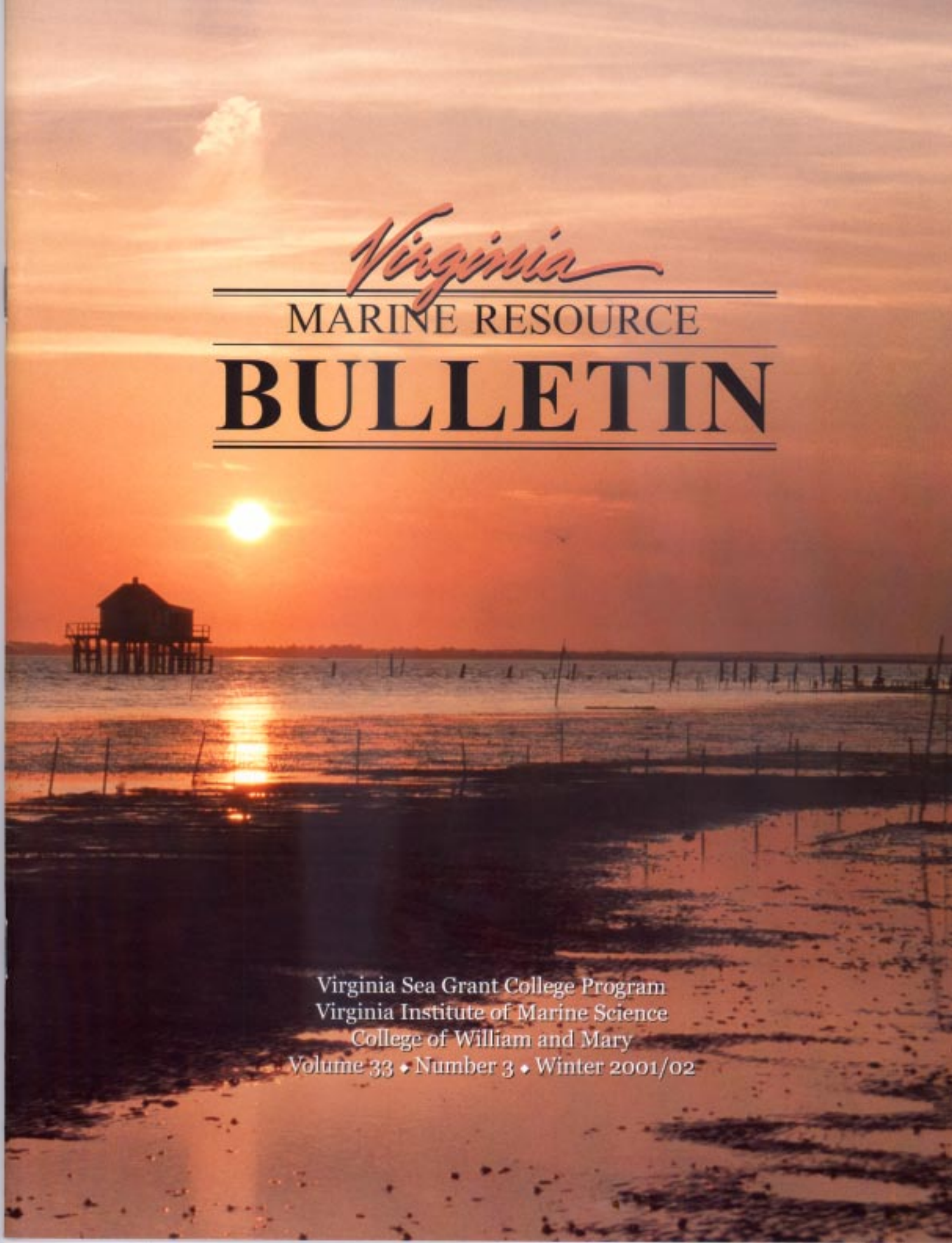

Virginia MARINE RESOURCE BULLETIN

Virginia Sea Grant College Program
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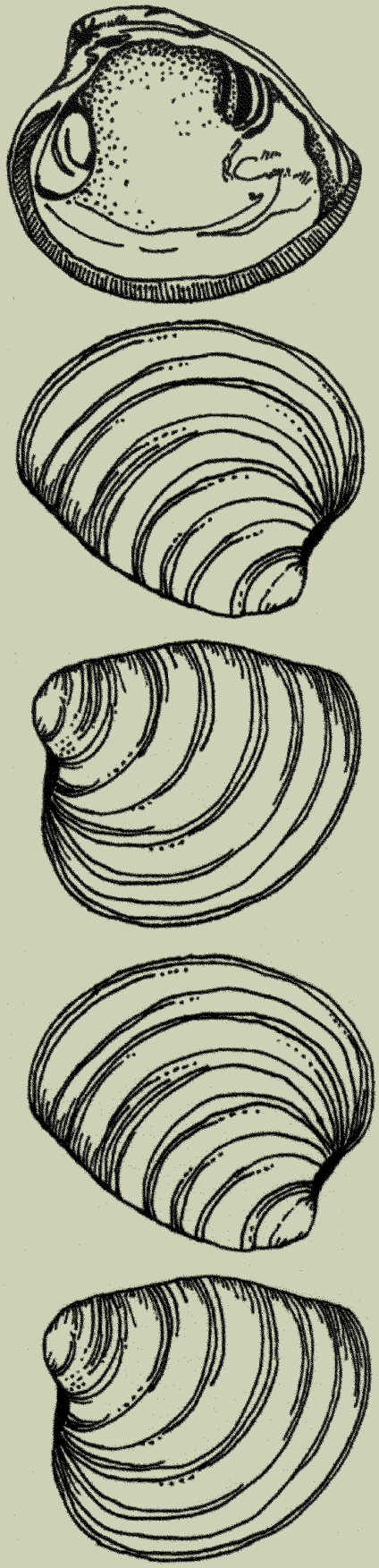

Following a series of fits and starts, the business of raising hard clams in Virginia is today well established. But like many sectors of the seafood industry, clam aquaculture continues to face seasonal challenges, and clam farmers still wrangle with forces largely outside their control – weather, predation by starfish and rays, shortages of planting-size seed, and limited grow-out areas for those wishing to get into the business or expand their operations, for example.

Virginia Sea Grant and the Virginia Institute of Marine Science continue working on several fronts to assist. Over the years, advisory specialists and researchers have helped hatchery managers refine breeding techniques and improve seed production levels. You will read inside about new, ambitious efforts to breed a "better" clam which one day might prove able to withstand a wider range of environmental conditions, and thus open up new sites for successful farming.

Also at the Institute, the Center for Coastal Resources Management has mapped Eastern Shore clam beds in an effort to further the debate over desired uses of subaquaceous areas. A significant finding of their analysis speaks to the importance of successful water quality management in areas where aquaculture occurs. Sustaining aquaculture as a viable economic undertaking clearly requires focused attention to riparian land uses and their water quality impacts.

On that note, it's important to recognize that cultured clams currently lead the state in revenues from aquaculture operations – in both dockside value and in the wider, rippling effects upon the state's economy, which are estimated at over 30 million dollars annually. Those in the business of raising clams remain optimistic about their future and strive to satisfy America's growing appreciation for this succulent bivalve.

Virginia
MARINE RESOURCE
BULLETIN

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Clam Farming Comes of Age

by Charlie Petrocci

With the falling tide, two men hand harvesting for clams wade the sand flats behind a marsh-lined bank. With long rusted rakes drawn tightly against their shoulders, they work backwards along an invisible transect. The tell-tale scrape of a clam reverberates up the shaft, and another clam is soon dropped into the basket suspended by an inner-tube tied to their belts. Dodging cownose rays and sharp oyster shells, they move with methodical rhythm.

Not more than 100 yards away, like sentinels, stands a line of white poles jutting from the shoreline. Layers of black netting can be seen just below the surface. At each corner of this fenced area are bright "keep out" signs, a warning for those who dare to trod inside. These are the boundary markers of a clam farm, staked and posted to keep out not only animal predators, but humans as well. The men take little notice and continue to work the areas around the fence, scratching a living from the bottom as they have done for generations.

As Eastern Shore watermen look to diversify operations, the idea of raising clams from seed continues to draw attention. The face of commercial fishing is changing, as prices for croaker, spot, weakfish and several other species have recently plunged to historic lows. The challenge is forcing many to look into other water-borne opportunities to stay competitive. Clam farming is one venture that has successfully kept watermen on the water.

"I started my clam planting in 1996," said Reggie Birch of Chincoteague. "It took me the first couple of years to figure out good ground and to get things going. I think it's beneficial to the resource, as we're harvesting what we plant and not taking any of the wild stock." Though hand harvesting for wild clams continues, a number of wild clam harvesters have embraced clam farming and now sometimes practice both.

Hard clam *(Mercenaria mercenaria)* farming has become a viable commercial form of aquaculture in Virginia only during the last 10-15 years. Virginia's Eastern Shore was the site of the first commercial clam hatchery in the United States when in 1956 a clam facility was developed in an old oyster shucking house near Atlantic, Virginia. Though the hatchery and nursery were successful, the field plantings were not. Predators and storms took their toll and the business venture was abandoned. But trial and error, driven by entrepreneurial spirit, eventually led to the successful development of present hatchery techniques for seed production and the ability to protect seed from predation. Currently, cultured clams are the most valued aquaculture crop in Virginia, topping $11 million in gross sales according to a 1998 study conducted by the U.S. Department of Agriculture.

Traditionally, wild clams were harvested using a variety of methods, including dredging from a boat, wading, and hand raking or "signing." These methods are all labor intensive, and the hand harvester is always at the mercy of the wind, rain, and ever-changing tides. Hand harvesters like 94-year-old Woose Reed of Chincoteague still love to be on the water. "I've been working the water for over 80 years and will probably do so to the day I can't do it anymore. Wading clams is about all I can do now though. My legs and back can't take it anymore." To protect him from sharp shells, Reed still wears the old-time hand sewn burlap moccasins once considered essential gear for clam waders.

Many of Virginia's coastal bays provided ample room for hand harvesting. Boatloads of clammers would go "down the bay" for a week at a time, sleeping on the boat and returning when they thought they made enough money. Many of the old-time clammers had nicknames, like one man they called "60" because it was said he could never count past 60 clams.

"In the old days it didn't matter what size clams were sold for, as most packing houses paid one price for all your clams, so they just counted them all together," reminisced fish packer William Lee Moore. "They didn't have any ice on the boats either, so sometimes to keep the clams from opening their mouths, which would dry them out, the clammers would put live terrapins on top of the clams to crawl around. I guess this kept the clams excited and they kept their mouths shut," he added. Technology has come a long way.

At one time huge clam houses could be found up and down the Eastern Shore. Chincoteague, for example, had a number of clam houses such as Burtons Seafood that shipped millions of clams a year to distant East Coast markets. Burtons Seafood was considered by many to be one of the largest clam packing houses in the U.S. It is rumored that in one day they hand counted over one million clams! Much of their business went to large distributors and to processors like the Campbells Soup Company, who purchased their chowder clams for soups.

In those days, larger clams brought higher prices. But somewhere around the early 1960s, market demand shifted from the larger chowders and cherrystone sized clams to those of the smaller littleneck and top neck size. Thus, the market for smaller clams began commanding better prices. The stage was set, at least from a buyer's perspective, for farm-raised littlenecks.

Once hatchery technology was refined, it didn't take long for private clam operations to sprout up around the Eastern Shore. Clam farming is a challenging venture, often hindered by biological, environmental, regulatory, and economic factors. Yet a number of individual and larger culture businesses have achieved great success. But like any growth industry, especially one engaged in the exploitation of "common ground areas," problems and challenges are bound to occur.

In 1996, for example, clam hatcheries on Virginia's Eastern

Shore claimed that agricultural runoff from local farms was harming their aquaculture operations. Hatchery owners contended that the plastic sheeting used in tomato farming was channeling herbicides and pesticides into local waters, killing juvenile clams in the process. Tomato farmers countered that the practice of "plasticulture" enabled them to apply less pesticides, which was more environmentally sound.

The Virginia Institute of Marine Science, along with several state agencies, worked on assessing the problem. Through field trials and water quality monitoring, it was determined that during times of heavy rain watersheds near plasticulture farms received larger amounts of pesticides than those near other traditional farming areas. Marine scientist Mark Luckenbach of VIMS proposed that the effects could be eliminated or reduced by controlling run-off from fields. Tomato farmers responded by installing retention ponds and modifying existing buffer zones to capture runoff. Currently, monitoring continues throughout the watershed to evaluate the effectiveness of these measures. This story is a good example of how two industries can cooperate for mutual benefit.

Another challenge has recently surfaced, and it involves the use of bottom areas. Most areas open for bottom leasing are the result of the Baylor Survey performed in the late 1880s, which designated oyster grounds. Now there is some question on whether future aquaculture operations should be sited based upon new surveys and not those from over 100 years ago. In addition, concerns have been raised by environmental groups about the loss of feeding and spawning habitat for a variety of fish and wading birds.

A long-time clammer, Reggie Birch of Chincoteague checks his clams for harvesting. Opposite, he holds market size clams.

With the escalating growth of clam aquaculture on the Eastern Shore has come concern for water use rights. Large tracts of bottom area are now legally leased from the state for clam farming. Quickly disappearing are the once public recreational and hand harvest areas.

"My family and I love to clam each summer on the Eastern Shore. It's become a traditional part of our vacation down here. Now we're seeing posted areas, "keep out" signs, and nets drifting in the water. It seems we're being squeezed into smaller areas to go clamming," said Robert Buchan of Pennsylvania.

"I think it's important for clam farmers to utilize the area they claim for planting. It seems there's a lot of leased bottom that is posted but sits unplanted. Nobody benefits from that," said Reggie Birch. So far, the waters of the Eastern Shore have accommodated recreation, as well as hand harvesting and farming of hard clams. But the jury is still out on how long that will last.

The Business of Clams

by Sally Mills

The geography of Virginia's Eastern Shore and preponderance of shallow, salty tidal creeks enabled the region to flourish amid a rich bounty of crabs, oysters, and clams. Over time, however, as dredging equipment tilled up shallow bottom areas, many of the bayside sites suitable for clamming in the wild were lost under layers of silt. On the seaside of the peninsula, wild hard clams *(Mercenaria mercenaria)* also appeared reluctant to return, and a host of reasons related to land use and farming are believed to play a role. The process of clams growing in the wild is a long and slow one, and human interactions both nearby and farther inland appear to be taking a negative toll.

As the prospect for harvesting wild clams waned, however, a new opportunity arose for those holding old oyster leases. These near-shore bottom areas leased by private landowners helped ease the shift, sometimes seamlessly, to those who wanted to experiment with the growing of cultured clams. The shift was made possible through early research conducted by the Bureau of Commercial Fisheries Laboratory in Milford, Connecticut, whose staff honed techniques for spawning, producing food for larvae, and controlling disease, among others. At the Virginia Institute of Marine Science's Wachapreague laboratory, director Michael Castagna and staff worked for many years to refine hatchery, nursery, and grow-out methods.

Early hatcheries

One of the first companies to seize the opportunity to culture clams was J.C. Walker Brothers, on the back leg of the main road traversing the coastal village of Willis Wharf. Situated on the Machipongo River just a few twisting miles to the Atlantic, this hatchery operation became a leader on the Eastern Shore, opening its doors to seed production in 1983. The business is still operated by family members Tom and Wade Walker, who are active in day-to-day operations.

The Walkers are known by customers throughout the region and beyond for stringent quality control standards. The algae room, the brood stock tanks, and the larvae room are tightly managed for cleanliness and consistent, optimal temperature. Quality checks for bacterial contamination are routinely performed, as are other early-warning systems. Even during peak production times, however, the company runs a lean shop, employing just a handful of full- and part-time staff.

Their formula appears to be working: J.C. Walker Brothers claims to have produced the largest volume of Virginia clam seed during 2001, selling approximately one-third – or about 30 million seeds – to other growers. The majority of raised clams are sold as littleneck and "choice" clams (as they are called in the Midwest) that are generally served raw or steamed versus in a chowder or other dish.

Demand for hard clams remains strong and prices, fairly stable over the past decade with only a slight dip several years ago. Today, Virginia clams sell between 23 and 30 cents apiece to the end user.

Margins are tight, however, and Virginia faces some tough competition from Florida producers. "If another state drops the price even a few cents per clam, it hurts a lot of people," admits hatchery manager Ann Arseniu. She adds with frustration, "The smaller growers will get out. There's just not enough profit margin in it."

Dr. Mike Peirson in the hatchery at Cherrystone Aqua-Farms.

Walker Brothers is blessed with an extraordinary site – on water that runs through a preserve held by the Nature Conservancy. The river channel is deep; the marshes, extensive. That marshland acts to buffer what occurs farther upstream, in the greater watershed. As a result, juvenile clams at the Machipongo hatchery benefit from excellent water quality.

"We have a fabulous location here. I believe the Machipongo River is *the* reason why clam aquaculture exists in Virginia," notes Tom Walker. He estimates that, over the years, more than 90% of the state's clam production has occurred on this river.

The business is where it wants to be right now. "We'd rather improve than just expand," Walker says, adding, "We've decided to grow only what can be competitively marketed. We stay away from marginal markets."

Farther south on the peninsula's opposite shore, Mike Peirson runs Cherrystone Aqua-Farms for the Ballard Fish & Oyster Company. Cherrystone Aqua-Farms has become an industry leader and a successful model for other Virginia producers interested in clam culture. It has come a long way since its first clam spawn in 1985. The company is respected for its innovative approaches and use of technology to garner efficiencies in operation. According to field manager Tom Gallivan, most of the technical innovations have taken place in the realm of algae production.

The company is also well known for its use of part-time, contract employees – "co-opers" – for high volume grow-out. "It's a great way to spread the risk around," notes Mike Oesterling, a marine biologist with Virginia Sea

Grant. "By contracting with others to plant in locations of varying salinity and environmental conditions, the company lowers its risk of loss." For their part, coopers enjoy a high rate of return on their investment while putting out limited capital. The partnership has resulted in roughly 80-100 million clams planted into assorted beds each year, with close to a 70% survival rate.

Today, trucks leave the Cape Charles facility twice daily, loaded with littleneck clams for markets in the mid-Atlantic and Northeast, as well as Chicago and California. In addition to traditional restaurant and seafood wholesaler customers, advances in shipping have made it possible for large grocery chains to hold and sell product – bolstering annual sales and providing more year-round stability.

Across the Chesapeake Bay

Along the western shore of the Chesapeake, the lower James and York river systems have long provided good growing areas for clams. While a small wild fishery still exists, a handful of hatcheries and nursery operators provide seed for the aquaculturist growing clams in the creeks feeding into the York and Mobjack Bay systems.

John Vigliotta runs the Ward Oyster Company on the Ware River. Although involved in relaying wild clams in the lower James for years, it was only recently that John ventured into growing clams from seed. Involvement in a nearby hatchery assures Vigliotta good brood stock to work with. "Still, there are no guarantees when it comes to seed," he cautions. But generally speaking, clam seed is getting easier to acquire. Vigliotta believes hatcheries up and down the East Coast are doing a better job. Some of his brood stock is aiding clam research at the Virginia Institute of Marine Science.

Vigliotta runs a one-man shop and does not use cooperative growers to take his seed to 20-mm size – a bit larger than the industry standard for planting. Getting seed to the bigger size presents some logistical challenges, especially during the winter months when clams face threats from plummeting temperatures, ice, and predation.

> *"In the short term, clam aquaculture will continue to be good in a few select locations. But over the long term, the state has to decide what it wants."*
>
> *Tom Walker, J.C. Walker Brothers*

"I'm still trying different options for overwintering," he concedes, adding that he may move his nursery operation to the Lynnhaven River where higher salinity would promote faster growth. "Right now, we're having a great year because of the drought. Salinity is running at 23-25 parts per thousand. We normally run at 17-20 parts per thousand around here."

Other challenges faced by clam growers? Water temperatures in summer can test the bivalve to extreme. Algae on trays and nets, and a host of predators – from toad eggs (or, sea squirts) to cownose rays, and recently, moon snails – make a daily nuisance of themselves. And an invasive species posing a threat to many bay fisheries, the Rapana whelk, has found its way into clam beds too. So far, it has been discovered on the eastern side of the Chesapeake Bay only, but scientists worry that circulation patterns in the lower estuary may disperse Rapana larvae out from their current range.

Without doubt, however, low or fluctuating salinity presents the primary challenge for many clam growers – and the most limiting factor to where such aquaculture can occur.

A balancing act

Many wonder how we're going to balance clam aquaculture with other activities in the near-shore environment. Dr. Mark Luckenbach, who currently runs the Institute's research laboratory at Wachapreague, has watched the

situation intensify. "The fact is, there is limited space to do this," notes Luckenbach, adding, "We used to talk about having to deal with use rights in the future. Well, the future is here."

Growers and regulators admit that shallow water conflicts are occurring. A clam farmer may now claim exclusive use of the bottom 12 inches of the water column under subaquaceous legislation passed in 1998. The law was instituted to legitimize what was already taking place, according to the Virginia Marine Resources Commission (VMRC) who regulates aquaculture for the state. Still, this sometimes translates to interference of the entire water column, and that's where conflicts arise.

The business of growing clams in state waters does not currently require a formal permit. Viewed along with other forms of aquaculture as "the private domain," the state has been reluctant to place too many regulatory burdens or oversight on the industry. But fly-overs early in the year will soon enable the VMRC to capture and digitize aerial photographs of clam beds, and more accurately measure how much land is currently used for grow-out.

So far, the practice of clam farming has moved forward with little problem, and growers tend to police themselves for fear of becoming overly regulated. If that changes, the idea of a 3-dimensional permit is not beyond possibility. Even so, a permit provides no protection from actions upstream. Land use throughout the riparian zone and beyond can cause tremendous harm to an aquaculture operation in the nearshore environment. "Everything on the mainland affects you," emphasizes Walker.

Mike Peirson with Cherrystone Aqua-Farms is keenly aware of this. A marina expansion on the shore just opposite his hatchery is underway on Kings Creek. The dredge spoil alone will fill a 12-acre hole in the ground. Dredging in the creek channel has begun, and will come within several yards of the Cherrystone clam beds.

"We pulled out all our clams," says Peirson, who witnessed dredging-related calamities just last year at his seaside hatchery. On the next creek down, Old Plantation, where the company has 26-27 million clams in grow-out, another land-disturbing project looms. A three-thousand-home "planned unit development" sand-

Employees of Cherrystone Aqua-Farms spread clam seed and protect beds with netting in Old Plantation Creek. Opposite page: Clam farmers work beds in Chincoteague Bay.

wiched between two golf courses is on the drawing board, and construction for the first course is just about complete. In addition to the potential for water quality impacts from course maintenance, one wonders how the new residents will feel about the poles lining the water at their doorstep.

"As more people move to the shore to live and retire, aesthetics will come into play," agrees Chip Neikirk with the Virginia Marine Resources Commission. While clam growers are allowed to mark the corners of each bed, in reality many more poles are sometimes used – partly to keep out people, and partly to keep out rays and other predators.

The netting over the clam beds becomes heavy when fouled with algae, leading some watermen to toss it overboard after gathering their clams. "While that has been a problem in the past, we try to police each other," says Tom Gallivan with Cherrystone Aqua-Farms. The approach appears to be working, at least for now.

Fitting into Bay stewardship

The business of aquaculture must also be balanced against cleanup goals for the entire Chesapeake Bay – including the restoration of underwater grasses, or SAV. Growers contend that their clam beds actually promote the return of SAV by filtering out particulates in the water column. Aerial photographs make a compelling case.

Scientists are not yet convinced, however. A Sea Grant study underway at VIMS hopes to better illuminate the relationship. At their study sites in Hungars and Cherrystone creeks on the lower bay, scientists measured water column nutrients, dissolved oxygen, suspended sediments, phytoplankton, and underwater light, and employed on-site chambers to measure seasonal exchanges of dissolved nitrogen. They are trying to determine if the algae associated with clam grow-out beds elicit a synergistic response: the clams, by removing particulates that block sunlight; and the algae, by taking up concentrations of nitrogen released by the clams. If so, does it result in any significant changes to local water quality, and how does it compare to natural SAV beds? The results of their work should be available in the near future.

Where are we headed?

While some 211,000 acres of underwater land are held in private oyster leases, many of those acres are not conducive to clam grow-out. In Old Plantation Creek, for example, all suitable areas have been grabbed up. "In the short term, clam aquaculture will continue to be good in a few select locations," notes Tom Walker. "But over the long term, the state has to decide what it wants."

Others echo that sentiment. Feeling frustrated by a lack of support from Richmond, the industry in general would like to see the state take measures to ensure that aquaculture has a bright future – by targeting funds accordingly. While money has been spent on efforts to bring back the native oyster, many in the seafood industry feel it is time to move forward with other ventures.

Also of concern is the fact that clam seed from various regions of the U.S. makes its way into Virginia waters – at times without a certified clean bill of health. Regulations for seed importation have been tightened in the past six years, but are not as strict as other states, say Virginia growers. When it comes to seed imports, 100% enforcement is impossible. This worries some regulators, who watched the oyster industry collapse virtually overnight with the arrival of MSX. They wonder if a new pathogen, possibly associated with out-of-state seed planted here, could bring a similar fate. Roy Insley with the VMRC vividly remembers the oyster decline. But speaking of disease spreading among the hard clam population, he notes optimistically, "We have the technical expertise to get a better handle on it now."

The movement of clam seed among regions throughout the coastal U.S. will be looked at closely when Sea Grant researchers and extension specialists convene next year. That's welcome news throughout the industry, because clam aquaculture holds great promise for the future. The market for clams remains vibrant and Virginia hatcheries and growers feel optimistic.

"We definitely haven't saturated the market yet," admits one hatchery manager, with a smile.

A Long-term Plan to Domesticate Wild Clams

by Mark Camara

Editor's Note: Accompanying the unfolding science of genetics is a vocabulary new to most of us. Bolded words in the text are explained in a glossary on page 12.

Successful early efforts to breed hard clams *(Mercenaria mercenaria)* in Virginia in the 1980s helped spawn a cultured clam industry that is now growing by leaps and bounds. Virginia is the second most important producer of clams on the East Coast, running a close second to Florida. At present, however, this industry depends upon seed stocks that are only a few generations removed from their wild cousins. The situation compares to the days when Native Americans first began to **domesticate** teosinte, the wild ancestor of modern corn – a plant so different from what we grow today that researchers had to examine its **DNA** to convince themselves of the connection. If history repeats itself, there's every reason to believe that attempts to domesticate and improve the hard clam through **artificial selection** will eventually add value to the tasty bivalve too. Improvement in yield could be realized, for example, by accelerating growth or increasing the meat-to-shell ratio. Farmed clams could further be selected for important market characteristics, such as prolonged shelf-life, or superior flavor.

To maintain its competitive edge against the rapidly expanding Florida industry – where a milder climate and longer growing season are quite favorable to clam aquaculture – the Virginia industry will have to develop more efficient growing practices and adopt strains of superior, genetically selected brood stocks. That's where the *Clam Breeding Project* at the Aquaculture Breeding and Genetics Technology Center comes in. The center was established at VIMS in 1997 by an act of the Virginia legislature with the mission to develop, adopt, and maintain innovative technologies for genetics and breeding of aquaculture species. Virginia Sea Grant supports the clam breeding project, which was initiated in 1998 as a long-term, programmatic effort at the center.

The center recognizes that commercial growers are not in a position to give adequate – let alone systematic – attention to the genetic make-up or the regional origin of the clams they plant. Because seed clams are often in short supply, growers are forced to plant whatever seed clams are available when needed. They are businessmen and, as such, are justifiably focused on bringing clams to market. Further, the complexity of designing and executing efficient selective breeding efforts while maintaining production levels are, simply put, beyond the capabilities of commercial-level hatcheries where output assumes the highest priority.

The objective at the center, therefore, is to provide technical assistance to domesticate and improve the nearly wild clam stocks currently used for commercial culture, first at the research scale, and to then disseminate the results to the Virginia aquaculture industry. The clam breeding project is already the most extensive breeding effort of its type on the East Coast, a truly original program intended to promote the economic development of a vital new marine industry. The project is currently in Phase III of what is envisioned as a five-phased development plan, as follows:

Phase I: Establishment and taking stock – In 1998, the center initiated the first phase of the program by taking stock of the bio-

Glossary of Terms

Allele: Alternative form of a gene. Most organisms carry two alleles of each gene in every cell of their body.
Artificial selection: Human-imposed breeding of specific individuals for the improvement of desirable traits.
Cross: Matings between specific individuals or lines for the purpose of genetic improvement or to study the genetic basis of traits.
Domesticate: Bring under the control of humans.
Dominant: Genes that produce the same trait whether they are in the homozygous or heterozygous condition.
DNA: The genetic material found in all cells.
Genotype: The identities of all the alleles carried by an organism.
Genetic diversity: The number of different alleles within a population.
Genetic fingerprinting: A technique for determining the genotype of an organism by directly examining the alleles it carries using molecular markers.
Inbreeding: Mating among relatives.
Inbreeding depression: The production of inferior or defective offspring due to inbreeding.
Heterozygous: Carrying two different versions (alleles) of a particular gene.
Heterozygosity: The proportion of genes in an individual or population that are heterozygous.
Homozygous: Carrying two identical versions (alleles) of a particular gene.
Homozygosity: The proportion of genes in an individual or population that are homoozygous.
Hybrid: Organisms produced by crossing parents from different lines or even species.
Hybrid vigor: An often observed phenomenon in which hybrids are superior to organisms produced by crosses within a line or species.
Line crossing: A selective breeding strategy that uses hybrid vigor to produce superior offspring.
Mass selection: A simple form of artificial selection in which superior individuals are mated with each other in the hopes of producing a superior population.
Molecular genetic marker: A small, directly observable piece of the genotype of an organism.
Pedigree: A family tree that charts out the parentage of individual organisms.
Recessive: Genes that only produce their trait when homozygous.
Recombination: The mixing or shuffling of alleles during sexual reproduction that creates new gene combinations.
Selective Breeding: See "artificial selection" above.

logical resources available. One of the outcomes of this activity was the *Clam Strain Registry*, an original accounting of clam stocks available for commercial culture and a precursor to a clam seed catalog from which clam growers will be able to select the stocks most appropriate to their grow-out sites.

Phase II: Field testing of existing strains – In 1999, the center began testing various popular strains of hard clams under commercial field grow-out conditions in cooperation with industry farmers. These first experiments involved planting the most promising commercial strains at a variety of locations chosen to represent the range of environmental conditions in which clam culture takes place in Virginia. Clams in these plantings were harvested and measured in November 2001 and provided valuable information about stock performance. A portion of the best clams harvested will be distributed to Virginia clam hatcheries as brood stock to produce the next generation of domesticated clam seed. But the best, fastest growing animals from each site will be retained and used in selective breeding efforts in subsequent phases of our breeding plan.

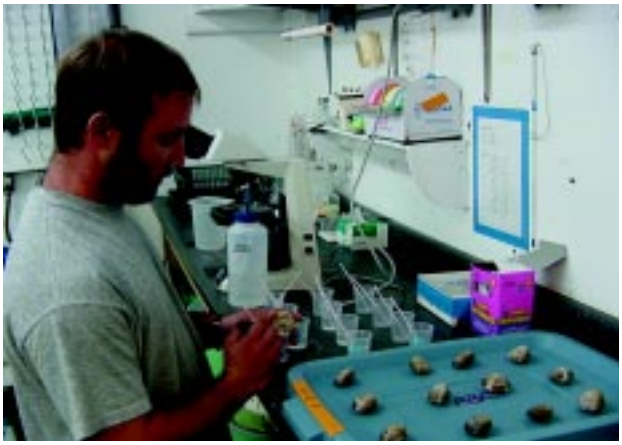
Phase III: Traditional selective breeding – While later phases of this project will center upon selective breeding to improve available clam strains,we are currently involved in:

- Mass selection - a relatively low-tech approach that uses information on the measurable traits of the animals (growth, for instance)

and makes some reasonable assumptions about their genetic basis. Although it may seem like a simple idea to just keep the best performers as the parents for the next generation, there's really a lot more to it than that. For example, if the best growing clams are all close relatives, then mating them with each other results in **inbreeding** problems. **Inbreeding depression** occurs because all organisms carry some load of defective versions of some genes or deleterious **alleles**. Ironically, one of the things that make clams so well suited to aquaculture – their high reproductive output – also increases the risks of inbreeding, because the entire production of a clam hatchery can be the product of only a few parent clams. If the brood stock happens to include a large number of close relatives, things can go downhill fast as a result of inbreeding depression.

Looking at "**genotype by environment interaction.**" This refers to the fact that different genotypes excel in distinct environmental conditions. Clams that grow best in clear, high salinity conditions of the Atlantic Ocean probably aren't well suited to the turbid, low salinity waters inside the bay, and there's probably no such thing as a "super-clam" strain that will do well under any conditions. The center is therefore producing a number of genetic strains tailored to particular environmental conditions.

Most traits important to the industry are influenced by a large number of genes, and sometimes only specific combinations of genes work well together. Some traits have a relatively simple genetic basis in which only one or a few genes control the trait, but this is rare.



Above, hatchery manager Tim Rapine collects sperm from male clams using a technique called "strip spawning." The technique allows control over which sperm are used to fertilize each female's eggs and therefore avoid cross-contamination. Right, Mark Camara and center staff plant seed clams in the York River.

Taking advantage of the best gene combinations is the basic idea behind **hybrid** corn. Corn geneticists try out huge numbers of genetic combinations in order to identify the best ones and then use that information to produce a hybrid seed. But there's a catch: these hybrids don't "breed true." Because they are produced by combining specific pairs of parental strains or even specific parental individuals, in the course of mating the hybrids with each other the normal processes of **recombination** that shuffle genes during sexual reproduction disrupt the good combinations, resulting in inferior offspring. Hybrid breeding produces a high quality, uniform product, but a farmer can't choose to keep only a portion of seed from his crop. If he does, he won't get the same results as with the original clam seed, because genetic shuffling occurs.

We don't yet know if the same thing happens with clams, but the center just put out an experiment designed to answer the question. Five of the most widely used commercial clam strains were paired

in all possible combinations. The resulting genetic groups were then planted at five sites and will be monitored for survival, growth, and susceptibility to a newly-emerged disease, quahog parasite unknown (QPX). If **line crossing** matings perform better than matings within lines, that would support the idea that clams show **hybrid vigor** and thus warrant investigating hybrid breeding strategies for clam domestication and improvement.

Phase IV: Molecular marker-based genetic selective breeding. Ironically, one of the main obstacles to clam domestication is the hatchery itself. The methods required to produce seed clams involve extravagant physical resources such as tanks and raceways, as well as the labor involved in caring for large numbers of cultures, so this approach isn't practical for more than a few groups or families. The result is rather modest selection intensities compared to those that are theoretically attainable and, therefore, modest expectations for genetic improvement.

The recent explosion of molecular techniques and the development of affordable technologies for **genetic fingerprinting** can, however, remove these barriers. It is now possible to assign parentage to individual clams after the fact in both natural and captive populations using the same kind of **molecular genetic markers** used in criminal investigations and paternity suits. With this level of information on relatedness, it is possible to design a selective clam breeding program that is both highly efficient and minimizes inbreeding without the need for physical tagging or separate rearing of genetically distinct groups. Reductions in cost and environmental variance result.

Phase V: Providing affordable genetic services. The clam breeding mission of the center builds upon a strong mutual commitment between scientists and industry. While it would be enormously helpful to the seafood industry if center staff were to develop better performing clam stocks, it would be a true revolution if the center could also enable the industry to develop its own specialty strains. The capacity to characterize clam stocks using molecular tools will ultimately allow the center to offer growers affordable "genetic services."

By connecting genetic expertise with hatchery and field operations, growers will be able to develop custom brood stocks tailored to their specific needs. This will be possible because the ability to resolve **pedigree** information retrospectively from mass spawns entirely eliminates the need to rear genetic groups separately. Select lines can be reared in a commercial production setting rather than the more controlled research environment without forfeiting the genetic information necessary for selective breeding. Growers interested in genetic improvement would need only to handle their selection lines in exactly the same manner as any other commercial cohort, and then measure the traits they wish to improve. Affordable genetic fingerprinting of the most desirable individuals at harvest size would then facilitate the design of an optimal selective breeding program at minimal cost.

Because this approach puts growers in control of both the traits they would like to improve and the selection sites – including those that are currently marginal for production – potential new sites may be opened up and further expand the clam aquaculture industry. Additionally, growers could develop trademark features, such as unique shell patterns or prolonged shelf-life, to bolster brand identification and add value to their product. As a consequence of this market diversification, the overall **genetic diversity** of clam aquaculture stocks will increase.

The Aquaculture Genetics & Breeding Technology Center is uniquely poised to work with the seafood industry to tackle the challenges of selective breeding. While obviously an ambitious effort, the clam breeding project is on track to make a real difference in how clam aquaculture proceeds in Virginia.

Mark Camara manages the clam breeding project at the Aquaculture Genetics & Breeding Technology Center.

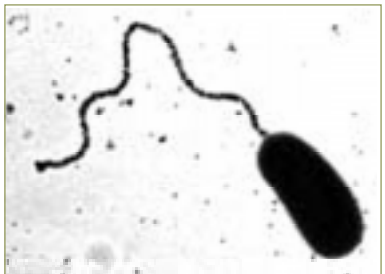
Where Clams are Concerned, Colder is Safer

by Angela Correa

Clams are one of Virginia's top seafood commodities. For this reason, finding ways to ensure the safety of the product while at the same time maximizing shelf life is a major concern of clam harvesters and processors. Current regulations call for rapid cooling of clams to about 10°C (50°F) post-harvest, but clammers note that overly rapid cooling of clams, especially in the summer months, leads to higher mortalities and product loss.

Clams, whether harvested or cultured, are constantly exposed to bacteria in the water. A small number of these bacteria species, most notably those grouped in the genus *Vibrio*, have the potential to be significant contributors to the incidence of illness in humans.

Vibrio spp. are naturally occurring bacteria commonly found in shellfish and other aquatic organisms. Two types, *Vibrio parahaemolyticus* and *Vibrio vulnificus*, are of concern. *V. parahaemolyticus* has been implicated in outbreaks of disease after consumption of raw or partially cooked shellfish. This bacterium causes gastroenteritis with typical symptoms including diarrhea, abdominal cramps, nausea, vomiting, headaches, fever, and chills. *V. vulnificus* is significantly more dangerous, and is capable of causing primary septicemia (severe blood poisoning) and wound infections via shellfish and seawater, respectively. The infective dose for a healthy person is reached when *Vibrionaceae* cells present in clams approach 10^6 cells in the intestine, but persons who are immunocompromised may be affected after having ingested a much lower dose. It is reasonable, therefore, to use *V. parahaemolyticus* and *V. vulnificus* levels as an indicator of clam safety.



Micrograph of V. parahaemolyticus, courtesy of Linda McCarter.

Sea Grant researchers Carolyn Brenton, George Flick, and Merle Pierson, worked with Robert Croonenberghs of the Virginia Division of Shellfish Sanitation, and Michael Peirson of Cherrystone Aqua-Farms to evaluate the microbiological quality and safety of quahog clams (*Mercenaria mercenaria*) during refrigeration at elevated storage temperatures. One of the goals of the study was to determine whether storing clams at a slightly higher temperature (12.8°C versus the current requirement of 10.0°C) significantly reduced the safety of the product.

In the study, four batches of clams were stored at four different incubation temperatures (3.3, 7.2, 10.0, and 12.8°C) for a period of three weeks, following a summertime harvest, and then a wintertime harvest. Every three days during the three weeks of storage, clams were analyzed for the presence of the bacteria *Vibrio parahaemolyticus* and *Vibrio vulnificus*.

The results showed that the highest counts of *V. parahaem-*

olyticus occurred in oysters harvested during the summer, after 12 days of storage at the highest refrigeration temperature (12.8°C). Overall, *V. parahaemolyticus* was isolated from 56% of the summer samples, and *V. vulnificus* was isolated from 11% of the summer samples. Interestingly, no *Vibrio* spp. were detected from the winter-harvested clams.

The study essentially confirmed that the FDA guideline – to chill shellfish to 10.0°C within 20 hours of harvest (in summertime) – is in fact a reasonable requirement in order to preserve the microbiological quality of the product. The increased initial mortalities which occur when clams harvested in warm waters are cooled rapidly can be decreased somewhat by cooling the shellfish as gradually as possible, especially at first.

The study also yielded a set of recommendations that will be of use to clam harvesters, growers, processors, and distributors (see sidebar).

Sea Grant research in seafood quality and safety works to provide consumers safe and wholesome products, and also supports seafood businesses by pinpointing answers to difficult questions related to safe and cost-effective handling of highly perishable seafood products.

Angela Correa is the Sea Grant communicator working at Virginia Tech.

Recommendations for Clam Harvesters, Packers, and Shippers

Because of the high incidence of *Vibrio* spp. during the summer months (56%) and the possibility that the microorganism may continue to grow post-harvest, the following recommendations are offered:

Suggestions for handling shellfish intended for raw consumption during hot weather (June through Mid-September). NOTE: Shucked product is not considered as being intended for raw consumption.

- When possible, harvest boats should work only during the cool part of the day, that is, boats should return to the landing and offload by 10:30 am.
- When possible, harvest from deeper, cooler water and leave the more shallow water areas for cool weather harvest.
- Make every effort to cool the shellstock gradually, as quickly as possible:
  - Shellstock should be washed until reasonably free of mud, either at the harvest site or upon arrival at the dealer. This will reduce the amount of time and energy required for chilling.
  - Place shellstock in the shade, under a canopy, on the harvest boats (this recommendation applies during both summer and winter months, because the incident energy from the sun can cause bagged product to exceed 90°F (32°C).
  - Place shellstock under refrigeration either in the truck as soon as it is offloaded from the boat or immediately upon arrival at the dealer.
  - Prevent shellstock from sitting out on the loading dock for more than the minimal time needed for loading and unloading (summer and winter)
  - Rapidly chill shellstock at plants. Potential methods include:
  - Placing shellstock in smaller piles in the shellstock cooler.
  - Placing shellstock in easily cleanable metal mesh containers with legs in the cooler.
  - Using chilled water in washer reels or grading machines/conveyors.

NOTE: These recommendations come from a study conducted by Carolyn Brenton, George Flick, and Merle Pierson at Virginia Tech.

Hard clams are called "quahogs" in other regions of the U.S.

In Search of Warm Water

by Sally Mills

In a creative response to the lack of adequate overwintering sites for hard clams in Virginia waters, Linda Crewe explores the warm water discharge pond at Virginia-Dominion Power's plant at Yorktown. Waters at the site typically range 15 degrees higher than surrounding areas, and should therefore offer a much-needed oasis for the bivalve to continue growing through January, according to Crewe. The extra growing time means she can bring them to plantable size (12 mm) by the end of May, and satisfy a seasonal shortage which generally occurs. If successful, she hopes to have 250,000 seed clams ready for spring planting. Crewe is experimenting with two different sizes in the clam beds at Yorktown to test performance under the unique growing conditions.

The project is funded by the Fisheries Resource Grant Program, which promotes innovation and creative ideas applied by commercial watermen in Virginia waters.

Linda Crewe holds clams grown near Yorktown.

Dr. Stanley Porter & Mr. Dick Harris of Virginia Beach fish for speckled trout in Rudee Inlet.

Releasing Speckled Trout

by Jon Lucy

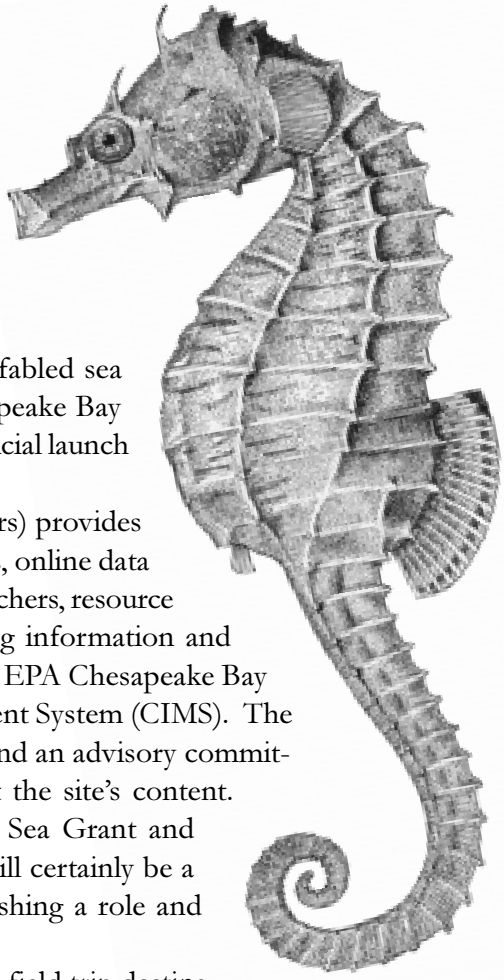
Speckled trout constitute a specialty fishery for avid recreational anglers. Growing interest in releasing more trout – even trophy-size fish 24 inches and larger – has led to a *Release Citation* by the Virginia Salt Water Fishing Tournament. To evaluate the actual benefits of anglers' release efforts, fishery managers must be able to factor hook and release survival rates into management plans. Assisted by local anglers, Jon Lucy is gathering such data to assess short-term (72-hour) survival rates through a project funded largely by VMRC recreational fishing license revenues.

Rudee Inlet provided data on year-old fish (primarily11-13") caught on lead head jigs with soft plastic grubs. In six trials conducted from October to early November (water temperatures 69-60ºF; 3-22 fish/trial; 69 fish total), all fish survived. Fish were placed in boat live wells; then transferred to net pens for 3-5 days. However, in a 6-fish trial that had to be discounted due to predation, one fish died in a boat live well before being placed in the net pen. If included in the data set, overall release mortality would have been 1.3% (1 death in 75 fish). Work will continue in spring 2002 to assess release mortality in the bait fishery.

ChesSIE lives!

www.bayeducation.net

by Susanna Musick



Cryptozoologists beware! ChesSIE has arrived. No, not the fabled sea creature, but an online resource center of current K-12 Chesapeake Bay science education materials. November 30, 2001 marked the official launch date for the new website.

ChesSIE (Chesapeake Science on the Internet for Educators) provides educators with access to quality Bay-related education resources, online data and professional development opportunities, and provides researchers, resource managers and other Bay stakeholders with a venue for sharing information and connecting with K-12 classrooms. ChesSIE is supported by the EPA Chesapeake Bay Program and is part of the Chesapeake Information Management System (CIMS). The site is maintained by the Virginia Institute of Marine Science, and an advisory committee and teacher focus group provide valuable feedback about the site's content. Adam Frederick, a marine education specialist for Maryland Sea Grant and ChesSIE advisory committee member, noted that "ChesSIE will certainly be a useful tool for us all in effectively communicating and establishing a role and identity within the watershed."

So, if you're looking for a restoration project in your area, a field trip destination, real-time data, or fun facts about the Bay, be sure to check out ChesSIE at http://www.bayeducation.net.

For further information about ChesSIE, please contact Susanna Musick at sxmusi@vims.edu.

On ChesSIE...

·Lesson plans & activities focused on Bay science
·Bibliographies of online Bay science teaching materials
·Grants and awards available to Bay educators
·Information about Chesapeake Bay Program educational projects and partners
·State departments of education and jurisdictional information
·Current student-centered projects throughout the watershed
·Bay data for teachers: CBP/CIMS, CBOS and other online data products
·Site directory and site search engine
·Bay education discussion list subscription information
·Bay educational facilities: aquariums, museums, science centers, field schools
·Bay science research centers and graduate programs
·Professional development opportunities for teachers, inservice, and graduate students
·Professional organizations and event calendars: NMEA, MAMEA, NSTA

Announcements

CEREMONY RECOGNIZES CLEAN MARINAS
The first Virginia Clean Marina ceremony was held at Two Rivers Yacht and Country Club on November 14, 2001. Five marinas were awarded the coveted *Virginia Clean Marina Award*, as follows: Hampton Public Piers; Salt Ponds Marina Point Marina; Two Rivers Yacht and Country Club; and Severn River Marina. Pictured here from left to right: Elwyn Darden, Assistant Secretary of Natural Resources; Peter Hall, Owner of Ginney Point Marina; David G. Brickley, Director of the Virginia Department of Conservation and Recreation; Charles Harvey, Harbormaster of Two Rivers Yacht and Country Club; and Andy Anderson, General Manager of Two Rivers Yacht and Country Club.

BLUE CRAB BOWL 2002 VIMS NOSB ODU

Twenty teams of high school students will convene on the campus of Old Dominion University in Hampton on Saturday, February 23rd, to compete in the fifth annual Blue Crab Bowl – a regional competition of the National Ocean Sciences Bowl (NOSB). The winning team will advance to the national competition to be held in Providence, Rhode Island, April 28-29, 2002.

This educational program was developed to stimulate interest among high school students in the ocean sciences and demonstrate to the public the importance of the oceans in our daily lives. One of the long-term goals of the Blue Crab Bowl is to foster the next generation of marine scientists, educators, and policy makers for the ocean sciences.

Visit www.vims.edu/adv/bcb for more details.

Announcements

EDUCATORS HONORED

Congratulations to the educators in the Marine Advisory Program at VIMS! The group was honored at a luncheon ceremony in Washington, D.C., on December 4, 2001 and received an award from the National Oceanographic Partnership Program for the Bridge website project. The trip gave them the opportunity to make a brief presentation to Congressional staff. While there, they met Dr. Rita Colwell, Director of NSF, and retired Navy Vice Admiral Conrad C. Lautenbacher, Jr., who was recently named Under Secretary of Commerce for Oceans and Atmosphere and the new Administrator of NOAA.

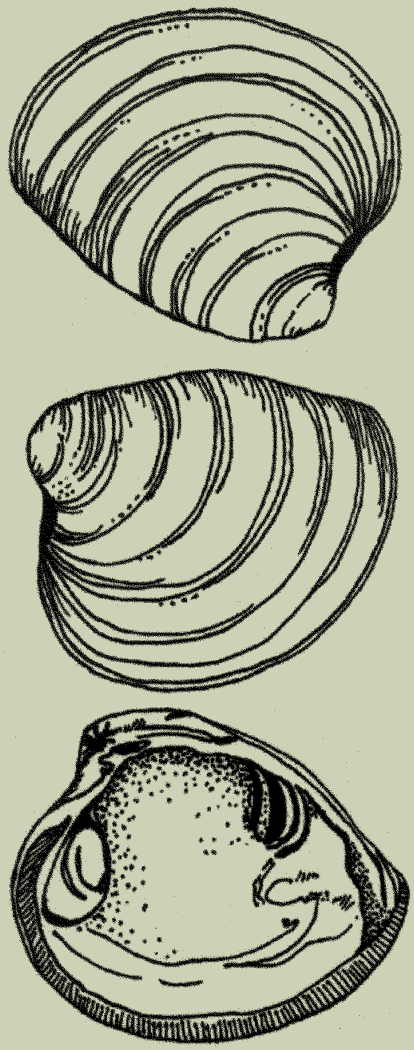
Marine educators, from left to right: Lisa Lawrence, Vicki Clark, Lee Larkin, Susanna Musick.

Teachers head back after field study at a barrier island during the summer course 2001.

SUMMER COURSE COMING

VIMS will once again offer a 2-credit graduate course for secondary school teachers at the Wachapreague Lab on the Eastern Shore this summer. Dates are July 7-12, 2002. Content this year will focus on fish biology and fisheries management, with extensive field and laboratory instruction provided by VIMS faculty. Teachers should expect a flyer in their mailbox in early spring.

For more information, contact Vicki Clark, vclark@vims.edu; or Susan Haynes, shaynes@vims.edu.



SELECTED RESOURCES
Available from Virginia Sea Grant

Call 804-684-7170 for ordering information or visit www.vims.edu/adv/pubs/index.html.

Clam Culture: The Possibilities and the Pitfalls, Michael Oesterling; Virginia Sea Grant Marine Resource Advisory No. 58; $3.

Marine Aquaculture in the Commonwealth of Virginia; Michael Oesterling; Educational Series No. 39; free.

Status of Clam Culture in the United States (workshop proceedings); VIMS et.al.; Virginia Marine Resource Report No. 2000-07; free.

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