How beach nourishment affects the habitat value of intertidal beach prey for surf fish and shorebirds and why uncertainty still exists

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Our research on ecological impacts of beach nourishment in North Carolina has involved monitoring of projects in the field, conducting process-oriented experiments on the beach and in unique wave tank mesocosms, and reviewing the statistical adequacy of sampling designs of beach nourishment monitoring studies. This work has led to tentative answers to long-standing questions and insight into why uncertainty over the ecological impacts still persists.

Monitoring of two projects in North Carolina, one on Bogue Banks and a second on Topsail Island, provides evidence that implies strongly that sediment grade used for beach fill influences the extent of impact and recovery for the intertidal beach macrofauna and thus their ecosystem service of feeding surf fishes and resident and migratory shorebirds. The fill materials used in both projects resulted in a substantial fining of beach sediments and increased sorting: one project also enhanced shell fragments. Nourishment on Bogue Banks using sediments taken from ICW maintenance dredging resulted in increasing the median phi index from 2.3 to 3.7 and produced an 86-99% reduction in abundance of the two dominant macrofaunal organisms, *Donax* spp. and *Emerita talpoida.* The project was completed in April at one site and 24 May at the other, yet the 86-99% reductions in abundance of macrofauna were evident in mid July. This implies that the habitat value of the intertidal beach was lost to vertebrate consumers for at least the spring and summer, if not longer. Nourishment (disposal) on Topsail Island using sediments dredged from an inlet channel resulted in fill placement on the beaches from April into May or early June in each of two successive years. This project resulted in fining of sediments (changing median phi from 1.25 to 2.25), an increase in sorting (changing phi from 0.9 to 0.4), and enhanced turbidity in the surf zone during active sediment pumping. The sedimentological differences persisted long enough that there was no detectable recovery between projects spaced a year apart. Impacts on the benthic macrofauna were dramatic and long-lasting. The biomass dominant, *Donax* spp., exhibited a >50% reduction in abundance integrated over the whole summer of peak production. A similar pattern was expressed by two of the most abundant amphipods, *Parahaustorius longimerus* and *Amphiporeia virginiana.* The mole crab *Emerita talpoida* virtually disappeared from the nourished beach for the full year after one of the two nourishment events. Only one common species, the polychaete *Scolelepus squamata*, exhibited enhanced abundance on the nourished beach. The body sizes of both *Donax variabilis* and *Emerita talpoida* were substantially smaller on the nourished beaches and never exhibited convergence with sizes on the control beaches during the two years of study. Consequently, this project resulted in reduction of habitat value of the intertidal beach for most surf fishes and shorebirds through reduced prey abundance and body size, a compound impact on production and trophic transfer.

Experiments conducted both in the field and in laboratory wave tanks reveal how aspects of changing sedimentology and turbidity affect important biological processes. Enrichment of surface sediments with shell debris (>1mm) decreased the burrowing rate of *Donax variabilis* by 65%. Florida pompano, when offered in choice experiments equal densities of *Donax variabilis* in both natural and shelly sands (1.7 vs. 12.5% shell), exhibited fourfold higher predation in the low-shell sediments. Using experimental mesocosms created in wave tanks with sloping swash zones and oscillating waves at periods set to match the natural beach habitat revealed important impacts of turbidity. *Donax variabilis* exhibited a 25% reduction in growth when subjected to turbidity of 96 NTUs as compared to controls with 9 NTUs. This effect was expressed only at low, but not at high, clam density. Feeding rate of Florida pompano in these same wave tanks was reduced by 30% when offered *Emerita talpoida* prey and 40% when offered *Donax variabilis* prey under conditions of 74-101 NTUs as compared to controls of 7-9 NTUs. Thus, exposure of the benthos to sufficiently enhanced turbidity during nourishment projects can reduce growth and production of benthic suspension feeders and can interfere with the ability of visually orienting surf fishes from successful feeding.

A brief review of past studies of beach nourishment provides insight into why uncertainty about ecological impacts of these dredge and fill projects still exists despite at least two decades of study. First, little process-oriented, experimental research has been funded by the US ACOE or any other funding agency to help build mechanistic understanding of impacts from first principles. Instead, the work funded has been almost exclusively monitoring, which is an inefficient, imprecise, and inadequate means of testing even important processes because many key variables are confounded in contrasting nourished and control sites. These include multiple sedimentological variables (eg, often increases in silts/clays and shell co-occur as well as sorting modifications), seasonal timing of the project, spatial scale, temporal frequency, history of previous modifications of the site, etc. Second, the monitoring that has been done on beach nourishment projects fails to meet the standards of acceptability of sampling design in the field of ecology. Several points of failure are evident in these past monitoring designs. Most importantly, the statistical designs for field monitoring must incorporate methods to insure that the studies have adequate power to detect effects of biological importance. This is not done. In fact, federal and state review of monitoring conducted as part of the permitting requirements does not involve any biostatistical analyses of power to detect impacts. Consequently, many of these studies are worse than no study at all because they conclude falsely an absence of biological impact when the most that can be concluded is that the project had little intrinsic potential to detect effects and accordingly did not.

The greatest looming challenge in environmental assessment of ecological and bottom habitat impacts of beach nourishment is the need to assess cumulative impacts. As sea level continues to rise, storms grow in frequency and intensity, and beach-front development continues, demand for nourishment projects will grow dramatically in the near future. The expanded spatial scope and temporal frequency of such projects pose a challenge of assessing cumulative impacts on bottom habitat and its ability to feed vertebrate consumers. Monitoring may help somewhat in assessing cumulative impacts but construction of models based on defensible process-oriented understanding will be required as well. This demands a new approach to environmental assessment, not business as usual.