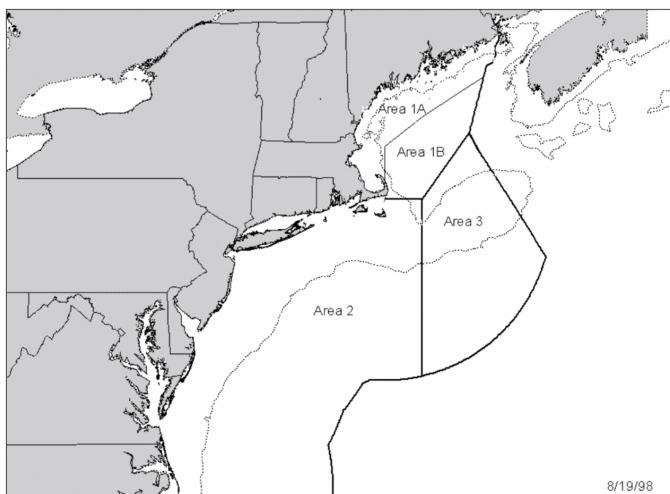


# Atlantic Herring - Marcel Gietzmann-Sanders

## The Resource

The Atlantic Herring Fishery deals in *Clupea harengus* along the Atlantic coast of the United States. The range of the fishery extends from the Gulf of Maine down to the Carolinas<sup>[1]</sup> while the range of the species itself extends up into Canada as well.



The species is highly migratory with at least three phases present<sup>[1]</sup>.

- (1) a late summer-early autumn spawning migration of ripening fish; (2) a rapid post-spawning migration to warmer waters to the south for overwintering; and (3) a spring-early summer feeding migration.

Spawning is especially interesting in Atlantic herring. First there seems to be some kind of "homing" behavior with herring:

a tagging study in Newfoundland which showed that adult Atlantic herring returned to the same spawning grounds year after year (Wheeler and Winters 1984).<sup>[1]</sup>

When they do aggregate to spawn, eggs are laid en masse on the seafloor where they are subjected to heavy predation pressure. Larvae then hatch and overwinter in coastal and estuarine waters.

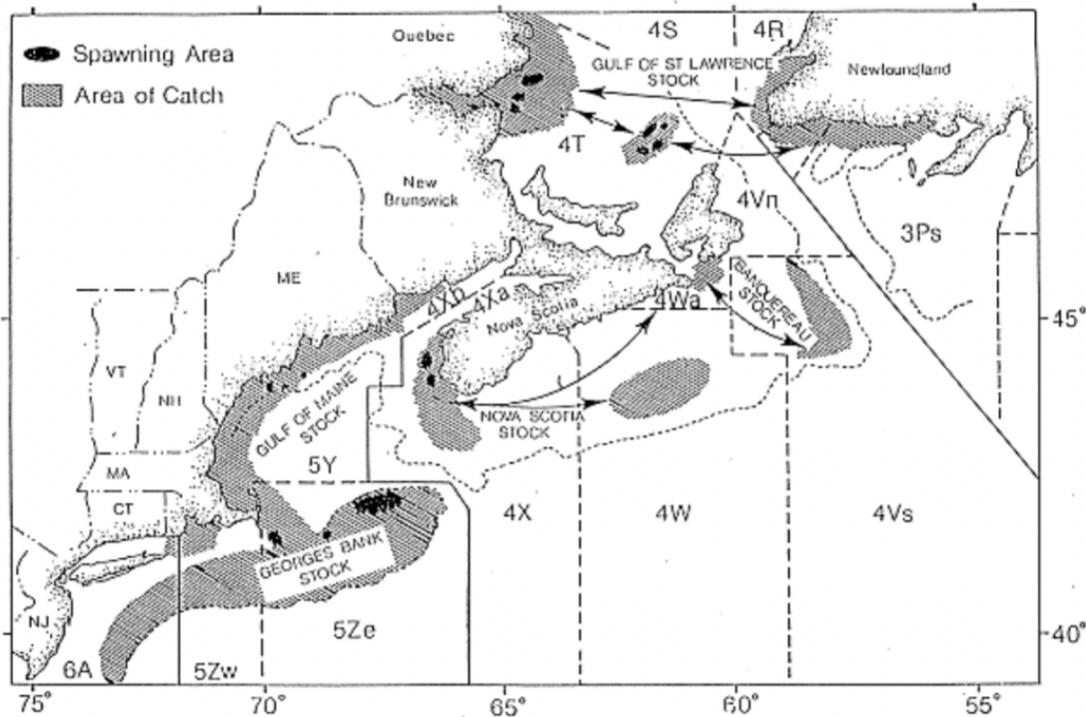
These larvae are a source of food for many marine animals, are very much at the will of their environment, and therefore can experience quite high mortality<sup>[1]</sup>.

All in all the density of these spawning clusters and the subsequent vulnerability of the larvae make herring very sensitive to spawning success. Given how easy it is to fish these aggregations spawning closures have been implemented in a few states.

Predation is another big vulnerability for herring as they are a food fish for many different species of marine mammal, fish, and bird.

Overholtz et al. (1991) also calculated that five species of whales, three species of dolphins, harbor porpoises and harbor seals consumed, on average, 19,300 mt (42.5 million lbs) of herring a year from 1988-92

These calculations indicate that between piscivorous fish, marine mammals and marine birds, approximately 30,000 mt of herring is consumed each year. This is probably an underestimate since it was based among other things, on a presumed low abundance of herring on Georges Bank and herring, at least during the spawning season, are known to be much more abundant in recent years as the offshore portion of the stock has recovered. However, even using an estimate of 50,000 mt, this only represents 2.5% of the estimated total stock size of Atlantic herring in 1990, and 50% of the



current commercial harvest.<sup>[1]</sup>

Given the uncertainty in these estimates and the magnitude of the predation, good estimates of natural mortality is of great importance when considering such things as MSY.

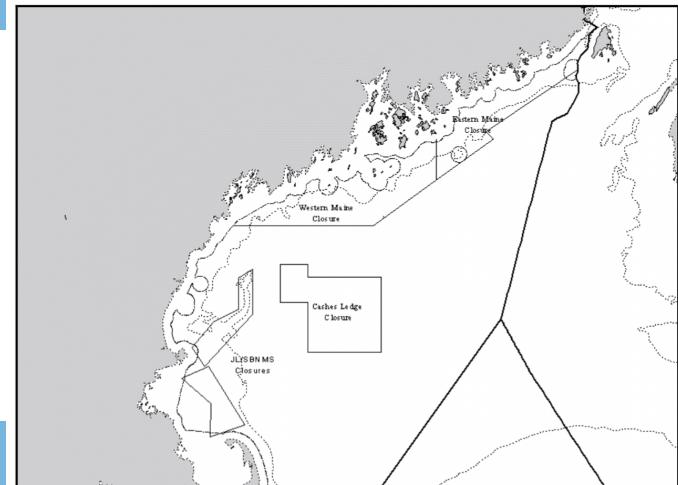
In terms of environmental factors affecting the resource much of this appears to be affects on spawning and the larval ages of stocks:

Mortality of Atlantic herring in the larval stage is very high since the larvae remain vulnerable to very low temperatures and a limited food

supply for a prolonged period during the winter, especially in the shallow nearshore and estuarine waters (Townsend and Graham 1981, Graham et al. 1991). Campbell and Graham (1991) developed an ecological model in order to examine which factors affected larval survival to the early juvenile stage.<sup>[1]</sup>

While temperatures in the Gulf of Maine are increasing faster than many other parts of the world<sup>[2]</sup> which could be considered a plus for herring larvae, this heating up in combination with runoff is also creating eutrophication<sup>[3]</sup> which can starve estuarine areas of oxygen and nutrients. Generally speaking however, I think its pretty unclear how warming is affecting herring populations.

Over its history this stock has had quite large swings in estimated abundance with a notable crash in the 1970s, a recovery after that, and then a crash again recently<sup>[4]</sup>.



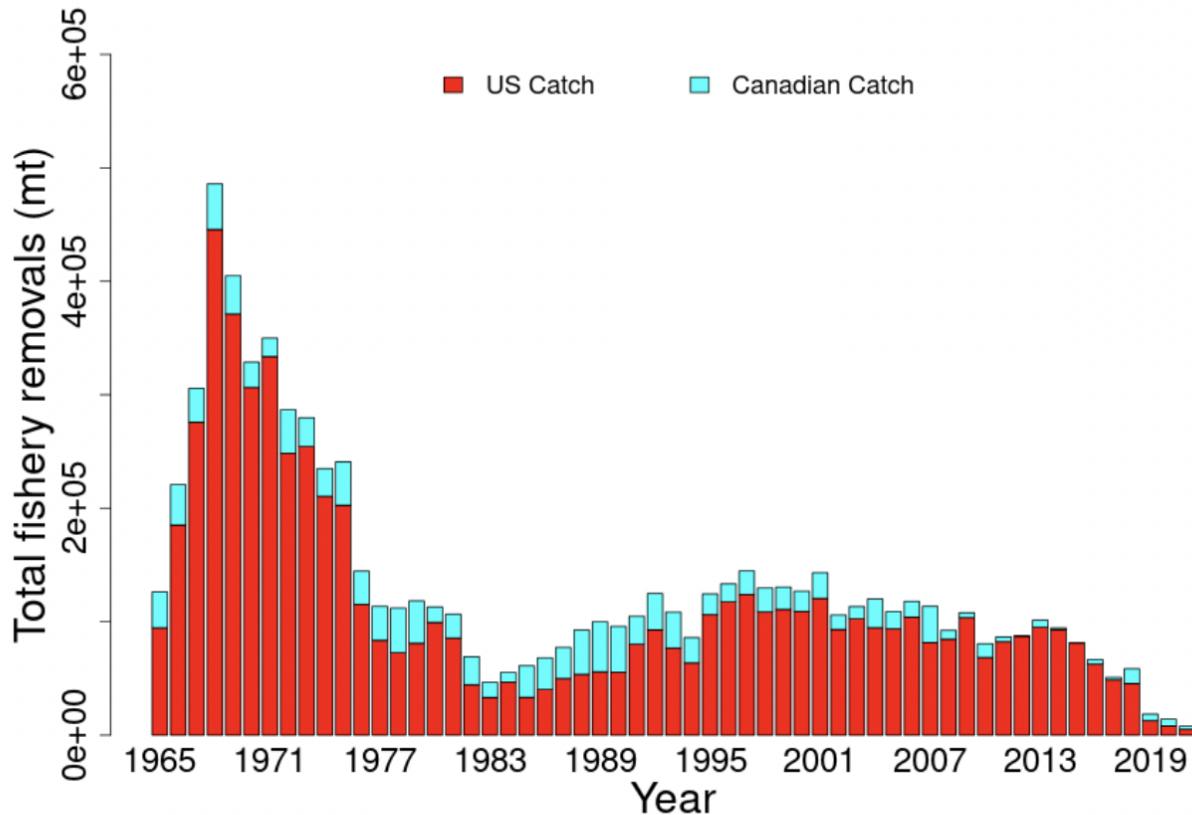


Figure 4: Total catch of Atlantic Herring between 1965 and 2021 by US and Canadian fleets.

## Technical Attributes of Fishing

Herring are primarily caught by commercial fishers using purse seines and mid water trawls. However gillnetting and fixed gear, such as weirs, are allowed and sometimes used<sup>[5]</sup>. There are no minimums set on gear sizes and mid water trawls are known to be reasonably selective<sup>[6]</sup> and thereby limit harvesting of bycatch. NOAA also notes<sup>[5]</sup>:

The Atlantic herring fishery can incidentally catch marine mammals. Currently, these takes are below limits that would require mitigation under the Marine Mammal Protection Act.

While there are no limits on gear size juveniles of age 2 are taken as sardines while smaller juveniles are typically not captured<sup>[1]</sup>.

Vessels fishing for herring that are less than 165 feet in length overall, less than 750 gross registered tons, or less than 3,000 shaft horsepower may be issued one of the herring permits listed below. Herring vessels exceeding the size and horsepower restrictions may be issued a herring at-sea processing permit.<sup>[7]</sup>

In 2014 there were ~2000 permits recorded for fishing Atlantic Herring<sup>[8]</sup> however it has been noted in the past that the vast majority of fish are caught by a minority of boats:

The fishery is dominated by a relatively small group of vessels, though a broader group of vessels lands some herring in small amounts (Table E.14). In 1997, nearly 98 percent of the landings were

made by 21 vessels, and 10 boats accounted for 92% of the catch. This same year, only 61 vessels averaged more than 2,000 pounds of herring on trips that reported landing herring.<sup>[1]</sup>

Finally in terms of history of the resource:

Historically, Gulf of Maine herring were harvested along the coast in fixed-gear weirs (a fence of long stakes driven into the ground with nets arranged in a circle). Today, herring are primarily harvested by mid-water trawlers and purse seiners.<sup>[5]</sup>

## Enhancement

There does not seem to be any enhancement procedures in place for this fishery.

## Habitat, environment, and ecosystem

Some of this has already been mentioned above in [The Resource](#). Atlantic herring range from coastal areas along the east coast of North America from the Canadian maritime provinces down to the Carolinas and extend out to George's Bank. There are also populations in other parts of the atlantic (there are European fisheries).

Herring do not exist throughout their range in large numbers at all times but instead migrate up and down latitudes throughout the year. They overwinter in warmer waters down south, move up north to feed in the spring, and then aggregate and spawn in the north during the late summer and fall.

Their spawning aggregations are relatively small in spatial extent making them quite vulnerable during spawning.

While the range does extend into Canada, the majority of the catch is taken by the United States making enforcement and management of the resource far easier.

Their eggs are laid in mass and experience heavy predation pressure before hatching 10 or so days later. The larvae then overwinter near their spawning grounds along the coasts or in estuaries where they continue to experience significant predation pressure and depend on warm enough temperatures and good sources of food to not die off en masse.

After over wintering they then recruit to the overall population and are sometimes caught as sardines.

Herring are a food fish for a wide variety of different animals including (but not limited to) seabirds, groundfish such as cod, whales, and seals. The predation from these species seems to be comparable to the fishing pressure exerted by humans.

While temperatures are warming throughout their range and it is well understood that herring juveniles and their prey are affected by these kinds of changes<sup>[9]</sup> it's still not well understood whether these changes are having positive or negative changes.

There are however significant changes in estuarine and coastal environments simply due to runoff and other kinds of pollution. And this almost always causes negative changes to juvenile fish.

## Stakeholders

The herring fishery captures herring primarily for canning and use as bait with some more artisanal uses as smoked goods or fresh fillets. Therefore there is a whole chain of stakeholders beginning with the fishermen themselves, moving onto the trucks who move the fish from dock to canneries (or other processors), the processors themselves, and then of course the consumer at the end of the line (which in the case of bait for things like lobster, tuna, etc means other fishermen) [1].

The herring is typically pumped into trucks that carry a combined mixture of herring and water, but are not cooled in any manner. For this reason, it is important the fish be landed soon after they are caught and transported as rapidly as possible. The typical truck is estimated to hold about 40,000 pounds (or just under 20 mt) of herring. [1]

So much for primary stakeholders. In terms of secondary stakeholders there are several. The Atlantic States Marine Fishery Council (ASMFC) is ultimately responsible for managing the stock [10] but because the stocks extend into state waters they work closely with the New England Fishery Management Council [11]. Both of these groups divide into a whole slew of committees and advisory groups who manage everything from the science to the enforcement and everything in between. In addition NOAA advises and provides support for much of the science and management decisions [1]. NOAA also seems to provide enforcement for federal waters [12]. States management enforcement in their own waters (up to 3 miles offshore).

Finally there are a variety of other stakeholders present from conservation organizations like the Pew Trusts [13] and Save the Bay in RI [14] to those interested in leaving enough food for the marine species that feed on herring [10].

The stakeholders are quite heterogeneous but it seems everyone is quite engaged and management is certainly being kept up to date. Primary stakeholders are clearly largely commercial with little to no one taking home herring for personal use besides use as bait in certain cases.

## Markets

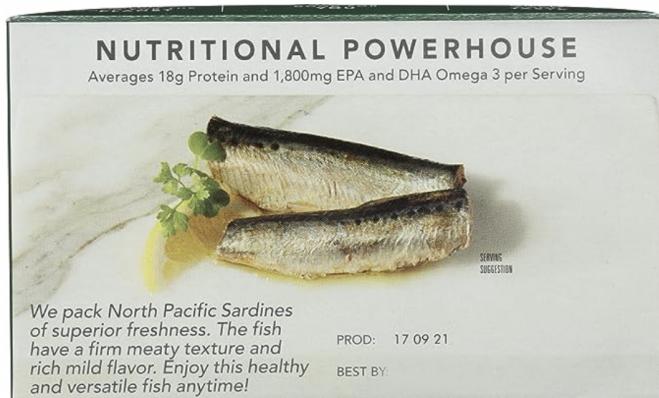
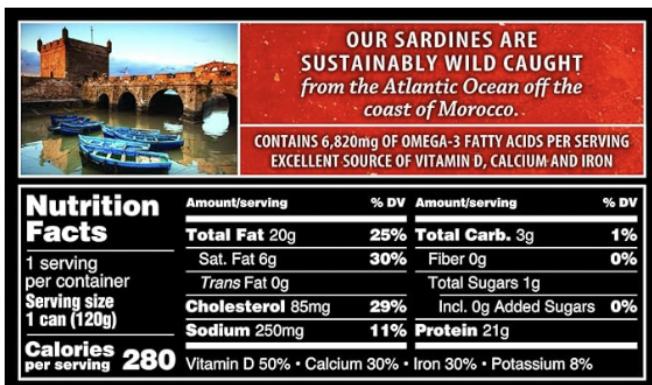
The Atlantic herring fishery is extremely valuable to the economy in the Northeast United States. Herring are sold frozen, salted, or canned as sardines in both U.S. and international markets and provide affordable bait to fishermen targeting lobster, blue crab, and tuna. [5]



A cursory tour of amazon.com shows us how this is marketed to consumers. Some of the descriptors used are:

- Great in pastas and seafood recipes (NOAA also mentions this [15])
- Loads of omega-3
- Sustainable
- As coming from a specific place

However quite a few of the sardine/herring packages don't do a great job of specifying where the fish is from. When they do the herring are often coming from elsewhere (Europe/Africa or the Pacific).



economics.

I could not, for the life of me, find much on the operational costs of the US herring fishery, but, as a proxy, the northeast herring fishery has a quite nice article on both the costs and how those costs are distributed amongst things like capital expenditure, labor, and fuel<sup>[24]</sup>.

Capital expenditure as a fraction definitely seems to change a lot between these countries but things like fuel costs and labor costs are reasonably stable across the board and therefore may represent a reasonable proxy for atlantic herring fishing. I'd reallly like to find something more specific to the USA.

What I did find were plenty of suppliers of nets, boats, and the like who hide all of their prices and request that you call for consultation.

## Arrangements

There are pretty clear rules around fishing herring<sup>[7]</sup>. Broadly summarizing:

- Fishing is open to all with very large vessels requiring specific kinds of permits.
- Each management area (see picture in [The Resource](#)) has specific allowable catch limits that total up

As bait they are sold wholesale<sup>[16]</sup>, to commercial fishermen<sup>[17]</sup>, or packaged for more recreational use<sup>[18]</sup>, and many recreational fishermen have tips on buying from asian seafood markets or catching your own herring.

Other processors provide not just bait and seafood but also things like pet food<sup>[19]</sup>. In all cases however there is clearly a wide array of places you can source your herring from (Pacific, Europe/Africa, East Coast) and in many cases folks aren't very specific about where their herring is coming from.

In terms of prices, herring for consumption seems to come in packages ranging from \$4 to \$8 and weighing 100 - 400g with ~200g being very common. Bait seems be about ~1 lb for \$10 - \$20<sup>[20] [18]</sup> if you're buying it for recreational use. The wholesale price according to this platform<sup>[21]</sup> is \$1-\$3 per pound which I'd suspect is pretty close to the commercial price of bait. It seems at least some people don't expect these prices to change dramatically in the near future<sup>[22]</sup>.

It also looks like most of the bait herring goes to the lobster fishery<sup>[23]</sup> and someone put together a model of how that may affect herring

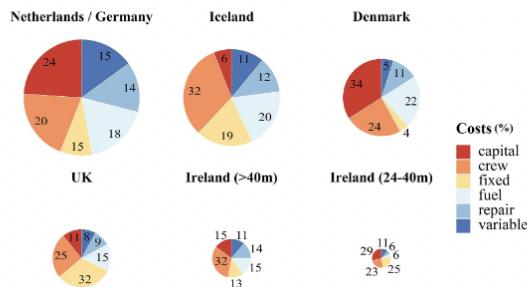
**Figure 5**

FIGURE 5. Cost structure [proportion (%) per kg landed] of the eight modeled fleets, average of years 2012 to 2014. The size of each pie chart shows the proportion of total costs per vessel in comparison to the other segments. Due to data privacy reasons the Dutch and German fleets as well as the two Danish fleets were aggregated (all segments shown here contain > 10 vessels). The cost structure of the Icelandic fleet was estimated by using United Kingdom costs structure.

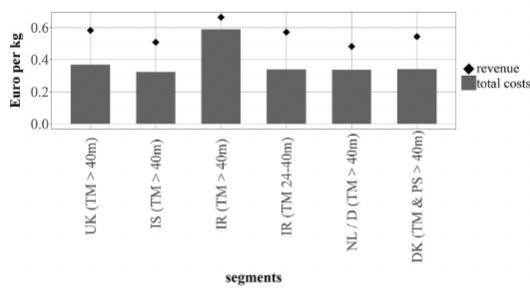
**Figure 6**

FIGURE 6. Total costs and revenue (Euro per kg landed) of the eight modeled fleets with an average of years 2012 to 2014. This also includes revenue from other species caught by those segments. Due to data privacy reasons the Dutch and German fleets as well as the two Danish fleets were aggregated (all segments shown here contain > 10 vessels). The cost structure of the Icelandic fleet was estimated by using United Kingdom costs structure.

to the overall ACL

- Once the fishery nears the ACL herring possession limits go into effect (2000lb)
- Once either haddock or river herring is nearing its catch limit a similar minimum possession limit goes into place in areas these species are likely to be caught
- There are also some spawning closures that go into affect to help support the rebuilding of the population<sup>[10]</sup>.

There used to be prohibitions on gear use in certain areas but:

In 2021, Amendment 8 to the Atlantic Herring FMP prohibited the use of midwater trawl gear inshore of 12 nautical miles (22 km) from the U.S./Canada border to the Rhode Island/Connecticut border and inshore of 20 nautical miles (37 km) off the east coast of Cape Cod with the intent of addressing issues of localized depletion and user group conflict (86 FR 1810, January 11, 2021). However, as a result of litigation by midwater trawl industry members, a Court ruled that this measure was arbitrary and capricious and violated the Administrative Procedure Act based on a conclusion that the available scientific information did not sufficiently support that localized depletion was occurring.<sup>[25]</sup>

So clearly this is not a conflict free space. Fishermen are litigating.

The body responsible for these rules seems to be the Atlantic States Marine Fisheries Commission who then delegates work to committees that range from technical to advisory with a board overseeing proceedings. Some of this work is delegating to similar bodies in NOAA and the councils in each of the states. At least every couple of years the technical board for the ASMFC meets and the management board for the fishery in the ASMFC seems to meet a few times every year. Much of what these groups do is driven by the Magnuson Stevens Act as most of the work is directed toward fulfilling its provisions<sup>[10]</sup>.

This governing body has been in place since before 2000 (reports listed go back to 1999) and is open to public comment. Clearly there is also litigation going on (see above) so fishermen are definitely involved in driving the direction of the fishery.

Given the ACL is the primary form of control here, landings seem to be reasonably well monitored and for particularly vulnerable zones observers have to be on board<sup>[7]</sup>. Reporting is the responsibility of the fishermen and failing to comply will incur investigation from NOAA<sup>[26]</sup>

## Outcomes

In 2021, commercial landings of Atlantic herring totaled approximately 11 million pounds and were valued at \$6.6 million, according to the NOAA Fisheries commercial fishing landings database.<sup>[5]</sup>

These are the lowest landings on record and while folks are still clearly out there making money all stakeholders are clearly concerned about the state of this fishery. It has been noted in recent stock assessments<sup>[27]</sup> that there are serious inconsistencies in the modeling parameters and that as a result estimates of recruitment and stock size are highly uncertain. Some of this is attributed to the fact that while the complex is treated as a single stock the life history of herring clearly is an amalgamation of several different complexes which are likely being fished at different levels.

In general it seems like fishing has stayed below the appropriate management points for the most part, however year after year the estimates of those points change rather dramatically<sup>[28]</sup>.

There is a clear issue in being able to model this stock and as a result we've ended up putting it into an depressed state.

## Trying to Understand the Decline

As a third person observer it seems like the fisheries have done a reasonable job keeping to the "law". However we still see this rapid decline in the stock assessment in the past few years. Why?

In looking into the modeling itself I found a couple of unnerving things.

1. The folks doing the modeling are aware of "retrospective pattern" whereby the conclusions each year have to be modified to actually represent the year they were trying to predict<sup>[29]</sup>.
2. In 2015 this pattern led folks to believe a 50% increase in estimated mortality was required to get things to line up<sup>[30]</sup>
3. Much of ASAP modeling depends on weights, but they've simply been using averages, and only averages from one kind of gear<sup>[30]</sup>

4. Furthermore when it comes to estimating mortality they have been using techniques that treat mortality as relatively global across the population<sup>[30]</sup> even if adjusted for by weight.
5. All in all given the fact that herring don't seem to mix greatly during spawning and that their life history (and early mortality) is highly dependent on the spawning group they are from that treating the entire stock as one single unit is questionable. Some people have even started to see if there are ways of differentiating stocks to facilitate other kinds of modeling<sup>[31]</sup>.

It seems like we need more data to understand why the models being used today are repeatably unable to replicate the observations we make year after year. Whether the issues are a result of poor estimates of mortality, age to weight, recruitment, etc. seems to be unknown but in 2015 the group responsible for modeling this stock themselves said that this needed to be treated as a research problem<sup>[30]</sup> as it is plain to them that the modeling being used is not sufficient for the needs. My conclusion thus far is that further instrumentation around this species is needed.