Subtidal Cultivation of the American Oyster, *Crassostrea virginica*, Utilizing a Flexible Belt

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INTRODUCTION

Historically, intensive cultivation of oysters has been practiced intertidally in bays or sounds where large tidal fluctuations create expansive intertidal flats at ebb tide. In the Pacific Northwest region of the United States and Canada, where tides may exceed ten feet, oyster farming is done almost exclusively in the intertidal zone. Harvesting and handling occurs when the waters recede (Beattie, 1982; Gunn and Saxby, 1982). In contrast, estuaries and coastal lagoons in the southeastern United States, Gulf of Mexico, and Caribbean have small tidal fluctuations, resulting in limited potential for intertidal oyster fishing or farming.

Subtidal oyster cultivation presents operational problems not encountered with intertidal farming and include the following:

1. Biofouling of containers is a persistent problem in subtidal cultivation of oysters, particularly in subtropical and tropical environments, since continuous submersion does not allow for periodic drying to eliminate macroalgae and soft-bodied invertebrates (Neudecker, 1982; Breber, 1981). Macrophytic algae clog container mesh and inhibit food flow to growing oysters. Rapid and extensive growth of various barnacles, sponges, ascidians, and bryozoans can form a complete mat over grow out containers and compete with oysters for food resources, thereby limiting oyster growth (Littlewood, 1988). Labor associated with cleaning and removing fouling organisms from oysters and their containers is the major contributor to operating costs; a great deal of time is spent hoisting the grow out containers onto a workboat or raft where they are cleaned and inspected.
2. Oyster predation is intense in the warm waters of the southeastern United States and Gulf of Mexico where benthic and free-swimming predators are abundant and active most of the year. Drills (*Thais haemastoma*), crabs (*Callinectes* spp. and *Menippe mercenaria*), and finfish (*Pogonias cromis* and *Archosargus probatocephalis*) may inflict extensive damage to unprotected juvenile oysters in Florida waters (Ingle, 1950). Intensive farming of cultchless oysters requires predator exclusion during the entire growing cycle since oysters (even 3" shell length harvest size) are always vulnerable to predation (authors' observation).

3. Processing and harvesting oysters subtidally employing hand tongs, rakes, or hand harvesting using scuba is labor intensive. Oyster cultivation requires specialized equipment to lift grow out containers to the surface mechanically. All current harvesting methods compromise efficiency and worker safety. Laws prohibiting the use of dredges and other mechanical devices for harvesting oysters exist in many areas. In the state of Florida, mechanical dredges are prohibited (Florida Statutes, 1987).
4. Alternative "off-bottom" oyster culture methods such as floating rafts, suspended longlines, and rack culture have proven technically feasible and are successful throughout the world (Imai, 1977; Curtin, 1971). However, they are prohibited in many states because they are navigation hazards or viewed as unaesthetic public nuisances. As a result, Florida and many Gulf States restrict the height of submerged structures on shellfish leases to six inches from the bottom (Devoe and Mount, 1988).

An innovative "on-bottom" oyster growing system is described in Figure 1 which utilizes a flexible belt apparatus, oyster growing containers and a specialized tender vessel for oyster container lifting to the surface for handling or harvest. Operational advantages of a flexible belt include:

- a modular design for easy transport;
- rapid deployment, handling, and harvest of oyster containers without specialized hoists;
- an efficient method for cleaning oysters and containers;
- minimal labor and exposure of workers to adverse working conditions.

DEVELOPMENT AND DESIGN

The design features of the flexible belt system include two parallel flexible lines (1/2" polypropylene rope) with a spreader and bridle at each end attached to anchors. A series of individual, removable, plastic mesh bags containing oysters are attached to the two parallel lines (Figure 1). The plastic mesh bags (double open-ended cylinders) are attached to the lines by folding each end over the rope and sealing with a 1" PVC closure with flanged ends to facilitate attachment. Bags are separated by individual crossbars which are detachable from the parallel lines and slide along the lines for desired positioning (Figure 2). Belt components are constructed entirely of PVC pipe to prevent corrosion, and do not require specialized manufacturing equipment.

The belt's modular construction facilitates handling the oyster containers as individual bags can be added or removed quickly and easily. Essentially, the oyster belt is constructed in the field as it is being deployed. Unused space on

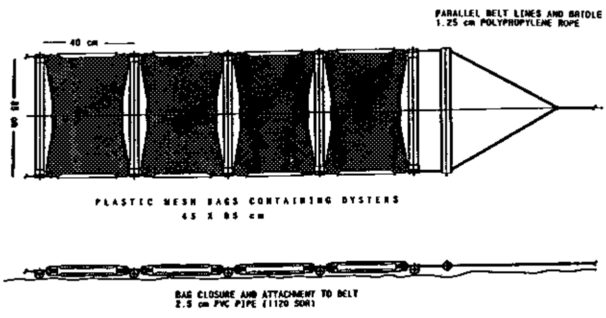

Figure 1. Top and side views of the flexible belt oyster grow out system showing parallel lines, bridle, and four removable compartments.

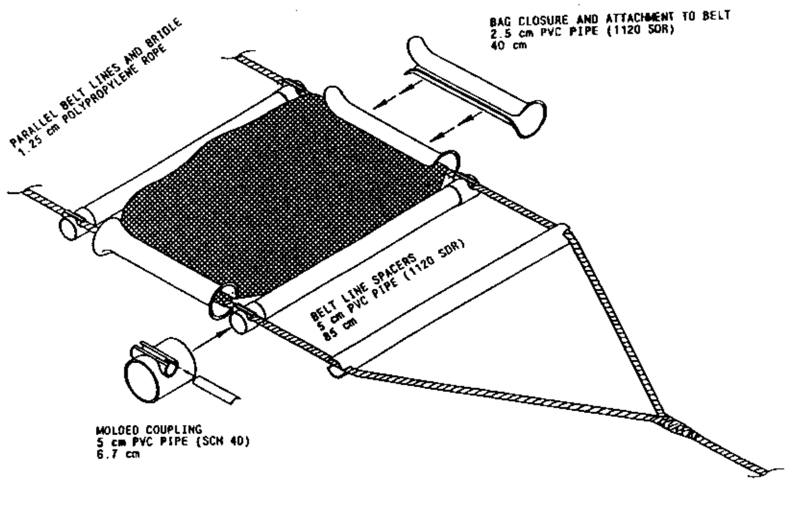

Figure 2. Construction detail of a single container unit attached to parallel flexible lines.

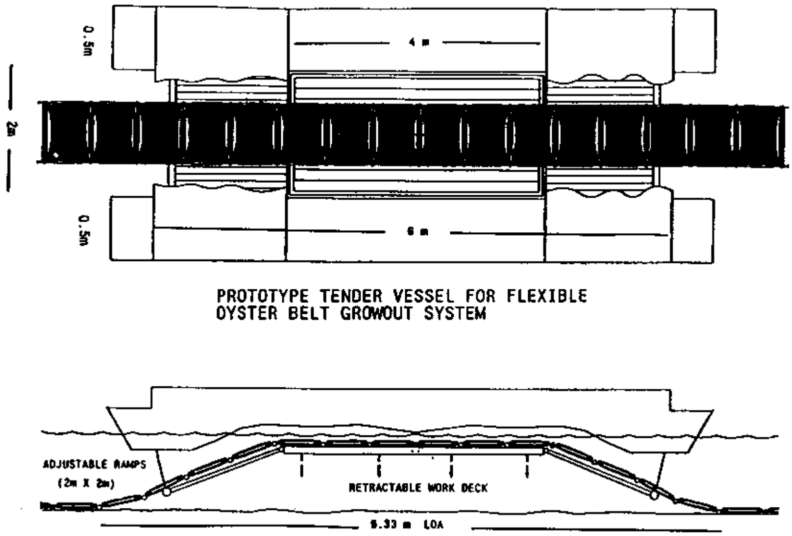

Figure 3. Top and side views of prototype tender vessel for flexible belt oyster grow out system. Design features include a retractable center work deck which can be submerged and adjustable ramps, fore and aft, for guiding the belt on-board.

the belt is merely a pair of lines.

Oyster containers in the flexible belt are lifted to the surface by a twin-hulled tender vessel with a submerged lower deck (Figure 3). The tender vessel consists of two hulls, 2' x 2' in cross section and 16' long, with a 45° vertical taper on one end as a rudimentary bow, for a total length of 18'. During construction, 6" lengths of metal tubing are securely attached to both the top and bottom inside edges of each hull. The hulls are assembled using five 6" lengths of tubing sized to telescope over the tubes affixed to the hulls. When pinned in place, the two hulls become a somewhat flexible vessel. A grating deck is attached to the tubing spacers on the bottom to form a submerged work deck, while 4' x 6' plywood deck sections are fitted to the top spacers to form a removable deck. Transoms may be constructed on the aft ends of the hulls for fitting small outboard engines. Forward and aft ramps (4' x 6' grates of PVC pipe) adjust for depth, and guide the belt to the submerged deck.

Once on board the tender vessel, the containers can be cleaned, removed for

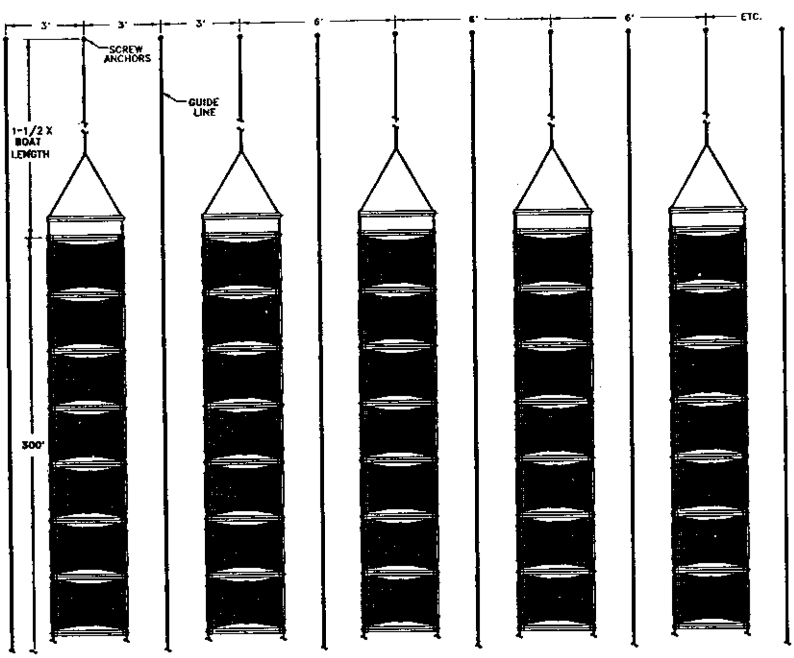

Figure 4. Flexible belt system and guidlines deployed on six foot centers. One acre plot contains 18 belt lines with 144 bags per belt (2592 bags/acre).

thinning, removed for redistribution of oysters, or harvested. The belt itself is not moved longitudinally; rather the tender vessel moves along the belt, raising it vertically, and lowering it to its original bottom position. Belt lines are deployed every six feet with a guide line every fourth set of lines. Guide lines are permanently affixed to the substrate to which the tender vessel is attached using "snatch blocks." Lines can be adjusted to position the tender vessel over each belt and to maintain alignment of the vessel. The fore and aft ramps allow the tender vessel to move in either direction along the belt, taking advantage of prevailing winds and current.

A single acre plot (400' x 108') will hold 18 belt lines (six foot centers) with 144 bags per belt, or 2592 bags/acre (Figure 4). The modular construction of the "oyster belt" provides an efficient way to remove oyster containers for periodic drying. Additionally, fouling occurs on the top surface of the bags where light and circulation enhance growth of algae and filter feeding organisms while the bottom portion of the bag remains free of fouling. Periodic turning of the oyster containers effectively eliminates these organisms and provides a method for cleaning without removing them from the belt. Stocking density, weights, and measures for growing oyster spat to harvest in mesh bags are presented in Table 1.

CONSTRUCTION AND LABOR COSTS

Construction and material costs for a one-acre planting of oysters is presented in Table 2. The flexible belt oyster grow out system is cost competitive with existing methods for off-bottom rack culture. An acre of flexible belt grow out containers, approximately 2600 bags deployed on 18 belts (six foot centers), stocked at 225 harvestable oysters per bag will yield 585,000 single oysters per acre. The costs for the belt system have been amortized over five years—the estimated life expectancy of the belt system.

Table 3 illustrates our estimated labor costs, based on a two-man crew and one tender vessel. With increased efficiency, a two-man crew could maintain, handle, and process over 1.5 million oysters on two acres containing flexible belts.

NOTE

Flexible belt equipment described in this document is the subject of U.S. Patent Pending Docket # 87P180.

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Table 1. Stocking density, weights, and measures for growing oyster spat to harvest in mesh bags. An average minimum weight (W_o) and volume (V_o) for individuals (N=50) was used to calculate total weight (TW) and volume (TV) for bags at the stocking rate given. Final weight (FW) and volume (FV) are approximate estimates for weight and volume of bags in which all oysters have grown to the next size class and all oysters survived.

Bag Mesh	Seive Size	Oysters/Bag	$\overline{W}$ (g)	$\overline{V}$ (ml)	TW_o (kg)	TV_o(l)	FW (kg)	FV (l)
0.75"	x > 1.25"	250	51.5	33.0	12.9	8.2	22.7	20.0
0.50"	1.25 > x > 1.0"	500	19.7	14.0	9.9	7.0	25.7	16.5
0.25"	1.0 > x > 0.75"	1500	6.9	5.0	10.3	7.5	29.5	21.0
0.13"	0.75 > x > 0.25"	4000	-.-	800/l		5.0	-.-	20.0
Large mesh spat bag (2 mm)	x > 0.13"	10,000	-.-	8500/l	-.-	1.2	-.-	12.5
Small mesh spat bag (@1 mm)	x > 2.2mm	50,000	-.-	50,000/l	-.-	1.0	-.-	5.9

Table 2. Material and construction costs for one acre planting of oysters using the flexible belt grow out system.

MESH BAG	$ 3.50
SPACERS (2" PVC) X 1	
2" coupling x 2, 30" of 2" Sch 160 PVC	
6" of 0.75" dia. Sch 40 PVC	
3" of 0.5" dia. Sch 200 PVC	1.54
CLOSURES	
16" of 1.0" dia. sch 200 PVC	0.34
ROPE (1/2" POLYPROPYLENE)	
6' x $0.065/ft	0.39
PVC CEMENT, ELECTRICITY, ETC.	0.11
ESTIMATED LABOR ($ 4.00/hr)	0.60
EQUIPMENT REPLACEMENT	0.25
TOTAL	$6.73
PLANTING AREA = 1 ACRE (43,560 FT)	
144 BAGS X 18 BELTS = 2592 BAGS/ACRE	$ 17,444.16
GUIDELINES (5/8" POLYPROPYLENE)	
400' X 4 X $ 0.09/ft	144.00
ANCHORS	
48" "SCREW" TYPE (@ $ 4.95) X 44	217.80
TOTAL BELT COST PER ACRE	$ 17,805.96
AMORTIZED OVER 5 YEARS	$ 3,516.19

Material and construction costs for 18 foot tender vessel with submerged belt ramp.

18 FOOT TWIN-HULLED TENDER VESSEL WITH SUBMERGED BELT RAMP

2' X 2' X 18' FIBERGLASS HULLS	
(@ $ 2,000 ea. X 2)	$ 4,000.00
MAIN DECK AND SUBMERGED WORK DECK	1,000.00
FORE AND AFT ARTICULATING RAMPS	
(@ $300.00 ea. X 2)	600.00
OUTBOARD ENGINES/ FUEL TANKS	
(7.5 hp, @ $900.00 ea. X 2)	1,800.00
ANCHOR, LINES AND MISCELLANEOUS HARDWARE	400.00
TOTAL	$ 7,800.00

Table 3. Labor costs for handling and processing 1 acre planting of oysters using the flexible belt system*

ACTIVITY	MAN HOURS/MONTH
LIFTING AND INSPECTING BELT LINE AND BAGS (15 minutes/belt; 144 bags/belt; one inspection/week)	36.0
HANDLING BAGS ON THE BELT SYSTEM (deployment, harvesting or flipping) 30 bags/hour	
50 % of bags handled biweekly	86.6
50 % of bags handled monthly**	43.3
THINNING - REDISTRIBUTION; CHANGE-OUT BAGS (2 days/month)	32.0
EQUIPMENT MAINTENANCE (2 days/month)	32.0
TOTAL	229.9

*Labor calculations based on two-man crew with a single tender vessel.
**Small mesh bags require more frequent handling than larger mesh.

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