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NATURAL GEOGRAPHY IN NEARSHORE AREAS (NaGISA): THE NEARSHORE COMPONENT OF THE CENSUS OF MARINE LIFE

GEOGRAFIA NATURAL EN AREAS COSTERAS (NaGISA): EL COMPONENTE COSTERO DEL CENSO DE LA VIDA MARINA

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ABSTRACT

The Natural Geography in Shore Areas (NaGISA, the Japanese word for beach) project is the nearshore component of the Census of Marine Life program. NaGISA targets nearshore marine biodiversity in large macrophyte communities (hard bottom macroalgal communities and soft sediment sea grass beds) in a depth zonation from high intertidal to 15 m water depth. The overall goal of NaGISA is to quantify nearshore biodiversity on a global scale by conducting a longitudinal and latitudinal gradient. Outreach to the public, involvement of local communities in the sampling, and education are important components of the NaGISA program.

KEYWORDS: biodiversity of beaches, hard bottoms, macroalgae, sea grasses

RESUMEN

El proyecto Geografía Natural en Áreas Costeras (NaGISA, el término japonés para 'playa') es el componente costero del Programa Censo de la Vida Marina. El objetivo de NaGISA es la biodiversidad marina en comunidades de grandes macrofitas (comunidades macroalgales de fondos duros y campos de plantas marinas de fondos blandos) en una zonación batimétrica desde el alto intermareal hasta los 15 m de profunidad. La meta general de NaGISA es cuantificar la biodiversidad en escala global mediante el desarrollo de gradientes longitudinales y latitudinales. Importantes componentes del proyecto NaGISA son la extensión al público, el concurso de comunidades locales en el muestreo y la educación.

PALABRAS CLAVES: biodiversidad de playas, fondos duros, macroalgas, pastos marinos

INTRODUCTION

The potential loss of marine biodiversity has recently spurred an increasing number of studies to identify the importance of biodiversity for ecosystem functioning (Loreau *et al.* 2001, Pachepsky *et al.* 2001, Pfisterer & Schmidt 2002). Biodiversity is one potential measure of ecosystem health, though the criteria are not always clear; high biodiversity may not necessarily represent the natural state of an ecosystem. But biodiversity can definitely be a measure of biological interactions such as competition, disturbance, facilitation, predation, recruitment, and productivity of a system (Petraitis *et al*. 1989, Worm *et al.* 1999, Mittelbach *et al*. 2001). On a larger scale, biodiversity measurements can serve as an indicator of the balance between speciation and extinction (McKinney 1998, Rosenzweig 2001).

Apart from our increasing appreciation of marine biodiversity in coral reefs and deep-sea regions (Grassle & Maciolek 1992, Stone *et al*. 1996, Gray 1997, Small *et al*. 1998, Knowlton 2001, Roberts *et al*. 2002), biodiversity in coastal areas other than coral reefs has started to receive more and more attention (Gray *et al*. 1997). Coastal marine biodiversity can be very high (Ray 1996), particularly because the three-dimensional structure of macroalgal habitats and seagrass communities support and enhance species richness (Van Oppen *et al*. 1996, Walker & Kendrick 1998, Duarte 2000, Engelhardt & Ritchie 2001, Duffy *et al*. 2001, Somerfield *et al*. 2002). Shallow water coastal areas, however, are also the areas most impacted by humans, and human impact such as industrial use, oil exploration, fisheries, pollution, invasive species, recreational activities, and habitat fragmentation can have severe effects on near-shore biodiversity (Gray 1997, Walker & Kendrick 1998, Bax *et al*. 2001, Tilman & Lehman 2001, Barnes 2002). On a larger scale, humanly induced global climate change can also have a significant impact (Scheffer *et al*. 2001).

Within the last decade, the need for nearshore biodiversity studies on a large spatial or even global scale has become increasingly obvious for the intent of conservation and establishment of Marine Protected Areas (Norse 1995, Costello 1998, Zacharias & Roff 2000, Eiswerth & Haney 2001, Shaffer *et al*. 2002). We have now started to understand that biologically diverse communities are more resilient to environmental and ecological stress and disturbances, e.g. from invasive species (Kennedy *et al*. 2002). The sustainable use of coastal biodiversity has to be one of the major efforts in our conservation and management efforts (Gray 1997, Price 2001). "The extent, cause and maintenance of biodiversity are among the most important biological issues of our time" (Diversitas Systematics Agenda 2000). Although many attempts have been made to measure and evaluate biodiversity, small-and large-scale comparisons are hampered because varying methods have been applied (France & Rigg 1998). For a comparative biodiversity assessment on multiple scales within an area, between areas, or among global gradients a unified approach is needed (e.g. Rabb & Sullivan 1995, Mikkelsen & Cracraft 2001). The Census of Marine Life, with its associated projects such as NaGISA, is such a framework for the global study of biodiversity.

CoML and NaGISA

The Census of Marine Life (CoML) is a major international research program assessing and explaining the diversity, distribution, and abundance of marine organisms throughout the world's oceans (expected to be completed by 2010). Technical and political barriers, as well as the vastness of the oceans, have kept these areas of the globe largely unexplored. New technologies, the end of the Cold War, and increased concerns about the health of life in the oceans are among the factors that, when combined, make the concept of a census feasible and necessary. During 1999, a group of scientists from many countries committed themselves to making CoML happen, and it is now active around the world. The History of Marine Animal Populations (HMAP) project, the Future of Marine Animal Populations (FMAP) project, and a series of Initial Field Projects are being combined together in the Ocean Biogeographic Information System (OBIS) database, which is becoming a powerful and accessible tool for viewing, understanding, and predicting the future of life in the oceans.

NaGISA (Natural Geography in Shore Areas) is one of the initial field projects within CoML that focuses on biodiversity in intertidal and shallow subtidal communities. The land and sea meet along millions of kilometers around the world, where the combination of solar, tidal, and wave energy have fuelled the evolution of some of Earth's most complex ecosystems, from temperate rocky intertidal to tropical coral reefs. A project studying near-shore areas has special challenges because it focuses on the zone most heavily affected by humans. It is also the zone most studied by humans, but because it is so diverse and so subject to influences from pollution to global warming and changing sea-levels, baseline studies are critically needed over most of the world's coasts. NaGISA is the Census of Marine Life project specifically designed to meet these challenges globally by standardizing a simple, economical, but powerful protocol for comprehensive coverage of shore zones out to 20m depth. At present, NaGISA targets sampling in rocky shore/large macrophyte areas and in seagrass soft substratum communities that are very complex and less well charac-

terized than coral reef communities. Providing complex three-dimensional structures, macroalgal rocky communities and seagrass communities are important habitats for many fish species (e.g. nursery or refuge areas) and an abundance of invertebrates. By employing a standard set of protocols (see below) in many areas, large-scale and even global comparisons can be made.

The NaGISA project was initiated by Yoshihisa Shirayama (Seto Marine Biological Laboratory, Kyoto University, Japan), and the Sloan Foundation has funded the establishment of NaGISA centers in Japan and Alaska. The Japan center is working to establish sampling in the Western Pacific and it aims to complete an equatorial longitudinal gradient from the east coast of Africa to the Palmyra Atoll. The Alaska center (ANaGISA) is organized by Brenda Konar and Katrin Iken (University of Alaska, Fairbanks, USA) and is working towards a pole-to-pole latitudinal transect along the Eastern Pacific coast and possibly the Western Atlantic coast.

NaGISA sampling protocol

The NaGISA sampling protocol is intentionally basic in design and is intended to yield baseline data for the sampling sites. This will allow the most flexibility for individual scientists to use the NaGISA protocol in conjunction with other ongoing projects, or to expand on the NaGISA baseline data for conservation, monitoring programs, or for testing ecological hypotheses. The economic design of the sampling protocol allows many countries to join. The protocols are published in Shirayama *et al*. (2002).

It is suggested that at least three core areas are sampled in each 20° bin along the proposed latitudinal and longitudinal transects. A core area is a larger geographic area with similar physical and environmental influences. An example of a core area in a recently funded NaGISA project in Alaska is Kachemak Bay (Fig.1). Each core area comprises several (ideally 3 or more) study sites, which will be sampled in replicates of five transects. In the example of Kachemak Bay, study sites would be Outside Beach, Jakolof Bay, Elephant Island, and Cohen Island (Fig. 1). Replicate transect samples at each site will be collected at the high, mid, and low intertidal and at 1, 5, and 10m subtidal water depth, with optional sampling at 15 and 20m depth. Targeted community types at present are large macroalgal/rocky shore communities and seagrass soft substrate communities. There are two levels of target sampling of increasing difficulty: (1) non destructive sampling of five quadrates for macroalgal and/or seagrass/soft-bottom communities (counts and photographic imaging), and (2) destructive sampling of five quadrates for each sampling strata at each site for standard identification of macrophyte, small macrobenthos, and meiobenthos.

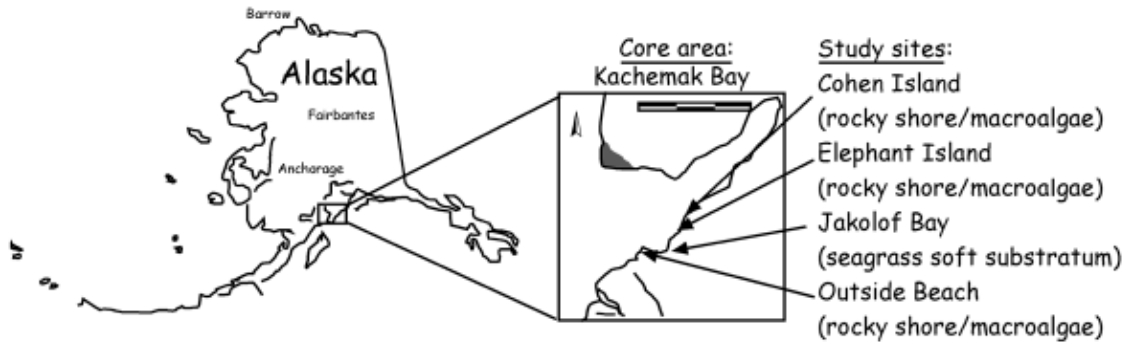

FIGURE 1: Example of a core area and study site distribution in south central Alaska.

FIGURA 1: Ejemplo de la distribución del área de núcleo y los sitios de estudio en el centro-sur de Alaska.

Area and site selection criteria

Ideally, core areas and study sites are selected by the following criteria:

Existing infrastructure

Nearby laboratory facilities are suited to accommodate sample processing and will likely facilitate planning and coordination of research efforts. A major benefit of locating monitoring sites near a research facility is that routine measurements of biodiversity and physical variables can often be carried out relatively cheaply using student labor or other on-site/near-site human resources. Laboratory infrastructure is particularly desirable for those locations that are likely to develop into long-term monitoring sites.

Baseline information

The existence of historical data for a site allows closer comparisons between former and current states, and may help in the process of site selection. In addition such information would be useful for future compilation of biological information.

Pristiness

It is desirable that monitoring should be carried out in areas that are as natural as possible, e.g. in reserves, within marine protected areas, or otherwise pristine areas.

Long-term stability of the site

It needs to be ascertained that a proposed sampling site is likely to remain the same during the monitoring period. Thus, it may be necessary to determine if coastal development is intended. It is important to eliminate human-caused variables as far as possible.

Accessibility

Sites that are more pristine are frequently the most remote and difficult to access. Some coasts are also subject to greater wave exposure and are less able to be regularly sampled. This also could be a potential safety hazard for scientists and local community people involved in sampling.

Biological character

Pre-selection criteria can include known biodiversity values. It is also important that the target habitats, i.e. 'homogenous' macroalgae-hard and/or seagrass-soft substratum habitats, have a shoreline extent of 20-200m to allow replicate sampling.

Sampling protocol

· Sampling of rocky substrates/macroalgal cover

At each study site, a stratified random sampling strategy will be employed, with strata representing vertical heights above and below low water datum. That is, for each site, five random replicate samples will be taken at high, mid, and low intertidal positions and 1, 5, and 10m subtidal water depths (15 and 20m depth strata are optional). The most expedient randomization procedure should be adopted. Sampling of each study site should take place at least once a year, during the period of expected highest diversity. It is recommended that sampling be repeated over two years to yield a minimum temporal resolution. A higher sampling frequency per year or over more than two years is encouraged where feasible.

For rocky substrates, three different quadrant sizes will be used at each sample location: 1x1m, 50x50cm, and 25x25cm (Fig. 2).

Within each 1x1m quadrant, a photographic image record (digital or film) will be made immediately prior to sampling. If conditions do not permit such a photographic record to be made (e.g. poor visibility), then a hand-drawn map should be constructed as an alternative. All macrophytes and conspicuous macrofauna (>2cm length) within the 1x1m quadrant will be identified *in situ*, and either counted or an estimate of percent cover made using a standard technique. Counts will be made of solitary macroflora and macrofauna whilst percent cover will be used for species whose individuals cannot be differentiated (e.g. colonial organisms).

Adjacent to the 1x1m quadrant, a 50x50cm quadrant will be placed. Within each 50x50cm quadrant, a 25x25cm quadrant shall be placed (always the same position within the larger sample). Within the 50x50cm quadrant, all macroalgae shall be completely removed, except for the 25x25cm area. This 50x50cm sample is taken in order to ensure sufficient algal reference material to support the *in situ* observation.

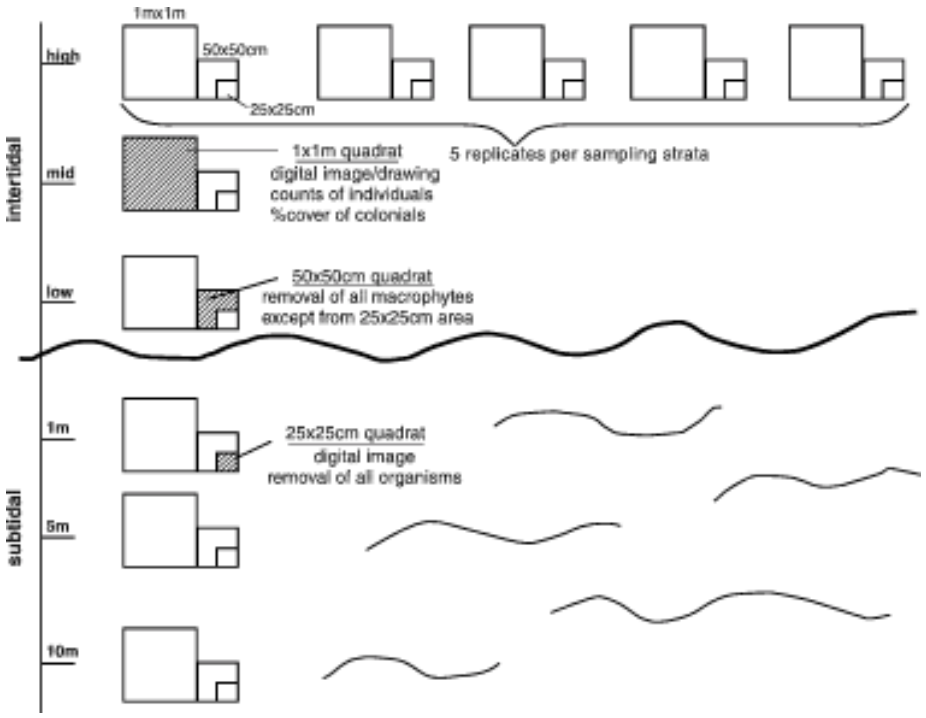

FIGURE 2. Sampling design for rocky shore/macroalgal habitats. Shown is vertical and horizontal quadrant sample design (only one row each shown as example) within a study site.

FIGURA 2. Diseño de muestreo para los habitantes de orillas rocosas/macroalga, mostrando el diseño de muestreo por cuadrantes verticales y horizontales (sólo una fila cada uno como ejemplo) dentro del sitio de estudio.

In each 25x25cm quadrant, a photographic image record (digital or film) should be made immediately prior to sampling. All macrophytes and fauna within the quadrant will be carefully and completely removed and placed into a 63 µm mesh bag. Hand scrapers will be used to facilitate removal of attached organisms.

· Sampling of seagrass soft substratum

At each study site, five random replicate samples are to be taken in the center of the seagrass bed. The most expedient randomization procedure should be adopted. Sampling of each study site should take place at least once a year, during the period of expected highest diversity, but more frequent sampling is encouraged where feasible.
For seagrass communities, two different quantitative samples will be taken at each location: a 50x50cm quadrant and a 15cm diameter cylindrical core.
In each 50x50cm quadrant, counts will be made of solitary fauna, flora, and seagrass shoots. Percent cover estimates (using a standard technique) will be made for encrusting colonial organisms.
In each 15cm diameter cylindrical core (to 10cm substrate depth), a photographic image record (digital or film) will be made immediately prior to sampling. All macrophytes and fauna within the core sample will be carefully and completely removed. All organisms will be transferred to a 63 µm mesh bag. If possible, cores will be sieved in the field using a 63 µm mesh sieve.

· Physical descriptions

When possible, the surface and bottom seawater temperature should be measured at each sample loca-

tion. In addition, the substratum should be visually classified according to the standard Wentworth convention for the description of sediments. GPS coordinates should be taken of all study sites. If possible, data loggers should also be placed at each study site to acquire temperature information. These loggers can be retrieved in year two of the sampling.

· Initial processing of direct samples

Resulting samples should be sieved on nested meshes of 0.5mm and 63 µm. Macrophytes remaining on the 0.5mm sieve should be carefully washed (and if necessary scraped) over the mesh to remove associated macrofauna. Both the floral and faunal component of the 0.5mm sample are to be retained, but should be stored separately. The material retained on the 63 µm sieve will largely comprise of meiofauna. All portions of the sample should be separately fixed and preserved using 5% neutralized* seawater formalin (2% formaldehyde).

· Secondary processing of direct samples

All macrophytes will be sorted for species and a wet weight determined. For each macroalgal species, a wet weight –dry weight ratio will be established. For this, wet weight of a small subsample per species will be taken, and then the sample will be dried at 60°C for 24h and weighed again. Dried samples will be re-weighed every 24h until a constant weight is reached. Selected samples will be pressed and vouchers made. All macrofauna also will be sorted by species and wet weight determined. Vouchers also will be made from these samples. Meiofauna (64 µm portion) will be stored for future work.

Analysis

Wet weight and, where possible, individual counts will be determined for all macroflora and macrofauna. From this, various parameters can be analyzed, including species richness, evenness, and dominant and rare species, as well as diversity indices calculated, such as the Shannon Weaver index and the Hurlbert biodiversity index. All data resulting from NaGISA sampling will be entered into the fully geo-referenced database OBIS (Ocean Biogeographic Information System) where these indices can be calculated, or large-scale comparisons can be made.

*Concentrated formalin (=35% formaldehyde) saturated with borax (sodium hexaborate).

Recommendations

The above protocol constitutes the minimum standardized sampling requirement for the proposed biodiversity determination, comparison, and monitoring study. The following recommendations represent actions that are considered useful optional additions to the program: (1) sampling to take place more than once a year, e.g. during potentially separate periods of highest diversity for macrophytes and associated fauna; (2) Sampling of additional habitats that occur at study site, e.g. mangrove, coral reef, unvegetated sediment, sandy beaches; (3) Creation of a macrophyte and macrofauna reference collection for the study site; (4) Taking of additional samples for future molecular studies (fixed and preserved in 100% ethanol); (5) Compilation of a site species inventory from existing information; (6) Construction of site history, e.g. adjacent terrestrial land “use”, potential anthropogenic impacts; (7) The addition of other surveys (fish, larger mobile invertebrates, etc.); (8) Measurement of other abiotic factors at each study site, e.g. light, current, salinity, chlorophyll *a*, suspended sediments, water chemistry, etc.

Sampling kit

The following is a basic sampling kit, needed to perform NaGISA transect sampling.

a. underwater digital camera
b. sorting sieves (0.5mm and 64µm)
c. 64µm mesh collecting bags
d. laptop computer capable of storing images and handling data
e. a floating, waterproof Global Position System
f. data logger (temperature etc.) to provide environmental context
g. sediment cores
h. quadrant and transect tapes
i. collecting vials for invertebrates
j. pressing paper and press for algal vouchers

k. drying oven
l. top-loading balance (1g-1000g range recommended)
m. formalin for voucher preservation

QUALITY INSURANCE OF DATA

Taxonomic identification of species is guaranteed through the involvement of taxonomic specialists. Taxonomists are a vital part of any NaGISA project; samples that cannot be positively identified in the field have to be identified by a specialist for that particular taxonomic group. It is encouraged that different groups working on NaGISA build a network and share their information and access to taxonomic specialists since taxonomic expertise for rare groups may not always be locally available. Enumeration of taxonomists should be considered in the funding requirements. Data with uncertain taxonomic identification should be clearly marked before data entry into the common database, OBIS.
Scientists also insure quality of data through the planning and organization of sampling, and the supervision of students and public (see below) involved. The close interaction between taxonomic experts and students is a valuable tool in capacity building.

OUTREACH

Outreach is an important component in NaGISA. The part of NaGISA working in the intertidal allows the involvement of local communities, youth groups, and students of many age groups. Participation in a real science project in their "front yard" will raise people's awareness about the diversity of marine communities, about the problems of overexploitation, habitat fragmentation, global warming, and the need for protection. Many other means of outreach are available within NaGISA, such as local presentations, web pages, participation in OBIS which is publicly accessible, etc.

FUNDING OF NAGISA TRANSECTS

Funding for sampling NaGISA transects should be raised locally. The nearshore character of NaGISA is ideally suited to meet local needs for coastal management, monitoring, or conservation issues. The basic character of NaGISA allows tailoring of proposals towards local questions, and to build on the NaGISA baseline data for further applied or scientific questions. Being a nearshore project with a large intertidal component, NaGISA can also be linked with a strong local community involvement or with student involvement during field classes (see above). This can reduce the cost of transect sampling considerably.

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