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GUIDELINES FOR BEACH NOURISHMENT: A NECESSITY FOR PROJECT MANAGEMENT

by

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ABSTRACT

Coastal communities worldwide are faced with difficult problems of shoreline erosion control. Beach nourishment has emerged as one of the preferred methods to buffer shoreline property and recreational interests from the potential of damage by coastal storm activity. Proponents of beach nourishment state that artificial fill placement has greater advantages over other "hard" coastal erosion control structures, in that the final product is a wide, aestheticly pleasing beach, which does not disrupt the natural beach processes. However, the rapidly rising cost of these projects and the lack of guideline criteria on project "success" has led opponents to question the long term erosion control per dollar value of these "soft" coastal erosion control structures. Considering the high cost in both dollars and time of implementing such a project, the majority of nourishment projects have been poorly monitored and inadequately documented. This is true with respect to both physical and biological factors. Aspects of beach restoration, such as placement of fill and subsequent redistribution of the profile, the long term life of the renourished beach and the predicted biological impacts of fill placement are inadequately known. With this lack of available data, regulatory officials have little scientific background on which to base permitting decisions, a situation which has resulted in many delays and denials in the permitting process. Our approach to this problem has been to integrate existing knowledge, with new observational and experimental data, to develop guidelines for maximizing the retention of fill material on a nourished beach, as well as to indicate ways in which to minimize decreases in productivity in beach and surf zone ecosystems by beach renourishment.

INTRODUCTION

The shoreline and beaches of Florida are a valuable natural resource to the economic stability of the state. Most of Florida's coastline and much of the rest of the nation's coastline is heavily developed or in the process of becoming fully utilized. Tremendous sums of private capital continue to be invested in shoreline development.

In the past few years the role of erosion control and shoreline management has been questioned. On one side of the controversy, some coastal

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scientists, conservationists and other advocates call for a federal initiative in controlling the subsidies for development and storm damage relief on dynamically changing barrier islands. The other view, particularly dealing with highly developed shorelines, states that the investment is too great to abandon upland structure storm protection and valuable recreational resources.

Beach restoration by artificial placement of fill material is usually accomplished either by the placement of sediment, obtained from a borrow area, on an eroded beach (beach nourishment) or by maintanence dredging of inlet navigation channels or sand traps with subsequent placement of this material on the downdrift beach to maintain artificially the longshore sand transport blocked by inlet coastal engineering structures (inlet sand bypassing). However, questions concerning the high cost of construction, appropriateness of using public funds and the long term effectiveness of projects have led to an array of technical, fiscal and permitting obstacles to successful completion of projects.

An examination of an inventory of past beach restoration and inlet sand bypassing projects has revealed a distinct lack of monitoring and compilation of field data on project performance and its resulting biological impact. This lack of standardization of important project monitoring data collection and reporting has made the task of evaluating project performance and environmental impact next to impossible. A review of the literature indicates that there has been a development of theoretical design criteria on these types of projects, but little has been done on field verification.

This paper will outline detailed studies that have been performed on recently completed projects to assess the fill sediment redistribution and profile response. This compilation of data has shed new light on project behavior, identified important monitoring criteria and provided a calibration of the standard design criteria. Present detailed field studies of sand beach organisms together with experimental studies of burial tolerances of important species have provided much of the data needed for biological impact planning for these projects. The recommended guidelines developed from this study should provide new insight for design and permitting of future projects. In the economic context, guidelines which reduce the permitting period would help to substantially diminish the rate of increase in project cost, as well as decrease the chance that a project needed for storm protection might be delayed until it is too late.

NEED FOR GUIDELINES

In order to understand the physical and biological processes that occur during a beach restoration project, a review of existing projects was undertaken. The initial problem encountered was to find projects where data collection and analysis were of sufficient detail and were archived in an easily retrievable format. Many project specifications did not require monitoring or if they did, were of a general nature. Of the limited monitoring information, no standardization of format, content or reporting period was evident. An inventory of some selected projects completed since 1975, was compiled. Unfortunately all aspects of project monitoring were not mutually comparable on each project. Therefore several different projects were used for the physical and biological analysis. These projects lacked standardization in: 1) project monitoring requirements, 2) reporting interval, 3) report

content, and 4) data analysis and presentation. New observational and experimental data were collected to supplement this lack of monitoring data.

The trend in the more recent projects completed in the state of Florida has been to require monitoring of both pre- and post-construction aspects. This type of data is proving to be useful in assessing project suitability and impact. To assist in compiling this project monitoring information and to help determine requirements on the type of project data to be collected in the future, a coordinating committee of user groups within the state of Florida was formed. The committee membership consisted of representatives with both engineering and biological backgrounds from the U.S. Army Corps of Engineers, Jacksonville District Office, the Florida Department of Environmental Regulation, the Florida Department of Natural Resources, the Florida Sea Grant Coastal Engineering Specialists along with the authors of this paper. Each group has its own specific interests and requirements in guidelines for both the design and regulatory tasks they are required to perform on a daily basis. One of the important tasks of the committee was to supply information on past projects.

In the past few years, the high cost of project regulation and implementation, dwindling source of public funding and the question of effectiveness of present beach nourishment technology has lead to the need to develop guidelines in the State of Florida addressing the monitoring of beach nourishment and sand bypass projects as to their performance and environmental impact. Work to produce guidelines for the Florida Department of Natural Resources (DNR) was started in 1979 on erosion control and sand bypass projects. As a result of these studies, a series of two documents (Stauble et.al., 1984a; Leadon, 1984) has been produced by the Florida DNR, Division of Beaches and Shores dealing with standardization of project monitoring as part of their erosion control and permit monitoring program. Additional considerations on this topic are found in Stauble et. al. (1983a) and Stauble and Nelson (1983, 1985). According to Chapter 161, F.S., of the Florida Statute, the Department of Natural Resources is responsible for beach and shore preservation. Chapter 161.091 establishs the erosion control fund account (ECA) where funds can be utilized to develop a comprehensive long-range, statewide plan for erosion control, beach preservation and hurricane protection. Emphasis of this program has been on funding beach restoration and renourishment projects, inlet sand bypassing and transfer projects, borrow sources availability studies and dune construction and preservation programs. Additional information on the Florida program is found elsewhere in these proceedings.

The Florida Department of Environmental Regulation also has a regulatory responsibility for beach nourishment projects. Chapter 253, F.S., establishes protection of the state's natural resources affected by dredging and filling activities and Chapter 403, F.S., allows for protection of water quality from such activities. Biological monitoring guidelines are of use to establish base line data, environmental impacts and recovery rates of organisms affected by nourishment projects.

The U. S. Army Corps of Engineers has been responsible for both design, construction and regulatory functions of past nourishment projects nationwide. The usual beach nourishment or sand bypass project on public beaches includes a match with federal and local dollars. Adams (1981) stated that from 1971 to

1981 the Jacksonville District placed more than 35,000,000 cubic yards of sand on Florida's beaches, as part of navigation and beach restoration programs. Since 1975 approximately $32 million has been spent by the state of Florida for such projects. This large expenditure of money has been spent primarily on project implementation and construction. Only a few of the more recent publicly funded projects have been required to adequately document project performance and monitor environmental changes. Privately funded projects also lack consistency in the documentation of past projects. Without this systematic collection of information on project performance and effectiveness, valuable data on physical and biological processes have been lost to regulatory officials and engineering staff. Of those projects that have included some sort of monitoring data, lack of standardization has limited the usefulness of data for application to design of new projects and interpretation of possible environmental effects.

PERFORMANCE MONITORING STANDARDS

These standards address the complete project including pre-construction, construction and post-construction time periods. The development of project monitoring standards is designed to support the following regulatory and design functions: 1) Systematic evaluation of project applications, 2) Assurance of project design compliance at completion, 3) Systematic evaluation of project performances, 4) Maintenance of monitoring data base of beach nourishment and inlet sand bypass projects and 5) Development of special studies or reports on status or achievements of the beach erosion control programs.

Borrow Area Monitoring Specifications

The borrow area, where the fill material is obtained to be placed on the beach, is an important area for consideration in nourishment projects. This sand must be of suitable quality and quantity to be considered for transfer to the eroding beach area. Often this information is collected before or during the permitting stage and is included in the project's general design report and is difficult to relate to subsequent monitoring reports.

The monitoring of the source area of beach nourishment and inlet sand transfer sediment is important to: 1) Assess the suitability of the proposed borrow material for erosion control purposes as beach fill, 2) Assess the effect of sediment removal on the borrow area and adjacent area due to changes in the coastal processes brought about by this removal and 3) Assess recovery of the borrow area through time and its suitability as a future source of renourishment when needed.

There are several types of borrow areas that may be suitable for supplying compatible beach sands and which are commonly available in most coastal areas. The range includes: nearshore shelf sand deposits, cape associated shoal sand ridges, inlet flood and ebb tidal deltas, estuarine bottom deposits or upland sources on a barrier island or mainland sand deposit. For sand bypass projects, the borrow area is usually the inlet navigation channel or designated sand trap area. These areas in the geological past, have been areas of high energy where suitable grain size sands were deposited. At the present time these regions may be under the influence of lower energy regimes and have additional non-suitable grain sizes deposited over or mixed with the former beach sands. It is therefore important to identify the

location and extent of the useful sediment. A study of both depth and area of the borrow site should be conducted with the use of cores to determine the quality and quantity of available sand. Pre-dredging surveys of the borrow area are very important for assessing the suitability, based on the theoretical models outlined in the Shore Protection Manual (U.S. Army, 1984). At present the selection of suitable borrow material is based on theoretical calculation procedures, of which the grain size characteristics of the borrow area are a major component (Hobson, 1977). Before this study, little systematic follow-up has occurred on the behavior of a project or whether the model correctly predicted fill retention (see sediment analysis section for further information on this subject.)

Several erosion control projects, particularly in South Florida have used sediment from environmentally sensitive borrow areas. Major concerns with borrow areas are the bathymetry of the borrow area and the effects of dredging on the physical and biological environment of the borrow pit and surrounding area. In the past, some projects have monitored only pre-dreging phases to obtain suitability data. Post-dredging monitoring of the borrow area has recently been required on more projects, mainly for a biological impact assessment.

Turbidity monitoring of dredging activity in the borrow area has recentily been included in project monitoring requirements to study the impact of dredging activities on adjacent environments. Data on turbidity standards is not well documented and the present limits of acceptable turbidity are set relatively low compared to natural background levels. More study is needed on identification of background levels in both the borrow area and the beach placement area and criteria for determination of acceptable project generated turbidity.

The time schedule of surveys and reporting on borrow area monitoring information includes: 1) Pre-nourishment borrow area survey to be included in the pre-project base line study report, 2) Post-nourishment borrow area survey to be included in the as-built monitoring report and 3) The 6, 12, 24, and 36 month borrow area surveys to be reported in the respective monitoring reports.

A hydrographic survey using fathometer and range locating equipment should be conducted prior to and immediately after the project of the borrow area and surrounding area including a nearby control area. This hydrography survey preferably relating to land based profile benchmarks or range lines can be used to construct bathymetric maps. Specific statistics on size, location and depth of suitable sediment should be included in the pre-nourishment report.

Sediment cores of a length sufficient to penetrate to the depth of dredge scour should be taken as close as possible to the bathymetric survey. The number and location of these cores are determined by project specific complexities and variation of sediment distribution and suitability requirements.

The number of separate size analysis to be run on each core will be determined by the complexity of the stratigraphy of the core. Composite grain size statistics can then be calculated for within borrow area sediment using the technique described in the Shore Protection Manual (U.S. Army, 1984).

A survey immediately after project completion of the same data will establish a starting point for borrow area behavior. The post-nourishment survey and subsequent monitoring surveys of surface sediment samples will be sufficient to identify the change in sediment characteristics as the borrow area recovers. The number and location of samples should be the same throughout the monitoring period. Grain size composite statistics of mean and sorting should be included in the specified reports.

A six month and 12 month survey of borrow area bathymetry and sediment grain size distribution will be required to assess borrow area behavior. Long-term monitoring at 24 and 36 months will assess the filling in of the borrow area and suitability of reusing the area for renourishment in the future. Control areas will indicated natural conditions for comparison. These areas should be chosen to be representative of pre-nourishment conditions within the study area. Physical monitoring data could also be useful in assessing the future use of the borrow area for additional maintenance of the project or for new projects in the same coastal area. To give a complete history of the project, the borrow area must be included in any monitoring guidelines.

Fill Placement

Fill placement is usually accomplished by hydraulic means through dredge pipe discharge. Projects not in close proximity to the borrow area require different methods of fill placement, including overland trucking or nearshore disposal by hopper barge. The material is then shaped into the design profile by earth moving equipment.

Since most design profiles, by their very nature are not in equilibrium with the local coastal processes, profile redistribution is to be expected. Commonly, scarping of the seaward edge of the fill occurs within a short time of fill placement. The wave forces seek to redistribute the sediment into a more "natural" profile shape. Little documentation is available to describe the rate or processes of this phenomenon. Commonly, monitoring profiles, when they are required, are initiated three to six months after project completion. In the case of the Indialantic/Melbourne Beach Project (Parson, 1982; Stauble, 1981 and Stauble et. al., 1983b), rapid redistribution occurred within the first two months, which would normally be omitted in any monitoring report.

Profile Specifications

Beach profile data before, immediately after and at specific intervals throughout the monitoring period are important to understand the behavior of the fill. By collecting a history of elevation changes, the following information can be obtained: 1) The state of the pre-nourished beach, 2) The volume of fill placed along the project, 3) The areas of erosion and accretion of fill material after placement and 4) Long-term need to renourish the project beach

A standardized profile collection and reporting system will provide an important data base of comparible project beach elevation changes from the immediate project fill behavior to long-term coastal changes. The State of Florida has established a statewide network of benchmarks specifically for

coastal surveying which is administered by the Department of Natural Resources (DNR). By using the DNR benchmark system, long-term repeatability of profiles can be accomplished. This data base will aid in studies to assess the volume of fill placed and its retention. Some projects establish construction profiles that were not tied into any permanent system and were lost after project completion. It is difficult to make any assessments of the long term project behavior and documentation of future renourishment needs in these instances.

In reviewing project data, it was evident that the profile monitoring varied greatly between projects (Stauble and Nelson, 1985). Profile locations and numbers within a project vary greatly and the inclusion of updrift and downdrift control profiles outside of the project area were not a common practice. The time interval between profiles varied from every 3 months to one year. The coverage along the project was dependent somewhat on the length of the project, but varied from a minimum interval of 100 ft to a maximum 1/2 mile between profiles. Control profiles were included in some projects, but with varying distances from the edges of the fill area. From a survey standpoint, the interval between profile data points varies, resulting in difficulty in comparing profiles from different projects due to different detail and scale presentations.

The time schedule outlined for profiles, includes a pre-nourishment survey of the existing beach and an immediate post-fill profile used as the as-built profile and the starting project profile for monitoring purposes. Many of the past projects did not include this information in a monitoring report and the data was filed in a separate location, if at all, making additional work to recover and correlate this data. General project information monitoring surveys should be required on a quarterly basis for the first year (3, 6, 9, 12 months) and on a biennial basis for the second year (18, 24 months). A 36 month profile will give a long-term profile readjustment information.

In order to understand the processes and rate of expected profile redistribution, a three dimensional approach was used. Of the projects that we have analyzed, a significant component of the fill material was redistributed in the longshore direction rather than in the more commonly described offshore direction. Control profiles outside the project allow for assessment of volume and direction of fill transported by the prevailing coastal processes (Figure 1).

From analysis of the project data in Stauble and Nelson (1985), the important parameters to assess project "success" (defined by volume remaining with time) were the volume of fill placed per length of project, the overall length of the project, the suitability of fill material and the wave climate. The projects with the largest fill volume placed per length of the project had the largest retention rate (Figure 2). Those projects with poorer matches of borrow material to native grain sizes lost more than the projects with good matches.

Sediment Analysis Specification

This section explains the collectiuon and analysis of fill area sediment samples for beach nourishment and inlet sand bypass projects. The following information of interest can be obtained: 1) The suitability of borrow area sand

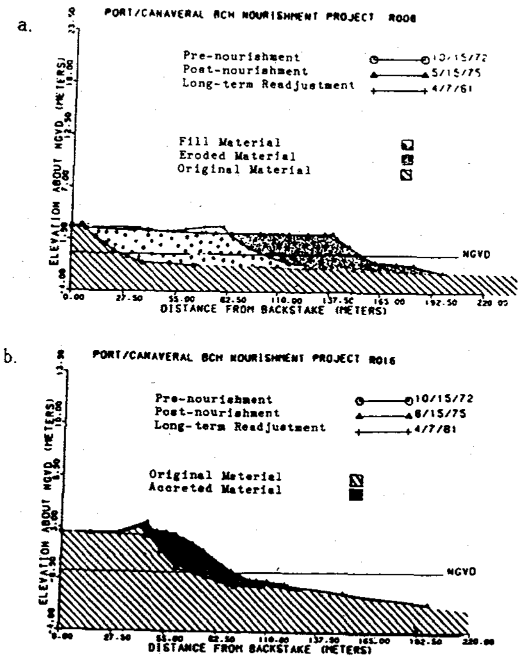

Figure 1. a. Monitoring of project profiles documents fill sediment redistribution and b. monitoring of control profiles documents fill sediment alongshore movenent.

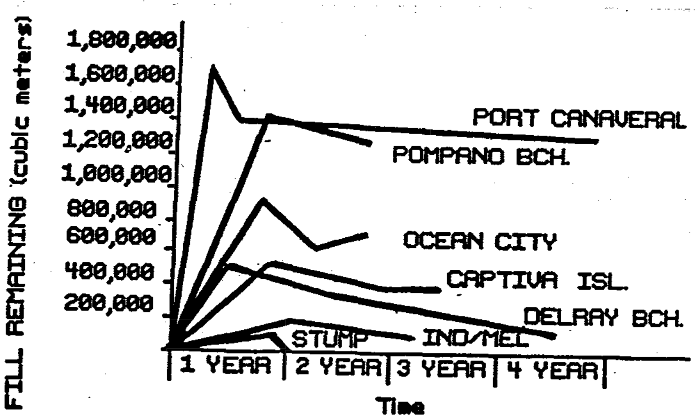

Figure 2. The fill remaining with time after fill placement for selected beach nourishment and inlet sand bypass projects, showing better fill retention with larger volume of fill placed.

for erosion control projects, 2) The native beach sand grain size distribution on beaches in need of renourishment, 3) The rate and process of resorting of fill material after placement on the project beach and 4) Assessment of long-term sediment characteristics and the need for renourishment.

Fill sediment will resort and reshape itself on the profile due to the coastal processes at work after fill placement. It is important to monitor changes in the grain size distribution as wave activity resorts the fill that is not in equilibrium with its new environment. Sampling schedules for sediment should coincide with the post-nourishment profile time frame. Sorting and redistribution of these materials through the life of the project and techniques to assess long-term needs to renourish a project are explained in Stauble et. al. (1984b). Before this research, little actual field information was available to calibrate these theoretical calculations. It was found that composite samples are needed to remove the variability in sediment distribution across a beach and in a borrow area. To date, no particular method of selection of areas to sample has been identified. Intertidal composite samples composed of mean high tide, mid tide, and low tide sediment samples, are more suitable for use in the models. Offshore sediments include fine sizes and changed little in their grain size distribution over the life of the projects studied. Fill was placed in the intertidal area in all projects studied and this area had the greatest redistribution of sediment grain sizes.

Characteristically, due to different energy conditions in the borrow area, fill sediment will usually have excess coarse and fine material, different sorting characteristics and possibly different mineral content. In past projects, excess coarse shell material and fine silt and clay material, not normally found on ocean beaches, have been present in the fill. To assess the suitability of the borrow sediment, native beach sand samples need to be collected and analyzed for grain size distribution parameters. The requirements for calculating fill factors and renourishment factors are summarized in the shore protection manual (U.S. Army,1984), with more details in Hobson (1977). The required parameters for using these methods are the native beach sand mean grain size and sorting and the borrow area sand mean grain size and sorting. The grain size distribution varies significantly across the beach profile (Bascom, 1959) and in the borrow area with location and depth, so Hobson (1977) suggests the technique of composite samples to give representative sample statistics of both the variable native beach and borrow area sands. Details on sediment sampling techniques and considerations are given in Stauble et. al., (1984a) and Stauble and Nelson (1985).

The Adjusted Shore Protection Manual method (recommended in the majority of cases by U.S. Army, 1984), gave the best calculation of actual fill behavior, provided a safety factor after Hobson (1977) was used. A safety factor of 3.0 Phi has been found to give the best results for the projects studied (Stauble et. al., 1984b). These fill factor models commonly use only the sediment mean and sorting values, which are not sufficient to describe the variability of the native, borrow and post-fill sediment behavior. This is because natural sediment distributions are not normally distributed as assumed in the models. Frequency distribution plots provide the best means of showing the differences between the native and borrow grain sizes over the entire sediment distribution.

Standardization of collection, analysis and presentation of beach nourishment sediment data is needed for better understanding of project behavior. It must be noted that grain size information alone is not sufficient to predict success of a project. Compatibility of the borrow material is but one of the factors to be considered in project planning, along with fill placement techniques, knowledge of coastal processes and interaction with other coastal structures (Dean 1983).

Littoral Environmental Monitoring Specifications

Supplementary data relating the littoral forces and other environmental parameters should be included to give a better understanding of fill behavior. The first pre-nourishment report of both beach nourishment and inlet sand bypass projects should include:

1) a brief description of the project and if applicable a description of the inlet,
2) a history of previous erosion control projects affecting the present project area,
3) description of historical structural improvements to the shoreline and associated inlet, and
4) Brief summary of coastal processes occurring in the project area including (if data are available) wave period, height; angle of wave approach, tide range, wind direction and velocity, measure of direction and quantity of longshore drift. For inlet sand bypass projects, information on tidal dynamics and morphology should also be included. Tidal range, tidal type, and tidal prism/cross sectional area data can give information on inlet hydraulics and stability (Leadon, 1984).

It would be advantageous to establish The U.S. Army Corps of Engineers littoral environmental observations (L.E.O.) form. This program is designed to be used on a daily basis. The important physical data collected are: 1) Wave period, breaker height, breaker angles, 2) Wind direction and velocity and 3) Longshore current direction and velocity.

The ability to identify storm events during construction and monitoring is enhanced by the L.E.O. program. Storm events should be identified and a frequency of occurrence should be included for each monitoring report period even if the L.E.O. program is not used.

BIOLOGICAL CONSIDERATIONS

Despite a need for rapid permitting to carry out beach nourishment in order to minimize both costs to taxpayers and the potential of storm losses in the interim before a project is completed, permitting agencies lack information to make the permitting process maximally efficient. In particular, adequate guidelines for maintenance of environmental quality appear to remain limited. Therefore, the present work is designed to approach the question of biological effects of beach nourishment to formulate specific guidelines for monitoring and project design.

The main focus in developing biological guideline criteria has been on the organisms found living in the nearshore zone of exposed high energy beaches of the Florida coast. For the past four years, sand beach animals, nearshore

fishes and animals from borrow areas have been actively studied at the Florida Institute of Technology (Spring, 1981; Johnson, 1982; Gorzelany, 1983; Nelson and Gorzelany, 1983; Stauble et al., 1983b). Research on the effects of beach nourishment on nearshore worm reefs is nearing completion.

Despite recent increases in available information on sand beaches (McLachlan, 1983), certain aspects of basic biological interactions in the surf zone have remained poorly known, nor has there been much attempt to apply existing knowledge to the planning of beach nourishment projects or to the biological monitoring of such projects. The proximate goals of the biological guideline project are to: 1) determine spatial scales of variability for beach organisms, 2) determine the degree of similarity in composition of beach faunas along Florida's shoreline, 3) determine experimentally the tolerances to sediment burial of important shore zone organisms, and 4) determine biotic community inter-relationships among the species of the shore zone. The ultimate goal is the synthesis of this new information with existing data to produce a set of guidelines to aid user groups in the permitting process. A brief review of several past beach nourishment projects will indicate the status of existing knowledge of the biological effects of beach nourishment and will suggest methods for the improvement of beach nourishment monitoring procedures.

Review of Available Data

Although a considerable body of information is available on the effects of dredging on benthic communities, much less is known about the specific environmental consequences of beach nourishment. Effects of dredging and beach nourishment were first reviewed by Thompson (1973), while Naqvi and Pullen (1982) have reviewed recent information.

Parr et al. (1978) analyzed the effects of deposition of 585,000 m^3 of dredged sediment from San Diego Bay on the nearshore fauna of Imperial Beach, California. They concluded that direct adverse effects of beach nourishment were few except for the direct burial of some less mobile organisms. In fact, an increase in diversity and abundance of organisms was observed following beach nourishment. However, these increases occurred during the summer when such increases are typical due to the seasonal decrease in physical disturbance from waves. They suggest that nearshore populations are adapted to seasonal sediment movement and will be little affected by receiving high sediment loads. They suggest that offshore organisms might be relatively more susceptible to increased sediment loadings, although no indications of this happening were actually observed.

Reilly and Bellis (1983) thoroughly studied the effects on the fauna resulting from a deposition of 902,174 m^3 of material which was dredged from an estuary and placed on a beach on Bogue Banks, N. C. Unlike Parr et al. (1978) only intertidal samples were taken. In this project, sediment deposition resulted in complete elimination of intertidal organisms since sediments were added to a depth of 2 m while the intertidal zone was moved 75 m seaward in a single day. Initial recruitment was in 15-30 days while subsequent larval recruitment of the mole crab _Emerita talpoida_ and littoral drift of small _Donax_ (coquina clams) into the nourishment area took place within 2 months. No large _Emerita_ or _Donax_ moved onto the nourishment beach following nourishment, and Reilly and Bellis (1983) concluded that this was due to mortality of larger animals in nearshore overwintering areas although this was not proved. Reilly and Bellis suggest that a delay in larval recruitment to the nourished beach was caused by high turbidity, again without supporting data. Reilly and Bellis (1983) concluded that the nourished beach recovered slowly. Although Donax densities failed to recover to control densities during the study, density of Emerita was comparable to controls immediately following the end of nourishment. The amphipod Haustorius canadensis, which lacks a pelagic larval stage, also had failed to recover as of the end of this study, which was only two months following the termination of nourishment.

Marsh et al. (1980) examined nearshore benthic communities near Hallandale Beach, Florida some 7 years after beach nourishment and offshore dredging. No long term effects of beach nourishment were observed for either the infaunal benthos or for the offshore coral reef biota. Culter and Mahadevan (1982) studied the long term effects of beach nourishment and borrow pit dredging on the benthic infauna of the nearshore zone of Panama City Beach, Florida some 3-4 years following nourishment. For the borrow areas, they found no differences between borrow sites and surrounding areas. They concluded that no long term adverse effects of beach nourishment had occurred either in the borrow pits or on the nourished beaches.

Gorzelany (1983) studied the biological effects of a beach nourishment project involving placement of approximately 413,000 m^3 of sand on the beaches of Indialantic and Melbourne Beach, Florida. There was no evidence from this study that beach nourishment caused any negative effects for any element of the nearshore infaunal community. Natural seasonal variability appeared much greater than any effect of nourishment. This nourishment project was carried out from mid-October through January, a period of low biological standing stock and low recruitment in the nearshore community which Gorzelany concludes may have been ecologically favorable. Additionally, there did not appear to be substantial movement of nourishment sediment into the more diverse offshore areas (Stauble et al., 1983b), which may have helped limit negative effects of the nourishment (Nelson and Gorzelany, 1983).

Saloman and Naughton (1984) studied the effects of deposition of an estimated 183,492 m^3 of dredged sand on the macrofauna of the swash zone and first sand bar at 23 sites along the beach at Panama City Beach, Florida. The deposited material was similar to existing beach material at most sites and turbidity associated with deposition appeared relatively low. On the basis of an intensive sampling program, they concluded that sand deposition resulted in decreases of number of species and number of individuals for a 5-6 week period for the swash zone populations. No differences between deposition and non-deposition areas were seen after this period. No effect of sand deposition was observed for the organisms located on the first sand bar.

A similar review of the effects of storms (Stauble and Nelson, 1985), including hurricanes, on the sand beach fauna indicates that there is little evidence that natural sediment transport is a major source of mortality for intertidal beach species. Apparently the adaptations which allow beach organisms to live in a region of high sediment transport also allow these species to survive storm generated wave action, sediment transport and turbidity.

New Observations

It is important to determine the spatial scales of variability for beach organisms in order to best design a sampling plan. For example, a major reason for utilizing nested sampling designs which include several parallel transects per sampling location is to minimize the effects caused by aggregation of organisms (mainly intertidal) along the beach. Such aggregations have been described in particular for Emerita talpoida, a common intertidal species, and have been related to beach cusp structures. Specific examination of the relationship between Emerita density and beach cusp structure failed to reveal any patterns in the Melbourne area nor were differences along the beach generally significant (Table 1). Additionaly, neither Parr et al. (1978) nor Reilly and Bellis (1983) reported any significant differences in total density estimates from the parallel transects they established within a sampling location. It would therefore appear that parallel transects may safely be omitted in favor of additional sampling locations.

Although experimental tolerances to sediment burial have been determined for several organisms with regard to offshore dredge spoil disposal (Mauer et al., 1978), no information has been available for beach organisms. The results of experimental burial studies on Donax spp., Emerita talpoida , and the snail Terebra dislocata are given in Table 2 (methods described in Stauble and Nelson, 1985). Emerita experienced no mortality in a 24 hr period when buried in up to 10 cm of fine sediment, but experienced 55% mortality when buried by 10 cm of coarse sediment through which it was unable to burrow. Donax experienced relatively greater mortality in fine rather than coarse sediments, with maximum mortality occurring for burial under 10 cm of sediment. Terebra dislocata showed little mortality for either fine or coarse sediments at any depth of burial used. These results suggest the organisms can deal with instantaneous burial by sediment at depths of up to 10 cm, although some mortality results. In the case of Donax spp., since the major part of the population is found at some distance from the beach (Nelson and Gorzelany, 1983) where deep burial should not occur, this suggests that the population should be affected only minorly outside the intertidal zone.

Specific recommendations for biological monitoring procedures.

Given the conclusions of past work summarized above, namely that available evidence points to minimal biological effects of beach nourishment, the question may be raised as to whether biological monitoring of beach nourishment projects is necessary at all. With presently available information, a decision against biological monitoring is decidedly premature. Only 4 studies are available which have any data to compare macrobenthic populations before and after beach nourishment (Parr et al., 1978; Reilly and Bellis, 1983; Nelson and Gorzelany, 1983; Salomon and Naughton, 1984). Of these studies, three have decided deficiencies in terms of temporal or spatial adequacy of sampling (Parr et al., 1978; Nelson and Gorzelany, 1983) or in data analysis (Reilly and Bellis, 1983). The need for biological monitoring of beach nourishment will not diminish in the future until a more substantial body of well designed and analyzed studies is available.

While every area is ultimately biologically unique, it is doubtful most monitoring sampling designs are constructed specifically to meet the requirements of a given area since detailed baseline studies would be required

Table 1. Summary of recommendations for a standardized monitoring approach to beach nourishment.

Factor	Recommendation	Explanation
Horizontal layout	Intersperse treatments	Improves confidence in statistical conclusion
Vertical layout	Sample across beach zones	Effects may differ in different zones.
Statistical analysis	Two-way ANOVA	Analyses both space and time effects.
Sample device	Hand held core	More efficient and easier to use.
Sample number	10 cores per area	Estimate within 50% of mean. Increased power of analyses.
Sample size	7.6 cm core	Decreases processing time. Efficiency near that of large core.
Sample frequency	1/month, 1/week for 1 month after project	Most effects are of short duration.

Table 2. Results of sediment burial experiments for <u>Emerita talpoida</u>, <u>Donax</u> spp., and <u>Terebra dislocata</u>. Numbers are mean % (std. dev.) surviving after 24 hrs burial by 0, 1, 5 or 10 cm of either fine (F, mean grain size - -0.8 phi) or coarse (C, mean grain size - 2.6 phi) sediment.

Species (sediment type)	Treatment			
	0 cm	1 cm	5 cm	10 cm
<u>Emerita talpoida</u> (C)	100(0)	97.5(5)	82.5(23.6)	45(17.3)
<u>Emerita talpoida</u> (F)	97.5(5)	100(0)	97.5(5)	95(5.7)
<u>Donax</u> spp. (C)	100(0)	100(0)	82.5(17)	85(5.7)
<u>Donax</u> spp. (F)	100(0)	100(0)	95(5.7)	70(24.5)
<u>Terebra dislocata</u> (C)	100(0)	95(10)	95(10)	90(11.5)
<u>Terebra dislocata</u> (F)	100(0)	100(0)	100(0)	100(0)

in each case in order to do so. The presently existing variability in methods (Stauble and Nelson, 1984) suggests that considerable improvement could be made towards increased standardization. Standardization of sampling effort and methodology would appear to offer greater rewards by providing a readily comparable data set from which conclusions concerning general biological impacts of nourishment activities could be drawn. Recommendations for a standarized sampling regime are summarized in Table 3 and discussed below.

In order to be able to detect effects of beach nourishment, it will be necessary to take replicate samples both temporally (before vs. after the project) and spatially (nourished vs. control locations). Statistically significant differences between nourished and control locations can <u>only</u> be demonstrated by comparison to differences among replicate measurements within treatments. Collection of equal numbers of replicate samples for all combinations of time and location will greatly simplify subsequent analysis.

Sampling of most beach nourishment projects presents a singular difficulty, namely that because the project falls on a single continuous stretch of beach, it is impossible to design a sampling layout which provides an adequate random assignment and interspersion of treatments. Interspersion of treatments in a random fashion is necessary to avoid the potential problem of the impingement of chance events on an experiment in such a way that only one treatment is affected, thus confusing the statistical interpretation of results (Hurlbert, 1984). Appropriate layout of sample locations can help to somewhat avoid the problems associated with the limitations on interspersion of treatments. Figure 3 compares two possible sampling designs. In the first case both the treatment (i. e. nourishment) and control sample areas are completely non-interspersed, which is a poor design. A better design is to split the control samples to either side of the nourishment area to achieve a better, although incomplete, degree of interspersion.

Design of sampling must be determined by the requirements of the methods to be used for data analysis. Analysis of variance (ANOVA) appears to offer the best general means for analysing the effects of an environmental impact. The preferred design of Fig. 3 is laid out in such a way as to be amenable for analysis of variance. A 2-way ANOVA design analysing both temporal and spatial variability simultaneously will be the most efficient method for analysing nourishment effects. Since it is quite clear that differences between vertical zones on a beach exist, a 2-way ANOVA should be done at each beach level sampled. The patterns observed at each beach level can then be discussed with respect to time and treatment effects.

Given the fact that there are vertical zones on the beach and that there is a rapid increase in species diversity and density of organisms as one moves down the beach into the subtidal area, it is necessary that beach sample locations consist of a transect across both the intertidal and subtidal zones of the beach. Improved sampling efficiency can be gained by an optimum sampling design on these transects. For example, recent studies (Gorzelany, 1983) indicate very few marine organisms are found in samples from the mean high tide line in Florida. Samples from this point have been required on previous monitoring designs (Nelson and Gorzelany, 1983). These samples necessitate considerable processing time and yet yield little useful information. Their elimination would have resulted in an immediate decrease of approximately 30% in sample processing time because of the disproportionate

Table 3. Summary of variability in the spatial distribution pattern of the intertidal mole crab Emerita talpoida on different spatial scales and in relation to beach cusp morphology. F values are from analysis of variance.

Factor Examined	Result
Variability within a:	
27 m cusp (3 m apart)	No significant variation, F=.09, p>.05
32 m cusp (5 m apart)	No significant variation, F=1.4, p>.05
54 m cusp (5 m apart)	No significant variation, F=1.1, p>.05
Comparisons between cusp peaks and cusp troughs (11 cusps total)	No significant difference between peaks and troughs, F=1.7, p>.05.
Fixed distances along the beach.	
10 m, Oct. 1981	Significant variation. F=3.2, p<.05.
19 m, Oct. 1982	No significant variation, F=1.1, p>.05

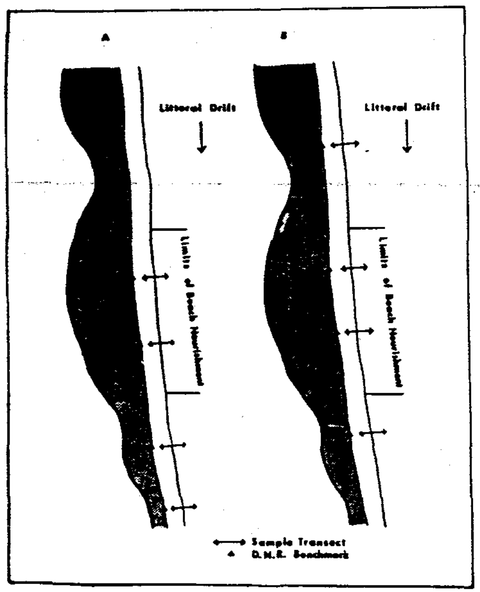

Figure 3. Comparison of two possible sample designs for monitoring of beach nourishment projects.

difficulties in sorting organisms from such coarse sediment.

It is recommended that analysis of the beach fauna be restricted to the macrofauna. The sand beach meiofauna is certainly diverse and abundant, but problems with sorting time and taxonomy would be prohibitive for most impact studies. In order to effectively sample the macrofauna, a sieve size of 0.5 mm is recommended. Although use of 0.5 mm rather than 1 mm will increase the sorting time due to retention of coarser sediment and increased numbers of animals (2-3 times more animals, Parr et al., 1978; Lewis and Stoner, 1981), it will generally ensure adequate sampling of smaller macrofaunal species and juveniles of the macrofauna.

In selection of specific sites to be sampled along a given transect, sites have been established based on fixed distances from shore (Nelson and Gorzelany, 1983), a fixed depth (Parr et al., 1978), or at general areas along the shore contour such as the swash zone or first offshore bar (Saloman and Naughton, 1984). A combination of these methods is suggested. Sampling an offshore zone rather than a fixed distance may result in considerable variability in the location of samples, yet a fixed interval may be inadvisable for samples in the swash zone. Therefore swash zone samples should be sampled in the region at the base of wave run-up on the beach. Offshore, subtidal locations should be selected to represent different zones such as the inshore trough and bar, but sample location should be determined from sample time to sample time by a fixed distance measured on a transect line. The actual distances will therefore be determined by the location of physical features of the beach and not by a priori fixed intervals. Because of the typically limited spatial extent of a beach nourishment project, fixed distances established in this way should sample equivalent zones for both nourishment and control areas. If this condition is not met, it will be more important to sample equivalent zones than equal distances and the sampling points must be adjusted accordingly.

The temporal interval of sampling is extremely important for detecting any nourishment effects. Based of a review of previous studies (Stauble and Nelson, 1985), a recommended sampling scheme is to sample monthly for several months before nourishment, weekly for one month following nourishment and monthly thereafter for 9-12 months. The few studies available suggest that this time interval should adequately cover any important changes (Parr et al, 1978; Reilly and Bellis, 1983; Nelson and Gorzelany, 1983; Saloman and Naughton, 1984).

Given the results of Parr et al. (1978) it would appear that obtaining precision levels better than 50% (i.e. estimating true means within 50%) for measured parameters such as number of species and number of individuals will be prohibitive in terms of the cost and time involved to process samples. Ten 7.6 cm diameter cores would appear to offer precision somewhat better than 50% for both estimates of abundance and number of species (Stauble and Nelson, 1985). It is therefore suggested that ten 7.6 cm diameter cores from each combination of location x time may be a sufficient level of replication.

Core size is set at 7.6 cm because analyses done in previous beach studies indicate that smaller cores sample equal numbers of species and better than 90% of the number of individuals (Reilly and Bellis, 1983). At the same time smaller cores result in significant savings in sample processing effort. Also, the use of more, smaller cores will increase the degrees of freedom and hence the power of statistical analyses (Green, 1979).

SUMMARY

Stauble and Nelson (1983) presented a proposed flow chart for standardizing and expediting the beach renourishment permitting process. We continue to believe that it is important that the initial permitting application be carried out in conjunction with basic pre-project monitoring procedures. During both pre- and post-construction periods, adequate monitoring of both biological and physical parameters must be carried out for effective asssessment of project success and biological community recovery. Increased standardization of monitoring requirements and monitoring methods are believed to hold great promise for streamlining both the permitting process as well as the assessment of project success. In the last regard, it must be emphasized that only by adequate archiving of project reports which have been monitored by standard methods will it be possible to accumulate an adequate overview of beach nourishment procedures on which to base future improvements.

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