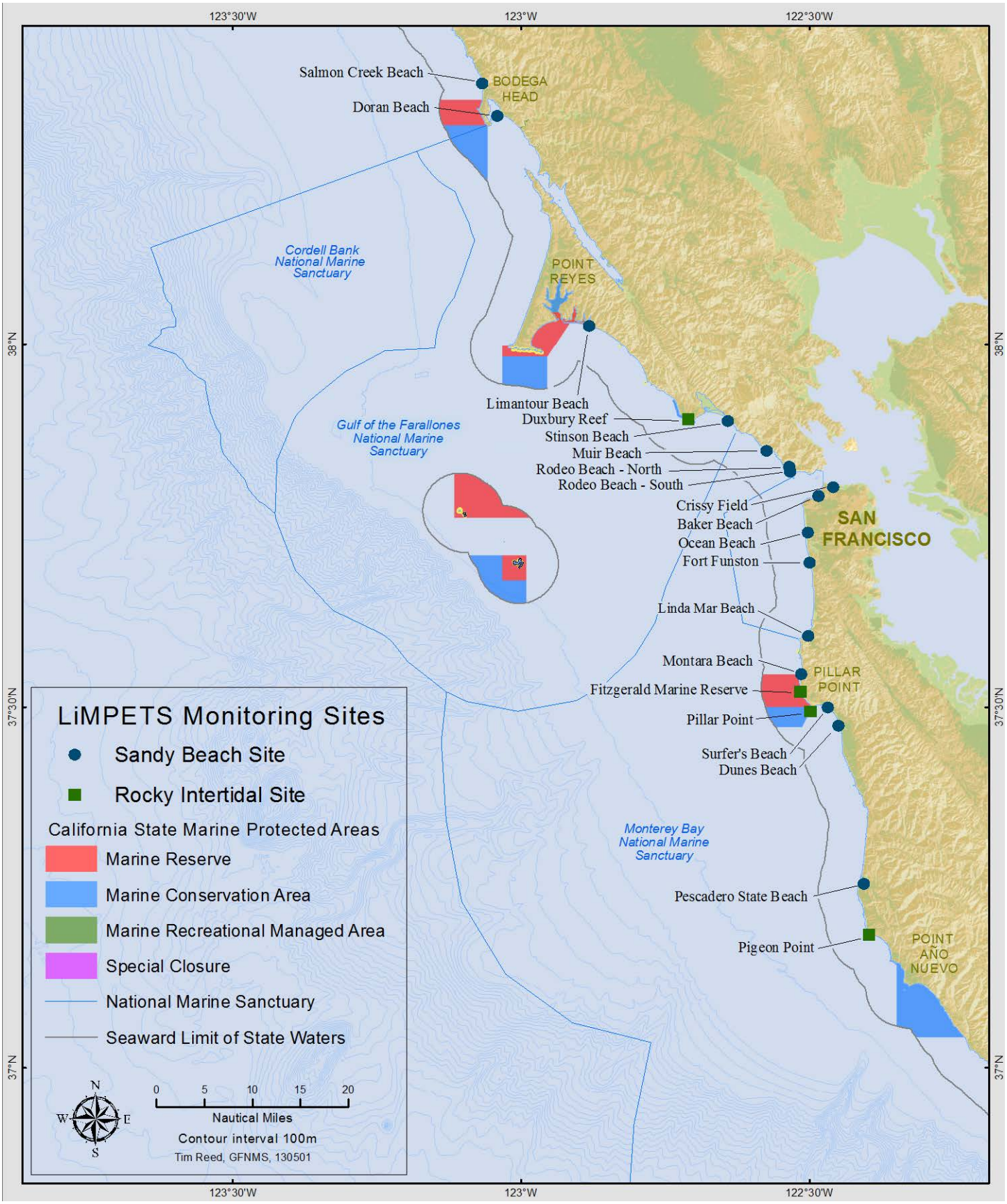


Figure 2. LiMPETS sandy beach and rocky intertidal sites within the NCC MPA region.

2.0 Sandy Beach Results

2.1 OVERVIEW OF THE LIMPETS SANDY BEACH DATA SET: HISTORIC VS. 'BASELINE'

Sixteen LiMPETS beach sites are located in the North Central Coast MPA region. All sites were established between 2001 and 2007. Nine (60%) beaches have 10+ years of survey data. The remaining beaches have 6 or more years of data. Muir Beach (Marin County), Ocean Beach (San Francisco) and Surfer's Beach (San Mateo County) have the largest quantities of data, with approximately 50 – 250 surveys conducted at each site since the year the site was established. Ocean Beach, due to its position in an urban center, is the most frequently and most consistently surveyed site within the region, averaging 21 surveys per year over a 12-year period. Overall, longevity of the dataset and the total number of surveys conducted at each site varies (Table 1).

Historically, it has been common practice for the LiMPETS program to accommodate the participating schools regarding their choice of sites and survey frequency. Because of this practice, the historic data set contains, at some popular sites such as Ocean and Surfers beaches, large quantities of data. However, inconsistencies in sample effort across sites and over time exist, especially at sites that are in remote locations. Inconsistencies also exist in the timing of surveys with tide height, flood-ebb, and spring-neap cycles. There is a recent effort, however, to conduct as many surveys as possible, considering school schedules, etc., during ebbing, neap tides when the tide is somewhat low, < 3 or 4 ft. Neap tides create a more narrow swash zone, increasing the ability for our 10-m transect to more adequately sample *E. analoga* populations (Dugan, J., personal communication).

The 'baseline' beach surveys conducted at Salmon Creek and Montara beaches were timed consistently during May, August, and October 2010 and 2011 (Table 2). All 'baseline' surveys were conducted during ebbing, neap tides.

2.2 HISTORIC POPULATION TRENDS

***Abundance: spatial and temporal variation* –** Historically, between 2001 and 2012, there exists a wide range of seasonal and interannual variation in *E. analoga* abundance at all LiMPETS sandy beach sites in the region. In this report, abundance is reported seasonally, as mean number of crabs per core. Seasons are defined as Spring (Mar - May), Summer (Jun - Aug), and Fall (Sept - Nov). We typically do not conduct surveys during winter months because high surf and cold, inclement weather conditions. From Fall 2001 – Summer 2012, student and adult citizen scientist volunteers processed over 37,000 core samples in the regional study area. In those samples, 82,219 crabs were processed.

Historic population trends of *Emerita analoga* vary between sites (Figures 4 and 5); however Ocean Beach, the most consistently and frequently sampled of the sandy beach sites, follows the general pattern of observed abundance and recruitment when comparing trends across all sites (Figure 3). Seasonally, at Ocean Beach, the data show that summer months are consistently times of highest abundance of *E. analoga*. Interannual trends in abundance are highly variable, appearing cyclical, with peaks and troughs (Figure 3). Two peaks in abundance occurred during the 12-year study period, once in the summer of 2003 (average 30 crabs per core) and again during the summer of 2010 (average 20 crabs per core). During these time periods, recruits dominated the sampled population, comprising >92% of

Beach name:	County:	Year established	Survey effort: total number surveys completed since site establishment
Salmon Creek	Sonoma	2002	19
Doran Beach	Sonoma	2001	9
Limantour Beach	Marin	2004	25
Stinson Beach	Marin	2001	32
Muir Beach	Marin	2002	55
Rodeo Beach - North	Marin	2003	19
Rodeo Beach - South	Marin	2006	13
Baker Beach	San Francisco	2001	19
Ocean Beach	San Francisco	2001	252
Fort Funston	San Francisco	2002	29
Linda Mar State Beach	San Mateo	2006	36
Montara Beach (south)	San Mateo	2006	8
Surfer's Beach	San Mateo	2002	64
Dunes Beach	San Mateo	2002	10
Pescadero State Beach	San Mateo	2007	10

Table 1. LiMPETS sandy beach site names (listed north to south), date of establishment, and total number of surveys conducted at each site (through December 31, 2012).

Beach name (county):	Coordinates (0 m): Lat and Long (DD)	Coordinates (50 m): Lat and Long (DD)	Survey Dates: 2010	Survey Dates: 2011	Total N (# cores):
Salmon Creek: Site S (Sonoma County)	38.3573 -123.0681	38.357383 -123.068383	May 25, 2010 August 16, 2010 October 7, 2010	May 26, 2011 August 24, 2011 October 20, 2011	300
Salmon Creek: Site N (Sonoma County)	38.360017 -123.068767	38.359567 -123.068733	August 16, 2010 October 7, 2010	May 26, 2011 October 20, 2011	200
Montara Beach (San Mateo County)	37.546017 -122.515183	37.545583 -122.515333	May 5, 2010 August 17, 2010 October 16, 2010	May 25, 2011 August 18, 2011 October 9, 2011	300

Table 2. Site locations, dates, and total number of samples (N) collected for 'baseline' assessment, 2010-2011.

the total sampled abundance. The two peak recruitment events occurred 7 years apart. Following these peak recruitment years, the data show summer abundance decreasing sharply over a 1-2 year period with adults, not recruits, dominating the population. Little to no recruitment was observed between 2006 and 2009. Abundance at Ocean Beach during these four consecutive years remained near zero and did not exceed a seasonal average of 0.5 crabs per core, with the exception of summer 2006 (1.2 crabs per core), the result of minor recruitment to the beach.

Historic population abundances of *E. analoga* at all LiMPETS sites within the NCC MPA region (Figures 4 and 5) follow similar trends to Ocean Beach. However, aside from Ocean Beach, most sites are not surveyed consistently from season to season or from year to year, making site-site comparisons difficult. Regionally, during the peak recruitment years of 2003 and 2010, highest observed abundances occurred in 2003 at Muir Beach (Marin Co.), Baker Beach (San Francisco) and Ocean Beach (San Francisco). Mean spring/summer abundance at these sites ranged from 30.0 - 32.4 crabs per core. Seasonal survey effort varied at each site from 50 samples at Muir, 90 samples at Baker, and 220 samples at Ocean Beach. During the summer of 2010, greatest abundances occurred at Ocean Beach and Pescadero Beach. Mean summer abundances were 19.6 and 32.7 crabs per core, respectively. Seasonal survey effort varied at these sites from 570 samples at Ocean Beach to 130 samples at Pescadero Beach.

During the 2003 recruitment event, many beaches experienced a peak in sampled abundance during either spring or summer (Figure 4A). Surveyed beaches, from north to south, included Stinson, Muir, Baker, Ocean, Ft. Funston, and Surfer's.

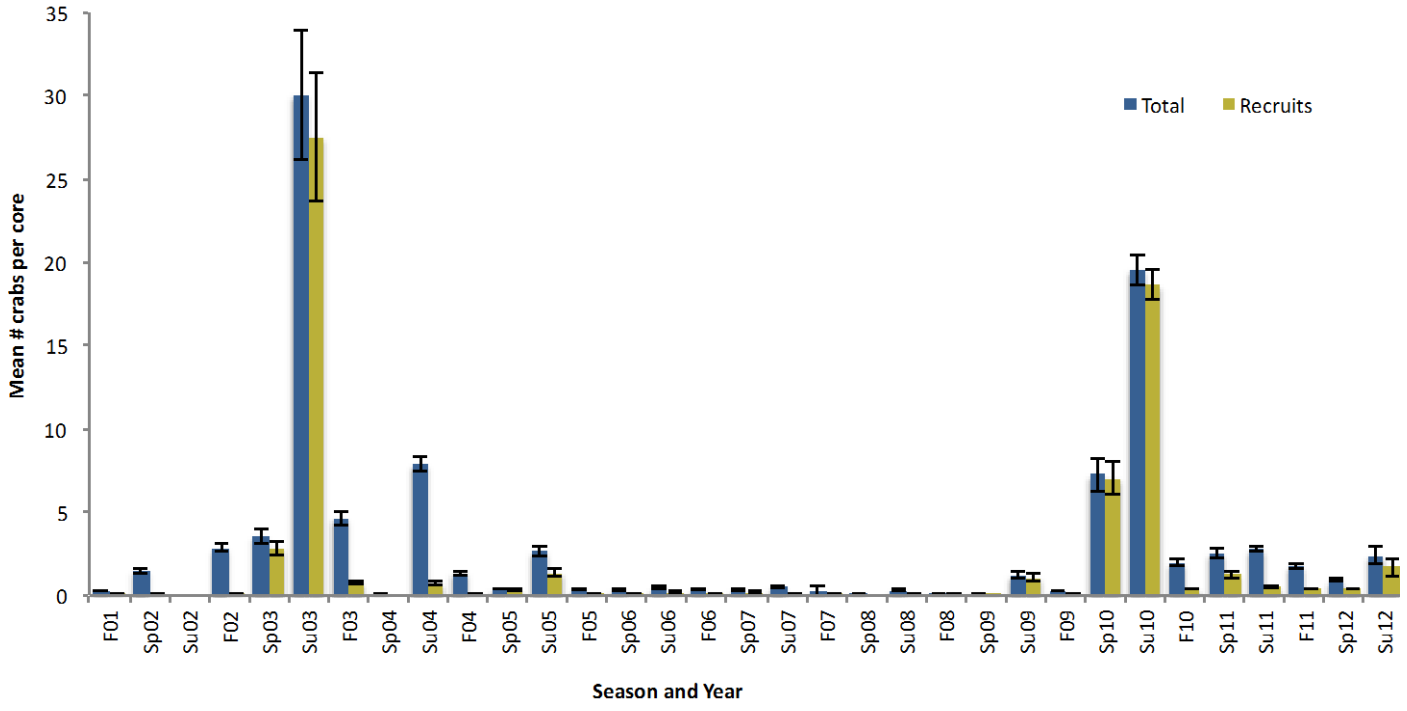


Figure 3. Seasonal and interannual trends in abundance and recruitment of *Emerita analoga* at Ocean Beach, San Francisco, CA: Fall 2001 – Summer 2012. Abundance is reported as the average number of crabs (or average number of recruits) per total cores sampled for each season (±SE). Core diameter is 15.5 cm. Total N = 14,515. A gap is shown during Summer 2002 because no surveys were conducted during these months.

During the 2010 recruitment event, not all beaches surveyed experienced a peak in sampled abundance during spring or summer (Figure 5). Surveyed beaches, from north to south, include Salmon Creek, Doran, Stinson, Muir, Rodeo North, Rodeo South, Baker, Ocean, Ft. Funston, Linda Mar, Montara, Surfer's, Dunes and Pescadero. Of the surveyed sites located north of the Golden Gate Bridge, 2 of the 6 beach sites, Stinson and Rodeo-South, experienced a small peak in recruitment and abundance. Average abundance at Stinson Beach was 4.8 crabs per core, and recruits comprised 85% of the sampled population. Average abundance at Rodeo Beach-South was 4.7 crabs per core, and recruits made of 95% of the sampled population. South of the Golden Gate Bridge, 3 of 6 sites, Ocean, Ft. Funston and Pescadero, experienced higher magnitudes of larval recruitment and greater overall abundance. In contrast to the north, abundances ranged from seasonal averages of 8.0 – 32.7 crabs per core, and recruits comprised >95% of the sampled population at each of these more southern sites (Figure 5).

Overall, there exists high variability in *E. analoga* abundance and recruitment along beaches in the North Central Coast MPA region over an eleven period. During this time, the most striking trend is the extremely low abundance, and at some sites the near disappearance of, populations of *E. analoga* across the entire region between 2006 and 2009 (Figure 4B). Though seasonal survey effort varied between sites, overall survey effort between 2006 and 2009 increased from all years prior due to increased participation by local schools.

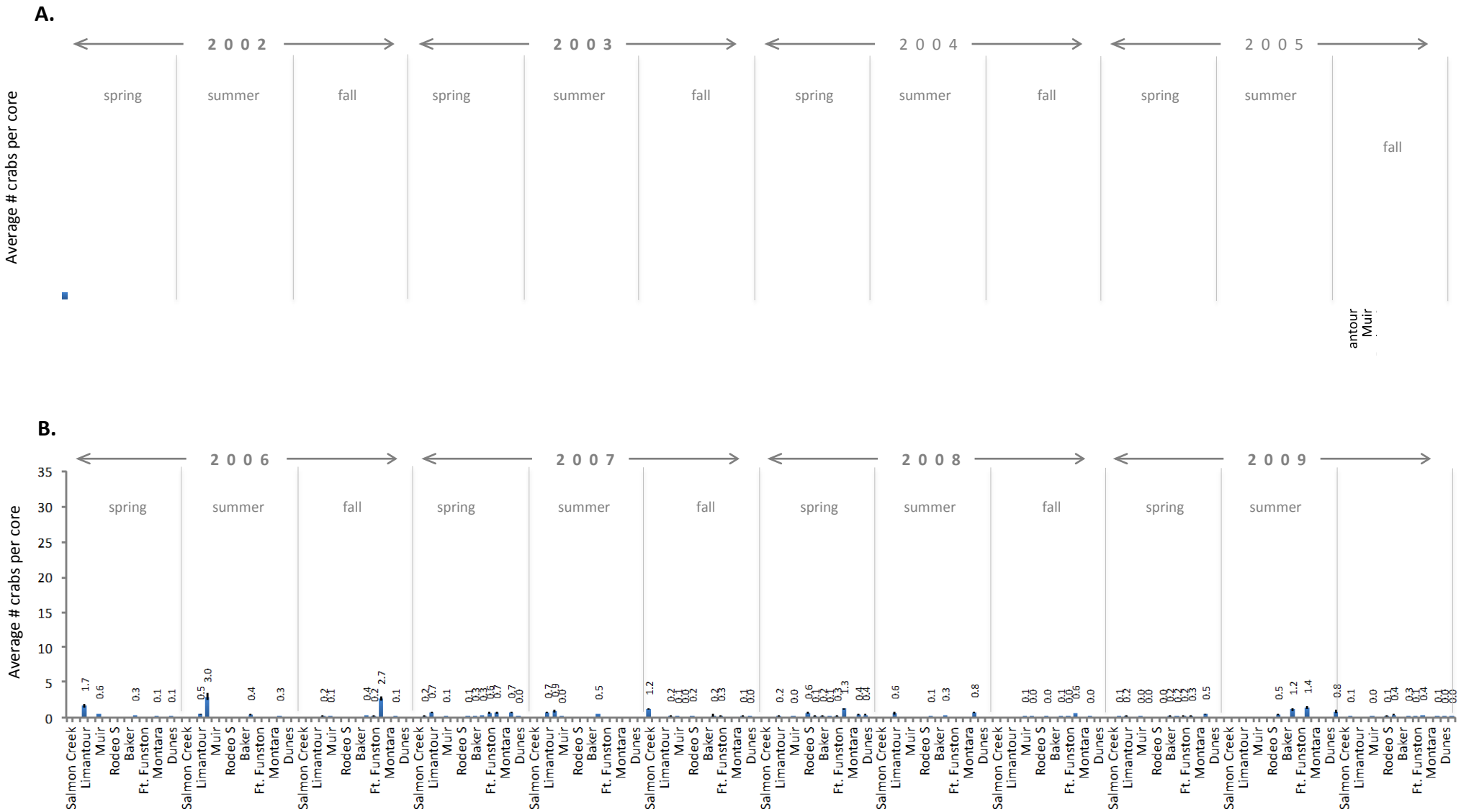


Figure 4 (A & B). Seasonal and interannual trends in abundance of *Emerita analoga* at all sites within the NCC MPA study region: Fall 2001 – Fall 2009. Abundance is reported as the average number of crabs per total cores sampled for each season (±SE). Existing data is shown for each site seasonally. Gaps are shown where no data exists at a site(s). For each season, LiMPETS sandy beach sites are ordered from north to south along the x-axis, with Salmon Creek to the north and Pescadero State Beach to the south. Not all sites are shown along the x-axis due to space.

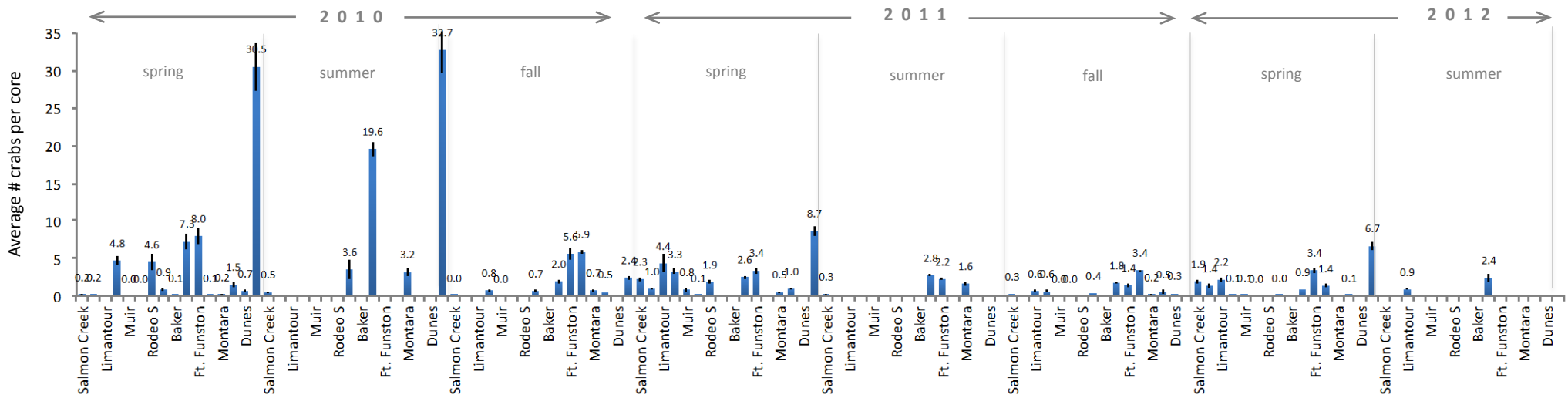


Figure 5. Seasonal and interannual trends in abundance of *Emerita analoga* at all sites with in NCC MPA study region: Spring 2010 – Summer 2012. Abundance is reported as the average number of crabs per total cores sampled for each season (±SE). Core diameter is 15.5 cm. Existing data is shown for each site seasonally. Gaps are shown where no data exists at a site(s). For each season, LiMPETS sandy beach sites are ordered from north to south along the x-axis, with Salmon Creek to the north and Pescadero State Beach to the south.

2.3 POTENTIAL DRIVERS: RESULTS FROM AN ANALYSIS OF HISTORIC TRENDS IN MOLE CRAB ABUNDANCE

In an effort to identify potential cause(s) or driver(s) of unexplained variation in Pacific mole crab abundance and recruitment over time within the NCC MPA region, a linear regression analysis was conducted using the long-term dataset at Ocean Beach, San Francisco, CA. Average seasonal abundance was paired with the Multivariate ENSO Index (MEI) to examine if a there is linkage between physical changes in the ocean such as MEI and changes in *E. analoga* abundance on the beach. In response to oceanographic changes, lag periods have been found to occur in some species before changes in abundance are evident onshore (Southward, 1991). Though data associated with these lag periods are lacking for *E. analoga* (and other species), we have incorporated a lag period in one of our analyses. Average seasonal abundance was paired with MEI values for the season prior (Figure 6B). MEI is a composite index using a number of variables to measure ENSO events. Positive MEI values are related to warm phase or El Niño events and negative values with to cool phase or La Niña events.

Figure 6 shows results from the linear regression. Averages of MEI by season do not predict abundance of *E. analoga* at Ocean Beach during that same season ($R^2 = 0.0026$, $p = 0.7830$). Averages of MEI by season do not predict abundance of *E. analoga* at Ocean Beach the following season ($R^2 = 0.0695$, $p = 0.1447$). Variation in onshore abundance and recruitment may be better explained by factors operating on longer, decadal climatic scales (Menge et al, 2011) rather than the shorter 3-7 year ENSO time scale.

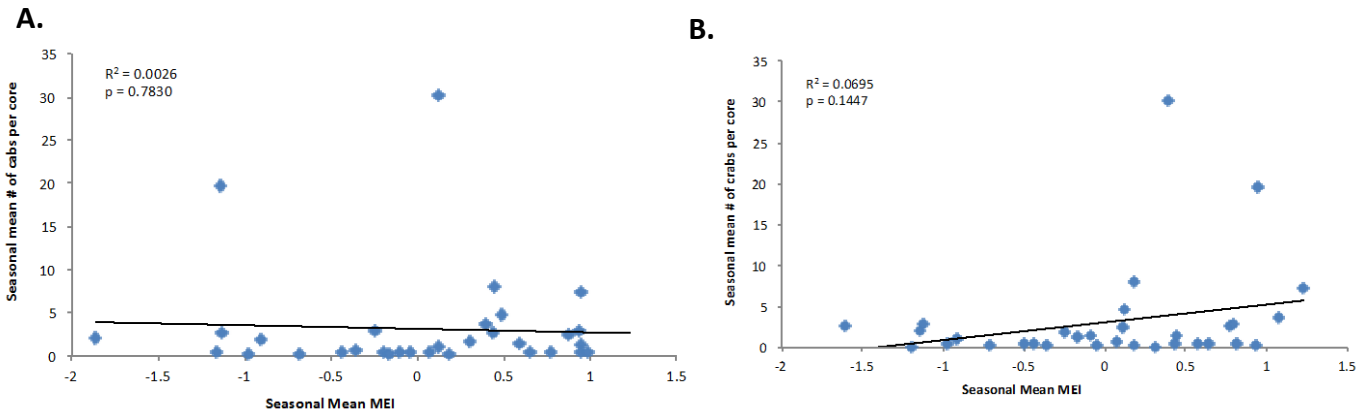


Figure 6. Linear regression showing A) seasonal mole crab abundance (Ocean Beach, San Francisco, CA) paired with seasonal MEI and B) seasonal mole crab abundance paired with MEI values for the preceding season.

2.4 'BASELINE' SPATIAL VARIABILITY IN RECRUITMENT AND ABUNDANCE

'Baseline' spatial variations in recruitment and abundance of *E. analoga* in the North Central Coast MPA study region (Salmon Creek to Pescadero) are depicted in Figures 7-12. Spatial variability in recruitment, and the mechanisms that drive this variability, are not well understood. Diehl 2009 suggests a mechanism whereby larval exchange of *E. analoga* across headlands may be restricted along the coast of California north of Point Conception. Point Reyes headland could therefore restrict larval exchange of *E. analoga* within the study region, and if this is the case, recruitment may vary spatially to the north and south of Point Reyes. However, more data is needed, particularly at sites north of Point Reyes, to better understand spatial variations in recruitment.

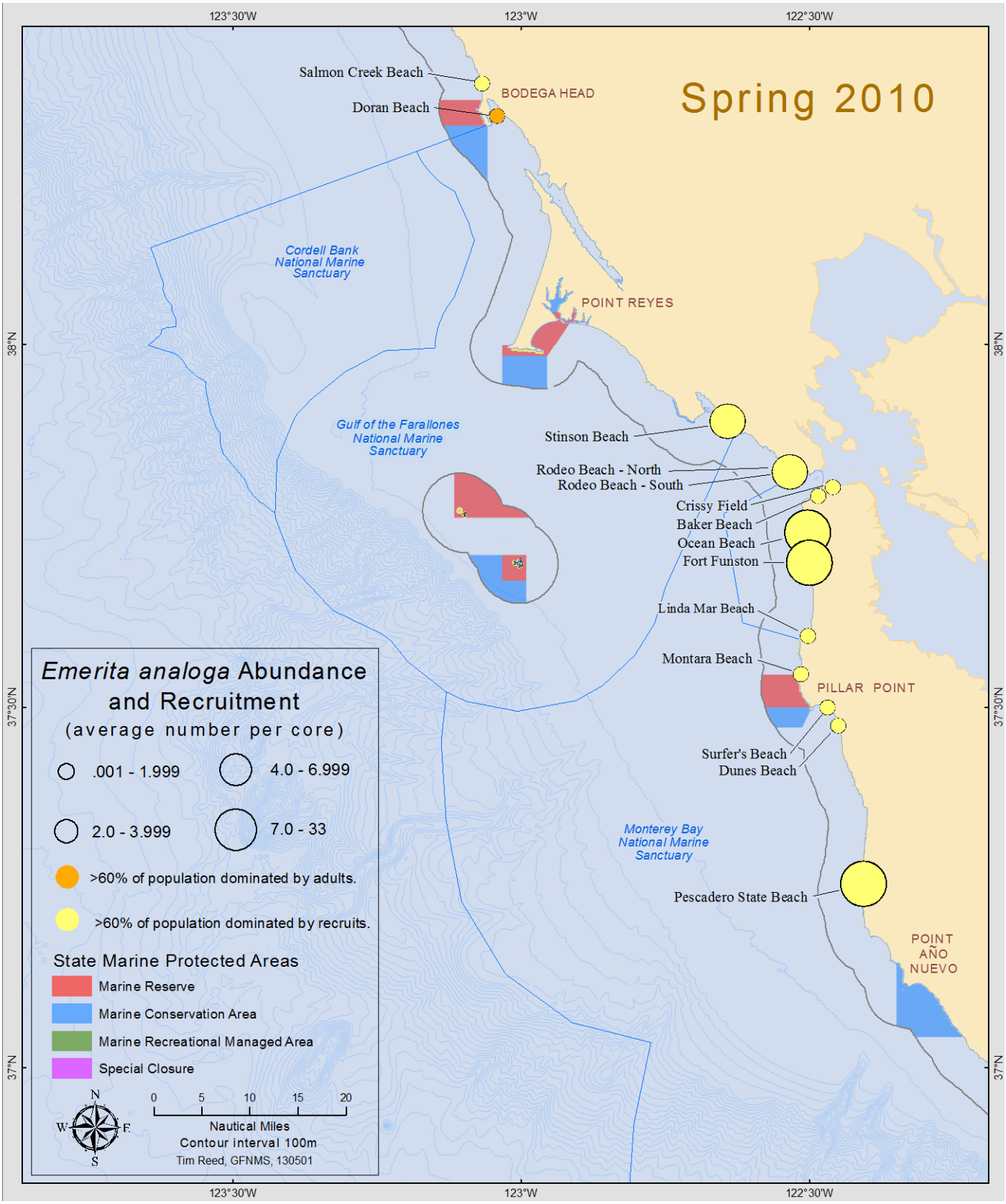


Figure 7. Spring 2010 - *Emerita analoga* abundance and recruitment at LiMPETS beach sites in the southern portion of the NCC MPA region.

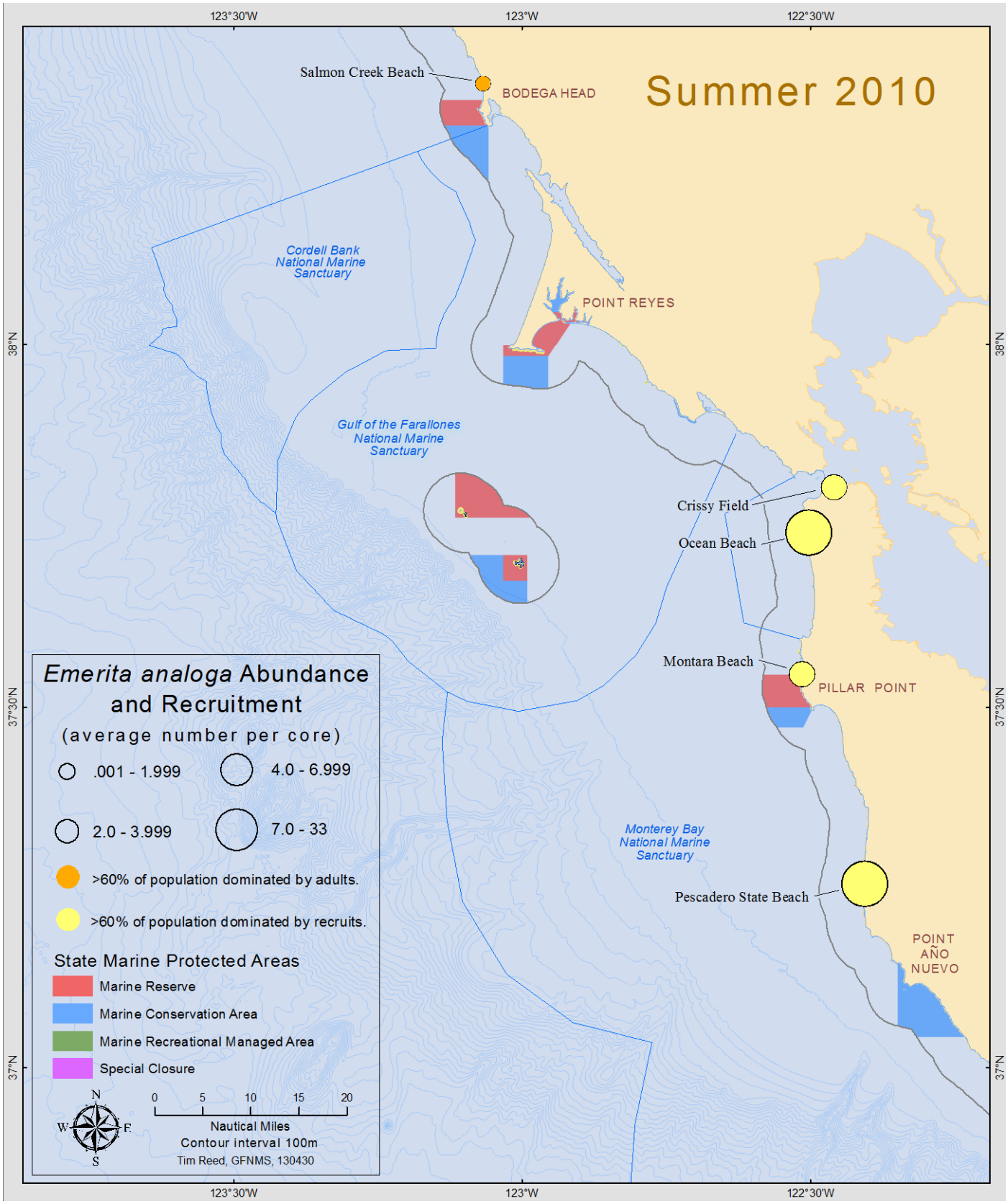


Figure 8. Summer 2010 - *Emerita analoga* abundance and recruitment at LiMPETS beach sites in the southern portion of the NCC MPA region.

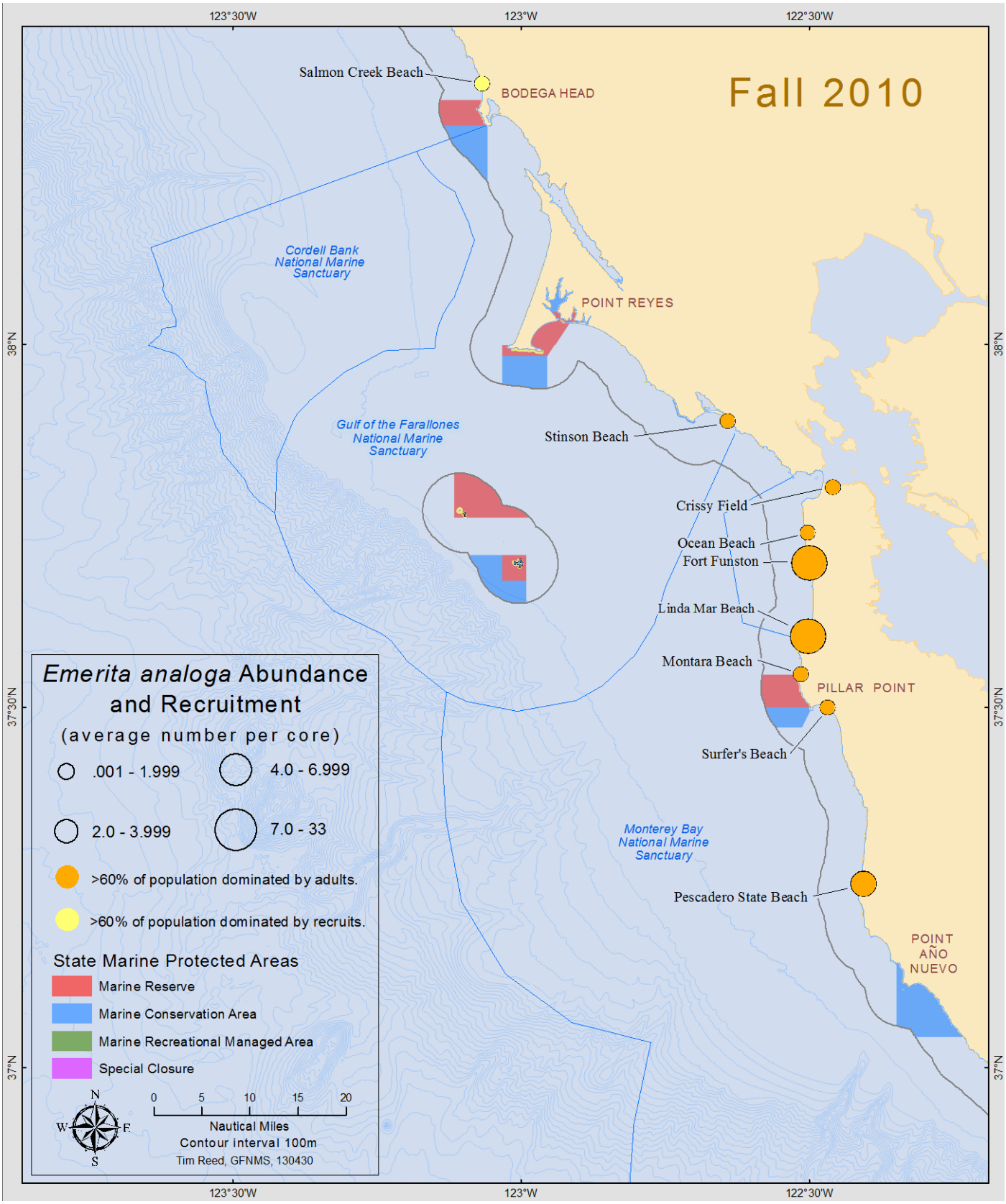


Figure 9. Fall 2010 - *Emerita analoga* abundance and recruitment at LiMPETS beach sites in the southern portion of the NCC MPA region.

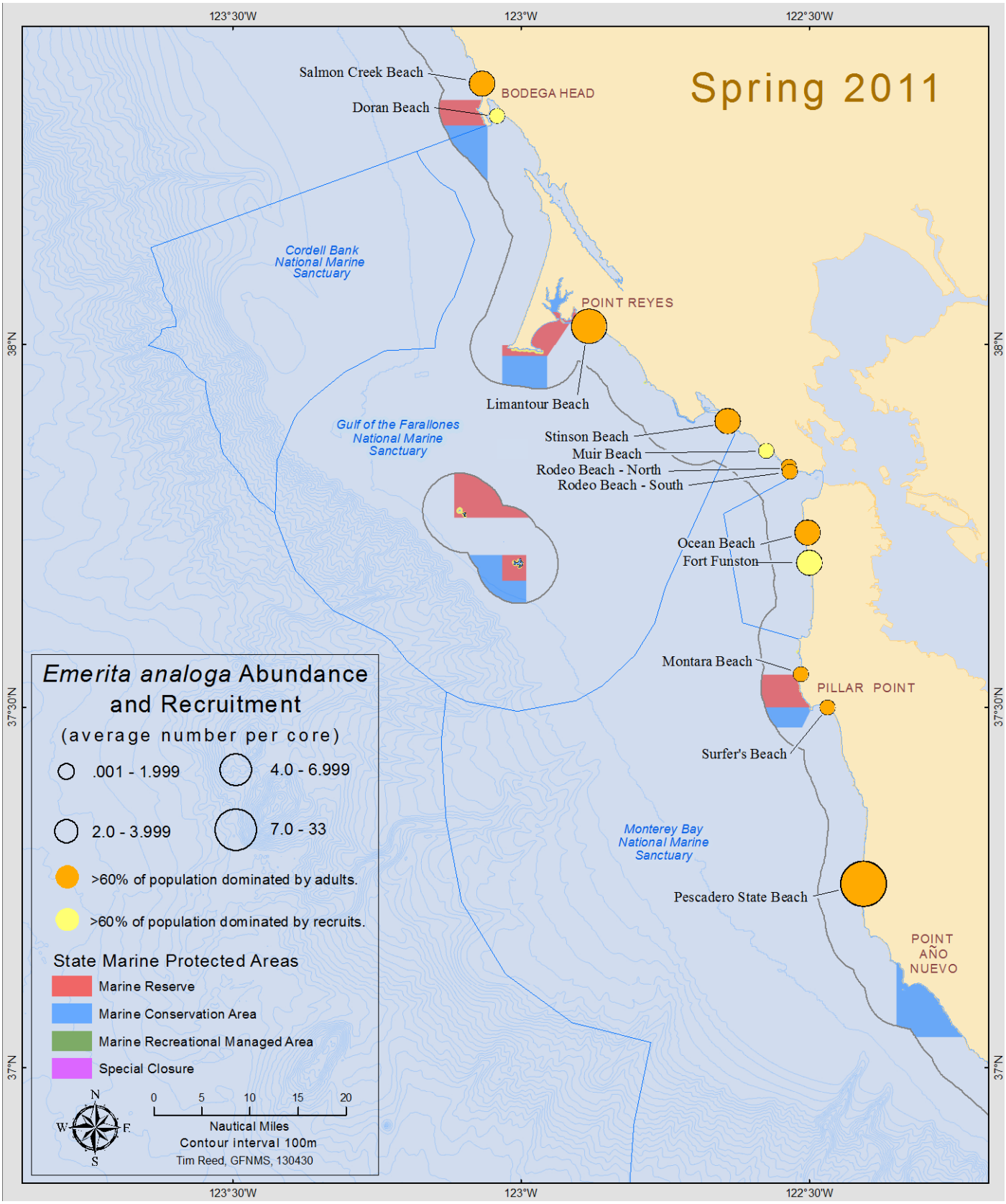


Figure 10. Spring 2011 - *Emerita analoga* abundance and recruitment at LiMPETS beach sites in the southern portion of the NCC MPA region.

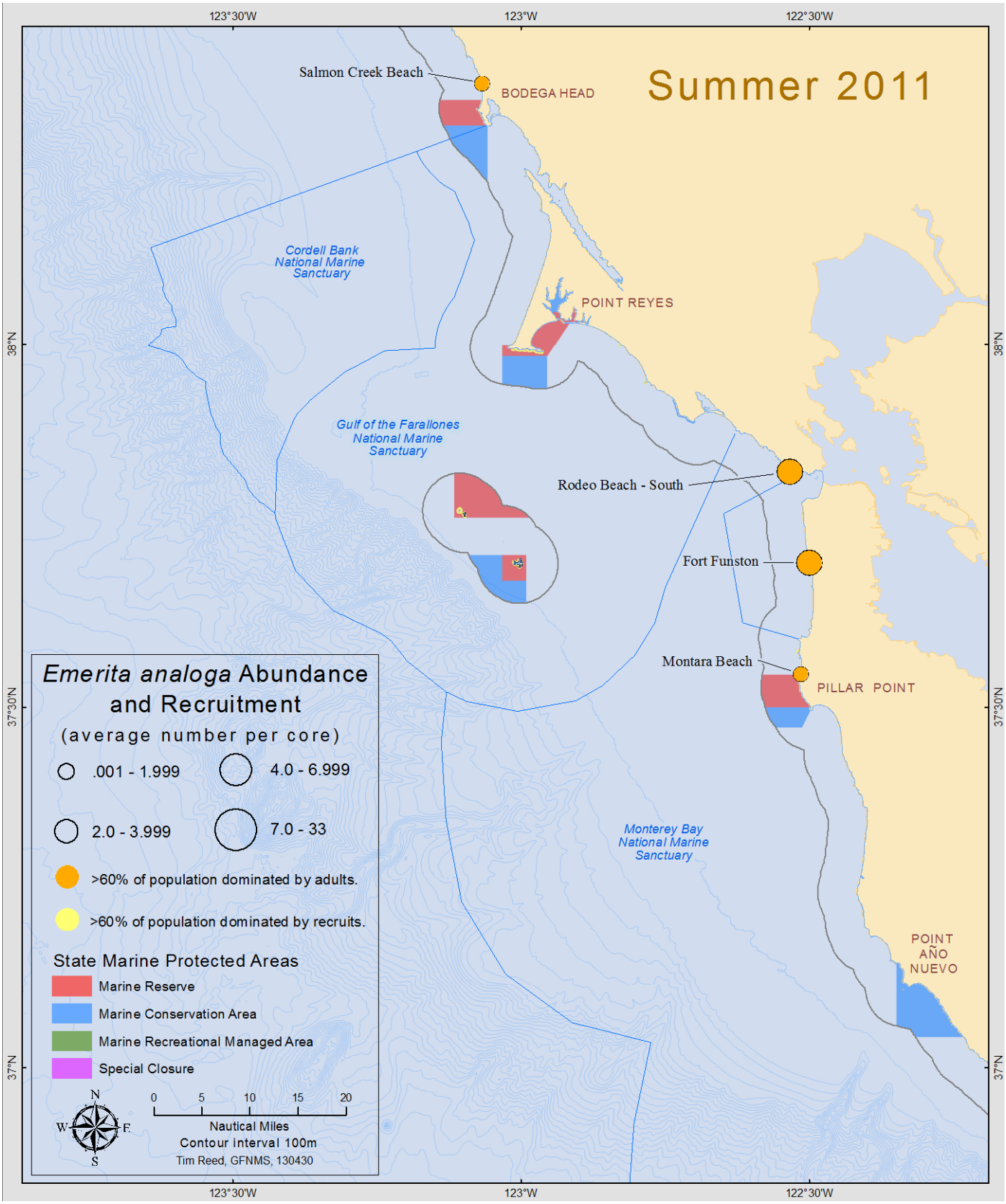


Figure 11. Summer 2011 - *Emerita analoga* abundance and recruitment at LiMPETS beach sites in the southern portion of the NCC MPA region.

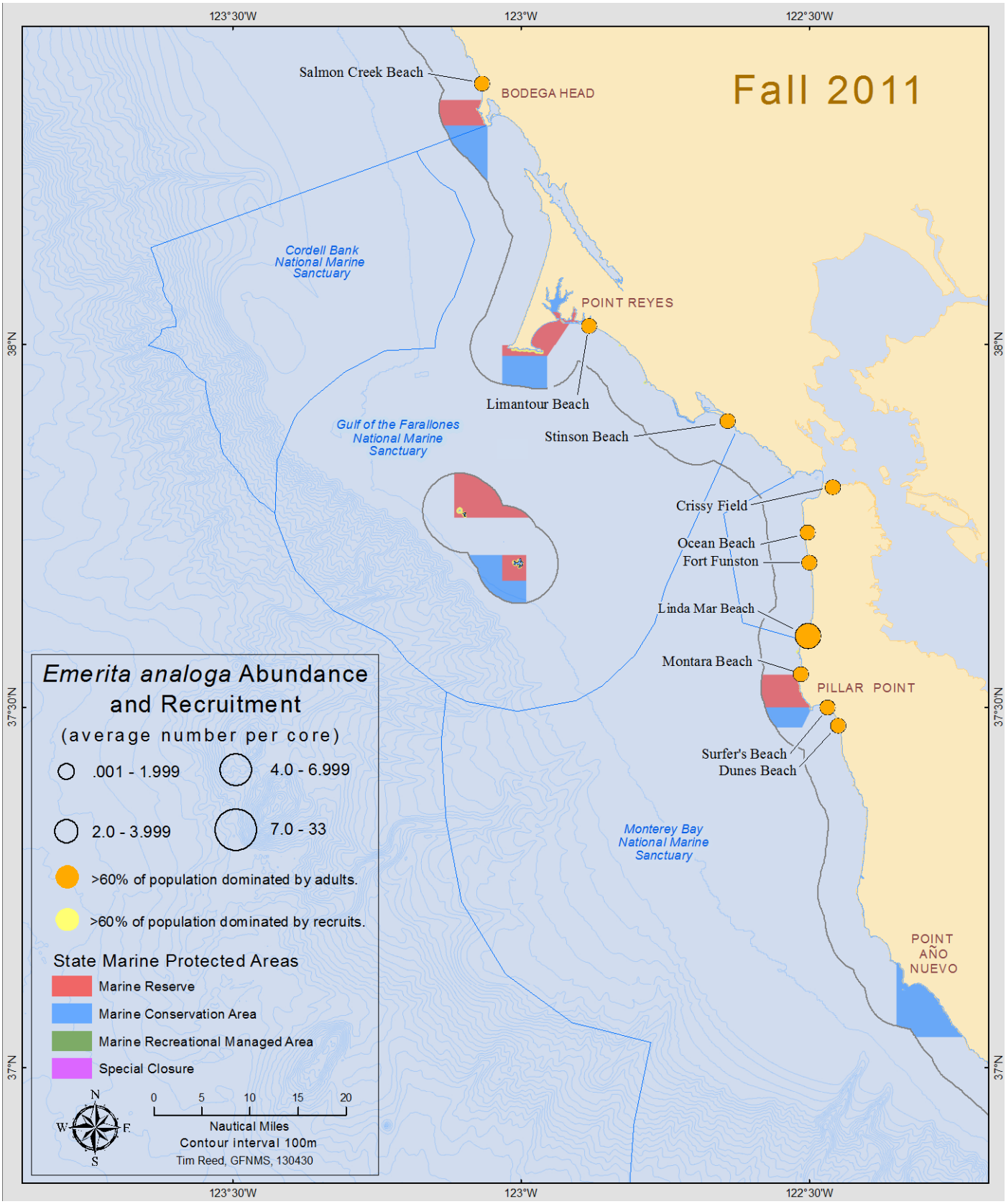


Figure 12. Fall 2011 - *Emerita analoga* abundance and recruitment at LiMPETS beach sites in the southern portion of the NCC MPA region.

2.5 BASELINE STATUS OF *Emerita analoga* POPULATIONS AT MONTARA AND SALMON CREEK BEACHES, 2010 – 2011

The 'baseline' beach surveys conducted at Salmon Creek Beach during 2010 and 2011 (Figure 14A) show that minor recruitment of young-of-the-year crabs occurred in both Spring 2010 and 2011. Recruit abundance during these spring seasons did not exceed 0.5 individuals per core, averaged across all spring survey dates for both Site N and Site S. Total sampled abundance was low, relative to other LiMPETS beach sites, and adults dominated the population.

The 'baseline' beach surveys conducted at Montara State Beach during 2010 and 2011 (Figure 14B) show that a peak in recruitment of young-of-the-year crabs occurred in Summer 2010. Recruitment continued, in diminished numbers, through Fall 2010; however, no recruits were observed during any survey in 2011. In 2011, adults comprised the entire sampled population during all seasonal surveys. The season of highest abundance at Salmon Creek Beach (Spring 2011) occurred during the period of lowest abundance at Montara State Beach. A high degree of variability exists over time and among sites.

Figure 13 (A & B): Location of LiMPETS survey areas along Salmon Creek and Montara beaches. All survey areas are 500 m^2, 50-m alongshore and 10-m seaward through the upper swash zone.

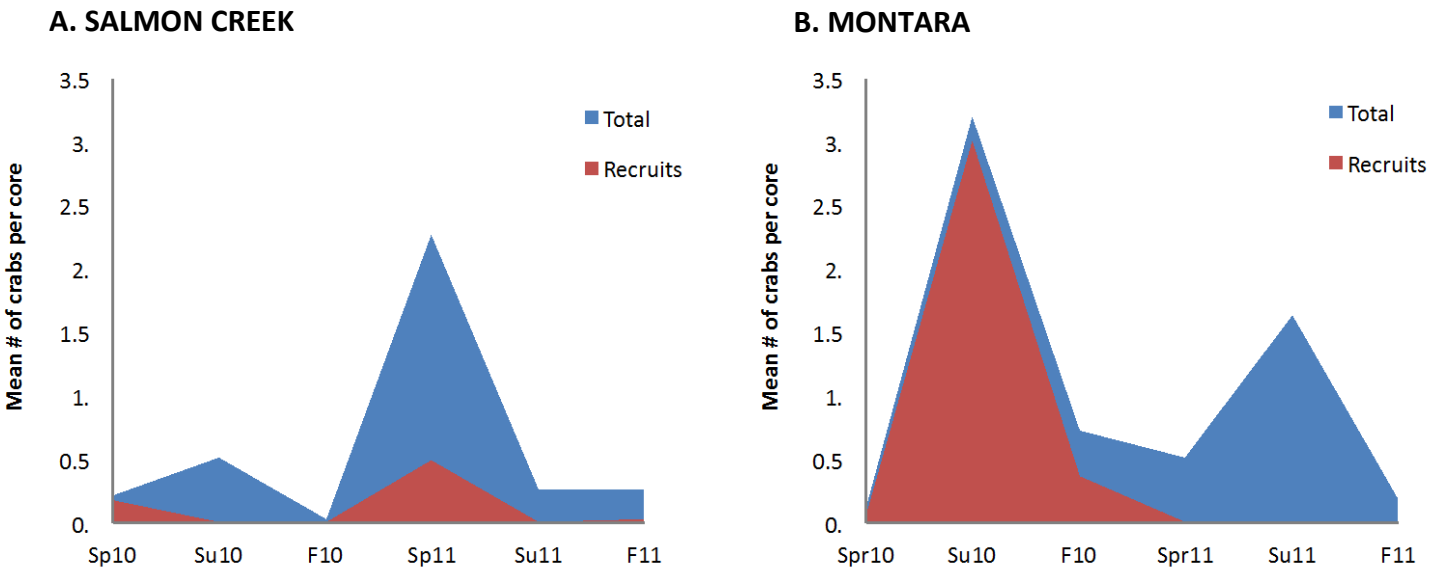


Figure 14. Baseline trends in abundance (adults and recruits) of *Emerita analoga* populations at A: Salmon Creek and B: Montara from Spring 2010 – Fall 2011. Abundance is reported as the average number of total crabs (blue) and average number of recruits (red) per total cores sampled for each season.

Seventh and eighth grade citizen scientists from Lower Lake Elementary, Lake County, CA gather after a grueling day of LiMPETS surveys, Salmon Creek Beach, CA.

2.6 OVERVIEW OF THE LIMPETS ROCKY INTERTIDAL DATA SET: HISTORIC VS. 'BASELINE'

Four LiMPETS rocky intertidal sites are located within the North Central Coast MPA study region. Overall, longevity of the historic dataset and the total number of surveys conducted at each site varies (Table 3). The 'baseline' rocky intertidal surveys were conducted seasonally at Duxbury Reef SMCA, Montara SMR, and Pillar Point, Spring 2010 through Winter 2012 (Table 4).

Historically, it has been common practice for the LiMPETS program to accommodate the participating schools regarding their choice of sites and survey frequency. Because of this practice, the historic data set contains, at the most accessible site at Montara SMR, relatively more frequent and consistent surveys over time. However, inconsistencies in sample effort across sites and over time exist, due to the seasonal timing of low tides during daylight hours and also due to the fact that schools often cannot spend the extra travel time that is necessary to reach sites that are in remote locations. Another challenge is that students often do not have the time to conduct all of the sampling methods used at our sites in one visit causing additional inconsistencies in the data collection effort among sites.

Rocky intertidal site:	County:	Year established:	Survey effort: total number surveys completed since site establishment
Duxbury Reef SMCA	Marin	2004	48
Montara SMR	San Mateo	2006	95
Pillar Point	San Mateo	2009	21
Pigeon Point	San Mateo	2006	29

Table 3. LiMPETS rocky intertidal sites (listed north to south), date of establishment, and total number of surveys conducted at each site (through December 31, 2012).

Rocky intertidal site (county):	Survey methods used at site:	Survey Dates: 2010-2011	Survey Dates: 2011-2012
Duxbury Reef SMCA (Marin County)	Vertical Transect: Sites A & B Random Quadrat: Sites A & B	April 2010 August 2010 November 2010 January 2011	April 2011 August 2011 November 2011 January 2012
Montara SMR (San Mateo County)	Vertical Transect Random Quadrat: Sites A & B Total Counts: stars/anemones Size Measurement: owl limpets	April 2010 August 2010 November 2010 January 2011	April 2011 August 2011 November 2011 *January 2012 - *no survey, high surf*
Pillar Point (San Mateo County)	Vertical Transect Random Quadrat Total Counts: stars	*May 2010 August 2010 November 2010 January 2011	April 2011 August 2011 November 2011 January 2012

Table 4. Rocky intertidal sites, methodologies, and survey dates used for the NCC MPA 'baseline' assessment, during the 2010 - 2012 time period.

2.7 BASELINE / HISTORIC POPULATION TRENDS:

Because the LiMPETS datasets at each of the four established sites contain <10 years of data, all results and analyses of LiMPETS rocky intertidal data are reported in this section, both historic trends and 'baseline' status.

Cover of mussels *(Mytilus californianus)*

Cover of mussels is one of the candidate focal species and attributes identified in the NCC Baseline Characterization RFP. The LiMPETS 'random quadrat' protocol estimates percent cover using a presence/absence approach in a square, gridded quadrat (0.25 m^2). Each of the 25 grids within the quadrat are 0.1 m x 0.1 m. 100% mussel cover using the LiMPETS method would mean that mussels were present within all 25 grids of the quadrat. Note that this method is different than the 'point-contact' method (Murray et al., 2006) and the values are generally higher.

At Montara SMR (Fitzgerald Marine Reserve), the permanent plot area where surveys are conducted does not contain a mussel bed. Mussels are present and are dispersed sparsely throughout the area. At Pillar Point, the unprotected reef adjacent to Montara SMR, the permanent plot area almost entirely encompasses a small mussel bed. Due to this difference in the community composition within the permanent plot at Pillar Point (mussel bed) and the permanent plot at Montara SMR (high/mid zone community without an intact mussel bed), we cannot make site-site comparisons of mussel cover.

Figure 15 shows temporal changes in mussel cover at Montara SMR. Cover declined from 2007 through 2010, with mean annual cover in 2010 at 1.5%. During the first three years of MPA implementation at Montara SMR, mussel cover increased from a mean cover of 1.5% in 2010 to 14% in 2012. This site has been a no-take reserve since 1969; therefore this increase is not likely in direct response to MPA implementation.

At Pillar Point, mussel cover inside the permanent plot remained stable in 2010 and 2011, 76%, 77% respectively. In 2012, mean annual cover decreased to 41%. Figure 16 shows the 'baseline' status of mussel cover at Montara SMR and Pillar Point *within the survey areas* during the first 3 years of implementation. Mussel cover increased at the protected reserve and decreased at the unprotected, reference site.

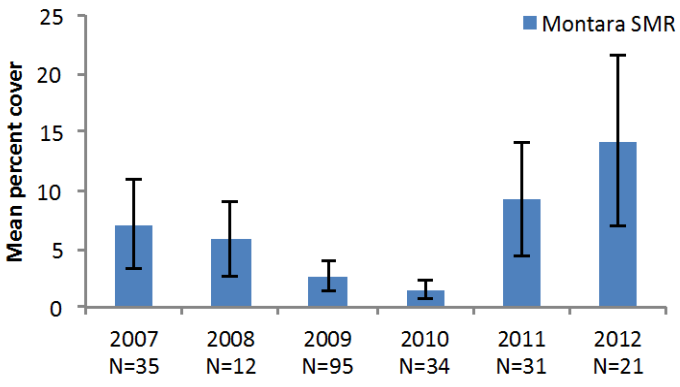


Figure 15. Mean annual percent cover of mussels (±SE) within a permanent plot at Montara SMR, 2007 – 2012.

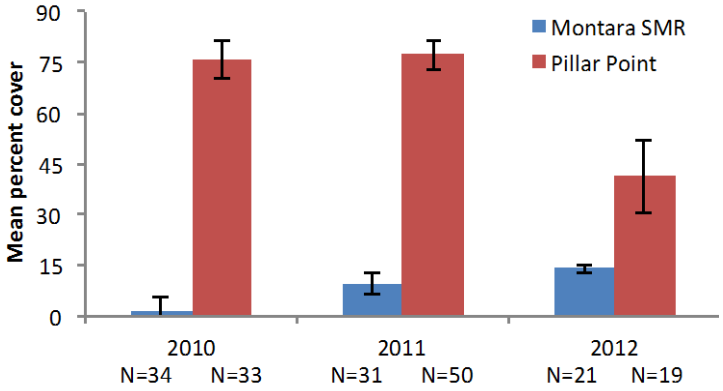


Figure 16. Mean annual percent cover of mussels (±SE) at Montara SMR and the adjacent reference site (Pillar Point) during the first three years of implementation, 2010 – 2012.

Sea star (Pisaster ochraceus) density

The LiMPETS 'total count' protocols estimate *P. ochraceus* density by conducting visual, timed counts within a permanent area of the reef. Pigeon Point and Pillar Point data results are reported here. Both sites are unprotected and outside of NCC MPAs. The LiMPETS site for sea star counts at Montara SMR needs to be reassessed due to the size and placement of the area. Data is therefore not presented in this report for Montara SMR. No data exist at Duxbury SMCA due to the lack of suitable areas to safely conduct sea star counts.

At Pigeon Point, surveys have inconsistently been conducted over a six-year period, 2007 – 2012. Though seasonal ups and downs in density exist, Figure 17 shows a significant, though relatively short-term decline in the density of *P. ochraceus* at the study site ($R^2 = 0.35$, $p = 0.00975$).

At Pillar Point, surveys were conducted seasonally between January 2010 and January 2012. Another reliable survey was conducted in December 2008 and was used to assess baseline status and trends for this report. At Pillar Point, the data reveal a seasonal trend in sea star density (Figure 17). Surveyed abundance was lowest in the month of May. Abundance increased through summer months, reaching a peak in winter (January). Abundance over time remained stable. Mean annual abundance of stars in the surveyed area was 4.8 individuals per $10m^2$ in 2010 and 3.8 individuals per $10m^2$ in 2011.

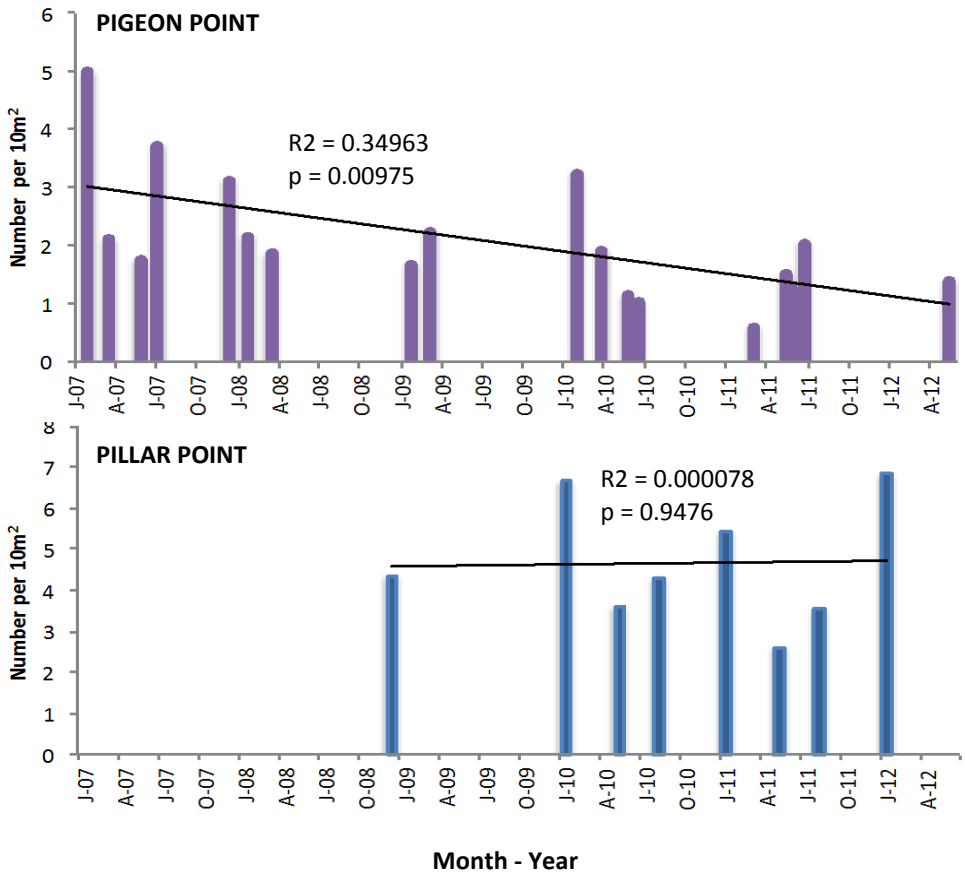


Figure 17. Sea star (*P. ochraceus*) density at Pillar Point and Pigeon Point, 2007-2012. A significant decline in sea star density over time is shown at the Pigeon Point site ($p<0.05$). No change over time was observed at Pillar Point.

Purple sea urchin (*Strongylocentrotus purpuratus*) density

Purple sea urchin, *S. purpuratus*, density is a candidate metric for ecosystem feature assessment identified in the NCC Baseline Characterization RFP. The LiMPETS 'random quadrat' protocol estimates urchin density by counting each individual found within a 0.25 m^2 quadrat. Quadrats are placed randomly in a permanent area. Typically, 10-20 replicates are conducted during each survey. Among our LiMPETS sites, only Montara SMR has a permanent area containing an urchin bed where these types of surveys are conducted.

Though surveys at Montara SMR have inconsistently, and somewhat infrequently, been conducted over a six-year period, the data show a short-term significant decline in urchins between 2007 and 2012 ($R^2 = 0.23$, $p = 0.04$) (Figure 18A). This decline is especially notable during the NCC baseline years, 2010-2012, when density declined from a mean of 34 urchins/m^2 in 2010 to only 9 urchins/m^2 in 2012 (Figure 18B).

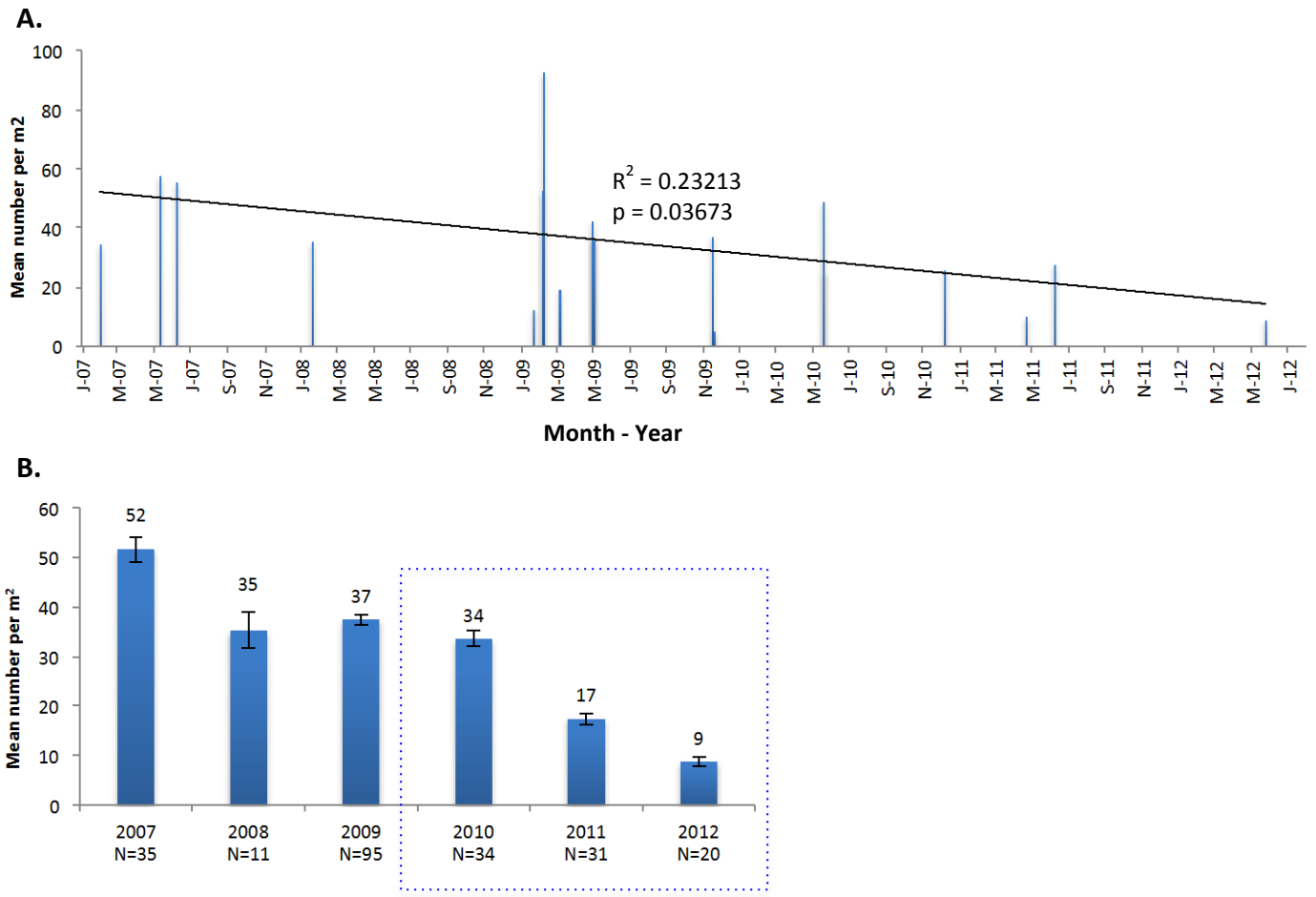


Figure 18. Sea urchin (*S. purpuratus*) density at Montara SMR over a 6-year period, 2007-2012: A) density over time using the mean of the n (# replicates per survey) per survey date and B) mean annual density (±SE). The dotted blue box highlights data from the NCC 'baseline' years (2010-2012). A significant decline in sea urchin density over time is shown at Montara SMR ($p<0.05$).

Cover of the fucoid alga, *Fucus gardneri*

Cover of fucoids is one of the candidate focal species and attributes identified in the NCC Baseline Characterization RFP. The LiMPETS 'random quadrat' protocol estimate percent cover using a presence/absence approach in a square, gridded quadrat (0.25 m^2). Each of the 25 grids within the quadrat are 0.1 m x 0.1 m. 100% fucoid cover using the LiMPETS method would mean that *F. gardneri* were present and attached within all 25 grids of the quadrat. Each survey is typically comprised of replicate counts of *F. gardneri* in 10 to 20 randomly placed quadrats within the permanent area.

For this report, seven years of data (May 2006 – April 2013) are shown within two of the NCC MPAs, Duxbury SMCA and Montara SMR. Cover declined significantly (p=0.00387) over time at Montara SMR (Figure 19). Notably, similar trends at both sites emerge during the 'baseline' years, 2010-2012 (Figure 20). During these years, *F. gardneri* cover declines at both sites, nearly disappearing from the permanent plots. These declines have continued into the first quarter of 2013. Cover at Montara SMR during the 'baseline' period ranges from an annual mean of 4.4% to 0.6% in the study area. Cover at Duxbury SMCA during the 'baseline' period ranges from an annual mean of 14.0% to 3.8% in the study area (Figure 20).

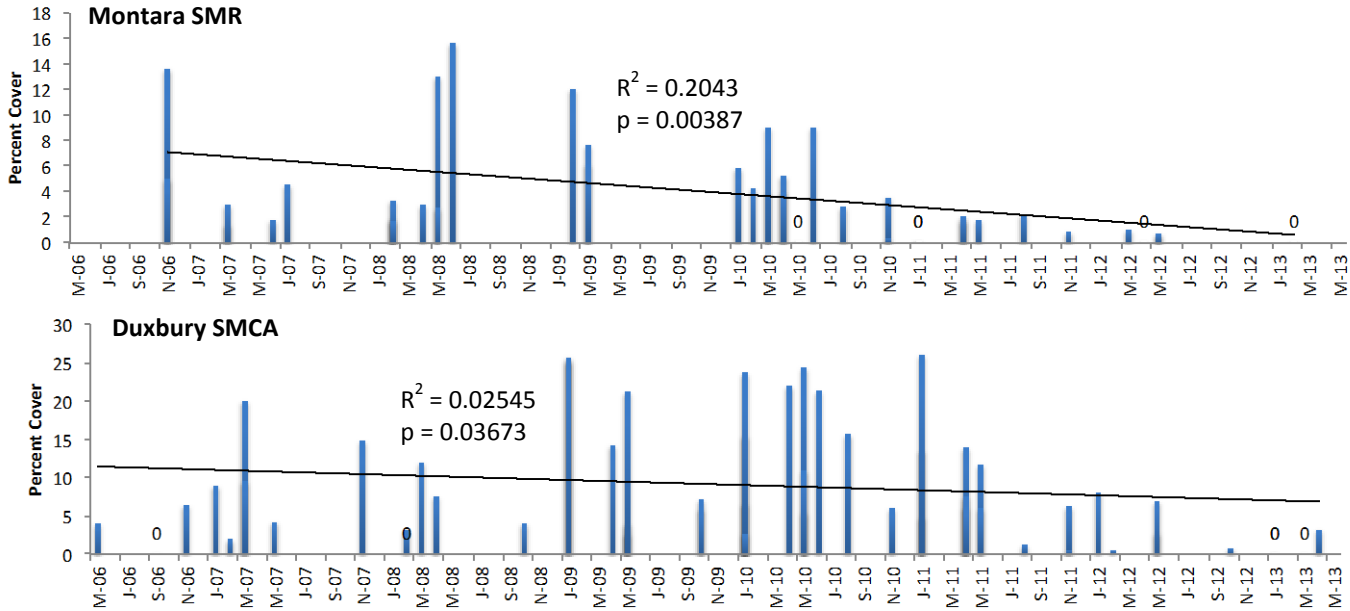


Figure 19. Survey mean of *Fucus gardneri* cover at Montara SMR and Duxbury SMCA over a 6-year period, 2006-2013. Zeros are displayed on survey dates when *F. gardneri* was not observed in the sampled area.

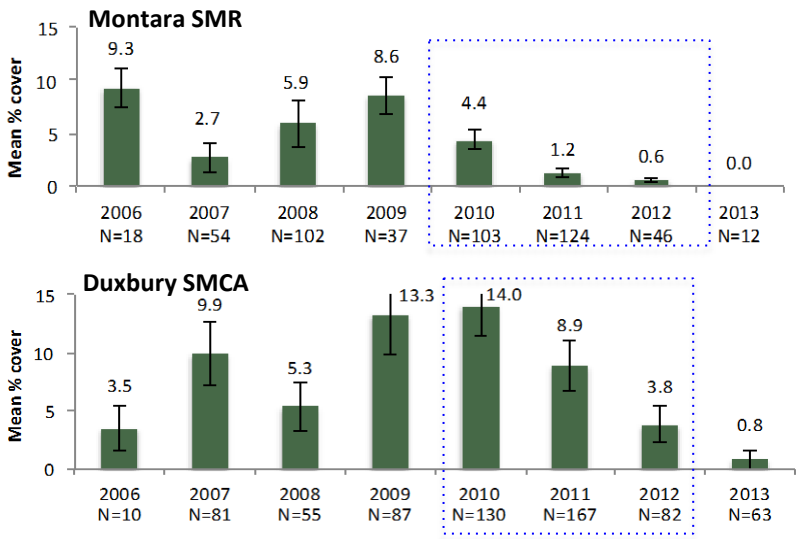


Figure 20. Annual mean percent cover of *Fucus gardneri* at Montara SMR and Duxbury SMCA over a 6-year period, 2006-2013. The total N (# replicates per year) are shown for all survey years. The dotted blue boxes highlight data from the NCC 'baseline' years (2010-2012).

Owl limpet (*Lottia gigantea*) density and size structure

Owl limpet density and size structure are candidate metrics for ecosystem feature assessment identified in the NCC Baseline Characterization RFP. All *L. gigantea* individuals (>2.0 cm in length) are counted and measured in a defined, permanent area. This method is conducted at two of the LiMPETS sites, Montara SMR and Pigeon Point. Data from both locations are presented below.

Seven years of data (2006 – 2012) are compared between two sites, Montara SMR and Pigeon Point, an unprotected site. Similar observed trends exist at both sites with highest owl limpet densities occurring in 2008/2009. The study site at Montara SMR has larger (7 cm and greater) owl limpets than Pigeon Point, shown by the lack of purple, turquoise, orange or aqua in each of the uppermost columns of data at Pigeon Point (Figure 21). Montara SMR also has a greater density of owl limpets than Pigeon Point. Note the difference in scale on the y-axes. Causes for larger, higher densities of owl limpets at Montara SMR may include long-term protection, food availability, and suitable habitat. Annual variability in density at both sites may be caused by storm events, food availability, recruitment, predation or harvesting.

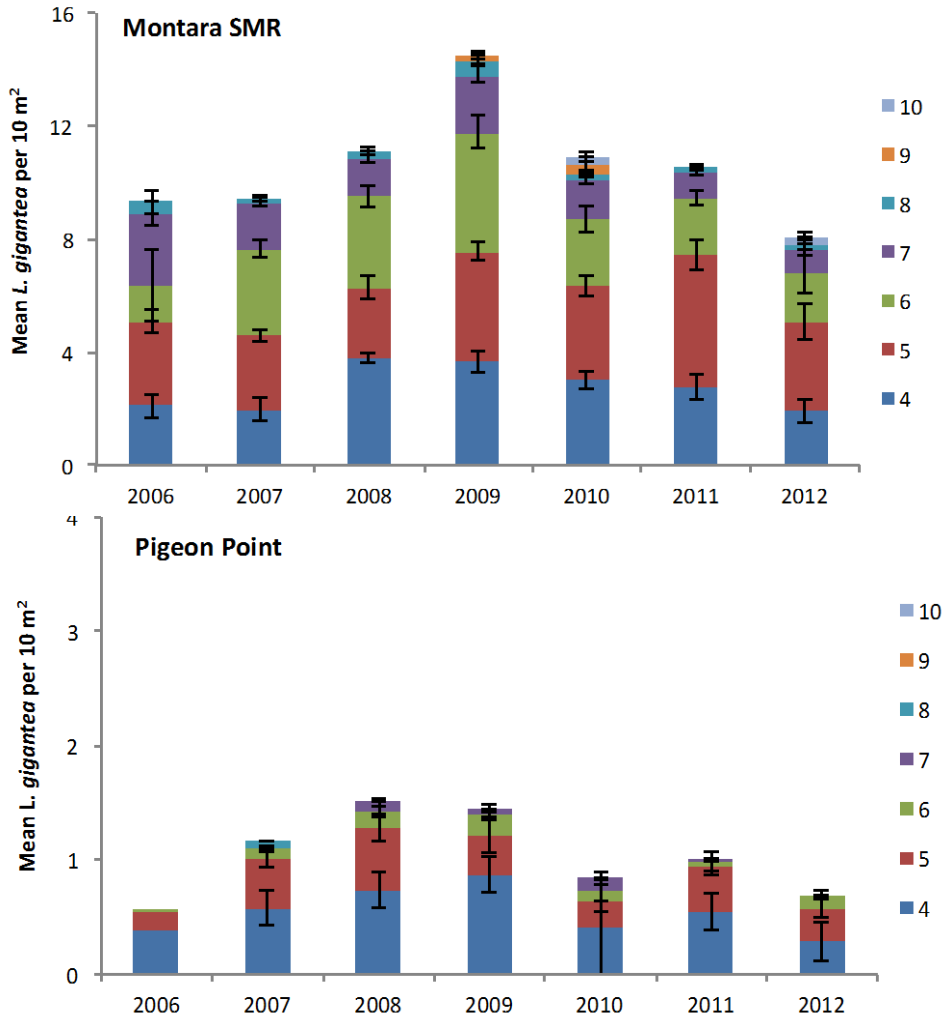


Figure 21. Mean annual abundance of owl limpets (*Lottia gigantea*) at Montara SMR and Pigeon Point, 2006-2012. Stacked columns show size structure (density (±SE) per cm) from smallest to largest. Smallest individuals (2.5-3.9 cm) are excluded from the data in the figure due to high incidence of identification error in the field. Legend shows size class (cm).

3.0 beyond the science

ENGAGEMENT, EDUCATION & IMPACT ON STUDENTS

This report's primary focus is on the project outcomes as they relate to the scientific findings of the LiMPETS long-term dataset. However, the involvement of citizen science programs such as LiMPETS, Beach Watch, Reef Check and California Collaborative Fisheries has served an important role in MPA baseline monitoring *beyond the science*. These regional citizen science programs have collectively engaged a somewhat diverse subset of community members throughout the region (fisherman, adult nature/diving enthusiasts and students) in baseline monitoring efforts.

The LiMPETS program is uniquely a regional, youth-based citizen science program with both scientific and educational objectives. In ten years, it has grown from a basic small-scale monitoring project with narrow education and science outcomes to a regional program that serves thousands of teachers and students annually. Over the years, the program design has been adapted and strengthened to better fit the needs and interests of teachers and students. The program offers a 5-unit curriculum linked to science and math education standards, a variety of web-based resources, online data entry and graphing tools, and a hands-on staff with academic training in science and education. The development of these resources has garnered increased interest and participation in the program that continues to grow on an annual basis. Beyond the resources, teachers and students participate because they want to make meaningful contributions to science, to engage in real world applications of STEM learning and the scientific process, and to make personal connections with their local ocean spaces.

The degree to which participants engage in LiMPETS educational activities varies. The program is designed to have flexibility, a necessity for teachers as time constraints and limited school resources make it difficult for classes to engage in out-of-school informal learning opportunities. The basic, required elements of the program for *teachers* include the completion of an 8-hour introductory training. During the training, teachers learn to implement the LiMPETS educational activities provided in the curriculum and practice monitoring techniques. Additionally, teachers learn the importance, scientific relevance and degree to which the LiMPETS long-term data set can contribute to ocean-based data needs and questions.

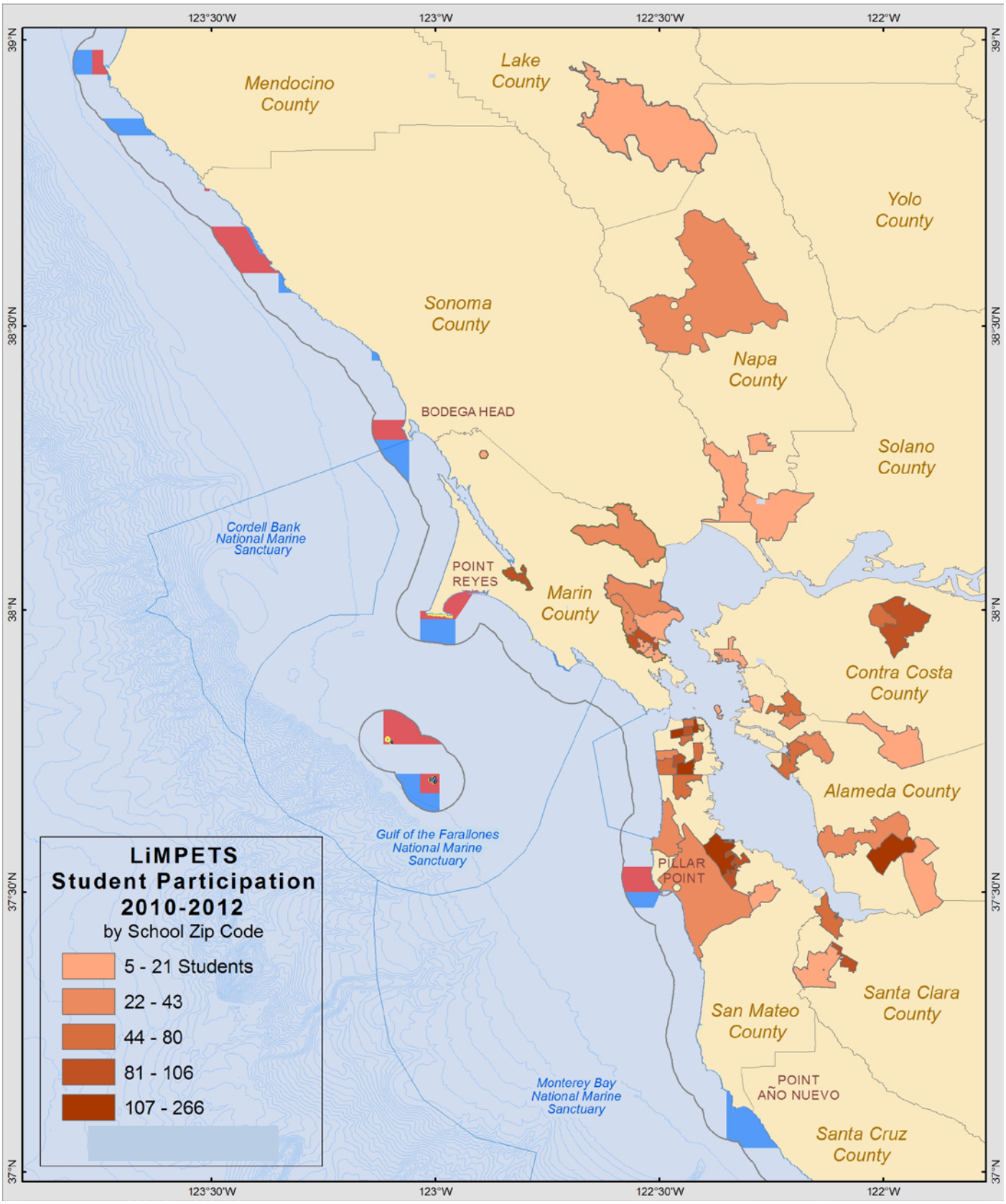
The basic required elements for *student*s include participation in 'standard' classroom trainings, field-based monitoring activities and online data entry. Although students are not required to conduct data analysis and interpretation activities, most teachers require their students to conduct some level of interpretation. An optional 'upper tier' of engagement is currently being piloted that allows students to ask questions of the data set, analyze and interpret data to address their questions, and communicate their findings to both the scientific and public communities through posters, blogs, film and other media. The student '*Field Blog'* is currently featured on the LiMPETS website.

During the NCC Baseline MPA project period, LiMPETS engaged students from diverse geographic and socioeconomic backgrounds in MPA baseline monitoring. A total of 60 schools and 3300 students were engaged in the project between 2010 and 2012. Participating students came from schools located in geographically diverse areas of the San Francisco Bay region, ranging from urban San Francisco and Alameda counties to rural Lake County (Figure 22). Most (85%) participating schools

however were concentrated in four counties that immediately surround the San Francisco Bay: Marin, San Francisco, Alameda and San Mateo. Though the socioeconomic diversity of participants is more difficult to assess than geographic scope, a majority (> 50%) of the student populations from 12 of the 60 schools that participated in MPA baseline monitoring were classified as "socioeconomically disadvantaged" (percentages gathered from annual SARC reports).

Continued assessments of the impact of LiMPETS on students (funded by NOAA's Bay Watershed Education and Training Program, the Packard Foundation and others) reveal that the sustained, in-depth nature of the program impacts the youth in our communities in a variety of positive, lasting ways. Short-term and longitudinal survey data show that after participation in LiMPETS, students demonstrate an increased understanding of the scientific process, an increased ability to think critically and analyze data, and an increased awareness of ocean conservation issues and MPAs. Students also report that they are more interested in science and/or science as a career after participating in LiMPETS. Finally, students indicate that their concern over protecting the ocean has grown or continues as an important belief because of their participation in LiMPETS.

Beyond these individual outcomes for students, engaging youth in the science of MPAs has a number of potential benefits. For the state, this includes broader support for MPAs and MPA implementation from a diverse young citizenry. For LiMPETS, benefits include increased relevance and credibility to our program. Students who engaged in MPA monitoring were motivated and empowered by the knowledge that their data was valued, was of immediate use, and would ultimately benefit the ocean conservation efforts of the state. Most importantly, one could argue, is the potential to begin to transform the collective values, knowledge, and interests of society (most importantly of our young citizenry) so that collaborative solutions to ocean-based problems can better be addressed now and in the critical years ahead.


123°30'W
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38°N
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37°N
Mendocino County
Lake County
Yolo County
Sonoma County
Napa County
Solano County
Marin County
Contra Costa County
Alameda County
Santa Clara County
San Mateo County
Santa Cruz County
BODEGA HEAD
POINT REYES
PILLAR POINT
POINT AÑO NUEVO
Cordell Bank National Marine Sanctuary
Gulf of the Farallones National Marine Sanctuary
Monterey Bay National Marine Sanctuary
LiMPETS
Student Participation
2010-2012
by School Zip Code
5 - 21 Students
22 - 43
44 - 80
81 - 106
107 - 266

Figure 22. Geographic scope of student participation (by school zip code) in LiMPETS and MPA monitoring, 2010-2012.

4.0 Discussion / Recommendations

Discussion

Description and analyses of the long-term LiMPETS sandy beach data set, 2001 - 2012, reveal a wide range of seasonal and interannual variation in *E. analoga* abundance across all LiMPETS sandy beach sites in the region. Variability is most extreme in the timing of large-scale recruitment events. Spring and summer of 2003 and 2010 were the only periods of large-scale recruitment observed within the North Central Coast MPA region. In contrast to these events, low abundance and/or the near disappearance of populations of *E. analoga,* at sites across the entire region, occurred between 2006 and 2009.

Analysis of these temporal variations in abundance and recruitment reveal that the Multivariate ENSO Index (MEI) does not predict abundance of *E. analoga* at Ocean Beach, the site with the most robust data set. Variation in abundance and recruitment may be better explained by factors operating on longer, decadal climatic scales (Menge et al, 2011), such as the Pacific Decadal Oscillation and the North Pacific Gyre Oscillation (Schultz et al., 2011), rather than the shorter 3-7 year ENSO time scale.

Description and analysis of the LiMPETS rocky intertidal data set, 2006 – 2012, reveal that short-term declines in the cover of fucoid algae (*Fucus gardneri*), sea star (*Pisaster ochraceous*) density, and purple sea urchin (*Strongylocentrotus purpuratus*) density are occurring within survey areas at rocky intertidal sites both inside and outside of MPAs. During the first three years of implementation, all species that were assessed for this report, fucoid algae (*Fucus gardneri*), mussels (*Mytilus californianus*), sea stars (*Pisaster ochraceous*), purple sea urchins (*Strongylocentrotus purpuratus*), and owl limpets (*Lottia gigantea*) experienced declines in density or cover – with the one exception of mussel cover at Montara SMR, which increased between 2010 and 2012. Owl limpets were larger and more abundant at Montara SMR than the unprotected site at Pigeon Point. Long-term protection of the intertidal at Montara SMR (as a no-take marine reserve since 1969) and regular enforcement by San Mateo County officials may be a primary reason for these differences between populations at the two sites.

Though long-term MPA protection may ultimately sustain rocky intertidal populations of some species such as owl limpets, it does not appear that the species analyzed for this report are responding quickly to MPA implementation. Indeed, most species have continued to decline within the MPAs for reasons that, most likely, are more complex than the illegal consumption of resources. A wide array of potential drivers/causes such as oceanic and climactic oscillations, predator/prey relationships, and human influences are possible.

Recommendations

- It is likely that high variability in *Emerita analoga* abundance throughout study region impacts beach ecosystems and communities, including communities inside of the NCC MPAs. Further inquiry into how these variations affect beach communities is needed to better understand the role of MPA implementation on the health of the region's beaches.
- Analysis of a wide array of potential driver/causes such as oceanic and climactic oscillations, predator/prey relationships, and human influences are outside of the scope of this report. But their influence over mole crab abundance and recruitment as well as rocky intertidal

population trends is clear. Collaboration, the establishment and maintenance of meaningful long-term data sets and further inquiry into the causes of these trends are recommended.

- Though the LiMPETS data set is somewhat limited and time scales are relatively short, the data and results described in this report reveal how MPA monitoring can benefit from the scientific data collected by young citizen scientist practitioners. Citizen science programs like LiMPETS have the potential to provide robust long-term MPA monitoring data that can support ocean policy and management. However, in order to do this effectively, citizen science programs need to develop strong partnerships with scientists so that, as a team, the partners can help to inform each other's work and engage in complementary MPA monitoring efforts.
- We support the objectives of the California Citizen Science Initiative and recommend that the California Ocean Science Trust continue to explore partnerships with citizen science programs to address the future long-term monitoring efforts of the state.

ACKNOWLEDGEMENTS

We gratefully acknowledge the valuable, enthusiastic contributions of LiMPETS partner organizations and citizens who volunteered their time for this project. Special thanks to Tim Reed of the Gulf of the Farallones National Marine Sanctuary for offering his expertise to help discuss, conceive of and create the many maps in this report. We thank California Sea Grant for funding this project and acknowledge the efforts of the collaborative partners, especially the California Ocean Science Trust and MPA Monitoring Enterprise, who continue to pursue the promising potential role of citizen science in MPA monitoring.

4.0 Appendix 16 – Rocky Intertidal Species List

Species / Group name:	Metric	LiMPETS survey method(s) used to monitor species/group
Feather boa kelp (holdfast) - *Egregia menziesii*	individuals per 0.25 m^2	vertical transect random quadrat
Sunburst anemone (>5cm) - *Anthopleura sola*	individuals per 0.25 m^2 individuals per 0.25 m^2 individuals per 10 m^2	vertical transect random quadrat total count in a permanent area
Giant green anemone - *Anthopleura xanthogrammica*	individuals per 0.25 m^2 individuals per 0.25 m^2 individuals per 10 m^2	vertical transect random quadrat total count in a permanent area
Unidentified large, solitary anemone - closed and covered with sand	individuals per 0.25 m^2 individuals per 0.25 m^2 individuals per 10 m^2	vertical transect random quadrat total count in a permanent area
Chitons - *Mopalia* spp./ *Nuttallina californica/Tonicella* spp./others	individuals per 0.25 m^2	vertical transect random quadrat
Whelks - *Acanthinucella* spp./ *Nucella* spp./*Ocinebrina* spp./others	individuals per 0.25 m^2	vertical transect random quadrat
Turban snails - *Chlorostoma brunnea/funebralis*	individuals per 0.25 m^2	vertical transect random quadrat
Hermit crabs - *Pagurus* spp.	individuals per 0.25 m^2	vertical transect random quadrat
Purple sea urchin - *Strongylocentrotus purpuratus*	percent cover %	vertical transect random quadrat
Green pin-cushion alga - *Cladophora columbiana*	percent cover %	vertical transect random quadrat
Dead man's fingers - *Codium fragile*	percent cover %	vertical transect random quadrat
Sea lettuces - *Ulva* spp.	percent cover %	vertical transect random quadrat
Surfgrasses (attached in square) - *Phyllospadix scouleri/torreyi*	percent cover %	vertical transect random quadrat
Flattened rockweeds - *Fucus gardneri/Hesperophycus californicus*	percent cover %	vertical transect random quadrat
Slender rockweeds - *Pelvetiopsis limitata/Silvetia compressa*	percent cover %	vertical transect random quadrat
Tar spot algae - *Mastocarpus* spp./*Ralfsia* spp./others	percent cover %	vertical transect random quadrat
Encrusting coralline algae (on rocks) - many species	percent cover %	vertical transect random quadrat
Upright coralline algae - *Bossiella* spp./ *Calliarthron* spp./*Corallina* spp.	percent cover %	vertical transect random quadrat
Scouring-pad alga - *Endocladia muricata*	percent cover %	vertical transect random quadrat
Stunted turkish towel - *Mastocarpus* spp./*Mazzaella affinis*	percent cover %	vertical transect random quadrat
Lawn alga - *Chondracanthus canaliculatus*	percent cover %	vertical transect

		random quadrat
Nori - *Porphyra* spp.	percent cover %	vertical transect random quadrat

Sea sacks - *Halosaccion glandiforme*	percent cover %	vertical transect random quadrat
Iridescent algae - *Mazzaella flaccida/splendens*	percent cover %	vertical transect random quadrat
Aggregating anemone (<5 cm) - *Anthopleura elegantissima*	percent cover %	vertical transect random quadrat
Nori - *Porphyra* spp.	percent cover %	vertical transect random quadrat
Honeycomb tube worm - *Phragmatopoma californica*	percent cover %	vertical transect random quadrat
Limpets - *Lottia* spp. (0.5 - 2.5 cm)	percent cover %	vertical transect random quadrat
Sea mussel - *Mytilus californianus*	percent cover %	vertical transect random quadrat
Leaf barnacle - *Pollicipes polymerus*	percent cover %	vertical transect random quadrat
Common acorn barnacles - *Balanus glandula/Chthamalus dalli/fissus*	percent cover %	vertical transect random quadrat
Pink acorn barnacle - *Tetraclita rubescens*	percent cover %	vertical transect random quadrat
Owl limpet – *Lottia gigantea*	individuals per 10 m^2	Size measurement in a permanent area

5.0 References

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