Technical Report

Commonwealth of Massachusetts DIVISION of MARINE FISHERIES

Massachusetts Division of Marine Fisheries Technical Report TR-86

River Herring Spawning Run Counting Method Guidance:

Standard Operating Procedures

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Summary: River herring are the most abundant diadromous (sea-run) fish in Massachusetts, providing forage for a wide range of fish and wildlife. River herring enter coastal rivers on spring spawning runs that attract the public's attention and require management to support their migratory, spawning and nursery habitats. The herring runs presently support limited fisheries while traditionally providing for popular and important recreational and commercial fisheries. Declining herring runs in the 1990s and 2000s prompted Massachusetts Division of Marine Fisheries (DMF) to close spring spawning run harvest coast-wide and to increase monitoring to provide more information on population status and support future management. DMF's herring monitoring efforts have focused on electronic and video fish counting systems. The public's interest in the status of river herring and related monitoring has grown in recent years with many non-governmental groups participating in volunteer visual counts of river herring. DMF routinely supports all aspects of river herring counting with technical support. This technical report provides standard operating procedures for three methods for river herring spawning run counting: video, electronic, and volunteer visual.

Standard Operating Procedures (SOP) for River Herring Counting

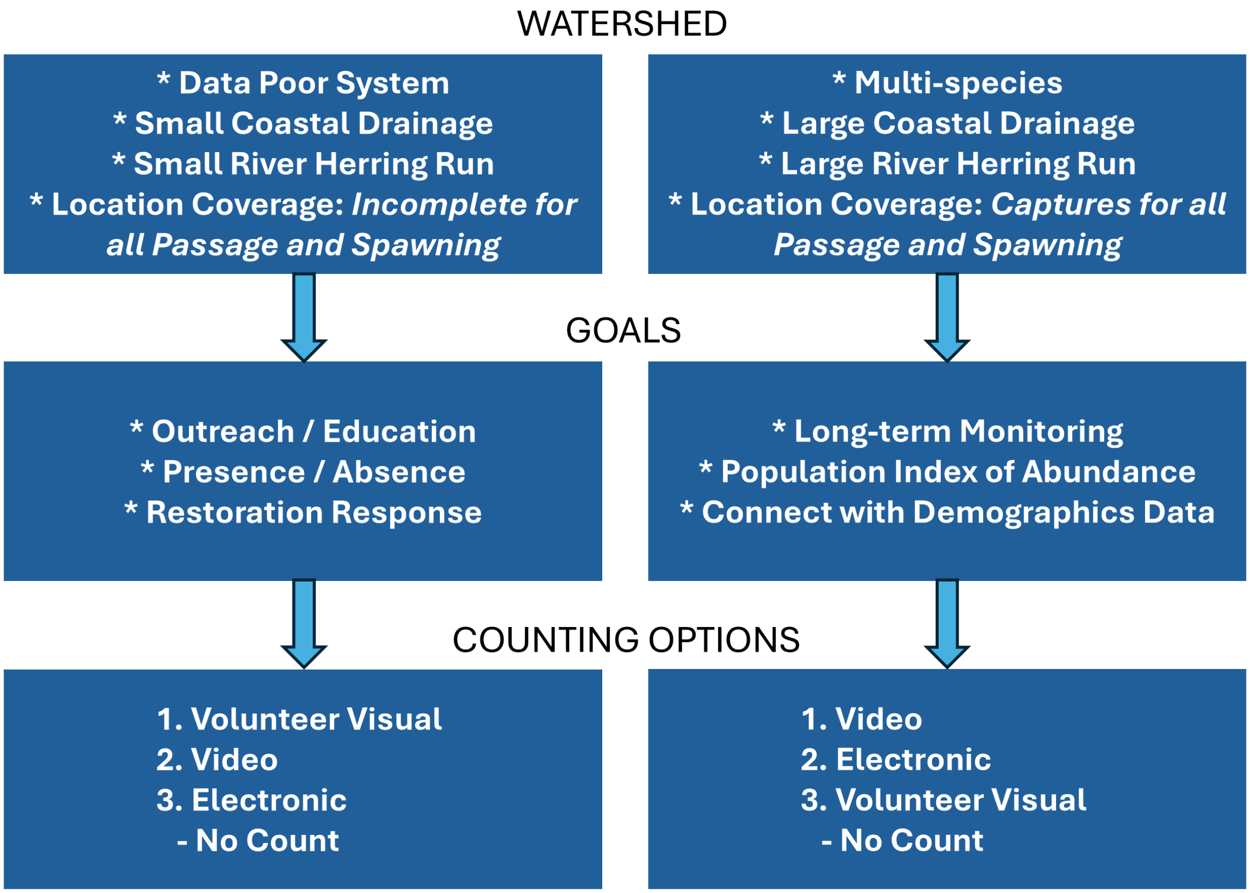
Introduction

The Massachusetts Division of Marine Fisheries (DMF) shares the interests of the public trust, towns, and other East Coast states in monitoring the health of river herring populations to support the management of these essential forage species and the restoration of traditional coastal fisheries. The sustainable management of fishery resources requires information on population status and demographics. This is challenging for all fish populations and no less so for diadromous fish that spend their lives in both freshwater and marine habitats. The dramatic spring spawning runs of river herring provide an opportunity to monitor the abundance of adult fish returning to natal rivers. The three common methods for estimating spawning run numbers are volunteer visual counts, electronic counters, and the use of video systems.

Efforts to count diadromous fish on spawning runs extends back over 100 years with West Coast salmon monitoring. In Massachusetts, early efforts included cooperative work at the University of Massachusetts to develop volunteer visual techniques in the 1970s, followed by the first deployment of a Smith-Root electronic counter by DMF at the Monument River in the early 1980s. DMF committed to providing technical assistance to counting efforts and establishing counting stations at all the major coastal drainage areas in Massachusetts over the last 20 years. Many lessons have been learned in the process. Several counting series have matured to the extent that they are now used as indices of abundance in Atlantic States Marine Fisheries Commission (ASMFC) river herring stock assessments; three of these also provide the basis for ASMFC Sustainable Fisheries Management Plans. However, there have been changes in technology and apparent changes in fish behavior that challenge existing counting practices. For example, Smith-Root, the primary vendor for electronic counters used by most states, is discontinuing manufacturing. Moreover, video counting is evolving with the implementation of machine learning, which could offset the costly and time-consuming processing of video images. Studies conducted in rivers in New England (Ellis and Vokoun 2009; Rosset et al. 2017; Dalton et al. 2022) indicate river herring spawning runs are occurring earlier than a few decades ago, and there is growing evidence of more night movements that confound the results of daylight visual counting (Alcott et al. 2021; Magowan et al. 2012; Rillahan and He 2023). With these changes and experiences, efforts should be made to improve, document, and standardize counting practices.

In 2013, DMF prepared a guidance document that addressed river herring counting methods:*https://www.mass.gov/doc/river-herring-counting-protocol/download*. This technical report updates the 2013 guidance document and provides SOPs for each of the three types of monitoring to guide present and future DMF staff and local partners in the collection of high quality run count data.

DMF regulates diadromous fish harvest and passage in coastal waters and rivers in Massachusetts (per MGL Chapter 130, Section 19) and manages diadromous populations. Management of diadromous fish in Massachusetts is shared with the Division of Fish and Wildlife (*Mass*Wildlife) with jurisdiction separated at the first dam in coastal rivers or other designated landmarks. River herring and striped bass are exceptions, with DMF jurisdiction throughout the Commonwealth (MGL Chapter 130, Section 19, 100A). Local groups interested in participating in river herring monitoring should contact DMF for technical assistance and eventual authorization if efforts include placing counting structures in fish passageways.



	Pros	Cons
Visual	Low cost, low tech-support, outreach benefits	Difficult to maintain data quality and volunteer pools
Electronic	24-hour records, low power, low data processing	Equipment availability, single species, higher cost
Video	24-hour records, census possible, multi-species recordings	Higher tech-support, higher power, costly image processing

Figure 1.1. Decision factors on watershed conditions and project goals that contribute to choices on river herring counting options. Counting options are ordered by the most viable method given watershed type and goals with pros and cons listed below for each counting method.

We preface the three SOPs with a decision matrix on the counting options (Figure 1.1). Generally, visual counting methods have low cost but can require large numbers of volunteers and effort to manage the volunteers and data processing. Electronic counting has the highest start-up cost among the three SOP methods but has good accuracy and lower management effort. Video has moderate start-up costs but comes with a high demand for technical management and a high processing cost. Acoustic imaging techniques have also been used recently in Massachusetts to count diadromous fish and to document behavior (Magowan et al. 2012 and Rillahan and He 2023). We do not address acoustic monitoring here because DMF has not applied these methods, in part due to the high start-up cost and technological experience needed to manage equipment and data processing.

SOP 1.0 - Visual Counting Guidelines and Protocols

Introduction.

By late in the 20th century, river herring populations in several coastal Massachusetts watersheds had declined to historical lows. The declines prompted the Massachusetts Division of Marine Fisheries (DMF) to establish a three-year moratorium on the sale and harvest of river herring state-wide in 2006. East Coast-wide concerns for the status of river herring prompted the Atlantic States Marine Fisheries Commission (ASMFC) to close commercial and recreational river herring fisheries in all coastal states by January 2012, unless an approved river herring Sustainable Fishery Management Plan (SFMP) was drafted and approved by ASMFC as required under Amendment 2 of the Interstate Fishery Management Plan (ASMFC 2009). Federal concerns for river herring led to the National Marine Fisheries Service (NMFS) listing blueback herring and alewife as "Species of Concern" and Endangered Species Act reviews were conducted in 2013 (Federal Register 78 FR48943) and 2019 (NMFS 2019) for these species. In both reviews, an Endangered Species Act listing was determined to not be warranted. Concerns remain as the 2024 ASMFC stock assessment for river herring found populations remained depleted relative to historical levels and have shown a flat trend in abundance since 2009 (ASMFC 2024).

The population declines generated growing public interest in the status, monitoring, and conservation of river herring in Massachusetts. Municipalities, watershed associations, conservation land trusts, and private organizations established herring visual counting programs at several Massachusetts coastal rivers dating back as far as the early-1970s (Rideout et al. 1979). Similar development of volunteer visual counting efforts followed in Maine (Bieluch et al. 2017). In recent years, Massachusetts river herring populations have been monitored in over 40 streams within 8 major coastal drainage areas using a variety of counting methods including visual counts, electronic and video monitoring systems (Figure 1.2). Volunteer visual counts are the most commonly used method comprising over 60% of monitoring efforts annually. On Cape Cod, the Association to Preserve Cape Cod (APCC) has been active for over a decade organizing a large number of local groups to conduct volunteer visual counts.

This section provides a summary of the principles and recommendations for establishing and conducting visual counts, and an overview and link to the DMF Visual Counting Program (*VisuCount*). This section also discusses the limitations of run size estimates derived from visual counting and the criteria for establishing time series population estimates for potential inclusion in the ASMFC stock assessment and SFMPs.

Principles for Visual Counts

DMF prepared a guidance document to conduct statistical sampling of river herring spawning runs to generate an estimate of run size (Nelson 2006). This approach built on the Rideout et al. (1979) method for estimating run counts by including a random stratified design with estimates of power, accuracy, and precision. This sampling design allows for the calculation of a relative index of abundance of the river herring spawning run if 10-minute visual counts are distributed appropriately for each daily sampling period.

Objectives for Conducting Visual Counts

The impetus to start a volunteer visual river herring count often originates with a sincere interest in learning more about a local run. This can be to support the education and outreach goals of a local organization or to support developing, ongoing, or completed aquatic restoration efforts. These objectives are an important part of any counting effort. From DMF's perspective, any consideration of starting a visual counting effort should include the objective for having the data contribute to ongoing natural resource management goals for river herring. As a member of the ASMFC, DMF works cooperatively with other

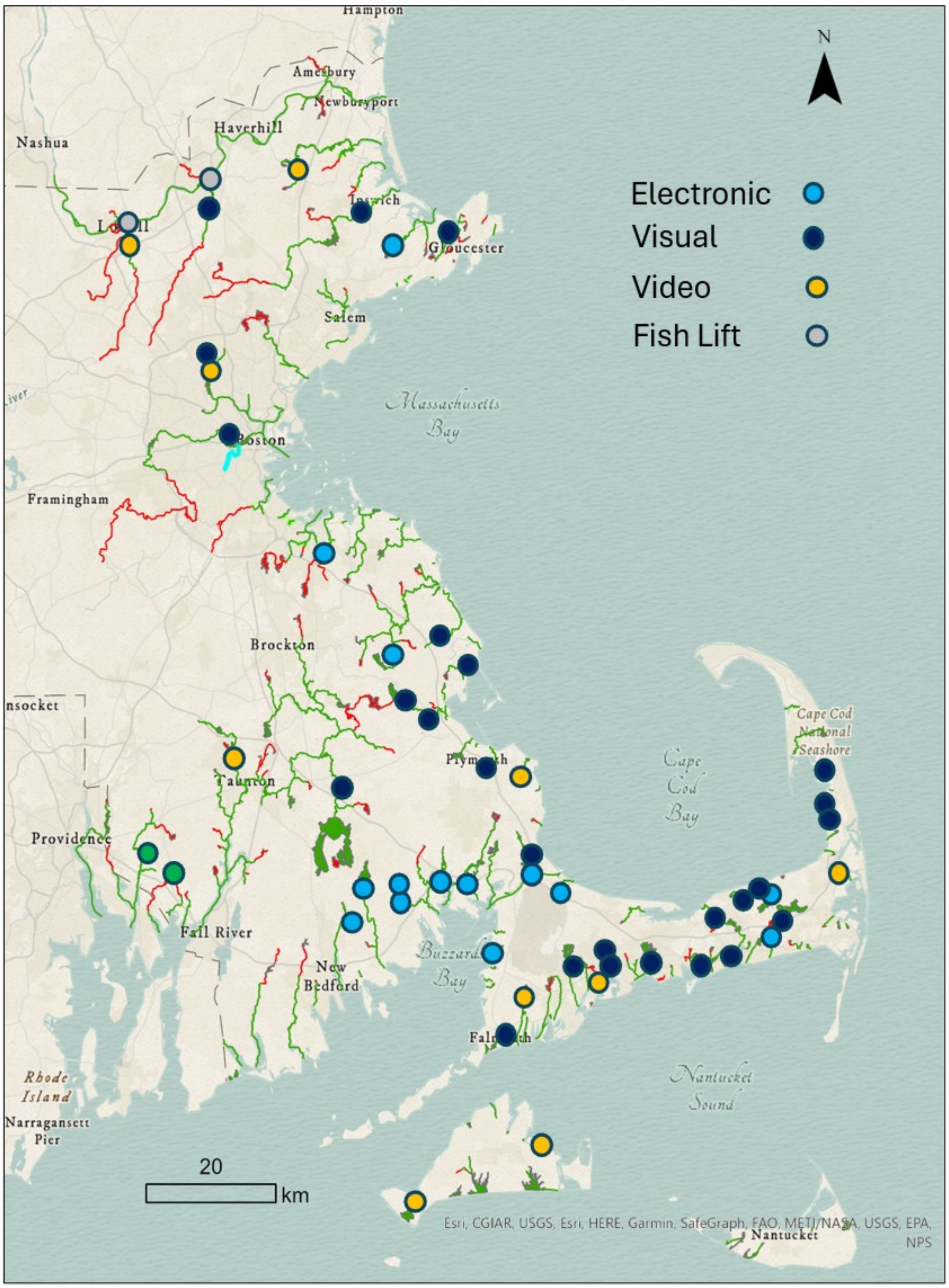


Figure 1.2 River herring counting stations in Massachusetts active during 2023-2024. A total of 52 stations counted river herring by Electronic Counters, (14), Volunteer Visual Counts (26), Video (10), and Fish Lift (2). Map source: DMF Diadromous Fish Data Layer: MassGIS Data: Diadromous Fish | Mass.gov.

Table 1.1. Massachusetts river herring counting stations accepted for the ASMFC river herring stock assessment as indices of abundance and/or Sustainable Fisheries Management Plans. Several counting stations began as volunteer visual counts and shifted to video or electronic counts.

River	Town	Watershed	Count Method	Count Onset	Index of Abundance	Biological Data	SFMP
Parker River	Newbury	North Shore	Visual/Video	1997	X	X	
Mystic River	Medford	Boston Harbor	Visual/Video	2012	X	X	
Back River	Weymouth	Boston Harbor	Visual/Electronic	1986	X	X	
Town Brook	Plymouth	South Shore	Video/visual	2008	X	X	
Monument River	Bourne	South Shore	Electronic	1980	X	X	
Stony Brook	Brewster	Cape Cod	Visual/Electronic	2007	X		
Herring River	Wellfleet	Cape Cod	Visual	2009	X		
Agawam River	Wareham	Buzzards Bay	Electronic	2001	X		
Wankinco River	Wareham	Buzzards Bay	Electronic	2007	X		
Mattapoisett River	Mattapoisett	Buzzards Bay	Electronic	1988	X		
Nemasket River	Middleborough	Taunton River	Visual	1996	X	X	X
Herring River	Harwich	Cape Cod	Visual/Electronic	2009		X	X
Herring Brook	Pembroke	South Shore	Visual/Electronic	2015			X

East Coast states to provide biologically and statistically reliable population demographics data to support both state management and coast-wide stock assessments for river herring (Sheppard and Chase 2024). As a requirement for inclusion in the stock assessment, the main criteria are a time series consisting of a minimum of 10 years of population estimates collected in a consistent and scientifically sound manner. Eleven river herring spawning run counts from Massachusetts were included in the ASMFC 2024 stock assessment as indices of abundance (ASMFC 2024). Most of these counting stations are presently video or electronic, however, two are visual count stations and another seven have included visual counts at some point in their time series (Table 1.1). Currently, there are several rivers with visual counts in Massachusetts that have the potential to be included in future stock assessments.

Sampling Equipment

The equipment required to conduct visual counts is minimal, and the low start-up costs make conducting visual counting an attractive option for many volunteer groups. The basic equipment for visual counting consists of a watch or stop-watch, a manual hand tally, and a logbook or datasheet to record information. In some locations where visibility is limited, a high contrast surface, such as a white board, can be installed along the bottom of the counting location to improve visibility and detection of passing fish (Figure 1.3). Optional equipment includes a thermometer to record air and water temperature during visual observations, although DMF recommends the use of continuous electronic temperature loggers for water temperature (Chase et al. 2020) and local airport temperature data series for accurate daily average air temperature. DMF also recommends that the water surface elevation of spawning ponds adjacent to counting locations is recorded with each visit using installed staff gauges. The DMF Fishway Crew have installed many white boards and staff gauges at counting locations and are available to provide this assistance.

Data sheets and logbooks should either be kept among individual counters or stored in a secure location at the counting station. The following information is required for run size estimation and should be recorded for all visual observations: Date, Start Time, End Time, and Count – where Start Time is the time when the visual count began, End Time is the time when the visual count ended, and Count is the total number of fish that passed upstream of the counting station. Optional data that can be recorded are air and water temperature, water surface elevation from a staff gauge, name of person who counted, weather conditions, and

Figure 1.3. Volunteer visual counting at the Mystic Lakes Dam fishway in Medford, MA. A white board used to improve visibility and detection of passing fish is shown.

additional comments. These optional data contain useful information on local conditions, although they are not required for run size estimation.

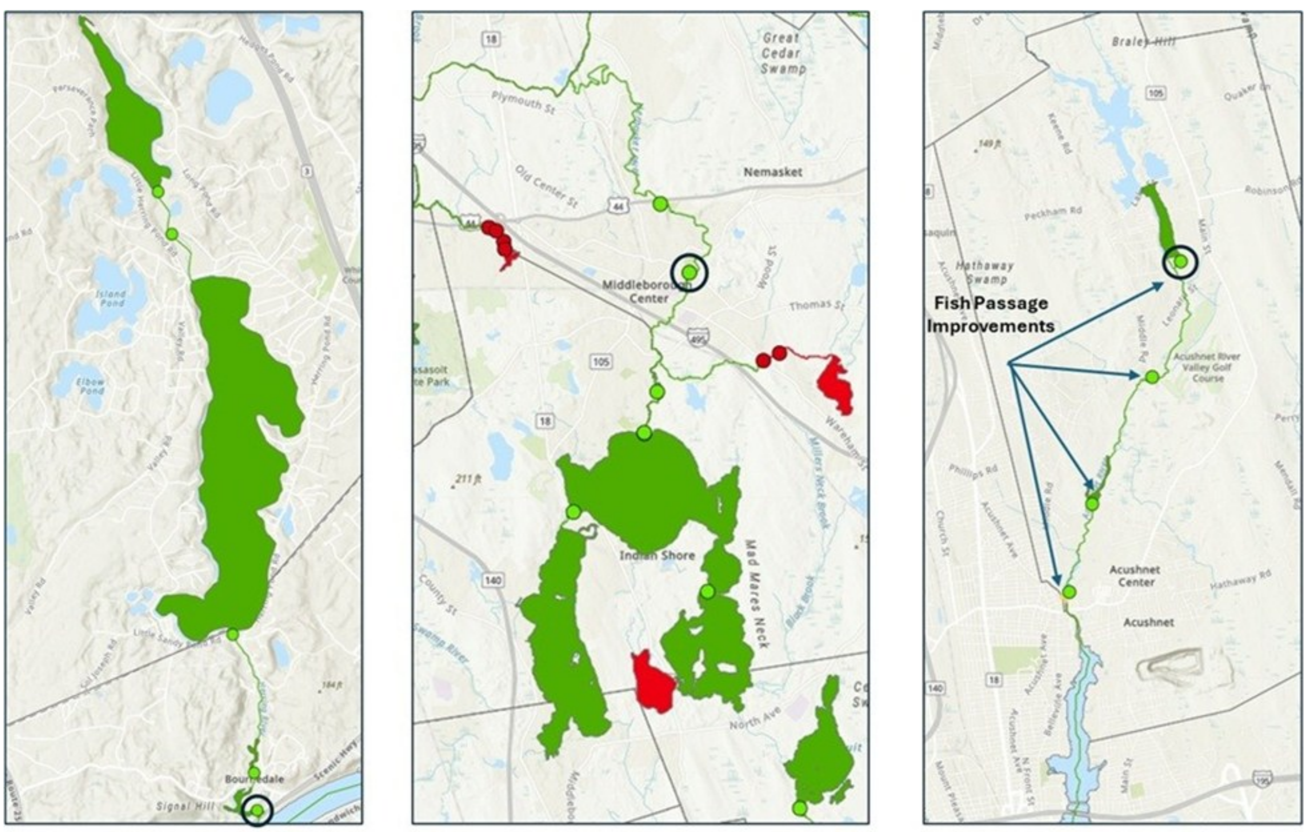
Most river herring counting efforts, including visual counts, are typically conducted at a constricted location on a stream, such as the exit of a fish ladder, to provide a field of view that can capture all passing fish. In addition, water clarity and depths should allow the counter to see through the water column from the surface to the bottom. Parking access and safe viewing locations are practical considerations for volunteer pools. In some watersheds, there may be limited options for selecting a counting station given the relatively few possible and suitable "choke points" for counting.

Another essential consideration for sampling locations is the objective of counting efforts. From a fisheries management perspective, the primary purpose of river herring counting efforts should be to establish long-term indices of spawning run abundance for regionally important river herring populations. Not all river herring runs will have a suitable counting location, the community support to sustain a long-term volunteer base, or connect to regional resource management priorities. Counts established more for education or outreach benefits, to promote restoration goals, or to document a response to restoration actions can also be useful. It is important to understand the counting goals and physical landscape of each river system and connect these to the selection of sampling locations.

Volunteer visual sampling locations close to tidal waters will be the best option for producing a relative estimate of abundance for a river herring spawning run that has long-term value for fisheries management. Locations further up in watersheds can provide a relative estimate of abundance for herring entering a specific spawning pond. If local groups are interested in learning more of the status of a poorly known herring run for outreach purposes, then location in the watershed may not be as important as finding a suitable viewing location with public access. In other cases, local groups may want to monitor the specific response to restoration actions and select station(s) specifically for that goal. It should be recognized the count estimates for the latter two approaches may not reflect population abundance and may not need to continue for a long time series.

Three types of relative run size estimates based on sampling location are shown in Figure 1.4. In the first example (Figure 1.4A), the counting location is near the outlet of the stream where it empties into tidal waters. Counts conducted at this location would represent an estimate of relative abundance for the daily count period for the entire watershed. These stations can have the highest potential to provide long-term, relative indices of abundance. In the second example (Figure 1.4B), the counting location is located upstream of lower passage restrictions and other potential spawning habitats such as main stem river, tributaries, and ponds. In these cases, the run counts may not represent all migrating spawning river herring. This estimate is also an index of relative abundance but represents a proportion of the watershed, or spawning run. These estimates are likely an underestimate of the total spawning population as it is assumed not all individuals migrated upstream of the counting station. The third example (Figure 1.4C) shows the counting station located at the location or upstream of recent fish passage improvements. The number of fish passing upstream of the counting station may become an index of relative abundance, but the time series will be influenced by the spawning run's response to the restoration actions. In this scenario, the estimate represents the proportion of the total population entering habitats that were previously difficult to access or were inaccessible prior to fish passage improvements. These restoration-response counts typically increase soon after restoration actions and may take several generations of river herring before stable population trends develop.

In all cases, it is useful to keep in mind that visual counts do not capture nighttime movements, thereby providing relative estimates of run size that can be biased by annual changes in the ratio of daytime to nighttime movements. Therefore, some regional consideration is needed for the distribution of visual counts and higher technology counts to meet the different objectives of counting river herring. Another useful term to consider is "Escapement", which indicates the number of fish



A. Relative Abundance (Full Watershed)

B. Relative Abundance (Partial Watershed)

C. Relative Abundance (Restoration Response)

Figure 1.4. Examples of different run size estimates based on sampling location. The black circle represents the location of the counting station on each stream

that are allowed to move upstream of a point where harvesting occurs (those that "escape" capture and are able to reach spawning habitat). This term is actively applied in Maine's SFMPs but not in Massachusetts because no runs are presently harvested.

Sampling Designs

Visual counting programs involve volunteer participants that conduct counts of herring passing at a designated location for a specified interval of time. Since each interval of time is a sample of overall passage, visual counting requires a statistical sampling design to provide accurate indices of abundance. The first documented visual counting program was established by Rideout et al. (1979) to estimate the alewife spawning run on the Parker River, Massachusetts. That visual counting program involved a subsampling procedure to estimate the relative population of alewife spawning runs within 10% error at the 0.05 level of probability (Rideout et al. 1979) by using 10-minute counts conducted hourly.

The Rideout et al. (1979) sampling protocol can produce precise and accurate relative run count estimates, however, the hourly sampling requirement was a challenging hurdle. Some counting groups attempted to follow this sampling scheme, but the hourly coverage of each day could not always be reached given the limits in numbers of participants and scheduling. Other groups have conducted counting programs without adhering to appropriate sampling techniques, resulting in statistically unreliable estimates.

To assist volunteer counting groups, DMF held a workshop at the DMF's Annisquam Marine Fisheries Station on February 2, 2005. Volunteer groups attended the workshop and provided feedback and insight into the characteristics (i.e. counting locations, herring migratory patterns and behavior) of their individual herring runs. Using this information, Nelson (2006) conducted a review of statistical designs for estimating herring run sizes as alternatives to the sampling scheme of Rideout et al. (1979). Nelson (2006) examined the level of error associated with departures from sampling requirements. Following the workshop, a Technical Report (TR-25) was prepared by Nelson (2006) to serve as a guide for community groups conducting or starting visual counting programs to produce statistically reliable estimates of herring run size.

For the purpose of this guidance document, we will summarize three common sampling designs detailed by Nelson (2006) and depicted in **Figure 1.5**. These are the three designs that have been applied most by volunteer visual counting efforts in Massachusetts in the last 20 years. The review of these results allows us to consider each in terms of precision, accuracy, reliability, and practical matters such as sustaining volunteer pools. All three designs target herring counting during the period of 7 am to 7 pm.

With a **one-way stratified random sampling** design (1W; Figure 1.5A), a minimum of two counts are conducted randomly within a specified observation period (or stratum) each day throughout the spawning season. An advantage to

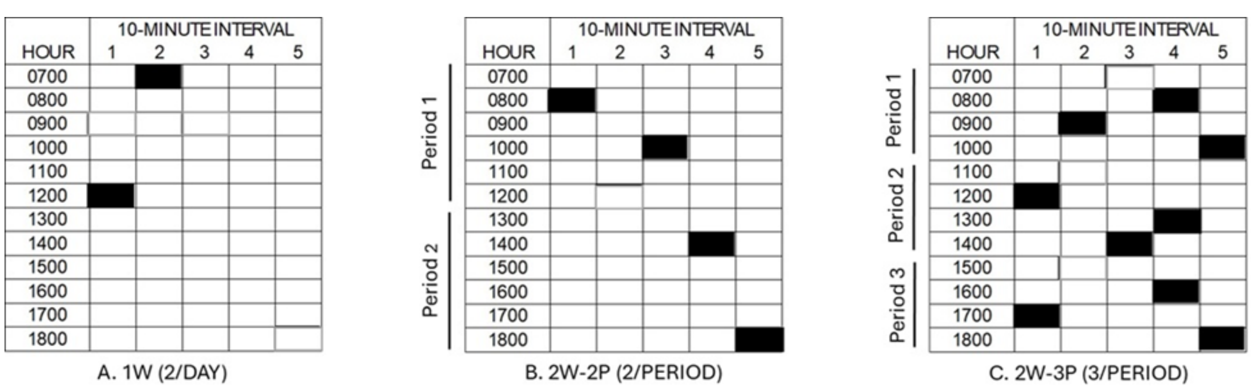


Figure 1.5. Stratified random sampling designs for conducting visual counts (adapted from Nelson 2006). Figure A is the one-way design with a minimum of two samples; Figure B is the two-way design with two daily periods; and Figure C is the two-way design with three daily periods.

this sampling design is that it requires minimal effort as estimates can be made from two counts a day. This design has inherent limitations as daily estimates of the number of fish passing could be over- or underestimated if there are hourly patterns in migration. In addition, the precision of the estimate can be lower than other sampling designs, particularly if the number of daily counts are limited to the minimum of two.

With a **two-way stratified random sampling** design, two strata are defined with a 12-hour sampling day as the first stratum and a second stratum created for hourly periods within each 12-hour sampling day. For all applications, samples should be drawn randomly, with consistent sampling within each sampling period for all days of the monitoring period. Figure 1.5B describes a two-way, two-period (2W-2P) design where the first stratum is a 12-hour sampling day that is divided into two 6-hour periods with a minimum of two counts conducted randomly within each period. The third design is a **two-way, three-period** (2W-3P) design, in which the 12-hour sampling day is divided into three periods (Figure 1.5C), and a minimum of three counts are conducted randomly within each period. The advantages of two-way stratified random sampling are that a higher number of samples can be spread across each day to minimize potential clumping and reduce variance of the total estimate (Nelson 2006). For these reasons, these designs are preferred over 1W and simple random sampling designs.

In 2022, DMF staff conducted a review of all volunteer visual count data due to quality assurance and control concerns. Some locations had common lapses in use of the stratified random sampling design including switching within season between one-way and two-way designs without correction during analysis. Counts were also found outside of the recommended 0700 to 1900 counting period and there was evidence of non-random loading of counts when fish were running strong. The data series for all counts were re-run with standardized stratum for each river, namely daily observation period and duration (start and end dates; Figure 1.6). Estimates of daily passage and total run sizes were then re-estimated using these newly standardized metrics (Figure 1.7. and Appendix A**).** This review process resulted in improved standardization of run count estimates, improved precision for some annual estimates, and the flagging of some annual counts that were censored for having insufficient data to generate an annual run count. Overall, this process improved data quality and informed guidance and communications with local counting groups, ultimately leading to the March 2025 DMF counting workshop.

Sampling Protocol

Following the results of the 2005 and 2025 herring counting workshops, analysis on sampling designs provided by Nelson (2006), and 2022 data review, DMF highly recommends that counting programs follow a 2W-3P stratified random sampling design in which volunteers make at least 3 ten-minute counts during each of three daily periods (0700-1100, 1100-1500, and 1500-1900) from April 1st to June 15th. DMF further recommends the following metrics and protocols for conducting visual counts and producing statistically reliable run size estimates:

1. Counting should be conducted every day at a designated location throughout the entire spring spawning migration (i.e. April 1 – June 15). Each location should have considerations and guidance for volunteers for improving visibility (best vantage point for viewing, installing white contrast counting boards, polarized sunglasses for sun glare).

Note: Some Massachusetts herring runs are trending to earlier onsets. Consideration should be made to starting in late March at some locations and during warmer springs. Early starting, alewife only, and low abundance runs often end before June 15th. In these cases, counting can cease after 5 days of zero counts after May 15th.

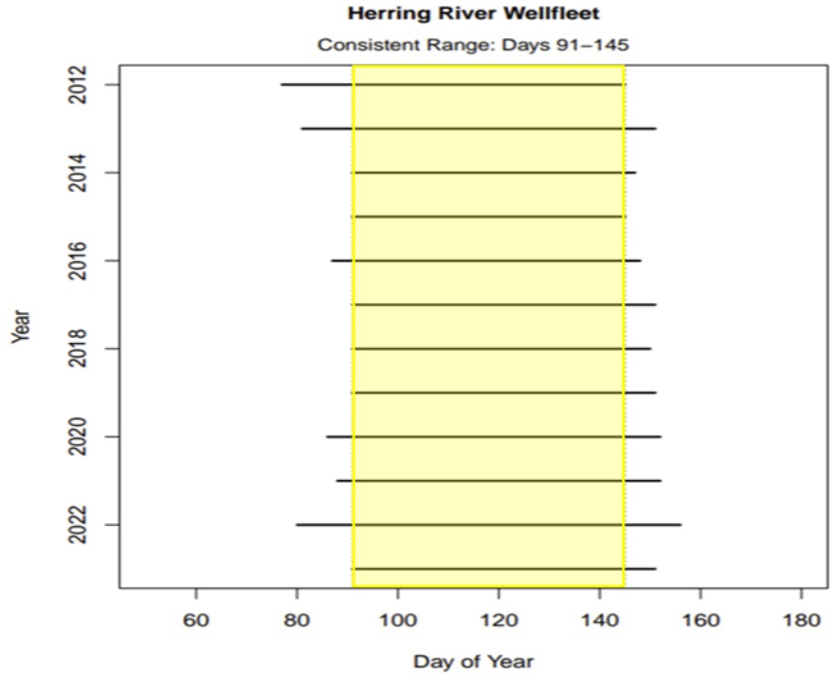
2. Counting should be conducted **every** day during the specified observation period (i.e. 0700 – 1900). Interests to count outside of this period should be discussed with DMF staff. Annual lapses in everyday counting or shifts in practices should be discussed with DMF to guide analyses and time series interpretation.

3. Counting should be conducted using 2-way stratified random sampling in which each daily observation period is divided into 3 sub-periods (2W-3P; i.e. 12-hr. daily observation period: 0700 – 1900). A minimum of **three** 10-minute counts should be conducted randomly for each of the following time periods:

- Period 1: 0700 – 1100
- Period 2: 1100 – 1500
- Period 3: 1500 – 1900

4. If the above sampling intensity cannot be met, it is recommended that volunteers conduct a minimum of **two** 10-minute counts for each sub-period. The lowest level of frequency to produce a run estimate is **two** 10-minute random counts each for the periods of 0700-1300 and 1300-1900. Any sampling frequency below this minimum reduces

(A) Standardized counting period



(B) Standardized daily observation period

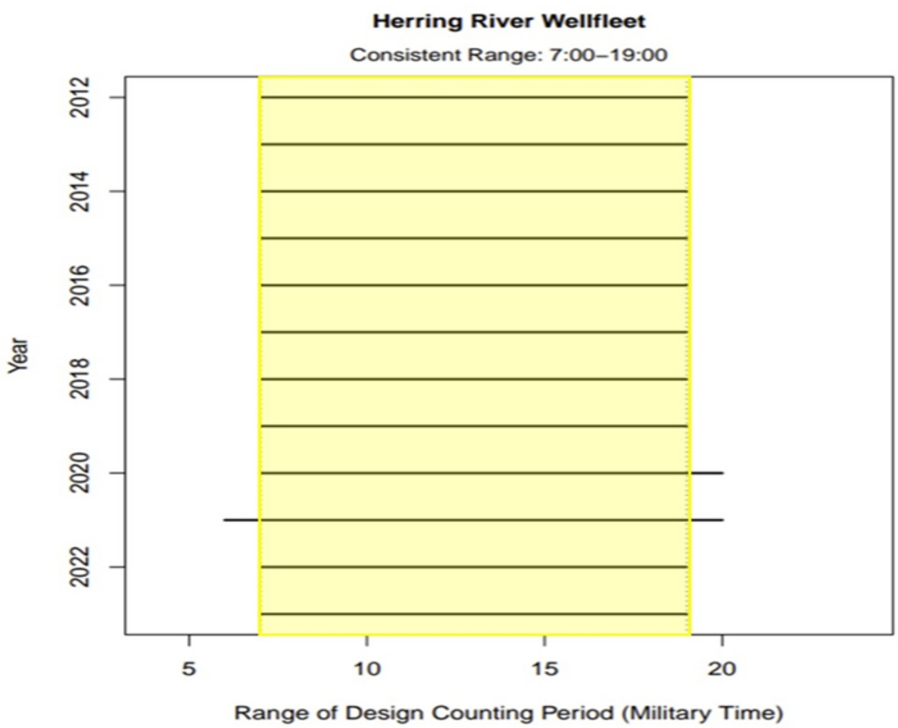
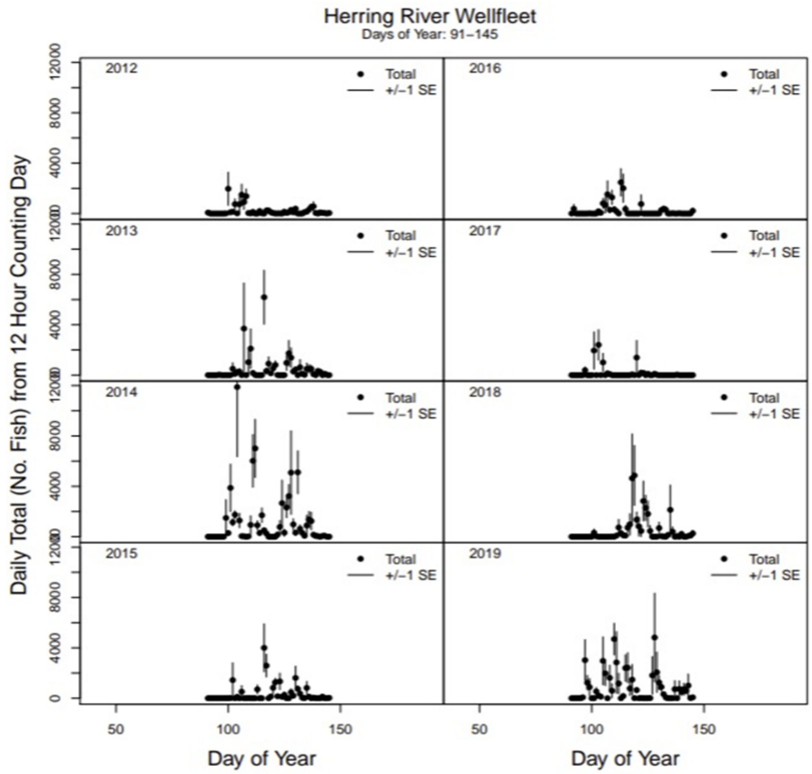


Figure 1.6. Standardized counting start and end dates (A) and daily observation periods (B) for estimating relative passage of river herring in the Herring River, Wellfleet, over the entire visual counting period (2012 – 2023). Standardized duration and daily observation periods are highlighted in yellow, observations outside of the yellow (standardized) ranges are excluded from the analysis.

A.



B.

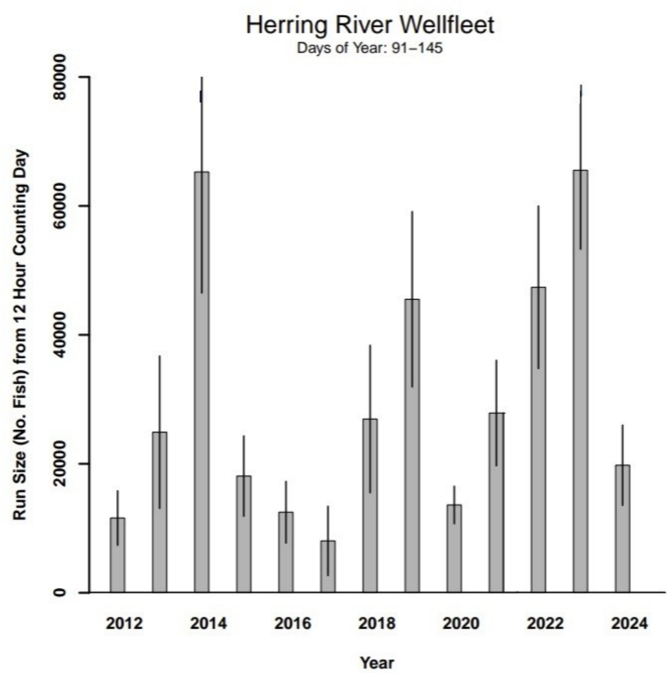


Figure 1.7. Estimates of daily passage (A) and total relative abundance (B) of river herring in the Herring River, Wellfleet, from 2012 – 2023 using newly standardized daily observation periods (0700 – 1900) and duration (April 1 – May 25).

the data quality of run counts to pilot or outreach indices with unreliable statistical properties.

5. If a counting group finds that it cannot sustain a 2-way stratified random sampling design, this should be discussed with DMF as soon as possible. We no longer recommend 1-way counting designs but recognize the potential for low site coverage to occur particularly during pilot seasons. One-way designs will not likely produce data quality to support management goals. Early planning for these low-frequency counts is important to consider options on having a 1-way count for just a pilot season or two or increasing volunteer pool to meet 2-way designs. Annual counts should not switch back and forth between 1-way and 2-way designs.

6. Counters should stand next to counting weir or substrate within suitable view of passing fish without alarming fish. Only herring that fully pass this location in an upstream direction should be counted. Keep counting duration consistent (10-minute counts are recommended)

7. Ideally, sample times for counts should be generated randomly. If random draws are too difficult for volunteer schedules, a quasi-random approach should be made with time slots distributed evenly throughout the daily periods. Consecutive counts independent of a random draw should not be made. Impulse counts when fish are present and concentrating counts within a specific time of day should not be made.

8. Each counter must record the DATE, TIME START, TIME END and number of herring (COUNT) on the data sheet for every count.

9. If available, counters should record the STAFF GAUGE measurement during each count.

10. If available, volunteers may record WATER TEMPERATURE, AIR TEMPERATURE, WEATHER CODE and relevant observations on the herring run or other diadromous fish in the COMMENTS section of the data sheet.

At times, particularly at or near the end of the spawning run, herring may simultaneously be passing upstream and downstream through the counting area. It is essential that fish migrating upstream be counted. If fish are observed migrating downstream, it is recommended that counters document it in the "Comments" section of the data sheet or logbook. However, counters should not attempt to count fish running downstream as this may distract from accurately counting fish running upstream. If there is high activity of herring passing both upstream and downstream of the counting station, it is recommended not to count during that period as the upstream count may not be accurate. In these cases, counters should consult with the count coordinator on substituting the assigned counting time slot.

Data Limitations

As previously noted, DMF prioritizes collecting time series of run size estimates in a scientifically and statistically correct manner. To do so, the run size estimates need to be collected using consistent or standardized metrics (i.e. count duration, daily observation period, counting interval) to reduce bias and caveats in the estimates as well as to identify trends in population size over time. The run size estimates derived from visual counting programs have several limitations. Because these estimates are derived from visual counts over a specified observation period and not conducted continuously throughout a 24-hour period, the estimates will not be a census of the total run size. Rather, the estimates derived from visual counts are indices of abundance, which if collected in a consistent manner from year to year, can infer population trends over time. These indices do not account for changes in river herring spawning phenology (the timing of spawning migrations). With standardizing counting periods, abundance indices will be estimated based on consistent counting durations (start and end dates) throughout the monitoring period. Inconsistent counting durations will affect the accuracy of the abundance indices and may confound trends in abundance over time. However, it is recommended that counting begins once herring are observed passing the counting station even if it occurs before the designated counting duration (i.e. April 1) as it is valuable to document any changes in spawning migration patterns.

Furthermore, the standardized metrics do not account for changes in diel migration patterns. Observations by DMF staff over time and DMF's processing of electronic and video counting data provide evidence that river herring movements are trending towards crepuscular and nocturnal movements in some runs. This pattern has developed in recent years and confounds the intention of the recommended sampling period of 0700 to 1900, which was based on traditional knowledge that herring movements were weighted towards daytime runs. This change creates a dilemma for DMF's recommendations for visual counts. Currently, we continue to recommend the sampling period from Nelson (2006) for consistency and suitable statistical properties. Ongoing volunteer visual daytime count series will be standardized as indices of daytime run size.

Counting at night in most cases will introduce biases related to visibility and concerns for volunteer safety and sustainable efforts. Also, changes in daily observation periods in existing counting programs will introduce uncertainty to abundance indices as the time periods are not consistent throughout the counting period. This uncertainty can be exacerbated if the time series includes efforts to concentrate counts within certain time periods with strong movements, either within the recommended time period or outside. We recommend that electronic and video stations be used to generate full run size estimates for locations where strong night movements are known and/or have distinct runs of both alewife and blueback.

DMF Visual Counting Software (*VisuCount)*

The *VisuCount* Data Entry and Analysis software is a web-based application program developed by DMF to estimate run sizes using visual count data. It is a modification of the original *VisuCount* visual-basic software and allows the user to manually enter or import data. The program features error checking, summarizing count data, estimating daily passage, total run sizes, and summarizing environmental data. The software is free to use and can be accessed at https://b7dq1w-gary-nelson.shinyapps.io/VisuCount/. DMF staff are also available to enter visual count data into *VisuCount,* process count data for volunteer groups, and provide technical assistance with *VisuCount* as needed. A user manual for the *VisuCount* program (VC Manual) is available in the "Help" tab in the program link above and provides complete instructions for creating estimates from raw visual count data.

Future Applications

As recommended above, DMF will continue to provide assistance for volunteer visual counting efforts, including technical review, installation of field counting white boards and staff gauges, and data processing. The future of river herring counting will likely depend less on electronic and volunteer visual counting and increasingly focus on AI supported video stations. Given the expected advances of new technologies and the large effort and duration required to bring volunteer visual counts to a level of data quality to support stock assessment and management needs, it is recommended that future support is focused on long -term volunteer visual counting stations with proven data quality; new stations will receive prudent consideration before starting. Volunteer visual counts have served an important role in pilot efforts to learn more on the status of poorly documented runs, inspire restoration efforts, and develop long-term indices of abundance at suitable locations. Two objectives that could see more application in the future are short-term outreach counts for an education project and counts to demonstrate restoration-response at locations not well suited for video or electronic counting.

DMF will provide guidance to current and future counting groups on data quality and coordinate a process to support high quality counting series that provides adequate coverage of Massachusetts herring runs by major coastal drainage areas. As part of this guidance, DMF held a river herring counting workshop in March 2025 at our New Bedford Laboratory as a 20-year update to the workshop held in Gloucester in 2005 that ushered in the present era of science-based monitoring of river herring spawning runs in Massachusetts.

SOP 2.0 - Smith-Root 1601 Electronic Counter

Introduction

Smith-Root (www.smith-root.com) has been manufacturing electronic resistivity counters (ERC) since the 1960s with early designs focused on West Coast salmon counting (Liscom and Volz 1975). Smith-Root counter arrays are set up to intercept fish during their upstream spawning migrations. Fish are counted when they swim through counting tubes with metal rings that are connected to an electronic counter. DMF first adopted this technology in 1984 at the Monument River in Bourne using the single-tube model 1100 Smith-Root counter. The Monument River count continues as one of the longest running river herring counts on the East Coast. About 10 years ago, DMF committed to using the newer Smith-Root model 1601 (SR-1601) fish counters, which achieve higher accuracy by employing multiple passage tubes. Evaluations of single-tube ERC counters have shown a significant negative bias leading to underestimated run counts due to simultaneous counting for river herring (Sheppard and Bednarski 2015) and other diadromous fish species (Dunkley and Shearer 1982; and Shardlow and Hyatt 2004). All DMF electronic counting stations presently use model 1601 counters. A few Model 1100 ERCs are still deployed in Massachusetts by local partners (Figure 2.1).

Principles for Electronic Counts

We focus on the Smith-Root counters because DMF and other states have consistently used these units. The Smith-Root ERC counters operate under the "Balanced Resistance Bridge Principal" where a fish passing through the tube changes the conductance, breaking the resistance bridge, resulting in a recorded count (Smith-Root 2017). The counters are designed to work in freshwater with conductivity between 0 and 500 microsiemen. The Smith-Root 1601 can support up to 16 counting tubes that are simultaneously monitored. This counter can accurately tally over 10 counts per second, exceeding the capacity of river herring movements. Individual tube counts are shown on separate displays on the counter box. These can be tallied and reset at any interval. Daily visits to record and reset counts and maintain the station are recommended. With proper counter array design and suitable flow range, counter accuracy can exceed 98% (Smith-Root 2017). DMF counters that are located correctly and well-maintained have routinely achieved 90-95% accuracy as estimated from field quality control checks (also called comparison counts).

Objectives for Conducting Electronic Counts

The primary goal of conducting an electronic count of river herring spawning run migrations is to provide a long-term index of abundance that can support inter-state, state, and local management of river herring populations and the ASMFC coast-wide stock assessment. Currently, four electronic counts served as indices of abundance in the ASMFC 2024 stock assessment (ASMFC 2024). Additionally, two electronic counts form the basis of SFMPs to allow river herring harvest in MA. Electronic counts are also useful to support research on river herring life history, to inform decisions and evaluations on aquatic restoration actions, and for outreach on a natural resource valued by citizens.

Sampling Equipment

The central piece of equipment used for electronic counting of river herring is a Smith-Root Model SR-1601 Counter Box. DMF shifted from single tube (SR-1100) counters to multi-tube (SR-1601) counters about 10 years ago. A Smith-Root Tunnel Junction Box (TJB-16) connects the SR-1601 counter box to wires that individually connect

Figure 2.1. Single tube counter installed at exit of Alaskan Steeppass fishway at Sippican River, Rochester, MA.

to each tube in the counting array. Counting tube arrays are custom fabricated by the DMF Fishway Crew. Power to the counting station can be provided by 110 V, a deep cycle 12 V battery, or a solar panel connected to a battery. Further details are provided later in the SOP under **Equipment List**. At the time of this publication, Smith-Root is no longer selling new SR-1100 or SR-1601 counters, although they are providing service to existing counters.

Sampling Locations

The selection of suitable locations to run Smith-Root electronic counters requires consideration for fish population size and species, spawning habitat location, site access, power, and river discharge and site flow manipulation. Large river herring runs with few other migratory species, average spring flows in the range of 5-100 cfs, and hydraulic control features at the site to adjust flows through the tube array can be good candidates for electronic counters. Access to 110 v power is favorable, although we have had good success with solar-powered sites. Setting up counters lower in the watershed downstream of spawning habitat is important as is avoiding tidal areas that experience changes in water conductivity. Video can be better suited for counting stations when numerous migratory fish species are present, and especially for rivers with sea lamprey (*Petromyzon marinus*) that can use their mouths to adhere to the inside of the counting tubes, causing an overestimation of fish counts.

Smith-Root electronic counters can be the "higher flow" option among the three SOP methods. Low flows can result in poor accuracy as fish hesitate to move steadily through the tubes. However, there is an optimal range for electronic counter performance as high tube velocity that approach upper swimming speeds for river herring (Haro et al. 2004; Castro-Santos 2005) can cause reduced accuracy and can delay upstream movements. We have found that data quality can suffer at sites with tube velocity <2 ft/s and >5 ft/s and overall stream flow under 2 cubic-feet-per-second (cfs). Most electronic counters are installed within the narrow dimensions of structural fishways; some have been used with in-stream weirs. As fishway flows decline to the 1-2 cfs, passage can require notched weirs even in relatively narrow fishways. In such cases, video or volunteer visual counting will be a better match than electronic counting. Secondly, fishways with an auxiliary spillway to manipulate flows through the counting tubes are much more favorable than a location with no ability to reduce or increase flow through the tubes. Parking access close to counting sites can be important since electronic counters should be checked every day to maintain passage and data accuracy.

Design/Installation

The DMF Fishway Crew fabricates custom electronic counter stations including tube arrays and fishway exit counter brackets (Figure 2.2). Tube arrays are sized to the fish population size and flow range. The Smith-Root 1601 counter can accommodate up to 16 tubes. For coastal Massachusetts herring runs, we have commonly set up 8 to 12 tube arrays with 4 tube arrays designed for lower flow systems. The tubes are 4" diameter, schedule 40 PVC, and 20" in length. Stainless steel hose clamps are used for wiring rings and these are set and wired on the tubes. The tubes are secured together in an aluminum frame and often stacked in rows of 4 or 5 tubes. We typically purchase enclosure boxes that are weather-proof to house the counter box, tunnel junction box, and power connection (Figure 2.3). The tube array and fishway exit bracket are often integrated as a custom-welded aluminum frame that fits into the fishway exit stop log slots (Figure 2.4). DMF has started to design down-running chutes to give adult herring an avenue to move downstream post-spawning (Figure 2.5). These chutes require adequate fishway width and flow to allow chutes to function without impacting upstream passage through tubes.

Electric counters can be powered by 110V AC from a local source, a stand-alone 12V battery, or a 12V battery connected to a solar panel. Depending on site conditions, local 110V can be the easiest design with least maintenance when available; however, solar power has become a reliable power source for some DMF fabrications. DMF no longer recommends direct battery power given the labor needed to keep fresh batteries available and the inevitable data loss when batteries lose power. However, both solar and 110V power systems are run through a 12V battery with a power inverter to avoid counter damage from power surges.

The size of the array will depend on the available flow, outlet dimensions, and run size. Through over a decade of SR-1601 use, DMF has had multiple sites with as few as 4 tubes capable of passing over 400,000 herring in a season and over 70,000 in a 24-hour period. To be conservative and facilitate safe passage, DMF often uses 8-12 tube arrays for runs with several 100 thousand fish and average flows near 10 cfs. The design should consider the range of spring flows and ability to manage flows with auxiliary spillways, fishway boards, and trash racks. Some sites may need debris booms to reduce the entrainment of debris to the tube openings. The DMF Fishway Crew is

Figure 2.2. Eight-tube counter for Monument River, Bourne, MA. Early test model with wood frame. An improved design was later deployed with a fabricated aluminum frame.

Figure 2.3. Smith-Root 1601 counter with 8 four-inch diameter tunnel counting array installed with 110 V power at the Benoit's Pond fish ladder exit on the Monument River, Bourne.

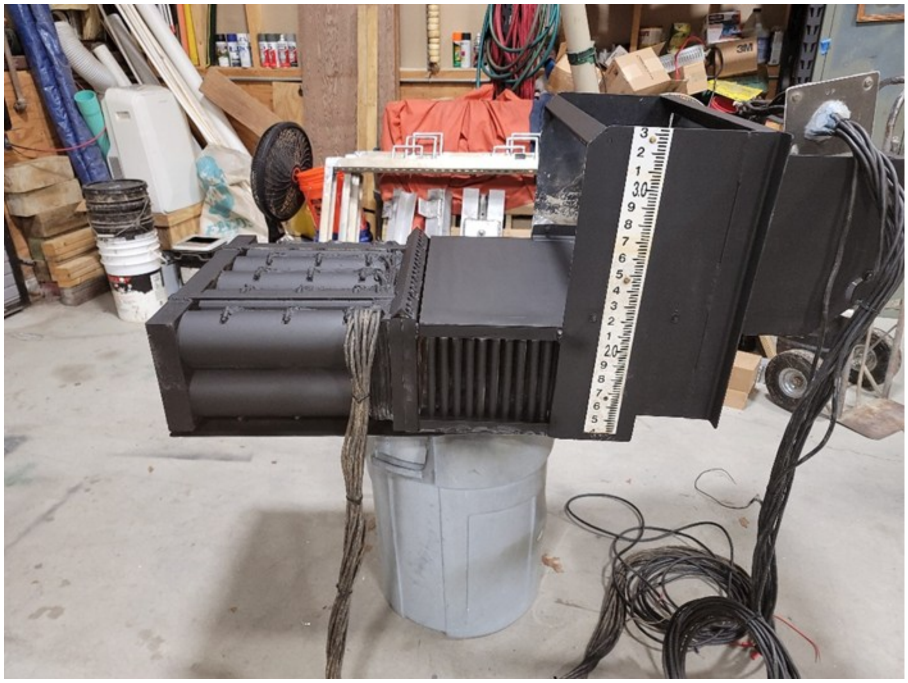


Figure 2.4. Custom 10-tube count with unique top down-running chute, side trash racks to dump flow to reduce water velocity and pond level staff gauge attached, Stony Brook, Brewster.

Figure 2.5. Smith-Root 1601 counter with downstream migration chutes installed, Herring River, Harwich.

available to fabricate debris booms for these locations.

Most electronic counters in Massachusetts are installed at fishway exits. It is important to consider how counters are integrated with fishway operations. Managing fishway flows with changing headpond elevations can be challenging and this can be heightened with a counting tube array. The counter array should be set at a suitable water depth to induce fish to pass readily through the tubes. The tubes should be fully submerged at all head pond water elevations. For fishways, the array will sit as low as possible on a stop log board at the fishway exit or flush to or on the concrete bottom of the fishway exit pool. As the spawning run advances, careful monitoring and maintenance will be needed to maintain suitable flows in the counting tubes for fish passage and data quality and the downstream fishway weirs and baffles. Site managers will need to become authorities on pond level fluctuations and stop log board management to make adjustments for each fishway and custom tube array enclosure.

A water surface elevation staff gauge should be installed at the head pond to develop a record of pond level fluctuations. Record the target range of water surface elevation and corresponding board height in the fishway exit stop log slots where the counter performs well and fish passage is suitable. These pond level data should be matched with tube velocity measurements to develop an understanding of suitable conditions for fish passage and counter operation. Every location has a range of water depth where the tube will sit optimally in terms of fish behavior, head pressure, and tube velocity. As stream flow declines during the migration, the array may need to be lowered to maintain suitable conditions. Record notes for each site to facilitate the installation each spring. Install counters a week prior to the typical known run onset to capture the start and record a few days with zero passage.

Operation and Maintenance

Background. ERC counters are powerful data collection tools but can easily provide inaccurate data if not consistently and routinely maintained. Flowing water and varying environmental conditions create a harsh environment on equipment. The resulting wear from constant exposure can lead to performance issues with counters. Additionally, changing water levels and velocities, compounded by debris in streams, all require daily inspections and maintenance. Managing tube velocity while providing target flows in a fishway or stream is essential to obtain an accurate count and support suitable fish passage, and this becomes more difficult both with larger fishways and streams with low flow.

Maintenance and Diagnostics. DMF staff should visit, or arrange for trained partners to visit, count stations every day of the passage season to ensure proper operation and to obtain daily counts. At each visit, staff should complete a basic maintenance and diagnostic check on the counter station. Visual inspection, battery tests, and water velocity checks should be made with each visit. If visibility is suitable and fish are present, a comparison count should be performed.

The primary causes of poor count data are out-of-range tube velocity influencing fish behavior, power failure, debris in tubes, wiring failures, and Smith-Root sensitivity error. Power failure is obvious and should be corrected immediately by replacing the battery or solar charge controller. When changing these components, remember to power the counter OFF before disconnecting and changing batteries and power back ON after reconnecting. Debris lodging in the counter tubes also can be apparent and easily corrected by removing debris. Poor comparison counts can be a flag for debris caught inside the tube and not easily seen with casual viewing. The sensitivity control on Smith-Root counters is factory-set based on ambient specific conductivity. This dial should not be touched by anyone other than the lead staff for that counter. Tube array electronic failure and tube velocity error have a range of complexity for diagnosis and troubleshooting. Responses to these issues should be discussed with DMF staff biologists.

1. *Data Recording***.** A standardized DMF data sheet should be used for all stations (Appendix B Table B.1). DMF will prepare and provide data sheets tailored for each station. In addition to Smith-Root counter data, water level staff gauge and battery voltage should be recorded with each visit. Record time-of-day in military time to the nearest 15 minutes.

2. *Visually assess counting array***.** With each visit, inspect the station for problem areas such as obviously low or high flows, impinged fish, debris, and blocked tubes. Observe behavior of fish entering and exiting the array. Problems and solutions should be noted in the *Comments* section of the field data sheet. If tube velocity appears out of the target range, and/or fish are observed hesitating or failing to pass, record tube water velocity before altering conditions and again after changes.

3. *Electronics Inspection***.** If a Smith-Root counter is powered by 110 V through an inverter to a 12 V storage battery, then the inspection is limited

to making sure the counter is powered and that wires are firmly connected and spaced without excessive bends. If the unit is powered by a solar panel run through a 12 V battery, then battery voltage checks should be made with each visit. Fully charged batteries should be in the range of 12 -14 V. On cloudy days, the battery may range from 11-12 V as the solar panel will generate less power. Charges below 11 V on sunny days are a flag for possible issues with the battery or solar charge controller. Checking voltage at the battery and coming into and out of the solar charge controller (Figure 2.6) can isolate which feature is failing.

NOTE: Before plugging or unplugging the counter from a power source, both the **POWER** and **COUNT** switches should be in the "OFF" (downward) position. The **POWER** switch should only be turned "ON" or "OFF" if the **COUNT** switch is already in the "OFF" position.

4. *Tube Count Reset Test***.** After recording all the count data on the field data sheet, use the **RESET** button to reset tube displays to zero. The tubes should then be tested using the **TEST** button. The button should be depressed fully at a deliberate pace. An uneven depression can lead to inconsistent test counts. Apply the **TEST** button several times unless fish are actively moving. Staff should be alert for tubes that do not count, count inconsistently, or double count. All these conditions may limit tube accuracy and should be addressed. If the issue cannot be diagnosed and corrected by staff, the tube should be blocked off. All issues and actions should be recorded in the field sheet *Comments*.

5. *Individual Tube Failure***. TEST** button checks can reveal single tubes that don't respond or send "ghost" counts to neighboring tubes. At times, such failure can be picked up during comparison counts (difficult for arrays with large numbers of tubes). Use the bottle test (run a plastic bottle half full of water on a string through the tubes) to confirm if individual tubes are working correctly. If error is found, check the tunnel junction box to make sure the wire in the middle row (white) is tightly connected. Next, reset that wire with the specific Smith-Root junction box tool to an unused space in the middle row. After this correction, test this tube with both the **TEST** button and the bottle test. If the tube continues to test incorrectly, then remove the array on site and view and test the wire connections on the underside of the array. Fix lose or broken connections if found. If these on-site tests fail, then the tube must be blocked off and the array needs full bench assessment in the off-season.

Figure 2.6. Example of suitable solar charge controller for electronic counters.

5. *Check Tube Velocity*. DMF staff should possess a suitable water flow meter for all site visits. Water velocity measurements should be coupled with counter comparison checks at a minimum frequency of weekly and up to every visit if needed. DMF staff experience has found that target velocities for SR-1601 counters with 4” tubes are 3.0 - 4.5 ft/s. However, velocity meters are not 100% accurate and readings may vary depending on the brand and model. It is important to take velocity readings over a range of flows at each station and observed fish passage to gain a firm understanding for the optimal readings given station conditions and velocity meter. Adequate fish passage and data accuracy can be achieved slightly outside this range. Corrective action should follow measurements outside this range, recognizing that water velocity <2.0 ft/s and >5.5 ft/s will cause some level of counting error, and typically an overestimation of counts.

When velocity is low, river herring may linger in the tubes causing extra counts of a single fish as the resistance bridge remains open. When velocity is too high, fish can struggle to pass through the tubes, causing multiple counts. High velocity can have higher rates of overcounting than low velocity and can have more variable effects related to individual tubes, individual arrays, and fish behavior at different counting sites. For example, the threshold above 4.5 ft/s when counting errors manifest with higher velocity can be different among Massachusetts counting stations.

If able, record velocity at the tube entrance (pond side) with flow meter wheel centered at each tube until the display is stable. Velocity at the tube exit (fishway side) will run a little faster than the entrance. In cases where the tube entrance cannot be accessed, measure at the tube exit. The measurement location and velocities for each tube should be documented on the field data sheets. If velocities are either too high or too low when staff arrives at a counter, corrective actions should be taken. Actions should be performed gradually at first and velocities rechecked to measure the effect of the action. After performing corrective actions, new tube velocities should be recorded on the field sheet along with notes on what action was performed. Corrective actions include the following:

High Velocities (>4.5 ft/s). If velocities are high, then water must be shifted to the fishway or stream through an outlet other than the available tubes. This can be done by: (1) stop log board manipulation at auxiliary channels; (2) removing debris from grates or bar racks; and (3) if one or more tubes are blocked due to electrical malfunction, troubleshoot and resolve to open blocked tubes.

Low Velocities (<3.0 ft/s). If velocities are low, then water supply to the fishway or stream must be restricted to send more flow to the tubes. This can be done by: (1) stop log board manipulation at auxiliary channels; (2) adding debris to grates or bar racks; (3) tubes that receive low numbers of counts can be blocked with 4” diameter test caps. Make sure there is an error in comparison counts before blocking a tube. The 3.0 ft/s is a low velocity to pay attention to, but not a threshold when error begins. Some stations have shown high accuracy of comparison counts when velocity is 2-3 ft/s. Test caps used to block tubes can be trimmed or widened with electrical tape to ensure a snug fit at both the upstream and downstream tube openings. Place a cap in the upstream side of the tube first. The downstream end must also be capped, or fish may enter the tube and potentially knock out the upstream cap.

NOTE: River herring typically prefer swimming along the bottom with higher numbers found passing the lower row of tubes and lower numbers in the top row. Review patterns in tube number counts before selecting which tubes to block.

NOTE: Rising water levels can lead to increased velocities while declines will lead to decreased velocities. Large rain events, especially early in the migratory season, often lead to velocity increases through rising water and mobilization of debris. Anticipate these conditions while performing counter maintenance.

6. *Perform a comparison count***.** When well-maintained and calibrated, a SR-1601 should be capable of routinely producing counts with >90% accuracy. Counter error is typically a result of multiple fish passing through a tube at once (underestimation or negative bias) or, debris in tubes, electrical errors, and fish entering and hesitating or not passing fully through the tube (overestimation or positive bias). The best way to assess accuracy in the field is to perform a comparison count. Comparison counts should be performed daily or whenever fish are passing at the time of a site visit. Daily counts can be limited by days with no fish present, weather conditions that reduce visibility, and high run counts that exceed the capabilities of staff to conduct accurate counts. Counts with no fish present have value; however, large numbers of such zero counts are not necessary. Daily comparison counts can be skipped if 2-3 zero counts have been made in a given week and no fish are present at the site.

Comparison counts are best conducted with two people, one viewing and operating the counter and one counting fish (Figure 2.7). If more staff are available on site, then multiple people can count fish to assess human error. Counts should be made for 5 minutes. This can be reduced to a 3-minute count if high numbers are passing. Counts with only one staff can be successful for identifying issues at low passage rates at some stations. Solo counts can be biased by missing a fish or two at the start or end of the count as the observer turns away from the tubes to view the electronic counter. This potential error can be evaluated during later data reviews by separating solo and multiple staff counts.

NOTE: Having two staff conduct comparison counts at the same time while the third staff member attends to the counter allows the calculation of Relative Percent Difference (RPD) of the two visual counts. This is a routine data quality metric for field precision with an allowable threshold of 5%. Having three staff available may not occur for some sites. This metric is simply a field precision check to identify possible errors in comparison counts. It is not used to adjust counts. If able, staff for each station should endeavor to conduct 5-10 RPD measurements per season.

All comparison counts should be recorded in the appropriate field on the data sheet. If error is <10%, the SR-1601 can be left at the current settings. If the daily check finds an error >10%, staff should investigate potential causes and make adjustments. The lead DMF staff biologist should routinely review the comparison counts and other field sheet records from volunteers weekly to track data quality and keep lines of communication open with volunteers to identify counter issues as soon as possible. At the end of the season, comparison counts should be processed in the station field data sheet (Appendix B Table B.2). The percent agreement in observed counts and electronic counts should be tallied both as the average daily % agreement and the cumulative season % agreement (Figure 2.8).

7. *Smith-Root Sensitivity***.** Smith-Root ERCs have sensitivity knobs on the counters that are turned clockwise to increase the resistance of the bridge. These are factory set to match the specific conductance of the water at the counting site. The sensitivity should be checked for new ERC units. If false counts are occurring, the resistance can be raised slightly until all comparison counts are accurate. The correct setting on the sensitivity knob should be marked with waterproof ink in case the knob is bumped off this setting. Once an ideal SR-1601 sensitivity setting is found, it should hold over the course of the season and adjustments to the

Figure 2.7. View during a comparison count of herring exiting Herring Brook counter tubes, Pembroke.

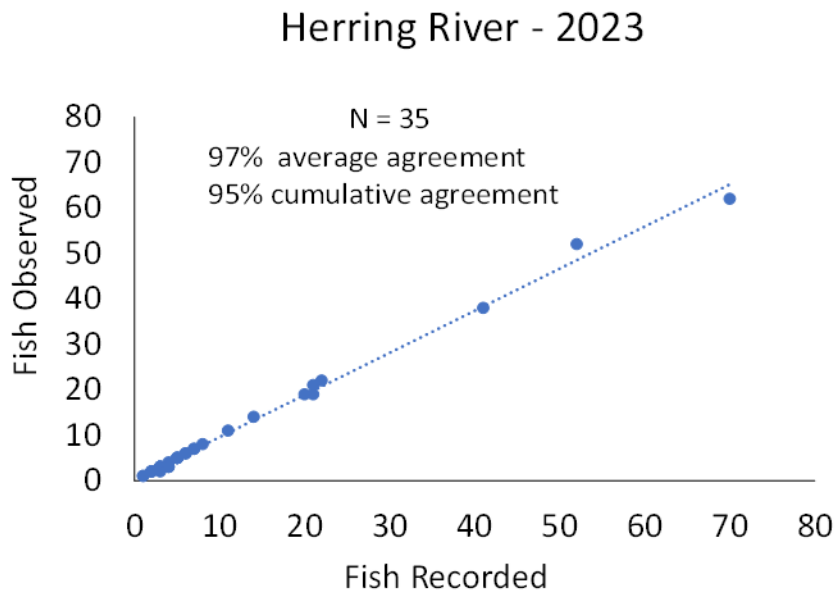


Figure 2.8. Scatterplot of Smith-Root electronic counter comparison counts recorded at the Herring River, Harwich, in 2023. Sixty-six comparison counts were made: 25 zero fish counts and six outliers (counters noted down-runner interference, debris in tubes or poor visibility) were removed. The remaining 35 counts with fish had 97% average agreement and 95% cumulative agreement.

counter and array should typically be flow-related. However, sometimes the sensitivity of the counter may need to be adjusted. In this case, the event should be recorded and changes to accuracy documented by several comparison counts. Given the potential for creating counting error with sensitivity changes, DMF staff should be consulted before adjustments are made to the sensitivity. Adjustments to sensitivity is a more common troubleshooting tool for single-tube SR-1100 counters than SR-1601. However, the same steps need to be taken where changes are carefully documented with comparison counts.

Tube Array Failure. Poor comparison checks can be caused by a single malfunctioning tube. Complete array malfunctions are infrequent. Failure of a single tube is not always apparent during comparison tests but should be revealed through repeated comparison tests and use of the **TEST** and **RESET** buttons. If a tube shows consistent error with these tests, it can be blocked off for the season or until a solution is made (often replacing terminal connections or re-wiring in the off-season). Record notes on testing. See the following section on *Technical Troubleshooting* and Appendix C for more details.

Count Data Adjustments

Given the above discussions on counting accuracy and error, there will be times where decisions need to be made on adjusting count data. Adjustments will depend on the timing of changes in counter performance and the documentation of conditions around those changes (water velocity, comparison counts, counts/hour, and staff gauge measurements). Decision steps are needed to respond in a standardized manner for adjusting or censoring daily count data.

DMF staff should transcribe counter field sheets for each season to an Excel template for each counting station. This template can be provided to other users of electronic counters. The spreadsheet allows for quality control and assurance checks of daily entries, comparison checks, and seasonal summary data. The annual process of transcription and data processing will allow for decisions on data adjustments.

Decision Steps for Count Adjustment

All potential cases of count data adjustment will be reviewed after the season with *final* QA/QC decisions made and documented in the annual spreadsheet by the DMF site manager. Within-season *preliminary* adjustments can be made if seasonally relevant for the site and the causes of the data issue are obvious and easily corrected. Appendix C provides more troubleshooting details and photographs related to electronic errors.

Power Failure. In the case of a 1-2 day power failure with acceptable comparison counts on the boundary days before power loss and after power correction, the average fish/hr for the two boundary days can be applied to the hours when power was out. If acceptable comparison counts were not made on boundary days, then best professional judgement (BPJ) is applied to either extrapolate the fish/hr for the boundary days to the days without power or assign no counts. For example, single day power outages can be adjusted using the boundary day fish/hr if BPJ finds no interfering conditions. Beyond 2 days of power failure, extrapolation is possible, but accurate comparison counts are needed on the boundary days, and the weather and boundary day total counts should be consistent and BPJ should find no outstanding questions on data quality. Otherwise, to be conservative, no assignment of counts should be made for power losses of 3 days and longer.

Tube Obstruction. The same data adjustment process used to address power failure can be applied to cases of tube obstruction; however, details on which tubes were obstructed will further drive decisions. Visual inspection and comparison counts will help identify tube obstruction. Complete array malfunctions are infrequent. Single tubes can malfunction more often, either from wiring failures or debris blockage. Decisions will need to be made over data adjustments for a single tube, one row of tubes, or all tubes based on the comparison counts and inspections. The fewer the tubes in the array, the easier this question is to resolve. An easy example of this type of error is when a stick is stuck in one tube causing false counts. In that case, the counts for that tube between accurate comparison counts will be censored.

More difficult decisions are needed for cases in larger arrays when it is uncertain which tubes are failing and when the error begins. Similar to power failure, the comparison counts from boundary days for 1-2 days of tube obstruction can support extrapolation using fish/hr of boundary days. In most cases of tube blockage >2 days, the data will be censored with possible exceptions for 3-day periods when there are clearly identified sources of tube error and suitable comparison counts on the boundary days.

Tube Velocity Error. Water velocity outside of the target range (3.0 to 4.5 ft/s) can cause fish to hesitate in tubes causing multiple counts of one fish. Comparison counts are essential to flag this problem and, ideally, will catch any problem within one day. Similar to power failure and tube obstruction, 1-2 day tube velocity errors can be corrected with suitable comparison counts on the boundary days. In cases of elevated flow from rain events, at some stations we have seen consistent error caused by high tube velocity with no possible corrective action until flows subside. Data adjustment in these cases will be highly dependent on the comparison counts. Diligent comparison counts can demonstrate consistent error in the percent agreement between fish observed and electronically counted and allow data adjustments for specific periods of high tube velocity.

NOTE: It should be clear that catching errors immediately during daily checks and having boundary day comparison counts are essential for making count adjustments. However, sometimes there are no fish passing to count. It may be tempting to use arbitrary methods to adjust data to avoid count loss during high passage periods. The better approach is to endeavor to make comparison counts as soon as able and if no fish are present, use the bottle check to at least confirm that troubleshooting has resolved the error.

Down-runner Management

As the migratory season winds down, decisions will be needed for each counting site on managing the post-spawning, down-running fish. The SR-1601 is not able to distinguish between uprunning and down-running fish. River herring appear reluctant to use the 4” tubes to move downstream but have been observed doing this at some sites. With experience at a given site, consideration should be made for modifying the array frame to allow for downstream-only passage. Counter arrays can cause migratory delays and mortalities as weak individuals become impinged on the upstream face of the array or in tubes. At this point, if the site has a bypass structure or downstream passage, flow can be directed to encourage down-running herring to use that passageway. If not, bar racks or screens should be removed to allow downrunners free egress and the season’s count should be concluded. Each site should have an end-of-season plan for consistent downrunning management with the annual execution documented in the counter spreadsheet.

Equipment List

Smith-Root Model SR-1601 Counter Box. DMF shifted from single tube (SR-1100) counters to multi-tube (SR-1601) counters about 10 years ago.

Tunnel Junction Box (TJB-16). The Smith-Root tunnel junction box connects counting tube wires to the SR-1601 counter box.

Enclosure Box. DMF has fabricated equipment enclosure boxes out of aluminum, adapted weather-proof plastic cases, and purchased steel weather-proof cases. The best option to date has been a series of McCallister weather-proof, painted steel cases to protect all electronics.

Battery. 12 V deep cycle.

Battery Adapter Cable. A cable with counter box power plug that attaches to battery. Attach wires with crip and nuts to battery terminal. Alligator clips can work but are not preferred as the potential exists for staff to bump the clips while servicing the counter, resulting in erroneous count numbers.

Solar Panel (if powered by solar). 45 W polycrystalline panel. Minimum of 2 amps.

Solar Charge Controllers. Solar charge controllers are needed if electronic counters are powered by solar panels. DMF's applications have used simple 12V/8-amp non-adjustable controllers as well as adjustable units up to 20 amps. The sealed, non-adjustable controllers seem to have better longevity. Controllers that do not require setting a manual restart button after an automatic shutdown due to low battery (often around 10.7 V) are essential for electronic counters. Use in-line fuses on both ends of the charge controller. Connect the controller to the battery first before connecting the live solar panel wires to the controller and going from controller to battery.

Onset Water Temp ProV2. Temperature logger to record hourly water temperature at all stations.

Staff Gauge. Durable metal or plastic water level staff gauge should be surveyed to benchmark near the fishway/counter to record head pond water level (relative ft) with each counter visit. DMF provides these for all counting stations.

Data Sheets and Datafiles. Common templates for electronic field sheets and station datafiles are available from DMF to customize for any station.

Smith-Root Technical Support. Smith-Root technicians can be consulted at 360-573-2064 on troubleshooting questions.

SOP 3.0 – Video System Counting

Introduction

Underwater video systems paired with motion detection software can be effective tools for counting fish passing both up and down a fishway or river channel constriction. Video counting of diadromous fish has been in practice for decades, most often at larger dams with fish lifts and specifically for salmonids (Easterly et al. 2005; Nicholson et al. 1994; Shardlow and Hyatt 2004). Traditional fish lift designs included a room for counting technicians with a viewing wall to observe fish as they exit the fishway or lift. Video cameras can be set up to provide a complete record of fish passing as an alternative to having technicians present to make visual counts. As technology has advanced, video has become far more adaptable and is now being used in various-sized fishways and to specifically target river herring.

Video counting systems have the advantage over electronic counters as suitable for a wider range of flows and have a lower start-up cost. Well-designed systems can provide reliable records of all species moving past the video station. Video monitoring can be unsuitable for locations with difficult lighting conditions, water turbidity, and flow surges. Stations with such problems may accommodate an electronic counter but may not also be suitable for visual counting. Two other disadvantages of video counting are a higher power requirement and large effort and cost to process video images. It is highly recommended to use 110V to power video counting systems. DMF have used solar-powered systems and found they need more power and are prone to more power disruptions than electronic counters. Software that uses motion detection to trigger video recording only when fish are within the camera field of view (versus a continuous record of video) can reduce processing time; however, video processing for a single spawning run presently takes 100s of hours and can come with a high labor cost.

Recent efforts on crowd-sourcing viewing and image analysis as well as machine-learning applications to identify and count fish automatically hold much promise for improved video processing in the future. Commercial and academic applications on river herring counting image processing with artificial intelligence programs are underway presently in Massachusetts (e.g. Marjadi et al. 2024). Ongoing crowd-sourcing image processing at the Mystic River and Town Brook in Massachusetts will offer insight on the potential for volunteer-based video processing in the future.

Principles for Video Counts

With video counting systems, migrating fish swim through an enclosure set in a fishway or channel constriction where an underwater video camera is set up perpendicular to flow to capture the entire field-of-view for fish passing upstream or downstream (Figure 3.1). The camera is connected to a laptop computer in a waterproof enclosure located near the camera. The laptop has software with motion detection features that save images in files as fish are detected passing by the camera. Present video systems do not produce a daily or seasonal count of fish. The images must be viewed by staff and counted to tally run counts. Underwater video systems can record high-quality images of passing fish that have the potential to produce a census of river herring migrations while documenting the movements of other aquatic life. The integration of a laptop operating system, camera software, local power and associated electronic connections requires a higher level of technical ability than both volunteer visual counting efforts and electronic counters.

Objectives for Conducting Video Counts

The primary goal of conducting a video count of river herring spawning run migrations is to provide a long-term index of abundance that can support interstate, state, and local management of river herring populations and the ASMFC coastwide stock assessment. Currently, two video counts served as indices of abundance in the ASMFC 2024 stock assessment (Table 1.1). Ongoing video counts are also useful to support research on river herring life history, to inform decisions and evaluations on aquatic restoration actions, and for outreach on a natural resource valued by citizens.

Sampling Equipment

The underwater cameras used by DMF are SeaViewer 950 Analog Drop Cameras with infrared lighting. Each system includes the camera, a 50ft cable, analog video capture adapter, and the control box, which has an on/off switch, dimmer control, and ports to plug in to power and a computer (Figure 3.2). The camera must also have infrared lighting as the only suitable lighting option for night images. In addition to the underwater camera system, a laptop and portable hard drives are used to record and store video. The underwater video camera cable connects to a control box, and both the control box and laptop computer connect to a power strip fed by local 110 V power source. DMF recommends 110 V power for all video applications with consideration of exceptions for solar-powered stations that have highly suitable local conditions. All electronic components are kept in a weather-proof enclosure box installed close to the power source.

Sampling Locations

Video counting can be used in areas where an electronic tube array is ineffective due to very low flows, high flows, potential passage obstruction, or where fish diversity prompts the interest to identify fish species. Video counting may not be favorable in locations with higher water turbidity or turbulence, which can set off motion detection features and increase the rate of false detections.

Figure 3.1. River herring passing through the Lake Sabbatia video station on Mill River, Taunton.

Figure 3.2. SeaViewer 950 video camera equipment (SeaViewer Cameras, 2024).

Wind fetch can be a factor that causes elevated sediment in the water column or water surges that set off false motion detections. Potential locations should be visited over a range of conditions to get a sense of whether video images might be compromised by lighting, turbidity, or flow surges. Similar to electronic counting systems, access for daily maintenance checks, 110 V power, and a structural fishway with stop log slots at the exit and an auxiliary spillway to regulate outflow are all highly favorable for siting video counting stations.

Design/Installation

Underwater video systems are housed in enclosures that fit the dimensions of a fishway exit or stream channel. Nearly all video enclosures used to date in Massachusetts have been custom fabricated out of wood or aluminum (Figure 3.3) by the DMF Fishway Crew. These enclosures are attached to the upstream exit of the fishway and typically have a "runway" or "crowder" on the enclosure floor and/or wall to guide fish to swim past the video camera field of view (Figure 3.4). The enclosure includes a camera box that is separated from the main flow of water by plexiglass or polycarbonate insert. Reflective tape should be applied to the opposite enclosure wall from the camera to provide a sharper image. One important design consideration is to minimize the intrusion and variability of natural light levels in the enclosure that will trigger motion detection when no fish are passing.

Video recording systems can also be set up above water with cameras facing down into the channel where fish will pass. The vertical orientation was applied by Burak (2011) for adult river herring, Gahagan et al. (2010) for juvenile herring, and at large hydropower fish lifts. This method introduces several technical difficulties related to surface glare and species identification and is not compatible with motion detection software. As a result, DMF has exclusively used submerged camera orientations in the horizontal view. However, future applications in stable viewing environments could consider above-water cameras with similar features presented in this SOP.

Software. DMF relies on an open-source software program called iSpy, which allows users to set motion detection settings, video capture length, and storage location. Live-feed video is streamed to the laptop into the iSpy program where individual videos are recorded and saved when the motion detection feature is triggered. The program saves video files directly to portable hard drives (of at least 1 TB) that are switched out weekly over the season. DMF uses iSpy for all video stations in Massachusetts. Salmonsoft, an alternative software used for video counting, records a 'rolling segment' where the tail will be deleted if no fish is detected

Figure 3.3. Custom fabricated aluminum video camera housing attached to fishway exit board slots.

Figure 3.4. Custom fabricated aluminum video camera housing for bottom floor crowder.

by the program's motion algorithm. When fish are detected, the program creates a digital video file according to the user's preference. This program greatly reduces the amount of video to review, has included viewing features, and creates spreadsheets for count data, but requires higher start-up costs and similar high processing time and daily attention to maintain the laptop, camera, and software. iSpy has the advantage of being free software but offers no counting support features.

Operation and Maintenance

Pre-Deployment Check. To ensure functionality, it is recommended that all equipment be "dry tested" before deployment in the field. This should be done by plugging all equipment into power and the laptop, setting preferences in iSpy, and triggering motion detection and video recording. Auto-update and re-start features should be disabled on the laptop. These features can interfere with iSpy operations. Power settings on the laptop should be set to not sleep or hibernate.

Assess Video Quality. Critically review saved video images within season to make immediate adjustments to settings. View images saved near dawn and dusk early in the season to determine if solar glare is casting shadows or bright flashes in the frame that can trigger false detections. Sun orientation will likely be a factor that needs addressing with modifications to the enclosure during the first few years of operation. It is important to also view images at night and at different times of the day to determine other light issues. If the source of the false detections is unclear, turn on **Border Highlighting** under Display Style in the iSpy motion detection settings. This will outline pixels in motion, making it easier to see what movement the software is detecting. High algal growth on the camera lens or plexiglass or debris in the enclosure can reduce data quality and should be addressed immediately.

Seasonal Maintenance. Professional staff should visit, or arrange for trained partners to visit, video stations every day of the passage season to ensure proper operation and maintenance. At each visit, staff should visually inspect the entire system and the following maintenance and diagnostic checks. Common issues that can cause video data loss include laptop failure (either from power loss or exposure to low temperatures (<40 F°) and reaching limits of file storage space. Video or data quality can be affected by algal growth in the camera enclosure and lens, debris trapped in the enclosure, and glare from light intrusion. We have found that light intrusion and daytime changes in sun angle can be the largest source of false detections. Diligent maintenance and attention to light intrusion can greatly reduce the time spent later viewing video clips saved from false detections.

Field Data Sheet. Standardized DMF data sheet should be used for all stations (Appendix D, Table D.1). DMF will prepare and provide data sheets customized for each station. The data sheet will have columns to check off suitable operation, data transfers, battery voltage, water level staff gauge, and appropriate notes with each visit. Time-of-day should be recorded in military time to the nearest 15 minutes.

Maintenance Checklist

1. *Power Supply***.** The laptop and video camera should be plugged into a power strip with an on/off switch and light. Confirm this connection has power with each visit.

2. *Check laptop***.** Ensure computer is still on and functioning. Confirm that the iSpy program is running and that videos are being recorded to the correct storage drive. If laptop has shut down due to cold temperatures, place insulating foam board around laptop and hard drive in enclosure box.

3. *Assess video quality***.** Watch several recently saved video images to look for false detections and check the quality of video images. If video images are blurry, it is possible that the lens, plexiglass divider, and the inside enclosure wall need to be cleaned. If false detections are occurring, attempt to determine the cause (typically debris, solar glare, and/or software settings).

4. *Clean Enclosure Glass***.** Wipe camera lens, plexiglass panel, and reflective background in enclosure with kitchen eraser sponges as needed (minimum of weekly for most sites). Remove any debris accumulated in the enclosure. After this maintenance, confirm in iSpy that the camera orientation is correct and not jostled by the cleaning.

5. *Transfer Image Files***.** Files of fish images saved on the laptop or external hard drive should be swapped out or downloaded at least weekly. Transfer to extra external hard drive or switch drive out and arrange for a set of back-up files that are both given the same file name based on the date range of images.

Software Settings – iSpy

Key settings for iSpy motion detection and image recording are the gain, trigger range, and custom areas of detection. These settings are likely to be unique for each site and require a dedicated phase of field trial and error to determine optimal settings. Other important settings include buffer, inactivity record, and maximum record time.

Trigger Range. Trigger range is probably the most important control in iSpy. This sets the minimum and maximum levels of motion detection (e.g. the percent change in pixels from frame to frame). Setting a maximum is good for ignoring whole scene changes, like sudden brightness changes due to weather variations while the minimum value allows for ignoring small changes like shifting light. If the trigger range is set at 9-90%, then motion detection (and recording) is only engaged when more than 9% and less than 90% of the pixels change from one frame to the next. DMF video stations have operated within a lower trigger range of 5-20% and upper from 50-90%.

Gain. Gain indicates the value applied as a multiplier to the changed pixels to increase (high) or decrease (low) the sensitivity of the motion detection. For recent applications, we have often set the gain to 3 to 4, because we have found that higher gain values lead to false detections from light reflections and shadows. The goal is to find the gain value that captures all fish of all sizes while reducing false detections.

Detection Zones. Detection zones are a feature that allows the highlighting of areas within the viewing frame where motion detected within those zones will trigger recording. This helps eliminate areas where light intrusion sets off motion detection. Setting the detection zones is part of the initial field setup process where tests are made with detection zones, gain, and trigger range to optimize fish detection.

Buffer. The buffer sets the number of seconds before a trigger event that will be saved in a recorded video clip. This feature allows the recording of the movement of a fish moving rapidly through the video frame. DMF typically sets the buffer at four seconds for recorded video.

Inactivity Record. The Inactivity Record is the number of seconds the video will continue to save a clip after motion is no longer detected. We have found that a suitable time after last motion detection is about 10 seconds as this leaves time for slow or hesitant fish to pass and be recorded in the same video clip. We have found settings below 10 seconds can result in larger numbers of clips of single fish movements and settings of 15 seconds or more can result in longer video clips with low fish passage.

Maximum Record Time. The Maximum Record Time is used to set the maximum time span for each video clip. This setting is dependent on the size of the herring run and local conditions that cause false detections. In most cases, the default is the maximum setting of 15 minutes.

Storage. Under the Storage Setting tab, Media Location must be linked to an external hard drive with at least 1 TB of space. Video recordings will be stored on the internal storage (C Drive) of the laptop if default settings are not changed or hard drives are linked incorrectly. External hard drives will have more storage capacity than laptops and allow easy transfer to backup storage.

Software Settings – Salmonsoft

DMF staff have not recently deployed Salmonsoft software at video counting stations. We recognize that it is an option that can be considered when designing video counting stations. More information on Salmonsoft (Portland, Oregon) is available from their website, https://www.wecountfish.com/.

Video Data Processing

Data Backups. Video counting systems can be prone to data loss. Routine field maintenance is essential to reduce the events that cause data loss. Common issues that can cause data loss include laptop failure (either from loss of power or exposure to low temperatures (<40 F°)) and inefficient storage space. It is essential to integrate routine site maintenance with a weekly process of saving backup files on redundant external hard drives to reduce data loss.

Video Quality. As video images are processed, record detailed notes on conditions that trigger false detections that can guide the next season's deployment. Create a file for each stations with clips saved that illustrate video quality issues.

Troubleshooting issues. If videos are reaching the maximum record time (under video recording settings) and/or recording one after another in time (i.e. recording extended periods, regardless of single video length) then motion detection settings are likely too sensitive. Decrease gain and/or trigger range until background noise no longer triggers recording. Debris continuously floating in the field of view or flashing solar glare and shadowing can also cause continuous video recording. In some cases, you can set detection zones in iSpy to exclude areas where glare/shadowing occurs with special care not to reduce the motion detection field too much. If this does not solve the issue, add materials to physically block the light from entering the enclosure or modify the enclosure itself. Visibility issues that occur during low light periods (when night vision is engaged) can be fixed using the light dimmer on the control panel.

Video Processing Software. Although any video viewing software will work to review videos for fish counting, we have found that VLC media player has the best key shortcuts, which make the stop-and-go nature of the videos for fish counting go faster. Download VLC here:

http://www.videolan.org/.

To create a time-sequenced que of video files click “Media” in taskbar, then “Open Multiple Files”, and add to select video files.

Key Controls in VLC

1. **SPACE BAR.** To start/pause video.
2. **[and].** To speed up the video by 0.1x (hold the key down for rapid speed increases/ decreases).
3. **= sign.** To jump speed back to 1.0x.
4. **SHIFT + LEFT Arrow or RIGHT Arrow.** To skip 3 seconds forward or back in video.
5. **E key.** To move video forward one frame at a time.

Data Format. Data format will be unique to project goals. We have included an example of our data logging spreadsheet in Appendix D (Table D.2).

Equipment List

Camera. SeaViewer 950 Analog Drop Cameras with infrared lighting. Each camera system includes the camera, a 50ft cable, and the control box.

Laptop. Most functional laptops can be used in this application. Target processing speed in the range of 3.0 to 5.0 GHz, RAM near 8 GB, and storage capacity of at least 250 GB. iSpy software downloads are available for Windows, Linux, and macOS operating systems. It is crucial that you download and test software with camera system before field deployment.

Video Capture Adapter. An analog video capture adapter that converts AV ports to USB is required to plug the camera into the laptop.

Weather-Proof Enclosure Box. Sized to accommodate laptop dimensions with 2-3 shelves for holding station equipment. DMF has found a

Figure 3.5. McCallister enclosure box with laptop, external hard drive, and SeaViewer 950 video camera cable.

good range of quality boxes available at McCallister (**Figure 3.5**).

Video Camera Enclosure. DMF custom fabricates the underwater enclosures out of aluminum.

Motion Detection Software. See above on Ispy and Salmonsoft.

External Hard Drive. At least 3x1 TB hard drives per station. All image files for a season will be saved on t two hard drives with one remaining in the office as a full backup.

Troubleshooting

See Appendix E for additional tips on troubleshooting hardware and software.

Acknowledgments

The Massachusetts Division of Marine Fisheries wishes to thank the large number of volunteers who go out each spring to count river herring out of support for these fish and interest in being part of a spring ritual. We know and appreciate that for every day volunteers were thrilled to see dozens of river herring shooting past the counting board there were many more days with rain and raw wind and nothing to see. We thank the Association to Preserve Cape Cod for coordinating counts on Cape Cod for the last decade. Jo Ann Muromoto led this task for many years, and we know this was no small effort to coordinate hundreds of volunteers at numerous locations. Gary Nelson deserves credit for being the architect of the statistical framework for volunteer visual counting. Thanks are due to Mike Palmer of APCC and Greg Skomal of DMF for their insightful reviews of this manuscript. We are grateful for the trials, experiences, and exchange of information on counting technologies from our counterparts in State fisheries agencies of New England. Finally, all who care for river herring in Massachusetts should join us in acknowledging the efforts of the DMF Fishway Crew, Ed Clark and Jimmy Rossignol, for ongoing efforts to design, fabricate, install, troubleshoot, remove and clean counting arrays, enclosures, and counting boards while servicing the fishways that hold this equipment. Ed Clark's (Figure 3.6) unique blend of fabrication skill and understanding of hydraulics and herring behavior allows all this to work every chaotic spring when the gear goes out.

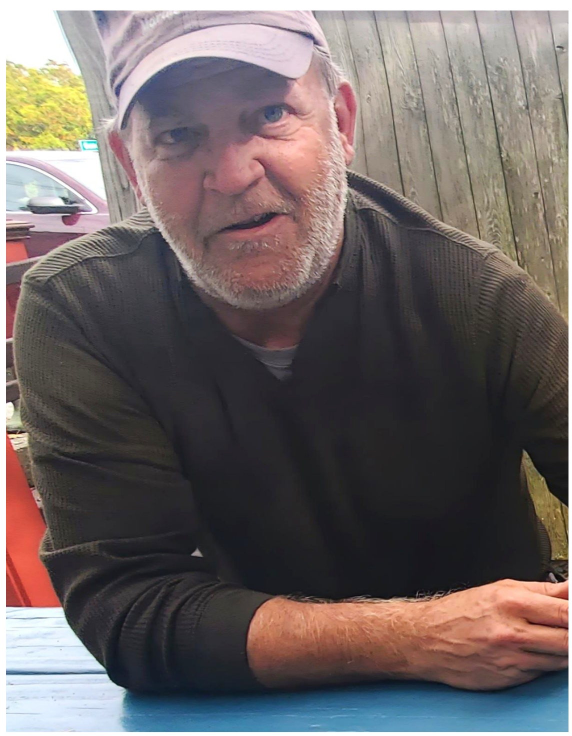


Figure 3.6. Ed Clark from DMFs Fishway Crew.

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Appendix A. Additional examples of re-estimated run counts.

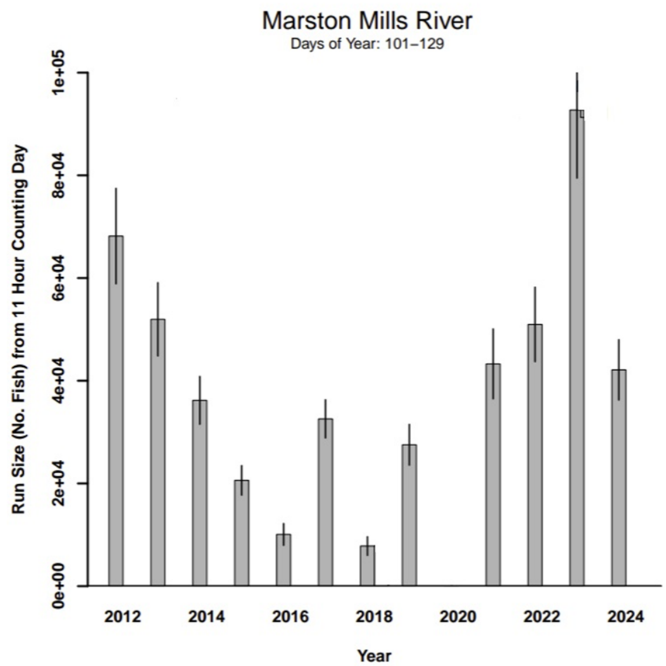

Figure A.1. Estimate of total relative abundance of river herring in the Marston Mills River, Barnstable, from 2012 – 2023 using newly standardized daily observation periods and duration.

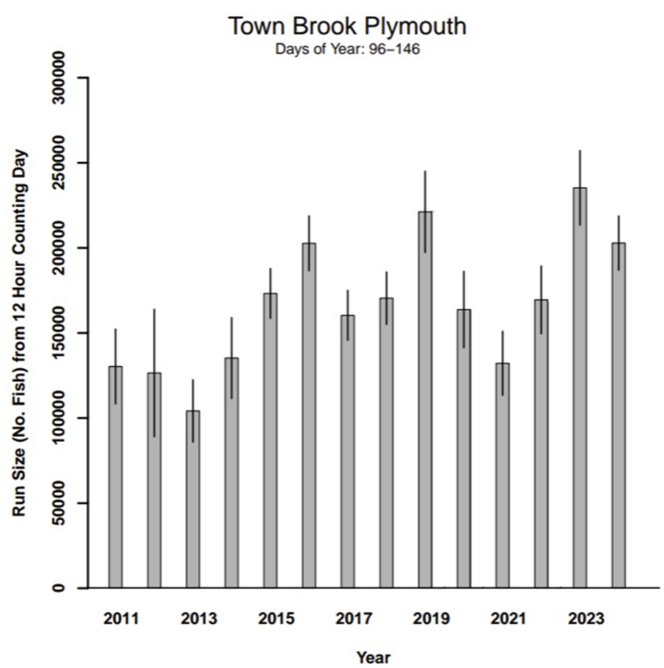

Figure A.2. Estimate of total relative abundance of river herring in Town Brook, Plymouth, from 2012 – 2023 using newly standardized daily observation periods and duration.

Appendix B. Examples of datasheets used in electronic counting.

Table B.1. Example of Excel spreadsheet used for annual river herring spawning run count at electronic stations. Datafiles include a separate spreadsheet for recording comparison counts and tube velocity measurements. DMF staff will assist with preparing a custom datafile for counting stations on request.

MASSACHUSETTS DIVISION OF MARINE FISHERIES — RIVER HERRING SPAWNING RUN COUNT

Station: | **Method:** Smith-Root 1601 | **Data Status:** | **Entered:**

Year: | **Audited:**

						Individual Tube Counts					Battery	Staff	
Date	**Staff**	**Time**	**Days**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CT6**	**TOTAL**	**(V)**	**Gauge**	**Comments**
3/25/2024	BB	9:15	1	25	16	14	32	28	14	129	12.8	2.44	

Appendix B cont.

Table B.2. Example of Smith-Root Electronic Counter field sheet. DMF staff will assist with preparing a custom datafile for counting stations on request.

Date:	Staff:	Time:	Weather:
Multiple Tube Counts	Battery Status:		Staff gage:
CT1	CT2	CT3	CT4
CT5	CT6	CT7	CT8
Visual count	Duration (min):	# observed:	# E-counted:
Visual count	Duration (min):	# observed:	# E-counted:
Comments:		Daily Total:	Season total:
Date:	Staff:	Time:	Weather:
Multiple Tube Counts	Battery Status:		Staff gage:
CT1	CT2	CT3	CT4
CT5	CT6	CT7	CT8
Visual count	Duration (min):	# observed:	# E-counted:
Visual count	Duration (min):	# observed:	# E-counted:
Comments:		Daily Total:	Season total:
Date:	Staff:	Time:	Weather:
Multiple Tube Counts	Battery Status:		Staff gage:
CT1	CT2	CT3	CT4
CT5	CT6	CT7	CT8
Visual count	Duration (min):	# observed:	# E-counted:
Visual count	Duration (min):	# observed:	# E-counted:
Comments:		Daily Total:	Season total:
Date:	Staff:	Time:	Weather:
Multiple Tube Counts	Battery Status:		Staff gage:
CT1	CT2	CT3	CT4
CT5	CT6	CT7	CT8
Visual count	Duration (min):	# observed:	# E-counted:
Visual count	Duration (min):	# observed:	# E-counted:
Comments:		Daily Total:	Season total:

Appendix C. Troubleshooting a Smith-Root Electronic Counter

The following four categories (A-D) of troubleshooting Smith-Root electronic counters are discussed in the main text of SOP 2.0. The categories of debris/false counts and electronic tube malfunction are more detailed. We cover these topics with more instructions and photographs below.

A. Water Velocity Influence on Fish Behavior *covered in SOP 2 text*

B. Power Failure *covered in SOP 2 text*

C. Debris/False Counts

One of the more common causes of false counts is debris lodged in the tubes. With each visit, inspect the tube upstream face for debris and reach in with your hands or a wood pole if able to remove debris. If false counts are still suspected, take a plastic bottle and fill it ½ to ¾ full of water. Attach a string to the cap and run it through the tube(s) in question (Figure C.1). If the bottle gets hung up on debris take time to remove all debris. If no counts, erratic, or false counts are recorded as the bottle passes, continue to the next step on Tube Malfunction.

D. Tube Malfunction

If comparison counts, test counts or the bottle test suggest a tube has malfunctioned, the tunnel junction box should be checked for wiring problems (Figure C.2 and C.3). If no problems are detected, a decision needs to be made to block tube(s) for the season or to pull the counter out of the water and proceed with checks of all connection points. Field testing of all connection points can be difficult, and removing the counting array can require 2 or 3 staff. Bench testing all components is the best approach for tube malfunction troubleshooting but is not always practical until the off-season.

The tunnel junction box wires attach at the bus bars and run down to hose clamps on the tubes that serve as the corresponding upstream and downstream connection points. First, testing the wires along The tunnel junction box wires attach at the bus bars and run down to hose clamps on the tubes that serve as the corresponding upstream and downstream connection points. First, testing the wires along the bus bar requires a Smith-Root plastic tool or fine flat edge screwdriver to open the wire terminal. Proceed with the following steps to test the integrity of the junction box to tube wiring:

1. Open the bus bar terminals with the tool and place one of the multimeter prongs in the upstream terminal for each tube and the other prong on the

Figure C.1. A soda bottle being used to test whether a tube is working properly. The bottle is attached to a string, then pushed through the tube while holding on to the string.

Figure C.2. A view of the cover of the tunnel junction box. Four screws to remove the box cover are located on the top corners.

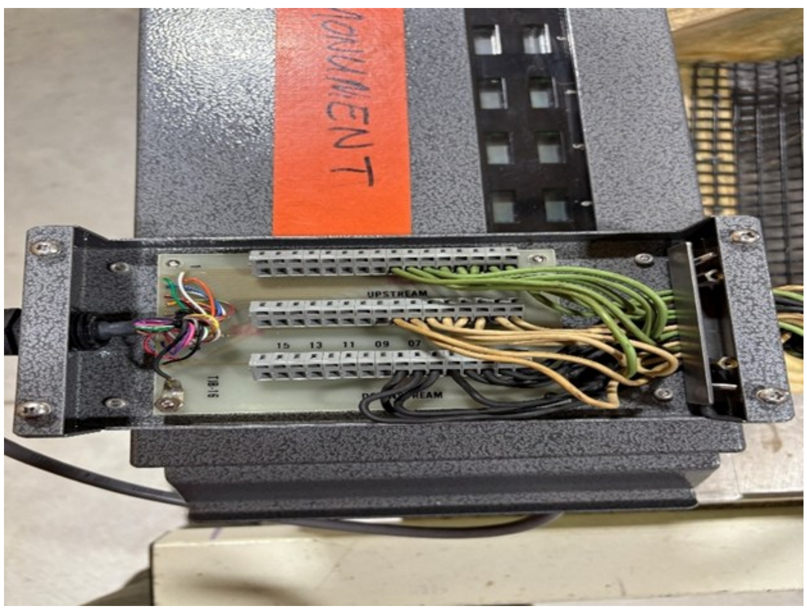

Figure C.3. Inside of the tunnel junction box. The top bus bar with green wires is for upstream wiring, the middle bar with white wires independently serves the middle tube ring and responds to water conductivity, and the lowermost bar with black wires is for downstream wiring. All three bars have numbered terminals to match each tube.

corresponding upstream hose clamp connection in the counting tube (Figure C.4 and C.5). Make sure the multimeter is set to 0-50 or 10 (Resistance, units ohms). If the tube is working correctly, it should read 6-8 ohms on contact. Next, repeat this test for the downstream bus bar and downstream tube connection, and for the middle bar to middle tube connection. The middle bar is separate from the two bus bars and may not have to same resistance value but will have a positive response near 6 ohms if functioning correctly.

Note: The upstream and downstream terminals are bus bars, and the midstream terminal is a ground and not bus bar. You will need to match the corresponding terminal with the corresponding tube to check those connections. It is recommended to label the bus bars with the corresponding tube numbers.

2. If the resistance checks are out-of-range or cause no multimeter response, first check each wire attachment to the three bars. Anything other than a firmly connected wire in the terminal can cause incorrect signals. Little to no copper wire should be exposed outside of the terminal.

3. If step #2 does not bring the resistance test into range, try moving the bus wire connection to another numbered terminal (Figure C.6). Test resistance range at the midstream tube channel. An in-range reading indicates that the original terminal has a problem. Switch the wire to another terminal

Figure C.4. The custom tool is being used to open a terminal to insert the prong to test resistance with the multimeter.

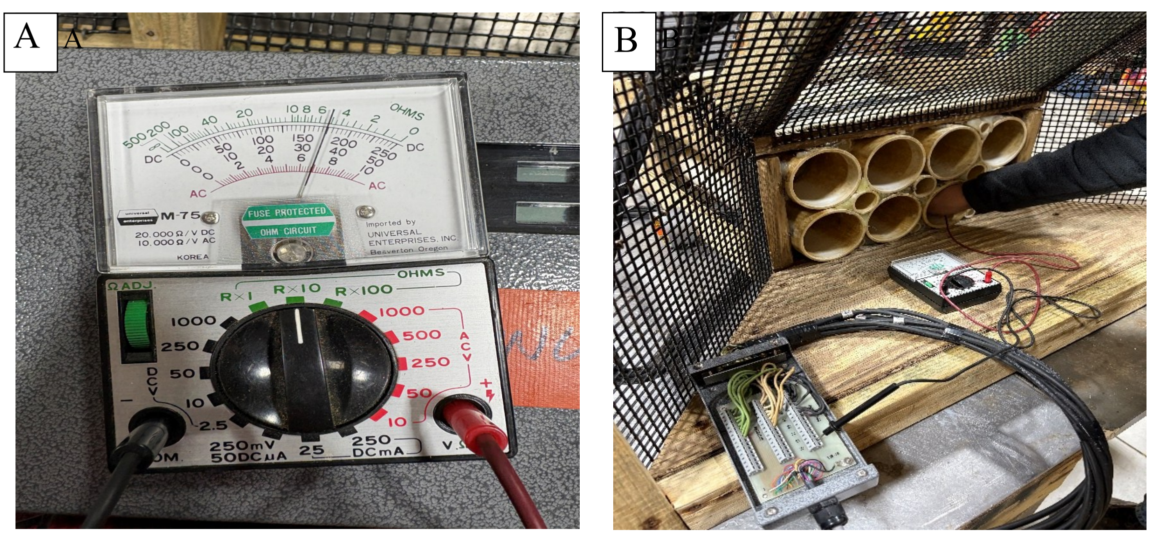

Figure C.5. A multimeter (A) set to the proper resistance setting (10R or 0-50R) to test each tube (B). Figure B shows the downstream connection for the target tube being tested. The multimeter is attached to the downstream bus bar and to the downstream hose clamp inside the tube.

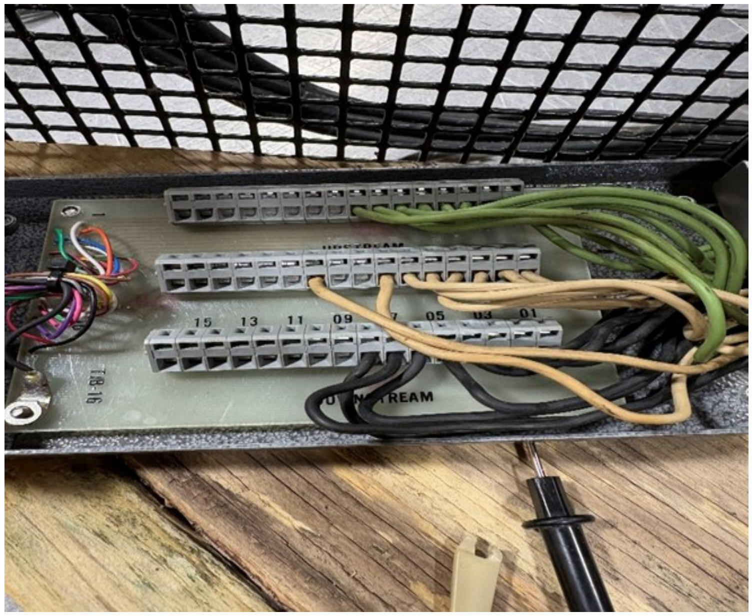

Figure C.6. The white wire on the left side of the middle bar is moved to another terminal to test for failure of the initial terminal.

may correct the problem but be sure to note the passage readings will be recorded on a new tube display along the 16-display counter box. If able, return to bottle test (Figure C.1) to confirm status.

4. Next, inspect the tube ring connection corresponding with poor resistance reading. This connection should be firm with high quality 100% waterproof silicon caulking covering the attachment hardware. Tighten bolt if loose with a 10 mm socket (Figure C.7). If the wire connection is corroded or broken, then repair with small amount of copper wire exposed (1/4 to 3/8"), twist on to the ring terminal and solder (Figure C.8). Finally, replace and tighten nuts.

5. Prior to reapplying caulking, test resistance again at junction box to make sure all connections are working. Once the caulking is dry (2 hrs), place

Figure C.7. A hose clamp with bolt for connecting the junction box wires to one of the tubes. The yellow ring terminal is where the wiring is attached, and the tube can be tightened typically with a 10 mm socket. .

the array back in the water and conduct bottle test to confirm all tubes are working correctly.

6. If none of these tube and junction box tests remediate the counting problem then the issue may be in the SR-1601 counter box. DMF staff have not serviced counter boxes and have routinely sent them back to Smith-Root for factory inspection and repair.

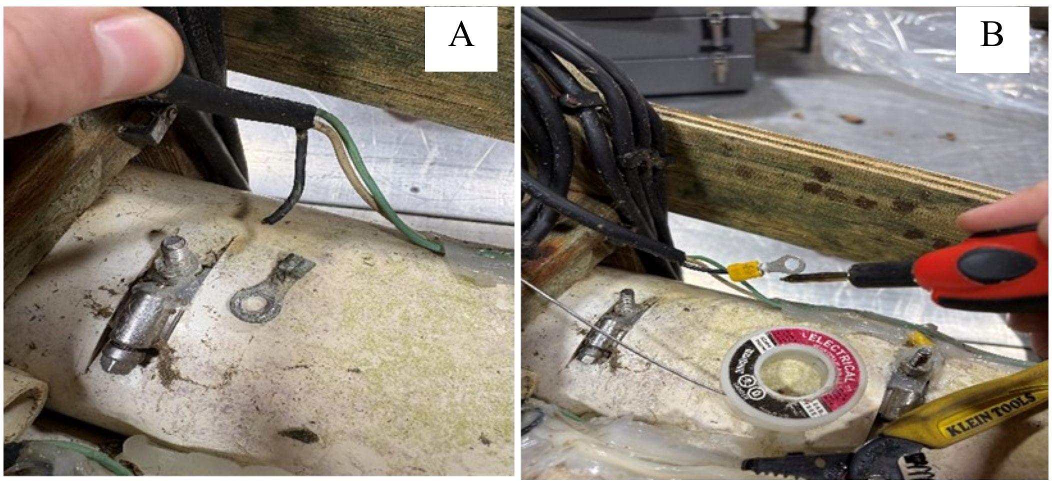

Figure C.8. A tube hose clamp connection where the wire has been disconnected from the fitting (A). A new fitting being put onto the end of the wire and soldered in place (B).

Appendix D. Examples of datasheets used in video counting

Table D.1. Example of Excel spreadsheet used for annual river herring spawning run count at video stations. Video images are typically downloaded weekly to external hard drive. The field sheet mainly serves as a daily check that the system is working correctly with any necessary notes.

MASSACHUSETTS DIVISION OF MARINE FISHERIES / TOWN OF ORLEANS

River Herring Monitoring

Site: Pilgrim Lake, Orleans **Partners:** Town of Orleans

Gear: Video Counter

Date	Time	Active? (Y/N)	Download (Y/N)	Notes	Staff Gauge	Crew Initials

Table D.2. Example of Excel spreadsheet used for annual river herring spawning run count at video stations. DMF staff will assist with preparing a custom datafile for counting stations on request.

Date	Clip Start Time	Species	Count	UP/DOWN	NIGHT VISION (Y/N)	Reviewer	Notes
2022-03-27	0:03:08	Herring	3	UP	Y	CR	
2022-03-27	0:03:08	Herring	1	DOWN	Y	CR	
2022-03-27	0:06:28	Eel	1	DOWN	Y	CR	
2022-03-27	0:10:08	Herring	1	UP	Y	CR	

Appendix E. Troubleshooting Video Monitoring Systems

A. Hardware Troubleshooting

If you suspect that a power failure occurred, follow these steps:

1. Check that your power source is producing adequate power. For hard-wired power, make sure the power strip is getting power and has not accidentally been turned off or unplugged. For a solar panel system, check that the battery is giving 12 V of charge. It is a good idea to have a backup battery in stock.

2. Check that the laptop is connected to the power source. If the computer has been disconnected from the power source, plug it back in and check whether its is receiving power again. Check the camera to ensure it is plugged in, getting power and turns on.

3. Check that the laptop will turn on and is charging. If plugged in, the computer should turn on and there should be a lightning bolt over a battery symbol in the bottom right-hand corner of the screen to indicate charging.

4. If using solar power check the solar charge controller and the connection between the solar panel and the battery. Keep a backup solar charge controller in stock to switch if the original fails. Use a multimeter to test whether the solar power is producing charge by placing the multimeter prongs on the end of the wire connectors. On sunny days readings of at least 12 V would indicate the solar panel is working, a reading of less would suggest something is wrong (cloudy days will produce less voltage).

If you suspect that the laptop is not working correctly, follow these steps:

1. Check that the laptop is on and functioning properly and that the program iSPY is open and running. If the computer opens, iSPY is open, and the computer is not frozen, then it is likely not a problem with the laptop.

2. If laptop is off and power is not the issue, try to turn computer back on. If computer will not turn on and overnight temperatures were below freezing, bring the laptop into the vehicle to warm up before attempting to turn on again. Once laptop is back on, check when the last video files were saved. If last videos were from overnight and temperatures dipped below freezing, the low temperature may have shut down the computer in the early morning. Insulating foam board can be placed in the enclosure box where the laptop and hard drive sit to prevent this issue.

3. If you are storing images collected from the camera on your computer, then it is also important to check your storage capacity with each visit. It is recommended that video files be saved to an external hard drive with at least 1TB of space to avoid running out of storage space on the computer's hard drive.

If you suspect a problem with the camera, follow these steps:

1. Check that live video is playing on iSPY. If there is no live video feed, there is a problem with the camera or camera connection.

2. Check that the camera is connected to the laptop. The camera should be connected to the laptop via the video capture adapter, which converts the AV ports from the video camera to USB that can be plugged into the laptop. It is helpful to have extra adapters on hand in case one fails or is damaged in the field.

3. If it appears that the camera is producing a live feed, but field of view is not centered on the channel where the fish should be moving, then it could be that the camera has been dislodged or blocked by debris. Check to make sure that the camera is facing the right direction, and that debris has been removed from the front of the enclosure.

B. Troubleshooting Software

An excessive occurrence of false detections, insufficient detections, continuous or extended image records, and poor images can be related to software settings. If there are no power issues with the laptop and camera seems to be working, follow these steps to troubleshoot these issues:

1. Check iSpy to ensure the live feed video is properly being shown and recorded.

2. Open the file where videos are being saved and watch several recently saved videos to look for false detections and quality of video. Watch videos from both day and night.

3. If videos are blurry or brownish it is likely that the camera lens, plexiglass divider and back wall (opposite of camera) of the enclosure needs to be cleaned. White kitchen eraser sponges or rags can

be used for cleaning these areas.

4. If false detections (videos with no fish) are being recorded first check to see if there is debris in the enclosure causing the motion detection feature to be trigged. If so, remove debris and check camera again to ensure complete removal from view.

5. If no debris is present, check to see if solar glare is causing detections. This may require the addition of a light shield to block solar glare inside the enclosure. There will likely be a time-of-day or sun-angle component to this problem that should be understood.

6. Check the water level in the enclosure if the water level becomes too high it can cause aeration bubbles in the enclosure which can trip the motion sensors. If water levels are too low, it can cause some of the camera to be partly out of the water or not enough water going through the box for fish to effectively pass.

If none of the above solutions work, you may need to adjust the software setting in iSpy.

1. First check the **Trigger Range** a typical range for detection (i.e. the percent change in pixels from frame to frame) is 9-90% which means that motion detection is only engaged when more than 9% and less than 90% of the pixels change from one frame to the next.

   a. If you find that motion is being detected and videos recorded from total brightness changes (day to night transition or passing clouds) in the box, you may want to lower the maximum range.

   b. If you find that video recording is being triggered by minor movements like a shifting light or small bubbles you may want to increase the lower end of the range.

2. Check the **Gain** (or sensitivity to motion detection) if you find the trigger range to be accurate yet there are still too many false videos, the gain can be lowered and examined for accuracy. If you find that there are single or smaller fish not being recorded by the motion detection, increase the gain to avoid missing fish that pass.

3. Check the **Detection zones** so they highlight areas where fish will move through but avoid problem areas with solar glare or aeration.

4. Check the **Buffer** time so that it is set to 3 or 4 seconds. If you find that the videos being captured start with a fish half in the frame you should increase the buffer time to capture entire transit through enclosure.

5. The **Inactivity Record** should be set to 10-15 seconds. If you are getting too many short video clips with only single fish, increase the inactivity record. If you have too many long clips with no activity at the back end, decrease the inactivity record.

6. Check the **Maximum record time**. If video files being recorded are too long and contain lots of false detection at the end of the video lower the maximum record time to shorten videos.

7. Check to see if the **Suppress Noise** function is on if not turn it on.

8. Check to see if the **Maximum frame rate** is set to **25** and **When recording = 10**.

9. Check to see if the **Use detector = Background modeling.** This will allow you to see what is triggering the motion detection to steer troubleshooting steps.