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Community based monitoring improves management of essential fish habitat for beach spawning California Grunion

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Abstract. California Grunion *Leuresthes tenuis*, a beach-spawning silverside teleost fish, spawns during tidally synchronized runs following the highest tides of new and full moons. The location of nests on heavily used urban beaches of southern California makes this endemic fish vulnerable to numerous human activities, including beach grooming, sand replenishment projects, desalination facilities, and coastal construction. These elusive fish cannot be assessed by typical fishery monitoring methods. In order to accurately assess the population, since 2002 spawning runs of *L. tenuis* have been monitored with the help of trained citizen scientist observers, called the Grunion Greeters. A web-based data acquisition system allows remote observers to assess spawning runs on local beaches and then report data through the internet. Data can be accessed instantaneously by the scientific team and shared with beach managers and stakeholders. This involvement of local citizen scientists in habitat monitoring has increased public awareness of beach biology and sensitivity to ecological concerns in beach management. Data are used for planning, adaptive management, and mitigation of impacts. The large long-term dataset also provided critical information about this endemic species and its essential fish habitat of spawning and incubation sites on sandy beaches. Beach spawning fish species occur worldwide; local monitoring and conservation efforts on behalf of these charismatic species may be a powerful method for increasing habitat protection and conservation of sandy beaches.

Key words: beach spawning, intertidal, monitoring, citizen science, recreational fisheries.

Résumé. ***Participation de la population dans l'amélioration de la gestion de l'habitat poisson pour les frayères de plage.*** Le Grunion de Californie *Leuresthes tenuis*, poisson téléostéen frayant sur la plage, fraie de façon synchronisée avec les plus hautes pleines mers qui surviennent aux nouvelles et pleines lunes. L'emplacement des nids sur les côtes urbaines de la Californie du sud intensivement utilisées rend ce poisson endémique vulnérable aux nombreuses activités humaines, y compris le nettoyage mécanisé des plages, des projets de remplissage de sable, des installations de dessalement et la construction côtière. Ces poissons élusifs ne peuvent pas être évalués par les méthodes typiques de suivi des pêcheries. Pour pouvoir évaluer la population, depuis 2002 les fraies de *L. tenuis* ont été suivies avec l'aide de citoyens observateurs scientifiques formés, dénommés "Grunion Greeters". Un système d'acquisition de données basé sur l'utilisation du Web permet aux observateurs éloignés (à distance) d'évaluer les phénomènes de fraie sur les plages locales et rapporter ensuite les données par Internet. Les données peuvent être accessibles instantanément par l'équipe scientifique et partagées avec les gestionnaires des plages et les parties prenantes. Cette participation des citoyens scientifiques locaux dans le suivi de l'habitat a augmenté la conscience publique de la biologie de la plage et la sensibilité aux préoccupations écologiques dans la gestion des plages. Les données sont utilisées pour la planification, gestion adaptée et réduction des impacts. Le grand ensemble de données à long terme a aussi fourni des informations importantes sur cette espèce endémique et sur son habitat essentiel dans les sites de fraie et d'incubation sur les plages sableuses. Les espèces de poisson frayant sur les plages sont présentes dans le monde entier; le suivi local et les efforts de conservation à travers ces espèces charismatiques peuvent être une méthode puissante pour augmenter la protection de l'habitat et la conservation des plages sableuses.

Mots clés : Ponte de plage, intertidal, suivi, science du citoyen, pêcheries de loisir

INTRODUCTION

In California, USA, an endemic beach-spawning teleost fish, the California Grunion *Leuresthes tenuis*, is justifiably renowned for its remarkable behavior during midnight spawning runs (Fig. 1). Along the heavily urbanized coast of California (Eschmeyer *et al.* 1983, Johnson *et al.* 2009), these silversides emerge from the waves in the swash zone, to spawn and deposit thousands of eggs under the sand. The sight of masses of silvery fish glittering in the dark along a wave swept shore is unforgettable, and this experience is highly prized by many members of the public (Spratt 1986, Martin *et al.* 2007). Like most natural phenomena, California grunion runs are highly variable in timing, strength, and duration (Thompson 1919, Walker 1949), and many California beaches are closed to the public after sunset. Thus, although many people try, few have actually encountered a legendary large grunion run.

Grunion spawning runs are timed to closely follow the syzygy tides of the new and full moon, from March to August (Walker 1952, Martin & Swiderski, 2001). Even though a schedule of potential grunion spawning nights is published each year by the state Department of Fish and Game, because of the inherent variability and logistic difficulties in observing spawning runs, and a lack of traditional fishery data, there has been concern that this species has declined or disappeared in some areas.

This natural phenomenon is also culturally important as a recreational fishery, with bare-handed grabbing by people of all ages as the fish emerge on shore (Gregory 2001). When emerged from water, the fish are so vulnerable to

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anglers that they have been protected since 1927 during the peak spawning months of April and May by a closed season with no take permitted, and during open season with no gear permitted (Clark 1938, Gregory 2001). During open season nights when recreational fishing is permitted, more anglers may be present than fish, and often nearly every *L. tenuis* that emerges is taken before spawning.

Unlike beach macrofauna, egg-encased *L. tenuis* embryos cannot move up and down with the tides. Protection of the nest site is critical as the embryos remain in place, vulnerable until hatching to human impacts including coastal construction, beach grooming, foot traffic, and vehicle traffic, along with terrestrial predators and natural sand disturbance.

L. tenuis nest by burying the eggs in sand in the littoral zone above the mean high tide line, and embryos develop out of water throughout incubation (Fig. 2). As tides increase before the next full or new moon, egg-encased grunion embryos are lifted free from the sand into the waves, where they hatch and begin larval life (Griem & Martin 2000, Speer Blank & Martin 2004). Spawning occurs every two weeks between March and August along the southern California coast, with a more abbreviated spawning season in the more northern parts of the range (Phillips 1943, Spratt 1980, Roberts *et al.* 2007).

On a natural beach, *L. tenuis* clutches are hidden from view, protected and kept moist by burial under sand (Thompson 1919, Walker 1952, Middaugh *et al.* 1983). However, today many California beaches are exposed to regular vehicular traffic and other human impacts. Beach grooming, or mechanized maintenance may use heavy equipment towing tines or rakes that reach down below the sand surface. This disturbance may destroy the eggs outright, or may turn them up to the surface where they are exposed to predation and desiccation (Martin *et al.* 2006). Knowing where *L. tenuis* nest can assist management agencies in avoiding vehicular traffic, coastal construction projects, and other disturbance of their nursery areas.

Figure 1: A spawning run of *L. tenuis*. Females dig into the wave swept sand with the tail and deposit clutches of hundreds to thousands of eggs. Males stay on the surface and provide milt. Photo by W. Hootkins © Grunion.org.

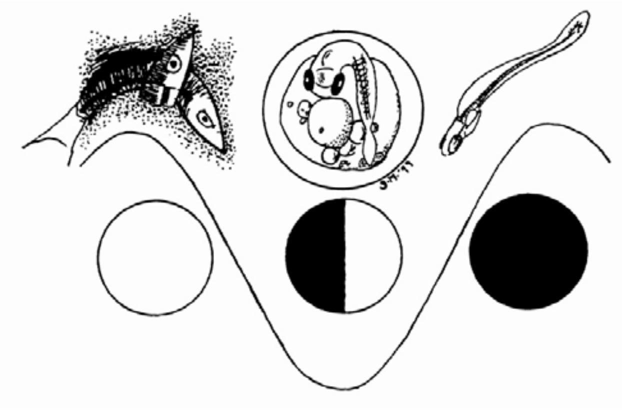

Figure 2: The life cycle of *L. tenuis* is highly dependent on the tidal cycle. Spawning occurs shortly after syzygy tides, and the eggs incubate buried under sand, above the mean high tide line, until washed out by the next rising syzygy tides. Art by G. Martin © Grunion.org.

Table I: The Walker Scale for assessment of California Grunion spawning runs, developed by K. Martin, M. Schaadt and S. Lawrenz-Miller, is named for Boyd Walker, whose pioneering research provided the scientific basis for understanding the periodicity of *L. tenuis* spawning runs in California. Scale increases exponentially with greater numbers of fish, greater area involved, and increased duration of the run.

Scale	Number of Grunion	Duration	Descriptor
W-0	No fish or only a few, no spawning	minutes	Not a run
W-1	Up to 100 fish scattered on the beach at a time, some spawning	minutes	Light run
W-2	100-500 fish spawning at different times, fish ashore with many of the waves	up to 1 hr	Good run
W-3	Hundreds of fish spawning at once on several areas of the beach, or locally intense run	up to 1 hr	Strong run
W-4	Thousands of fish together, little sand visible between fish	up to 1 hr	Excellent run
W-5	Fish covering the beach several individuals deep, a silver lining of the surf along a large area for over an hour	Over 1 hr	Incredible run

Sandy beaches are essential habitat for numerous organisms that may not initially be obvious to beach-goers or managers, even those who visit frequently (Schlacher *et al.* 2008). Some animals use the habitat intermittently, at times of day when few observers are present. Thus public education and involvement in habitat monitoring should improve public understanding and lead to more ecologically sensitive management of sandy beaches (Martin *et al.* 2006).

L. tenuis, a charismatic marine fish, has been made the focus of an annual monitoring project involving hundreds of volunteers. Teams of observers provide detailed data in real time, making it possible to address multiple management situations quickly and effectively along this unique species' entire habitat range. In addition they provide many important details about the spawning sites on sandy beaches, considered Essential Fish Habitat (Robbins 2006) according to the US Magnuson-Stevens Act. Previously Walker (1949) reported data from all *L. tenuis* spawning runs over three years at Scripps Beach. In April of 1947, he asked volunteers to monitor runs for two nights across the habitat range along the coast of California and northern Baja California, Mexico. In performing similar, but much more extensive monitoring, Grunion Greeters use a metric called the Walker Scale (Table I). This was developed in honor of Boyd Walker, who defined the method for predicting the spawning schedule by monitoring every run on one beach over three years (Walker 1949, 1952).

MATERIAL AND METHODS

Training for monitoring

Volunteers to observe spawning runs of *L. tenuis* were recruited locally with partnerships including public aquariums, environmental organizations, museums, universities and colleges, and other affinity groups. Locations for the workshops typically were donated by partner organizations. Funding from foundations and agencies made it possible to offer the workshops and training to the public at no charge. Because traditional fishery methods fail to assay this unique species, professional biological consultants were also encouraged to attend at no charge.

Volunteers were at least 18 years of age, willing to provide their own transportation and work without supervision during the late night hours of the monitoring effort. Each signed a waiver holding the organizers and affiliated groups not responsible for accidents or injury. For safety, they were asked to work in groups of at least two, but the second individual need not have attended the training workshop.

Each local workshop was self-contained and included printed materials, videos, several short presentations, and small gifts for the participants. Annual attendance at one workshop was requested, and this was enforced as a requirement for individuals to earn awards for monitoring effort. No formal commitment was demanded from workshop participants, but attendees were expected to attend at least one run. Participants were given a list of dates for monitoring and a choice of beach sites. They enrolled online to monitor specific times and sites. After monitoring three runs or more, participants received an incentive such as a t-shirt, cap, or sport fleece.

Data acquisition

Grunion Greeters assessed *L. tenuis* spawning populations for the specific location of the run, the duration, and the relative strength of the run as judged by the Walker Scale (Table I). With internet access nearly universal, a web-based data form was used. Grunion Greeters received paper copies of the data acquisition form and instruction in how to report their observations at the training workshops. They carried the paper form to the beach during monitoring, and afterwards, filled out the form online within 24 hours. Many submitted the form within an hour of returning from the run, in the middle of the night on a home computer. Other forms of communication available included "hot-line" phone calls, e-mails, photographs, and videos.

Monitoring effort by volunteers was centered on the peak spawning months, in April, May, and June in most locations but into July in more northern parts of the habitat (Roberts *et al.* 2007, Johnson *et al.* 2009). Monitoring occurred on the third and fourth nights after new and full moons, although the fish also occasionally ran on some days just before or after the monitored days. Volunteers could and did choose to monitor on alternate nights or beaches other than those on the official list.

Reliability and verification of the reports

Reports were verified by parallel reports from multiple observer teams and by sampling for clutches on beaches where runs were reported.

Spawning beach characteristics

Data collected include the physical condition of the beach, weather and waves, presence of beach wrack, and predators, related to the spawning run location. On days following the spawning runs, the incubation conditions for the clutches were observed during collecting trips to record the physical and environmental variables in the distribution of nest sites.

RESULTS

Training for monitoring

The project began with one workshop in 2002. By 2009 workshops were held in ten different cities across coastal California, spread throughout the majority of this species' habitat range. As unusual as this program is, and as demanding as the requirements are for participation, over 3200 people have volunteered for training since the program began, including numerous professional biologists. Over 140 agencies and organizations, from the local to the national and international level (Table II), have partnered with the Grunion Greeters.

Data acquisition

Monitors were asked to report data within 24 hours. Follow up for failure to file a report was a major focus of management effort and time, but few experienced difficulties with the online data form. The data form was publicly available to anyone online, but volunteers self-identified in order to earn rewards, therefore data from untrained monitors could be easily identified and examined separately. Professional monitors for coastal construction projects provided additional detailed reports. Reports from up to fifty beaches per run series were submitted, across over 500 km of shoreline. In 2009 nearly 900 reports were submitted. More than 33,000 volunteer hours have been provided over 8 years. Phone calls, e-mails, photographs, and videos were additional rich sources of information and allowed observers to report unusual events that called for rapid response or mitigation. Variability in run strength over broad areas occurred on a given run series, and over the season (Fig. 3).

Reliability and verification of the reports

Reports were compared from different volunteer teams or scientists observing the same spawning run on the same beach simultaneously for congruity in observations. Typically the reported data were the same. On rare occasions they differed, usually by no more than one level on the Walker Scale. In 2008, reports from 35 different beaches with two observer teams were compared and score between teams were highly correlated by Spearman Rank Correlation ($p=0.006$, $N=35$, $Rho=0.83$). Untrained observers were less reliable and there was a tendency to overestimate the size of the run, although they provided valuable “presence” data. The number of observations and the size of the spawning runs have increased in size and strength over recent years (Fig. 4).

Table II: Key to the success of the Grunion Greeter program, over 140 cooperating organizations have assisted with local involvement of volunteers and implementation of findings in the past decade.

Region	Cooperating organizations
San Diego County	Birch Aquarium at Scripps, Buena Vista Audubon Society, Camp Pendleton Marine Corps Station, City of Imperial Beach, City of Oceanside, City of San Diego, City of Solana Beach, Coronado Naval Air Base, Mira Costa College, Palomar College, Project Pacific, SANDDAG, San Diego Science Festival, San Diego State University, San Elijo State Beach Interpretive Association, Scripps Institution of Oceanography, Southwest Wetlands Interpretive Association, Tijuana River Estuarine Research Reserve, University of California- San Diego, Volunteer San Diego
Orange County	Bolsa Chica State Beach Interpretive Association, California State University- Fullerton, City of Huntington Beach, City of Laguna Beach, City of Newport Beach, City of San Clemente, City of Seal Beach, County of Orange, Crystal Cove Alliance, Doheny State Beach Interpretive Association, Fullerton College, Muth Interpretive Center in Newport Bay, Ocean Institute at Dana Point, Orange County Coastal Coalition, Southern California Ecosystems Research Program, Strategies 4 Sustainability, Whittier College
Los Angeles County	Aquarium of the Pacific in Long Beach, Cabrillo Marine Aquarium, California State University Northridge, “Chance for Children” camp for at-risk children, City of Long Beach, City of Malibu, City of Santa Monica, GLOW Art Festival, Grunion.org, Heal The Bay- Santa Monica, Las Virgenes Resource Conservation District, LA Works, Leo Carillo State Beach Interpretive Rangers, Los Angeles Audubon Society, Los Angeles County Beach Commission, Los Angeles County Beaches and Harbors, Los Angeles County Fire Department- Lifeguard Division, Los Angeles County Natural History Museum, Malibu Watershed Council, Marina Del Rey Marine Science Academy, Occidental College, Pepperdine University, Pomona College, Pt. Mugu State Park Whale Fiesta, Roundhouse Aquarium at Manhattan Beach, Santa Monica Bay Restoration Commission, Santa Monica Baykeepers, Santa Monica Mountains Preservation Trust, Santa Monica Pier Aquarium, University of California Los Angeles, University of Southern California
Ventura County	California State University Channel Islands, City of Oxnard, Ormond Beach Task Force, Oxnard City College, Ventura County Coastal Coalition
Santa Barbara County	City of Santa Barbara, County of Santa Barbara, Goleta Beach Task Force, Santa Barbara Channel Keepers, Santa Barbara Natural History Museum, Ty Warner Sea Center, University of California Santa Barbara
San Luis Obispo County	Oceano Dunes State Vehicular Recreation Area
Monterey County	Monterey Bay Aquarium Research Institute, Moss Landing Marine Laboratory, Pacific Grove Museum, University of California Santa Cruz
San Francisco Bay Area	Chrissy Field Interpretive Association, City of Alameda, City of Marshall, City of Oakland, City of San Leandro, Cordell Banks National Marine Sanctuary, East Bay Regional Parks District, Golden Gate National Recreation Area, Lawson’s Landing, Port of Oakland, Pt. Reyes National Seashore, San Francisco State University, Stanford University, University of California Berkeley
Statewide, California	Beach Ecology Coalition, California Clean Beaches Task Force, California Coastal Coalition, California Coastal Commission, California Department of Fish & Game, California Marine Life Protection Act, California Sea Grant College, California Sediment Management Working Group, California State Parks, California Waterboards, Southern California Academy of Sciences, Trout Unlimited – Southern California Chapter
National / International	American Institute of Fishery Research Biologists; American Shore & Beach Preservation Association; Calidad De Vida, Tijuana, Mexico; National Fish and Wildlife Foundation; National Geographic Society; National Wildlife Federation; NatureServe National Phenology Network; No Bad Days Tourism of San Felipe, Mexico; Society for the Study of Sandy Beaches; Surfrider Foundation (National, also chapters in San Diego, Orange County, and West LA-Malibu); US Army Corps of Engineers; US Environmental Protection Agency- Oil Spill Preparedness and Response Team; US Geological Survey; US National Marine Fisheries Service; US National Oceanic and Atmospheric Administration; US National Park Service, US National Science Foundation, Citizen Scientist Toolkit Conference; US NSF- COSEE- West; Wildlife Watch Week; Young Round Square of the Americas Conference
Private Companies that use Grunion Greeter training, data, or methods	Beach Tech, Bonterra Consulting, ECorp Consulting, Entrix Environmental Consulting, Chambers Group Environmental Consulting, CoastalWatch Communication Systems, Littoral Ecological & Environmental Services, MBC Consulting, Moffat and Nichols, Nautilus Environmental, San Marino Environmental Associates, Science Applications International Corporation, Southern California Edison Power Plants

Table III: Characteristics of sandy beach habitat for *Leuresthes tenuis*.

General characteristics of spawning beaches	Microtidal intermediate beaches, open coast and in harbors and bays Relatively low slope, or the lowest slope along the beach Coarse, well-drained sand May be surfing beaches with well-formed, regular breakers
Spawning runs	May be concentrated near coastal structures that refract waves, such as jetties, piers, and breakwaters On a beach with cusps, runs are within the cusps Rocky outcrops, cobbles and vegetation are avoided, but sand between is used May be attracted to area of water outflow such as a creek mouth or estuary
Incubation sites	Often at the same tidal height as the wrack line Depth 5 to 10 cm initially, sand transport may bury to 20 cm Moisture content 2% to 8% by weight Temperatures between 15 and 25 C are tolerated, average 20+/-3 C
Things that may prevent or stop a run	Steep beach slopes Severe weather, harsh waves, complex surf Excessive human interference: shouting, splashing in water, flashing lights, grabbing fish
Things that do not stop or prevent a run	Steady lights, for example from streets or piers Steady noise Natural predators Quiet, unobtrusive human observers

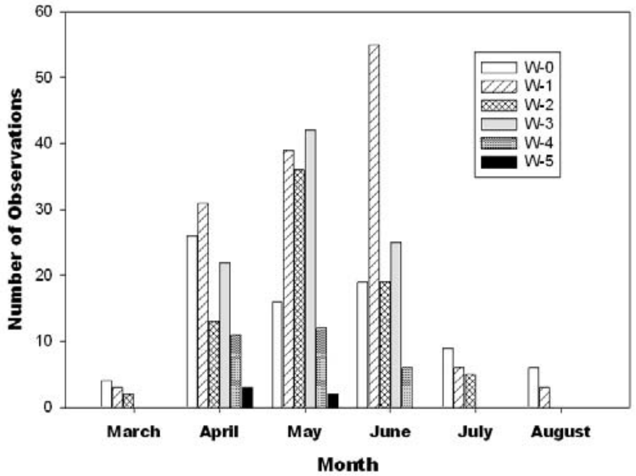

Figure 3: Walker Scale data from southern California in 2007 indicates runs peaked during the Closed Season, April and May, but occurred throughout the season.

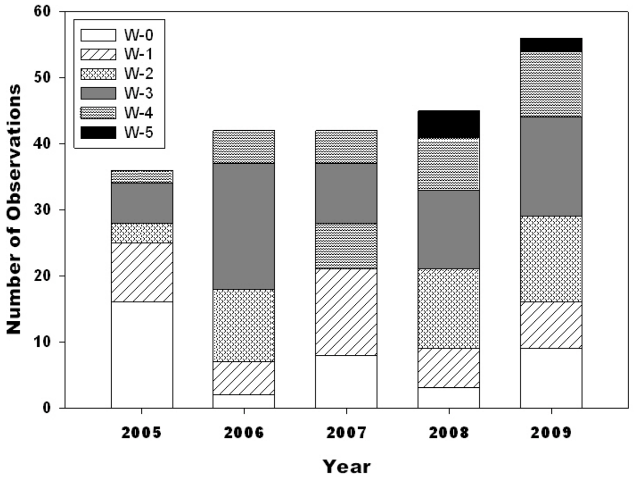

Figure 4: Walker Scale (see Table I) data from the late April run series across 5 years, as reported by Grunion Greeters. Both the number of observations and the run strengths increase over time.

Reports were periodically verified by daytime visits of the scientific team to locations where spawning was reported. Sampling by digging for nests and eggs across the spawning site provided an independent measure of the strength and location of the runs, and the number and location of nests were found to be consistent with reports made during run observations.

Spawning beach characteristics

Weather, waves, presence of beach wrack, and predators were reported during the spawning runs. Following the spawning runs, the incubation conditions for the clutches were observed. Based on thousands of reports and field observations, physical characteristics of *L. tenuis* spawning beaches were described (Table III). In general *L. tenuis* spawn on intermediate type microtidal open coast beaches, although they also spawn within bays and harbors. Any sandy beach within the habitat range can hold a spawning run unless it is too steep. Coarse sand is typical, but spawning may occur even in shell hash if no other sites are available. If the substrate is too fine or silty, poor drainage and low oxygen levels may occur for the eggs. If the beach is overlain with cobbles, it will not be visited, but if the rocks are interwoven with stretches of sand, boulders and intermediate cobble cover do not discourage spawning. On beaches with cusps, the area in the center of the cusp is more likely to be used than the horns, and wave refraction can concentrate the runs near structures such as jetties, piers, and breakwaters.

During the runs, *L. tenuis* may follow surf breaks. Well formed breakers from spilling and surging waves are better for spawning runs than higher-energy plunging waves, and complex surf or severe weather may prevent a run. Areas of outfalls such as creek mouths and estuaries may attract spawning runs, but whether this is an attraction to lower salinity or a shallower beach slope is not known. Runs that occur within bays or harbors occur without wave action, and the fish spawn at the water's edge as the tide ebbs.

Because of tidal spawning, oviposition occurs at the water's edge and incubation takes place above the water line. Eggs are deposited by females that dig tail first into the soft sand, leaving only the head visible. Their body size means that clutches are placed from 5 to 10 cm deep, but subsequent sand transport can either increase or decrease the depth of burial. Clutches are typically found between 5 and 20 cm below the surface but may be as deep as 30 cm or completely exposed at the surface by sand movement after spawning takes place.

DISCUSSION

Managers of sandy beaches must consider multiple human users for a wide variety of benefits such as recreation, sports, fishing, leisure, and relaxation. Traditional beach management has focused on human health and safety (Bird 1996), with less attention to protection of natural habitat. However, beaches are now recognized as habitat for numerous organisms, even though these may not initially be obvious to beach-goers (McLachlan & Brown 2006). Progressive beach management has been encouraged to preserve ecological functions (James 2000).

Involving the public in assessing beach animals is one way to improve public knowledge of beach biota and to provide management data that conserves vital beach ecological components and habitat functions. Data may also be used for assessing species populations over time, local conservation of essential habitat, and resource valuation for mitigation of shoreline impacts.

Because *L. tenuis* cannot be assessed by traditional fisheries methods (Gregory 2001), Grunion Greeter observations of spawning runs have become the major way to assess the population (Fig. 3). These reports constitute the most extensive long-term data set across multiple locations in existence for *L. tenuis* (Figure 4), building on previous work by Walker (1949). Use of an online format allows rapid recovery of spatially diverse data, providing timely data necessary for adaptive management across a large area. With smart phone technology, observers can submit data online while still on the beach.

L. tenuis spawn during semilunar high tides, above the mean high tide line in the littoral zone. On the open coast, waves and swells create upwash in the swash zone (McArdle & McLachlan, 1991), and allow fish to choose specific tidal heights above the falling tide line, permitting extended runs of an hour or more (Martin *et al.* 2007). Within bays or harbors, *L. tenuis* may spawn aquatically at the water's edge as the tide ebbs (Johnson *et al.* 2009), as there are no great waves to carry them to a higher tide level out of water. This may be the ancestral form of beach spawning for this species (Martin & Swiderski 2001), carried over from its sister species the Gulf Grunion *L. sardina* (Thomson & Muench 1976, Bernardi *et al.* 2003).
The buried embryos remain moist but not saturated in the zone of retention (McLachlan 1990, McLachlan & Brown 2006), therefore they have high oxygen levels (Martin & Strathmann 1999, Griem & Martin 2000). The surface sand may be dry and extremely hot, but at the depth of incubation, temperatures are moderated by shade and moisture, allowing rapid development of the embryos (Smyder & Martin 2002, Martin *et al.* 2009). Anthropogenic changes in a sand-gravel beach led to habitat degradation for a different beach spawning fish species, the surf smelt (Rice 2006), because of changes in the microclimate experienced by the embryos.

The intermediate type microtidal open coast beaches favored by *L. tenuis* for spawning (Table III) are highly dynamic and not often in equilibrium (Short 1987). These beaches may change contours and slope dramatically within a year or even within the spawning season, particularly after storm events (Griggs *et al.* 2005). Thus *L. tenuis* at a given beach site may use different sections for spawning as the season progresses. In many cases nearly the entire length of the beach is used for spawning over the course of a season, although usually not all at the same time (Martin *et al.* 2006).

According to the provisions of the US Magnuson-Stevens Act, sandy beaches are critical habitat for California Grunion, vital for spawning, embryonic development, and early life stages (Robbins 2006; Matsumoto & Martin, 2008). Many California beaches are groomed with mechanized maintenance, raking the upper layers of sand in order to clean away wrack and litter. In 2002, a study showed negative effects of mechanized beach maintenance on nest sites for grunion in San Diego, California (Martin *et al.* 2006, 2007). A change in local beach grooming practices was implemented to protect the nests.

Through an outreach to beach managers starting in 2004, improvements in seasonal beach grooming protocols were implemented throughout *L. tenuis* habitat range in California. Now, during the spawning season, mechanized maintenance remains above the wrack line at the highest tide line, away from the intertidal zone where *L. tenuis* eggs may be buried. This change was facilitated by the Grunion Greeters, who understood the situation and could explain the reasons to the public, and watched their local agencies to ensure protocols are followed. The outreach has led to the incorporation of a new non-profit public benefit organization to develop ecologically sensitive Best Management Protocols for sandy beaches, the Beach Ecology Coalition.

Spawning site data for *L. tenuis* have been incorporated into the maps developed by the US National Oceanographic and Atmospheric Administration's Oil Spill Prevention and Response team, as part of their Environmental Sensitivity Index (Jensen *et al.* 1998) for the state of California. *L. tenuis* are vulnerable to oil spills at all life stages (Gellert *et al.* 1994, Middaugh *et al.* 1993). Grunion Greeter data indicated the spawning sites and impact of a fuel oil spill by the *Cosco Busan* in San Francisco Bay in 2007 (Incardona *et al.* 2008).

Thanks to increased attention to this species brought by the Grunion Greeters, the timing of coastal construction projects is now regulated by government agencies in order to avoid impacting the spawning areas of *L. tenuis* runs.

When knowledge of specific locations of nests is absolutely necessary, for example during coastal construction projects, volunteer observations are not appropriate. With increased understanding of the widespread but patchy nature of the nesting sites, paid consultants are now required as a condition of the construction permit. Numerous biological consultants monitor with methods described here in order to appropriately advise management of coastal construction projects. When negative impacts have resulted, data from Grunion Greeters have been used for resource valuation to mitigate shoreline impacts.

Multiple local, state, and national agencies use the information provided by local Grunion Greeters for adaptive management (Table II). The support and publicity from a well-regarded local group can encourage participation and lead to a form of peer pressure for other groups and organizations to become involved. Beach spawning fish species occur worldwide (Martin *et al.* 2004) and conservation efforts on behalf of these charismatic species may be a powerful method for increasing habitat protection and conservation of sandy beaches.

There are some drawbacks to managing such a wide area with volunteers for observations. Finding a spawning group of *L. tenuis* can be difficult, and requires a level of patient observation that is not common among the general public. Even presence/ absence data can be unreliable, as a false negative may result if observers leave the beach too early or do not walk along the entire length of the shoreline. Allowing volunteers to choose their monitoring location and date provides them with a sense of control and commitment to the program, but can be problematic. Certain beach locations or amenities are more appealing to volunteers. A concentration of many Grunion Greeters at one location or time may result in negligible coverage of other sites on some important monitoring dates. More prescriptive site assignments have not met with much success because of the uncertainty of participation inherent in any volunteer activity. Some monitoring times are more difficult, for example nights with later tides or weeknights are less desirable than early or weekend times. Participation is a particular concern for this activity that takes place on a set schedule in remote locations, late at night, outdoors. Nevertheless, tens of thousands of volunteer hours have been provided over the years from very loyal and trustworthy individuals.

The heavily urbanized coastline of southern California is undergoing rapid change with increasing development and sea level rise (Griggs *et al.* 2005). Coastal armoring moves beaches to more reflective characteristics (McLachlan & Brown 2006) that result in habitat loss for nesting. Increased population pressure may render fishing pressure on the spawning aggregations untenable. Future Grunion Greeter data may reveal effects of climate change, and possibly point to the need for improvement in conservation regulations for this unique, charismatic beach species.

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