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Alternate cultch for bottom oyster cultivation

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I. BACKGROUND

Some members of the oyster industry have proposed the use of tire chips as an alternate cultch for bottom oyster cultivation. Two uses have been advanced:

A. Annual application as replenishment for spat settlement on existing oyster beds.

B. Application as a bed preparation material. Conventional preparation is to lay a several-inch course of oyster shell. On softer bottoms the shell tends to sink into the bottom. Being of low specific gravity (S.G. ≅ 1.15), tire chips would sink less than shell (S.G. ≅ 2.6).

In the fall of 1987, VIMS obtained yearling oysters attached to tire chips and others attached to shell. The oyster meats were tested for bioaccumulation of metals and certain organic compounds. No bioaccumulation was observed in this limited sampling. These results were reported to the Virginia Marine Resources Commission (VMRC) in March 1988 along with recommendations for additional toxicity and related tests:

A. Potential Toxicity to Zooplankton/Phytoplankton

Some latex rubber compounds have been shown to be toxic to phyto- and zooplankton. Given the potential for application to large surface areas, the possibility of toxicity to the food chain warrants evaluation.

B. Benthic Resource Value of Tire Chips Plots

The biological communities living in and on estuarine bottoms are an important food source to fish and crustaceans and thus represent a "benthic resource value." The same is true for an oyster rock bottom. The benthic resource value of a tire chip bottom is unknown. Because tire chips are virtually non-biodegradable and are resistant to boring organisms, some differences in benthic resource value (relative to oyster shell) might be expected.

C. Mobility of Tire Chips

Given the low effective weight when submerged (0.15 tire chips; 1.6 oyster shell), it is anticipated that tire chips will be relatively mobile under waves/currents. Field and laboratory mobility tests were proposed.

A hierarchal test series was proposed. If toxicity to zooplankton or phytoplankton was observed, the test program would be discontinued since such toxicity would lead to a recommendation against the broadcast application of tire chips.

At the April VMRC meeting, the Commission requested that VIMS consider other materials which may be proposed as alternate cultch and evaluate which of those materials would require toxicity and other tests. Moreover, it was to be determined whether simultaneous testing of multiple alternates would lead to cost savings.

II. PURPOSE

This report examines candidate alternate cultch and the costs associated with toxicity and other tests for multiple substrates. Materials tailored for oyster hatchery and off-bottom cultivation were not considered. Materials which might be suitable for bottom cultch were further screened with respect to current (or potential) availability and harvestability.

III. DISCUSSION

Since the early 1900's a number of alternate materials have been considered for cultch. Table 1 provides a listing of alternate cultch for bottom cultivation. Many have been discussed in the literature. Our focus here is on formulated materials which may exhibit toxicity or compromise benthic resource value. However, also included is a processed natural material, expanded shale (SOLITE®). This material may be a useful alternate for bed preparation and/or cultch.

A. Tire Chips

1. Mobility: Of the alternates listed in Table 1, tire chips have the lowest (aside from wood) effective density in water ($0.15\ g/cm^3$). Tire chips may thus be expected to exhibit relatively high mobility under waves and currents in open water conditions. Limited anecdotal evidence indicates tire chips placed on leased beds in the Rappahannock River were unstable.

2. Settlement: Limited laboratory and field tests performed in Maryland (1979) indicate that tire chips were about one-fifth as effective as oyster shell in attracting oyster settlement. A very limited test with caged cultch of shell and tire chips in Mobjack Bay indicated settlement was about equivalent.

3. Permanency in the Environment: Tire chips are nonbiodegradable in the marine environment and very resistant to physical abrasion. Therefore, tire chips should be considered as having extraordinary longevity.

4. Toxicity and Related Studies: Limited testing was performed by VIMS on field strike on tire chips. Those results, communicated earlier to VMRC, indicated no substantive differences between yearlings on tire chips versus adjacent yearlings on shell. No tests have been performed on potential toxicity to zoo-/phytoplankton or on relative benthic resource value.

B. Stabilized Fly Ash

Power plant coal combustion waste, stabilized by hardening to cinder block-like consistency, has been investigated by the University of Delaware for use as fish reef and oyster setting substrate.

1. Mobility: The specific gravity of the test blocks used varied between 2.2 and 2.5 g/cm^3, values less than but close to oyster shell. No formal mobility tests have been performed.

2. Settlement Characteristics: Data from the Delaware laboratory studies indicate settlement rates on oyster shell to be considerably higher than on coal waste mixtures or concrete. With aging in seawater the coal waste mixtures exhibited improved settlement, in one case comparable to unseasoned oysters. Field tests with natural set again demonstrated superior setting on oyster shell.

3. Permanency in the Environment: No data are available but the longevity of coal waste mixtures is likely to be years to decades depending upon parcel surface area exposed relative to parcel volume and the degree of initial consolidation.

4. Toxicity and Related Studies: The principal exudates of concern are trace metals. Seawater solubility studies at the University of Delaware on disaggregated fly ash indicated highest solubility for arsenic and selenium followed in decreasing order by iron, manganese, zinc, copper, nickel, cadmium, lead and cobalt.

a. Bioaccumulation in oysters. A limited suite of metals (cadmium, copper, iron, nickel and zinc) was studied in the Delaware laboratory and in field tests. Oysters set on fly ash mixtures concentrated iron, while zinc and copper concentrations did not differ significantly from uncontaminated oyster tissue. Cadmium and nickel concentrations were below detection limits of the instruments used (or due to instrument malfunction).

b. Toxicity to zoo-/phytoplankton. No tests have been conducted; however, the Delaware report indicates that arsenic concentrations (for some fly ash mixtures) approached levels associated with acute toxic effects on embryonic/larval stages of some vertebrate species (unspecified). Additional tests addressing toxicity to plankton should be required in any consideration of the use of stabilized fly ash for oyster cultch.

c. Benthic resource value. No tests have been conducted; however, the University of Delaware has studied the off-bottom fouling communities of three coal waste mixtures and concrete on fish-reef simulations. While all four substrates attracted epifaunal colonization, the concrete substrate was most successful. Differences between fly ash composition mix had no effect on taxa richness. With respect to biomass the success of coal waste substrates appears to be dependent upon composition and the degree of consolidation.

C. Slag

Slag is a nonmetallic product resulting from the interaction of fluxing compounds and impurities in smelting and refining of metals. The composition is thus variable and dependent upon ore treatment process and ore source.

1. Mobility: No tests have been performed. Slag density is variable and dependent upon composition and air entrapment upon cooling.

2. Settlement Characteristics: Laboratory and field tests in Maryland indicated that slag attracted less oyster settlement than either oyster shell or tire chips. Laboratory results indicate oyster shell was dramatically superior to slag.

3. Permanency in the Environment: Unknown, but likely to be comparable to natural sedimentary rock.

4. Toxicity and Related Tests: No test data are known. Toxicity is not expected to be a significant factor.

D. Asphalt

Asphalt is prepared by pyrolysis of coal tar. The principal exudates of concern are hydrocarbon compounds and, secondarily, metals.

1. Mobility: No tests have been performed.

2. Settlement Characteristics: No tests have been performed.

3. Toxicity and Related Tests: No tests have been performed for the estuarine environment.

D. Expanded Shale (SOLITE®)

Solite is a shale rock expanded in a rotary kiln process. Applications of this processed natural material are in structural lightweight aggregate and lightweight concrete.

Mention is herein included because of the potential this material offers in the preparation of untreated leased grounds. The specific gravity of SOLITE is approximately 1.6 (effective density in water of 0.6 g/cm^3 with very little change from prolonged immersion). Compared to conventional methods of bed preparation with heavier oyster shell, SOLITE would be expected to sink less deep in a soft substrate. As important, it may offer an alternative to the use of oyster shell, a diminishing resource, for bed preparation.

In addition to its use as a substrate conditioning material, SOLITE may be a favorable alternate replenishment material for oyster settlement.

1. Mobility: No tests have been performed. This material has a higher submerged effective density (0.6) than tire chips (0.15) but less than that of oyster shell (1.6).

2. Settlement Characteristics: No laboratory tests have been performed. Field tests were performed on intertidal flats in South Carolina from 1960-1962. Thus far the report discussing those results has not been traced. Discussion with the South Carolina Department of Natural Resources provided commentary that the results were not favorable. However, the site selected was apparently a very soft intertidal bottom with high sedimentation rates.

3. Permanency in the Environment: While no formal tests have been conducted, expanded shale with planar bedding should be susceptible to biological erosion and decomposition in a time frame of ten years.

4. Toxicity and Related Tests: No tests have been performed. As a natural material composed of clay and silt, no toxicity would be anticipated.

IV. AVAILABILITY OF MATERIALS

Of the five materials discussed, SOLITE and tire chips are available in volume. Cost estimates for SOLITE have been provided to VIMS (Bruce Cann of Solite, 804-329-8135). The estimates should be considered working numbers only, as future testing may require additional gradation. For material stockpiled at Chesapeake, Virginia, and Port Royal, Virginia, the costs are:

Location	Cost Per Ton	Equivalent Cost Per Virginia Bushel
Port Royal	\$38.45	\$1.42
Chesapeake	\$40.45	\$1.50

Stabilized coal waste in solid chip form is not yet available in quantity. The availability of slag or waste asphalt has not been assessed.

V. POSSIBLE TESTING PROGRAM

Given the potential of SOLITE as alternate cultch (intermediate in weight, no toxicity and like oyster shell in permanency), it should be included in a test series. Table 2 provides a tentative test sequence for the Commission's consideration. The following description of the tests includes discussion of test costs when running multiple substrates simultaneously.

A. Laboratory Settlement and Mortality Tests

These tests would utilize larvae from the VIMS Oyster Hatchery. Each alternate substrate (SOLITE, tire chips and stabilized coal waste) would be independently tested against oyster shell utilizing laboratory cultured algae for larvae food. While new spat are readily identified on oyster shell, such is not likely on SOLITE. The studies at Delaware demonstrate the difficulty on stabilized coal waste. Consequently, it will be necessary to continue weekly counts over a several week period. This information will also provide inferences.

Previous studies have examined settlement for tire chips and stabilized coal waste. However, the experimental designs were different and both differ from that proposed herein. Therefore, there is a need for additional tests if objective inferences are to be drawn.

Costs for multiple, simultaneous tests are shown in Table 3. The cost for laboratory settlement tests of two or three substrates are essentially the same. The cost differential between one and two substrates is due to required additional personnel. As of June 1988 the availability of stabilized coal waste for testing purposes is unknown.

B. <u>Field String Surveys</u>

The laboratory setlement studies use filtered seawater with cultured larvae and algal food. In the field situation the fouling communities and water column suspended solids may differentially affect settlement success. Thus, off-bottom field tests offer the opportunity to evaluate these responses without suffering the expected high mortalities from predation and siltation associated with placement on the bottom.

VIMS performs weekly placement of oyster shell strings to assess the potential strike at a number of stations in the James River. Since these costs are already programmed, only the additional funds for materials and counting spat on the additional substrates are required. Given the anticipated difficulty in counting the very small new spat on SOLITE, tire chips and stabilized coal waste, these strings would be stored for a few weeks to allow sufficient growth for reliable counts.

The costs portrayed in Table 3 are based on placing weekly substrate for eight weeks, assuming ten strings per week. The cost differences between the number of substrates reflect the proportional increases in personnel time for counting.

C. <u>Mobility</u>

The tests proposed would permit a basis to define the conditions under which the various substrates would be expected to be dislodged and transported. Laboratory flume and field tests are envisioned.

The laboratory flume tests are intended to define the critical bottom shear stress for transport in unidirectional flow. While such tests cannot duplicate all of the possible bottom roughness conditions likely to be encountered in the field, they would provide the information on basic hydraulic properties of the test substrate. This data will permit use of existing theory to estimate the wave and tidal conditions under which the materials are likely to move.

Field experiments at VIMS are intended to serve as a test of the predictive power gained by the flume experiments. At a site off of VIMS beach plots of the test substrate will be established in a defined layout for a period of one week. Also deployed at the site will be an instrumented tripod to measure waves and currents. Bottom photography and diver observation will indicate transport tendency to be evaluated against observed hydraulic forces. In turn, these will be compared with theoretical expectations.

The cost differential portrayed in Table 3 represents the additional costs associated with multiple flume tests. Each substrate requires an independent test.

D. Toxicity Tests

1. Zooplankton: A mysid, a copepod from natural populations, and oyster embryos and straight-hinge larvae are the test organisms proposed. The toxicity end points selected are those indicative of sublethal effects on growth and reproduction of the species or, in the case of the oyster embryos, production of morphological abnormalities.

   Treatments will include exposures to unweathered tire chips, aerobically weathered chips, anaerobically weathered chips and controls. A similar protocol would apply for stabilized coal waste.

2. Phytoplankton: Natural, mixed estuarine plankton populations will be utilized in microcosm tests. Treatments will be as in the zooplankton case with the tests conducted over one year to examine effects on the seasonally changing phytoplankton community. Chlorophyll will be used for the autotrophic biomass measurements. Appropriate measures of cell counts, taxonomic and trophic classification will be utilized for the test series.

   Table 3 indicates no cost savings by running multiple substrates simultaneously. For the zooplankton tests the majority of the costs for testing each substrate lies in the personnel cost needed to count and monitor the test animals, chemical analysis costs and supplies, all of which approximately double with each additional substrate. For the phytoplankton case, increasing the number of substrates beyond one requires the addition of personnel as well as increasing the level of effort of existing personnel. In addition, each substrate requires the addition of microcosm apparatus.

E. Benthic Resource Value

The question to be addressed in this test is whether the quantity and quality of benthic resources potentially available to higher consumers (such as bottom-feeding crabs and fishes) is substantially different on alternate substrate as compared to a bed of oyster shells. The benthic resource value between plots of unweathered tire chips, plots of shell and untreated bottoms would be compared. The salient points of the test are:

1. To establish tire chip (or stabilized coal waste) and shell plots on a barren, soft bottom at a site where salinities fall within 5 to 15 ppt. While the benthic resource value changes with salinity, we see little point in performing tests in high salinity areas. We assume that in those disease endemic areas no planting would occur;

2. To mimic the situations of tire chip or shell use to prepare an oyster bed. The bed materials would be at least 20 cm thick;

3. To utilize three treatments--fresh tire chips (or stabilized coal waste), shell and soft bottom (control). Three plots of each treatment would be used, each plot to exceed 500 square meters;

4. To conduct the study during a 12-month period (late winter to late winter). The rationale is to emplace the bed materials in late winter and to sample the substrate in late spring and late fall. This strategy will allow comparisons over a single "biological year" and thereby avoid confounding the results by mixing various milti-year recruitments and succession; and

5. To determine differences, comparisons of biomass and taxonomic changes would be performed.

The preponderance of project costs is associated with processing benthic samples. This is directly proportional to the number of plots. Therefore, little cost savings result from simultaneous testing of substrates.

VI. SEQUENCE OF TESTING

In approaching decisions as to the extent of testing of any alternate substrate, a sequential test series is proposed for consideration. In the cases of tire chips and stabilized coal waste for which toxicity tests are recommended, Table 2 indicates starting the phytoplankton toxicity after the zooplankton tests. If the more susceptible zooplankton indicate toxicity impacts, the test program would stop. An additional screening step not reflected in Table 2 could be imposed. If the laboratory settlement and field string tests indicated a wide disparity between alternate substrates, only the most favorable substrate would be selected for additional tests. This would delay the initiation of zooplankton tests until the fall of 1988 and, thus, would also offset the phytoplankton tests, if applicable. The availability of stabilized coal waste test material remains to be determined.

In the case of SOLITE, no toxicity or benthic resource tests are required. Table 2 indicates tests of bottom application in the summer and fall of 1989. No cost estimates have been constructed since the test design and location would be influenced by results of earlier tests.

Table 4 portrays the costs for testing multiple substrates assuming a full test program for each substrate.

TABLE 1 - ALTERNATE BOTTOM CULTCH

	MOBILITY FACTOR		OYSTER SETTLEMENT TESTS		TOXICITY/RELATED TESTS			
					Oyster BioAccum. Metals/Organics			
Material	Specific Gravity	Immersed Density g/cm^3	Laboratory	Field	Lab	Field	Toxicity to Phyto-/Zooplankton	Benthic Resource Value
I. NATURAL								
OYSTER SHELL	~2.6	1.6	X	X				
OTHER BIVALVES								
CLAMS/VARIOUS				X				
SCALLOP				X				
MUSSEL				X?				
SNAILS				X?				
ROCK CHIPS	2.4-2.8	1.4-1.8						
SLATE				X				
SHALE				X				
LIMESTONE				X				
GYPSUM								
WOOD/BRUSH	N/A							
II. PROCESSED NATURAL MATERIALS								
BRICK CHIPS (WASTE)	~2.1	1.1						
CEMENT BLOCK/ CONCRETE (WASTE)	2.0-2.2	1.1	X	X				
EXPANDED SHALE (SOLITE)	1.6	0.6		X?				
GLASS	2.6	1.6		X				
ASBESTOS				X				
TILE				X				
III. FORMULATED MATERIALS								
TIRE CHIPS (WASTE)	1.15	0.15	X	X		X		
STABILIZED FLY ASH (WASTE)	2.2-2.5	1.2-1.5	X	X	X	X		
SLAG (WASTE)	<2.0	<1.0	X	X				
ASPHALT CHIPS (WASTE)	~2.2	1.2						

TABLE 2 - POSSIBLE TEST SEQUENCE

	1988 SUMMER	1988 FALL	1989 WINTER	1989 SPRING	1989 SUMMER	1989 FALL	1990 WINTER	1990 SPRING	1990 SUMMER	1990 FALL
SOLITE										
Laboratory Settlement	<-----	----->								
Field "Shell" String	<------>									
Mobility Tests		<---->								
Bottom Deployment for Strikes					<------	------>				
TIRE CHIPS										
Laboratory Settlement	<-----	----->								
Field "Shell" String	<---->									
Mobility Tests		<---->								
Zooplankton Toxicity	<------	------>								
Phytoplankton Toxicity		<------	------	------	------>					
Benthic Resource Value Phase 1					<------	------	------	------	------>	
STABILIZED COAL WASTE										
Laboratory Settlement	<-----	----->								
Field "Shell" String	<------>									
Mobility Tests		<---->								
Zooplankton Toxicity	<------	------>								
Phytoplankton Toxicity	<------	------	------	------	------>					

TABLE 3 - COSTS FOR TESTS AS A FUNCTION OF THE NUMBER OF SUBSTRATES

TEST	ONE SUBSTRATE	TWO SUBSTRATES	THREE SUBSTRATES
LABORATORY SETTING, SURVIVAL, GROWTH	$ 6,530	$ 10,090	$ 10,290
FIELD STRING SURVEY	3,920	7,840	11,759
MOBILITY	7,160	8,400	9,650
ZOOPLANKTON TOXICITY	28,250	53,840	80,320
PHYTOPLANKTON TOXICITY	68,560	159,900	210,890
BENTHIC RESOURCE VALUE	112,000	224,000	-0-

$31,699

TABLE 4 - COSTS FOR TEST SEQUENCES

	SOLITE	SOLITE AND TIRE CHIPS	SOLITE, TIRE CHIPS AND STABILIZED COAL WASTE
LABORATORY SETTLEMENT	$ 6,530	$ 10,090	$ 10,290
FIELD STRING SURVEY	3,920	7,840	11,760
MOBILITY	7,160	8,400	9,650
ZOOPLANKTON TOXICITY	N/A	28,250	53,840
PHYTOPLANKTON TOXICITY	N/A	68,560	159,900
BENTHIC RESOURCE VALUE	N/A	112,000	224,000
	$17,610	$235,140	$469,440