United States Patent [19]

Boots

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[54] **ARTIFICIAL REEF**

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[52] **U.S. Cl.** **119/1;** 119/4; 61/3; 61/4

[51] **Int. Cl.** **A01k 61/00;** E02b 3/04

[58] **Field of Search** 61/3, 4, 5, 37; **119/1,** 119/4

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[57] **ABSTRACT**

A method and apparatus for preventing erosion of a beach, including an artificial reef for subsurface placement adjacent a shoreline and made up of a base reef set on the seabed and an upper reef preformed and mounted to the base reef or formed in situ on the base reef by a sabellariid marine organism thereby forming a composite reef to build up accretion of sand on the shore side of the reef and to prevent erosion of a beach.

4 Claims, 6 Drawing Figures

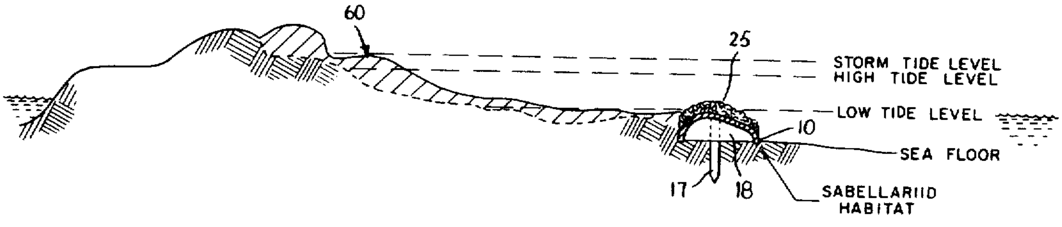
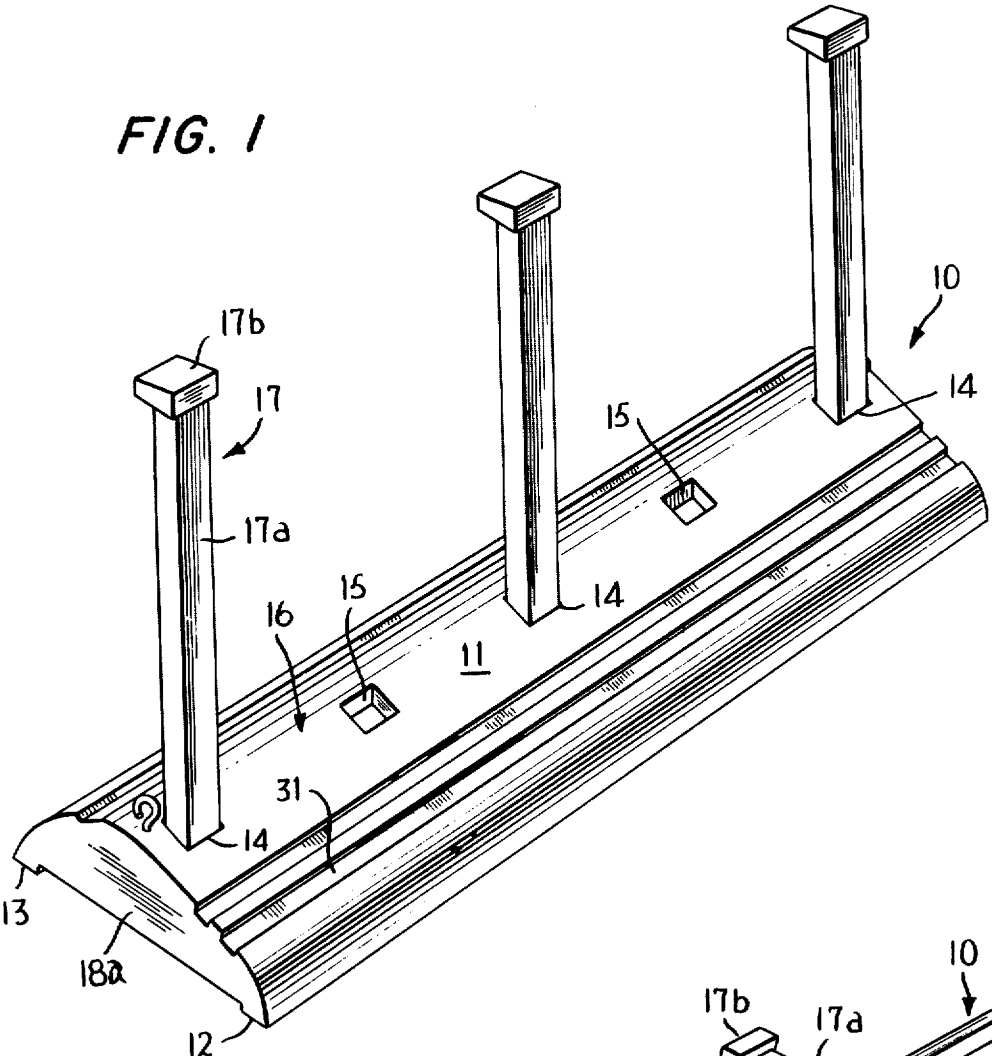


FIG. 1


17b
17
17a
16
15
11
14
15
10
14
31
14
13
18a
12

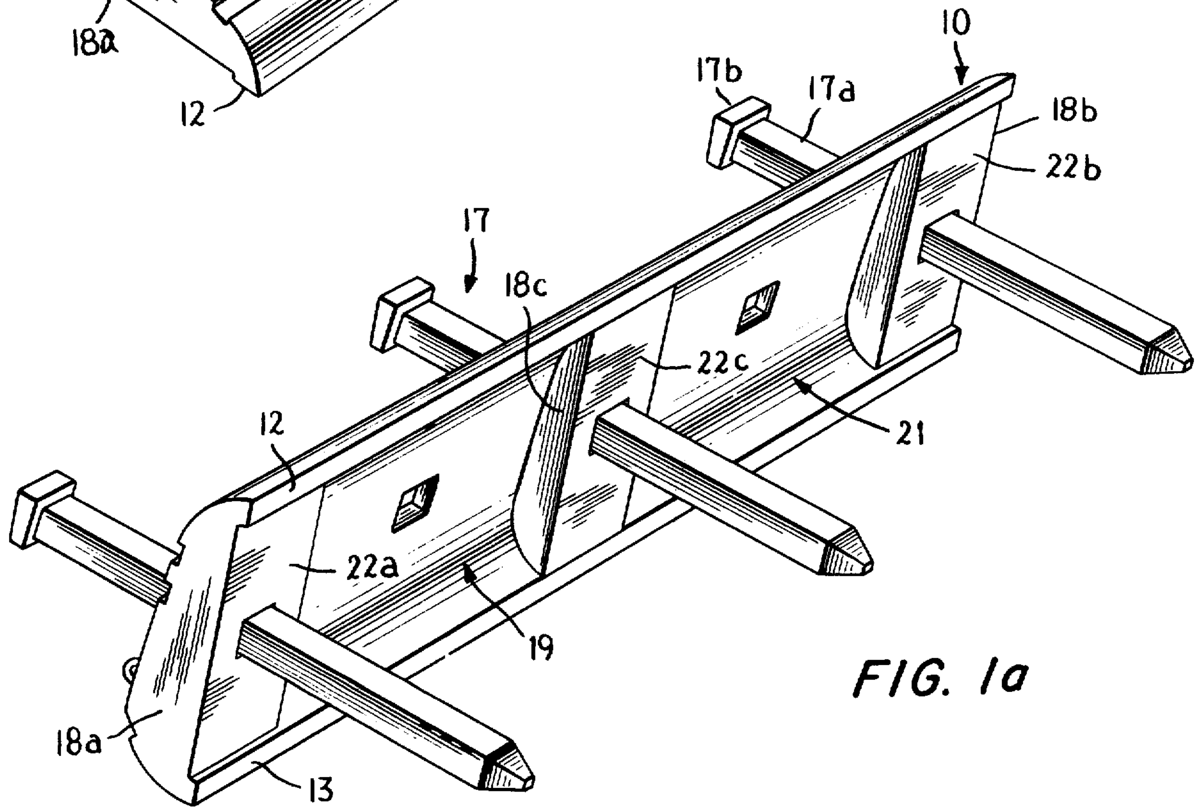

10
17b
17a
18b
22b
17
18c
22c
21
12
22a
19
18a
13

FIG. 1a

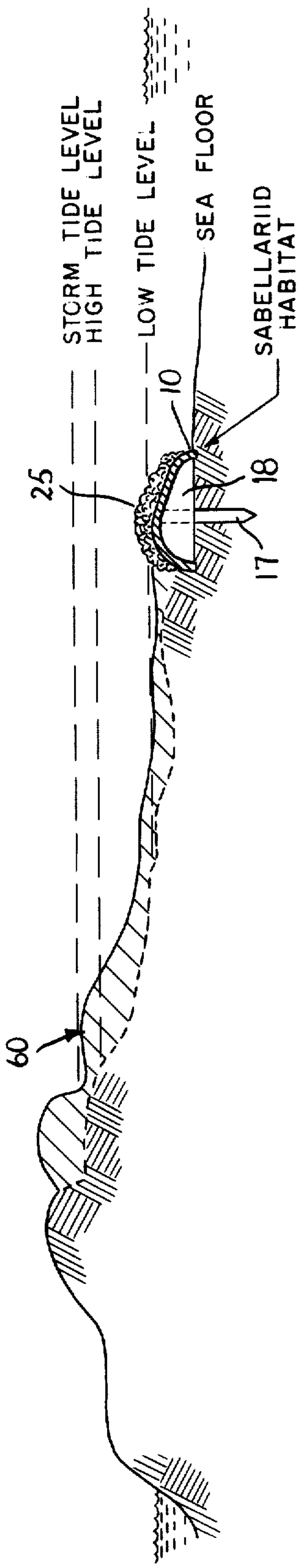

STORM TIDE LEVEL
HIGH TIDE LEVEL
LOW TIDE LEVEL
SEA FLOOR
SABELLARIID HABITAT
25
10
18
17
60

FIG. 2

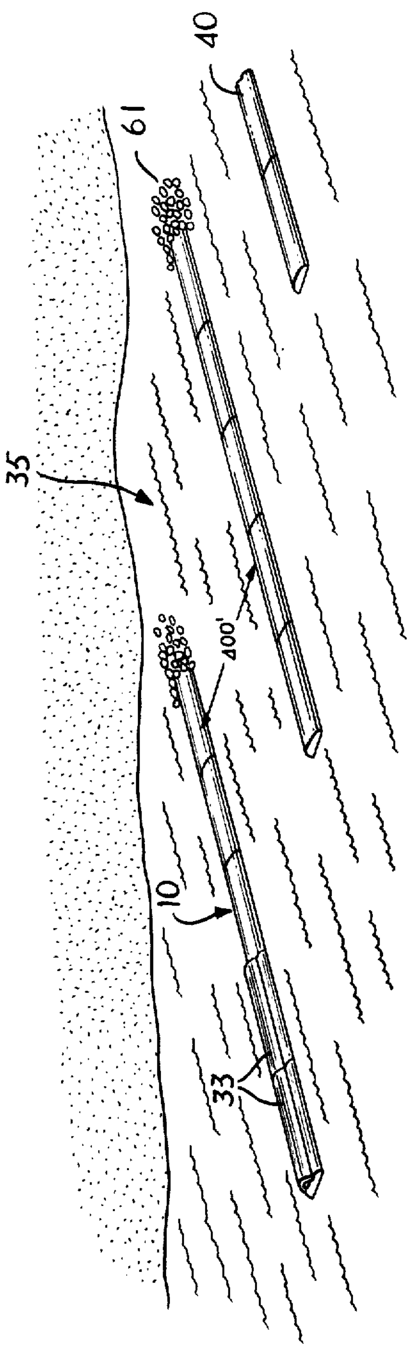

40
61
35
400'
10
33

FIG. 3

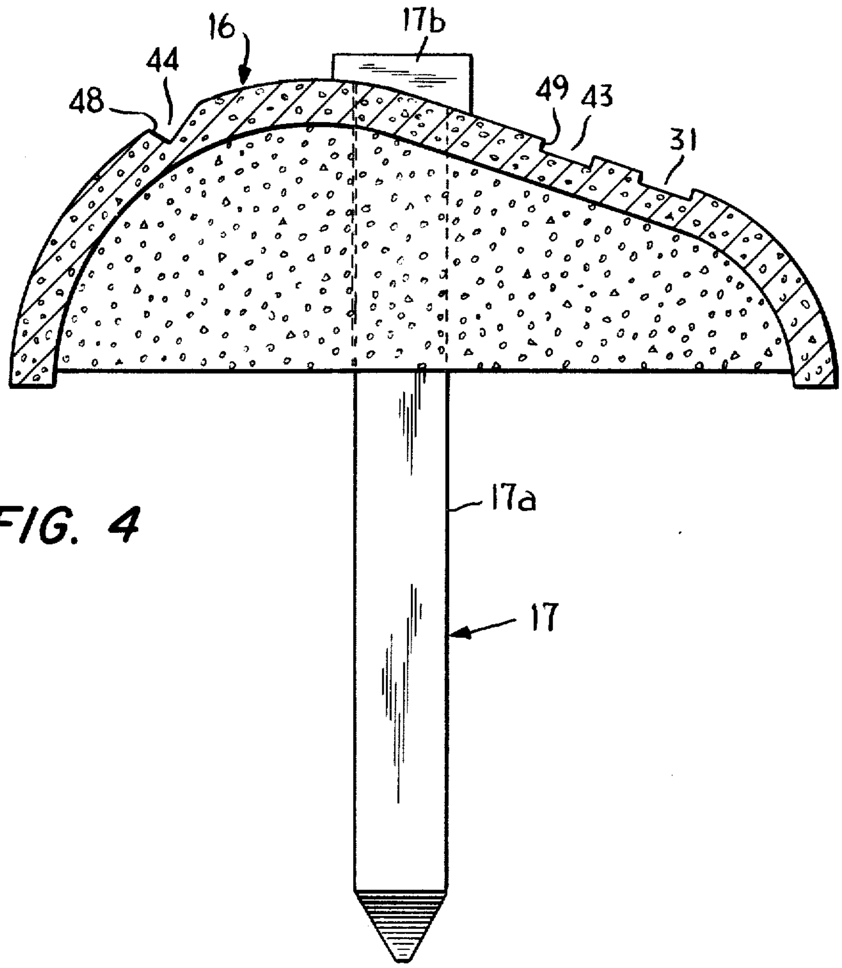


FIG. 4

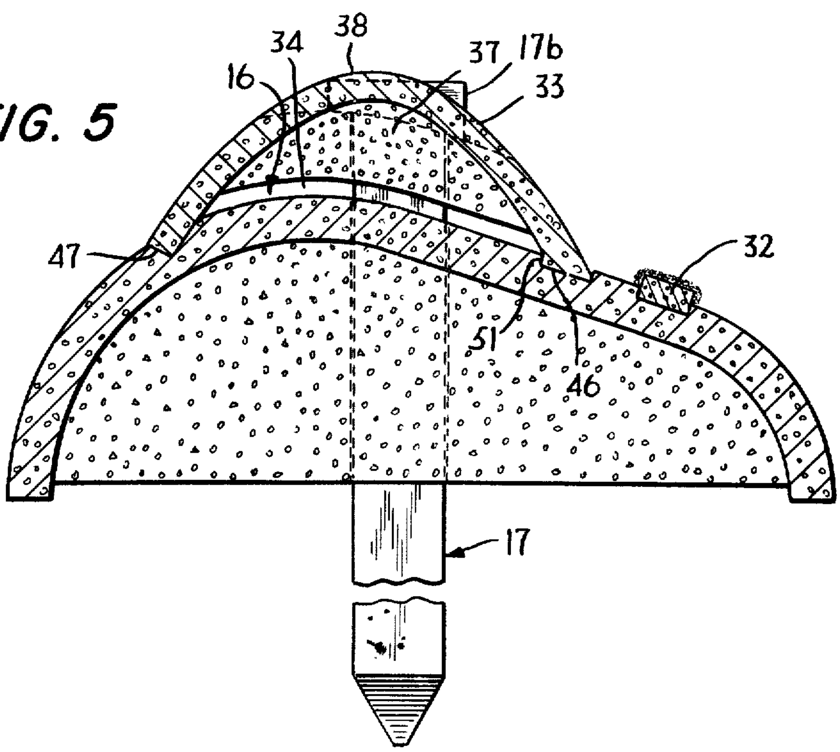


FIG. 5

ARTIFICIAL REEF

The present invention relates to artificial ocean reefs and in particular to a composite reef which includes one or more base reefs built up in height by either a marine organism implanted thereon or an upper reef element mounted thereon, the composite reef serving to interrupt the prevailing ocean currents and wave patterns in the vicinity of the beach to restore balance between accretive and erosive influences on the beach.

BACKGROUND OF THE INVENTION

The ecological problems of the shoreline have recently been receiving a great deal of attention, particularly in the form of studies, national in scope, in which the significance and extent of the shore erosion has been assessed. For example, it has recently been determined that of the approximately 85,000 miles of total shoreline of the United States, significant or critical shoreline erosion appears over approximately 2,700 shoreline miles.

The erosion of sand beaches is one aspect of the general shoreline problem referred to above and is especially significant in view of its commercial impact for certain shore communities.

The degradation of sand beaches through natural erosion is a complex problem. The most pervasive and persistent influence on alteration of the beach appears to be the continuous assault by the ocean, particularly those ocean currents developed during severe storms. An additional contribution to beach erosion is often made by the so-called littoral currents adjacent the beach which move in a direction parallel to the shoreline.

Under normal circumstances the movement of beach sand onto and off of the beach reaches an equilibrium state in which sand is deposited on and removed from the beach in a substantially regular cyclical process. This process appears to vary with weather conditions which affect the intensity and direction of the prevailing wave and wind action.

Critical beach erosion normally results when this natural balance is upset in some way, and there is a resulting net movement of sand away from the beach. Such interference with the natural accretion-degradation cycle typically results when sea walls or the like are emplaced on the shore in order to protect a commercial or residential development from the sea. During a storm, for example, aggravated ocean waves impinge upon the sea walls and are deflected downwardly thereby to carry sand off the beach and into the ocean. In the absence of normal protective sand dunes, nothing remains on the shore with which to replace the sand that has been removed from the beach in this manner. Over a period of time the result may be a net flow of sand from the beach. Such erosion by severe storms frequently exceeds the economic capabilities of the nearby communities to replenish the beach materials.

Even under normal weather conditions, the ocean turbulence at the shoreline causes a suspension in the water near the shoreline of sand and shell fragments. These suspended materials may be transported along and substantially parallel to the shore by a phenomenon known as the littoral or longshore current. This current results from interference between incoming waves, which generally approach the shore obliquely, and backwash from the beach.

Normally beach materials transported in this fashion are being picked up and deposited at various locations along the shore. Over a sufficient period of time, the littoral transport of beach materials would not be expected to create an erosion problem. However, this natural balance of ecological forces acting on the beach may be interrupted by the presence of artificial or natural interference with the normal ocean current and wave action adjacent the beach. For example, river currents emptying into the sea can cause the littoral material to be deposited outwardly away from the land. Dredging operations near the shoreline can also cause the littoral material to settle out of the water away from the beach. In addition, man-made formations which project outwardly from the shore frequently act to disrupt the movement of the longshore currents thereby causing an unnatural deposition of littoral material away from the shoreline. The effect of these occurrences in a particular location is frequently a net flow of sand away from the beach. A critical erosion situation may thereby quickly develop.

Many different attempts have been made heretofore to develop a solution to these problems. One approach has been to ignore the erosion process and to replenish an eroding beach periodically with sand and other suitable materials from some other source. This approach is expensive and is only suitable in situations where sand may be readily obtained from nearby inlets, bays or other areas without damaging the regional ecology. Where such a supply of beach material is not readily available, the cost of obtaining the necessary sand is generally prohibitive.

Another approach which has been attempted heretofore is the construction of artificial groins or the like which may be spaced along the shoreline oriented substantially perpendicularly to the shoreline. The use of such groins not only significantly degrades the appearance of the beach but is generally only effective when large amounts of sand are being transported by the longshore currents. In addition, construction of such groins, while tending to induce the accretion of sand on the updrift side, frequently results in serious erosion of the beach on the downdrift side. The net result of such erosion is generally a requirement for substantial amounts of sand from other areas with which to replenish the eroded area. The cost of such groins, along with the added cost of importing sand from another source, makes this solution to the problem impractical for most communities.

Still another approach for preventing beach erosion is the construction of artificial breakwaters. Such breakwaters may take the form of massive stone structures which are placed in the sea outwardly from the beach area and substantially parallel to the shore. Generally, these breakwaters serve to interrupt wave action before the wave actually reaches the shore, thereby to induce a relatively calm area on the beach side of the breakwater. As a result of the induced calm, the suspended sand in transit may be deposited inwardly of the breakwater. Beaches which are located downdrift of the breakwater, however, may be deprived, as a result of the breakwater, of sufficient amounts of naturally deposited beach materials with which to offset the natural forces of sand depletion. Thus, as to such downdrift beaches, the normal deposition of the suspended materials is interrupted with the result that there is frequently a net movement of sand away from the beach.

SUMMARY OF THE INVENTION P

An object of the present invention is to provide a practical method and apparatus for offshore reef construction which serves to correct an imbalance in the natural accretion-degradation cycle so as to prevent substantial erosion of a beach area by the net movement of beach materials away from the shore.

Another object of the present invention is to provide an offshore submerged reef structure in a form which may be transported to and implaced in the desired offshore location and built up to a desired height.

Still another object of the present invention is to provide a means and method for securing an offshore reef structure to the ocean floor.

A further object of the present invention is to provide an offshore reef structure which will tend to entrap sand and other materials within an internal cavity thereof so as to become substantially self-stabilizing.

A still further object of the present invention is to provide an offshore reef structure which is an artifical habitat for a reef building marine organism known as phragmatopoma lapidosa, or sabellariid.

Yet another object of the present invention is to provide a method for implanting a sabellariid colony on an artificial reef structure submerged adjacent a shoreline.

Another object of the present invention is to provide a system of sabellariid reefs adjacent a shoreline and oriented so as to facilitate the accumulation of sand in the beach area.

These and other objectives of the present invention can be achieved by constructing one or more artificial reefs within the ocean along the shoreline. Although such reefs would ordinarily be too heavy and cumbersome to be handled and set in place or, if built of lighter weight materials, destroyed by the impact of the ocean currents and waves, the present invention provides a composite reef made up of a heavy and durable base reef element built up in size, and particularly in height, by an upper reef element composed of a marine organism implanted thereon or a preformed upper reef element mounted thereon. In this manner a heavy, durable artificial reef can be built up in situ to a size and height that would ordinarily be too cumbersome to handle and set in place.

The base reef element is preferably secured to the ocean floor by pile members or stakes which are passed through the base element and driven into the ocean floor. The base reef element may serve as the habitat for an implanted marine organism, such as a sabellariid organism, which over the years will continue to grow and build up the size and height of the reef. On the other hand, if the artificial reef is used in deeper waters where an increase of height in the base reef is required immediately to permit the reef to be effective, a preformed upper reef element may be mounted on the base reef element and the marine organism may be implanted on the upper reef element or eliminated entirely.

The base reef element is preferably of inverted U-shaped cross section having openings therein to permit sand and other particulate matter normally held in suspension in the sea water to deposit and settle within the reef structure to afford it greater anchorage and stability.

The composite artificial reefs are preferably arranged substantially end-to-end and relative to the shoreline so as to interfere with the destructive shoreline currents by deflecting the incoming waves. This deflection interrupts the rhythm and intensity of the incoming waves and thereby minimizes the adverse effects of the waves on the beach. In addition, the interruption permits sand and other suspended particles in the ocean water to settle out and accumulate on the shore side of the reef.

BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the present invention, reference may be had to the accompanying drawings, in which:

FIG. **1** is a perspective view of a base reef element adapted for securement to the ocean floor;

FIG. **1***a* is a perspective view of the underside of the base reef element of FIG. **1**;

FIG. **2** is a schematic sectional view of one embodiment of the artificial reef anchored in position adjacent the shoreline and showing accumulated beach material on one side thereof;

FIG. **3** is an elevated view of a portion of a beach protected by a reef system of the present invention;

FIG. **4** is a cross sectional view of the reef of FIG. **1**; and

FIG. **5** is a cross sectional view of the base reef element having a preformed upper reef element mounted thereon.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and in particular to FIG. **1**, there is illustrated a base reef, generally indicated by reference numeral **10**, which is adapted for use in an artificial reef system. The base reef **10** is preferably of substantially inverted U-shaped cross section having a relatively flat, downwardly sloped surface **11** on its outer seaward side. The base reef **10** rests on the lower terminal edges **12** and **13**.

The base reef **10** is provided with a plurality of openings **14** and **15** spaced along the top **16** of the base reef. The openings **14** are each adapted to receive a concrete pile or stake **17** which secure the reef to the ocean floor.

The base reef **10** is placed in the ocean with the sloping portion **11** facing away from the shoreline. Thus, the surface **11** intercepts and deflects the incoming wave currents up and over the top of the reef. The slope of the surface **11** ensures that the vertically downward component of force imparted by the impact of a wave moving substantially horizontally against the reef acts to urge the base against the ocean floor. The horizontal component of force imparted by the wave impact is, as a result of the slope of the surface **11**, insufficient to unseat the reef.

Although this configuration of the reef is preferred because it provides increased stability to resist anticipated wave forces without excessive or unmanageable weight, nevertheless other configurations may be suitable provided that the resulting unit is not too heavy to prevent it from being handled and set in position.

The reef is preferably constructed of prestressed concrete, although other non-corrosive materials, such as ordinary reinforced concrete or asphalt, might also be utilized. Prestressed concrete is preferred because of its strength. It is also light enough to keep the total weight of each base reef within manageable limits.

As shown in FIG. **1***a*, each of the individual base reefs **10** has a plurality of substantially vertical integrally formed wall sections or baffles **18***a*, **18***b* and **18***c* which provide support for the undersurface of the arch. These wall sections divide the interior of the reef into chambers **19** and **21**.

A vertical bore communicating with the openings **14** extends through each of the wall sections. The bores permit passage of the anchoring piles downwardly through the wall sections and into the seabed to secure the reef to the ocean floor. The close tolerance between the piles and the interior surface areas defining the boreholes serves to stabilize the reef against rocking and swaying about the piles.

The openings **15** formed in the reef establish flow communication between the chambers **19** and **21** and the media surrounding the reef structure. Sand and other materials normally suspended in the ocean water pass through these openings and these materials settle to the bottom and gradually fill the chambers.

The holes **15** also permit the water pressure within the chambers **19** and **21** to correspond substantially to the pressure of water flowing across the base reef unit. A pressure imbalance might otherwise occur as impacting waves are deflected by the reef and flow across the crown thereof. Such an imbalance might, over a period of time, develop instability in the reef.

The lower edges **22***a* and **22***b* of the two end walls **18***a* and **18***b*, respectively, are above the terminal edges **12** and **13** of the base reef. The lower edge **22***c* of the middle partition **18***c* is substantially coplanar with the terminal edges **12** and **13** of the reef and, therefore, rests on the seabed. This arrangement prevents the flow of water between the chambers **19** and **20** so that water within each of the chambers becomes relatively quiescent. Under these conditions, materials suspended in the water beneath the reef will more readily settle out and accumulate within the chambers. The accumulation beneath the reef gradually increases with the passage of time to stabilize the reef.

The walls **18***a* and **18***b* close the ends of the reef. The closed ends are preferred because the reef will tend to be better stabilized. For example, where wall sections are recessed inwardly from the ends of the base reef, a horizontal ledge is defined by the undersurface of the arch adjacent each end. Wave turbulence developed during a storm may result in the application of an upward force against each such ledge. In the course of time, such a force might loosen the anchorage of the reef.

The piles or spikes **17** can be prefabricated from reinforced concrete and formed with a shank portion **17***a* and a larger head **17***b*. The piles or spikes can also be made of corrosion resisting steel, steel treated for corrosion resistance or other suitable non-corrosive material. The spikes are inserted through the reef and driven into the ocean floor until the relatively wide diameter head **17***b* engages the top of the reef. In this way, each base reef **10** may be essentially "nailed" to the ocean floor.

It may not be desirable to bring to bear against the head **17***b* the driving forces required to insert the spike into the ocean floor. Thus, in accordance with an alternate embodiment of the invention, the reef units may be fastened to the seabed by means of augered piles. In this technique a hollow drill is passed successively through each of the holes **14** in the reef and thence into the seabed for a predetermined distance. Concrete or other suitable material is introduced through the hollow drill into the holes drilled in the ocean bed. The drill is withdrawn while the material is still fluent so that the material will fill the holes drilled in the ocean bed and the passages through the walls **18***a*, **18***b* and **18***c*. The concrete may then be suitably capped off at the top of the reef and allowed to harden forming the piles or spikes which anchor the reef.

The reef structure may be adapted to serve as a fixed and stable habitat for a natural reef building marine organism **25**, for example, of the type known as phragmotopoma lapidosa, or sabellariid. An article detailing the nature and function of these organisms has been published by D. W. Kirtley, in the January 1968 issue of National History Magazine and is entitled "The Reef Builders". These marine organisms act to build a structure generally consisting of a plurality of cylindrical compartments glued together by the organism to form a colony of interconnected tubes. The organism lives within the compartment or tube that it builds. Each organism has a number of teeth and a plurality of feeding tentacles with which it grasps fragments of sand or crushed shell from the water. The fragments are licked clean of incrusting plants and are coated with a mucus cement-like glandular secretion. Each fragment is thereafter wedged into the tube structure.

This marine organism has been known to construct large natural reefs consisting of a honeycomb pattern of tube colonies. These natural reefs have been found in areas in which there is an abundance of tube building materials carried by turbulent waters. Colonies of this organism have been known to build an incrustation approximately ten inches thick within approximately six weeks.

An artificial reef structure composed of a plurality of individual base reefs **10** linearly aligned end-to-end along the ocean floor, such as is illustrated in FIG. **3**, will be more readily adapted as a suitable sabellariid habitat if oriented so as to be substantially perpendicular to the direction of the prevailing wave flow for the locale, or that is to say, parallel to the crests of the incoming waves. This arrangement is preferred since nutrients for the organism are carried inwardly with prevailing wave crests, and sabellariid covering a reef which is oriented substantially parallel to the crest lines of the incoming waves are more favorably disposed to intercept and absorb a maximum amount of such nutrient. While in the course of time, the sabellariid **25** may be expected to grow to cover most of the exterior surface area of the reef units, as indicated generally in FIG. **2**, the greatest concentration of tube colonies will occur in the more nutritious environment of the ocean side of the reef.

The natural rough texture of the concrete in the base reefs **10** may itself establish a surface suitable to sustain implantation of the organism. The surface of each of the base units may also be specially prepared to serve as a sabellariid habitat, for example, by providing a plurality of longitudinal grooves or recesses **31** and **43**, as shown in FIGS. **1** and **4**. Such grooves may provide a relatively safe location or shelter within which the organism might attach itself to the base reefs and begin its tube colony development. They may also serve to accomodate inserts **32** on which the organism has already become established. As illustrated in FIG. **5**, inserts **32** of a suitable material may be placed in the grooves **31** and **43** and attached to the base reef with the organism established on the surfaces which protrude outwardly from the surface of the reef. The grooves **31** may be approximately 1 to 2 inches deep, approximately 6 inches wide and from approximately 3 feet to a length substantially coextensive with the length of the corresponding base unit.

The sabellariid can be grown on strips **32** of suitable material, such as concrete, either in a remote "garden" containing a suitable nutrient media, or in the ocean itself. After sufficient growth of the sabellariid, the strips of concrete containing the incipient colonies to be transplanted are transported to the submerged reef units and fastened to the reef by any suitable means, for example, by fasteners or by use of an epoxy or waterproof adhesive. The transplanted colonies of sabellariid are more likely to survive the relocation when they are placed on the upper regions of the reef, preferably on the side facing the incoming waves.

Rapid sabellariid growth may be accelerated by providing patches of jellied food compositions on the surface of the reef near the developing sabellariid transplants. In the water, the prepared food substances ooze over and around the sabellariid thus facilitating growth of the natural structure.

The artificial reef implanted with the sabellariid organism, which I have characterized as a Sabecon reef, provides considerable advantages over prior artificial reef structures. The sabellariid have been known to survive hurricanes and have demonstrated a remarkable ability for rapid repair of any damage to the tube colonies. Thus, the Sabecon reef of the present invention requires little or no supervision and can be expected to maintain itself at virtually no expense to the shoreline community for repair and renovation. In addition, utilization of the natural growth tendencies of sabellariid colonies to develop the size of the reef permits savings with respect to initial expenditures for construction of the reef. Since the sabellariid can be relied upon to grow rapidly to an effective height, the base reefs can be made smaller and lighter than would otherwise be required, thereby facilitating their manipulation into proper position on the seabed.

If the artificial reef is to be placed in relatively deep offshore waters where added height is required immediately, the additional height can be obtained by mounting upper reef units **33** to the base reefs **10**, as shown in FIG. **5**. The upper reef units **33** are mounted along the crowns **16** of the base reefs **10** and can be arranged in end-to-end contiguous relationships, as shown, separated by gaps. The upper reefs can also be arranged to bridge and lock together adjacent base reef units.

As shown in FIG. **5**, each of the secondary units **33** is of substantially inverted U-shaped configuration. When mounted on top of a base reef, an interior space **34** is defined between it and the crown **16** of the underlying base reef. When the entire reef is submerged, water fills the space **34** and thus enters the chambers **19** and **21** beneath the reef through the openings **15** in the base unit.

Supplemental support from beneath the arch of each of the upper reef units **33** may be provided by one or more vertical walls **37** extending between the base reef **10** and the undersurface of the upper reef. The walls **37** are preferably integrally formed with the upper reef.

The upper reefs **33** are mounted on the base reefs by suitable mounting means, preferably by the piles or spikes **17** passing through passages through the walls **37** which passages are aligned with the openings **14.** The secondary reefs may thereby be attached to the base reefs after the latter have been submerged and set in place on the seabed.

If desired the upper reef unit **33** may be provided with a plurality of holes (not shown) to establish communication through the space **34** to the chambers **19** and **21** beneath the base reef **10** and to equalize the water pressure beneath and above the artificial reef.

With reference to FIG. **4,** each of the base reefs **10** may be provided with at least a pair of longitudinal recesses or grooves **43** and **44.** The grooves **43** and **44** are substantially parallel and are separated by the crown **15** of the base reef. The distance between the grooves is equal to the linear distance between the supporting edges **46** and **47** of the upper reef **33** so that the grooves **43** and **44** can receive the supporting edges **46** and **47,** respectively, when the upper reefs are mounted on the base reefs. To facilitate maximum stability, the grooves **43** and **44** may be shaped to conform precisely to the particular configuration of the base edges **46** and **47.** For example, the groove **44** may be provided with a seat or ledge **48** to engage the lower end **47** of the upper reef. Forces directed against the seaward side of the upper reef **33** will be transmitted through the arch of the reef **33** and tend to urge the end **47** against the seat **48.**

The groove **43** may be provided with an outwardly extending lip or shoulder **49** adapted to engage a corresponding surface **51** adjacent the end **46** of the upper reef. The interfaces between the ends **46** and **47** of the upper reef and the grooves **43** and **44** of the base reef assists the upper reef in resisting forces which might otherwise tend to displace the upper reef laterally relative to the base reef.

A reef system constructed in accordance with the present invention may consist of several substantially parallel rows of contiguous base reefs, as shown in FIG. **3,** each preferably submerged with the upper end thereof below the mean low water level and oriented substantially perpendicular to the direction of flow of the prevailing wave crests. The parallel rows of such artificial reefs may use only the base reef elements with or without sabellariid implants in shallow waters and composite reefs, consisting of an upper reef mounted on a base reef, in deeper waters, as shown in FIG. **3.**

The linear rows of reefs may be spaced apart, as indicated by the reference numeral **35,** at distances of approximately 400 feet. This separation between reefs permits waves reflected from the shoreline to escape through the downdrift reefs with only minimal interference. The littoral currents are thereby preserved in part although their capacity to effect a net flow of sand away from the beach is attenuated. The spacing **35** is ideally too close to allow a wave which passes over the outermost reef **40** from regaining its rhythm before impacting against the next reef on its way toward the shore. At the same time, the spacing **35** is sufficient so that some vestige of the prevailing littoral current is retained to preserve the quality of beach areas downdrift of the reef system. In such a reef system, the incoming waves will dissipate part of their energy in passing over each of the rows, building up sand or other deposits **60** on the shore side of each row, as shown in FIG. **2.**

In circumstances of excessive or prolonged ocean turbulence, it may be desirable to provide a plurality of sand bags or the like (not shown) to lie against each lineal row of the reef system along the entire length of the row on the landward side. The presence of the sand bags inhibits erosion of the seabed adjacent the reef and thereby helps to ensure long term stability. In addition, the inner end of each of the reefs may be enveloped within a pile of rocks or sand bags **61**, as shown in FIG. **3**, to facilitate stability of the reef.

I claim:

1. A method for protecting a shoreline against undesirable erosion by positioning an artificial reef offshore to serve as a favorable habitat for sabellariid marine organism, comprising the steps of submerging a plurality of solid one-piece base reefs substantially end-to-end on the seabed adjacent and oblique to the shoreline, such that one end of the artificial reef is closer to the shoreline than the other end, each of said base reefs having an upper crown portion and a pair of spaced depending sidewalls each forming a substantially continuous interface surface extending from the seabed to the top of said reef, the lower ends of said sidewalls being adapted to be set on the seabed to define a chamber extending the length of the base reef between the seabed and the interior surface area of said sidewalls and said crown, said base reefs having an opening into said chamber in said crown to provide access to the chamber for sand and water, the mean water level relative to the seabed at the points of placement of said base reefs being no less than the height of the artificial reef, and permitting the sabellariid organisms to form an upper reef on said base reefs.

2. The method of claim **1** comprising the steps of securing a prefabricated upper reef on at least some of said base reefs, said upper reef having a cross section of inverted substantially U-shape open at the bottom with the lower ends thereof engaging an upper surface of said base reefs and having chamber defined between said upper surface of said base reefs and the interior surface area of said upper reef.

3. A method of building an artificial reef for placement on a seabed adjacent a shoreline, comprising the steps of submerging a base reef adjacent the shoreline, cultivating a colony of sabellariid marine organisms on a transplant support in a nutrient media, transporting said transplant support to the base reef, and affixing said transplant support to the base reef, the organisms on said support forming an upper reef on the base reef to increase the height of the reef.

4. The method of claim **3** comprising the step of applying a nutrient composition to the surface of said base reef to facilitate growth on said base reef of said sabellariid marine organisms.

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