

FEATURE

Citizen Science on the Beach: Grunion Greeters in California

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Volunteer Iris observes California Grunion *Leuresthes tenuis* as they climb onto a beach to bury eggs in the sand. Photo credit: L. Merwin.

Citizen scientist “Grunion Greeters” have proven to be effective monitors for beach-spawning runs of the California Grunion *Leuresthes tenuis*, for nearly two decades. This marine fish fully emerges from water to spawn on sandy beaches on the Pacific coast of California and Baja California. This spectacular display provides a rare nonconsumptive experience for the public with a wild fish. This native, endemic species rarely appears in trawls and does not take a hook, so population status is not possible to obtain by traditional fishery methods. In a unique recreational fishery, people capture these fish with bare hands on the sand, but no catch report is required. Volunteer Grunion Greeters provide hyperlocal, detailed data that can be obtained no other way. Methods, lessons learned, and use of the data in management are explained. The Grunion Greeters discovered that California Grunion recently made a northward range extension, but are declining broadly across the core habitat. Active monitoring by citizen scientists has brought renewed attention to this charismatic, vulnerable fish, along with its first long-term data set and policies to increase protections.

BACKGROUND

How can one monitor the population of a charismatic but elusive fish that cannot be assessed by traditional fishery methods? With the help of thousands of volunteers, we developed a unique citizen science program, the “Grunion Greeters.” Direct observation of spawning runs provides hyperlocal, repeatable results that inform resource management across the habitat range, with data that can be obtained no other way. Results are repeatable and reliable, and have led to conservation policies that reduce human impacts on this endemic species.

Famous for its midnight runs, the California Grunion *Leuresthes tenuis* (Atherinopsidae) is an icon of southern California, the subject of popular evening programs for coastal aquariums. Celebrated in film, song, and story, this species is emblematic of California beach culture, surfing up from waves to spawn in beach sand. During some months of the season, children and licensed adults can legally capture the fish while they are out of water, using only their bare hands. No gear is ever allowed. This is a forage fish, and is used for bait and food by humans.

California Grunion emerge from waves to bury their eggs under sand, out of sight above the mean high tide mark (Figure 1). Runs occur within a 2-h window following a semilunar high tide after a full or new moon, always at night (Martin 2015). Because of their tidal synchrony, runs may be forecast, and a schedule of the likely runs is posted annually by the California Department of Fish and Wildlife for the benefit of the public.

Sandy beaches are essential fish habitat for California Grunion, the place where spawning occurs. Grunion eggs remain out of water, buried in moist sand throughout incubation, until the next semilunar tides release them and trigger hatching (Griem and Martin 2000). Beaches in California are heavily visited by the public and are subject to many human uses that create adverse impacts for wildlife (Defeo et al. 2009). One example is beach grooming, a form of mechanical maintenance of beaches by heavy equipment (Schooler et al. 2017). A tractor or loader pulls a rake to remove trash and wrack from a beach and smooth out the surface. Beach grooming has been done on many public beaches in California since the 1960s (Figure 2).



Figure 1. A spawning run of California Grunion. Fish emerge from waves at high semilunar tides to bury eggs under sand. Appearing in photo: P. Vasquez. Photo credit: V. Vasquez.



Figure 2. Beach grooming with heavy equipment disturbs the upper layer of sand on a beach. This practice is common along the coast of California to remove trash and natural debris. Photo credit: K. Martin.

The incident that triggered the formation of this citizen science project happened in 2001, when a resident of San Diego noticed a flock of birds following a maintenance tractor raking the beach. She observed the birds were consuming orange eggs that had been turned up by the tines, and correctly identified these as recently spawned eggs of the California Grunion (Martin et al. 2006). This citizen notified San Diego City Council member Scott Peters of her concern that beach grooming was harming the grunion population by destroying these eggs on the beaches. In response, he contacted a local environmental organization, Project Pacific, asking whether or not beach grooming could be harming grunion eggs. Author MS, Project Pacific's president, reached out to Jeffrey Graham and Richard Rosenblatt, ichthyologists at Scripps Institution of Oceanography (hereafter, Scripps). They said it was quite possible, and they had thought about the issue themselves.

Peters went to the full council and raised this concern about harm to the California Grunion. He called for a vote, directing Project Pacific to gather an expert panel to meet and discuss the issue. After the first panel meeting in May 2001, a newspaper ran an article that was seen by author KM, who did field research on grunion eggs. She contacted MS and asked to be involved. The panel included representatives from resource agencies, parks personnel, and city council staff, as well as scientists.

The panel met several more times over the next few weeks and determined a study was necessary. Project Pacific applied for a National Fish and Wildlife Foundation Challenge Grant with help from Graham and Rosenblatt and the City of San

Diego. Also, KM applied for a Rapid Response California Sea Grant. Both grants were awarded.

To understand the status of the grunion population in San Diego, it was clear that no one scientist or lab group could monitor the large area involved, with 10 sites and all runs occurring within the same 2-h period of night. Thus, to expand capacity, members of the public were invited to volunteer to be citizen scientists, dubbed the Grunion Greeters.

During the summer of 2001, Project Pacific conducted a pilot program to determine if volunteers could be recruited and organized to monitor grunion runs. They went to La Jolla, Pacific Beach, and Ocean Beach on several nights and collected very basic information about the runs, including an estimate of numbers in a prescribed area (Figure S1). This helped determine that working with volunteers was feasible; however, their data were inconsistent and few grunions were seen without training.

The population status of the California Grunion was unknown at that time (Sandrozinski 2013), because traditional fishery methods are not effective for this species. These planktivorous fish avoid trawl nets and fishing hooks, and are rarely seen, except when out of water during the spawning runs. They are the subject of a unique recreational fishery, caught using only bare hands (Clark 1926). However, there is no bag limit and no reporting requirement for the catch, so no data were available from that source.

PROJECT DESCRIPTION

Training workshops have been a feature of the Grunion Greeters program since the beginning. These cover the biology



Figure 3. Grunion Greeters observing spawning runs. (A) M. Lawler and C. Kilgallen. Photo credit: S. Hicks. (B) L. Audet. Photo credit: E. Ang.

of the grunion, the ecology of the sandy beach, the way to observe these fish with minimal disturbance, the method for reporting the data, and personal safety. Schedules for observation nights and times, beach maps, and detailed instructions are provided. Volunteers sign up for specific beach locations and nights, and then are reminded by email to go to the run and to report data online afterwards (Figure 3).

In March 2002, the first workshop to train volunteers was hosted by Birch Aquarium at Scripps. Because of the enormous response, a second workshop was held. Adult volunteers were recruited from the community by contact with environmental groups, the Birch Aquarium at Scripps, and local news outlets. Over 200 people responded to the initial call for volunteers. In the first year, Grunion Greeters received a windbreaker jacket as a small reward for three or more reports over the course of the observation season in April, May, and June (Figure 4). Volunteers were recruited from the community by contact with environmental groups, Birch Aquarium at Scripps, volunteer organizations, and local news outlets. Because runs always occur late at night, volunteers needed to be adults, able to work independently in teams of at least two people.

A metric, the Walker scale, was previously developed for comparing grunion runs over times and locations (Martin et al. 2021). This metric is incorporated into the training with photos and examples, providing a way to score the approximate number of fish on shore and the extent and duration of the peak of the run (Figure S2). Quality assurance protocols included comparisons of independent reports from volunteers at the same beach at the same time, and comparisons of reports from biologists with reports from volunteers (Martin et al. 2011). Reports can also be verified by assessing the ease of finding clutches of eggs buried on shore in the appropriate locations (Martin et al. 2021). Weather conditions, presence of predators or human hunters, specific locations, and timing of the runs are also reported to the online database (Figure S3). Statistics show that the Walker scale data are reliable and repeatable between experienced observers (Martin et al. 2021).

Since the start of the project in 2002, Grunion Greeters have reported their data online via a portal (www.grunion.org) linked to a database. This portal provides instant access to the data for the scientific team. The project website provides updated information, frequently asked questions, videos, and

other features to engage the public as well as recruit volunteers. During workshops, paper data forms are distributed and explained in detail.

Information on the website includes the regulations for the recreational fishery, and a link to the website for this species hosted by the California Department of Fish and Wildlife. A closed season during the peak spawning season provides some protection for these endemic fish. Contact information to report illegal take, poaching out of season, or any use of gear is posted, and game wardens respond to these tips.

In 2003, KM secured funds from California Sea Grant to continue and expand beyond the City of San Diego.



Figure 4. Certificate of participation, design by M. Studer, after a format by S. Hinton for B. Walker.

Additional grants and expansion continued over subsequent years to the present, most critically with major funding from the National Fish and Wildlife Foundation, the National Oceanic and Atmospheric Administration, and the National Marine Fisheries Service Southwest Region Habitat Conservation Division. This enabled the program to expand to most of the habitat range of the California Grunion, several hundred kilometers of coastline from Pt. Conception to upper Baja California, with the help of additional community partners.

By 2007, up to 10 workshops to train volunteers were held annually, in collaboration with local groups such as Birch Aquarium at Scripps, Aquarium of the Pacific in Long Beach, California, and Cabrillo Marine Aquarium in San Pedro, California; environmental organizations including Surfrider Foundation, Heal the Bay, Santa Barbara Channel Keepers, and Audubon Society; and colleges and universities. In general, training workshops are local and in-person with community partners, enhancing the sense of belonging. Organizations that hosted the training workshops also contributed to volunteer recruitment, along with additional community partners that publicized the trainings. Volunteers were recruited by newspaper articles, media interviews, and local colleges and universities that often gave extra credit for student participation in the program. Groups such as the Audubon Society invited MS to give lectures about grunion at local club meetings. As the program expanded, the term “Citizen Science” had become a popular trend. As a result, Websites such as Volunteer Match and SciStarter launched, providing additional options for recruitment. Other citizen science organizations formed and began conducting events, such as the Citizen Science Expo, providing venues to publicize the program to an interested audience. Ultimately, the most effective recruitment tool for volunteers was word of mouth by current volunteers.

When a spawning range extension of California Grunion was identified to San Francisco Bay in 2003 (Roberts et al. 2007; Martin et al. 2013), additional workshops farther north taught Grunion Greeters to seek new locations. By 2022, over 5,000 volunteers attended a Grunion Greeter workshop at locations from Imperial Beach to San Francisco Bay (Table 1), with thousands of reports from more than 50 beaches.

The data form questionnaire is linked on the website and publicly accessible. Thus, reports have come in from some people that did not undergo in-person training. All respondents must provide contact information, so that data can be verified by email or phone conversations, or site visits to assess nest presence, if necessary. Follow-up phone calls and emails are generally made within 1 week of the report. Reports are rejected if incomplete or unverifiable. An infographic of the Walker scale is posted on the website, and a link to the publication with the complete description of the method (Martin et al. 2021) is on the same webpage as the data questionnaire link.

In recent years, in-person training workshops have not been possible. During the pandemic in 2020, training moved online with videos on the website, and the website links to the run schedule. Greeters can join an email distribution list to be reminded of forecast run dates and times. This is an efficient method for training new volunteers and refreshing past participants, but it does not provide the high levels of commitment and engagement seen with in-person communications.

Long-term sustainability of the program depends on funding for hosting the website, survey access, and the expenses of a small nonprofit association. The staff contribute many

Table 1. Workshop locations and community partners span the habitat range of the California Grunion, providing local engagement.

County	City	Workshop Host
San Diego	San Diego	Birch Aquarium at Scripps Institute of Oceanography
	Cardiff	Mira Costa College
	Oceanside	Buena Vista Audubon Society
	Imperial Beach	Tijuana Estuarine Research Reserve
Orange	Newport Beach	Muth Interpretive Center
	Dana Point	Ocean Institute
	Irvine/Costa Mesa	Surfrider Foundation, Orange County Chapters
Los Angeles	Long Beach	Aquarium of the Pacific
	San Pedro	Cabrillo Marine Aquarium
	Santa Monica	Heal the Bay, Santa Monica Pier Aquarium
	Malibu	Pepperdine University
Ventura	Oxnard	Ventura Community College Marine Center
Santa Barbara	Santa Barbara	Santa Barbara Channel Keepers
		Marine Science Institute, University of California Santa Barbara
Monterey	Pacific Grove	Pacific Grove Museum
		Monterey Bay Aquarium Research Institute
Contra Costa	Oakland	Port of Oakland
Alameda	Alameda	East Bay Regional Parks District

volunteer hours, and are paid only when grant funds are available. Expenses for printing educational materials and web hosting have often been supplied by Pepperdine University in support of public outreach and research. Necessary expenses also include management and tracking of volunteers, and data analysis and archives. In-person workshops generate higher levels of participation and more data, but have greater expenses for printing, refreshments, and travel, even though locations and local support are typically donated by community partners.

USE IN MANAGEMENT:

- (1) *Beach Grooming Practices.* The concern the citizen had initially about the effects of beach grooming on grunion eggs was confirmed, that the practice destroys grunion eggs on the beach (Martin et al. 2006). The beach manager in San Diego, Dennis Simmons, and his crew provided field assistance during the study. His response to the results was to develop new protocols for use during grunion season that avoid mechanized maintenance below the semilunar high tide line. This practice was explained, along with its purpose, to his staff of equipment operators in a training session with the coauthors of this paper. Beach grooming has since been evaluated more critically by many municipalities and resource managers for additional negative ecological impacts (Schooler et al. 2017). The Grunion Grooming Protocol is now standard practice in most coastal areas of California during grunion season.
- (2) *Outreach to Beach Managers.* The changes that protected grunion nesting sites inspired Simmons to consider

other ways that beach management practices could be more ecologically sensitive. He began to communicate with beach managers nearby, along with resource managers, and other scientists that work on beaches. Seeing the effectiveness of collaboration within this network of diverse stakeholders, Simmons and author KM founded a nonprofit educational organization, the Beach Ecology Coalition (<http://www.beachecologycoalition.org>), to connect beach managers, equipment operators, lifeguards, resource managers, ecologists, and environmental activists. The group meets twice a year at different locations along the California coast to share scientific information, effective management solutions, and topics of shared interest such as sea level rise, sand replenishment projects, beach-dependent species, and mitigation for extreme weather events. The group provides a collegial setting for diverse stakeholders to discuss issues and common concerns with current, relevant data in a nonconfrontational way, a form of translational science (Martin et al. 2022).

- (3) *Best Management Practices.* The Beach Ecology Coalition is composed of many experts and practitioners, facilitating collaborations and problem solving. Best management practices for beaches have been developed, reviewed, and posted so they can be incorporated into many beach management programs.
- (4) *Permitting for Coastal Construction Projects.* Methods for mitigation and monitoring for grunion nests are used by the California Coastal Commission, the California State Lands Commission, and local, state and federal resource agencies in evaluation and permitting coastal construction projects (King et al. 2018). The Walker scale monitoring method developed with the Grunion Greeters (Martin et al. 2021) is now used by professional biological monitors and the U.S. Army Corps of Engineers for mitigation in beach sand projects. These observations by consultants are also contributed to the Grunion Greeter database (Martin and Adams 2020).
- (5) *Recreational Fishing Regulations.* Grunion Greeter data accumulated over two decades are the only long-term data set for adults of this species. The only other population data comes from scarce larval captures in manta tows (Nishikawa et al. 2019) or power plant entrainment (Miller and McGowan 2013). In recent years the data show a decline in the size of grunion spawning runs over much of the habitat range (Martin et al. 2020a). In 2019, a petition was submitted by the authors to the California Fish and Game Commission to increase protection of this endemic species from recreational take by lengthening the closed season and adding bag limits. Hundreds of Grunion Greeters contributed signatures and public comment in support of these changes. In 2022, the Game Commission voted unanimously in favor of these added protections, helping to preserve this natural spectacle and further validating the contributions of citizen science to management.
- (6) *Oil Spills and Damage Assessment.* Grunion Greeter data were used to inform response to the Cosco Busan fuel oil spill in San Francisco Bay in 2007 and the Refugio Beach Oil Spill from a pipeline rupture in 2016. In both cases, significant impacts to California Grunion were seen after these toxic spills (Martin et al. 2020b).

LESSONS LEARNED/BEST PRACTICES

The following are some of the practices we find most useful in working with citizen scientists.

- *Data must be relevant.* Data gathered by nonprofessional citizen scientists are sometimes devalued or considered less accurate than more traditional forms of scientific inquiry. The Grunion Greeter program benefited from the start with high credibility from the early, consistent participation of many academic scientists, along with well-regarded community partners, such as the Birch Aquarium at Scripps and volunteer-focused environmental organizations (Table 1). The cooperation of the City of San Diego, both from the beach maintenance department and the City Council, were critical for the success of the initial study verifying the problem, and for the willingness to find an appropriate solution. Over the years, reliance on Grunion Greeter data by government agencies and resource managers increased the impact of the program and showed the importance of volunteer contributions to provide otherwise unobtainable data.
- *Effective education for volunteers improves results.* Training volunteers improves the quality of data and the commitment of the participants. Ideally, volunteers attend refresher training annually, both for current information and for the social connections formed.
- *Request data that volunteers can provide accurately.* Many years of working with volunteers has honed our data questionnaire and explanations to be as clear and intuitive as possible. Our data questionnaire was developed over time to elicit the most reliably repeatable observations. Some questions of interest to the scientists, for example wave type or height, were difficult for nonscientists to evaluate, and the results were not useful. It is important to consider the abilities of both novices and experienced observers.
- *Simplify data submission.* Initially we found it took more effort to get volunteers to submit data after the runs, than to get them out on the beach in the first place. The current questionnaire can usually be filled out within 5 min on any computer, or even a smartphone at the beach. Always, incomplete or inconsistent data are either checked with a follow-up conversation, or rejected from further analysis.
- *Engaged volunteers commit to action.* Volunteers are engaged during grunion season in multiple ways, via workshops, webpages, videos, personal and group emails, and social media such as Facebook and Instagram, and in partnership with local community organizations. Frequent messages and feedback are important for maintaining enthusiasm for this project that requires volunteers to lose sleep, go independently out in the dark, and watch for a phenomenon that may or may not happen. In addition to group emails, individual responses to volunteers from the project leaders are usually answered within 24h. Many Grunion Greeters have volunteered over multiple nights and years. The importance of recognition, clear information, appreciation, and encouragement are vital for continued participation.
- *Rewards are a powerful incentive for participation.* When funding allows, volunteers receive a reward such as a T-shirt, travel mug, baseball cap, or other token for their participation. Most volunteers state that the rewards are unimportant to them, that they value the opportunity to contribute to the sustainability of sandy beaches, and in-



Figure 5. (Top left to right) Grunion Greeter logos and gear generate enthusiasm among volunteers. (Bottom left) R. Pearson and G. K. K. Mata. Photo credit: K. Martin. (Bottom right) S. Corbett. Photo credit C. Lindeman.

creased ecological knowledge is sufficient reward. Nevertheless, participation for multiple nights greatly improves when a reward is offered. A certificate is given in recognition to all participants annually (Figures 4, 5).

- *The need for safety is paramount.* The nighttime observation activity can be social and fun, but carries risks for the volunteers, who are outdoors on their own on a dark beach. Safety is always our highest priority. Fortunately, there have been no serious safety incidents over the years, but constant reminders are sent to the volunteers to maintain awareness of the surroundings and leave immediately if they feel unsafe.
- *Experience with participatory science leads to stewardship.* Volunteers feel respected, knowing their efforts and data directly contributed to scientific research, species protection, and management policy change for the better. Grunion Greeters became remarkable stewards for not only grunion, but for sandy beach ecosystems. They also became involved in local beach management issues.

CONCLUSIONS

- Volunteers are not “free,” but they are cost effective. They can vastly increase the geographic scope and impact of a project.
- Grunion Greeters provide hyperlocal, reliable data that can be obtained no other way, on a species that cannot be monitored by traditional fishery methods.
- Regular engagement of volunteers maintains enthusiasm with updates and refreshers for methods.
- Use of citizen science data by resource managers and government agencies validates the efforts of the volunteers.

NEXT STEPS

Long-term sustainability of the program depends on local stakeholder involvement of advocates and practitioners. Expenses include educational materials, web hosting, and management of volunteers and data. Project leaders contribute many volunteer hours, paid only when grant funds are available.

Increased interest in beach ecology is gratifying but it comes with heightened awareness of threats and concerns about habitat loss. California Grunion have been named a Key Indicator Species for climate change on beaches for California's Marine Protected Areas. Progress on management policies, scientific publications, and other effective use of data gathered are important to communicate to volunteers to maintain engagement with the public and stakeholders. It is indisputable that the detailed, hyperlocal long-term dataset for this endemic fish, the California Grunion, would not be possible without the dedication of thousands of volunteers, the Grunion Greeters.

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REFERENCES

Clark, F. N. 1926. Conservation of the grunion. *California Fish and Game* 12:163–166.

Defeo, O., A. McLachlan, D. S. Schoeman, T. A. Schlacher, J. Dugan, A. Jones, et al. 2009. Threats to sandy beach ecosystems: a review. *Estuarine Coastal and Shelf Science* 81:1–12.

Griem, J. N., and K. L. M. Martin. 2000. Wave action: the environmental trigger for hatching in the California grunion *Leuresthes tenuis* (Teleostei: Atherinopsidae). *Marine Biology* 137:177–181.

King, P. G., C. Nelsen, J. E. Dugan, D. M. Hubbard, and K. L. Martin. 2018. Valuing beach ecosystems in an age of retreat. *Shore and Beach* 86:1–15.

Martin, K. L. M. 2015. Beach spawning fishes: reproduction in an endangered ecosystem. Taylor and Francis Group, CRC Press, Oxford, UK.

Martin, K., T. Speer-Blank, R. Pommerening, J. Flannery, and K. Carpenter. 2006. Does beach grooming harm grunion eggs? *Shore and Beach* 74:17–22.

Martin, K. L. M., and L. C. Adams. 2020. Case study: effects of repeated sand replenishment projects on runs of a beach-spawning fish, the California Grunion. *Journal of Marine Science and Engineering* [online serial] 8:178. Available: <https://bit.ly/3xZ7usZ> (June 2022).

Martin, K. L. M., K. A. Hieb, and D. A. Roberts. 2013. A southern California icon surfs north: local ecotype of California Grunion *Leuresthes tenuis* (Atherinopsidae) revealed by multiple approaches during temporary habitat expansion into San Francisco Bay. *Copeia* 2013:729–739.

Martin, K. L. M., C. L. Moravec, A. D. Martin, and R. D. Martin. 2011. Community based monitoring improves management of essential fish habitat for beach spawning California Grunion. Pages 65–72 in A. Bayed, editor. *Sandy beaches and coastal zone management. Proceedings of the Fifth International Symposium on Sandy Beaches*, Rabat, Morocco.

Martin, K. L. M., E. A. Pierce, V. V. Quach, and M. Studer. 2020a. Population trends of beach-spawning California Grunion *Leuresthes tenuis* monitored by citizen scientists. *ICES Journal of Marine Science* 77:2226–2233.

Martin, K. L. M., D. R. Reed, D. J. Simmons, J. E. Steers, and M. Studer. 2022. The beach ecology coalition: enhancing ecosystem conservation and beach management to balance natural resource protection and recreational use. Pages 232–250 in S. M. F. Ferreira and S. C. G. Fernandes, editors. *Sandy beaches as endangered ecosystems: environmental problems and possible assessment and management solutions*. Taylor and Francis, CRC Press, Oxford, UK.

Martin, K. L. M., M. Schaadt, and S. Lawrenz-Miller. 2021. The Walker scale: details of a method for assessing beach-spawning runs of California Grunion *Leuresthes tenuis* (Atheriniformes: Atherinopsidae). *Ichthyology and Herpetology* 109:940–948.

Martin, K. L. M., D. Witting, and R. Donohoe. 2020b. The 2015 Refugio Beach oil spill. Field and laboratory assessment of injury to California Grunion *Leuresthes tenuis*. Appendix G-2 in Refugio Beach Oil Spill Trustees, editors. *Refugio Beach oil spill draft damage assessment and restoration plan/environmental assessment*. California Department of Fish and Wildlife, California State Lands Commission, California Department of Parks and Recreation, Regents of the University of California, U.S. Department of the Interior, U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration. Available: <https://bit.ly/3Npu8jW> (June 2022).

Miller, E., and M. McGowan. 2013. Faunal shift in southern California's coastal fishes: a new assemblage and trophic structure takes hold. *Estuarine, Coastal and Shelf Science* 127:29–36.

Nishikawa, H., E. N. Curchitser, J. Fiechter, K. A. Rose, and K. Hedstrom. 2019. Using a climate-to-fishery model to simulate the influence of the 1976–1977 regime shift on anchovy and sardine in the California Current System. *Progress in Earth and Planetary Science* [online serial] 6:article 9. Available: <https://bit.ly/3yhj66n> (June 2022).

Roberts, D., R. N. Lea, and K. L. M. Martin. 2007. First record of the occurrence of the California Grunion, *Leuresthes tenuis*, in Tomales Bay, California; a northern extension of the species. *California Fish and Game* 93:107–110.

Sandrozinski, A. 2013. California Grunion. Status of the fisheries report, an update through 2011. California Department of Fish and Wildlife, Sacramento.

Schooler, N. K., J. E. Dugan, D. M. Hubbard, and D. Straughan. 2017. Local scale processes drive long-term change in biodiversity of sandy beach ecosystems. *Ecology and Evolution* 7:4822–4834.

SUPPORTING INFORMATION

Additional supplemental material may be found online in the Supporting Information section at the end of the article.

Figure S1 Data form used by initial volunteers to assess grunion runs in 2001, developed by Project Pacific. Data were not easily obtainable or comparable. This was discarded after one summer.

Figure S2 The Walker scale ranks grunion spawning runs according to the density of fish on the beach, the extent of the beach involved in the run, and the duration of the run. The scale is relatively easy to understand by volunteers and has been vetted over 20 years with Grunion Greeters and scientists. This Figure was previously published in *Ichthyology and Herpetology*, Martin et al. 2021.

Figure S3 Data form in use by Grunion Greeters, providing locality, weather conditions, Walker scale rankings, and information about various activities or conditions that could affect the runs. Available: www.grunion.org (July 2022). 