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Anthropogenic Impacts on Rocky Intertidal Mollusks in Southern California: Historical Baselines and Extent of the Problem (Project # R/CZ-194) - Completion Report

Project Overview

Anthropogenic activities such as illegal harvesting and trampling is generally considered to be responsible for a decline in the biological diversity of rocky intertidal habitats along the southern California coast (Littler, 1980; Littler et al. 1991; Murray and Bray 1994; Lindberg et al. 1998; Murray et al. 1999; Roy et al. 2003). Yet relatively little information exists about the nature and extent of such declines, largely due to the lack of baseline data against which one can compare the exploited or disturbed populations. This is a difficult problem because at present very few rocky intertidal assemblages in southern California are undisturbed enough to serve as an ecological baseline(s) against which other sites can be compared. Similarly, reliable ecological census data from the past are very rare and we will never be able to quantify temporal changes in abundances of species except at a few localities (such as that by Barry et al. 1995). However, data on past species occurrences (i.e. presence/absence data) can be compiled much more easily and across much larger spatial and temporal scales. Museum collections and the literature are a rich source of such data and once compiled they have the potential to provide us with a picture of how species occurrence patterns have changed over the last century or so. The primary goal of this project was to use historical data collected over the last century to construct a long-term perspective that can be used to quantify the ecological consequences of anthropogenic impacts on rocky intertidal molluscan species and populations. In particular, we refined and expanded a database of historical occurrences and body sizes of rocky intertidal molluscan species at multiple localities in southern California. These data, for the first time, provide a comprehensive picture of our knowledge of past occurrences of rocky intertidal molluscan species in southern California. We then used analyses of site occupancy patterns over time to identify sites with the best historical data on species occurrences and undertook ecological surveys at a selected subset of these localities. We are using comparative analyses of the historical information and the survey data to quantify how patterns of site occupancy as well as body sizes of individual species have changed over time.

Summary of accomplishments and main findings

Database

We examined collections at multiple major museums (e.g. The National Museum of Natural History, Smithsonian Institution; Natural History Museum of Los Angeles County; Santa Barbara Museum of Natural History; Museum of Paleontology, University of California Berkeley) and undertook extensive literature searches to compile information about past occurrences of individual

intertidal gastropod species along the southern California coast. These data were entered into a relational database developed for this project. This Microsoft Access database consists of 8 linked tables and a series of interrelated forms that serve as user-friendly interfaces for data entry. The database currently has information for 384 rocky intertidal localities in southern California and 266 species of rocky intertidal invertebrates. This includes all the common species of intertidal gastropods. The two species with the largest number of past occurrences in our database are *Acanthinucella spirata* (503 past occurrences) and *Fisurella volcano* (423 past occurrences).

While examining museum collections we found that a considerable fraction (roughly 40%) of the museum material for the species we have looked at did not have precise dates of collection. However, the vast majority of these specimens do have information indicating the collectors and/or the former collections to which the specimens belonged. We have therefore been able to estimate dates of collection for the majority of these specimens by gathering biographical information (birth, death, earliest and latest years of documented collection) for more than 250 individuals who have collected mollusks in Southern California, as well as recording the earliest and latest known dates of collection for specimens previously stored in more than 55 (mostly private) collections that are presently housed in major public museums. The use of such biographical information substantially improved both the spatial and temporal coverage of our database. All the data we have compiled are available to other researchers and we are in the process of making the data searchable through our website.

Temporal trends in site occupancy

Temporal coverage for most rocky intertidal species in southern California extends back multiple decades - the oldest record for 52% of species is before 1940 and 23 species (8.6%) have their oldest record prior to 1900. In contrast, temporal coverage for most localities is very low (median = 2 years) and most sites (60%) have less than 10 years of coverage. However, 48 sites in our database have a temporal coverage of 50 years or more and 8 sites provide a record of more than 100 years. Thus despite the lack of historical data for most sites, we have been able to identify more than 40 sites in San Diego, Orange and Los Angeles counties for which there are substantial amounts of data on past species occurrences. This list includes: the Scripps intertidal, Point Loma, Bird Rock, La Jolla Cove and the entrance channel of Mission Bay in San Diego County; Dana Point, Corona del Mar, and Laguna Beach in Orange County; Point Fermin, White's Point, Portuguese Bend, and Malibu Beach in Los Angeles County.

Overall, our data reveal an important temporal bias in sampling. Most of the available information about the occurrences of rocky intertidal molluscan species in southern California is from the 1950s to the 1970s, and there is very little data available post-1980. As shown below (Fig. 1) this trend is evident for

individual species as well as for the combined dataset. In fact, only 32 species in our database have records of occurrence after 1990. This is potentially an important finding since it suggests that our knowledge of occurrences of rocky intertidal species in southern California has been declining over the last

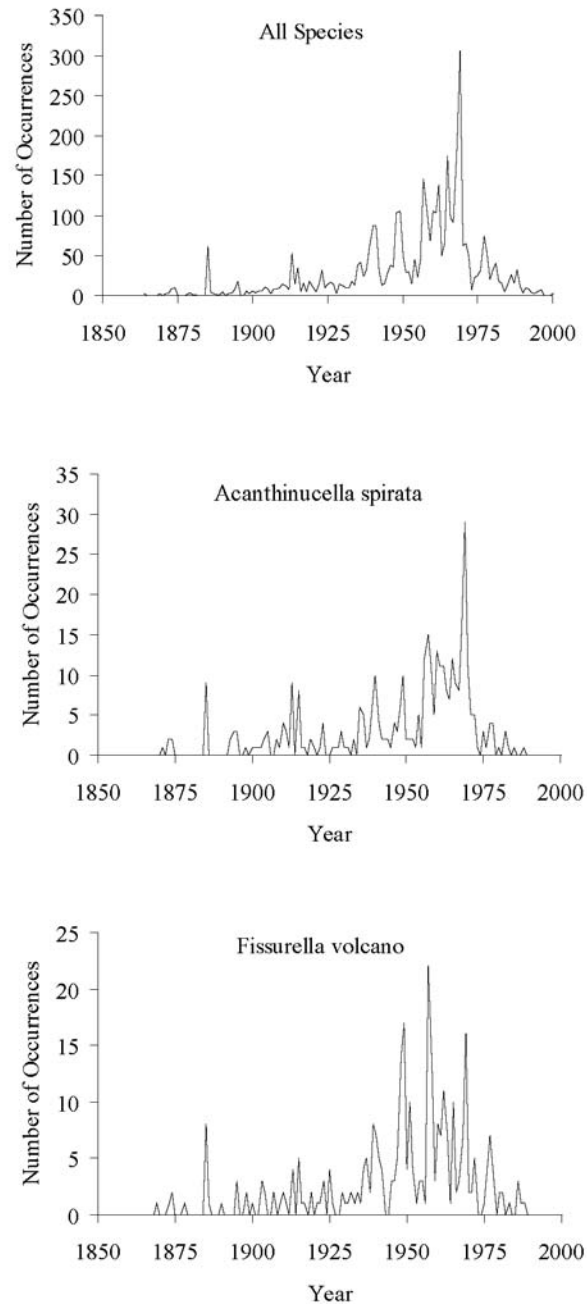


Fig. 1. Historical records of occurrences of species. The top panel shows the pattern for all species of rocky intertidal gastropods in our database, the middle and bottom panels depict the information for the two species with the most information, *Acanthinucella spirata* and *Fissurella volcano*, respectively.

couple of decades (at least as evidenced by information available in the public domain) and highlights the need for better monitoring of rocky intertidal species.

Statistical Methods for analyzing temporal patterns

In order to identify local extinctions of species, long-term monitoring programs are essential. However, such data are unavailable for many species and localities, and we have to rely on historical information about occurrences, such as those compiled here (Shaffer et al. 1998). But due the intrinsically incomplete nature of such records, the absence of a species at a particular locality does not necessarily indicate that it went locally extinct. Failure to observe a species may also result from failures of sampling, or because of short term variation in that species' abundance. As a result, the observed last occurrence of a species at a locality usually will occur some time before the true local extinction of that species. By accounting for the vagaries of sampling, probabilistic methods can be used to generate confidence intervals on the true local extinction times of populations, which can be valuable for evaluating whether or not a species that has not been sighted recently is likely to be extinct (Solow 1993; Burgman *et al.* 1995; Solow 2005; Roberts 2006). A number of different methods have been proposed to generate confidence intervals on the timing of local extinctions and these methods not only differ in their computational complexity, but also in the stringency of their assumptions about the nature of sampling. However, at present it is not clear how the performance of each of these methods varies under different ecological and sampling scenarios. Without such information it is difficult to know which method would provide the most reliable estimate of extinction time. We used a simulation approach to evaluate the performance of seven methods proposed to estimate the upper bound of the extinction times under different ecological and sampling scenarios. Results of these analyses show that some of the methods used to evaluate extinction times are highly susceptible to Type 1 error. In general many of these methods tend to perform poorly when sampling intensity decreases over time, such as that seen for rocky intertidal gastropods in southern California after the 1970s (Fig. 1). On the other hand, a few methods are quite robust to such temporal declines in sampling these are the ones that are most appropriate for analyzing historical data such as those collected here. Overall, methods that take into account, either directly or indirectly, the differences in sampling quality generally perform the best, even when sampling is quite poor. These analyses, for the first time, provide a tool that researchers can use to select statistical methods that are most appropriate for analyzing patterns of local extinctions using a particular set of data. A manuscript presenting these results is almost complete and we intend to submit it for publication in the very near future.

Field surveys

We have undertaken field surveys at a number of localities in San Diego, Orange and Los Angeles counties that have a good historical record. These sites include Cabrillo National Monument, Bird Rock, Scripps Intertidal Reserve, Dana Point, Abalone Cove, White's Point and Point Fermin. At each site we undertook exhaustive searches for species that are known to have occurred there in the past. In addition, we used timed searches and transect sampling to document the species present there. Finally, for some species with historical information about body size, we measured body sizes of present day populations to test whether human impacts have led to changes in sizes of species, a common consequence of human harvesting (e.g. Keough et al. 1993, Roy et al. 2003).

Website (<http://www.biology.ucsd.edu/labs/roy/CBRISC/CBhome.html>)

We have developed and maintain a website for this project. This website provides background information about project, a general description of the methods we use and the nature of the database. In addition, the website allows visitors to search for and retrieve past occurrence data for several species. We are currently working to make data for the other species also available through this website.

Human impacts and the composition of rocky intertidal communities in southern California

Comparisons of the historical data on species occurrences and body sizes reveal a complex picture of how human impacts are changing the compositions of rocky intertidal molluscan assemblages in southern California. While there is little evidence for widespread local extinctions of species, body sizes of individual species have become significantly smaller. The latter trend was first documented across all of southern California using an earlier version of this database by Roy et al. (2003). The revised and updated database now shows that the trend also holds at the scale of individual localities. For example, at San Pedro the size of the largest individuals of the owl limpet (*Lottia gigantea*) has declined dramatically over time (Fig. 2). Similar trends are evident for other species at localities with good historical records. One notable exception to this is the Cabrillo National Monument where large individuals of many species of rocky intertidal gastropods are still common. This suggests that the size declines observed at individual localities are largely driven by size selective harvesting of these species for human consumption.

In addition to temporal declines in body size, significant changes in the distribution and abundance of some species are also evident from our data. For example, *Mexicanthina lugubris*, a species whose historical range extended only up to Ensenada, Baja California, has been steadily expanding its northern range limit and is now the most abundant high intertidal predatory gastropod throughout San Diego and into Orange county, occurring in densities of up to 200 individuals/sq meter. The timing of this range expansion correlates with a

warming trend seen in coastal sea surface temperatures suggesting a potential link to global warming.

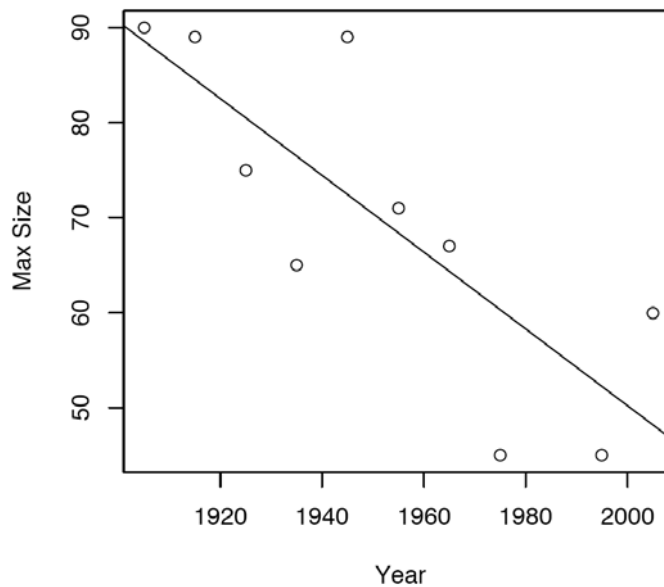


Figure 2. Decline in maximum body size of individuals of *Lottia gigantea* at San Pedro, Los Angeles county. Data points prior to the year 2000 represent museum specimens while the post-2000 data come from field surveys by Phillip Fenberg, a graduate student associated with this project.

Long term data on the occurrences and abundances of species are essential for assessing how ecological communities respond to natural disturbances and anthropogenic impacts. While the data collected during this project provides such information for multiple species of rocky intertidal gastropods, our data also show that information about the occurrences of many intertidal species in southern California have declined substantially over the last few decades. This lack of information is disturbing from a management perspective and suggests that intertidal monitoring efforts over the last couple of decades have either not archived voucher materials or have archived them in repositories not easily accessible (i.e. not in public museums). Neither alternative is desirable since effective monitoring programs should be based on information that is verifiable through voucher materials archived in the public domain. There is clearly an urgent need for better monitoring of rocky intertidal habitats in southern California.

Future directions

The data compiled during this project is part of an ongoing effort to better understand how rocky intertidal communities responds to anthropogenic impacts

such as harvesting and trampling. We plan to (i) further analyze the data collected so far (ii) expand and refine the historical database as we identify additional sources of information and (iii) continue ecological surveys of localities with good historical data. We intend to apply the insights and methods developed during the course of this projects to address similar questions in other rocky intertidal systems. The issue of how anthropogenic activities are affecting rocky intertidal biodiversity is a global issue and the methods we developed to study the problem in southern California could be applied elsewhere. In particular, our postdoctoral research associate, Marcelo Rivadeneira, supported by Sea Grant funds in year 2, is from Chile and has worked on intertidal ecology of that region as a part of his graduate work. Dr. Rivadeneira has just accepted a research scientist position in Chile and we plan to initiate research projects similar to this one in south America.

Outreach Activities

As a part of our outreach activities, K. Roy has highlighted the results from this project in public presentations as well as at scientific conferences. A 45 minute public presentation on the effects of anthropogenic impacts on rocky intertidal habitats was developed as a part of this research project. This was presented as a part of the Perspectives on Ocean Science Public lecture at Birch Aquarium, La Jolla. It has also been broadcast by UCSD TV and the video is freely available online from Google Video (<http://video.google.com/videoplay?docid=7236642512703612568&q=Kaustuv+Roy&hl=en>) and Yahoo video (<http://video.yahoo.com/video/play?vid=1093023715&fr=yfp-t-501>).

Personnel

In addition to the P.I. (K. Roy), two graduate students, two postdoctoral research associates and two undergraduate students were associated with various aspects of this project.

Graduate students: Benjamin Pister (supported as a Sea Grant trainee) and Phillip Fenberg (supported by the EPA). Benjamin Pister successfully defended his Ph.D. thesis in July 2007 and has accepted the position of park biologist at Cabrillo National Monument.

Postdoctoral research associates: Gene Hunt (supported with other funds) and Marcelo Rivadeneira (supported by Sea Grant funds in year 2).

Undergraduate students: Kristin Frame and Kathleen Pangan

Publications

Fenberg, P.B. and Roy, K. (2007). Ecological and evolutionary consequences of size-selective harvesting: how much do we know? *Molecular Ecology* (in press).

Rivadeneira, M.M., Hunt, G. and Roy, K. (in prep). The use of sighting records to estimate the timing of extinctions.

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