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Where the Weird Things are: A Collection of Species Range Extensions in the Southern California Bight

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Abstract.—A large-scale monitoring program associated with the establishment of a marine protected area network in southern California provided an opportunity to observe and document unique or rare species across the region. Scientists and students from several educational and research institutions surveyed 145 subtidal reefs, 39 intertidal reefs, and five sandy beaches from 2011–2017, a period of time where oceanographic and climatic conditions changed serially and dramatically. In conjunction with an increase in monitoring frequency and locations, dramatic shifts in oceanographic climate during this same time period likely caused shifts in tolerable habitat conditions for many nearshore species. Here we describe range extensions, both to the north and south, of 14 marine fish, invertebrate, and algae species as observed during the 2011–2012 South Coast MPA Baseline Program and subsequent monitoring efforts.

The Southern California Bight (SCB) spans a significant environmental gradient and is subject to the influx and removal of species based upon subtle regional changes as well as large-scale changes in climate and oceanographic conditions. Past reports of new or unusual species to the SCB were typically a product of large-scale oceanographic phenomena such as El Niño/Southern Oscillation events (Engle and Richards 2001; Richards and Engle 2001; Pondella and Allen 2001; Radovich 1961), increases in invasive species vectors through port expansion (Haaker 1979; Pondella and Chinn 2005), new capture/observation technologies, or simply a product of motive and opportunity. The opportunity to observe and document a unique or rare species across the entirety of the SCB presented itself with the establishment of marine protected areas (MPAs) in southern California and the subsequent baseline monitoring program for those newly established MPAs in the South Coast Study Region (SCSR).

Here we describe extensions of published geographical ranges of species as noted during the baseline (2011–2012) characterization surveys of the SCSR, specifically the Kelp and Shallow Rock Ecosystems (Pondella et al. 2015) and Rocky Intertidal Ecosystems (Blanchette et al. 2015) surveys, as well as subsequent and additional monitoring efforts by these programs. The original baseline studies surveyed 39 intertidal reefs and 94 subtidal reefs (to 30 m) from Government Point (near Point Conception) to Cabrillo National Monument (near the US/Mexico border), including all eight of California's Channel Islands and Begg Rock. The inclusion of 51 additional subtidal reefs in

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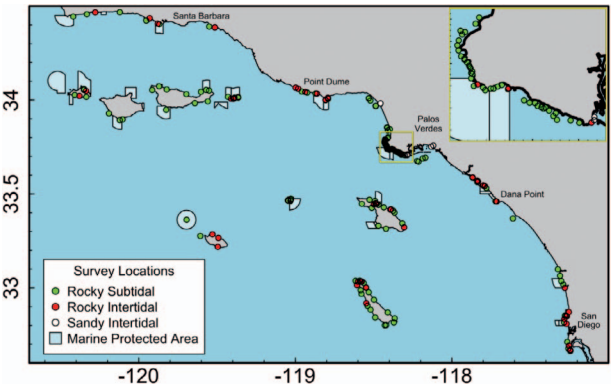

Fig. 1. Map of SCB sampling locations for rocky subtidal (green circles), rocky intertidal (red circle), and sandy intertidal surveys (white).

subsequent monitoring efforts increased the number of subtidal reefs surveyed in the SCSR during 2011–2017 to 145. During this same time period, five sandy intertidal areas in Los Angeles County were also surveyed by biology classes from Occidental College (Fig. 1).

In addition to increased monitoring frequency and locations, there have been dramatic shifts in oceanographic climate during this same time period. The beginning of 2012 marked the end of a nearly two-year long La Niña event and the beginning of a 32-month period of El Niño/Southern Oscillation (ENSO) neutral conditions.[1] By late 2013, an anomalous mass of warm water ("the blob"; Bond et al. 2015) began to spread from the northeast Pacific to as far south as Mexico, increasing sea surface temperatures up to 2.5°C above normal. In conjunction with this anomaly, one of the strongest and most persistent El Niños recorded began in late-2014 before finally fading in May of 2016.[1] These Pacific Ocean-wide oceanographic anomalies created large fluctuations in local sea surface temperatures throughout the SCSR monitoring program and beyond (Fig. 2). These serial changes in oceanographic climate during this same time period are known to alter the existence and strength of oceanic circulation within the SCB, specifically with respect to the Davidson Countercurrent (McClain and Thomas 1983), and likely caused shifts in tolerable habitat conditions for many nearshore species (Engle and Richards 2001; Richards and Engle 2001; Tegner and Dayton 1987; Love et al. 2015; Love et al. 2016; Love 2016; Pondella and Allen 2001, Radovich 1961). These environmental changes coincided with a period of intensive biological monitoring (both in temporal frequency and high number of locations), providing numerous opportunities to observe even temporary excursions of species outside their typical biogeographic borders. During this time, we observed fourteen species range outside of their typical range in the SCB (Table 1).

Materials and Methods

Range extensions described herein were observed as a product of three separate monitoring programs, two of which were related to MPA baseline monitoring of the SCSR. Kelp

[1] Climate Prediction Center. 2016. Historical El Nino/La Nina episodes. Available from: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml. Accessed 17 September 2016.

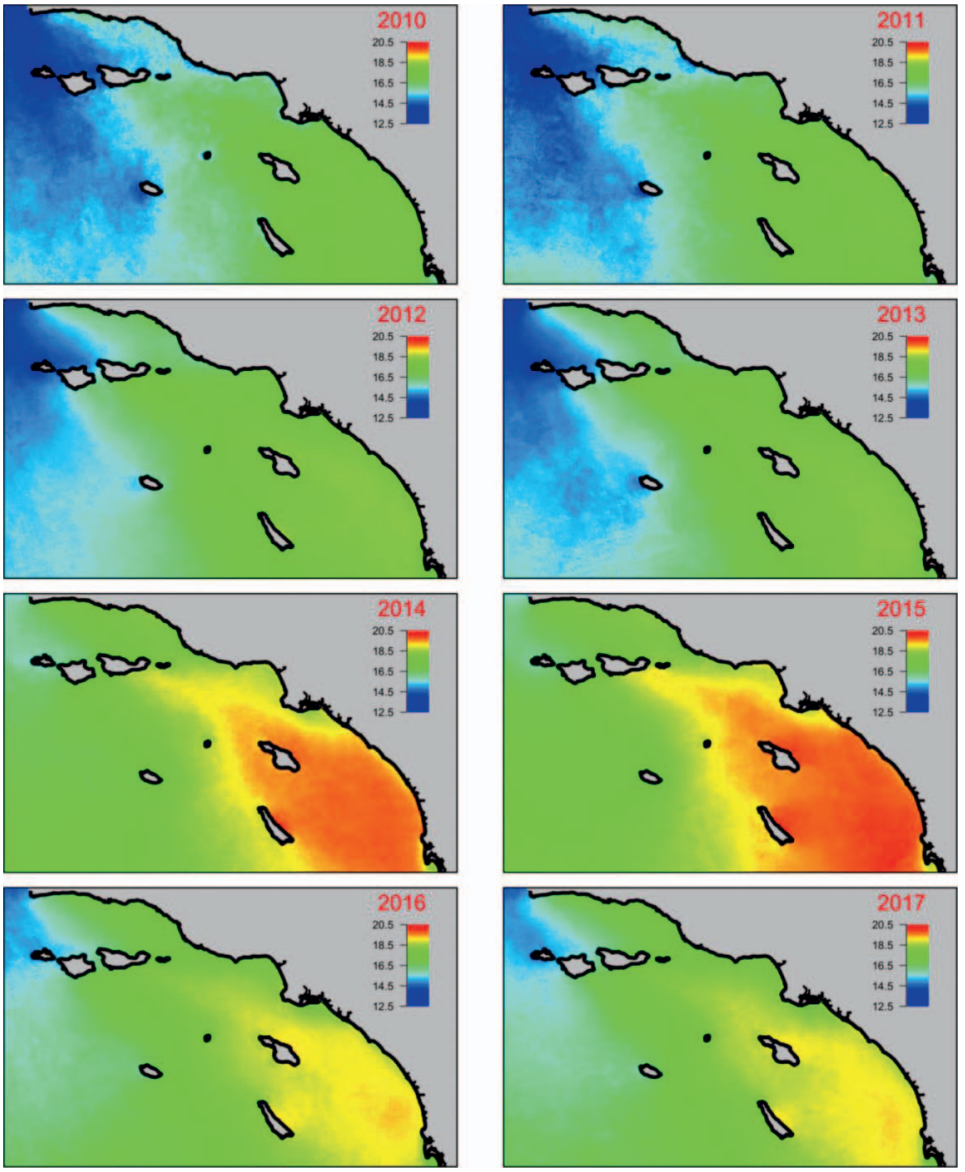

Fig. 2. Annual mean sea surface temperature data shown from 2010–2017. SST data were obtained from merged MODIS 1 km resolution data from MODIS-Aqua, MODIS-Terra, and VIIRS-NPP composited over 15-day intervals by the California Current Ecosystem Long-Term Ecological Research program based at Scripps Institution of Oceanography (available from: http://www.wimsoft.com/CAL/).

and Shallow Rock Ecosystems monitoring was performed by the Vantuna Research Group (VRG) at Occidental College and the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). At each site fish, invertebrates, and algae were surveyed by divers using band transects and/or benthic point contact surveys at various depths (3-30m) on rocky

Table 1. List of species with descriptions of previously described range limits, new localities, direction and scale of range extension, and categorizations for classifying overall confidence in potential range extensions, following rapid-assessment classification trees in Robinson et al. (2015). "Present in Winter" classification from Robinson et al. (2015) was replaced with "Anti-forcing Presence" (e.g. found north of previously described limits during a below average SST year) to reflect oscillation of oceanographic conditions during the study period. Y = Yes, N = No, H = High, M = Moderate, L = Low, S = Strong, W = Weak.

Species	Previous Limit	Extension Direction	New Locality	Scale of Extension	Boundary Confidence	Mobility	Multi-year Presence	Anti-forcing Presence	Detectability	Strength of Consistency	Overall Confidence
Analipus japonicus	Point Conception, CA	South/ Island	Crook Point, San Miguel Island, CA	50 km; first Channel Island Nat'l Park record	H	L	N	Y	L	M	M
Desmarestia dudresnayi subsp. *foliaceae*	Monterey Bay, CA	South	Resort Point, Palos Verdes, CA	500 km	H	L	Y	N	L	M	M
Saccharina latissima	Santa Catalina Island, CA	South	Matlahuayl State Marine Reserve, La Jolla, CA	100 km	H	L	N	N	L	W	L
Nereocystis luetkeana	Point Conception, CA	South	Castle Rock, San Clemente Island, CA	225 km	H	L	N	Y	H	W	L
Odonthalia floccosa	Government Point, CA	South	Crystal Cove, Laguna Beach, CA	250 km	H	L	N	Y	L	M	M
Osmundea sinicola	Santa Cruz Island, CA	North	Coal Oil Point, CA	40 km	H	L	N	N	L	W	L
Polymastia pacifica	San Nicolas Island, CA	Mainland	Long Point, Palos Verdes, CA	First mainland record for SCB	L	L	N	N	H	W	L
Trikentrion helium	San Onofre, CA	North	Ridges, Palos Verdes, CA	100 km	L	L	Y	Y	H	S	L
Schuchertinia milleri	Southern CA	South	Long Point, Palos Verdes, CA	unknown	L	L	Y	Y	H	S	L
Savalia lucifica	Santa Catalina Island, CA	North	Abalone Cove, Palos Verdes, CA	30 km	H	L	Y	Y	H	S	H
Lovenia cordiformis	San Pedro, CA	North	KOU Rock, Palos Verdes, CA	5 km	H	L	N	N	L	W	L
Ophionereis annulata	San Pedro, CA	North	Honeymoon Cove, Palos Verdes, CA	15 km	H	L	N	N	L	W	L
Hyporhamphus rosae	Santa Ana River, CA	North	Marina del Rey, CA	60 km	H	L	N	N	H	W	L
Isopsetta isolepis	Ventura, CA	South	Cabrillo Beach, San Pedro, CA	110 km	H	L	N	N	L	W	L

reefs.[2] These 145 sites were surveyed between one and eight times from 2011–2017 with each survey covering between 240 m^2 and 960 m^2 depending on the reef's depth range. Rocky Intertidal Ecosystems monitoring was performed by the University of California Santa Barbara, the University of California Santa Cruz, California State University Fullerton, Cal Poly Pomona, and NOAA Channel Islands Marine Sanctuary. This monitoring program also utilized band transects as well as quadrats to survey invertebrate and algal species.[3] These 39 sites were each surveyed a single time from 2012–2013, covering between 100 m^2 and 1,800 m^2 depending on the land-to-ocean length of the rocky intertidal area. Sandy intertidal areas were sampled sporadically for fishes by students at Occidental College using a 30-m × 1.8-m beach seine equipped with a 1.8-m × 1.8-m × 1.8-m bag (1.2-cm mesh wings and 0.6-cm mesh in bag) at a depth of 0-2 m. The five survey locations were each sampled annually from 2011–2017 with estimates of total areal sampling at each site ranging from 974 m^2 to 8,766 m^2. For each species range extension reported below, photographs were taken and/or voucher specimens were collected and curated into the museum collection at the Moore Laboratory of Zoology at Occidental College. Additionally, levels of confidence in potential range extensions were assigned to each species using the rapid-assessment classification described in Robinson et al. (2015), modified to reflect the multi-directional nature of this collection of extensions, sampling methodology, lack of seasonal variation and/or repeated sampling for some methods, and strong forcing from oceanographic conditions (Table 1).

Results

Kingdom Chromista
Phylum Ochrophyta
Class Phaeophyceae
Order Ralfsiales
Family Ralfsiceae

Analipus japonicus (Harvey) Wynne – sea fir

Previous reported range.—Japan (Okamura 1936) north to Alaska, south to Point Conception, CA (Abbot and Hollenberg 1976).

New record.—Crook Point, San Miguel Island, CA

Remarks.—This is the first record of this species inside Channel Islands National Park, and this range extension to the south represents the first observations of this species within the Southern California Bight.

Order Desmarestiales
Family Desmarestiaceae

Desmarestia dudresnayi subsp. *foliaceae* (Pease) Peters, Yang, Küpper and Prud'Homme van Reine (Fig. 3a).

[2] Pondella, D. J., J. E. Caselle, J. T. Claisse, J. P. Williams, K. Davis, C. M. Williams, and L. A. Zahn. 2015. South Coast baseline program final report: Kelp and shallow rock ecosystems. California Sea Grant, San Diego, CA. 224 pp.

[3] Blanchette, C. A., P. T. Raimondi, R. Gaddam, J. Burnaford, J. Smith, D. M. Hubbard, J. E. Dugan, J. Altstatt, and J. Bursek. 2015. Baseline characterization of the rocky intertidal ecosystems of the South Coast Study Region. California Sea Grant, San Diego, CA. 120 pp.

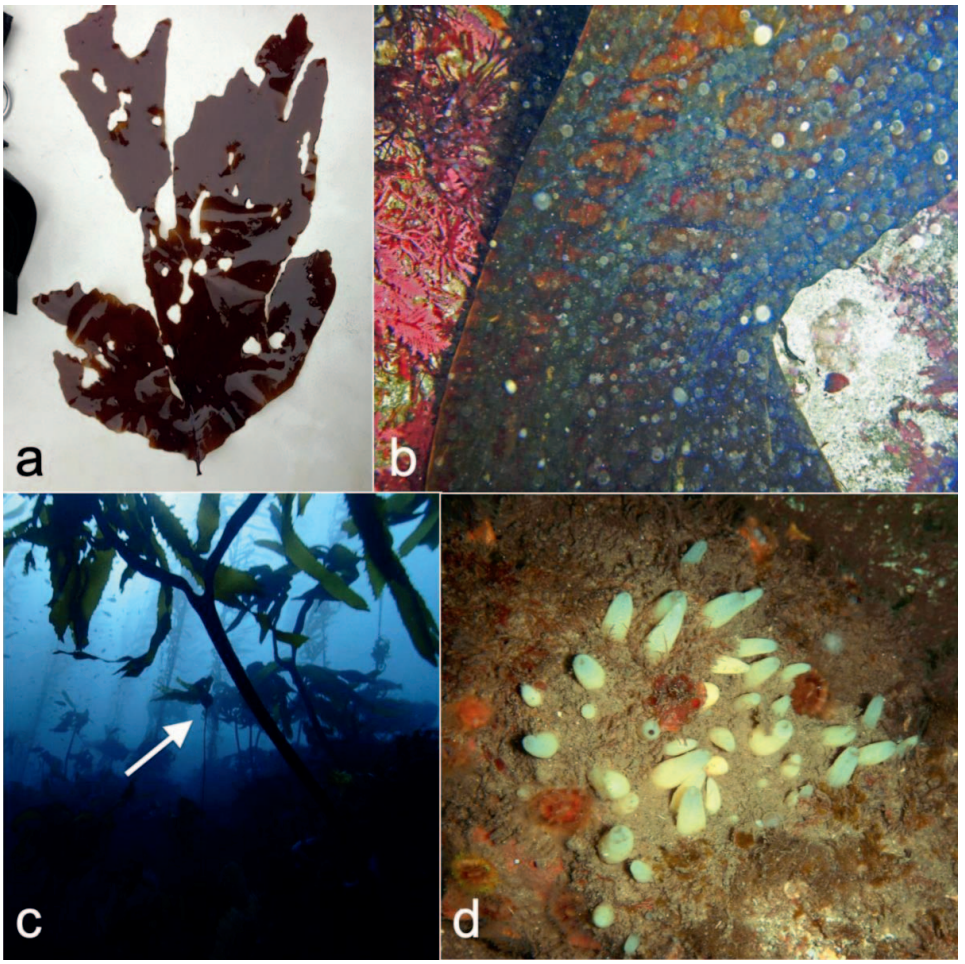

Fig. 3. (a) *Desmarestia dudresnayi* subsp. *foliaceae* from Cairns, Palos Verdes, CA at 5 m depth on 16 October 2015; (b) sugar kelp (*Saccharina latissima*) from Matlahuayl State Marine Reserve, La Jolla, CA at 10 m depth on 15 October 2011; (c) bull kelp (*Nereocystis luetkeana*; white arrow) from Castle Rock, San Clemente Island, CA at 23 m depth on 21 December 2012; (d) aggregated nipple sponge (*Polymastia pacifica*) from Long Point, Palos Verdes, CA at 20 m depth on 12 August 2011. Photos by J.P. Williams.

Previous reported range.—British Columbia, Canada to Monterey Bay, CA (Scagel et al. 1989).

New record.—Cairns (between Whites Point and Point Fermin), Palos Verdes, CA; 5 m depth; 16 October 2015.

Remarks.—These records represent a substantial range extension of approximately 500 km to the south. Individuals were also found at Honeymoon Cove, Palos Verdes on 2 July 2014 and Resort Point, Palos Verdes on 12 August 2014 (both at 10 m depth).

Order Laminariales

Family Laminariaceae

Saccharina latissima (Linnaeus) Lane, Mayes, Druehl and Saunders, sugar kelp (Fig. 3b)

Previous reported range.—Circumboreal south to Santa Catalina Island, CA (Scagel et al. 1989).

New record.—Matlahuayl State Marine Reserve, La Jolla, CA; 10 m depth; 15 October 2011.

Remarks.—We observed many individuals at this site during a particularly cold (8ºC) period of time, and represents a greater than 100 km range extension to the south.

Nereocystis luetkeana (Mertens) Postels and Ruprecht – bull kelp (Fig. 3c)

Previous reported range.—Kamchatka Peninsula (Klochkova et al. 2009), Commander Islands (Selivanova and Zhigadlova 1997), Alaska (Abbott and Hollenberg 1976) south to Point Conception, CA (Vadas 1972).

New record.—Castle Rock, San Clemente Island, CA; 23 m depth; 21 December 2012.

Remarks.—A single immature individual approximately 2 m in height was found mixed in giant kelp (*Macrocystis pyrifera*) with southern sea palm (*Eisenia arborea*). While drifted individuals have been observed as far south as San Diego, this observation of an attached individual represents a greater than 200 km range extension to the south and the first record of this kelp in the SCB. Castle Rock is a rocky spine that protrudes from the northwest tip of San Clemente Island and is subject to strong currents from the north. Vadas (1972) posited that water south of Point Conception is too warm for gametophyte fertility and young sporophyte growth, suggesting that this individual is likely a singleton and not part of a sustained range expansion.

Kingdom Plantae
Phylum Rhodophyta
Class Florideophyceae
Order Cermiales
Family Rhodomelaceae

Odonthalia floccosa (Esper) Falkenberg

Previous reported range.—New Caledonia (Payri 2007) and Japan (Yamada 1935) north to Alaska, south to Government Point, CA (Abbot and Hollenberg 1976; Masuda 1998).

New record.—Crystal Cove, Orange County, CA.

Remarks.—These records represent a range extension of nearly 250 km to the south.

Osmundea sinicola (Setchell and Gardner) Nam

Previous reported range.—Santa Cruz Island, CA to Isla Revillagigedo, Mexico, including Gulf of California (Abbot and Hollenberg 1976).

New record.—Coal Oil Point, Santa Barbara, CA.

Remarks.—This observation represents a small (~40 km) range extension to the north.

Kingdom Animalia
Phylum Porifera
Class Demospongiae
Order Polymastiida
Family Polymastiidae

Polymastia pacifica Koltun, 1966, aggregated nipple sponge (Fig. 3d)

Previous reported range.—Aleutian Islands, AK to San Nicolas Island, CA (Gotshall 2005).

New record.—Long Point, Palos Verdes, CA; 20 m depth; 12 August 2011.

Remarks.—Not to be confused with the senior homonym *Polymastia pacifica* Lambe 1893. Found several individuals colonizing a boulder near sand/rock interface, mixed in with brown cup corals (*Paracyathus stearnsi*). May represent the first non-island record in the Southern California Bight.

Order Axinellida
Family Raspailiidae

Trikentrion helium Dickinson, 1945, mitten sponge (Fig. 4a)

Previous reported range.—Guerrero, Mexico to San Onofre, CA (Gomez et al. 2002; Luke 1998; Van Soest et al. 2012).

New record.—Ridges (north of Rocky Point), Palos Verdes Peninsula, CA; 17 m depth; 3 July 2013.

Remarks.—Recorded in many locations along Palos Verdes from 2010–2017 at depths of 15–25m, typically covered in fine sediment. Represents a range extension of nearly 100 km to the north, however there is some confusion over the taxonomic separation of this species and *T. catalina* that may muddle identification of individuals and therefore range descriptions. Identification confirmed with SEM images of spicules showing diagnostic triacts with only one spined ray (Figs. 4b and 4c).

Phylum Cnidaria
Class Hydrozoa
Order Anthoathecata
Family Hydractiniidae

Schuchertinia milleri (Torrey, 1902) – hedgehog hydroid (Fig. 5a)

Previous reported range.—British Columbia, Canada to Carmel, CA (Haderlie et al. 1980); listed as Southern California in Gotshall (2005) with many unpublished observations in Channel Islands National Park, San Nicolas Island and Begg Rock

New record.—Long Point, Palos Verdes Peninsula, CA; 13 m depth; 22 August 2012.

Remarks.—Several records from Palos Verdes in 2012 and 2013 from depths of 15-25 m. This species appears to be fairly common within the northern portion of the SCB, but observations at Palos Verdes Peninsula have not been reported.

Order Zoantharia
Family Parazoanthidae

Savalia lucifica (Cutress and Pequegnat, 1960), luminescent parazoanthid (Figs. 5b and 5c)

Previous reported range.—Santa Catalina Island, CA to San Benitos Islands, Mexico (Gotshall 2005).

New record.—Abalone Cove, Palos Verdes Peninsula, CA; 17 m depth; 27 March 2015.

Remarks.—Found frequently along the southern portion of Palos Verdes Peninsula where sedimentation heavily impacts reefs. Skeletons from deceased gorgonians are often the tallest remaining structures after sediment deposition and reef burial; these parazoanthids colonize nearly all of them. This location represents a range extension of about 30 km to the north.

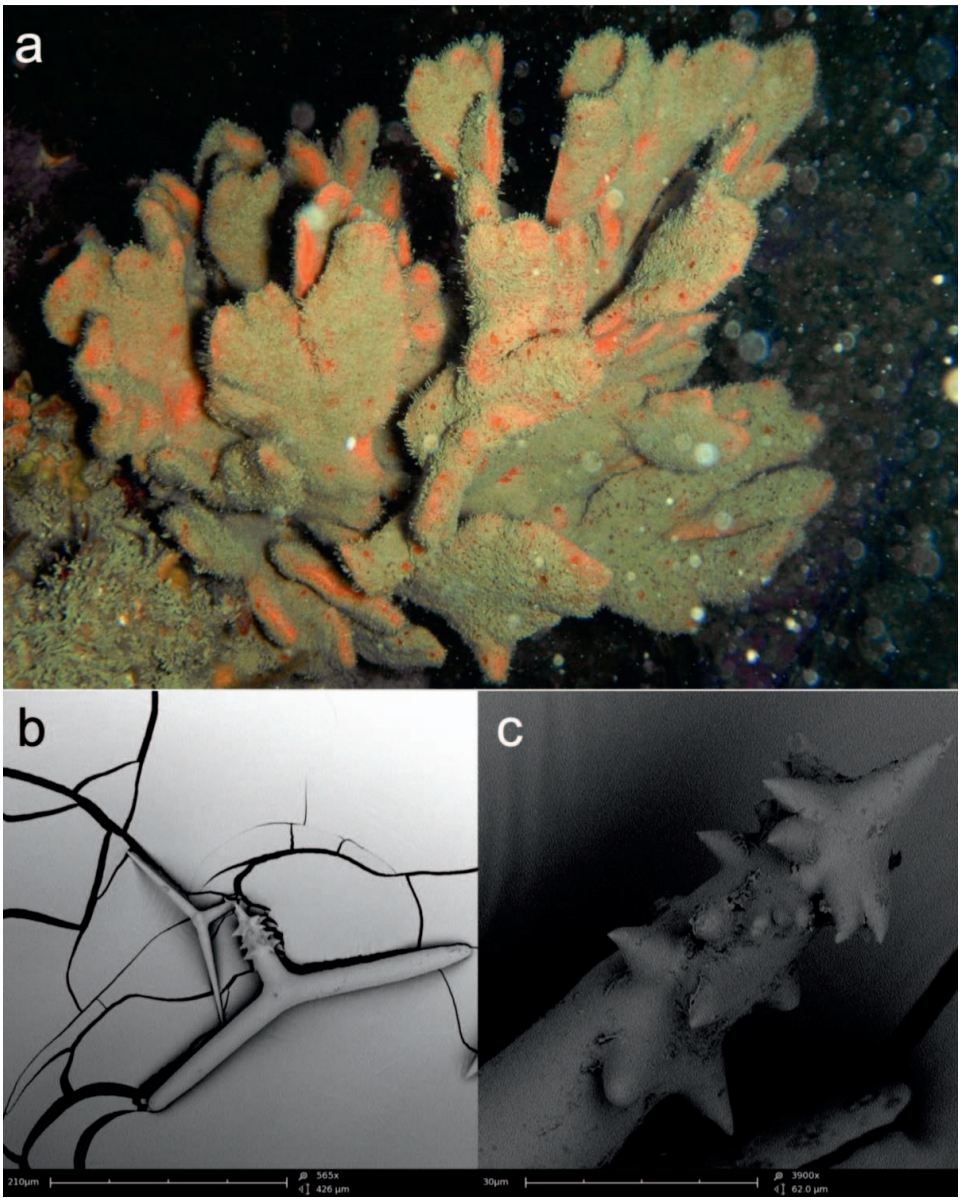

Fig. 4. (a) Mitten sponge (*Trikentrion helium*) from Ridges, Palos Verdes Peninsula, CA at 17 m depth on 3 Jul 2013. (b,c) SEM images of spicules from *T. helium* showing diagnostic triacts with only one spined ray. Photos and imaging by J.P. Williams.

Phylum Echinodermata
Class Echinodea
Order Spatangoida
Family Loveniidae

Lovenia cordiformis Agassiz, 1872, heart urchin (Fig. 5d)

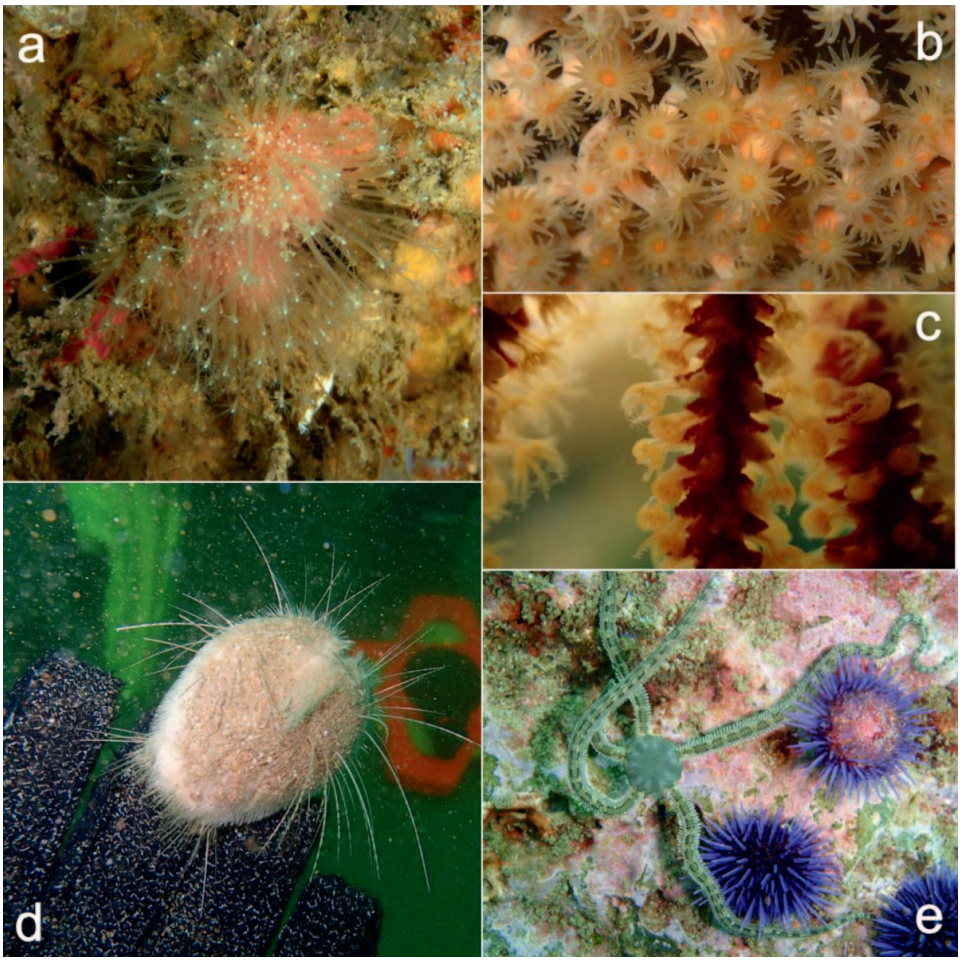

Fig. 5. (a) Hedgehog hydroid (*Schuchertinia milleri*) from Long Point, Palos Verdes Peninsula, CA at 13 m depth on 22 August 2012; (b) luminescent parazoanthid (*Savalia lucifica*) attached to the skeleton of a dead California gorgonian (*Muricea californica*; c) from Abalone Cove, Palos Verdes Peninsula, CA at 17 m depth on 27 March 2015; (d) heart urchin (*Lovenia cordiformis*) from KOU Rock, Palos Verdes Peninsula at 15 m depth on 2 October 2013; (e) ringed brittlestar (*Ophionereis annulata*) from Honeymoon Cove, Palos Verdes Peninsula at 5 m depth on 22 June 2016. Photos by J.P. Williams.

Previous reported range.—San Pedro, CA to Colombia and Galapagos Islands (Gotshall 2005; Muñoz and Lodoño Cruz 2016).

New record.—KOU Rock (between Bunker Point and Whites Point), Palos Verdes Peninsula, CA; 15 m depth; 2 October 2013.

Remarks.—This observation represents a very small range extension to the north, but also clarifies the limit as a coastal location rather than a city. The urchin was found buried in sand during buried reef sediment depth surveys when it was struck by an air jet probe.

Class Ophiuroidea
Order Ophiurida

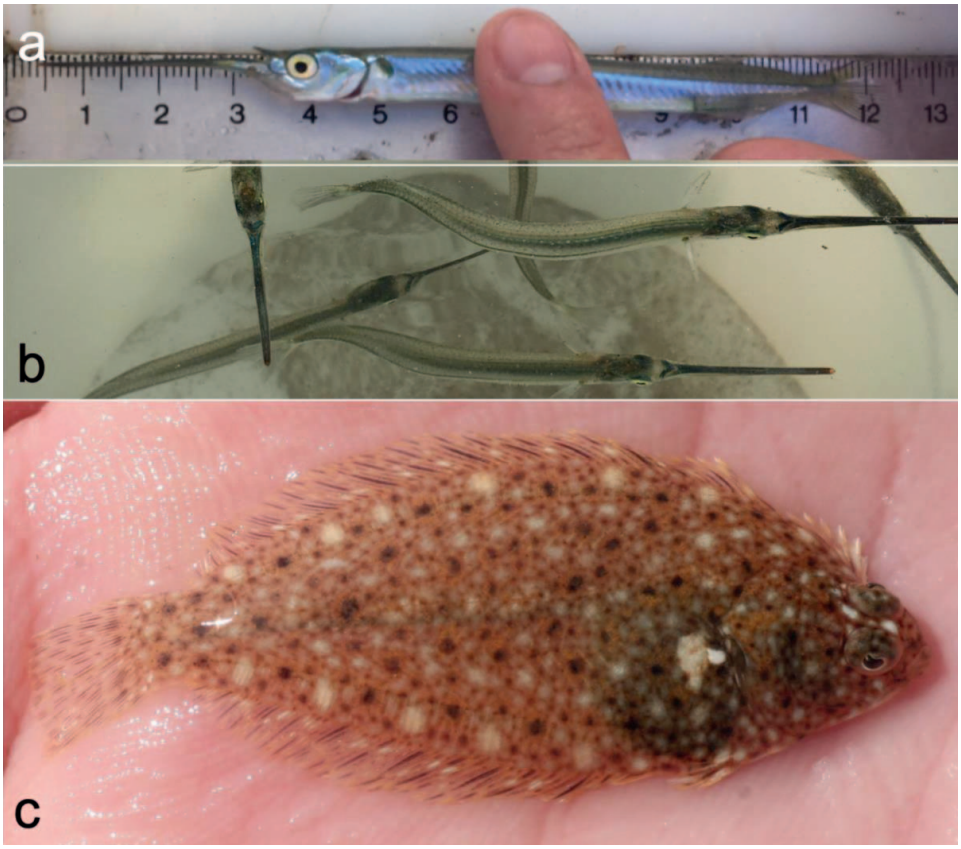

Fig. 6. (a) California halfbeak (*Hyporhamphus rosae*) from Mother's Beach, Marina del Rey, CA captured by beach seine on 24 October 2017 being measured (photo by D. Kirk) and (b) swimming in a bucket (photo by C. Pollock); (c) butter sole (*Isopsetta isolepis*) from Inner Cabrillo Beach, San Pedro, CA captured by beach seine on 2 April 2013. Photo by D.J. Pondella.

Family Ophionereididae

Ophionereis annulata (Le Conte, 1851), Ringed Brittlestar (Fig. 5e)

Previous reported range.—San Pedro, CA to Ecuador and Galapagos Islands (Ricketts and Calvin 1962).

New record.—Honeymoon Cove, Palos Verdes Peninsula, CA; 5 m depth; 22 June 2016.

Remarks.—These brittle stars were found sheltering underneath urchin spine canopy with mixed cobble, and represent a range extension of under 15 km, but also clarifies the limit as a coastal location rather than a city.

Phylum Chordata
Class Actinopterygii
Order Beloniformes
Family Hemiramphidae

Hyporhamphus rosae (Jordan and Gilbert, 1880), California halfbeak (Figs. 6a and 6b)

Previous reported range.—Santa Ana River, CA to Mazatlan, Mexico (Miller and Lea 1972).

New record.—Mother's Beach, Marina del Rey, CA; intertidal; 24 October 2017.

Remarks.—A total of 22 individuals from 7-13 cm SL were captured in four beach seining replicates during an Occidental College Biology 260 field trip, and represent a range extension of approximately 60 km.

Order Pleuronectiformes
Family Pleuronectidae

Isopsetta isolepis (Lockington, 1880), butter sole (Fig. 6c)

Previous reported range.—Ventura, CA to Southeastern Bering Sea and Aleutian Islands (west to Amchitka Island, AK) (Kramer et al. 2008).

New record.—Inner Cabrillo Beach, San Pedro, CA; intertidal; 2 April 2013.

Remarks.—A total of four juveniles (all approximately 3 cm SL) were captured in two beach seining replicates from a beach inside the Port of Los Angeles during an Occidental College Biology 356 field trip, and represent a range extension of approximately 110 km. All four individuals are stored in the museum collection in the Moore Laboratory of Zoology at Occidental College (VRG C39-2727).

Discussion

Fourteen species were observed and documented outside of their published range during these surveys including six algal species (five to the south, one to the north), six invertebrate species (one to the south, one to the mainland, and four to the north), and two fish species (one to the south, one to the north). The large-scale nature of these surveys in concert with the extended time frame of the monitoring programs (from the SCSR baseline through 2017) allowed for an extensive look at the nearshore subtidal and intertidal fauna in the region. The range extensions documented here are certainly, at least in part, a product of the large swings in oceanographic conditions throughout the SCB as evidenced by range extensions to both the north and south. The intensive, multi-agency, collaborative surveys performed as a product of MPA baseline monitoring provided greater opportunity for more thorough sampling of these habitats and a more accurate baseline for species distributions. We cannot be certain that these new locality observations are permanent and true range extensions, nor that they would not have been noticed in the past had there been similarly intensive sampling efforts. In fact, utilizing a modified version of a rapid assessment classification (Robinson et al. 2015) resulted in a high confidence for a true range extension only for *Savalia lucifica* (Table 1). Three macroalgal species were classified as moderately confident, while all other species were classified as low confidence. Large magnitude poleward shifts in species distributions are predicted for the west coast of North America in concert with strong, along-shore isotherm shifts (Morley et al. 2018), and with more frequent and expansive surveys being performed, further range extensions (in terms of distance and number) are expected in the near future.

Acknowledgments

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