NOAA Technical Memorandum NMFS-NE-311

Design, implementation, and results of a collaborative shortfin squid (*Illex illecebrosus*) electronic size monitoring pilot project

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
October 2023

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Design, implementation, and results of a collaborative shortfin squid (*Illex illecebrosus*) electronic size monitoring pilot project

Anna Mercer, Joshua Moser, Thomas Swiader Jr., Sarah Salois

NOAA Fisheries, Northeast Fisheries Science Center, Cooperative Research Branch, 28 Tarzwell Drive, Narragansett, RI 02882

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Citation: Mercer A, Moser J, Swiader Jr T, Salois S. 2023. Design, implementation, and results of a collaborative shortfin squid (*Illex illecebrosus*) electronic size monitoring pilot project. US Dept Commer Northeast Fish Sci Cent Tech Memo 311.

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ABSTRACT

The northern shortfin squid (*Illex illecebrosus*) is a data-poor species that supports a productive commercial fishery that was valued at over $24 million in 2020. Due to the species' complex life history and dearth of data, the fishery is managed using a static quota rather than biological reference points. Given the economic importance of this species, the Mid-Atlantic Fisheries Management Council's Shortfin Squid Working Group and Northeast Fisheries Science Center's (NEFSC) Shortfin Squid Research Track Stock Assessment Working Group recommended enhanced data collection to enable quantitative assessment and management of this species. In response, the NEFSC's Cooperative Research Branch (CRB) initiated the Shortfin Squid Electronic Size Monitoring Pilot Project (ILXSM) in 2021. The goals of the project were to 1) develop and pilot electronic technology to enable shortfin squid processors to sample individual squid size and weight throughout the fishing season, and 2) produce a standardized data stream to better understand the shortfin squid fishery and population structure. In order to achieve these goals, the project team used an Agile software development framework to modify the Biological Information System Software (BLISS) to enable the collection of paired shortfin squid size and weights using Bluetooth measuring boards and Bluetooth scientific scales. The project team partnered with and trained the 6 largest shortfin squid processors along the East Coast to collect squid size and weight data using the electronic equipment. Each processor was supplied with sampling equipment and software that allows direct upload into the NEFSC Oracle Database and matching with Vessel Trip Report data. The ILXSM electronic data collection systems were piloted during the 2021 and 2022 fishing seasons. In 2021, 36,942 individual paired lengths and weights were collected using the ILXSM system. An additional 60,691 weights were collected using traditional sampling approaches at each processor. In 2022, 26,094 individual paired lengths and weights were collected using the ILXSM system. An additional 8,108 weights were collected using traditional sampling approaches at each processor. The data collected through ILXSM can be used to track the growth and condition of shortfin squid throughout fishing season, as well as the movement of smaller squid onto the continental shelf. The ILXSM data are being used in research on the oceanographic drivers of shortfin squid and will be integrated into a new length-based assessment model for this species. This project directly addressed the need to improve data availability to support the assessment and management of the northern shortfin squid fishery by improving both the efficiency and quantity of data collection.

1. INTRODUCTION

The northern shortfin squid (*Illex illecebrosus*), is a migratory, semelparous species with a sub-annual lifespan that is distributed throughout the shelf and slope waters of the Northwest Atlantic (Dawe and Beck 1985; Hendrickson and Holmes 2004; Arkhipkin et al. 2015). This species is described by rapid growth with highly variable body size and recruitment (Hendrickson 2004; Hendrickson and Hart 2006). Shortfin squid is a data-poor species whose population dynamics are not well described by fishery-independent surveys, which do not operate during the summer months when shortfin squid inhabit the continental shelf (Hendrickson and Holmes 2004). Furthermore, fishery-independent surveys lack the spatiotemporal resolution necessary for shortfin squid stock assessment methods (NEFSC 2022). Therefore, the management and assessment of

this fishery relies heavily on fishery-dependent data sources which have varying degrees of spatial and temporal resolution (Lowman et al. 2021; Jones et al. 2022; Mercer et al. 2023).

Shortfin squid migrate onto the continental shelf during the summer months, where they are commercially harvested by a bottom trawl fishery. The U.S. shortfin squid fishery was valued at more than $24 million in 2020 (NOAA Fisheries, 2023; see Fig 1). Since 1997, 6 squid processors along the eastern coastline of the United States have been responsible for handling 75-90% of the total shortfin squid landings from U.S. waters. Historically, the U.S. shortfin squid fishery has specialized in producing smaller size classes of squid (100-200 g) to fill gaps in the global squid supply. More recently, there has been a shift in the proportion of shortfin squid landings sold to bait markets to those targeted toward human consumption (Mercer et al. 2022).

Between 2017 and 2021, there was an increase in the availability of shortfin squid, resulting in a surge in the economic value of the fishery (Figure 1; NEFSC 2022; Hendrickson and Showell 2019; Salois et. al. 2023). In response, processors invested in expanding and modernizing their facilities and initiated new processes for documenting product quality for inventory and marketing purposes. Even with the expanding availability and value of shortfin squid, the U.S. fishery has experienced early closures as a result of quota-constrained fishing seasons (Hendrickson and Showell 2019). The shortfin squid quota has remained fairly static in large part to insufficient data streams, resulting in a lack of stock assessment and management tools (NEFSC 2022; Mercer et al. 2022).

The 2021 Northern Shortfin Squid Research Track Stock Assessment (RTA) reviewed existing data sources and explored novel modeling approaches but was unable to produce a functional stock assessment model, in part due to data limitations. The RTA report recommended exploring Real-Time Management (RTM) approaches for this highly variable sub-annual stock and detailed requirements for in-season data collection (NEFSC 2022). However, there are a suite of logistical and technical challenges associated with collecting biological data for shortfin squid. First, due to the rapid growth and seasonal migration of shortfin squid, characterization of size and growth requires high-frequency sampling of dorsal mantle lengths (mm) and body weights (g) throughout the summer season. The Northeast Port Biological Sampling Program (NEPBSP) measures shortfin squid dorsal mantle lengths and aggregate weight from a subset of commercial fishing trips, but the frequency and quantity of data collected by NEPBSP are insufficient for tracking growth and movement of shortfin squid. Thus, the Northeast Fisheries Science Center (NEFSC) Cooperative Research Branch (CRB) partnered with the fishing community to develop the Illex Electronic Size Monitoring pilot project (ILXSM) to address the need for high frequency shortfin squid mantle lengths and weights as identified by the stock assessment and fishery management process.

The goal of the ILXSM is to standardize and streamline shortfin squid biological sampling efforts. By working with industry partners to collect paired shortfin squid body weights and mantle lengths across the entire fleet (e.g., both freezer trawlers and wet boats) throughout the fishing season, the ILXSM program seeks to improve the efficiency, quantity, and representativeness of shortfin squid biological data collection. Shortfin squid mantle lengths and body weights are collected by most shortfin squid processors but are primarily recorded on paper forms. In 2021, the NEFSC CRB partnered with the 6 major shortfin squid processing facilities across the East Coast to pilot the use of electronic measuring boards, scales, and tablets for collection of paired shortfin squid weight and length data (Table 1; Figure 2). These data are directly accessible to the

processors, as well as uploaded directly into the NEFSC Biological Sample Monitoring (BSM) database.

The resulting standardized data stream produced by ILXSM is of great value to the fishing industry, science community, and management as they seek to gain greater understanding of shortfin squid availability, productivity, and distribution. ILXSM is a powerful tool with the potential to advance in-season modeling approaches by providing electronic, near real-time data collection to pair with current tow-based catch and effort fishing data collected by the Study Fleet (Jones et al. 2022). Furthermore, ILXSM has the potential to aid in multiple stock assessment goals, including evaluating the effects of differential growth and maturity within seasons and between years, as well as the identification of pre-season indicators of shortfin squid availability.

This report describes the approaches, technology, and preliminary results of the ILXSM. Specific methods for each component of this project are detailed, including descriptions of the collaborations that were fundamental to developing and operating the project, as well as the technology used, training conducted, sampling procedures employed, and data auditing conducted. Preliminary results are also shared to exemplify the value of the data collected through this program.

2. METHODS

2.1 Collaboration

This project was approached collaboratively by scientists from the NESFC and the fishing industry. The NEFSC CRB coordinated the project, including recruitment of industry partners, data system testing, training and technical support for industry partners, project documentation, data auditing, and data analysis. The NEFSC Information Technology Division provided software and hardware development and data management support for the project, and utilized Jira software for issue tracking. The NOAA Office of the Chief Information Officer (OCIO) provided guidance on documentation management and tablet configuration. The NEFSC Population Dynamics Branch (PDB) provided advice on data output needs and sampling protocols for this project.

Six shortfin squid processors were key partners in this project, from conception through implementation (Table 1). All shortfin squid processors participated in ILXSM pilot program voluntarily. Prior to project kickoff, the NEFSC CRB communicated with industry partners about the goals, methods, staffing, and technical requirements of the project, including operational space and power supply access. Together with each processor, the project team identified the timeline, approaches, and staff training protocols. Staff at each processing facility are the primary collectors of biological data. Ongoing and open communication among project partners were prioritized throughout the project.

2.2 Data System Development and Testing

A lightweight and portable electronic data collection system was developed by the NEFSC to increase efficiency and standardize shortfin squid size and weight data collection at processing facilities across the region. This data collection system, the BSM, consisted of 4 components: an electronic fish measuring board (*Big Fin Scientific* 75cm Data Collection System 5 [DCS5] Fish and Field board), a digital scale with Bluetooth connectivity (*Marel M1100* Bench Scale), and a ruggedized tablet running a custom Android application designed for efficient biological data

collection (Samsung Galaxy Tab Active 3 tablet with BLISS software; Figure 3). The *Big Fin Scientific* 75cm DCS5 Fish and Field board (BFSMB) is equipped with a DCS5 Linear Sensor Kit-75cm-EP, DCS5 Measurement Deck Kit - 75cm, DCS5 Micro Edition Control Box, and a Nose Stop Kit. The electronic fish measuring board measures to millimeter precision. The Type 2 Marel Bench (Land) Scale (model number M1100) has Bluetooth capabilities, with an Accuracy Class of III, that can record weights from 0 to 3 kg. The M1100 scale was configured to display in grams with recording sensitivity set to record one value every 0.5 seconds. The accuracy of this scale is 0.5 g when weights range from 0 to 1.5 kg and 1 g accuracy for weights ranging from 1.5-3 kg. An American Society for Testing and Materials (ATSM) class-5 1 kg weight cylinder was distributed to each facility for scale calibration purposes. The Samsung Tab Active 3 (TA3, model number SM-T570NZKEN20) uses the Android operating system. We chose this particular version of tablet, called the ruggedized multi tablet, as it was designed for use in harsh conditions.

Each TA3 was installed with Biological Information System Software (BLISS), a mobile application designed and developed by the NEFSC to collect and submit biological data. The TA3 operates solely on Wi-Fi connections, as the tablets do not include Long-Term Evolution (LTE) capabilities. Internet access is required for uploading data into the NEFSC Oracle database tables and keeping the tablet and BLISS software up to date. Assembly of the measuring board, BFSMB, Bluetooth integrations, and testing began in April 2021 and were completed by June 2021. Further refinement of the BLISS software was conducted to enable efficient shortfin squid length and weight collection, troubleshoot bugs, and improve performance and utilization before distribution. Bluetooth communications were made by connecting the BFSMB, M-1100, and TA3 devices after which, the functionality of all components in the data collection system were tested for accuracy.

2.3 Sampling Procedure

Dialogue with industry partners contributed to the refinement of sampling protocols and influenced the development of instruction manuals. Each processor had their own strategy for sampling (e.g., number of squid sampled from each fishing trip) prior to the start of the project. As part of the pilot program, processors were encouraged to continue using their original strategies as they became acquainted with the new technology. All processors, however, were asked to collect paired mantle length and body weights for at least 100 shortfin squid from each fishing trip. Because the data from the ILXSM program are used by processors for quality assurance and marketing purposes, the number of squid sampled per trip frequently exceeded what was required for scientific purposes.

2.4 Industry Training

The rollout of equipment and industry training began in June 2021. Each industry partner (The Town Dock, NORPEL, Seafreeze Shoreside, Seafreeze Ltd., Lund's Fisheries Inc., and L D Amory & Co.) was equipped with a BSM system. An ILXSM team member visited each facility a minimum of once per year for training and support. Each training visit provided hands-on training for each of the Quality Assurance/Quality Control (QA/QC) processor staff members on the use of the BSM system, protocols, and procedures. In addition, we provided an ILXSM binder including a Quick Start Pamphlet, BLISS User Guide, TA3 Help Guide and a M-1100 Help Guide to each facility. Early in 2023, a series of training videos were developed to provide step-by-step instructions on how to use the equipment, as well as tips for troubleshooting common issues. These

videos were made available in 2 languages, English and Spanish, and are stored on the home screen of each Samsung tablet for quick access.

2.5 Data Security and Storage

Before distribution, each tablet was configured with the BLISS app and registered with a NOAA service account. The tablets submit data to the NEFSC's Oracle database through the use of an application programming interface (API) which enables data entered to be uploaded directly into the NEFSC's BSM database. The weight and length data collected are owned by the processor that collects those data and are shared with the NEFSC for scientific research.

Each participating processing facility was required to sign an Individual Computer/Network/Data Access Agreement and Equipment User Agreements (EUA) with the NEFSC. This user agreement states that all components of the BSM system are federal government property and that each user is responsible for ensuring secure storage and maintenance.

2.6 Data Management and Auditing

Members of the ILXSM project team performed regular data audits to ensure data quality. The auditing procedure cross-referenced ILXSM data to the federal Vessel Trip Report (VTR) database to ensure that all trip data were correct. Additional audits on the mantle length and gram weight data were also conducted using biologically reasonable ranges, with mantle lengths from 50 mm to 300 mm and individual weights ranging from 7 g to 650 g. At the close of each season, the project team consulted with processors to obtain feedback on which procedures they found to be successful and to identify areas that presented challenges or required improvement. More specifically, questions were aimed to evaluate experiences of industry partners with the ILXSM project, including communication pathways, technology performance, sampling/auditing procedures, and challenges. Each processor was also asked to provide suggestions for improvement.

3. RESULTS AND DISCUSSION

With global demand for squid increasing and the fleet and volume of the shortfin squid fishery growing, advancing assessment and management approaches to maximize the value of shortfin squid are of high priority. This requires data that are not collected through traditional fishery monitoring or research efforts. Specifically, high-frequency, region-wide size and weight sampling is required to gain a better understanding of the complex cohort and population structure of this stock. The ILXSM project addresses this very need.

The pilot year of ILXSM had many successes, including consistent participation from processors and the implementation of a new electronic biological sampling system. All 6 volunteer squid processing facilities participated throughout the duration of the fishing season in 2021, acquiring samples from 34 vessels in the first year (Table 1; Figure 4a). While overall availability of squid decreased in the second year of the project as compared to the first, ILXSM had similar engagement from processors and collected data from 14 vessels (Table 1; Figure 4a). Data collected through ILXSM represented the wide spatial extent of the fishery, with 14 and 17 statistical areas sampled in year 1 and 2, respectively (Figure 2, Figure 4b). From 2021 to 2022,

ILXSM collected a total of 131,835 samples. Of those samples, 68,799 were individual weights and 63,036 were paired lengths and weights (36,942 collected in year 1 and 26,094 in year 2).

As with any pilot project, there were lessons learned and room for improvement. For example, the project rollout would have benefited from multiple staff training sessions at the processing facilities throughout the fishing season. Furthermore, since the ILXSM pilot project marked the first deployment of the BLISS software and the BSM system at processing facilities, a variety of bugs and technical issues presented themselves throughout the project, ranging from Bluetooth connectivity issues to failures uploading data. Other challenges included the maintenance of an "In Compliance" status on the Samsung tablets (TA3) and biological data not being uploaded into the BSM database on the day of sampling. These inconsistencies were largely due to the volunteer-based nature of the project, as well as the spatial scope, as many of the participants' facilities are geographically distant to the NEFSC project team members. The geographic distance made training and on-demand support difficult. For instance, there is roughly 600 miles between the northernmost processor in New Bedford, MA, and the southernmost processor in Hampton, VA. Therefore, providing in-person support to multiple processors at once wasn't possible. Other considerations were made to account for the natural range of languages and technical abilities of processing facility staff. In an effort to address these challenges, the project team supplied user manuals and quick-start guides, as well as multiple training videos to each industry partner. Additionally, methods for remotely accessing tablets were explored. The ability to remotely access tablets would greatly improve the project team's ability to keep the tablets in compliance, help users troubleshoot issues in real-time, increase overall user abilities, and assist with data uploading issues.

Cooperative research efforts such as the ILXSM project play a critical role in documenting the rapidly changing dynamics of commercially important marine resources, such as shortfin squid. In 2 years of operation, the data collected through ILXSM has successfully characterized catch differences across years, months, and space. These data have been critical to quantifying observations made by fishers in the shortfin squid fishery and understanding the dynamics of the stock and fishery. Specifically, the collection of paired length and weight data across both fishing seasons (Figures 5 and 6) has been critical to the identification of differences in the quantity and size distribution of squid caught in 2021 (higher quantities, larger individuals) as compared to those caught in 2022 (smaller quantities, smaller individuals; Figure 5). Another valuable aspect of this data stream is its potential to be linked with other catch data streams (e.g., weekly landings, Study Fleet, VTR), which provide the higher spatial resolution necessary for linking size and weight data to oceanographic features, as well as understanding the representativeness of a sample in a given week.

Collaborations between members of the fishing industry and science community, such as the ILXSM project, are essential to promoting the long-term conservation and management of important living marine resources. This is especially important for data-poor stocks like the shortfin squid, whose dynamics are not well captured by fishery-independent data sources alone. The ILXSM project serves as an example of how collaborations between industry and science can be designed and implemented to meet the data needs for stock assessments and fisheries management.

ACKNOWLEDGEMENTS

We humbly extend our gratitude to every individual who has contributed to the success of the ILXSM project, specifically Lisa Hendrickson (NEFSC), Erin Kupcha (NEFSC), Mark Beaurgaurd (NEFSC) and Murali Mood (NEFSC), Matthew Hill (NEFSC), Cory Thornton (NOAA Office of the Chief Information Officer: NOAA-OCIO), and David Bedell (NOAA-OCIO). This project would not be possible without the support and collaboration of Illex processors. Special thanks to Wayne Reichle, Jeff Kaelin, Joshua Farinella, Jessica Greenwood and Mario Adolfo Gonon Ramos from Lund's Fisheries; Brianna Hughes, Christopher Barra, Katie Almeida, and Melanie Robichaud from The Town Dock; Meghan Lapp, Phil Ruhle, Benjamin Barbera and Jessica Westcott from Seafreeze Shoreside; Chris Joy, James Barbera, Rubin Mota, JoAnna Duenas, Ivan Xiquin, and Jacinto Xiquin from Seafreeze Ltd; and Meade Amory from L. D. Amory Company, INC.

TABLE AND FIGURES

Table 1. Descriptions of each participating northern shortfin squid (*Illex illecebrosus*) processing facility. Location refers to the physical location of the facility. Maximum freezing rate is an indicator of the processing capacity of each facility displayed as the maximum amount of squid that can be frozen in 1 day (24 hours). Vessel Type references the number and hold type (FT = Freezer Trawler; RSW = Refrigerated Sea Water; ICE = Ice) of the unique fishing vessels that landed northern shortfin squid in each year at each facility.

Processor	Location	Max Freezing Rate (lbs/day)	Vessel Types 2021	Vessel Types 2022
NORPEL	New Beford, MA	950,000	4 RSW, 4 ICE,	1 RSW
Town Dock	Narragansett, RI	225,000	2 FT, 1 RSW, 5 ICE	2 FT, 1 ICE
Seafreeze Shoreside	Narragansett, RI	300,000	4 RSW, 2 ICE	2 RSW
Seafreeze Ltd	North Kingstown, RI	670,000	3 FT	3 FT
Lund's Fisheries	Cape May, NJ	1,100,000	1 FT, 8 RSW	9 RSW
L.D. Amory Seafood Co.	Hampton, VA	80,000	2 RSW	1 RSW, ICE

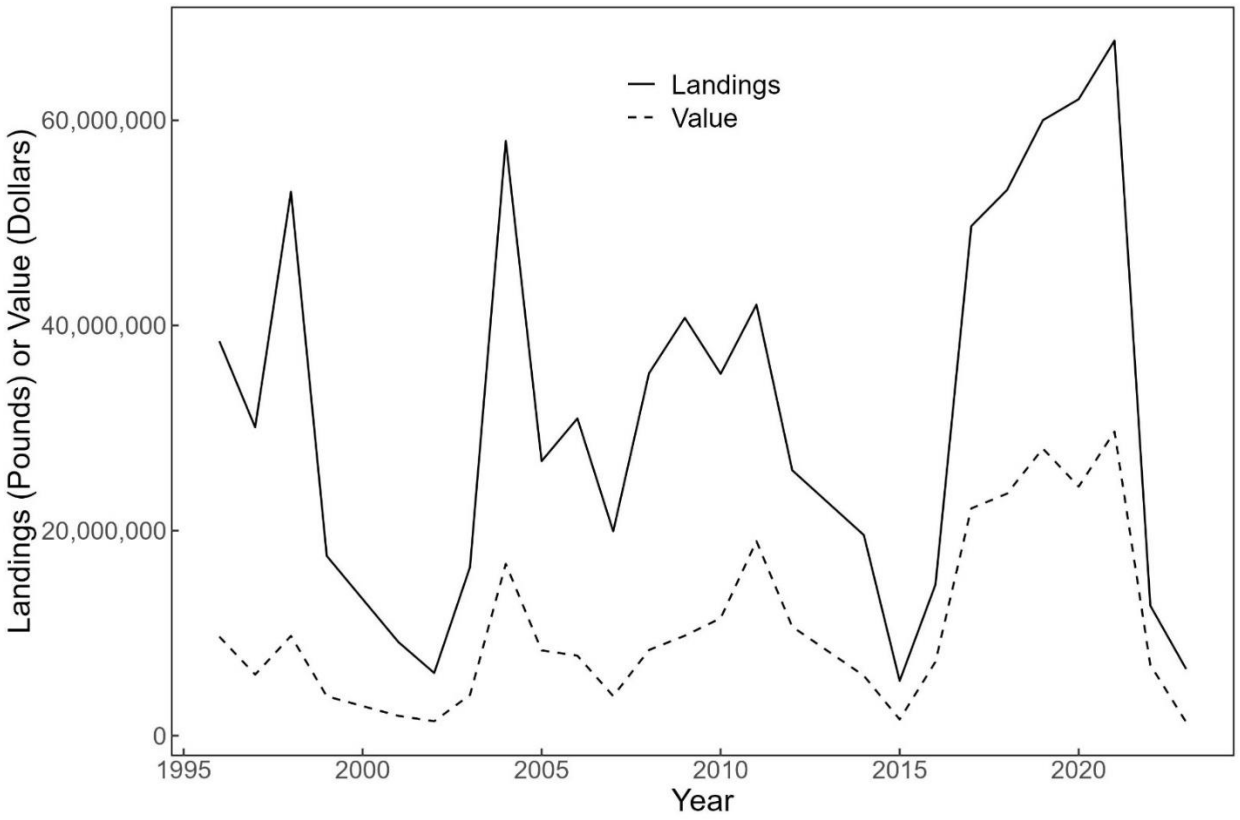

Figure 1. Annual landings and economic value of northern shortfin squid (*Illex illecebrosus*; NOAA, Fisheries 2023). Annual landings are quantified in pounds (lbs) and indicated by the black solid line. The economic value is quantified by annual revenue in U.S. dollars and is indicated by the dashed line.

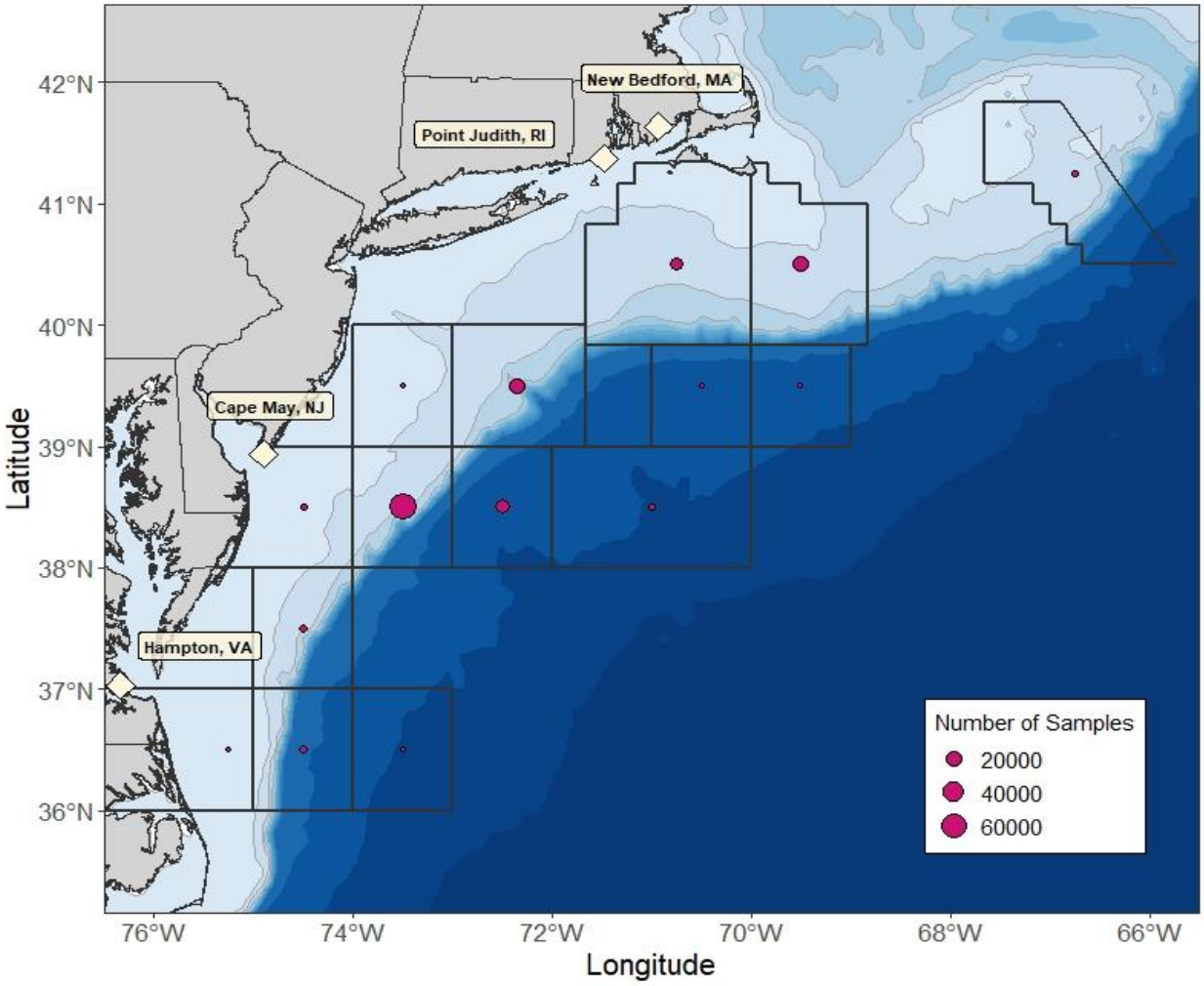

Figure 2. Map of Northeast United States Continental Shelf Large Marine Ecosystem (NES LME). Bathymetry is indicated by a blue color gradient, where increasing depth corresponds to darker shades of blue. The black polygons overlaid on the bathymetry depict the boundaries of the Greater Atlantic Region Fisheries Statistical Areas. The location of each point, indicated in magenta, demarks the centroid of the statistical area polygon. The size of each point represents the number of northern shortfin squid (*Illex illecebrosus*) samples reported through Shortfin Squid Electronic Size Monitoring Pilot Project in the associated statistical area. Filled off-white diamonds indicate the locations of participating northern shortfin squid processing facilities.

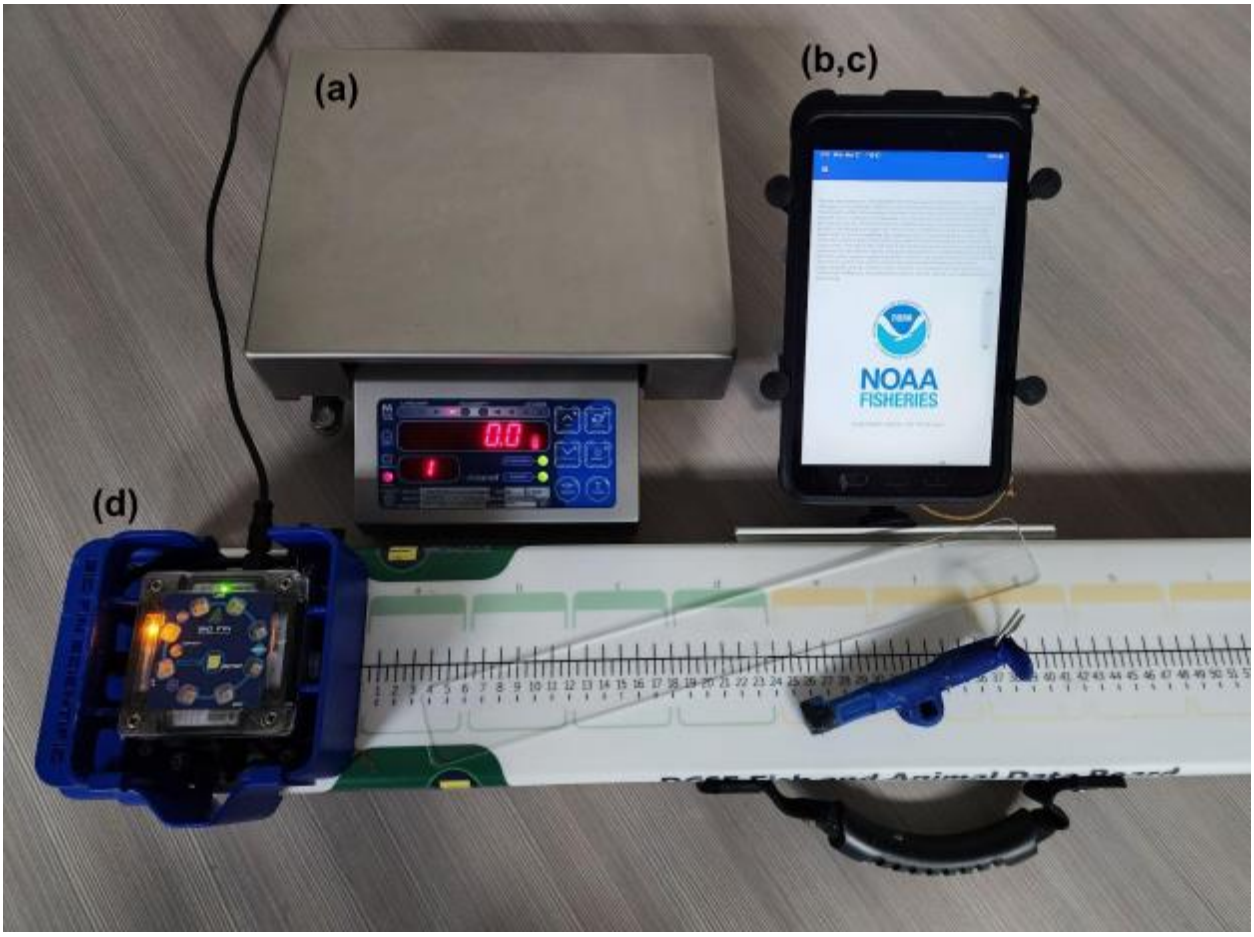

Figure 3. Picture of the Shortfin Squid Electronic Size Monitoring Pilot Project data collection system that consists of 4 components: (a) digital scale with Bluetooth connectivity (Marel M1100 Bench Scale); (b,c) ruggedized tablet running a custom Android application designed for efficient biological data collection (i.e., Samsung Galaxy Tab Active 3 tablet with Biological Information System Software); and (d) electronic fish measuring board (Big Fin Scientific 75cm Data Collection System 5 Fish & Field board).

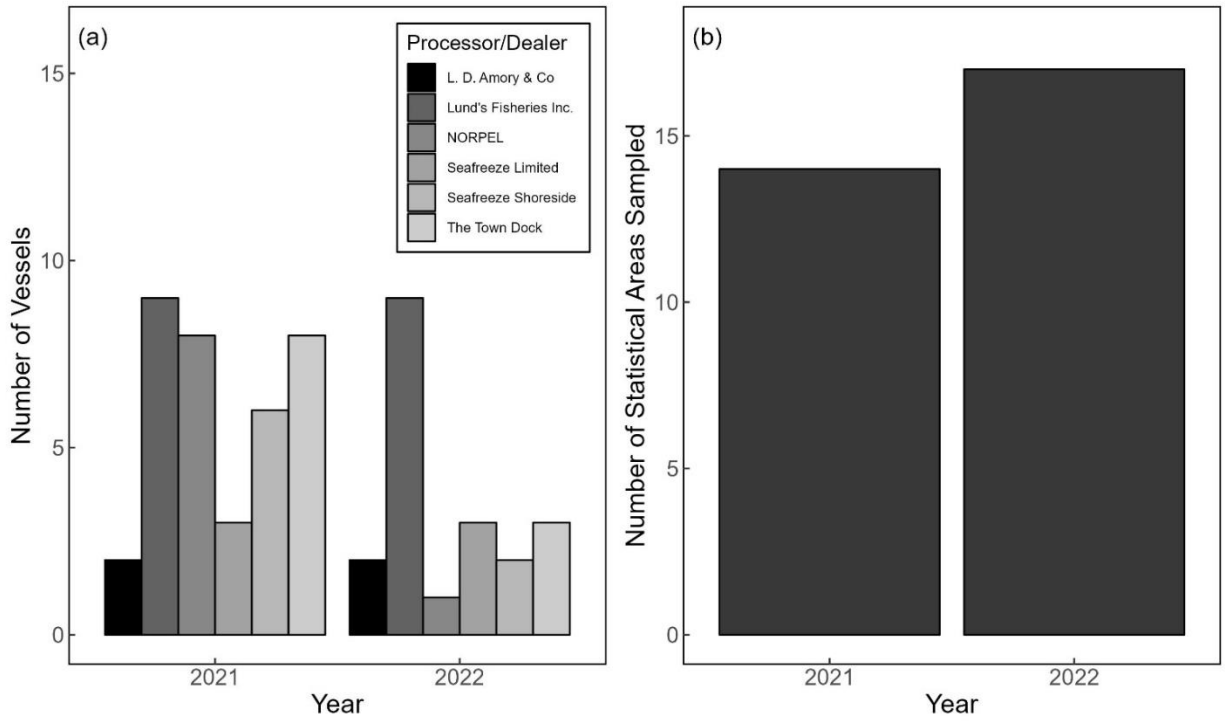

Figure 4. Summary of the Shortfin Squid Electronic Size Monitoring Pilot Project data collection for 2021 and 2022: (a) Number of vessels that landed at each participating processing facility in year 1 (2021) and year 2 (2022); and (b) total number of statistical areas sampled in each year across all participating processors.

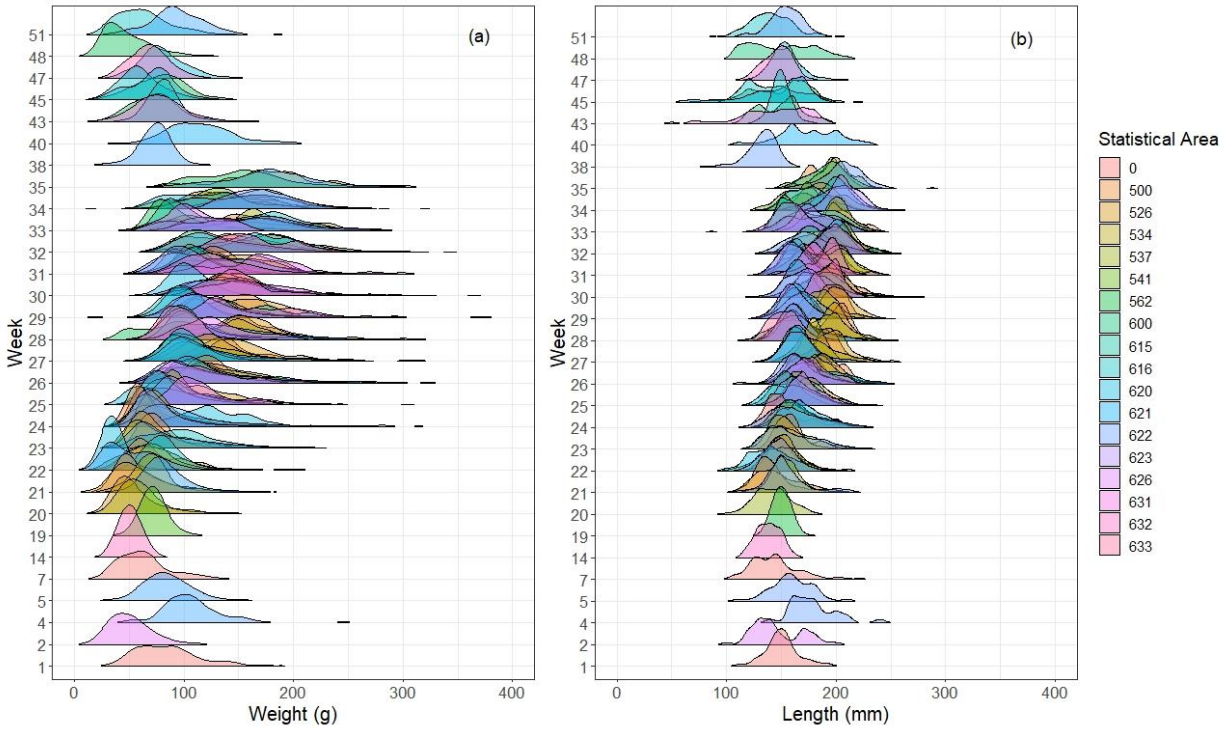

Figure 5. Weekly distributions of northern shortfin squid (*Illex illecebrosus*) (a) body weight (in g) and (b) mantle length (in mm) samples for 2021 and 2022. Color of each distribution reflects the statistical area from which northern shortfin squid samples were harvested.

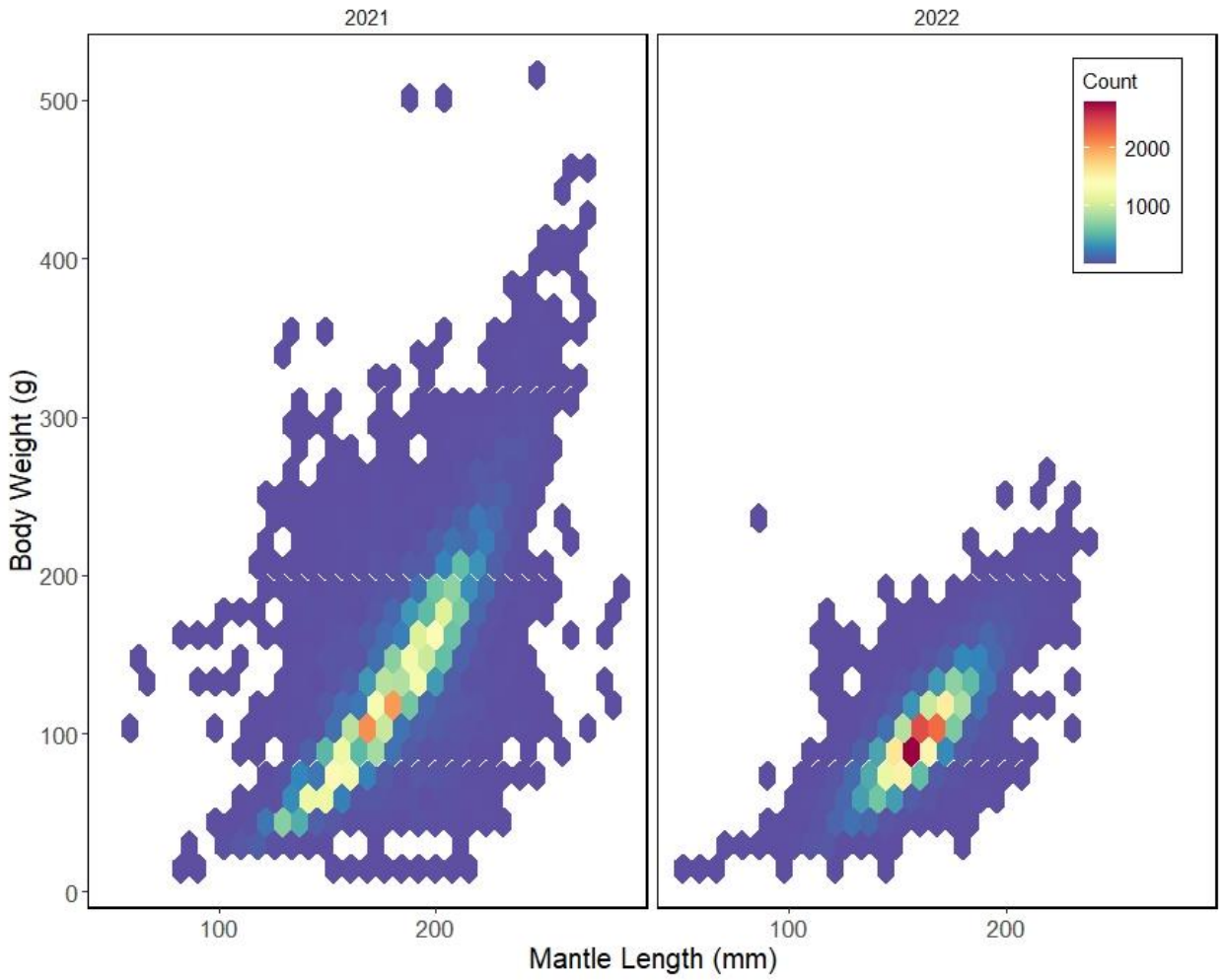

Figure 6. Density heat maps of mantle length (mm) as a function of body weight (g) in year 1 (2021) and year 2 (2022) of the Shortfin Squid Electronic Size Monitoring Pilot Project

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