Pilot-scale Production Economics of *C. ariakensis* Oysters
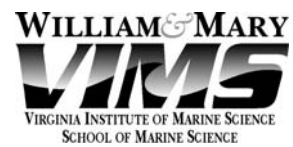
Summary of Virginia Seafood Council Industry Grow-out Trials (2003-2005)

Virginia Fishery Resource Grant Program
Thomas J. Murray
Marine Business Specialist
Virginia Sea Grant Marine Advisory Program
Gloucester Point, Virginia
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Background and Introduction

The "Virginia Fishery Resource Grant Program" (VFRGP) was initiated by the Virginia Legislature to "protect and enhance the Commonwealth's coastal fishery resource through the awarding of grants in four areas":

1) New fisheries equipment or gear;
2) Environmental pilot studies on issues including water quality and fisheries habitat;
3) Aquaculture or mariculture of marine-dependent species; and
4) Seafood technology.

The VFRGP is based on the simple approach that experienced fishermen can develop effective ideas for improving productivity or reducing costs. Typically, attempting such an idea or change entails a cash outlay that is too large a risk for an individual fisherman to justify, particularly if benefits from the idea would also be gained by others in the industry. The VFRGP serves to fund just those costs associated with that change in a fisherman's operation so that he or she does not bear all of the risk and expense for improving industry productivity.

As part of its ongoing competitive process, the VFRGP funded a two-year initiative to provide overall project management for the Virginia Seafood Council's (VSC) non-native oyster pilot grow-out study. The funding provided for a professional science manager to assist the VSC in conducting the research and serve as a liaison between industry and the various entities interested in research implementation. The position was funded for the two-year grow-out experiment, and information developed as part of this demonstration project is summarized herein.

The cooperative Virginia Seafood Council/Virginia Institute of Marine Science (VIMS) industry-based field trial was designed to address two main objectives: 1) to determine if growing triploid *C. ariakensis* in Virginia's Chesapeake Bay and the seaside of the Eastern Shore was economically feasible for both large and small companies; and 2) to produce some initial market assessment of triploid *C. ariakensis*. In order to determine economic feasibility, each participant agreed to track their input costs including fuel, labor, supplies, etc. This information is meaningful when related to income generated from oysters sold into both half-shell and shucking markets.

Another objective of this project involved the evaluation of differing grow-out methods. Several types of gear were used, which enabled some general comparison among grow-out methods and growth of *C. ariakensis* in various environments.

Methodologies Employed

Grow-out methods used in the VSC field trials included: traditional "Taylor floats," off-bottom cages, long-line systems (bags on bottom), re-bar racks, land-based crab shedding tanks, and an experimental raft system. Some of these grow-out systems were part of separate Virginia Fishery Resource Grant Program (VFRGP) project grants, but were also components of the VSC field trials. For example, "Shores and Ruark Seafood" (Urbanna) grew the triploid *C. ariakensis* in an experimental long-line system that was approved for development by a VFRGP grant. In addition, "Shore Seafood" (Saxis) employed an experimental raft system during the fall and winter to grow out triploid *C. ariakensis* that was also part of a separate VFRGP grant.[1]

Generally, Methods Included

- *Off-bottom cages* – ADPI/OBC bags constructed of rigid polyethylene with varying mesh and bag sizes were the primary method of containment. The mesh size used depends on the size of the oyster to be contained. The bags are then secured inside a 4' x 4' cage, with feet, constructed of metal with a total height of not more than 12" off the bottom. The cages can also be anchored using hooks made of iron reinforcing bar.

- *Bags on rack* – Racks consist of $^3/_8$" to $^1/_2$" reinforcing bar welded to produce vertical sides of approximately 18" and a length of 10' to 20'. These racks were driven into the bottom in rows, end to end, with working aisles of approximately 3' to 4' between rows. The racks have an off bottom height of not more than 12". ADPI/OBC bags were strapped side by side onto the rack using wire ties, nylon self-locking cables, or rubber bungee cords.

- *Long-lined bags on bottom* – ADPI/OBC bags were secured together by a long line and anchored to the bottom. The number of bags per line varied according to site. Hard bottom sites were typically chosen to ensure that bags did not become silted over.

- *Floats* – "Taylor floats" typically were used, consisting of a 4" PVC rectangular ring with a 1 inch coated hard wire basket secured using several tie wraps. Oysters contained within ADPI/OBC bags are then placed inside the floats.

- *Crab shedding tanks* – An existing land-based flow through system was used to further nursery seed from the deployment size of 20mm up to approximately 40mm.The rectangular wooden tanks, which typically house soft crabs before they molt, are approximately 48" x 96" x 12" with a central drain that was screened to prevent escapement. Oysters contained within ADPI/OBC bags were placed inside the tank.

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[1] The use of this system had to be temporarily discontinued during the summer 2004 due to the close proximity of units (stacks of tray inserts in the raft) and the possibility of reproduction imposed by the conditions set forth in the VSC's Army Corps of Engineers permit extension document. A complete description of the VSC-VFRGP project sites and methods may be found at <http://www.vims.edu/vsc/sites.html>.

A significant aspect of this project involved diverse marketing strategies employed by each grower. For example, some of the larger shucking facilities processed oysters on site and sold oysters via their established retail and food service customers. Alternatively, smaller aquaculture farms sold primarily "shell stock" oysters to retail, restaurant and food service institutions, and/or directly to the consuming public. A few aquaculture farms also sold shell stock oysters to larger shucking facilities to determine meat yields.

In conjunction with the VSC industry field trial, VIMS implemented a companion study entitled "Biosecurity and Comparative Field Trials of Triploid *C. ariakensis* with *C. virginica*" which enabled scientists, industry members, and state and federal agencies to collect and have access to related biological and ecological data (Hudson et al., 2005).[2] The biological (growth and mortality) data are summarized here in conjunction with the economic information gathered from the growers.

As a result of damage sustained during Hurricane Isabel in September 2003, two participants were unable to participate in the VSC project. Therefore, only 8 field sites housed oysters. Nine growers participated, however, as two growers occupied one field site and shared the 100,000 oyster allotment.

Results

C. ariakensis deployed at all sites during October 2003 grew very well and generally obtained market size by the spring of 2004. Despite cooler water temperatures and potentially lower food availability, *C. ariakensis* grew quickly once acclimated to site-specific environmental conditions. Triploid *C. virginica*, deployed concurrently, did not immediately grow like *C. ariakensis*. In fact, *C. virginica* generally grew very little from deployment until mid-spring 2004. On average, across all sites *C. ariakensis* grew 38% faster (range 15%-65%) than *C. virginica* and suffered significantly less mortality (7% relative to 20%, respectively)[3].

Some *C. ariakensis* were lost due to winter icing at the Saxis, Burgess, Kinsale, Urbanna, Yorktown (Crewe) and Chincoteague sites. Although *C. virginica* experienced little winter icing mortality, growers reported that *C. ariakensis* appeared to be more sensitive to severe cold temperatures if exposed.

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[2] The VIMS biosecurity project is updated at <http://www.vims.edu/vsc/>.
[3] The mortality comparison is derived from the VIMS biosecurity project. *C. ariakensis* mortality within the commercial trials was reported to be 10%; there was no comparison with *C. virginica* as part of the VSC trial.

Comparison of average shell height growth for all VSC sites for *C. ariakensis* and *C. virginica*. Error bars represent one standard error. (Hudson et al., 2005)
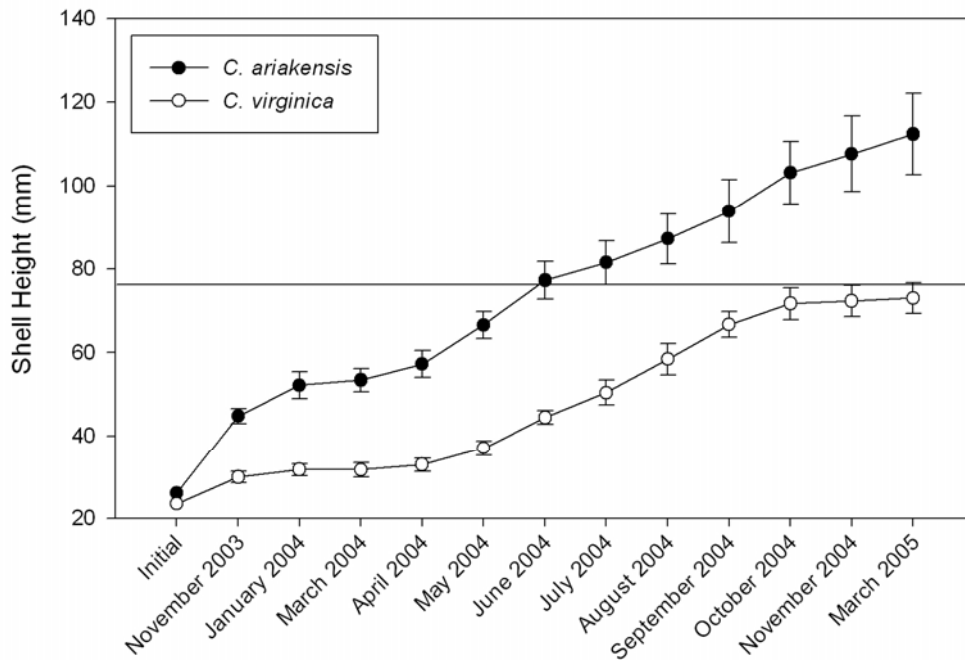
Within 7 months of field planting (spring 2004), *C. ariakensis* were beginning to reach market size (76mm.). Growers at higher and moderate salinity sites were marketing hundreds to thousands of *C. ariakensis* primarily for the half-shall market. *C. virginica* was growing but not nearly at the rate of *C. ariakensis*, nor were the *C. virginica* of marketable size. As depicted above, on average, *C. ariakensis* reached market size within 9 months of deployment. In contrast, on average the *C. virginica* still had not reached market size after 18 months of deployment.

Given the delay in deployment and general disruption from Hurricane Isabel, a new federal permit extension was issued by the U.S. Army Corps of Engineers on July 1, 2004 which included nine additional grow-out conditions. This is noteworthy because one of the new conditions required the growers to prematurely harvest oysters and/or further reduce the density of oysters per unit (i.e., cage, bag, or float). *It is believed that this measure directly impacted the results of the industry trials.* This requirement imposed inefficiencies in terms of grow-out economics as well as resulting product marketability. The new permit condition required the growers to purchase more gear while expending more labor in culturing the *C. ariakensis*. Additionally, the condition put the growers in a position where they had to harvest smaller ("standard") oysters and disadvantageously sell the "culls" on the market at a time of year when oyster product demand is comparatively low.[4] In summary, these additional constraints increased variable costs while also reducing per-unit value.

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[4] The greatest demand for oysters occurs traditionally around Thanksgiving, Christmas, and Lent.

Grow-out Costs

As depicted in the table below, costs of production varied significantly from site to site. Some growers, (Sopko-Hudgins, Ruark-Urbanna, and Crewe-Yorktown) used existing materials and supplies and primarily older cages to contain oysters. Other growers (Mason-Chincoteague, Bevans-Kinsale, and Leggett-Yorktown) chose to purchase new coated wire cages, which totaled from $1,000 to $4,000 in initial investment costs. In general, minimal initial investments were made in labor, fuel, and other miscellaneous aquaculture expenses. Per-unit labor appears to be consistent with typical aquaculture techniques, although as noted above, increased biosecurity and required harvest and splitting of oysters as part of permit extension conditions increased these per-unit labor costs.

When using an imputed labor cost of $10.00/hour the average wage bill for all trials was $4,095, or 37% of the variable costs of grow-out. The average annual cost of supplies was $5,740, or 52% of grow-out expenses. These supply costs vary considerably both in amount and type between the different grow-out methods outlined above. The treatment of most of these inputs as annual expenses (including such things as wire, cages, floats, bags, cables, etc.) likely understates the annual grow-out profit estimated here, as much of these materials may be re-used for more than one grow-out cycle. The decision to expense these costs here was made because of the variability of such costs and the fact that typically such materials may be expensed under Internal Revenue Service guidelines. Assigning a standard useful life to fabricated gear such as floats, cages, etc. would be arbitrary given their custom made nature. With the exception of the oyster culture raft (Saxis), which is depreciated over an estimated useful life of 7 years, other gear and equipment are expensed.

Virginia Seafood Council Oyster Grow-out Average Cost and Returns 2003-2005	
Cost Category	Average (Range)
Labor Cost	$4,095 ($2,580-$5,280)
Supplies	$5,740 ($700-$10,484)
Fuel	$223 ($50-360)
Seed	$879 ($773-1,000)
Electricity	$12.50 (0- $100)
Total Cost	$10,951 ($4,499-$16,035)
Oysters Sold	87,985 (77,320-99,998)
Total[5] Revenue	$20,999 ($18,557-$23,000)
Balance	$10,049 ($2,801-$17,677)

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[5] Oysters were sold both as shucked and half-shell product. The gross revenues reflected here include the shucked sales. The overall average sales price was $.24 per oyster. When adjusting for the cost (value added) of the shucking operation, the average revenue from oysters going into shucking should be reduced by $.03-$.04 per oyster to an estimated $.20-$.21 per oyster based upon the average price estimated by industry of $42-$44 per gallon.

Grow-out Returns

Within 8 months of deployment, initial market information was gathered. From December 2003 through June 2004, growers reported approximately 204,940 triploid *C. ariakensis* had been sold to both the half-shell and shucked markets. Also, from July through August 2004 another 78,950 *C. ariakensis* were marketed in both sectors. Product was distributed to both novice and experienced oyster consumers, and to large and small half-shell and shucked markets (Appendix 2).

Overall, at the completion of the trials in March 2005 growers had marketed 703,878 *C. ariakensis* oysters reportedly worth $167,998.10. Oysters were sold both as shucked and half-shell product. The overall average sales price was $.24/oyster. The gross revenues reflected here include the shucked sales.

Cost by Site	Kinsale	Burgess	Urbanna	Hudgins	Yorktown (Crewe)	Yorktown (Leggett)	Saxis	Accomack	Chincoteague
Labor Hours	516	528	344	258	149	223	445	483	330
Labor Cost	$5,160.00	$5,280.00	$3,440.00	$2,580.00	$1,490.00	$2,230.00	$4,450.00	$4,830.00	$3,300.00
Supplies	$5,553.00	$9,441.00	$9,516.00	$700.00	$202.00	$4,783.00	$10,484.00[6]	$2,342.00	$2,904.00
Fuel	$200.00	$275.00	$360.00	$295.00	$150.00	$175.00	$90.00	$190.00	$50.00
Seed[7]	$885.20	$939.00	$773.20	$924.00	$404.90	$499.98	$775.00	$837.58	$999.98
Electricity	$0.00	$100.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cost	$11,798.20	$16,035.00	$14,089.20	$4,499.00	$2,246.90	$7,687.98	$15,799.00	$8,199.58	$7,253.98
Oysters Sold	88,520.00	93,900.00	77,320.00	92,400.00	40,490.00	49,998.00	77,500.00	83,752.00	99,998.00
Total[8] Revenue	$21,244.80	$22,536.00	$18,556.80	$22,176.00	$10,122.50	$12,499.50	$18,600.00	$19,262.96	$22,999.54
Balance	$9,446.60	$6,501.00	$4,467.60	$17,677.00	$7,875.60	$4,811.52	$2,801.00	$11,063.44	$15,745.56

Combined Virginia Seafood Council Oyster Grow-out Costs and Returns 2003-2005

[6] The raft culture system capital cost ($6,500) is amortized (5%) over a 7-year expected useful life rather than expensed as other grower supplies.

[7] Each grower (8) paid $1,000 for the triploid technology and nothing for the actual seed. For the sake of budgeting, $0.01 per oyster is a reasonable proxy. Personal communication, S.K. Allen, ABC, April 20, 2005.

[8] Oysters were sold both as shucked and half-shell product. The gross revenues reflected here include the shucked sales. The overall average sales price was $.24 per oyster. When adjusting for the cost (value added) of the shucking operation, the average revenue from oysters going into shucking should be reduced by $.03-$.04 per oyster to about $.20-$.21 each, based upon the average price estimated by industry of $42-$44 per gallon.

Discussion

This pilot project has demonstrated that culturing triploid *C. ariakensis* is feasible in Virginia waters even under relatively rigid grow-out protocols. Initial investments ranged from a few hundred to a few thousand dollars depending on the purchase of new or used grow-out systems. One challenge for industry arises from the fact that *C. ariakensis* have proven to grow quite fast, relative to the native oyster. This creates a situation where the *C. ariakensis* need to be tended on a more frequent basis than the native oyster. Otherwise, crowding and smothering may occur which ultimately leads to mortality.[9] Using existing aquaculture techniques, it appears as a result of this project that a relatively small investment of $1,500 to $10,000 when combined with skilled shellfish culture management can realistically grow out 100,000 triploid *C. ariakensis* with gross returns ranging from $18,600 to $23,000.[10]

Based upon these demonstrations, it is evident that a profit can be made with triploid *C. ariakensis* aquaculture. Even though initial investments in more elaborate systems can be high, such capital costs would be amortized over a period of time and the grow-out returns realized for several year classes of oysters. Further, the relatively short period from field planting to market grow-out provides enhanced cash flow. This suggests that *C. ariakensis* is an attractive oyster for such small-scale culture relative to other oyster varieties. Accelerated growth is additionally attractive to growers who, faced with decades of increasing oyster mortality due to diseases, value the reduced risk associated with a shorter grow-out period. Indeed, a positive grow-out cash flow in one to two years of operation is unprecedented in Virginia's molluscan shellfish aquaculture industry.

Preliminarily market returns indicate that this oyster is an exceptional shucking product. Growers were encouraged with meat yields as high as 11-14 pints/bushel compared to an expected range of 7-8 pints/bushel for *C. virginica*. Furthermore, industry's initial response to shucking *C. ariakensis* was positive. Operators of shucking houses grade oysters according to the number of pints that can be produced from a bushel of culled oysters. The relative quality of oysters is primarily determined by this yield. The table below summarizes shucking yield relative to industry evaluation of shucking quality.

Oyster Yield Per Bushel and Industry Grade	
4 Pints	Poor
5 Pints	Below Average
6 Pints	Average
7 Pints	Good
8 pints	Very Good
9-10 Pints	Exceptional

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[9] Given the rapid growth of *C. ariakensis,* the industry is considering relatively low stocking rates per bag to accommodate it. This is expected to reduce labor costs and further minimize biosecurity questions.

[10] The average price received for all sales of "half shell" *C. ariakensis* was $.215 each. The average price for shucked *C. ariakensis* was $42-44 per gallon.

These results confirm that *C. ariakensis* presents the potential for an exceptionally profitable shucked product. Processors find it advantageous to buy oysters which yield the most meats per bushel, reducing the volume of shell stock to be handled. This is reflected in the fact that, traditionally, processors pay premium prices for higher grade (yield) oysters. Additionally, shucking houses processing *C. ariakensis* reported that the oyster is easily opened and shuckers could readily remove the meat product from the shell stock.

In contrast, the *C. ariakensis* half-shell product was reportedly not as well accepted, relative to *C. virginica*, as the shucking product. A relatively short shelf life seems predominant regardless of salinity. Oysters that were kept dry and in ambient air temperatures often lasted only one to two days. Oysters kept in cool storage (~ 45-50°F) survived for up to 3-5 days, although those oysters kept in cold storage (32°F) were subject to a slightly earlier mortality. Growers observed during this initial trial that grow-out method may have an effect on shelf life. For example, oysters that remained inter-tidally since deployment, even through cold winter months, may have had a longer shelf life.

As reported, several grow-out methods were employed during the VSC demonstration project. Interesting differences and experiences were observed. For example, long-line bags on bottom (Urbanna) seem to expedite the growth of *C. ariakensis*. This may be due in part to the native habitat of *C. ariakensis*, which can be muddy bottom. In addition, crab-shedding tanks, which are bio-secure, appear to be an effective intermediate step in culturing *C. ariakensis* (Burgess). Prior to field deployment, tanks can be used to increase shell height, possibly avoiding predation from crabs and/or skates. Industry members learned that oysters should be removed from tanks prior to freezing conditions; otherwise, mortality may become a problem. Floats encourage oysters to grow very quickly as they take advantage of surface phytoplankton blooms. Oysters in floats are also protected during freezing temperatures, as the basket of the float sits a foot or more below the water's surface (VSC).

Discussion of Near-term Impacts

Discussion

There are an estimated one to two dozen commercial oyster farms in Virginia, with annual production capability at around 250,000 oysters per farm.[11] Most animals are sold to local niche markets, including restaurants, grocery stores, and farmers markets, in addition to some online sales. While all growers are interested in increasing production, small-scale producer markets may not support significant increases. However, smaller scale aquaculture farms producing 300-900 bushels/year are considered realistic scenarios and a profitable scale of operation based upon current culture techniques. It appears that the culture of *C. ariakensis* represents a potential for expansion of this current capability as demonstrated in the VSC field trials.

The potential for large-scale oyster planting, such as traditionally practiced in Virginia, appears to be promising with the allowance of extensive culture of C. *ariakensis*. Current interest in

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[11] Currently Virginia does not specifically license or permit shellfish aquaculture operations; therefore an exact accounting of the firms involved in shellfish aquaculture is not available. The estimates here are based upon informal market assessments conducted as part of the Virginia Fishery Resource Grant Program.

remote setting and continued culture of triploid animals suggests a real development opportunity may be furthered with the use of non-native oysters. It is believed that current hatchery potential for triploid oysters is fixed; however, continued success in triploid grow-out would foster additional industry investment in existing commercial hatcheries. Based upon these initial grow-out trials, both on-bottom culture of shucking products and expansion of aquacultured half-shell products may be economically feasible.

Near-term Impacts

To put this investigation into the current economic context of Virginia's oyster industry, it is important to compare the VSC limited pilot trials (which produced gross grower revenues of $168,000) with the entire traditional oyster fishery in Virginia.   That industry reportedly harvested 23,804 lbs. of oyster meats valued at $100,972 during 2004.

Clearly, the prospect for significant enhancement of the oyster producing sector has been demonstrated with these trial introductions. Sales of *C. ariakensis* contributed a total economic impact of $310,000 to the Commonwealth. When the production details of *C. ariakensis* are combined with the existing aquaculture capacity represented by small, yet knowledgeable, growers, the potential for immediate expansion seems clear.   With implementation of *C. ariakensis* grow-out by the 24 small-scale oyster aquaculturists in Virginia, a first year harvest of approximately 4 million oysters could be easily expected. The "farm gate" value based upon recent prices would approximate $1.0 million the first year, with a total economic impact to the state of $1.84 million.

Detailed Production and Grow-out Results by Site

As with *C. virginica*, *C. ariakensis* growth varies considerably from one region to another (and even from one part to another) and from year to year on the same grounds.

High Salinity VSC Sites Grow-Out Variable Costs and Returns 2003-2005			
Costs and Returns	Accomack	Chincoteague	Average
Labor Hours	483	330	406.50
Labor Cost	$4,830.00	$3,300.00	$4,065.00
Supplies	$2,342.00	$2,904.00	$2,623.00
Fuel	$190.00	$50.00	$120.00
Seed	$837.52	$999.98	$918.75
Electricity	$0.00	$0.00	0
Total Cost	$8,199.52	$7,253.98	$7,726.75
Oysters Sold	83,752	99,998	91,875
Total Revenue	$19,262.96	$22,999.54	$21,131.25
Balance	$11,063.44	$15,745.56	$13,404.50

Overview of Comparative Growth and Mortality

The following graphs summarize the VSC field trial results comparing growth rates and mortality between *C. ariakensis* and *C. virginica*. These data were collected during the trials in conjunction with the bio-security monitoring of the VSC project in its first year (Hudson et al., 2005). The data are first summarized for projects completed in three salinity regimes and then depicted for each VSC trial site.

Comparison of growth for *C. ariakensis* and *C. virginica* in a high salinity regime. Values represent shell height growth averaged over all sites with similar salinities. Error bars represent one standard error. (Hudson et al., 2005)
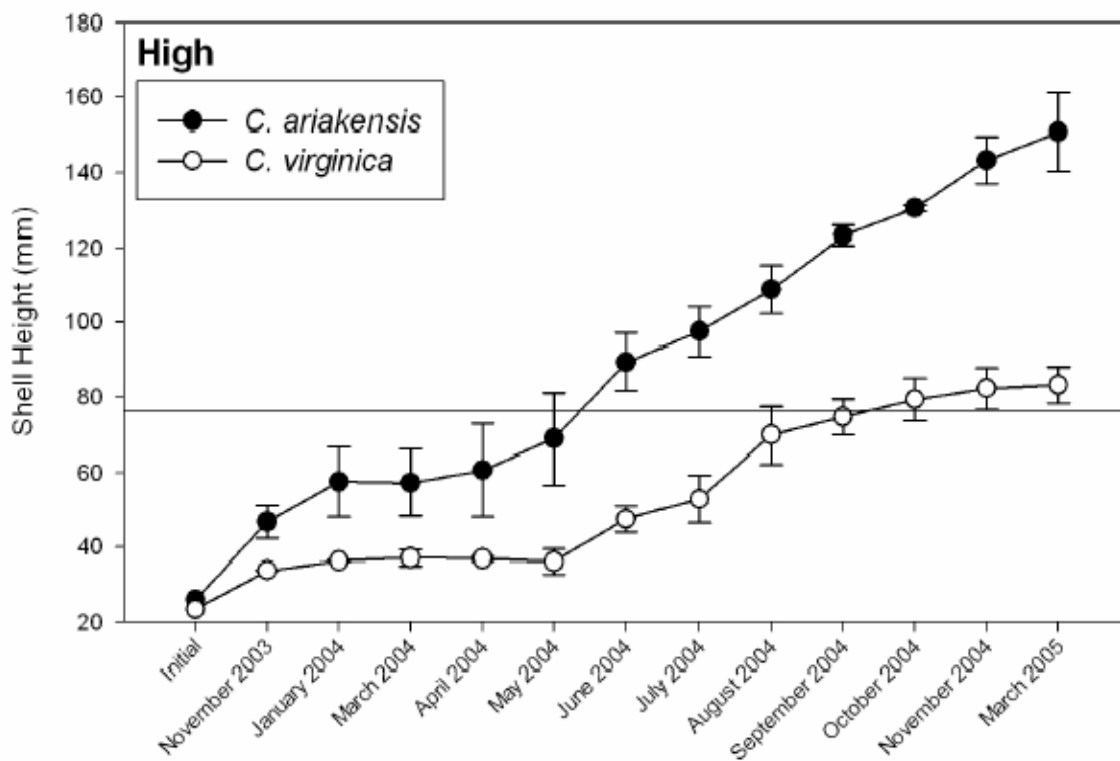
Comparison of growth by VSC site for *C. ariakensis* and *C. virginica* at individual sites within the high salinity regime. Values represent shell height growth averaged at individual site. (Hudson et al., 2005)
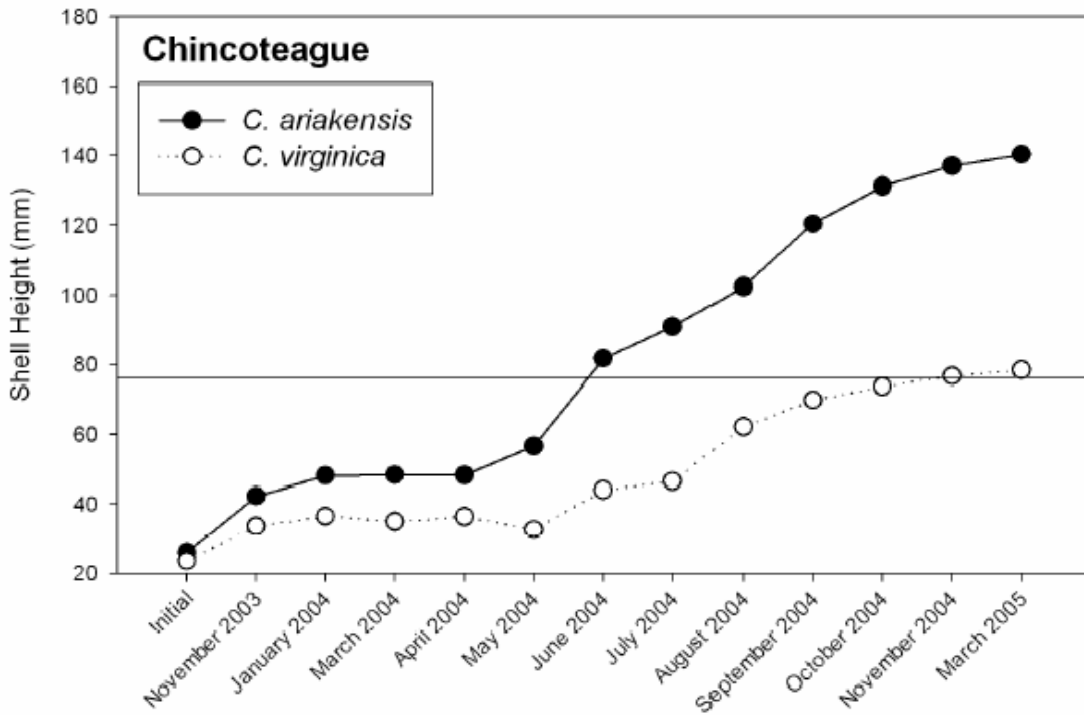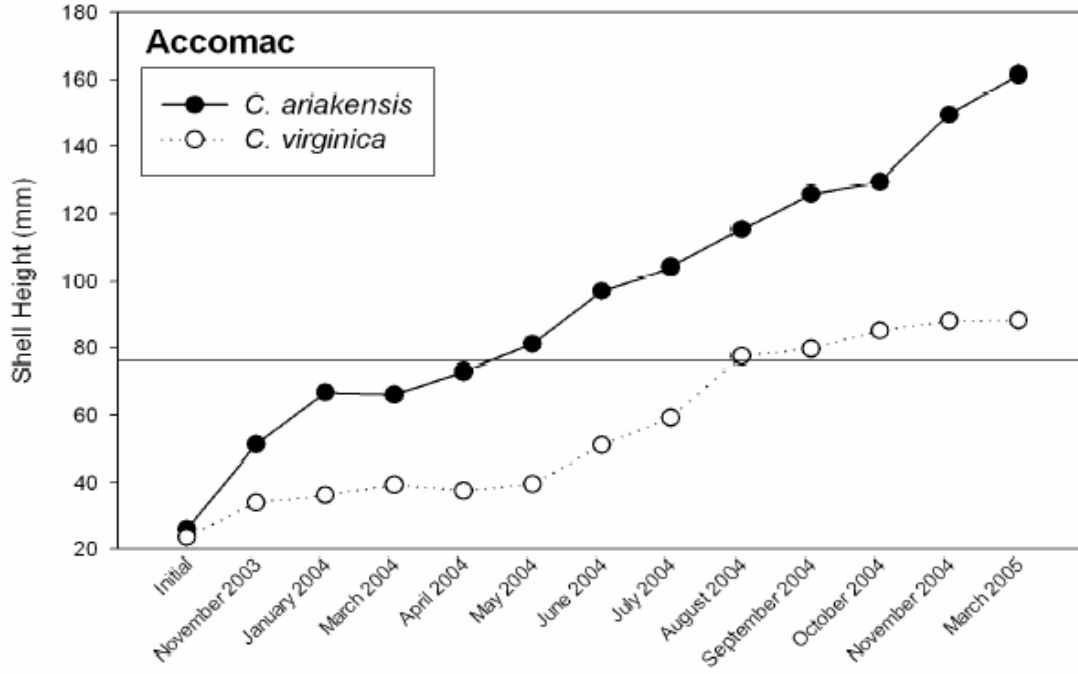
Medium Salinity VSC Sites Grow-out Variable Costs and Returns 2003-2005			
Costs and Returns	Hudgins	Saxis	Yorktown Combined
Labor Hours	258	445	372
Labor Cost	$2,580.00	$4,450.00	$3,720.00
Supplies	$700.00	$10,484.00	$4,985.00
Fuel	$295.00	$90.00	$325.00
Seed	$924.00	$775.00	$904.88
Electricity	$0.00	$0.00	$0.00
Total Cost	$4,499.00	$15,799.00	$9,934.88
Oysters Sold	92,400	77,500	90,488
Total Revenue	$22,176.00	$18,600.00	$22,622.00
Balance	$17,677.00	$2,801.00	$12,687.12

Comparison of growth for *C. ariakensis* and *C. virginica* in a medium salinity regime. Values represent shell height growth averaged over all sites with similar salinities. Error bars represent one standard error. (Hudson et al., 2005)

Comparison of growth by VSC site for *C. ariakensis* and *C. virginica* for individual sites within a medium salinity regime. Values represent shell height growth averaged at individual site. (Hudson et al., 2005)

Yorktown
- C. ariakensis
- C. virginica
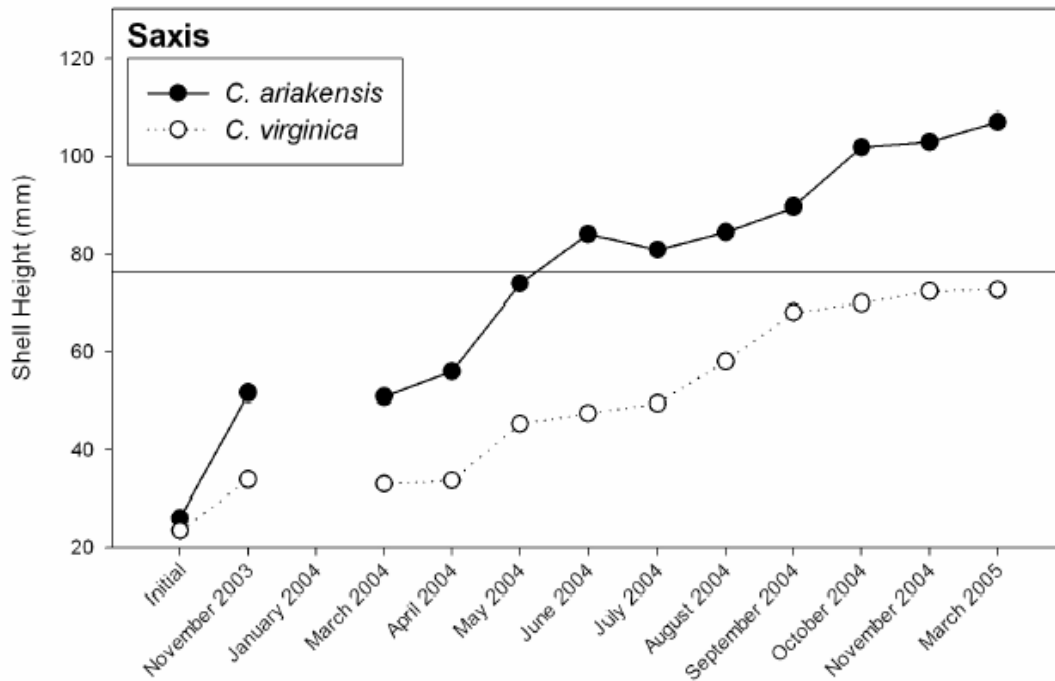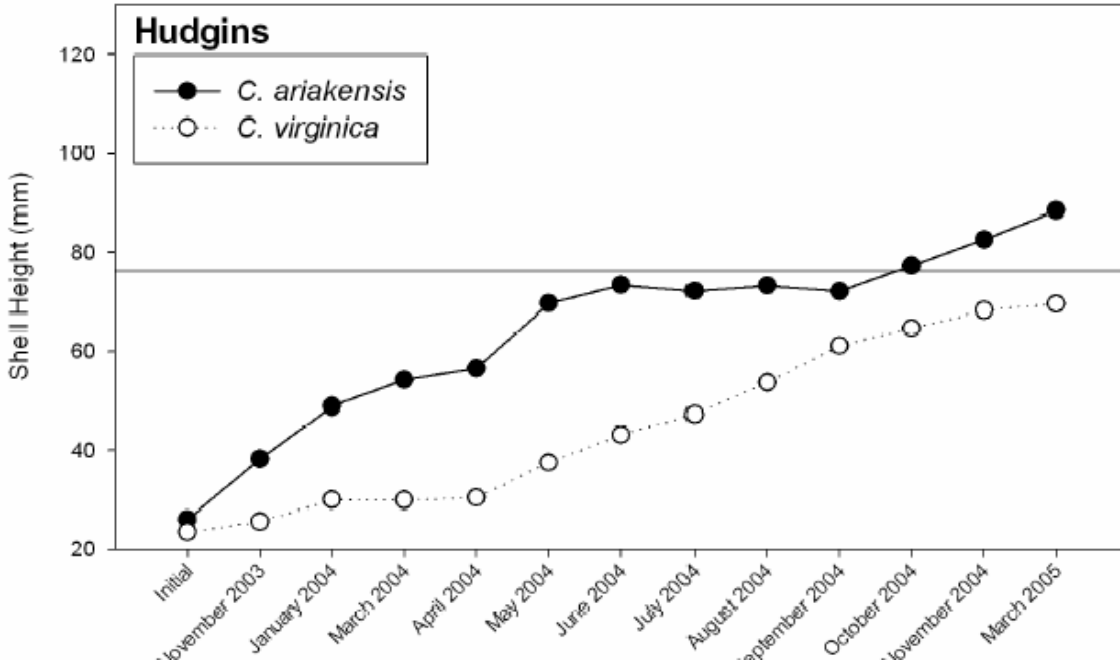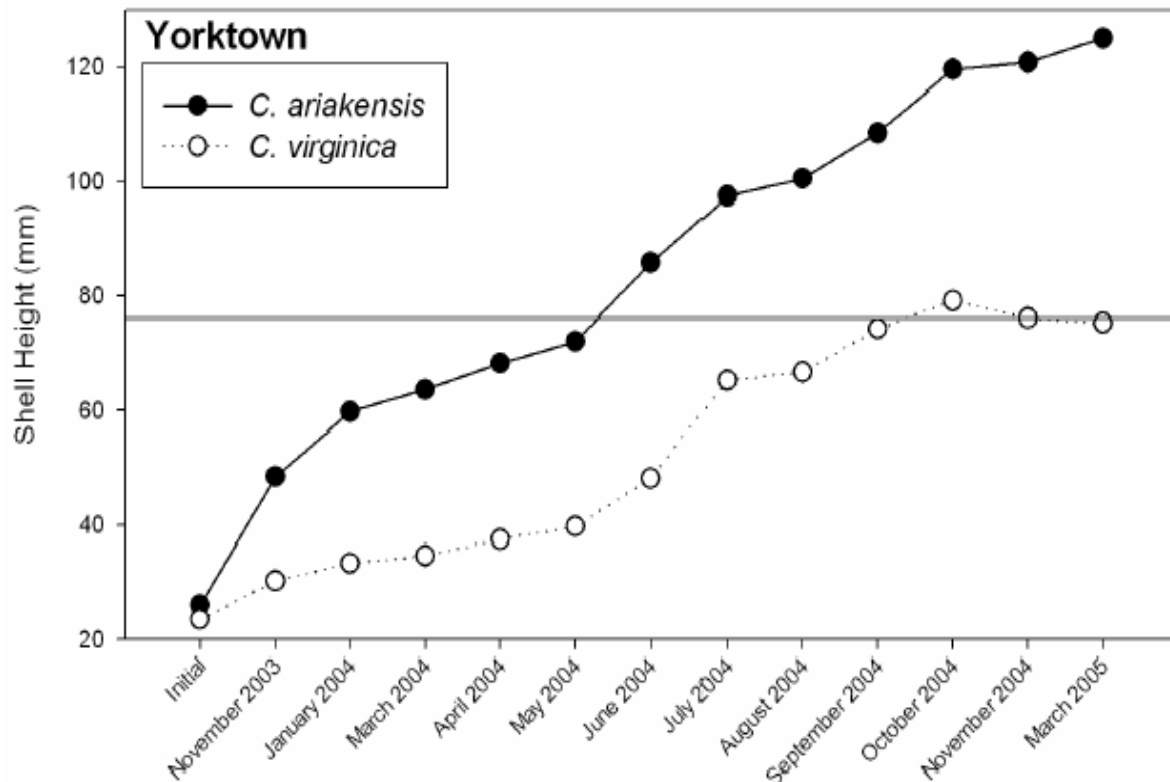
Low Salinity VSC Sites Grow-out Variable Costs and Returns 2003-2005				
Costs and Returns	Kinsale	Burgess	Urbanna	Average
Labor Hours	516	528	344	463
Labor Cost	$5,160.00	$5,280.00	$3,440.00	$4,626.67
Supplies	$5,553.00	$9,441.00	$9,516.00	$8,170.00
Fuel	$200.00	$275.00	$360.00	$278.33
Seed	$885.20	$939.00	$773.20	$865.80
Electricity	$0.00	$100.00	$0.00	$33.33
Total Cost	$11,798.20	$16,035.00	$14,089.20	$13,974.13
Oysters Sold	88,520.00	93,900.00	77,320.00	86580.00
Total Revenue	$21,244.80	$22,536.00	$18,556.80	$20,779.20
Balance	$9,446.60	$6,501.00	$4,467.60	$6,805.07

Comparison of overall growth for *C. ariakensis* and *C. virginica* within a low salinity regime. Values represent shell height growth averaged over all sites with similar salinities. Error bars represent one standard error. (Hudson et al., 2005)
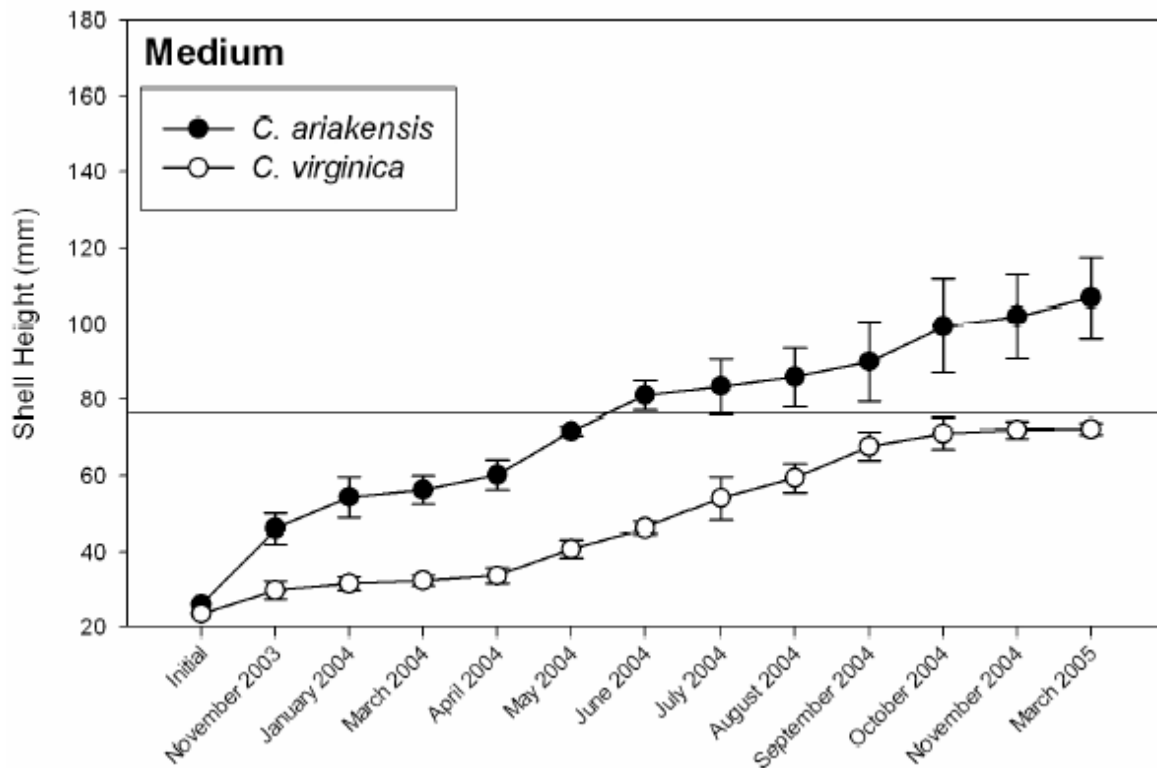

Comparison of growth by individual VSC site for *C. ariakensis* and *C. virginica* within a low salinity regime. Values represent shell height growth at individual site. (Hudson et al., 2005)
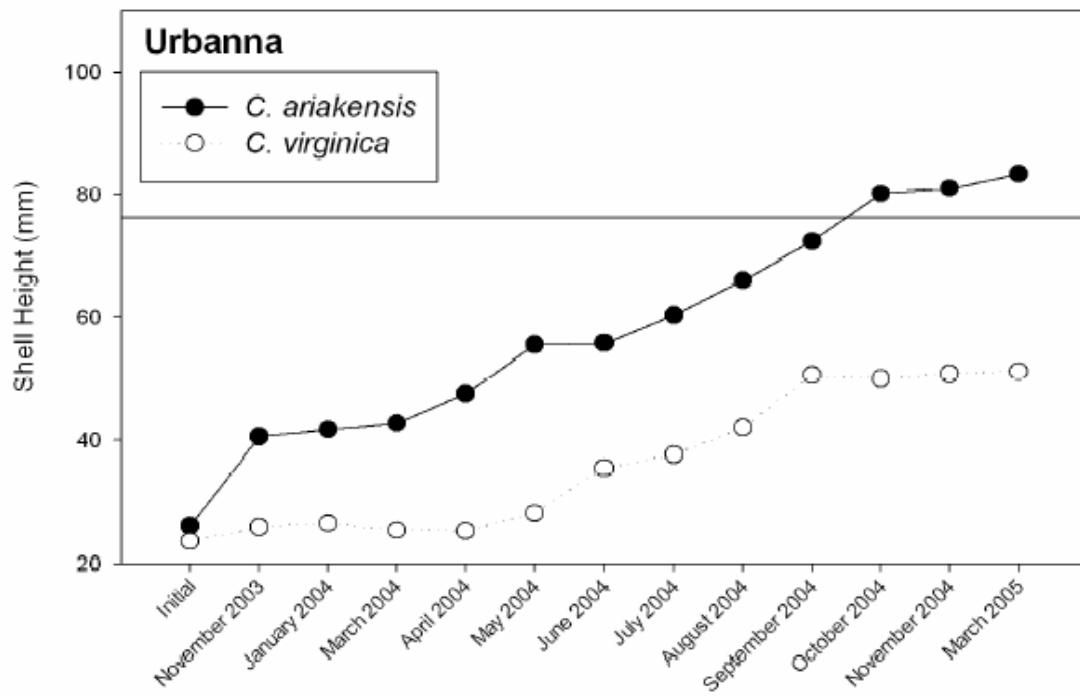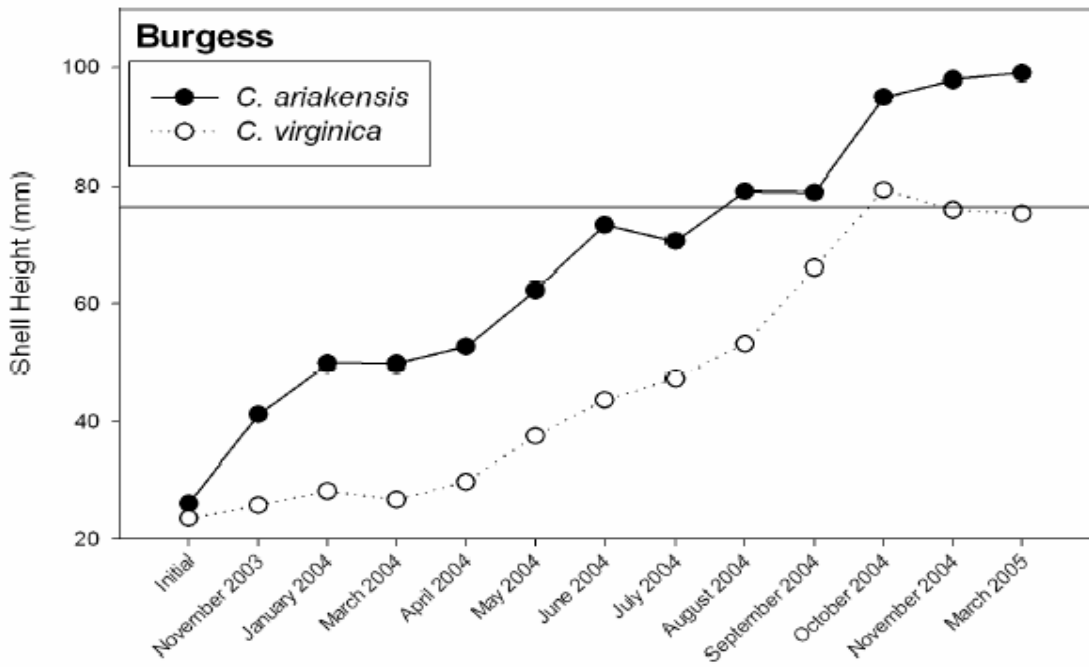
Overview of Comparative Growth and Mortality
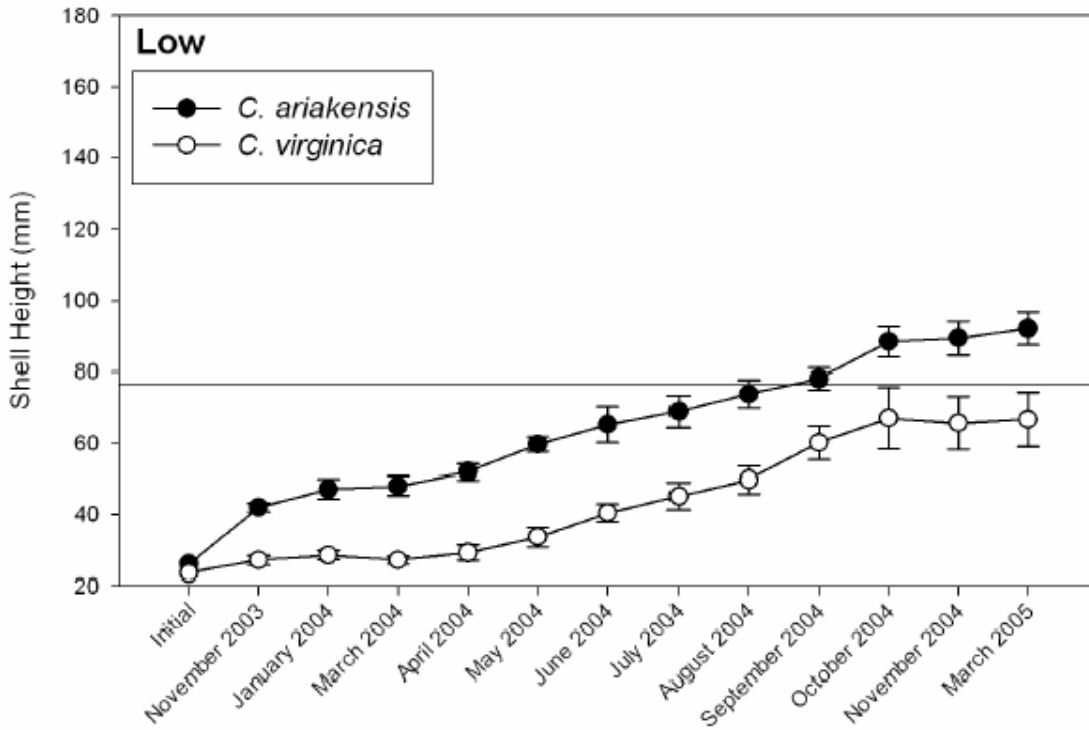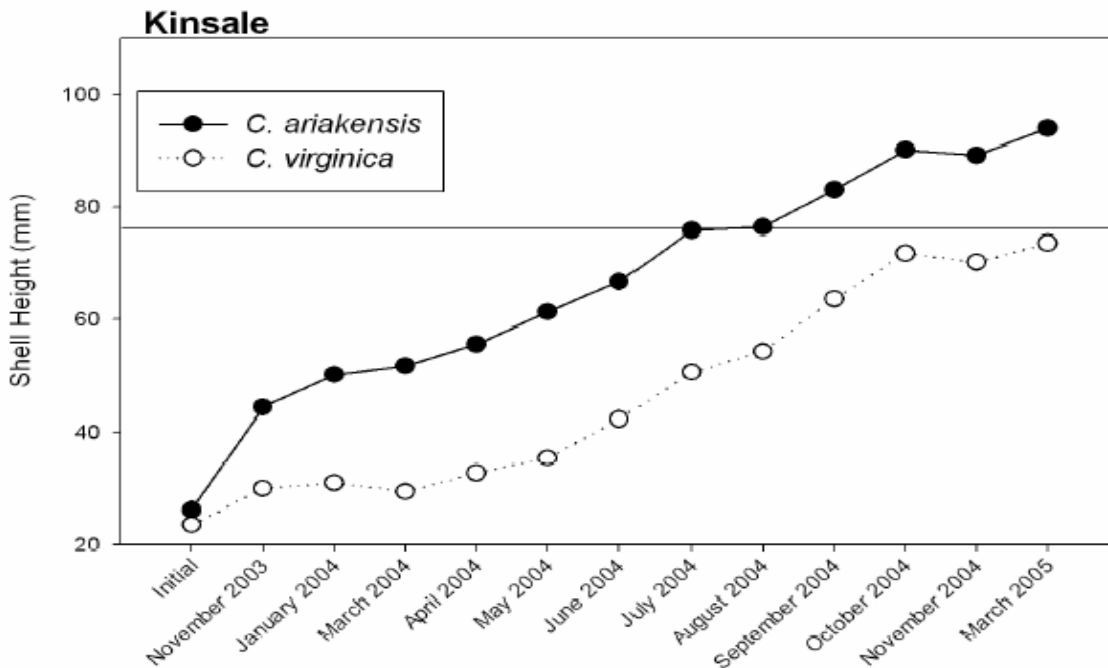
Growth data show *C. ariakensis* outperforming *C. virginica* without exception at every site (every salinity regime). Disease sampling from all sites has indicated light infections for both species, a situation that might be peculiar to the time period of the project. However, it is also possible that triploidy, *per se,* may decrease the incidence of disease.[12] Except for a couple of incidents of icing that killed both species, mortality has been relatively low, somewhat higher in *C. virginica* than *C. ariakensis*. These results are also contrary to those of Grabowski et al. (2004) who reported relatively higher mortalities across sites, and higher mortality in *C. ariakensis* than *C. virginica* at high salinity.

It is likely that high salinity and most medium salinity sites can realize nearly 100% harvest within a year. Not known is whether the same can be realized at lower salinity sites, since growth is somewhat slower there. In addition to the clear advantage of improved cash flow and return on investment, a major advantage of a one-year crop rotation would be accommodation of the concerns for biosecurity in non-native *C. ariakensis* aquaculture.

The table below summarizes the disposition of oysters from the nine individual grow-out investigations (eight sites) in terms of oysters sold and mortality per trial. Overall deployment of 790,054 *C. ariakensis* oysters was reported, with 703,878 oysters ultimately marketed and a final mortality rate of 10.3% (81,796)[13].

Appendix 1

<table>
<tr><td colspan="9">Overall Disposition of <i>C. ariakensis</i> in VSC Field Trials 2003-2005.
(Figures in italics are mortality numbers. Figures in bold are number marketed.)</td></tr>
<tr><td>Kinsale</td><td>Burgess</td><td>Urbanna</td><td>Hudgins</td><td>Yorktown (Crewe)</td><td>Yorktown (Leggett)</td><td>Saxis</td><td>Accomack</td><td>Chincoteague</td></tr>
<tr><td><i>320</i></td><td><i>500</i></td><td><i>9,500</i></td><td><i>7,400</i></td><td><i>7,500</i></td><td>1,500</td><td><i>14,004</i></td><td>100</td><td>5,500</td></tr>
<tr><td><i>6,600</i></td><td><i>600</i></td><td><i>6,700</i></td><td>20,600</td><td>12,100</td><td>7,500</td><td><i>8,500</i></td><td>20,589</td><td>58,050</td></tr>
<tr><td><i>4,000</i></td><td>18,000</td><td><i>1,200</i></td><td>7,000</td><td><i>2,000</i></td><td>15,189</td><td>32,200</td><td>24,075</td><td><i>5,280</i></td></tr>
<tr><td>15,340</td><td>7,500</td><td>27,000</td><td>35,200</td><td>15,134</td><td><i>1,042</i></td><td>4,000</td><td><i>1,650</i></td><td>13,600</td></tr>
<tr><td>7,500</td><td>46,400</td><td><i>5,280</i></td><td>17,600</td><td>2,900</td><td>4,189</td><td>40,950</td><td>5,000</td><td>14,432</td></tr>
<tr><td>53,380</td><td>22,000</td><td>35,720</td><td>12,000</td><td>6,660</td><td>14,080</td><td>350</td><td>32,488</td><td>7,216</td></tr>
<tr><td>12,300</td><td></td><td>14,600</td><td></td><td>3,346</td><td>7,040</td><td></td><td>1,500</td><td>1,200</td></tr>
<tr><td></td><td></td><td></td><td></td><td>350</td><td>500</td><td></td><td></td><td></td></tr>
<tr><td>99,440</td><td>100,000</td><td>100,000</td><td>99,800</td><td>49,990</td><td>51,040</td><td>100,004</td><td>85,402</td><td>105,278</td></tr>
</table>

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[12] Personal communication, Stan Allen.
[13] This compares with 7% mortality associated with the VIMS biological studies attendant to this grow-out project.

Cumulative Mortality

Cumulative mortality is the sum of all interval mortalities and in *C. ariakensis* was less than *C. virginica* across all sites. The average percent cumulative mortality was corrected to exclude the documented event mortality as it was not species specific and does not accurately reflect a difference in natural mortality between the species.

The documented events occurred at 3 sites. Two sites incurred a freezing event in the first winter and one site experienced a siltation event in July 2004. Freezing mortality at the 2 sites was obvious; the bags exhibiting mortality were on the top layer of the container and completely covered in ice. The bags underneath, which remained underwater, exhibited no mortality. This occurred at 2 of the highest energy sites which endured freezing temperatures under low tide conditions. The siltation event was also obvious. At the July collection, one of the cages was partially buried with a *C. virginica* replicate bag covered in sand. The silted bag experienced approximately 50% mortality and minimal mortality was seen in the other 2 replicates.

Location	Species	% Cumulative Mortality Including Documented Event Mortality	% Cumulative Mortality Without Documented Event Mortality
Urbanna	*C. ariakensis*	3.88	3.88
	C. virginica	9.04	9.04
Burgess	*C. ariakensis*	7.77	7.77
	C. virginica	15.30	15.30
Kinsale	*C. ariakensis*	4.35	4.35
	C. virginica	9.96	9.96
Yorktown	*C. ariakensis*	6.92	6.92
	C. virginica	**22.09**	8.28
Hudgins	*C. ariakensis*	9.60	9.60
	C. virginica	10.95	10.95
Saxis	*C. ariakensis*	**19.00**	7.52
	C. virginica	**78.77**	32.18
Accomack	*C. ariakensis*	0.00	0.00
	C. virginica	7.56	7.56
Chincoteague	*C. ariakensis*	**6.90**	0.25
	C. virginica	**36.11**	34.63

Appendix 2

Appendix 2. VSC Market Trials Shucked Oyster Yield And Values By Market Outlet				
Yield (gal)	**Size**	**# Bushels**	**$/gal**	**Revenue ($)**
27	standards	33.2	$35	$ 945
5	counts	3.5	47	235
125	selects	86.9	42	5,250
34	counts	23.6	46	1,564
47	counts	32.7	46	2,162
24	selects	16.7	41	984
24	counts	16.7	46	1,104
40	standards	22.8	42	1,680
50	selects	28.5	42	2,100
100	selects	67	42	4,200
100	selects	67	42	4,200
90	selects	50	45	4,050
72.6	selects	46.5	45	3,267
42	selects	24	45	1,890
53.5	standards	42.8	45	2,407
83.4	selects	67	45	3,753
83.4	selects	67	45	3,753
83.4	selects	67	45	3,753
	selects	1		25
	selects	1		45
3.25	selects	2		90
3.5	selects	2		90
3.38	counts	2		90
3.38	counts	2		90
3.38	counts	2		90
	counts	2		90
	counts	2		90
	counts	2		90
	counts	2		90
3.38	counts	2		90
3.25	counts	4		180
3.13	counts	2		90
	counts	2		90
	counts	2		90
	counts	2		90
6.4	counts	3		135
	counts	2		90
	counts	1		45
3	counts	2		90
	counts	1		45
	counts	2		90
	counts	2		90
5.5	counts	4		180
	counts	2		90

Appendix 2. VSC Market Trials Shucked Oyster Yield And Values By Market Outlet				
Yield (gal)	Size	# Bushels	$/gal	Revenue ($)
	counts	2		$ 90
	counts	2		90
	counts	10		450
	counts	4		180
	counts	2		90
	counts	2		90
	counts	1		45
6.25	counts	4		180
	counts	4		180
	counts	5		225
	counts	6		270
	counts	3		135
	counts	3		135
	counts	5		223
	counts	3		135
	counts	4		180
	counts	4		180
	counts	6		275
	counts	3		135
	counts	3.5		134.5
	counts	5.3		243
	counts	1		45
	counts	3.3		150
	counts	16.7		750
	counts	16.7		850
	counts	18.5		943.5
	counts	15.8		807.5
	counts	6.7		340
	counts	6.7		500
200	selects	120	45	9,000
75	selects	50	45	3,375
58.5	selects	39	45	2,632.5
96.25	counts	55	45	4,331.25
50.75	counts	29	45	2,283.75
101.25	counts	81	45	4,556.25
73.3	counts	51	45	3,298.5
77.6	counts	54	45	3,492
Tot. 1864.75		Tot. 1462.1	Avg. 44.0769	
Average gal/bu.	1.275392		56.22	

Appendix 3

Appendix 3. VSC Market Trials Half-shell Oyster Yield And Values By Market			
Market	**# Sold**	**$/Oyster**	**Revenue**	**Market Outlet**
half-shell	103	$0.34	$35.00	farmers market
half-shell	26	$0.31	$8.00	farmers market
half-shell	24	$0.33	$8.00	farmers market
half-shell	12	$0.33	$4.00	farmers market
half-shell	12	$0.33	$4.00	farmers market
half-shell	90	$0.33	$30.00	farmers market
half-shell	61	$0.27	$16.24	farmers market
half-shell	200	$0.25	$50.00	VIMS/Stan Allen
half-shell	12	$0.33	$4.00	farmers market
half-shell	19	$0.32	$6.00	farmers market
half-shell	72	$0.33	$24.00	farmers market
half-shell	198	$0.24	$47.00	farmers market
half-shell	100	$0.25	$25.00	restaurant
half-shell	60	$0.33	$20.00	farmers market
half-shell	120	$0.25	$30.00	restaurant
half-shell	36	$0.33	$12.00	farmers market
half-shell	100	$0.25	$25.00	restaurant
half-shell	392	$0.29	$114.00	farmers market
half-shell	300	$0.25	$75.00	restaurant
half-shell	60	$0.33	$20.00	farmers market
half-shell	100	$0.25	$25.00	restaurant
half-shell	300	$0.25	$75.00	restaurant
half-shell	255	$0.33	$84.15	farmers market
half-shell	500	$0.25	$125.00	restaurant
half-shell	90	$0.33	$30.00	farmers market
half-shell	100	$0.25	$25.00	direct to consumer
half-shell	200	$0.25	$50.00	restaurant
half-shell	100	$0.25	$25.00	John Glass
half-shell	174	$0.33	$58.00	farmers market
half-shell	500	$0.25	$125.00	restaurant
half-shell	100	$0.25	$25.00	direct to consumer
half-shell	168	$0.33	$58.00	farmers market
half-shell	100	$0.25	$25.00	direct to consumer
half-shell	300	$0.25	$75.00	restaurant
half-shell	240	$0.29	$71.00	farmers market
half-shell	300	$0.25	$75.00	restaurant
half-shell	242	$0.29	$73.75	farmers market
half-shell	400	$0.25	$100.00	direct to consumer
half-shell	400	$0.25	$100.00	restaurant
half-shell	100	$0.25	$25.00	direct to consumer
half-shell	150	$0.29	$45.00	direct to consumer

Appendix 3. VSC Market Trials Half-shell Oyster Yield And Values By Market				
Market	# Sold	$/Oyster	Revenue	Market Outlet
half-shell	200	$0.25	$50.00	restaurant
half-shell	60	$0.33	$24.00	farmers market
half-shell	200	$0.25	$50.00	direct to consumer
half-shell	300	$0.25	$75.00	restaurant
half-shell	100	$0.25	$25.00	restaurant
half-shell	160	$0.29	$50.00	farmers market
half-shell	200	$0.25	$50.00	restaurant
half-shell	200	$0.25	$50.00	restaurant
half-shell	174	$0.33	$58.00	farmers market
half-shell	200	$0.25	$50.00	restaurant
half-shell	114	$0.33	$38.00	farmers market
half-shell	200	$0.25	$50.00	restaurant
half-shell	24	$0.42	$10.00	direct to consumer
half-shell	300	$0.25	$75.00	restaurant
half-shell	144	$0.33	$48.00	farmers market
half-shell	300	$0.25	$75.00	restaurant
half-shell	133	$0.33	$42.25	farmers market
half-shell	233	$0.28	$65.00	farmers market
half-shell	300	$0.25	$75.00	restaurant
half-shell	100	$0.25	$25.00	direct to consumer
half-shell	18	$0.33	$6.00	farmers market
half-shell	304	$0.31	$93.00	farmers market
half-shell	200	$0.25	$50.00	restaurant
half-shell	200	$0.25	$50.00	restaurant
half-shell	262	$0.30	$79.00	farmers market
half-shell	69	$0.29	$20.00	direct to consumer
half-shell	200	$0.25	$50.00	restaurant
half-shell	152	$0.25	$38.00	restaurant
half-shell	182	$0.31	$56.00	farmers market
half-shell	300	$0.25	$75.00	restaurant
half-shell	200	$0.25	$50.00	restaurant
half-shell	114	$0.33	$38.00	farmers market
half-shell	300	$0.25	$75.00	restaurant
half-shell	138	$0.33	$46.00	farmers market
half-shell	100	$0.25	$25.00	farmers market
half-shell	200	$0.25	$50.00	restaurant
half-shell	154	$0.28	$43.00	farmers market
half-shell	100	$0.25	$25.00	shucking house ½ shell
half-shell	150	$0.25	$37.50	direct to consumer
half-shell	200	$0.25	$50.00	restaurant
half-shell	100	$0.25	$25.00	shucking house ½ shell
half-shell	66	$0.33	$22.00	direct to consumer
half-shell	200	$0.25	$50.00	restaurant
half-shell	200	$0.25	$50.00	shucking house ½ shell

Appendix 3. VSC Market Trials Half-shell Oyster Yield And Values By Market				
Market	# Sold	$/Oyster	Revenue	Market Outlet
half-shell	200	$0.25	$50.00	shucking house ½ shell
half-shell	200	$0.25	$50.00	restaurant
half-shell	100	$0.25	$25.00	direct to consumer
half-shell	160	$0.28	$45.00	shucking house ½ shell
half-shell	192	$0.33	$64.00	farmers market
half-shell	172	$0.29	$49.00	farmers market
half-shell	200	$0.25	$50.00	restaurant
half-shell	124	$0.32	$40.00	farmers market
half-shell	200	$0.25	$50.00	restaurant
half-shell	200	$0.25	$50.00	restaurant
half-shell	1300	$0.17	$221.00	restaurant
half-shell	1000	$0.17	$170.00	restaurant
half-shell	1700	$0.17	$289.00	restaurant
half-shell	2000	$0.25	$500.00	retail market
half-shell	1500	$0.25	$375.00	direct to consumer
half-shell	2000	$0.25	$500.00	direct to consumer
half-shell	3000	$0.25	$750.00	direct to consumer
half-shell	50	$0.50	$25.00	direct to consumer
half-shell	3000	$0.25	$750.00	direct to consumer
half-shell	2500	$0.25	$625.00	direct to consumer
half-shell	3000	$0.25	$750.00	direct to consumer
half-shell	2000	$0.20	$400.00	Retail market
half-shell	3000	$0.25	$750.00	direct to consumer
half-shell	2500	$0.25	$625.00	direct to consumer
half-shell	3000	$0.20	$600.00	direct to consumer
half-shell	2000	$0.25	$500.00	direct to consumer
half-shell	4000	$0.17	$680.00	direct to consumer
half-shell	3000	$0.20	$600.00	direct to consumer
half-shell	3000	$0.20	$600.00	direct to consumer
half-shell	50	$0.50	$25.00	direct to consumer
half-shell	2000	$0.20	$400.00	direct to consumer
half-shell	4800	$0.20	$960.00	direct to consumer
half-shell	3000	$0.20	$600.00	direct to consumer
half-shell	2000	$0.20	$400.00	direct to consumer
half-shell	300	$0.30	$90.00	direct to consumer
half-shell	200	$0.30	$60.00	direct to consumer
half-shell	300	$0.25	$75.00	direct to consumer
half-shell	2000	$0.27	$540.00	RETURNED DEAD
half-shell	200	$0.25	$50.00	restaurant
half-shell	200	$0.25	$50.00	direct to consumer
half-shell	300	$0.25	$75.00	restaurant
half-shell	2000	$0.25	$500.00	direct to consumer
half-shell	3000	$0.25	$750.00	direct to consumer
half-shell	750	$0.25	$187.50	direct to consumer

Appendix 3. VSC Market Trials Half-shell Oyster Yield And Values By Market				
Market	# Sold	$/Oyster	Revenue	Market Outlet
half-shell	300	$0.25	$75.00	restaurant
half-shell	300	$0.25	$75.00	direct to consumer
half-shell	500	$0.25	$125.00	direct to consumer
half-shell	2000	$0.28	$560.00	direct to consumer
half-shell	250	$0.28	$70.00	direct to consumer
half-shell	500	$0.28	$140.00	direct to consumer
half-shell	500	$0.28	$140.00	direct to consumer
half-shell	2500	$0.25	$625.00	direct to consumer
half-shell	250	$0.25	$62.50	restaurant
half-shell	1000	$0.16	$160.00	direct to consumer
half-shell	250	$0.20	$50.00	direct to consumer
half-shell	1500	$0.16	$240.00	direct to consumer
half-shell	750	$0.16	$120.00	direct to consumer
half-shell	500	$0.16	$80.00	direct to consumer
half-shell	200	$0.25	$50.00	direct to consumer
half-shell	750	$0.16	$120.00	no information
half-shell	1500	$0.16	$240.00	direct to consumer
half-shell	250	$0.16	$40.00	restaurant
half-shell	250	$0.16	$40.00	restaurant
half-shell	500	$0.16	$80.00	direct to consumer
half-shell	250	$0.16	$40.00	direct to consumer
half-shell	250	$0.16	$40.00	direct to consumer
half-shell	7500	$0.16	$1,200.00	direct to consumer
half-shell	5000	$0.12	$600.00	direct to consumer
half-shell	5500	$0.12	$660.00	direct to consumer
half-shell	500	$0.25	$125.00	direct to consumer

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