Atlantic States Marine Fisheries Commission

ISSUES AND OPTIONS (v2)

**UNDERDEVELOPMENT AND CONSIDERATION FOR
AMENDMENT 3 TO THE INTERSATE FISHERY MANAGEMENT PLAN FOR
ATLANTIC HERRING**

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The Atlantic Herring Plan Development Team

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This draft document was developed for the Atlantic Herring Section's review and discussion during the November 2015 ASMFC meeting week. It is not intended to solicit public comment as part of the Commission/State formal public input process. However, comments will be accepted at the appropriate time during the Section's meeting. Also, as this document is further developed into the Draft Amendment 3 for Public Comment and if it is approved, a public comment period will be established to solicit input on the issues contained in the document.

EXECUTIVE SUMMARY

The executive summary highlights all of the sections of Draft Amendment 3 that contain a management decision. The summary is intended to be a shortened version of the document that will be distributed at public hearings. Draft Amendment 3 in its entirety will be presented at the Winter Section meeting.

1.0 INTRODUCTION

The Atlantic States Marine fisheries Commission (ASMFC) is developing an amendment to its Interstate Fishery Management Plan (FMP) for Atlantic Herring (*Clupea harengus*) under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFMA). The U.S. Atlantic herring fishery is currently managed as a single stock through complementary plans by the Atlantic States Marine Fisheries Commission (ASMFC) and New England Fishery Management Council (NEFMC). ASMFC has coordinated interstate management of Atlantic herring in state waters (0-3 miles) since 1993—currently managed under Amendment 2 and Addenda I-VI to the ASMFC Fishery Management Plan (FMP). Management authority in the exclusive economic zone (EEZ, 3-200 miles from shore) lies with the New England Fishery Management Council (NEFMC) and NOAA Fisheries. Based on the 2015 Operational (Update) Assessment, Atlantic herring is currently not overfished and overfishing is not occurring.

1.1 Statement of the Problem

While Atlantic herring reproduce in the same general season each year, the onset, peak and duration of spawning may vary by several weeks annually (Winters and Wheeler, 1996) due to changing oceanographic conditions (e.g., temperature, plankton availability, etc.). In an effort to protect the integrity of the spawning stock and allow for increased recruitment, the ASMFC developed a system of seasonal spawning closures that accounted for this interannual variability in spawning time. However, at the time of development in the early 1990s, limited data were available to derive the critical parameters of the spawning closure system which is based on the female gonadal somatic index (GSI). Given concerns over the adequacy of the system to protect spawning fish in the areas they spawn, the Commission initiated the development of Draft Amendment 3 to the Interstate Atlantic Herring Fishery Management Plan (FMP).

The current monitoring system uses samples collected from the commercial fishery, which is dependent on interactions with spawning fish. Samples from Maine and Massachusetts are analyzed separately, and sometimes contain too few fish to confidently characterize spawning stages. The current population of herring is quite different today as the stock has rebuilt, and there is a broader range of age classes with older and larger fish compared to the stock during overfished conditions. Given a broad range of age classes, fish arrive at the spawning grounds at a different times (larger fish can swim faster and arrive earlier than smaller fish). There is evidence to support modifications to the spawning monitoring program will more adequately protect spawning fish in the areas where they spawn.

At the request of the fishing industry, Draft Amendment 3 also includes options to remove the fixed gear set-aside provision. Currently, the set-aside of 295 mt is available to fixed gear fishermen up to November 1, after which the remaining set-aside becomes available to the rest of the Area 1A fishery. The November 1 date was set because, typically, herring have migrated out of the Gulf of Maine by that time of the year. Anecdotal evidence suggest herring are in the Gulf of Maine after November 1, therefore fixed gear fishermen requested the set-aside be available to them for the remainder of the calendar year.

Members of industry also suggested a requirement for fish holds to be empty of fish prior to trip departures. This provision would encourage less wasteful fishing practices by creating an incentive to catch amounts of herring as demanded by markets. The New England Fishery Management Council included a complementary provision in its Framework Adjustment 4 to the federal Atlantic Herring FMP.

2.0 SPAWNING AREA EFFICACY

2.1 Spawning Area Closure Monitoring System

The PDT conducted a review of scientific literature and analyzed GSI data for a decade to inform an updated GSI-based spawning monitoring system (see Appendix 1. *Technical Report on Atlantic Herring GSI-Based Spawning Monitoring Program*). Currently GSI samples are obtained directly from the commercial herring fishery, however it is not always possible to collect sufficient data to inform the start of the spawning closure, therefore a system that forecasts closure dates is recommended by the PDT (Option C).

Option A. Status Quo

Closures in a given area will begin based on the spawning condition of Atlantic herring as determined from commercial catch samples. Commercial catch sampling shall begin by at least August 1 for the Eastern and Western Maine areas, and by at least September 1 for the Massachusetts/New Hampshire area. If sufficient samples are not available, closures will begin on the default dates.

Sufficient sample information shall mean at least two (2) samples of 100 fish or more, in either length category, taken from commercial catches during a period not to exceed seven days apart.

Closures in a given area will begin seven days after the determination that female herring in ICNAF gonadal stages III - V from that specific area have reached the following spawning conditions: female herring greater than 28 cm in length have reached a mean gonadosomatic index (GSI) of 20%; or female herring greater than or equal to 23 cm and less than 28 cm in length have reached a mean GSI of 15%.

Length refers to the mean natural total length, measured from the tip of the snout to the end of the caudal fin in normal position. “GSI” shall mean gonadosomatic index calculated by the following formula. Length refers to the mean natural total length, measured from the tip of the snout to the end of the caudal fin in normal position. “GSI” shall mean gonadosomatic index calculated by the following formula:

GSI = [Gonad Weight / (Total Body Weight - Gonad Weight)] x 100 percent.

Option B. Status Quo with Adjustments (new verbiage is underlined)
Closures in a given area will begin based on the spawning condition of Atlantic herring as determined from <u>fishery dependent or independent samples</u>. Sampling shall begin by at least August 1 for the Eastern and Western Maine areas, and by at least September 1 for the Massachusetts/New Hampshire area. If sufficient samples are not available, closures will begin on the default dates.

Sufficient sample information shall mean at least two (2) samples of 100 fish or more, in either length category, taken from <u>fishery dependent or independent source within a spawning closure area by Maine, New Hampshire or Massachusetts. The fishery will remain open if sufficient samples are available, but they do not contain female herring in ICNAF gonadal stages III – V.</u>

Closures in a given area will begin seven days after the determination that female herring in ICNAF gonadal stages III - V from that specific area have reached the following spawning conditions: female herring greater than 28 cm in length have reached a mean gonadosomatic index (GSI) of 20%; or female herring greater than or equal to 23 cm and less than 28 cm in length have reached a mean GSI of 15%.

Length refers to the mean natural total length, measured from the tip of the snout to the end of the caudal fin in normal position. "GSI" shall mean gonadosomatic index calculated by the following formula. Length refers to the mean natural total length, measured from the tip of the snout to the end of the caudal fin in normal position. "GSI" shall mean gonadosomatic index calculated by the following formula:

GSI = [Gonad Weight / (Total Body Weight - Gonad Weight)] x 100 percent.

Option C: GSI_{30}-Based Forecast System
Closure date for a spawning area will be projected based on a minimum of three (3) fishery dependent or independent samples, each containing at least 25 female herring in ICNAF gonadal stages III-V. Because larger herring spawn first, female GSI values will be standardized to that of a 30 cm fish, (95th percentile of observed female herring lengths) using the following formula:

$$GSI_{30} = GSI_{obs} + 1.84 * (30 - TL_{cm})$$

When a significant positive relationship is detected between GSI_{30} and date, the slope of this line will be used to forecast a closure date. The forecasted closure date will be the day where GSI_{30} is projected to exceed the selected trigger value. As additional samples are collected, the forecast will be updated and fine-tuned. Once the forecasted date is within 5 days, the spawning closure will be announced. If no significant increase in GSI_{30} is detected prior to the default closure date, the default closure date would apply.

GSI_{30} Trigger Value: Spawning occurs at the completion of maturity stage V. Therefore, a point near the high end of observed GSI values for stage V fish should be used as the trigger. A higher value closes the fishery later and just prior to spawning, whereas a lower value provides additional protection for maturing fish.

70th Percentile : GSI_{30} Trigger = 23
Closes the fishery at an earlier date to provide more protection for maturing fish, but may not provide complete protection for spawning fish.

80th Percentile: GSI_{30} Trigger = 25
Closes the fishery in the later stages of maturity, but before spawning.

90th Percentile: GSI_{30} Trigger= 28
Closes the fishery just prior to spawning.

2.2 Default Closure Dates

The PDT recommends adjusting the method for triggering a closure in a spawning area. Because all GSI samples are obtained directly from the commercial herring fishery, it is not always possible to collect sufficient data to inform the start of the spawning closure. As such, default closure dates were established for each of three spawning areas with a presumed general north-south progression of spawning.

Analysis of GSI data from 2004-2013 suggests onset of spawning can vary by five or more weeks from year to year. This observation is corroborated by scientific studies on herring spawning times (Boyar 1968; Grimm 1983; Stevenson 1989; Winters and Wheeler 1996). Median trigger dates were calculated for the period 2004-2013 using the formula and trigger values described under Issue 1.1 Option C. In other words, Sub-Options B1-B3 represent the average date that trigger would have been reached in previous years. Insufficient data were available for the Eastern Maine area, so a value derived from literature sources (Stephenson 1989) is used for all options other than the status quo for the Eastern Maine area.

Option A: Status Quo

If sufficient samples are not available, closures will begin on the following dates.

Eastern Maine Spawning Area:	August 15
Western Main Spawning Area:	September 1
Massachusetts/New Hampshire Spawning Area:	September 21

Option B: Default Dates Associated with GSI_{30} Trigger Values
If sufficient samples are not available, closures will begin on the following dates associated with the respective GSI_{30} trigger value.

- **Sub-Option B1: 70th Percentile (GSI_{30} Trigger = 23)**
  Closes the fishery at an earlier date to provide more protection for maturing fish, but may not provide complete protection for spawning fish.

Eastern Maine Spawning Area:	August 28
Western Maine Spawning Area:	September 25
Massachusetts/New Hampshire Spawning Area:	September 25
Tri-State (WM-MA/NH) Spawning Area*:	September 25

- **Sub-Option B2: 80th Percentile (GSI_{30} Trigger = 25)**
  Closes the fishery in the later stages of maturity, but before spawning.

Eastern Maine Spawning Area:	August 28
Western Maine Spawning Area:	October 4
Massachusetts/New Hampshire Spawning Area:	October 4
Tri-State (WM-MA/NH) Spawning Area*:	October 4

- **Sub-Option B3: 90th Percentile (GSI_{30} Trigger = 28)**
  Closes the fishery just prior to spawning.

Eastern Maine Spawning Area:	August 28
Western Maine Spawning Area:	October 17
Massachusetts/New Hampshire Spawning Area:	October 17
Tri-State (WM-MA/NH) Spawning Area*:	October 17

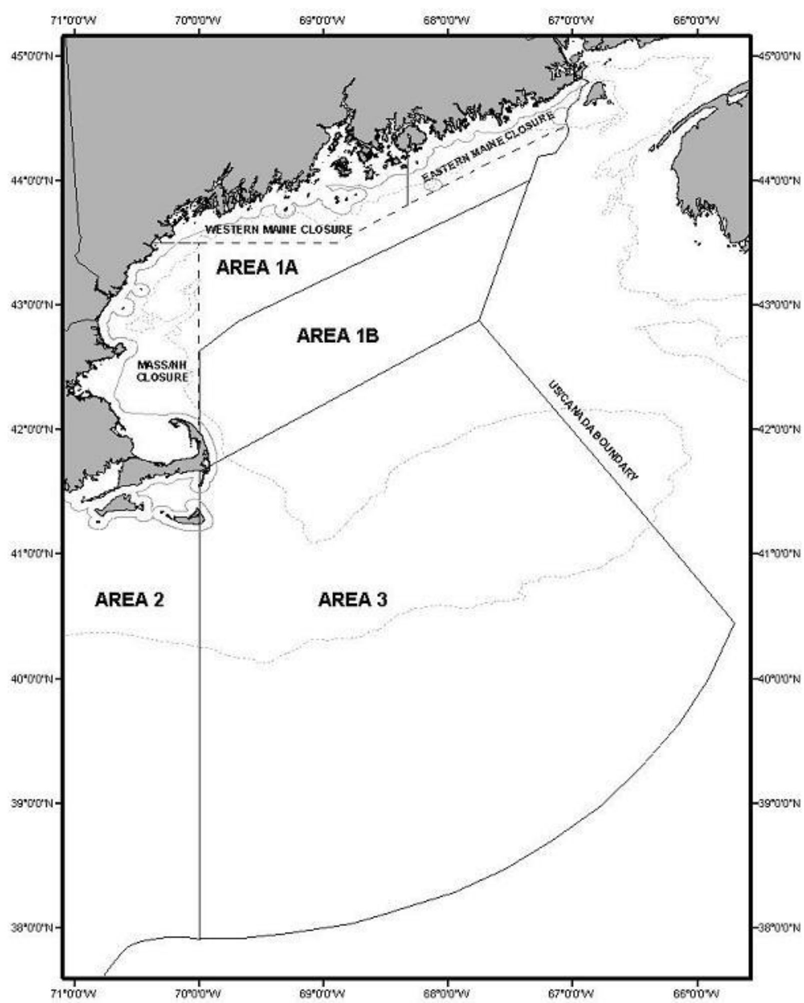
**Tri-State Spawning Area options if Option 2.3 B is selected.*

2.3 Spawning Area Boundaries

The PDT evaluated 1) sub-dividing MA/NH, and 2) combining Western Maine and MA/NH. Anecdotal reports from industry suggested there was variation in the spawning season within the MA/NH area (i.e., spawning occurs earlier to the north). A potential alternative to sub-divide the MA/NH area was initially proposed. However, upon review of the GSI data from both the Massachusetts Division of Marine Fisheries and Maine Division of Marine Resources sampling programs, this does not appear to be the case. In fact, both programs track each other well and the combined dataset appears well-suited to continue to inform the initiation of the MA/NH spawning closure. Therefore, the PDT has found the current spawning area boundaries within MA/NH are adequate and further sub-areas are not warranted.

Additionally, there is no significant difference in the spawning onset times in the Western Maine and MA/NH area after adjusting to a standard 30 cm fish, which leads the PDT to recommend merging these two areas into one to increase the number of samples available to inform spawning closures (Option B).

Figure 1. ASMFC Atlantic Herring Spawning Areas



Option A. Status Quo
Maintain the spawning area boundaries (figure 1):

Eastern Maine Spawning Area
All waters bounded by the following coordinates:

Maine coast	68º 20' W
43º 48' N	68º 20' W
44º 25' N	67º 03' W

North along US/Canada border

Western Maine Spawning Area
All waters bounded by the following coordinates:

43º 30' N	Maine coast
43º 30' N	68º 54.5' W
43º 48' N	68º 20' W

North to Maine coast at 68º 20' W

Massachusetts/New Hampshire Spawning Area
All waters bounded by the Massachusetts, New Hampshire and Maine coasts, and 43º 30' N and 70º 00' W

Option B. Update Spawning Areas: Combine the WM and MA/NH spawning areas, resulting in two spawning areas.
Eastern Maine Spawning Area
All waters bounded by the following coordinates:

Maine coast	68º 20' W
43º 48' N	68º 20' W
44º 25' N	67º 03' W

North along US/Canada border

Tri-State (WM-MA-NH)
All waters bounded by the Massachusetts, New Hampshire and Maine coasts, and:

Cape Cod north to 43º 30' N and 70º 00' W

43º 30' N	68º 54.5' W
43º 48' N	68º 20' W

North to Maine coast at 68º 20' W

2.4 Spawning Closure Period

It has become evident the current GSI observations are not particularly useful for describing the duration of the spawning period, because fishery-dependent (or commercial catch) samples are not available after the start of the closure. Several earlier studies in the GOM concur that the typical duration of herring spawning within a particular area is approximately 40 days. It is fairly common to find spawning herring in fishery samples after the initial four week closure. Therefore, it appears the current 4-week closure period is inadequate given the goals and objectives of this management action. Increasing to a 6-week closure (42 days) would provide a better match for the available information on the duration of GOM herring spawning.

Analysis of GSI data from 2004-2013 suggest larger fish spawn earlier than smaller fish. This finding is corroborated by studies documenting a size-dependent maturation process (Boyar 1968; Ware and Tanasichuk, 1989; Oskarsson et al., 2002; Slotte et al., 2000). As the age structure of the herring resource expands with the recovery, it is possible spawning events will lengthen.

CLOSURE PERIOD

Option A: Status Quo

By default, all spawning closures in all spawning areas selected under Issue 2.2 will last four (4) weeks.

Option B: Six Week Spawning Closure

By default, all spawning closures in all spawning areas selected under Issue 2.2 will last six (6) weeks.

RE-CLOSURE PROTOCOL

Option A: Status Quo

Catch sampling of the fishery will resume at the end of the initial four-week closure period. If catch sampling indicates significant numbers of spawn herring are still being harvested, closures will resume for an additional two weeks. Significant numbers of spawn herring is defined as 25% or more mature herring, by number in a catch sample, have yet to spawn. Mature or “spawn” herring are defined as Atlantic herring in ICNAF gonadal stages V and VI.

Option B: Defined Protocol

Sampling will resume in the final week of the initial closure period or at the end of the initial closure period. If one (1) sample taken from within a spawning closure area, by Maine, New Hampshire or Massachusetts, indicates significant numbers of spawn herring then closures will resume for an additional two (2) weeks. Significant numbers of spawn herring is defined as 25% or more mature herring, by number in a sample, have yet to spawn. Mature or “spawn” herring are defined as Atlantic herring in ICNAF gonadal stages V and VI. Sample is defined as a minimum of 100 randomly selected adult sized fish from a fishery dependent or independent source.

Option C: No Re-Closure Protocol

Samples will not be collected at the end of an initial closure period to inform the possibility of a re-closure.

3.0 FIXED GEAR SET-ASIDE PROVISION ADJUSTMENT

In recent years, Atlantic herring has been known to occur along the mid-coast of Maine through November. Fixed-gear fishermen have requested to remove the rollover date, thereby maintaining access to a dedicated quota for the fixed gear fishery after November 1. Fishermen expect a demand for bait in the lobster fishery through end of the year.

Historically, the fish have migrated away from the Gulf of Maine coast by November. In the past decade, fixed gear landings have not fully utilized the set aside of 295 mt (e.g., utilization over a 10-year average is 197.4 mt, or 67% of the set-aside) and landings after November 1 have been 0 mt since 1993.

The PDT noted, should fixed-gear fishermen exceed the 295 mt set-aside, they have access to the total Area 1A sub-quota. There is no biological basis for or against adjusting the rollover provision of the fixed-gear set aside, but there may be socioeconomic reasons. In addition, if the rollover provision is changed then there will be inconsistent set aside measures between state and federal rules.

Table 1. Atlantic Herring Landings from Fixed Gear Fishery Before and After November 1 Rollover Date

Year	Sub-ACL Closure Date	Area 1A Sub-ACL (mt)	Cumulative Catch (mt) by Dec 31	Fixed Gear Landings (mt)	
				Jan-Oct	Nov-Dec
2004	11/19/2004	60,000	60,071	49	0
2005	12/2/2005	60,000	61,570	53	0
2006	10/21/2006	50,000	59,980	528	0
2007	10/25/2007	50,000	49,992	392	0
2008	11/14/2008	43,650	42,257	24	0
2009	11/26/2009	43,650	44,088	81	0
2010	11/17/2010	26,546	27,741	823	0
2011	10/27/2011	29,251	29,359	23	0
2012	11/5/2012	27,668	25,057	0	0
2013	10/15/2013	29,775	29,820	C	C
2014	10/26/2014	33,031	33,428	C	C

Note: "C" denotes that the value cannot be reported due to confidentiality.

Option A: Status Quo
The fixed gear set-aside will be available to fixed gear fishermen in Area 1A until November 1. If the set-aside has not been utilized by the fixed gear fisheries west of Cutler by November 1, it will then be made available to the remainder of the herring fleet fishing in Area 1A until the directed fishery in 1A closes. *Fixed gear fishermen can continue fishing and landings will count towards the Area 1A sub-quota.* If 92% of the Area 1A TAC has already been reached by November 1 (and the directed herring fishery in 1A is therefore closed), the set-aside will be released as part of the 5% set-aside for incidental catch in 1A (at a 2,000 lb trip limit).

Option B: Remove the rollover provision
The fixed gear set-aside will be available to fixed gear fishermen west of Cutler through December 31. When 92% of the Area 1A TAC has been reached, all directed Atlantic herring fisheries in Area 1A will closed. Unused portions of the fixed gear set-aside will not be rolled from one year to the next.

4.0 EMPTY FISH HOLD PROVISION

Currently, the interstate and federal Atlantic Herring FMPs do not require an empty fish hold prior to departing the dock. However, there is concern that unsold herring are dumped at sea if there is not enough market demand for the resource. Additionally, fish from multiple trips can be mixed if the holds are not completely emptied—this has the potential to compromise landings data used to inform harvest control measures and bycatch avoidance programs, particularly for river herring. Furthermore, leaving fish in the vessel's hold prevents portside samplers from observing the entirety of a trip.

The New England Fishery Management Council (NEFMC), in Draft Framework Adjustment 4, approved a requirement for vessel holds to be empty of fish prior to leaving a dock. The Council adopted Alternative 2.1.2, Alternative 2, Option C: a waiver may be issued for instances when there are fish in the holds after inspection by an appropriate law enforcement officer. This alternative would only apply to Category A and B boats. The intent is for waivers to be issued for refrigeration failure and non-marketable reported fish. Option B, below, matches the NEFMC preferred option. *This is currently a proposed rule to the federal FMP, if it does not become effective federally then states will be responsible for implementing the empty fish hold provision.*

Option A: Status Quo
No empty fish hold provision. There is no requirement to empty vessel holds of fish prior to a fishing trip departure.

Option B: Empty Fish Hold Provision *(The intent is to mirror the provision in the federal plan, contingent on federal adoption)*
This option would require that fish holds on Category A/B Atlantic herring vessels are empty of fish before leaving the dock on any trip when declared into the Atlantic herring fishery. A waiver may be issued for instances when there are fish in the hold after inspection by an appropriate law enforcement officer (the intent is for waivers to be issued for refrigeration failure and non-marketable fish that have been reported by the vessel). Only vessels departing on a fishing trip (i.e. declared into the fishery) are

required to have holds empty of fish. As such, waivers would not be required for vessels transporting fish from dock to dock. This option is contingent upon federal adoption.

Option C: Empty Fish Hold Provision *(This option is similar to Option B, with the additional underlined text, contingent on federal adoption)*
This option would require that fish holds on Category A/B Atlantic herring vessels with ability to pump fish are empty of fish before leaving the dock on any trip when declared into the Atlantic herring fishery. A waiver may be issued for instances when there are a pumpable quantity of fish in the hold as determined by an appropriate law enforcement officer (the intent is for waivers to be issued for refrigeration failure and non-marketable fish that have been reported by the vessel). Only vessels departing on a fishing trip (i.e. declared into the fishery) are required to have holds empty of fish. As such, waivers would not be required for vessels transporting fish from dock to dock. This option is contingent upon federal adoption.

Option D: Empty Fish Hold Provision *(The intent is to mirror the provision in the federal plan, not contingent on federal adoption)*
This option would require that fish holds on Category A/B Atlantic herring vessels are empty of fish before leaving the dock on any trip when declared into the Atlantic herring fishery. A waiver may be issued for instances when there are fish in the hold after inspection by an appropriate law enforcement officer (the intent is for waivers to be issued for refrigeration failure and non-marketable fish that have been reported by the vessel). Only vessels departing on a fishing trip (i.e. declared into the fishery) are required to have holds empty of fish. As such, waivers would not be required for vessels transporting fish from dock to dock.

Option E: Empty Fish Hold Provision *(This option is similar to Option B, with the additional underlined text, not contingent on federal adoption)*
This option would require that fish holds on Category A/B Atlantic herring vessels with ability to pump fish are empty of fish before leaving the dock on any trip when declared into the Atlantic herring fishery. A waiver may be issued for instances when there are a pumpable quantity of fish in the hold as determined by an appropriate law enforcement officer (the intent is for waivers to be issued for refrigeration failure and non-marketable fish that have been reported by the vessel). Only vessels departing on a fishing trip (i.e. declared into the fishery) are required to have holds empty of fish. As such, waivers would not be required for vessels transporting fish from dock to dock.

Atlantic States Marine Fisheries Commission

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Technical Report on Gonadal-Somatic Index-Based Monitoring System for Atlantic Herring Spawning Closures in US Waters

for Draft Amendment 3 to the Atlantic Herring Fishery Management Plan

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January 2015

Introduction

While Atlantic herring reproduce in the same general season each year, the onset, peak and duration of spawning may vary by several weeks annually (Winters and Wheeler, 1996). It is believed that this behavioral plasticity is an evolutionary adaptation that takes advantage of optimal oceanographic conditions (e.g, temperature, plankton availability, etc.) to maximize offspring survival (Sinclair and Tremblay, 1984; Winters and Wheeler, 1996). In an effort to protect the integrity of the spawning stock and allow for increased recruitment, the ASMFC developed a system of seasonal spawning closures in the early 1990s that accounted for this interannual variability in spawning time. Historically, managers have focused on protecting the bulk of spawning during the fall season (August through October), but Atlantic herring are also known to spawn from late July through December. Acknowledging that macroscopic identification of the maturity stage of individual fish is a somewhat subjective process, the closure rule was based on a female gonadal somatic index (GSI), which is assumed to increase linearly as herring approach full maturity (Figures 1 and 2; Equation 1).

1) $GSI = 100 \times [W_{gonad}]/[W_{gonad} - W_{total}]$

At the time of the rule's creation, it was recognized that smaller herring generally have lower GSI values than larger herring (Figure 3). Consequently, separate triggers were established for two size classes: GSI = 15 for 23-27 cm; and GSI = 20 for 28+ cm. According to the closure rule, once two consecutive samples of herring achieve an average female GSI in excess of either trigger, the fishery closes for four weeks. Because all GSI samples are obtained directly from the commercial herring fishery, it is not always possible to collect sufficient data to inform the start of the spawning closure. As such, default closure dates were established for each of three areas that presumed a general north-south progression of spawning (Table 1). Despite the design of the closure system, it is fairly common to find spawning herring in fishery samples after the closure. To counteract this, a closure extension rule was established that mandated a two-week additional closure if fishery-dependent sampling revealed that greater than 25% of a post-closure sample contained fish in spawning condition (Stage V or VI).

When the rules were first established in the early 1990s, limited data were available to derive the critical parameters of the GSI-based spawning closure system (i.e., size categories; GSI triggers; default dates; closure duration). Given recent concerns over the adequacy of the system, which initiated the development of Draft Amendment 3 to the Interstate Atlantic Herring Fishery Management Plan (FMP), the Herring Plan Development Team felt that a re-examination of these parameters was warranted in light of an additional two decades worth of GSI sampling data.

Factors Affecting GSI

There is substantial variability in average GSI from one sample to the next, and it is often unclear whether this change is tracking the expected progression of gonad development of the population or is simply a function of the fish size, sample location, gear type, or year. The combined MADMF/MEDMR dataset of fishery-dependent samples includes 8,474 GSI observations (5,435 maturity observations) from 385 samples and covers three inshore spawning areas (Eastern Maine, Western Maine, Massachusetts-New Hampshire); three gear types (purse seine, midwater trawl, and bottom trawl); 15 years (1998-2013); three months (Aug-Oct); and 13 length bins (from 22 to 34 cm). Unfortunately, data are lacking for many factor level combinations (e.g., MWT samples are generally unavailable at the same time/area as other gear types), thereby preventing an analysis of the simultaneous influence of each factor on GSI/maturity using the full dataset. Nonetheless, we can evaluate the influence of several factors by examining a subset of the data. To this end, a generalized linear model (GLM) relating the GSI of female herring to a suite of factors (GSI ~ DAY + YEAR + LENGTH + AREA) was constructed using data from non-midwater trawl trips from the years 2004-2013.

Size

The current size-based closure system assumes that smaller herring achieve full maturity at a lower GSI than larger herring. While this has been demonstrated for the closely related Pacific herring (Ware and Tasanichuk, 1989), there is little evidence for such a relationship in our sample data (Figure 4). An alternative explanation for the observed size-GSI relationship (Figure 3) is a size-dependent arrival on the spawning ground (i.e., larger herring spawn earlier). This phenomenon had been documented in several other herring populations (Boyar 1968; Ware and Tanasichuk, 1989; Oskarsson et al., 2002; Slotte et al., 2000), and is believed to be related to a size-dependent maturation process (Ware and Tanasichuck, 1989), or swimming speed (i.e. larger herring arrive earlier to spawning grounds) (Slotte et al, 2000). Regardless, there is clear evidence of a decreasing average fish size as the spawning season progresses (Figure 5).

While it is true that smaller GOM herring generally have lower GSI than larger fish (at a given point in time), it is likely that all sizes achieve a similar maximum GSI, just at different times. As expected, the GLM estimated a strong positive relationship between length and GSI (Table 2 - for every 1 cm increase in length, there is a corresponding increase in GSI of 1.84 points). This slope for the LENGTH parameter can be used to standardize GSI observations to a common herring size, thereby removing the influence of length from GSI sample data.

Year

The strongly significant year effect indicates that the GSI for a given length/date may shift by six (6) or more points from year to year (Table 3). This suggests that the onset of spawning can vary by five or more weeks, underscoring the need for a GSI-based monitoring system instead of fixed closure dates. Several other studies corroborate this level of interannual variability in spawning time (Boyar 1968; Grimm 1983; Stevenson 1989; Winters and Wheeler 1996).

Day

The slope of the DAY parameter (0.19) in the GLM model represents the rate at which GSI increases per day, after controlling for the effects of other factors. Theoretically, this rate could be used to forecast the date when GSI (after adjusting for LENGTH) exceeds a trigger value from a single sample of fish. However, there is likely some interannual variability in this rate, and it would be more prudent to use samples from within a season to estimate the slope of the DAY parameter to forecast a closure date.

Area

The Eastern Maine (EM) spawning area was identified as having a significantly higher GSI than the other two areas, meaning that spawning occurs earlier in EM than elsewhere. Interestingly, the Western Maine (WM) and Massachusetts-New Hampshire (MA-NH) spawning areas do not appear to have significantly different spawning times. This suggests that these two areas should have a similar default date, or could even be combined to increase the number of samples available for informing spawning closures. Several earlier studies describe the timing of herring spawning in the GOM through the use of fishery-dependent maturity data and direct observation of demersal egg beds (Table 3 - Boyar et al., 1973; Cooper et al., 1975; McCarthy et al., 1979; Stevenson 1989). While these investigations confirm an earlier spawning time in EM than in MA-NH, there is no historical evidence to inform the timing of spawning in the WM area.

Fishing Gear

An alternative GLM was attempted that included gear type (bottom trawl vs purse seine) as an additional predictor variable (GSI ~ DAY + YEAR + LENGTH + AREA + GEAR); While GEAR was a marginally significant predictor of GSI, this more saturated model did not improve fit to the data, as measured by the Bayesian Information Criterion (BIC). This suggests that it is appropriate to combine samples obtained from these gear types. It should be noted that midwater trawl samples were excluded from this analysis, as this gear rarely operates at the same time/location as the other gears, preventing an objective determination of whether this gear type influences the GSI of a sample.

Proposed Changes to the Closure System

Given that larger herring spawn earlier, it makes sense to standardize GSI observations to a large size class (e.g., 30 cm – 95th percentile of observed lengths), so that the closure period is inclusive of most spawners. Therefore, the observed GSI of each individual fish should be adjusted using the formula (Formula 2), where *a* is the slope of the length parameter from the GLM (*a*=1.84) and *b* is the reference length class (*b*=30 cm):

2) $GSI_{30} = GSI_{obs} + a * (b - TL_{cm})$

Herring are determinate spawners, releasing all of their eggs in a single batch (Kurita and Kjesbu, 2008). Therefore, spawning can be considered imminent at the end of Stage V (i.e., full maturity). However, a range of GSI values has been observed within Stage V that likely represents the final progression of the maturity cycle (Figure 6). Therefore, a point near the high end of the distribution of Stage V GSI values could be considered a reasonable measure of the onset of spawning. Managers could select different points from this distribution as a trigger value, depending on their objectives or risk tolerance. A higher value would shift the fishery closure nearer to the expect onset of spawning, whereas a lower value would shift the closure earlier to provide more protection to pre-spawning fish.

Once the fishery-dependent sampling program has a sufficient number of samples (e.g., a minimum of three) with a significant positive slope to the GSI_{30}~DAY relationship (α= 0.05), a fishery closure date could be forecasted (i.e., the date when GSI_{30} exceeds $GSI_{trigger}$). This forecast could be updated as additional samples are acquired and an official closure date selected when the forecast is within a certain number of days (e.g., 5 days). If insufficient samples are available to predict the $GSI_{trigger}$ date prior to the default closure date, the default date would apply.

Using GSI sample data from previous seasons, we can estimate the date at which a $GSI_{trigger}$ would have been reached in each year (Figure 7). The average trigger date provides some representation of what an appropriate default closure date might be (Figure 8). Depending on the trigger value used, the average date for the MA-NH area is 4-24 days later than the most robust literature account for this area, which observed the arrival of herring egg beds on Jeffreys ledge between 1972 and 1978 (Table 3 – McCarthy et al., 1979). Most of the contemporary GSI sampling effort has been focused inshore of Jeffreys Ledge, suggesting spatial and/or interannual variation of spawning time within this area. Unfortunately, there are no literature sources available to inform the default date for Western Maine. The GLM model found no significant difference between the two areas; therefore, it appears reasonable to combine the two areas, increasing the number of samples available to inform a larger Tri-State (WM-MA-NH) spawning area (Table 2). With such few GSI samples available to describe the EM area, the historical information of when herring eggs have been observed on lobster traps is likely more applicable for this area (Table 3 – Stevenson 1989).

Contemporary GSI observations are not particularly useful for describing the duration of the spawning period, because fishery-dependent samples are not available once the closure commences. However, several earlier studies in the GOM concur that the typical duration of herring spawning within a particular area is approximately 40 days (Table 3). Therefore, it appears the current 4-week closure period is inadequate and increasing to a 6-week closure (42 days) would provide a better match for the available information on the duration of GOM herring spawning.

By using the sequence of individual samples obtained in previous years, we can apply the proposed closure rules to simulate the performance of the forecasting algorithm. For example, in 2011 a September 11 closure would have been announced on September 6, assuming a choice was made to select a closure date at five days prior (Figure 9).

There are several benefits to the GSI-based closure system as outlined in this paper:

1) By providing a forecasted closure date once an increase in GSI_{30} is detected, all interested parties (samplers, managers, industry) will have advance notice as to when the spawning closure is likely to occur, allowing them to plan their activities accordingly.
2) Because the forecasting model uses the GSI information from all samples to project a closure date, there isn't pressure to obtain two consecutive samples just prior to spawning, a task that has proven difficult in many years. For this reason, default closure dates due to insufficient samples would occur less often.
3) Aligning the assumptions of the closure system with the current understanding of the reproductive ecology of herring will improve the accuracy of and maximize the effectiveness of spawning closures.
4) By directly taking into account the effect of length on GSI, perceived discrepancies between sampling programs (MADMF, MEDMR) can be reconciled.

Ideally, we would have GSI and maturity samples from before, during, and after the spawning season. This would provide a better idea of maximum GSI (i.e. appropriate trigger value), and how that coincides with the presence of Stage V (full maturity) and Stage VI (spawning) fish. Unfortunately, because the GSI-monitoring program is entirely fishery-dependent, there are essentially no samples available once the spawning closure begins. A directed fishery-independent effort to obtain herring samples during and after the closure could provide this information and be used to further refine the parameters of the closure system in the future.

References

Boyar, H. C. 1968. Age, length and gonadal stages of herring from Georges Bank and the Gulf of Maine. ICNAF Research Bulletin 5:49-61

Boyar, H. C., Cooper, R. A., and Clifford, R. A. 1973. A study of the spawning and early life history of herring on Jeffreys Ledge. ICNAF Research Document 73/96:1-27

Cooper, R. A., Uzmann, J. R., Clifford, R. A., and Pecci, K. J. 1975. Direct observations of herring (Clupea harengus harengus L.) egg beds on Jeffreys Ledge, Gulf of Maine in 1974. ICNAF Research Document 75/93:1-6

Graham, J. J., Joule, B. J., and Crosby, C. L. 1984. Characteristics of the Atlantic Herring (Clupea harengus L.) Spawning Population Along the Maine Coast, Inferred from Larval Studies. Journal of Northwest Atlantic Fisheries Science 5:131-142

Grimm, S. K. 1983. Changes in time and location of herring (Clupea harengus L.) spawning relative to bottom temperatures in Georges Bank and Nantucket Shoals areas, 1971-77. NAFO Science Council Studies 6:15-34

Kurita, Yutaka, and Olav S. Kjesbu. 2009. Fecundity estimation by oocyte packing density formulae in determinate and indeterminate spawners: theoretical considerations and applications. Journal of Sea Research 61: 188-196.

McCarthy, K., Gross, C., Cooper, R., Langton, R., Pecci, K., and Uzmann, J. 1979. Biology and geology of Jeffreys Ledge and adjacent basins: an unpolluted inshore fishing area, Gulf of Maine, NW Atlantic. ICES Marine Science Conference Papers E44:1-12

Oksarsson, G. J., Kjesbu, O. S., and Slotte, A. 2002. Predictions of realised fecundity and spawning time in Norwegian spring-spawning herring (Clupea harengus). Journal of Sea Research 48:59-79

Sinclair, M., and M. J. Tremblay. 1984. Timing of Spawning of Atlantic Herring (*Clupea harengus harengus*) Populations and the Match-Mismatch Theory. Canadian Journal of Fisheries and Aquatic Sciences 41:1055-1065

Slotte, A., Johannessen, A., and Kjesbu, O. S. 2000. Effects of fish size on spawning time in Norwegian spring-spawning herring. Journal of Fish Biology 56:295-310

Stevenson, D. K. 1989. Spawning locations and times for Atlantic herring on the Maine coast. Maine DMR Research Reference Document 89/5:1-19

Ware, D. M., and Tanasichuk, R. W. 1989. Biological Basis of Maturation and Spawning Waves in Pacific Herring (*Clupea harengus pallasi*). Canadian Journal of Fisheries and Aquatic Sciences 46:1776-1784

Winters, G. H., and Wheeler, J. P. 1996. Environmental and phenotypic factors affecting the reproductive cycle of Atlantic herring. ICES Journal of Marine Science 53:73-88.

Table 1. Current default dates for herring spawning closures in the GOM

Spawning Closure Area	Default Closure Date
Eastern Maine (EM)	August 15th
Western Maine (WM)	September 1st
Massachusetts/New Hampshire (MA-NH)	September 21st

Table 2. Output from GLM (GSI ~ DAY + YEAR + LENGTH + AREA).

ANOVA Table:

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			4052	131631		
J	1	18802	4051	112829	1032.017	< 2.2e-16 ***
as.factor(YEAR)	9	4554	4042	108275	27.773	< 2.2e-16 ***
LENGTH	1	32700	4041	75575	1794.853	< 2.2e-16 ***
AREA	2	1990	4039	73585	54.627	< 2.2e-16 ***

Coefficients:

	Estimate	Std. Error
(Intercept)	-83.585212	1.949353
J	0.190262	0.005731
as.factor(YEAR)2005	1.514119	0.595370
as.factor(YEAR)2006	2.999203	0.673709
as.factor(YEAR)2007	1.297457	0.551941
as.factor(YEAR)2008	1.573861	0.630355
as.factor(YEAR)2009	1.881865	0.572551
as.factor(YEAR)2010	0.889922	0.591108
as.factor(YEAR)2011	6.144499	0.572099
as.factor(YEAR)2012	5.147404	0.576039
as.factor(YEAR)2013	5.373736	0.572403
LENGTH	1.838863	0.042996
AREAMA-NH	-2.504169	0.325561
AREAWME	-2.775418	0.265547

Table 3. Literature accounts of the timing and duration of herring spawning in the GOM.

Study	Years	Method	Area	Average First Spawning	Average Last Spawning	Average Season Length (days)
Boyar et al., 1973	1972	Maturity	MA-NH	Sep 10	Oct 20	40
Cooper et al., 1975	1974	Eggs (scuba)	MA-NH	Sep 29	Oct 25	26
McCarthy et al., 1979	1972-1978	Eggs (scuba, sub, grab)	MA-NH	Sep 20	Oct 30	40
Stevenson 1989	1983-1988	Eggs (lobster traps)	EM	Aug 28	Sep 20	40

Figure 1. Observed GSI of female herring by ICNAF maturity stage from 2013 fishery dependent samples from the MA-NH spawning area.

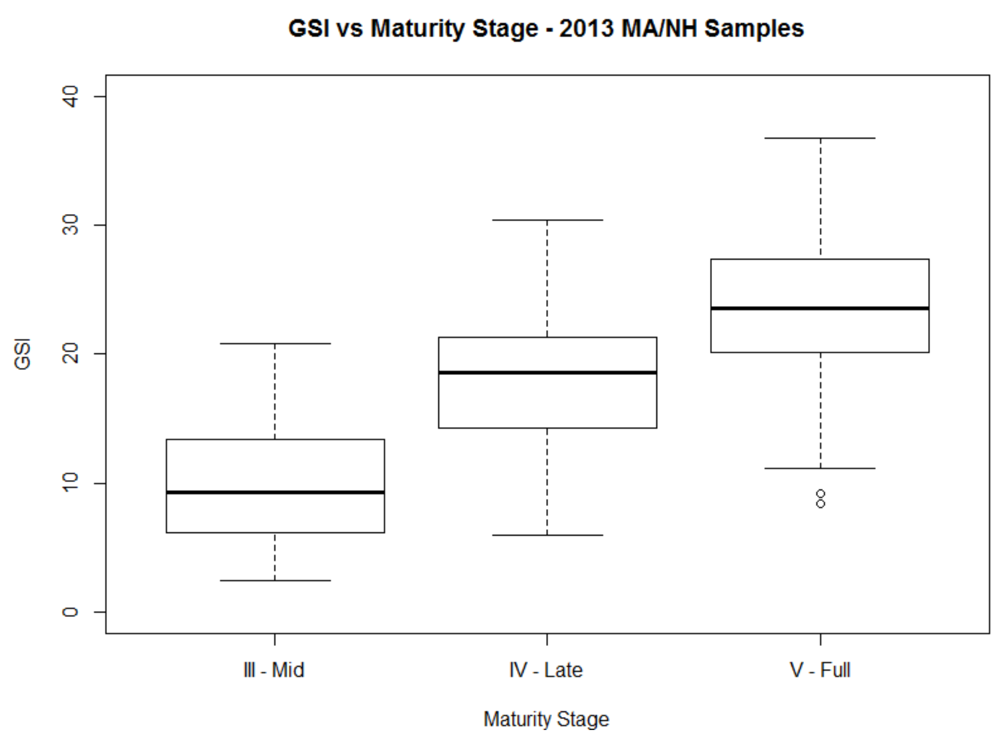


Figure 2. Female GSI by date from 2013 MA-NH samples. The red line indicates a significant positive linear relationship between GSI and sample date.

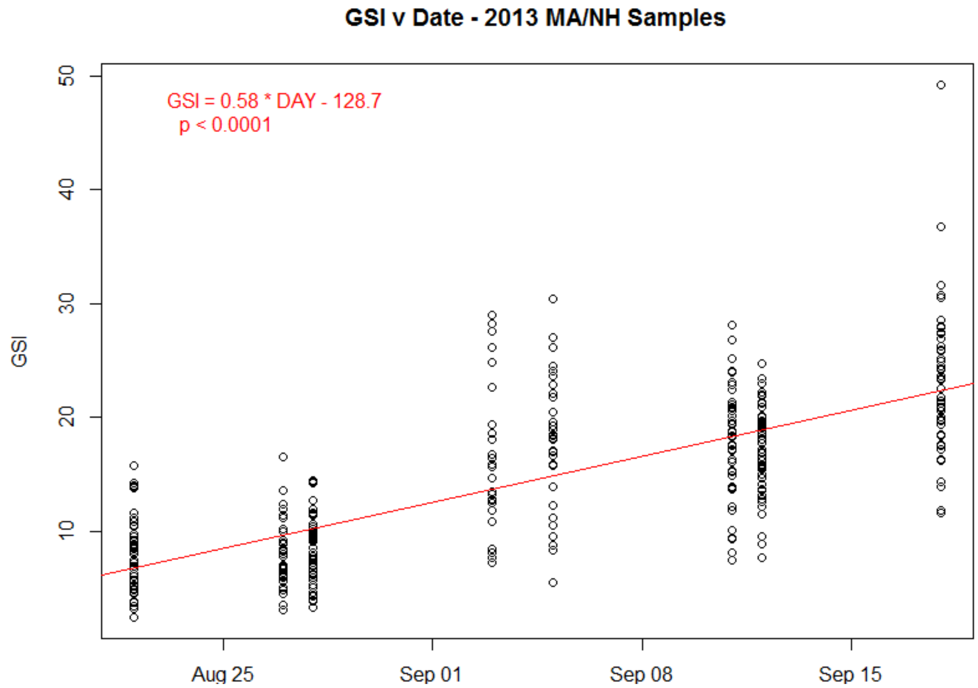


Figure 3. Boxplots of GSI by length bin from all sample data (based on total length).

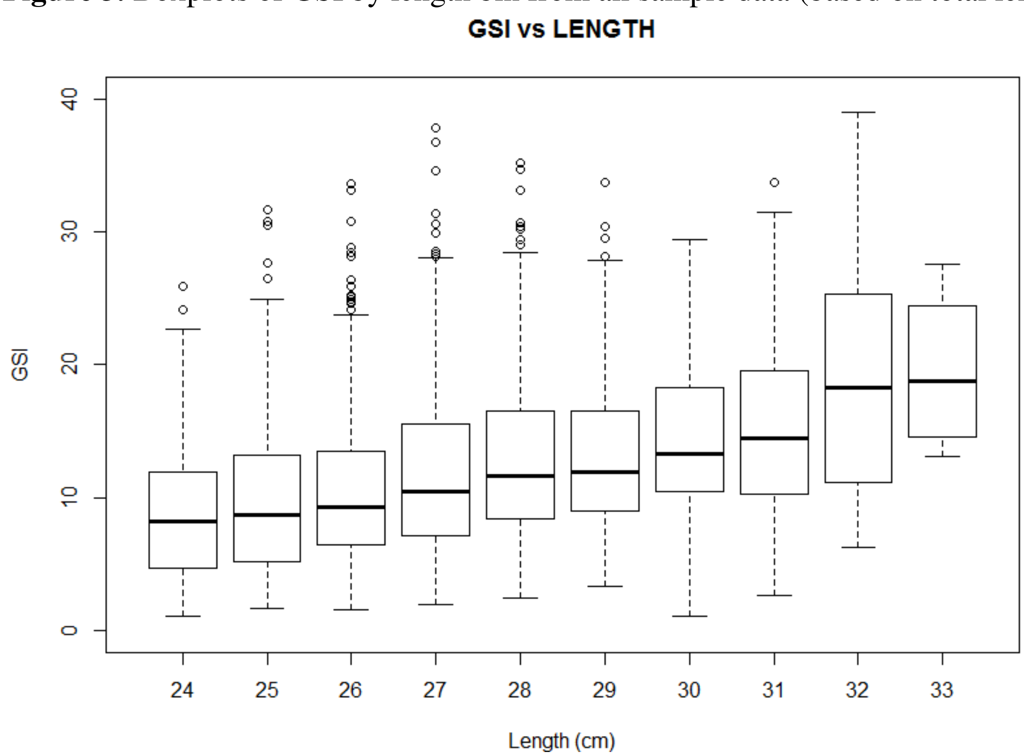


Figure 4. Boxplots of GSI at Stage V (full maturity) by length bin. The current size-based GSI triggers are shown in red (GSI = 15 for 24-27 cm; GSI = 20 for 28+ cm).

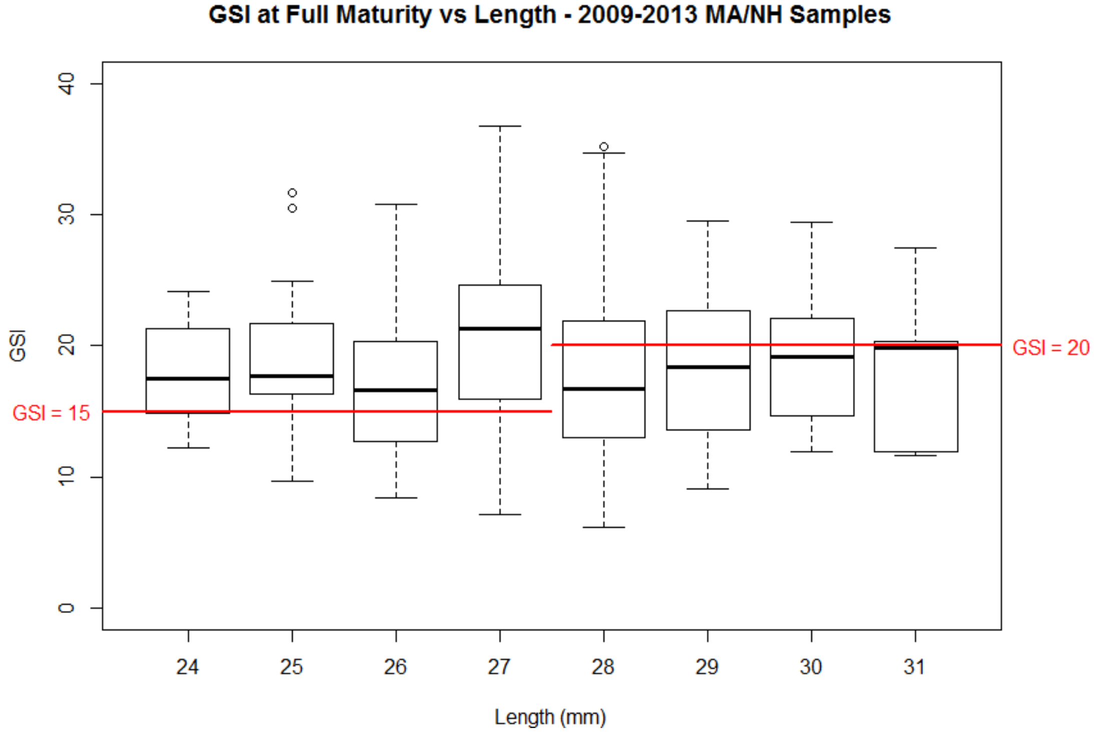


Figure 5. Observed fish length from MEDMR sampling of the MA-NH fishery in 2010. Note the significant decrease in observed fish length over the course of the season.

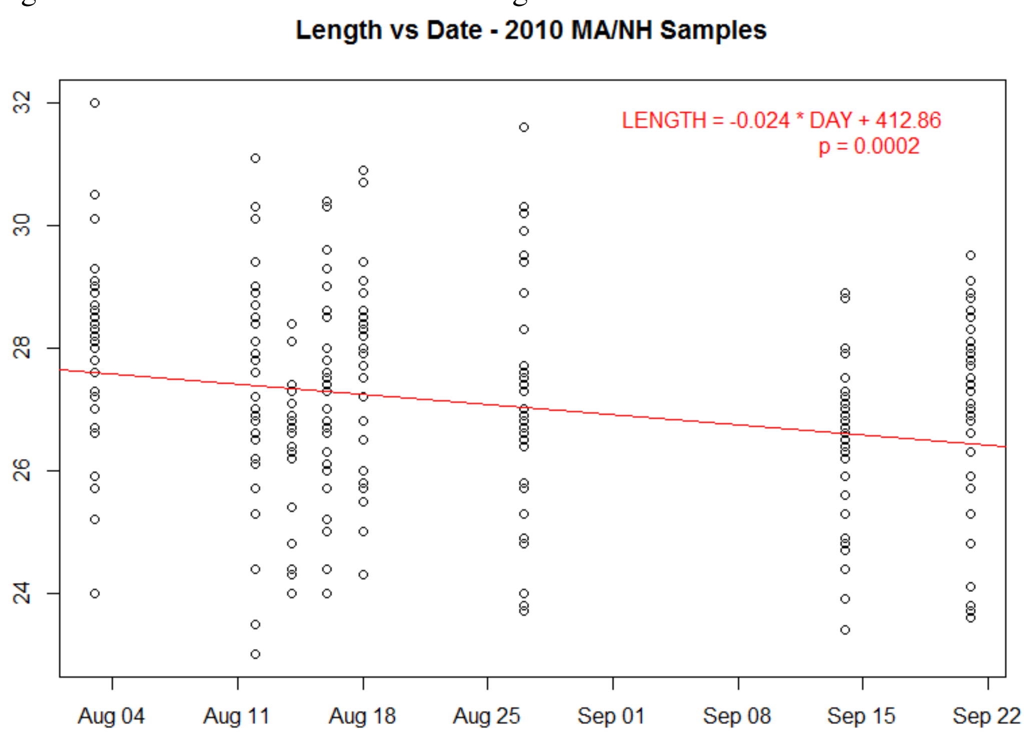


Figure 6. Distribution of GSI values for herring classified as Stage V (full maturity). The GSI value at a series of quantiles are shown in red.

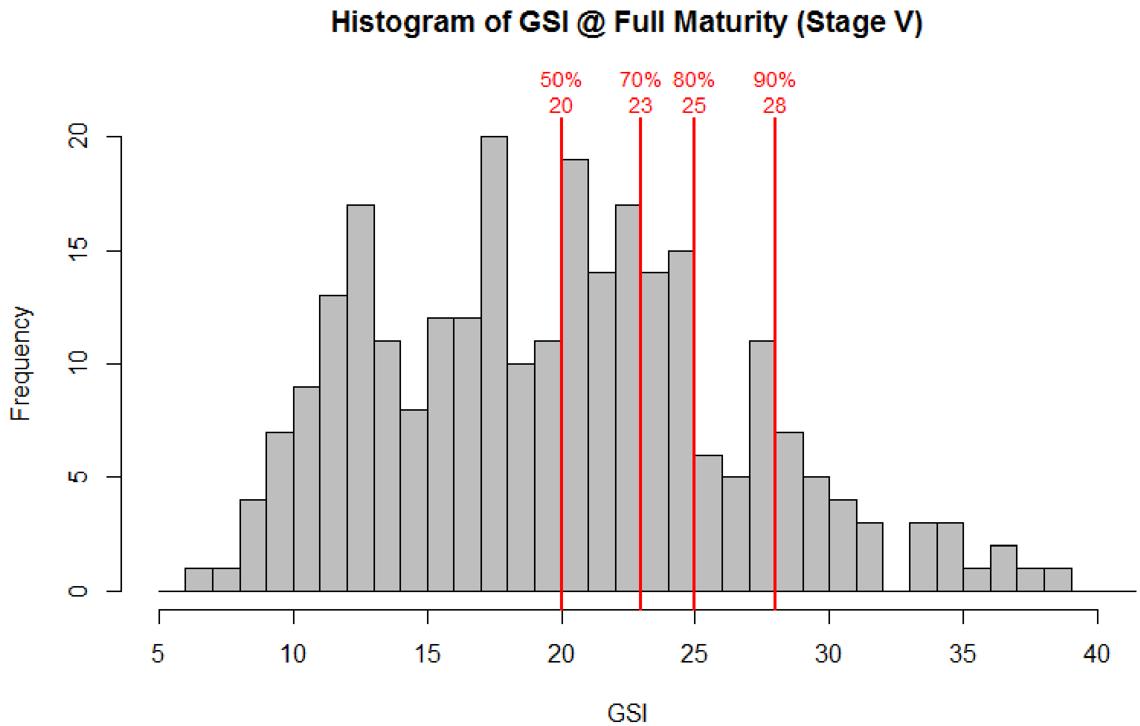


Figure 7. Forecasted dates when GSI_{30} exceeded a range of $GSI_{trigger}$ values for sample data from the Western Maine (WM) and Massachusetts-New Hampshire (MA-NH) spawning areas combined. A diagonal line represents a significant linear relationship between GSI_{30} and sample date. Gray points with error bars represent the mean GSI_{30} per sample +/- 2 standard errors.

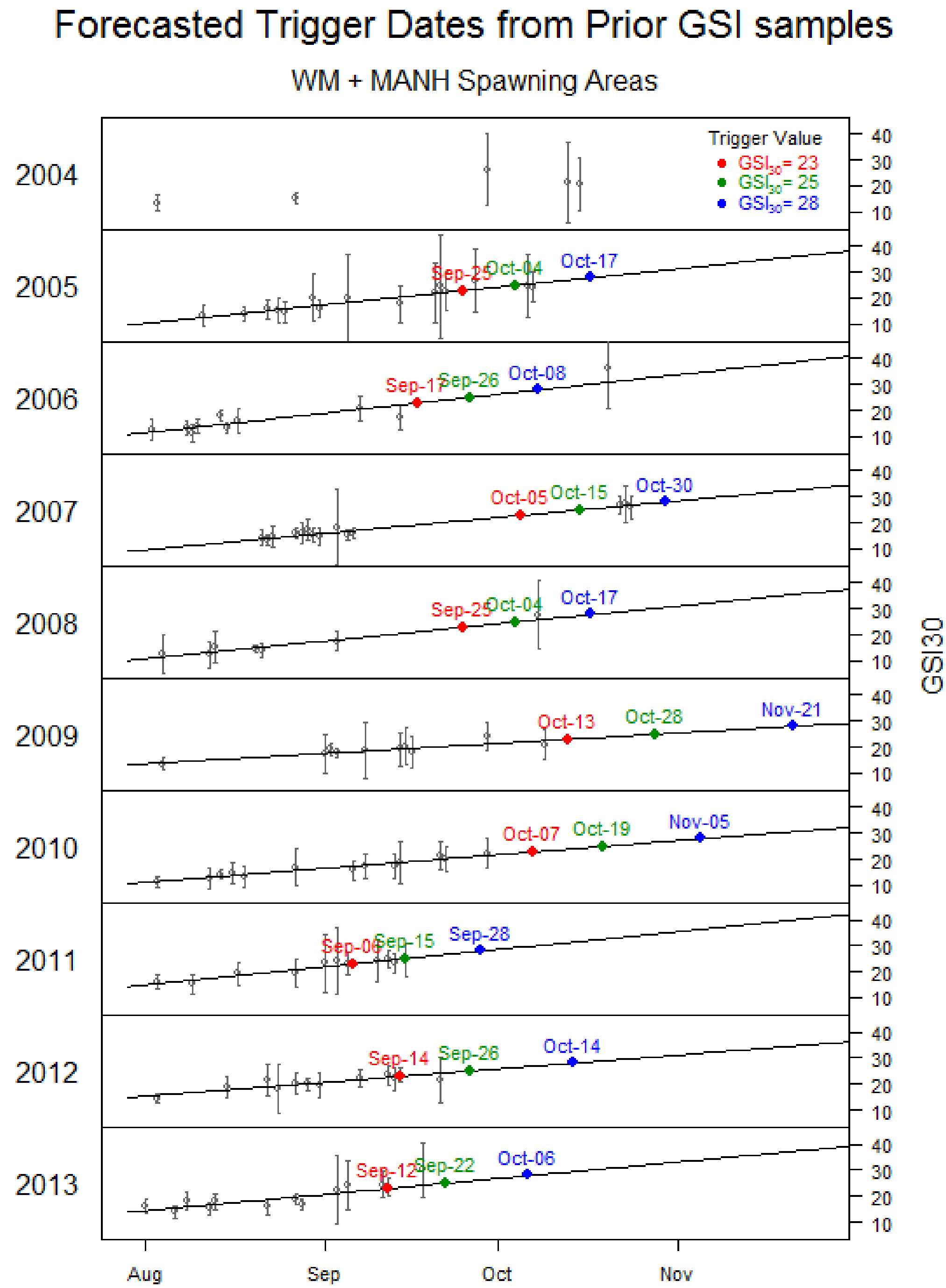


Figure 8. Boxplots of forecasted trigger dates for the WM and MA-NH spawning area combined (same data from Figure 7). The median date for each trigger value is labeled and could be used to set a default closure date for when sufficient samples are unavailable to forecast a trigger date.

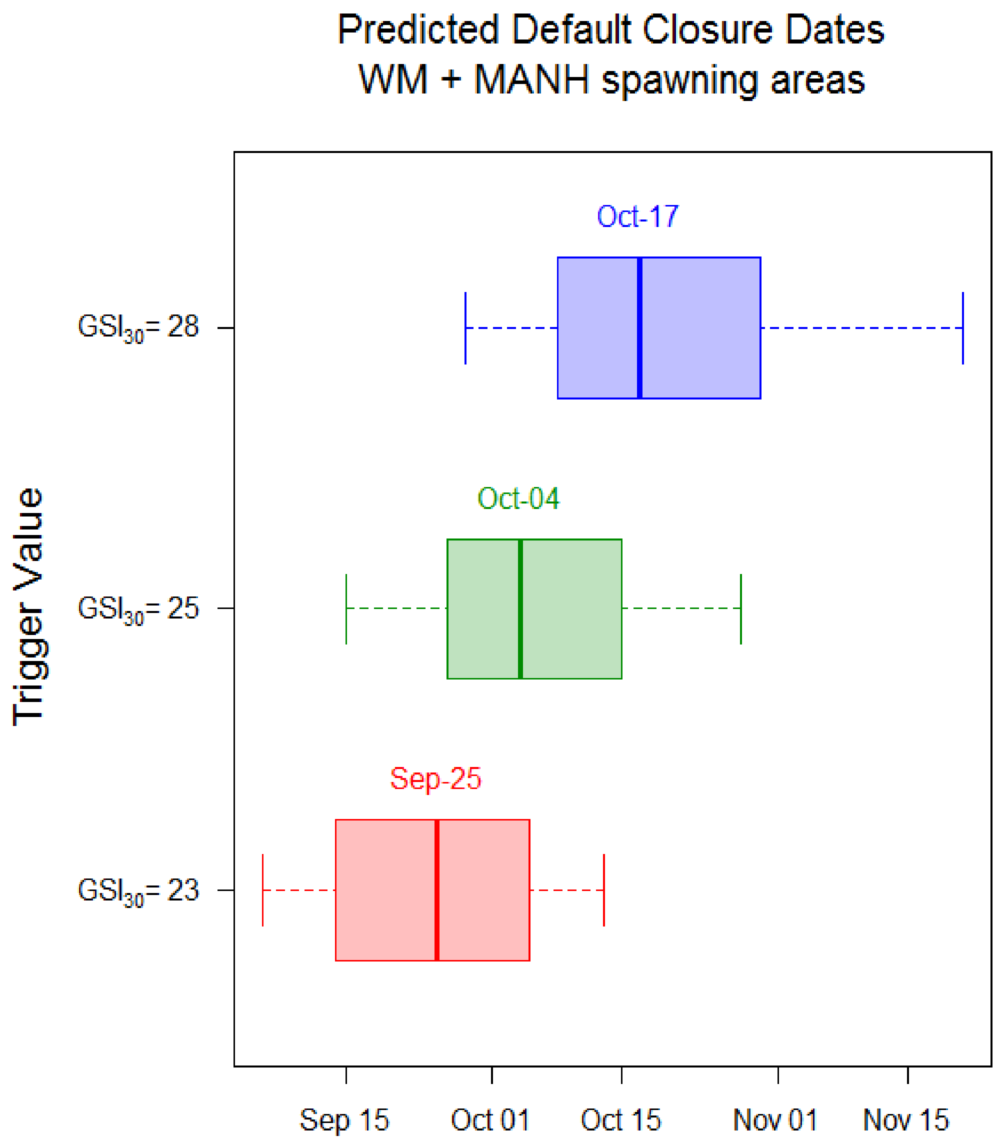
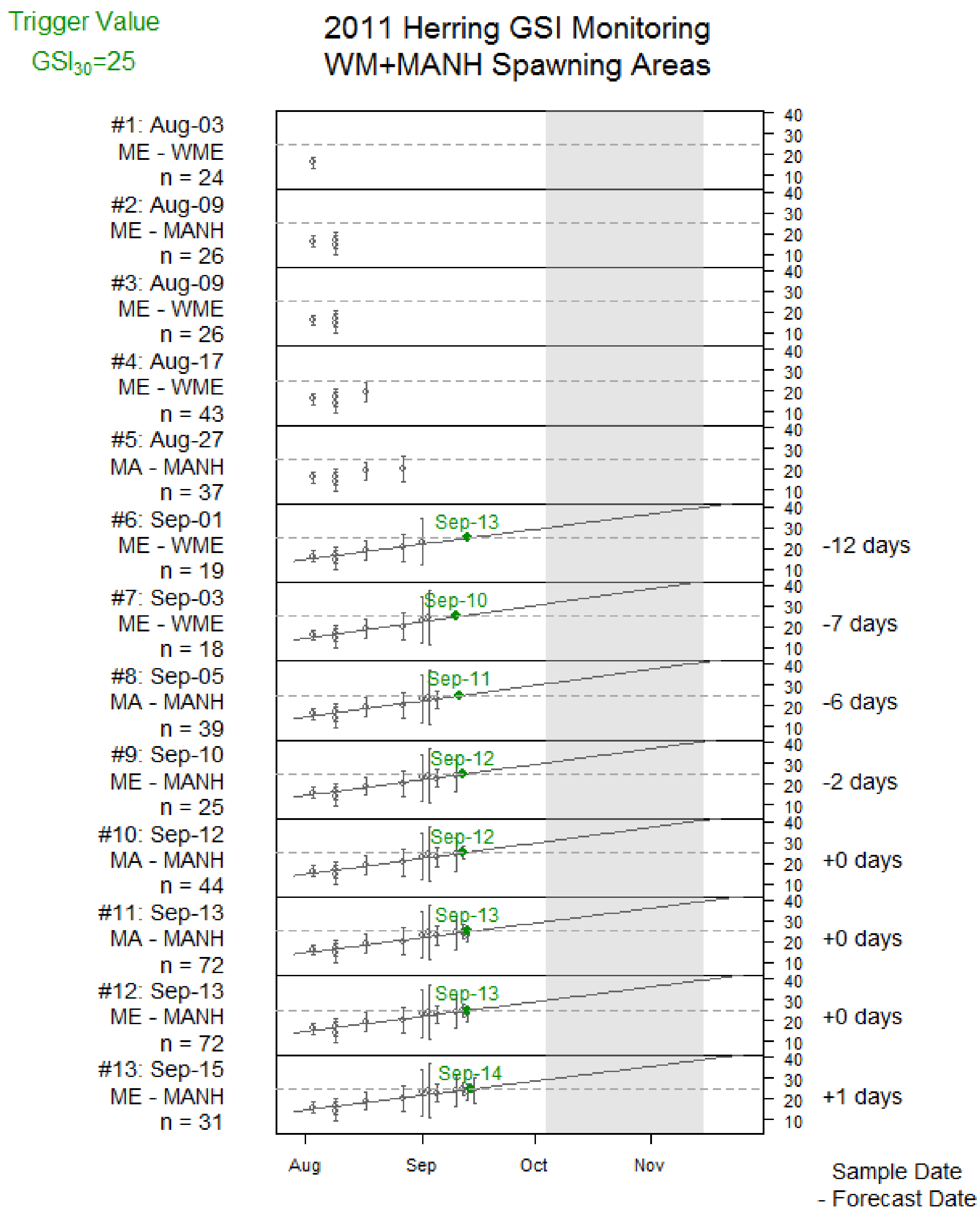


Figure 9. An example implementation of a modified GSI-based closure system using 2013 sample data from the MA-NH spawning area. A significant linear increase in GSI_{30} is detected after six samples (Sep-1st). Projecting this relationship forward, a closure date is forecast for Sep-13th. As additional samples are collected, the linear relationship and forecasted closure date are updated. If the choice was made to select a closure date at 5 days prior, a Sep 11th closure would have been announced on Sep 6th. The gray region identifies default t closure period associated with the trigger value used in this example (GSI_{30} = 25).



ASMFC Atlantic Herring Advisory Panel
Conference Call - October 23, 2015 – 10:00 AM
Issues and Options Draft Amendment 3 to the Atlantic Herring IFMP

Meeting Staff: Ashton Harp (ASMFC)

Advisory Panel (9): Jeff Kaelin (Chair - NJ), Greg DiDomenico (NJ), Philip Ruhle Jr. (RI), Shawn Joyce (NH), Stephen Weiner (MA), Patrick Paquette (MA), Jennie Bichrest (ME), Mary Beth Tooley (ME), Peter Moore (ME)

Public (2): Terry Stockwell (Section Chair - ME), Brad Schondelmeier (MADMF)

The Atlantic States Marine Fisheries Commission's Atlantic Herring Advisory Panel met via conference call on October 23, 2015 to discuss the issues and options in Draft Amendment 3. These reflect the guidance given to the Plan Development Team (PDT) at the August Section meeting—to, primarily, develop options that protect spawning fish in the Gulf of Maine. The Section will consider options for public comment when it meets on November 2, 2015.

Prior to considering the discussion document, an advisor voiced concern that the document provides no biological analysis or socio-economic analysis, so that weighing some of the spawning closure options becomes difficult. The January 2015 TC report was mentioned as helpful, relative to better understanding the forecasting system being recommended, but the AP, generally, had remaining questions about how the system would work.

It was also noted that the problem statement should include a discussion of the current status of Atlantic herring's spawning stock status and that Table 3 and Figure 2 of the Council's 2016-2018 Herring Specifications document could be included to provide this information. Some advisors suggested that any additional spawning protection in the Gulf of Maine should be tied to spawning stock status, coastwide, since extending the GOM closure period for an additional two weeks would have significant economic impacts on herring fisherman and the lobster fishery, where bait demand is high during the late summer and fall period.

Issue 1: Spawning Area Efficacy (Section 2.0)

2.1 *Spawning Area Closure Monitoring System*

There was consensus in support of *Option C, GSI_{30}-Based Forecast System.* Advisors supported the forecast system's likely ability to better target closures to periods of time when the majority of fish are spawning. Advance warning prior to a closure was voiced as a positive, which is provided by the forecasting system's announcing closures 5 days before the forecasted date. Advisors voiced concern about the fact that last week's opening and reclosing of the MA/NH spawning area all took place within 24 hours, which caused significant disruption to the fishery. Some advisors suggested that much of the fish in that area had already spawned and that the weather was better than it had been for a month. Advisors commented that the goal of this program should not be to save every spawning herring, particularly given the coastal spawning stock condition today. Advisor's also supported this option as it requires that projections would be based on a minimum of 3 samples. One advisor supported the status quo, Option A.

REQUEST: The AP asked the TC why is the forecasting system standardized for larger fish (30 cm) when the current GSI (gonadosomatic index) is based on fish under 28 inches?

There was no consensus relative to which of the three *GSI_{30} Trigger Value* options should be chosen.

2.2 *Default Closure Dates*

As noted above, the AP could not come to a consensus on the appropriate GSI_{30} trigger value due to uncertainty of the outcome. Five people felt the 70th percentile trigger value would provide additional protection so fishing just prior to spawning would not happen. One person was opposed to the 70th percentile option, they felt the fishery would have to stay closed longer to accommodate maturing fish and spawners.

REQUEST: The AP asked, how do each of the percentile triggers compare or relate to the status quo approach?

2.3 *Spawning Area Boundaries*

There was a general consensus in support of *Option A, status quo,* which has the effect of maintaining the three spawning areas. The AP voiced concern and reluctance to combine the Western Maine and Massachusetts/New Hampshire spawning areas. Advisors felt Option B would likely result in a large coastal shutdown based on a few samples. In addition, the AP felt there was not sufficient biological evidence to support anything other than status quo.

REQUEST: The AP suggested that a chart depicting the spawning area boundaries would be helpful for the public and that the document should also reflect fishing effort in these areas over time; the NMFS should be able to supply VMS (vessel monitoring system) data

2.4 *Spawning Closure Period*

Closure Period

There were seven advisors in support of the status quo, Option A, a four week closure with the fishery being closed for an additional two weeks, if necessary, and three in favor of Option B, a six week closure. A participant commented they were not entirely in favor of a six week closure, but it was better than the status quo given the potential damage (i.e. fishing on spawners) that one herring boat can impose in just a couple of days. A participant in favor of status quo commented that there is not enough social and economic data to justify a six week closure and the document should outline the effects it could potentially have on lobster fishermen.

Re-closure Protocol

Three advisors were in favor of the status quo and two participants were in favor of option B, defined protocol. Those in favor of Option B liked that it only involved one sample to initiate a re-closure, which is why other advisors opposed it.

Issue 2: Fixed Gear Set-Aside Provision Adjustment (Section 3.0)

The AP was unanimously in favor of the *status quo, Option A*.

REQUEST: The AP asked that the document include historical landings in the fixed gear fishery. This information should also be available in the Council's specifications document.

Issue 3: Empty Fish Hold Provision (Section 4.0)

There was general support for an empty fish hold provision in the fishery and the issue has been addressed by the Council. Five advisors were in favor of Option E, an empty fish hold provision, limiting the requirements to vessels with the ability to pump fish, that is not contingent on federal adoption and two participants were in favor of Option B, an empty fish hold provision, with the pumping limitation, that is contingent upon federal adoption of the same provision.

Other Comments:

- The AP discussed the benefit of reinstating a tolerance for spawning fish in the fishery because it would provide the opportunity to regularly collect samples of herring for GSI analysis from vessels that are working in the area to be closed. REQUEST: The majority of AP members requested that the Section consider adding a tolerance option to draft Amendment 3. One advisor did not support this suggestion.
- Add information relative to current status of the fishery (i.e., SSB) in the introduction of the document.
- A participant said they were confused about the goals and objectives of the draft amendment, there should text added to the document that describes that protecting spawning fish is a goal, in addition to maintaining the fishery and markets. Protecting spawning fish exclusively is unrealistic.
- One participant noted that although the spawning stock biomass is above the target, there is still a need to update the spawning closure system. The spawning closure system is necessary irrespective of the status of the stock.

ACTION: The Chair suggested that the AP be polled to see who would like to continue being an AP member and re-populate the AP if necessary. Nine of sixteen members participated in the conference call.

The AP call ended at 12:00 PM