Assessing Sanctuary Shorelines: A Role for Volunteers, Particularly High School Students, in Resource Management

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During 2001-2003, we developed a rocky intertidal monitoring program to be used by NOAA's National Marine Sanctuary program on the west coast of the US. The goals were to 1) inform the public about the rocky intertidal habitat and the species that live there, 2) directly involve students (7^{th} - 12^{th} grade) and other volunteers in the field, and 3) collect and archive data that can be analyzed to detect changes in intertidal life over time. We developed protocols and species lists, and tested the student's ability to identify and monitor intertidal species compared to that of professional intertidal technicians. With limited preliminary training (a classroom visit for protocol and species overview, and a few field trips to learn the species using photo-identification sheets and to do practice counts), the students were able to collect data in the field that were comparable to those collected by professionals. Protocols have been established for 10 sites in the Monterey Bay National Marine Sanctuary, and used by 6 school groups to date. These protocols, currently posted on the website <http://simp.ucsc.edu>, are being incorporated now into a education and research program coordinated by the five west coast national marine sanctuaries called Long-term Monitoring Program and Experiential Training for Students (LiMPETS), with the website <http://limpets.noaa.gov>.

Introduction

The rocky intertidal on the west coast of North America supports one of the richest and most diverse biotas in the world (Stephenson and Stephenson, 1972; Ricketts *et al*., 1985). Moderate climate, energetic waves, and productive nearshore waters all contribute to this wealth. This biota is subject to constant change, today largely from anthropogenic causes. At some sites, especially in southern California, harvesting and trampling have lead to dramatic decreases in the abundance and diversity of the biota (Ghazanshahi *et al.,* 1983; Brosnan and Crumrine, 1994; Addessi, 1995; Murray *et al.*, 1999). The very accessibility of the intertidal has lead to more and more people visiting it. And while reckless collecting might be decreasing now in response to better understanding, simply walking around on the rocks may be disturbing to some species, leading to unpredictable changes (Beauchamp and Gowing, 1982). Moreover, by its very nature, the intertidal zone is exposed to many of the pollutants produced by human society. Contaminants released into the air fall on the surface of the sea and are carried into the intertidal, as are chemical contaminants such as oil spills. Waste materials dumped on the land are washed into the sea across the intertidal, some of it remaining there. Indeed, the animals and plants of the intertidal may be affected more severely by human activities than those in most other parts of the sea. Fortunately, because of their accessibility, they also may be the easiest to monitor, and so can serve as our marine canaries.

In response to a rise in both air and sea temperatures, we also can expect the distribution of species along our coast to change. Along the west coast of North America, many intertidal species are found from Alaska to Point Conception (northern species) or from northern California to Baja California (southern species), both co-occurring in central California (Newman, 1979). Global warming may result in a northward shift in the distributions of these species. Indeed, that was what was seen when species abundance was compared between the early 1930s and the mid 1990s at one site in Monterey Bay: several common southern California species that were rare or absent in the 1930s are now abundant in the Monterey Bay area (Sagarin *et al*., 1999).

Moreover, global warming will likely cause a rise in sea level (Titus and Narayanan, 1995). The tightly organized zonation patterns of the intertidal, with species sorted into bands according to tidal height, may be particularly sensitive to global warming. A rise in sea level not only could shift the different zones higher on the shore, but the zonation pattern itself could change as the shoreline configuration and associated wave forces change (Denny, 1995; Schoch and Dethier, 1996). In addition, long-term, interannual cycles of sea level could influence zonation patterns (Denny and Paine, 1998).

Although there is evidence that there have been major changes over the past century in the rocky intertidal biota of western North America, especially in southern California, it is almost all anecdotal (Foster *et al*., 1988; Murray *et al*. 1999). Until relatively recently, long-term monitoring programs of the rocky intertidal were few (*e.g.,* by the Channel Islands National Park (Davis *et al*., 1994), Diablo Canyon Nuclear Power Station (PG&E, 1984), and the Minerals Management Services (Kinnetics, 1992; Raimondi *et al*., 1999). In addition, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), supported by the David and Lucille Packard Foundation, is an ambitious effort to expand long-term monitoring along this coast <http://www.piscoweb.org/>. These programs offer great promise in providing long-term data that can be used to detect changes in the future. However, they are large, expensive, and employ highly trained technicians to collect and analyze the data.

Another approach to monitoring environmental change is to utilize members of the public. The Audubon Society has taken this approach with their annual Christmas Bird Count <http://www.audubon.org/bird/cbc/index.html> for over a century. In the past decade the Great Annual Fish Count (http://www.fishcount.org/) has taken that example into the sea. A variety of groups have made special efforts to involve school groups in monitoring programs, *e.g.*, the Federal interagency GLOBE program <http://www.globe.gov/globe_flash.html>.

Over the past three years (2000-2003) we developed a program for school groups and other volunteers to monitor the rocky intertidal of the Monterey Bay National Marine Sanctuary. Not only will this program provide another set of long-term data that can be used to follow changes, but it will also introduce people of all ages to the rich biota of the rocky intertidal, and build up a group of well-informed, concerned citizens who will watch over the habitat in the future. In addition, it is our hope that by being involved in this program, people will gain a better idea about how science is carried out, both in the field and when interpreting data. The protocols we developed were originally posted on the website <http://simp.ucsc.edu>, but with the completion of Sea Grant support, the website was incorporated into a website of the National Marine Sanctuary http://limpets.noaa.gov to become part of the Long-term Monitoring Program and Experiential Training for Students (LiMPETS), which will serve the west coast of the US. The description give here of the program is an expansion and modification of two previously published accounts (Pearse et al., 2002; Osborn et al., 2003).

Sites

The sites we selected for intertidal monitoring are in the Monterey Bay National Marine Sanctuary. They vary from being flat intertidal platforms to irregular, rocky outcrops. Each is unique with respect to wave exposure, width of the vertical zonation bands, bedrock and topography, and species composition. In choosing the sites, we looked for some commonality with respect to the following characteristics: the site should be 1) suitable for a vertical transect to be run from the high intertidal to the low intertidal, preferably through a mussel bed, 2) not be too dangerous with respect to incoming waves and slippery slopes, 3) easily accessible from the shore and to appropriate schools, and 4) close to public parking and a restroom. We did not develop programs to monitor tidepools or boulder fields at the sites because they are difficult to define and require other protocols than we using (Ambrose, 2002.).

We established 10 sites within the Monterey Bay National Marine Sanctuary for intertidal monitoring. These are, from north to south: Davenport Landing, Wilder Ranch State Park, Natural Bridges State Beach, Almar Avenue, Rockview Drive, 33rd Avenue (Soquel Point), and Opal Cliffs within Santa Cruz County; Point Pinos and Carmel Point within Monterey County; and San Simeon within San Luis Obispo County.

The northernmost site in Santa Cruz County, Davenport Landing, is fully exposed to the open ocean, while the southernmost sites, Rockview Drive, 33rd Avenue, and Opal Cliffs, are protected within Monterey Bay; there is a gradation in exposure for the sites in between. Five of the sites in Santa Cruz County are on soft mudstone platforms. In contrast, the Rockview Drive site extends over large basalt and sandstone boulders that were placed on the shore to impede coastal erosion (Osborn, 2003). Additionally, 5 of the sites extend across the intertidal, and have a mid-zone mussel bed, while the 33rd Avenue and Opal Cliffs site are on a surfgrass bed in the low zone; they have been monitored annually since before a domestic sewage outfall was discontinued in 1976 (Pearse *et al.,* 1998). UCSC undergraduates monitored 3 other sites periodically between the early 1970s and the mid 1990s (Foster *et al.,* 1988; Pearse, unpublished data).

The Monterey and San Luis Obispo sites are rocky outcrops of granite and basalt, exposed to the open ocean. The topography at both Point Pinos and Carmel Point is very broken up, with many nooks and crannies; making quantitative sampling particularly challenging. On the other hand, these two sites are among the most diverse and spectacular anywhere in the world

Species

There are well over 1,000 species of invertebrates and algae found in the rocky intertidal of central California; selecting those to monitor is no easy task (Dethier, 2002). The criteria that we used to select species for monitoring include ecological importance (major space competitors, predators, or herbivores), sensitivity to disturbance (from trampling, harvesting, and pollution), being near the edge of their distribution limits (northern and southern), and ability to be easily recognized and quantified. For example, owl limpets (*Lottia gigantea)*, and ochre sea stars (*Pisaster ochraceus*), are large, conspicuous animals, and ecologically important as herbivores and predators, respectively. Scouring pad algae (*Endocladia muricata*), sea mussels (*Mytilus californianus),* and surfgrasses (*Phyllospadix scouleri/torreyi*), are competitive dominants in the high, mid, and low zones, respectively, each providing habitat for many other species. Moreover, people harvest owl limpets and sea mussels, scouring pad algae are sensitive to trampling, and surfgrasses are sensitive to chemical pollution associated with sewage disposal. Sunburst sea anemones (*Anthopleura sola*) and pink acorn barnacles (*Tetraclita rubescens*) are examples of southern species near their northern limit in Monterey Bay; their abundance is expected to increase if global warming continues (Pearse and Francis, 2000; Newman and Abbott, 1980, respectively).

Species had to be easily identifiable in the field to be included on our list. We tested numerous species in the field with students and excluded or combined those that were difficult for them to distinguish. For example, the green algae *Enteromorpha* spp. and *Ulva* spp. were combined on our lists because they could not be consistently deciphered as separate species or even genera. Ecologically, both are good indicators of recent or repeated disturbances, so together they represent a taxon that is good to monitor. In another example, smaller limpets that are major grazers upon rocks were all combined as one taxon (*Lottia* spp.) because even professionals have a hard time consistently identifying them to species.

Currently, we have 34 taxa of algae and invertebrates listed for monitoring (see: http://simp.ucsc.edu/Species/monspec.html/ for complete list). Of those species, 14 are monitored at all our sites, and 14 others are monitored at all sites except the surfgrass-dominated permanent plots at 33rd Avenue and Opal Cliffs. Most of the 28 taxa are found in the high and mid zones of the rocky intertidal along the entire west coast, from Canada to Mexico and should be suitable for monitoring at many other sites. If that were done, it would be possible to follow trends in the major species over a wide area of the coast to determine whether changes are local or widespread.

Sampling protocols

We developed protocols for three approaches to sample the rocky intertidal, depending on the sites and species involved: 1) Fixed quadrats along a permanent vertical transect that crosses the intertidal from the top of the high zone through a mussel bed and into the low zone; 2) Random quadrats placed within large fixed plots covering more-or-less uniform areas, usually of mussel beds; 3) Total counts and measurements of selected larger animals within defined areas.

All sites, except the 33rd Avenue and Opal Cliff sites, have a permanent vertical transect marked with stainless steel eyebolts. At specified locations along these transects, depending on the length of the intertidal transect, the abundance of selected algae and invertebrates in quarter-meter-square quadrats is determined and recorded. Photographs of each of the permanent quadrats are available on our web page for printing before going into the field, facilitating placing the quadrats in the exact same place. Counting all the individuals of some taxa within the whole quadrat, *e.g.*, feather boa kelp holdfasts, chitons, turban snails, whelks, and hermit crabs, gives an estimate of the abundance of these taxa. In addition, some larger species are too patchy and far apart to be found often within the small quarter-meter-square quadrats (*e.g.,* solitary sea anemones, sea stars). Where suitable at some sites, band quadrats, 1 meter by 3 meters or more are placed perpendicular to the transect at specified locations, and all the individuals within them counted [Fig. 1].

1. Alternative Family Education Homeschool Association of Santa Cruz students and teacher collecting data at the Almar Avenue site. The central tape marks the vertical transect and the square is on one of the permanent quadrats.

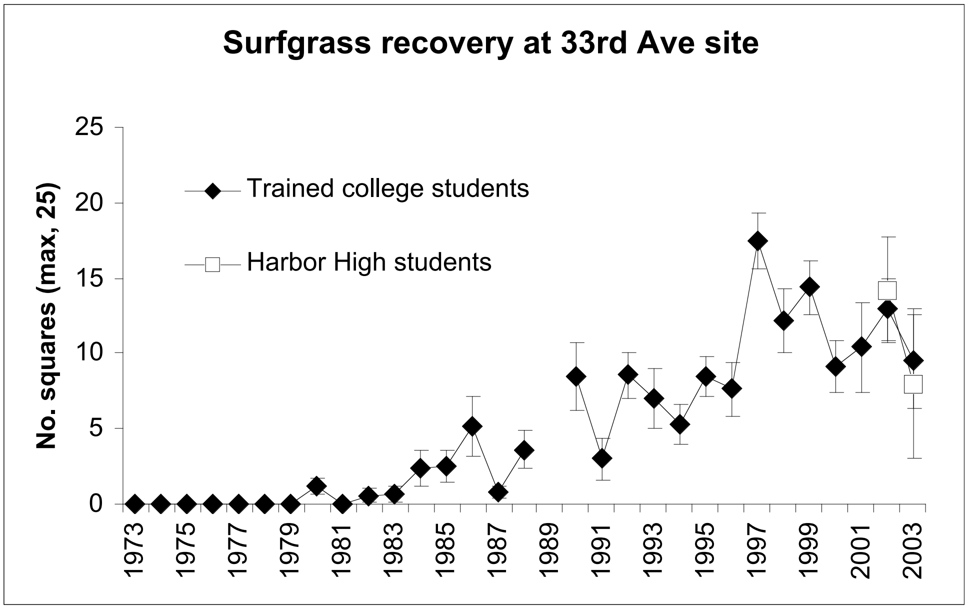
However, many of the taxa grow as aggregations, clones, colonies, or simple growths so that individuals are very difficult to identify and count, *e.g.*, most species of algae, aggregating sea anemones, honeycomb tubeworms, sea mussels, and barnacles. For these taxa, the quadrats are divided with nylon line into 25 10x10cm squares, and the number of squares occupied by any part of the taxon counted. This method is similar to various types of percent cover methods that are more often used in intertidal surveys (Murray, 2002), but it is easier, quicker, and gives a quantitative estimate of relative abundance that is repeatable and easy to comprehend. It can be considered as a modified point-contact method where the "points" are 10x10cm squares, and only a limited number of easily identifiable taxa are counted.

Some conspicuous, ecologically important species are too sparse or sequestered to be adequately counted within quarter-meter-square or even band quadrats. These include territorial owl limpets (>1.5 cm in length), abalones, and ochre sea stars, which can be counted in larger, well-defined areas. Teams of 2-3 students carefully search the area and count all the individuals of the specified species that they can find. They can also measure the individuals to get size estimates. Of course, sometimes individuals are missed, or counted twice, and the number seen depends on when the counts are done during the tidal cycle, so different teams will get different numbers. But if done by several teams, reliable estimates can be obtained [Fig. 2].

2. Monterey Academy of Ocean Science students collecting data at the Carmel Point site. The central tape marks the vertical transect and the square is on one of the permanent quadrats; the outer tapes on each side mark the delineated areas for counting sea anemones, sea stars, abalones, and owl limpets.

In addition to the counts in the permanent quadrats along vertical transects, randomized counts are done of algae and invertebrates in quarter-meter-square quadrats within large permanent plots at 5 sites in Santa Cruz County. Random sampling permits more readily standard statistical comparisons over time than fixed sampling. The permanent plots, ranging in size from 45 to 270 m_, cover relatively uniform areas dominated by a few species (sea mussels, aggregating sea anemones, surfgrasses), and were monitored by undergraduates at UCSC beginning in the early 1970s (Foster, *et al*., 1988; Pearse *et al.,* 1998), and can now be taken over by our program [Figs. 3,4].

3. Harbor High School students preparing to collect data from randomly placed quadrats within a large permanent plot dominated by seagrasses at the 33rd Avenue site.

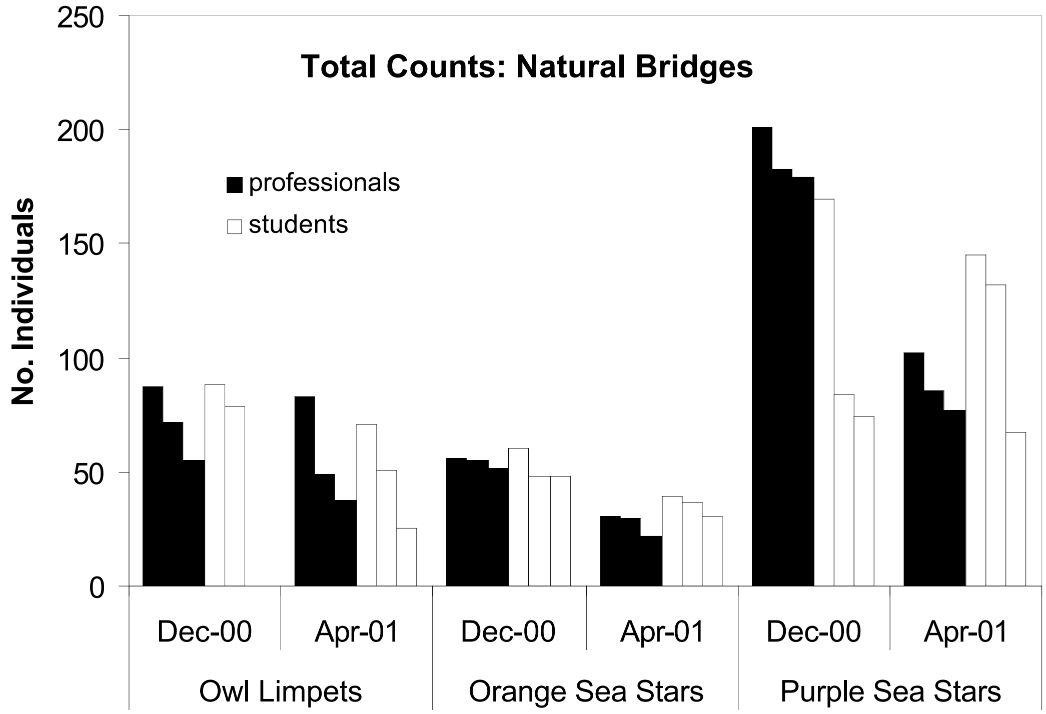


4. Recovery of surfgrasses (*Phyllospadix* spp.) at a site adjacent to an intertidal domestic sewer outfall as estimated by random counts within a 450-m_ permanent plot, counted annually by trained college students and colleagues (diamonds), and for 2002 and 2003 by Harbor High School students (squares). Sewage discharge terminated in June 1976. Means and 95% confidence limits shown.

Validation

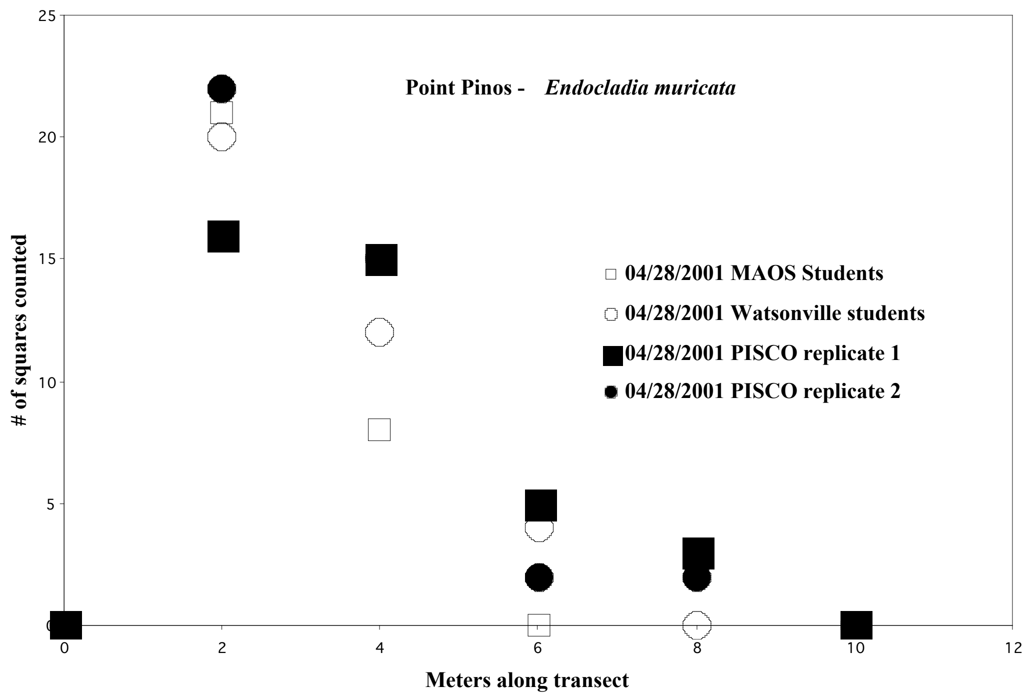
Although getting high school students and volunteers into the intertidal may be a great educational experience, there is always the question of whether students are able to collect reliable data, even with the taxa selected for ease in identification. To test the reliability of student counts, we had teams of students and professionals do replicate counts both of large species within delineated areas and of species in the same quarter-meter-square quadrats on the vertical transects.

For the counts of owl limpets and ochre sea stars (orange and purple/brown separately) on two different days, student and professional teams counted nearly the same number of easy-to-spot orange stars, but there was more variation among the teams for both the owl limpets and purple/brown sea stars [Fig. 5]. The variation among the teams of professionals was nearly as great as those for the students. These differences among teams, whether by students or professionals, need to be taken into consideration when comparing counts. It is probably best to always have several replicate counts that can be averaged to get a reasonable estimate of actual abundance.



5. Replicate counts of large owl limpets (*Lottia gigantea*) and orange and purple varieties of ochre sea stars (*Pisaster ochraceus*) in the same delineated area at Natural Bridges on two different dates by 2-3 teams each of professional researchers in the PISCO program (solid bars) and students from Aptos High School (open bars).

Similarly, replicate counts for species within the same quarter-meter-square quadrats along the permanent vertical transects revealed nearly the same variation between teams of professionals as student teams, with little difference between the two groups [Fig. 6] These results provide reassurance that our monitoring program can provide reliable data suitable for use by resource managers and other interested people interested in tracking long-term changes along our shores.



6. Replicate counts of scouring-pad algae (*Endocladia muricata*) in the same quarter-meter-square quadrats along the vertical transect at the Point Pinos site done on the same day by teams of professional researchers in the PISCO program and students from the Monterey Academy of Ocean Sciences (MAOS) and Watsonville High School.

Procedures

In order to familiarize students and volunteer groups with the species and monitoring protocols, teachers and group leaders need to check the LiMPETS website and then contact program coordinators in the sanctuaries to arrange classroom visits or, if appropriate, to pick up classroom kits to use themselves. The kit includes a slide show introducing the program: goals, what to wear into the field, the purpose of monitoring, photos of the sites, ecology of a few key species, and some data.

For classroom activities, there are life-sized photo-quadrats big enough to fit quarter-meter-square quadrats partitioned with nylon line into 25 10x10cm squares—the same quadrats as used in the field. Using data sheets identical to those used in the field, and aided by laminated photo-identification sheets, groups of students can do practice counts in the classroom. Depending on the number of students and the amount of time in the classroom, they can count 2-5 of the photo-quadrats. Then several species can be selected and the counts obtained by the different student groups can be put on the board for discussion. Slight differences in the counts among the different student teams can be noted and the students can explore reasons for such differences, such as misidentifications or slight movement of the quadrats.

There are shell collections in the classroom kits as well. These allow the photo-quadrats to become 3-dimensional; students can feel barnacle or mussel shells to better familiarize themselves with the species. An activity on two selected species – owl limpets and turban snails – asks students to read a few paragraphs on each and then answer questions together, such as "describe an owl limpet farm?; why do you think we monitor owl limpets?; how and what do turban snails eat?; what color is their blood and why?; or why do you think we monitor turban snails?"

For the first visit into the intertidal, the students should have clipboards, pencils, laminated photo-identification sheets with all the species to be monitored, and a specific assignment. A list of all the species to be monitored is given to each student; the assignment is to write descriptions, in their own words, of the algae or animals after they find them; students can also draw the algae or animals to help them remember. In this way, students can create their personalized identification sheets to laminate and bring into the field with them the next time for a practice count, and every time thereafter.

After the classroom activities and preliminary field trips, the students should be ready to do the counts for real. They need the previous background and exposure to the species and the field to become familiar with the whole experience. We have found that reliable data are collected after these initial steps are executed. This is a "check-out" process as well, so teachers and the sanctuaries' coordinating staff can interact and answer questions.

For the field counts themselves, the necessary equipment includes quarter-meter-square quadrats (students work best in groups of 3, 2 counting and 1 recording, so the number depends on the number of students), meter tapes, data sheets, laminated photo-identification sheets (one for each student), clipboards with rubber bands to hold down datasheets in the wind, pencils, and knee pads. The students should provide their own change of clothes, field gear, and snacks. If there are enough students, several groups can count the same quadrat on the vertical transects for comparison, but every quadrat along the vertical transect should be counted to plot the species' distribution across the intertidal. For doing random counts in the permanent plots, a minimum of 10-20 quadrats should be counted to obtain statistically useful data. And for counts of larger species in the delineated area, several teams of 2-3 students each should do them (see Fig. 2.) It is probably a good idea for the teacher/leader to collect all the data sheets at the end of the field trip for data entry later.

After the classroom activities and preliminary field trip are completed, the teacher/leader will be given a passcode from the sanctuary coordinator for entering data into the program's website. The data can then be entered into the program's website for long-term storage and analysis, preferably by the students themselves. There are some checks in the data entry system on the website to make sure data are entered properly. After the data are entered, the students—and anyone else—will be able to download both their own and past data to create graphs for specified species, sites, or dates. These data also provide material for teaching about statistical analyses and critical reasoning.

Participant response

The following schools and volunteer groups (with the sites they worked at) have participated in our program: San Lorenzo High (Davenport Landing), Aptos High (Natural Bridges), Alternative Family Education Homeschool Association of Santa Cruz (Almar), Harbor High (Rockview and 33rd), Watsonville High (Point Pinos), and the Monterey Academy of Ocean Sciences (Point Pinos and Carmel Point). Their participation has varied in both intensity and style, depending very much on the teachers. In most cases, the teachers identified particularly keen students who wanted the experience, and accompanied the students into the field. Some of these students remained involved until they graduated, and some branched out with independent projects that they did on their own. In one case, a teacher assigned small groups of students to work at a site on their own as a special annual project; that project developed into a science fair poster in 2003, and will likely continue to do so. At the other extreme, two of the teachers involved their whole classes in the program, training the students in the classroom and with a field trip in the fall, and then doing the counts in the spring. Having all the information available on the web allows for considerable flexibility so the teachers can choose how they want to participate in the program.

On the other hand, to gather comparable data among the different sites and over time, there needs to be consistency in how the different schools work in the program. Moreover, the program coordinators within the sanctuaries have limited time, and will find it difficult to follow disparate approaches by the different teachers. It is our hope that the program will continue to maintain flexibility in how people work in it, while at the same time the program coordinators refine the procedures to a manageable level. It would be best if data were collected at each site at least once every spring.

In addition to schools, volunteer groups could easily work in this program, adopting sites that their members could take over as their own. Volunteers in Save Our Shores, for example, accompanied us on several visits to the Almar Avenue site. In addition, docents at Natural Bridges State Beach joined us on several visits to the Natural Bridges site, and members of the Student Oceanography Club at the Monterey Bay Aquarium joined us at the Point Pinos site. With the increase in volunteer programs today, involved with hands-on environmental issues, we can see many groups becoming involved with the sanctuaries' intertidal monitoring program.

Further developments

This program was initially developed for the Seymour Marine Discovery Center of the University of California, Santa Cruz. The staff at the Seymour Center, especially Kevin Keedy and Julie Barrett Heffington, were helpful in the preliminary development. The website describing the protocols, site descriptions, and species lists, as well as containing the interactive database, was turned over to the education and research programs of the Monterey Bay National Marine Sanctuary Program in

March 2003. It is being incorporated as the rocky intertidal components of the National Marine Sanctuaries' LiMPETS program (Long-term Monitoring Program and Experiential Training for Students), and was presented to the first LiMPETS workshop, March 13-16, 2003 held at the Headlands Institute, Golden Gate National Recreational Area. We anticipate it growing further and continuing for many years into the future..

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A great many people contributed to this project in many different ways, and we can only acknowledge a few here. The vision, enthusiasm, and encouragement of two high school teachers, Greg McBride of Aptos High and Heather Murphy of Harbor High, were essential in getting the program underway. Although they approached it in very different ways, they guided us in shaping all aspects of what we did in both the classroom and the field. Other teachers joined us a little later, also with enthusiasm and wisdom, and we thank in particular Steve Clark, Geoff von Saltza, and Kelley Kiefer (Monterey Academy of Oceanographic Sciences), Burnee Yew and Satina Ciandro (Watonsville High), Jane Orbuch (San Lorenzo Valley High), and Mark Thomas (Alternative Family Education Homeschool Association.). And of course the many students who joined us in the field, in all kinds of weather, were the foundation of everything we did. We thank in particular, Migueltzinta Solíz, an inspiration who joined us for over two years and helped involve other homeschool students.

Fleur O'Neill of Save Our Shores facilitated bringing in adult volunteers, and Kevin Keedy, Susanne Hebert, and Julie Barrett Heffington of the Seymour Marine Discovery Center worked to keep us realistic. Tamara Sasaki of the California Department of Parks and Recreation introduced us to the Wilder Ranch State Beach site. We thank Rani Gaddam and Renate Eberl who repeatedly volunteered their help in the field. Pete Raimondi of the Partnership for Interdisciplinary Study of Coastal Oceans (PISCO) provided invaluable advice and encouragement, and freed his technicians to do comparative counts along side the students; these professionals included: Cate Roscoe, Dave Lohse, Dawn Jech, Erin Maloney, Hilary Hayford, Jan Friewald, Jared Figurski, Jenny Raum, Mark Readdie, and Maya George. Marti Atkinson, Jen Holm, Jami Rose, Habib Krit, and John Artim were essential in developing our website. Finally, Dawn Hayes, Michelle Roest, Lisa Emanuelson, Josh Pederson, and Andrew White facilitated the smooth transition of the program into the Monterey Bay National Marine Sanctuary.

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