Sudden Unusual Mortality Syndrome (SUMS) In Oysters: Workshop Report

Virginia Institute of Marine Science, Gloucester Point, Virginia 22-23 January 2024

The recent emergence of elevated mortality of eastern oysters, *Crassostrea virginica*, at farms along the United States (US) Atlantic and Gulf of Mexico coasts threatens the sustainability of aquaculture production of this key resource species. Observed since at least 2012, when it was first reported by aquaculturists in Virginia, the mortality events remain enigmatic. The mortalities often occur around periods of peak oyster reproduction (spring and early summer) but may also affect oysters outside this temporal window. It typically affects domesticated oysters in their second and final season of intensive culture prior to harvest, though there is some evidence that even extensively planted oysters may also be affected, and potential effects on wild oysters remain unresolved. There appears to be no parasitic or other infectious agent, although work on "summer mortality" in other systems, for example, Pacific oyster culture in Europe and the Pacific Northwest, has revealed underlying bacterial etiologies that may be more widespread. Whatever the causes of this syndrome, the reality is that it has been documented to cause sudden mortality exceeding 70% at farms widely spanning the Atlantic and Gulf coasts and is an urgent concern for eastern oyster aquaculture interests at the national level.

The workshop operated under six expressed objectives:

1. Define sudden unexplained spring/summer mortalities and differentiate them from other common mortality events.
2. Compile the best available data on a range of issues and describe the frequency and magnitude of the sudden mortality issue over the past decade.
3. Review past and ongoing studies of this problem.
4. Generate a list of current working hypotheses of potential causes of these mortalities.
5. By consensus, rank these hypotheses by order of importance, likelihood, and testability to define three to five of the most promising research priorities.
6. Build a collaborative approach to collecting preliminary data, testing these hypotheses with open communication among teams.

Due to its rising significance, the mortality syndrome has become a prominent area of focus for research at numerous institutions in the eastern and southern US. This has resulted in a steady increase in the amount of published scientific literature on the subject each year, contributing to a better understanding of the syndrome. Nonetheless, we recognize a need to accelerate research focusing on the syndrome to move more rapidly toward solutions that will sustain aquaculture production. With support from the NOAA Fisheries Office of Aquaculture, this workshop was convened to characterize the state of the science behind the mortality syndrome, highlight urgent questions, and identify key priorities for future research that would more fully illuminate the causes of mortality and possible strategies for mitigation. Twentyeight workshop participants representing eight universities from New York to Texas convened at the VIMS campus in Gloucester Point, Virginia, from January 22-23, 2024. These institutions included Stony Brook University, University of Maryland Center for Environmental Science (UMCES), Virginia Institute of Marine Science (VIMS), North Carolina State University, University of Florida, Auburn University, Louisiana State University, and Texas A&M University Corpus Christi. Additional attendees represented the University of Washington and the Pacific Shellfish Institute,to bring perspective from the realm of the Pacific oyster, also affected by unusual mortality, and NOAA Fisheries Office of Aquaculture (see Appendix).

The workshop began with an initial series of short presentations by participants on past, current, and planned work on the unusual mortality to define and understand its extent, nature, and impacts. This was followed by group discussion that progressed toward identifying key research priorities, as we describe in the sections below.

Participant presentations

After an initial introduction by Bill Walton, Ryan Carnegie provided VIMS pathology perspective on the syndrome, noting the number and geographic extent of industry submissions for pathology (over 150 since 2012, from Maryland to Texas), and the observation that the role in the mortality of major parasites such as *Perkinsus marinus* (dermo) and *Haplosporidium nelsoni* (MSX) was minimal based on infection prevalence and intensity data. Industry reports of mortality

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have been most frequent in spring and early summer. Observed gill pathology, hemocytosis sometime progressing to necrosis and erosion of gill epithelia, suggests possible external stressors, but the potential involvement of microbial (bacterial, viral) pathogens should also be considered, given the limited microbiological work conducted in the context of mortality events. Unlike in Europe, Australia, and Canada, microbiology represents something of a 'blind spot' in the east and south of the US, where the pathology focus has been on parasitic protozoans. Carnegie suggested that the mortality syndrome may be viewed as hypothetically representing the interplay of environmental factors, farm-level husbandry, and the genetics and physiology of the oysters in culture.

Tal Ben-Horin (NC State) provided perspective on the in-depth exploration of factors behind oyster mortality in North Carolina. The syndrome in North Carolina contrasts somewhat with that observed elsewhere, with histopathology focused on the digestive gland, and mortality more pronounced in mid to late summer. Microbiological analyses have revealed water column increases in *Vibrio* spp. abundances concurrent with mortality, but not increases within oysters, and with no one *Vibrio* species being predominant, so there is currently no suggestion of a primary etiological role for these bacterial species. Transplants of oysters away from affected higher salinity areas to mesohaline environments were observed to have mitigated mortality impacts, highlighting the contribution of local environmental conditions to the mortality. Certain genetic lines were observed to be substantially more affected than others. Ben-Horin emphasized the possible auto-immune contributions to the mortality events, indicating self-damage caused by defense responses of oysters experiencing the syndrome.

Bill Walton (VIMS) discussed Gulf of Mexico-based field work on the comparative performance of diploids and triploids, initiated following initial industry reports of mortality in 2016. In the Gulf, experimental work has suggested a heightened susceptibility of triploid oysters to mortality in some cases, which has not been so clearly observed in the Atlantic. He has not observed a clear relationship between oyster size and mortality, despite industry reports of the largest, fastest-growing oysters being most affected. Work in progress is investigating the role of genetic diversity in driving mortality, and work is planned to look more closely at diploid and triploid performance across a range of commercial sites, with concurrent environmental monitoring to try to gain perspective on the role of environmental stressors in mortality.

Jessica Small (VIMS) presented on the performance of VIMS Aquaculture Genetics and Breeding Technology Center (VIMS ABC) breeding lines. These lines have been substantially selected for performance across different salinities, and the variation in *P. marinus* and *H. nelsoni* disease impacts that would co-vary with salinity. The lines are continually re-infused with new diversity via family breeding, and inbreeding levels across the lines do not seem high or likely to contribute to mortality variation. There is a strong genotype X environment (G X E) interaction for oyster mortality in diploid VIMS ABC lines, so genetic variation could plausibly be contributing to mortality. The G X E interaction seems less pronounced with tetraploid lines.

Joey Matt (Texas A&M Corpus Christi) discussed a genetic evaluation of a triploid mortality event based on a 2019 study at VIMS. He observed strong site differences in mortality presentation, some sites displaying spring/summer mortality and others not, and a variable susceptibility of triploid lines to mortality that appeared heritable. He suggested that pedigree may have a strong influence on "liability score", the susceptibility of a line to mortality; and that tetraploid line seems particularly important in shaping susceptibility of triploids to mortality.

Julia Grenn (VIMS) presented findings on how culture practices such as biofouling control and stocking density could influence water quality parameters inside oyster bags. Percent blocked (by biofouling) and percent full (of oysters) in her study accounted for much of the variation in dissolved oxygen levels within bags, with bags more highly fouled and more highly stocked displaying very low oxygen conditions at times because of reduced flow through the bag. Grenn's work highlights how different husbandry practices could generate acutely stressful conditions within oyster bags, and indicates the important role husbandry could be playing in mortality events. Discussion reflected on the potential secondary effects of reduced flow within bags, for example bacterial blooms in response to an initial wave of oyster deaths further decreasing water quality and the bacteria themselves challenging the health of oysters in the bags.

Andrea Tarnecki and Kayla Boyd (Auburn University) described their oyster mortality research in the northern Gulf of Mexico with work spanning genetics and physiology. They reported that selected lines tend to grow best in the environments for which they are selected, and that tetraploid comparisons have revealed variation among crosses and differential survival of lines by location—evidence of G X E interactions—and reemphasized that genetics plays an important role in the survival of oysters grown in different environments. Comparing diploid and triploid oysters, they found that low salinity significantly decreased the temperature at which both ploidies exhibited metabolic depression, but that triploids may be more sensitive to higher temperatures at low salinity due to increased valve/shell closures post-metabolic depression compared to diploids. Ongoing work will look more closely at thermally shocking larvae to induce increased thermal tolerance during grow-out as adults, differences in molecular responses to acute thermal stress between diploids and multiple lines of triploids, and the role of phytoplankton community composition and nutrition in oyster performance.

Christopher Brianik (Stony Brook University) described the experimental disease challenges and field studies he and his advisor, Bassem Allam, performed around Long Island, New York, and insights into diploid and triploid immunology. Triploids were found to be more susceptible than diploids to *Vibrio* sp. challenge as larvae, but differences in susceptibility to general health challenges (e.g., *P. marinus*) in the field between diploids and triploids generally disappeared with further growth and development. Immunological studies assessing various parameters such as hemocyte cell counts and sizes, phagocytosis, reactive oxygen species (ROS) production, and mitochondrial count and membrane potential found no ploidy differences in hemocyte counts; a tendency (often not significant) for ROS production to be higher in triploids; higher hemocyte cell mortality in triploids; generally higher phagocytosis rates in triploids; no differences in mitochondrial numbers or membrane potential; and a generally greater susceptibility of triploids to stress. Brianik suggested that reduced mitochondrial compensation in triploids could underlie greater mortality in triploids where this occurs.

Leslie Sturmer (University of Florida) provided perspective on oyster mortality in Florida's off-bottom aquaculture industry. She noted that the mortality syndrome has become more prevalent over the last several years, with growers generally expecting 30% mortality beginning in March, but with mortality sometimes reaching much higher levels. Since 2020, Florida growers have supported a systematic approach to better understanding factors contributing to mortality. In a study conducted at two sites, Alligator Harbor and Oyster Bay, mortality was higher in triploids produced from Florida rather than Louisiana tetraploids, highlighting the potential involvement of tetraploid genetics in susceptibility and the role of breeding to mitigate mortality impacts.

Bobbi Hudson (Pacific Shellfish Institute) offered insight into summer mortality of Pacific oysters on the West Coast, which has occurred for decades and may share common features and potential causes of the mortality syndrome in eastern oysters. She noted that Pacific coast growers tend to view triploid oysters as inferior to diploids, which has been suggested by a number of studies. Growers try to diversify seed sources to hedge against differences in susceptibility to mortality among oyster lines. Ongoing work examines the role of environmental stressors in influencing mortality in diploids and triploids, and the spatial/geographic pattern of mortality which requires close engagement with industry to gain farm-level perspective. The most notable factor identified thus far is tidal elevation, with culture in the more stressful higher intertidal environment producing greater mortality. Hudson noted work by pathologist Ralph Elston that ruled out infection by the virus OsHV-1 and protozoan parasites as contributing to mortality, but which suggested that pathology to gonad and gills may be associated with mortality, with the gill pathology in particular suggesting environmental stressors as potential causes. There is some similarity in the pathology observations reported by Elston to those observed on the Atlantic and Gulf of Mexico coasts. In general, Hudson believes these mortality events to be getting more frequent and intense. There has recently been unexplained manila clam mortality as well—a parallel perhaps to hard clams on the East Coast displaying recent mortality. Carnegie suggested that we might envision clam mortality reflecting more challenging environmental conditions tipping animals over the edge to mortality, possibly in conjunction with genetic and husbandry influences, as with the hypothetical oyster model.

Steven Roberts (University of Washington) highlighted recent work on triploid oysters and heatwaves, and current work on epigenetic mechanisms driving triploid susceptibility and leveraging carryover effects (epigenetics) to improve field performance across generations. Regarding recent work, Roberts relayed findings that higher mortality in triploid oysters was most obvious and pronounced under multi-stressor conditions and was related to dysregulation in triploids of stress-related proteins following exposure to multiple stressors—they were incorrectly responding to stress. Ongoing work on epigenetics considers the importance of carryover effects, whether priming by challenge with a stressor at an early stage could produce improved performance subsequently in the field. Roberts reflected that optimal performance in the hatchery may not translate to performance under different and more challenging conditions of field settings. We should question whether we are either inadvertently selecting or otherwise priming oysters in domestication to fail under the complex stress regime of commercial aquaculture farms.

Louis Plough (UMCES) similarly reflected on the need to improve oyster stress tolerance and general resilience but noted the challenge in accomplishing this most effectively.

Sarah Bodenstein (Louisiana State University) presented a review of her research on multiple stressors and energetic budgets of diploids and triploids. Multiple stressors (e.g., desiccation for 48 hours, tumbling) generally produced greater mortality, though not necessarily with ploidy effects. Bodenstein noted that triploids may experience higher mortality under environmental stressors (e.g. low salinity, high temperatures), though neither gonadal development nor energetic imbalance was the primary cause. Triploid oysters were observed to have reduced gametogenesis and a higher scope for growth than diploids (relating to larger gill areas and clearance rates) in her analyses. Bodenstein emphasized the importance of looking "below" the organismal response level to the cellular and chromosomal levels to understand ploidy differences in susceptibility to stressors. A paper in review highlights transcriptomic differences between triploid and diploid oysters in response to low salinity challenges.

Jerome LaPeyre (Louisiana State University) continued to describe work on comparative responses of diploid and triploid oysters to environmental stressors in Louisiana. In experimentation with low-salinity and high-temperature challenges, divergent results emerged from different treatments: triploid mortality far higher at low salinity (2 ppt); diploid mortality higher at elevated temperature with normal salinity (20 ppt); high mortality in both ploidies under elevated temperature and low salinity, but with triploids dying most rapidly. Triploids were observed to osmo-conform more slowly than diploids after a salinity change, and to more slowly regulate hemolymph pH and tissue water content. LaPeyre emphasized the need to consider the compounding effects of multiple stressors, which may not be a primary challenge, but which may be important in pushing oysters over the edge to mortality. Considering genetic questions, LaPeyre highlighted tetraploid origin and diversity (most or all Gulf tetraploids deriving from Mid-Atlantic lines), effects of diploid broodstocks, and phenotype differences as areas of potential concern or relevance. Tetraploid inbreeding effects and cytogenetic stability are unknown. LaPeyre also raised the question of links to gametogenesis, the disruption of meiosis and mitosis in triploids, and the possibility of seed hardening to limit energy storage as a possible means of mitigating mortality effects during a subsequent window of challenge.

Finally, Mark Brush (VIMS) presented his modeling analysis of water quality and primary productivity associated with clam and oyster mortality events in Cherrystone Creek, Virginia, in 2022 and 2023. Essentially, the modeling can ask when, under what conditions, would bivalve filtration have been expected to crash. For 2022, a year with extended periods of very warm water in which substantial clam and some oyster mortality were observed, the model predicted broad periods of crashing filtration in clams between July and September, though a suppression of filtration was not apparent for oysters. For both clams and oysters, estimated carrying capacity for both species was reduced during 2022 relative to the prior year due to impacts of temperature and water column productivity. The work highlighted the potential value of modeling oyster and clam performance vis-à-vis key environmental values to not only understand current or past mortality events, but possibly to forecast future events early enough for growers to be able to make decisions to mitigate impacts.

Group discussion

Discussion began around the presentations described above and ranged broadly afterward, coalescing around several areas:

Toward a case definition for the mortality syndrome. First, is it just triploids, and "triploid mortality", as some publications have referred to it? The case for this being primarily a triploid phenomenon has continued to erode, though triploidy may be considered a risk factor. Fundamentally, this seems a phenomenon that is about stress, particularly environmental (temperature, salinity; low dissolved oxygen, pH, or seawater chemistry altered in some other way; interacting potentially with microbiome or pathogens), single-factor or multi-factorial; exacerbated by conditions of husbandry (containerized versus extensive culture, planting density, effectiveness of biofouling control); acting on oysters of underlying genetic or physiological status that may render them susceptible to challenge by external stressors.

Significantly, the mortality is not obviously caused by any major pathogen, such as *P. marinus* or *H. nelsoni.* As to rates and timing, the mortality is most obvious, and most obviously characteristic of this syndrome, when it is sudden and sharp. Still, elevated mortality can be more protracted and still relate to an oyster population's inability to tolerate stress imposed on it in the circumstances of its culture. Sharp peaks in mortality are often around the timing of peak gonadal development in both diploids and triploids, underscoring the potential role of gametogenic state and reproductive physiology in the mortality syndrome. Are wild oysters affected? Where they are closely monitored, as in Chesapeake Bay, natural populations of oysters do not typically display anything close to the very high mortality seen in the worst-affected aquacultured populations without some clear causal factor. The mortality that is observed in sub-adult and adult oysters aligns well with the timing and intensity of the annual disease outbreaks caused by *H. nelsoni* and *P. marinus*. Nonetheless, it would be interesting to see whether 'wild-type' oyster lines cultured intensively alongside domesticated lines would display similar mortality under environmental challenge plus the stress of culture.

What is the geographic distribution of the syndrome? While most reports have emerged from the Mid-Atlantic through the Gulf of Mexico, the actual distribution of the syndrome may be even broader, and local distributions within this vast geographic scope are far from clear. Understanding the breadth of impacts, documenting the degree to which this is a problem across geography and numbers of farms, will be important for justifying increased research investment in this area, from NOAA and other agencies. But how to do this? Creating a network of collaborating farms as 'sentinels' for the syndrome is one possibility to track the frequency and extent of events across a subset of farms and growing areas. Creating a way to obtain information across a very large number of farms across the regions, like a 'Waffle House Index' of shellfish aquaculture producers to reveal patterns in challenges to production (where the Waffle House Index is an informal indicator used by FEMA to gauge severity of adverse impacts caused by storms), would provide richer perspective, a large dataset that could be modeled along with regionally collected environmental data to identify key environmental drivers and (one would hope) eventually lead to predictive capacity. But the question remains of how to most efficiently engage industry. Incentives may be important. Confidentiality surely is. Expectations need to be managed with clear communication as to what analyses might achieve in the short term and what they will not. The shellfish mortality reporting form in use on the West Coast is not used to the extent it was hoped it would be. How best to effect "passive surveillance" (i.e., farm-based, industry-driven observation and reporting) for disease outbreaks by known or emerging pathogens is recognized as a challenge to aquatic animal health management worldwide.

How to improve the general resilience of oysters in production? The group talked about genetic markers for stress resistance, but no single marker is likely to solve all problems. It noted that breeding for broader-spectrum resilience against stressors and pathogens, rather than narrow resistance against a single pathogen or factor, would be advantageous, but tradeoffs need to be understood and considered. It may be that at present we are over-emphasizing fast growth or other specific goals (e.g., disease resistance) in breeding efforts at the cost of survival.

Along with a refocusing of breeding programs on general resilience, understanding of the roles of within-line diversity, relative performance of specific crosses (including age/generations, origins, and pedigree of lines) for promoting improved survival could lead to improved resilience via breeding with diploids, triploids produced from 2n X 4n crosses, and tetraploids. More needs to be understood about tetraploid oyster biology, given the foundational importance of tetraploids to oyster breeding in the East and South of the U.S. Better understanding the performance of selected lines in the field is also essential, as this will continually inform selected line development. Once broodstock are distributed from breeding programs to hatcheries, these programs do not have a way to track the genetics of the biological material (eyed larvae or seed) produced from that broodstock. Hatcheries have limited perspective on how their various crosses and cohorts perform in the field. Creating a mechanism for improved data collection on line performance in the field, and for reporting back to breeding programs, nurseries, and hatcheries to guide line development and application at the front end of production, could additionally be beneficial.

Substantial discussion focused on the potential of 'hardening', or priming oysters at an early stage to better withstand future challenges. Hardening is widely practiced already in parts of the world, challenging oysters at a young age before much has been invested in them, for better survival later when they have substantially increased in value—thus it is an approach with economic appeal, low in cost and high in potential benefit. It would be worthwhile to consider what means of priming, applied to what life stage (as early potentially as the parental generation, the priming expressed epigenetically), would be most effective.

Are there other ways to decrease risk? Some growers grow multiple lines and ploidies as a hedge against mortality that may affect select lines more than others. While it may be possible to diversify among selected lines and ploidies, diversifying with regard to planting time might be another avenue. Would oysters produced later in the season and planted to grow-out locations in the fall, such that they would be smaller when approaching the spring-early summer window of challenge, experience lower mortality? Can density or spatial distributions of planting on a farm be manipulated to reduce either the primary syndrome effects, or the secondary effects associated with the deaths of the first oysters? Can we ascertain what makes a good site versus a bad site for the syndrome, and use that information for site selection to avoid excessive mortality?

Can we better understand the syndrome mechanistically?

The syndrome relates to the interaction of stress with oyster genetics and physiology, and intersections with the oyster reproductive cycle in particular have long been noted in eastern as well as Pacific oyster systems. The nature of these interactions in mechanistic terms is worth understanding for potential benefit in identifying levers of potential mitigation or control, including through breeding. Data presented by meeting participants suggest that investigation of the cellular pathobiology of the syndrome may be more illuminating than higher-level, organismal investigations.

On a different scale, understanding the progression of an outbreak in epidemiological terms may reveal additional means of control. How does mortality arise and spread, and how much is caused by the husbandry factors that can be controlled at the farm level, as opposed to the ambient environmental stressors? How much mortality is from the syndrome in a primary sense, as opposed to the secondary effects of water quality degradation from the first wave of deaths to affect a cage?

Research priorities

Within the broad categories of I) Risk categorization and understanding of SUMS, II) Risk management, and III) Communication, the group distilled discussions above down to nine distinct research priorities, ranked in order of priority as follows by consensus.

1) Mechanistic understanding of mortality events, including energy budgets, pathobiology, etc. (Risk categorization and understanding of SUMS)
2) Preparing oysters to withstand stress in all phases, for example through hardening or priming against future challenges (Risk management)
3) Breeding for increased, general resilience (Risk management)
4) Understanding the frequency, extent and history of mortality events, including epidemiology and progression, monitoring and reporting (Communication)
5) Communicating risk factors and recommended management practices to industry (Communication)
6) Harmonizing data collection and information sharing among researchers and extension (Communication)
7) Understanding SUMs in wild populations, and adaptation to environmental stressors in natural populations (Risk categorization and understanding of SUMS)
8) Understanding relationships and interactions between restoration production and commercial aquaculture, and the potential role of seed limitation or reduced choice in SUMS and other mortality events (Risk categorization and understanding of SUMS)
9) Measure reproductive investment in susceptible diploids (Risk categorization and understanding of SUMS)

Next steps

The meeting closed with consideration of next steps to address the issue of SUMS. The group discussed moving forward as a collaborative, ongoing network focused on the issue of SUMS and grow-out health with the goal of improving grow-out performance in shellfish aquaculture. This collaboration could initially develop from the group attending the workshop. In addition, this network could reasonably be positioned as a third pillar on bivalve health alongside the Regional Shellfish Seed Biosecurity Program (focused on seed health and shipments) and the Bivalve Hatchery Health Consortium (focused on hatchery production) as we work to build more cohesion regionally to research and extension in shellfish aquaculture health from spawning through harvest. The group is using the SE/GOM Oyster Mortality group on the Aquaculture Information Exchange as a forum for communication.

The group will begin to collate data and perspectives on the extent and frequency of SUMS events, essentially building out from the VIMS database of industry reports of unusual mortality since 2012. Collected data about SUMS events will include the location, timing, and duration of the event, site (water quality) conditions, the ploidies affected, oyster pedigree or provenance, and mortality rate observed.

Discussion continued on the topic of what data might be collected presently, even in advance of formal grant funding and included the following:

- Polling growers to get a sense of the extent and frequency of SUMS;
- Collecting genetic samples from pathology submissions for eventual genotyping of survivors from events, which can be compared to pre-event samples (broodstock, seed) that have also been collected for reference populations;
- Working with hatcheries and farms to determine the success of seed distributed widely to different environments and culture settings from single sources;
- Gaining insight into nutritional contributions to oyster stress and mortality through ongoing work at VIMS (funded by NOAA Saltonstall-Kennedy, Hamish Small lead PI);
- Incorporating wild-caught spat into intensive culture deployments to better understand the susceptibility of wild oysters to SUMS in intensive culture; and
- Beginning to explore hardening possibilities through small-scale experimentation.

Communication in the coming months should focus on creating collaborations to begin addressing the priorities emerging from workshop discussions.

Finally, the group discussed producing a manuscript for journal submission based on the workshop output and the geographic and temporal compilation of SUMS events to date, and possible submissions to upcoming NOAA and USDA funding competitions to advance the science of SUMS via extramural funding.

Appendix: Participant List

Bassem Allam	Stony Brook University
Corinne Audemard	Virginia Institute of Marine Science
Tal Ben-Horin	North Carolina State University
Sarah Bodenstein	Louisiana State University
Kayla Boyd	Auburn University
Christopher Brianik	Stony Brook University
Mark Brush	Virginia Institute of Marine Science
Ryan Carnegie	Virginia Institute of Marine Science
Nate Geyerhahn	Virginia Institute of Marine Science
Julia Grenn	Virginia Institute of Marine Science
Bobbi Hudson	Pacific Shellfish Institute
Karen Hudson	Virginia Institute of Marine Science
Matt LaGanke	Virginia Institute of Marine Science
Jerome La Peyre	Louisiana State University
Joey Matt	Texas A&M University Corpus Christi
Jan McDowell	Virginia Institute of Marine Science
Adriane Michaelis	Virginia Institute of Marine Science
Louis Plough	University of Maryland
Kimberly Reece	Virginia Institute of Marine Science
Scott Rikard	Auburn University
Steven Roberts	University of Washington
Andrew Scheld	Virginia Institute of Marine Science
Hamish Small	Virginia Institute of Marine Science
Jessica Small	Virginia Institute of Marine Science
Leslie Sturmer	University of Florida
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