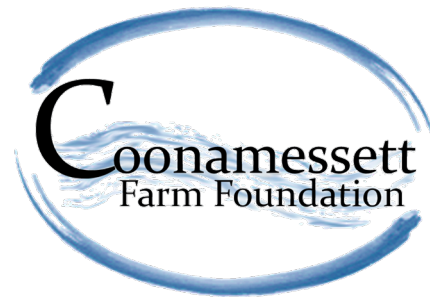




Sea Scallop Growth and Reproduction Research to Support Improved Resource Management

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1.0 EXECUTIVE SUMMARY

Project Title: Sea Scallop Growth and Reproduction Research to Support Improved Resource Management

Year Awarded: 2022

RSA Priorities Addressed By This Research: Scallop RSA High Priority Non-survey Research Priority #2 - Scallop biology, specifically reproduction, timing of spawning, age, growth, and yield

Industry Partners:

Collecting Biological Samples: F/V Tricia Lynn, F/V Nemesis, F/V Midnight Our, F/V Helltown, F/V Kahuna, F/V Three Graces, F/V Three Sons, F/V White Cap, F/V Outlaw, F/V Godzilla, F/V Bada Bing, F/V Isabel & Lilee, F/V Joanne A III, F/V Sandra Anne.

RSA Compensation Fishing: F/V Tricia Lynn, F/V Nemesis, F/V Midnight Our, F/V Helltown, F/V Kahuna, F/V Three Graces, F/V Three Sons, F/V White Cap, F/V Outlaw, F/V Godzilla, F/V Bada Bing, F/V Isabel & Lilee, F/V Joanne A III, F/V Sandra Anne, F/V Jessica Heather, F/V Ernest & Michael, F/V Miss Emma, F/V Roen Keil, F/V Rolex, F/V Small Stuff

The goal of this study was to contribute to the body of knowledge needed to improve sea scallop stock assessment for the Georges Bank Stock Area and ensure sustainable management of this fishery in the face of changing oceanographic conditions. In collaboration with 14 sea scallop captains, the Cape Cod Commercial Fishermen's Alliance and Coonamessett Farm Foundation piloted an industry-based biological sampling program that provides monthly insights into how meat yields and spawning seasonality changes throughout the year. The lessons learned during the pilot serve as a foundation to create a cost-effective, long term sampling program to track gonad-based reproductive potential and support more accurate scallop stock assessments in the face of changing climate and a shrinking scallop biomass.

This pilot project was designed to create an affordable way for dayboat fishermen to bring 25 live sea scallops (*Placopecten magellanicus*) to a shoreside lab where technicians recorded size, weight of soft tissues, sex, and reproductive stage. This data is regularly collected at sea during traditional summer surveys but is not collected year-round to track seasonal changes. Over the course of 22 months (4/21/2022 to 1/9/2024) and 73 trips, 25 scallops were collected weekly, weather permitting, resulting in 1763 individual samples.

The reproductive stages of sea scallops were plotted by trip to examine seasonal changes and estimate spawning periods. Reproductive cycles were described based on macroscopic observations, gonadal mass index (GMI) and gonadosomatic index (GSI). Shell height-meat weight relationships were also modelled. A conversion factor was developed to allow comparisons between wet weights and dry weights. From this, two models were developed to evaluate the relationship between the wet and dry weights of two important sea scallop soft tissues: the abductor muscle (meat) and the gonad. The results of this project provide a template to collect important data needed by fisheries managers, for science-driven management decisions that strengthen the country's valuable commercial scallop fishery.



2.0 SUMMARY OF RESULTS AND DISCUSSION

Objective 1: Identify spawning seasonality through examination of gonads.

A total of 1,738 scallops distributed on the tows shown in **Figure 1** were collected and examined for shell height/width, meat wet weight, gonad wet weight. A total of 1,486 scallops were included on the visual examination of reproductive stages (**Figure 2a**); the highest percentages of ripe scallops occurred from July through September in both years. A total of 1,565 scallops were included in the GMI analysis, and 380 scallops were included on the GSI analysis; with both analyses two spawning periods were evident, in spring and fall (**Figure 2b, 2c**).

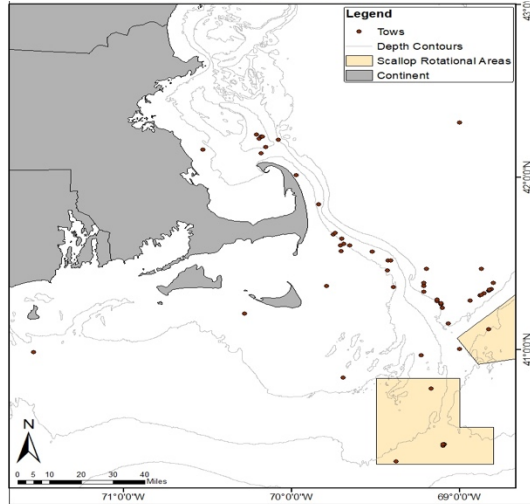
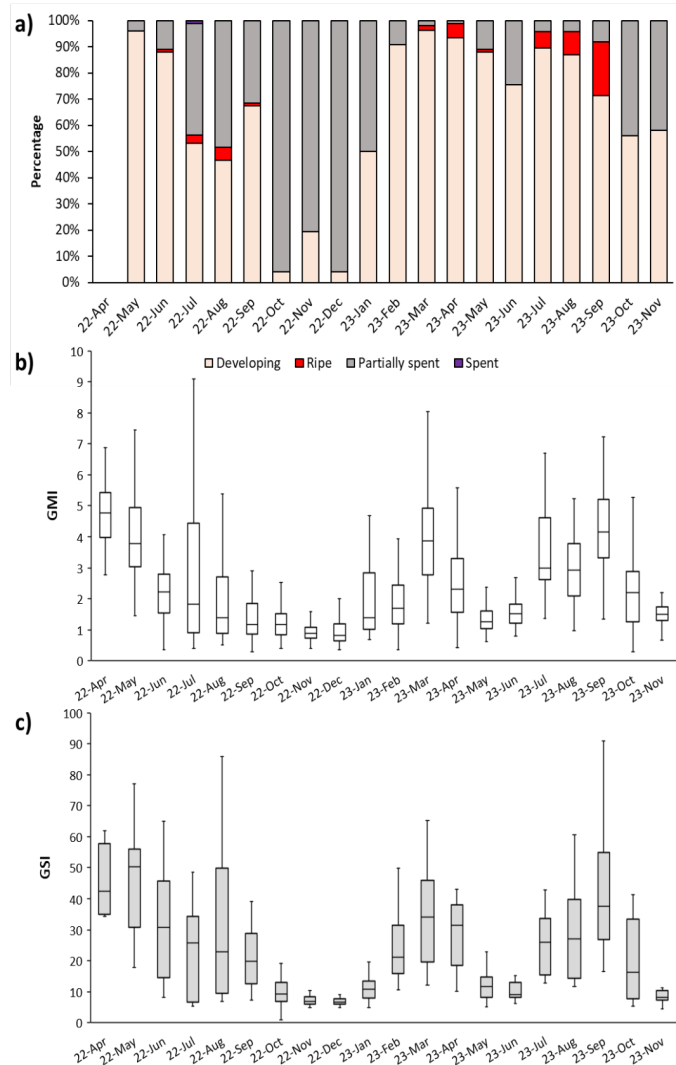


Figure 1. Sampling Tows occurred April 2022-January 2024, year-round on a weekly basis. Sampling location was wherever the regular commercial trips were towing (opportunistic)

Figure 2. Seasonal a) stage results determined through macroscopic observations and b) changes in the GMI and c) changes in the GSI for scallops by month. For the GMI and GSI plots, boxes end at the first and third quartiles of the distribution of GMI and GSI values, with the whiskers extending to the minimum and maximum values.





Objective 2: Explore the seasonality of relationships between scallop morphometrics and soft tissue weights.

A total of 1,738 scallops were examined for shell height/width, meat dry/wet weight, gonad dry/wet weight. After QAQC 1,587 scallops were included in the SHMW analysis. Scallop shell heights ranged from 73.39 mm to 163.57 mm and meat weights varied from 5.85 g to 76.17 g. Temporal distributions of the collected shell heights and meat weights are shown in **Figure 3**. Predicted meat weights were estimated for all scallops combined by season, meat weights were predicted to be highest during the Spring and lowest during the Fall. (**Figure 4**).

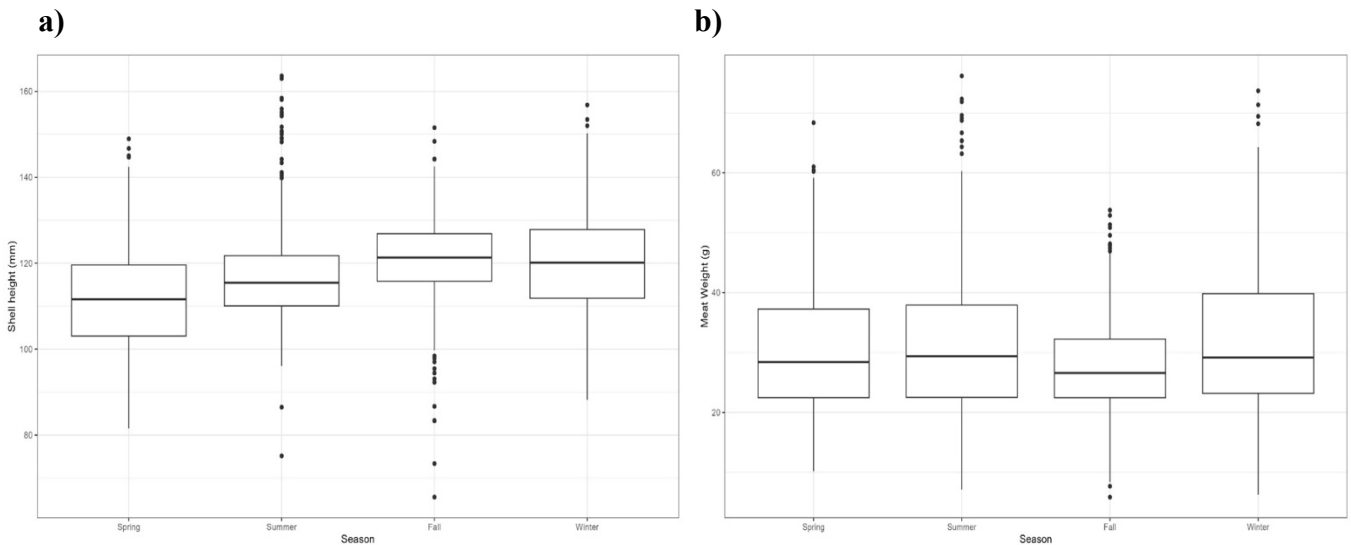


Figure 3. Temporal changes in the distributions of collected **a)** shell height and **b)** meat weight samples. The markers inside the boxes show the median values for each month. Boxes end at the first and third quartiles of the distribution of values for each variable, with the whiskers extending to the minimum and maximum values.

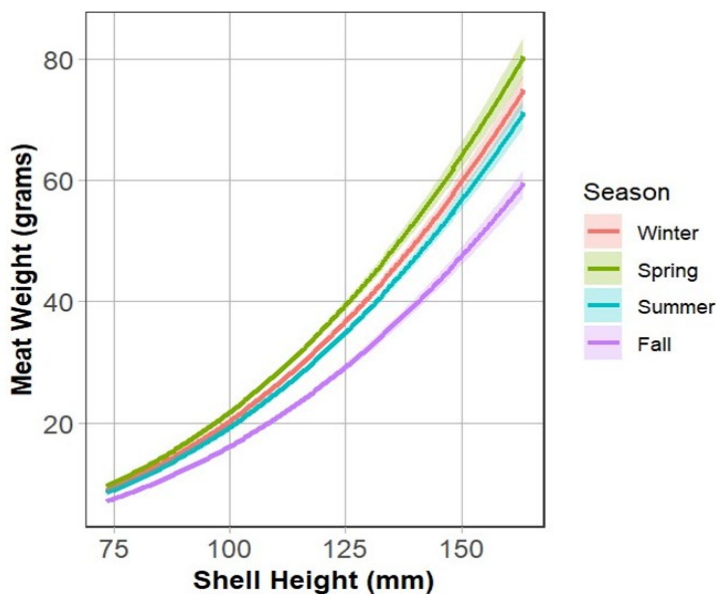


Figure 4. Shell Height Meat Weight Relationship curves. Created with generalized linear model.



Objective 3: Develop a conversion factor to allow comparisons between wet weights and dry weights.

After QAQC, dry sea scallop meat and gonad weight pairs were modelled for 400 of the scallops sampled for this project. Conversion factors for wet weights and season as predictors of dry weight were obtained after fitting models to the paired data using R Statistical Software (v4.3.0 R Core Team 2023). For both the dry sea scallop meat and gonad weight, season was found to be a significant predictor of the observed trend. For both meat and gonad dry weights, the ratio of wet-to-dry weight was observed to be the highest in Fall. The ratio of wet-to-dry meat weight was lowest in the Spring, while the ratio of wet-to-dry gonad weights was lowest in both the Spring and Summer. The seasonal dry weights as predicted by the models using the observed wet weights also follow the observed seasonal wet-to-dry ratio trend (**Tables 1 & 2**).

For the relationship between wet and dry meat weight, the most parsimonious model was the one that included area and wet meat weight, with both being significant predictors of the observed trend (**Figure 5**). The most parsimonious model for predicting the relationship between wet and dry gonad weights was one that included an interaction between season and area (**Figure 6**).

Despite some limitations with these data, we were able to successfully model the relationship between wet and dry meat and gonad weight and provide a means for converting wet weights to dry weights. A general conversion factor (Wet-to-Dry) across all seasons for the abductor muscle is 4.29 and 6.73 for the gonad tissues (**Tables 1 & 2**). The application of the Generalized Linear Models (GLM) accounts for variation of the conversion factor by season and area (**Tables 3 & 4**).

***Table 1.** Mean observed dry and wet scallop meat weight and predicted mean dry meat weight by season. Also presented is the observed conversion factor (Wet/Dry Ratio) relative to the conversion factor using the dry meat weight as predicted by the generalized linear model.*

Observed Values						
	<i>n</i>	<i>Wet Meat Weight (g)</i>	<i>Std Dev.</i>	<i>Dry Meat Weight (g)</i>	<i>Std Dev.</i>	<i>Ratio (Wet/Dry)</i>
<i>Winter</i>	72	34.111	13.10	8.087	3.62	4.329
<i>Spring</i>	95	29.163	8.90	7.223	2.29	4.065
<i>Summer</i>	126	30.653	11.20	7.398	3.13	4.268
<i>Fall</i>	107	28.667	7.21	6.466	1.98	4.521

Predicted Values			
	<i>Dry Meat Weight (g)</i>	<i>Std Dev.</i>	<i>Ratio (Wet/Dry)</i>
<i>Winter</i>	8.092	3.41	4.270
<i>Spring</i>	7.174	2.39	4.100
<i>Summer</i>	7.436	2.95	4.174
<i>Fall</i>	6.501	1.78	4.437



Table 2. Mean observed dry and wet scallop gonad weight and predicted mean dry gonad weight by season. Also presented is the observed conversion factor (Wet/Dry Ratio) relative to the conversion factor using the dry gonad weight as predicted by the generalized linear model.

Season	n	Observed Values				
		Wet Gonad Weight (g)	Std Dev.	Dry Gonad Weight (g)	Std Dev.	Ratio (Wet/Dry)
Winter	72	9.570	7.04	1.578	1.44	7.165
Spring	95	9.775	6.01	1.874	1.34	5.701
Summer	126	10.404	7.42	2.061	1.65	5.707
Fall	107	6.947	6.38	1.045	1.26	8.351

Season	Predicted Values		
	Dry Gonad Weight (g)	Std Dev.	Ratio (Wet/Dry)
Winter	1.628	1.34	6.275
Spring	1.884	1.30	5.432
Summer	2.062	1.63	5.394
Fall	1.086	1.18	6.837

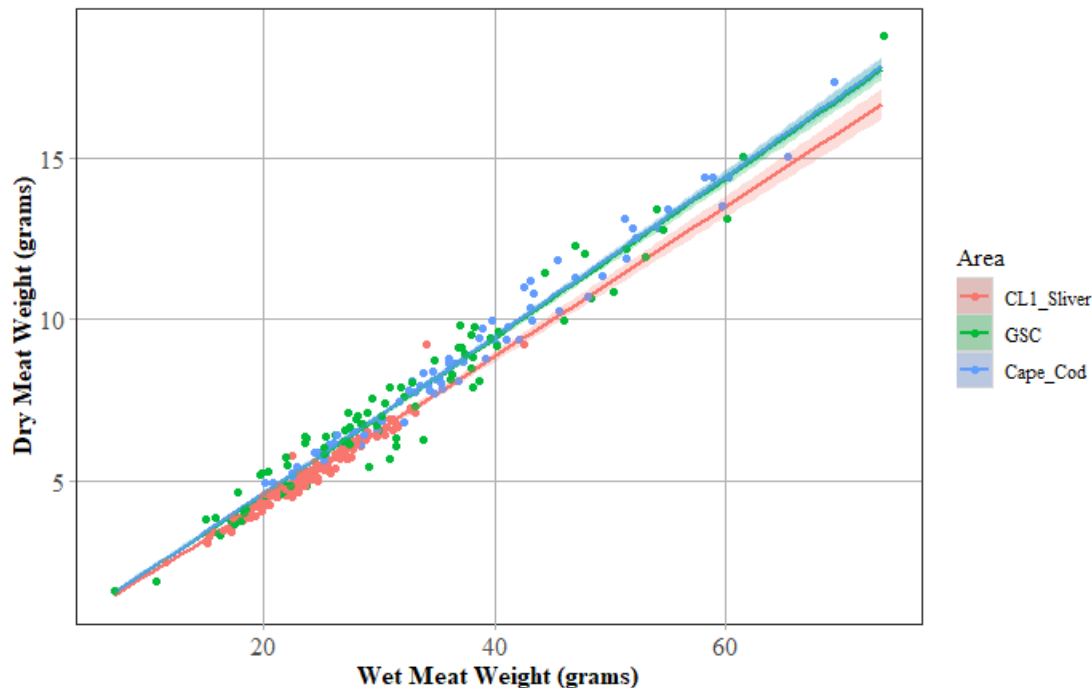


Figure 5. Predicted dry scallop to wet scallop gonad weight (g) by area relative to observed trends. Sample size n=400. Calculated conversion factor of 4.29 across all areas (Closed Area 1 Sliver, Great South Channel, and Cape Cod).

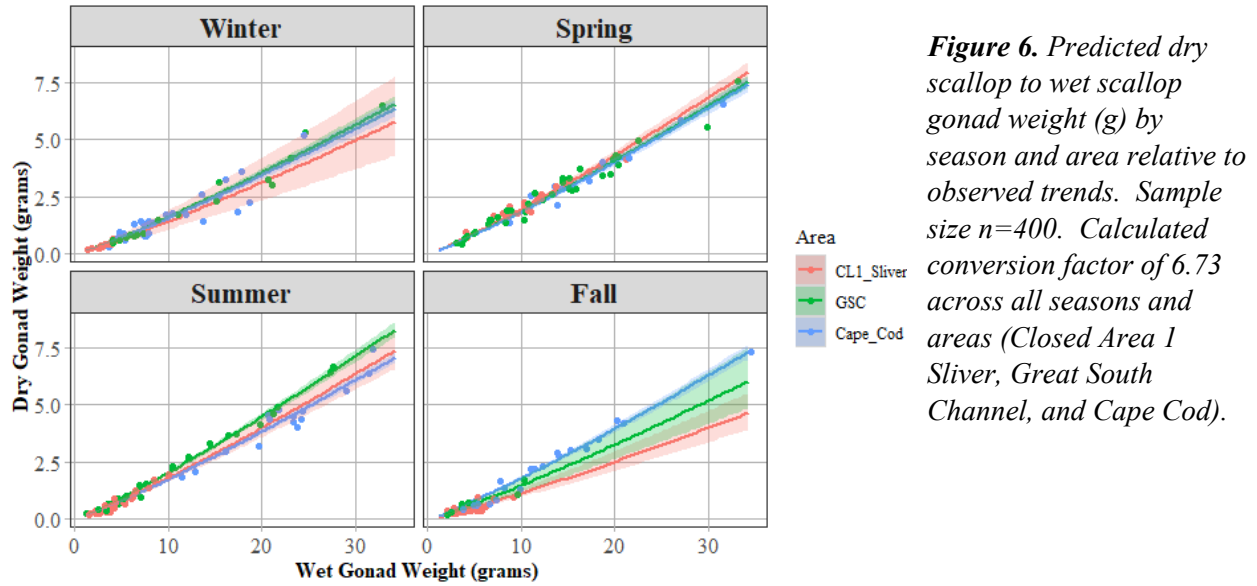


Figure 6. Predicted dry scallop to wet scallop gonad weight (g) by season and area relative to observed trends. Sample size n=400. Calculated conversion factor of 6.73 across all seasons and areas (Closed Area 1 Sliver, Great South Channel, and Cape Cod).

Table 3. Modelled dry abductor muscle (meat) weight coefficients for the area-based model.

	Estimate	Std. Error	t value	Pr(> t)
<i>(Intercept)</i>	1.87286	0.00735	254.95	< 2e-16
<i>log(WetMeatWeight)</i>	1.04252	0.01175	88.712	< 2e-16
<i>CL1_Sliver</i>	-0.0683	0.01089	-6.277	1.26E-09
<i>Great South Channel</i>	-0.0057	0.00803	-0.71	0.478

Table 4. Modelled dry gonad weight coefficients for the area-based model.

	Estimate	Std. Error	t value	Pr(> t)
<i>(Intercept)</i>	0.05829	0.02935	1.986	0.04798
<i>log(WetMeatWeight)</i>	1.14429	0.01741	65.723	< 2e-16
<i>Spring</i>	0.15328	0.03467	4.422	1.40E-05
<i>Summer</i>	0.10733	0.03174	3.381	0.00083
<i>Fall</i>	0.14034	0.03406	4.12	4.98E-05
<i>CL1_Sliver</i>	-0.0964	0.1503	-0.641	0.52173
<i>Great South Channel</i>	0.03255	0.03578	0.91	0.36374
<i>Spring:CL1_Sliver</i>	0.16562	0.15231	1.087	0.2778
<i>Summer:CL1_Sliver</i>	0.14041	0.15804	0.888	0.37507
<i>Fall:CL1_Sliver</i>	-0.3574	0.17055	-2.096	0.03702
<i>Spring:Great South Channel</i>	-0.0166	0.04436	-0.375	0.7081
<i>Summer:Great South Channel</i>	0.12583	0.04343	2.897	0.00406
<i>Fall:Great South Channel</i>	-0.2257	0.11832	-1.908	0.05744



Objective 4: Pilot an affordable industry-supported biological sampling program that could be expanded more broadly in the scallop fishery as well as transferred to other fisheries to support applied science and management with finer scale temporal data than are available through traditional sampling means. Work closely with NEFSC to ensure resulting data is useful to management.

The project successfully piloted a biological sampling program that collected fine scale temporal data to improve our understanding of monthly trends in spawning cycles and meat yield and created wet to dry conversion ratios. Access to Scallop RSA compensation fishing was used to compensate participating vessels, along with a stipend of \$36/trip. Fourteen LAGC scallop vessels participated in collecting weekly samples; 43% (six) provided 86% of the samples. While there was strong support for and interest in participating in the project, it proved to be more efficient and effective to work with fewer vessels to coordinate sampling schedules with vessels that landed closer to the lab location. Having 24/7 staff coverage available all week to accept and process one sample per week is unrealistic but trying to pre-schedule exact days and times is almost impossible except during the high season when the fleet is fishing almost every day. Processing the 25 scallop samples in the lab took from 4 to 8 hours depending on how clean they were and the speed of the technician.

Best Practices for future program expansion

Considering the results and lessons learned in conducting this pilot, we did determine that weekly samples are valuable data that are accessible and should be continued to be collected, with several modifications to program design:

- a) Use a deck log to standardize location, reduce error, and streamline data entry.
- b) Install eMOLT sensors to record surface and bottom water temperature.
- c) Continue targeting weekly samples but ultimately set a monthly goal. Increase sample size to three to five trips per week. Weather windows in the winter may mean that most LAGC vessels are fishing on the same day, which limits the number of samples that can be processed in a given week unless you have multiple technicians or hold samples overnight.
- d) Identify key areas to be re-sampled each month, to develop year-round trends.
- e) It is most cost effective for this sampling to be opportunistic. Some vessels would be willing to conduct a series of short tows at reference stations.
- f) All summer and early fall trips should hold samples in chilled seawater.
- g) Involve a fisheries monitoring company or organization with several lab technicians that have the flexibility to match their schedule to align with the landing from each fishing trip.
- h) Distribute technicians across various ports to capture the range of the fishery (NY/NJ, RI/New Bedford, Cape Cod, Gloucester, Portland).
- i) Schedule analyses to ensure that timely results are available to the PDT/Council.
- j) Recent ambiguity between reproductive stages means that future research should use histology to assess the reproductive stage.

Cost Estimates for future program expansion

With protocols and analysis methodology now already in place, replication of the existing program would be cheaper than the pilot. The cost estimates are for a future program include 1 trip per week (1300 samples/year at \$65,170) as well as 3 trips per week (3600 samples/year at \$141,527) and assume that non-consumable supplies/equipment must be purchased in the first year (calipers, scale, standards, knives, cooler). Estimate assumes RSA funding and has



commensurate RSA compensation fishing management costs included. Additional expenses to continue dry weights and add histological verification of gonad development stage would be \$14,738 for 1300 samples and \$37,382 for 3600 samples.

Incorporating precise and accurate reproductive aspects during stock assessment processes is very important for the long-term sustainability of a fishery. The current scallop stock assessment depends on estimates of reproductive potential associated with meat weight, which makes it unsuitable for an accurate stock assessment for the species. Therefore, a long-term industry-based sampling program could provide ongoing basic life history and morphometric parameters (e.g., timing of spawning, morphometrics, soft tissue ratios). In addition, a long-term program would empower LAGC fishermen to participate in the scientific process and continue to build trust between the LAGC fishing industry and the NEFSC. Members of the LAGC fleet are supportive of this research because it allows them to contribute to better management of the resource they rely on for their livelihoods.

3.0 SPECIAL COMMENTS

Using LAGC scallop vessels to collect biological samples and scallop data is a cost-effective way to provide monthly insights into how meat yield and scallop spawning changes throughout the year (\$36-\$50/scallop depending on volume). It also increases the area and months sampled beyond what the observers and surveys can accomplish with existing schedules.

Due to the logistical challenges presented by shoreside processing, the follow-on research pivoted to have fishermen sample at sea with Commercial Fisheries Research Foundation's Image Based Research Fleet, which was first piloted in 2023-2024 and uses electronic monitoring cameras to allow the captain to easily and accurately collect shell size, meat yield, sex, reproductive stage and location/date onboard the vessel. This allows for an expanded geographic range and removes the need for an on-call technician to receive and process the samples upon landing. It is possible that the shortfall of soft tissue sampling in the Image-Based project could be overcome by a small amount of live animal subsampling in the lab or having fishermen preserve samples to bring home. Fishermen are currently collecting images for data extraction using a NEMM Portable Sampling System and bringing home a total of 500 gonad samples for histological verification. <https://www.cfrfoundation.org/scallop-image-fleet-overview-page>

Additionally, National Fish & Wildlife Foundation award #85562 is allowing the project team to collect additional 500 gonads for histological sampling and train an AI algorithm with histologically-verified images of gonads to automate identification of gonad development stage.

Data Availability:

The project data are stored by CFF following their data management plan. Data requests should be directed to CFF, Details available at their website:

www.coonamesettfarmfoundation.org/data-management

Full Technical Report: <https://capecodfishermen.org/wp-content/uploads/2024/11/Technical-Report-NA22NMF4540050.pdf>