SUMMARY REPORT

ARMOR ROCK HABITAT SURVEY OF HAMPTON ROADS TUNNEL

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16. Abstract

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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INTRODUCTION

Hampton Roads is the body of water connecting the James, Nansemond, and Elizabeth Rivers with the Chesapeake Bay. It lies between the cities of Norfolk and Hampton, Virginia. "Roads" means safe harbor, and Hampton Roads is one of the largest natural harbors in the world.

The Hampton Road's Bridge-Tunnel (HRT) was built to facilitate the flow of traffic to Virginia's port area. The crossing was previously made by ferry; the addition of the tunnel reduced the time required for a trip between Norfolk and Hampton by approximately 45 minutes. It was anticipated that the improvement in transportation would contribute to the growth of industry and military installations in the area. Average daily traffic in 1957 was 5519 vehicles with a predicted increase to 10,000 by 1980 (Anderson, 1957). In fact, it reached 10,000 in 1964, and by 1980, it had risen to approximately 44,000. In 1988, the average daily traffic reached 73,833, with a maximum 24-hour traffic count of 94,600 during the Memorial Day weekend.

The HRT spans the James River estuary and the lower Chesapeake Bay connecting the cities of Hampton and Norfolk. Two large wave-built spits, Willoughby Spit and Old Point Comfort, extend into the harbor beyond the tunnels. The facility consists of paired sunken tube tunnels, two man-made islands, and paired north and south bridge approaches. The tunnels span the 60-foot deep channel; the islands are located in shallower water on either side. The combined length of the approach bridges and tunnel is 3.5 miles. Initial construction at the site included the islands, support buildings, and a single two-lane tunnel. The bridge approaches were begun in December 1954 and completed in November 1957. In response to traffic demands, a second tunnel and approaches were constructed parallel to the first between August 1970 and June 1976.

At the time of the initial construction, the Hampton Roads Bridge Tunnel was the longest underwater tunnel built by the trench-type construction method. With a portal-to-portal length of 7,479 feet, it was the sixth largest highway tunnel in the world. It was also the first tunnel constructed with both portals emerging on manmade islands in the middle of the watercourse.

The islands were constructed to extend 11 feet above sea level, 2 feet above the highest tide of record. Hampton Roads tidal changes average approximately 2 1/2 feet, and they rarely rise above 6 feet during extreme weather conditions. Retaining walls extend 14 feet above sea level, thereby providing additional protection for the tunnel portals, and as a further precaution, waterproof floodgates were installed at each end of the tunnel. One manmade island, Fort Wool, already existed at the site prior to the construction of the tunnel crossing.

The tunnel islands were initially constructed from more than 5,500,000 cubic yards of material dredged from the Hampton Roads channel. Stone dikes were built surrounding the area of the proposed islands, and dredged material was deposited within these boundaries. The bottom material at the South Island site was mud and silt, which was considered inadequate for support of the intended facilities; consequently, approximately 900,000 cubic yards of this material was dredged and towed to sea for disposal. Greater than 1,250,000 cubic yards of dredged material was obtained from a site about a mile and a half east of south island to replace the removed material and complete construction of the island. A total of 2,608,410 cubic yards of dredging was required for the first tunnel crossing.

The north island was 1400 feet long and the south island was 1250 feet in length. Both islands were rectangular and 170 feet wide. The south island was connected to Fort Wool by an extension designed to forestall erosion caused by the strong currents that flowed between the two manmade islands. In the fall of 1955, a tropical storm washed away approximately twenty per cent of the south island before it was completed. Subsequently, greater than 130,000 tons of rip rap were used to armor the slopes of the two islands to protect against the action of waves, tides, and currents.

The tunnel islands were enlarged to accommodate the second tunnel portals. Tunnel construction began with enlargement of the south island because of the unstable foundations at the site. A layer of clay and silty clay approximately 100-feet thick was located beneath the area of the south island. Because of restrictions on dredging and because of financial considerations, the sand drain and surcharge method was chosen to consolidate the bottom sediment forming the foundation of the south island. Approximately 6,000 vertical columns of sand (termed *sand drains*) were placed 125 feet through the south island and into the underlying bay bottom. The island was covered with a 26-foot layer of sand. The weight of the sand pressed water from the underlying soil and into the sand drains. The water rose through the sand drains to the surface and into the bay. The method was successful, and 13 feet of settlement occurred from consolidation of the foundation material. Subsequently, the sand surcharge was used as backfill over the new tunnel. An underwater blanket of graded gravel was placed over the existing bottom adjacent to the island. Armor rock was removed from the western side of both islands and the south end of the south island to allow for expansion. Stone dikes were placed to define the extension and subsequently filled with sand obtained either from the dredging for the tunnel tube or from a borrow pit. Because of environmental considerations, restrictions were placed on the contractor to minimize the silting of the surrounding waters during this process. Replacement coarse armor rock of igneous or metamorphic origin weighed between 250 and 1500 pounds; less than 10 percent consisted of pieces 10 to 250 pounds.

The police station and maintenance shop are located on the North Island, which has a greater amount of activity. The south island, which is the larger of the two, has a greater amount of unoccupied land and is joined to Fort Wool by a rip rap extension. Neither island is open to the public except for motorist emergencies.

Initial construction at the Hampton Roads tunnel site predates environmental monitoring, but environmental surveys were conducted to assess the impact of construction for the second tunnel crossing. The Virginia Institute of Marine Sciences (VIMS) on a contract from VDOT evaluated the effects of dredging operations and concluded that the dispersal of escaped spoil was rapid because of high water flow rates and turbulent mixing in the Hampton Roads waterway (Boon and Thomas, 1974). Further studies by VIMS examined the hard shell clam (*Mercinaria mercinaria*) population as an index of the effect of construction activities on the environment of Hampton Roads. The study concluded that the existing tunnel structures and the construction of the second tunnel had not reduced the hard clam population in the area (Haven et al., 1974).

Hampton Roads functions ecologically as an estuary, a semi-enclosed coastal area where rivers and streams drain into the sea. Hampton Roads is fed by several large rivers and some smaller ones. Several of the rivers, including the Elizabeth and Nansemond are tidal tributaries with little efflux of fresh water. The James River, however, has a significant fresh water effluent into Hampton Roads and the Chesapeake Bay.

Because of the nature of water flow in an estuary, organisms in this environment confront two ecologic challenges: (1) maintenance of their position despite heavy currents and (2) exposure to changes in salinity (Smith, 1974). The primary populations of marine organisms that survive well under these conditions are benthics and fish.

PURPOSE AND SCOPE

The present study examines the marine life of the Hampton Roads tunnel islands approximately 36 years after construction. An aim of the study was to examine the differences in marine organism populations following the transformation of a soft sandy bottom to a hard substrate artificial habitat. Although a number of studies have examined the effectiveness of artificial substrates in attracting and increasing fish populations, few have examined the populations of marine life that colonize the hard substrates. Artificial reefs located in temperate waters, such as in Virginia, have received relatively little attention. This study examines the range of artificial reef community inhabitants on the Hampton Roads Tunnel island.

The organisms occurring on the island armor rock and in the soft sediment surrounding the islands, which was typical of preconstruction conditions, were sampled and identified. The number of species identified and measurements of biomass occurring on the armor rock community were compared with the populations found in the surrounding soft sediments. Benthic data were compared with results of previous studies by others that had established normal population patterns for particular seasons and habitats in this area.

During work on the project, the investigators became aware of significant populations of common terns and black skimmers breeding on the islands. The breeding population of birds has been monitored since 1983 by the Virginia Game and Inland Fisheries and the College of William and Mary as part of their 10-year study of shorebird populations in Virginia. The initial counts of the population in 1983 showed a total of 700 adult common terns and 118 adult black skimmers. The population of breeding adults grew dramatically in the subsequent years of the census. In 1986, the adult common tern population had increased to 2000 individuals, and the black skimmers had increased to 746.

The establishment of shorebird colonies on artificial tunnel islands has not previously been reported. Consequently, the present study was extended to examine the islands' unique function as a shorebird nesting site and sanctuary. Factors responsible for the establishment of colonies on the Hampton Roads tunnel islands were examined as well as VDOT's role in maintaining a habitat suitable for the birds.

METHODS

A total of six sites were selected for data collection, three on each island. The locations were selected for variety of water conditions surrounding the islands in order to ensure that the marine life sampled would be diverse. One site was located on each of the three sides of the islands on which there is no bridge approach. The sides where the bridges approached the islands were less accessible for sampling. Preliminary dives suggested that the growth and animals located there were not significantly different from the study sites.

Artificial Substrates

Concrete blocks 16 by 4 by 3 inches constructed of various types of aggregates were obtained from the VTRC concrete lab. The concrete blocks were placed at each of the selected sites on the two tunnel islands in May of 1985. Reef species are known to colonize much more rapidly in the summer (Talbot et al., 1978); consequently, the substrates were placed so that the study period would span a summer season. They were placed in May and retrieved in September and October. A total of 12 blocks were placed at each site. Of the 12 blocks, 4 were placed on the armor rock approximately 3 feet from where it ended in the sand. A second group of 4 blocks was placed adjacent to the riprap in the sand, thereby forming extensions of the riprap. A third set of blocks was placed 3 to 5 feet out in the sand.

The blocks were checked periodically during the summer to make sure they remained in place and to monitor growth. Abundant growth was evident within 2 weeks at some sites. The innermost group of substrates, placed on the armor rock itself, was occasionally exposed at low tide, which led to desiccation of the attached marine growth. Many blocks in the outermost group of substrates became covered by sand as a result of wave action. The intermediate group of substrates, immediately adjacent to the riprap, colonized well, remained covered by water even at low tide, and were not buried by the sand during the study. Accordingly, 3 blocks from each site were recovered in September and October. Immediately after retrieval, each block was placed in a fine mesh bag to contain the organisms and immersed in 10 percent formaldehyde solution.

Analysis of the blocks was performed by the marine lab at Old Dominion University under the direction of Daniel Dauer, Ph.D., and Michael Ewing. A point census analysis was used to determine the percentage of coverage of the blocks by different species. A plot of randomly arranged 2-dimensional dots was generated by computer. The pattern was transferred to a piece of plexiglas the size of the concrete blocks. The plexiglas template was placed over the surface of the block to be analyzed, and the organisms at each point on the matrix were identified and tabulated. The number of points lying over an individual species, divided by the total number of points per block (approximately 130), yielded the percentage of coverage by that species. Organisms that were obvious on the block but not covered by a point and therefore not counted were identified and recorded as well but not included in the calculations.

Point census analyses were originally intended to sample only the superior surface of each block where the greatest growth should occur. As expected, most of the blocks had prolific growth on one surface and minimal or no growth on the opposite surface, which had been resting on the sand. However, some blocks had evidently shifted in orientation underwater, and significant growth had occurred on both surfaces. In these cases, point census analyses of both "top" and "bottom" surfaces were done.

The organisms were removed from the surface of each block that was sampled in the point census. Burrowing tube worms were carefully removed from the block surface with small picks until the total organic material covering each block was removed. The organic material from each block was placed into aluminum loaf pans, weighed, and dried at 60°C for 48 hours in a drying oven for complete desiccation. The samples were weighed again after drying. Biomass was calculated by dividing the surface area of the block into the weight of the dried organic material removed from the block. The dried organic material from the block surfaces was burned to ash in a 600°C muffle furnace for 4 hours. The ash samples were weighed and ash free dry weights computed by division of the weight difference by the surface area of the block.

Dredge Samples

Grab samples were obtained in May from the bottom sediment beyond the armor rock at the same locations at which the substrates were placed. A Hackmen dredge was employed. Three samples were collected at each site. Each dredge sample was placed immediately in jars containing 10 percent formaldehyde. Old Dominion University marine lab analyzed the organisms contained in the dredge samples.

After fixation, the formalin solution was removed, and the samples were stained using Rose Bengal protein stain. The material in the samples was then washed through a 1/2 mm sieve bucket to separate the organisms from the sediment. The residue retained on the sieve was placed into white porcelain sorting pans. The material was sorted under a dissecting microscope and the red-stained organic material was separated. The organisms removed were stored in 70 percent alcohol until identification to the lowest practical level using dissecting and/or compound microscopes.

The total number of organisms in each sample was tabulated. The average number of organisms per mm^2 was calculated by dividing the total number of organisms per sample by the area of the dredge opening (0.0232 mm^2).

The organisms from each sample were placed into aluminum weighing pans, weighed, and dried at 60°C for 24 hours. Desiccated samples were weighed and the biomass determined by dividing the organic sample weight by the area of the dredge opening. The dried organic material was turned to ash in a muffle furnace at 600°C, and the ash free dry weight was calculated by dividing the weight difference by the area of the dredge.

DISCUSSION

Artificial Reefs

The Hampton Roads tunnel islands which are constructed from large irregular rock are comparable to artificial reef formations. As with all forms of artificial reefs, the hard surfaces provide areas of attachment for a number of marine organisms, and migrant populations of fish are attracted to these concentrations of marine life to feed. Rubble mound structures have proved to be highly productive. In one study of a rubble-armored manmade island, Rincon Island, off the coast of California, the estimated total wet-weight biomass of the island was 215,787 kilograms (475,800 pounds) of plants and 113,761 kilograms (250,840 pounds) of attached animals (Johnson and deWit, 1979). This contrasted with a wet-weight biomass of the soft bottom sediment of a comparable sized area of only 871 kilograms (1,920 pounds), which is 378 times less than the armor rock island.

Rock-constructed habitats have proved durable. Although many manmade reefs tend to cause bottom sediment disturbance with alternating scour and accumulation of silt around the reef margins, this is lessened on quarry rock reefs (Grant et al., 1982). The stability of the large rocks forming the armor of the island promotes settlement by a number of species (Osman, 1977; Buckley, 1982). Their irregular contours provide shelter for juvenile fish and shellfish. The reef occupies a relatively small area compared to the native sandy bottom but may considerably increase the diversity and number of species by providing increased surface area and growth in another dimension. Many artificial reef designs lack the high vertical profile of a rubble structure that extends above the water. This feature promotes settlement by a wide variety of organisms that colonize at different levels (Hurme, 1979; Prince, et al., n.d.). Structures constructed in this way are clearly marked for navigation and location, and are easily accessible from shore for sport fisherman. Since the original environment remains present in abundance, the reef encourages the proliferation of additional species with minimal cost to the previous population.

Artificial reef building was first employed in the United States in 1860 to enhance fishing (Stone, 1985). The use of artificial reefs has escalated throughout the 1900s, and there has been a dramatic increase in the last 30 years. The increasing interest since 1960 in artificial reef development projects is the result of the growing demands on sport fishing resources and the evidence of decline in some fish populations. Estimates of the benefits of artificial reefs to the economy are impressive. South Carolina estimated an income of $10 million from 9 artificial reefs in 1977 (South Carolina Recreational Fisheries, 1978).

Artificial reefs have been shown to increase the fish populations of an area from 11 to 16 times (Unger, 1966). One study comparing preconstruction fish populations with the populations found after a reef was installed showed an increase of 300 to 1,814 times (Parker et al., 1979). Artificial reefs are a source of nourishment for fish populations by providing a substrate for attachment of aquatic plants and animals (Prince, et al., n.d.). Artificial reef populations closely resemble natural patch reefs in the number of fish, the composition of species, and seasonal fluctuations in population. Even in close proximity to natural patch reefs, the artificial reefs do not compete for fish populations but instead increase the overall numbers. New habitats are initially colonized by juveniles (Talbot, Stone). This may be the mechanism by which increasing available habitat increases numbers without disrupting the populations present on nearby natural reefs. The artificial reefs provide support and protection and reduce competition for a greater number of individuals than would normally succeed in a more mature community. It has been postulated that marine environments are habitat limited, not nutrient limited (Buckley, 1982), since the oceans appear to be a fertile environment with ample capacity to increase growth.

The diversity in marine systems may relate to the fact that they are non-equilibrium systems (Stephens and Zerba, 1981; Talbot et al., 1978). Which organisms colonize a reef are considered by many authors to be a chance phenomenon dependent only on the availability of a suitable substrate (Buckley, 1982). Unlike many land ecosystems, competitive and associative interactions appear to have little influence on the distribution of marine organisms (Talbot, et al., 1978). Instead, environmental unpredictability, chance, and patch environments may be the determinants in marine species distribution (Sale and Dybdahl, 1975). Other studies, however, have shown that a significant percentage of reef species demonstrate habitat selection (Talbot, et al., 1978), such that their settlement could be affected by the artificial reef design. Design features that appear to be particularly important include the size of openings and niches within the reef.

Significant factors in artificial reef construction include durability, expense, and the ability to attract and promote the growth of marine organisms. Common materials have been automobiles, rocks, tires, ships, plastic domes, and scrap concrete. Concrete and tires have been widely used because of their availability and low cost. Artificial reefs with open spaces have significant advantages. Spaces and sizes of structures determine the amount of interaction with the surrounding benthic and pelagic environments and the types of species present (Buckley, 1982). In studies of temperate reef structures, the presence of fish species seems to depend in part on habitats of suitable size to accommodate the juvenile and mature individuals. Studies suggest that habitat selection is size related and time limited for juvenile members. High relief reefs have been shown by the Japanese to attract larger finfish populations (Grant, 1984). Regardless of materials used, expense is a major issue.

A pilot artificial reef study was conducted in Virginia comparing the success of four types of reef construction in recruiting fish (Feigenbaum et al., 1985). This study evaluated high and low profile tire reefs, concrete pipe pyramids, and fabricated concrete igloos in 6 to 18 meters of water in the Chesapeake Bay and along the Eastern Shore. Tire reefs were the most productive of the types of reefs tested, increasing the number of fish sampled by more than 10 times.

Artificial reefs have been investigated by a number of researchers as a method of mitigation for potential damage to marine or wetland environments (Grant et al., 1982; Feigenbaum, Research foundation of SUNY, 1984).

Macroalgae

A primary factor in the early settlement of an artificial reef is the establishment of sessile algae (Fager, 1971; Buckley, 1982). Not only do these organisms provide food, but the microhabitats provided by their holdfasts and filamentous structure are used by a number of invertebrates that also serve as a food source (Huekel, 1980).

Jetties, retaining walls, and other manmade structures rapidly become colonized by macroalgae (Ott, 1972). Our concrete blocks became colonized with algae within 24 hours. Manmade structures are important habitats for the algae populations especially along the mid-Atlantic shorelines where sandy bottoms offer relatively few natural substrates.

Benthics

Benthic organisms, or benthos, inhabit the bottom, or benthic zone, of fresh and salt water habitats. They include species that live on the surface of the soft sediment (epifauna) and those that burrow into the bottom to feed on decaying organic material. Some live deep in the soft sediment (infauna), reaching the water for respiration through tube-like extensions. The organisms found in the benthic zone may not be restricted to this microhabitat, but they are well adapted to the fairly stagnant conditions that may be found there. Benthics constitute an important tier in the marine life food chain. Benthic populations are sensitive to the effects of pollution because of their minimal mobility. Since they reflect the water quality around them, they are frequently used as an index of water contamination (Sinclair, 1973).

In polluted areas, sensitive organisms are killed or their reproduction is inhibited, thereby reducing the diversity of species. The population of pollution tolerant species expands in the absence of their predators. Tolerant species of polychaetes include *Capitella capitata, Neanthes succinea,* and *Streblospio benedicti* (Reish, 1979). *Capitella* is the most universal and abundant polluted water benthic organism; consequently, it is the most commonly used indicator of pollution. However, since the organism normally resides in estuaries, its presence does not necessarily indicate a high level of pollution. It has a short life history and is therefore able to colonize an area rapidly (Reish, 1979).

Polychaetes, which are segmented worms, are often the dominant species in the soft bottom (Reish, 1979). In some studies, they have accounted for approximately 43 percent of the biomass and 70 percent of the annual productivity (Knox, 1977). They are a significant food source for fish and birds in shallow tidal zones. The principle abiotic conditions that have the most effect on benthic organisms include salinity, temperature, sediment size, dissolved oxygen content, and depth of the water. The primary determinant in the distribution of benthic organisms is sediment size (Reish, 1979). A large amount of sediment variability may exist in estuaries—from fine clay, to silt, to sand—depending on river runoff and current patterns. A number of species exhibit wide seasonal variation.

Dredging can affect benthic organisms in several ways: displacement from original habitat, burial under sediment, release of toxic chemicals from the sediment, and increased water turbidity (Reish, 1979). An increase in water turbidity has minimal effect on polychaetes. Studies have shown that a dredged area may repopulate within about 4 weeks (McCauley et al., 1977). Polychaetes have shown the ability to surface after being buried under sediment.

The benthic organisms identified during the present study were compared with population studies done by Boesch (1972, 1973) in the Hampton Roads area. Of the 81 different benthic organisms identified in the grab samples obtained from the sediment adjacent to the islands, approximately 50 percent were also described in Boesch's studies. Most of these organisms were described by him as summer or seasonal with sandy habitats. Construction of the islands involved sand deposits and may have contributed to the abundance of sand-dwelling benthics in the immediate vicinity of the islands.

Fish survive well in estuaries because of their motility and ability to escape adverse conditions. Some fish use estuaries as a breeding ground, since juveniles of the species tolerant to salinity changes are moderately protected within its waters. Fish populations on reefs appear to exhibit high turnover rates. This has been attributed to predation, seasonal variation, and emigration based on change in habitat requirements of maturing juveniles (Talbot, 1978). Storm-induced habitat disruption is felt to have a minimal influence on reef populations (Talbot, 1978).

Bird Populations

Birds use the islands for breeding, stopover, winter residence, and feeding from the reef offshore. The large breeding colonies of common terns and black skimmers are the islands' greatest contribution to the avifauna. Suitability of the islands for nesting has also encouraged nesting pairs of killdeer, mallards, and wrens.

Common Terns

Common terns in their Atlantic range naturally nest on barrier island beaches. In Virginia, where there is apparently ample suitable nesting habitat (Erwin, 1979), greater than 80 percent of the beach nesting shorebirds (common and least terns, herring gulls, and black skimmers) nest on barrier islands, which is their natural habitat (Erwin, 1980). In areas where the natural nesting grounds are in short supply, usually because of human disturbance, the displaced common terns nest on dredge spoil deposition islands or natural marsh islands. Some differences have been noted in nesting behavior (construction, spacing, and location of nests; colony stability; and reproductive success rates) between natural and alternative sites such as dredge spoil islands (Erwin and Smith, 1985; Erwin, et al., 1981; Erwin, 1977). The birds appear to prefer their traditional breeding grounds and are more productive on them (Erwin and Smith, 1985). Virginia tern populations have more natural nesting ground than in neighboring states such as New Jersey or North Carolina, where, probably because of heavy recreational beach development, the great majority of colonial nesters employ artificial nesting grounds.

Black Skimmers

The black skimmer breeding season is similar to that of the common terns; it extends from late April or early May through late July or early August. Black skimmers breed in dense colonies and frequently associate in breeding colonies with other seabirds. In Virginia, the most common association is with common terns, although nesting associations have occurred with gull-billed terns as well (Soots & Parnell, 1975; Erwin, 1977). The association may serve several purposes. The earlier nesting common terns may provide a location cue to the black skimmers (Erwin, 1977). Common terns are also a more aggressive species, and the black skimmers benefit from this in colony protection from predators.

Black skimmer colonies are generally located on bare or sparsely vegetated barrier or dredge spoil islands (Soots and Parnell, 1974, 1975). Black skimmer colonies have considerable yearly variation in location (Erwin, 1977). The nests are simple scrapes, and egg laying begins around the third week of

May. Clutch sizes are slightly larger compared to other seabirds, averaging four eggs (Erwin, 1977).

Terns and skimmers may breed in the same places for many years or abandon previous sites for new ones. The seeking of new sites is believed to result from instability at the previous site (Morris and Hunter, 1976).

A significant amount of available natural island habitat is unoccupied by colonial seabirds in Virginia. However, Burger and Lesser (1978) found that despite the low percentage of islands utilized by the birds (13 percent of 259 in their study), only three unoccupied islands in the survey were similar in certain parameters to the islands used for nesting. Size, location relative to other islands or the mainland, and the depth of water surrounding the island appear to be particularly important.

Both species of colonial birds found on the Hampton Roads South island demonstrate considerable variation in the microenvironment of their nesting area (Erwin, 1977). It may range from open sand to dense, low grasses. In fact, on this island, some variability exists in vegetation throughout the island during the nesting season. Through the years, the island has also become more heavily vegetated.

If the Hampton Roads tunnel islands are analyzed by the criteria for selection of colony sites of common terns defined by Burger and Lesser (1978), an interesting pattern emerges. The south Hampton Roads Tunnel island closely resembles the "average" island preferred by common terns in size, dimensions, and location. The north island, in contrast, is unlike the typical nesting islands in size and distance from shore.

Factors that probably contribute to the desirability of the south island as a nesting site include absence of predators, availability of food, lack of human disturbance, and low, sparse vegetation intermixed with loose gravel. The major predators of these birds are rats, foxes, dogs, and gulls. In 1985, rats were identified on the south Hampton Roads island, causing concern about the effects of their predation on the eggs and young birds. VDOT implemented a rat eradication program in the fall of 1985, and no evidence of rat predation was observed in the following breeding season. Foxes and dogs are not found on the island. Herring, great black backed and ring billed gulls have been observed on the island, but nesting has not occurred. The location of the island at the junction of Hampton Roads and the Chesapeake Bay ensures an adequate supply of fish. During the nesting season between May and July the primary areas of nesting on the South Island are roped off, and signs are posted to discourage human visitation. In general, short periods of human intrusion do not appear to have a significant effect on bird colonies, but a prolonged stay in proximity to the colony may cause the parents to be absent from the nests long enough to expose the eggs to the hot sun or to predation by gulls. Activities of the VDOT employees on the island conform well to these requirements, since most of the area of the colonies remains unused throughout the year except for the occasional passage of vehicular traffic to which the birds rapidly become accustomed.

Studies of the vegetation and birdlife of dredge spoil islands have shown the use of the islands for colonial bird nesting to be related to the succession of plants (Soots and Parnell, 1975). Common terns and black skimmers begin nesting on dredge islands when sparse vegetation is established. Chicks use the patchy vegetation as shelter from the sun, while nests are built on the bare shelly areas or clumps of seaweed washed ashore. The birds prefer a coarse shelly substrate and do not nest on silty islands (Soots and Parnell). The HRT islands are covered with gravel that resembles a shelly substrate. VDOT has adopted a pattern of mowing that does not disrupt the nests and maintains the vegetation at a height attractive to the birds.

It would appear that artificial islands could be designed using these criteria to attract or discourage nesting.

Management

VDOT has been cooperating with the Virginia Game and Inland Fisheries and William and Mary College to promote the safe nesting of the birds. The sensitive nature of the colonies is marked by signs, and personnel avoid these areas during the nesting season. Of considerable importance to the development of the wildlife on the island is the fact that the island is closed to the general public. VDOT has maintained a program of rat eradication and mowing schedules are arranged to prevent disturbance of the colonies.

Artificial nesting sites are of vital significance to shorebirds for continued population growth and stability. In states such as New Jersey, there are few available nesting sites; the restriction of birds to a few highly concentrated sites leaves them vulnerable to natural or manmade disasters such as oil spills or severe predation (Erwin, 1980).

RESULTS

The grab samples of March, April, and September yielded individuals from 81 genera, 64 of which could be identified to species (see the Appendix). The most abundant of the 12 phyla represented was the Polychaetes. Individuals of the phylum Polychaetes comprised 34.6 percent of the total organisms collected. A single organism in the Oligachaeta (*Tubicifoides* spp.) was the most prevalent and caused that phylum to rank second in species abundance, 32.4 percent in the spring and 21.9 percent in the fall.

The spring samples were dominated by Polychaetes (40.87 percent of individuals), but the phylum Amphipoda had the greatest number of individual organisms in October because of the large representation of *Caprilla penantis* (spring 1.1 percent, fall 39.7 percent). Prominent Polychaete organisms in the samplings were *Mediomastis ambiseta* (spring 6.8 percent, fall 11.7 percent), *Spio setosa* (spring 15.6 percent, fall 0 percent), *Nereis succinea* (spring 6.0 percent, fall 4.1 percent), *Polydora ligni* (spring 8.4 percent, fall 1.3 percent), *Sabellaria vulgaris* (spring 1.3 percent, fall 2.1 percent), *Streblospio benedicti* (spring 2.9 percent, fall 0.5 percent), and *Glycinde solitaria* (spring 0.1 percent, fall 2.1 percent). Species of other phyla comprised less than 1 percent of the total organisms.

Rank dominance analysis revealed similar trends to the percentage of abundance, but prompted consideration of several other species as important contributors to the population. In addition to the species previously listed, *Actevina canaliculata*, *Tellina agilis*, *Corophim insidiosum*, *Unciola serrata*, and *Bravia clavata* had total rank dominance scores greater than 5. A seasonal pattern was evident for some species.

The concrete substrates were added to an already stable reef community. The block surfaces readily colonized with marine growth similar to that already present on the surrounding hard substrate surface. Despite differences between concrete and rock substrates, rocks of comparable size to the blocks removed from the islands during sampling had populations similar to the concrete substrates. The concrete blocks had some instability during the study because of their small size, thereby contributing to the formation of growth on the upper and lower surfaces of the blocks, and this may have also been responsible for the areas of exposed free surface.

The block substrates were colonized with algae within 24 hours. It covered an average of 10.8 percent of the surface area of the blocks. There was a wide range, however, from no measured coverage to 29.3 percent. Red algae was the most abundant (9.2 percent), and it ranked third in rank dominance score.

In comparison with the soft sediment population that consisted primarily of small benthic organisms, the growth on the hard substrates was composed of hard and soft marine communities in a greater number of taxa. The additional organisms consisted of those requiring hard substrates, such as mollusks, barnacles, sponges, and algae. In comparing the taxa identified from the substrates and the dredge samples, only 5 species were found in both groups: 4 Annelida Polychaeta and 1 Chordata: Urochordata (Molgula manhattensis). The other 17 genuses identified on the substrates represent populations present as a result of the addition of the rock substrates. In analyzing the samples, the AFDW is tremendously greater in the samples from the substrates, which reflects the increase in carbon available. Increased carbon allows the support of higher levels of the food chain (another trophic level) and encourages feeding by fish and other creatures.

The investigators identified 26 species of birds during visits to the islands. In addition to the large nesting colonies of common terns and black skimmers, 6 other bird species were observed nesting on the islands. This includes mallard, killdeer, barn swallow, house wren, song sparrow, and house sparrow. The islands are used by numerous species as a stopping point during migration and are frequently visited by common bird species throughout the year.

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APPENDIX

Benthic Macrofaunal Taxa Identified from GRAB Samples

Benthic Macrofaunal Taxa Identified from Ekman GRAB Samples Collected in the Vicinity of the Hampton Bridge Tunnel

CNIDARIA : ANTHOZOA Anthozoa spp.

RHYNCHOCOELA

Nemertea spp.

ANNELIDA : POLCHAETA

Apoprionospio pygmaea (Hartman)
Capitellidae sp. (juv.)
Capitella capitata (Fabricius)
Cirratulidae spp. (juv.)
Clymenella torquata (Leidy)
Eteone heteropoda (Hartman)
Eumida sanguinea (Oersted)
Exogone dispar (Webster)
Glycera americana (Leidy)
Glycera dibranchiata (Ehlers)
Glycera sp. (juv.)
Glycinde solitaria (Webster)
Gyptis brevipalpa (Hartmann-Schroder)
Heteromastus filiformis (Claparede)
Hydroides dianthus (Verrill)
Leitoscoloplos fragilis (Verrill)
Maldanidae sp. (juv.)
Mediomastus ambiseta (Hartman)
Nereis succinea (Frey and Leuckart)
Paraprinospio pinnata (Ehlers)
Pectinaria gouldii (Verrill)
Phyllodoce arenae (Webster)
Podarke obscura (Verrill)
Polycirrus eximius (Leidy)
Polydora ligni (Webster)
Polydora socialis (Schmarda)
Polynoidae sp. (juv.)
Sabella microphthalma (Verrill)
Sabellaria vulgaris (Verrill)
Scolelepis bousfieldi (Pettibone)
Scolelepis texana (Foster)
Spiochaetopterus oculatus (Webster)
Spionidae sp. (juv.)
Sthenelais boa (Johnston)
Streblospio benedicti (Webster)
Syllides verrilli (Moore)

ANNELIDA : OLIGOCHAETA

Tubificoides spp.

MOLLUSCA : GASTROPODA

Acteocina canaliculata (Say)
Crepidula fornicata (Linne)
Crepidula sp. (juv.)
Epitonium rupicola (Kurtz)
Eupleura caudata (Say)
Mitrella lunata (Say)
Nudibranch sp. (juv.)
Odostomia sp.
Rictaxis punctostriatus (Adams)
Turbonilla interrupta (Totten)
Turridae sp.
Urosalpinx cinerea (Say)

MOLLUSCA : BIVALVIA

Ensis directus (Conrad)
Gemma gemma (Totten)
Mercenaria mercenaria (Linne)
Parvilucina multilineata (Tuomey & Holmes)
Tellina agilis (Stimpson)

ARTHROPODA : TANAIDACEA

Leptochelia savignyi (Kroyer)

ARTHROPODA : ISOPODA

Edotea triloba (Say)
Erichsonella filiformis (Say)
Idotea balthica (Pallas)
Leptochelia savignyi (Kroyer)

ARTHROPODA : AMPHIPODA

Ampelisca vadorum (Mills)
Ampithoe longimana (Smith)
Ampithoe valida (Smith)
Aonidae sp. (juv.)
Caprella penantis (Leach)
Corophium insidiosum (Crawford)
Cymadusa compta (Smith)
Elasmopus levis (Smith)
Erichthonius brasiliensis (Dane)
Gammarus mucronatus (Say)
Melita appendiculata (Say)
Unciola serrata (Shoemaker)

ARTHROPODA : DECAPODA

Pagurus sp.
Pinnixa sayana (Stimpson)
Pinnixa sp. (juv.)
Rhithropanopeus harrisii (Gould)
Upogebia affinis (Say)
Xanthidae sp (juv.)

PHORONIDA

Phoronis psammophila (Cori)

CHORDATA : UROCHORDATA

Molgula manhattensis (DeKay)