SCALLOP ENHANCEMENT WORKSHOP

OCTOBER 29 – 30, 2024

SESSION DESCRIPTIONS AND ABSTRACTS

OPENING PLENARY

THE HISTORY, PRODUCTION AND SCIENTIFIC ADVANCEMENT OF THE TINDUFF HATCHERY AND ITS ROLE IN THE FRENCH SCALLOP FISHERY

Florian Breton, Tinduff Hatchery, France

The Tinduff Hatchery is a maritime cooperative that was established in 1983.

At that time, fishermen became aware that the riches of the sea are not infinite. In the 1950s, 2,500 tons of scallops (Pecten maximus) were caught annually in the Bay of Brest. Due to the combined effects of fishing mechanization and unfavorable weather conditions (particularly the harsh winters of '62-63), the catch dropped to 30 tons by the late 1970s. This led to the initiation of a project to restock the Bay of Brest.

Drawing inspiration from various techniques used around the world, scientists from IFREMER and professionals from the Bay of Brest worked on the reproduction of scallops. It wasn't until the years 1995-1996 that the impact of the seedings became truly significant.

Each year, between 7 and 10 million spats are produced. The juveniles are spread over natural beds in early autumn and/or spring. It takes about 2 to 3 years for the scallops to reach commercial size. Depending on the year, the seeding scallops account for 30 to 70% of the scallops caught.

The seeding scallops serve a dual purpose: they represent an important part of the fishery and contribute to the reproduction of the entire stock. These restocking and stock-supporting actions aim to mitigate some of the fluctuations in natural recruitment, which are strongly influenced by the environment, and thus maintain a minimum stock available for fishing.

The hatchery not only ensures the restocking of the Bay of Brest but also collaborates closely with other French fishing committees. From Granville to La Rochelle, fishing committees purchase spats to reintroduce into their beds.

This forward-thinking approach is now frequently cited as an example both nationally and globally as a sustainable resource management strategy.

In recent years, leveraging its experience, the Tinduff Hatchery has developed as a technical platform supporting scientific projects.

Session 1: Seed Production

The Atlantic Sea Scallop, *Placopecten magellanicus*, is a commercially important fishery in the northeast United States. It is consistently one of the most valuable fisheries in the region, supports fishers, boats, communities, and has high cultural status. The fishery has experienced a recent boom with high prices and growing demand. NOAA Fisheries and the New England Fisheries Management Council manage the fishery. The stock is not currently overfished or subject to overfishing.

However, there are concerns about the long-term sustainability of the fishery as demand grows. There are also concerns that a changing environment, with regard to coastal ocean temperatures and carbonate chemistry, may shrink the range of the fishery. Finally, loss of habitat as other marine sectors, e.g. wind energy development, expand may reduce the scale of the fishery.

Definitions

Recruitment: transition of early life-history animals into the fishery

Enhancement: increasing the number of animals available for recruitment

Background

There are two basic strategies for enhancement of shellfish during early life history: increasing survival of natural larval production and producing hatchery-based seed.

Current Status

Aquaculture production of seed has been very successful for some fisheries, such as oysters. In the case of sea scallops, there has been limited success developing reliable hatchery methods to produce seed that would be available for enhancement. There is currently an active, funded research project, with multiple partners, designed to develop repeatable hatchery methods.

Currently the only source of seed for enhancement or production is the collection of spat in coastal waters. Spat collection has provided an opportunity for expansion of the fishery, but is a minimal component of the overall industry.

Guiding Questions

- Can a better-informed and more robust effort to collect spat significantly increase the number of seed available for enhancement efforts?
- Would a better understanding of physical oceanography boost that effort?
- Is there a role for spawner sanctuaries and how would they be selected?
- Is there a significant role for hatchery-produced seed, pending advancements in reliable hatchery techniques?
- What is the appropriate balance of the approaches above as part of a broader strategy?
- What types of information are needed to improve nursery methods and grow out of post-set animals in preparation for outplanting?

References/Links/Resources

Maine Scallop Aquaculture Report. Des Fitzgerald. October 2021. Gulf of Maine Research Institute.

NOAA Species Directory: Sea Scallops [Atlantic Sea Scallop | NOAA Fisheries]

NEFMC: Sea Scallop Management Plan [Sea Scallop - Management Plans - NEFMC]

Hart et. al. 2020. Spillover of sea scallops from rotational closures in the Mid-Atlantic Bight (United States) ICES Journal of Marine Science.

Coleman et. al. 2021. The coupled effects of stocking density and temperature on Sea Scallop (Placopecten magellanicus) growth in suspended culture. Aquaculture Reports.

Naidu et. al. 2009. Relative efficacy of two artificial substrates in the collection of sea scallop (Placopecten magellanicus) spat. Journal of World Aquaculture Society.

Abstracts

SEA SCALLOP SPAT COLLECTION IN SOUTHERN MAINE

Nate Perry, Pine Point Oyster Company, LLC

The successful and sustainable collection of Atlantic sea scallop (*Placopecten magellanicus*) larvae is essential for both the further development of the sea scallop mariculture sector and for the purpose of enhancing wild stocks. Collection efforts require the collaboration of traditional marine operations and the marine sciences. This presentation focuses on practical considerations for the collector based on the author's own experience.

A COLLABORATIVE APPROACH TO DEVELOPING HATCHERY CULTURE OF THE ATLANTIC SEA SCALLOP (*Placopecten magellanicus*)

Sydney Avena[1,5], Christopher Davis[1], Anne Langston Noll[1], Cody Jourdet[2], Brian Beal[3,4], Brea Salter[4], Tessa Houston[4], Damian Brady[5], Timothy Bowden[6], Jennifer Perry[6], Sue Ishaq[6], Kyle Brennan[6], Nichole Blackmer[6], Mark Dixon[7], and Gary Wikfors[7]

[1]Maine Aquaculture Innovation Center, 193 Clarks Cove Road, Walpole, ME 04573; [2]Mook Sea Farm, 321 State Route 129, Walpole, ME 04573; [3]University of Maine at Machias, 116 Obrien Ave, Machias, ME 04654; [4]Downeast Institute, 39 Wildflower Ln, Beals, ME 04611; [5]University of Maine School of Marine Sciences, 193 Clarks Cove Road, Walpole, ME 04573; [6]University of Maine, School of Food & Agriculture, 168 College Ave, Orono, ME 04469; [7]NOAA NMFS, Northeast Fisheries Science Center, 212 Rogers Ave, Milford, CT 06460

The Atlantic sea scallop (*Placopecten magellanicus*) is becoming a valuable, commercially-farmed product in Maine's overall aquaculture industry, supplementing the domestic supply of wild-caught scallops. Although most successful aquaculture industries throughout the world are supported by commercial hatcheries, solving problems inherent with husbandry methods during the hatchery phase for sea scallop larvae is a major challenge to overcome. The sea scallop's lengthy larval phase, which can last up to 45 days, has proved to be a challenge, especially when coupled with larval sensitivity to environmental conditions and hatchery expenses. Despite this,

related scallop species in other parts of the world with similarly-long larval phases are being cultured in commercial hatcheries. Although there have been some research-scale successes with sea scallop hatchery production, repeatable, large-scale seed production has remained elusive and unreliable.

This project focuses on "cracking the code" of early stage sea scallop culture to improve survival and growth, thereby developing guidelines for successful husbandry that can be replicated reliably to help sustain and grow the sea scallop aquaculture industry in Maine. Three hatcheries are engaged in this effort: Mook Sea Farm, the University of Maine's Darling Marine Center, and the Downeast Institute, with Mook Sea Farm producing cohorts of juvenile sea scallops four years in a row. Here, we discuss findings and remaining challenges from four years of larval experiments. Larval culture parameters investigated include static culture versus flowthrough culture, the effect of buffering and buffering compounds, temperature, tank size and shape, UV filtration, and larval diet. Growth rate and percent survival were reported for each hatchery trial. High mortality in the larval D-stage continues to be the primary barrier to successful production across hatcheries, with continued research needed to identify major stressors and mitigation strategies.

UPDATES FROM MAINE: LIFE HISTORY AND LARVAL DYNAMICS OF CULTURED AND WILD SEA SCALLOP POPULATIONS

Phoebe Jekielek[3], Caitlin Cleaver[2], Madison Maier[3], Anya M. Hopple[3], & Carla Guenther[1]

[1]Maine Center for Coastal Fisheries, 13 Atlantic Ave, Stonington, ME 04681; [2]Colby College, 4000 Mayflower Hill Dr, Waterville, ME 04901; [3]Hurricane Island Center for Science and Leadership, 19 Commercial Street, Rockland, ME 04841

The Atlantic sea scallop (*Placopecten magellanicus*) fishery is one of the most economically significant in the United States, valued at approximately $479M in 2022. However, rising market demand and climate change vulnerability have positioned Maine's growing sea scallop aquaculture industry as a critical complement to wild capture fisheries. A major challenge lies in the limited understanding of the relationship between cultured and wild populations, particularly in terms of larval dynamics and the biological impacts of aquaculture practices on the species.

This abstract bridges the gap between two key studies that explore these interdependencies. The first study examines morphometric differences between cultured and wild scallops, revealing that farmed scallops exhibit significantly larger adductor, gonad, and viscera masses in larger size classes (80 – 110 mm), while wild scallops have larger shell masses. These findings might suggest aquaculture has the potential to passively enhance reproductive output, with possible ecological and economic benefits for both the aquaculture and wild fisheries sectors.

Complementing this is the first two-years of an ongoing investigation into the spatial and temporal distribution of scallop larvae along Maine's coast. Results show that larval abundance is higher in offshore and eastern sites compared to inshore and western locations, with fall-deployed spat lines showing significantly larger yields than those deployed in winter. These spatial patterns provide essential insights into the natural recruitment dynamics that support Maine's aquaculture and wild harvest industries.

By interweaving the biological insights from morphometric comparisons with the ecological data on larval distribution, this research develops a comprehensive perspective on how scallop farming and wild populations interact. The findings inform an integrated strategy for scallop enhancement's potential to maintain or increase production in Maine's nearshore state waters fishery.

SESSION 2: PLANTING AND TRANSPLANTING

Definition

The terms 'planting' and 'transplanting' are often used interchangeably, but have different meanings. 'Planting' usually describes the introduction of hatchery-origin or wild-collected smaller scallops into a receiving area, while 'transplanting' better describes scallops in a natural habitat, but moved from one location to another.

Relevance

Planting of hatchery-generated or wild-collected seed, and transplanting of wild scallops have both been used as stock enhancement or management interventions, but with varying degrees of success and levels of husbandry required. Species, location, growth rate, susceptibility to predation, and management of co-occurring species are just a few of many variables, and practitioners have to marry examples from elsewhere together with local experience and expertise, to arrive at a positive result. This session will be dedicated to discussing planting and transplanting efforts globally, to examine potential applicability to the northeastern US.

Background

Trials of planting and transplanting have been sporadic in the northeast US and Canada, both in coastal and offshore waters. Work by Smolowitz et al. (1999) suggested that transplanting scallops was a viable operation for nearshore waters, and that principal obstacles were not biological or operational, but rather social and regulatory. Continued work in transplanting and stock enhancement in years since has resulted in optimism about operational success, but acknowledges challenges with permitting and operating in a multiple-use environment (R. Smolowitz, personal communication). In Maine, the most structured efforts are summarized in Schick and Feindel (2005), and indicated mixed results, encouraging continued study. Beal (2009), working in coastal Maine waters, found encouraging results in both planting wild-collected seed, and larger transplanted individuals, though wild spat collections were low and sporadic.

Canadian efforts have yielded mixed results, generally indicating success in spat collection and nursery production, but limited or uneven yields for seeded grounds (Cliche and Guigere, 1998), and the tendency for seeded grounds to attract predators (Frenette, 2006).

Elsewhere, shorter-term successes in New Zealand's Challenger fishery, and longer term efforts such as in the Bay of Brest indicate that planting and transplanting can have positive and achievable outcomes. The largest and longest-term successful operation is the scallop industry of Hokkaido, Japan. This massive, intensive effort relies on wild spat collection from several areas, followed by nursery production using pearl- and lantern nets. Once scallops reach 40-50mm, they are transported to beds which have been prepared to remove predators such as starfish (Kosaka, 2016).

Current Status

In the US, the only regular planting/transplanting work is undertaken by the Coonamessett Farm Foundation. We note here however that industry members will experiment on their own, in transplanting undersized stock from one place to another in hopes that it 'takes' and that they represent a source of expertise for this discussion.

Guiding Questions

- What types of planting/transplanting strategies make sense for coastal and offshore waters; financially, operationally and with respect to the multiple uses of the US EEZ and state-waters fisheries?
- Predator control is a common theme in scallop enhancement elsewhere: what do we need to do, to research and/or implement such activities for the US fishery?
- How can we harness the expertise and capacities of both industry and science/regulatory worlds, to investigate opportunities most effectively?
- Availability of seedstock is key to any enhancement activity. How do we make best use of our present options: transplanting, spat collection, hatchery production, passive seeding, nursery culture?
- How do we assess success…or failure of transplanting operations?

References

Beal, B.F. 2009. A Collaborative Effort to Examine New Strategies for Managing Closed Bottom Habitats for Sea Scallops. Final report to the Northeast Consortium. 24p. https://downeastinstitute.org/wp-content/uploads/2018/08/6_-29-nec-scallop-final-report-b.-beal-downeast-instit.pdf

Cliché, G. and M. Giguere. 1998. Final report of the research program on scallop culture and restocking (REPERE), 1990-1997. Can. Ind. Rept. Fish. Aquat. Sci. No. 247. 86 p.

Frenette, B. 2006. RAPPORT D'ACTIVITÉS DE PECTEN UPM/MFU Inc. CONCERNANT LE PROGRAMME D'ENSEMENCEMENT DU PÉTONCLE (Phase I) ET LA CULTURE EN HAUTE MER (Phase II) POUR L'ANNÉE 2005. PECTEN Maritime Fishermen's Union, 55p.

Kosaka, Y. 2016. Scallop fisheries and aquaculture in Japan. IN: Scallops: Biology, Ecology, Aquaculture and Fisheries, third edition; S. Shumway and G. J. Parsons, editors. Elsevier, The Netherlands. pp 891-936.

Schick, D. and S. Feindel. 2005. Maine Scallop Fishery: Monitoring and Enhancement. Final Report to the Northeast Consortium. 73p.

Smolowitz, R. 1999. Sea Scallop Enhancement and Sustainable Harvesting. Final Report from the Westport Scalloping Corporation to the NOAA Saltonstall-Kennedy Program. Project # 95-NER-139. 490p.

Abstracts

TEN-YEARS OF TRANSPLANTING: AN OVERVIEW OF SEA SCALLOP TRANSPLANTING RESEARCH IN NEW ENGLAND

Farrell Davis[1], Victoria Brendler[11], Andrew Corso[11], Luisa Garcia[11], Natalie Jennings[11], Ryan Munnelly[11], Ronald Smolowitz[2]

[1]Coonamessett Farm Foundation, Inc.; [2]Coonamessett Farm

Coonamessett Farm Foundation, Inc. (CFF) and its predecessor have a 30-year history of developing bottom-sowing techniques to enhance wild scallop harvest and support a sustainable fishery. The focus of the work has been on transplanting wild sets of sea scallops to areas of presumed better growth conditions. The offshore environment where most of the sea scallop resource occurs and a scarcity of information regarding certain biotic and environmental processes have presented unique challenges to this research, making development of new tools and techniques a necessary for transplanting and subsequent monitoring. Time-lapse camera systems have been one such development enabling monitoring for 12-72 hours post transplanting. This has provided information on several predatory interactions with transplanted sea scallops, including previously undescribed predation by the northern moon snail, *Euspira heros*. Fine-scale towed optical surveys suggested that sea scallops will disperse from the central release location at a rate of ~7 cm per day^{-1}. Large numbers of sea scallops transplanted from the Nantucket Lightship to a protected shallower region showed growth at the population level, supported by mark and recapture providing individual-based growth rates. In addition to monitoring methods, CFF has investigated strategies and gears for reducing incidental mortality. Although all the evaluated gears had an average incidental mortality rate of ~20%, each gear type had its own advantages and disadvantages. Trawls had lower rates of shell damage than a sea scallop dredge but higher rates of bycatch. Though much of the work done over the past decade suggests that transplanting is viable avenue for enhancing sea scallop resources, integrating transplanting into the management of US sea scallop fishery requires sustained commitment from fisheries managers to protect research efforts from fishing activities and a modified management framework.

SCALLOP ENHANCEMENT INVESTIGATIONS ON THE EAST COAST OF CANADA

Leslie-Anne Davidson, Fisheries and Oceans Canada (retired)

An interest in scallop enhancement started on the east coast of Canada when several other countries began to apply Japanese scallop enhancement methodology to increase the density of their scallop species. Investigations were initiated to determine if sea scallop (*Placopecten magellanicus*) densities would increase if enhancement practices were applied. In Canada, fishing areas are divided into various Regions for management purposes. Scallop enhancement investigations were launched in both the Gulf and the Québec Regions. In both Regions, the work started in 1990 with studies aiming to gain knowledge for culture and restocking. A plethora of partners were involved in the research to determine the biological and technical feasibility of culture and enhancement techniques for wild sea scallops. In the Gulf Region, a small-scale scallop enhancement project was conducted from 2000 to 2008. In the Québec

Region a commercial scallop enhancement project ran from 2000 to 2007. The fishing industries in both Regions were the main proponents of the enhancement projects. The federal and provincial governments were involved in the funding, monitoring and integration of these activities in the fisheries. The two Regions exchanged biological and technical information and both were successful in their endeavors which included: spawning monitoring; plankton monitoring; collection-gear efficiency; timing of deployment and retrieval of collection gear; the release of scallop spat on beds; monitoring scallop density and growth; and harvesting. Studies in both Regions demonstrated increased density of commercial-size scallops on the wild scallop beds. In Canada, most of the enhancement activities have been conducted under research permits or through the temporary modification of fisheries management plan strategies. Infra structure to incorporate enhancement activities was not established, so scallop enhancement activities were discontinued.

SEED PRODUCTION FOR SCALLOP ENHANCEMENT AND HANGING CULTURE, AND DISRUPTION OF SPAWNING SEASON DUE TO TRANSPLANTATION OF SCALLOP

Yoshinobu Kosaka, Former Manager of the Scallop Department at the Aomori Prefectural Aquaculture Center

Before 1970 scallop production fluctuated greatly and was sluggish at less than 20,000 tons since 1950. Since the 1970s, scallop production in Japan has increased dramatically through hanging and sowing culture and went between 500,000 and 600,000 tons lately. The main production areas are Hokkaido and Aomori Prefecture. Hanging culture is carried out in Mutsu Bay in Aomori Prefecture and Funka Bay in Hokkaido, while seed release is carried out along the Okhotsk coast of Hokkaido. A series of hanging culture techniques were developed in the early 1970s, particularly the development of a seed collector using an onion bag, which made it possible to obtain large numbers of spats reliably. All of these techniques were developed in Aomori Prefecture.

Stable production of many seeds is necessary for scallop enhancement and hanging culture. it is first necessary to secure the individuals of adult scallops to ensure seedlings. Furthermore, information on gonads and larvae is issued every week to ensure the timing to set the spat collector.

As scallop production in Japan increases, transplantation of seedlings has become widespread.

However, because the spawning season of transplanted scallops is the same as that in their native habitat, the spawning season will differ from that of scallops in the transplanted area, which could have a major impact on seed production. This suggests that the spawning season is determined genetically, not environmentally.

Furthermore, the spawning season also varies depending on the age of the scallops.

SUCCESS FACTORS OF SCALLOP SOWING CULTURE SYSTEM IN JAPAN

Koji Miyoshi[1] (Proxy presenter, Keiichiro Hamano[2])

[1]Central Fisheries Research Institute, Hokkaido Research Organization, Yoichi, Hokkaido, Japan; [2]Japan Fishing Machine, LLC, Japan

New Scallop fishery techniques in Hokkaido have expanded rapidly after the early 1970s when aquaculture techniques were developed. Notably, the sowing culture system has maintained an annual production of about 300,000 tons since the 2000s. hundreds of millions of young scallops (~1 year old; >40 mm) are sowed on the seabed with this aquaculture system. After 3 or 4 years, they grow to a commercial size (>100 mm) and are harvested by dredge nets. This presentation outlines the bottom-culture techniques along Hokkaido, the factors contributing to their success, and introduces the latest fishing ground visualization technology. The sowing culture system in Japan premised on planned production, emphasizes "securing the necessary number of seeds" before seeding, and subsequently focuses on "how to grow them larger and ensure their survival." To support the latter, we have designed a new recording apparatus to continuously capture seabed images, rapidly and efficiently monitoring scallop survival and the seabed environment. This non-invasive system can acquire images of more than 10,000 m^2 of seabed per day. Furthermore, we have developed a seabed-image analysis application that automatically detects and counts scallops in these images. This fishing ground visualization system can classify the seabed environment at 2,000 m^2 per hour, with scallop detection accuracy exceeding 90% across various seabed patterns. we aim to bridge the gap between estimated resources and actual catch by leveraging image analysis and machine learning. These advanced management techniques could reduce the potential relative error in scallop stock estimation to less than 5%, significantly enhancing the sustainability and efficiency of scallop sowing culture along Hokkaido.

SESSION 3: ECOLOGICAL CONSIDERATIONS

A fundamental understanding of how an organism interacts with their environment is critical to the development of a resource enhancement program. For sea scallops, this understanding begins with knowledge of the animal and radiates out into the requirements and challenges that it faces at the individual and population level. The oceanography of the Gulf of Maine, Georges Bank and the mid-Atlantic Bight define the environment of the U.S. scallop resource and are important factors that constrain scallop spatial distribution and productivity. Implicit to this are oceanographic characteristics that influence thermal regimes, food availability and larval dispersal. In addition to factors that define scallop distribution, interaction with other species that occupy the same habitats represent a major aspect of the role of sea scallops in this system.

Definition

Ecology: the scientific study of the interaction between living organisms and their environment.

Background

The sea scallop, *Placopecten magellanicus*, exists in an environment shaped by both biotic and abiotic factors. Distributed throughout the Northwest Atlantic Ocean from Cape Hatteras, NC to the Canadian Maritimes, this boreal species prefers temperatures less than approximately 20°C above which mortality occurs (Dickie, 1958). As such, this thermal tolerance dictates where the species exists at various life history stages. In the northern part of its range, adult sea scallops can be found almost to the intertidal zone where at lower latitudes the species is restricted to the deeper, cooler waters of the continental shelf (Shumway and Parsons, 2016).

The sea scallop is dioecious with both males and females releasing sperm and eggs into the water column for fertilization (Shumway and Parsons, 2016). The resulting fertilized eggs develop through typical molluscan developmental stages and persist in the larval from for 4 to 6 weeks where they drift with the prevailing currents until settlement on the benthos. Settled scallops progress through the juvenile to adult stages where the life cycle with the commencement of reproductive viability at roughly age 3 (Shumway and Parsons, 2016). Sea scallops are benthic filter feeders the extract plankton and other organic matter from seawater. Sea scallop productivity and reproductive output are dependent upon these food sources which vary across time and space as a function of oceanographic features (Friedland et al, 2024; Kowaleski et.al., 2024).

While sea scallops have evolved a life history strategy (high fecundity, long larval stage that distributes animals broadly) that can result in high population levels, this population is affected by a number of both abiotic and biotic factors. Scallops have a fairly narrow temperature tolerance range and with the observed warming of ocean waters, thermally related mortality is a potential threat to both the range and productivity of the stock (Hare et. al, 2016; Rheuban et.al., 2018). Potential changes to the mid-Atlantic cold pool, which represents a persistent cold water mass along the mid-Atlantic Bight is an important feature that supports the sea scallop populations in that area (Friedland et. al., 2022). In addition to thermal stressors, ocean chemistry is also changing with at trend towards a more acidic environment. This acidification has the potential to disrupt essential biological processes (e.g. shell formation and maintenance), which also have implications for benthic molluscs generally and sea scallops specifically (Pousse, et. al., 2023; Steeves, et. al; 2024).

While future changes to oceanographic conditions and water chemistry represent abiotic considerations in the definition of future scallop habitat, scallops area also subject to biotic features that have been shown to shape populations. Predation is an ecological pressure that can shape populations and scallops are the prey of a number of marine organisms including fishes (cod, wolfish), vertebrates (sea turtles) and invertebrates (starfish, lobster, crabs). In addition to predation the scallops are subject to a suite of parasites. Recently, two parasites, the nematode, *Sulcasaris sulcata*, and a shell blister disease (caused by organisms inhabiting the shell) have been increasingly observed in this species (Rudders et. al., 2023, Roman and Rudders, 2022).

As we consider the concept of sea scallop resource enhancement, there are critical abiotic and biotic considerations that are material to consider. What defines productive scallop habitat is a complex interplay between the oceanographic seascape, the ecosystem of the continental shelf and the biological attributes of scallops. Evaluating these characteristics are critical to consider and any enhancement program's success will be predicated upon understanding these processes.

Current Status

There is wealth of knowledge surrounding the basic biology and ecology of sea scallops as well as the environment in which they live. Many data gaps exist, however, especially in the context of a changing oceanographic and climatic environment. As this environment changes into the future, uncertainty as to how sea scallops will respond at the individual and population level exist. Defining which knowledge gaps underpin a successful enhancement program, filling those gaps, and developing innovative strategies will be fundamental to the development of a successful enhancement program.

Guiding Questions

- What are the most critical physical oceanographic processes that might influence the success of a long-term resource enhancement program?
    - What are some important physical oceanographic data gaps that exist that need to be filled to inform a stock enhancement program?
- What are the most critical biological/ecological processes that might influence the success of a long-term resource enhancement program?
    - What are some important biological/ecological data gaps that exist that need to be filled to inform a stock enhancement program?
- What are some potential strategies to mitigate against environmental changes that are expected to impact the sea scallop resource.

References

Dickie, L. M. (1958). Effects of high temperature on survival of the giant scallop. *Journal of the Fisheries Board of Canada*, *15*(6), 1189-1211.

Friedland, K. D., Miles, T., Goode, A. G., Powell, E. N., & Brady, D. C. (2022). The Middle Atlantic Bight Cold Pool is warming and shrinking: indices from in situ autumn seafloor temperatures. *Fisheries Oceanography*, *31*(2), 217-223.

Friedland, K. D., Fratantoni, P., Silver, A., Brady, D. C., Gangopadhyay, A., Large, S. I., ... & Melrose, D. C. (2024). Changing source waters on the Northeast US Continental Shelf: Variation in nutrient supply and phytoplankton biomass. *Continental Shelf Research*, *281*, 105319.

Hare, J. A., Morrison, W. E., Nelson, M. W., Stachura, M. M., Teeters, E. J., Griffis, R. B., ... & Griswold, C. A. (2016). A vulnerability assessment of fish and invertebrates to climate change on the Northeast US Continental Shelf. *PloS one*, *11*(2), e0146756.

Kowaleski, K. R., Roman, S. A., Mann, R., & Rudders, D. B. (2024). Extreme population densities reduce reproductive effort of Atlantic sea scallops in high-density recruitment events. *Marine Ecology Progress Series*, *746*, 67-85.

Pousse E, Poach ME, Redman DH, Sennefelder G, Hubbard W, Osborne K, et al. (2023) Juvenile Atlantic sea scallop, *Placopecten magellanicus*, energetic response to increased carbon dioxide and temperature changes. PLOS Clim 2(2): e0000142. https://doi.org/10.1371/journal.pclm.0000142

Rheuban, J. E., Doney, S. C., Cooley, S. R., & Hart, D. R. (2018). Projected impacts of future climate change, ocean acidification, and management on the US Atlantic sea scallop (Placopecten magellanicus) fishery. PLoS One, 13(9), e0203536.

Roman, S.A. and Rudders. D.B**.** 2022. High Precision Dredge Survey to Assess the Mid-Atlantic Sea Scallop Resource Area in 2019 and 2020. VIMS Marine Resource Report No. 2022-1. 131 pp.

Rudders, D. B., Roman, S. A., Fisher, R., & McDowell, J. (2023). Observations on a Reemerging Epizootic of the Sea Scallop, Placopecten magellanicus, Resource. *Journal of Shellfish Research*, *42*(1), 51-60.

Steeves, L., Honecker, M., Meseck, S. L., & Munroe, D. (2024). Effects of Ocean Acidification and Summer Thermal Stress on the Physiology and Growth of the Atlantic Surfclam (Spisula solidissima). *Journal of Marine Science and Engineering*, *12*(4), 673.

Abstracts

HYDROGRAPHIC CONDITIONS OF THE NORTHWEST ATLANTIC OCEAN

Glen Gawarkiewicz, Woods Hole Oceanographic Institution

The Northwest Atlantic Ocean underwent significant change in 2023/2024 relating to recent hydrographic conditions. While the region has undergone significant warming, a cold fresh pulse from the north appeared in the Middle Atlantic Bight shelf and slope in late 2023 and was enhanced in the spring of 2024. The spatial and temporal nature of this pulse will be discussed including some of the ecosystem impacts.

CHANGES IN PRIMARY PRODUCTION AND SCALLOP HABITAT IN THE NORTHEAST US CONTINENTAL SHELF ECOSYSTEM (NES)

Kevin Friedland, Ph.D., NOAA Fisheries, Northeast Fisheries Science Center

The Northeast US Continental Shelf Ecosystem (NES) is a highly productive system which is influenced by a number of water sources. These water sources can vary in their contribution to the NES and each source is unique with respect to their characteristics (temperature, salinity, nutrients). In turn, these characteristics can have an impact upon primary productivity which is important for filter feeding organisms such as the sea scallop, *Placopecten magellanicus*. Recent work has examined the contributions of a number of water sources as it relates to sea scallop fishery production across the Gulf of Maine, Georges Bank and Mid-Atlantic Bight regions. Results suggest that shelf water associated with the Labrador Current (cooler fresher water) favors primary production and these higher levels of chlorophyll *a* concentrations are correlated with increased scallop fishery yield. Fishery yield generally is linked to the amount of habitat available to a stock. In the case of the sea scallop, habitat modelling efforts have shown that scallop habitat area has increased over time and as a result, interactions with other species in the NES have also increased.

ADAPTIVE APPROACHES TO PREDATOR CONTROL IN SCALLOP SEED PRODUCTION AND ENHANCEMENT

Yoshinobu Kosaka[1] and Kouji Miyoshi[2] (Proxy presenter, Keiichiro Hamano[3])

[1]Former Manager of the Scallop Department at the Aomori Prefectural Aquaculture Center; [2]Central Fisheries Research Institute, Hokkaido Research Organization; [3]Japan Fishing Machine,LLC

The success of scallop seed production and enhancement largely depends on effective predator control. While scallops face predation from various organisms including starfish, crustaceans, and cephalopods, starfish control is particularly crucial. isopods and juvenile starfish decimate spat populations in a spat collector because they can prey on over 100 spats daily. In sowing-based scallop fisheries, starfish predation accounts for 70% of total damage within the first year after release, until scallops reach a size of approximately 70 mm shell height. Various control methods are employed: dredge nets for pre-release removal, and star mops or star pots for post-release control to minimize habitat disruption to mitigate these losses. However, as starfish are keystone species, their complete removal can lead to ecological imbalances, such as increased competition from amphipods affecting scallop growth. In some areas, predator control costs had exceeded fishing profits. To address these challenges, concepts such as the Predator-prey mass ratio (PPMR), which considers individual sizes to evaluate interactions between predators and prey, have proven effective. This approach is leading to the use of larger seed scallops and adjustments in release density. Additionally, the establishment of buffer zones around fishing grounds is being implemented. These ecosystem-based adaptive management strategies contribute to the healthy sustainability of the fishery.

SESSION 4: REGULATORY AND MANAGEMENT REGIMES

Definitions

"Management" refers to the development and implementation of the Atlantic Sea Scallop Fishery Management Plan (FMP) by the New England Fishery Management Council and NOAA Fisheries and the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) and other applicable law. "Regulatory" refers to the rules put in place by the Magnuson-Stevens Act and the New England Fishery Management Council/NOAA Fisheries through the FMP to implement the FMP.

Relevance

The Atlantic Sea Scallop FMP is one of the highest grossing fisheries in the United States. The fishery is entirely dependent on natural recruitment. This has led to large fluctuations in harvestable biomass from year-to-year. Furthermore, Atlantic sea scallops are vulnerable to habitat loss from other ocean users and the impacts of climate change. These uncertainties have increased interest in stock enhancement from the scallop industry and the New England Fisheries Management Council.

Background

The Atlantic sea scallop fishery's management unit ranges from the shorelines of Maine through North Carolina to the outer boundary of the Exclusive Economic Zone. The Atlantic Sea Scallop FMP, established in 1982, includes a number of amendments and framework adjustments that have revised and refined the fishery's management. The Council sets scallop fishery catch limits and other management measures through specification or framework adjustment. The Magnuson-Stevens Act allows NMFS to approve, partially approve, or disapprove measures proposed by the Council based on whether the measures are consistent with the FMP, the Magnuson-Stevens Act and its National Standards, and other applicable law. Implementing a robust scallop enhancement program would be a fundamental change to the FMP.

Sea Scallop market dynamics and ultimately the profitability of the fishery are impacted by this management framework, along with many other factors including health of the scallop resource, consumer demand, and scallop prices. It's unclear, however, the degree to which stock enhancement could impact market dynamics (either positively or negatively) such as through changes to consumer perceptions or preferences for scallop products.

Current Status

To date, there have been discussions about scallop transplanting and other stock enhancement initiatives, but no official actions have been taken by the Council. The Council has included resource enhancement as a research priority for its scallop research set-aside program, and several projects have been funded. The Council recently recommended longer-term funding of enhancement projects through the research set-aside program (up to 4 years vs. up to 2 years). The Council is currently developing a strategic plan for the next 3-5 years of the fishery that could include aspects of resource enhancement.

Guiding Questions

- What are the key management and regulatory issues that will need to be addressed to implement scallop enhancement (either as a pilot or more broadly)?
- Given these issues, what specific next steps should be considered? Who should be involved? Think in terms of short-term and long term.
- How do we continue the dialogue to address the key issues?

References/Links/Resources

https://www.nefmc.org/management-plans/scallops

https://www.fisheries.noaa.gov/species/atlantic-sea-scallop/commercial

https://www.ecfr.gov/current/title-50/chapter-VI/part-648/subpart-D

Abstracts

SCALLOP MARKET DYNAMICS: AN OVERVIEW OF RESEARCH

Robert Murphy, Northeast Fisheries Science Center, NOAA Fisheries

Among the most economically and culturally important fisheries in the United States, the Atlantic Sea Scallop fishery is tightly regulated via effort controls, rotational area management, and individual fishing quotas. Sea Scallop market dynamics and ultimately the profitability of the fishery is impacted by this management framework, along with many other factors including variability in the stock of Sea Scallops, consumer demand, and scallop prices. This presentation will provide context for the Sea Scallop market dynamics by discussing two research efforts from economists at the Northeast Fisheries Science Center that attempt to characterize important aspects of and influences on the Sea Scallop market. In particular, this will include research that examined trends in vessel characteristics, fishing effort, costs, and prices to determine if and why fishermen profit and productivity may have changed over time. This will also include a brief overview of an economic evaluation of the impact of the IFQ program on fishermen revenue. Finally, to provide context for other conditions that may impact the financial viability of the fishery, the presentation will touch on research by the presenter (R. Murphy) conducted previous to his arrival at NOAA, that examined the fishery's perceptions of threats (e.g., environmental changes, public perceptions of scallop fishing, etc.) and their ability to adapt to these threats.

MANAGEMENT AND REGULATION OF THE ATLANTIC SEA SCALLOP FISHERY

Travis Ford[1] and Jonathon Peros[2]

[1]NOAA Greater Atlantic Fisheries Regional Office, [2]New England Fisheries Management Council

The Atlantic sea scallop fishery's management unit ranges from the shorelines of Maine through North Carolina to the outer boundary of the Exclusive Economic Zone. The Atlantic sea scallop fishery is one of the highest grossing fisheries in the United States. The Atlantic Sea Scallop Fishery Management Plan (FMP), established in 1982, includes a number of amendments and framework adjustments that have revised and refined the fishery's management. The Council

sets scallop fishery catch limits and other management measures through specification or framework adjustment. The Magnuson-Stevens Fishery Conservation and Management Act allows NOAA Fisheries to approve, partially approve, or disapprove measures proposed by the Council based on whether the measures are consistent with the FMP, the Magnuson-Stevens Act and its National Standards, and other applicable law. Implementing a robust scallop enhancement program would be a fundamental change to the FMP. Developing such a program through the FMP would be a multi-year process requiring continuous coordination between the Council, NOAA Fisheries, the scallop industry, and other interested parties