Comparing volunteer and professionally collected monitoring data from subtidal rocky reefs in southern California

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Abstract

Volunteer-based citizen monitoring has increasingly become part of the natural resources monitoring framework, but it is often unclear whether the quality from these programs is sufficient for integration with traditional efforts conducted by professional scientists. At present, the biological and physical characteristics of California's rocky reef kelp forests are concurrently monitored by two such groups, using similar methodologies – underwater visual census (UVC) of fish, benthic invertebrates, and reef habitat, though the volunteer group limits their sampling to transects close to the reef surface and they use a more constrained list of species for enumeration and measurement. Here we compared the data collected from 13 reefs that were sampled by both programs in 2008. Both groups described relatively similar fish communities, total fish abundance and abundance of the dominant fish species, though, there were some differences in the measured size-distributions of the dominant fish species. Descriptions of the benthic invertebrate community were also similar, though there were some differences in relative abundance that may have resulted from the less detailed sub-sampling protocols used by the volunteers. The biggest difference was in characterization of the physical habitat of the reefs, which appeared to result from selection bias of transect path by the volunteer program towards more complex structured sections of a reef. Changes to address these differences are relatively simple to implement and if so, offer the promise of better integration of the trained volunteer monitoring with that of professional monitoring groups.

Introduction

Citizen-based groups are increasingly contributing to ecosystem monitoring (Foster-Smith and Evans 2003, Pattengill-Semmens and Semmens 2003, Schmeller *et al*. 2009, Léopold *et al*. 2009, USEPA 2010; http://yosemite.epa.gov/water/volmon.nsf/Home?openform). These data can be collected at a reduced cost, as citizens volunteer the work and often supply their own equipment (e.g., Levrel *et al*. 2010). These data can fill spatial and temporal gaps in traditional monitoring programs conducted by academic or governmental professional scientists (Sharpe and Conrad 2006, Delaney *et al*. 2008, Schmeller *et al*. 2009. Other benefits of volunteer monitoring programs include increased interactions between the public and the scientific community, education about ecosystems and resource management, fostering of local stewardship, and increased scientific literacy of the general public.

The biggest impediment to incorporation of these volunteer monitoring programs with professionally collected data is concern about data quality. A number of studies have demonstrated that trained volunteers can produce data of comparable quality to professionals for a variety of parameters and habitats, including beach microbiology (Noble *et al*. 2003), subtropical reef fauna (Halusky *et al*. 1994), or freshwater macroinvertebrates (Fore *et al*. 2001). However, there are also many volunteer programs

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for which data quality has not been assessed. In absence of comparative examinations, anecdotal concerns about data quality or methodological modifications to simplify data collection have led volunteer efforts to be underutilized in management decision-making.

One type of sampling for which volunteer and professional have not yet been compared, is for subtidal rocky reef/kelp forest ecosystems. In southern California, professional scientists at a series of research institutes routinely monitor the biological and physical components of rocky reefs, sometimes for permit compliance interests or for regional assessments, such as the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) (http://www.piscoweb.org/research/science-by-discipline/ecosystem-monitoring/kelp-forest-monitoring/subtidal-sampling-protoco) and the California Department of Fish and Game's Cooperative Research and Assessment of Nearshore Ecosystems (CRANE; e.g., Tenera Environmental 2006, Pondella 2009). In 2008, these groups of scientists came together to conduct a probabilistic survey of rocky reef ecosystems in the Southern California Bight using a unified methodology and sampling protocol (Southern California Bight Regional Monitoring Program); referred to hereafter as the Bight program (Bight '08 Rocky Reef Committee 2008). Starting in 2005, the non-profit Reef Check Foundation created a state-wide volunteer monitoring program referred to as Reef Check California (RCCA). The RCCA program was designed to draw upon the large number of recreational SCUBA divers in California, many of whom have interest in protecting natural resources. RCCA provides the volunteers with extensive training and certification in survey techniques and species identification (Dawson and Shuman 2009).

RCCA uses the same general sampling protocols as the professional monitoring programs, which involve SCUBA-based UVC of fish, benthic invertebrates, algae, and physical habitat structure in rocky reef ecosystems (Bight '08 Rocky Reef Committee 2008, Dawson and Shuman 2009). RCCA protocols, however, include several modifications to the spatial sampling schemes and the extent of taxa recorded to simplify the process and increase quality of the data collected by volunteers. Thus far, there has been no comparison of the data obtained by these two groups. Here we compare measures of habitat characterization, species composition and abundance of fish and benthic between data collected at the same reefs by RCCA-trained volunteers and Bight-Program professional scientists.

Methods

Bight Sampling Protocol

The Bight sampling program was developed to provide a comprehensive assessment of the fish, benthic invertebrate fauna, benthic algae, and physical habitat characteristics of a rocky reef (summarized in Table 1). This protocol is based on protocols previously developed by PISCO and used by the CRANE program (Bight '08 Rocky Reef Committee 2008). A particular reef, or sub-sections of large contiguous reefs, is divided into 4 depth strata: inner (~5 m deep), middle (~10 m deep), outer (~15 m deep), and, when present, deep (~25 m deep). Within each stratum, SCUBA divers conduct transect-based, visual surveys of the biota and physical habitat. Within each stratum there are two 30-m benthic transects, along which physical habitat characteristics (vertical relief, substrate, and benthic cover), benthic invertebrate fauna, and benthic algae are measured. Physical habitat characteristics are measured using the uniform point contact (UPC) method. Vertical relief, substrate type, and benthic cover at 1-m points along the length of the transect, while benthic invertebrates and algae are counted in a 2-m swath along the length of the transect. Fish abundance and length are recorded along four 30 x 2 x 2 m bottom transects, four 30 x 2 x 2 m mid-water transects, and four 30 x 2 x 2 m transects counting fish just below the kelp canopy (when present). This yields a maximum of eight physical habitat, eight benthic invertebrate, and 48 fish transects at each sample site (Table 1). All transects within a given stratum are conducted along isobaths where depth is kept constant, ±2.5 m. When the benthic invertebrates are surveyed, data are recorded in 10-m intervals along the transect. If the abundance of an individual species is greater than 30 within an interval, the distance at which 30 individuals is reached is recorded. No other individuals of that species are counted within that interval, and the abundance was scaled for the entire 10-m interval. The size of all fish <15 cm total length (TL) are visually estimated to the nearest 1-cm interval, while those fish >15 cm TL are estimated to the nearest 5-cm interval. Bight divers record all species of fish that occur, but only identify a set list of algae (21 taxa) and benthic invertebrates (87

Table 1. Comparison of procedural and taxonomic schemes between the RCCA and Bight sampling programs.

Unit of Measure	RCCA		Bight	
	Number	Sample Type	Number	Sample Type
Procedural Scheme				
Sampling Strata	2		4	
Canopy Fish Transects/Stratum	0	Fish	4	Fish
Mid-Water Fish Transects/Stratum	0	Fish	4	Fish
Benthic Fish Transects/Stratum	9	Fish	4	Fish
Benthic Transects/Stratum	3	Algae, Invertebrates, and Uniform Point Contact	2	Algae, Invertebrates, and Uniform Point Contact[a]
Taxonomic Options				
Benthic Taxa - Possible (Unique to the Program)	28 (2)		87 (64)	
Algal Taxa - Possible (Unique to the Program)	8 (2)		27 (10)	
Fish Taxa - Possible (Unique to the Program)	33 (2)[b]		138 (107)[c]	

[a] Bight uses a more detailed report of benthic flora/fauna in the cover measurements

[b] Fish sized into "small", "medium", and "large" classes

[c] Fish sized into 1-cm classes if <15cm TL and 5-cm classes ≥15cm TL

taxa), comprised of common taxa that can be identified underwater without magnification (Appendix 1).

RCCA Sampling Protocol

The RCCA sampling program was designed to mimic the PISCO/CRANE protocols as closely as possible, with some minor spatial modification intended to make the program accessible to trained volunteers (Dawson and Schuman 2009; Table 1). An area of reef approximately 250 m in shore length and 250 m wide (perpendicular to shore) with a maximum depth of approximately 18 m is divided into inshore and offshore strata. Within each stratum, SCUBA divers swam three 30 x 2 m transects, measuring the physical characteristics (UPC method), benthic invertebrates, and algae. Fish abundance and length were measured along nine 30 x 2 x 2 m bottom transects; three over the same transects for benthic invertebrates/physical habitat and an additional set of three on either side. This yields a maximum of 6 physical habitats, 6 benthic invertebrate, and 18 fish transects at each sample site. When measuring the benthic invertebrates, if the abundance of an individual species is >50 for a transect, the distance along the transect where the 50th individual occurs is recorded and no more are counted. The measured abundance can then be extrapolated to the 30-m length of the transect. The RCCA divers are only trained to record the presence of a constrained list of fish (33 potential species), benthic invertebrates (28), and macroalgae (8) in an effort to simplify the amount of required taxonomic skill and to focus on taxa that are most commonly observed, protected, actively fished, or of ecological importance (Dawson and Schuman 2009; Appendix 2). The size of most fish are visually estimated into small (<15 cm), medium (15 to 30 cm), and large (>30 cm) size classes, with the exception of larger species (e.g., *Ophiodon elongates* or *Sebastes paucispinis*), which have bigger medium (15 to 50 cm) and large (>50 cm) size classes.

Data Selection

Though both programs sample a greater number of sites, we focused our comparative analyses on 13 sites (sections of reef where transects were conducted) that were sampled by both the Bight and RCCA programs in 2008 (Figure 1). Some sites were sampled multiple times throughout the year, so sampling events were selected to minimize the number of days between sampling visits by the two programs (Table 2). Furthermore, comparisons were limited to data collected in common between the two programs, so only data from bottom transects were considered. The mean depth of the bottom fish transects was used to match a stratum from the Bight program (typically inner and middle) to the inshore and offshore depth strata in the RCCA sampling scheme.

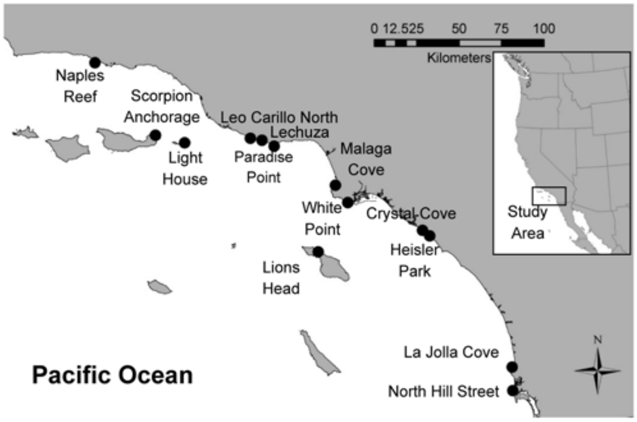

Figure 1. The 13 sample sites located throughout the Southern California Bight. The inset shows the region in relation to the western coast of North America. Site abbreviations are in Table 2.

The shallower strata will be referred to as the inner strata and the deeper strata as the outer depth strata (Table 2). Comparisons were also limited only to the list of fish and benthic fauna measured by RCCA (Appendix 2). Any data from un-matched Bight strata (typically outer and deep strata) and from mid-water or canopy transects were excluded from our analyses, as they did not have comparable data within the RCCA dataset. Though algae composition and abundance data are measured by both programs, these data were excluded due to the incomplete nature of the data set at the time of analysis.

Data Analysis

The physical structure of the reefs was compared as measures of vertical relief, which were reported categorically as flat (0 to 10 cm), low (10 cm to 1 m),

Table 2. Comparisions of transect depth and site sampling date at the paired sites and strata between the RCCA and Bight sampling programs. Δ date and Δ depth are the RCCA value - that of the Bight value. As such, negative values indicate a deeper transect or later sampling date at the respective Bight site-stratum.

Sampling Site	RCCA		Bight		Δ Date	Δ Depth
	Sample Date	Stratum	Sample Date	Stratum	RCCA-Bight	RCCA-Bight
Crystal Cove (CC)	12/2/08	Inner Outer	11/7/08	Inner Outer	25	-1.2 -6.6*
Malaga Cove (MC	4/27/08	Inner Outer	7/7/08	Inner Mid	-71*	-1.8 -3.6*
Light House (IC)	11/5/08	Inner Outer	10/23/08 10/1/08	Inner Outer	24	0.1 -2.8
Leo Carillo North (LC)	9/6/08	Inner Outer	10/30/08	Inner Mid	-54	1.7 -1.5
Lechuza (LZ)	9/6/08	Inner Outer	10/21/08	Mid Outer	-45	-1.5 -2.3
Paradise Point (PP)	9/6/08	Inner Outer	10/30/08	Inner Mid	-54	1.8 -0.9
Heisler Park (HP)	12/11/08	Inner Outer	11/15/08	Inner Mid	26	2.8 -0.7
Lions Head (LH)	11/24/08	Inner Outer	9/4/08	Inner Mid	81*	4.3* 1.0
La Jolla Cove (LJ)	7/26/08	Inner Outer	11/2/08	Inner Mid	-99*	2.8 0.3
Naples Reef (NR)	10/18/08	Inner Outer	10/20/08 10/20/08	Inner Outer	-2	-1.9 -0.2
North Hill Street (NHS)	9/13/08	Inner Outer	10/31/08	Inner Mid	-48	-0.4 0.1
Scorpion Anchorage (SA)	10/29/08	Inner Outer	8/12/08	Inner Inner-Mid	78*	0.9 -1.6
White Point (WP)	9/27/08	Inner Outer	9/25/08	Inner Mid	2	2.6 -0.3

*Value exceed a difference between sampling programs of 3-m depth or 60 days moderate (1 to 2 m), and high (>2 m), and as substrate types of sand, cobble, boulder, or bedrock. These data were compared using a Mantel-Haenszel Chi-Square analysis of mean frequency along replicate transects within a stratum, using SAS v9.2 (Stokes *et al*. 2000). Community structure of the fish and benthic invertebrates were compared with a one-way analysis of similarity (ANOSIM) with dataset as the treatment variable, using Bray-Curtis similarity values calculated from square-root transformed abundance data. These data were also graphically analyzed using a non-metric multidimensional scaling (nMDS) ordination plots. All multivariate analyses were done using Primer-e v5 (Clarke and Warwick 2001). For these, and all subsequent comparisons, strata (inner vs. outer) were analyzed separately to reduce the influence of depth on any observed similarities or differences.

Species richness (S), Shannon-Weiner Diversity (H') of fish and benthic invertebrates, as well as total abundance of fish within each stratum were compared between the two sampling programs using a 2-way analysis of variance (ANOVA) in SAS v9.2, with site and dataset as the treatment variables (Littell *et al*. 2002). Data were transformed when necessary to maintain normality and homoscedasticity of the model residuals. Post-hoc comparisons of Tukey-Kramer adjusted least square means (α = 0.05) were done to compare differences between the two sampling programs and site-specific interaction terms. Because of the taxonomic constraints of the RCCA program, all measures of species richness, diversity, and abundance do not reflect the complete fish or invertebrate communities of the reef ecosystems, but only the dominant taxa.

Taxon-specific abundance of the top seven most frequently observed fish (*Chromis punctipinnis*, *Embiotoca jacksoni*, *Girella nigricans*, *Hypsurus caryi*, *Oxyjulis californica*, *Paralabrax clathratus*, and *Semicossyphus pulcher*) and benthic invertebrates (*Strongylocentrotus purpuratus*, *S. franciscanus*, large anemones [e.g., *Urticina* spp., *Anthopleura* spp.], *Patiria miniata*, *Muricea* spp., *Pisaster giganteus*, and *Lithopoma* spp.) was compared within each stratum between the two sampling programs using a two-way general estimating equation (GEE) with site and dataset as the treatment variables in SAS v9.2. The GEE models were fit with a negative binomial distribution to minimize overdispersion of the data due to the count nature of the data, the large number of zeros in the dataset, and because the variance in each treatment was greater than the mean (Stokes *et al*. 2000). Post-hoc comparisons of the treatment levels were made with Tukey-Kramer adjusted least square means (α = 0.05). Species-specific size distributions of the top 7 most abundant and frequently observed fish across all 13 sites using a Mantel-Haenszel Chi-Square analysis between the two programs in the inner and outer depth strata (Stokes *et al*. 2000). For comparison, the size-class data collected by the Bight program (reported in 1- or 5-cm intervals) were combined into the small <15 cm), medium (15 to 30 cm), and large (>30 cm) intervals used by the RCCA program.

Results

Physical Habitat

Substrate type was significantly different between the two sampling programs in both the inner and outer strata (Figure 2), with RCCA reporting a greater incidence of bedrock than the Bight program. Conversely, the Bight program reported greater amounts of sand and boulder habitat, with both programs reporting relatively little amounts of cobble-dominated habitat (Figure 2a,b). Similarly, there was little agreement in measures of vertical relief between the two sampling programs. In the inner strata, RCCA reported a greater incidence of low and moderate relief habitat, while the Bight program reported a greater incidence of flat habitat. In the outer strata, RCCA reported a greater percentage of low relief habitat, while the Bight program reported more flat habitat along the transects (Figure 2c,d).

Benthic Invertebrates

Both programs reported relatively similar benthic invertebrate communities, though the RCCA data was dominated by the urchins *S. purpuratus* and *S. franciscanus*, whereas abundance in the Bight data was more evenly distributed among species (Table 3). The orange sponge *Tethya aurantia* and the stalked tunicate *Styela montereyensis* were the only relatively abundant taxa (~5% of total abundance) observed in the Bight program that were not on the RCCA targeted species list (Table 3; Appendix 1). The ANOSIM analysis, which takes into account the abundance and species composition of the entire community on a sample-by-sample basis, indicated that the benthic invertebrate communities described by the two sampling programs were not significantly different in either the inner and outer strata (Figure 3).

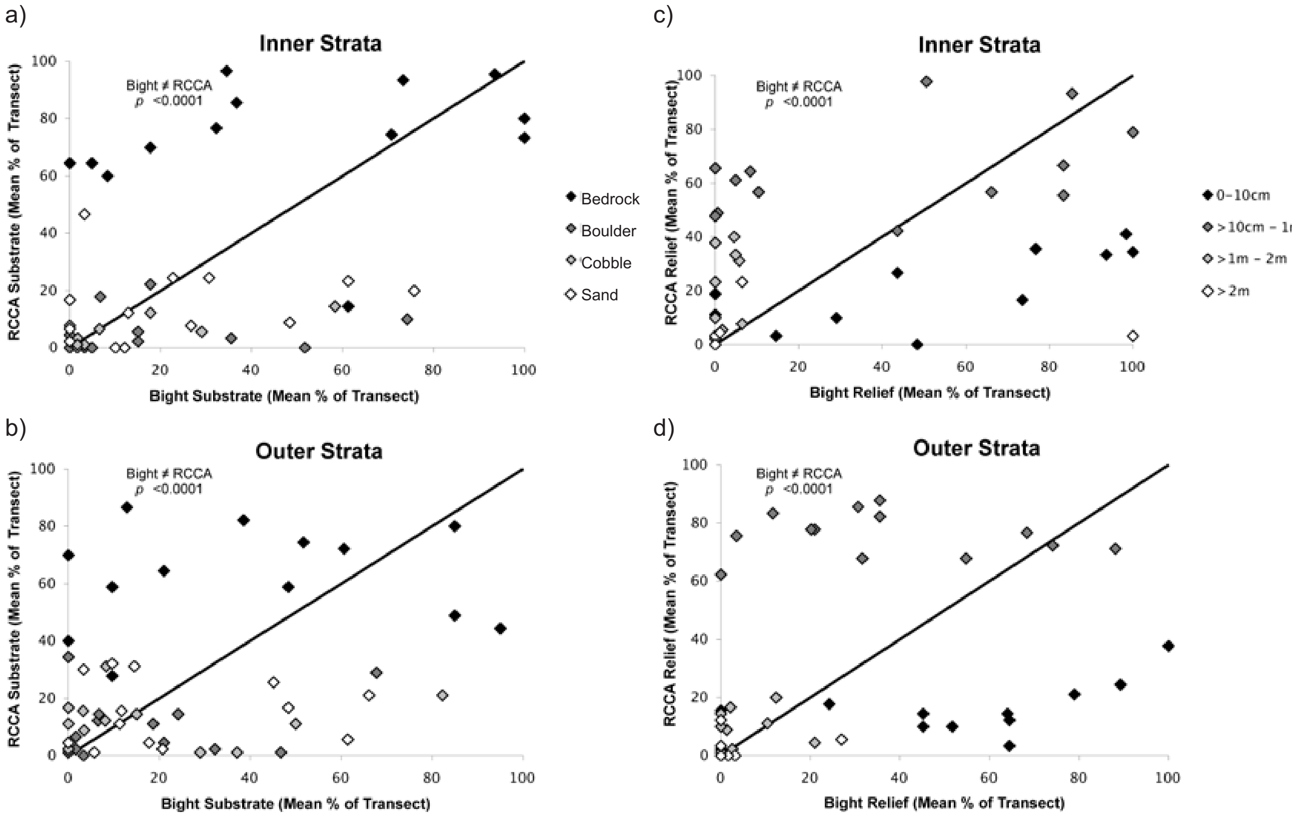

Figure 2 Paired site-by-site comparisons of substrate (a and b) and vertical relief (c and d) measured along transects by the Bight and RCCA sampling programs. The heavy line represents a theoretical 1:1 agreement between the datasets. Results from Mantel-Haenszel Chi-Square analysis testing differences in mean relief or substrate between the Bight and RCCA sample programs are also presented in each panel.

The very low R values (<0.100) in the ANOSIM analyses and the ordination from the nMDS, which had stress values >0.1, are indicative overlap of species composition between the communities, despite some differences in abundance noted below (Figure 3).

There were some significant, though inconsistent between strata, differences in the univariate measures of benthic invertebrate community structure between the two sampling programs. Benthic invertebrate species richness was significantly greater for the RCCA in the inner strata, but the outer strata were similar between the programs (Figure 4a). There were significant differences in the site-dataset interaction from the inner and outer strata because of the greater site-to-site variation in the species richness measured by the Bight program (Figure 4a). Shannon-Wiener diversity was significantly greater in those communities from the Bight program along the inner transects, but there was no difference in the communities observed by the two programs in the outer strata (Figure 4b). The significant site-dataset interactions among the inner and outer strata was, like the species richness, a reflection of the greater variability in species diversity among sites observed by the Bight program compared to that observed by the RCCA program (Figure 4b) and results from the dominance of urchins in the RCCA data (Table 3), which reduces diversity but does not affect species richness.

There were several differences in the abundance of the dominant benthic invertebrates when taxa were compared individually (Table 3). The RCCA program reported significantly more *S. purpuratus* in both the inner (p <0.0001) and outer (p = 0.0185) strata and *S. franciscanus* in the inner strata (p <0.0001). The Bight program reported significantly greater abundances of anemones from the inner (p <0.0001) and outer (p = 0.0008) strata, *P. miniata* in the outer strata (p <0.0186), Muricea spp. from the outer strata (p = 0.0119), and P. giganteus from the inner strata (p = 0.0006). There were no differences in the abundances of *Lithopoma* reported by the two programs, nor *P. miniata* and *Muricea* spp. from the inner strata, or *P. giganteus* from the outer strata. At four of the five sites where there were large differences in depth or sample date (Table 1), there were some differences in the abundance of at least one of the dominant benthic invertebrates between the programs, but there were no consistent patterns in those site-specific differences.

Fish

There were even fewer differences for the fish than there were for the benthic invertebrates collected by the two sampling programs and the goby *Lythrypnus dalli* was the only numerically dominant fish species observed by the Bight program that was not on the RCCA species list (Table 4). The ANOSIM indicated that there were statistically significant differences in the community composition of the fish observed by the Bight and RCCA sampling programs in both the inner and outer strata, but with low R values (<0.100). This is consistent with the nMDS ordination plots (Figure 5a,b), which showed no clear visual separation of the communities sampled by either program and had large stress values (>0.20).

There was significantly greater species richness of the fish observed along transects from the inner strata by RCCA than by Bight, but there was no statistical difference observed between the two programs in the outer transects (Figure 4c,d). Additionally, the site-dataset interaction term was significant for the inner and outer strata, indicating greater site-to-site variability in species richness observed by the Bight program compared to the RCCA (Figure 4c). RCCA also observed fish communities with significantly greater Shannon-Weiner diversity along transects from both the inner (p = 0.0058) and outer (p = 0.0372) strata. The site-dataset interaction was also significant in the inner (p = 0.0085) and outer (p = 0.0052) strata, again due to the greater site-to-site variability within the Bight dataset (Figure 4d).

There were no significant differences in the total abundance ($\log_{10}$+1 transformed) of fish observed by the Bight and RCCA sampling programs along transects from either the inner (p = 0.1213) or outer (p = 0.3267) strata, though there were significant differences among the site-dataset interaction term for total fish abundance for both the inner (p <0.0001) and outer (p = 0.0014) depth strata. This was due primarily to greater site-to-site variance in total abundance observed by the Bight program. Of the seven most abundant species of fish observed across all 13 sites, only *G. nigricans* and *H. caryi* differed significantly between the two programs (Table 4). The RCCA program observed more *G. nigricans* along transects from both inner and outer depth strata than did the Bight program. The Bight program observed more *H. caryi* along transects from the inner strata.

The size distribution of fish observed by the two programs differed significantly (p = 0.0007) in the inner strata, but not in outer strata (p = 0.5564). When the individual species were analyzed separately, there were no consistent differences between the two programs (Figure 6). There were significant differences in the size distributions of *C. punctipinnis* and *O. californica* from the inner strata, where the Bight program reported smaller fish than the RCCA, but this difference was not apparent in the outer strata. There were also differences in the distribution of the *P. clathratus* and *S. pulcher* from both strata, where the Bight program reported larger fish than the RCCA program. There were no statistical differences in the size frequencies for the other species.

Discussion

We found differing degrees of agreement between the two sampling programs for the three sampling elements, with the greatest agreement for the fish, lesser agreement for the benthos and poor agreement for the physical habitat descriptors. These differences are likely related to three types of error or bias in the data and in our analyses. The difference in the physical habitat variables likely result from procedural differences in how the two programs select respective transect starting points and directions, which can bias the micro-habitats (e.g., boulder fields or sandy patches) that are sampled. The RCCA haphazardly selects the direction of a transect, while the Bight transects are based on pre-determined compass headings. The RCCA transect selection allows for active selection of more “interesting” habitats (i.e., greater relief or structural complexity) by volunteer divers, which would account for the greater amounts of bedrock and boulder substrates with greater relief in the RCCA dataset. This bias in physical habitat could propagate to some of the observed differences in benthic invertebrates. Bias in transect selection would have comparably less influence on the fish community, due to their relative mobility, as we observed in the data.

Table 3. Mean abundance (number/transect) and density (number/m^2) of all benthic invertebrates observed across the 13 sampling sites from the Inner Strata and Outer Strata by the Bight and RCCA programs. The results from a comparison of abundance between the two programs for the top seven most abundant taxa across both programs are also presented. Differences were tested with a post-hoc tukey-kramer adjusted least square means comparison (α = 0.05) of a 2-way negative binomial GEE, where site and sampling program were the treatment factors.

Bight					RCCA					
Species	Mean Abundance (#/transect)	Mean Density (#/m^2)	Relative Abundance (%)	Frequency (%)	Species	Mean Abundance (#/transect)	Mean Density (#/m^2)	Relative Abundance (%)	Frequency (%)	Abundance Difference
Strongylocentrotus purpuratus	58.35	0.972	21.8	75.0	*Strongylocentrotus purpuratus*	305.43	5.091	64.00	83.3	RCCA>Bight
Strongylocentrotus franciscanus	53.04	0.884	19.8	75.0	*Strongylocentrotus franciscanus*	102.43	1.707	21.47	83.3	RCCA>Bight
Anthopleura sola [b]	23.23	0.387	8.7	41.7	*Patiria miniata*	15.48	0.258	3.24	47.2	RCCA=Bight
Patiria miniata	22.65	0.378	8.5	54.2	*Muricea spp.*	10.98	0.183	2.30	33.3	RCCA=Bight
Pisaster giganteus	18.73	0.312	7.0	83.3	*Lithopoma* spp.	10.52	0.175	2.20	44.4	RCCA=Bight
Styela montereyensis [e]	16.88	0.281	6.3	33.3	*Megathura crenulata*	7.60	0.127	1.59	52.8	
Megathura crenulata	13.58	0.226	5.1	45.8	*Pisaster giganteus*	5.97	0.100	1.25	58.3	RCCA<Bight
Parastichopus parvimensis	12.15	0.203	4.5	25.0	Anemone	4.92	0.082	1.03	27.8	RCCA<Bight
Urticina lofotensis [b]	10.92	0.182	4.1	8.3	*Parastichopus parvimensis*	4.33	0.072	0.91	41.7	
Cypraea spadicea	7.12	0.119	2.7	12.5	*Kelletia kelletii*	2.59	0.043	0.54	58.3	
Lithopoma undosum [d]	6.88	0.115	2.6	58.3	*Centrostephanus coronatus*	2.23	0.037	0.47	16.7	
Kelletia kelletii	6.00	0.100	2.2	25.0	*Cypraea spadicea*	1.72	0.029	0.36	16.7	
Pisaster ochraceous [e]	3.58	0.060	1.3	33.3	*Pisaster brevispinus*	1.41	0.024	0.30	25.0	
Muricea californicaa	3.27	0.054	1.2	37.5	*Lophogorgia chilensis*	0.51	0.009	0.11	8.3	
Tethya aurantia [e]	2.85	0.047	1.1	33.3	*Crassedoma giganteum*	0.51	0.009	0.11	25.0	
Muricea fruticosa [a]	1.69	0.028	0.6	33.3	*Panulirus interruptus*	0.41	0.007	0.09	22.2	
Metridium spp.[e]	0.85	0.014	0.3	4.2	*Parastichopus californicus*	0.13	0.002	0.03	2.8	
Crassedoma giganteum	0.81	0.013	0.3	20.8	*Haliotis corrugata*	0.03	0.0004	0.01	2.8	
Aplysia californica [b]	0.73	0.012	0.3	8.3	Sheep/Decorator Crab	0.03	0.0004	0.01	2.8	
Pisaster brevispinus	0.65	0.011	0.2	16.7						
Centrostephanus coronatus	0.46	0.008	0.2	8.3						
Pachycerianthus fimbratus [b]	0.46	0.008	0.2	16.7						
Anthopleura elegantissima [b]	0.38	0.006	0.1	8.3						
Lytechinus anamesus [e]	0.35	0.006	0.1	16.7						
Pycnopodia helianthoides [c]	0.35	0.006	0.1	8.3						
Urticina spp.[b]	0.31	0.005	0.1	12.5						
Lophogorgia chilensis	0.27	0.004	0.1	12.5						
Norrisia norrisi [e]	0.27	0.004	0.1	8.3						
Panulirus interruptus [e]	0.27	0.004	0.1	16.7						
Dermasterias imbricata [e]	0.19	0.003	0.1	8.3						
Parastichopus californicus	0.08	0.001	0.0	8.3						
Sheep/Decorator Crab	0.04	0.001	0.0	4.2						
Orthasterias koehleri [e]	0.04	0.001	0.0	4.2						
Pugettia richii [e]	0.04	0.001	0.0	4.2						

Table 3. Continued

Bight					RCCA					
Species	Mean Abundance (#/transect)	Mean Density ($\#/m^2$)	Relative Abundance (%)	Frequency (%)	Species	Mean Abundance (#/transect)	Mean Density ($\#/m^2$)	Relative Abundance (%)	Frequency (%)	Abundance Difference
Strongylocentrotus franciscanus	48.46	0.808	23.2	75.0	*Strongylocentrotus purpuratus*	159.89	2.665	54.2	83.3	RCCA >Bight
Strongylocentrotus purpuratus	46.00	0.767	22.1	66.7	*Strongylocentrotus franciscanus*	66.66	1.111	22.6	88.9	RCCA=Bight
Patiria miniata	28.23	0.471	13.5	54.2	*Patiria miniata*	15.69	0.262	5.3	61.1	RCCA<Bight
Pisaster giganteus	10.69	0.178	5.1	87.5	*Muricea* spp.	12.89	0.215	4.4	47.2	RCCA<Bight
Tethya aurantia [e]	9.77	0.163	4.7	33.3	*Lithopoma* spp.	11.67	0.194	4.0	66.7	RCCA=Bight
Muricea californica [a]	9.65	0.161	4.6	66.7	*Pisaster giganteus*	7.46	0.124	2.5	77.8	RCCA=Bight
Centrostephanus coronatus	7.65	0.128	3.7	12.5	*Kelletia kelletii*	4.36	0.073	1.5	63.9	
Pachycerianthus fimbratus	6.31	0.105	3.0	16.7	*Parastichopus parvimensis*	2.67	0.044	0.9	52.8	
Urticina lofotensis [b]	6.23	0.104	3.0	8.3	*Centrostephanus coronatus*	2.49	0.041	0.8	19.4	
Styela montereyensis [e]	5.69	0.095	2.7	37.5	*Megathura crenulata*	2.46	0.041	0.8	50.0	
Parastichopus parvimensis	4.58	0.076	2.2	20.8	Anemone	2.13	0.035	0.7	30.6	RCCA<Bight
Kelletia kelletii	4.23	0.071	2.0	29.2	*Lophogorgia chilensis*	1.95	0.032	0.7	19.4	
Megathura crenulata	4.12	0.069	2.0	33.3	*Pisaster brevispinus*	1.79	0.030	0.6	36.1	
Lithopoma undosum [d]	3.62	0.060	1.7	41.7	*Cypraea spadicea*	1.41	0.024	0.5	22.2	
Cypraea spadicea	2.77	0.046	1.3	16.7	*Panulirus interruptus*	0.79	0.013	0.3	13.9	
Anthopleura sola [b]	2.19	0.037	1.1	20.8	*Crassedoma giganteum*	0.64	0.011	0.2	30.6	
Muricea fruticosa [a]	1.58	0.026	0.8	33.3	Sunflower/Sun Star	0.08	0.001	0.0	5.6	
Lophogorgia chilensis	1.54	0.026	0.7	33.3	Sheep/Decorator Crab	0.08	0.001	0.0	5.6	
Parastichopus californicus	1.42	0.024	0.7	16.7	*Cancer spp.*	0.03	0.000	0.0	2.8	
Aplysia californica [b]	0.96	0.016	0.5	12.5	*Haliotis corrugata*	0.03	0.000	0.0	2.8	
Lytechinus anamesus [e]	0.65	0.011	0.3	12.5						
Urticina spp. [b]	0.38	0.006	0.2	8.3						
Pisaster ochraceous [e]	0.23	0.004	0.1	12.5						
Pycnopodia helianthoides [c]	0.23	0.004	0.1	8.3						
Crassedoma giganteum	0.19	0.003	0.1	12.5						
Pisaster brevispinus	0.19	0.003	0.1	8.3						
Dermasterias imbricata [e]	0.15	0.003	0.1	12.5						
Linckia columbianus [e]	0.15	0.003	0.1	8.3						
Orthasterias koehleri [e]	0.15	0.003	0.1	8.3						
Panulirus interruptus	0.15	0.003	0.1	12.5						
Anthopleura elegantissima [b]	0.12	0.002	0.1	4.2						
Sheep/Decorator Crab	0.08	0.001	0.0	4.2						
Asterina armatus [e]	0.04	0.001	0.0	4.2						
Astrometis sertulifera [e]	0.04	0.001	0.0	4.2						
Cucumaria spp. [e]	0.04	0.001	0.0	4.2						
Metridium spp. [b]	0.04	0.001	0.0	4.2						
Pugettia producta [e]	0.04	0.001	0.0	4.2						

[a] Bight taxa grouped together as *Muricea* spp. for comparison to RCCA data
[b] Bight taxa grouped together as Anemone for comparison to RCCA data
[c] Bight taxa grouped together as Sunflower/Sun Star for comparison to RCCA data
[d] Bight taxa grouped together as *Lithopoma* spp. for comparison to RCCA data
[e] Taxa observed by Bight program, but not on the RCCA targeted species list

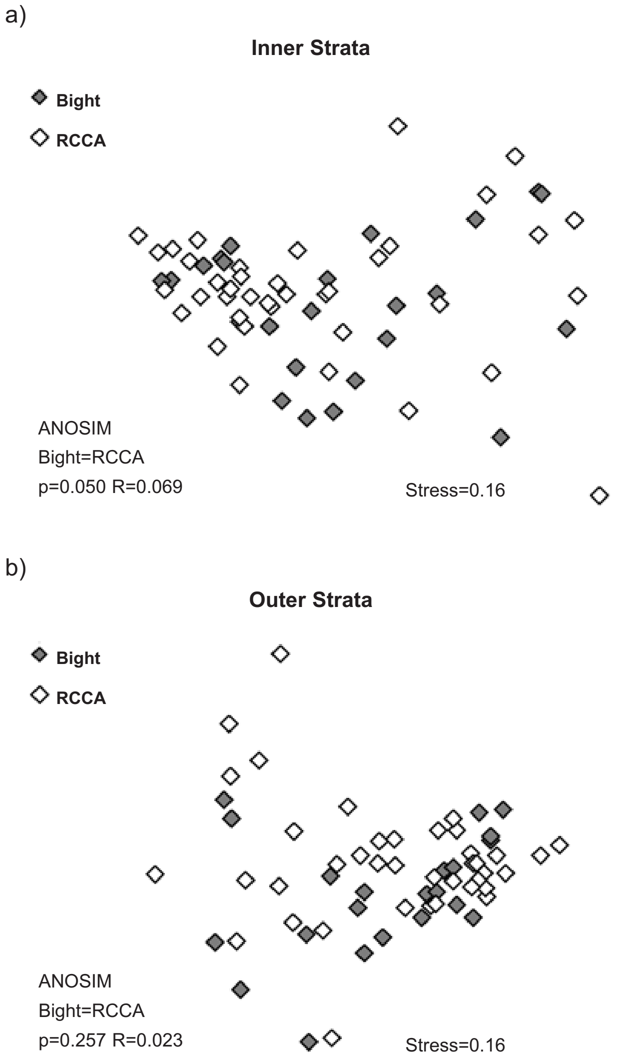

Figure 3. nMDS plots of benthic invertebrate communities observed by Bight and RCCA sampling programs in inner (a) and outer strata (b). Results of ANOSIM analyses where sampling program (Bight vs. RCCA) was the treatment variable are also presented. All calculations were based on Bray-Curtis similarity values calculated from square root-transformed species abundances.

Another procedural difference between the Bight and RCCA sampling designs that could explain some of the observed differences is how they estimate the abundance of high density invertebrates and the size-spectra of fish. The extrapolation procedure and the spatial scale used by the RCCA (50 individuals/30 m) and Bight (30 individuals/10 m) likely influenced the estimates of the most abundant benthic invertebrates. With organisms that have patchy distributions, like urchins, counting a limited number and extrapolating to a larger area or length can produce erroneous, typically over-inflated, estimates of total abundance when a high density patch is encountered (e.g., Schroeter *et al*. 2009). Though both the Bight and RCCA programs use this approach, the smaller distances and multiple measures per transect used by the Bight program lessen the error associated with extrapolating across patchy distributions compared to the RCCA protocol and create a divergence in the abundance estimates of the two programs. Similarly, the way the two programs estimate the size of fish (fine- and course-grained) may account for some of the differences that were observed for the larger, more mobile taxa. It bears noting, the greater number and finer-grain size classes of the Bight contain more information that can be essential for estimating fish population structure/productivity (e.g., Pauly and Morgan 1987) and assessing the habitat quality of rocky reefs (i.e., Bond *et al*. 1999, Oakes and Pondella 2009).

A second underlying cause for observed differences between RCCA and the Bight program could be related to observer error in the datasets. Previous studies (Halusky *et al*. 1994, Mumby *et al*. 1995) have demonstrated that trained volunteers, particularly those with less experience, are less accurate than trained professionals in taxonomic identifications and the sorting of data into size classes. RCCA volunteers are not novice SCUBA divers and they undergo a thorough training process (Dawson and Schuman 2009), but there is still typically a mix of experience-levels among divers conducting the surveys. This could explain some of the fish size differences we observed since some RCCA divers would be less experienced in correcting for underwater parallax, particularly under varying surge and visibility conditions. Diver experience could also have led to some of the greater diversity observed in the RCCA dataset, since less experienced divers will often actively seek out the rare and more interesting species. Moreover, the errors associated with individual divers can be additive, as RCCA typically uses multiple divers for sampling different replicate transects on a reef, whereas all replicates are typically surveyed by a single pair of divers in the Bight sampling.

A third source of the difference between the two programs could be related to our study design. This comparative study was conducted in a post-hoc manner, assembling data that were not synoptically collected, but were from the same reef. This led to both small scale spatial and temporal differences in site pairings, but we were able to address them. The two programs sampled most of the sites within an aver-

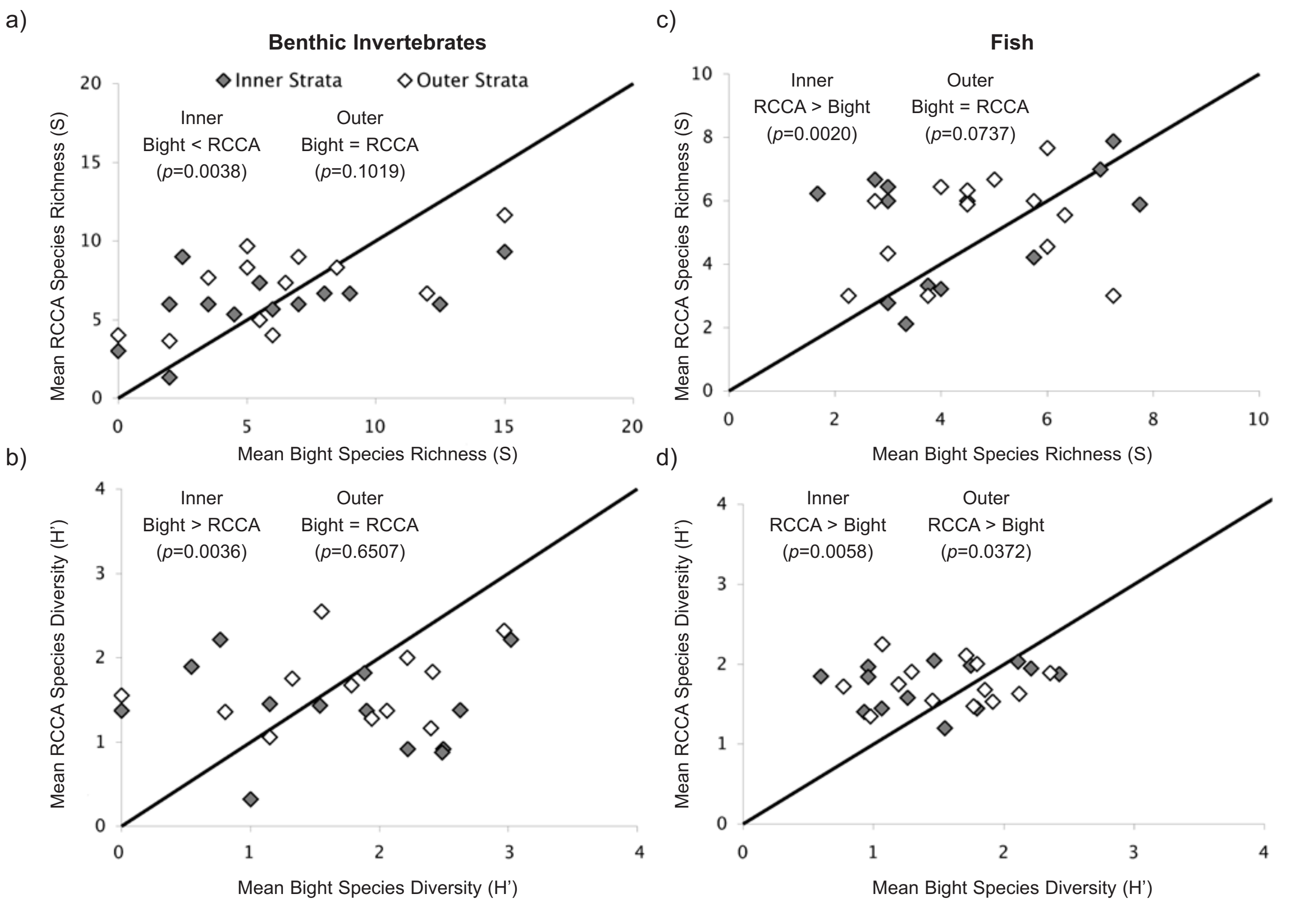

Figure 4. Comparison scatter plots of mean species richness (S; a and c) and mean species diversity (H'; b and d) for benthic invertebrate and fish communities observed by the CRANE and RCCA sampling programs. Dataset results from a 2-way ANOVA, with site and dataset as treatment factors, are presented for each stratum. The solid line represents a 1:1 agreement between the datasets. Species richness and diversity values are based upon only those species on the RCCA species lists, not the entire community of rocky reefs.

age of 31 days from each other, but four sites were sampled more than 60 days apart (Table 2). Patterns in both fish and benthic invertebrates (species richness, diversity, and abundance) were compared between the programs at these four sites, but there was no apparent influence of the time between sampling in the differences between the RCCA and Bight programs at these four sites compared to the others. There also exists the possibility that the two programs were sampling different parts of a given reef, particularly as the RCCA divers typically accessed the reef by swimming in from shore, while the majority of Bight sampling was done from anchored boats. We were unable to test the geospatial aspect specifically due to a lack of precise latitude-longitude data, but we were able to compare the influence depth on the fish and benthic invertebrate data. Most of the transects were an average of 1.3 m in depth from each other within a given depth stratum, but the difference between three sets of transects were greater than 3 m. However, site-specific differences in the fish and benthic invertebrate communities were not consistently different at those sites compared to those that were closer together in depth. As such, we believe the differences in time and depth that arose from our study design had minimal influence on our comparisons, but the geospatial location on the reef had unknown impact. This type of error, much like the transect bias, would most severely affect the physical habitat characterization and the differences observed in the benthic invertebrate communities.

When the results of our study are considered as a whole, there was reasonable agreement between the data collected by the two programs and the observed differences were likely a product of biases and error inherent to the sampling programs and our analyses. The results suggest that some changes to the RCCA procedures are advisable if data collected by volun-

Table 4. Mean abundance (number/transect) and density (number/m²) of all fish observed across the 13 sampling sites from the Inner Strata and Outer Strata by the Bight and RCCA programs. The results from a comparison of abundance between the two programs for the top seven most abundant taxa across both programs are also presented. Differences were tested with a post-hocTukey-Kramer adjusted least square means comparison (α= 0.05) of a 2-way negative binomial GEE, where site and sampling program were the treatment factors.

Bight					RCCA					
Species	Mean Abundance (#/transect)	Mean Density (#/m²)	Relative Abundance (%)	Frequency (%)	Species	Mean Abundance (#/transect)	Mean Density (#/m²)	Relative Abundance (%)	Frequency (%)	Abundance Difference
Oxyjulis californica	20.19	0.337	32.70	63.5	*Chromis punctipinnis*	14.09	0.235	39.50	50.4	RCCA=Bight
Sardinops sagax [a]	19.23	0.321	31.14	1.9	*Oxyjulis californica*	8.22	0.137	23.04	83.8	RCCA=Bight
Chromis punctipinnis	7.98	0.133	12.92	28.8	*Hypsypops rubicundus*	2.32	0.039	6.51	50.4	
Paralabrax clathratus	2.38	0.040	3.86	65.4	*Paralabrax clathratus*	2.09	0.035	5.84	64.1	RCCA=Bight
Embiotoca jacksoni	2.23	0.037	3.61	53.8	*Embiotoca jacksoni*	2.07	0.034	5.80	53.0	RCCA=Bight
Paralabrax nebulifer	1.77	0.029	2.87	19.2	*Halichoeres semicinctus*	1.79	0.030	5.01	48.7	
Hypsurus caryi	1.71	0.029	2.77	25.0	*Semicossyphus pulcher*	1.65	0.027	4.62	48.7	RCCA=Bight
Semicossyphus pulcher	1.21	0.020	1.96	30.8	*Girella nigricans*	1.57	0.026	4.41	26.5	RCCA>Bight
Brachyistius frenatus [a]	1.10	0.018	1.78	17.3	*Paralabrax nebulifer*	0.62	0.010	1.75	14.5	
Hypsypops rubicundus	1.00	0.017	1.62	38.5	*Hypsurus caryi*	0.40	0.007	1.13	22.2	RCCA<Bight
Oxylebius pictus [a]	0.63	0.011	1.03	19.2	*Rhacochilus vacca*	0.19	0.003	0.53	14.5	
Atherinopsis californiensis [a]	0.48	0.008	0.78	1.9	*Sebastes atrovirens*	0.18	0.003	0.50	9.4	
Halichoeres semicinctus	0.46	0.008	0.75	21.2	*Rhacochilus toxotes*	0.12	0.002	0.34	8.5	
Girella nigricans	0.23	0.004	0.37	11.5	*Embiotoca lateralis*	0.10	0.002	0.29	6.8	
Rhacochilus vacca	0.23	0.004	0.37	13.5	*Anisotremus davidsonii*	0.09	0.001	0.24	3.4	
Phanerodon furcatus [a]	0.21	0.004	0.34	11.5	*Sebastes carnatus*	0.04	0.001	0.12	4.3	
Sebastes atrovirens	0.13	0.002	0.22	11.5	*Sebastes auriculatus*	0.03	0.001	0.10	2.6	
Cymatogaster aggregata [a]	0.08	0.001	0.12	3.8	*Sebastes chrysomelas*	0.03	0.0004	0.07	2.6	
Heterostichus rostratus [a]	0.06	0.001	0.09	1.9	*Sebastes mystinus*	0.02	0.0003	0.05	0.9	
Lythrypnus dalli [a]	0.06	0.001	0.09	1.9	*Sebastes serranoides/S. flavidus*	0.02	0.0003	0.05	1.7	
Sebastes carnatus	0.06	0.001	0.09	5.8	*Sebastes serriceps*	0.02	0.0003	0.05	1.7	
Sebastes serriceps	0.06	0.001	0.09	1.9	*Heterodontus francisci*	0.01	0.0001	0.02	0.9	
Anisotremus davidsonii	0.04	0.001	0.06	3.8	*Ophiodon elongatus*	0.01	0.0001	0.02	0.9	
Sebastes chrysomelas	0.04	0.001	0.06	3.8	*Scorpaenichthys marmoratus*	0.01	0.0001	0.02	0.9	
Sebastes mystinus	0.04	0.001	0.06	1.9						
Balistes polylepis [a]	0.02	0.0003	0.03	1.9						
Heterodontus francisci	0.02	0.0003	0.03	1.9						
Medialuna californiensis	0.02	0.0003	0.03	1.9						
Ophiodon elongatus	0.02	0.0003	0.03	1.9						
Paralichthys californicus [a]	0.02	0.0003	0.03	1.9						
Scorpaenichthys marmoratus	0.02	0.0003	0.03	1.9						
Sebastes serranoides [a]	0.02	0.0003	0.03	1.9						

Table 4. Continued

Bight					RCCA					
Species	Mean Abundance (#/transect)	Mean Density (#/m^2)	Relative Abundance (%)	Frequency (%)	Species	Mean Abundance (#/transect)	Mean Density (#/m^2)	Relative Abundance (%)	Frequency (%)	Abundance Difference
Chromis punctipinnis	11.29	0.188	28.54	44.2	*Oxyjulis californica*	12.09	0.201	30.68	77.8	RCCA=Bight
Oxyjulis californica	6.98	0.116	17.65	63.5	*Chromis punctipinnis*	11.53	0.192	29.27	53.0	RCCA=Bight
Paralabrax clathratus	4.65	0.078	11.76	71.2	*Paralabrax clathratus*	3.16	0.053	8.03	80.3	RCCA=Bight
Lythrypnus dalli [a]	3.65	0.061	9.24	7.7	*Hypsypops rubicundus*	2.74	0.046	6.94	48.7	
Semicossyphus pulcher	2.33	0.039	5.88	53.8	*Halichoeres semicinctus*	2.32	0.039	5.88	46.2	
Paralabrax nebulifer	1.77	0.029	4.47	30.8	*Girella nigricans*	2.01	0.033	5.10	26.5	RCCA>Bight
Hypsurus caryi	1.73	0.029	4.38	21.2	*Semicossyphus pulcher*	1.74	0.029	4.43	53.8	RCCA=Bight
Hypsypops rubicundus	1.54	0.026	3.89	40.4	*Embiotoca jacksoni*	1.63	0.027	4.14	47.0	RCCA=Bight
Brachyistius frenatus [a]	1.31	0.022	3.31	9.6	*Hypsurus caryi*	0.80	0.013	2.04	20.5	RCCA=Bight
Embiotoca jacksoni	1.04	0.017	2.63	44.2	*Paralabrax nebulifer*	0.40	0.007	1.02	22.2	
Rhacochilus vacca	0.67	0.011	1.70	17.3	*Embiotoca lateralis*	0.36	0.006	0.91	10.3	RCCA<Bight
Halichoeres semicinctus	0.56	0.009	1.41	28.8	*Rhacochilus vacca*	0.21	0.003	0.52	14.5	
Oxylebius pictus [a]	0.48	0.008	1.22	13.5	*Rhacochilus toxotes*	0.15	0.003	0.39	7.7	
Medialuna californiensis [a]	0.46	0.008	1.17	7.7	*Sebastes atrovirens*	0.10	0.002	0.26	6.8	
Girella nigricans	0.33	0.005	0.83	13.5	*Anisotremus davidsonii*	0.07	0.001	0.17	2.6	
Phanerodon furcatus [a]	0.21	0.004	0.53	5.8	*Sebastes carnatus*	0.03	0.001	0.09	3.4	
Sebastes atrovirens	0.10	0.002	0.24	9.6	*Sebastes caurinus*	0.03	0.0004	0.07	2.6	
Rhinogobiops nicholsii [a]	0.08	0.001	0.19	5.8	*Heterodontus francisci*	0.01	0.0001	0.02	0.9	
Caulolatilus princeps [a]	0.06	0.001	0.15	3.8	*Scorpaenichthys marmoratus*	0.01	0.0001	0.02	0.9	
Sebastes caurinus	0.06	0.001	0.15	5.8	*Sebastes chrysomelas*	0.01	0.0001	0.02	0.9	
Rhacochilus toxotes	0.04	0.001	0.10	3.8						
Sebastes auriculatus	0.04	0.001	0.10	3.8						
Sebastes carnatus	0.04	0.001	0.10	3.8						
Sebastes serranoides [b]	0.04	0.001	0.10	3.8						
Atherinopsis californiensis [a]	0.02	0.0003	0.05	1.9						
Cephaloscyllium ventriosum [a]	0.02	0.0003	0.05	1.9						
Cymatogaster aggregata [a]	0.02	0.0003	0.05	1.9						
Heterodontus francisci	0.02	0.0003	0.05	1.9						
Leiocottus hirundo [a]	0.02	0.0003	0.05	1.9						
Myliobatis californica [a]	0.02	0.0003	0.05	1.9						

[a] Bight species grouped together with *Sebastes flavidus* for comparison to RCCA data

[b] Species observed by Bight program, but not on the RCCA targeted species list

a)

b)

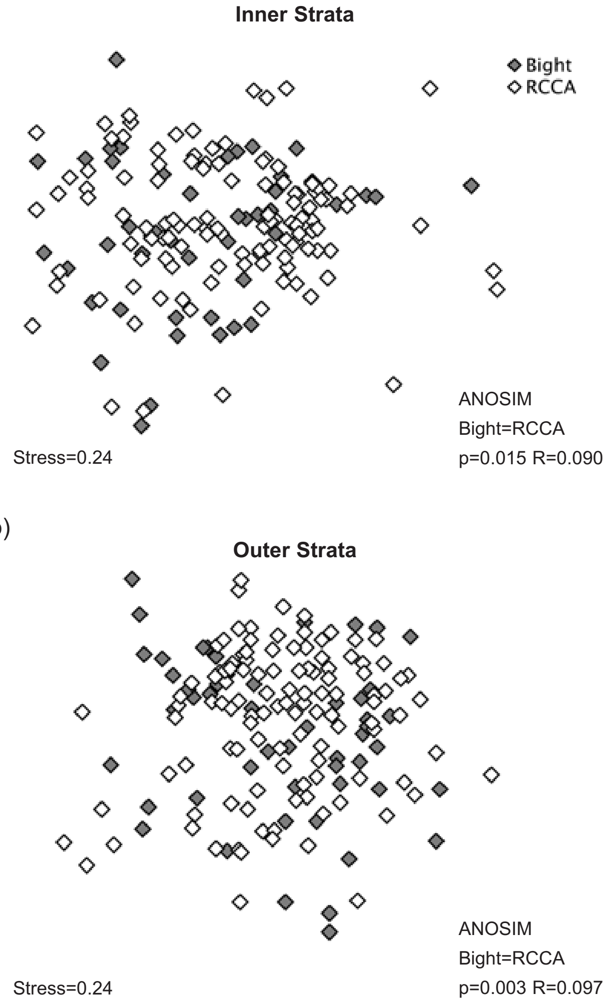

Figure 5. nMDS plots of fish communities observed by Bight and RCCA sampling programs in inner (a) and outer strata (b). Results of ANOSIM analyses where sampling program (Bight vs. RCCA) was the treatment variable are also presented. All calculations were based on Bray-Curtis similarity values calculated from square root-transformed species abundances.

teer and professional scientists are to be integrated; particularly the use of a predetermined, random transect selection procedure by RCCA. However, any decision about the extent to which data from these programs can be merged ultimately depends on the intended use of the data. If the management of an ecosystem as a whole (either structurally or functionally) is of primary interest, than monitoring programs like the Bight, PISCO, or CRANE programs that collect a wide variety of detailed biological and physical data would be most appropriate. The sampling reductions to accommodate volunteers (elimination of the mid-water habitat and outer transects, more limited targeted species list) will preclude extensive use of RCCA data. Conversely, if management and monitoring of select components of the rocky reef ecosystem (e.g., community dominants or stress tolerant/indicative taxa) is of primary interest, than the RCCA data collection may be a cost effective manner for achieving such assessments. Our analyses and those of others (e.g., Fore *et al*. 2001, Pattengill-Semmens and Semmens 2003, Léopold *et al*. 2009) suggest that trained volunteers can be taught the appropriate skills to produce similar data to professional scientists, as long as there is sufficient guidance and supervision, a rigorous sampling scheme, and that the taxonomic scope of the work is constrained. If the differences identified in this paper are addressed through minor procedure modifications, then managers of Southern California's rocky reef ecosystems should be able to use the data collected by the trained volunteers of the RCCA program in concert with those data collected by professional scientists.

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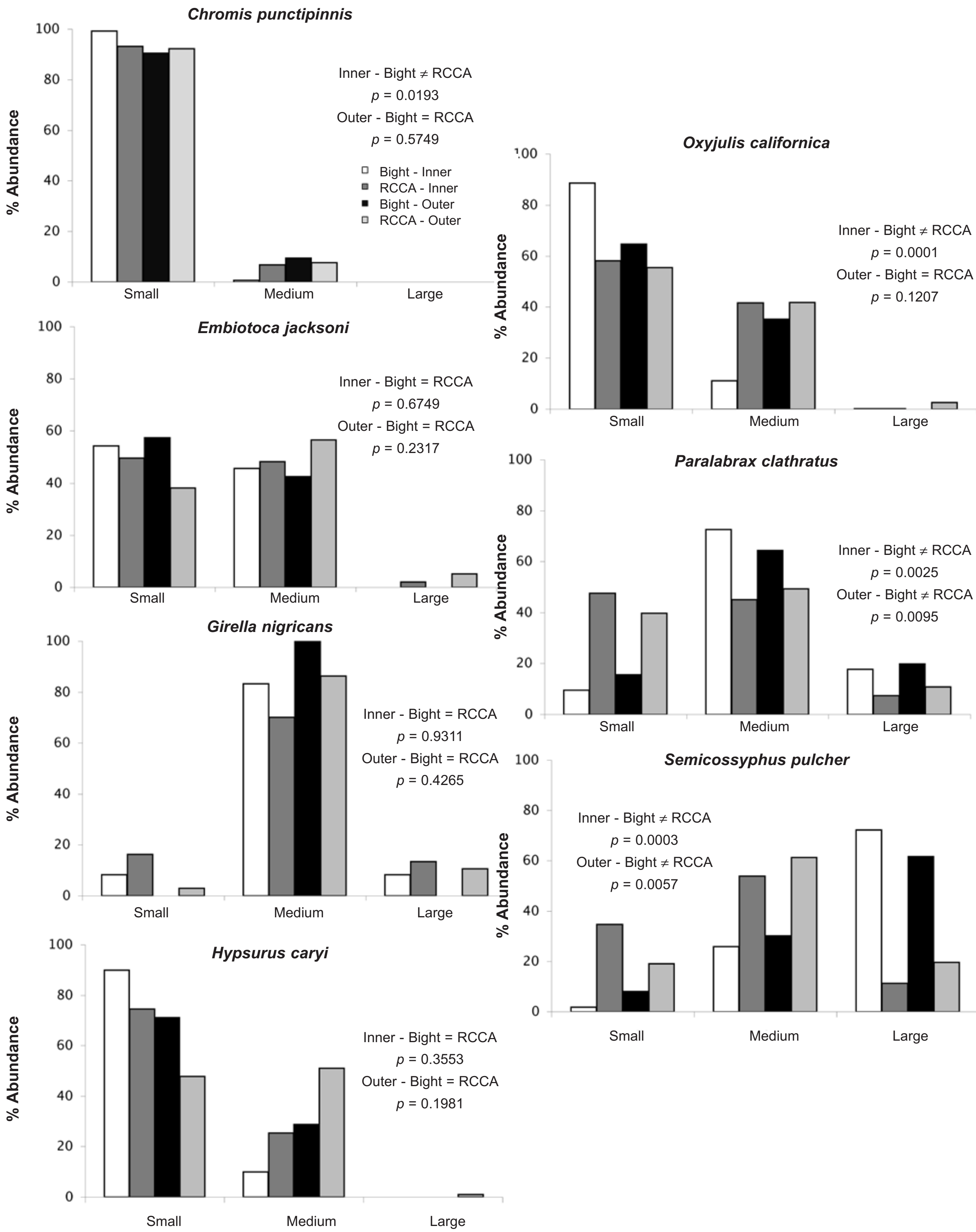

Figure 6. Relative abundance (%) of the seven most abundant/frequently observed species of fish reported by the Bight and RCCA programs from the inner and outer strata. Differences in size-class distribution were compared using a Mantel-Haenszel Chi-Square analysis, the results of which are presented in each panel.

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Appendix 1. Species lists used by the Bight sampling program for algae, benthic invertebrates, and fish. Algae and benthic invertebrates lists are a limeted to conspicous or taxa of interest. The fish list is all taxa observed by the Bight program participants across the entire southern California Bight, over multiple years.

Algae	Benthic Invertebrates	
Agarum fimbriatum	*Anisodoris nobilis*	*Lophogorgia chilensis*
Alaria marginata	*Anthopleura artemisia*	*Loxorhychus grandis*
Codium fragile	*Anthopleura elegantissima*	*Loxorhynchus/Scyra* spp.
Costaria costatum	*Anthopleura sola*	*Lytechinus anamesus*
Cystoseira osmundacea	*Anthopleura* spp.	*Mediaster aequalis*
Desmarestia ligulata	*Anthopleura xanthogrammica*	*Megathura crenulata*
Dictyoneuropsis reticulata	*Aplysia californica*	*Metridium* spp.
Dictyoneurum californicum	*Aplysia vaccaria*	*Mexichromis porterae*
Egregia menziesii	*Asterina armatus*	*Mimulus foliatus*
Eisenia arborea	*Astrometis sertulifera*	*Mitra idae*
Laminaria farlowii	*Balanus nubilis*	*Muricea californica*
Laminaria setchellii	*Cadlina leuteomarginata*	*Muricea fruticosa*
Laminaria spp.	*Calliostoma* spp.	Mussel
Macrocystis pyrifera	*Cancer antennarius*	*Navanax inermis*
Mastocarpus papillatus	*Cancer* spp.	*Norrisia norrisi*
Nereocystis luetkeana	*Centrostephanus coronatus*	*Octopus bimaculoides*
Pelagophycus porra	*Ceratostoma foliatum*	*Ophioplocus esmarki*
Pleurophycus gardneri	*Craniella arb*	*Ophiothrix spiculata*
Pterygophora californica	*Crassedoma giganteum*	*Orthasterias koehleri*
Sargassum spp.	*Cryptochiton stelleri*	*Pachycerianthus fimbratus*
Undaria pinnatifida	*Cucumaria miniata*	*Panulirus interruptus*
	Cucumaria spp.	*Parastichopus californicus*
	Cypraea spadicea	*Parastichopus parvimensis*
	Dermasterias imbricata	*Parastichopus* spp.
	Diaulula sandiegensis	*Patiria miniata*
	Diodora aspera	*Pisaster brevispinus*
	Eugorgia rubens	*Pisaster giganteus*
	Flabellina iodinea	*Pisaster ochraceous*
	Gorgonian	*Pugettia producta*
	Haliotis corrugata	*Pugettia richii*
	Haliotis cracherodii	*Pugettia* spp.
	Haliotis fulgens	*Pycnopodia helianthoides*
	Haliotis kamtschatkana	*Strongylocentrotus franciscanus*
	Haliotis rufescens	*Strongylocentrotus purpuratus*
	Haliotis spp.	*Styela montereyensis*
	Haliotis wallalensis	*Stylantheca porphyra*
	Henricia leviuscula	*Stylaster californianus*
	Hermissenda crassicornis	*Tegula* spp.
	Kelletia kelletii	*Tethya aurantia*
	Leptasterias hexactis	*Toxadocia* spp
	Linckia columbianus	*Urticina lofotensis*
	Lithopoma gibberosum	*Urticina piscivora*
	Lithopoma spp.	*Urticina* spp.
	Lithopoma undosum	

Appendix 1. Continued

Fish

Alloclinus holderi
Alopias vulpinus
Anarrhichthys ocellatus
Anisotremus davidsonii
Apodichthys fucorum
Apodichthys sanctaerosae
Artedius corallinus
Atherinidae spp.
Atherinops affinis
Atherinopsis californiensis
Aulorhynchus flavidus
Bait
Balistes polylepis
Bathymasteridae spp.
Blenniidae spp.
Bothidae spp.
Brachyistius frenatus
Caulolatilus princeps
Cebidichthys violaceus
Cephaloscyllium ventriosum
Chaetodon falcifer
Cheilotrema saturnum
Chirolophis nugator
Chitonotus pugetensis
Chromis punctipinnis
Citharichthys sordidus
Citharichthys spp.
Citharichthys stigmaeus
Clinidae spp.
Clinocottus analis
Clupeidae spp.
Cottidae spp.
Cymatogaster aggregata
Embiotoca jacksoni
Embiotoca lateralis
Embiotocidae spp.
Engraulis mordax
Ernogrammus walkeri
Galeorhinus galeus
GBY Rockfish young of year
Gibbonsia elegans
Gibbonsia spp.
Girella nigricans
Gobiesox maeandricus
Gobiidae spp.
Gymnothorax mordax
Halichoeres semicinctus
Hermosilla azurea
Heterodontus francisci
Heterostichus rostratus
Hexagrammos decagrammus
Hexagrammos lagocephalus
Hyperprosopon analis
Hyperprosopon argenteum
Hyperprosopon ellipticum
Hypsurus caryi
Hypsypops rubicundus
Jordania zonope
Kasatkia seigeli
KGB Rockfish young of the year
Leiocottus hirundo
Lepidogobius lepidus
Lethops connectens
Liparis mucosus
Liparis spp.
Lythrypnus dalli
Medialuna californiensis
Mola Mola
Mugil cephalus
Myliobatis californica
Neoclinus stephensae
Neoclinus uninotatus
Oligocottus snyderi
Ophiodon elongatus
Orthonopias triacis
Oxyjulis californica
Oxylebius pictus
Paralabrax clathratus
Paralabrax maculatofasciatus
Paralabrax nebulifer
Paralichthys californicus
Phanerodon atripes
Phanerodon furcatus
Pholididae spp.
Platyrhinoides triseriata
Pleuronectidae spp.
Plueronichthys coenosus
Porichthys notatus
Prionace glauca
Rathbunella hypoplecta
Rhacochilus toxotes
Rhacochilus vacca
Rhinogobiops nicholsii
Rockfish unidentified spp.
Rockfish young of the year unidentified
Ronquilus jordani
Sarda chiliensis
Sardinops sagax
Scomber japonicus
Scorpaena guttata
Scorpaenichthys marmoratus
Scorpaenodes xyris
Sebastes atrovirens
Sebastes auriculatus
Sebastes carnatus
Sebastes caurinus
Sebastes chrysomelas
Sebastes dalli
Sebastes diploproa
Sebastes entomelas
Sebastes hopkinsi
Sebastes melanops
Sebastes miniatus
Sebastes mystinus
Sebastes nebulosus
Sebastes paucispinis
Sebastes pinniger
Sebastes rastrelliger
Sebastes rosaceus
Sebastes saxicola
Sebastes serranoides
Sebastes serriceps
Sebastes umbrosus
Semicossyphus pulcher
Seriola lalandi
Sphyraena argentea
Squatina californica
Stereolepis gigas
Stichaeidae spp.
Synchirus / Rimicola spp.
Syngnathus spp.
Synodus lucioceps
Torpedo californica
Trachurus symmetricus
Triakis semifasciata
Unidentified Fish
Xenistius californiensis
Zalembius rosaceus

Appendix 2. Species lists used by the RCCA program for algae, benthic invertebrates, and fish. All lists are limited to taxa selected by RCCA as commercially, ecologically, or culturally important.

Algae	Benthic Invertebrates	Fish
Scientific Name	Scientific Name	Scientific Name
Caulerpa taxifolia	*Actinaria*	*Anisotremus davidsonii*
Eisenia arborea	*Cancer spp.*	*Chromis punctipinnis*
Laminaria spp.	*Centrostephanus coronatus*	*Embiotoca jacksoni*
Macrocystis pyrifera	*Crassedoma giganteum*	*Embiotoca lateralis*
Nereocystis luetkeana	*Cryptochiton stelleri*	*Girella nigricans*
Pterygophora californica	*Cypraea spadicea*	*Halichoeres semicinctus*
Sargassum spp.	*Haliotis corrugata*	*Heterodontus francisci*
Undaria pinnatifida	*Haliotis cracherodii*	*Hexagrammos decagrammus*
	Haliotis fulgens	*Hexagrammos lagocephalus*
	Haliotis kamtschatkana	*Hypsurus caryi*
	Haliotis rufescens	*Hypsypops rubicundus*
	Haliotis sorenseni	*Ophiodon elongatus*
	Haliotis wallalensis	*Oxyjulis californica*
	Kelletia kelletii	*Paralabrax clathratus*
	Lithopoma spp.	*Paralabrax nebulifer*
	Lophogorgia chilensis	*Rhacochilus toxotes*
	Loxorhynchus spp.	*Rhacochilus vacca*
	Megathura crenulata	*Scorpaenichthys marmoratus*
	Muricea spp.	*Sebastes atrovirens*
	Panulirus interruptus	*Sebastes auriculatus*
	Parastichopus californicus	*Sebastes carnatus*
	Parastichopus parvimensis	*Sebastes caurinus*
	Patiria miniata	*Sebastes chrysomelas*
	Pisaster brevispinus	*Sebastes melanops*
	Pisaster giganteus	*Sebastes mystinus*
	Strongylocentrotus franciscanus	*Sebastes nebulosus*
	Strongylocentrotus purpuratus	*Sebastes paucispinis*
	sunflower/sun star	*Sebastes rastrelliger*
		Sebastes serriceps
		Sebastes spp. 1 (S. miniatus/S. pinniger)
		Sebastes spp. 2 (S. flavidus/S. serranoides)
		Semicossyphus pulcher
		Stereolepis gigas