An Analysis of Ten Years of Intertidal Monitoring: Evaluating the Biophysical Data Collected by the Saanich Inlet Shorekeepers Program

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V7N 4C1

2011

Canadian Technical Report of Fisheries and Aquatic Sciences 2957

Fisheries and Oceans Canada
Pêches et Océans Canada

Canada

Canadian Technical Report of
Fisheries and Aquatic Sciences

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Fisheries and Aquatic Sciences 2957

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AN ANALYSIS OF TEN YEARS OF INTERTIDAL MONITORING: EVALUATING THE BIOPHYSICAL DATA COLLECTED BY THE SAANICH INLET SHOREKEEPERS PROGRAM

by

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Cat. No. Fs 97-6/2957E ISSN 0706-6457

Correct citation for this publication:

Macdonald, J.S., and MacConnachie, S. 2011. An analysis of ten years of intertidal monitoring: Evaluating the biophysical data collected by the Saanich Inlet Shorekeepers Program. Can. Tech. Rep. Fish. Aquat. Sci. 2957: xii + 42 p.

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EXECUTIVE SUMMARY

Annually, during the spring, for the past 10 years, groups of diligent volunteers have been collecting biological and environmental samples from intertidal locations in coastal British Columbia. The Shorekeeper Program was initiated and has been continually supported by Fisheries and Oceans Canada (DFO). It was conceived as an efficient way to monitor environmental quality in a portion of the coastal ecosystem with known sensitivities to human development while engaging the public in the regulatory process (Jamieson et al. 1999). DFO has been responsible for the care of the data, once collected, the analysis, and reporting the results. A review of the first three years of data evaluated sampling protocol and data quality, and made many relevant suggestions that led to constructive changes to the program (Jamieson et al. 2002). The present study provides an additional review of the above parameters, as well as an assessment of the scientific validity of the program and its utility for resource management. The data examined in this study were collected from six sites by the Saanich Inlet Preservation Society between 1999 and 2008. Observed spatial and temporal variability in biological characteristics were compared to known influences of common environmental drivers such as substrate, beach elevation and environmental exposure. Recommendations that may guide future Shorekeeper protocols are provided.

The six sites were dissimilar with substrate characteristics that varied from mud to bedrock and were distributed at elevations that differed among sites. Substrate character and vegetative cover varied temporally at some sites for reasons that were not readily apparent, except for possible correlations with differences in hydrological or meteorological exposure. Over 13,000 individual organisms collected from 1937 quadrats were scrutinized using ordination techniques to identify a small suite of biological variables indicative of substrate type and tidal elevation. Individuals were described as being present or absent to incorporate both percent cover and taxa count data into a single analysis. Taxa diversity was determined to be a valid metric to describe community structure and demonstrated a weak positive correlation with the range of habitat heterogeneity among sites. Biological diversity did not increase in the presence of eelgrass as reported by other authors, likely a result of a sampling bias. However, diversity was higher in the presence of other vegetative cover types.

The Shorekeeper Program provides a promising method to monitor taxa presence and biological community composition and measure environmental trends in shallow sloping intertidal habitats on Canada’s Pacific coast. It provides a database from which to draw a subset of scientifically defensible indicators specific to substrate, elevation and site location. The experimental design is less well-suited to measure acute environmental impacts but may serve to identify the reference condition in the event of future environmental alteration in the vicinity of Shorekeeper collection sites. Nor is it well-suited as the primary source of data to examine ecosystem function or ecological processes. This would require a

comprehensive description of environmental gradients and biological responses at a multi-trophic level, and are generally measured over a broad geographical range. These requirements are beyond the scope of the Shorekeeper program particularly if it is operated in the absence of contextual knowledge. A strong argument in support of the program and its volunteers lies outside the realm of scientific evaluation. Enabling citizens to monitor marine ecosystems promotes conservation, protection and restoration of coastal habitats and their associated species, while providing a venue for feedback on public concerns. To this end, this paper commends the citizen scientists of the Shorekeeper Program, while highlighting the results of their efforts and making recommendations that may increase fieldwork efficiency and improve data quality.

ABSTRACT

Macdonald, J.S., and MacConnachie, S. 2011. An analysis of ten years of intertidal monitoring: Evaluating the biophysical data collected by the Saanich Inlet Shorekeepers Program. Can. Tech. Rep. Fish. Aquat. Sci. 2957: xii + 42 p.

Biophysical data collected from intertidal habitats in Saanich Inlet by the Shorekeepers Program were analyzed to document spatial and temporal patterns in taxa distribution. This program was evaluated for its effectiveness as an instrument to monitor an important component of a coastal ecosystem which has received little formal scientific attention by the department. In Saanich Inlet, as with most intertidal locations, beach elevation and substrate type had a fundamental influence on biological distributions. Community assemblages that were influenced by these environmental gradients were chosen from 207 taxa categories collected during annual visits to six beaches for 10 years by trained volunteers. They are proposed as indicators of a functioning intertidal ecosystem. This program shows promise as a method to monitor taxa presence and biological community composition and to measure environmental trends in shallow sloping intertidal habitats on Canada's Pacific coast. Recommendations are made to increase fieldwork efficiency and improve data quality.

RÉSUMÉ

Macdonald, J.S., and MacConnachie, S. 2011. An analysis of ten years of intertidal monitoring: Evaluating the biophysical data collected by the Saanich Inlet Shorekeepers Program. Can. Tech. Rep. Fish. Aquat. Sci. 2957: xii + 42 p.

Les données biophysiques recueillies dans des habitats intertidaux de l’inlet Saanich dans le cadre du Programme des gardiens du littoral (Pêches et Océans Canada) ont été analysées aux fins de documentation des profils spatiaux et temporels de la distribution des taxons. On a évalué l’efficacité du Programme à surveiller une composante importante d’un écosystème côtier ayant fait l’objet de peu d’études scientifiques officielles. Dans l’inlet Saanich, à l’instar d’autres sites intertidaux, l’élévation de la plage et le type de substrat avaient une influence fondamentale sur la distribution biologique. Des assemblages de communautés qui ont réagi à ces gradients environnementaux ont été choisis parmi 207 catégories de taxons prélevés lors des visites annuelles à six plages par des volontaires formés, sur une période de 10 ans. On propose que ces assemblages servent d’indicateurs d’un écosystème intertidal fonctionnel. Le Programme se révèle prometteur en tant qu’instrument de surveillance de la présence des taxons et de la composition biologique des communautés ainsi qu’outil de mesure des tendances environnementales dans les habitats intertidaux inclinés et peu profonds du littoral pacifique du Canada. Les recommandations formulées visent à accroître l’efficience des travaux de terrain et à améliorer la qualité des données.

INTRODUCTION

Canadians in coastal regions face numerous challenges to the sustainability of their coastal marine resources. Shallow coastal zones, particularly those adjacent to industry and upland runoff, are subject to inputs of biological nutrients, heavy metals and hydrocarbons in concentrations that reflect the popularity of coastal property development (Nixon et al. 1986, Burd et al. 2008). Meade (1981) estimated that less than 5% of river-borne sediment reaches deep-sea habitats suggesting a record of human-derived inputs exists in coastal marine habitats on our coast. Furthermore, invasive species, second only to habitat loss with respect to their impact on biodiversity (Sala et al, 2000), are frequently encountered in intertidal and shallow subtidal areas. Non-indigenous species can have serious economic consequences including bio-fouling by tunicates, bryozoans and algae, intertidal invasions by bivalves and the introduction of intertidal predators such as the European green crab (*Carcinus meanus*). Habitats in developed areas are often subject to direct and indirect modification or destruction in response to sea-level rise and other sources of increased coastal erosion (Sobocinski et al. 2010). The global threat of climate change may be manifested in coastal regions through alteration of currents, water levels and weather patterns (DFO 2010a). Yet, shallow coastal habitats are highly productive. Phytoplankton, the base of the food chain for many intertidal species, is most abundant in shallow water (Strickland 1983), and shallow water habitats offer protection as nursery areas for juvenile fish of many species in temperate locations (Macdonald et al. 1984 and Macdonald and Chang 1993).

In Canada, the responsibility for the protection of these habitats and the fisheries they support rests with the Federal Department of Fisheries and Oceans (DFO). This is done through the *Oceans Act*, passed in 1997 which promotes an integrated, scientifically defensible and ecosystem-based approach rather than monitoring and regulating fish and fisheries in isolation of each other (DFO 2005). To be truly integrated, this approach must capture the relevant knowledge on a full range of trophic levels and habitats on which the floral and faunal assemblages depend, and be receptive to public participation into the decision-making process. Increasingly, the department has sought public participation in scientific panels advisory groups and scientific inquiries, to aid in decision making, inform policy development and seek a deeper understanding of societal concerns (e.g.) PNCIMA - marine advisory technical team, Southern Gulf Island National Park Reserve - advisory committee). More recently the public has also been engaged in field-oriented activities to acquire knowledge necessary to preserve, protect and enhance habitats (e.g. the Pacific Streamkeepers Program 2009) or develop a physical and biological inventory of local ecosystems as a step towards monitoring for natural or anthropogenic change (e.g. Community Aquatic Management Program, Thériault et al. 2006). By encouraging direct citizen engagement in science activities, the common pursuit of data exposes scientists, managers and the public to new knowledge.

The Shorekeeper Program on Canada's Pacific coast is another example of public integration into departmental interests. It was developed in 1996 to monitor intertidal invertebrate and macroalgae communities on shallow sloped beaches on Canada's Pacific coast. Data were to be scientifically defensible and represent a range of carefully recorded substrates, elevations and exposures. Hosted by Fisheries and Oceans Canada, this program began as a draft background document (Smiley and Levings 1996) culminating into a "Shorekeepers Guide" three years later (Jamieson et al. 1999). Since then, local community volunteers under the direction of trained leaders have followed the modules in the guide to perform annual biophysical collections, during extreme low tides in the spring, on numerous beaches from the northern coast of B.C. to the Saanich Peninsula (Figure 1a). To be effective, this approach required methodological consistency over a broad spatial/temporal scale and was expected to generate large amounts of highly credible data. Three years into the program, an audit identified a number of shortcomings in the sampling procedures, the data quality and the approaches to data analysis. Consequently, many modifications were made to the procedure (Jamieson et al. 2002). However, this audit did not address the overall utility of data collected by the Shorekeeper Program for use by resource managers or as a scientific database. Its value to discriminate community structure among sites, years and habitat type was not assessed, nor was its ability to identify acute or chronic environmental impacts. Ultimately, the true value of this program rests on its relevance to ecosystem-based management goals and its ability to track patterns in marine environmental quality.

Now, with access to 10 years of data, this report explores data collected from six sites in Saanich Inlet by one group of Shorekeeper volunteers, the Saanich Inlet Protection Society (SIPS)(Figure 1b). It assumes that the critical program shortfalls identified in the previous audit were addressed with modifications to the procedures (Jamieson et al. 2002) and that QA/QC measures have ensured a database that accurately reflects soft and hard bottom intertidal community structure during spring low tides on southern Vancouver Island. This report assesses the scientific defensibility and the overall utility of a Shorekeeper-based approach to measure ecosystem status and trends in support of Canada's *Oceans Act*. There may be a role for volunteers to contribute to State of the Ocean Reports as they apply to shallow coastal intertidal areas where the department has allocated little monitoring effort (DFO 2010a).

METHODS

The nucleus of the Shorekeepers' Program was a monitoring protocol designed to enable members of the public to collect highly credible data for use by resource management agencies. Leadership training procedures and technical support for the volunteers was made available through contacts in DFO. Data, once collected, was input, stored and analysed by DFO staff. A 34 step protocol that covered numerous aspects of habitat monitoring including site selection, boundary definition, physical features, mapping and documentation of the plants and animals in each habitat, is carefully described in the guide (Jamieson et al. 1999). This guide includes modules describing data entry and report preparation, and provides a training curriculum for instructors. For a detailed description of sampling methods and materials the reader is referred to this guide. However, the authors wish to draw attention to selected procedures in the sampling design as they are pertinent to the assessment of the database and may be subject to modification.

Surveys occurred once a year during late spring to take advantage of very low tides that occurred during daylight. In this manner, biases associated with seasonal variation in intertidal community structure were minimized prior to making inter-annual comparisons, and comparisons among other factors (e.g. substrate type, elevation etc.). Volunteers were encouraged to return to the same study area each year for three to five years to establish initial baseline data from which future samples could be contrasted. Following this, a schedule with less frequent visits to the study areas could be established but SIPS has returned annually to some sites for more than 10 years.

Site selection was based on the goals expressed by individual survey teams. In the case of SIPS, the goal was to describe the ecology in local intertidal habitats and potential upland pressures, documenting changes in community structure, and ultimately estimating the overall health of Saanich Inlet. Many other Shorekeeper groups were established on the Pacific Coast (n=20, Figure 1); each was encouraged to develop an individual focus. In some cases, issues of interest for each group were specific, e.g., monitoring the impact of a local shore-based industry or a fishing activity. Other groups may have concern for particular plants, animals or their habitat, or simply a general interest in temporal changes to the environmental quality of an area. All groups focus on intertidal samples. In practise, sites were likely chosen with consideration to access and personal preferences and were rarely selected randomly or with an interest in replicating environmental variables (e.g. habitat type, elevation etc.). The six locations evaluated in this report represent a wide range of substrate types, exposures and beach elevations, and differed widely in the size of the area surveyed. Upland activities that may influence the intertidal communities were also variable. While the sites were not replicates or randomly selected they may have been representative of the area. They were among a larger set of sites (n=10) sampled by SIPS that were the most consistently sampled over an extended period of up to 10 years.

The SIPS did not initiate their program to measure the effect of a specific impact. They are using a monitoring design to provide baseline biological data that can be used to measure temporal trends and/or provide pre-impact or reference state data against which departures in state can be measured once the time and location of the impact is known. However, the volunteers completed an area description for each site (Form 2, Part 3 – Jamieson et al. 1999) that estimated the type, timing and degree of development in the upland area adjacent to the study site and in the watershed beyond where hydrological linkages may have influenced spatial and temporal variation in community structure. These activities provide an opportunity to use the database to test the data's sensitivity to environmental impacts with a more sophisticated before-after-control-interaction (BACI) impact study. Should no impact be detected in association with these activities, an evaluation based on the known biological responses to intertidal habitat drivers and reference to intertidal assemblage surveys in the literature is a valid measure of Shorekeeper Program methods and database accuracy. The program provided various habitat driver characteristics as a component to the collection procedure (e.g. substrate, elevation), and others such as current speed and wave exposure in aquatic ecosystems adjacent to each of the six sites were available through the DFO at the Institute of Ocean Science Sidney B.C. Canada (unpublished data, R. Thomson). These data may not be available or in as high a resolution, at locations sampled by other Shorekeeper groups.

Site boundaries were carefully surveyed and ranged in shoreline length from 50 to 100m with consideration to the ability to assess an individual site in one day. Backshore and foreshore areas were categorized into a choice of one of nineteen discrete habitat units with a minimum size of 25m^2, that combine estimates of both biological cover and substrate type. In practise only eight habitat unit categories were commonly identified on the foreshore of the six Saanich sites (cover-type – step 13, Jamieson et al. 1998)(Rock-r, Cobble/Shell-c, Sand-s, Mud-u, *Fucus sp.*-fa, *Ulva sp.*-ua, *Zostera sp.*-e, Macroalgae-oa). A ninth unit, high elevation salt marsh (m), was identified less commonly (four years) at one of the sites. A geological bottom type variable, substrate composition, was also recorded within each habitat unit as a list of five of thirteen most common base materials, from bedrock to mud (step 14). Substrate type at individual quadrat locations was not recorded, but was assigned later to assist with data interpretation. It was based on extrapolations from both the habitat unit and bottom type in which the quadrat was located. Generating quadrat specific variables after-the-fact, created some unavoidable uncertainty particularly when assigning cobble or rock substrates to quadrats located in *Fucus sp.* or Macroalgae habitat units. Elevations at the upper and lower boundaries of each habitat unit were measured based on a datum established at low water. Slope of each unit was also calculated using a clinometer to measure elevation at the top and bottom boundaries. Slope estimates of the entire width of each site were a mean of the slopes of all habitat units within the site for all years, with confidence limits ($p=0.05$). Elevations of individual quadrats were not measured in the field but estimates for each were generated by extrapolation from upper and lower habitat unit elevations. The mean elevation of substrate categories at each site were plotted with measures of variation based on the elevations of quadrats within the category.

Quadrats were laid out on equally spaced transects at equally spaced intervals across the habitat unit. The number of quadrats were chosen subjectively to maximize effort in habitats rich in marine life and tended to range from six to fifteen per habitat unit. Large quadrats (50x50cm) were used in hard impenetrable substrates, smaller ones (25x25cm) in locations where bottom material could be exposed to a minimum of 10cm depth. Bottom material once removed was sieved with a 5mm mesh to facilitate the collection of animals which were identified to the lowest possible taxonomic level in the field before being returned. On occasion, unidentified plants of animals were preserved for positive identification at a later date but the vast majority of identification occurred in the field. Biological abundance was recorded as counts if the taxa were mobile and not too numerous to count. The abundance of attached plants and animals and those too numerous to count (e.g. barnacles) were estimated as percent cover in four categories (<25%, 25-49%, 50-75% and >75%). Data forms used by volunteers to collect field records were later transferred to a Microsoft Access relational database and maintained by DFO representatives who were also responsible for the analysis and reporting of these data. During this analysis a quadrat was the unit of replication for all investigations of species-environment relationships.

Geographical information system (GIS) technology was used to map the location of habitat units annually and provide estimates of the area of each. Habitat characteristics as represented by geological substrate and vegetative cover were compared annually and among sites with a correspondence analysis followed with a plot of the two leading axes (Minitab 2007). These results were also plotted using a traditional bar graph to provide additional resolution at specific sites and times. The mean number of habitat units at each site were plotted with measures of variation among years as an estimate of site complexity and structural heterogeneity – factors responsible for species diversity assuming the species are habitat specialists (Ricklefs 1979).

Once tabulated in a master file, the number of taxonomic categories was reduced in a two-step process to prepare for exploratory data analysis. Taxa categories that were ill-defined were removed (e.g. 'large white egg mass') or combined in higher taxonomic categories in cases where they were taxonomically difficult to distinguish to the species level. Taxa that occurred in less than 1% of the samples were then removed as they provided little biological information. Taxa that were measured as quantitative counts ('mobile') were combined for analysis with taxa that were measured categorically ('attached') by dichotomization both into binary, presence-absence measurements.

Following biological variable reduction the 55 taxa variables that remained were transformed into their scores on principal components (PC) to examine the structure of the entire database and to identify a subset of variables using the magnitude of the eigenvector coefficients as a measure of the contribution of each variable to the major trends in the data. The goal was to describe the entire community with fewer variables and perhaps identify indicators of habitat impact (Green 1979). Scores for these biological principal components were plotted against environmental variables (i.e) substrate and quadrat elevation and other site characteristics) to examine relationships between taxa assemblages and their environment. Plots of the first two principal components scores were also produced for a similar purpose. The PC analysis was repeated individually with samples collected from the most common substrates, cobble, rock and sand. By restricting further analysis to data within individual substrate strata a gradient defined by site was evaluated with the influence of substrate removed.

The presence and absence database with the full complement of biological variables provided numbers of taxa per quadrat and therefore an estimate of species diversity. Regressions measuring the response of biological diversity to sample elevation and to site complexity, provided insight into intertidal community organization. Interval plots of mean annual taxa/quadrat with measures of variation described the influence of habitat type and other site characteristics on biological diversity.

RESULTS

Despite their geographic proximity, the six sample sites had dissimilar environmental characteristics. Wave and wind exposure ranged from minimal levels at sites well within Saanich Inlet to medium or high levels closer to the inlet’s mouth (Figure 2). Currents were largely weak within Saanich Inlet except near the mouth at the Moses site where tidal action provided currents approaching 0.04m/sec. In the absence of empirical information, it is speculated that tidal mixing depressed temperatures and raised salinities in the late spring and early summer at Moses relative to the other sites, but the degree to which this influenced primary productivity is difficult to estimate (Strickland 1983). Cobble and Sand/Mud were the most common substrates and were encountered at all sites (Figure 3). Substrate size declined from Hagan through Tseycum and Towner to TenTen which is reported as being composed of mud despite being categorized as sand most years (Figure 4). Moses and Jimmy’s were the most consolidated, largely classified as rock or the vegetative cover that normally attaches to hard, stable surfaces. They were also the smallest sites, primarily because they were the steepest (Figure 5). Temporal habitat unit continuity existed at most sites with the exception of Moses where much of the low elevation habitat normally categorized as having quantities of macroalgae, was reported as bare cobble in 1999, 2000 and 2006, and *Ulva sp.* was more established in 1999 than during other years (Figure 4, Appendix 1).

When land development occurred adjacent to the monitoring sites it was restricted to agriculture or residential subdivisions and the sites were usually bordered by some form of vegetation (Table 1). During the monitoring period a number of irregular events occurred at the sites either in the intertidal zone (e.g. clam harvest) or in upland watersheds (e.g. agricultural expansion) that were linked by hydrologic processes to the beaches. These were minor impacts with no clear association with an alteration of invertebrate assemblages.

During 10 years of data collection at six intertidal locations in Saanich Inlet citizen volunteers from the SIPS collected 13,079 individuals from 1937 quadrats and identified 207 plant and animal taxa categories. One hundred and forty five of these taxa were categorized to the genus level or lower and several were identified as invasive or cryptogenic species (Table 2). The reduced database of biological variables, when plotted in space defined by the first two principal components (Figure 6), provided meaningful information regarding the possible influence of several environmental variable gradients on intertidal community assemblages. Of the eight taxa variables that loaded heavily on PCI (Table 3) six, including barnacles, limpets and mussels, responded positively to gradients in intertidal elevation (Figure 7). This assemblage was more common on rock, cobble and beds of *Fucus sp.*, which were common at higher elevations, than on unconsolidated substrates (Figure 8). Conversely, the seventh and eighth variables, *Zostera spp.* and *Macoma balthica*., loaded negatively on PCI and were found at the lowest elevations on sand and in association with *Ulva sp*. A second assemblage, composed of six taxa variables that loaded on PCII also deserve consideration as intertidal community indicators (Figure 6, Table 3). Four clam species, a polycheate and the grapsoid shore crab, did not respond to sample elevation (PCII, Figure 7), but were more commonly associated with sand and cobble than with any other substrate (Figures 6 and 8).

The influence of elevation on community assemblages is confounded with vertical stratification of substrate type at most sites. Rock occurred at the highest elevations, above cobble and both were above sand at the lowest elevation (Figure 9). There were exceptions; bedrock was found at comparatively low elevations at Moses. Similarly, the mean elevations of sand and cobble samples were not entirely comparable across all sites. The relative amount of each substrate category also differed among sites (Figures 3 and 4, Appendix 1). Cobble and sand were universally represented and bedrock occurred at four of the six sites, but most commonly at Moses and Jimmy’s. Further ordination treated these substrates independently removing them as a confounding influence in a comparison of biological assemblages among the six sites and ten years of collections.

Among sites, particularly on rock and cobble substrates, Moses showed large temporal variations in biological communities (Figures 10, 11, 12, 13). In 1999, 2000 and 2006 an assemblage of *Macoma balthica* and a brittle star and many plants were prominent in cobble substrate at Moses (PCI -Table 4). These were the years in which the habitat units normally classified as macroalgae were classified as bare cobble (Figure 4). In most years, a mollusc deficiency particularly bivalves distinguished Moses from other sites (PCII -Table 4). On rock substrate, two of the plants taxa identified in cobble, *Ulva spp*. and *Leathesia difformis*, and the gastropod *Batillaria cumingi*, were more common at Moses than elsewhere (PCI -Table 5). In sand substrate, TenTen and Tseycum were separated from each other and from the rest of the sites (Figures 14 and 15); TenTen because of fewer molluscs and more *Zostera spp*. (PCI –Table 6) and Tseycum because of less *Zostera spp*., fewer *Macoma balthica* and sipunculid worms.

Sites with greater habitat heterogeneity, as measured by the mean number of habitat units per year, tended to have greater taxa diversity (Figure 16). Hagan was the exception to this relationship and needed to be removed for it to be statistically significant ($P<0.05$, Figure 17). Taxa diversity was higher in cobble, *Fucus* and algae habitat units than in rock or *Zostera*, and was lowest in a small marsh noted at high elevation at Tseycum on four of the ten years of sampling (Figure 18). Habitat elevation was potentially a confounding factor, not significant on its own because quadrats with few taxa were found at all elevations, but because the highest taxa counts were found at the lowest elevations on the beach in coincidence with macrophytes (Figure 19).

DISCUSSION

Based on this evaluation of the efforts of volunteers belonging to the Saanich Inlet Preservation Society, the Shorekeeper Program provides a promising method to monitor taxa presence and biological community composition of shallow sloping intertidal habitats on Canada’s Pacific coast. These are habitats that warrant greater scrutiny by the regulatory agencies that are charged with their protection. A recent Science Advisory Report on ecosystem status and trends in Canada’s marine ecozones, noted deficiencies in this kind of ecosystem information (DFO 2010a). This Departmental review paper reports a paucity of structured or recurrent monitoring of intertidal habitats with the majority of monitoring that does occur targeted towards species of economic interest (e.g. clam surveys in intertidal locations) while excluding observations of other assemblages that live in association with the target species. These opinions have been expressed for many years by coastal research experts. Thomas et al. (1983) described intertidal community structure in the Quoddy region of southern New Brunswick as being poorly studied. Similar opinions have been expressed regarding both intertidal and shallow subtidal habitats in southern B.C. (Burd et al. 2008) and Washington State (Sobocinski 2010).

A well-executed Shorekeeper Program can address this information gap, using an approach that is reminiscent of early coastal surveys by Ed Ricketts, who has been called a “professional naturalist” (Hedgpeth in Ricketts and Calvin 1939). It should be of no surprise that the beach elevation and substrate type, which are fundamental factors in the biological distributions in Saanich Inlet, are two of the three environmental factors identified as having wide-spread geographical influence by Ricketts and Calvin (1968). Smith and Carlton (1975) as editors to the seminal intertidal Light's Manual, reinforce these fundamentals, adding detail to the environmental and physiological processes associated with variation in elevation. The barnacles *Chthamalus dalli*, and *Balanus glandula*, and the gastropods *Lottia pelta* and *Littorina sp*., identified by PCI in figure 6, are commonly understood to be associated with hard substrates in mid to supra-littoral zones (Ricketts and Calvin 1968, Thomas et al. 1983). Similarly, the assemblage composed largely of common bivalves identified by PCII are likely indicators for soft unconsolidated substrates (Burd et al. 2008). The fidelity of ten years of Shorekeeper's data to the basic principles of intertidal distributions provides an indirect measure of confidence in the Shorekeeper's approach. In other words, in this study the expected response to the absence of a large habitat impact was an absence of atypical signals. Therefore, the data collected by the Shorekeeper's in Saanich Inlet is reliable; a finding common to the biological data collected by many volunteer-based programs (Cohn 2008). A third environmental factor, exposure to wave shock, was more difficult to corroborate in Saanich Inlet on account of the narrow range of exposures represented by the six sites. Most locations in the Saanich vicinity are classified as protected bays or estuaries with only modest levels of wave shock. However, the Moses site may be exposed to currents and winds of sufficient strength relative to the other sites to be measurably different with respect to the biological community, having fewer of many penetrable sediment-dwelling species of bivalves. Bertasi et al. (2007) demonstrated an inverse relationship between exposure to currents and settlement of macrofauna. Moses may also be temporally less stable than the other sites, particularly Jimmy's Beach. If true, this was manifested in cobble and bedrock substrates in several years (e.g. 1999, 2000 and 2006) when key members of the biological assemblages were sampled with greater frequency than other years; possibly a response to variation in annual wave shock or to increased tidal currents and associated exposure to nutrients.

However, temporal patterns at Moses may be an artifact of sampling protocol, a function of uncertainty in the classification of cobble habitat among years (cobble vs macroalgae). This may have added error to the estimation of the influence of substrate gradients on biological assemblages, exaggerating the temporal variation in habitats and underestimating the number of cobble-based samples. If substrate characteristics were recorded as part of the sampling protocol at each quadrat location (and stored as a separate substrate variable), there would have been no need to extrapolate quadrat-specific substrate data after-the-fact, and the quadrat records could be used to back-check the assignment of habitat unit locations. Biological cover and substrate estimates, and even elevations, should be taken in association with individual quadrats during the field collections in recognition of their direct influence on biological distributions. Quadrat locations should continue to be assigned to strata, defined solely by substrate, but be randomized along transects to avoid violation of the statistical assumption of independence of errors (Zar 2010).

The Shorekeeper Program exists primarily to monitor the intertidal environment, and could perhaps be modified to track intertidal invasive species. Its also suited to collect baseline information for trend analysis (although project purpose was specific to individual Shorekeeper groups). It is not particularly well suited as the pre-impact portion of an environmental impact study because the nature of the impact, its location and timing are not known (Green 1979). Should it be called upon for pre-impact information, its long time series is beneficial, but the design (single collection/year) does not provide for the estimation of the copious seasonal variation common to these habitats (Ferraro and Cole 2007); this is a necessity for an optimal impact assessment (Livingston 1977). A difference in sampling date by a few weeks among years could confound interannual comparisons (Jamieson et al. 2002). Regardless, results from this study when examined with reference to contemporaneous anthropogenic actions enabled an evaluation of its sensitivity to environmental impacts. For example, clam harvesting openings from 2002 to 2004 at Moses may have caused some declines in the population of the clam *Macoma balthica* but other non-target members (e.g. *Ophiuroidea*) of the same biological assemblage showed similar trends (Cobble - PCI). Furthermore, during 2002 and 2003 populations of other common bivalves (e.g. *Protothaca staminea*) were unaffected and assemblages of clams in cobble at Moses were indistinguishable from other sites where, presumably, commercial harvests were not occurring (PCII). However, in 2004, the last year of the harvest, the assemblage of common, commercial clams at Moses was at a level lower than at any other site. At Jimmy's Beach, neither eelgrass planting in 2001 or the loss of cobble during a winter storm in 2004 were measurable as changes to the community assemblages. However, the minimal exposure to wind and currents at Jimmy's relative to the other sites may have accounted for greater temporal stability, denoted by smaller ellipsoids on most of the principal component plots. Anthropogenic activities adjacent to Tseycum in 2003 and TenTen in 2004 were also undetectable in the biological record. Therefore, as a program to collect pre-impact data, Shorekeepers may not be ideal and is likely not a reliable gauge for 'small' local changes where natural fluctuations and sampling error overwhelm anthropogenic signals.

Nevertheless, efforts by the Saanich Inlet Protection Society have produced a preliminary survey of intertidal species assemblages in several substrates in the protected waters of southern Vancouver Island. They can also provide the baseline component for a hypothesis led study, to be called upon should major impacts befall this area or areas with similar physical characteristics in the inside waters of the Pacific coast (Silvertown 2009). More importantly, they identify a number of potential indicator assemblages composed of far fewer variables than originally collected, and specific, by substrate and elevation, to southern Vancouver Island intertidal habitats. A restricted focus on these indicators in future monitoring, could provide opportunities for each group of volunteers to increase sampling efficiency, freeing up time to possibly broaden their geographical scope. Techniques to reduce variable number to a subset of key species have long been seen as desirable in ecosystem investigations of multivariate data (Austin and Greig-Smith 1968, Spight 1976). The 10 to 20 taxa variables that were identified via ordination accounted for a fraction of the overall variation in the matrices, but contained the greatest amount of information relative to other taxa in the original suite of variables. A large amount of unexplained variation is common in environmental surveys and likely speaks to the dynamic nature of intertidal habitats and the influence of many interacting environmental factors (Ferraro and Cole 2007). While this study was not able to demonstrate these taxa to be the most sensitive to impact effects, they were common to the areas sampled and are frequently of commercial value (e.g. clams). They are also sedentary and thus relatively simple to sample (Blanchet et al. 2008). Green (1979) extols molluscs as environmental indicators in fresh and saltwater for similar reasons. He suggests, as do many others, that many are sensitive to a variety of pollutants (Burd et al. 2008), and physical disturbances (particularly *Macoma balthica* – Whomersley et al. 2010). Other monitoring programs use inshore fish communities as indicators of change to ecosystem health because of their visibility and ease of identification (CAMP – Thériault et al. 2006). The plethora of articles that review the efficacy of indicator taxa based on their sensitivity to a variety of human induced impacts should be consulted before selecting a final subset of key indicator variables (e.g. Kelso et al. 1977 or Dauvin 2007).

In studies designed to examine the influence of environmental gradients on species distribution, the interpretation of results is often hampered by correlation among the predictor variables. Studies such as this one, where transects cross environmental gradients are particularly susceptible to interdependence among variables (Green 1979). Species distribution distinctions among Saanich Inlet sites were partially explained by site-specific substrate composition and further explained by the site-specific elevations where the substrate was found. Thus for example, the biological assemblages typical of rock substrate were comparable among those sites where the high elevations were composed of rock, but were dissimilar at Moses where the rock habitat was at a lower elevation. Improved selection protocol that seeks to replicate sites based on environmental similarity and to concentrate efforts on specific and easily defined strata within environmental gradients (e.g. clams in cobble substrate at 1-2m datum) could create a more efficient Shorekeepers' Program that is more sensitive to impact detection (Elliott 1979). Further efficiencies could be attained by adopting a less frequent sampling schedule at sites following the collection of three to five years of data successively. Sampling effort could then be transferred to additional sites to increase the geographical coverage of the program (Jamieson et al. 1998).

The Shorekeepers' Program promotes the use of visual percent cover estimates for sessile organisms as a means to avoid time-consuming counts of abundant organisms or to quantify large amounts of algal overstory. This approach is well accepted and can actually provide superior results to measurements at random points within a quadrat (Dethier et al. 1993). However, the inclusion of both continuous taxa counts and discrete percent cover data into the same analysis can only be done if both are expressed as binary values (Gilbert 1968). Binary data is well suited for investigation by ordination, with little loss of useful information compared to similar analysis with taxa abundance (Norris and Barkham 1970). A Shorekeeper program designed to collect only presence-absence data could save the time normally spent counting individuals and may actually collect more ecologically relevant information on a per unit effort basis (Green 1979). However, this may run counter to the original study goals where participants, from volunteers to scientists, may wish to measure and compare sites in terms of abundance, production or biomass.

Taxa diversity is frequently reported as a simple means to define complex community structure (Ricklefs 1979). Diversity, as described by many multimetric diversity indices that have been growing in complexity approaching that of the community they are meant to describe, have been used to document biological response to all manner of anthropogenic (Whilm and Dorris 1968, Blanchet et al. 2008) and natural habitat variation (Ferraro and Cole 2007). While many feel that diversity indices may unnecessarily complicate and obscure (Ricklefs 1979, Green 1979), taxa diversity (as simple counts of numbers of taxa) remains a biologically meaningful measure that may reflect interactions among species and their environment or among the species themselves. Green (1979) describes a number of studies where displays of simple taxa number are used successfully to supplement other descriptors. Of particular interest for the purposes of this study is a supposition that habitat heterogeneity has a positive effect on numbers of taxa (Poole 1974, Ricklefs 1979, Gray et al. 2002); a supposition weakly supported by the Saanich Inlet data if numbers of habitat units/site are used to represent habitat heterogeneity. Paine (1966) found no evidence to support this theory in subtidal coastal habitats. However, Burd et al. (2008), while examining subtidal benthos in Strait of Georgia, found number of taxa declined with increasing total organic carbon (%TOC) or total nitrogen which are thought to indicate declining habitat heterogeneity (Bernard 1978). This was not the case near pulpmills and mine drainage sites where diversity was generally low. Ferraro and Cole (2007) found a similar, albeit weaker, relationship between %TOC and taxa diversity on tidal flats in Willapa Bay in Washington State. They also describe greater taxa abundance and community structure in *Zostera marina* (eelgrass) and *Spartina alterniflora* (cord grass) than in bare mud/sand and subtidal habitats. *Zostera sp.* beds have been described as a source of habitat complexity and related factors according to Bostrom and Bonsdorff (1997). This was apparently not the case with the data from Saanich Inlet where taxa numbers were depressed in *Zostera sp*. beds relative to most other habitat types particularly *Ulva sp*., *Fucus sp.* and other algae. No estimate of eelgrass bed density is available from the Saanich sites for comparison with Ferraro and Cole nor are there sediment chemistry data (e.g.) %TOC). However, it is conceivable that eelgrass roots may inhibit burrowing animals, particularly bivalves (Burd et al 2008), or possibly there was a systemic reluctance, within the program, to disturb eelgrass habitat thus creating bias in the data.

The goals of most Shorekeeper programs, and their appeal to regulatory organizations, are loosely associated with the measurement of ecosystem change or estimating habitat quality in support of ecosystem-based management (Jamieson et al. 1999). However, the concept 'ecosystem quality' is elusive, generally being defined by human objectives because of difficulties defining natural multispecies reference conditions or measuring the functional role of an ecosystem process (Tillin et al. 2008). Habitat quality may only make sense when applied to a single species where the objective is to manage a commercial fishery, protect a threatened species or assess the role of an individual that modifies habitat structure (e.g. benthic engineers - Hall et al. 1997, Naiman et al. 2002, Ferro and Cole 2007, Macdonald et al. 2010). A Shorekeepers' Program could be aligned to track single taxa in a single appropriate habitat unit and, if the taxa had keystone qualities within the community (Paine 1974), it may be viewed as an ecosystem indicator and the program would support ecosystem-based management ideals. However, the Saanich Inlet data, as analysed in this paper seeks to identify a reference condition with multiple taxa variables in multidimensional space defined by environmental gradients. Tillin et al. (2008) suggest that this approach, while still useful, provides a less comprehensive valuation of habitat quality than a functional approach that documents, quantifies and manages ecosystem processes. A Shorekeeper's Program run by volunteers is not suited to meet the needs of this type of ecosystem analysis largely because measures of ecosystem functioning are not well developed (Tillin et al. 2008) and critical pathways of effects span geographical areas much too large for a volunteer-run program to examine. Here then is another consideration when planning for volunteer engagement in programs that support prosperous fisheries and sustainable aquatic ecosystems within the Ocean Action Plan (DFO 2005). Volunteer contributions will have the greatest value if they rest within a program of broader ecosystem-based science. To be vital, ecological reference condition data, collected by groups like the Saanich Inlet Preservation Society, need to be considered in unison with an understanding of, for example, inputs from upland watershed, adjacent coastal and oceanic circulation patterns, meteorological trends, and sediment chemistry. The proximity of the DFO's Institute of Ocean Science and years of science interest in Strait of Georgia provides context for information collected by the Saanich Inlet Preservation Society and other operations in the southern Strait of Georgia. Volunteers may best be employed at locations where existing data and science support can provide these linkages to create a multidisciplinary program based on ecosystem principles.

Perhaps the strongest argument in support of the Shorekeeper Program and its volunteers lies outside the realm of scientific evaluation. By enabling citizens to monitor marine ecosystems, we promote and educate conservation, protection and restoration of coastal habitats, and their associated species, while receiving feedback in local knowledge and public concerns (Cohn 2008). Citizens and the communities they represent are more likely to support regulatory directives if they feel an ownership of both the resources and the data that contribute to their regulation. Finally, citizen science is cost effective. Silvertown (2009) suggests that future projects that require the collection of large volumes of data over a wide geographical area will only succeed with the help of volunteers. To this end, this paper commends citizen scientists, while highlighting the results of their efforts and making recommendations that may increase fieldwork efficiency and improve data quality.

RECOMMENDATIONS

- Substrates at the six sites differed spatially and temporally. Choosing sites with similar characteristics or a study focus on specific substrates and elevations would reduce natural variation and improve our ability to assess impacts of interest.
- Substrate and elevation should be estimated at each quadrat location. With these elevation data, slope observations at each site may no longer be necessary.
- Methods to consistently discriminate among ‘sand’ and ‘mud’ substrates should be devised and enacted at each quadrat location.
- Substrate should be estimated independently of cover; i.e.) a new variable should be restricted to geological definitions and measured as part of the field protocol.
- Only a small number of the total taxa variables were required to describe biological trends in the data. Volunteers could be asked to concentrate on a suite of species chosen from preliminary sampling, existing literature from monitoring studies in the same geographical area and literature reviews of indicator species.
- Substituting binary data for quantitative estimates (counts or percent cover) of taxa importance could save sampling time and provide more information per unit effort.
- Three factors (substrate, site, elevation) had a significant influence on community structure but several additional factors if available, could add context to the volunteer’s observations (e.g. water temperature, %TOC, %TN, wind, wave and current exposures, linkages to adjacent land and water-use activities, etc.).
- Quadrats should be situated in each habitat unit in a random manner (transects could continue to be used) to ensure independence of errors.
- Sites could be sampled annually for three to five years and then less frequently to free up resources to examine other locations (Jamieson et al. 1999).

- A continual data validation procedure should be incorporated into the sampling procedure. This may require the assignment of a departmental employee to accompany a Shorekeeper group for portion of their annual sampling.
- A strong volunteer leader is required to motivate the others and ensure data consistency. The department should support the leader and others with regular feedback as a reward for their efforts (Silvertown 2009).

OBSERVATIONS

- The Shorekeeper Program could be employed to measure an anticipated impact but is best suited for monitoring designs that measure environmental trends, the distribution and progression of invasive species, and/or act to define a baseline reference condition against a future impact(s), unpredictable in space and time.
- The program is less well designed to evaluate ecological processes or pathways of effects.
- Taxa diversity estimated by simple taxa counts (not complicated diversity indices) provided an additional means for spatial and temporal comparison of habitat types and sites.
- In terms of these 6 intertidal habitats, there is no glaring evidence of a decline in “ecosystem health” in the Saanich Inlet region but many gaps remain in our knowledge.

ACKNOWLEDGEMENTS

First and foremost we wish to thank the volunteers of the Saanich Inlet Preservation Society for the years of dedicated service contributing to an important cause. This includes the members of the Tseycum, Tsartlip and Pauquachin First Nations for their assistance with collections and access to their traditional areas. We also wish to express appreciation to the many other Shorekeeper Programs, their leaders and volunteers doing similar work at many locations on Canada’s Pacific coast. Thanks are also extended to several DFO staff members many of them now retired, whose professional skills during the early phases of the Shorekeeper development created a program able to stand the test of time. This includes the leaders during the program’s formative years. Dr. Glen Jamieson, Dr. Colin Levings, Mr. Brian Smiley and Mr. Brad Mason. Dr. Thomas Therriault’s insight in aquatic invasive species provided a valuable contribution.

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TABLES

Site	Land use	Road	Vegetation	Comments
Hagan Bight 1999	Pasture	None	Mixed forest (deciduous + coniferous)	
Hagan Bight 2000	Pasture	None	Mixed forest + shrub	
Hagan Bight 2001-2008	Pasture	None	Mixed forest	
Jimmy's Beach 2001	Residential + landscaped	Gravel road	Deciduous forest + shrub	2001-eelgrass planted
Jimmy's Beach 2002	Residential	Gravel road	Deciduous forest + shrub	
Jimmy's Beach 2003-2006	Undeveloped	None	No vegetation	2004-winter storm removed cobble from beach
Jimmy's Beach 2008	Residential	Gravel road	Deciduous forest + shrub	
Moses Point 1999	Residential + landscaped	Gravel road	Mixed forest + shrub	
Moses Point 2000	Residential	Paved road	Mixed forest	
Moses Point 2001-2004	Residential	None	Mixed forest + shrub	2002-2004-area open for clamming
Moses Point 2005-2008	Residential + landscaped	None	None	2005-area closed to clamming
Ten Ten Creek 1999	Non-residential + landscaped	Mixed roads (gravel + paved)	Shrubs	
Ten Ten Creek 2000-2002	Non-residential + landscaped	Gravel road	Mixed forest + shrub	
Ten Ten Creek 2003-2008	Non-residential + landscaped	Mixed roads	Shrubs	2004-Pendray cattle farm expansion 2004-Removal of settlement pond
Towner Park 1999	Undeveloped	Gravel road	Coniferous + shrub	
Towner Park 2000	Undeveloped	Gravel road	Mixed forest + shrub	
Towner Park 2001	Undeveloped	Gravel road	Mixed forest + shrub	
Towner Park 2005-2008	Residential	Gravel road	Shrubs	
Tseycum Creek 1999-2001	Residential	Gravel road	Coniferous + shrub	
Tseycum Creek 2002-2003	Residential	Mixed roads	Marsh + shrub	2003-Riprap wall installed Extensive scouring of foreshore
Tseycum Creek 2004-2008	Residential	Undefined road	No vegetation	

Table 1: Documentation of the characteristics of adjacent upland areas that may have had an influence on the biological communities found at each study site. The dates of potentially influential upland events have been noted in the 'Comments' column.

Annelida

Abarenicola pacifica
Axiothella rubrocincta
Eudistylia vancouveri
Euzonus sp.
Glycera rugosa
Halosydna brevisetosa
Nereis brandti
Nereis vexillosa
Nereis virens
Notomastus tenuis
Pecinariidae sp.
Serpula vermicularis
Spirorbis sp.

Nemertea

Amphiporus sp.
Emplectonema gracile
Paranemertes peregrina
Tubulanus polymorphus

Chordata

Family: Ascidiacea
Leptocottus armatus
Oligocottus maculosus
Family: Pholidae
Porichthys notatus
Psettichthys melanostictus

Bryophyta

Ascomycota

(*Verrucaria sp.*)

Echinodermata

Cucumaria miniata
Dendraster excentricus
Dermasterias imbricata
Desmarestia ligulata
Eupentacta sp.
Evasterias troschelii
Holothuroidea
Leptosynapta clarki
Ophiuroidea sp.
Pisaster ochraceus
Pycnopodia helianthoides
Solaster sp.

Cnidaria

● *Anthozoa sp.*
Epiactis sp.
Urticina crassicornis

Platyhelminthes

Leptoplana sp.
Notoplana sp.

Ectoprocta

(*Schizoporella unicornis*)

Sipuncula

(*Phascolosoma agassizi*)

Porifera

(*Haliclona* sp.)

Mollusca

Amphissa sp.
Batillaria attramentaria
Calliostoma ligatum
Clinocardium ciliatum
Clinocardium nuttallii
● *Crassostrea gigas*
Crepidula adunca
Cryptochiton stelleri
Haminoea vesicula
Haminoea virescens
Lirabuccinum dirum
Littorina scutulata
Littorina sitkana
Lottia digitalis
Lottia pelta
Macoma balthica
Macoma inquinata
Macoma nasuta
Macoma secta
Mopalia ciliata
Mopalia muscosa
● *Mya arenaria*
● *Mytilus sp.*
Nucella emarginata
Nucella lamellosa
● *Nuttallia obscurata*
Panopea abrupta
Petaloconchus compactus
Pododesmus cepio
Polinices lewisii
Polyplacophora
Protothaca staminea
Saxidomus giganteus
Siliqua patula
Tectura persona
Tectura scutum
Tegula funebralis
Tellina modesta
Tonicella lineata
Tresus capax
● *Venerupis philippinarum*

Arthropoda

Balanus glandula
Callianassa californiensis
Callistoma sp.
Cancer magister
Cancer productus
Chthamalus dalli
Cirolana harfordi
Crangon sp.
● Family: Gammaridae
Gnorimosphaeroma sp.
Hemigrapsus nudus
Hemigrapsus oregonensis
Heptacarpus
Idotea resecata
Idotea wonesenski
● Order: Isopoda
Lophopanopeus bellus
Megalorchestia sp.
Neomolgus littoralis
Neotrypaea californiensis
Oregonia gracilis
Pagurus samuelis
Petrolisthes eriomerus
Pugettia producta
Pugettia richii
Semibalanus cariosus
Orchestia traskiana
Upogebia pugettensis

Rhodophyta

Bangia fuscopurpurea
● *Ceramium sp.*
Corralline algae
Endocladia muricata
Gigartina exasperata
Gracilaria sjoestedtii
Halosaccion glandiforme
Hildenbrandia
Lithophyllum
Mastocarpus papillatus
Mazzaella cordata
Odonthalia floccosa
Petrocelis franciscana
Prionitis lanceolata
Pseudolithophyllum sp.
Rhodomela larix

Ochrophyta

Alaria marginata
Fucus distichus
Fucus gardneri
Laminaria saccharina
Leathesia difformis
Nereocystis luetkeana
Ralfsia
● *Sargassum muticum*

Chlorophyta

Cladophora sp.
● *Enteromorpha sp.*
Lola lubrica
● *Percursaria sp.*
Ulva lactuca

Magnoliophyta

Phyllospadix
Salicornia virginica
● *Zostera japonica*
Zostera marina

Table 2: A biological inventory of 145 of the 207 taxa groups that were identified to species or taxa level from collections during a 10 year period by the Saanich Inlet Preservation Society at six sites in Saanich Inlet. Invasive or cryptogenic species are identified (●). Note that *Mytilus sp.* was identified by the volunteers as *M. edulis* but resolution to species could not be confirmed.

Taxa Category	**PCI**	**PCII**	**PCIII**
Fucus sp.	***0.279***	-0.149	-0.135
Chthamalus dalli	***0.204***	-0.027	-0.155
Balanus glandula	***0.319***	0.045	-0.094
Zostera sp.	***-0.222***	-0.152	-0.031
Mytilus edulus complex	***0.288***	-0.027	-0.146
Littorina sp.	***0.335***	0.087	0.098
Lottia pelta	***0.257***	0.011	-0.138
Macoma spp. (balthica)	***-0.228***	***0.251***	-0.126
Protothaca staminea	-0.022	***0.395***	-0.118
Hemigrapsus spp. (nudus)	0.152	***0.222***	-0.092
Nuttallia obscurata	0.074	***0.345***	0.091
Venerupis philippinarum	0.079	***0.371***	0.020
Glycera rugosa	-0.148	***0.230***	-0.170
Gracilaria sp.	-0.067	-0.042	***-0.282***
Cladophora sp.	0.077	-0.131	***-0.208***
Leathesia difformis	-0.019	-0.156	***-0.331***
Ulva sp.	-0.213	-0.063	***-0.317***
Pagurus sp.	0.057	-0.061	***-0.252***
Ophiurodea	-0.050	-0.051	***-0.310***

Table 3: Eigenvector coefficients (PC loadings) listing the biological assemblages (each joined with a vertical line) most responsible for the variation among substrates described by the principal components in Figure 6. The most common member of a genus that discriminates among substrates is listed in brackets.

Taxa Category	**PCI**	**PCII**	**PCIII**
Ulva spp.	***0.308***	0.022	-0.230
Ophiuroidea	***0.341***	0.082	0.257
Macoma spp. (balthica)	***0.312***	-0.138	-0.216
Zostera spp. (japonica)	***0.295***	0.060	0.243
Gracillaria spp.	***0.264***	0.028	0.112
Leathesia difformis.	***0.254***	0.082	0.161
Notomastus tenuis	***0.242***	-0.231	-0.152
Balanus glandula	-0.066	***-0.263***	0.145
Protothaca staminea	0.152	***-0.358***	-0.120
Hemigrapsus spp. (oregonensis)	0.050	***-0.278***	0.055
Nuttallia obscurata	-0.087	***-0.288***	0.107
Venerupis philippinarum	-0.031	***-0.343***	-0.008
Lottia pelta	-0.017	***-0.240***	0.083
Littorina spp.	-0.207	-0.198	***0.293***
Zostera spp. (japonica)	0.295	0.060	***0.243***
Ulva spp.	0.308	0.022	***-0.230***
Ophiurodea	0.341	0.082	***0.257***

Table 4: Eigenvector coefficients (PC loadings) listing the biological assemblages most responsible for the variation among sites described by the principal components in Figure 10. Site comparisons are based on assemblages found in cobble. Each assemblage is indicated with a vertical line. The most common member of a genus that discriminates among site is listed in brackets.

Taxa Category	PCI	PCII	PCIII
Ulva sp.	***0.310***	-0.000	0.052
Littorina spp.	***-0.297***	0.127	0.088
Batillaria cumingi	***0.329***	0.167	0.006
Leathesia difformis	***0.395***	0.115	0.107
Notomastus tenuis	0.073	***0.299***	-0.142
Mastocarpus sp.	0.067	***0.332***	-0.194
Leptoplana sp.	0.057	***0.311***	-0.167
Axiothella rubrocincta	0.083	***0.409***	-0.245
Gnorimosphaeroma sp.	0.023	***0.335***	-0.165
Pseudolithophyllum sp.	0.037	0.064	***0.312***
Hemigrapsus nudus	-0.138	0.138	***0.267***
Lottia pelta	-0.186	0.175	***0.258***
Haminoea vesicula	0.139	-0.040	***0.311***
Ophiuroidea	0.126	-0.041	***0.245***

Table 5: Eigenvector coefficients (PC loadings) listing the biological assemblages most responsible for the variation among sites described by the principal components in Figure 12. Site comparisons are based on assemblages found on bedrock. Each assemblage is indicated with a vertical line.

Taxa Category	PCI	PCII	PCIII
Mytilus edulis complex	***0.337***	0.158	-0.159
Balanus glandula	***0.321***	0.019	0.061
Batillaria cumingi	***0.300***	-0.017	-0.126
Venerupis philippinarum	***0.276***	0.154	-0.008
Protothaca staminea	***0.257***	-0.016	0.208
Littorina spp.	***0.276***	0.122	-0.050
Zostera spp.	***-0.226***	***0.403***	0.002
Phascolosoma agassizi	0.041	***0.297***	-0.065
Ulva spp.	0.079	***-0.262***	0.144
Dendraster excentricus	-0.017	***-0.259***	***0.379***
Macoma spp. (balthica)	0.018	***0.260***	***0.293***
Notomastus tenuis	0.049	0.215	***0.283***
Pagurus spp.	0.142	-0.094	***-0.251***
Hemigrapsus nudus	0.199	0.063	***0.249***
Crassostrea gigas	0.154	0.183	***-0.295***
Glycera rugos	0.049	-0.182	***0.260***

Table 6: Eigenvector coefficients (PC loadings) listing the biological assemblages most responsible for the variation among sites described by the principal components in Figure 14. Site comparisons are based on assemblages found in sand. Each assemblage is indicated with a vertical line. The most common member of a genus that discriminates among site is listed in brackets.

FIGURES

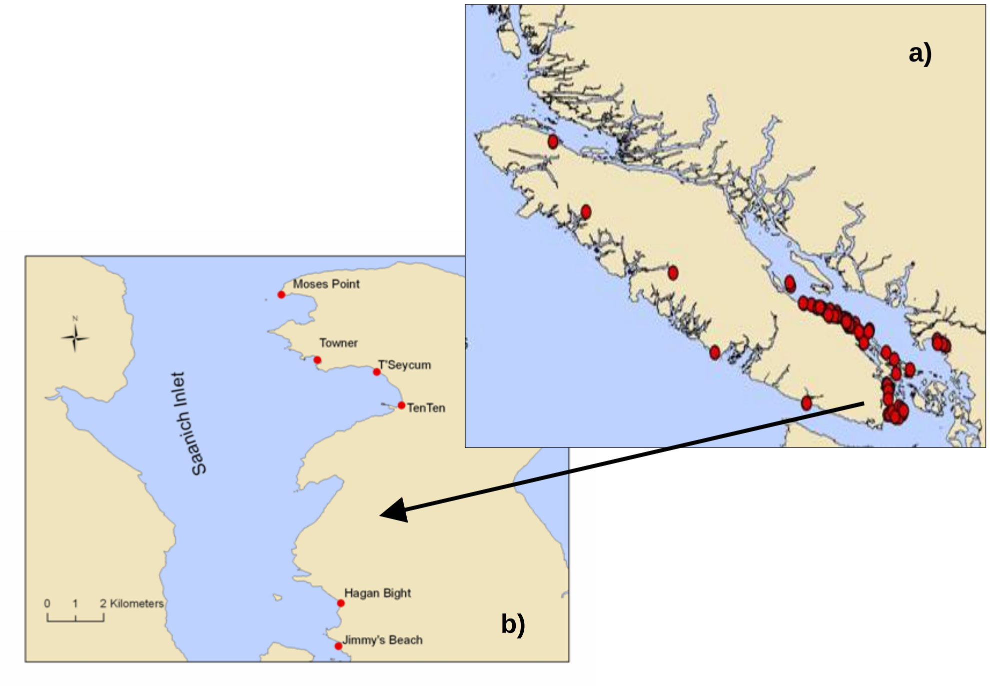
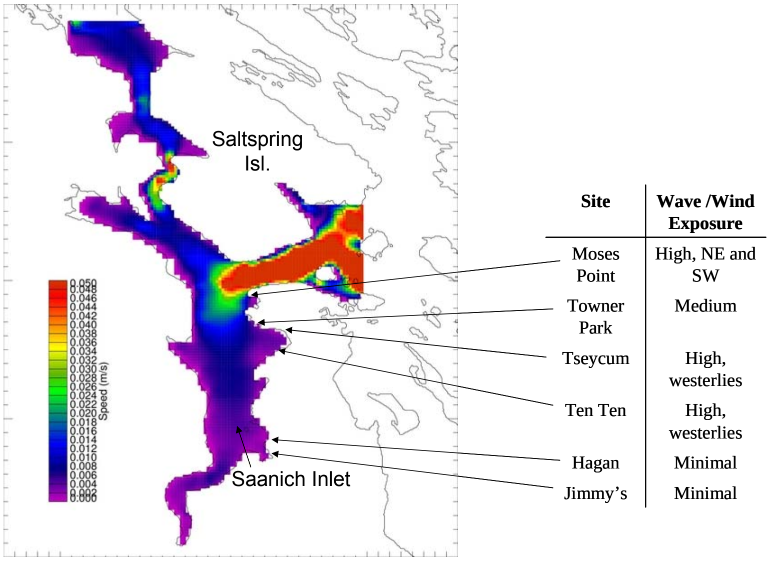


Figure 1. Many Shorekeeper Programs were initiated in the late 1990’s most commonly at locations along the southern coast of B.C. (a). The most active groups, in Boundary Bay and Saanich Inlet, have been in operation 10 years. Six sites in Saanich Inlet were analyzed to evaluate the efficacy of the Shorekeeper Program (b).



Site	Wave /Wind Exposure
Moses Point	High, NE and SW
Towner Park	Medium
Tseycum	High, westerlies
Ten Ten	High, westerlies
Hagan	Minimal
Jimmy’s	Minimal

Figure 2. The Saanich Inlet sites were subjected to a range of oceanographic and meteorological conditions that are typical at many sites in the protected inside waters of coastal B.C.

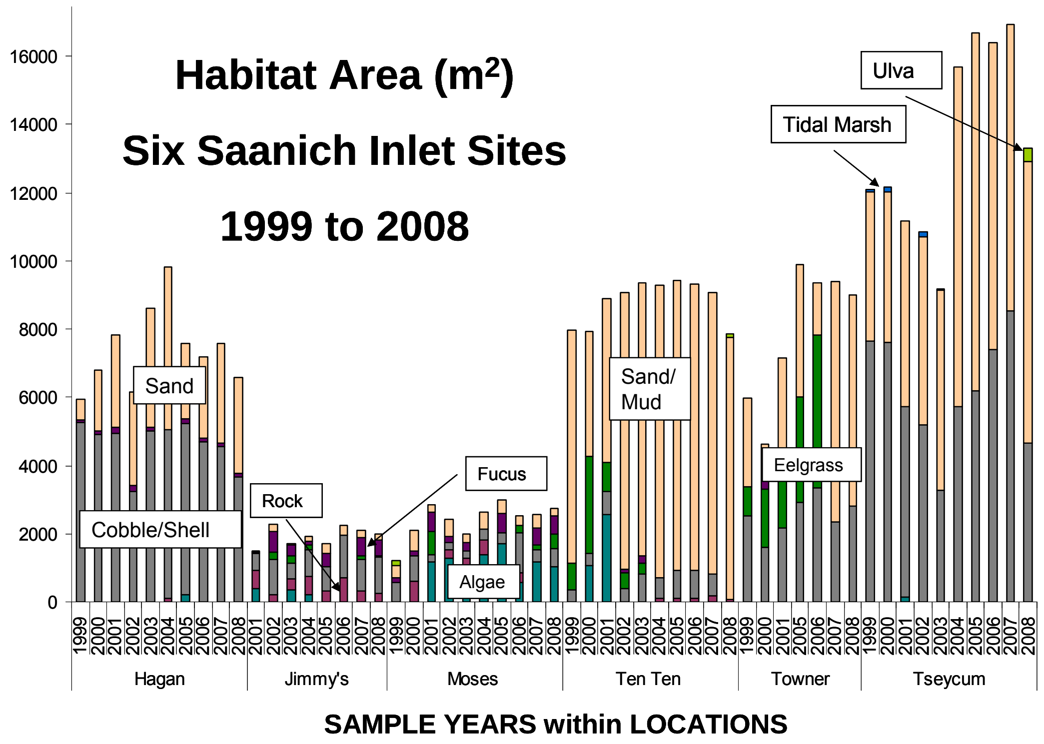


Figure 3. The habitat area (m^2) by cover or geological substrate category identified in a survey of habitat units at each of six Saanich Inlet sites between 1999 and 2008. A spatial and temporal analysis of these data compared substrate characteristics among the six sites (Figure 4). Observations from field books suggest that the finest substrates occurred at TenTen but were only occasionally classified by the volunteers as mud. For the purposes of the analyses the finest substrates at all sites were classified as sand.

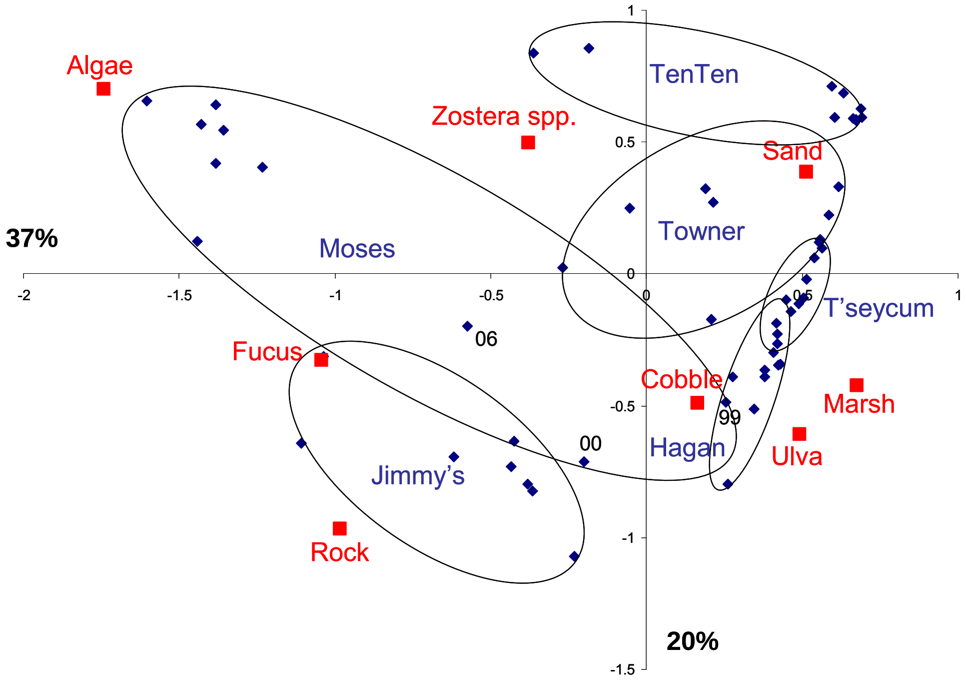


Figure 4. Plots of the six sites in multidimensional space as defined by the habitat units at each location. Habitat units were defined by both biological cover and substrate type. The annual means are indicated with a '◊' symbol and all means for a site were enclosed in an ellipse that was fit by eye. The years in which three unusual observations were made at Moses are indicated. The first two axes described nearly 60% of the variation in the substrate data.

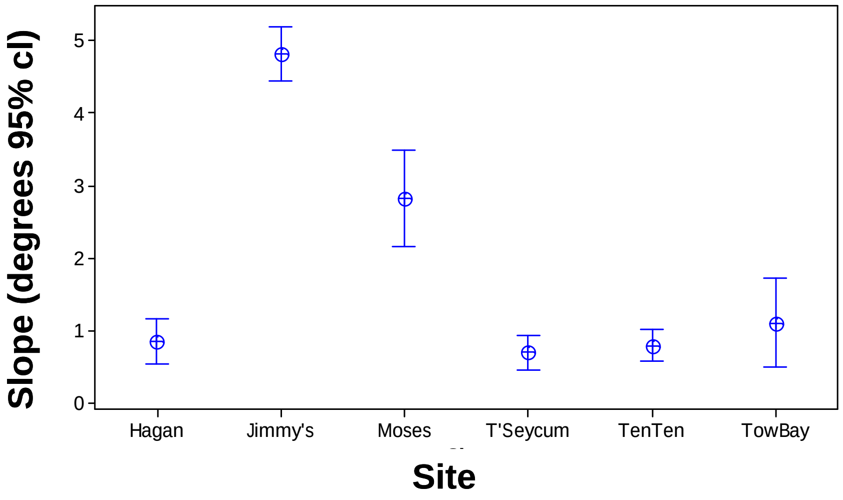


Figure 5. Mean slopes of individual habitat units calculated among years by site with 95% confidence limits. Slopes were calculated by comparing elevations at the top and bottom of each habitat unit. As such, the sample sizes at each site varied with the number of habitat units.

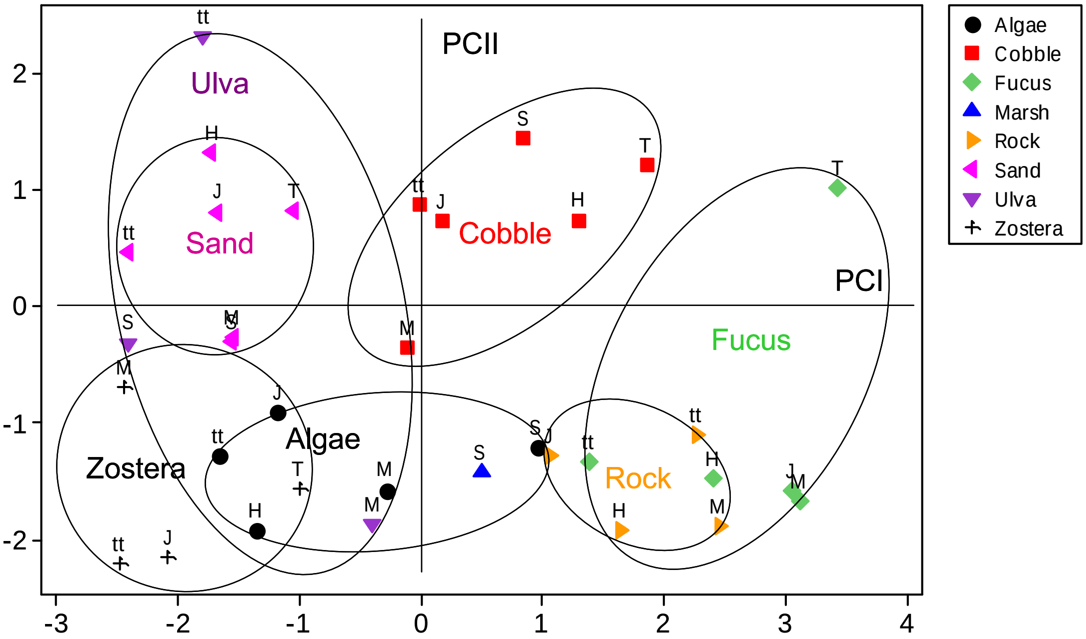


Figure 6. Fifty-five biological variables (taxa) plotted in space defined by the first two principal components to identify the biological assemblages in Table 3, that discriminate among benthic habitat units. Symbols are the mean principal component scores (1999-2008) for each benthic category at each site, surrounded by an ellipse that was fit by eye. The first three PC's described less than 20% of the overall variation in the biological database. Sites are identified as Hagan (H), Jimmy's (J), Moses (M), Towner Bay (T), TenTen (tt), and Tseycum (S).

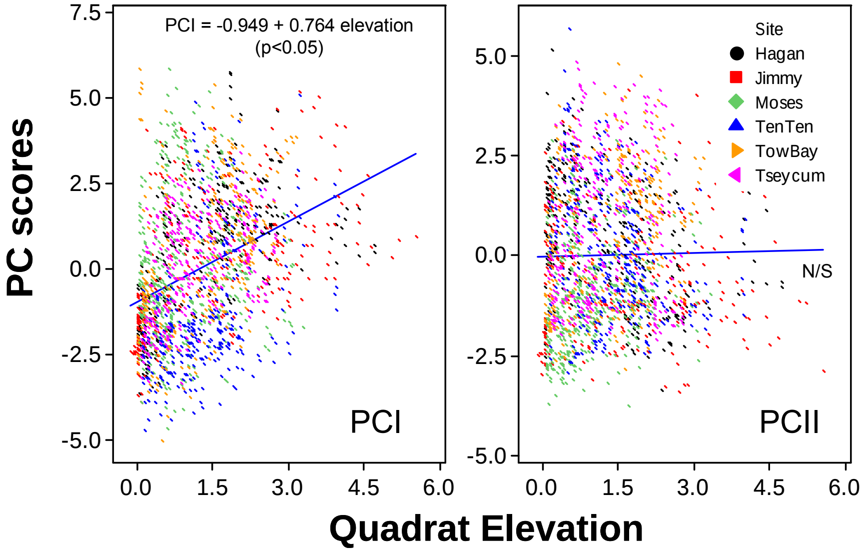


Figure 7. Regression analysis of the influence of quadrat elevation on the presence/absence of individuals in the biological assemblages defined by PCI and PCII in Figure 6. Sites are indicated by colour - the symbols are too small to be identified by eye.

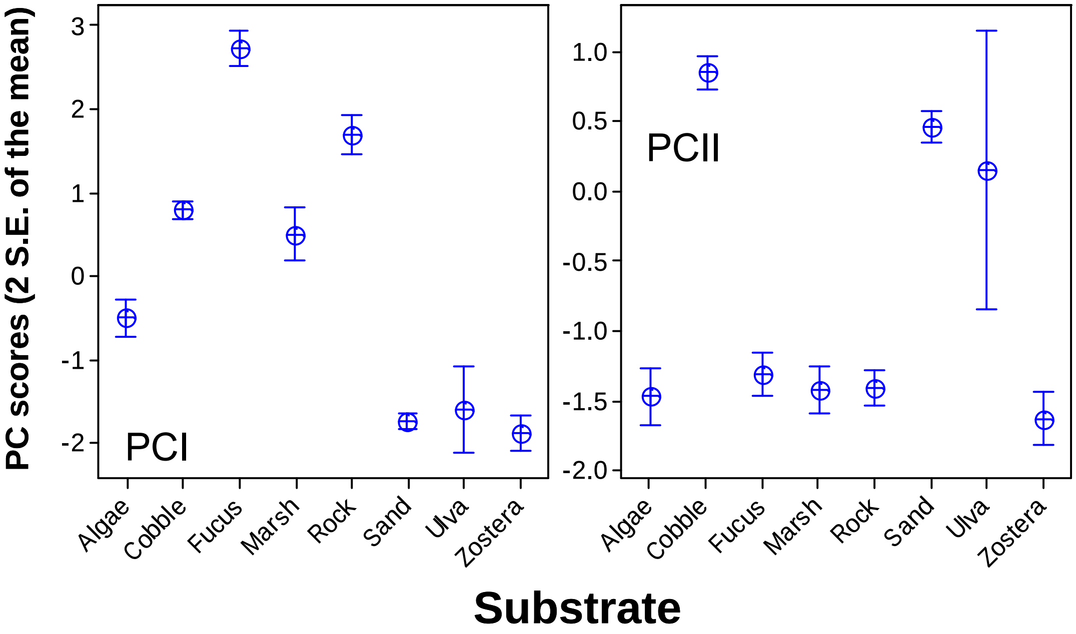


Figure 8. An interval plot depicting the discrimination among benthic habitat units based on the first two principal components in Figure 6 and the variation in biological assemblages they describe (Table 3). Vertical bars describe two standard errors of the mean eigenvector coefficients among quadrats deployed at each site, all years.

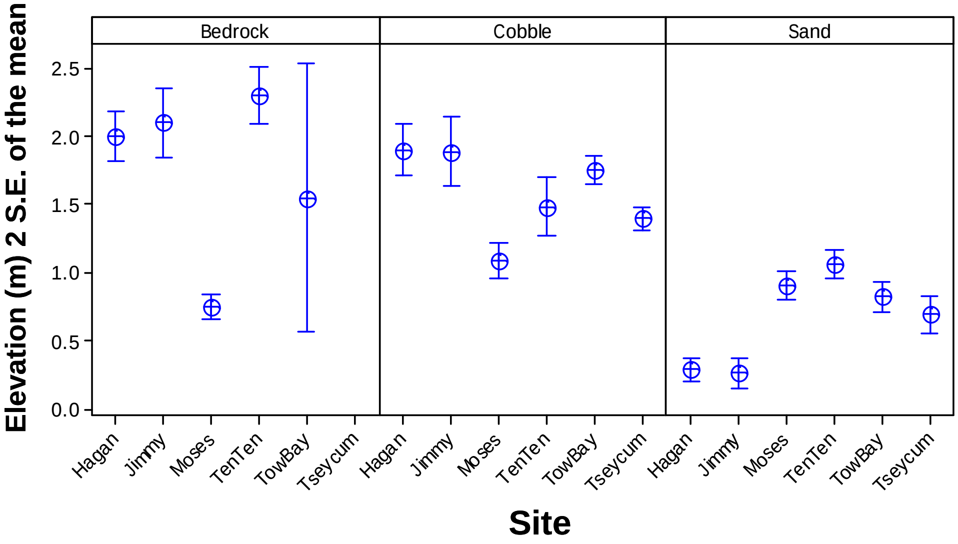


Figure 9. Mean elevation estimates of quadrats in the three most common substrates at each site among all years. Vertical bars are two standard errors of the mean. Bedrock was not present at Tseycum. Sand data includes a few occasions where the habitat was classified as mud. Quadrat number in each substrate category were sand n=561, cobble n=748 and rock n=352. Individual quadrat elevations were not taken during the field work but were recreated using GIS plots (Appendix 1) and the beach elevations at upper and lower boundaries of each habitat unit.

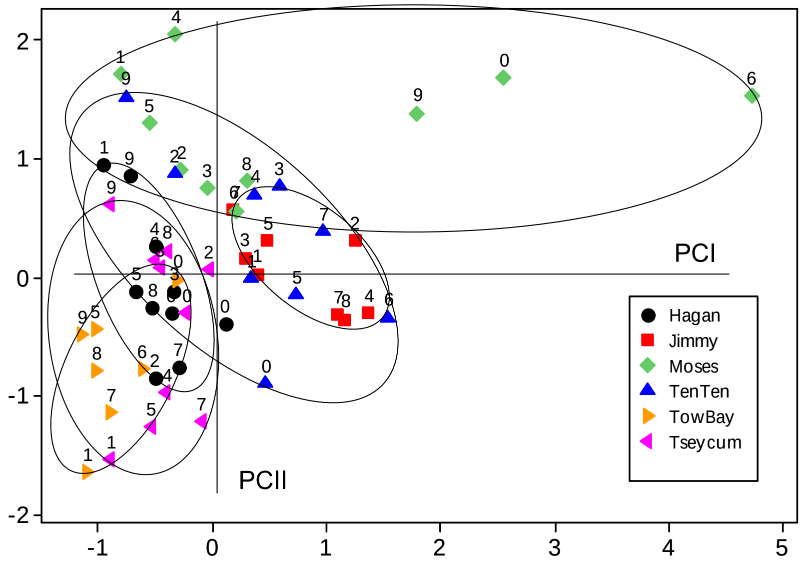


Figure 10. Fifty-five biological variables (taxa) plotted in space defined by the first two principal components to identify the biological assemblages in Table 4, that discriminate among cobble habitats at each site. Symbols are the mean principal component scores among quadrats at each site, each year (identified by the last number of the year), surrounded by an ellipse that was fit by eye. The first three PC's described less than 20% of the overall variation in the biological database.

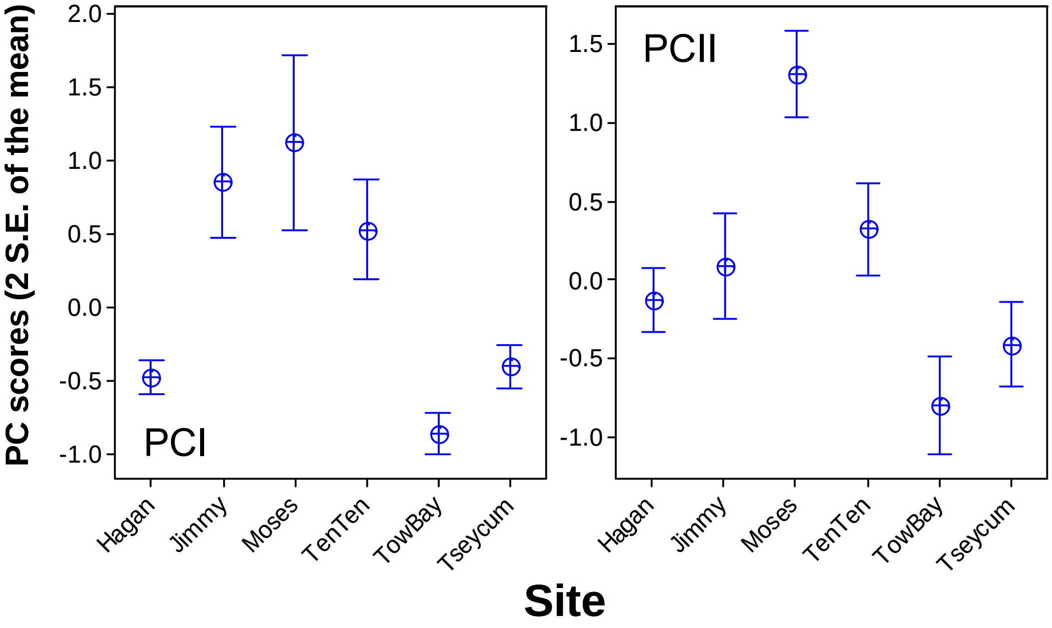


Figure 11. An interval plot depicting the discrimination among sites based on the first two principal components in Figure 10 and the variation in biological assemblages they describe (Table 4). Vertical bars describe two standard errors of the mean eigenvector coefficients among quadrats deployed in cobble habitats at each site, all years.

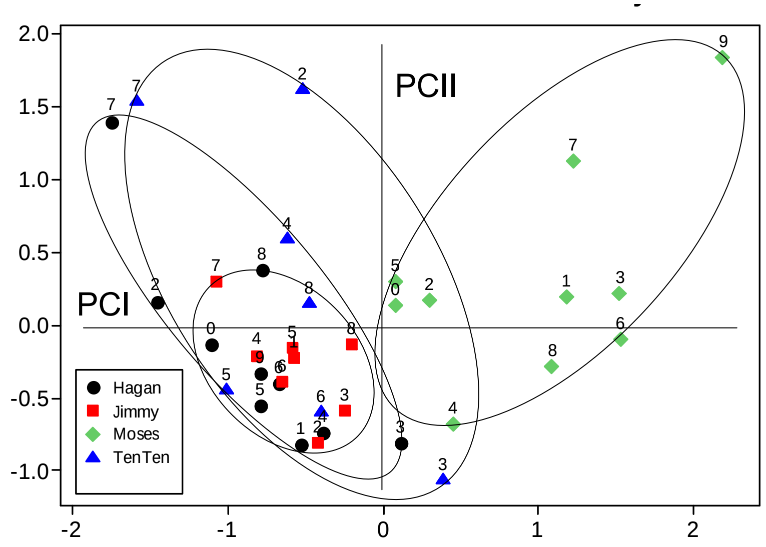


Figure 12. Fifty-five biological variables (taxa) plotted in space defined by the first two principal components to identify the biological assemblages identified in Table 5 that discriminate among bedrock habitats at each site. Excluded from the analysis are Tseycum and Towner Park because of the absence or rarity of bedrock substrate. Symbols are the mean principal component scores among quadrats at each site, each year (identified by the last number of the year), surrounded by an ellipse that was fit by eye. The first three PC's described less than 20% of the overall variation in the biological database.

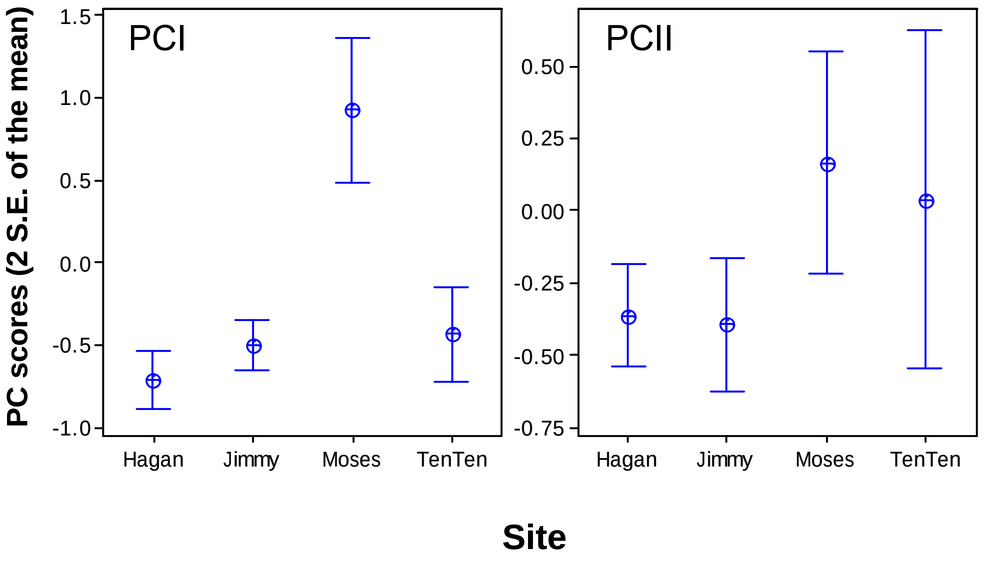


Figure 13. An interval plot depicting the discrimination among sites based on the first two principal components in Figure 12 and the variation in biological assemblages they describe (Table 5). Vertical bars describe two standard errors of the mean eigenvector coefficients among quadrats deployed in bedrock habitats at each site, all years.

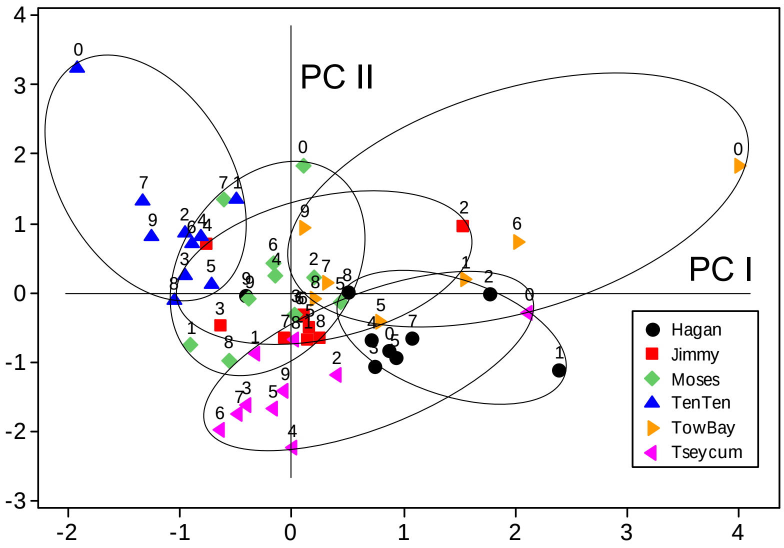


Figure 14. Fifty-five biological variables (taxa) plotted in space defined by the first two principal components to identify biological assemblages (Table 6) that discriminate among sand habitats at each site. Symbols are the mean principal component scores among quadrats at each site, each year (identified by the last number of the year), surrounded by an ellipse that was fit by eye. The first three PC's described less than 20% of the overall variation in the biological database.

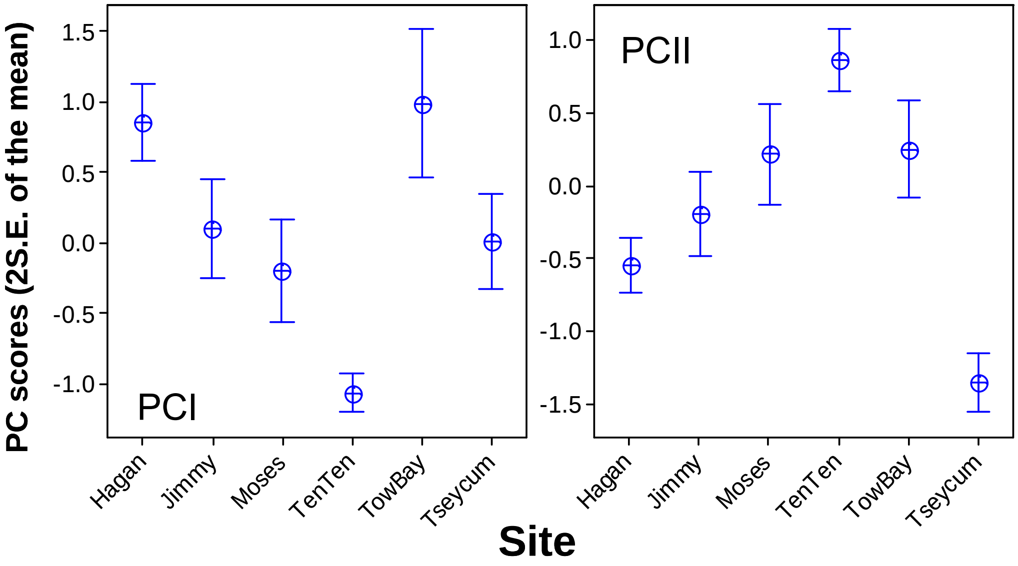


Figure 15. An interval plot depicting the discrimination among sites based on the first two principal components in Figure 14 and the variation in biological assemblages they describe (Table 6). Vertical bars describe two standard errors of the mean eigenvector coefficients among quadrats deployed in sand habitats at each site, all years.

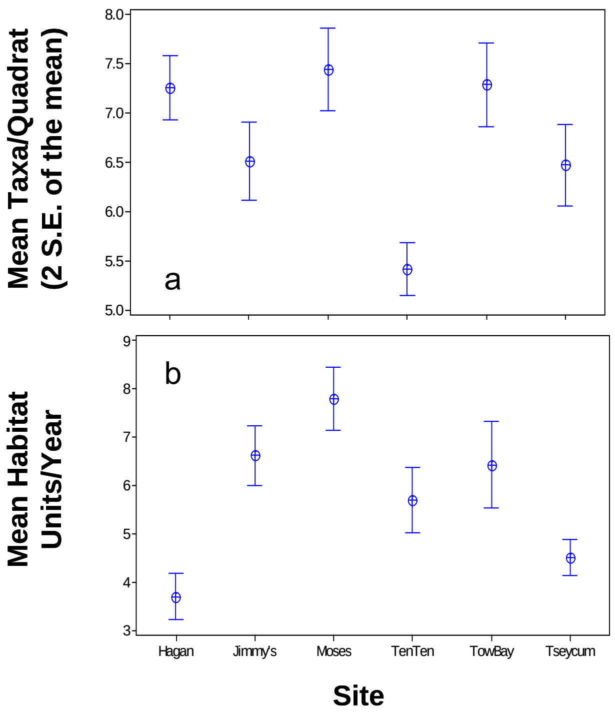


Figure 16. Mean taxa identified in quadrats collected at each site during the study (a), in comparison to the mean number of habitat units per year (b), as a measure of habitat heterogeneity at each site. Vertical bars describe two standard errors of the mean.

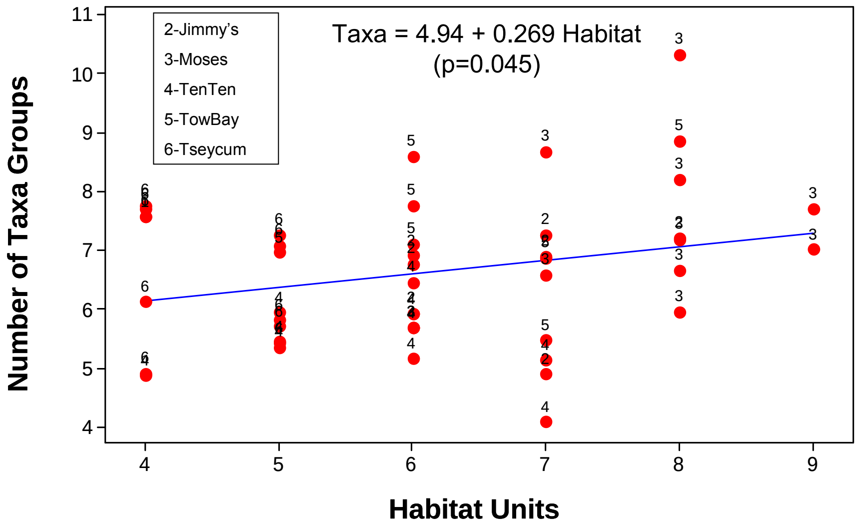


Figure 17. Regression of habitat heterogeneity (number of habitat units) vs taxa diversity with Hagan data excluded from the analysis (Figure 16). Numbers identify sites as indicated in the legend.

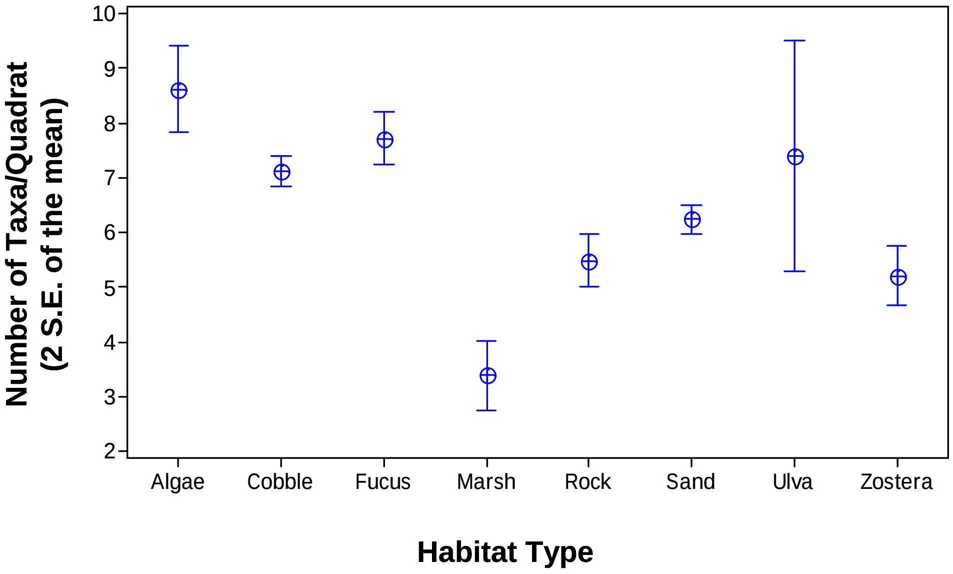


Figure 18. Mean taxa diversity among years in quadrats by habitat unit at the sites in which they were found. Vertical bars describe two standard errors of the the mean.

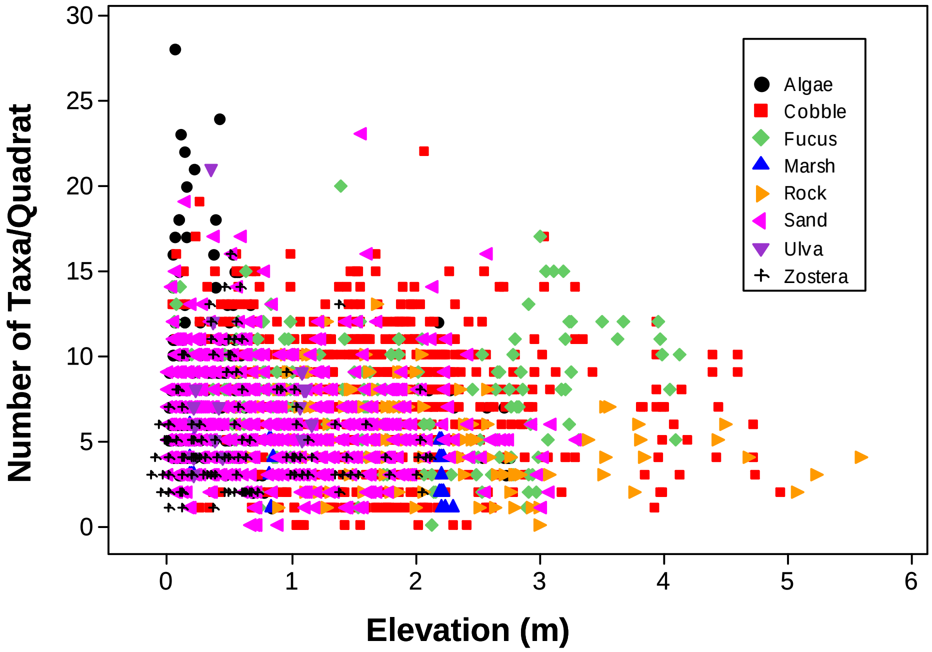


Figure 19. The influence of quadrat elevation on taxa diversity in all habitat units. Individual habitat units are described in the legend by symbol and colour. A regression of elevation on taxa diversity is not significant ($p>0.05$).

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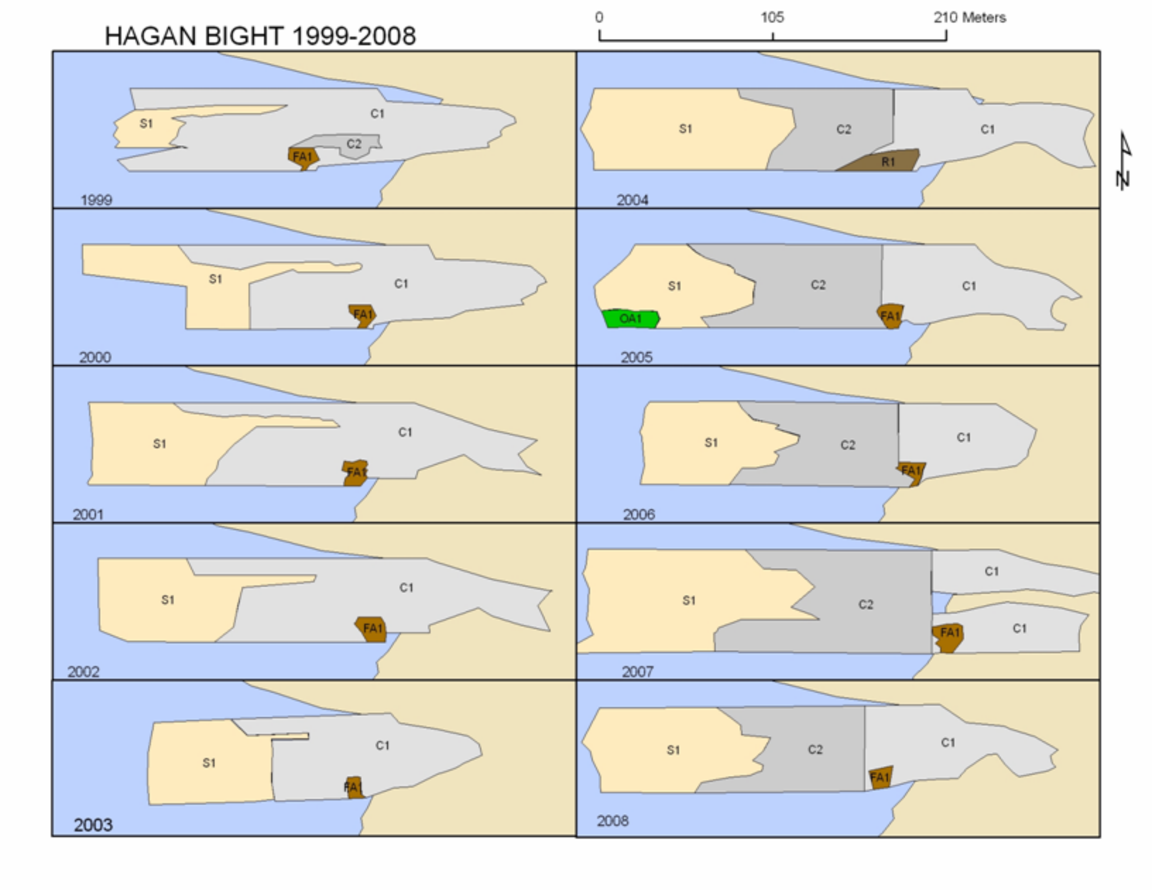
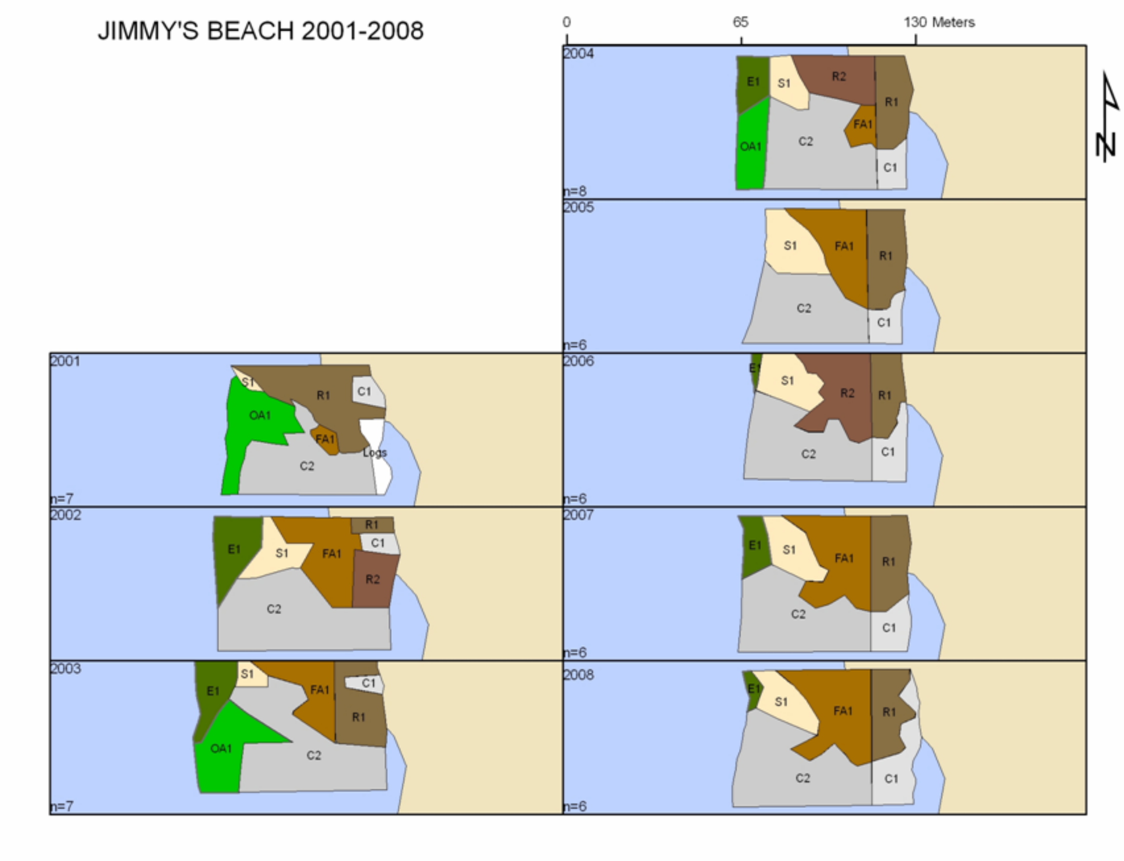
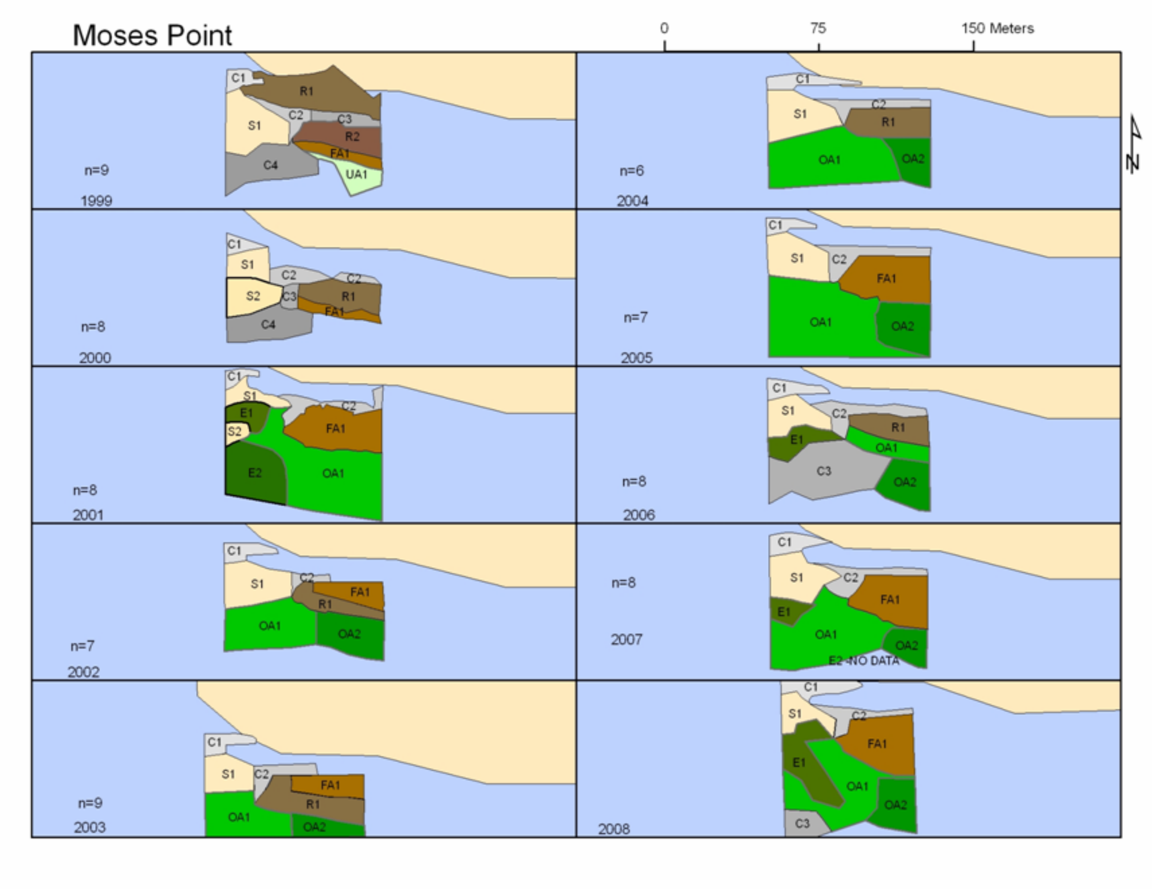
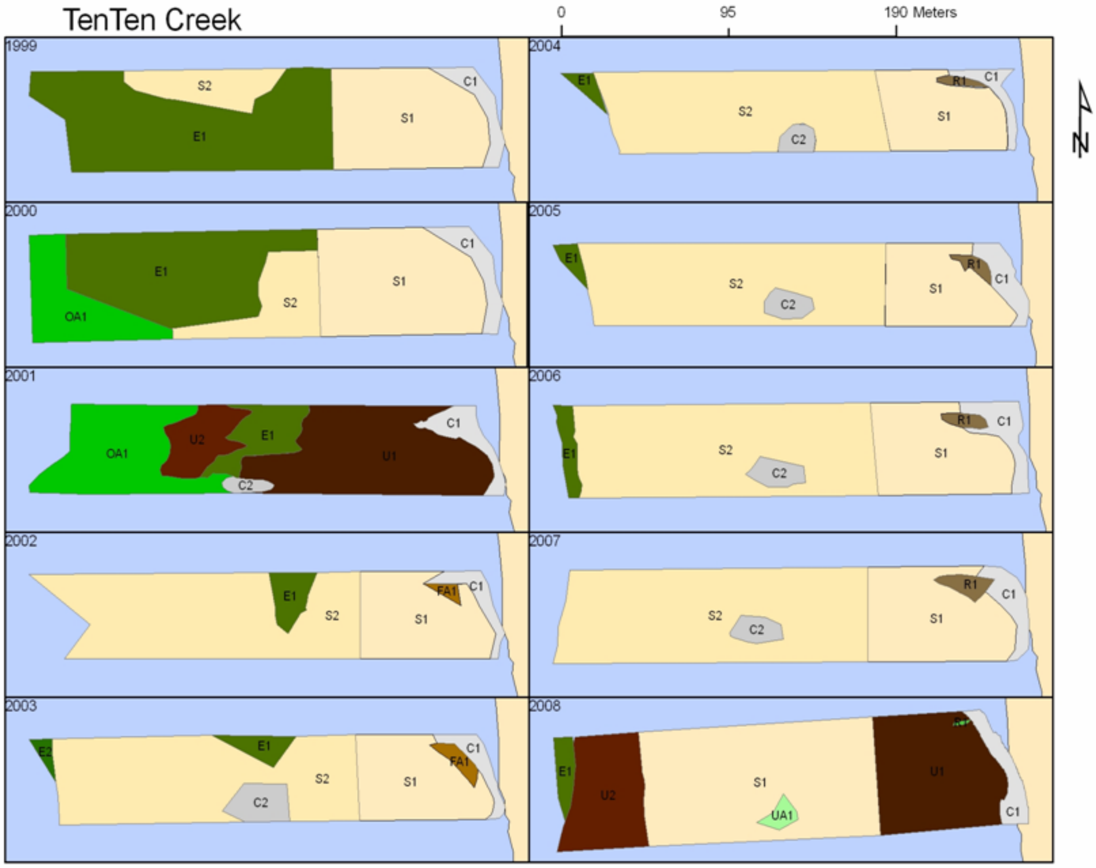
APPENDIX

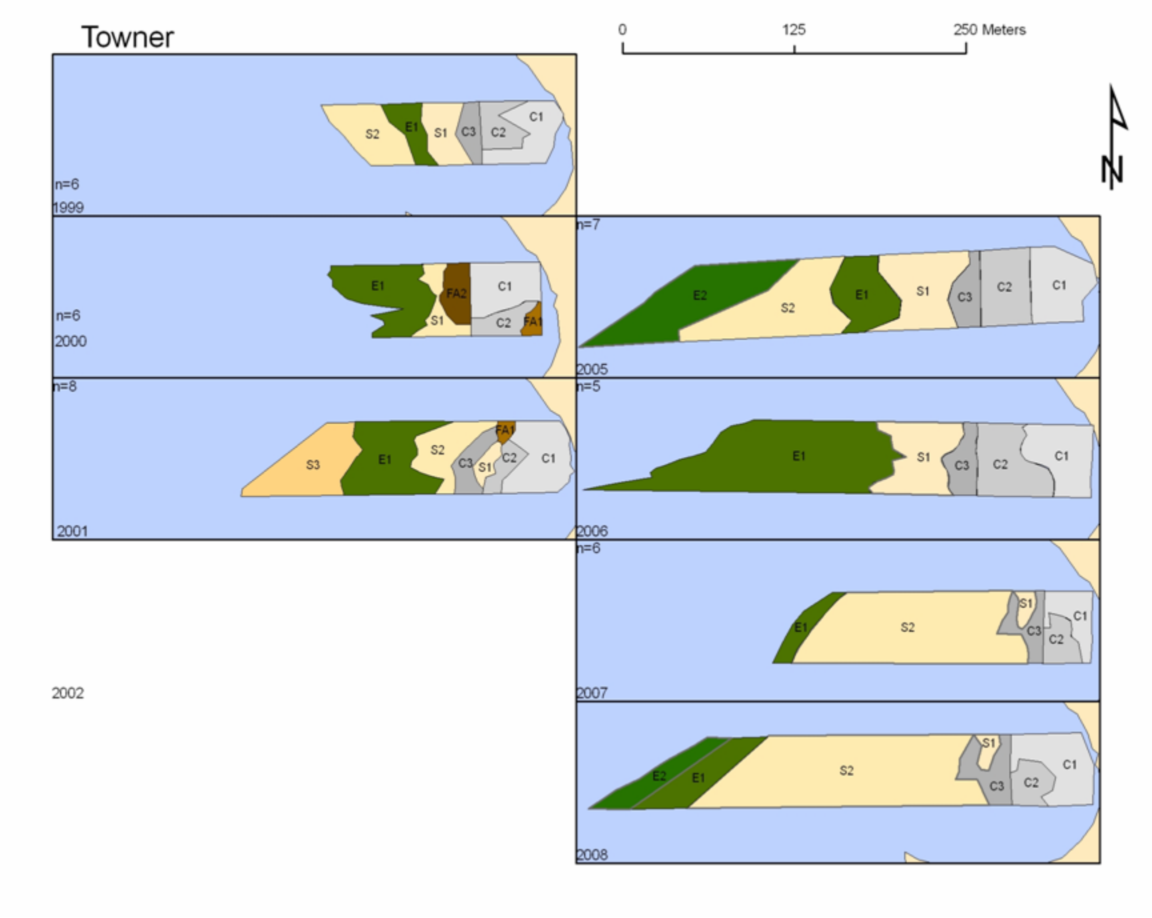
Appendix 1: GIS plots of habitat units at each site and each year from the site surveys that preceded the biological collections. Habitat codes are, Rock-r, Cobble/Shell-c, Sand-s, Mud-u, Fucus-fa, Ulva-ua, Eelgrass-e, Macroalgae-oa, Marsh-m. A single type of habitat could occur discretely at several locations within a site in a given year and were numbered sequentially with the habitat code. Elevation estimates referenced to datum were taken at the boundary between habitat units and were used subsequently to estimate elevation of individual quadrats.




JIMMY'S BEACH 2001-2008
0
65
130 Meters
N
2001
S1
R1
C1
OA1
FA1
Logs
C2
n=7
2002
R1
E1
S1
FA1
C1
R2
C2
2003
S1
E1
FA1
C1
R1
OA1
C2
n=7
2004
E1
S1
R2
R1
FA1
OA1
C2
C1
n=8
2005
S1
FA1
R1
C2
C1
n=6
2006
E1
S1
R2
R1
C2
C1
n=6
2007
E1
S1
FA1
R1
C2
C1
n=6
2008
E1
S1
FA1
R1
C2
C1
n=6


Moses Point
0
75
150 Meters
N
C1
R1
S1
C2
C3
R2
FA1
C4
UA1
n=9
1999
C1
C2
S1
R1
OA1
OA2
n=6
2004
C1
S1
C2
C2
S2
C3
R1
FA1
C4
n=8
2000
C1
S1
C2
FA1
OA1
OA2
n=7
2005
C1
S1
E1
C2
S2
FA1
E2
OA1
n=8
2001
C1
S1
C2
R1
E1
OA1
C3
OA2
n=8
2006
C1
S1
C2
FA1
R1
OA1
OA2
n=7
2002
C1
S1
C2
FA1
E1
OA1
OA2
E2-NO DATA
n=8
2007
C1
S1
C2
FA1
R1
OA1
OA2
n=9
2003
C1
S1
C2
FA1
E1
OA1
OA2
C3
2008


TenTen Creek
0
95
190 Meters
N
1999
S2
E1
S1
C1
2000
E1
OA1
S2
S1
C1
2001
OA1
U2
E1
U1
C1
C2
2002
E1
S2
S1
FA1
C1
2003
E2
E1
S2
S1
C2
C1
FA1
2004
E1
S2
C2
S1
R1
C1
2005
E1
S2
C2
S1
R1
C1
2006
E1
S2
C2
S1
R1
C1
2007
S2
C2
S1
R1
C1
2008
E1
U2
S1
UA1
U1
C1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0
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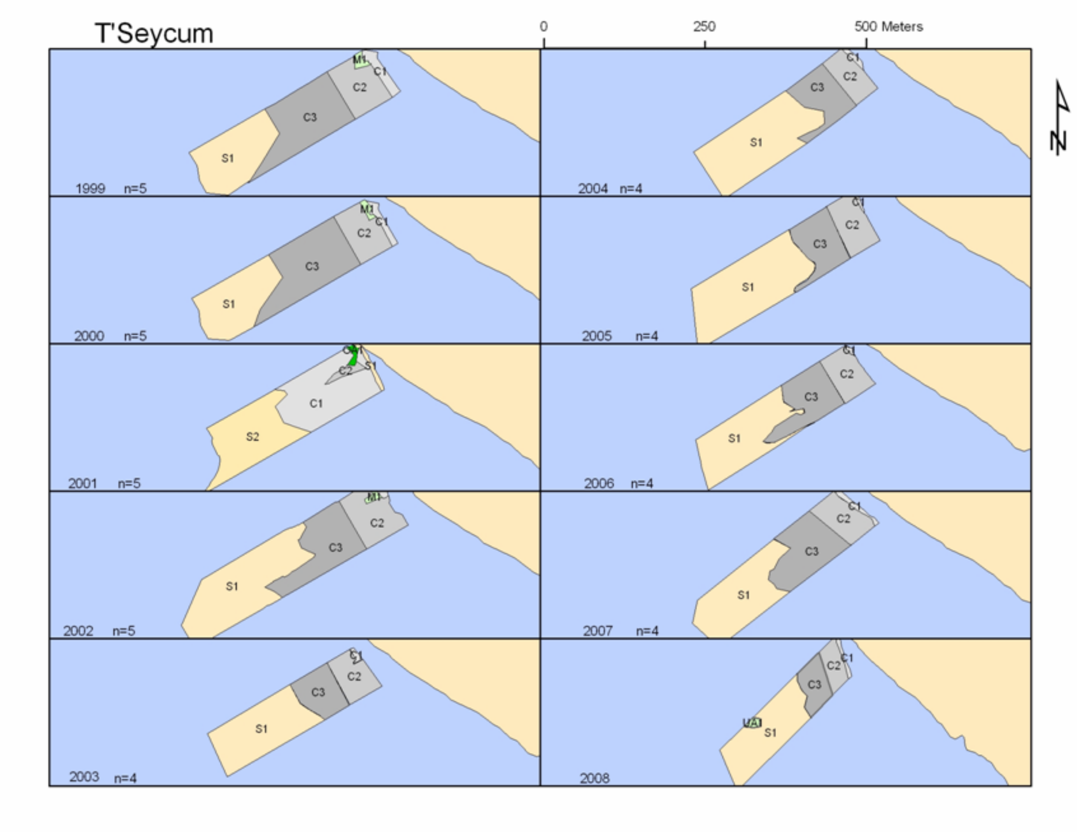
1999
S2
E1
S1
C3
C2
C1
n=6
2000
E1
FA2
S1
C1
C2
FA1
n=8
2001
S3
E1
S2
C3
S1
FA1
C2
C1
2002
n=7
2005
E2
S2
E1
S1
C3
C2
C1
n=5
2006
E1
S1
C3
C2
C1
n=6
2007
E1
S2
S1
C3
C2
C1
2008
E2
E1
S2
S1
C3
C2
C1


T'Seycum
0
250
500 Meters
N
M1
C1
C2
C3
S1
1999 n=5
C1
C2
C3
S1
2004 n=4
M1
C1
C2
C3
S1
2000 n=5
C1
C2
C3
S1
2005 n=4
C1
C2
S1
C1
S2
2001 n=5
C1
C2
C3
S1
2006 n=4
M1
C2
C3
S1
2002 n=5
C1
C2
C3
S1
2007 n=4
C1
C2
C3
S1
2003 n=4
C1
C2
C3
UA1
S1
2008