Sea star abundance from surveys along the Oregon and Northern California rocky intertidal coastline from 2000 to 2024

Website: https://www.bco-dmo.org/dataset/990963
Version: 1
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Project
» LTREB: Testing tipping points in a model rocky intertidal meta-ecosystem – Climate-change, increasing variances, and response mechanisms (LTREB Intertidal Tipping Points)

Contributors	Affiliation	Role
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Abstract
This dataset includes sea star abundance data collected as part of the study described below. See the "Related Datasets" section for size structure data. Mass mortality from disease epidemics can challenge the resistance and resilience of populations and communities. Assessing the impacts of such events and their consequences is crucially dependent on long-term datasets In 2013-16, sea star wasting disease (SSWD) caused population-wide crashes of the archetypal keystone species, the sea star Pisaster ochraceus, along the North American west coast. We used two long-term datasets to assess the resilience of Pisaster populations to this perturbation in Oregon: a 16-year time series (2007-2023) of annual predation rate at 7 sites, and a 23-year time series (2001-2024) of density and size of Pisaster at 8 sites. In spring 2015, a novel and massive Pisaster recruitment event occurred at all sites, averaging 3.00 ± 0.57 recruits m-2 (± SE), an 8,100% increase compared to pre-SSWD. Elevated but spatiotemporally variable recruitment has persisted over the subsequent decade. Before SSWD, population size structure was relatively stable, consisting mostly of large adults with virtually no recruitment. After the outbreak, density, average size, and biomass density declined at nearly all sites, while SSWD persisted at low levels, averaging ~4% symptomatic per year. As of the current period (2021-2024), density and biomass density had recovered at all sites and often overshot prior levels, but average body size recovered at only 3 of 7 sites. However, the 2014 crash and the post-2014 recruitment events apparently destabilized the populations; density remains more variable among years at all but two sites.

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Coverage

Location: Oregon and Northern California rocky intertidal coastline
Spatial Extent: **N**:45.02574539 **E**:-117.79941 **S**:33.54476929 **W**:-124.56512
Temporal Extent: 2000-07-05 - 2024-08-20

Dataset Description

This time series is part of the LTREB project listed on this page (Award DEB-2050017) and was supported by the prior awards listed in the “Awards” section on this page.

SSWD = Sea star wasting disease

Organism identifiers (Life Science Identifiers, LSIDs):
Pisaster ochraceus, urn:lsid:marinespecies.org:taxname:240755
Pisaster, urn:lsid:marinespecies.org:taxname:240754

Methods & Sampling

Our studies took place at eight sites along the Oregon coast spanning ~260 km from 44.5N to 42.75N latitude (Fig. 1, Table S1 of Gravem et al (2025)). All are predominantly rocky shores with relatively gentle slopes and have typical patterns of zonation, with a high-intertidal zone dominated by barnacles and fucoid algae, a mid-intertidal zone dominated by mussels, and a low-intertidal zone with a diverse assemblage of macrophytes and sessile invertebrates.

Belt Transects

Because of the importance of *Pisaster* in influencing community structure through its consumption of mussels and other prey, in 2000-2001 we initiated a program of ~twice-annual belt transects to quantify sea star size structure and density at each site. Surveys generally occurred in spring (April or May) and summer (July, August, or September), but in some years surveys were more or less frequent. Belt transects were replicated (n = 5) in 2 x 5 or 2 x 10 m rectangular areas (plots or belts) sampled below the bottom edge of mussel beds in the same location each year, with plot size enlarged to 2 x10m at years or sites when *Pisaster* abundance was low. Belt replicates were spaced throughout the defined study site to capture the density of *Pisaster* just below mussel beds. In each belt, researchers carefully searched for and collected all sea stars present and then wet weighed and measured arm lengths (madreporite to tip of opposite arm). Sea stars were often abundant, so when we reached the threshold of 200 animals in site and sample date, we finished that transect, then discontinued weighing and measuring in subsequent transects. Instead, we counted the remaining sea stars in these transects to capture densities. When sea stars were sparse, we surveyed additional transects (up to 10 total) to assess size structure of 200 animals where possible, but these additional transects were not used for density calculations since they were not replicated over time. After measurements, all sea stars were returned to their respective belt plots. Overall, we performed 440 surveys over 24 years at these 8 sites, which included 1,582 transects and measurements of 143,241 individual sea stars.

We calculated density as the count in each plot divided by plot area, which we calculated separately for each life stage for measured animals (see below). We calculated average size in each transect as the average wet weight. Since time constraints, the SSWD pandemic, or field scale failure sometimes forced us to measure only arm lengths but not weights, we developed an equation for estimating weights based on lengths as [wet weight in grams = 0.417 * (arm length in cm)$^{2.574}$]. We calculated biomass density as the total weight of animals per meter^2 in each transect. This is a potentially more accurate measure of ecological importance since *Pisaster* can vary several orders of magnitude in size and since potential predation rates and top-down control of mussels can increase dramatically as sea stars grow.

Sea Star Wasting Surveys and Disease Phases

In 2014-2015, when the pandemic was at outbreak levels in Oregon, we quantified disease occurrence using frequent (biweekly to monthly) surveys at each site. For disease frequency surveys, we searched a large area (100s of m^2) within the study site for all sea stars. We recorded if the animal was apparently healthy or not, and if not, recorded the symptom(s), including lesions, deflation, arm loss, arm twisting, losing grip and disintegration. We calculated percent diseased as the percent of the total animals that exhibited any SSWD symptom. After 2015, disease occurrence mostly was quantified in the belt transects supplemented by periodic wider surveys as above. Since we had never observed a prior outbreak of SSWD nor instances of disease symptoms, we assumed pre-SSWD percent diseased was 0.

Using our disease frequency and demographic data, we divided the SSWD outbreak into 4 phases, with *Pre-SSWD* (or P*re-wasting*) as before 2014, *During outbreak* as 2014 when symptoms peaked, *Post-SSWD* (or *Post-wasting*) as 2015-2020 when small outbreaks continued to occur and adult populations were clearly still low, and *Current* as 2021-2024 when adult populations had begun to recover at several sites (though small outbreaks continued to occur).

Categorization of Life Stages

We categorized different life stages of *Pisaster* into recruits (which we sometimes split into young-of-year recruits and older recruits), juveniles, and adults. Post-larval individuals (several weeks or months old) were not targeted by our surveys. We defined 'young-of-year (YOY) recruits' ranging in size from 0.01 to 1 g wet weight and 3 to 14 mm arm length. We define older recruits as individuals of 1 to 5 g wet weight, ~1.4 to 2.6 cm in arm length, and based on our size structure histograms are ~2-3 years old. We defined juveniles as individuals 5 to 80 g and ~2.6 to 7.7 cm arm length (this corresponds to roughly 2-6 years old) and defined adults as >80g, and >7.7cm arm length.

Data Processing Description

See associated paper - Gravem and Menge 2025. Metapopulation-scale resilience to disease-induced mass mortality in a keystone predator: From stasis to instability. Ecosphere. 2025;16:e70426. DOI: 10.1002/ecs2.70426

BCO-DMO Processing Description

* Sheet BT_Density of submitted file "BCODMO_BTMasterAnnot_2000-2024_2025-03-06_SAG.xlsx" was imported into the BCO-DMO data system for this dataset. Values "NA" imported as missing data values. Table will appear as Data File: 990963_v1_belt-transect_density.csv (along with other download format options).

Missing Data Identifiers:

* In the BCO-DMO data system missing data identifiers are displayed according to the format of data you access. For example, in csv files it will be blank (null) values. In Matlab .mat files it will be NaN values. When viewing data online at BCO-DMO, the missing value will be shown as blank (null) values.

Supplemental Files:

* Validation Lists extracted from sheet ValidationList in BCODMO_BTMasterAnnot_2000-2024_2025-03-06_SAG.xlsx. Reformatted to not imply this is a table but rather unique lists of controlled vocabulary elements the study used.

* Table within BCODMO_SiteList_STARS_2023-04-11_SAG.xlsx added as supplemental file sitelist_stars.csv

Problem Description

None

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Related Publications

Gravem, S. A., & Menge, B. A. (2025). Metapopulation-scale resilience to disease-induced mass mortality in a keystone predator: From stasis to instability. Ecosphere, 16(10). Portico. https://doi.org/10.1002/ecs2.70426
Results

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Related Datasets

IsRelatedTo

Gravem, S., Menge, B. A. (2026) **Sea star size structure from surveys along the Oregon and Northern California rocky intertidal coastline from 2000 to 2024.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-01-30 http://lod.bco-dmo.org/id/dataset/990975 [view at BCO-DMO]
Relationship Description: Results from the same belt transects.

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Parameters

Parameter	Description	Units
TransectSurveyID	Unique identifier for each transect listing Site_Transect_Year_SurveySet. [Example: FC_BT2_2021_A].[DataType: Character]	unitless
SurveyID	Unique identifier for each survey listing Site_Year_SurveySet. [Example: FC_2021_A].[DataType: Character]	unitless
TransectID	Unique identifier for each transect location, irrespective of date, listing Site_Transect. [Example: FC_BT2].[DataType: Character]	unitless
GroupCode	Group that took and entered the data. [CON;LiMPETS;OSU;UCSB;UCSC].[DataType: Character]	unitless
Region	Geographic Regions: Oregon, NorCal, CenCal, SoCal. NorCal is PSG and south. CenCal is PPT and south, SoCal is ALEG and south.. [Oregon;NorCal;CenCal;SoCal].[DataType: Character]	unitless
Cape	Full cape name. Annotated using SiteList_STARS. [See sitelist_stars.csv].[DataType: Character]	unitless
CapeNum	Cape order from North to South. [See sitelist_stars.csv].[DataType: Number]	unitless

SiteCode_STARS	Abbreviation that denotes the site where the data was collected. Site codes are unique to specific locations along the coast. . [See sitelist_stars.csv].[DataType: Character]	unitless
Site	Full site name. Annotated using SiteList_STARS. [See sitelist_stars.csv].[DataType: Character]	unitless
SiteNum	Site order from North to South.. [See sitelist_stars.csv].[DataType: Number]	unitless
Latitude	Latitude of site.. [See sitelist_stars.csv].[DataType: Number]	decimal degrees
Longitude	Longitude of site. [See sitelist_stars.csv].[DataType: Number]	decimal degrees
SiteType	Type of Site for the STARS Project. Core or Ancillary. [Core;Ancillary].[DataType: Character]	unitless
Year	Year of Survey as a number. [Year].[DataType: Number]	unitless
AvgSurveyDate	Date. [Date].[DataType: POSIXct]	unitless
SurveyPeriod	The survey sets for a given site within a calendar year. Labeled as A, B, C etc. Often are spring and summer surveys labeled A and B, but some years have just one survey (A) and some have 3 (A,B,C) or 4 (A,B,C,D). [A, B, C, D].[DataType: Character]	unitless
Season	Season of the year according to the month: Months 12-2= WN, 3-5=SP, 6-8=SU, 9-11=FA. [SP, SU, FA, WN].[DataType: Character]	unitless
SeasonCode	Abbreviation that denotes season as well as year that the data was collected. Is written as abbreviation of season followed by YYYY. . [SP2021, FA2018, etc.].[DataType: Character]	unitless
YearOfSSWS	Year SSWS occurred. Usually 2013 in California and 2014 in Oregon. [See sitelist_stars.csv].[DataType: Number]	unitless
DateofSSWS	Date SSWS occurred in the region according to Gravem et al. 2020. . [DataType: POSIXct]	unitless
YrSinceSSWS	Years elapsed since SSWS. [Year- YearOfSSWS in number of years].[DataType: Number]	unitless
DiseasePhase3	Before, During or After Disease Outbreak. [DataType: Character]	unitless
DiseasePhase4	Pre, During Post, or Recovery Phase of Disease Outbreak. [DataType: Character]	unitless
Transect	Transect Number with 'BT' to indicate Belt Transect. Typically 5 per site. If extra transects of known area were done, they are entered as BT6, BT7, etc. If extra transects were done of unknown area, named BTN and surface area is entered as ND. [BT1, BT2...BT8, BTN].[DataType: Character]	unitless
TransectArea_m2	Area searched in meters squared. Usually 10, indicating 5 x 2 m transect. [DataType: Number]	meters squared (m2)

SpeciesCode	A 6 digit code for the species. Usually PISOCH or LEPSPP. [ACASPP;CONCAL;LEPSPP;NONE;NUCCAN;NUCEMA;NUCLAM;NUCLIM;NUCOST;OCESPP;PISOCH]. [DataType: Character]	unitless
Tot_Indivs	The number of animals in a given transect, species and survey. [DataType: Number]	count
Tot_Biomass_g	Total biomass of seastars in the transect, in grams. [DataType: Number]	grams (g)
Density_m2	Density of seastars in individuals per m2 in the transect. [DataType: Number]	individuals per meter squared (#/m2)
Biomass_g_m2	Biomass density of seastars in grams per m2 in the transect. [DataType: Number]	grams per meter squared (g/m2)

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Project Information

LTREB: Testing tipping points in a model rocky intertidal meta-ecosystem – Climate-change, increasing variances, and response mechanisms (LTREB Intertidal Tipping Points)

Coverage: West coast of North America

NSF abstract:

In recent decades, ocean ecosystems, long thought to be immune to change, have undergone disruptions to their structure, diversity, and geographic range, yet the actual underlying reasons for such changes in oceanic biota are often unclear. Coastal intertidal zones (i.e., the shore between high and low tides) have long served as important ecological model systems because of advantages in accessibility and ease of observation, occupancy by easily studied and manipulated organisms of relatively short lifespans, and exposure to often severe environmental conditions. This research will address the stability of a well-known rocky shore system along the Oregon and California coasts. Prior long-term research indicates that, although casual observation suggests these systems are stable, in fact, they may be on the cusp of shifting into another state, losing iconic organisms like mussels and sea stars, and becoming dominated by seaweeds. These changes might be comparable to losing trees and large predators from terrestrial systems. This study would result in the training of undergraduates and graduate students, including individuals from under-represented groups. Additionally, this study would include outreach to the general public.

The researchers will focus particularly on impacts of increasing and more variable warming on community recovery. For example, climate oscillations (e.g., El Niño), coastal upwelling, and particularly temperature have all changed in recent decades in ways leading to increased stress on intertidal biota. In apparent response, coastal ecosystems evidently have become less productive, organismal performance (growth, reproduction) has declined, and key dynamical processes (species interactions) have weakened. The new research will pursue these strong hints of an impending “tipping point” by (1) continuing the projects that led to the insights of increasing instability, (2) adding new projects that will pinpoint ecological changes, and (3) expanding the region of work to include locations in California. Research will assess whether or not sea stars recover from wasting disease, experimentally test if species interactions are indeed weakening, quantify the annual inputs of new prey and changes in abundance, diversity, stability, and resilience of intertidal communities, and document changes in the physical environment. Using field observations and experiments, the research will provide insight into impacts of environmental change, particularly warming, on the future of coastal ecosystems, and more generally, into possible future states of Earth’s ecosystems. Using these data, we will test the hypothesis that direct and indirect effects of climate change are driving, or may drive these systems into new, alternative states.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1061233
NSF Division of Ocean Sciences (NSF OCE)	OCE-0726983
NSF Division of Ocean Sciences (NSF OCE)	OCE-1448913
NSF Division of Environmental Biology (NSF DEB)	DEB-2050017
NSF Division of Environmental Biology (NSF DEB)	DEB-1554702
NSF Division of Environmental Biology (NSF DEB)	DEB-1050694

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