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(54) **Title:** NUTRIENT ENRICHED MINERAL SUBSTRATE FOR PROPAGATING MARINE LIFE

(57) **Abstract:** Many types of artificial reefs have been deployed in the world's oceans, bays and estuaries. These range from sinking ships to dispersing old building debris. In most approaches, the material placed in the marine environment lacks any nutrients needed for growth or concern regarding proper chemical conditions necessary to start and sustain life. In this discovery, concrete is made from both inorganic and organic components. The inorganic components are selected to include species that will be used to create a receptive surface to start and sustain life. Moreover, other conditions such as pH, chemical toxicity, nutrient levels and biodegradability are considered in the formulation. Additionally, there is an organic component that is part of the concentration mixture which provides trace nutrients and serves to weaken the structures so it will biodegrade over time. The biodegradable concrete slowly releases small quantities of resources (over months and years) providing a steady flux of essential nutrients.

Title of the Invention

Nutrient Enriched Mineral Substrate for Propagating Marine Life

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Related Applications:

Patent #	Issued date	Inventor	Title
US2017090	15-Oct-35	Jr William Eggert	Fertilizer and method of fertilizing
US3155609	3-Nov-64	Pampel Leonard Fredrick	Stabilization of a closed or open water system through the selective utilization of light
US3238279	1-Mar-66	Tarlton John	Method for curing concrete products
US3572292	23-Mar-71	Canadian Patents Dcv	Artificial oyster clutches
US4047962	13-Sep-77	Copeland Concrete Products Inc.	Construction composition
US4080929	28-Mar-78	Millnitz Ronald	Method and apparatus for brooding fish
US4395970	2-Aug-83	Kunkle Arthur	Open clean habitat for shell fish
US4594965	17-Jun-86	Asher Jr Donald	Marine husbandry system
US4468885	4-Sep-84	Mandish Theodore	Hydroponic system with floating plant trays and precast concrete sidewalls
US4843112	27-Jun-89	Beth Israel Hospital Assoc.	Bio-erodible implant composition
US4788937	6-Dec-88	Keyser George	Oyster bed fostering
US4903636	27-Feb-90	James Kroeker	Artificial habitat for aquatic animals
US4844015	4-Jul-89	Univ Of Delaware	Artificial oyster cultch
US4996943	5-Mar-91	Univ Of Delaware	Process for preparing cultch for Mollusca
US4997311	5-Mar-91	Doren David Van	Artificial reef
US5579724	3-Dec-96	Chauvin; Leroy	Oyster holder for oyster growing system
US6036933	14-Mar-00	Pretoria Portland Cement Comp. Ltd	Calcium carbonate precipitation method
US5803660	8-Sep-98	Warren; Donald	Integrated reef building system
US5704313	6-Jan-98	Gibbs; Mitchell	Rotating aquarium

US5836265	17-Nov-98	Barber; Todd Ryan	Reef ball
US5782204	21-Jul-98	Tidaltronics Inc.	Wavemaker for living aquariums
US5921203	13-Jul-99	Gibbs; Mitchell	Rotating aquarium
US5967088	19-Oct-99	Lin; Hsi-Chun	Watertight plug structure for an aquarium
US6264736	24-Jul-01	Board of Supervisors of LSU and Agricultural and Mech. College	Pressure-assisted molding and carbonation of cementitious materials
US6520116	18-Feb-03	Penn Cove Shellfish Llc	Method and apparatus for supporting aquacultured mussels
US6467993	22-Oct-02	Philip Utter	Fish attractive device
US6539894	1-Apr-03	Eagle Net Sea Farms Inc.	Aquaculture farm system and method
US6578523	17-Jun-03	Gilles Gagnon	Mussel cultivation device
US7997231	16-Aug-11	Madelaine Joy Fernandez	Composition suitable for aquatic habitat repair, replacement and/or enhancement
US6897382	24-May-05	Neptco Jv Llc	High modulus fibers primarily surrounded by and encased by a saturant that fills the interstices between each fiber and having a melting point below 300 degrees Celsius and a melt viscosity of less than 1000 centipoise.
US6896445	24-May-05	Eric Engler	Modular artificial reef, sea wall and marine habitat
US6962130	8-Nov-05	Kennedy James	Garden pond shelter reef
US7285238	23-Oct-07	Reefmattes Llc	Reef artifact
US2006011289 5	1-Jun-06	Laurent Olivier	System for raising aquatic animals
US7144196	5-Dec-06	Ora Technologies Llc	Biologically-dominated artificial reef
US7736430	15-Jun-10	William Marsh Rice Univ.	Compositions and methods for controlling the setting behavior

			of cement slurries using carbonated fly ash
US7748349	6-Jul-10	Open Ocean Systems Inc.	Submersible cage and system for fish farming
US2008021675 7	11-Sep-08	Kuo-Tang Tseng	Breeding tank
US7827937	9-Nov-10	David Walter	Marine line form habitat
US7735274	15-Jun-10	Calera Corp.	Hydraulic cements comprising carbonate compound compositions
US2009002004 4	22-Jan-09	Constantz Brent	Containing salt-water derived, crystalline and/or amorphous carbonate such as aragonite; building, construction materials
US7744761	29-Jun-10	Calera Corp.	Carbon dioxide sequestration; industrial waste gas streams from power plants; for construction materials, concrete, cements
US2009000102 0	1-Jan-09	Constantz Brent	Desalination methods and systems that include carbonate compound precipitation
US8006645	30-Aug-11	Spartz Karen	System and method for aquaculture of marine life forms
US7790012	7-Sep-10	Calera Corp.	On applying a low voltage across the anode and cathode, OH ⁻ forms at the cathode and protons form at the anode without Cl ₂ or O ₂ forming at the anode; depending on electrolytes used, NaOH, forms in 2 nd electrolyte in contact with cathode and HCl form in 1st electrolyte in contact with the anode
US2011003672 8	17-Feb-11	Calera Corp.	Low-energy electrochemical proton transfer system and method
US2009016945 2	2-Jul-09	Constantz Brent	Methods of sequestering CO ₂
US7753618	13-Jul-10	Calera Corp.	Rocks and aggregate, and methods of making and using the same

US2010002468 6	4-Feb-10	Brent Constantz	Contacting a CO ₂ containing gaseous stream with a water to dissolve CO ₂ , placing the water under precipitation conditions sufficient to produce a carbonate containing precipitate product (CaCO ₃ , MgCO ₃ or calcium magnesium carbonate); CO ₂ sequestering; reducing global warming;
US7754169	13-Jul-10	Calera Corp.	An aqueous solution of flue gas/combustion ash contacted with carbon dioxide; hydration of oxides to hydroxides; precipitated to provide calcite and magnesium carbonate; building material product for hydraulic cement, pozzolanic cement, and an aggregate; sulfur trioxide, NO _x gas also used
US2010000044 4	7-Jan-10	Brent Constantz	Methods and systems for utilizing waste sources of metal oxides
US2010031958 6	23-Dec-10	Savannah River Nuclear Solutions, Llc	Carbon dioxide capture from a cement manufacturing process
US7875163	25-Jan-11	Calera Corp.	Low-voltage, low-energy electrochemical system and method of producing hydroxide ions and/or bicarbonate ions and/or carbonate ions utilizing significantly less than the typical 3V used across the conventional anode and cathode to produce the ions; reduced carbon dioxide emissions
US7749476	6-Jul-10	Calera Corp.	Production of carbonate-containing compositions from material comprising metal silicates
US2010011181 0	6-May-10	Brent Constantz	Non-cementitious compositions comprising CO ₂ sequestering additives

US2012005537 6	8-Mar-12	Aalborg Portland A/S	Portland limestone calcined clay cement
US2010025803 5	14-Oct-10	Brent Constantz	Compositions and methods using substances containing carbon
US2010031379 4	16-Dec-10	Constantz Brent	Production of carbonate- containing compositions from material comprising metal silicates
US2010023946 7	23-Sep-10	Brent Constantz	Methods and systems for utilizing waste sources of metal oxides
US2011006760 0	24-Mar-11	Constantz Brent	Methods and compositions using calcium carbonate
US2011007130 9	24-Mar-11	Constantz Brent	Methods and Systems for Utilization of HCl
US2011005408 4	3-Mar-11	Constantz Brent	Hydraulic cements comprising carbonate compound compositions
US8177909	15-May-12	Calera Corp.	Methods and compositions using calcium carbonate
US2012003130 3	9-Feb-12	Constantz Brent	Calcium carbonate compositions and methods thereof
US2011028392 9	24-Nov-11	Stewart Hardison	Mooring structure with habitat features for marine animals
US8267045	18-Sep-12	Spartz Karen	System and method for aquaculture of marine life forms
DE102010021 606A1	24-Nov-11	Stiftung Alfred- Wegener- Institut Für Polar- Und Meeresforschu ng	Vorrichtung zur Habitaterschließung im Unterwasserbereich eines Offshore-Bauwerks
DE102010021 606B4	12-Apr-12	Stiftung Alfred- Wegener- Institut Für Polar- Und Meeresforschu ng	Vorrichtung zur Habitaterschließung im Unterwasserbereich eines Offshore-Bauwerks
EP2253600A1	24-Nov-10	Aalborg Portland A/S	Portland limestone calcined clay cement
EP2484650A1	8-Aug-12	Egis Eau	Structure including a plurality

			of blocks of non-reinforced fibrous, shell-containing concrete and method for manufacturing such a structure
FR2627951A1	8-Sep-89	Sermar Sa	Underwater farm for study of marine flora and fauna - is formed by concrete block with numerous holes and recesses
FR2858920A1	25-Feb-05	Guilbaud Stephane Roger	Oyster rearing procedure consists of attaching each one to plastic mesh on bottom of maturing bed by blob or mortar
GB2061081A	13-May-81	Highlands & Islands Dev Board	Shellfish culture
GB2421884A	12-Jul-06	Aurora Mar Ltd	C shaped pegs for attachment to ropes for shellfish cultivation
JP2000302500 A	31-Oct-00	Sekisui Chemical Co Ltd	Active powder, cement composition, and hardened cement
JP2006025720 A	2-Feb-06	Okabe Co Ltd	Structure for creating seaweed bed and method for creating seaweed bed by using the same
JP2006223297 A	31-Aug-06	Sakata Yasunari	Method for treating surface of cement based cured product for adhesion of seaweed, raft method by underwater exposure of porous material bagged in net, hanging method, mat method, and fish or shellfish- living environment-maintaining method in seaweed bed or artificial fishing bank by these methods
JPH01179634 A	17-Jul-89	Itokawa Koyo; Aso Toshio	Man-made gathering place for seaweed of water permeable concrete
JPH0598654A	20-Apr-93	Raito Kogyo; Nihon Cement; Nittoc Construction; Fuji Concrete Kogyo; Kyowa Concrete Kogyo	Concrete block for greening

JP2000178057 A	27-Jun-00	Shimizu Construction Co Ltd	Vegetation concrete and its production
NZ511126A	28-Sep-01	Searl Seafoods PTY LTD	Shellfish aquaculture method and apparatus with platform located above sea bed and constructed to retain support blocks
NZ531711A	25-Jun-04	MOLLUSC PTY LTD	A method of tagging a shellfish and a detectable shellfish produced by such a method by incorporating tag into shell as shellfish grows
WO200101918 0A1	22-Mar-01	Hajime Kobayashi	Seaweed field forming material and its block
WO200403109 6A1	15-Apr-04	Madelaine Joy Fernandez	Composition suitable for aquatic habitat repair, replacement and/or enhancement
WO201003990 9A1	8-Apr-10	Calera Corp.	Compositions and methods using substances containing carbon
WO201004845 7A1	29-Apr-10	Calera Corp.	Reduced-carbon footprint concrete compositions
WO201005145 8A1	6-May-10	Calera Corp.	Non-cementitious compositions comprising CO ₂ sequestering additives
WO201107934 6A1	7-Jul-11	Samuel Bennett	Artificial marine habitat
WO201114740 0A2	1-Dec-11	Stiftung Alfred- Wegener- Institut Für Polar- Und Meeresforschu ng	Device for developing habitats in the underwater area of an offshore construction

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Elliott, M., Burdon, D., Hemingway, K., and Apitz, S. 2007. Estuarine, coastal and marine ecosystem restoration: confusing management and science - A revision of concepts, estuarine. *Coastal and Shelf Science*, 74: 349-366.

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Joint Research Agreement:

This work was conducted by faculty and students at Valdosta State University, a component of the University System of Georgia. MIC Systems Inc. (Valdosta, Ga.) assisted in supporting the efforts of the PI. Only the parties of Valdosta State University (Valdosta, Georgia, USA) and the University System of Georgia (Atlanta, Georgia, USA) claim the intellectual property outlined in this application.

Field of Invention:

The current invention relates to a mineral based composition that effectively grows organisms in a marine environment. The mineral based material is composed of both organic and inorganic components that provide a surface for nucleation to take place that is capable of sustaining an ecosystem that reflects the diversity of life seen in the area.

Brief Summary:

This invention involves a method to produce concrete that is used as both a surface and a nutrient source for marine life to nucleate and grow. The construction includes both organic and inorganic nutrients that slowly leach from the concrete into the marine environment. Care is taken in selecting the materials needed for the composition of the concrete. For example, slags and ashes can produce a concrete that has extremes in acidity, basicity or toxicity. Calcium carbonate and other carbonate minerals not only serve as a pH buffer but also provide needed carbonates that are released at a slow rate for organisms such as oysters, corals and bryozoans. Most concrete construction inventions focus on making the strongest possible material for use in building structures. The concrete described in this invention is designed to slowly degrade, releasing its nutrients and eventually resulting in a natural mineral deposit (i.e. silicates and carbonates) on the ocean floor, leaving a thriving marine ecosystem in its place.

Background of the Invention:

Many inventions and discoveries have been revealed that examine or utilize different materials and surfaces for the growth of life in fresh and salt water environments. These materials have included car tires, automobiles, trains, planes, ships, bridges, building debris, fly ash, rocks and shells. In most of these cases, there is no strategy by the designer to provide a specific organism an advantageous surface that includes the correct nutrient composition, provides a proper shelter, or has the correct chemical parameters needed such as pH, redox potential, ionic strength and dissolved oxygen levels at the surface-water interface.

Mussels are a type of shellfish that adhere to a range of structures including rocks. The glue that holds mussels to the rock is composed of DOPA proteins. These proteins draw on the mussel but can also draw on a bacterial film that is present on the surface. These proteins take part in the mussel's adhesion process to a surface that involves both iron and silicates. In order to maximize the adhesion and growth of the mussel to a surface, a source of sugar should be available to start a bacterial biofilm, both iron and silicates should be present on the surface for adhesion, and amino acids should be available in the matrix to contribute to the growth of the binding protein. In addition, chemical species including amino acids, vitamins, trace minerals and starches, which are all needed to support life in the earliest stages, should be available in sufficient quantities. A strategy for growing mussels should then include the slow release of many of these species to help them survive and prosper.

A coral's nutrient cycle can be complex and draw on several sources. One such source that corals draw on is dissolved organic matter (DOM) which is a brood of chemicals that includes sugars, amino acids, urea, carbohydrates and functionalized hydrocarbons (i.e. stearic

and palmitic acid). Corals rely heavily on trace levels of these species from the surrounding water supply, including over a dozen amino acids. The energy source for many corals is derived from zooxanthellae (algae prominent on coral reefs) photosynthesis. This process would require some nutrients to help the photosynthetic algae to grow as well as a steady supply of carbon dioxide to produce carbohydrates in a complex cycle. Corals also require dissolved inorganic matter which can be delivered as nanoparticles and include species such as calcium, magnesium, copper and iron at appropriate concentrations. There must also be some flexibility in designing the structure if specific species of corals are being cultivated. For example, most gorgonians have a large fan-shape configuration and are perpendicular to the local water currents and tidal flows. With the correct geometry, the gorgonians can catch plankton from the water supply more efficiently. While this outlines some of the parameters in effectively growing corals, a process needs to take into account the slow release of specific chemicals, both organic and inorganic, as well as the restriction of other chemical species. For instance, corals are very sensitive to species such as chromium, so a steel object (i.e. train or ship) that typically contains over ten percent chromium will leach the toxic species over time and therefore minimize the growth of specific coral species. Another example is the overuse of phosphate which can encourage the growth of certain species of algae that then coat corals and prevents their growth. In designing a surface with slow releasing chemical species, it is important to select to include and not include certain species to optimize the growth rate of corals.

Another example of a carbonate based marine organism that benefits from this invention is the oyster. Specific species such as the *Crassostrea gigas* (Pacific Oysters), *Crassostrea sikamea* (Kumamoto Oysters), *Crassostrea virginica* (Atlantic Oysters), *Ostrea edulis* (European Flats), and *Ostrea lurida* or *Ostrea conchaphila* (Olympia Oysters) can benefit from this

technology. While oysters are known as a food source, they also provide tremendous advantages in natural ecosystems as well as to humans. For example, oyster beds can help stabilize a shoreline and prevent erosion. There are many examples of using oyster colonies to save existing property from being engulfed by the sea. Oyster colonies can also play a tremendous role in maintaining clean water. A single adult oyster can filter up to fifty gallons of water per day, removing various unwanted microbes and chemicals.

Oyster beds have been destroyed by human intrusion through dredging, excessive fertilizer use, over-harvesting, herbicides and pesticides that run off into the ocean, accidental ship groundings, freshwater flow shortages, oil spills and disease. Replacing or extending these oyster beds, which may stretch many miles, is a monumental task. A technique is needed that is economical and applies the concepts of green technology to replenish these oyster bars since they continue to decrease in size or have been completely destroyed. Currently, repurposed oyster shells are collected and dispersed to serve as a medium for new oyster larvae, or spat, to settle on and grow. This approach has not only exhausted many of the oyster shell reserves making them less available, but it has also led to an increase in their price. Other approaches include utilizing large cement structures that can weigh between five hundred and two thousand pounds to serve as a surface for oyster growth; however, this approach is limited for two reasons. First, oysters often live in shallow waters and the large cement structures must be transported to deeper water locations using a barge with a crane to operate successfully. Second, once these structures are put in place, they are difficult or impossible to relocate if needed. In many cases, an approach where a surface can be placed near an existing oyster bar to colonize the spat and then be moved to another area is necessary to rejuvenate an oyster population. This would require a small,

easily deployable and transportable device. Even in deeper water, economics would limit reintroducing an oyster bar if just large, expensive structures were used.

Another field to be considered when placing a bioactive material in the ocean is biofilms and the potential drugs they can produce. Currently, many drugs that are harvested from the ocean are produced by symbiotic bacteria that reside within a host organism. There are a plethora of examples: ara-A extracted from a marine sponge is an antiviral drug, ara-C extracted from a marine sponge is an anticancer drug, cephalosporins from a marine fungi are an antibiotic, conotoxins extracted from Cone snails are used for chronic pain, GTS21 extracted from a Nemertine worm is used for Alzheimer's disease, LAF389 extracted from a sponge is a cancer drug, Yondelis (ET743) extracted from a sea squirt is used against soft tissue sarcoma, dolastatin-10 extracted from a sea slug is used against cancer, ILX651 from a sea slug is used to battle cancer, cemadotin extracted from a sea slug is used against cancer, discodermolide extracted from a deep ocean sponge is used against cancer, IHTI286 extracted from a sponge is used to treat cancer, aplidin extracted from a sea squirt is used to battle cancer, and Bryostatin-1 from a bryozoan is used as a medication in cancer, HIV and Alzheimer's diseases. These drugs provide some insight to the proliferation of medicines that have been identified from marine life over recent decades. These drugs are identified in their host organisms at very low concentrations (i.e. 10^{-7} to 10^{-8} percent) making them available in extremely limited quantities. In most cases, these host organisms are incapable of supplying the significant quantities needed for medicinal applications. A surface that provides nutrients to grow bacterial films, for either surveying an ecosystem for new pharmaceutical agents or for producing known agents, would be a significant improvement over existing methods.

Detailed Description:

This invention focuses on a process to make a solid, mineral-based, bioactive structure that can serve as a nucleation point for a host of marine life. The process involves mixing together a series of compounds to form a final composition that will harden and provide a source of nutrients for feeding. Products found in the cement and final concrete mixture include calcium oxide (CaO), silicon dioxide (SiO₂), aluminum oxide (Al₂O₃), iron oxide (Fe₂O₃), magnesium oxide (MgO), diphosphorous pentoxide, sulfur trioxide, tricalcium aluminate (Ca₃Al₂O₆), tetracalcium aluminoferrite (Ca₄Al₂Fe₂O₁₀), dicalcium silicate (Ca₂SiO₅C₂S₂₀), tricalcium silicate (Ca₃SiO₄ C₃S₅₅), sodium oxide (Na₂O), potassium oxide (K₂O), gypsum (CaSO₄.2H₂O), and calcium carbonate (CaCO₃). Depending on the reactants used and the conditions present in the kiln, the qualitative and quantitative composition of the products can vary. These are normal components of concrete that are routinely mixed in various proportions to optimize different parameters. Concrete composed of these materials can, by itself, be a very poor surface to serve as a nucleation point for marine life. For example, reacting sulfur trioxide with water produces sulfuric acid resulting in a pH that would minimize the ability of organisms to thrive on the surface. Various types of slags and fly ash can also produce a chemical environment incapable of sustaining life. Additional chemical species are added to optimize surface conditions, such as pH, and to provide a slow release of key nutrients essential for life.

In this process, many nutrient and chemical species are added to optimize surface conditions which include: calcium carbonate, cellulose, sugars (i.e. sucrose, glucose, fructose, etc.), sodium bicarbonate, proteins, peptides, chitin, lignin, urea, ammonia and/or ammonium, sodium oxide, potassium oxide, iron oxide, potassium, sulfate, magnesium, strontium, phosphate, nitrate, nitrite, silicates, boron, copper, iron, manganese, molybdenum, zinc, vitamin A, vitamin

D, glutamic acid, aspartic acid, leucine, lysine, proline, threonine, isoleucine, valine, serine, alanine, tyrosine, methionine, arginine, phenylalanine, tryptophan, glycine, histidine, vitamin C, vitamin E, niacin, magnesium, thiamin (B1), riboflavin (B2), vitamin B6, pantothenic acid, vitamin K, folic acid, biotin, vitamin B12, iodine/iodide, selenium, chromium, tin, vanadium, lithium, barium, nickel, cadmium, lead, cobalt, silver, and titanium. Many of these species, such as lithium, chromium, sulphate and nitrate are part of various salts and can contain a charge. Some of these species, such as the vitamins and amino acids, are added in at trace levels.

In this process, the bulk components—lime or calcium oxide, silica, alumina, iron oxide, gypsum, and calcium carbonate—are placed in a container. Typically, they are obtained by mixing Portland cement with limestone sand and silica based sand. The remaining components, each present at lower than one percent of the total mass, are mixed with water. The water volume used to dissolve or suspend the trace species (in milliliters) is typically twenty percent of the bulk components mass (in grams). For example, if the bulk components weigh one kilogram or one thousand grams, then two hundred milliliters of water is used to dissolve and solubilize the remaining species, many of which are nutrients. This chemically enriched solution is then added and mixed in with the bulk material. Additional water is added until the material reaches a proper texture where it will dry and harden.

This nutrient enriched concrete mixture is poured into a mold and allowed to dry. In this work, the exact composition can vary according to physical and chemical conditions as well as the marine organism that is sought during the grow-out process. For example, when growing oysters or corals, organisms that have a high demand for calcium carbonate, a significant part of the additives to the cement in its transition to concrete is limestone dust. Likewise, scientific studies have shown that corals are very dependent on twelve specific amino acids for their

growth; subsequently, these make up about 0.0003% of the final concrete mixture by mass percentage. Similarly, some chemicals are minimized to remove unwanted growth. For instance, the addition of high levels of phosphate can result in high growth rates of unwanted algae that can coat the cement material with a green matt preventing other species, such as corals, from nucleating to the surface and growing. In many cases, concrete mixtures can result in a material that has a high or low pH which is the result of additives such as fly ash. In our mixture, an amphiprotic species such as sodium bicarbonate is added to serve as a buffer. As the concrete saturates, the electrolyte dissociates and forms inert sodium ions and bicarbonate ions. The bicarbonate ions quickly pick up a hydrogen ion or neutralize hydroxide ions; this serves as a buffer and maintains the pH of the surface in the 6-8 range which is the condition needed for living creatures to survive. The actual pH can be fine-tuned to be slightly acidic or slightly basic, as required by a specific organism.

Iron levels and the form that iron is delivered in can be important for various marine organisms. Iron is often contained in cement in relatively high concentrations as insoluble iron oxide. This form can be very difficult or impossible for most marine creatures to dissolve and consume. Iron is a limiting nutrient in the marine environment, so its availability is critical for the survival of many life forms. Given these conditions, iron may be added to concrete mixtures as a salt (i.e. iron (III) chloride) or in a complex (i.e. iron-hemoglobin) so that it can be used by marine species.

Sugars can be delivered in different forms such as mono, di and trisaccharides. Higher quantities of sugar can be used to trigger the rapid growth of biofilms that are composed largely of bacteria. These biofilms are of great use in searching the ocean for marine natural products or

drugs that come from the sea. Bacterial biofilms are also a food source for many marine creatures of higher trophic levels and can serve as a starting point for an ecosystem.

Natural polymers such as cellulose, starch, lignin and chitin can be added to serve as an organic nutrient as well as a material to slightly weaken the concrete contributing to its ability to biodegrade over time. The state and condition of these compounds can also be important. For example, in some grow-outs, some fresh (green) pine needles were ground up and added to a mixture at approximately 0-2% of the total mass. In addition to cellulose and lignin present in the pine needles, the material contained potential nutrients such as chlorophyll, sap and cell components. In another example, fresh chitin from shrimp shells were ground up and added at a low total mass percent (approximately 0.1%). When added, the chitin was covered with a bacterial film that was incorporated into the nutrient enriched concrete giving it an additional component that contributed to its bioactivity.

There are additional considerations when making a nutrient enriched concrete. While there are a host of organic type molecules that serve as nutrients, they can also weaken the concrete structure which enhances its ability to biodegrade. Many concretes made for typical industrial purposes, such as for buildings and large pipes, desire strong, long-lasting concrete. In this invention, the concrete is designed to eventually biodegrade and leave behind a natural residue composed of common minerals such as silica, alumina and carbonates. This degradation is designed to last over several years. If organics are added at high concentrations, then the concrete will either decay too quickly in the marine environment or will produce a material that will not hold its form at all. The concentration of the more economical organic species, such as the sugars, is typically kept below 0.3% of the total mass.

Some chemical species are required at trace levels in order for life to be sustained. These include species such as copper and manganese. These species can also be toxic at higher concentrations to many forms of life. Their levels in the final concrete structure are on the order of tens of parts per million providing an essential nutrient that is below toxic levels.

Another important factor for nucleating and raising some marine species, particularly in their early phases of life, is protection. These concrete structures are often designed with grooves and small holes that provide a safe location for microscopic larvae, such as for corals or oysters, to begin their life cycle. Marine predators such as fish and crabs will often scour a surface for food, such as larvae, impacting the production of a species. Holes, grooves and crevices give larvae a chance to nucleate and grow to a size where they cannot be easily consumed.

In a typical composition of this invention, nutrients comprise the mass percentages as follows: 100 parts Portland cement, 35 parts calcium carbonate sand, 2 parts silica based sand, 2 parts sodium bicarbonate, 0.01 parts sum total of sugars, 0.01 parts sum total of vitamins, 0.005 parts sum total of essential amino acids, 0.01 parts sum total of nitrate, ammonium and phosphate, 0.1 parts sea salts, 0.1 parts cellulose and chitin, 0.001 parts starch, and 0.001 parts total iron, copper and zinc chloride.

Claims:

What is claimed is:

- 1) A method of forming a nutrient enriched concrete mixture with water in which the hydroxide ion concentration is below 0.001 Molar and the hydronium ion concentration is above 0.001 Molar in the aqueous suspension, and it contains a suspended and dissolved bulk inorganic composition, a trace inorganic composition, and a trace organic composition.
- 2) The method of claim 1 where carbonate and/or bicarbonate components, considered a bulk constituent, comprises at least one percent of the total solid mass.
- 3) The method of claim 1 where additional inorganic minerals and salts are composed of silicates such as but limited to silicon dioxide and silicon trioxide, aluminates such as but not limited to aluminum oxide, oxides of alkaline earth metals such as but not limited to calcium oxide and magnesium oxide, and additional soluble and insoluble salts that contain hydroxides, water molecules, chlorides, sodium ions, potassium ions, calcium ions, sulfate ions, magnesium ions, iron ions, and fluoride ions; the sum of these species total at least thirty percent of the total final mass.
- 4) The method of claim 1 where salts of transition metals such as but not limited to zinc, copper, manganese, molybdenum, silver, lead, boron, and cobalt total at least one part per million by mass of the dried concrete.
- 5) The method of claim 1 where salts of inorganic anions such as but not limited to nitrates, nitrites, ammonium, phosphates, sulfides, iodides, bromides, sulfites total at least one part per million by mass.

- 6) The method of claim 1 where salts of other cations such as but not limited to lithium, barium, strontium, tin and selenium total at least ten parts per billion of the total concrete mass.
- 7) The method of claim 1 where a mixture of vitamins may contain one or more of the following species: vitamin A, vitamin C, vitamin D, vitamin E, vitamin K, thiamin(B1), riboflavin(B2), niacin, vitamin B6, folic acid, vitamin B12, biotin, and pantothenic acid total at least one part per million by mass.
- 8) The method of claim 1 where a mixture of amino acids may contain one or more of the following: glutamic acid, aspartic acid, leucine, lysine, proline, threonine, isoleucine, valine, serine, alanine, tyrosine, methionine, arginine, phenylalanine, tryptophan, glycine, and histidine total at least one part per million by mass.
- 9) The method of claim 1 where a natural source of cellulose and lignin are included in the final concrete mixture and total at least one part per million by mass.
- 10) The method of claim 1 where a protein source, such as but not limited to albumin, is included in the final concrete mixture and totals at least one hundred parts per billion by mass.
- 11) The method of claim 1 where the natural polymer chitin is included at a mass percent concentration of at least one parts per million.
- 12) The method of claim 1 where urea is included in the concrete mixture and has a total mass percent concentration of at least ten parts per billion.
- 13) The method of claim 1 where marine microbes such as bacteria may be included in the mixture increasing the bioactivity of the final concrete mixture.

- 14) The method of claim 1 where there is a sugar source, typically a combination of monosaccharide's, disaccharides and trisaccharides, is included in the concrete mixture and totals at least one part per million by mass.
- 15) The method of claim 1 where the function of adding chemical species such amino acids, vitamins, sugars, proteins, urea, citric acid, trace elements, etc. is to serve as nutrients for the growth of marine life.
- 16) The method of claim 1 where the addition of nutrients serves to decrease the strength of the concrete allowing it to slowly degrade leaving behind inert chemical species such as silicates, aluminates and carbonates that are naturally found in nature.
- 17) The method of claim 1 where incorporating organic and inorganic nutrients essential for life results in the slow and controlled release of these species over an extended period of time.
- 18) The method of claim 1 where the chemical species selected are mixed with cement to form concrete and deployed in the environment in such a procedure as to qualify as a green technology with a particular emphasis on the practices of sustainability.