Electronic Supplementary Material

Material and Methods

Tomašových A., Kidwell S.M.: Nineteenth-century collapse of a benthic marine ecosystem on the open continental shelf

1. Living and death assemblage compositions

The compositions of living and death assemblages are compared on the basis of species abundances (with only a few taxa determined only to genus level, such as *Modiolus* sp.) and abundances of functional guilds (trophic and life-position characters). Species abundances in living assemblages correspond to summed time series generated by annual monitoring by wastewater agencies of benthic communities in far-field reference areas that have the same spatial coordinates as the samples used to estimate the age-frequency distributions of dead shells: these sites are Short Bank in Santa Monica Bay (Edwards et al.

2003) sampled by the City of Los Angeles and the western and eastern parts of the Palos Verdes shelf sampled by the Los Angeles County Sanitation District. In Santa Monica Bay, data on living assemblages were pooled from five-closely spaced stations sampled between 1987 and 1991 and between 2000 and 2014 in 59-70 m water depth (stations C6, C7, C8, D1, and Z2 of the City of Los Angeles, Environmental Monitoring Division). Data on SMB death assemblages are based on shelly remains sieved from samples collected from these five stations in 2012 and 2014. Sieve residues at these stations are muddy sands with gravel and dispersed shells. Data on living assemblages from the Palos Verdes shelf reflect summed abundances from station 0C close to Redondo Canyon (western PV shelf) and from station 10C close to the San Pedro Sea Valley (eastern PV shelf), both collected in 61 m water depth between 1972 and 2009 by Los Angeles County Sanitation Districts, Treatment Plant Monitoring Group. Data on WPV and EPV death assemblages are based on shelly remains sieved from samples collected from these stations in 2010 and 2012. Death assemblages are dominated by brachiopod valves at station 0C and by scallops at station 10C. Death assemblages were sieved with a 1 mm mesh size and the number of individuals of a given species or a guild corresponds to the total number of valves with a hinge line or umbo preserved (i.e., maximum number of individuals approach, Gilinsky and Bennington 1994).

Total abundances of bivalves and rhynchonelliformean brachiopods were transformed to proportional abundances. Bivalve species were assigned to nine functional guilds, using the information about the feeding from Word (1979), Jones and Thompson (1986), and Macdonald et al. (2016) to supplement general information in Todd (2000). Infaunal bivalve guilds are: carnivorous (septibranchs), chemosymbiotic (lucinids, solemyids, thyasirids), commensal (mostly lasaeids, in the burrows of other infaunal organisms), facultative deposit-feeding (mixed deposit- and suspension-feeding; e.g., tellinids), and obligate deposit-feeding (both nonsiphonate and siphonate; e.g., *Nuculana*, *Macoma*). There are two guilds of suspension-feeding bivalves: epifaunal suspension-feeding (individuals typically attached only as juveniles; e.g. large-bodied scallops *Chlamys* and *Leopecten*, small kelp-scallop *Leptopecten*), infaunal suspension-feeding bivalves (e.g., venerids, cardiids), and rock-boring bivalves. Attached epifaunal suspension-feeding brachiopods (*Laqueus* and *Dallinella*) constitute a tenth guild.

The spatial distributions of living brachiopods (*Laqueus erythraeus*) and scallops (*Chlamys hastata* and *Leopecten diegensis*) on the mainland shelf (Fig. 1 main text) are based on living assemblages from 2,419 grabs, dredges and trawls collected in the Southern California Bight since 1956. Grab samples include time series generated since 1990 for Santa

Monica Bay (City of Los Angeles, Dorsey et al. 1995), since 1972 for the Palos Verdes shelf (Los Angeles County Sanitation Distrits, Ferraro et al. 1991; Stull et al. 1986; Stull 1995; LACSD 2014), and since 1984 for the San Pedro shelf (Orange County Sanitation District, Diener et al. 1995), and samples collected in 2003 and 2004 by San Diego Sanitation District at Point Loma and South Bay outfalls (City of San Diego 2004a, b). Grab and trawl samples with living assemblages were collected during Bight-wide spatial surveys performed in 1956-1959 (mostly Orange Peel buckets, Jones 1969), 1975-1976 (BLM survey), 1977 (60-m control survey), 1985, 1990, 1994, 1998 (Smith et al. 2001), 2003, and 2008. These datasets create our reference for the spatial distribution of brachiopods and scallops in the Southern California Bight in the second half of the 20th century. Occurrence data for these species in death assemblages displayed on the same maps in Fig. 1 are based on 463 grab samples collected in 1975-1976 (BLM survey), 2003-2004 (surveys at Point Loma and South Bay outfalls), 2008-2013 (surveys at Los Angeles County Sanitation Districts), 2012-2014 (surveys at City of Los Angeles), 2003 (surveys at Orange County Sanitation District), 2003, 2008, and 2013 (Bight-wide surveys).

The bathymetric distributions of living and dead brachiopods (*Laqueus erythraeus*) on mainland and island shelves are based on the same samples and supplemented with information from bottom photographs collected between Malibu (34.05º N) and the southernmost limit of the San Pedro Shelf (33.55º N; Fig 1) (Edwards et al. 2003; Wong et al. 2012). The number of occurrences with living *Chlamys* and *Leopecten* is extremely small and does not allow us to assess their bathymetric range sizes. All occurrence data of these three species are available at Data Dryad: http://dx.doi.org/10.5061/dryad.0r76j.

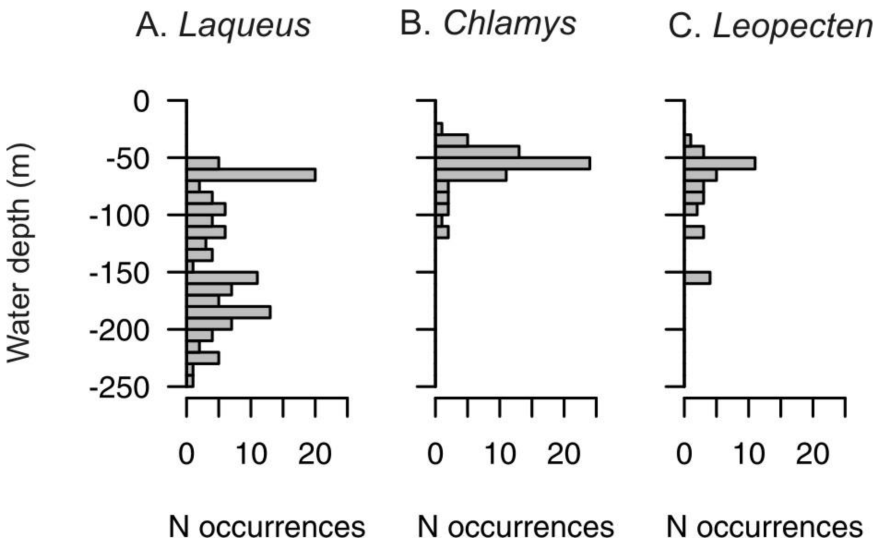


Figure S1 – A-C. Bathymetric distribution of samples containing dead shells of epifaunal suspension-feeding shell-gravel fauna on the mainland shelf of the Southern California Bight, showing broader and generally deeper-water occurences of the brachiopod *Laqueus erythraeus* (A) relative to the scallops *Chlamys hastata* (B) and *Leopecten diegensis* (C).

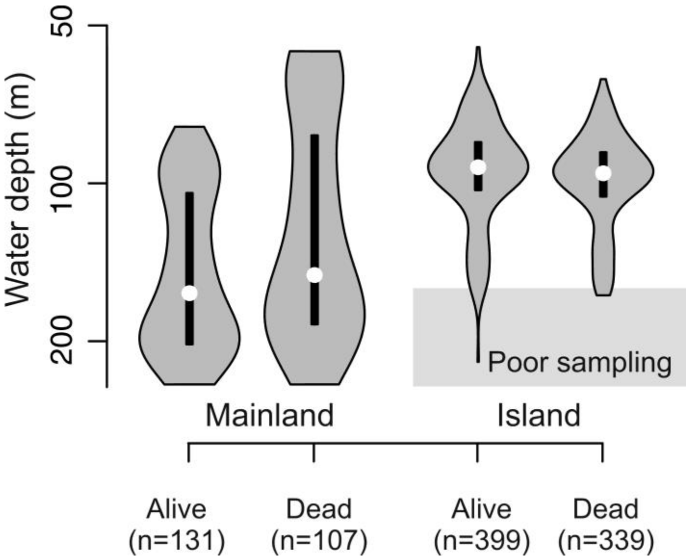


Figure S2 – Violin plots that combine boxplots with a kernel density plot show that living shells of *Laqueus* on the mainland shelf of the Southern California Bight do not occur at depths shallower than 87 m, whereas dead shells of *Laqueus* are frequent between 50-90 m. On island shelves, living *Laqueus* is abundant in depths as shallow as 50 m. The white circles correspond to median water depth and black vertical bars represent inter-quartile depth range defined by the 25th and 75th percentiles (Hintze and Nelson 1998).

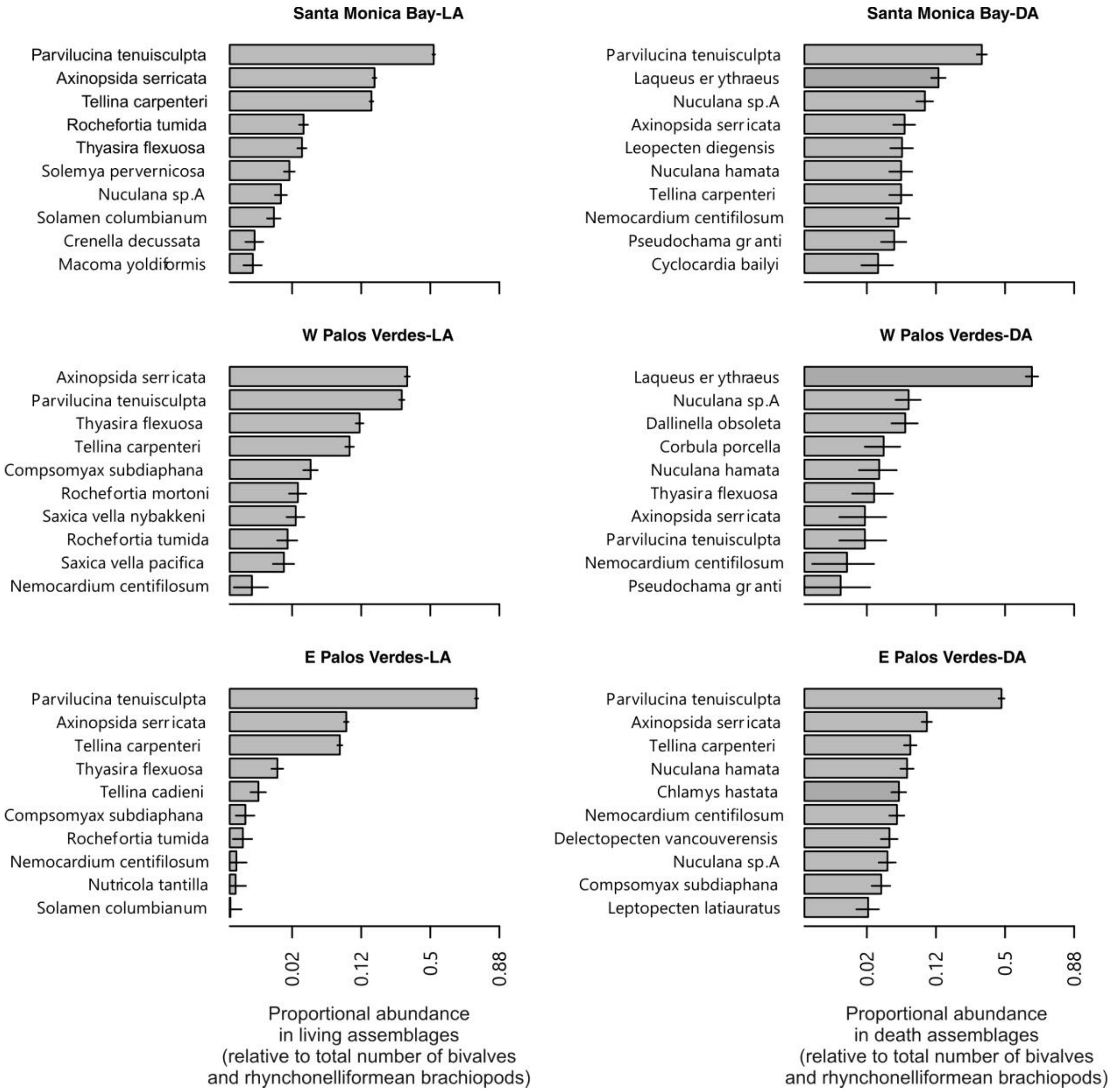


Figure S3 - Proportional abundances of the ten most common species in living (LA) and death assemblages (DA) from three primary study areas. The brachiopod *Laqueus erythraeus*, which is completely absent in these living assemblages, is the 2nd, 1st, and 15th most common species in counterpart death assemblages (does not appear in bottom graph). The scallop *Chlamys hastata*, also absent in living assemblages, is the 5th most abundant species in the death assemblage on the eastern Palos Verde shelf. SMB death assemblages are dominated by *P. tenuisculpta* (34%), but the brachiopod *L. erythraeus* is the second most species (13%), the scallop *Leopecten diegensis* is the fifth most common species (5%), and the scallop *C. hastata* is also present (2%). WPV death assemblages are dominated by the brachiopods *L. erythraeus* (69%) and *Dallinella obsoleta* (5%); *C. hastata* is rare (<1%). EVP death assemblages are dominated by *P. tenuisculpta* (47%) and *A. serricata* (10%); *C. hastata* is common (4%), and *L. erythareus* is also present (1%).

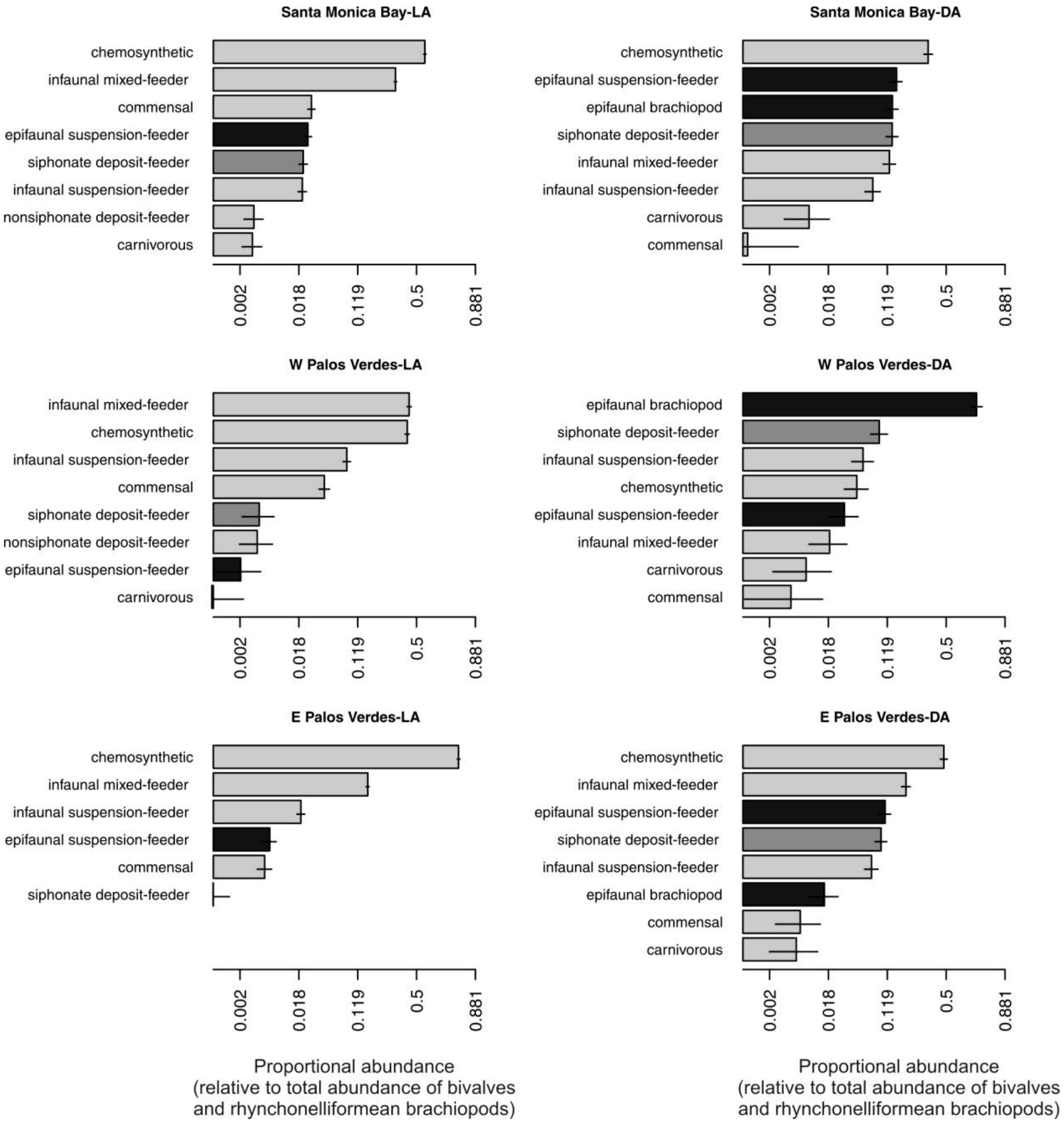


Figure S4 - Proportional abundances of guilds (functional groups) show a significant increase in proportional abundance of epifaunal suspension-feeding bivalves and brachiopods (black bars) in death assemblages (DA, in the right columns) relative to their abundance in living assemblages (LA, left columns). Proportional abundances of siphonate deposit-feeders (Nuculanidae, dark gray bars) are also higher in death assemblages.

2. Materials for age-frequency distribution

To establish the frequency distribution of shell postmortem ages (elapsed time since death) for the brachiopod *Laqueus erythraeus*, we used shells sieved from Van Veen grab samples (top ~10-15 cm of seabed) collected during macrobenthic surveys of three parts of the mainland shelf of the Southern California Bight. These areas are: (1) Santa Monica Bay (SMB): 31 shells (22 ventral valves and 9 dorsal valves) from station AHF24205 sampled in 1975 as part of the BLM survey, in 81 m water depth on Short Bank (118.55ºW, 33.85ºN); (2) Western Palos Verdes shelf (WPV): 99 shells from two closely-spaced sites (station 4134 in the Bight 2003 survey at 61 m with 18 dorsal valves and 21 ventral valves, 118.427ºW, 33.8198ºN, and station 0C in the LACSD 2008 survey at 78 m with 60 ventral valves, 118.4305ºW, 33.8072ºN); (3) Eastern Palos Verdes shelf (EPV): 60 shells (29 dorsal valves and 31 ventral valves) from 10C station in the LACSD 2008 and 2009 surveys (two grabs) at 61 m water depth (118.2968ºW, 33.685ºN). Regional age-frequency distribution (pooling three areas) is thus based on five Van Veen grabs. With the exception of the station 0C where ventral valves were dated only, most valves that were identifiable and larger than 5 mm found at other stations were dated.

3. Calibration of shell ages

To determine shell ages, small chips of shell from the anterior (ontogenetically oldest) portions of valves were removed from 196 specimens of *Laqueus*. The extent of amino acid racemization (AAR) in these fragments was analyzed at Northern Arizona University using reverse-phase high-pressure liquid chromatography (RP-HPLC) following the procedures of Kaufman and Manley (1998). Specimens were leached 20% by weight with a dilute solution of HCl. The fragments were dissolved in 7M HCl and the resulting solutions were hydrolysed at 110°C for 6 hours to release amino acids from their peptide chains and to recover the total hydrolysable amino acid population. Concentrations and D/L values of four amino acids were measured for each shell: aspartic acid (Asp), glutamic acid (Glu), serine (Ser), alanine (Ala). Asp and Glu were used in age calibrations because they tend to have the highest reproducibility (Kaufman and Manley 1998). We use four screening criteria to detect aberrant specimens (Kosnik and Kaufman 2008), including relation between (1) serine concentrations (standardized by the concentration of Glu and aspartic acid D/L^e, (2) serine concentration (standardized by the concentration of Asp) and glutamic acid D/L^e, (3) total concentrations of aspartic acid and glutamic acid, and (4) aspartic acid D/L^e and glutamic acid D/L, where *e* is an exponent that linearizes the bivariate relationship. Six shells were flagged as outliers and were removed from analyses.

To calibrate AAR data, one live-collected specimen of *Laqueus* collected in 1994 was used to establish baseline ratios, and eleven of the 196 dead shells were subjected to AMS radiocarbon dating (Table S1). The dead shells were drawn from all three sites, collected between 1975 and 2009, and dated in 2013 at the Poznan Radiocarbon Laboratory. To avoid contamination, 30% of the outer shell mass was removed prior to AMS analysis in an ultrasonic bath and in 0.5M HCl, and then treated in 15% H_2O_2 again (for 10 min in an ultrasonic bath). The remaining carbonate was dissolved with concentrated H_3PO_4 in a vacuum line. ^{14}C was measured with a "Compact Carbon AMS" (Goslar et al. 2004). Conventional ^{14}C ages were calculated using correction for isotopic fractionation (Stuiver and Polach 1977), on the basis of ratio $^{13}C/^{12}C$ measured in the AMS spectrometer simultaneously with the ratio $^{14}C/^{12}C$. Radiocarbon ages were converted to calendar years using Calib6.0 (Stuiver and Reimer 1993) and the Marine13 data (Reimer et al. 2013). A variable regional marine reservoir correction (ΔR) was applied according to Hendy et al. (2013). ΔR for shells with ^{14}C age located outside of the interval calibrated by Hendy et al. (2013) was set to ΔR = 263 years (sd = 96 years), i.e., average value based on shells collected in the 20th century (Hendy et al. 2013). The reported calendar ^{14}C age is the median of the age probability function, with the two sigma age range (Table S1).

These 12 specimens were used to calibrate the rate of AAR applying Bayesian model-fitting procedures described by Allen et al. (2013). Asp and Glu D/L values were fit using four mathematical functions to model the relation between age and D/L values, with and without fitting a non-zero initial D/L, and two uncertainty models (lognormal and gamma) using R language (R Development Core Team 2013). The combination of two amino acids, two uncertainty models, four functions, and two intercepts gives 32 different age models.

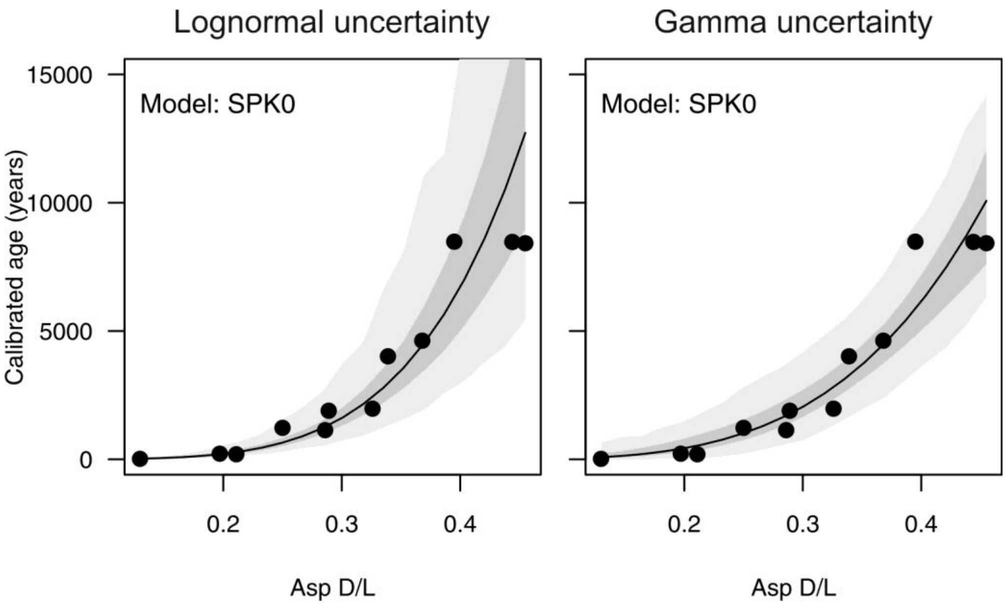
The reported final age corresponds to the median age based on posterior distribution of ages predicted by calibration models (that differ in kinetics, uncertainty structure, and amino acids) weighted by evidence supporting each model (Table S2). We found that the model with simple power-law kinetics with the initial D/L value fixed to zero (SPK0) and a lognormal uncertainty for Asp (with parameters equal to log(a) = 13.363; log(b) = 1.603 and variance = 0.101) has the smallest Bayesian Information Criterion (BIS) and thus strongest support (Fig. S6). Calibrated ages are reported relative to the year 2013, i.e., the time of dating. They are adjusted relative to the year of their collection in calculations of loss rates only. Subtracting the mean of IQRs (estimated for each shell separately) expected with calibration uncertainty (or 95% ranges) from the raw whole-assemblage IQR (or 95% range) generates an estimate of time averaging corrected for calibration error (Dominguez et al. 2016). When sampling shell-ages from a lognormal distribution (with its mean determined by the log-transformed age of a given shell, and its standard deviation corresponding to the square root of log-transformed variance obtained from the best calibration model, i.e., SPK0), we use an upper truncation limit of 12,000 years when sea level at present-day water depths of ~80 m reached zero meters.

4. Inferring production history

To estimate the effects of AMS-AAR calibration uncertainty on the robustness of the AFD shape (Fig. 3 in main text) and mode (Fig. S7A), we resample individual shell ages from the distribution of ages expected under calibration uncertainty (as in Yanes et al. 2007), and compute the 2.5th and 97.5th percentile of the mode. As mentioned above, we use a lognormal distribution as the best calibration distribution, with its mean determined by the log-transformed age of a given shell, and its standard deviation corresponding to the square root of log-transformed variance. With this approach, the observed mode of the distribution (and thus the last peak in production) falls within the 19th century.

To restore original production levels from the observed AFD, we first quantify rates and age-dependency of shell loss rates from the surface mixed layer (where loss is via either disintegration or burial below the mixed layer) to factor out their effects from those of variation in production on the shape of the AFD. We find that a two-phase exponential model of skeletal loss (Tomašových et al. 2014) with variable production (Tomašových et al. 2016) outperforms a one-phase exponential model, assuming that production has a sudden onset (minimum age ~100 years) and a sudden termination (maximum age ~12,000 years) in production (when the water depth was too shallow). The AIC after corrected for a small sample size (AICc) is equal to 3083 for a one-phase model ($\lambda = 0.0008$; no change in loss rate over time per cohort), whereas it is equal to 3008 for the two-phase model ($\lambda_1 = 0.006$; $\tau = 0.0003$; $\lambda_2 = 0.0005$; rate of loss declines abruptly over time). Therefore, these estimates of loss rate of skeletal remains from the surface mixed layers, derived from the two-phase model, are used rather than a single, constant rate of loss as determined by one-phase exponential model. The loss rates estimated with this approach are then used to estimate the survival function (equation 14 in Tomašových et al. 2016), which allows us to explicitly reconstruct the mode of the production trajectory (last time of full shell production) and its recent decline (dividing the preserved distribution by the survival function, Fig. 4A in main text). The parameters of the two-phase model are robust to fluctuations in production whose periods are shorter than the time scales of shell loss (Tomašových et al. 2016). Contrary to Tomašových et al. (2017), we do not account for the difference between the number of dated specimens and the total number of specimens in the assemblage because most dead valves found in five Van Veen grabs that were both identifiable and larger than 5 mm were dated. Loss rates effectively reflect the loss of disarticulated valves rather than the loss of whole shells (i.e., two valves) because all specimens here that were dated were disarticulated. Therefore, the number of preserved specimens predicted on the basis of the two-phase model is halved when converting this number to density of individuals, making this a conservative estimate of density (assuming that both valves of every dead individual are present). Assuming that the typical maximum lifespan of *Laqueus* is 12 years (Buening and Spero 1996), then the expected living yearly density of living individuals of *Laqueus* per 0.5 m^2 (area sampled by five Van Veen grabs) at past times of maximum production was ~10 (thus ~20 individuals/ m^2, text Fig. 4).

We estimate the mode of the shell-age frequency distribution using the half-sample method developed by Bickel and Fruhwirth (2006). The reconstructed trajectory in production (obtained by dividing the preserved distribution by the survival function of the two-phase exponential model) explicitly shows that the offset between the observed mode of the AFD (~1850 AD) and the timing of the last interval of maximum production is ~25 years, that is the true last peak in production was ~1825 AD. The upper [described as upper in text] 95% confidence interval on the timing of this true mode is in ~1870 AD (Fig. S7B).


Lognormal uncertainty

Gamma uncertainty

Figure S5 – The relationship between postmortem calendar age (estimated by AMS) and the D/L values of Aspartic acid of the brachiopod *Laqueus erythraeus* are best-fit by the simple power-law kinetic model (SPK0). The two graphs show the fit modeled with lognormal (left plot) and gamma (right plot) uncertainty, with 95% confidence (dark bands) and 95% prediction intervals (light grey bands).

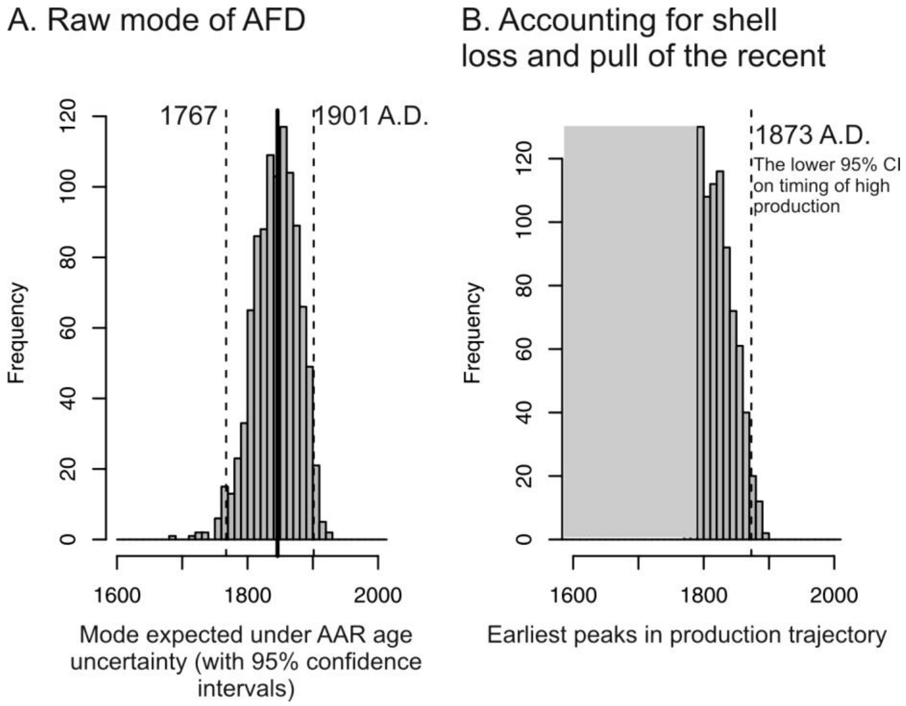


Figure S6 – A: The resampled distribution of the mode of the age-frequency distribution (full distribution shown in Text-figure 3D and gray line in Text-figure 4A) that is expected given the uncertainty of the AAR-AMS calibration (dashed lines represent lower and upper 95% confidence intervals), showing that the observed (raw) mode of the distribution falls within the 19th century. Note that younger shells are to the right along the x-axis, which is in calendar years AD. B: Estimate of the youngest time (lower 95% confidence interval) when *Laqueus* might have still had high population sizes, based on the reconstructed trajectory of production (black line in Text-figure 4A) that takes shell loss into account.

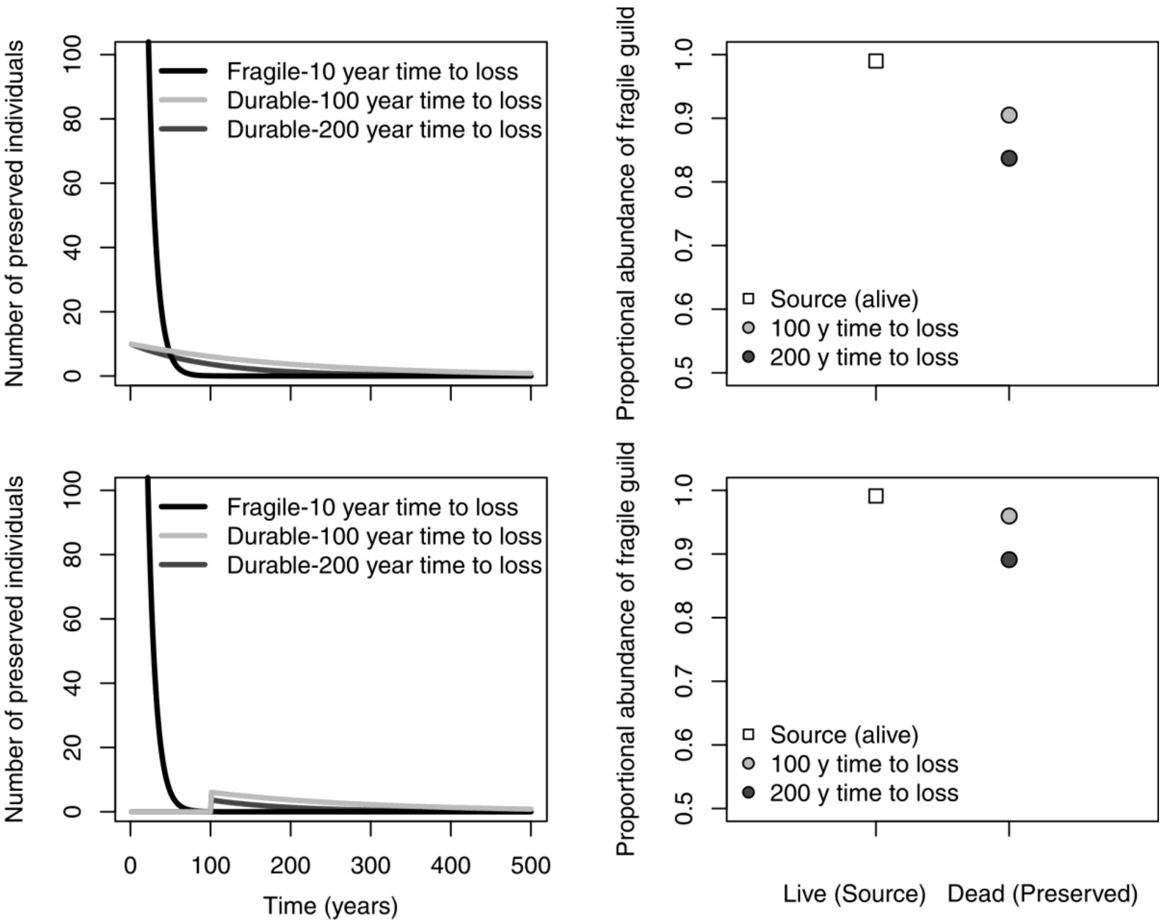


Figure S7 – The effect of the higher durability of calcitic epifaunal suspension-feeders (brachiopods and scallops, mean time to loss = 100 years) relative to that of small-sized aragonitic infaunal bivalves (mean time to loss = 10 years) on the proportions of these two guilds in death assemblages. We assume that the calcitic guild produces only 1% of all shells by the source community, that is, their living populations have always been small (white squares in right plots). *Top row:* Under temporally-constant production of both guilds (with an annual abundance of 990 living individuals in the aragonitic guild and 10 living individuals in the calcitic guild), the proportion of aragonitic shells in the death assemblage is still expected to be >90% (gray circle), despite the 10-fold preservational advantage of the calcitic shells. *Bottom row:* The proportion of the aragonitic shells should be >95% when the calcitic guild is absent from the living assemblage over the last 100 years (gray circle). Black circles show the small effect on proportional abundances if the calcitic epifauna had an even higher durability than we have modeled (mean time to disintegration = 200 years rather than 100 years). The preservational advantage of calcitic shells is thus not sufficient to make them dominate a death assemblage (such as observed in our samples) if their abundance in the source living community has always been low. Their observed high abundance as dead shells must reflect some higher abundance in the past than they have now.

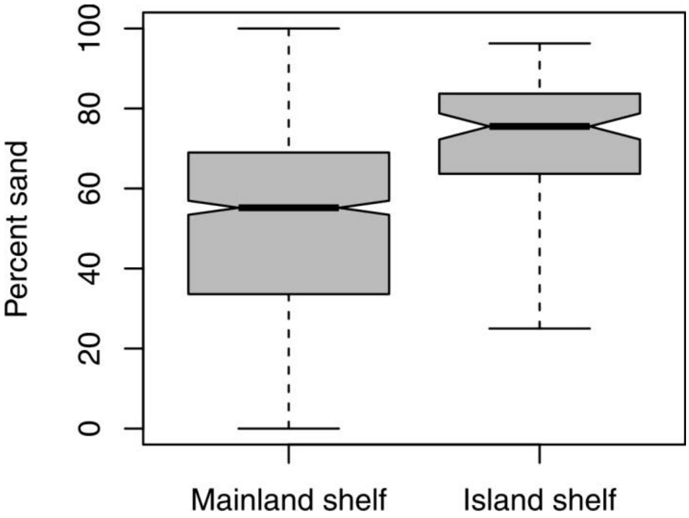


Figure S8 – The percent sand is higher on the island shelves than on the mainland shelves of the Southern California Bight at water depths exceeding 35 m. The grain-size data are based on Bight surveys 1994, 1998, 2003, and 2008 (Bergen et al. 1998; Ranasinghe et al. 2003, 2007, 2012).

Table S1 - Geographic coordinates, water depth (m), radiocarbon and calibrated ages, and D/L of Aspartic and Glutamic acids of the eleven specimens of *Laqueus erythraeus* used to calibrate the rate of amino acid racemization, plus information on one live-collected specimen.

Survey-station	Specimen ID	Poznan ID	Conventional 14C age	Conventional 14C age error (2 s.d.)	delta R	Calibrated year (median probability) BC/AD	Lower 95% conf. bound on calibrated year BC/AD	Upper 95% conf. bound on calibrated year BC/AD	Sampling year	Water depth (m)	Latitude	Longitude	Asp D/L	Glu D/L
LACSD survey-0C	LE0C-06	Poz-51470	855	49	347	1817	1704	1910	2006	61	33.8072	-118.4305	0.211	0.084
LACSD survey-0C	LE0C-49	Poz-51472	875	49	347	1793	1686	1907	2006	61	33.8072	-118.4305	0.197	0.075
LACSD survey-0C	LE0C-55	Poz-51473	2400	49	102	39	-102	164	2006	61	33.8072	-118.4305	0.326	0.122
LACSD survey-0C	LE0C-56	Poz-51475	1710	49	191	876	758	1003	2006	61	33.8072	-118.4305	0.286	0.095
LACSD survey-0C	LE0C-59	Poz-51476	1775	49	174	786	682	904	2006	61	33.8072	-118.4305	0.250	0.093
BLM survey-24205	LE24205-14	Poz-51477	2315	49	86.7	120	-4	251	1975	81	33.8500	-118.5500	0.289	0.106
BLM survey-24205	LE24205-23	Poz-51479	8160	63	263	-6410	-6551	-6257	1975	81	33.8500	-118.5500	0.455	0.179
BLM survey-24205	LE24205-27	Poz-51480	8220	63	263	-6469	-6609	-6352	1975	81	33.8500	-118.5500	0.395	0.152
BLM survey-24205	LE24205-29	Poz-51481	8210	63	263	-6459	-6602	-6339	1975	81	33.8500	-118.5500	0.444	0.177
Bight survey 2003-4134	LE4134-11	Poz-59172	4665	49	263	-2610	-2775	-2463	2003	78	33.8198	-118.4270	0.368	0.126
Bight survey 2003-4134	LE4134-6	Poz-59173	4220	49	263	-2001	-2149	-1864	2003	78	33.8198	-118.4270	0.339	0.126
Bight survey 1994-1476	LE1476-1	Live collected	NA	NA	NA	1994	1994	1994	1994	116	33.5651	-118.1463	0.130	0.054

Table S2 – Calibration statistics for the rate of amino acid racemization (AAR) based on paired AAR and radiometric analyses of *Laqueus erythraeus* and two models of uncertainty. Models with BIC values less than 6 units relative to the model with minimum BIC are shown. Explanations: k = number of parameters; SPK = simple power-law kinetics; TDK = time-dependent reaction kinetics; 0 = the initial D/L value is fixed at zero; 1 = the initial D/L value is estimated from data.

Amino acid	Model	ln(a)	ln(b)	c	ln(R0)	ln(d)	BIC	ΔBIC
Gamma uncertainty								
Asp	SPK0	12.23	1.34	NA	NA	5.32	190.52	0.00
Asp	TDK0	11.72	1.26	NA	NA	5.43	191.28	0.76
Asp	TDK1	11.63	1.05	-0.04	-2.77	5.29	192.99	2.47
Asp	SPK1	12.26	1.35	-38.70	-755.42	5.38	193.00	2.48
Glu	APK1	13.17	NA	0.90	-3.13	5.66	193.67	3.15
Asp	APK1	11.18	NA	1.10	-2.19	5.73	195.32	4.80
Glu	SPK0	14.95	1.20	NA	NA	5.88	195.70	5.18
Glu	TDK0	14.90	1.20	NA	NA	5.88	195.83	5.31
Glu	TDK1	13.64	0.82	0.50	-3.29	5.59	196.12	5.60
Asp	CPK1	5.57	1.33	1.15	-2.18	5.67	196.19	5.67
Asp	CPK0	4.75	1.53	NA	NA	5.94	196.58	6.06
Lognormal uncertainty								
Asp	SPK0	13.36	1.60	NA	NA	-2.29	187.68	0.00
Asp	TDK1	12.11	1.17	0.15	-2.62	-2.48	187.70	0.02
Asp	SPK1	12.89	1.51	1.08	-2.19	-2.17	188.65	0.97
Asp	TDK0	12.87	1.55	NA	NA	-2.18	189.38	1.69
Asp	CPK1	4.04	1.72	1.57	-2.10	-2.09	193.45	5.77

5. History of land use (livestock grazing and cultivation)

Many historical accounts provide a basic narrative of land use in the Los Angeles coastal plain, which encompasses the alluvial part of present-day Los Angeles and Orange Counties (~1 million acres out of 3.25 million total; Cleland 1922, 1941; Burcham 1957). Before the arrival of Spanish missionaries with livestock (cattle, horse, sheep), the plain was a thicketed prairie with a diverse fauna of grazers and browsers that supported ~5000 hunter-gatherers (observations of 1769 Spanish expedition). Starting in 1771, large numbers of cattle were raised by the mission (and by 'ranchos' and the Los Angeles pueblo, an agricultural community of immigrants allied with San Gabriel Mission) to supply an export trade in hides and tallow, which was managed by the Spanish Crown until 1832 secularization of mission lands. Cattle for beef became the focus in the 1850s and 1860s, when a ruinous drought and collapse of demand shifted the focus to sheep. Repeal in 1876 of the 1850 Trespass Act, so that cattle rather than farmland had to be fenced, shifted the economic balance permanently from open-range grazing to cultivation in the late 19th century, and by the early 20th century all (beef) cattle were fenced and dairy operations became dominant. Los Angeles County remained largely agricultural until the late 20th Century: it was the top agricultural producing county in the US from 1909-1949 (Surls and Gerber 2016).

We used two main sources to quantify this narrative for ecological impact (Table S3). For the "Mission Period" of California history (1771-1832), we use numbers of livestock (cattle, horse, sheep) based on decennial data from the San Gabriel and San Fernando Missions as compiled by Bancroft (1884, 1885, 1886), and convert these to Animal Unit Equivalents (AUE; each cow and horse is one unit, each sheep is 0.2 unit, a standard method of estimating demand on forage in US range management). The San Fernando Valley is the alluvial upper part of the Los Angeles River watershed; the San Gabriel mission lands encompassed the remainder of the Los Angeles River watershed and the San Gabriel and Santa Ana watersheds. For the "American Period" (1850-2000), we use decennial data from US Census reports for Los Angeles County (plus Orange County once it was partitioned from LA Co), converting livestock numbers to AUE and using data on the area of cultivated ('improved') farmland to plot land conversion from rangeland. For the intervening decades 1830-40, the cattle trade continued and by casual accounts thrived. In the absence of reporting authorities, we assume that by-then-private ranches ('ranchos'; Spanish land grants to individuals, dating to the 1780s) continued to maintain their herds and that these animals would have continued to increase as they had over previous decades of laissez-faire management, notwithstanding wholesale slaughter by the missions of their own herds in 1832.

For cultivation, missions reported volume of harvested goods rather than land area tilled; because crops were for subsistence rather than export during this period, we assume that the area tilled was never more than that reported in the first US census of 1850 and was generally much lower, in proportion with the lower human population.

Carrying capacity (dashed line in Fig. 4B in main text) for free-range livestock in the early 19th century is assumed to have been 10 acres per AUE (Cleland 1941 Chapter IV, based on reports from that period). For the approximately 1 million acres (405,000 ha) of alluvial plain used for grazing (Cleland 1941), the maximum sustainable number of livestock in the region would thus have been 100,000 AUE. We model the carrying capacity as starting to decline in 1850 with the first conversion of rangeland to cultivation (expansion of orchards, vineyards, and grain cultivation out of river bottoms, start of dry-farming). We abandon carrying capacity as a useful metric in 1900 AD and arguably could abandon it earlier: by the 1870s, ranchers had entirely fenced their beef cattle and were managing them intensively.

As stressed by Burcham (1957), although the original Spanish cows were smaller (probably ~0.8 AUE) than cows in the 1950s (and see opinion of Cleland 1941), both mission and US-Census livestock data for the 19th century are almost certainly under-estimates of grazing pressure on the landscape, given: large, uncounted herds of wild horses in the mission period, requiring culling as early as 1805; direct sales by mission-era ranchers of hides to local traders, bypassing the Spanish Crown; somewhat chaotic conditions between mission secularization and repeal of the Trespass Act, a period encompassing the Gold Rush, when tens of thousands of cattle were driven through the region en route to new markets in central California; and, in all US censuses, a focus on animals ‘on farms’. We thus assume that 1 cow = 1 AUE for the entire history of the livestock on the alluvial plain, a very modest correction against certain under-estimation.

6. Sediment yield over time

Our calculation of sediment yield from the land (Fig. 4C in main text), and thus the history of siltation pressure on the adjacent continental shelf, applies empirical estimates of sediment erosion for different land types (measured in US tons per acre per year) to the proportional representation of those land types in the watershed. Table S4 summarizes our reasoning for temporal change in land use types, which we estimated for every 50-year increment of time from 1750 to 2000 AD.

Estimated sediment yield per acre by land use (Table S5) draws on modern and historical studies from arid to humid climates mostly in the US. These estimates are probably conservative for the semi-arid southern California watershed if sediment yields are higher under semi-arid than under arid and humid climates, as found by some meta-analyses (e.g., Langbein and Schumm 1958, Wilson 1973; but see Milliman and Farnsworth 2013 that rates are only consistently high in humid settings and highly variable elsewhere). Sediment yield is a function of infiltration (rainfall the permeates into the soil rather than running off as surface flow, which is required to erode and transport sediment) and soil erodibility (function of grain size, slope, biomass cover). We rely primarily on multi-year studies and average values when a range is reported, making our estimates conservative.

The most reliable basis for estimating the magnitude of effect of land use on sediment yield between the 19th century and both earlier (pre-1769) and later times (soil conservation methods devised in the 1930s and applied through the late 20th to today) is the field experience of agronomists that a ~10-fold difference in yield exists between mis-managed and well-managed lands, regardless of climate (citations in Table S5). Globally, land subject to repeated plowing for crops yields the highest sediment per unit area, regardless of setting; grazed land that has been compacted or bared of vegetation (early/old-style or heavy grazing category in Table S3 and Fig 4F in main text) has the second highest sediment yields. Substituting alternative yield rates to the history of land use in Table S2 thus does not alter the basic trajectory of yield over time -- yield is always highest in 1900 AD, before the onset of soil conservation methods for croplands (early cultivation category); it affects only the magnitude of yield per unit time (y-axis) and total sediment estimated to have been removed from the watershed (area under the curve).

The maximum annual yield estimated here for the 1 million acres of alluvial plain -- ~9 megatons -- is ~10x the sediment yield of present-day, i.e. late 20th and early 21st century southern California watersheds as calculated by others on the completely independent basis of stream gauge data and short-lived radioistopic analysis of marine deposits (e.g., Inman and Jenkins 1999, Warrick and Farnsworth 2009, Clark and Lee 2009). Warrick and Farnsworth (2009) suggested that sediment yields were 2-10x higher during the 19th century than in the late 20th century owing to massive differences in land use then, mostly from grazing, based on their compilation of sedimentation rates from cores in coastal lagoons throughout California. Our estimates for southern California, derived from data on livestock and other agricultural data, fall at the high end of that core-based estimate.

Table S3 – Acres cultivated (harvested; 1 acre = 0.405 hectare) and number of cattle, horses, and sheep on the Los Angeles alluvial plain (non-mountainous part of modern-day Los Angeles and Orange Counties), with livestock summed into total Animal Unit Equivalents (AUE), where one cow or one horse is one unit and a sheep (or goat) is 0.2 units. LA+OC: data summed from separate accounts for Los Angeles and Orange Counties; LA incl of OC: data from Los Angeles County as it was known at the time, inclusive of present-day Orange County; LA pueblo = Los Angeles pueblo, an agricultural community of immigrants allied with the nearby San Gabriel Mission; SG San Gabriel Mission; SF San Fernando Mission, in the San Fernando Valley, which is the upper reaches of the Los Angeles River; ranchos = dedicated to cattle-raising, operated by private individuals as land grants from the Crown starting in the 1780s or granted by the Mexican government in the 1830s-40s. Data are not available for livestock held by all entities within the watershed for all decades in the 1770s-1840s interval, and so AUE estimates are conservative. Livestock held by Mission San Juan Capistrano not included, although it lies within modern-day Orange County; these animals might have grazed as far north as the Santa Ana watershed, further increasing actual numbers of animals on the coastal plain, but range is not confirmed; the mission reported 8-13k cattle per year from ~1800-1834. Zeros for farmed land from 1760 – 1840 reflect no published data for land tilled, but values would have been negligible compared to the late 19th and 20th centuries.

year	cattle (not dairy)	horses & mules	sheep & goats	total AUE	Farm (acres harvested)	Source, entities censused
2012	5713	7870	1853	13954	50854	US Census of Agriculture 2012; Volume 1, Chapter 2: County Level Data, Tables 9, 11, 12, 13, 14, 18 [LA+OC]
2002	1878	6958	2255	9287	34626	US Census of Agriculture 2002; Volume 1, Part 5: California; Chapter 2 County Data; Table 1 County Summary Highlights 2002; Tables 11, 12, 15, 16 [LA+OC]
1974	22042	6044	19989	32084	100031	US Census of Agriculture 1974 (publ. 1977), Vol 5, part 5 California, County Data Tables 2, 12, 14, 16 [LA+OC]
1950	37235	10265	11300	49760	625531	US Census of Agriculture 1950, Preliminary Area Reports: Farms, Farm Charateristics, Farm Products [LA+OC]
1925	16900	20484	10292	39442	489147	US Census of Agriculture 1925 (publ. 1927); Part III Western States, Table 1 farms and farm acreage, Table 3 live stock [LA+OC]
1910	26000	37859	66061	77071	608461	Thirteenth Census of the United States taken in the year 1910 (publ. 1913): Agricultural Census. Statistics for California, Table 1 Farms and farm property, by counties [LA+OC]
1900	22200	34564	83860	73536	755561	Twelfth census of the United States, Taken in the Year 1900 (publ. 1902). Census Reports Vol. V, Agriculture Part 1, Tables 1 and 35 [LA+OC]
1890	26203	26053	217896	95835	533342	Report on the statistics of agriculture in the United States at the eleventh census, 1890 (publ. 1894). County level data Tables 5, 8, 10, 12 [LA+OC]
1880	7061	9456	330350	82587	303380	Compendium of the Tenth US Census for 1880 (publ. 1883). Vol. 1. Table VII farm area, TABLE XLIX live stock [LA incl of OC]
1870	19178	10287	247603	78986	234883	Ninth Census of the US, 1870 (publ. 1872): Volume 3. The Statistics of Wealth and Industry of the United States. Table V. Productions of Agriculture in the United States in each State and Territory, by Counties [LA incl of OC]
1860	1078	14726	94639	34732	20,600	Agriculture of the United States in 1860 (publ. 1864); compiled from the original returns of the Eighth Census. [LA incl of OC]
1850	88454	5838	6541	95600	2648	The Seventh Census of the United States, 1850 (publ. 18xx). Table XI--Agriculture [LA incl of OC]
1840	60164	4016	2575	64695	0	Bancroft 1885, Chapter XXII Local Annals of Los Angeles District. 1831-1840. pp 629. [data for SG Mission in 1840 and SF Mission in 1846; assume that herds of pueblo & ranchos continued to increase from their 1830 numbers]
1834	82220	4240	10660	88592	0	Bancroft 1885, Chapter XXII Local Annals of Los Angeles District. 1831-1840. pp 629. [data for SG and SF Missions in 1834; assume that herds of pueblo & ranchos continued to increase from their 1830 numbers]
1830	72275	2785	17810	78622	0	Bancroft 1885, Chapter XXII Local Annals of Los Angeles District. 1831-1840. pp 629. [data for SG and SF Missions, LA pueblo & ranchos in 1830s]
1822	33604	5481	19456	42976	0	Bancroft 1886, Chapters VI, VIII,, XVI, XXV [data for SG Mission for 1821, pueblo & ranchos for 1823, SF Mission for 1822]
1810	23395	1638	14714	27976	0	Bancroft 1886, Chapters VI, VIII,, XVI, XXV [data for SG & SF Missions and LA pueblo; no data for ranchos]
1800	22617	0	14660	25549	0	Bancroft 1886, Chapters VI, VIII,, XVI, XXV [data for SG Mission, Pueblo and ranchos in 1800, & for newly established SF Mission in 1801]
1790	7201	0	6451	8491	0	Bancroft 1884, Ch VI, VIII,, XVI, XXV [data SG Mission & Pueblo; no data for ranchos established in 1780s]
1783	1200	0	2280	1656	0	Bancroft 1884, Ch VI, VIII,, XVI, XXV [data for SG Mission & Pueblo]
1773	18	0	0	18	0	Bancroft 1884, Ch VI, VIII,, XVI, XXV [only SG Mission existed]
1760	0	0	0	0	0	Bancroft 1884, Ch VI, VIII,, XVI, XXV [Spanish arrived by land 1769; SG Mission not established until 1771]

Table S4 - Changes in land use on the Los Angeles alluvial plain from 1750 to 2000 AD.

Date	Conditions at time, reasoning
1750	100% prairie, pre-European contact (first colonists in 1769, with cattle, horse, sheep arriving in 1771); occupied by ~5000 hunt-gatherers, landscape burning likely but no cultivation
1800	Conservatively, 50% prairie or lightly grazed and 50% moderately grazed: cultivation limited to river bottoms and small gardens; by the 1780s, Spain had already granted large tracts of the outlying coastal plain to ranchers and so possible that ~100% of area was already grazed to some extent
1850	Area still <1% cultivated = 2648 acres according to the 1st US Census, which also reported ~1 million acres 'unimproved farms', meaning ~100% of area was grazed; grazing intensity probably heavy because AUE had been near or above carrying capacity since the 1820s/30s; maximum 1% residential (Los Angeles City, population 1600 whites)
1900	52% of land cultivated (528,000 acres) for citrus, nuts, wheat, but without soil conservation methods, which were not developed until the 1930s-40s; 32% unimproved farmland was grazed but fenced and thus livestock and pastures were managed to some degree for economic sustainability; start of LA as a metropolis, estimate 10% residential land (100,000 people, all races) and 6% commercial (railroads arrived in 1870s; 6% is estimate probably too high)
1950	45% of land cultivated, assume that modern, soil-conserving methods were applied everywhere; 28% unimproved farmland, assume is grazed pasture and was well-managed; post-war urbanization and industrialization, human population 20x that of 1900, thus estimate 20% of land residential and 7% is commercial/industrial
2000	Estimates informed by land-use analysis of Ackerman & Schiff (2003), who considered only the lower parts of watersheds to avoid dam interference in runoff; we assume that all lands identified by them as 'open' (wild), constituting 47% of the total area surveyed, are high relief and thus not alluvial; excluding those wild lands reduced their study to ~25% of Los Angeles County, which is very close to the 31% of that area considered to be alluvial by historical workers such as Cleland 1941 and Burcham 1957. We thus use Ackerman and Schiff's (2003) apportioning of the alluvial plain as 80% residential, 18% commercial/industrial, and 2% agriculture. These estimates compare closely with the 2002 US Census for Los Angeles County, with 2% cultivated (24,000 acres); Census provides no data on unimproved farmland (grazed) but that land use type constituted 16% of area in 1972 and 0% in 2012. Thus we assume 0% of alluvial plain was grazed lands in 2000.

Table S5 - Values of sediment yield per acre per land use type.

Land type	Sed yield (ton/acre-year)	Reasoning (references)
Wild	0.001	Consistent estimates for prairie and ungrazed pasture, 1920s to 1990s; runoff is typically clear water (Weaver & Noll 1935, Jawson et al. 1982, Gebel et al. 2014)
Grazed, late-style or light	0.2	Grazed US lands in 1950 and 2000, lightly grazed elsewhere; stock are shifted seasonally, extra water sources to reduce trampling of streams; probably a reasonable estimate for lightly grazed lands in late 18th and early 19th centuries (Berg et al. 1988, Jawson et al. 1982, Sharma 1997, Bartley et al. 2010)
Grazed, early-style or heavy	5	Heavily grazed or overgrazed natural range or pasture; multiple authors cite that heavily grazed land has a sediment yield ~10x that of lightly grazed land in the same region; yields can range to 50 t/a-y (Weaver & Noll 1935, Sharma 1997, Duley & Miller 1923)
Cultivation, late-style or advanced	1.3	'Advanced', no-till cultivation, minimizing sediment loss, as in late 20th century Oklahoma and Maryland (Berg et al. 1988, Yorke & Herb 1978)
Cultivation, early-style	15	'Old-style' cultivation without soil conservation; mid-range value of published estimates, can be 30 ton/acre even in modern-day US when soil conservation methods not applied; highest sediment yield of all land uses owing to repeated plowing; multiple authors indicate yields are ~10x no-till methods (Weaver & Noll 1935, Duley & Miller 1923, Berg et al. 1988, Gebel et al. 2014)
Residential	0.1	Very low unless new construction; dissolved contaminants and nutrients important (Ellis 1996)
Commercial /Industrial	0.3	Very low, man-made debris, dissolved contaminants (Ellis 1996)

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8. Table with shell ages

Summary of radiocarbon-calibrated shell ages of *Laqueus erythraeus* estimated by amino-acid racemization (with 95% confidence intervals), with water depth (m), sampling year, and D/L of Aspartic and Glutamic acids.

Specimen ID	Site ID	Water depth (m)	Site	Sampling year	Age (y before 2013)	Age-2.5% (y before 2013)	Age-97.5% (y before 2013)	Asp D/L	Glu D/L
4134-1	4134	78	W Palos Verdes	2003	108	71	158	0.174	0.076
4134-10	4134	78	W Palos Verdes	2003	164	113	230	0.189	0.08
4134-11	4134	78	W Palos Verdes	2003	4623	4476	4788	0.368	0.126
4134-12	4134	78	W Palos Verdes	2003	182	126	253	0.193	0.075
4134-13	4134	78	W Palos Verdes	2003	380	285	493	0.224	0.087
4134-14	4134	78	W Palos Verdes	2003	269	196	363	0.209	0.079
4134-15	4134	78	W Palos Verdes	2003	211	150	289	0.199	0.07
4134-16	4134	78	W Palos Verdes	2003	471	360	608	0.234	0.086
4134-18	4134	78	W Palos Verdes	2003	405	306	523	0.227	0.076
4134-2	4134	78	W Palos Verdes	2003	269	196	363	0.209	0.075
4134-20	4134	78	W Palos Verdes	2003	4708	3561	6200	0.372	0.149
4134-21	4134	78	W Palos Verdes	2003	168	116	236	0.19	0.074
4134-22	4134	78	W Palos Verdes	2003	211	150	289	0.199	0.086
4134-23	4134	78	W Palos Verdes	2003	943	747	1170	0.269	0.115
4134-24	4134	78	W Palos Verdes	2003	4068	3099	5288	0.361	0.114
4134-25	4134	78	W Palos Verdes	2003	339	250	449	0.219	0.074
4134-27	4134	78	W Palos Verdes	2003	2969	2319	3779	0.339	0.129
4134-28	4134	78	W Palos Verdes	2003	4832	3645	6375	0.374	0.164
4134-29	4134	78	W Palos Verdes	2003	217	153	296	0.2	0.088
4134-3	4134	78	W Palos Verdes	2003	1465	1173	1812	0.294	0.133
4134-30	4134	78	W Palos Verdes	2003	136	91	193	0.182	0.069
4134-31	4134	78	W Palos Verdes	2003	250	181	338	0.206	0.086
4134-32	4134	78	W Palos Verdes	2003	128	85	184	0.18	0.069
4134-33	4134	78	W Palos Verdes	2003	1417	1138	1753	0.292	0.107
4134-34	4134	78	W Palos Verdes	2003	147	100	208	0.185	0.067
4134-35	4134	78	W Palos Verdes	2003	228	162	309	0.202	0.093
4134-36	4134	78	W Palos Verdes	2003	461	351	595	0.233	0.088
4134-37	4134	78	W Palos Verdes	2003	155	106	219	0.187	0.09
4134-38	4134	78	W Palos Verdes	2003	302	220	405	0.214	0.088
4134-4	4134	78	W Palos Verdes	2003	159	109	225	0.188	0.074
4134-40	4134	78	W Palos Verdes	2003	222	157	302	0.201	0.084
4134-41	4134	78	W Palos Verdes	2003	118	78	171	0.177	0.076
4134-42	4134	78	W Palos Verdes	2003	1015	805	1255	0.273	0.109
4134-43	4134	78	W Palos Verdes	2003	222	157	302	0.201	0.075
4134-5	4134	78	W Palos Verdes	2003	155	106	219	0.187	0.082
4134-6	4134	78	W Palos Verdes	2003	4014	3877	4162	0.339	0.126
4134-7	4134	78	W Palos Verdes	2003	1846	1473	2282	0.308	0.12
4134-8	4134	78	W Palos Verdes	2003	1568	1258	1935	0.298	0.096

4134-9	4134	78	W Palos Verdes	2003	222	157	302	0.201	0.075
10C-1	10C	61	E Palos Verdes	2008	3385	2616	4337	0.348	0.156
10C-10	10C	61	E Palos Verdes	2008	256	186	346	0.207	0.083
10C-11	10C	61	E Palos Verdes	2008	1214	968	1493	0.283	0.137
10C-12	10C	61	E Palos Verdes	2008	2759	2162	3497	0.334	0.144
10C-13	10C	61	E Palos Verdes	2008	723	567	912	0.255	0.088
10C-14	10C	61	E Palos Verdes	2008	1300	1045	1601	0.287	0.104
10C-15	10C	61	E Palos Verdes	2008	461	351	595	0.233	0.093
10C-16	10C	61	E Palos Verdes	2008	738	578	929	0.256	0.13
10C-17	10C	61	E Palos Verdes	2008	461	351	595	0.233	0.118
10C-2	10C	61	E Palos Verdes	2008	6179	4591	8246	0.393	0.156
10C-3	10C	61	E Palos Verdes	2008	2236	1762	2802	0.32	0.146
10C-4	10C	61	E Palos Verdes	2008	5800	4302	7737	0.388	0.16
10C-5	10C	61	E Palos Verdes	2008	1417	1138	1753	0.292	0.12
10C-6	10C	61	E Palos Verdes	2008	233	167	316	0.203	0.068
10C-7	10C	61	E Palos Verdes	2008	979	775	1214	0.271	0.116
10C-8	10C	61	E Palos Verdes	2008	461	351	595	0.233	0.113
10C-9	10C	61	E Palos Verdes	2008	797	626	998	0.26	0.102
LEOC-1	0C	61	W Palos Verdes	2008	177	123	247	0.192	0.075
LEOC-10	0C	61	W Palos Verdes	2008	405	306	523	0.227	0.071
LEOC-11	0C	61	W Palos Verdes	2008	143	97	203	0.184	0.065
LEOC-12	0C	61	W Palos Verdes	2008	263	191	355	0.208	0.076
LEOC-13	0C	61	W Palos Verdes	2008	239	171	323	0.204	0.079
LEOC-14	0C	61	W Palos Verdes	2008	155	106	219	0.187	0.071
LEOC-15	0C	61	W Palos Verdes	2008	168	116	236	0.19	0.068
LEOC-16	0C	61	W Palos Verdes	2008	196	138	271	0.196	0.082
LEOC-17	0C	61	W Palos Verdes	2008	317	232	423	0.216	0.083
LEOC-18	0C	61	W Palos Verdes	2008	115	75	166	0.176	0.087
LEOC-19	0C	61	W Palos Verdes	2008	121	80	175	0.178	0.066
LEOC-2	0C	61	W Palos Verdes	2008	132	88	188	0.181	0.076
LEOC-20	0C	61	W Palos Verdes	2008	186	130	259	0.194	0.079
LEOC-21	0C	61	W Palos Verdes	2008	738	578	929	0.256	0.096
LEOC-22	0C	61	W Palos Verdes	2008	355	262	466	0.221	0.078
LEOC-23	0C	61	W Palos Verdes	2008	105	69	154	0.173	0.071
LEOC-24	0C	61	W Palos Verdes	2008	177	123	247	0.192	0.077
LEOC-25	0C	61	W Palos Verdes	2008	115	75	166	0.176	0.067
LEOC-26	0C	61	W Palos Verdes	2008	132	88	188	0.181	0.076
LEOC-27	0C	61	W Palos Verdes	2008	244	176	330	0.205	0.077
LEOC-28	0C	61	W Palos Verdes	2008	168	116	236	0.19	0.061
LEOC-29	0C	61	W Palos Verdes	2008	201	142	277	0.197	0.057
LEOC-3	0C	61	W Palos Verdes	2008	206	146	283	0.198	0.07
LEOC-30	0C	61	W Palos Verdes	2008	211	150	289	0.199	0.067
LEOC-32	0C	61	W Palos Verdes	2008	1072	850	1321	0.276	0.093
LEOC-33	0C	61	W Palos Verdes	2008	481	369	621	0.235	0.082
LEOC-34	0C	61	W Palos Verdes	2008	288	210	389	0.212	0.071
LEOC-35	0C	61	W Palos Verdes	2008	159	109	225	0.188	0.076

LEOC-36	0C	61	W Palos Verdes	2008	217	153	296	0.2	0.081
LEOC-37	0C	61	W Palos Verdes	2008	182	126	253	0.193	0.078
LEOC-38	0C	61	W Palos Verdes	2008	159	109	225	0.188	0.059
LEOC-39	0C	61	W Palos Verdes	2008	710	555	896	0.254	0.099
LEOC-40	0C	61	W Palos Verdes	2008	355	262	466	0.221	0.08
LEOC-41	0C	61	W Palos Verdes	2008	324	238	431	0.217	0.08
LEOC-42	0C	61	W Palos Verdes	2008	461	351	595	0.233	0.076
LEOC-43	0C	61	W Palos Verdes	2008	943	747	1170	0.269	0.09
LEOC-44	0C	61	W Palos Verdes	2008	275	200	372	0.21	0.063
LEOC-45	0C	61	W Palos Verdes	2008	191	134	265	0.195	0.061
LEOC-46	0C	61	W Palos Verdes	2008	233	167	316	0.203	0.091
LEOC-47	0C	61	W Palos Verdes	2008	217	153	296	0.2	0.081
LEOC-48	0C	61	W Palos Verdes	2008	196	138	271	0.196	0.073
LEOC-49	0C	61	W Palos Verdes	2008	220	106	327	0.197	0.075
LEOC-5	0C	61	W Palos Verdes	2008	155	106	219	0.187	0.078
LEOC-50	0C	61	W Palos Verdes	2008	147	100	208	0.185	0.059
LEOC-51	0C	61	W Palos Verdes	2008	452	343	584	0.232	0.089
LEOC-52	0C	61	W Palos Verdes	2008	186	130	259	0.194	0.085
LEOC-53	0C	61	W Palos Verdes	2008	172	120	241	0.191	0.07
LEOC-54	0C	61	W Palos Verdes	2008	2488	1961	3137	0.327	0.113
LEOC-55	0C	61	W Palos Verdes	2008	1974	1849	2115	0.326	0.122
LEOC-56	0C	61	W Palos Verdes	2008	1137	1010	1255	0.286	0.095
LEOC-57	0C	61	W Palos Verdes	2008	228	162	309	0.202	0.101
LEOC-59	0C	61	W Palos Verdes	2008	1227	1109	1331	0.25	0.093
LEOC-6	0C	61	W Palos Verdes	2008	196	103	309	0.211	0.084
LEOC-60	0C	61	W Palos Verdes	2008	132	88	188	0.181	0.087
LEOC-61	0C	61	W Palos Verdes	2008	397	299	512	0.226	0.09
LEOC-62	0C	61	W Palos Verdes	2008	151	103	214	0.186	0.076
LEOC-63	0C	61	W Palos Verdes	2008	524	401	675	0.239	0.106
LEOC-7	0C	61	W Palos Verdes	2008	414	314	535	0.228	0.066
LEOC-8	0C	61	W Palos Verdes	2008	228	162	309	0.202	0.074
LEOC-9	0C	61	W Palos Verdes	2008	159	109	225	0.188	0.076
10C-18	10C	61	E Palos Verdes	2009	347	255	457	0.22	0.103
10C-19	10C	61	E Palos Verdes	2009	2925	2286	3721	0.338	0.172
10C-20	10C	61	E Palos Verdes	2009	324	238	431	0.217	0.091
10C-21	10C	61	E Palos Verdes	2009	7089	5238	9548	0.404	0.178
10C-22	10C	61	E Palos Verdes	2009	7622	5610	10299	0.41	0.139
10C-23	10C	61	E Palos Verdes	2009	2137	1685	2656	0.317	0.143
10C-24	10C	61	E Palos Verdes	2009	442	335	572	0.231	0.095
10C-25	10C	61	E Palos Verdes	2009	172	120	241	0.191	0.094
10C-26	10C	61	E Palos Verdes	2009	581	448	743	0.244	0.112
10C-27	10C	61	E Palos Verdes	2009	1111	882	1368	0.278	0.086
10C-28	10C	61	E Palos Verdes	2009	1417	1138	1753	0.292	0.13
10C-29	10C	61	E Palos Verdes	2009	617	480	786	0.247	0.119
10C-30	10C	61	E Palos Verdes	2009	1489	1195	1843	0.295	0.125
10C-31	10C	61	E Palos Verdes	2009	164	113	230	0.189	0.087

10C-32	10C	61	E Palos Verdes	2009	1214	968	1493	0.283	0.115
10C-33	10C	61	E Palos Verdes	2009	2341	1845	2942	0.323	0.144
10C-34	10C	61	E Palos Verdes	2009	1192	950	1468	0.282	0.127
10C-35	10C	61	E Palos Verdes	2009	683	532	863	0.252	0.093
10C-36	10C	61	E Palos Verdes	2009	828	654	1035	0.262	0.129
10C-37	10C	61	E Palos Verdes	2009	546	418	701	0.241	0.11
10C-38	10C	61	E Palos Verdes	2009	1595	1278	1967	0.299	0.147
10C-39	10C	61	E Palos Verdes	2009	405	306	523	0.227	0.113
10C-40	10C	61	E Palos Verdes	2009	1675	1342	2067	0.302	0.131
10C-41	10C	61	E Palos Verdes	2009	630	490	804	0.248	0.138
10C-42	10C	61	E Palos Verdes	2009	2005	1584	2484	0.313	0.145
10C-43	10C	61	E Palos Verdes	2009	3901	2974	5061	0.358	0.13
10C-44	10C	61	E Palos Verdes	2009	5874	4355	7835	0.389	0.169
10C-45	10C	61	E Palos Verdes	2009	182	126	253	0.193	0.096
10C-46	10C	61	E Palos Verdes	2009	2718	2133	3442	0.333	0.139
10C-47	10C	61	E Palos Verdes	2009	339	250	449	0.219	0.076
10C-48	10C	61	E Palos Verdes	2009	442	335	572	0.231	0.096
10C-49	10C	61	E Palos Verdes	2009	683	532	863	0.252	0.107
10C-50	10C	61	E Palos Verdes	2009	4122	3143	5361	0.362	0.162
10C-51	10C	61	E Palos Verdes	2009	6416	4753	8579	0.396	0.149
10C-52	10C	61	E Palos Verdes	2009	5800	4302	7737	0.388	0.16
10C-53	10C	61	E Palos Verdes	2009	3688	2827	4753	0.354	0.159
10C-54	10C	61	E Palos Verdes	2009	388	292	503	0.225	0.122
10C-55	10C	61	E Palos Verdes	2009	324	238	431	0.217	0.103
10C-56	10C	61	E Palos Verdes	2009	1489	1195	1843	0.295	0.132
10C-57	10C	61	E Palos Verdes	2009	452	343	584	0.232	0.088
10C-58	10C	61	E Palos Verdes	2009	535	409	688	0.24	0.108
10C-59	10C	61	E Palos Verdes	2009	3846	2937	4982	0.357	0.15
10C-60	10C	61	E Palos Verdes	2009	843	667	1054	0.263	0.15
LE24205-1	24205	81	Santa Monica Bay	1975	1621	1299	1999	0.3	0.1
LE24205-10	24205	81	Santa Monica Bay	1975	2527	1990	3189	0.328	0.118
LE24205-11	24205	81	Santa Monica Bay	1975	1758	1408	2174	0.305	0.118
LE24205-12	24205	81	Santa Monica Bay	1975	960	761	1191	0.27	0.096
LE24205-13	24205	81	Santa Monica Bay	1975	1130	899	1392	0.279	0.094
LE24205-14	24205	81	Santa Monica Bay	1975	1893	1762	2017	0.289	0.106
LE24205-16	24205	81	Santa Monica Bay	1975	1788	1430	2208	0.306	0.096
LE24205-17	24205	81	Santa Monica Bay	1975	1846	1473	2282	0.308	0.106
LE24205-18	24205	81	Santa Monica Bay	1975	2203	1731	2752	0.319	0.118
LE24205-19	24205	81	Santa Monica Bay	1975	1072	850	1321	0.276	0.109
LE24205-2	24205	81	Santa Monica Bay	1975	1940	1539	2402	0.311	0.098
LE24205-20	24205	81	Santa Monica Bay	1975	2236	1762	2802	0.32	0.129
LE24205-21	24205	81	Santa Monica Bay	1975	2203	1731	2752	0.319	0.126
LE24205-23	24205	81	Santa Monica Bay	1975	8423	8270	8564	0.455	0.179
LE24205-24	24205	81	Santa Monica Bay	1975	875	693	1093	0.265	0.097
LE24205-25	24205	81	Santa Monica Bay	1975	1702	1364	2102	0.303	0.097
LE24205-27	24205	81	Santa Monica Bay	1975	8482	8365	8622	0.395	0.152

LE24205-28	24205	81	Santa Monica Bay	1975	943	747	1170	0.269	0.104
LE24205-29	24205	81	Santa Monica Bay	1975	8472	8352	8615	0.444	0.177
LE24205-3	24205	81	Santa Monica Bay	1975	2137	1685	2656	0.317	0.126
LE24205-30	24205	81	Santa Monica Bay	1975	1130	899	1392	0.279	0.093
LE24205-31	24205	81	Santa Monica Bay	1975	1541	1237	1904	0.297	0.116
LE24205-32	24205	81	Santa Monica Bay	1975	1393	1119	1722	0.291	0.116
LE24205-33	24205	81	Santa Monica Bay	1975	960	761	1191	0.27	0.101
LE24205-34	24205	81	Santa Monica Bay	1975	1111	882	1368	0.278	0.089
LE24205-4	24205	81	Santa Monica Bay	1975	1256	1004	1547	0.285	0.113
LE24205-5	24205	81	Santa Monica Bay	1975	1465	1173	1812	0.294	0.098
LE24205-6	24205	81	Santa Monica Bay	1975	1072	850	1321	0.276	0.11
LE24205-7	24205	81	Santa Monica Bay	1975	3194	2482	4078	0.344	0.128
LE24205-8	24205	81	Santa Monica Bay	1975	2104	1658	2610	0.316	0.101
LE24205-9	24205	81	Santa Monica Bay	1975	9431	6832	13037	0.428	0.143

9. Table with species abundances – total abundances of bivalve and brachiopod species in mid-shelf living assemblages (sums of individuals collected alive – between 1972 and 2009 at Palos Verdes shelf stations 0C and 10C, and between 1987-1991 and between 2000-2014 in Santa Monica Bay at five stations C6, C7, C8, D1, and Z2) and death assemblages (sums of individuals, using maximum number of individuals approach), with Santa Monica Bay stations sampled between 59-70 m (station C6 sampled in 2012 and 2014, station C7, D1, and Z2 sampled in 2012, station C8 sampled in 2014), Western Palos Verdes shelf station 0C at 61 m (grabs sampled in 2008, 2010, 2012, and 2013), and Eastern Palos Verdes shelf station 10C at 61 m (grabs sampled in 2008, 2010, 2012).

	LA-Santa Monica Bay	DA-Santa Monica Bay	LA-Western Palos Verdes shelf	DA-Western Palos Verdes shelf	LA-Eastern Palos Verdes shelf	DA-Eastern Palos Verdes shelf
Acila castrensis	1	0	5	1	1	13
Adontorhina cyclia	1	0	1	0	0	4
Amygdalum politum	4	0	0	0	12	0
Asthenothaerus diegensis	7	0	3	0	13	0
Axinopsida serricata	1675	44	1071	20	977	692
Cardiomya pectinata	24	6	0	4	0	32
Chama arcana	0	0	0	0	1	0
Chione undatella	0	1	0	0	0	0
Chlamys hastata	0	17	0	3	0	153
Compsomyax subdiaphana	52	5	96	8	57	119
Cooperella subdiaphana	7	1	6	0	20	1
Corbula porcella	1	0	11	21	0	19
Crassadoma gigantea	0	0	0	0	0	1
Crenella decussata	62	0	0	0	11	0
Cryptomya californica	0	1	2	0	0	0
Cuspidaria parapodema	14	2	3	1	2	2
Cyathodonta pedroana	0	0	0	0	0	1
Cyclocardia bailyi	0	21	0	0	0	0
Cyclocardia ventricosa	0	0	1	0	0	0
Dallinella obsoleta	0	6	0	34	0	3
Dallinella occidentalis	0	4	0	0	0	0
Delectopecten vancouverensis	13	10	0	5	0	165
Donax californicus	0	0	0	0	0	1
Ennucula tenuis	39	0	9	1	2	1

	LA-Santa Monica Bay	DA-Santa Monica Bay	LA-Western Palos Verdes shelf	DA-Western Palos Verdes shelf	LA-Eastern Palos Verdes shelf	DA-Eastern Palos Verdes shelf
Ensis myrae	0	4	0	0	1	7
Entodesma pictum	3	0	0	0	3	0
Liopecten diegensis	0	41	0	0	0	3
Gari fucata	0	0	0	0	0	2
Glycymeris septentrionalis	0	1	0	0	0	0
Heteroclidus punctata	1	0	0	0	0	0
Hiatella arctica	25	8	4	0	3	87
Irusella lamellifera	0	0	0	0	0	1
Kellia suborbicularis	0	0	0	0	1	2
Laqueus erythraeus	0	108	0	491	0	58
Leptopecten latiauratus	1	9	0	4	0	82
Limaria hemphilli	0	0	0	0	0	7
Limatula saturna	0	2	0	0	3	4
Lucinisca nuttalli	23	2	0	0	0	0
Lucinoma annulatum	28	10	7	4	31	20
Lyonsia californica	37	0	10	0	16	0
Macoma carlottensis	4	0	11	0	18	0
Macoma indentata	0	0	0	0	0	1
Macoma sp.	11	0	1	0	0	0
Macoma yoldiformis	59	1	15	0	29	10
Mactrotoma californica	0	1	0	0	0	0
Modiolus sp.	31	4	2	1	15	13
Neaeromya compressa	0	0	0	0	4	0
Nemocardium centifilosum	57	37	18	6	44	184
Neolepton salmoneum	12	0	0	0	0	0
Nuculana hamata	11	40	0	19	1	252
Nuculana minuta	0	1	0	0	0	0
Nuculana penderi	16	0	1	3	0	4
Nuculana sp.	31	0	0	0	1	0
Nuculana sp. A (previously N. elenensis)	132	76	6	39	0	135
Nuculana taphria	8	0	8	1	10	59
Nutricola lordi	0	6	0	0	2	0
Nutricola ovalis	0	0	0	0	0	34
Nutricola tantilla	0	0	0	0	43	0
Orobitella californica	0	0	0	0	1	0
Pandora bilirata	5	4	3	4	7	10
Pandora filosa	2	0	0	0	0	0

	LA-Santa Monica Bay	DA-Santa Monica Bay	LA-Western Palos Verdes shelf	DA-Western Palos Verdes shelf	LA-Eastern Palos Verdes shelf	DA-Eastern Palos Verdes shelf
Parvilucina tenuisculpta	5291	287	962	33	9574	1673
Periploma discus	16	0	2	0	4	0
Petricola sp.	1	0	1	0	0	0
Pseudochama granti	0	33	0	7	0	16
Rochefortia compressa	9	0	4	0	0	0
Rochefortia grippi	7	0	10	0	0	1
Rochefortia mortoni	9	0	67	0	10	0
Rochefortia tumida	251	1	50	4	53	28
Saxicavella nybakkeni	2	0	63	0	3	4
Saxicavella pacifica	0	0	45	1	0	0
Saxidomus nuttalli	0	0	0	0	3	0
Semele rubropicta	0	1	0	0	0	0
Siliqua lucida	0	0	0	1	0	0
Solamen columbianum	108	9	2	1	37	20
Solemya pervernicosa	168	0	0	0	1	0
Solen sicarius	2	0	0	0	1	3
Tellina bodegensis	0	0	0	0	0	1
Tellina cadieni	0	0	2	0	83	0
Tellina idae	1	1	1	0	0	0
Tellina modesta	5	0	1	0	5	0
Tellina nuculoides	0	0	0	0	0	1
Tellina sp.	8	0	0	0	0	0
Tellina sp.B-T. carpenteri	1554	40	279	2	822	249
Thracia curta	1	0	2	0	3	0
Thracia sp.	0	0	0	0	1	0
Thracia trapezoides	13	3	4	2	2	2
Thyasira flexuosa	240	0	362	20	143	37
Trachycardium quadragenarium	0	1	0	0	0	3
Yoldia seminuda	0	0	0	2	0	0

10. Table with guild abundances – total abundances of guilds of bivalves and rhynchonelliformean brachiopods in mid-shelf living assemblages (sums of individuals collected alive – between 1972 and 2009 at Palos Verdes shelf stations 0C and 10C, and between 1987-1991 and 2000-2014 in Santa Monica Bay at five stations C6, C7, C8, D1, and Z2) and death assemblages (sums of individuals, using maximum number of individuals approach), with Santa Monica Bay stations sampled between 59-70 m (station C6 sampled in 2012 and 2014, station C7, D1, and Z2 sampled in 2012, station C8 sampled in 2014), Western Palos Verdes shelf station 0C at 61 m (grabs sampled in 2008, 2010, 2012, and 2013), and Eastern Palos Verdes shelf station 10C at 61 m (grabs sampled in 2008, 2010, 2012).

	LA-Santa Monica Bay	DA-Santa Monica Bay	LA-Western Palos Verdes shelf	DA-Western Palos Verdes shelf	LA-Eastern Palos Verdes shelf	DA-Eastern Palos Verdes shelf
boring suspension-feeder	3	0	0	0	3	0
carnivorous	38	8	3	5	2	34
chemosymbiontic	5751	299	1332	57	9749	1734
commensal	276	1	132	4	69	31
infaunal mixed-feeder	3317	108	1382	22	1934	954
epifaunal brachiopod	0	118	0	525	0	61
epifaunal suspension-feeder	245	133	8	22	82	551
infaunal suspension-feeder	204	65	270	43	233	391
nonsiphonate deposit-feeder	40	0	14	2	3	14
siphonate deposit-feeder	210	117	15	64	12	450