DESCRIPTION OF STOCK

BIOLOGICAL PROFILE

Physical Description (1)

Southern flounder exhibit a unique body type compared to most other fish species, belonging to a special subgroup known as flatfishes (2). While most fish species are considered to be bilaterally symmetrical and have body parts equally distributed on each side of their body, flatfish species, including southern flounder, possess both eyes on one side of the body and are considered to lack symmetry. Newly hatched southern flounder larvae initially have bilateral symmetry but after currents carry them into the estuaries they undergo metamorphosis (Figure 5.1; Francis and Turingan 2008; Schreiber 2013).

Due to this metamorphosis, southern flounder are known to be "left handed" because the right eye shifts and the eye-side of the flounder is the left side (Daniels 2000) (3). Southern flounder also exhibit a unique pattern of pigmentation where the "top" side of the fish is darker and the "bottom" side is typically white colored. Southern flounder tend to be bottom dwellers and can use the dark pigmentation on the "top" side to blend into the surrounding habitat to hide from predators and ambush prey (Arrivillaga and Baltz 1999). (4)

Distribution

Southern flounder are widely distributed along the United States (Blandon et al. 2001) (5). In the Atlantic Ocean, southern flounder reside in coastal habitats from North Carolina to Cape Canaveral, Florida with a few observations north of North Carolina. In the Gulf of Mexico southern flounder can be found from northern Mexico to Tampa, Florida. Genetic studies have indicated there is little to no movement of southern flounder between the Gulf of Mexico and Atlantic Ocean as the peninsula of Florida acts as an ecological barrier (Blandon et al. 2001; Anderson and Karel 2012; Midway et al. 2014).

Tagging studies show that southern flounder are capable of undergoing movements from North Carolina to Florida (Craig et al. 2015; Loeffler et al. 2019). Additionally, genetic studies indicate that individuals from North Carolina to Florida are capable of spawning together and that the Atlantic Ocean population is well mixed (Wang et al. 2015). While each Atlantic state manages southern flounder in their own waters, based on this life history information, a multi-state cooperative group stock assessment was used to determine the status of the unit stock (see *Stock Status Section* below).

Habitat

More information is known about habitat use for southern flounder in the estuary than for the ocean. As southern flounder mature around age-2, they migrate out of the estuaries and spawn in the ocean; this migration to the ocean spawning grounds is not well understood (Figure 5.2). No surveys or large-scale fisheries exist for these fish in the ocean. As a result, it is difficult to directly observe where adult southern flounder go after they leave the estuary and determine what drives their habitat selection once offshore. The location and/or the number of offshore spawning ground(s) is currently unknown (Midway and Scharf 2012), though research is currently underway to determine these locations and migratory pathways. Most of the direct examination of southern flounder habitat use has occurred within estuarine environments where juveniles are easily accessible for scientific study (Burke et al. 1991; Fitzhugh et al. 1996; Froeschke et al. 2013).

Larval southern flounder are transported into sounds and estuaries during late winter and early spring by wind-driven currents (Figure 5.2; Taylor et al. 2010) and survival is greatly influenced by a number of variables. Once within the estuary, southern flounder typically settle in low salinity areas (Burke et al. 1991; Miller et al. 1991; Lowe et al. 2011). Despite the tolerance of young juvenile southern flounder to various salinities, low dissolved oxygen values have been shown to inhibit growth of newly settled southern flounder (Taylor and Miller 2001; Del Toro-Silva et al. 2008). As southern flounder age they can tolerate prolonged periods of low dissolved oxygen and are thought to remain in low oxygen areas as a trade-off to expending energy by moving into other areas where environmental conditions may not necessarily improve (Ellis 2007).

In addition to water quality influences, bottom structure and water depth are important drivers of juvenile southern flounder habitat selection. The presence of sea grass and/or marsh edge has been shown to have a positive effect on southern flounder abundance (Nañez-James et al. 2009; Furey and Rooker 2013) and these structures have been known to serve as refuge for estuarine juvenile fishes (Rooker et al. 1998; Stunz et al. 2002). Several studies have indicated that water depths of less than three feet are significantly related to southern flounder abundance (Walsh et al. 1999; Furey et al. 2013; Froeschke et al. 2013). Potentially, the use of shallow near-shore areas by southern flounder during their juvenile period increases survivorship by protecting individuals from predators (Manderson et al. 2004). However, southern flounder overwintering in the estuary may select deeper waters or move to down-estuary areas near ocean inlets where environmental conditions are more stable during winter months (Hollensead 2018). For additional information on how habitat and water quality affect southern flounder see *Ecosystem and Fishery Impacts Section.*

Reproduction

Southern flounder migrate out of North Carolina estuaries from mid-October to mid-November to spawn (Hollensead 2018). No direct observation of spawning has been observed in the wild, but laboratory experiments have been conducted to quantify southern flounder fecundity (number of eggs) and fertilization success (Watanabe et al. 2001).

In North Carolina, 50% of females are considered mature by 16 inches total length (TL) and ages 1 or 2 (Midway and Scharf 2012). This length at maturity is larger than what has been reported in Florida (8.4 inches TL) and the Gulf of Mexico (12 inches TL; Topp and Hoff 1972; Corey et al. 2017), indicating a potential shift in length-at-maturity maturity the further south the species occurs (Lee et al. 2018).

Age and Growth (6,7,8)

Growth rate and length-at-age in North Carolina are highly variable for southern flounder (Fitzhugh et al. 1996). Juvenile female southern flounder exhibit a higher growth rate than male southern flounder (Midway et al. 2015) and females generally attain a larger maximum size compared to males (Fischer and Thompson 2004). In North Carolina, the maximum age is older for females at nine years compared to six years for males and maximum length was 33 inches TL for females and 20 inches TL for males (Lee et al. 2018). Additional information on age and growth of southern flounder can be found in the annual Southern Flounder Fishery Management Plan Update located here: http://portal.ncdenr.org/web/mf/stock-overview.

Predator-Prey Relationships (9)

Southern flounder are bottom dwelling, ambush predators that use their unique coloring to camouflage themselves in order to opportunistically feed on a wide range of prey species (Burke 1995; Arrivillaga and Baltz 1999). Young juvenile southern flounder generally eat small invertebrate species (Ellis 2007) before shifting to a diet made up of mostly other fish species (Fitzhugh et al. 1996). In general, the most common prey fish species encountered in adult southern flounder diets are bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), and spotfin mojarra (*Eucinostomus argenteus*; Wenner 1990). Some predators of southern flounder include sandbar sharks (*Carcharhinus plumbeus*; Ellis and Musick 2007) and bird species (Kellison et al. 2000; Hossain et al. 2002).

STOCK STATUS

Stock Unit Definition

The biological unit stock assumed for the stock assessment (Flowers et al. 2019) is based on multiple tagging studies (Ross et al. 1982; Monaghan 1996; Schwartz 1997; Craig and Rice 2008), genetic studies (Anderson and Karel 2012; Wang et al. 2015), and an otolith morphology study (Midway et al. 2014), all of which provide evidence of a single stock occurring in waters of North Carolina, South Carolina, Georgia, and the east coast of Florida.

Assessment Methodology

Landings and dead discards were incorporated into a quantitative model that estimates both historical and current population sizes and harvest rates. Landings and dead discards were available from the commercial and recreational fishery. Eight fishery-independent surveys were also input into the model. These included recruitment indices from North Carolina, South Carolina, and Florida and adult indices from North Carolina, South Carolina, Georgia, Florida, and a near-shore ocean survey from Cape Hatteras, North Carolina to Cape Canaveral, Florida.

When considering population size and long-term viability, stock assessments most often use a measure of female spawning stock biomass to determine the population's health. Female spawning stock biomass includes female fish that are mature and capable of producing offspring. Fishing mortality, abbreviated as *F*, is a measure of how fast fish are being removed from the population by the different fisheries. Removals include those fish that are kept and those that are discarded dead or die after release.

The stock assessment's current (2017) estimates of female spawning stock biomass and fishing mortality rates were compared to levels that are considered sustainable. These sustainable levels are based on established reference points that include a target and threshold. The threshold is the minimum level required for sustainability and when the target level is achieved, the stock is considered healthy. If current female spawning stock biomass is less than the threshold for biomass, the stock is said to be overfished. If the current harvest rate is greater than the associated threshold, the current rate of removals is too high and overfishing is said to be occurring. Overfishing is the state of removing fish at an unsustainable rate and will ultimately reduce the female spawning stock biomass and result in an overfished stock.

Current Stock Status

Results show that spawning stock biomass (SSB) has generally decreased since 2006 (Figure 5.3) and recruitment, while variable among years, has a generally declining trend (Figure 5.4). Fishing mortality did not exhibit much inter-annual variability and suggests a decrease in the last year of the time series (Figure 5.5).

The model estimated a value of 0.35 for $F_{35\%}$ (fishing mortality target) and a value of 0.53 for $F_{25\%}$ (fishing mortality threshold). The estimate of $SSB_{35\%}$ (target) was 5,452 metric tons and the estimate of $SSB_{25\%}$ (threshold) was 3,900 metric tons.

The level of female spawning stock biomass that represents the minimum level of sustainability for southern flounder was estimated at 8.6 million pounds. The stock assessment estimate of female spawning stock biomass for southern flounder in 2017 was 2.3 million pounds. Because the current (2017) estimate of female spawning stock biomass is below the threshold reference point, the stock is considered overfished. The probability that the 2017 estimate of SSB is below the threshold value is 100%.

The assessment model estimated that fishing mortality can be no greater than 0.53 for a sustainable southern flounder population. The current (2017) estimate of fishing mortality from the stock assessment was 0.91, which is above the threshold fishing mortality reference point. Because the current (2017) fishing mortality is above the threshold, overfishing is occurring. The probability the 2017 fishing mortality is above the threshold value is 96%.

Projections

Calculations were made to determine the reductions in total catch necessary to end overfishing and to reach the fishing mortality target. Additionally, a series of projections were performed to examine future stock conditions under various management scenarios. The calculations of percent reductions indicate that to end overfishing a 31% reduction in total catch (landings plus discards from all fleets) would be required. However, while this reduction is sufficient to end overfishing in two years, it is not sufficient to rebuild SSB to meet the 10-year schedule to end the overfished status (Figure 5.8).

Projections were also carried out to determine the fishing mortality and the associated reduction in total catch necessary to end the overfished status and to reach the SSB target within 10 years (by 2028, assuming management imposes regulations beginning in 2019). The projections indicate that a F equal to 0.34 and a 52% reduction in total catch is needed for the SSB to reach the SSB threshold by 2028 and end the overfished status (Figure 5.9). To reach the SSB target by 2028, F would need to be lowered to 0.18 and total catch would need to be reduced by 72% (Figure 5.10).

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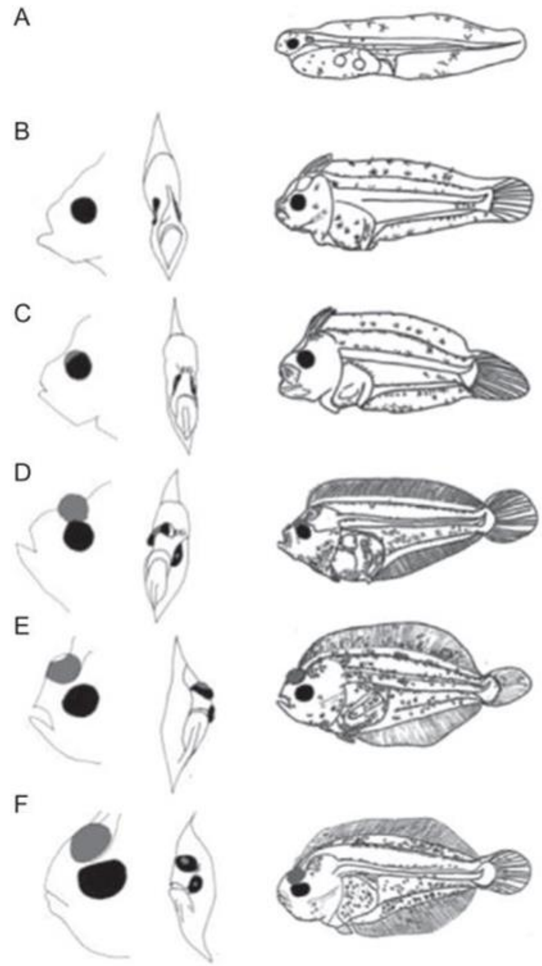

Figure 5.1. Metamorphosis of the summer flounder *Paralichthys dentatus*. (A) Hatched yolk-sac larva. (B) Pretransformation larva before eye migration commences. (C) Early metamorphosis and the beginning of eye migration. (D) Mid-metamorphosis. (E) Metamorphic climax, right eye has migrated over the dorsal midline. (F) Young juvenile. Left column in B–D shows the migration of the eye across the skull; migrating right eye is shaded in gray. Rightmost column shows whole-body morphological changes at each stage. Image originally printed in Martinez and Bolker 2003.

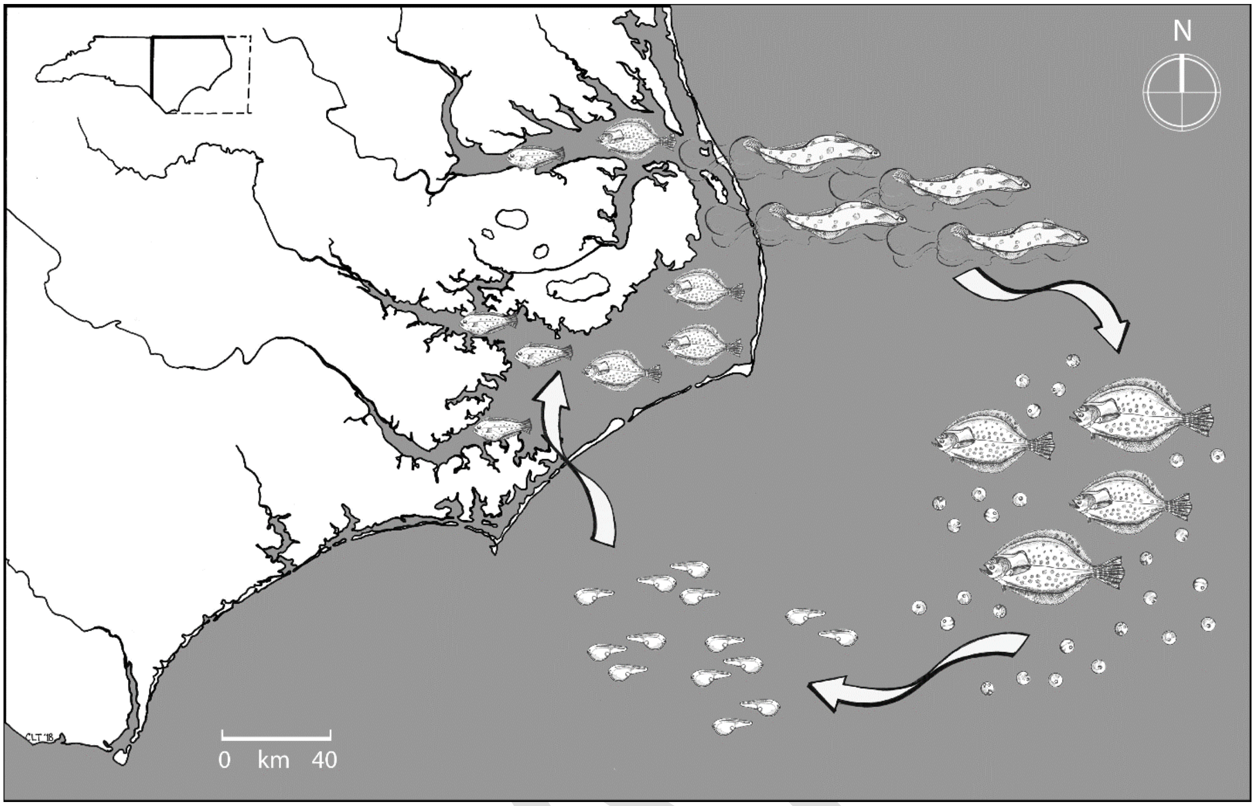

Figure 5.2. Artist interpretation of the southern flounder life cycle. Originally printed in Hollensead dissertation 2018.

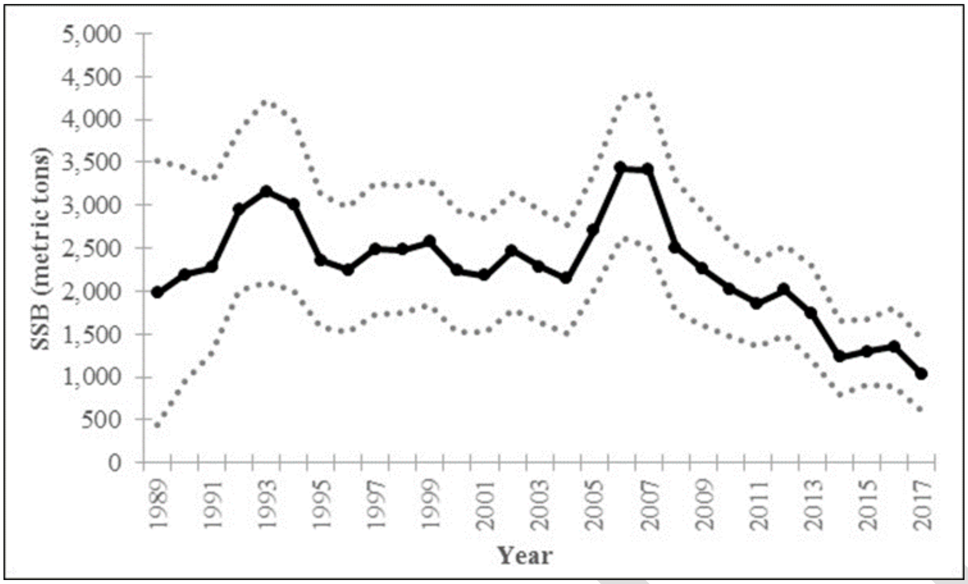

Figure 5.3. Predicted female spawning stock biomass (SSB) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations of the predicted values. (Source: Flowers et al. 2019)

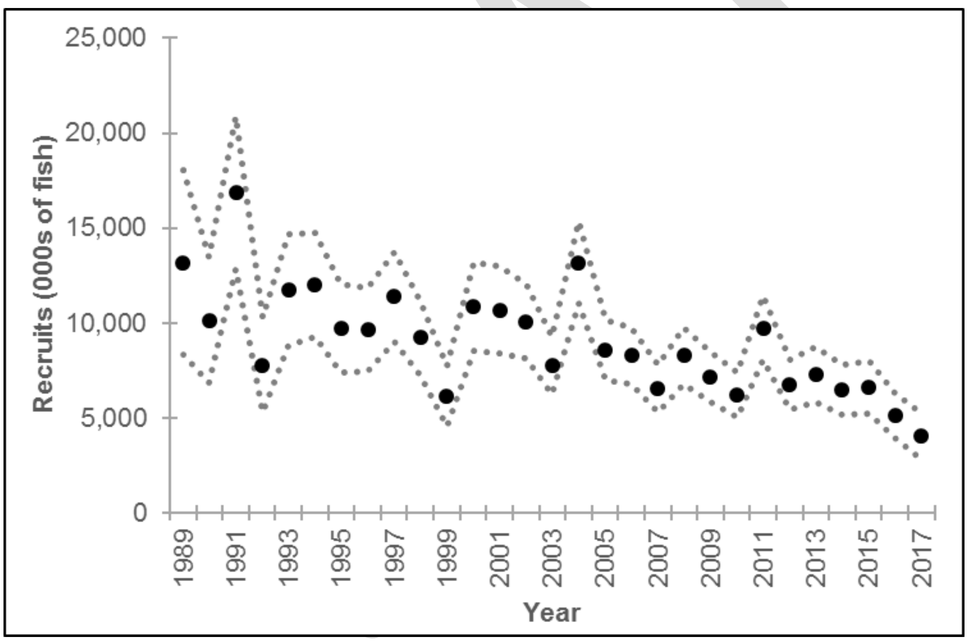

Figure 5.4. Predicted number of recruits (thousands of fish) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations of the predicted values. (Source: Flowers et al. 2019)

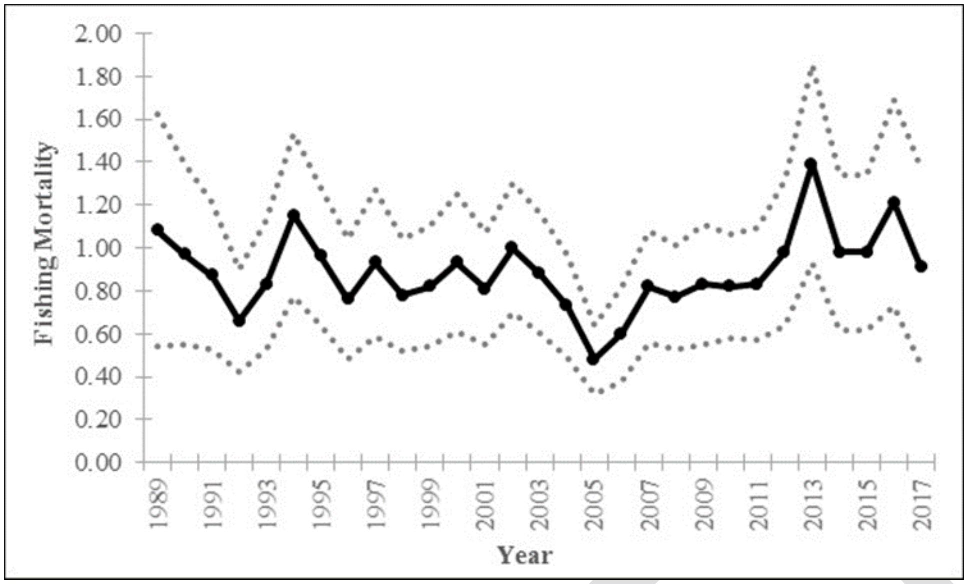

Figure 5.5. Predicted fishing mortality rates (numbers-weighted, ages 2–4) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations of the predicted values. (Source: Flowers et al. 2019)

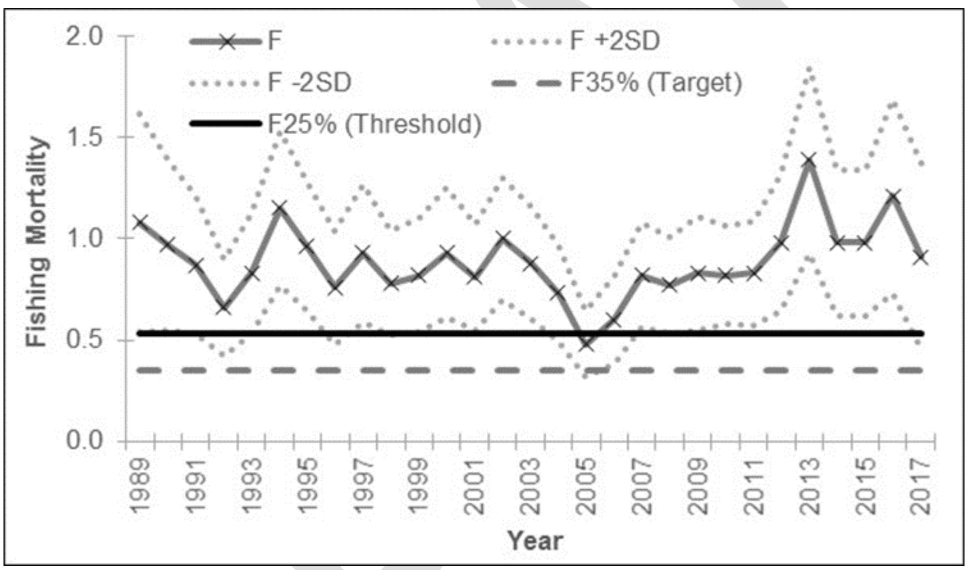

Figure 5.6. Estimated fishing mortality rates compared to established reference points, 1989–2017. (Source: Flowers et al. 2019)

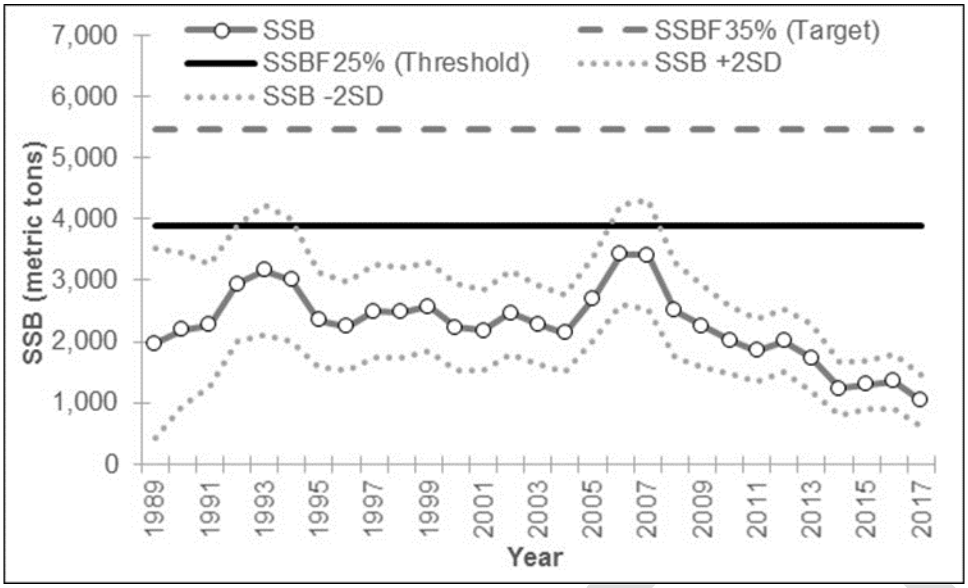

Figure 5.7. Estimated spawning stock biomass compared to established reference points, 1989–2017. (Source: Flowers et al. 2019)

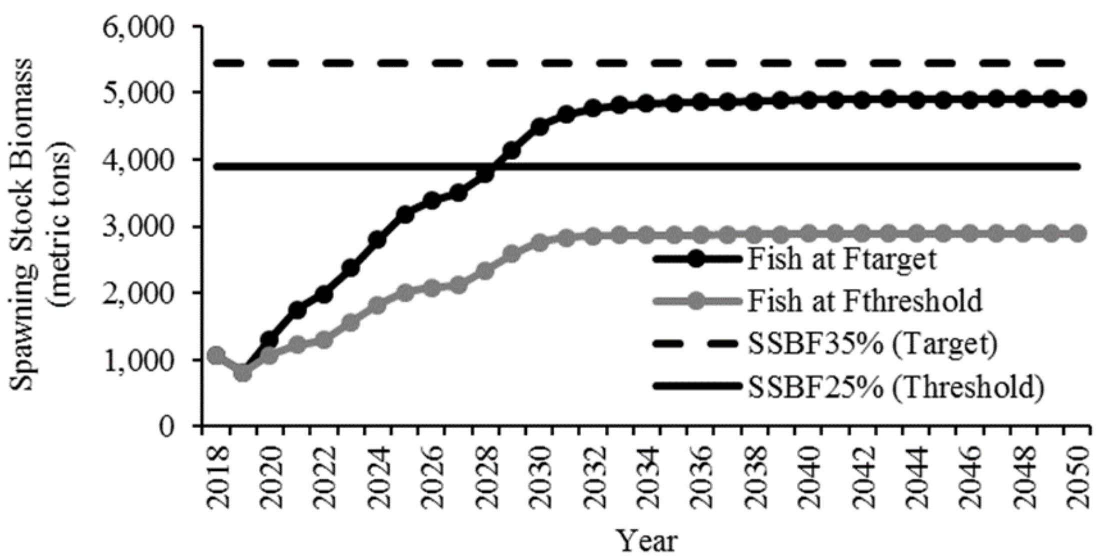

Figure 5.8. Projections of SSB related to fishing at a level to end overfishing in the required two-year period. (note: SSB does not rebuild within required ten-year time period). (Source: Flowers et al. 2019)

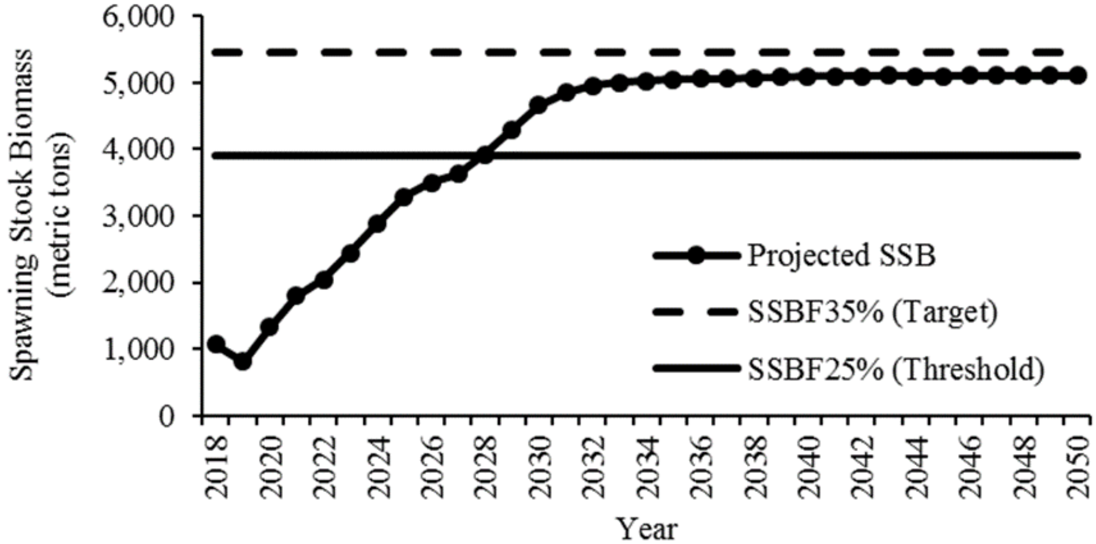

Figure 5.9. Predicted future spawning stock biomass (metric tons) assuming the fishing mortality value necessary to end the overfished status by 2028. (source: Flowers et al. 2019)

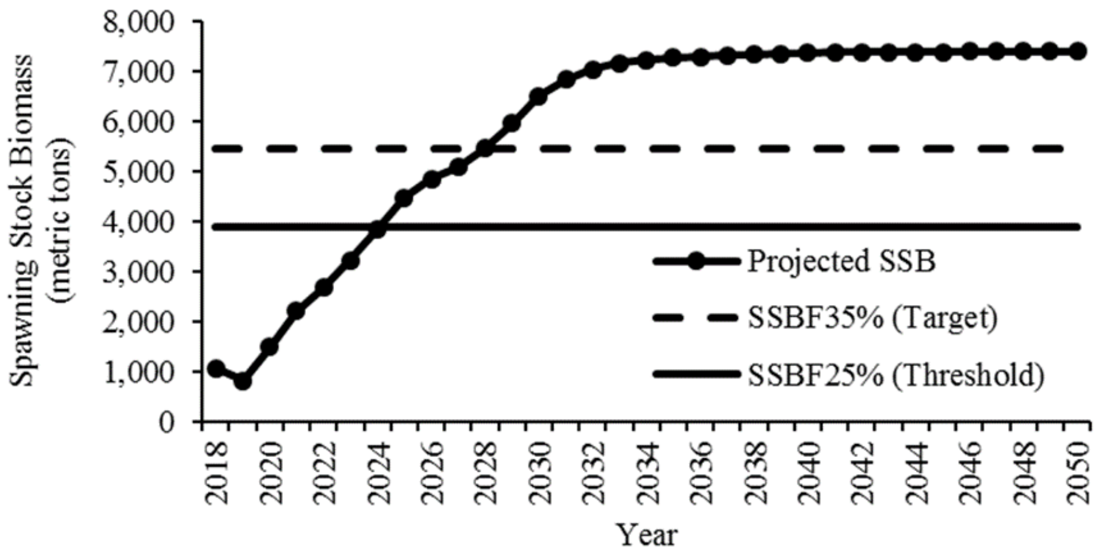

Figure 5.10. Predicted future spawning stock biomass (metric tons) assuming the fishing mortality value necessary to reach the SSB_{Target} by 2028. (Source: Flowers et al. 2019)

Text Boxes and Images

1.) Picture of flounder up close

2.) The scientific name of the southern flounder is *Paralichthys lethostigma*. This translates to "parallel fish with forgotten spots". The description of *Paralichthys* remarks on the compressed body shape of flounder while *lethostigma* remarks to the lack of large conspicuous ocellated spots common to many other flounder species.

3.) LEFTEYE FLOUNDER - Flounder are classified into families based on the side of their head their eyes are on, left or right. Southern flounder belong to the left eye flounder family because in almost all cases the right eye migrates to the left side of their head as it develops from

4.) Species Identification- There are three main flounder species landed in North Carolina: southern, summer, and Gulf. They can be identified by the location or lack of ocellated spots. ***point to L&S brochure

PICTURE included with this, ocellated spot found on summer and Gulf and another is the non-ocellated from southern flounder

5.) UNIT STOCK - The biological unit stock for southern flounder inhabiting southeast U.S. waters includes waters of North Carolina, South Carolina, Georgia, and the east coast of Florida.

6.) OTOLITH - Southern flounder like all bony fish have otoliths or ear bones that the fish use for balance. Researchers can use fish otoliths to age the fish as they have rings in them much like rings in a section of a tree.

7.) Picture of otolith for here.

8.) Southern flounder from NC are the oldest observed in the species range

9.) AMBUSH PREDATORS - Southern flounder are ambush predators which means they use camouflage to hide from prey as they lie and wait for an opportunity to strike.