Ecological Indicators 60 (2016) 802–814

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Evaluating ecological states of rocky intertidal communities: A Best Professional Judgment exercise

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ARTICLE INFO

Article history:
Received 17 December 2014
Received in revised form 30 July 2015
Accepted 8 August 2015

Keywords:
Ecological evaluation
Rocky intertidal habitats
Macroalgae
Macroinvertebrates
Biological communities
Best Professional Judgment
Anthropogenic disturbance

ABSTRACT

A Best Professional Judgment (BPJ) exercise was performed to determine the level of agreement among experts in evaluating the ecological states of western North American rocky intertidal communities. Species-abundance and environmental data from 12 central and 11 southern California sites were provided to 14 experts who independently ranked communities from best to worst and assigned each to one of five categories based on the degree of deviation from an expected natural biological state. Experts achieved Spearman correlations of 0.49 (central California) and 0.30 (southern California) in their rankings and averaged 75.4% and 70.0% Euclidean Similarity (ES) in their community evaluations. These ES values compare favorably with agreement levels found for similar exercises with soft bottom macroinvertebrate assemblages. The experts emphasized macrophytes with functional characteristics related to morphology and sessile macroinvertebrates in their assessments. Several challenges were noted in interpreting rocky intertidal data sets, the most prominent of which are high spatial and temporal variation and site-to-site differences in natural disturbance regimes, features that lead to multiple, expected community states. Experts required detailed, physical habitat descriptions to develop community composition expectations that differed for different shore types, and expressed concern about evaluating rocky intertidal communities based on only a single sampling event. Distinguishing natural from anthropogenic disturbance without information on the sources and magnitudes of anthropogenic perturbation was also found to be challenging because the biological responses to these stressors are often similar. This study underscores the need for long-term data sets that describe the dynamics of populations and communities and rigorous testing of expert judgments to firmly establish broadly applicable and consistent links between community states and anthropogenic stressors on rocky shores.

1. Introduction

Coastal managers often rely on species composition and abundance data to evaluate the ecological states of biological communities and to interpret the extent of anthropogenic impacts. Although multivariate approaches, such as non-metric multidimensional scaling (Clarke and Gorley, 2006), are powerful tools for differentiating community structures, analyses based on biological data can be difficult to interpret, particularly when the effects of multiple potential stressors need to be considered in a setting of large natural biological variation. Moreover, coastal managers rarely have access to temporal data sets with the history needed to evaluate community state in the context of natural community dynamics.

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http://dx.doi.org/10.1016/j.ecolind.2015.08.017
1470-160X/

Biotic indices that translate complex ecological data into simpler metrics are sometimes used as communication tools for representing community states. Such indices are widely used for benthic macroinfaunal communities (Borja et al., 2000, 2014; Dauvin et al., 2012) where they have gained acceptance from coastal managers for characterizing the degree of anthropogenic perturbation (Borja et al., 2009; Díaz et al., 2004; Weisberg et al., 1997). In response to a call from the European Water Framework Directive (EC, 2000), efforts have been made to develop indices for phytoplankton (Revilla et al., 2009) and macroalgae (Orfanidis et al., 2001, 2003; Scanlon et al., 2007; Selig et al., 2007; Sfriso et al., 2009; Wilkinson et al., 2007), including attempts to develop indices for rocky intertidal and shallow, subtidal habitats (Ballesteros et al., 2007; Bermejo et al., 2012; Díez et al., 2012; Juanes et al., 2008; Panayotidis et al., 2004; Pinedo et al., 2007; Wells et al., 2007). However, for rocky coastal environments, these efforts remain on-going and a consensus has yet to be achieved on which rocky intertidal population and community responses serve to consistently differentiate natural from anthropogenic stress across different types of shores and geographic regions, an important property of a widely useful index (see Murray et al., 2006).

By their nature, rocky intertidal communities offer several challenges to evaluators of community state and to index development. First, these communities occupy heterogeneous habitats with considerable spatial and temporal variation in key abiotic environmental drivers. This can lead to multiple possible community structures that change over time, even for habitat patches within the same physical site, complicating efforts to evaluate ecological state. Second, rocky shore communities are simultaneously subjected to significant physical (e.g., wave action, sand scour, substratum instability, aerial emersion) and biological (e.g., predation) natural processes, whose effects are often difficult to differentiate from all but the most severe anthropogenic (e.g., poor water quality, trampling, harvesting) impacts. Third, the rocky intertidal zone is strongly influenced by tides, where submersion and emersion regimes limit the shore positions that can be occupied by most species (Knox, 2001; Raffaelli and Hawkins, 1999). This produces well known, vertical patterns of species abundances on the shore and makes it essential that community data used to determine and compare the ecological states of sites are obtained from samples taken over equivalent intertidal positions. Fourth, the composition, orientation (slope, aspect) and relief (rugosity) of the rocky substratum itself has a strong influence on species distributions and abundances, within and among sites (Schoch and Dethier, 1996; Wells et al., 2007).

A step toward advancing our understanding of anthropogenically impacted communities is to determine the level of consensus achieved by experts when asked to identify a community's ecological state based upon the response signatures captured by biological data. Best Professional Judgment (BPJ) exercises have been used successfully to make state judgments in many fields (Meyer and Booker, 2001). For example, in aquatic environments, BPJ has been used to evaluate and compare benthic indices (Borja et al., 2014; Dauvin et al., 2012; Ranasinghe et al., 2008; Teixeira et al., 2012), to determine consistency in judging sediment quality (Bay et al., 2007), and to ascertain the level of agreement in identifying the degree of disturbance in benthic macroinfaunal communities (Borja et al., 2014; Dauvin et al., 2012; Teixeira et al., 2010; Thompson et al., 2012; Weisberg et al., 2008). To our knowledge BPJ has yet to be used to evaluate the ecological states of rocky intertidal communities.

Here, we convened a team of rocky intertidal experts to conduct a BPJ exercise to determine: (1) the level of agreement in identifying the states of rocky intertidal communities and (2) which attributes of the biological data were found most useful in making state evaluations. We also assess how well the level of expert agreement attained for rocky intertidal communities compares with similar BPJ exercises performed to evaluate the ecological states of benthic macroinfaunal samples from soft bottom habitats where knowledge of biological indicators of anthropogenic stress is much more fully developed.

Table 1
Names and locations of western North American rocky intertidal sites containing macroorganism communities evaluated by experts.

Site name	Latitude (°N) (DD.DD)	Longitude (°W) (DD.DD)
Central California sites		
Pigeon Point	37.19	122.40
Año Nuevo	37.11	122.33
Hopkins Marine Station	36.62	121.91
Point Lobos	36.51	121.94
Hazard Canyon	35.29	120.88
Shell Beach	35.17	120.70
Stairs	34.73	120.62
Partington Cove	36.17	121.70
Lucia	36.01	121.54
Duck Pond	35.86	121.42
Terrace Point	36.95	122.06
Point Sierra Nevada	35.73	121.33
Southern California sites		
Buck Gully	33.59	117.87
Cabrillo: Zone 1	32.67	117.25
Crystal Cove	33.57	117.84
Dana Point	33.46	117.71
Heisler Park	33.54	117.79
La Jolla Caves	32.85	117.27
Lechuza Point	34.03	118.86
Old Stairs	34.07	119.00
Paradise Cove	34.01	118.79
Scripps	32.87	117.25
Sequit Point	34.03	118.86

2. Methods

Experts evaluated the states of rocky intertidal communities using biological data commonly collected in rocky intertidal sampling programs: site-scale data representing the abundances of macrophyte (macroalgae and surfgrasses) and macroinvertebrate (invertebrates discernible in the field with the unaided eye) populations. Similar procedures to those employed in BPJ exercises for benthic macroinfaunal communities were used (see Thompson et al., 2012; Weisberg et al., 2008). Biological and physical environmental data sets for a range of sites were collected, standardized, and given to each expert, and instructions for ranking and scoring site communities were provided so experts could prepare their evaluations.

2.1. Sites

Our study focused on 23 sites from western North America: 12 from central California and 11 from southern California (Table 1); sites were chosen from a potential pool of 34 central California and 31 southern California mainland sites for which comparable data sets were available. Selected sites had a geomorphology consisting primarily of rock outcrops or benches; sites composed largely of cobble or other unstable substrata were not included. Selected sites were distributed over most of the two study regions. Central California sites ranged from Pigeon Point (37.19° N; 122.40° W) to Stairs (34.73° N; 120.62° W). Southern California sites were located south of Point Conception, a major biogeographic boundary, and were distributed along the coastline from Old Stairs (34.07° N; 119.00° W) to Cabrillo Zone 1 (32.67° W; 117.25° W). Sites directly exposed to high levels of contamination, such as sewage or papermill discharges, were not available for sampling because current regulations have eliminated these direct, obvious intertidal impacts in the study region. For this study, sites exposed to the most extreme anthropogenic disturbances were those near urban centers, receiving high levels of human visitation, close to subtidal discharges of treated sewage effluents, or proximal to storm drains or urban runoff pathways. Sites least exposed to anthropogenic influence were located in rural areas removed from urban centers with limited human access. The selected sites are believed to be representative of the range of ecological states for these types of rocky shore now found along this portion of the western North American coast. All site data used in this study were collected during a single 1–2 day sampling period between 2000 and 2007.

2.2. Experts

Fourteen experts with 10 to >40 years of experience working on community-level, field sampling of western North American rocky intertidal communities took part in the exercise. Almost all had extensive field sampling experience in central California whereas only a few had similar sampling experience in southern California; one expert had the majority of experience outside of California, although at locations biogeographically similar to central California. Most experts routinely perform fieldwork and analyze rocky intertidal population and community data to examine natural or anthropogenic drivers of community state. All 14 experts participated in the central California exercise while 13 submitted evaluations for southern California.

2.3. Data sets

Data were obtained using common rocky intertidal community sampling procedures. At each site, a 30 m transect parallel to the shoreline and above the high tide zone was established to provide a baseline for locating 11 additional transects running perpendicular to the ocean; these 11 transect lines, separated by 3 m intervals, followed the contours of the substratum. Cover data for macrophytes and macroinvertebrates were collected along the 11 transects using a point intercept method; intervals between points were adjusted along transects with respect to the extent of the sampled habitat in order to achieve approximately 100 points per transect. In addition to point data, counts were obtained for mobile macroinvertebrates and converted to density. This was accomplished by counting the mobile macroinvertebrates contained in three 50 cm × 50 cm quadrats randomly placed in high, mid, and low zones along each of the 11 transects ($n = 33$ quadrats). Estimates of the tidal heights of sampled points and quadrats were made and measures of selected physical environmental features performed. Biological data in this exercise consisted of species abundances (cover and density) for each site, presented in a species by site Excel matrix, plus several summary and diversity calculations made from these data; experts were also given key environmental features and the sampling date for each site (Table 2). The summary and diversity calculations were provided to facilitate the ability of experts to perform their analyses should they wish to use this information; no suggestions were made regarding the utility of these calculations or any other approach for evaluating the ecological states of the rocky intertidal communities.

2.4. Exercises

Unlike the BPJ exercises performed on benthic macroinfaunal communities, which relied on a single evaluation (Borja et al., 2014; Dauvin et al., 2012; Teixeira et al., 2010; Thompson et al., 2012; Weisberg et al., 2008), three trials were performed in this study. In addition, a linear, five point scale, consistent with the European Water Framework Directive's five classes for categorizing ecological state (EC, 2000), was employed to capture expert evaluations, instead of the four point scale used in the comparative macroinfaunal BPJ exercises. Adjustments were made in the type and amount of information provided after Trials 1 and 2 to clarify instructions and address questions raised during post-trial discussions. Thus, experts were informed by discussions stemming from the previous trial before submitting their responses for the ensuing trial. Between trials, experts were given several weeks to individually process post-trial discussion and then were provided data sets and asked to submit their own independent evaluations for the next trial.

For Trial 1, experts were given data from 31 central California intertidal communities. The names and locations of sites were not provided prior to evaluations, requiring experts to make assessments using only site-specific biological and environmental data; no indication of the sources or magnitudes of anthropogenic stressors were included. Experts were asked to assign each community's state to one of five categories regardless of the nature of perceived disturbance: (1) undisturbed; (2) largely undisturbed; (3) neutral (i.e., between largely undisturbed and moderately disturbed); (4) moderately disturbed; and (5) strongly disturbed. In addition, experts were asked to identify the five sites believed to be most strongly influenced by anthropogenic disturbance. Responses were summarized, presented to experts, and discussed during a post-exercise meeting.

For Trial 2, 12 of the original central California sites were selected for further analysis. Added to these central California sites were 11 sites from southern California, a biogeographically different and more urbanized section of the western North American coast. The southern California sites were added to the exercise to enlarge the range of anthropogenically influenced conditions and

Table 2
Biological and environmental data provided for evaluations of western North American rocky intertidal communities. Qualitative metrics (e.g., very low, low, moderate, high, very high) were used for parameters indicated with an asterisk (*). Degree of freshwater influence was assessed by providing source and proximity.

Biological data	Environmental data
Mean biological cover	*Site location*
Mean abiotic cover (bare rock, sand, tar)	Site name
	Latitude
Macrophytes	Longitude
Mean cover for site	Biogeographic affinity
Mean cover by 0.3 m tidal interval	
	Substratum
Macroinvertebrates	Substratum geological formation
Mean cover for site	*Substratum character (degree of consolidation)
Mean cover by 0.3 m tidal interval	*Susceptibility to substratum breakout
Mean density for site	*Substratum relief
Mean density by 0.3 m tidal interval	Substratum slope (degrees)
	Primary substratum type (e.g., bedrock, boulders)
Species and taxon diversity (separately for cover and density data)	
Number of sampled taxa	*Physical disturbance agents*
Total cover or number of organisms	*Degree of wave exposure
Simpson's $1 - \lambda$ index	Wave exposure (primary direction)
Shannon's H' index (ln)	Degree of freshwater influence
Pielou's J' index (ln)	*Degree of sand influence
Margalef's D' index	
	Other
Species and taxon characteristics	Protection status
Classification	*Degree of human visitation
Functional group (macrophytes)	Site overview photographs
Trophic group (macroinvertebrates)	

to increase the diversity of biological communities subject to evaluation. For the southern California sites, experts were not provided site locations, but for central California the site locations and expert rankings in the first trial were known from post-Trial 1 discussion. Experts were again asked to independently assign each site to one of the same five disturbance categories, without information on anthropogenic impacts, and to rank the sites from least to most disturbed (separately for central and southern California sites). No attempts were made to distinguish anthropogenic from other forms of disturbance because of difficulties in making this distinction revealed during post-Trial 1 discussion.

The same set of sites was used in Trial 3, but besides the biological data, experts were provided additional environmental data including photographs and verbal descriptions of the physical characteristics of each site. This was done in response to feedback following Trial 2 where experts felt the need for more information on site characteristics to better allow them to establish an expected, un-impacted community state. Post-Trial 2 discussions also revealed problems scoring communities exposed to different forms and magnitudes of natural environmental disturbance (e.g., wave exposure), particularly given a "one-off" biological data set. Thus, for Trial 3, the disturbance scale was modified to reflect the degree to which the biological data match expectations because rocky intertidal biology is known to differ for sites with different environmental features and natural disturbance regimes. This approach required experts to first independently categorize sites using the available natural environmental data and then to use the biological data to determine the degree to which the observed community state deviated from expectations for that type of site. Again, information on the sources and magnitudes of anthropogenic disturbance were not provided. For Trial 3, the linear scale was refined as follows: (1) undisturbed or within the envelope of states that characterize the "best that it could be" potential condition for a site of this type; (2) largely undisturbed or near to but outside a state that characterizes the "best that it could be" potential condition for a site of this type; (3) neutral (i.e., between categories 2 and 4); (4) moderately disturbed or removed from a state that characterizes the "best that it could be" potential condition for a site of this type; and (5) strongly disturbed or far removed from a state that characterizes the "best that it could be" potential condition for a site of this type. No attempt was made to adjust scores based on whether deviations from the expected state were due to anthropogenic factors or extreme natural disturbance events.

To determine the most informative elements of the biological data, experts identified and rated the usefulness of selected biological attributes in making their evaluations. Again, a five point scale was employed: (1) provides critical information of primary importance; (2) provides valuable information of importance; (3) provides information of value; (4) provides information but used as a secondary factor; and (5) provides little, if any, information and of limited or no use. Lastly, experts rated the usefulness of the non-biological variables made available for characterizing site types based on natural environmental features. This was done using the same five-point scale.

2.5. Data analyses

Descriptive statistics [means ± 1 SD and CV (%)] were used to summarize the aspects of the biological data most useful in making state evaluations and the different environmental parameters used to characterize site types. Two approaches were employed to determine the level of agreement achieved in using the biological data to judge community states: expert rankings from "most" to "least" disturbed and assigned scores using the final, linear five point disturbance scale. Separate analyses were performed for central California and southern California and final Trial 3 results were used to determine the level of agreement and for comparisons with BPJ exercises for benthic macroinfaunal communities. Community state scores also were compared across the three rocky intertidal trials to examine changes in the level of agreement as the exercise progressed.

2.5.1. Rankings

PRIMER-e v6 (Clarke, 1993; Clarke and Gorley, 2006) was used to compute Spearman's correlation coefficients (r) between each rocky intertidal expert pair based on Trial 3 responses. Significance of r was determined using two-tailed probability tables and $\alpha \leq 0.05$ and ≤ 0.01.

2.5.2. Deviation-from-expectation disturbance scores

Two methods were used to analyze agreement among experts in scoring sites: (1) mean scores and CV for each community calculated among all experts and for the responses of each expert; and (2) PRIMER-e v6 analyses based on pairwise similarities calculated between each expert pair followed by cluster and non-metric multidimensional scaling (MDS); these were performed treating the experts as samples and the sites as variables (Clarke, 1993; Clarke and Gorley, 2006).

For the PRIMER-e v6 similarity analyses, the matrix of between-expert scores was constructed using the Euclidean Distance coefficient converted to a Euclidean Similarity (ES), expressed as a percentage, by the formula:

$$100 \times \left[1 - \sqrt{\frac{\sum_{i=1}^{n}(D_i)^2}{nm^2}}\right]$$

where D = the difference between the scores of an expert pair, i = the community examined, n = the number of cases or communities scored by each expert, and m = the maximum difference possible between a pair of expert scores (4 in this study using the 5 point disturbance scale). Experts (samples) were then grouped using cluster analysis (group average) and subjected to MDS. Cluster groups (≥60% and ≥80%) were overlaid on MDS plots to show patterns of expert similarity. For comparisons with benthic macroinfaunal BPJ exercises, pairwise ES values were calculated from expert scores reported by Borja et al. (2014), Dauvin et al. (2012), Teixeira et al. (2010), Thompson et al. (2012), and Weisberg et al. (2008).

Analyses of expert responses for the three trials were based on the 12 central and 11 southern California sites assessed during Trial 3 and limited to comparisons of mean site disturbance scores and mean pairwise similarity values computed from these scores. However, differences among the three central California and two southern California trials also were tested statistically using repeated measures analyses with site and expert being categorical factors and trial being the repeated measure. Within subject effects were modeled using a Pillai Trace F approximation when appropriate (>2 trials). Because of the lack of independence among pairwise similarity (%) values within each trial, only descriptive statistics (means ± 1 SD) are presented to compare trial-to-trial differences in expert responses.

3. Results

3.1. Trial-by-trial results

Disturbance scores changed significantly for central (Multivariate Repeated Measures Analysis; $p < 0.001$) and southern (Univariate Repeated Measures Analysis; $p < 0.001$) California rocky intertidal communities following post-trial discussions. For central California, the mean site score did not differ significantly between the first two trials (3.09 vs. 3.04; $p = 0.328$) but was significantly

Table 3
Central California. Spearman's correlation coefficients (r) between rocky intertidal experts based on site community rankings using trial 3 results. Red values (*) – significant correlations ($p \leq 0.01$); blue values (‡) – significant correlations ($p \leq 0.05 \geq 0.01$); yellow-shaded cells, negative correlations; based on two tailed tests.

	Experts (n=14)													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A														
B	**0.806***													
C	**0.788***	**0.699‡**												
D	**0.921***	**0.755***	**0.762***											
E	0.536	0.497	**0.685‡**	0.552										
F	0.532	0.448	0.350	0.524	0.315									
G	0.280	0.021	0.014	0.175	-0.049	0.427								
H	**0.602‡**	0.252	0.259	0.497	0.105	0.462	**0.720‡**							
I	**0.592‡**	**0.622‡**	0.490	**0.685‡**	0.441	**0.713‡**	0.434	0.483						
J	0.504	0.091	0.308	0.280	0.182	0.406	**0.650‡**	**0.825***	0.175					
K	**0.602‡**	0.545	0.406	**0.650‡**	0.140	0.469	**0.629‡**	**0.601‡**	**0.650‡**	0.392				
L	**0.732***	0.545	0.503	**0.664‡**	**0.706‡**	0.517	0.448	**0.650‡**	**0.664‡**	0.490	0.427			
M	**0.655‡**	0.559	0.552	**0.818***	**0.601‡**	0.538	0.175	0.231	**0.664‡**	0.000	0.448	**0.594‡**		
N	**0.673‡**	**0.587‡**	**0.832***	**0.741***	**0.699‡**	0.503	-0.091	0.301	0.462	0.315	0.385	0.462	**0.587‡**	

($p < 0.001$) lower for Trial 3 (2.04), probably due to changes in and improved understanding of the disturbance scale; similar results occurred for southern California between the two trials (3.31 vs. 2.94). For central California, mean similarity increased progressively across the three trials (63.5%; 70.7%; 75.4%) while variation decreased (CV = 9.4%; 8.4%; 6.2%), indicating improvements in the level of expert agreement. For southern California, a small increase in mean similarity also was observed (67.4% vs. 70.0%) between the two trials along with a small increase in CV (7.0% vs. 8.8%).

3.2. Central California communities – Trial 3

Expert agreement in ranking communities, as measured by Spearman's correlation coefficient r, averaged 0.49 for central California (Table 3). Thirty-two of 91 calculations resulted in an r value $\geq$0.60; 39.6% of r values were significant at $p \leq 0.05$ and 10.9% at $p \leq 0.01$. Only one expert showed negative correlations with peers and only in two cases; all other correlations were positive. State scores for central California sites ranged from 1.36 to 2.86 with an overall mean of 2.04 (Table 4). Five of the 12 communities were scored the same by a majority of experts but none received the same score from all experts. Only one community received at least one score of 5, whereas ten were given scores of 1 by at least one expert. The mean CV averaged 35.4% across all site communities. The average state score for an individual expert ranged from 1.50 to 2.58 and the mean CV from 13.9% to 69.3% (Table 4).

ES between experts averaged 75.4% and ranged from 57.3% to 89.8% for central California (Table 5). Similarity between experts was $\geq$80.0% in 21 and $\leq$60.0% in 2 of 91 cases; the mean CV was 8.3%.

Table 4
Central California. Rocky intertidal experts disturbance scores for site communities using trial 3 results. Scores are on a 1–5 scale with 1 being least and 5 being most disturbed.

	Experts (n = 14)															
Site	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Mean	CV (%)
4	2	2	3	2	1	2	2	2	2	2	1	1	1	2	1.79	32.4
5	2	2	2	3	2	2	2	2	2	3	2	2	2	2	2.14	16.9
9	1	1	2	2	1	2	1	2	1	1	1	1	1	2	1.36	36.6
11	2	1.5	3	3	2	2	2	2	3	3	2	2	1	2	2.18	27.9
17	1	1.5	2	3	2	2	1	2	3	1	1	2	1	2	1.75	40.0
18	2	3	3	3	3	3	2	2	3	2	5	2	4	3	2.86	30.3
19	2	2	3	3	1	3	2	2	3	2	4	1	1	2	2.21	40.3
22	1	1	2	1	1	3	2	2	1	3	1	2	1	2	1.64	45.3
23	1	1	2	2	1	1	3	2	2	2	2	2	1	3	1.79	39.2
24	3	2	4	4	2	2	3	3	2	2	3	3	1	3	2.64	31.9
29	3	3	2	3	1	4	3	2	3	2	3	3	2	2	2.57	29.4
30	1	1	1	2	1	1	2	2	1	1	2	1	4	2	1.57	54.2
Mean	1.75	1.75	2.42	2.58	1.50	2.25	2.08	2.08	2.17	2.00	2.25	1.83	1.67	2.25	2.04	35.4
CV (%)	43.1	41.3	32.8	30.7	44.9	38.5	32.1	13.9	38.5	36.9	57.2	39.1	69.3	20.1	38.5	

Table 5
Central California. Pairwise ES between rocky intertidal experts based on site community disturbance scores for trial 3. Red values – similarities ≥80%; blue values – similarities ≤60%.

	Experts (n=14)													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A														
B	88.6													
C	77.2	74.5												
D	75.0	73.5	82.3											
E	78.4	81.6	70.2	68.6										
F	77.2	80.2	75.0	73.0	68.6									
G	82.3	79.0	77.2	75.0	72.1	75.0								
H	82.3	80.2	82.3	79.6	78.4	77.2	85.6							
I	78.4	81.6	78.4	80.9	75.0	78.4	76.1	78.4						
J	78.4	76.6	76.1	70.2	75.0	76.1	80.9	80.9	75.0					
K	71.1	74.5	71.1	73.0	66.9	71.1	71.1	69.4	74.0	65.4				
L	83.9	81.6	74.0	74.0	79.6	76.1	83.9	83.9	77.2	79.6	66.9			
M	66.9	72.5	57.3	59.8	73.0	62.5	66.9	68.6	63.2	63.2	66.9	66.2		
N	77.2	77.8	82.3	79.6	76.1	75.0	85.6	89.8	78.4	78.4	73.0	80.9	68.6	

As depicted in MDS plots, cluster analysis revealed that all experts grouped together at ≥60.0% similarity; two groups of experts, one consisting of 2 and the other of 6, achieved ≥ 80.0% similarity in their state scores (Fig. 1a).

3.3. Southern California communities – Trial 3

The mean r for southern California ($r = 0.30$) was lower than for central California and only 14 of 78 calculations resulted in an r value ≥0.60 (Table 6); 13 of the 78 correlations were significant at $p \leq 0.05$ and only 1 at $p \leq 0.01$. Negative r values were observed for three experts in a total of nine cases; all other correlations were positive. Southern California state scores were generally higher than central California indicating a higher level of site disturbance and ranged from 2.38 to 4.08 with a mean of 2.94 (Table 7). Only one of the eleven communities was scored the same by a majority of experts; none received the same score from all experts. Unlike central California, at least one expert assigned a score of 5 to four of the eleven communities and only five communities were given at least one state score of 1. The mean CV averaged 30.2%. The average score for an individual expert scoring all communities ranged from 2.18 to 3.55 and the mean CV from 9.8% to 56.8% (Table 7).

For southern California, ES between experts was less than for central California, averaging 70.0% and ranging from 48.9% to 92.5% (Table 8). Similarity between expert pairs was ≥80.0% in 11 (14.1%) and ≤60.0% in 8 (10.3%) of 78 cases; the mean CV was 12.6%. As depicted in the MDS plot, cluster analysis revealed that all experts grouped together at ≥60.0% similarity. However, only one group of four experts clustered at ≥80.0% (Fig. 1b).

3.4. Useful elements of biological data sets

Most rocky intertidal experts relied on the abundances of macrophytes and sessile macroinvertebrates in making their

Table 6
Southern California. Spearman's correlation coefficients (r) between rocky intertidal experts based on site community rankings using trial 3 results. Red values (*) – significant correlations ($p \leq 0.01$); blue values (‡) – significant correlations ($p \leq 0.05 \geq 0.01$); yellow-shaded cells, negative correlations; based on two tailed tests.

	Experts (n=13)												
	A	C	D	E	F	G	H	I	J	K	L	M	N
A													
C	0.282												
D	0.682‡	0.645‡											
E	0.309	0.255	0.409										
F	0.645‡	0.591	0.736‡	0.364									
G	0.146	0.296	0.579	0.155	0.305								
H	0.564	0.591	0.709‡	0.718‡	0.582	0.364							
I	-0.245	0.145	0.045	0.591	0.291	0.164	0.382						
J	0.091	0.236	0.464	0.082	0.618‡	0.187	0.036	0.400					
K	0.427	0.473	0.627‡	0.136	0.609	0.096	0.582	0.136	0.455				
L	0.601	0.264	0.683‡	0.651‡	0.743‡	0.429	0.820*	0.465	0.342	0.610			
M	-0.009	-0.209	-0.073	0.327	0.036	0.159	0.118	0.518	0.127	0.100	0.287		
N	0.109	0.118	-0.227	0.318	-0.100	-0.674‡	0.209	0.109	-0.300	0.091	-0.087	0.209	

Table 7
Southern California. Rocky intertidal experts disturbance scores for site communities using trial 3 results. Scores are on a 1–5 scale with 1 being least and 5 being most disturbed.

	Experts (n = 13)														
Site	**A**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**Mean**	**CV (%)**
1	5	3	4	3	5	3	3	4	3	2	4	5	3	3.62	26.6
2	2	3	3	1	4	2	3	3.5	4	4	2	4	3	2.96	32.7
3	2	2	3	4	2	1	3	4	3	1	2	5	3	2.69	43.9
4	2	3	3	1	2	3	3	3	2	1	1	4	3	2.38	40.3
5	3.5	2	3	1	4	2	3	3	3	4	3	4	3	2.96	29.6
6	3	5	5	4	5	3	4	4	3	5	4	4	4	4.08	18.6
7	3	3	3	2	2	2	3	3	2	4	2	4	4	2.85	28.1
8	3	3	4	2	4	2	3	3.5	3	5	2	2	3	3.04	30.4
9	3	2	3	1	3	3	3	2	3	1	2	2	3	2.38	32.2
10	3	2	3	2	3	2	3	3.5	2	2	2	3	3	2.58	22.2
11	4	4	3	3	4	2	3	3	2	2	2	2	3	2.85	28.1
Mean	3.05	2.91	3.36	2.18	3.45	2.27	3.09	3.32	2.73	2.82	2.36	3.55	3.18	2.94	30.2
CV (%)	29.8	32.4	20.0	53.5	32.7	28.5	9.8	18.2	23.7	56.8	39.1	31.8	12.7	29.9	

assessments; abundances of mobile macroinvertebrates were generally found to be less useful (Tables 9 and 10). Of lesser importance were overall biotic cover patterns, biological diversity, and community level analyses, metrics and approaches commonly used to analyze communities based on data sets for all populations. Experts identified disturbance indicators to be high abundances of small, fast-growing, opportunistic algae such as *Ulva* spp., small, red turf-forming and green filamentous algae and low-lying, crustose seaweeds. Annual macrophytes such as *Scytosiphon* spp. and *Petalonia* spp. and the anemone *Anthopleura elegantissima* were used to characterize sand-disturbed habitats. Experts focused on high abundances of perennial, upper shore rockweeds, lower shore kelp and other large brown seaweeds, and surfgrasses as low disturbance indicators. In addition, high abundances of larger mobile invertebrates known to be extracted from rocky shores by humans, such as black abalone and owl limpets, were considered as possible indicators of low anthropogenic impact.

3.5. *Physical environmental attributes used to categorize communities*

Experts focused mostly on three physical environmental variables to characterize community types: the degree of sand influence, the degree of wave exposure, and the nature of the primary substratum (Table 11). Experts almost uniformly agreed that the degree of sand influence was of critical importance in characterizing natural disturbance levels on central and southern California shores. The degree of wave exposure was similarly identified as an important parameter for characterizing central California sites but was thought to be slightly less important for mainland southern California, where wave exposure is generally significantly lower. Primary bench type was the most important of the six substratum parameters for which information was provided. Of the physical environmental parameters, biogeographic affinity and latitude were thought to be less useful in categorizing site communities.

Table 8
Southern California. Pairwise ES between rocky intertidal experts based on site community disturbance scores for trial 3. Red values – similarities ≥80%; blue values – similarities ≤60%.

	Experts (n=13)												
	A	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
A													
C	71.6												
D	75.9	**80.1**											
E	62.1	68.0	62.3										
F	75.9	71.8	**80.1**	**53.5**									
G	70.6	72.8	68.0	65.5	60.8								
H	77.1	**81.5**	**86.9**	66.3	73.9	75.0							
I	73.9	75.3	**85.4**	64.8	74.2	64.8	**85.4**						
J	70.6	71.8	75.0	64.6	69.8	75.0	**81.5**	76.5					
K	**56.5**	65.5	64.6	**50.6**	62.3	**56.0**	63.8	61.0	63.8				
L	74.7	71.8	70.8	73.9	68.0	77.4	73.9	69.2	76.2	62.3			
M	62.1	60.8	69.8	**52.9**	60.8	**54.8**	70.8	77.7	65.5	**48.9**	**59.4**		
N	75.9	**80.1**	**84.9**	63.8	70.8	71.8	**92.5**	**83.6**	77.4	64.6	70.8	71.8	

Table 9
Importance of biological attributes used by rocky intertidal experts in making determinations of community state. Lower values indicate greater importance. Reported are means (±1 SD) based on the following scale: (1) provides critical information of primary importance; (2) provides valuable information of importance; (3) provides information of value; (4) provides information but used as a secondary factor; and (5) provides little if any information; of limited or no use. Data collected separately for central and southern California rocky intertidal assessments but pooled because of consistency in results.

Biological attribute	Mean response	±1 SD
Abundances of species groups or selected taxa	1.18	0.37
Overall cover patterns	1.71	0.64
Biological diversity	2.79	0.99
Community level analyses	3.07	1.27
Species distributions by tidal elevation	3.21	1.19

4. Discussion

Experts found judging the ecological states of rocky intertidal communities to be challenging. Nevertheless, the final agreements achieved for central and southern California rocky intertidal macroorganism communities were within the range of those obtained for comparable BPJ exercises performed on soft bottom, benthic macroinfaunal assemblages (Borja et al., 2014; Dauvin et al., 2012; Teixeira et al., 2010; Thompson et al., 2012; Weisberg et al., 2008), where, in most cases, agreement was reported to be very good. Based on mean ES and the percentage of evaluated communities with 100% or majority expert agreement (Table 12), our BPJ results for central (e.g., mean ES = 75.4%) and southern (70.0%) California rocky shores were slightly lower than those found for southern California (80.0%) and San Francisco Bay (82.1%) soft bottom, polyhaline habitats (Weisberg et al., 2008), but slightly higher than for tidal freshwater (63.9%) and mesohaline (65.0%) macroinfaunal assemblages from the San Francisco Bay region (Thompson et al., 2012). Agreement levels based on ES were very similar to calculations from expert scores reported in separate BPJ exercises for polyhaline macroinfaunal communities from the Mediterranean Sea, North Atlantic, U.S. west and east coasts (69.4%; Teixeira et al., 2010), the Mediterranean Sea and North Atlantic (77.0%; Dauvin et al., 2012), and Chile (73.1%; Borja et al., 2014). Rocky intertidal experts fared less well based on most comparisons of the percentage of cases where experts were in full or majority agreement in their state evaluations (Table 12). However, comparisons of expert agreement among BPJ exercises are difficult to make when

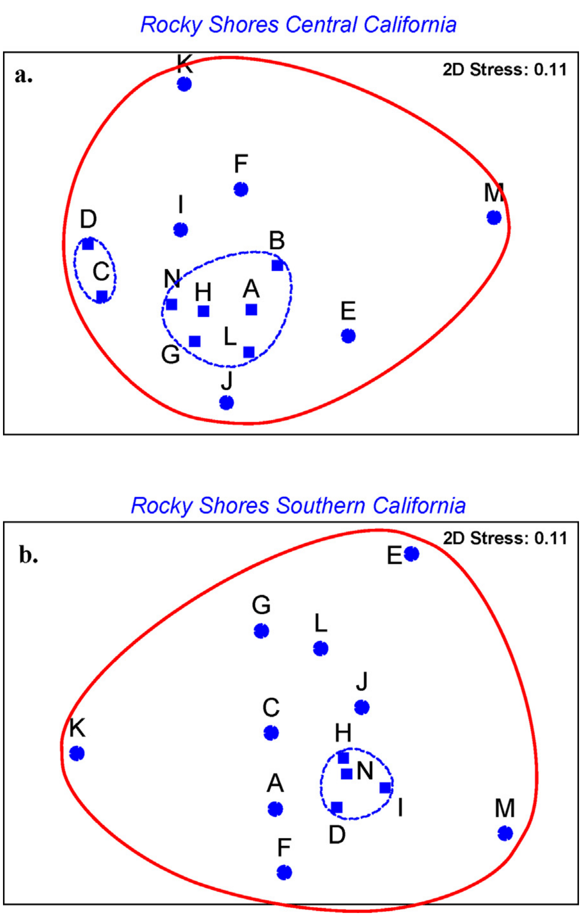

Fig. 1. MDS plots of experts (indicated by letters A–N) based on ES calculated from disturbance scores submitted for central California (a) and southern California (b). Rocky intertidal communities. Plots display clustering overlays at 60% (red solid lines) and 80% (blue dashed lines) similarity.

Table 10
Species and taxa frequently found by most rocky intertidal experts to be useful for evaluating community state. High abundances of species and taxa believed to reflect either high or low disturbance states.

High disturbance indicators	Low disturbance indicators
Ulva spp.	Rockweeds (e.g., *Silvetia*, *Hesperophycus*, *Fucus*, *Pelvetiopsis* spp.)
Porphyra spp.	
Benthic diatoms	Owl limpets (*Lottia gigantea*)
Blue-green algae	Black abalone (*Haliotis cracherodii*)
Crustose red and brown algae (calcified and non-calcified)	Surfgrass (e.g., *Phyllospadix* spp.)
Small red turf-forming algae (e.g., *Polysiphonia*, *Ceramium* spp.)	Kelps and large brown seaweeds (e.g., *Egregia menziesii*, *Laminaria* spp., *Eisenia arborea*, *Alaria* spp., *Stephanocystis* spp.)
Non-native seaweeds (e.g., *Sargassum muticum*, *Caulacanthus okamurae*)	
Sand-influenced taxa (e.g., *Anthopleura elegantissima*, *Scytosiphon* spp., *Petalonia* spp., *Neorhodomela larix*, *Gymnogongrus linearis*, *Phaeostrophion irregulare*, *Codium setchellii*, *Laminaria sinclairii*)	
Filamentous green algae (e.g., *Chaetomorpha* spp., *Cladophora* spp.)	

Table 11
Importance of physical attributes used to categorize rocky intertidal sites. Lower values indicate greater importance. Reported are means (±1 SD) of expert responses based on the following scale: (1) provides critical information of primary importance; (2) provides valuable information of importance; (3) provides information of value; (4) provides information but used as a secondary factor; and (5) provides little if any information; of limited or no use. Data collected separately for central and southern California rocky intertidal assessments but pooled because of consistency in results with the exception of the degree of wave exposure, which was considered to be more important in categorizing central California (mean response = 1.29) vs. southern California (2.00) sites. Qualitative metrics (e.g., very low, low, moderate, high, very high) were used for parameters indicated with an asterisk (*). Degree of freshwater influence was assessed by providing source and proximity.

Physical attribute	Mean response	±1 SD
*Degree of sand influence	1.18	0.37
*Degree of wave exposure	1.64	0.72
Primary substratum type (e.g., bedrock, boulders)	1.93	1.00
*Susceptibility to substratum breakout	2.36	0.82
*Substratum relief	2.54	0.93
Degree of freshwater influence	2.64	0.72
*Substratum character (degree of consolidation)	2.71	1.38
Substratum slope (degrees)	2.86	1.03
Substratum: geologic formation	2.93	1.33
Wave exposure (primary direction)	3.32	0.99
Site biogeographic affinity	3.82	1.38
Site latitude	3.96	1.31

Table 12
Comparisons of expert evaluations for central and southern California rocky intertidal communities with published results for exercises for benthic macroinfauna performed for San Francisco Bay and southern California polyhaline (Weisberg et al., 2008), San Francisco Bay mesohaline, San Francisco Delta tidal freshwater (Thompson et al., 2012), Mediterranean, North Atlantic, and US West and East coast polyhaline (Teixeira et al., 2010), Mediterranean and North Atlantic polyhaline (Dauvin et al., 2012), and Chilean polyhaline (Borja et al., 2014) communities. ES calculations were executed using raw experts disturbance scores reported in each study.

	Rocky intertidal macroorganisms		Soft bottom benthic macroinfauna						
	Central California, USA (this study)	Southern California, USA (this study)	San Francisco Bay (polyhaline), USA	Southern California (polyhaline), USA	San Francisco Bay (mesohaline), USA	San Francisco Delta (tidal freshwater), USA	Med. Sea, No. Atlantic, US West and East coasts	Med. Sea, No. Atlantic	Chile
Metrics for experts, communities evaluated, expert comparisons, and scoring scales									
No. experts	14	13	9	9	8	7	16	4	12
No. Communities evaluated	12	11	11	24	20	20	48	124	12
No. pairwise expert comparisons	91	78	36	36	28	21	120	6	66
Disturbance scoring scale	1–5	1–5	1–4	1–4	1–4	1–4	1–4	1–4	1–4
Expert agreement metrics									
% Communities with 100% expert agreement	0	0	18.2	4.2	0	0	4.2	40.3	0
% Communities with majority agreement	41.7	9.0	100.0	100.0	45.0	85.0	62.5	81.5	75.0
Mean ES (%)	75.4	70.0	82.1	80.0	65.0	63.9	69.4	77.0	73.1
Standard deviation	6.2	8.8	7.8	4.2	8.0	10.5	5.3	2.8	7.3
CV (%)	8.3	12.6	9.6	5.3	12.2	16.5	7.7	3.6	10.0
Maximum ES (%)	89.8	92.5	100.0	88.0	78.9	81.7	80.8	81.1	86.4
Minimum ES (%)	57.3	48.9	73.4	71.4	47.8	44.7	58.6	73.2	60.3

the numbers of experts and communities evaluated, procedural differences such as the scoring scale and number of evaluation trials, and the approaches for determining agreement levels vary.

In contrast to rocky habitats (see Díez et al., 2012), greater progress has been made in developing assessments of ecological state for other environments. This is particularly true for soft bottom benthic habitats, where much is known about macroinfaunal species and community responses to anthropogenic stress. For these communities, several indices of ecological state are now being widely employed and attempts are being made to evaluate their use over expanded geographic scales (e.g., Borja et al., 2014; Dauvin et al., 2012; Teixeira et al., 2010, 2012). State evaluations of rocky intertidal communities, however, present challenges that often go beyond those for benthic macroinfaunal and many other community types. These include the high spatial heterogeneity and site-to-site variability in natural environmental disturbance regimes that characterize rocky shores and difficulties in the ability to consistently use globally applicable, biological signatures to assign deviations from an expected natural state to anthropogenic stressors. In addition, the characteristics of taxa and the sampling protocols commonly employed to generate species abundance data differ in significant ways for these community types.

It has long been recognized that spatial variation in rocky intertidal communities is high due to environmental features such as substratum characteristics, tidal position, and exposure to wave energy, sand influence, and freshwater input. Climatic variability and natural disturbances, for example from storm waves or extreme low tide desiccation events, also can generate significant temporal variation in community structure. This variability requires experts to integrate small and large scale habitat features together with spatial and temporal effects of multiple, frequent natural disturbances in making state evaluations. Prior work has acknowledged that spatial and temporal variability need to be addressed and incorporated into index development for state assessments of rocky shore communities, and that these sources of variation make it difficult to differentiate natural community dynamics from those caused by anthropogenic factors (e.g., Ballesteros et al., 2007; Echavirri et al., 2007; Orfanidis et al., 2001, 2003; Wells et al., 2007).

Spatial and temporal variation also create challenges in evaluating the states of soft bottom macroinfaunal communities even though the biological signatures of common anthropogenic perturbations (e.g., organic and other forms of sediment contamination) are generally well known and differ from those driven by major natural disturbances (Bilyard, 1987; Borja et al., 2003; Díaz and Rosenberg, 1995; Díaz et al., 2004; Marques et al., 2009; Pearson and Rosenberg, 1978; Pinto et al., 2009). Difficulties are most strongly encountered in transitional or tidal freshwater and estuarine habitats characterized by small-scale environmental gradients and a high frequency of natural disturbance (Dauvin, 2007; Elliott and Quintino, 2007). For example, high spatial and temporal variability were reported to be major sources of lower expert agreement in BPJ exercises conducted on mesohaline and tidal freshwater macroinfaunal communities (Thompson et al., 2012). In fact, development of biologically based indices for estuaries has lagged because of the confounding effects of multiple natural environmental stressors (Elliott and Quintino, 2007). By contrast, environmental conditions in soft bottom polyhaline habitats are generally more stable and vary over larger spatial scales (Ranasinghe et al., 2012) making common anthropogenic disturbances easier to detect. As a consequence, the low variation in expert scores observed in BPJ evaluations of soft bottom, polyhaline communities was attributed mostly to differences in views on the relative importance of accepted biological indicators of anthropogenic perturbation not the signatures themselves (Teixeira et al., 2010; Weisberg et al., 2008). Nevertheless, the challenge of separating anthropogenic from natural disturbance was noted in a BPJ exercise performed on polyhaline macroinfaunal communities (Teixeira et al., 2010).

Species types and abundances provide the biological information for determinations of community state. The types of species used in our rocky shore BPJ exercise consisted of macroinvertebrates and macrophytes instead of the smaller, macroinfaunal organisms commonly used in soft bottom assessments. Besides mostly being larger in size, these macroorganisms generally have longer life spans, slower turnover rates, and their populations often respond more slowly to disturbances compared with benthic macroinfauna. Soft bottom macroinfauna are also more directly exposed to sediment contamination and other anthropogenic impacts and their distributions and abundances are known to be strong indicators of responses to such environmental stressors (Bay et al., 2007; Bilyard, 1987; Díaz et al., 2004). However, it is difficult to identify consistent biological indicators of anthropogenic perturbation on rocky shores because there is high natural variation among sites in the abundances and even the presence of many species (Foster, 1990; Zabin et al., 2012) and anthropogenic impacts are added to the effects of fluctuating and often stressful natural disturbances. In addition, the biological responses to many of these perturbations are similar to naturally occurring stressors in rocky intertidal habitats. Thus, it is difficult to distinguish anthropogenic – driven from natural changes in community composition, particularly where the sources or types of anthropogenic perturbations are unknown and their effects are not extreme.

Commonly used sampling procedures for generating and analyzing community data also differ for rocky intertidal macroorganisms and benthic macroinfauna. The macroinfaunal community is usually characterized by data obtained from a single core sample whose contents are sorted and identified in the laboratory. By contrast, rocky intertidal community data are generally derived from multiple, field-identified samples distributed over a range of tidal elevations, an approach that likely generates greater average richness and more consistency in species content across multiple sites. For example, the richness of benthic macroinfaunal communities for western North American polyhaline, mesohaline, and tidal freshwater habitats averaged 30, 14, and 9 taxa and ranged from 1 to 73, 3–25, and 3–24, respectively (Thompson et al., 2012; Weisberg et al., 2008). These values are very different from those for the rocky intertidal communities examined in this study, where richness averaged 53 (central California) and 45 (southern California) and ranged from 30 to 78 and 34–60 taxa, respectively. This is important because macroinfaunal experts often used low community richness as a strong indicator of anthropogenic impact in their evaluations (Teixeira et al., 2010; Thompson et al., 2012; Weisberg et al., 2008).

Differences in data collection also create differences in associating biological with environmental variables between these two community types. Structuring environmental parameters (e.g., grain size, depth, sediment contaminants) are strongly linked to macroinfaunal species in core samples. However, on rocky shores, key physical environmental variables (e.g., substratum characteristics, wave action, sand influence) typically represent conditions averaged over much coarser spatial scales and can be difficult to associate with site-level species distributions and abundances.

Unlike the BPJ infaunal exercises, we did not complete rocky intertidal state evaluations in a single trial. Rocky shore experts remained uncomfortable in making their final state evaluations after the first two BPJ trials because of differing interpretations of the scoring system and difficulties in relating environmental to biological data. After learning the identities of the sites, experts also expressed concern that sites subjected to high levels of anthropogenic impact were poorly represented in the first central California trial. As expected, small increases in the level of expert agreement were reached from the first to the last trial, likely due to changes in the evaluation scale and because more information became available. In fact, the agreement achieved during the first central California trial (ES = 63.5%) was very similar to those obtained for mesohaline (ES = 65.0%) and tidal freshwater (ES = 63.9%) benthic communities, agreement levels found at the low end of the range of ES values calculated for soft bottom macroinfaunal communities (Table 12). However, the increase in expert agreement was less as was the average agreement achieved for southern California intertidal communities, most likely because these occurred at sites exposed to greater geographic variation in ocean conditions and many experts were less familiar with this region.

Difficulties in achieving uniform understanding of the evaluation scale are common in BPJ exercises (Bay et al., 2007). Because of the high spatial and temporal variability of rocky shores, experts wanted more information on site features before making final determinations and sought changes in application of the disturbance scale to incorporate site-to-site uniqueness in natural disturbance regimes. As expected, the addition of urban southern California sites added potentially anthropogenically disturbed communities to our BPJ exercise. The range of anthropogenic impacts represented by the rocky intertidal data sets, however, was still limited compared to the ranges of conditions examined in the macroinfaunal BPJ exercises (Borja et al., 2014; Dauvin et al., 2012; Teixeira et al., 2010; Thompson et al., 2012; Weisberg et al., 2008), where a wide range of contamination conditions were evaluated. Less expert agreement is likely when assemblages are located nearer the center of the disturbance scale and highly impacted communities are under-represented (Borja et al., 2009; Teixeira et al., 2010) as was the case in our rocky intertidal BPJ exercises.

Experts agreed that evaluations of the ecological states of rocky intertidal and other spatially and temporally variable communities are strongly challenged when judgments are based only on a single snapshot in time because a single sampling point does not allow evaluations to take into account recent, major natural disturbance or recruitment events or to be made in the context of the range of expected states for that site. The need to sample rocky shore macroorganisms over multiple years to identify natural variation in community dynamics has long been known (e.g., Southward, 1995). A range of community structures is the norm for any site, and in our exercise the goal was to capture deviation from an expected ecological state regardless of whether driven by anthropogenic or major natural disturbances.

Although there is high variation among rocky intertidal sites in species abundances and even species presence (Foster, 1990, Zabin et al., 2012), most experts relied on the abundances of certain species types in making their final evaluations, particularly macrophytes with functional characteristics related to morphology (*sensu* Littler and Littler, 1980) and sessile macroinvertebrates; most experts placed less importance on mobile macroinvertebrates such as littorine (*Littorina* spp.) snails, whose distributions and abundances are often highly variable and difficult to interpret. Interestingly, compared to macroalgae, macroinvertebrates have not been widely employed in most efforts to develop tools that identify the ecological states of rocky intertidal communities (but see Díez et al., 2012).

Experts placed little importance on higher order macroalgal taxa (e.g., red to brown or red to green ratios) but did identify smaller, short-lived, morphologically simple macroalgae with fast growth rates and high reproductive outputs (e.g., opportunists such as *Ulva* spp. and small, red and green turf-forming and filamentous algae) as possible indicators of recent or continuous disturbance. By contrast, slower growing, longer-lived, and morphologically complex rockweeds, lower-shore, large brown seaweeds, and surf grasses were thought to be possible indicators of more stable, less impacted communities. This is consistent with prior studies that have demonstrated increases in the abundances of simple, opportunistic seaweeds and declines in morphologically complex, perennial brown seaweeds in response to anthropogenic disturbances (e.g., Benedetti-Cecchi et al., 2001; Díez et al., 2009; Eriksson et al., 2002; Mangialajo et al., 2008; Wells et al., 2007).

Macrophyte types (functional groups; opportunistic species) have been used in the past to characterize the ecological status of coastal communities (Littler and Littler, 1981, 1984; Murray and Littler, 1984) and have been commonly employed in attempts to develop an ecological evaluation index for rocky intertidal and shallow subtidal communities (Ballesteros et al., 2007; Bermejo et al., 2012; Díez et al., 2012; Guinda et al., 2008; Juanes et al., 2008; Orfanidis et al., 2001, 2003; Panayotidis et al., 2004; Wells et al., 2007). However, despite their usefulness in characterizing rocky intertidal communities, abundances of macrophyte types alone cannot always differentiate natural from anthropogenic disturbance, especially where impacts are not severe. For example, high abundances of *Ulva* spp. and other smaller, opportunistic algae not only characterize sewage-impacted rocky shores (e.g., Littler and Murray, 1975) but also shores disturbed by naturally occurring sand (Airoldi, 2003; Littler et al., 1991; Murray and Bray, 1993) and boulder movements (Sousa, 1979, 1980). Large, conspicuous macroinvertebrates, such as owl limpets and black abalone (Addessi, 1994; Keough et al., 1993; Miller and Lawrenz-Miller, 1993; Sagarin et al., 2006), and intertidal rockweeds (Bokn and Lein, 1978; Mangialajo et al., 2008; Oliveira and Qi, 2003; Rodriguez-Prieto and Polo, 1996; Vogt and Schramm, 1991) are affected by human activities; reduced abundances of these taxa were also considered by experts to be indicators of anthropogenic disturbance as was the presence of non-indigenous species based on the premise that disturbed habitats are more susceptible to invasion (Byers, 2002; Dukes and Mooney, 1999).

Abundances of environmentally sensitive and tolerant taxa were identified as important criteria for detecting anthropogenic disturbance in BPJ infaunal exercises (Borja et al., 2014; Dauvin et al., 2012; Teixeira et al., 2010; Thompson et al., 2012; Weisberg et al., 2008) and are regarded as strong indicators of community state in soft bottom habitats (Borja et al., 2000; Dauvin, 2007; Muxika et al., 2005). Unfortunately, knowledge of tolerant and sensitive indicator taxa is less developed for rocky intertidal communities, and the reliability of using species sensitive to environmental degradation to identify un-impacted sites is questionable (Scanlon et al., 2007; Wells et al., 2007). In rocky intertidal habitats, where natural variation is high, and multiple and often unknown stressors are the norm, there is no consensus on either a universal disturbance paradigm or reliable, globally applicable biological indicators of anthropogenic impact (see Murray et al., 2006).

Managers are often asked to make ecological evaluations of coastal communities that take into account the effects of multiple natural and anthropogenic stressors. BPJ exercises can inform such efforts by summarizing expert opinion on the states of ecological communities over a wide range of available data, determining the degree of expert consensus, helping to identify key biological indicators, and by calibrating and evaluating index performance where an accepted index exists (Borja et al., 2014; Dauvin et al., 2012; Ranasinghe et al., 2008; Teixeira et al., 2010, 2012; Thompson et al., 2012; Weisberg et al., 2008). In this BPJ exercise, rocky intertidal experts found evaluations of ecological state to be difficult and challenging for the western North American communities assessed. Nevertheless, the level of agreement achieved in evaluating the ecological states of these communities fell within the range obtained for BPJ exercises performed on much better understood macroinfaunal communities. This study underscores the difficulties in distinguishing deviations from an expected natural state on rocky shores working from "one-off" species abundance data and coarse-grained physical site descriptions without information on the sources and magnitudes of anthropogenic perturbation. Such difficulties should be expected for rocky intertidal and other habitats subjected to multiple disturbances, and high spatial and temporal variation, particularly where biological responses to natural and anthropogenic stressors can be similar. Hence, if the goal is to use BPJ exercises to identify anthropogenically impacted or strongly disturbed sites for rocky shores, long-term data sets must be available and expert opinions must be subjected to rigorous testing to firmly establish consistent links between community states and known anthropogenic stressors.

Acknowledgments

This exercise grew out of discussions on data needed to monitor and evaluate the ecological states of west coast rocky intertidal communities initiated by participants in the Multi-Agency Rocky Intertidal Network (MARINe), a partnership of agencies, universities and private groups committed to determining the health of rocky intertidal habitats. The U.S. Bureau of Ocean Energy Management (BOEM), a primary sponsor of MARINe, the University of Southern California (USC) Sea Grant program (National Oceanic and Atmospheric Administration (NOAA)), the Santa Monica Bay Restoration Commission (SMBRC), and the Southern California Coastal Water Research Project Authority (SCCWRP) provided fiscal and logistic support for this project. Pete Raimondi's group at the University of California, Santa Cruz (UCSC) provided the data sets, which were obtained with funding from MARINe, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), and the Division of Water Quality (Ocean Unit) of California's State Water Control Board (SWCB). We are particularly grateful to Mary Elaine Helix (BOEM) and Guangyu Wang (SMBRC) for providing travel funds for expert participants for post-exercise workshops and Linda Duguay, Phyllis Grifman, and Susan Zaleski (USC Sea Grant) for arranging for logistics and underwriting costs of an initial workshop at the Catalina Island Wrigley Institute of Environmental Studies (WIES). We also thank Liz Whiteman [California Ocean Science Trust (OST) and the OST's Marine Protected Area Monitoring Enterprise] and Dominic Gregorio (Ocean Unit of the Division of Water Quality, SWCB) for their interest and inputs. SCCWRP sponsored meetings and webinars essential to the completion of this project and Rani Gaddam (UCSC), Christy Bell (UCSC), Melissa Miner (UCSC), and Carol Blanchette (Marine Science Institute; University of California Santa Barbara) provided assistance in collecting and compiling data sets and in developing physical descriptions of rocky intertidal sites. Professor K.R. (Bob) Clarke (PRIMER-E Ltd) provided advice in data analysis. We also are grateful for the comments provided by reviewers that were used to improve the manuscript and would like to thank Heliana Teixeira (Scientific/Technical Project Officer; Institute for Environment and Sustainability) for sharing some of the analytical procedures used in a BPJ exercise on benthic macroinfaunal communities. The views expressed herein are those of the authors and do not necessarily reflect the views of BOEM, NOAA, OST, SMBRC, or SWCB, or any of their subagencies.

References

Addessi, L., 1994. Human disturbance and long-term changes on a rocky intertidal community. Ecol. Appl. 4, 786–797.

Airoldi, L., 2003. The effects of sedimentation on rocky coast assemblages. Oceanogr. Mar. Biol. Annu. Rev. 41, 161–236.

Ballesteros, E., Torras, X., Pinedo, S., García, M., Mangialajo, L., Torres, M., 2007. A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European water framework directive. Mar. Pollut. Bull. 55, 172–180.

Bay, S., Berry, W., Chapman, P.M., Fairey, R., Gries, T., Long, E., MacDonald, D., Weisberg, S.B., 2007. Evaluating consistency of best professional judgment in the application of a multiple lines of evidence sediment quality triad. Integr. Environ. Assess. Manage. 3, 491–497.

Benedetti-Cecchi, L., Pannacciulli, F., Bulleri, F., Moschella, P.S., Airoldi, L., Relini, G., Cinelli, F., 2001. Predicting the consequences of anthropogenic disturbance: large-scale effects of loss of canopy algae on rocky shores. Mar. Ecol. Prog. Ser. 214, 137–150.

Bermejo, R., Vergara, J.J., Hernández, I., 2012. Application and reassessment of the reduced species list index for macroalgae to assess the ecological status under the Water Framework Directive in the Atlantic coast of Southern Spain. Ecol. Indicat. 12, 46–57.

Bilyard, G.R., 1987. The value of benthic infauna in marine pollution monitoring studies. Mar. Pollut. Bull. 11, 581–585.

Bokn, T., Lein, T.E., 1978. Long-term changes in fucoid association of the inner Oslofjord, Norway. Norw. J. Bot. 25, 9–14.

Borja, A., Franco, J., Perez, V., 2000. A Marine Biotic Index to establish the ecological quality of soft bottom benthos within European estuarine and coastal environments. Mar. Pollut. Bull. 40, 1100–1114.

Borja, A., Marín, S., Núñez, R., Muxika, I., 2014. Is there a significant relationship between the benthic status of an area, determined by two broadly-used indices, and best professional judgment? Ecol. Indicat. 45, 308–312.

Borja, A., Miles, A., Occhipinti-Ambrogi, A., Berg, T., 2009. Current status of macroinvertebrate methods used for assessing the quality of European marine waters: implementing the Water Framework Directive. Hydrobiologia 63, 181–196.

Borja, A., Muxika, I., Franco, J., 2003. The application of a Marine Biotic Index to different impact sources affecting soft-bottom benthic communities along European coasts. Mar. Pollut. Bull. 46, 835–845.

Byers, J.E., 2002. Impact of non-indigenous species on natives enhanced by anthropogenic alteration of selection regimes. Oikos 97, 449–458.

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. Aust. J. Ecol. 18, 117–143.

Clarke, K.R., Gorley, R.N., 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, UK, 190 pp.

Dauvin, J.C., 2007. Paradox of estuarine quality: benthic indicators and indices, consensus or debate for the future. Mar. Pollut. Bull. 55, 271–281.

Dauvin, J.C., Alizier, S., Rolet, C., Bakalem, A., Bellan, G., Gomex Gesteira, J.L., Grimes, S., de-la-Ossa-Carretero, J.A., Del-Pilar-Ruso, Y., 2012. Response of different benthic indices to diverse human pressures. Ecol. Indicat. 12, 143–153.

Díaz, R.J., Rosenberg, R., 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanogr. Mar. Biol.: Annu. Rev. 33, 245–303.

Díaz, R.J., Solan, M., Valente, R.M., 2004. A review of approaches for classifying benthic habitats and evaluating habitat quality. J. Environ. Manage. 73, 165–181.

Díez, I., Bustamante, M., Santolaria, A., Tajadura, J., Muguerza, N., Borja, A., Muxika, I., Saiz-Salina, J.I., Gorostiaga, J.M., 2012. Development of a tool for assessing the ecological quality status of intertidal coastal rocky assemblages, within Atlantic Iberian coasts. Ecol. Indicat. 12, 58–71.

Díez, I., Santolaria, A., Secilla, A., Gorostiaga, J.M., 2009. Recovery stages over a long-term monitoring of the intertidal vegetation in the 'Abra de Bilbao' area and on the adjacent coast N Spain. Eur. J. Phycol. 44, 1–14.

Dukes, J.S., Mooney, H.A., 1999. Does global change increase the success of biological invaders? Trends Ecol. Evol. 14, 135–139.

EC, 2000. Directive 2000/60/EC of the European Parliament and of the Council: establishing a framework for community action in the field of water policy. Official Journal of the European Communities (OJ L327) 43, 1–73.

Echavirri, B., Juanes, J.A., García-Castrillo, G., 2007. Medium-term responses of rocky bottoms to sewage discharges through a deepwater outfall in the NE Atlantic. Mar. Pollut. Bull. 54, 941–954.

Elliott, M., Quintino, V.M., 2007. The estuarine quality paradox, environmental homeostasis and the difficulty of detecting anthropogenic stress in naturally stressed areas. Mar. Pollut. Bull. 54, 640–645.

Eriksson, B.K., Johansson, G., Snoeijs, P., 2002. Long-term changes in the macroalgal vegetation of the inner Bullmar Fjord, Swedish Skagerrak coast. J. Phycol. 38, 284–296.

Foster, M.S., 1990. Organization of macroalgal assemblages in the Northeast Pacific: the assumption of homogeneity and the illusion of generality. Hydrobiologia 192, 21–33.

Guinda, X., Juanes, J.A., Puente, A., Revilla, J.A., 2008. Comparison of two methods for quality assessment of macroalgae assemblages under different pollution types. Ecol. Indicat. 8, 743–759.

Juanes, J.A., Guinda, X., Puente, A., Revilla, J.A., 2008. Macroalgae, a suitable indicator of the ecological status of coastal rocky communities in the NE Atlantic. Ecol. Indicat. 8, 351–359.

Keough, M.J., Quinn, G.P., King, A., 1993. Correlations between human collecting and intertidal mollusc populations on rocky shores. Conserv. Biol. 7, 378–390.

Knox, G.A., 2001. The Ecology of Seashores. CRC Press, Boca Raton, Florida, USA, 555 pp.

Littler, M.M., Littler, D.S., 1980. The evolution of thallus form and survival strategies in benthic marine macroalgae: field and laboratory tests of a functional form model. Am. Natur. 116, 25–44.

Littler, M.M., Littler, D.S., 1981. Intertidal macrophyte communities from Pacific Baja California and the upper Gulf of California: relatively constant vs. environmentally fluctuating systems. Mar. Ecol. Prog. Ser. 4, 145–158.

Littler, M.M., Littler, D.S., 1984. Relationships between macroalgal functional form groups and substrata stability in a subtropical rocky-intertidal ecosystem. J. Exp. Mar. Biol. Ecol. 74, 13–34.

Littler, M.M., Littler, D.S., Murray, S.N., Seapy, R.R., 1991. Southern California rocky intertidal ecosystems. In: Mathieson, A.C., Nienhuis, P.H. (Eds.), Ecosystems of the World, Volume 24. Intertidal and Littoral Ecosystems. Elsevier, Amsterdam, The Netherlands, pp. 273–296.

Littler, M.M., Murray, S.N., 1975. Impact of sewage on the distribution, abundance and community structure of rocky intertidal macro-organisms. Mar. Biol. 30, 277–329.

Mangialajo, L., Chiantore, M., Cattaneo-Vietti, R., 2008. Loss of fucoid algae along a gradient of urbanization, and structure of benthic assemblages. Mar. Ecol. Prog. Ser. 358, 63–74.

Marques, J.C., Salas, F., Patrício, J., Teixeira, H., Neto, J.M., 2009. Ecological Indicators for Coastal and Estuarine Environmental Assessment – A User Guide. WIT Press, Southampton, UK, 208 pp.

Meyer, M.A., Booker, J.M., 2001. Eliciting and Analyzing Expert Judgment. A Practical Guide. Society for Industrial and Applied Mathematics, Philadelphia, Pennsylvania, USA, 459 pp.

Miller, A.C., Lawrenz-Miller, S.E., 1993. Long-term trends in black abalone, *Haliotis cracherodii* Leach, 1814, populations along the Palos Verdes Peninsula, California. J. Shellf. Res. 12, 195–200.

Murray, S.N., Ambrose, R.F., Dethier, M.N., 2006. Monitoring Rocky Shores. University of California Press, Berkeley, California, USA, 220 pp.

Murray, S.N., Bray, R.N., 1993. Benthic Macrophytes. In: Dailey, M.D., Reish, D.J., Anderson, J.W. (Eds.), Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, California, USA, pp. 304–368.

Murray, S.N., Littler, M.M., 1984. Analysis of seaweed communities in a disturbed rocky intertidal environment near Whites Point, Los Angeles, Calif., USA. Hydrobiologia 116/117, 374–382.

Muxika, I., Borja, A., Bonne, W., 2005. The suitability of the marine biotic index (AMBI) to new impact sources along the European coasts. Ecol. Indicat. 5, 19–31.

Oliveira, E.C., Qi, Y., 2003. Decadal changes in a polluted bay as seen from its seaweed flora: the case of Santos Bay in Brazil. Ambio 32, 403–405.

Orfanidis, S., Panayotidis, P., Stamatis, N., 2001. Ecological evaluation of transitional and coastal waters: a marine benthic macrophytes-based model. Mediterr. Mar. Sci. 2, 45–65.

Orfanidis, S., Panayotidis, P., Stamatis, N., 2003. An insight to the ecological evaluation index (EEI). Ecol. Indicat. 3, 27–33.

Panayotidis, P., Montesanto, B., Orfanidis, S., 2004. Use of low budget monitoring of macroalgae to implement the European Water Framework Directive. J. Appl. Phycol. 16, 49–59.

Pearson, T.H., Rosenberg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol.: Annu. Rev. 16, 229–311.

Pinedo, S., García, M., Satta, M.P., de Torres, M., Ballesteros, E., 2007. Rocky-shore communities as indicators of water quality: A case study in the Northwestern Mediterranean. Mar. Pollut. Bull. 55, 126–135.

Pinto, R., Patricio, J., Baeta, A., Fath, B.D., Aneto, J.M., Marques, J.C., 2009. Review and evaluation of estuarine biotic indices to assess benthic condition. Ecol. Indicat. 9, 1–25.

Raffaelli, D., Hawkins, S., 1999. Intertidal Ecology, second ed. Kluwer Academic Publishers, Dordrecht, The Netherlands, 356 pp.

Ranasinghe, J.A., Weisberg, S.B., Smith, R.W., Montagne, D.E., Thompson, B., Oakden, J.M., Huff, D.D., Cadien, D.B., Velarde, R.G., Ritter, K.J., 2008. Calibration and evaluation of five indicators of benthic community condition in two California bay and estuary habitats. Mar. Pollut. Bull. 59, 5–13.

Ranasinghe, J.A., Welch, K.I., Slattery, P.N., Montagne, D.E., Huff, D.D., Lee II, H., Hyland, J.L., Thompson, B., Weisberg, S.B., Oakden, J.M., Cadien, D.B., Velarde, R.G., 2012. Habitat-related benthic macrofaunal assemblages of bays and estuaries of the western United States. Integr. Environ. Assess. Manage. 8, 638–648.

Revilla, M., Franco, J., Bald, J., Laza, A., Seoane, S., Valencia, V., 2009. Assessment of the phytoplankton ecological status in the Basque coast (northern Spain) according to the European Water Framework Directive. J. Sea Res. 61, 60–67.

Rodriguez-Prieto, C., Polo, L., 1996. Effects of sewage pollution in the structure and dynamics of the community of *Cystoseira mediterranea* (Fucales, Phaeophyceae). Sci. Mar. 60, 253–263.

Sagarin, R.D., Ambrose, R.F., Becker, B.J., Engle, J.M., Kido, J., Lee, S.F., Miner, C.M., Murray, S.N., Raimondi, P.T., Richards, D.V., Roe, C., 2006. Ecological Impacts on the limpet *Lottia gigantea* populations: human pressure over a broad scale on islands and mainland intertidal zones. Mar. Biol. 150, 399–413.

Scanlon, C.M., Foden, J., Wells, E., Best, M.A., 2007. The monitoring of opportunistic macroalgal blooms for the water framework directive. Mar. Pollut. Bull. 55, 162–171.

Schoch, G.C., Dethier, M.N., 1996. Scaling up: the statistical linkage between organismal abundance and geomorphology on rocky intertidal shorelines. J. Exp. Mar. Biol. Ecol. 201, 37–72.

Selig, U., Eggert, A., Schories, D., Schubert, M., Blumel, C., Schubert, H., 2007. Ecological classification of macroalgae and angiosperm communities of inner coastal waters in the southern Baltic Sea. Ecol. Indicat. 7, 665–678.

Sfriso, A., Facca, C., Ghetti, P., 2009. Validation of the Macrophyte Quality Index (MaQI) set up to assess the ecological status of Italian marine transitional environments. Hydrobiologia 617, 117–141.

Sousa, W.P., 1979. Experimental investigations of disturbance and ecological succession in a rocky intertidal algal community. Ecol. Monogr. 49, 227–254.

Sousa, W.P., 1980. The responses of a community to disturbance: the importance of successional age and species life histories. Oecologia 45, 72–81.

Southward, A.J., 1995. The importance of long time-series in understanding the variability of natural systems. Helgoländer Meeresun. 49, 329–333.

Teixeira, H., Borja, A., Weisberg, S.B., Ranasinghe, J.A., Cadien, D.B., Dauer, D.M., Dauvin, J.C., Degraer, S., Diaz, R.J., Grémare, A., Karakassis, I., Llansó, R.J., Lovell, L.L., Marques, J.C., Montagne, D.E., Occhipinti-Ambrogi, A., Rosenberg, R., Sardá, R., Shaffner, L.C., Velarde, R.G., 2010. Assessing coastal benthic macrofauna community condition using best professional judgment – developing consensus across North America and Europe. Mar. Pollut. Bull. 60, 589–600.

Teixeira, H., Weisberg, S.B., Borja, A., Ranasinghe, J.A., Cadien, D.B., Velarde, R.G., Lovell, L.L., Pasko, D., Phillips, C.A., Montagne, D.E., Ritter, K.J., Salas, F., Marques, J.C., 2012. Calibration and validation of the AZTI's Marine Biotic Index (AMBI) for southern California marine bays. Ecol. Indicat. 12, 84–95.

Thompson, B., Weisberg, S.B., Melwani, A., Lowe, S., Ranasinghe, J.A., Cadien, D.B., Dauer, D.M., Díaz, R.J., Fields, W., Kellogg, M., Montagne, D.E., Ode, P.R., Reish, D.J., Slattery, P.N., 2012. Low levels of agreement among experts using best professional judgment to assess benthic condition in the San Francisco Estuary and Delta. Ecol. Indicat. 12, 167–173.

Vogt, H., Schramm, W., 1991. Conspicuous decline of *Fucus* in Kiel Bay (Western Baltic): what are the causes? Mar. Ecol. Prog. Ser. 69, 189–194.

Weisberg, S.B., Ranasinghe, J.A., Dauer, D.M., Schaffner, L.C., Diaz, R.J., Frithsen, J.B., 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. Estuaries 20, 149–158.

Weisberg, S.B., Thompson, B., Ranasinghe, J.A., Montagne, D.E., Cadien, D.B., Dauer, D.M., Diener, D., Oliver, J., Reish, D.J., Velarde, R.G., Word, J.Q., 2008. The level of agreement among experts applying best professional judgment to assess the condition of benthic infaunal communities. Ecol. Indicat. 8, 389–394.

Wells, E., Wilkinson, M., Wood, P., Scanlan, C., 2007. The use of macroalgal species richness and composition on intertidal rocky seashores in the assessment of ecological quality under the European Water Framework Directive. Mar. Pollut. Bull. 55, 151–161.

Wilkinson, M., Wood, P., Wells, E., Scanlan, C., 2007. Using attached macroalgae to assess ecological status of British estuaries for the European Water Framework Directive. Mar. Pollut. Bull. 55, 136–150.

Zabin, C.J., Danner, E.M., Baumgartner, E.P., Spafford, D., Miller, K.A., Pearse, J.S., 2012. A comparison of intertidal species richness and composition between Central California and Oahu, Hawaii. Mar. Ecol. 34, 131–156.