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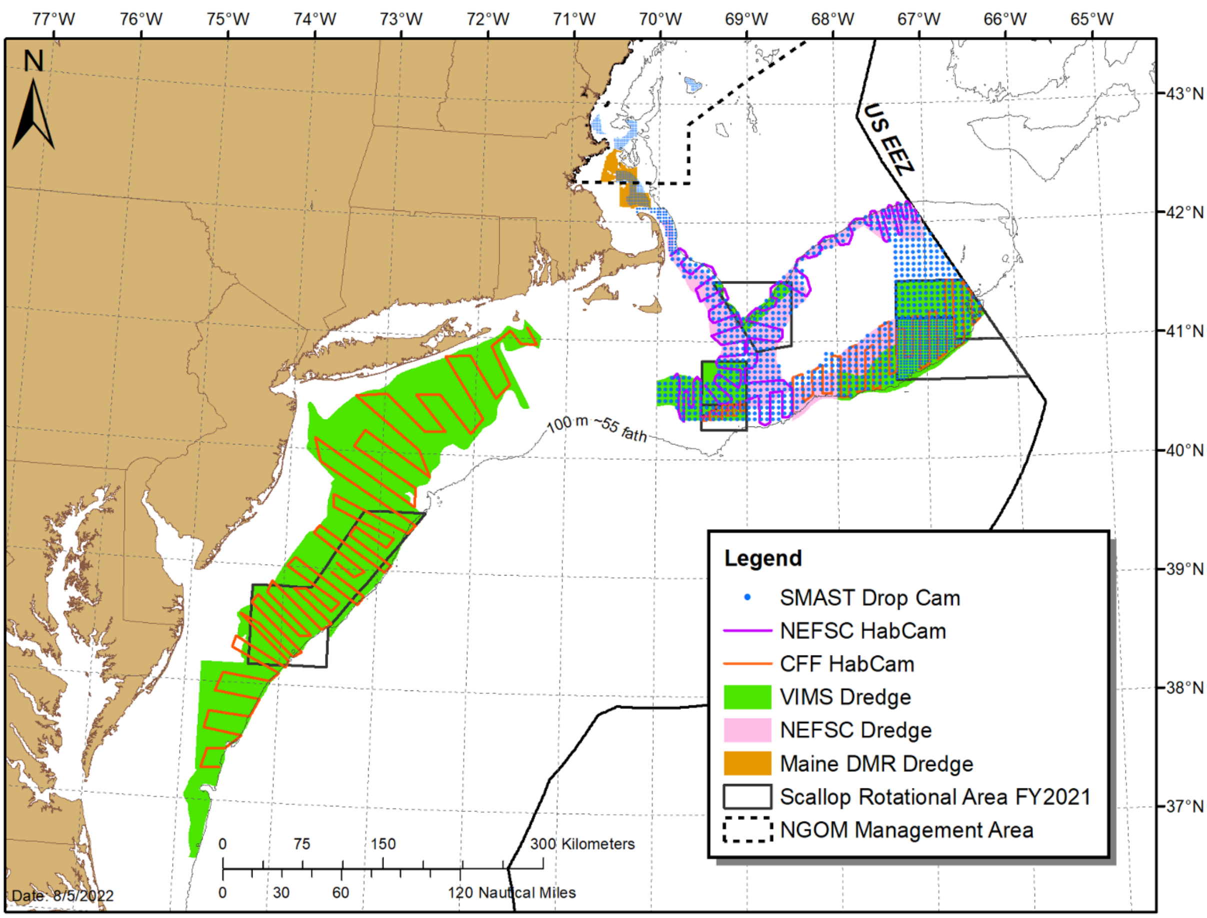
Atlantic Sea Scallop Survey Working Group Report and Recommendations



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Prepared by

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and

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1.0 EXECUTIVE SUMMARY

The New England Fishery Management Council (Council) formed the Scallop Survey Working Group (SSWG) as part of its 2021 scallop priorities to develop recommendations that could help improve the Atlantic sea scallop survey system. The purpose of the SSWG was to (1) facilitate collaboration around integrated approaches to conducting scallop surveys that support stock assessment and management, and (2) explore mechanisms for implementation of new approaches. The SSWG developed recommendations to address four Terms of Reference, including survey spatial coverage, sampling intensity and frequency, data standardization, storage, and access, potential impacts from the development of offshore wind, and data needs to support future stock assessments. The working group included two Co-Chairs representing the Council and the Northeast Fisheries Science Center (NEFSC), members with a broad range of expertise related to survey design, scallop biology, stock assessment, ecology, and wind energy, as well as contracted facilitators.

This report includes an introductory overview of the background, purpose, and process of the SSWG, the Terms of Reference (TORs), a description of how the SSWG addressed each TOR with recommendations for new approaches and rationale and implementation strategies for consideration by the Council in consultation with the NEFSC. In addition, the report provides conclusions about the current and future state of the scallop survey system.

Information in the report and considered in the recommendations for survey improvements was generated through a series of working group and topical sub-group meetings conducted from March 2021 to August 2022. The report focuses on actionable recommendations stemming from assessments of the current scallop survey system, which are presented in summary tables and figures. The report references previous reviews of the scallop survey system, including the Scallop Survey Peer Review (2015), the most recent benchmark stock assessment for scallops (2018), and the Council's Research Set-Aside Program Review (2019), as well as additional background information and NOAA guidance documents.

To address the Terms of Reference, the SSWG provided the following recommendations:

TOR #1: Describe the current survey system, including survey (dredge and optical) methods, design, and data products, as well as the process for determining annual survey coverage.

- The SSWG provided a description of the current system and recommended continued development of alternative survey sampling designs with a subsequent peer-review.

TOR #2: Describe and assess a coordinated strategy for sea scallop resource assessment surveys and investigate opportunities and methods for implementation.

- The Council and NEFSC should adopt Scallop Survey Guiding Principles to inform survey-related decision-making, RSA priorities and program adaptations, and future science and management efforts and advice.

- The NEFSC should prioritize scallop survey data management and provide resources for dedicated personnel for data/database management.
- The NEFSC should dedicate sufficient annual resources to develop and maintain an operational scallop survey data repository using FAIR (findable, accessible, interoperable, reusable) data management principles.
- Standardize scallop survey data format and delivery.
- Establish a process to check for autocorrelated data for model-based estimation methods.
- Conduct a review of automated detection technology.
- The Council should maintain data tables for management applications.
- The Council should revise the language used to describe the Scallop RSA survey priorities for inclusion in the RSA Notice of Federal Funding Opportunity.
- The Council and NOAA should revise the Scallop RSA Program to allow for longer-term awards (up to 5 years) and collaboratively develop a rigorous, standard process to ensure coordination of annual survey spatial coverage and sampling intensity.

TOR #3: Identify survey methods, tools, and designs to monitor and assess the scallop resource in a changing ocean environment that includes offshore wind installations and changes in resource and fishery distribution.

- Provide additional resources in order to implement a NOAA Northeast federal survey mitigation program.
- Conduct simulation modeling to characterize the impacts of offshore wind energy development on the scallop survey system and assess the feasibility of alternative sampling methods.
- Develop guidelines for offshore wind monitoring surveys to collect data and generate data products to supplement the scallop survey system.
- The scallop survey enterprise should develop robust strategies that can be implemented over multiple timescales.
- Utilize existing information to inform future survey strategies.
- Ensure mitigation approaches and implementation strategies are coordinated between NEFSC and RSA survey partners.

TOR #4: Identify and catalogue the survey data products needed to support stock assessment approaches in the future and outline a process for modifying the scallop survey system to collect identified data products.

- The SSWG compiled a catalogue of survey data products and survey collection methods to support future stock assessment needs.

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3.0 BACKGROUND AND PURPOSE

3.1 BACKGROUND

Successful management of the Atlantic sea scallop fishery has been supported by annual fishery-independent surveys, including dredge and optical systems that provide distribution, abundance, biomass, density, and biological information for the full range of the US scallop resource (NEFMC, 2022; NEFSC, 2018). Surveys are conducted by NOAA Fisheries and research institutions that are funded by the Scallop Research Set-Aside (RSA) Program. The annual surveys have provided invaluable information to support scallop stock assessment and management for multiple decades. Moving forward, the stock-wide survey system could benefit from enhanced coordination among survey groups to ensure sampling designs, spatial coverage, and data standardization meet science and management objectives, as well as plan for future impacts from the development of offshore wind energy and climate change.

In 2015, NOAA Fisheries coordinated the "Review of Sea Scallop Survey Methodologies and Their Integration for Stock Assessment and Fishery Management" (Cadigan et al., 2015). The review included dredge survey methods from the NEFSC and Virginia Institute of Marine Science (VIMS), and optical survey methods from HabCam (NOAA Fisheries and Arnie's Fisheries) and the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST). The objectives of the review were to assess the strengths and weaknesses of each sampling approach, identify the complementary features of each survey methodology, and consider opportunities for each method as part of a stock-wide scallop survey sampling program in the future. The review panel summary report included several recommendations to improve the individual survey methods, many of which have been addressed by the various survey groups in recent years. The panel also provided recommendations for integrating survey results, optimizing survey frequency, combining survey methods, and collaborations among survey investigators and institutions. Specifically, they recommended devising an optimal and integrated statistical survey design recognizing the value of different sampling methodologies and designs (Cadigan et al., 2015).

The Council conducted a review of New England Research Set-Aside Programs in 2019, which included specific focus on scallop surveys (NEFMC, 2019). The review recognized that scallop surveys are pieced together based on proposals submitted to the RSA program and suggested that a long-term survey strategy with consistent implementation of a structured design may be more effective and efficient for stock assessment and management purposes. The report listed several factors to be considered in the general approach of a scallop survey program, including spatial coverage, sampling design and technology, and methods for assimilating survey data. The review included a series of options for improving efficiency and effectiveness of resource surveys ranging from short-term, relatively simple coordination meetings to long-term, multi-institutional arrangements (NEFMC, 2019).

A benchmark stock assessment for scallops was conducted and reviewed in 2018, including research recommendations related to surveys (NEFSC, 2018). The first recommendation in the assessment report stated, *"Further investigate methods for better survey coordination between various survey programs, including survey design, timing, and standardized data formatting for* *easier sharing."* There was also a recommendation to collect information needed for the management of the Gulf of Maine fishery, including fishery-independent surveys. Several other research recommendations focused on specific aspects of dredge or optical survey methods that have been addressed by individual survey groups in recent years but have not been coordinated across survey methods (NEFSC, 2018).

In 2019, the NEFSC presented the Council with a range of implications for fishery-independent surveys stemming from development of offshore wind energy, including scallop surveys. The presentation stated that the *R/V Hugh Sharp*, which has conducted the federal portion of the scallop survey as a chartered University-National Oceanographic Laboratory System (UNOLS) vessel since 2007, is not likely to operate in wind energy areas (NEFSC, 2019). For all scallop surveys, sampling designs within wind energy areas may be disrupted and new designs will be needed, requiring calibration and transition processes. Coordination among scallop survey groups is needed to design an approach for full spatial coverage of the resource, ensure data quality standards, and identify methods for data assimilation. There have been regional discussions about incorporating data from new surveys focused on impact monitoring in individual wind energy areas to supplement data gaps created by the placement of wind turbines (NAS, 2018; RODA, 2020), but there have been no evaluations specific to scallop surveys.

To address these issues, the Council established the Scallop Survey Working Group in February 2021 to: (1) facilitate collaboration around integrated approaches to scallop surveys that support stock assessment and management; (2) make recommendations about specific issues stemming from the Council's Research Set-Aside Program Review (2019), the Scallop Survey Peer Review (2015), and the 2018 Scallop Assessment (SARC 65); and (3) address the likely disruption that offshore wind development will have on scallop surveys and monitoring operations. The working group provided recommendations for consideration by the Council and NEFSC in response to the approved SSWG Terms of Reference. Recommendations from the SSWG are expected to inform the Council and NEFSC about performance and challenges of the current scallop survey system and provide potential guiding principles, coordination strategies, and proposals for alterative survey designs to enhance data collection protocols, standardization of data products, and mechanisms to achieve scallop science and management objectives. The report identifies recommendations and improvement opportunities for the Council and NEFSC to consider for future scallop surveys.

3.2 Purpose, Process, and Membership

3.2.1 Scallop Survey Working Group Purpose

The SSWG was established to:

1. Facilitate collaboration around integrated approaches to conducting scallop surveys that support stock assessment and management;
2. Explore mechanisms for implementation.

3.2.2 Organization, Practices, and Procedures

The objective for the SSWG was to develop recommendations addressing specific Terms of Reference. The group reported directly to the Council and recommendations will be forwarded by the Council to the NEFSC (Figure 1). The Council established a Statement of Organization, Practices, and Procedures for the SSWG that outlined the purpose, objectives, organizational structure, membership criteria, timeline, meetings, and organizational support. The administrative costs associated with SSWG operations were supported by the Council, contracted facilitators supported group activities, including communications, meetings, and report writing, and members of the SSWG did not receive financial compensation for participation.

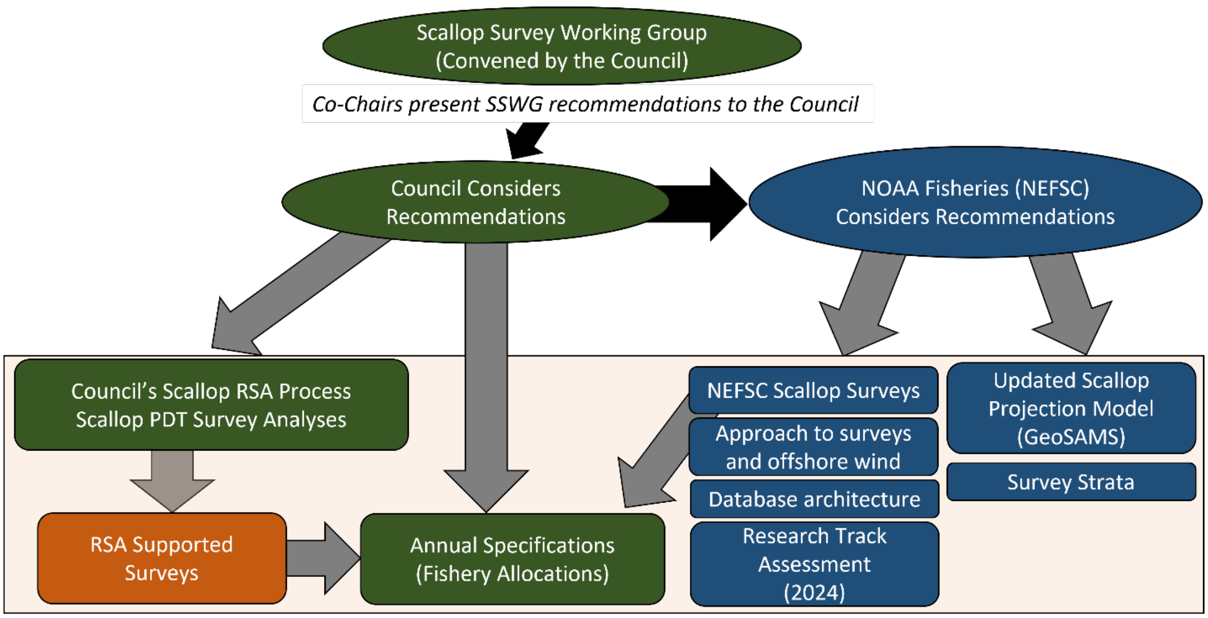

Figure 1. Flowchart of applications of SSWG recommendations for Terms of Reference.

The SSWG efforts commenced in February 2021 and concluded in September 2022. The full working group met eight times and topic-specific sub-groups met multiple times between SSWG meetings (Figure 2). All background information and documents are available on the Council's website under Scallop Survey Working Group.

Jan-Mar 21	*Apr-Jun 21*	*Jul-Sept 21*	*Oct-Dec 21*
Form SSWG Hire Contractor	1st meeting Approved TORs	2nd Meeting Sub-Group Work 2021 Survey Review	3rd Meeting Guiding Principles Survey Coordination
Jan-Mar 22	***Apr-May 22***	***Jun-Jul 22***	***Aug-Sept 22***
4th Meeting Sub-Group Work Data and Wind	5th Meeting Sub-Group Work RSA and Assessment	6th Meeting Recommendations 2022 Survey Review	7th Meeting Final Report and Presentation

Figure 2. Timeline of SSWG activities between January 2021 and September 2022.

3.2.3 Scallop Survey Working Group Membership

The Council released a Request for Applications for the Scallop Survey Working Group in February, 2021 and the group was officially charged on March 2, 2021. The SSWG was led by two Co-Chairs, Dr. Bill DuPaul and Mr. Peter Chase, who were jointly responsible for conducting meetings and presenting final recommendations. The SSWG included members with expertise in invertebrate survey design, dredge and optical survey methods, survey statistics, stock assessment methods, impacts of offshore wind development on fishery-independent monitoring, geostatistics, scallop biology, habitat and management, and the Scallop RSA Program. The Council contracted Fishery Applications Consulting Team to facilitate the SSWG with assistance from Tidal Bay Consulting (Table 1).

Table 1. Scallop Survey Working Group membership, affiliation, and working group role.

Name	*Affiliation*	*Role and Sub-Group*
Peter Chase	NOAA Northeast Fisheries Science Center	Co-Chair
Bill DuPaul	NEMFC Scallop Plan Development Team	Co-Chair
Dave Bethoney	Commercial Fisheries Research Foundation	Member, Wind
Han Chang	NOAA Northeast Fisheries Science Center	Member, Data
Scott Gallager	WHOI/Coastal Ocean Vision	Member, Data
Dvora Hart	NOAA Northeast Fisheries Science Center	Member, Data, Assessment
Chad Keith	NOAA Northeast Fisheries Science Center	Member, Data
Paul Kostovick	NOAA Northeast Fisheries Science Center	Member, Data
Andy Lipsky	NOAA Northeast Fisheries Science Center	Member, Wind
Amber Lisi	Maine Department of Marine Resources	Member, Data, Wind
Roger Mann	Virginia Institute of Marine Science	Member, Wind, Assessment
Drew Minkiewicz	Fisheries Survival Fund	Member, Wind
Tasha O'Hara	Coonamessett Farm Foundation	Member, Data
Jonathon Peros	NEFMC Scallop Plan Coordinator	Member, Data, Wind, RSA
Dave Rudders	Virginia Institute of Marine Science	Member, Data, Wind
Liese Siemann	Coonamessett Farm Foundation	Member, Data, Wind
Ryan Silva	NOAA Greater Atlantic Regional Fisheries Office	Member, Data, RSA
Kevin Stokesbury	School for Marine Science and Technology	Member, Data, Wind
Paul Rago	MAFMC Science and Statistical Committee	Member, Wind
Cate O'Keefe	Fishery Applications Consulting Team	Facilitator
Jessica Joyce	Tidal Bay Consulting	Facilitator
Sam Asci	NEMFC Scallop Plan Development Team	Staff Support

4.0 TERMS OF REFERENCE

The SSWG's initial task in spring of 2021 was to develop a clear set of Terms of Reference for approval by the Council's Executive Director in consultation with the Director of the NEFSC. The SSWG Co-Chairs, Council staff, and facilitator drafted TORs that were iteratively reviewed by the full working group in March and April 2021. The Council's Executive Director approved the Scallop Survey Working Group Terms of Reference (TORs) through a memorandum dated April 30, 2021. The Scallop Survey Working Group Terms of Reference included the following:

1. **Describe the current survey system, including survey (dredge and optical) methods, design, and data products, as well as the process for determining annual survey coverage.**

   Description:
   - *This TOR will include descriptions of the current survey system, including survey tools and methods, the process used to determine annual spatial coverage by survey type, and the data collected in each survey. This information will serve as a description of the current approach for the scallop survey system and will be referenced in relation to SSWG recommendations for TORs 2, 3, and 4.*

2. **Describe and assess a coordinated strategy for sea scallop resource assessment surveys and investigate opportunities and methods for implementation. Address each of the following areas:**
   a. **Spatial coverage, including the Northern Gulf of Maine;**
   b. **Sampling frequency and intensity within and between surveys;**
   c. **Data standardization, delivery, access, and storage;**
   d. **Automated scallop detection;**
   e. **RSA survey priority setting process and long-term planning.**

   Description:
   - *This TOR will include, but not be limited to, the following items for each identified topic:*
     - *Assess the strengths and weaknesses of the current scallop survey system, including uncertainties and gaps in data outputs to meet objectives and needs of science and management.*
     - *Describe new or alternative approaches for optimizing the survey system.*
     - *Investigate opportunities and methods to implement strategies across all survey groups including the new and alternative approaches.*

3. **Identify survey methods, tools, and designs to monitor and assess the scallop resource in a changing ocean environment that includes offshore wind installations and changes in resource and fishery distribution.**

   Description:
   - *This TOR will include, but not be limited to, the following items:*
     - *Description of the likely impacts of offshore wind installations on the current survey domain and methods on a present and multi-year timescale.*

- *Identification of existing and new scallop survey strategies for population assessments under changing conditions in stock and habitat parameters, and changes in stock distribution as a result of natural or anthropogenic factors.*

4. **Identify and catalogue the survey data products needed to support stock assessment approaches in the future and outline a process for modifying the scallop survey system to collect identified data products.**

   <u>*Description:*</u>

- *This TOR will include, but not be limited to, the following items:*
  - *Description of survey data outputs needed to support potential changes to stock assessment models, including age samples and ageing methods, growth information and density-dependent effects, scallop meat weight sampling, and estimates of fecundity.*
  - *Consider survey data products and survey spatial scale needed to support a spatially explicit methodology for forecasting the abundance and distribution of sea scallops by incorporating spatial data from surveys, landings, and fleet effort.*

5.0 TOR #1 – DESCRIBE CURRENT SURVEY SYSTEM

Describe the current survey system, including survey (dredge and optical) methods, design, and data products, as well as the process for determining annual survey coverage.

Description:

- *This TOR will include descriptions of the current survey system, including survey tools and methods, the process used to determine annual spatial coverage by survey type, and the data collected in each survey. This information will serve as a description of the current approach for the scallop survey system and will be referenced in relation to SSWG recommendations for TORs 2, 3, and 4.*

The SSWG described the scallop survey system as the collective surveys from the NEFSC and RSA-funded survey partners and focused on survey methods, designs, and data products from the most recent period following the 2015 "Review of Sea Scallop Survey Methodologies and Their Integration for Stock Assessment and Fishery Management" to characterize the current survey system. The working group compiled a Scallop Survey Metadata Catalogue (Appendix 1) to accompany descriptions of each survey application (Table 2) and described the current process for determining annual survey spatial coverage and sampling intensity. The SSWG also considered ongoing efforts by the NEFSC to redesign the sampling methods for the dredge survey, which may redefine scallop survey sampling strata and sampling approaches in the future. Collectively, the descriptions of current survey methods, the Scallop Survey Metadata Catalogue, overview of the process to determine annual survey spatial coverage, and recommendations for future application of alternative survey sampling designs, address TOR #1.

Table 2. Scallop survey system components (coverage areas include the Mid-Atlantic Bight (MAB), Georges Bank (GB), the Great South Channel (GSC), and the Gulf of Maine (GOM).

Survey	*Tool*	*Coverage*	*Timing*	*Vessel*
NEFSC Dredge	8' dredge with liner	MAB, GB, GSC	May-June	*R/V Sharp*
VIMS Dredge	8' dredge with liner; 13-15' dredge unlined	MAB, GB, GSC	May-June	Commercial
ME Dredge	7' dredge unlined	GOM	May-July	Commercial
SMAST	Drop Camera	MAB, GB, GSC, GOM	May-June	Commercial
NEFSC HabCam	HabCam V4	MAB, GB, GSC	May-June	*R/V Sharp*
WHOI/COV HabCam	HabCam V2, V5, V6	MAB, GB	May-July	Commercial
CFF HabCam	HabCam V3	MAB, GB, GSC	June-August	*F/V Kathy Marie*

5.1 SURVEY TOOLS, METHODS, DESIGNS AND DATA PRODUCTS

5.1.1 Northeast Fisheries Science Center Scallop Survey

5.1.1.1 Overview

The standardized NEFSC Sea Scallop Survey began in 1979 and has covered an area from Cape Hatteras to Georges Bank. The survey aims to determine the distribution and abundance of scallops and associated fauna utilizing two sampling devices: an 8-foot wide New Bedford style, lined, standardized sea scallop dredge and the stereo-optic towed camera array, HabCam V4 (Figure 3). Fifteen minute dredge hauls are made at stations that are randomly selected using the NEFSC shellfish strata to provide unbiased abundance measurements. The HabCam survey is conducted using transects across bathymetry lines in the same area as the dredge tows. There are three parts to the survey covering the Mid-Atlantic Bight, Southern New England, and Georges Bank (for additional information see NEFSC 2014; Hart, 2015; Chang et al., 2017; https://www.fisheries.noaa.gov/inport/item/22564).

5.1.1.2 Survey Platform and Timing

Since 2008, the NEFSC scallop survey has been conducted aboard the UNOLS vessel *R/V Hugh R. Sharp*. The *R/V Sharp* is a 146 foot vessel with specifications that allow for sampling in all scallop strata, accommodates both the dredge and HabCam sampling tools, and has adequate berthing to support the survey crew. The survey is conducted annually, normally in May and June, with a target of 30-35 seadays per year.

Figure 3. NEFSC Sea Scallop Survey dredge (left) and HabCam V4 (right).

5.1.1.3 Statistical Design and Spatial Coverage

To maximize efficiency, the NEFSC scallop survey focuses sampling in areas that are not extensively covered by other survey programs. Dredge stations and HabCam tracks are planned prior to the survey and adjustments can be made at sea depending on survey progress as influenced by a range of factors (e.g., weather conditions, vessel/gear performance, etc.).

5.1.1.3.1 NEFSC Dredge

The NEFSC dredge survey employs a random stratified design using the NEFSC shellfish strata, which were defined by bathymetry and area. Over time, some strata have been dropped from the survey due to low abundance of scallops in order to focus sampling on more productive areas. Spatial management measures for scallops, groundfish, habitat, and other purposes overlap several strata so that parts of the strata are inside and outside of these management boundaries. The strata have been split to account for scallop density variation inside versus outside. Allocation of stations to strata vary by year based on a compromise between the optimal allocation method using variances from the previous year's survey data, and the need to have survey coverage in all areas. Stratified means and variances are calculated using standard methods (Hart, 2015).

5.1.1.3.2 NEFSC HabCam

The HabCam V4 system is towed by the survey vessel to a depth within 1-2 meters off the seafloor. The survey track design is based on the concept that higher mean densities are located along the center or one side of the survey landscape because scallop densities typically decrease in habitats deeper and shallower than the optimal habitat for a region. The shape and direction of HabCam tracks include long transects in the direction of the gradient of density. The length of the long transects are alternated with one long transect extending to the boundary of the survey area, followed by a short transect extending to the edge of the high density area. This design covers the higher density areas more intensely than the more marginal areas to improve survey efficiency. The high density areas are computed every year based on previous years' density estimates. HabCam tracks are pre-determined based on the density concept combined with researchers' knowledge of where the current stock biomass and incoming cohorts are located. The survey tracks are bounded by subregions (e.g., SAMS areas, shellfish strata, resource regions) and survey transects are centered on high density areas and oriented orthogonal to the depth contour (NEFSC, 2014; Chang et al., 2017).

5.1.1.4 Sampling

5.1.1.4.1 NEFSC Dredge

The NEFSC dredge survey measures all scallops from most tows, unless catches are large, and a subsample of scallops are measured and expanded to the entire catch. Recruits, defined as two-year old scallops in the size range of 35-75mm, are mostly captured in the dredge with its 38mm liner. Pre-recruits, under 35mm, can pass through the dredge liner and are not typically observed, unless caught in very large numbers, qualitatively indicating a strong year class. Shells from a subsample of the catch are saved for shell ring growth analysis in the laboratory. Meat, gonad, and whole weights are recorded for the scallops saved for aging. Counts and weights of scallop predators, including crabs and sea stars, are collected on specified tows, and biological samples of finfish and other research-specific samples (e.g., DNA samples, "trash" samples, etc.) are collected upon request (Hart, 2015).

5.1.1.4.2 NEFSC HabCam

The HabCam V4 is towed along the survey track at speeds of ~6-7 knots and rapid photo streams (6 images per second) are sent to the ship over a fiber-optic cable, where they are recorded on large scale servers. Digital still images are collected at a frequency of ~35% overlap of adjacent images that can be stitched together to form a mosaic of the seafloor. Each image has associated metadata including longitude, latitude, time, depth, altitude, pitch and roll, etc. The altitude of each image is critical for determining the field of view of the image and measuring objects. Blocks of images are selected for annotation based on the spatial extent and density. Abundance, size, and behavior data are extracted from each image, and shell height is calculated in pixels then converted to mm (NEFSC, 2014).

5.1.1.5 Data Products

5.1.1.5.1 NEFSC Dredge

Standardized indices of abundance and biomass are computed as stratified means, then expanded into absolute abundances by applying an estimate of survey dredge efficiency (Hart, 2015). NEFSC dredge data results are reported for each survey/SAMS area as total number in millions (abundance), total weight in metric tons with standard error (biomass), mean meat weight, average size, number per square meter (density), and number of survey tows. Data products for management include (1) survey charts depicting distribution of scallop abundance by size class (pre-recruits <35mm, recruits 35-75mm, adults >75mm) and distribution of total biomass (2) length frequency plots by SAMS areas, and (3) estimates of exploitable biomass by area (see Hart and Chang, 2021 for example).

5.1.1.5.2 NEFSC HabCam

Scallop abundance and biomass data from HabCam are highly spatially autocorrelated and zero-inflated, reflecting the patchiness of scallop distributions and the continuous nature of observations. The NEFSC applies a form of regression kriging to account for large-scale trends and covariates in the data. The GAM+OK model includes Generalized Additive Models on spatially aggregated data with kriged model residuals. Model-based estimation methods are used to extrapolate observations along the observed track to generate abundance and biomass estimates for larger areas (NEFSC, 2014; Chang et al, 2017). NEFSC HabCam data results are reported for each survey/SAMS area as total number in millions (abundance), total weight in metric tons with standard error (biomass), mean meat weight, average size, number per square meter (density), and number of annotated images. Data products for management include (1) survey charts depicting distribution of scallop abundance by size class (pre-recruits <35mm, recruits 35-75mm, adults >75mm) and distribution of total biomass (2) length frequency plots by SAMS areas, and (3) estimates of exploitable biomass by area (see Chang et al., 2021 for example).

5.1.2 Virginia Institute of Marine Science Scallop RSA Survey

5.1.2.1 Overview

The VIMS Sea Scallop Research Program has been conducting cooperative industry-based dredge surveys of the scallop resource since 2000. The RSA-funded survey system tows two dredge configurations: an 8-foot wide NMFS survey dredge to provide a representative sample of the age structure of the population, and a commercial scallop dredge. Fifteen-minute dredge tows are made at stations that are randomly selected within the NEFSC shellfish strata, and collected scallops and finfish are counted and measured to estimate abundance and biomass of the scallop stock to support management of allowable harvest and prevent overfishing of the scallop resource (for additional information see Rudders and Roman, 2018; Rudders et al., 2019; https://www.vims.edu/research/units/centerspartners/map/comfish/scallop/index.php).

5.1.2.2 Survey Platform and Timing

The VIMS survey is conducted aboard commercial scallop fishing vessels with the capacity to sample in all scallop strata and accommodate the research and fishing crew. Vessel characteristics include a minimum of 850 horsepower, and operations require at least six vessel crew members to assist the scientific crew. The survey has been conducted annually since 2000, normally in May and June. Specific timing for survey areas is dependent upon awarded RSA projects, with a target to conduct surveys at a similar time year over year (e.g., the Mid-Atlantic Bight survey is normally conducted in May).

5.1.2.3 Statistical Design and Spatial Coverage

Sampling stations for the VIMS surveys are selected using a stratified random sampling design. Stations are allocated to strata using a hybrid approach consisting of both proportional and optimal allocation techniques using available data from previous surveys of the same areas. To assure that all strata have some representation of stations, a portion of the total pool of samples are allocated proportionally to stratum areas. The remaining samples are allocated based on scallop abundance in weight and number observed in prior year's surveys. Strata consist of the NEFSC core scallop survey strata, as well as additional strata that have important scallop habitat but are not well covered (Rudders and Roman, 2018).

The VIMS survey has covered the Mid-Atlantic Bight resource region from the Virginia/North Carolina border to Block Island, Rhode Island every year since 2015. The Mid-Atlantic survey includes both open and rotational management areas of the scallop resource. Additionally, the VIMS survey has been conducted in multiple areas within the Georges Bank region, including the rotational management areas in the Nantucket Lightship area, Closed Areas I and II, and open areas of the Great South Channel and northern and southern portions of Georges Bank. Survey coverage is determined either annually or biennially based on identified areas of importance for the resource and ultimately by awarded RSA projects.

5.1.2.4 Sampling

At each station, the vessel simultaneously tows both the survey and commercial dredges for 15 minutes at a speed of ~4 knots. The survey dredge consists of 2-inch rings, a 4-inch diamond mesh twine top, and 1.5-inch diamond mesh liner. The commercial dredge consists of a 13, 14, or 15-foot commercial dredge (Turtle Deflector Dredge of New Bedford style) compliant with current gear regulations and equipped with 4-inch rings, a 10-inch diamond mesh twine top, and no liner (Figure 4). For each paired tow, the scallop catch from both dredges are separated, placed in baskets and measured or sub-sampled. Size frequency of the entire catch is estimated by expanding the catch at each shell height by the fraction of total number of baskets sampled. Meat and gonad weights are collected from a subsample of scallops at each station, and reproductive state, sex, meat quality, and presence of disease is recorded. Disease information recorded includes nematode infections, shell blister disease, and gray meats. Shells from a subsample of stations are saved and returned to the laboratory for aging. Other samples include finfish, sea stars, crabs, other invertebrates, and debris (Rudders and Roman, 2018).

Figure 4. VIMS survey-configured commercial dredge (left), catch sampling (center), and biological sampling of meats and gonads (right).

5.1.2.5 Data Products

Catch data from each dredge is used to estimate swept area biomass within the survey domain by SAMS area. Stratified mean weight per tow is calculated from the catch data as an expanded size frequency distribution with an area-specific shell height to meat weight relationship. Similar to the NEFSC survey, estimates of survey dredge efficiency are applied to the VIMS survey data. The total area of the sampled SAMS area is calculated and applied to scale the biomass estimates to the areas of interest. VIMS dredge data results are reported for each survey/SAMS area as total number in millions (abundance), total weight in metric tons with standard error (biomass), mean meat weight, average size, number per square meter (density), and number of survey tows. Data products for management include (1) survey charts depicting distribution of scallop abundance by size class (pre-recruits <35mm, recruits 35-75mm, adults >75mm) and distribution of total biomass; (2) length frequency plots by SAMS areas; and (3) estimates of exploitable biomass by area (see Roman and Rudders, 2021 for example).

5.1.3 Gulf of Maine Scallop RSA Survey

5.1.3.1 Overview

The Maine Department of Marine Resources and the University of Maine have collaboratively conducted cooperative industry-based dredge surveys of portions of the scallop resource in federal waters of the Gulf of Maine, including the Northern Gulf of Maine scallop management area, for several years. The RSA-funded survey system tows a single 7-foot wide unlined dredge in areas of known scallop aggregations to assess abundance, density, biomass, and distribution of scallops in near-shore regions and on banks and ledges throughout the Gulf of Maine (for additional information see Hodgdon et al., 2021; Lisi et al., 2021; https://www.maine.gov/dmr/science-research/species/scallops/index.html; https://umaine.edu/aquaculture/scallop-research-collaborative/).

5.1.3.2 Survey Platform and Timing

The Maine survey is conducted aboard commercial scallop fishing vessels with the capacity to sample in all scallop strata and accommodate the research and fishing crew. The survey is normally conducted between May and July. Specific timing for survey areas is dependent upon awarded RSA projects, coordination with other ongoing resource surveys, and vessel availability.

5.1.3.3 Statistical Design and Spatial Coverage

Sampling stations for the Maine surveys are selected using a stratified random sampling design. Strata are defined as regions with historic scallop aggregations, including Machias Seal Island, Platts Bank, Ipswich Bay, Jeffreys Ledge, and Stellwagen Bank (Figure 5). An overlay of 1km^2 cells within each region is subsampled as "substrata" based on scallop density delineations using fishermen input, information from VTR and VMS, and previous survey data (Hodgdon et al., 2021). Survey coverage is determined based on awarded RSA projects.

5.1.3.4 Sampling

At each station, the vessel tows a 7-foot unlined dredge consisting of 2-inch rings, a 4-inch twine top, and rock chains. The dredge is towed for 5 minutes at ~3.5 knots. At each station, scallop counts, lengths, and weights are recorded. Up to 100 scallops are measured for each tow, and 10% of the catch is subsampled if more than 1,000 scallops are caught. The survey also records information about flatfish, sea stars, and monkfish (Lisi et al., 2021).

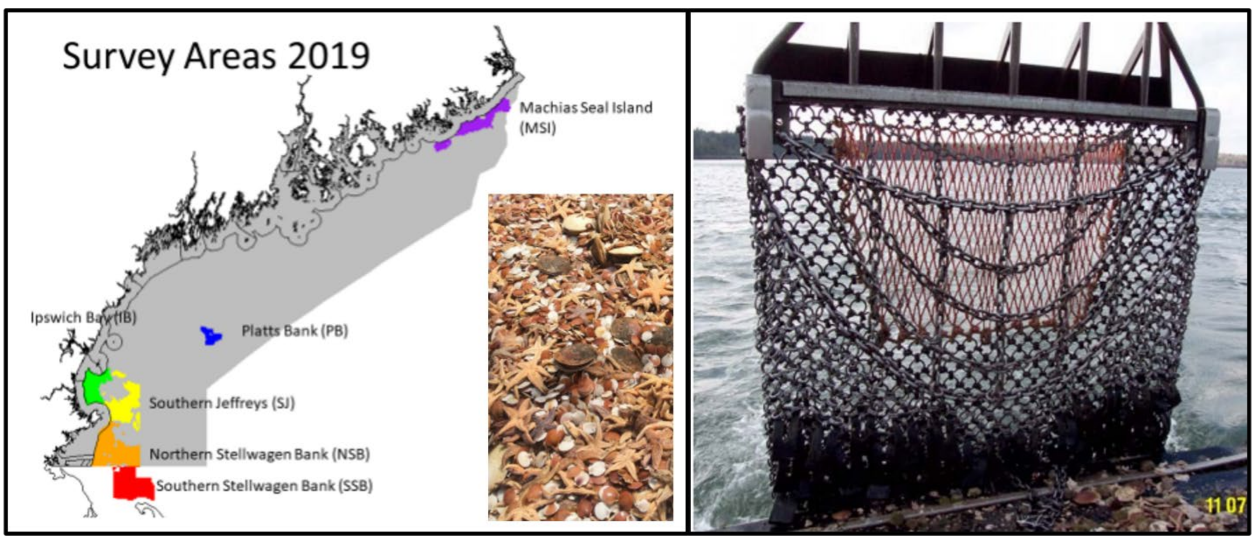

Figure 5. Maine DMR/UMaine Gulf of Maine survey areas overlaid on the Northern Gulf of Maine management area (gray shading) with sample catch of scallops, sea stars, and sand dollars (left), and the Maine sampling dredge (right).

5.1.3.5 Data Products

Stratified mean weight is calculated from the catch data as an expanded size frequency distribution with a shell height to meat weight relationship. Similar to the NEFSC survey, estimates of survey dredge efficiency are applied. The total area of the region is calculated and applied to scale the biomass estimates to the areas of interest. Maine dredge data results are reported for each surveyed area as total number in millions (abundance), total weight in metric tons with standard error (biomass), mean meat weight, average size, grams per square meter (density), and number of survey tows. Data products for management include (1) survey charts depicting distribution of scallop abundance by size class (pre-recruits <35mm, recruits 35-75mm, adults >75mm) and distribution of total abundance and biomass; (2) length frequency plots by area; and (3) estimates of exploitable biomass by area (see Hodgdon et al., 2021 for example).

5.1.4 School for Marine Science and Technology Scallop RSA Survey

5.1.4.1 Overview

The SMAST Marine Fisheries Field Research Group has been conducting cooperative industry-based optical surveys of the scallop resource since 1999. The RSA-funded survey technique employs a drop camera system consisting of lights, digital still cameras, and live-feed video cameras deployed from commercial vessels. Four replicate drops of the camera system are conducted at grided station locations to collect counts and measurements of scallops and other taxa to provide estimates of abundance, biomass, and density of scallops and other macroinvertebrates, and sediment and habitat distributions throughout the scallop resource range (for additional information see Stokesbury, 2002; Stokesbury et al., 2004; Bethoney and Stokesbury, 2018; Stokesbury and Bethoney, 2020; http://webserver.smast.umassd.edu/lab_stokesbury/).

5.1.4.2 Survey Platform and Timing

The SMAST survey is conducted aboard commercial scallop fishing vessels with the capacity to sample in all scallop resource areas, accommodate the sampling pyramid, hydraulic winch, and wheelhouse mobile studio, as well as the research crew. The mobile studio, including monitors, computers for image capturing, data entry, and survey navigation, is assembled in the vessel's wheelhouse and the sampling pyramid is lowered from the side of the vessel. The survey has been conducted annually since 1999, normally in May and June with some survey coverage starting in late April and extending to early July. Specific timing for survey areas is dependent upon awarded RSA projects.

5.1.4.3 Statistical Design and Spatial Coverage

The survey applies a centric systematic sampling design with stations on a fixed grid of varying resolution (e.g., broad-scale surveys are conducted on a 5.6 km^2 grid; fine-scale surveys are conducted on a 2.8 km^2 grid or finer). Stations are pre-determined, and the orientation of the sampling grid can be adjusted to overlap or offset stations annually. At each station, four replicate quadrats are sampled by lowering the camera to the seafloor on the first drop, recording images and observations of scallops, lifting the camera until the seafloor is not visible, then lowering the camera again and repeating the process to sample four quadrats (Figure 6; Stokesbury, 2002; Stokesbury et al., 2004; Bethoney and Stokesbury, 2018).

The SMAST survey has covered the entire scallop resource range, as well as specific regions or management areas depending on awarded RSA projects. The SMAST broad-scale survey has been applied in the Mid-Atlantic and Georges Bank resource regions, including open and rotational management areas. Fine-scale, area-specific surveys have been conducted in open and rotational management areas in the Mid-Atlantic, Georges Bank, the Great South Channel and the Gulf of Maine. Survey coverage is determined either annually or biennially based on awarded RSA projects and fine-scale surveys can be nested in broad-scale surveys (Stokesbury and Bethoney, 2020).

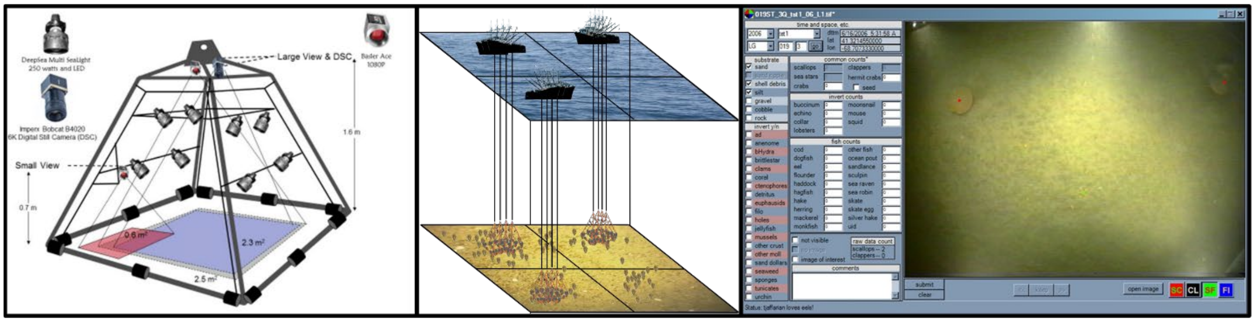

Figure 6. SMAST sampling pyramid with lights and cameras (left), quadrat sampling design (center), and custom image annotation application (right).

5.1.4.4 Sampling

At each station, the sampling pyramid, supporting two downward facing cameras and lights, provide a 2.3m^2 and 2.5m^2 image of the seafloor. Quadrat images from all cameras and video footage from the live-feed video camera are transmitted via cable to the wheelhouse studio and saved on portable storage devices. Onboard the vessel, station location, scallop counts, and water depth are recorded. Post-survey data processing uses the high resolution digital still images as the primary data source for scallop counts, measurements, and identification of other macrobenthos and substrate type. Video footage is used to aid in the identification of scallops and fill any data gaps. Images are annotated manually through a customized application with 50 taxa of macrobethos and a range of substrate types. After initial annotation, a quality control check is performed to review data entries for accuracy. Scallops are measured by pixelated lines drawn from the umbo to the top of the scallop shell, and pixel measurements are converted to mm using a calibrated ratio (Bethoney and Stokesbury, 2018).

5.1.4.5 Data Products

Spatially-specific estimates of scallop density and size are calculated for each area based on the average shell height and mean density. Scallop density is multiplied by the total area surveyed to estimate the number of scallops in the area. Scallop numbers are then multiplied by the frequency of scallops and estimated meat weight in 5mm size bins, and the sum of all scallops produces an estimate of total scallop biomass. SMAST drop camera data are reported for each survey/SAMS area as total number in millions (abundance), total weight in metric tons with standard error (biomass), mean meat weight, average size, number per square meter (density), and number of survey stations. Data products for management include (1) survey charts depicting distribution of scallop density by size class (pre-recruits <35mm, recruits 35-75mm, adults >75mm) and distribution of total density; (2) length frequency plots by SAMS areas; and (3) estimates of exploitable biomass by area (see Cassidy and Stokesbury, 2021 for example).

5.1.5 Woods Hole Oceanographic Institution HabCam System

5.1.5.1 Overview

The Habitat Mapping Camera System (HabCam) is a towed habitat mapping vehicle that provides a glimpse of the seafloor through optical imaging. The vehicle flies over the ocean bottom taking six images per second to create a continuous image ribbon. On the surface, researchers get real-time images and data in a non-invasive way. The images provide information about ecosystem changes over different temporal and spatial scales, calculate biodiversity, classify habitats, map hard to survey species, and promote interest in ocean and ecosystem science. Woods Hole Oceanographic Institution (WHOI) originally designed HabCam as a tool to survey sea scallops with funding from the Scallop RSA program. Early applications of HabCam included shadow-tow surveys to assist with calibrating the NEFSC dredge survey during the transition from the *R/V Albatross* to the *R/V Sharp*. Since 2006, HabCam has iteratively evolved, with changes to the overall structure of the vehicle, enhanced light and camera technology, and additional oceanographic instrumentation (for additional information see Taylor et al., 2008; Gallager et al., 2017; https://habcam.whoi.edu/; https://www.coastaloceanvision.com/hab-cam).

5.1.5.2 Survey Platform and Timing

A range of HabCam surveys have been conducted by WHOI, NEFSC, Arnie's Fisheries, the HabCam Group, Coonamessett Farm Foundation, and Coastal Ocean Vision (COV). HabCam versions V2, V3, and V4 are deployed from the stern of the vessel, supported by a steel A-frame. These versions have been used aboard the *R/V Sharp*, *F/V Kathy Marie*, and other commercial scallop fishing vessels. HabCam V5, also known as "v-fin", is a benthic stereo-imaging vehicle built into a 4-foot wide modified dihedral fin frame that was designed to be lighter, more compact, and more maneuverable than prior HabCam iterations, which allows it to be used on a wide range of vessels (Figure 7). V-fin is towed on a smaller fiber optic cable that is deployed over the side of a vessel. HabCam V6, also known as the Habitat Aware Reconnaissance and Imaging Module (HARIM), is a 3-foot long, 12.75-inch diameter system that can be integrated with autonomous underwater vehicles to perform adaptive surveys based on real-time processing of side-scan acoustic and stereo optical imaging. HabCam surveys have been conducted at various times of the year dependent upon awarded RSA projects.

5.1.5.3 Statistical Design and Spatial Coverage

The survey design consists of systematic linear zigzag transects that are orthogonal to the direction of water transport along the shelf to provide descriptive information about scallop patchiness. The HabCam surveys conducted by WHOI, Arnie's Fisheries, the HabCam Group, and COV have covered portions of the scallop resource at varying spatial scales depending on awarded RSA projects. The surveys have been applied to cover broad-scale resource regions in the Mid-Atlantic Bight, including open and rotational management areas. Fine-scale, area-specific surveys have been conducted in open and rotational management areas in the Mid-Atlantic, on Georges Bank, and in the Great South Channel. In addition to assessing the scallop population, the WHOI/COV HabCam system has examined dredge disturbance with an objective to assess how dredging impacts the community composition, recolonization, and resiliency of benthic habitats across different substrates.

5.1.5.4 Sampling

The system is equipped with stereo cameras, side-scan acoustics, sensors, and a spectrometer to assist in color correction of the images. Automated classification of substrate and other targets including scallops, sea stars, and demersal finfish are conducted by applying Deep Learning algorithms. COV has been able to achieve 95% accuracy for scallop identification when animals were clearly defined visually, and down to 65% accuracy when scallop shells were partially obscured by sediment and other organisms. The algorithm is applied to make gross identifications on the entire image set and to flag images for manual annotation.

Figure 7. HabCam V5 sampling system (left), and example image of scallops from HabCam system.

5.1.5.5 Data Products

Data is made available in various formats, including raw point data and binned abundances that are built into Google Earth and GIS shape files. Interpolated scallop abundance using ordinary kriging and depth as a co-variate is the standard output from the WHOI/COV survey. Raw data for scallop size and spatial distributions are provided to the NEFSC for incorporation in the GAM+OK model that includes all HabCam data. Habitat shapefiles are generated from track image information on substrate, epifauna, and other solitary, encrusting species. WHOI/COV HabCam data are reported for each survey/SAMS area as total number in millions (abundance), total weight in metric tons with standard error (biomass), mean meat weight, average size, number per square meter (density), and number of annotated images. Data products for management include (1) survey charts depicting distribution of scallop density by size class (pre-recruits <35mm, recruits 35-75mm, adults >75mm); (2) length frequency plots by SAMS areas; and (3) estimates of exploitable biomass by area (see Gallager et al., 2017 for example).

5.1.6 Coonamessett Farm Foundation Scallop RSA Survey

5.1.6.1 Overview

Coonamessett Farm Foundation (CFF) has been conducting cooperative industry-based optical surveys utilizing the HabCam V3 since 2017. The CFF HabCam survey is a continuation of the industry-based HabCam survey initiated by WHOI and the HabCam Group in 2006. The HabCam V3 survey transitioned in 2017, and CFF has had sole control over the survey since

2018. The RSA-funded HabCam V3 survey uses a non-invasive imaging system with dual cameras and oceanographic sensors to provide a "snapshot" of the environment. The system is towed 24 hours per day by a commercial scallop fishing vessel outfitted with a steel A-frame, collecting over a half million images each full day. The primary objective of the survey is to document the distribution, survival, and growth of sea scallops to inform science and management decisions (for additional information see O'Hara et al., 2020; https://www.coonamessettfarmfoundation.org/habcam-surveys).

5.1.6.2 Survey Platform and Timing

The CFF HabCam survey is conducted aboard the *F/V Kathy Marie*, a commercial scallop fishing vessel, that is outfitted with a steel A-frame to support deployment of the towed HabCam V3 system off the stern (Figure 8). The onboard HabCam system includes a mobile studio with monitors and survey navigation equipment to allow onboard scientists the ability to "fly" the vehicle over the seafloor. The survey has been conducted annually since 2017, normally in June and July. Specific timing for survey areas is dependent upon awarded RSA projects.

5.1.6.3 Statistical Design and Spatial Coverage

The survey design consists of systematic linear zigzag transects that are predetermined in consultation with the NEFSC to focus on areas with known scallop concentrations. The CFF HabCam V3 survey has covered portions of the scallop resource at varying spatial scales depending on awarded RSA projects. The survey has been applied to cover the broad-scale resource region in the Mid-Atlantic Bight, including open and rotational management areas. Fine-scale, area-specific surveys have been conducted in open and rotational management areas in the Mid-Atlantic, on Georges Bank, and in the Great South Channel. Survey coverage is determined either annually or biennially based on awarded RSA projects.

5.1.6.4 Sampling

The HabCam V3 system is flown at ~2m off the seafloor at a speed of 4-5 knots, and a survey track of ~100 nautical miles is imaged each 24 hours. The field of view of the system's cameras is ~1m^2 with six images collected per second. Images are transmitted to the vessel via fiber-optic cable and recorded on servers. A subset of the images is annotated manually using customized software, and the locations and labels for each organism are recorded into data files. Image annotation rate varies by area depending on scallop density, technical resources, and input from the NEFSC. Onboard annotations include scallop counts and measurements, as well as counts of finfish, sea stars and other organisms. Scallop shell heights are measured when the hinge is visible, and widths are measured in the absence of a visible hinge. Annotated images are checked for quality control at a target rate of 50-100%. Additional instrumentation on the towed vehicle provides altitude, depth, temperature, salinity, pitch, and roll (O'Hara et al., 2020).

5.1.6.5 Data Products

The CFF HabCam biomass estimation process includes converting scallop length in pixels to shell heights in mm based on the image field of view and camera altitude. Each shell height is converted to a meat weight using location-specific shell height to meat weight relationships. CFF provides raw annotation data to the NEFSC to generate resource-wide, model-based biomass estimates, with HabCam V3 data combined with HabCam V4 data from NEFSC surveys. Biomass estimates are generated through application of the GAM+OK model. Alternatively, biomass estimates have been derived using a stratified mean estimation by depth, with images aggregated over ~2,000m segments to minimize spatial autocorrelation along tracks. CFF HabCam data are reported for each survey/SAMS area as total number in millions (abundance), total weight in metric tons with standard error (biomass), mean meat weight, average size, number per square meter (density), and number of annotated images. Data products for management include (1) survey charts depicting distribution of scallop density by size class (pre-recruits <35mm, recruits 35-75mm, adults >75mm); (2) length frequency plots by SAMS areas; and (3) estimates of exploitable biomass (see O'Hara et al., 2021 for example).

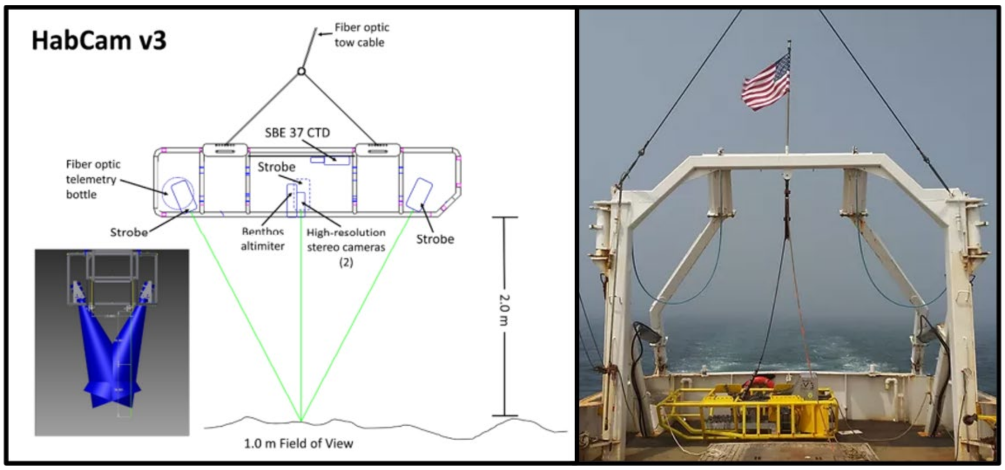

Figure 8. CFF HabCam V3 sampling system (left), and *F/V Kathy Marie* with HabCam V3 (right).

5.2 SURVEY SPATIAL COVERAGE DETERMINATION

5.2.1 Research Set-Aside Program Survey Coverage Process

The Scallop Research Set-Aside Program is a process coordinated by the Council and NOAA. No federal funds are provided for the RSA program, instead funding for research is provided by the sale of set-aside allocations of scallops from open and rotational management areas, which are awarded though a competitive grant process. The Scallop RSA Program was formally included in the Atlantic Sea Scallop Fishery Management Plan in 1999. Currently, 1.275 million pounds of total annual allocated landings are set aside to fund research projects, including surveys, that support scallop management (for more information see the Program Review of New England Research Set-Aside Program Final Report and the Council's Operations Handbook).

RSA survey coverage is informed by several steps through the overall RSA process. The Scallop Plan Development Team (PDT) and Advisory Panel provide input about needed survey priorities to the Scallop Committee, and the Committee's recommendations are considered for approval by the full Council. The Council's approved set of priorities forms the basis for the Notice of Federal Funding Opportunity. Interested applicants may submit proposals to address the survey priorities on an annual or biennial cycle. Each RSA proposal is subject to a thorough review, including a technical evaluation that considers the following:

- Importance and/or relevance and applicability of the proposed project;
- Technical/scientific merit;
- Overall qualifications of the project;
- Project costs; and
- Outreach and education.

NMFS convenes a survey technical review panel comprised of federal and non-federal subject matter experts that is focused on survey design and analysis methods. Additionally, NMFS, in close consultation with the Council, convenes a management review panel that critiques the management relevance of all proposals. Management panelists will frequently make recommendations to reduce survey redundancy and fill survey coverage gaps. The objective of these panels is to review and critique proposals to enhance NOAA's understanding related to the program priorities. Project selection is based on technical review scores and recommendations from the review panels. NMFS may leverage additional selection factors that are standard to NOAA competitive grant programs (for more information see Notice of Federal Funding 2022/2023 Sea Scallop Research Set Aside).

RSA survey coordination occurs during the pre-award survey negotiation process. Proposed survey spatial coverage and sampling intensity may be modified in response to reviewer scores and comments, survey technology, operational logistics, and geographical proximity to proposed survey locations. The management and technical review panels provide input about needed spatial coverage and sampling scale based on up-to-date information from annual surveys, fishery management scenarios, and fishery-dependent data. The panels consider the survey proposals collectively to ensure spatial coverage and sampling intensity objectives are met (Figure 10). The panels do not make consensus recommendations about awards, instead the review comments assist NOAA in understanding annual survey needs to support science and management. NOAA conducts negotiations with survey applicants to modify proposals to ensure the overall scallop survey system meets objectives. This process is conducted annually, and NOAA includes negotiated modifications or refinements in RSA award conditions or amendments for individual applicants.

5.2.2 NEFSC Survey Coverage Process

The NEFSC scallop survey conducted by the *R/V Sharp* has varied slightly in length from year to year. The variation is a result of increased operating costs impacting the amount of funding available to contract vessel sea days. The cost of a sea day aboard the R/V Sharp has increased since 2013 (Figure 9). The scallop survey currently targets a minimum of 30-35 sea days per year, deploying both the dredge and HabCam components while at sea. Target sea day coverage is typically determined in early winter for the subsequent spring/summer survey season. This timing overlaps with the RSA review and project selection process and allows coordination between the survey coverage components. In an effort to make the most efficient use of the sea days, NEFSC sampling is focused in areas that are not extensively covered by the RSA survey program. This has been described as a "filling the gap" approach to ensure that all scallop resource areas are covered (Figure 10).

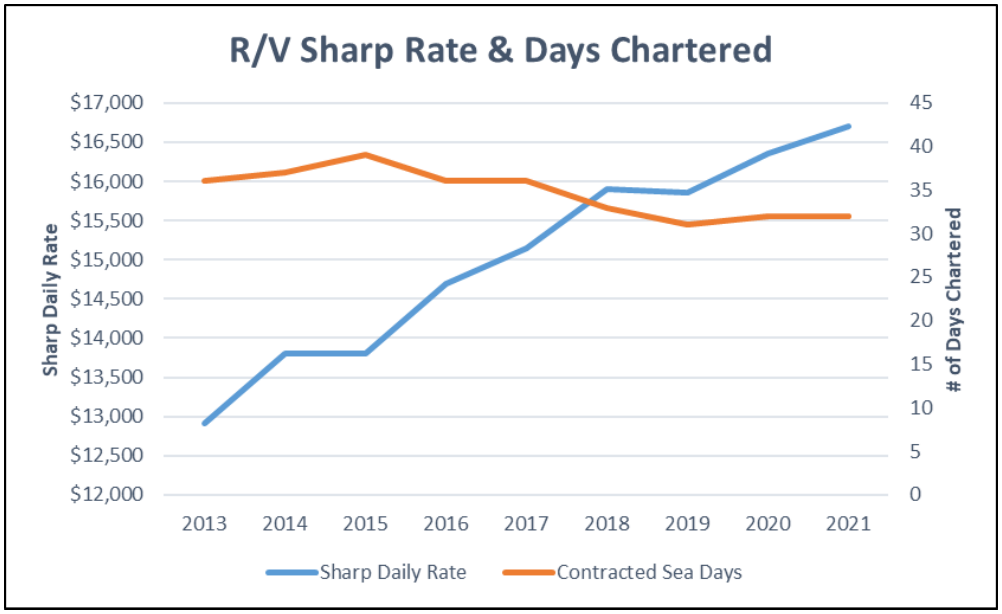

Figure 9. ***R/V Sharp*** **daily rate for vessel contract (blue line) and NEFSC contracted sea days (orange line) for 2013 to 2021.**

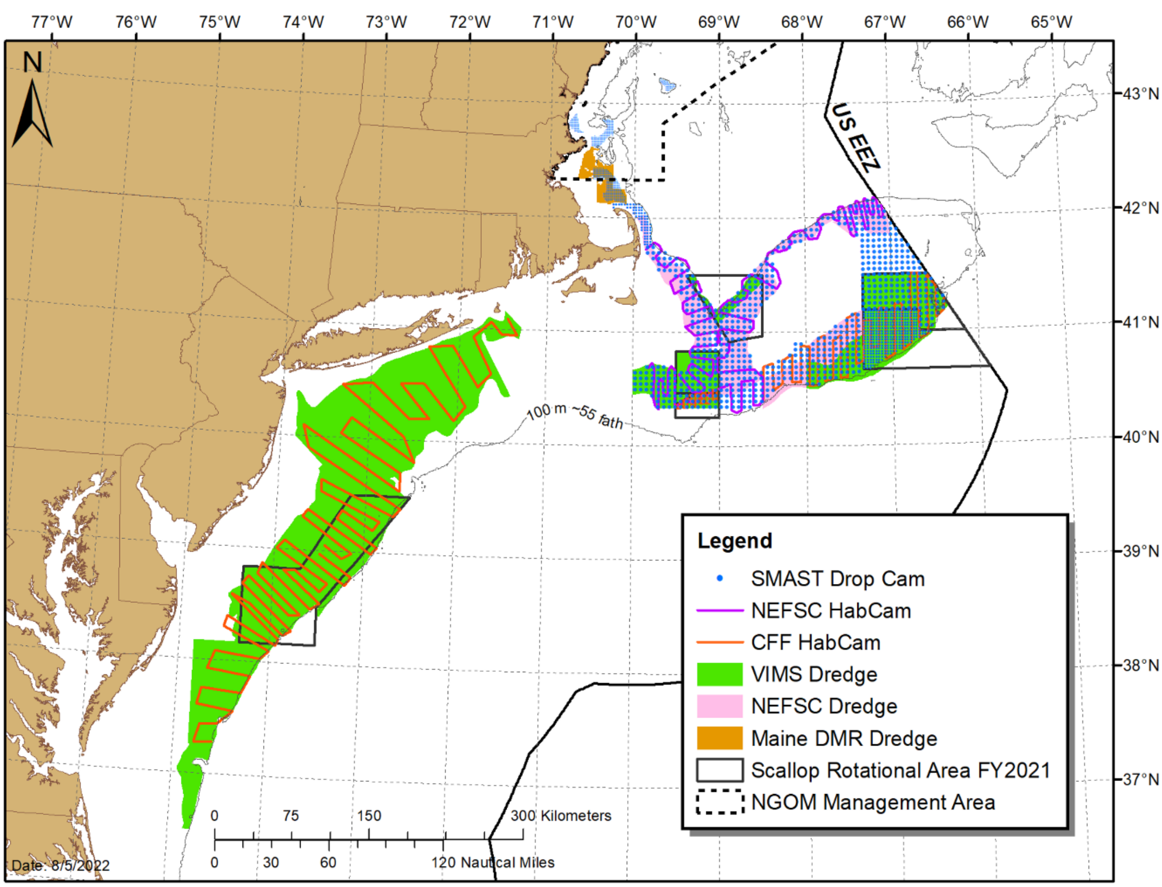

Figure 10. Example of combined survey coverage from all scallop survey components, including RSA-funded surveys and NEFSC surveys.

5.2.3 NEFSC Shellfish Strata

The NEFSC, in collaboration with Dr. Paul Rago, initiated a research project in 2021 to examine alternative sampling designs for the NEFSC scallop dredge survey. The project focused on advancing sampling designs to improve the current random stratified sampling of NEFSC shellfish strata (Figure 11). The SSWG considered the ongoing research to inform potential sampling methods for future scallop surveys. The research was predicated upon known issues for survey sampling designs. Simple random sampling within a stratum is unbiased in expectation but can be inefficient if the realization yields stations too close together and problematic if known "hot spots" do not show up in the sample. Systematic sampling ensures equal coverage over space but does not allow inferences from design-based variance estimation.

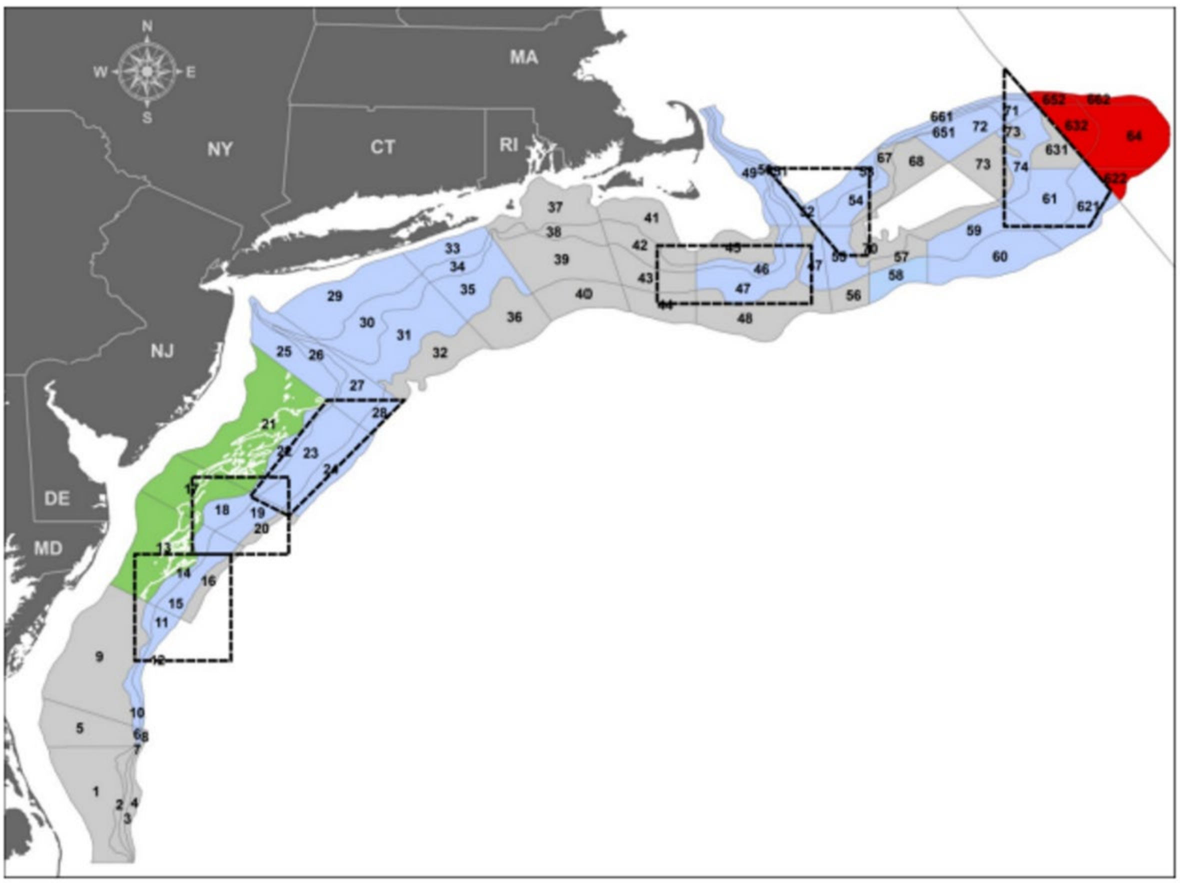

Figure 11. NEFSC shellfish strata used for scallop surveys. NEFSC and VIMS combined regularly surveyed strata are shown in blue and the >40m fathom portions shown in green (white lines in green shaded areas depict the 40 fathom line). Surveyed strata prior to 1989 are shown in gray and green. In prior years, the Canadian side of Georges Bank was surveyed (red). Black dashed lines depict historic scallop rotational management areas (from Hart, 2015).

A well-reviewed approach for land-based ecological sampling, but novel application for fishery-independent surveys, is the Generalized Random Tessellation Stratified (GRTS) approach. GRTS addresses the simple random and systematic sampling issues by maintaining the random aspect of sample selection while ensuring an appropriate degree of spatial coverage and distance between samples. In overly simplistic terms, the GRTS method generates random samples from a spatially-distributed population based on a hierarchical method for ordering potential sampling sites, estimates inclusion probabilities for sampling locations, and applies a local variance estimation to account for spatial structure of observations (Figure 12; Rago, 2021).

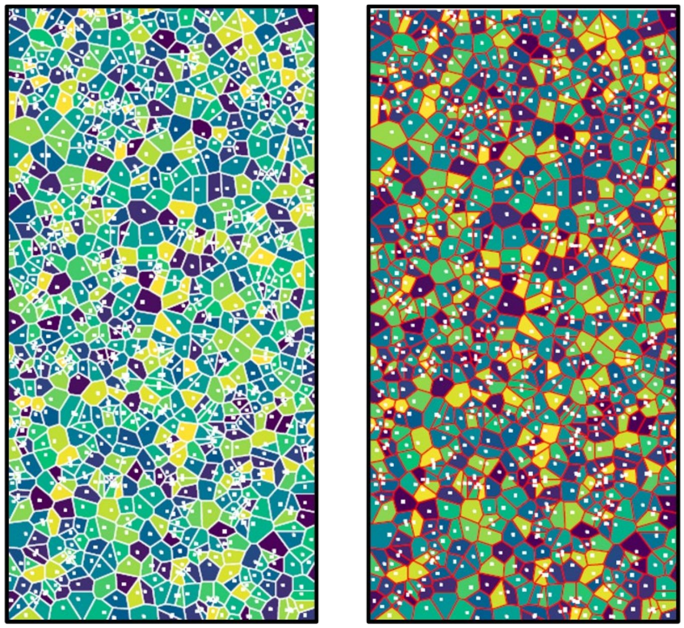

Figure 12. Sample locations (white dots) overlaid on a tessellated survey domain with random sample locations (left) and spatially-balanced GRTS sample locations (right).

The GRTS approach, including equal inclusion probabilities, may be feasible as a general scallop survey strategy. It has the ability to be flexible with changing conditions (e.g., resource or management changes), and will generally provide more precise results than simple stratified or systematic sampling designs. The GRTS approach with equal inclusion probabilities and local variance estimation could provide spatially balanced samples, bridge the gap between systematic and stratified random designs, reduce the magnitude of variance across survey areas, and easily adapt to sampling issues at-sea (e.g., preclusion of sampling sites from gear conflict, shipwrecks, or potential wind installations; Rago, 2021).

The SSWG considered the ongoing efforts to advance NEFSC sampling strategies and supported continued development of the GRTS approach. The group recognized the ongoing efforts by the NEFSC as a parallel project that is outside of the SSWG scope of work. The SSWG supported continuation of the efforts and recommended that all relevant survey partners be informed of potential changes to survey and sampling designs. The SSWG recommended that any new survey sampling design should be peer-reviewed through an appropriate process that includes expertise related to the GRTS approach, scallop population dynamics, and other survey technical and scientific approaches.

6.0 TOR #2 – COORDINATED SURVEY STRATEGY

Describe and assess a coordinated strategy for sea scallop resource assessment surveys and investigate opportunities and methods for implementation. Address each of the following:

- **a. Spatial coverage, including the Northern Gulf of Maine;**
- **b. Sampling frequency and intensity within and between surveys;**
- **c. Data standardization, delivery, access, and storage;**
- **d. Automated scallop detection;**
- **e. RSA survey priority setting process and long-term planning.**

Description:

- *This TOR will include, but not be limited to, the following for each identified topic:*
  - *Assess the strengths and weaknesses of the current scallop survey system, including uncertainties and gaps in data outputs to meet objectives and needs of science and management.*
  - *Describe new or alternative approaches for optimizing the survey system.*
  - *Investigate opportunities and methods to implement strategies across all survey groups including the new and alternative approaches.*

The SSWG considered recommendations for a "simulated", "optimized", "structured" survey design from the 2015 Peer Review of Sea Scallop Methodology, the 2018 benchmark stock assessment, the 2019 Review of New England RSA Programs, and input from the Council in response to updates from the working group. The SSWG highlighted several benefits of the current survey system that may be lost under an optimized approach that focuses on cost efficiencies, specific sampling tools, or a single structured design, including:

- Multiple independent survey estimates provide a mechanism to check and compare estimates of abundance, biomass, density, etc., along with a wealth of area-specific information to support the annual spatial management system;
- The data needs of some resource areas benefit from redundant surveys that use different sampling designs and technologies (e.g., optical and dredge);
- The inclusion of multiple partner organizations provides flexibility within the survey system and lowers risk of lost spatial coverage under anomalous conditions (e.g., Covid);
- The competitive nature of the RSA program has promoted innovation and improvements across survey types;
- Alternative survey designs may be more adaptable and spatially balanced when applied for specific sampling tools;
- RSA survey cost efficiencies are aligned with management and industry expectations.

The SSWG concluded that the current scallop survey system meets science and management needs and that increased coordination across the survey system may be achieved through Survey Guiding Principles and adaptations to the RSA program to ensure that survey coverage, sampling intensity, and sampling frequency meet science and management objectives. The working group did not endorse a simulation analysis of a single optimized scallop survey system, rather they focused on recommendations aimed at improving the current system through increased communication, coordination, and standardization of data collection and products.

The SSWG addressed each topic in TOR #2 in an incremental approach, starting with an assessment of the current system, followed by brainstorming about potential new or alternative approaches, and finally drafting recommendations for consideration by the Council and NEFSC with strategies for implementation. The SSWG provided recommendations related to (1) survey spatial coverage, sampling intensity, and sampling frequency; (2) data topics and automated scallop detection; and (3) RSA coordination strategies (Figures 13, 14, and 16). In combination, the three sets of recommendations address TOR #2 objectives for a coordinated strategy for sea scallop resource assessment surveys.

6.1 SPATIAL COVERAGE, SAMPLING INTENSITY, AND FREQUENCY

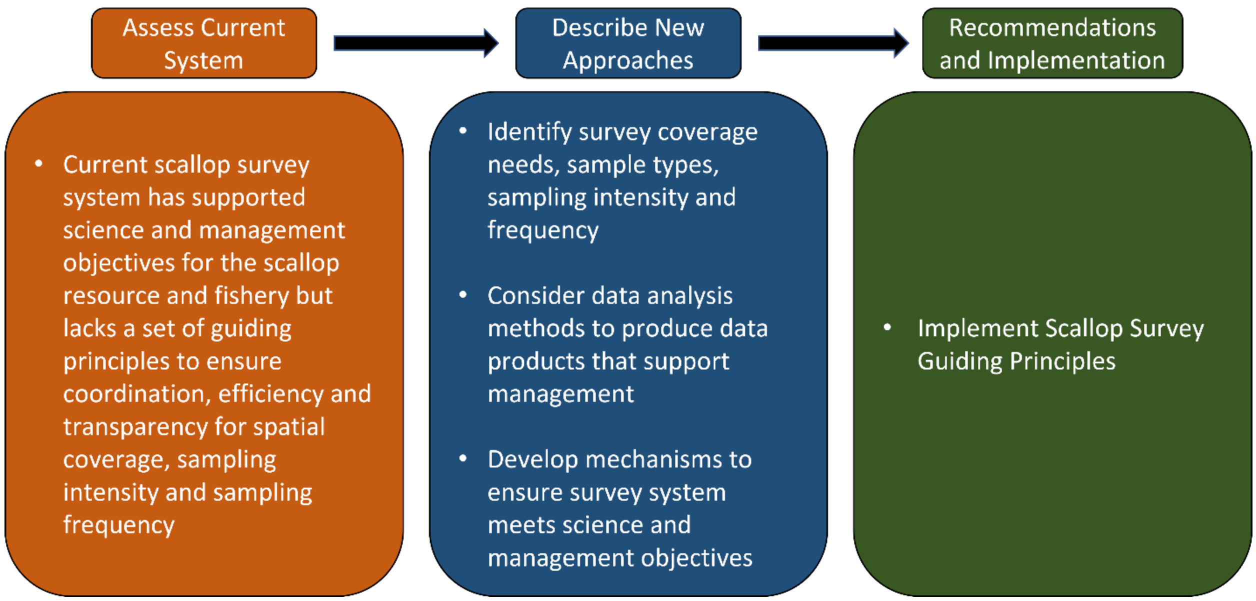

Figure 13. SSWG iterative approach to address survey spatial coverage, sampling intensity, and sampling frequency.

6.1.1 Assessment of current system

The SSWG considered strengths, weaknesses, efficiency, and transparency (Table 3), as well as scope/scale/timing, and uncertainties (Table 4) of the current scallop survey system related to survey spatial coverage, sampling intensity, and sampling frequency. The working group indicated that the current system's strengths are the adaptable, flexible, and stable scope, scale, and timing of the overall survey and the multiple independent data products from highly qualified survey teams. Identified weaknesses included low or missing coverage in areas outside of the SAMS management areas, lack of coordination and long-term planning for the overall scallop survey, and minimal ability for exploratory surveys. The current survey system has inefficiencies due to the lack of a standardized prioritization process to determine spatial coverage and lack of transparency for coordination between the NEFSC and RSA survey processes. Determination of survey coverage and intensity in the Gulf of Maine and Northern Gulf of Maine (NGOM) management area was highlighted as an area of uncertainty, as well as coverage and intensity of the changing distribution of the overall scallop resource.

Table 3. SSWG assessment of the strengths, weaknesses, efficiency, and transparency of the current scallop survey system spatial coverage, sampling intensity, and sampling frequency.

Evaluation Topic	***Strengths***	***Weaknesses***	***Efficiency***	***Transparency***
Spatial Coverage	• Robust coverage most years • Adaptable and flexible • Stable funding for coverage • Multiple independent surveys • Highly qualified partners • Diverse, complimentary tools	• Emphasis on SAMS areas, may be missing areas • Recruitment may be overlooked • Minimal exploratory surveys • Too dependent on previous conditions • Lack of standard procedures and coordination • RSA precludes long-term planning	• Lack standard, quantitative prioritization process • RSA can be inefficient • RSA admin costs could be reduced • NEFSC coverage process reduces planning ability • Need clarification on RSA and NEFSC survey relationship • Need coverage objectives for RSA	• RSA selection process for coverage unclear • NEFSC coverage process unclear • Lack of information about NEFSC plans • Confidential nature of grant process
Sampling Intensity	• Adaptable by area • Multiple surveys reduce uncertainties • High sampling rates	• Lack of coordination • Low or missing sampling in areas • High costs of vessel time for some surveys • Minimal adaptive sampling	• Lack standard, quantitative prioritization process • Define when multiple surveys are needed • NEFSC use of contracted vessel is not efficient	• RSA selection process for intensity unclear • Survey group intensity decisions unclear • No standards for required level of intensity • NEFSC intensity decisions lack transparency
Sampling Frequency	• Annual coverage • Stable frequency • Established time series for multiple surveys • Support management and assessment	• Missing biological information with annual survey • Lack of fall/winter information • Snapshot carried through management process	• Surveys are conducted efficiently each year • Time series have relatively consistent start and end dates	• Surveys are highest RSA priority annually • Survey anomalies (e.g., Covid) were addressed through PDT process with high transparency

Table 4. SSWG assessment of the scope/scale/timing and uncertainties/gaps of the current scallop survey system spatial coverage, sampling intensity, and sampling frequency.

Evaluation Topic	***Scope/Scale/Timing***	***Uncertainties/Gaps***
Spatial Coverage	• May miss scallops outside of SAMS areas • Sometimes scallops are undetected in survey, but attract fishing pressure • Ad hoc process for determining priority areas • Could be informed by fishing patterns not just SAMS areas • HabCam transect coverage needs additional clarification	• Variations between survey estimates and data combination methods • Need better predictors of growth and mortality • Need to quantify added value of multiple surveys in specific areas • Need to standardize process to prioritize spatial coverage • Lack of coverage leads to projection uncertainties • Need more comprehensive coverage of GOM • Survey coverage hasn't changed as much as resource distribution
Sampling Intensity	• May not be appropriate scale outside of SAMS areas • HabCam sampling intensity needs additional clarification • Intensity should adapt to changing resource • GOM sampling intensity needs improvement • High density areas create challenges for specific tools	• Extrapolation of estimates across areas varies • Optimize HabCam annotation rate • Methods to address patchiness • Appropriate sampling is unknown in GOM • Overemphasis on access areas • Consider intensity for each survey tool
Sampling Frequency	• Annual survey is appropriate • Seasonal shifts in distribution not well understood • Need longer term planning to ensure continued annual surveys • Opportunities to explore more frequent data collection in key areas	• Fishing during and after surveys can create uncertainties • Lack of information on condition factor • GOM surveyed intermittently • Lack of information on shifts in spawning season • Consider use of fishery dependent data

6.1.2 Description of new approaches

The SSWG discussed new approaches and processes for a coordinated survey strategy (Table 5) and considered a hierarchical approach to define survey objectives. The SSWG drafted an overarching problem statement to guide discussion of new approaches:

> *The current scallop survey system has supported science and management objectives for the scallop resource and fishery but lacks a set of guiding principles to ensure coordination, efficiency and transparency for spatial coverage, sampling intensity, and sampling frequency.*

Table 5. SSWG description of new approaches for spatial coverage, sampling intensity, and sampling frequency.

Evaluation Topic	***New Approaches to Consider***
Spatial Coverage	• Better coordination in advance of surveys • Improve process for determining spatial coverage of surveys • Address RSA selection of spatial coverage transparency issues • Develop criteria for determining spatial coverage • Consistent coverage of the entire resource area • Longer term survey planning • More adaptable survey designs • Re-stratification of shellfish strata • Creation of shellfish strata in GOM • Consider survey of entire Georges Bank, including Canada
Sampling Intensity	• Improve the process for determining sampling intensity needs • Consider trade-offs of broad and fine scale surveys by area and resource • Consider appropriate scale for collecting biological samples vs. estimating abundance/biomass • Consideration of HabCam CV estimates based on sampling intensity • Consideration of HabCam annotation rate • Develop criteria for determining sampling intensity • Explore opportunities for additional data collection in key areas • Consider variable survey strata by survey method
Sampling Frequency	• Determine appropriate sampling frequency for GOM and low priority areas • Consider sampling frequency in relation to RSA grant duration • Consider costs and benefits of sampling frequency • Consider use of fishery dependent data streams in projections to inform seasonal variations • Consider use of other research survey information to enhance seasonal variation information

6.1.3 Recommendations and implementation strategies

The SSWG recommended that the Council and NEFSC adopt Scallop Survey Guiding Principles to inform survey-related decision-making, RSA priorities and program adaptations, and future science and management efforts and advice.

Rationale:

The Scallop Survey Guiding Principles were developed to ensure adequate survey coverage, sampling intensity, frequency, and sampling types needed to generate data products to support annual scallop management, while maintaining flexibility in the system to continue the provision of independent estimates from survey partners. The Scallop Survey Guiding Principles document (Appendix 2) is intended to be a living document that provides guidance for surveys and data products for long-term use. The guidance may be considered and applied to align with SSWG recommendations related to survey coordination, data standardization, and impacts from offshore wind energy development. The Council, Scallop PDT, and NEFSC should determine appropriate implementation and administrative oversight related to the guidelines. The SSWG recommended that future modifications to the Scallop Survey Guiding Principles should be made in consultation with all scallop survey partners. The SSWG recommended the following Scallop Survey Guiding Principles:

Survey Coverage:

- The entire scallop resource and spatial distribution of the fishery should be surveyed annually. The overall resource survey will consist of multiple survey partners, including the NEFSC and RSA-funded organizations, using dredge and optical tools. The primary objective of these surveys is to provide length frequencies, abundance, and biomass estimates that are used by the Scallop PDT.
- Specific resource areas (e.g., rotational management areas, areas of identified recruitment, areas with anomalous biology or mortality, and areas of importance to the fishery) should be covered with redundant surveys that use different sampling technologies (e.g., optical and dredge) to provide multiple independent estimates of abundance, biomass, and density.
- Areas outside of the currently known scallop resource and spatial distribution of the fishery that could potentially support scallop biomass should be surveyed regularly on a longer-term time step, as informed by the Scallop PDT, scallop survey partners, and the scallop fishing industry.
- The Northern Gulf of Maine management area and Gulf of Maine resource area should be included in regular survey coverage.
- Efforts should be made to match appropriate sampling tools, designs, and methods with specific conditions of survey areas (e.g., habitat type, gear conflict regions, wind farms).
- Survey coverage determination should consider areas of current and future offshore wind energy development.

Sampling Intensity and Frequency

- Underlying conditions of survey areas should be considered to determine required sampling levels (e.g., schedule of rotational management areas, recruitment and cohort tracking, abundance and density, condition factor, disease and predator prevalence).

- Surveys should be conducted on multiple spatial scales with higher sampling intensity directed to priority areas.
- HabCam survey annotation rates and data delivery expectations should be identified and agreed to during RSA negotiations and established in RSA awards.
- Sampling objectives should be considered in the pre-survey planning phase (e.g., optical track allocation, dredge sampling locations within strata), as well as post-survey analysis phase (e.g., estimates of precision, accuracy, and bias).

Types of Sampling

- Samples required from all resource and fishery areas to support annual management, stock assessment, and science include scallop counts, measurements, and biological samples. The overall scallop survey system includes, but is not limited to, collection of meat and gonad weight, age and growth samples, reproductive state, sex, disease documentation, and meat quality. Each survey method collects different types of samples that are integrated to support scallop science and management.
- Collection of additional biological and environmental information should be conducted, and efforts should be made to increase utilization of data products that are not directly applied to scallop science and management (e.g., ecosystem monitoring, habitat mapping, predator abundance and distribution estimates, etc.).

Data Analysis

- Analysis of survey data should generate data products to support annual scallop management for each SAMS/survey area, as identified by the Scallop PDT, including biomass, abundance, density, average meat/gonad weight, and length frequency.
- Data analysis should be based on standardized criteria defined by the Scallop PDT (e.g., area-specific shell height to meat weight (SH:MW) equations, defined size classes for pre-recruits, recruits and adults, dredge efficiency, commercial dredge selectivity).
- The process for HabCam surveys to check for autocorrelated data for model-based estimation methods includes:
    - Aggregate the annotated data by 750m segments
    - Calculate Moran's I statistics for only the positive aggregated data points for each area to check whether the data are spatially autocorrelated using reviewed methods (e.g., ArcGIS, QGIS, R function in Moran.I in library ape)
    - If data are not spatially autocorrelated ($p>0.05$), review potential reasons for the lack of correlation with NEFSC and Council staff (e.g., too few images were annotated, or spatial structure is absent)
    - In the absence of autocorrelation, the NEFSC will recommend appropriate methods to generate biomass estimates to the Scallop PDT (e.g., stratified mean estimation Chang et al., 2017).

Data Delivery

- Survey data products must be available by August of the year the survey is conducted.
- Survey data delivery format should follow guidelines for standardization, as defined by the Scallop PDT.
- Survey data from all survey partners should be made accessible upon request, as defined by the RSA Data Sharing Plan requirements.

6.2 Data Standards, Storage, Access, and Auto Detection

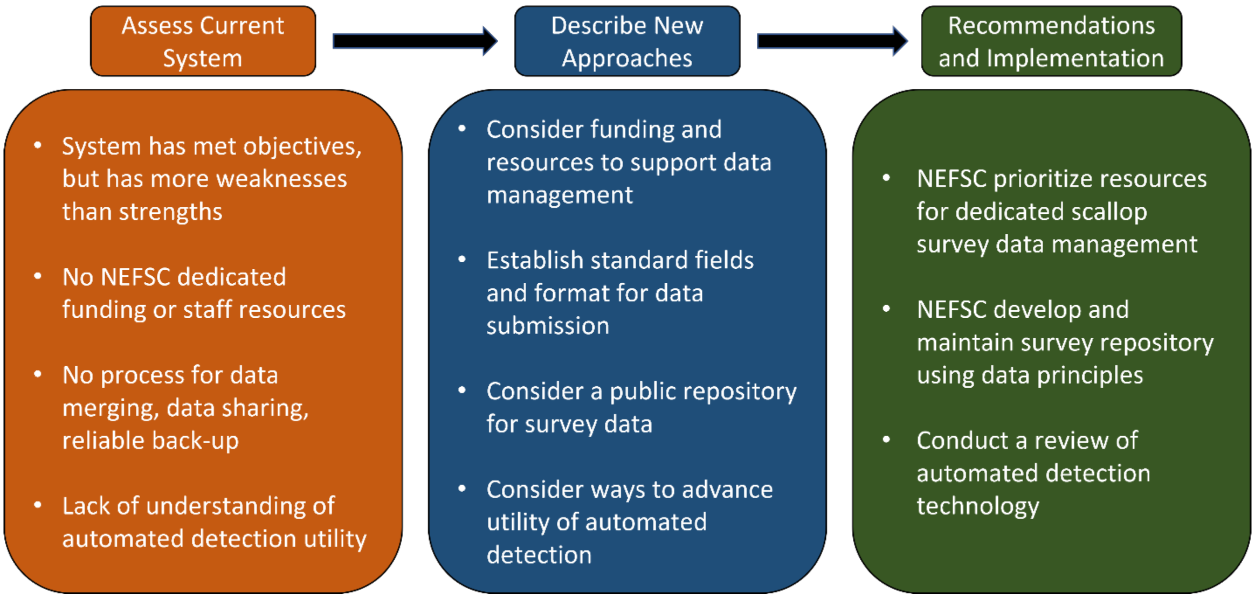

Figure 14. SSWG iterative approach to address data standards, storage, access, and automated detection.

6.2.1 Assessment of current system

The scallop fishery is one of the most valuable fisheries in the U.S., generating hundreds of millions of dollars annually, but there is no dedicated NOAA funding or staff resources to ensure survey data standardization, access, and storage. The SSWG assessed the strengths and weaknesses of the current scallop survey data management system and determined that the system is inefficient, disjointed, and vulnerable to data loss and data merging errors (Table 6). They noted that the system has been able to support science and management objectives to date, but emphasized that potential data loss, lack of coordination, or loss of experienced personnel could risk collapse of the data management process.

The SSWG identified data management deficiencies as the most serious issue in the current scallop survey system. Data standardization and coordination among survey groups was highlighted as a current challenge, and the lack of standardized data fields across all survey groups was identified as a major weakness that creates time lags in data processing and limits broad accessibility to data products. Survey data and data products are stored on personal laptop computers, manually merged, and output in flat files with minimal ability for data sharing, accessibility, or repeatable analyses. Reliance on NEFSC resource assessment specialists to manage survey datasets diverts resources away from advancing science and management objectives. The group concluded that the system is unsustainable in its current form.

Table 6. SSWG assessment of the strengths and weaknesses of the current scallop survey data management system.

Evaluation Topic	*Strengths*	*Weaknesses*
Standardization		• No standardization of data fields or databases • Current databases are poorly designed • Organizing data for management takes a substantial amount of time; multiple steps to make data usable for management purposes • No standardized annotation rates for HabCam data
Delivery	• Standardized data report for management allows for survey comparisons	• Data processing is time consuming and grueling • Lack of staff resources to handle work • Data is not available online
Access	• Improvements in data sharing over time, but not coordinated • Summary of data available on the Council's website	• Data is not accessible and not easily shared • Survey groups are not sharing data with each other • There is no mechanism to enforce data sharing • No application programming interface (API) that can facilitate sharing • Value of optical data has not been leveraged; data that is available is not very useful, just an image • No standards for putting images online
Storage	• Groups manage their own data • Untapped data within each survey group	• Data is not centralized • Data is stored on external drives in boxes and on personal laptops; risk for data loss • Unclear how each group manages their data • No dedicated funding for data storage • Databases are not being supported or maintained • No plans to put data online

6.2.2 Description of new approaches

The SSWG considered what is encompassed under the term "data" as related to the scallop survey. Optical surveys produce several levels of data, ranging from video and photo files, to annotated image "raw data", to calculations of density, abundance, and biomass estimates by area. Dredge surveys produce station level counts and biological samples, as well as calculations of swept-area biomass by area. The working group noted that new approaches for data management will need to consider the definition of data in relation to standardization, delivery, access, and storage. Members of the SSWG commented that RSA funds may be appropriate to support data management but noted that RSA priorities and the competitive nature of the RSA grant program may pose challenges to the use of RSA funds to support long-term data storage and management. The group also considered the topic of data sharing and what constitutes public data and noted that the National Science Foundation's Data Sharing Policy may be relevant to consider. The group recognized that not all data products collected from the scallop surveys are used in management, and that data could be leveraged to support science and management objectives for other species and resources.

The SSWG highlighted the critical need for dedicated survey data management personnel and database infrastructure. They suggested ideas for new and alternative approaches for data management, including contracting external IT professionals to lead development of database and storage options, standardized data fields across all survey groups, housing data products in a centralized location managed by a third-party organization, and advancing automated annotation of optical survey data. They underscored the importance of a long-term, reliable, accessible data storage platform for standardized scallop survey data and stressed the need for additional resources to support this effort. The SSWG emphasized that a coordinated, standardized approach for data collection and delivery is an urgent priority (Table 7).

Table 7. SSWG definitions for timing to implement recommendations.

Rating	*Definition*
URGENT (essential)	Topic that has been identified as necessary to support management and science; expected that recommendations would be implemented within 1-2 years and postponement would have a significant impact on management.
IMPORTANT (near-term)	Topic that has been identified as likely to aid in near-term or ongoing management and science objectives; expected that recommendations would be implemented within 2-5 years and postponement would not have an immediate impact on management but could inform decisions in the near-term.
STRATEGIC (future)	Topic that has been identified as a longer-term goal with potential to improve the current system or develop new methods or technology; expected that recommendations would be implemented within 5+ years.

6.2.3 Recommendations and implementation strategies

The NEFSC should prioritize scallop survey data management and provide resources for dedicated personnel for data/database management.

Rationale:
The "Foundations for Evidence-Based Policymaking Act of 2018" (Evidence Act; Public Law 115-435) requires that all NOAA data be open and usable by the public without restriction unless such sharing is expressly prohibited by law or regulation. NOAA's Data Strategy, released in 2020, outlines goals to align data management leadership roles across the organization, govern and manage data strategically, share data as openly and widely as possible, promote data quality improvements, and engage stakeholders to maximize the value of NOAA data (NOAA, 2020). These requirements and goals must be applied to scallop survey data management.

Implementation Strategies:
- The SSWG emphasized the need for the NEFSC to consider available and additional funding and staff resources to support scallop survey data management.
- The NEFSC should work with all scallop survey partners to identify methods to standardize data and increase efficiencies for survey data management.
- The NEFSC could consider prioritizing data needs as URGENT, IMPORTANT, and STRATEGIC to assess risk and vulnerabilities and inform contingencies for data storage, access, and delivery.

The NEFSC should dedicate sufficient annual resources to develop and maintain an operational scallop survey data repository using FAIR (findable, accessible, interoperable, reusable) data management principles.

Rationale:
The SSWG highlighted that the current data storage approach is vulnerable to potential data losses, and the lack of data standardization can lead to data processing errors. Some survey data is currently stored on personal laptop computers and antiquated external hard drives. Data merging and quality control is currently reliant on resource assessment specialists and is a burdensome, inefficient process. Scallop survey data are disjointedly housed by individual survey partners, and NOAA's current metadata portal (InPort: www.fisheries.noaa.gov/inport/) is not sufficient to support full data sharing of all sources of scallop data (e.g., NEFSC and RSA partners; dredge and optical datasets.)

The FAIR data principles indicate that data should be findable, accessible, interoperable, and reusable (European Commission, 2018). The principles emphasize machine-actionability with machine-readable metadata for discovery of datasets.
- Findable: metadata and data should be easy to find for humans and computers
- Accessible: once found, users need to know how to access data
- Interoperable: data need to interoperate with applications for analysis, storage, and processing
- Reusable: data/metadata should be well-described for replication and combination

Implementation Strategies:

- The SSWG recommended that the NEFSC develop the scallop survey data repository to include standard data fields and quality assurance criteria that can be shared through web services in machine-readable format (e.g., JSON, XML, etc.).
- Initial development of the scallop survey data repository should focus on dredge survey data to inform database structure and identify integration and interface tools.
- The repository should be developed to allow additional survey data streams to be added and integrated.
- The NEFSC should explore cost and capability for storage of images from optical surveys.
- The repository must be operational beyond development phases and must be maintained in perpetuity.
- The SSWG recommended this as an URGENT priority to be initiated within the next 1-2 years (Figure 15).

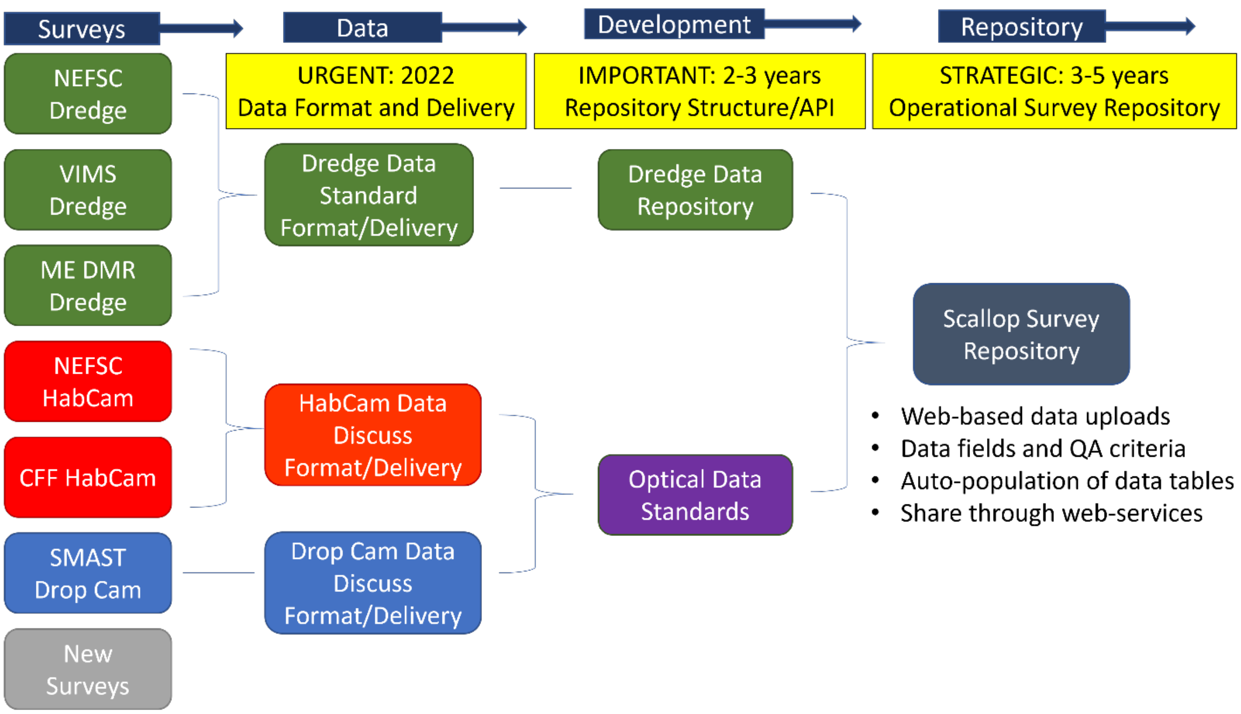

Figure 15. SSWG recommended steps and timeline for development of the scallop survey data repository.

Standardize scallop survey data format and delivery.

Rationale:

The SSWG noted that scallop survey data collection fields and protocols differ among the range of survey partners and that manual merging of datasets is time-consuming and error-prone. The SSWG identified standardization of survey data format and delivery to the NEFSC as a logical first-step to increase efficiencies in data management. Standardized data formats and delivery processes can serve as the basis for development of the scallop survey data repository.

Implementation Strategies:

- The SSWG recommended collaborations between the NEFSC and survey partners in the near-term (2022) to identify standard data fields and delivery format.
- Archived survey datasets should be standardized to facilitate integration in the scallop survey data repository within two to three years (by 2025).

Establish a process to check for autocorrelated data for model-based estimation methods.

Rationale:

Deriving biomass from geostatistical models is the preferred method for HabCam optical data. Low image annotation rates in areas with low scallop density have resulted in non-correlated data in some years, precluding the use of geostatistical modeling approaches to estimate biomass. The SSWG recognized time and resource constraints for image processing and recommended an adaptive process to (1) identify whether or not data are autocorrelated and take steps to try to achieve autocorrelation, if possible; and (2) apply an alternative estimation method if autocorrelated data is lacking.

Implementation Strategies:

- HabCam survey annotation rates and data delivery expectations should be identified and agreed to during RSA negotiations and established in RSA awards.
- The process for HabCam surveys to check for autocorrelated data for model-based estimation methods includes:
  - Aggregate the annotated data by 750m segments
  - Calculate Moran's I statistics for only the positive aggregated data points for each area to check whether the data are spatially autocorrelated using reviewed methods (e.g., ArcGIS, QGIS, R function in Moran.I in library ape)
  - If data are not spatially autocorrelated ($p>0.05$), review potential reasons for the lack of correlation with NEFSC and Council staff (e.g., too few images were annotated, or spatial structure is absent)
  - In the absence of autocorrelation, the NEFSC will recommend appropriate methods to generate biomass estimates to the Scallop PDT (e.g., stratified mean estimation Chang et al., 2017).
- This process should be included in the Scallop Survey Guiding Principles and should be updated as needed.

Conduct a review of automated detection technology.

Rationale:

Manual annotation of optical survey images is resource-intensive and time-consuming. The annual scallop management process operates under a tight timeline and the preferred method to derive biomass estimates from HabCam data relies on relatively high annotation rates to support geostatistical models. Advancing the utility of automated detection technology could substantially increase the speed and rate of image annotation. Several survey partners have developed automated detection tools, including training datasets, machine-learning algorithms, and detection software. The SSWG recommended that a review of the technology is needed in the near-term to advance the utility and application of automated detection.

Implementation Strategies:

- The NEFSC and Council should prioritize organization of a peer-review process to advance the utility of automated detection technology.
- Define objectives and Terms of Reference for a review of automated detection technology, including, but not limited to the following:
  - Identify what software has been applied and what tools are useful
  - Define data products and statistical analysis of accuracy and precision
  - Consider pathways to operationalize automated detection
- Identify an appropriate review panel with technical expertise, for example:
  - Regional Fisheries Science Centers
  - NOAA Center for Artificial Intelligence
  - NOAA Automated Image Analysis Strategic Initiative
  - ICES Working Group on Machine Learning in Marine Science
- The SSWG recommended this as an URGENT priority to be initiated within two years (2023/2024). The review should include all relevant survey partners, be updated as needed, and not be conducted as part of a Research or Management Track Assessment.

The Council should maintain data tables for management applications.

Rationale:

In 2021, the Council compiled survey data products in a single location, including survey biomass, projected exploitable biomass, and allocated and landed pounds by year, region, SAMS area, and survey type for 2015 to 2021. The compiled data facilitated analyses to support evaluation of rotational management performance, projection performance, and understanding of the impacts of various management measures. The SSWG noted that continued maintenance of the compiled survey data products would be useful for scallop science and management.

Implementation Strategies:

- Council staff should continue to review and update data tables on an annual basis.
- The Council should consider potential mechanisms to share data products and/or identify potential partners/services to house data with public accessibility.

6.3 RSA Survey Priorities and Planning

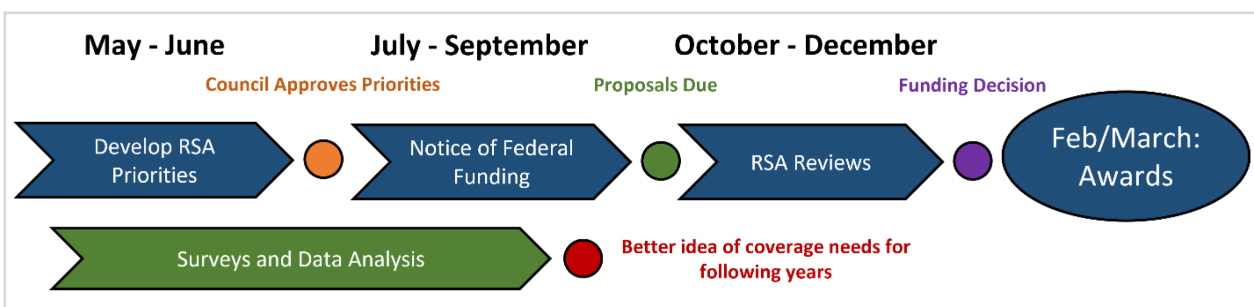

Figure 16. Annual timing of RSA survey process and availability of updated survey information.

6.3.1 Assessment of Current System

The SSWG reviewed the current RSA survey priorities, award cycle timing, and survey coverage determination process (Figure 16). The group highlighted the disconnect between survey priority setting, occurring in the spring of the award solicitation year, and actual survey needs, occurring in the subsequent spring/summer. They noted that the Council's "best guess" of survey needs when setting priorities is not always aligned with data needs to support management in the following year, which can result in RSA proposals that need to be modified through the RSA pre-award negotiation process. This has caused added burden to applicants to revise proposals and survey plans and increased administrative burden to modify grant applications. Additionally, there is no existing mechanism to support coordination among survey partners.

The SSWG's assessment of strengths and weaknesses of the current system (Table 3) informed deliberations about a coordinated approach for scallop surveys. The working group developed a set of objectives for RSA planning and coordination to focus discussions and recommendations for program improvements, including:

- Address the disconnect between priorities, proposals, and actual survey needs;
- Increase flexibility to match surveys with science and management needs (e.g., Survey Guiding Principles);
- Reduce the resources required to support annual grants, including proposals and administration;
- Ensure all survey partners (including NEFSC) have input in research objectives;
- Support survey groups for continued focused research efforts (e.g., area-specific research topics, build and maintain time series, data collection/analysis of other species, habitat, and environmental indicators, innovation of new survey technology, etc.);
- Match survey tools to specific area conditions (e.g., habitat/gear constraints in survey areas, need for biological samples);
- Better align RSA surveys with the NEFSC survey planning process (i.e., move away from "filling the gaps" approach).

6.3.2 Description of new approaches

The working group considered two broad concepts to improve the RSA program and enhance coordination among all survey components, (1) longer-term RSA survey awards, and (2) effort-based RSA survey awards. The SSWG developed a "strawman proposal" around the longer-term award concept and recommended that NOAA and the Council continue developing implementation strategies for longer-term RSA awards.

The SSWG's proposal for longer-term RSA survey awards includes the ability to apply for and be awarded scallop survey RSA funding for up to five years. The current RSA program allows for two-year survey awards and increasing the award timeline for additional years would not fundamentally change the nature of the grant program or administrative process. The SSWG proposed an iterative approach for implementation that could increase award timelines for broad-scale resource regions (e.g., Mid-Atlantic, Georges Bank, and Gulf of Maine).

Longer-term survey awards would require a rigorous process to determine annual spatial coverage and sampling intensity. The current RSA program has the ability to make annual award amendments for two-year awards based on survey needs identified by the Scallop PDT and NEFSC, but the SSWG recommended that a more formalized process including input from management, science, technical, and fishing industry experts would improve standardization and transparency. The SSWG proposed that NOAA and the Council develop a standard process to review long-term awards on an annual basis to ensure that the overall survey system meets science and management objectives and adapt the existing RSA post-award negotiation process to revise survey awards based on identified coverage and sampling needs (Figure 17).

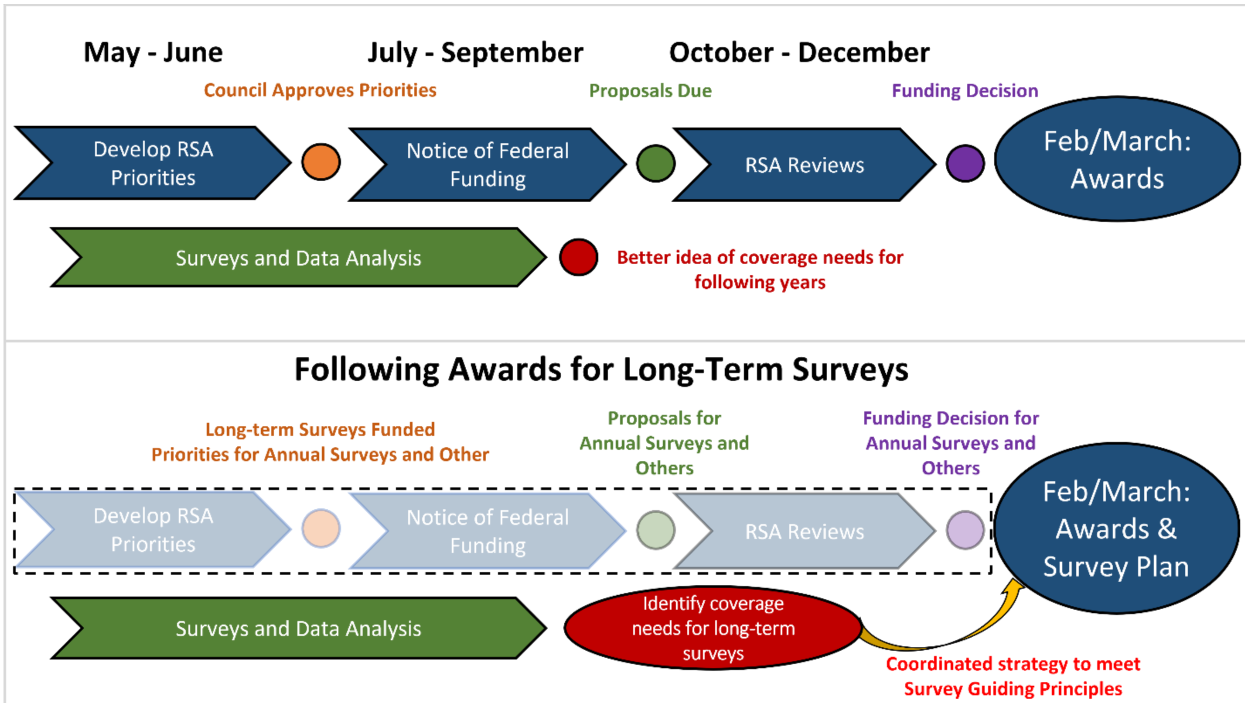

Figure 17. Annual timing of RSA survey process (top) and potential annual process for review and determination of survey coverage for proposed longer-term RSA survey awards (bottom).

The SSWG identified several potential benefits from longer-term awards, including reduced administrative burden (e.g., proposal writing, review process, NOAA oversight), consistency in survey data collection and provision of data products, programmatic stability for survey partners, longer-term planning for industry decision-making, increased collaborations among survey partners, and additional outreach and academic opportunities. They recommended that the 2023 Notice of Federal Funding Opportunity (for surveys beginning in the 2024 survey season) include longer-term survey solicitations.

The SSWG proposed maintaining annual RSA survey awards for specific areas to complement a longer-term approach. The group noted that not all survey designs and areas need to be funded for long periods of time and recommended that fine-scale, area-specific surveys could be maintained on a one- to two-year award cycle.

6.3.1 Recommendations and implementation strategies

The Council should revise the language used to describe the RSA survey priorities for inclusion in the RSA Notice of Federal Funding Opportunity.

Rationale:
To immediately address the mismatch of identified RSA survey priority areas and actual survey needs, the SSWG recommended simplifying the language used in the RSA Notice of Federal Funding Opportunity for the Scallop Resource Surveys priority. The suggestion was to remove the ranked list of specific survey areas and clarify the intent of RSA-funded surveys.

Implementation Strategy:
This recommendation was advanced by the Scallop PDT, Scallop AP, and Scallop Committee in the spring of 2022, and the following text was adopted by the Council in June 2022:

> *Industry-based scallop surveys using dredge and/or optical tools conducted at varying sampling intensities (e.g., intensive and resource-wide), and analysis of collected survey data needed to support annual Atlantic Sea Scallop fishery management and scallop science needs. This includes industry-based surveys within Georges Bank and/or Mid-Atlantic resource areas, and the Gulf of Maine including the Northern Gulf of Maine Management Area.*
>
> *Survey results must be available by August of the year in which the survey is conducted (e.g., survey results that would inform 2024 fishing effort decisions must be available by mid-August 2023). The survey or surveys do not need to be carried out by a single grant recipient. In addition, the data needs of some resource areas benefit from redundant surveys that use different sampling technologies (e.g., optical and dredge). Survey data will be used to develop estimates of total and exploitable biomass to be used for setting fishery catch limits and allocations. Successful projects may be asked to provide data in a standardized format. The primary objective of these surveys would be to provide length frequencies, abundance and biomass estimates that are used by the Scallop Plan Development Team.*

The Council and NOAA should revise the Scallop RSA Program to allow for longer-term awards (up to 5 years) and collaboratively develop a rigorous, standard process to ensure coordination of annual survey spatial coverage and sampling intensity.

Rationale:
The SSWG reviewed RSA program requirements and guidelines from NOAA and the Council and determined that a follow-on process that includes input from NOAA General Counsel and Council administration is needed to advance the proposal for longer-term RSA survey awards.

Implementation Strategies:
The SSWG recommended that NOAA and the Council develop an implementation strategy for longer-term RSA survey awards and consider the following topics:

- The RSA program is a federal, competitive grant program with specific legal and confidentiality requirements;
- Area coverage determination must avoid any conflict of interest from survey applicants;

- Longer-term survey awards do not require a Cooperative Agreement with NOAA unless there is close coordination between NOAA and the external partner;
- Longer-term survey awards must consider annual availability of RSA resources. If there are inadequate resources to cover RSA proposed surveys, awards are not given;
- Price per pound for RSA compensation is reviewed and updated annually, and awards are adjusted to reflect updated price (e.g., increase/decrease awarded pounds to align with research budget).
- The RSA survey technical review panel may not be required to review long-term surveys awards after the initial proposal review.
- The RSA management review panel process could be adapted, or a new standardized review process could be developed, to determine annual survey spatial coverage and sampling intensity needs.

7.0 TOR #3 – IMPACTS FROM WIND DEVELOPMENT

Identify survey methods, tools, and designs to monitor and assess the scallop resource in a changing ocean environment that includes offshore wind installations and changes in resource and fishery distribution.

<u>*Description:*</u>

- *This TOR will include, but not be limited to, the following items:*
  - *Description of the likely impacts of offshore wind installations on the current survey domain and methods on a present and multi-year timescale.*
  - *Identification of existing and new scallop survey strategies for population assessments under changing conditions in stock and habitat parameters, and changes in stock distribution as a result of natural or anthropogenic factors.*

The SSWG addressed TOR #3 with a similar incremental approach as TOR #2, starting with a description of the likely impacts of offshore wind installations on the current survey system and domain, followed by brainstorming about potential new or alternative survey strategies, and finally drafting recommendations for consideration by the Council and NEFSC with strategies for implementation related to survey mitigation approaches, guidelines for offshore wind company monitoring efforts, development of new survey tools, and required resources to implement a mitigation approach (Figure 18). In combination, the recommendations address TOR #3 objectives to identify survey approaches to monitor and assess the scallop resource in a changing ocean environment and should be considered as components of an overall scallop survey mitigation program.

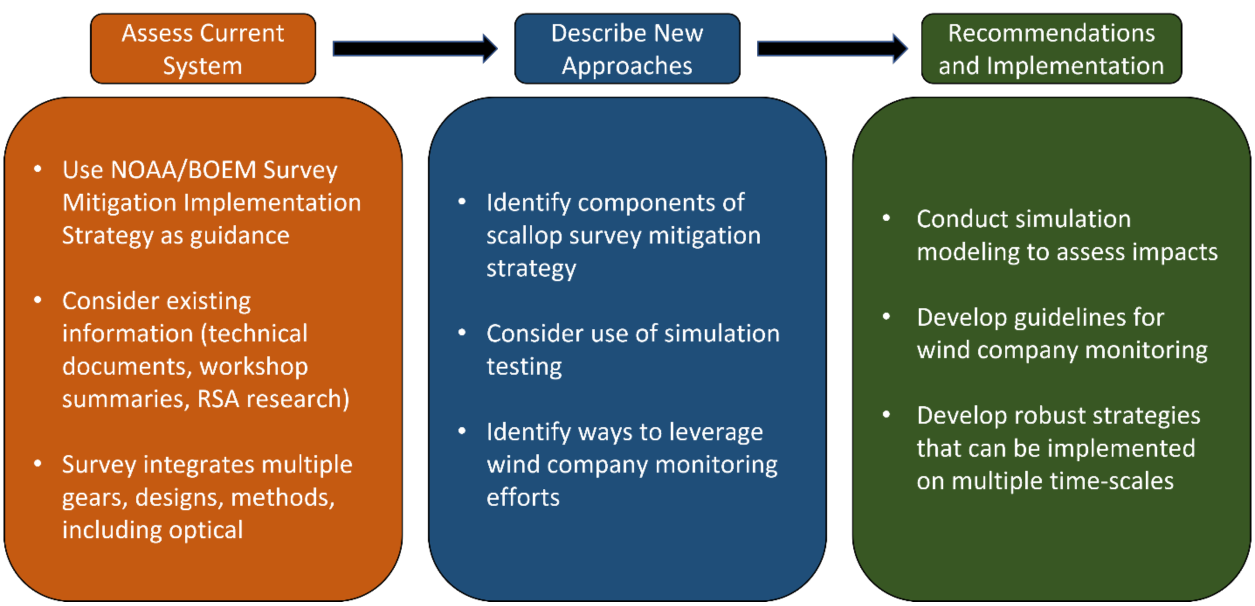

Figure 18. Iterative approach to address potential impacts from offshore wind installations on the scallop survey system.

7.1 IMPACTS ON CURRENT SURVEY SYSTEM

NOAA has identified four impacts to fishery-independent resource surveys resulting from the development of offshore wind energy, including:

- Preclusion of sampling platforms from wind development areas due to operational and safety limitations;
- Impacts on survey statistical designs, which are the basis for scientific assessments, advice, and analyses;
- Alteration of benthic and pelagic habitats, in and around wind energy development areas, requiring new designs and methods to sample new habitats;
- Reduced sampling productivity through navigation of wind energy infrastructure.

To address these impacts, NOAA defined six mitigation components for resource surveys, including:

- *Evaluation of survey design*: Evaluate and quantify effects and impacts of proposed project-related wind development activities on survey operations and on provision of scientific advice to management.
- *Identification and development of new survey approaches*: Evaluate or develop appropriate statistical designs, sampling protocols, and methods, while determining if scientific data quality standards for the provision of management advice are maintained.
- *Calibration of new survey approaches*: Design and carryout necessary calibrations and required monitoring standardization to ensure continuity, interoperability, precision, and accuracy of data collection.
- *Development of interim provisional survey indices*: Develop interim ad hoc indices from existing non-standard data sets to partially bridge the gap in data quality and availability between pre-construction and operational periods while new approaches are being identified, tested, and calibrated.
- *Wind energy monitoring to fill regional scientific survey data needs*: Apply new statistical designs and carryout sampling methods to effectively mitigate survey impacts due to offshore wind activities from operations for the operational life span of the project.
- *Development and communication of new regional data streams*: New survey approaches will require new data collection, analysis, management, dissemination, and reporting systems. Changes to surveys and new approaches will require substantial collaboration with fishery management, fishing industry, scientific institutions, and other partners.

The draft "NOAA Fisheries and BOEM Federal Survey Mitigation Implementation Strategy – Northeast U.S. Region" was released in March 2022 as a framework for mitigating the impacts of offshore wind on NOAA Fisheries Surveys, including the NEFSC Sea Scallop Dredge Survey and Integrated Benthic Habitat Survey (HabCam). The NOAA/BOEM Strategy can also serve as a framework to inform mitigation strategies for other resources surveys, including the suite of RSA-funded scallop surveys. The SSWG considered the spatial extent of offshore wind development (Figure 19) as related to NOAA's four impact topics to identify specific impacts to the scallop survey system, considering both the current and potential future survey platforms, designs, and sampling methods (Table 8; Figure 20).

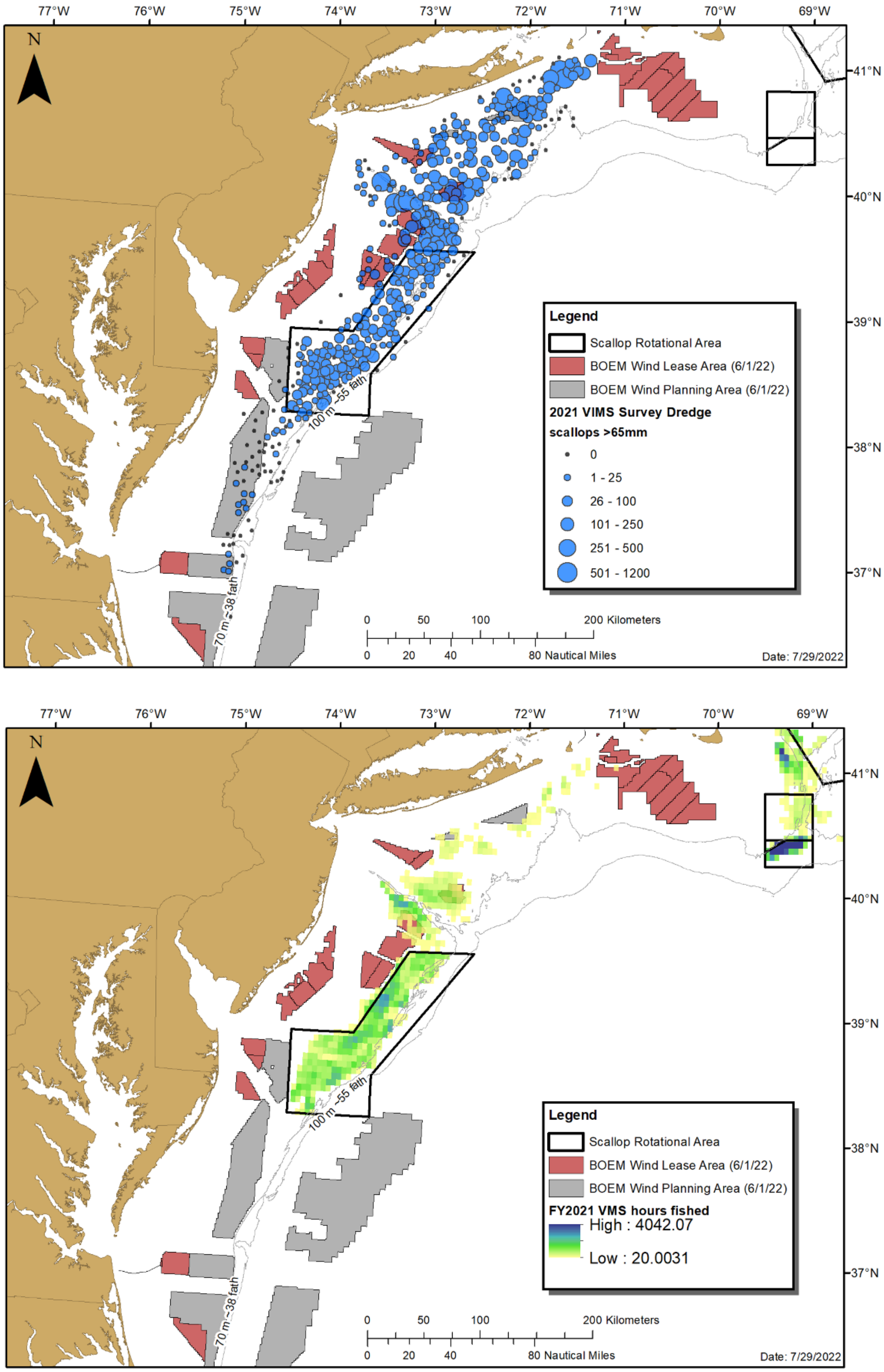

Figure 19. Scallop distribution from the 2021 VIMS dredge survey (top) and scallop VMS hours fished (bottom) overlaid with BOEM wind lease (red shading) and wind planning (gray shading) areas and scallop rotational management areas.

Table 8. Impacts to the scallop survey system from the development of offshore wind energy.

Impact Topic	***Scallop Survey Impacts***
Preclusion of Sampling Platforms	• Possible impacts to all scallop survey vessels/tools (i.e., gear/vessel operability)
	• Impacts to survey area coverage and survey timing
	• Variable impacts associated with fixed and floating wind turbine arrays
	• Physical parameters of turbine layout will affect navigability/operability of survey vessels/tools
	• NEFSC Survey – R/V Sharp completely precluded
	• RSA surveys may not be completely precluded
	• Towed sampling tools (dredge and HabCam) may have higher impacts than stationary sampling tools (Drop Cam)
	• Potential to survey from smaller vessels, but not guaranteed
Statistical Design	• Impacts to random stratified designs and survey spatial scales
	• Some statistical designs are possible (transect and grid), but will require adjustments to area expansion estimates
	• Challenges for using *a priori* information to inform future survey designs
	• Potential for new survey designs that can accommodate gaps in sampling
Habitat Alteration	• Addition of hard substrate at base of turbines or along submarine cables could impact sampling ability
	• Changes in scallop distribution, abundance, aggregations, vital rates will impact sampling design
	• Changes in pelagic habitat from "wind wake" may impact survey detectability of recruitment
	• Changes in species composition in and around turbines may impact sampling efficiency
	• Increased sedimentation/turbidity may impact visibility for optical tools
Reduced Sampling	• Potential loss of biological sampling ability
	• Increased transit and sampling time may reduce survey productivity
	• Increased costs for use of commercial vessel platforms (e.g., fuel, insurance, safety gear, sea day expenses)
	• Reduced pool of vessels to conduct surveys
	• Additional sampling constraints (e.g., daytime only, weather)
	• Required calibrations

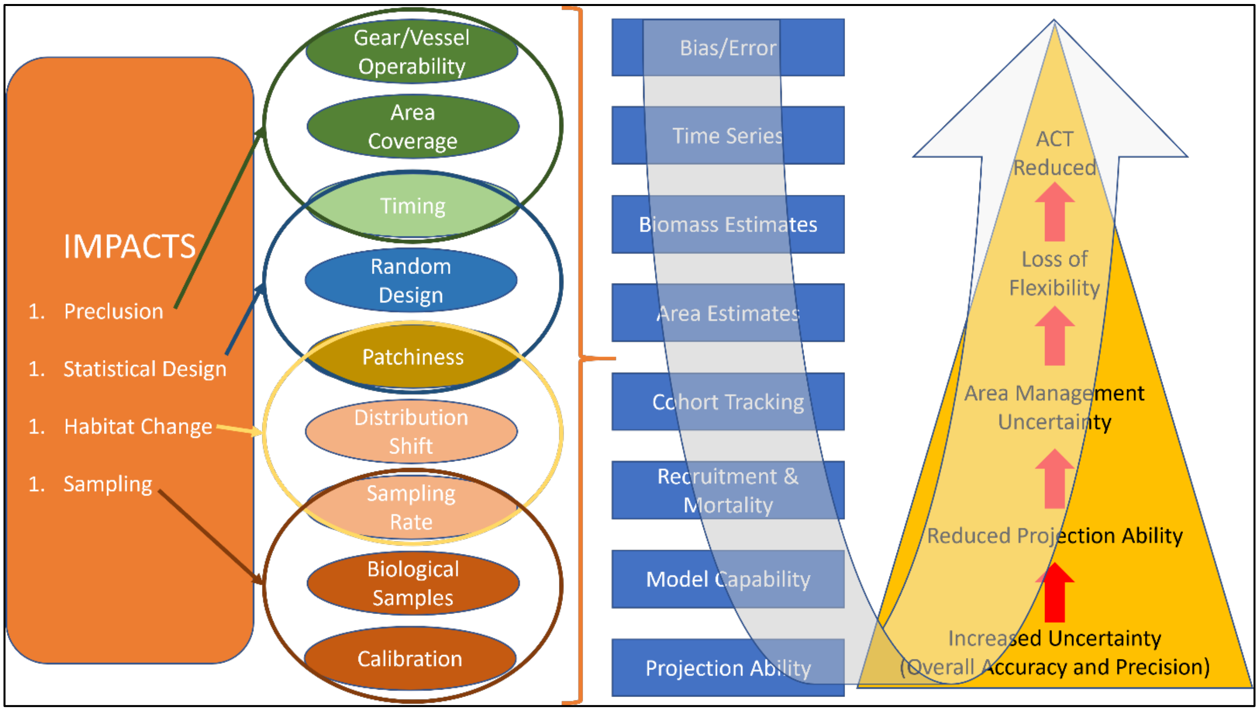

Figure 20. Potential effects and impacts of wind development activities on scallop survey operations and on provision of scientific advice to management.

The SSWG followed the framework of the NOAA/BOEM (2022) survey mitigation components and mitigation implementation strategy to develop recommendations for mitigating impacts to the scallop survey system that should be considered as components of an overall scallop survey mitigation program.

7.2 Recommendations and Implementation Strategies

Provide additional resources in order to implement a NOAA Northeast federal survey mitigation program.

Rationale:
The SSWG emphasized the need for dedicated new and additional annual resources to develop and implement a program to mitigate impacts from the development of offshore wind on the scallop surveys. The group highlighted the extensive spatial and temporal scales of offshore wind development on the east coast and strongly recommended that new sources of funding and dedicated personnel are needed to address impacts to fishery resource surveys. The SSWG specifically emphasized that there are currently insufficient resources to both maintain the current scallop survey needs and develop and implement a survey mitigation program, and that such a major change to the marine user environment requires new annual dedicated resources.

Conduct simulation modeling to characterize the impacts of offshore wind energy development on the scallop survey system and assess the feasibility of alternative sampling methods.

Rationale:

The SSWG highlighted unique strengths and challenges of the scallop survey system in relation to the development of offshore wind energy. The ability to apply a variety of sampling tools and methods (e.g., random stratified dredge, transect towed optical, and grid stationary optical) at different spatial scales throughout the scallop resource range, combined with the ability to integrate data products from multiple survey designs to generate biomass and density estimates provides a high level of flexibility to meet science and management objectives. However, there is uncertainty about the utility of all survey tools and methods within and around wind turbine arrays, as well as the potential for increased uncertainty in generated data products resulting from changes to survey designs. The SSWG raised questions about the implications of unavailable and unknown scallop biomass for stock assessment and management advice. The SSWG noted that the NEFSC, in collaboration with UMass Dartmouth and BOEM, are conducting simulation modeling to better understand impacts from offshore wind energy on the *R/V Bigelow* Bottom Trawl Survey through the Survey Simulation Evaluation and Experimentation Project (SSEEP) and recommended that a simulation modeling approach could be applied for scallop surveys with a set of defined questions. Simulation modeling for the scallop survey does not have to reflect efforts for the bottom trawl survey.

Implementation Strategies:

- The SSWG recommended that the NEFSC and Council consider mechanisms to coordinate, fund, and conduct simulation modeling to evaluate impacts from the development of offshore wind energy and identify potential mitigation strategies.
- The SSWG recommended that the Council include simulation modeling to characterize impacts from wind areas on scallop surveys in the 2023/2024 Scallop RSA Priorities, as well as future RSA Priorities.
- The SSWG suggested that a simulation modeling approach should consider, but not be limited to, the following questions:
    - What are the impacts on the ability to support science and management?
        - Consider the effects of lost coverage areas, lost biological sampling ability, and shifts in survey timing on estimates of uncertainty.
        - Consider implications of increased uncertainty for stock assessment, projection models, and catch advice.
        - Consider multiple spatial and temporal scales that may inform design of new surveys as wind energy development advances.
    - How do we expect wind installations may alter habitat and impact ability to conduct surveys?
        - Consider effects of changes to the physical environment, as well as possible changes in scallop distribution, abundance, density, and vital rates on the ability to conduct surveys and generate data products.
- The SSWG recommended that simulation modeling efforts should consider all available relevant information, including redesigned scallop survey strata and explorations of excluding historical survey tows from wind areas, and should examine the overall scallop survey system rather than focus on individual survey tools.
- The SSWG noted that this is an IMPORTANT recommendation that may be developed over multiple years while continuing to conduct existing surveys.

Develop guidelines for offshore wind monitoring surveys to collect data and generate data products to supplement the scallop survey system.

Rationale:
BOEM guidance for permitting offshore wind energy projects includes recommendations for pre- and post-construction monitoring surveys to be conducted by energy companies. The SSWG noted that information collected from these surveys may be useful to fill gaps or supplement data collected by existing scallop surveys. Currently, there are not federal requirements for scallop-specific data collection by these surveys, and state-specific requirements are not coordinated. The SSWG recommended providing guidelines and protocols to enhance scallop-related data collection and generated data products.

Implementation Strategies:
- The SSWG emphasized that differences in data collection protocols between wind monitoring and existing resource surveys should be minimized.
- The SSWG recommended that NOAA and the Council provide information from the Scallop Survey Guiding Principles document to offshore wind energy companies to serve as guidance for data collection during monitoring surveys.
- The NEFSC and Council should consider Scallop RSA-funded projects focused on testing the feasibility of scallop data collection on wind company monitoring surveys to assess the utility of alternative survey tools and designs and the quality of generated data products to support science and management.
- The SSWG recommended that the NEFSC and Council evaluate methods to integrate new and alternative survey data products, considering calibration needs and estimates of uncertainty.
- The SSWG suggested that NOAA and the Council coordinate with BOEM to identify key wind company personnel to ensure that data is publicly available and assist in developing strategies to leverage data collection efforts.

The scallop survey enterprise should develop robust strategies that can be implemented over multiple timescales.

Rationale:
Siting, planning, and permitting of offshore wind energy projects has ramped up in recent years, but construction is just beginning. The existing scallop survey system is likely to continue normal operations in the near-term, but new survey tools and designs that are capable of operating in a variety of turbine configurations and spatial scales will be required in the future. The SSWG emphasized the long-term, large-scale proposals for offshore wind energy on the east coast and recommended the need to start planning and developing new tools in the near-term. The group noted that the NEFSC is currently developing autonomous underwater optical systems that may be operable in and around wind installations in the future and suggested that new survey tools could also be developed through RSA projects.

Implementation:
- Develop, test, evaluate, and implement new survey tools to supplement existing tools.

- Consider individual and cumulative spatial and temporal scales and designs of wind installation areas.
- Consider all types of wind installations (e.g., fixed and floating arrays, undersea cables).
- The SSWG recommends that strategies be developed iteratively as wind energy installations advance.

Utilize existing information to inform future survey strategies.

Rationale:
The SSWG highlighted several areas of completed or ongoing research that could be useful to inform future survey strategies in the context of offshore wind energy development. The Scallop RSA program has funded several projects related to changes in scallop distribution resulting from natural and anthropogenic drivers, effects of climate change on scallop biology, and development of underwater optical technology. The SSWG strongly recommended the use of existing information on the utility of survey tools and sampling designs, habitat and population modeling, and assessment and projection methods to inform future survey strategies in and around wind development areas.

Implementation Strategies:
- The SSWG recommended consideration of RSA project reports to characterize impacts associated with the development of offshore wind energy and design future survey approaches.
- The SSWG recommended that RSA project reports and other scallop research related to wind impacts continue to be made publicly available and be included in NOAA's tracking of research products, as described in the NOAA/BOEM mitigation implementation strategy Objective 4.3.
- The SSWG recommended examination of existing information about habitat types and features that preclude or impact normal survey operations (e.g., gear conflict areas, shipwrecks, boulder fields, artificial reefs, etc.) to provide insight about potential impacts from wind arrays.
- The SSWG recommended consideration of work products from other global regions, including the ICES Working Group on Unavoidable Survey Effort Reduction.

Ensure mitigation approaches and implementation strategies are coordinated between NEFSC and RSA survey partners.

Rationale:
The NOAA/BOEM mitigation implementation strategy is generally focused on impacts to NOAA Fisheries surveys, including the NEFSC dredge and HabCam surveys. The scallop survey system includes several partner organizations beyond the NEFSC that must be considered as mitigation implementation strategies are developed.

Implementation Strategies:
- The SSWG highlighted actions under Goal 3 of the NOAA/BOEM strategy:
    - Goal 3: *Collaboratively plan and implement NOAA Fisheries survey mitigation with partners, stakeholders, and other ocean-users.*

8.0 TOR #4 – FUTURE STOCK ASSESSMENT NEEDS

Identify and catalogue the survey data products needed to support stock assessment approaches in the future and outline a process for modifying the scallop survey system to collect identified data products.

Description:

- *This TOR will include, but not be limited to, the following items:*
    - *Description of survey data outputs needed to support potential changes to stock assessment models, including age samples and ageing methods, growth information and density-dependent effects, scallop meat weight sampling, and estimates of fecundity.*
    - *Consider survey data products and survey spatial scale needed to support a spatially explicit methodology for forecasting the abundance and distribution of sea scallops by incorporating spatial data from surveys, landings, and fleet effort.*

The SSWG addressed TOR #4 by first considering whether the current survey system collects and produces data products needed to support the existing stock assessment and projection models. The group then considered what additional or alternative data products would be required to support stock assessment and projection approaches in the future. The SSWG discussed potential alternative stock assessment methods that could be applied for scallops in the future, but they suggested that the Research Track Assessment for Sea Scallops is the most appropriate process to identify specific methods and analyses. The catalogue of data collection approaches and data products addresses TOR #4 objectives to support stock assessment and projection approaches in the future.

8.1 CATALOGUE OF DATA COLLECTION AND PRODUCTS

The scallop stock is currently assessed with a length-based, dynamic, non-equilibrium model based on a forward simulation approach, called the Catch at Size Analysis (CASA) model. The scallop stock assessment approach also includes a Stochastic Yield Model (SYM) for calculating reference points and their uncertainty. Annual scallop management is supported by the Scallop Area Management Simulator (SAMS) model used to project scallop abundance and landings (NEFSC, 2018). The SSWG evaluated the data products from the current scallop survey system and concluded that the system collects the required information to generate data products to support the CASA and SYM assessment models and the SAMS projection model (Appendix 1).

In recent years, there has been interest in investigating alternative assessment methods for scallops, potentially using an age-based approach. An age-based model calibrates a length-based model and includes a description as to whether or not the age-length relationship is constant throughout the exploited range of the fishery and/or constant over time. It can also improve description of recruitment in species where age estimation for small/young individuals is difficult, and description of mortality where age estimation of large/old individuals is difficult, both of which are the case for scallops (Mann et al., 2019). There has also been interest in applying scallop gonad weight instead of adductor muscle (meat) weight to assess stock status and calculate biological reference points. Additionally, a geostatistical projection model

(GeoSAMS) to characterize spatial variation in scallop distribution is under development. The SSWG considered the survey data requirements needed to support development of an age-based assessment approach, a fecundity-based reference points approach, as well as a geostatistical projection model (Table 9).

Table 9. Scallop survey data needs and requirements to support future stock assessment and projection methods.

Assessment Topic	***Scallop Survey Needs***
Age Samples and Aging Methods	• Continued collection of age samples (shells) for laboratory analysis
	• Continue explorations of aging methods using resilium
	• Annual age samples are required to produce annually-specific age-length keys, survey and fishery ages, annual growth information
Density-Dependent Effects	• Integrate information from other resource surveys beyond scallops
	• Characterization of condition factor by examining shells at sea and in the laboratory
Fecundity Estimates	• Continued collection of gonad weights at sea (wet weights)
	• Continue evaluation of wet and dry gonad weight ratios
	• Annual samples are required to develop gonad-based biological reference points
Spatial Scale	• All types of scallop survey data are needed from regions off Cape Cod, the Gulf of Maine, and the Northern Gulf of Maine management area to support inclusion in stock assessments, in addition to Georges Bank and Mid-Atlantic resource areas
	• Sampling should link the Great South Channel to the Gulf of Maine
	• Future surveys and assessments should consider changing distribution and geographic range of the scallop resource
	• Survey coverage should encompass areas of deeper water further offshore
Geostatistical Projections	• Autocorrelated data from HabCam is required to support geostatistical modeling approaches

9.0 CONCLUSIONS

The Scallop Survey Working Group thoroughly assessed the current scallop survey system (TOR #1), including the collective survey coverage and sampling intensity, data management, and RSA survey priorities and processes and concluded that the overall system represents one of the best data collection programs in the world. The group highlighted several strengths, including multiple independent estimates of biomass, abundance, and density, as well as the ability to integrate estimates to provide robust information to support scallop science and management objectives. The working group focused recommendations on areas for improvement, emphasizing the need for better coordination in determining survey coverage and critically needed investments for data management.

The SSWG's addressed TOR #2 by developing consensus-based iterations of ideas for new approaches. The group did not endorse an optimized structured design for future surveys. Instead, they collaboratively and collegially developed recommendations for guiding principles and coordination strategies under the objective of supporting data collection protocols and delivering data products to provide highest quality information for science, management, and the fishing industry.

The SSWG also considered future needs of the scallop survey system in a changing environment that includes offshore wind energy installations (TOR #3) and potential new approaches for stock assessments and projections (TOR #4). The group noted that aspects of the scallop survey system may help to minimize impacts from offshore wind development, including a range of tested and applied physical and optical survey tools, ability to adapt to model-based survey designs, and methods to integrate multiple data streams. They noted that data collection protocols and required data products to support alternative assessment approaches have been developed and time series of information are expanding. They focused recommendations on survey needs over multiple time-scales, recognizing the scope and scale of wind energy planning and changes in scallop distribution resulting from climate change.

The SSWG appreciated the opportunity to consider and provide recommendations for potential improvements to the scallop survey system. Working group members and the broader community of survey partners remain committed to assisting the Council and NOAA in implementing recommendations and advancing the scallop survey.

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Atlantic Sea Scallop Survey Working Group Report: Appendix 1

NEFSC Cruise & Tow Data Fields

Attribute	Data Type	Description	Notes
CRUISE_ID	NUMBER(10)	Uniquely identifies a cruise/survey	
OPERATION_ID	NUMBER(10)	Uniquely identifies a single operation within a cruise	The operation_id represents our legacy STATION identifier that organizes and identifies all data collected for each dredge or HabCam tow
STRATUM	VARCHAR2(5)	A predefined area where a net dredge, or other piece of gear was deployed. Code consists of 2 parts: Stratum group code number (2 bytes) and stratum number (3 bytes). Stratum group refers to if area fished is inshore or offshore North or South of Cape Hatteras or the type of cruise (shellfish, State of MA, offshore deepwater). The stratum number (third and fourth digits of code) refers to area defined by depth zone. See SVDBS.SVMSTRATA. The fifth digit of the code increases the length of the stratum number for revised strata after the Hague Line was established. Stratum group code: 01 = Trawl, offshore north of Hatteras; 02 = BIOM; 03 = Trawl, inshore north of Hatteras; 04 = Shrimp; 05 = Scotian shelf; 06 = Shellfish; 07 = Trawl, inshore south of Hatteras; 08 = Trawl, Offshore south of Hatteras; 09 = MA DMF; 99 = Offshore deepwater (outside the stratified area). A change in Bottom Trawl Stratum for the Gulf of Maine-Bay of Fundy has been in effect since Spring 1987, and may be summarized as follows: Previous strata: 01350; Present strata:	
LATITUDE	NUMBER(9,4)	GPS captured latitude in the form of Degrees Minutes Decimal Minutes and hemisphere (e.g., DDMM.MMMM N or S)	Collected at a one second log rate and used to derive the following elements: Begin Operation Latitude (Degrees Decimal Minutes), End Operation Latitude (Degrees Decimal Minutes), Begin Operation Latitude (Decimal Degrees), End Operation Latitude (Decimal Degrees).
LONGITUDE	NUMBER(9,4)	GPS captured longitude in the form of Degrees Minutes Decimal Minutes and hemisphere (e.g., DDMM.MMMM W or E)	Collected at a one second log rate and used to derive the following elements: Begin Operation Longitude (Degrees Decimal Minutes), End Operation Longitude (Degrees Decimal Minutes), Begin Operation Longitude (Decimal Degrees), and End Operation Longitude (Decimal Degrees)
TOW_DISTANCE	NUMBER(5,3)	Distance in nautical miles the vessel travelled while the dredge was fishing (Between the Start Dredge and Haul Back button presses)	

VESSEL_SPEED	NUMBER(3,1)	GPS captured vessel speed in knots	Collected at a one second log rate and used to derive minimum, maximum, and average vessel speed during an operation
AVG_VESSEL_SPEED	NUMBER(4,2)	Mean vessel speed in knots during the dredge fishing operation (Between Start Dredge and Haul Back button	Calculated using the VESSEL_SPEED logged data
VESSEL_COURSE	NUMBER(4,1)	GPS captured course the vessel made good in degrees.	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
VESSEL_HEADING	NUMBER(4,1)	Vessel compass heading.	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
VESSEL_NAME	VARCHAR2(2)	Vessel name abbreviation (2	
DEPTH	NUMBER(5,1)	vessel sounder depth in meters below the surface	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck. Logged data are used to create derived depth data fields (e.g., min, max, and average depth).
SETDEPTH	NUMBER(4)	Depth to the nearest meter when the dredge started fishing	
ENDDEPTH	NUMBER(4)	Depth to the nearest meter when the dredge stopped fishing	
MINDEPTH	NUMBER(4)	Minimum depth to the nearest meter during dredge fishing	
MAXDEPTH	NUMBER(4)	Maximum depth to the nearest meter during dredge fishing	
AVGDEPTH	NUMBER(4)	Mean depth to the nearest meter during the dredge fishing	
DREDGE_DEPTH	NUMBER(6,2)	Depth of dredge in meters below the surface	Collected at a one second log rate with a StarOddi sensor
DREDGE_TEMPERATURE	NUMBER(4,2)	Seawater temperature in degrees Celsius at the dredge depth	Collected at a one second log rate with a StarOddi sensor
DREDGE_WINCH_SPEED	NUMBER(2)	Dredge winch payout rate measured in meters/minute	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
DREDGE_WINCH_WIREOUT	NUMBER(5,1)	Dredge winch wire deployed measured in meters	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
DREDGE_WINCH_TENSION	NUMBER(7)	Dredge winch wire tension measured in pounds	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
DREDGE_HEAVE	NUMBER(3)	Dredge heave measured in degrees	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
DREDGE_PITCH	NUMBER(3)	Dredge pitch measured in degrees	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
DREDGE_ROLL	NUMBER(3)	Dredge role measured in degrees	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck
TIMESTAMP	TIMESTAMP	Oracle timestamp includes both date and time with time measured to the nearest millisecond	Collected at a one second log rate starting when the gear is deployed and stopped when the gear is back on deck

TOW_DURATION	NUMBER(4.2)	Dredge towing duration to the nearest hundredth of a minute	
STREAM_DREDGE	DATE	Date/time to the nearest second when the dredge started being deployed	
START_DREDGE	DATE	Date/Time to the nearest second when the dredge started fishing	
HAUL_BACK	DATE	Date/Time to the nearest second when the dredge started being hauled back	
DREDGE_AT_SURFACE	DATE	Date/Time to the nearest second when the dredge was at the surface	
SURFACLE_WATER_TEMPERATURE	NUMBER(6,3)	Sea surface water temperature measured in degrees Celsius	CTD used to capture data but only on a subset of overall tows.
BOTTOM_WATER_TEMPERATURE	NUMBER(6,3)	Sea bottom water temperature measured in degrees Celsius	CTD used to capture data but only on a subset of overall tows.
SURFACE_WATER_SALINITY	NUMBER(6,3)	Sea surface water salinity measured in parts per thousand	CTD used to capture data but only on a subset of overall tows.
BOTTOM_WATER_SALINITY	NUMBER(6,3)	Sea bottom water salinity measured in parts per thousand	CTD used to capture data but only on a subset of overall tows.
DREDGE	VARCHAR2(50)	Name uniquely identifying the dredge used during an operation	
DREDGE_ACCESSORY	VARCHAR2(50)	Name uniquely identifying the dredge accessory attached for rock tows	
CTD	VARCHAR2(50)	Name uniquely identifying the CTD used during an operation	
INCLINOMETER	VARCHAR2(50)	Name uniquely identifying the bottom contact sensor used during an	
OPERATION_COMMENTS	VARCHAR2(4000)	Any information provided about the operation by watch leadership	

NEFSC Biological Data Fields

Aggregate Catch Attributes			
Attribute	**Data Type**	**Description**	**Notes**
SPECIES_NAME	VARCHAR2(80)	Field identified species name	
ITIS_TSN	NUMBER	Integrated Taxonomic Information System (ITIS) Taxonomic Serial Number (TSN) assigned a species	The ITIS TSN has been collected since 2011 on bottom trawl surveys and starting in 2017 on scallop surveys. A lookup table has been established to match legacy SVSPP species codes to their ITIS TSN.
SVSPP	VARCHAR2(3)	A standard code which represents a species caught in a trawl or dredge. Refer to the SVDBS.SVSPECIES_LIST	
CATCHSEX	VARCHAR2(1)	Code used to identify species that are sexed at the catch level. See SVDBS.SEX_CODES	
RECCATCHNUM	NUMBER(8)	The total number of individuals of a given species in the sample	
EXPCATCHNUM	NUMBER(8)	The total number of individuals of a given species after sub-sampling expansion factor has been applied.	
RECATCHWT	NUMBER(9,3)	The total weight of all individuals of a species in the sample	
EXPCATCHWT	NUMBER(9,3)	The total weight of all individuals of a species after sub-sampling expansion factor has been applied	
CATCH_COMMENT	VARCHAR2(500)	Any comments related to species at the aggregate level	
Aggregate Length Attributes			
LENGTH	NUMBER(5,2)	Length of species stored in cm	
RECNUMLEN	NUMBER(8)	Total number of individuals of the given length in the sample	
EXPNUMLEN	NUMBER(8)	Total number of individuals of the given length after sub-sampling expansion factor has been applied.	
Individual Organism Attributes			
INDID	NUMBER(6)	Unique identifier for an organism	
LENGTH	NUMBER(5,2)	Individual organism length stored in cm	Represents the accepted measurement standard for a given species (e.g., sea scallop - Shell height); Lengths are measured in mm but stored as cm in presentation database model
WEIGHT	NUMBER(7,3)	Individual weight of the organism prior to further processing	
SEX	VARCHAR2(1)	Code identifying the sex of the organism	
MATURITY	VARCHAR2(2)	Code identifying the stage of gonad maturation of the organism	
SHELL_WIDTH	NUMBER(5,2)	Width measurement stored in cm for sea scallops	
GONAD_WEIGHT	NUMBER(7,3)	Weight of sea scallop gonad measured in kg	
MEAT_WEIGHT	NUMBER(7,3)	Weight of the sea scallop adductor muscle measured in kg	
AGE_SAMPLE	VARCHAR2(240)	Barcode value of saved age sample	
COMMENSAL_ORGANISMS	VARCHAR2(240)	Identification of commensal organisms present in sea scallop	Multiple choice of Liparid and Red hake available
DISEASE_PRESENT	VARCHAR2(240)	Identification of disease present in sea scallop	Multiple choice of Shell Blisters, Nematodes, Orange Nodules, and Gray Meats available
EXPANSION_FACTOR	NUMBER(11,6)	Sub-sampling expansion factor applied to the organism	

NEFSC HabCam Data Fields		
Attribute	**Data Type**	**Description**
imagename	imagename(text)	Stereo image file for this database entry
lat	lat(numeric(10,6)	Habcam Vehicle Lattitude
lon	lon(numeric(11,6)	Habcam Vehicle Longitude
head	head(numeric(12,2)	Habcam Vehicle Heading
pitch	pitch(numeric(7,2)	Habcam Vehicle Pitch
roll	roll(numeric(22,2)	Habcam Vehicle Roll
alt1	alt1(numeric(12,2)	Habcam Vehicle Altimeter reading
alt2	alt2(numeric(12,2)	Habcam Vehicle Second Altimeter reading
vehicle_depth	vehicle_depth(numeric(7,2)	Habcam Vehicle Depth from surface
s	s(numeric(7,2)	Salinity level
t	t(numeric(7,2)	Turbidity level
o2	o2(numeric(7,2)	Disolved Oxygen sensor measurement
cdom	cdom(numeric(7, 2)	CDOM (Colored Dissolved Organic Matter) sensor measurement
chlorophyll	chlorophyll(numeric(7,2)	chlorophyll sensor measurement
backscatter	backscatter(numeric(7,2)	Ocean backscatter sensor measurement
therm	therm(integer)	Water temperature measurement
internal_ph	internal_ph(numeric(7,4)	Measured internal sensor acidity level
external_ph	external_ph(numeric(7,4)	Measured external sensor acidity level
timestamp	timestamp(timestamp with time zone)	Exact date and time vehicle measurements were recorded
st_alt	st_alt(numeric(12,2)	Altitude calculated from Stereo camera image
fov	fov(numeric(7,4)	Stereo Camera field of view value
fov_src	fov_src(text)	Stereo Camera field of view calculation
mm_px	mm_px(numeric(7,4)	Size of each image pixel in millimeters
bottom_depth	bottom_depth(numeric(12,4)	Distance to bottom from ocean surface

VIMS Data Fields

Data Table and Field	Definition
Trip Table	
Cruise ID	Unique cruise identifier
Vessel Name	Vessel name
LOA	Vessel length (ft)
HrsePowr	Vessel horsepower
DocNum	USCG Documentation Number
PermNum	Permit number
Captain	Captain's name
GearWid	Commercial dredge width (ft)
CrewSize	Number in crew
Grounds	Area fished
DateBeg	Date trip began (M/D/YY)
DateEnd	Date trip ended (M/D/YY)
ProjDesc	Description of project
Comments	Comments or problems
Stratum Area Tables	
Stratum	NMFS stratum
Area	Area (km2)
SurveyArea	Survey domain
Comments	Comments or problems
SAMS Areas Tables	
SAMS_Area	Area designation from yearly SAMS shapefiles
Region	Region designation from yearly regional shapefiles
Zone	Zon3e designation from yearly regional shapefiles
Stratum	Strata designation from NMFS strata
Area	Area (km2)
Weight	Weight of stratum area within region/zone
Comments	Comments or problems
Station Table	
StationID	Unique station identifier
CruiseID	Unique cruise identifier
Tow	Sequential numbering of tows within a trip
Station	Station number
Decklog	Was there a deck log (Y/N)
ScalSamp	Were scallops sampled (Y/N)
FishSamp	Were fish sampled (Y/N)
TowStartDate	Date the town started (M D Y)
TowStartTime	Time that tow started - UTC Time Zone
TowEndDate	Date that tow ended (MDY)
TowEndTime	Time that tow ended - UTC Time Zone
LatDBeg	Latitude degrees - start of tow
LatMBeg	Latitude minutes (Decimal) - start of tow
LonDBeg	Longitude degrees - start of tow
LonMBeg	Longitude minutes (Decimal) - start of tow
LatDEnd	Latitude degrees - end of tow
LatMEnd	Latitude minutes (Decimal) - end of tow
LonDEnd	Longitude degrees - end of tow
LonMEnd	Longitude minutes (Decimal) - end of tow
ClosArea	Tow in closed area (Y=Closed Area, N=Open Area)
TowType	S=survey, T=tow duration
GearConfigPrt	Gear configuration on Port side (Commercial or Survey dredge)
GearConfigStbd	Gear configuration on Starboard side (Commercial or Survey dredge)
Depth	Depth recorded at the beginning of tow (fathoms)
WireOut	Amount of Wire Out (fathoms)
WSpdMin	Minimum wind speed (knots)
WSpdMax	Maximum wind speed (knots)
WindDir	Wind direction (compass degrees)
SeaStMin	Minimum Wave Height (ft)
SeaStMax	Maximum Wave Height (ft)
TowQualP	Tow quality Port side (G=good, F=foul, H=hang)
TowQualS	Tow quality Starboard side (G=good, F=foul, H=hang)

BiomassTowsSurv	Survey Dredge Tow included in biomass calculations (Y/N)
BiomassTowsComm	Commercial Dredge Tow included in biomass calculations (Y/N)
AvgDepth	Average depth over the course of the tow from the inclinometer (fathoms)
AvgTemp	Average bottom temperature over the course of the tow from the inclinometer (F)
AvgAngle	Average dredge angle over the course of the tow from the inclinometer (degrees)
TowDist	Tow distance from inclinometer (m)
Comments	Comments or problems
Recordr	First recorder initials
Stratum	NMFS Shellfish Stratum Number
Subarea	Name of subarea
extent	Indicator variable designating whether the station was in the NMFS SAMS estimation area of the extended VIMS area
Inclnmtr	Inclinometer used (Y/N)
InclnFil	Inclinometer filename
Proposed_Lat	Generated latitude from proposed station location (decimal degrees)
Proposed_Lon	Generated longitude from proposed station location (decimal degrees)
SAMS_Region	Final SAMS area region used for biomass calculations in a year
SAMS_Zone	Final SAMS area zone used for biomass calculations in a year
Commercial Dredge Specs	
NumberOfSupports	Number of Supports
ShoeCondition	Dredge shoe condition
CuttingBarShoeDistance	Cutting bar shoe distance
WheelsPresent	Wheels present (Y/N)
WheelDiameter	Wheel diameter
PressurePlateDimensions	Pressure plate dimensions
PressurePlateAngleOfAttack	Pressure plate angle of attack
RockChainSize	Rock chain size
RockChainNumUpDowns	Rock chain number of vertical and horizontal rows
RockChainNumTicklers	rock chain number of tickler chains
RockChainAttachmentPoint	rock chain attachment point on dredge
SweepChainSize	Sweep chain size
SweepLinkNum	Sweep chain number of links
UnderRingBagRingSize	Size of rings under bag
UnderRingBagDiamond	Under ring bag mesh
UnderringBagBelly	Under ring bag belly size
UnderRingBagLinkConfig	under ring bag link configuration
ChafingGearType	Chafing gear type
ChafingGearAmount	Chafing gear amount
ClubStickLength	Club stick length
ClubStickCookieNum	Number of cookies on club stick
ClubStickCookieSize	Size of cookies on club stick
TopRingBagApron	Top ring bag apron size
TopRingBagExtensions	top ring bag extension number
TwineTopMeshSize	Twine top mesh size
TwineTopMeshOrientation	Twine top mesh orientation
TwineTopMeshDimensions	Twine top mesh dimensions
TwineTopNumMeshes	Number of meshes in twine top
TwineTopNumRings	Number of rings in twine top
Species Code Table	
SpCode	Unique identifier for each species
CommonName	Species common name
Number Table	
NumberID	Uniquely identifies each number entry
Len_Mode	Length class of animals that were grouped with respect to a subsampling fraction
NumberCaught	Number caught (scallops = number of bushel baskets, finfish = number of individuals)
NumberMeasured	Number measured (scallops = number of bushel baskets, finfish = number of individuals)
FractionSampled	Fraction of total sampled (NumberMeasured/NumberCaught)
SH:MW and Meat Quality Table	
SHMW_ID	Unique identifier for each SHMW record
Shell_Height	Shell height measurement (mm)
Market	Marketability score from 1 (worst) to 4 (best)
Color	Color score from 1 (worst) to 4 (best)
Texture	Texture score from 1 (worst) to 4 (best)
Disease	Disease score from 4 (no disease) to 1 (severe)

Meat_Weight	Weight of adductor muscle meat (g)
Nematodes	Nematode presence indicated by 0/1
Incidence	Number of nematode lesions observed
Gonad_Weight	Weight of gonad (g)
Size Frequency Table	
SizeFreqID	Unique identifier for each size frequency entry
Length	Total length (mm)
NumberAtSize	Sum of the unexpanded number of organisms at each length
Age Table	
AgeID	Uniquely identifies each number entry
Station ID	Unique identifier for station
ShellNum	Unique shell identifier
AgeMethod	E for external ring, R for resilium
ShellHeight	Total length (mm)
Resilia	Resilium age
H0 - H17	1st to 18th measurement increments (mm)
CommDredgeID	Unique identifier for commercial dredge configuration used on cruise
CruiseID	Cruise identifier
Dredge_Type	Indicates dredge type - New Bedford or Turtle Deflector
TowWireDiameter	Diameter of tow wire
BullRing Diameter	Diameter of bull ring
ShackleSize	Size of shackles
DredgeWidth	Width of commercial dredge
Maturity Table	
MaturityID	Unique identifier for maturity data
SpCode	NMFS Species Code
Length	Length of Animal
Sex	Sex of animal
Stage	Reproductive stage of animal
Garbage Table	
GarbageID	Code for trash
TrashSpecies	Species code
SpeciesName	Species or species group classification
Hakes Table	
HakeID	Cod for hake
HakeSpecies	Number indicating the hake species
Turtle Table	
TurtleID	Unique identifier for each turtle captured
TurtleSpecies	Turtle species name
WhereinDredge	Location in dredge of turtle catch
EstSize	Size of turtle
TurtleStatus	Turtle condition upon catch
TurtleInjured	Turtle injuries present
DescriptionofInjuries	Description of turtle injuries
Resuscitate	Was resuscitation required
ReleaseCondition	Turtle condition upon release
Comments Table	
CommentID	Unique identifier for each comment
StationID	Identifies the tow
Comment	Comment or problem
Level	For certain comments, level of catch
Side	Identifies side

Maine DMR Data Fields

Data Field	Definition
PROJECT_NAME	Survey project name
PROJECT_SEQ_NO	Survey project sequence number
DMR_TRIP_IDENTIFIER	Unique trip ID
TRIP_START_DATE	Survey start date
TRIP_START_TIME	Survey start time
TRIP_END_DATE	Survey end date
TRIP_END_TIME	Survey end time
TRIP_PORT_CODE	Departure port
TRIP_COMMENTS	Comments
TRIP_UPDATE_DATE	Trip data modifications date
TRIP_UPDATE_USER	Trip data modifications person
SURVEY_TYPE	Survey type
TRIP_TYPE	Trip type
WEATHER	Weather conditions
PRECIP	Precipitation (Y/N)
WIND_SEA	Wind and sea height
CAPTAIN	Captain's name
LBS_LANDED	Pounds of scallops landed
CRUISE	Cruise name
EFFORT_SEQ_NO	Effort number
DMR_EFFORT_IDENTIFIER	Unique effort ID
EFFORT_START_DATE	Effort start date
EFFORT_START_TIME	Effort start time
EFFORT_END_DATE	Effort end date
EFFORT_END_TIME	Effort end time
LOCATION_ID	Unique effort location ID
GEAR_CODE	Survey gear code
GEAR_QUANTITY	Number of dredges
GEAR_COMMENTS	Comments about gear
EFFORT_COMMENTS	Comments about effort
EFFORT_UPDATE_DATE	Effort data modifications date
EFFORT_UPDATE_USER	Effort data modifications person
TOW_STATION	Station for tow
AREA	Area for tow
DREDGE_IN_TIME	Time of dredge deployment
DREDGE_IN_LATDD	Latitude at dredge deployment
DREDGE_IN_LONDD	Longitude at dredge deployment
TOW_START_LATDD	Latitude at dredge tow start
TOW_START_LONDD	Longitude at dredge tow start
HAULBACK_LATDD	Latitude at dredge haul back
HAULBACK_LONDD	Longitude at dredge haul back
DEPTH	Water depth
BOTTOM_TYPE	Bottom substrate
TOW_TYP	Tow status
TOWABLE	Ability to tow dredge
STRATUM	Stratum of tow
PICT_ID	Tow picture ID

TOW_LENGTH	Tow length
TOW_WIDTH	Tow width
TOW_SPEED	Tow speed
TIDE_ASPEC	Tide aspects
TIDE_STATUS	Status of tide
WIRE_OUT	Length of wire out
SPECIES_ITIS_CODE	Species code
CATCH_WEIGHT	Catch weight
CATCH_WEIGHT_TYPE	Catch weight type
DISPOSITION	Species disposition
REPORTED_QUANTITY	Species quantity
CATCH_WEIGHT_UNIT	Catch weight units
CATCH_COMMENTS	Catch comments
CATCH_UPDATE_DATE	Catch data modifications date
CATCH_UPDATE_USER	Catch data modifications person
VOLUME	Catch volume
SAMP_PROP	Sampling properties
CLAPPERS	Scallop clappers
ABUND	Abundance
LEGAL_VOL	Volume of legal sized catch
SUBL_VOL	Volume of sub-legal sized catch
FREQUENCY	
SAMPLE_LENGTH	Sample length
SAMPLE_LENGTH_TYPE	Sample length type
SAMPLE_LENGTH_UNIT	Sample length unit
SAMPLE_WEIGHT	Sample weight
SAMPLE_WEIGHT_TYPE	Sample weight type
SAMPLE_WEIGHT_UNIT	Sample weight unit
SEX	Sex
SAMPLE_COMMENTS	Sample comments
SAMPLE_UPDATE_DATE	Sample data modifications date
SAMPLE_UPDATE_USER	Sample data modifications person
DIAM_A	Shell diameter measurements
DIAM_B	
SHELL_LENGTH	Shell length
SHELL_DEPTH	Shell depth
SAMP_MEAS	
SUB_AREA	
logSH	Modeled shell height
logMT	Modeled meat weight
samp_count	Number of samples
LF	Length frequency
pred_MT	Projected exploitable biomass
prerecruit_MT	Biomass of pre-recruits (<35mm)
recruit_MT	Biomass of recruits (35-75mm)
harvestable_MT	Biomass of adults (>75mm)

SMAST Data Fields

Data Field	Definition
surveyYear	Year
cameraControlPK	Camera ID
resolution	Survey grid resolution (km)
areaLongName	Survey region
areaShortName	Survey sub-area
areaControlPK	Sub-area ID
station	Station #
quadrat	Quadrat #
latitude	Latitude
longitude	Longitude
depthFathoms	Water depth (fm)
surveyDTTM	Sample date and time
updatedPK	Laboratory annotation information ID
surveyRawDataPK	Onboard annotation information ID
imageExists	Image at each quadrat (presence/absence)
isImageOfInterest	Special images (presence/absence)
sand	Presence/absence/counts of species and substrate types
sandRipple	
shellDebris	
silt	
gravel	
cobble	
rock	
wasVisible	
scallops	
clappers	
seed	
seaStars	
crabs	
hermitCrabs	
echinodermOther	
lobster	
sandDollars	
ad	
anemone	
bHydra	
brittleStar	
buccinum	
clams	
coral	
ctenophores	
detritus	
euphausids	
filo	
holes	
jellyFish	
moonsnail	

moonsnailEggCase	Presence/absence/counts of species and substrate types
mouse	
mussels	
otherCrustaceans	
otherMolluscs	
seaweed	
skateEggCase	
sponges	
squid	
urchin	
tunicate	
cod	
dogfish	
eel	
oceanPout	
flounder	
haddock	
hagfish	
hake	
herring	
mackerel	
monkFish	
otherFish	
sandlance	
sculpin	
seaRaven	
seaRobin	
skate	
silverHake	
unidentifiedFish	
Icelandic	
seacuke	
comments	Comments
modified	Was annotation modified during QA/QC
createdDTTM	Annotation date and time
scallopsAtEdge	Were scallops on the edge of image
imageHasBeenChecked	QC check
imageHasBeenMeasured	Measurements performed
rowIsLocked	No further modifications to annotations
measurement	Scallop height (mm converted from pixels)

WHOI/COV Data Fields

Data Field	Definition
timestamp	
imagename	
lat	Latitude
lon	Longitude
heading	Vessel heading
alt1	HabCam height from the seafloor from 200kHz pinger
st_alt	HabCam height from stereo rectification
vehicle_depth	HabCam depth
pitch	Rotation of HabCam vehicle from horizontal front to back
roll	Rotation of HabCam vehicle from horizontal side to side
yaw	Rotation of HabCam vehicle from vertical side to side
salinity	Salinity
temperature	Temperature
O2	Dissolved oxygen
cdom	Colored dissolved organic matter
chlorophyll	Chlorophyll A
pH	Hydrogen ion concentration
N	Nitrate (um/L)
bottom_depth	Water depth from vessel (fm)
fov	Field of view (radians)
fov_src	Field of view (m^2)
mm_px	mm per pixel spatial calibration
int_cal	Intrinsic calibration coefficient matrix
ext_cal	Extrinsic calibration matrix

CFF Data Fields

Data Field	Definition
Imagename	Annotated image identifier
orgID	Species ID code
Organism	Species name
shapeID	Annotation shape ID code
Shape	Annotation shape
x1	Coordinates for annotation, up to 4 x-y pairs, scallops are lines or points, other species are rectangular boxes
y1	
x2	
y2	
x3	
y3	
x4	
y4	
subID	Substrate ID code
Substrate	Substrate type
Date	Data collection date
Time	Data collection time
Altitude	HabCam height from the sea floor
Water_depth	Depth measured by the vessel
Heading	HabCam compass direction
Pitch	Rotation of HabCam vehicle from horizontal front to back
Roll	Rotation of HabCam vehicle from horizontal side to side
Vehicle_depth	HabCam depth in water column
Lat_ddmm	Latitude - degree minutes from vessel
Long_ddmm	Longitude - degree minutes from vessel
Lat_decdeg	Latitude - decimal degrees from vessel
Long_decdeg	Longitude - decimal degrees from vessel
Temperature	Water temperature
Conductivity	Water conductivity
Salinity	Water salinity
Speed	Vessel speed
FOV	Field of View

Atlantic Sea Scallop Survey Working Group Report: Appendix 2

Atlantic Sea Scallop Survey Working Group
Scallop Survey Guiding Principles

Background

The Scallop Survey Working Group (SSWG) recommended that the New England Fishery Management Council (Council) and Northeast Fisheries Science Center (NEFSC) adopt Scallop Survey Guiding Principles to inform survey-related decision-making, RSA priorities and program adaptations, and future science and management efforts and advice. The Guiding Principles were developed to ensure adequate survey coverage, sampling intensity, frequency, and sampling types needed to generate data products to support annual scallop management, while maintaining flexibility in the system to continue the provision of independent estimates from survey partners. This is intended to be a living document that provides guidance for surveys and data products for long-term use. The guidance may be considered and applied to align with SSWG recommendations related to survey coordination, data standardization, and impacts from offshore wind energy development. The Council, Scallop Plan Development Team (PDT), and NEFSC should determine appropriate implementation and administrative oversight related to the guidelines. The SSWG recommends that future modifications to Survey Guiding Principles should be made in consultation with all scallop survey partners.

Survey Coverage:

- The entire scallop resource and spatial distribution of the fishery should be surveyed annually. The overall resource survey will consist of multiple survey partners, including the NEFSC and RSA-funded organizations, using dredge and optical tools. The primary objective of these surveys is to provide length frequencies, abundance, and biomass estimates that are used by the Scallop PDT.
- Specific resource areas (e.g., rotational management areas, areas of identified recruitment, areas with anomalous biology or mortality, and areas of importance to the fishery) should be covered with redundant surveys that use different sampling technologies (e.g., optical and dredge) to provide multiple independent estimates of abundance, biomass, and density.
- Areas outside of the currently known scallop resource and spatial distribution of the fishery that could potentially support scallop biomass should be surveyed regularly on a longer-term time step, as informed by the Scallop PDT, scallop survey partners, and the scallop fishing industry.
- The Northern Gulf of Maine management area and Gulf of Maine resource area should be included in regular survey coverage.
- Efforts should be made to match appropriate sampling tools, designs, and methods with specific conditions of survey areas (e.g., habitat type, gear conflict regions, wind farms).
- Survey coverage determination should consider areas of current and future offshore wind energy development.

Sampling Intensity and Frequency

- Underlying conditions of survey areas should be considered to determine required sampling levels (e.g., schedule of rotational management areas, recruitment and cohort tracking, abundance and density, condition factor, disease and predator prevalence).
- Surveys should be conducted on multiple spatial scales with higher sampling intensity directed to priority areas.
- HabCam survey annotation rates and data delivery expectations should be identified and agreed to during RSA negotiations and established in RSA awards.
- Sampling objectives should be considered in the pre-survey planning phase (e.g., optical track allocation, dredge sampling locations within strata), as well as post-survey analysis phase (e.g., estimates of precision, accuracy, and bias).

Types of Sampling

- Samples required from all resource and fishery areas to support annual management, stock assessment, and science include scallop counts, measurements, and biological samples. The overall scallop survey system includes, but is not limited to, collection of meat and gonad weight, age and growth samples, reproductive state, sex, disease documentation, and meat quality. Each survey method collects different types of samples that are integrated to support scallop science and management.
- Collection of additional biological and environmental information should be conducted, and efforts should be made to increase utilization of data products that are not directly applied to scallop science and management (e.g., ecosystem monitoring, habitat types, predator abundance and distribution, etc.).

Data Analysis

- Analysis of survey data should generate data products to support annual scallop management for each SAMS/survey area, as identified by the Scallop PDT, including biomass, abundance, density, average meat/gonad weight, and length frequency.
- Data analysis should be based on standardized criteria defined by the Scallop PDT (e.g., area-specific shell height to meat weight (SH:MW) equations, defined size classes for pre-recruits, recruits and adults, dredge efficiency, commercial dredge selectivity).
- The process for HabCam surveys to check for autocorrelated data for model-based estimation methods includes:
    - Aggregate the annotated data by 750m segments
    - Calculate Moran's I statistics for only the positive aggregated data points for each area to check whether the data are spatially autocorrelated using reviewed methods (e.g., ArcGIS, QGIS, R function in Moran.I in library ape)
    - If data are not spatially autocorrelated ($p>0.05$), review potential reasons for the lack of correlation with NEFSC and Council staff (e.g., too few images were annotated, or spatial structure is absent)
    - In the absence of autocorrelation, the NEFSC will recommend appropriate methods to generate biomass estimates to the Scallop PDT (e.g., stratified mean estimation Chang et al., 2017).

Data Delivery

- Survey data products must be available by August of the year the survey is conducted.
- Survey data delivery format should follow guidelines for standardization, as defined by the Scallop PDT.
- Survey data from all survey partners should be made accessible upon request, as defined by the RSA Data Sharing Plan requirements.