An Updated Population Viability Model for the U.S. DPS of Smalltooth Sawfish Incorporating Improved Estimates of Bycatch for the Southeast Shrimp Trawl Fishery and a Large-scale Mortality Event Associated with a Toxic Algal Bloom

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Credit: Mote Marine Lab

Population Viability Analysis

- ✓ Population viability analysis (PVA) is a modeling tool that estimates the future size and risk of extinction for populations of organisms

  -Predicts the probability of the population persisting into the future

  -Explores consequences of management actions in the light of uncertain data and an ambiguous future

- ✓ A wide range of modeling approaches are used in PVA, from simple models based on abundance trends to complex individual-based habitat models

Population Viability Analysis

✓ Builds upon two previous publications:

AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS
Aquatic Conserv: Mar. Freshw. Ecosyst. (2014)
Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/aqc.2434

Recovery potential of smalltooth sawfish, Pristis pectinata, *in the United States determined using population viability models*

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ABSTRACT

1. Determining the recovery potential of endangered species is an important component for developing strategies necessary to return populations to healthy levels. Many species of endangered marine animals have been regarded as having low productivity and therefore, an inherent inability to rapidly recover from severe depletion.

2. An age-structured Leslie matrix model was constructed for the US population of smalltooth sawfish, *Pristis pectinata*, to determine their ability to recover under scenarios using different life history inputs and the effects of bycatch mortality and catastrophes.

3. Population growth was highest (λ=1.237 yr^{-1}) when age-at-maturity was 7 yr and decreased to 1.150 yr^{-1} when age-at-maturity was 11 yr.

4. Despite a high level of variability throughout the model runs, in the absence of fishing mortality or climate catastrophic effects the population grew at a relatively rapid rate approaching carrying capacity in 40 or 50 yr when the initial population was 600 or 2250 females, respectively. Population projections under various levels of fishing mortality resulted in extinction when mortality was highest, initial population size was small, and age-at-maturity was 11 yr. Scenarios testing the potential effects of extreme cold exposure showed little difference to those scenarios testing the effects of fishing mortality.

5. Using the optimistic estimates of population size, lower age-at-maturity and the lower level of fisheries-related mortality, smalltooth sawfish in US waters appear to have the ability to recover within the foreseeable future. Effective management and recovery of this species can only be achieved by keeping fishing-related mortality low.

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KEY WORDS: elasmobranch; conservation; extinction risk; Leslie matrix; productivity

INTRODUCTION

Determining the recovery potential of endangered species is an important component for developing strategies necessary to return populations to healthy levels. Many species of endangered marine animals have been regarded as having low productivity and therefore, an inherent inability to

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Trouble in the trawls: Is bycatch in trawl fisheries preventing the recovery of sawfish? A case study using the US population of smalltooth sawfish, *Pristis pectinata*

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ABSTRACT

All five species of sawfish (Family Pristidae), are among the most threatened families of elasmobranchs, and face significant threats from fishing, in particular trawl fisheries, and habitat loss. Unfortunately, there is little data on the level of sawfish taken in trawl fisheries outside Australia and the United States and case studies from these areas can provide a "risk analysis" for populations elsewhere. In the United States, bycatch risk for smalltooth sawfish is significantly higher for the southeast shrimp trawl fishery than all other fisheries assessed. Using new estimates of life history and population size, an updated population viability model was developed and trajectories using different scenarios of initial population sizes, fishery catches and post-release mortality were projected for 100 years. The simulated population trajectories for the assumed initial population sizes and fishing mortality ranged between population extinction, quasi-extinction, to a slight reduction in population size and in some cases the population continuing to recover. The most pessimistic scenarios were when the initial population was lowest and post-release mortality in the shrimp trawl fishery was highest. Quasi-extinction for some scenarios was between 6.9 and 22.8 years. While some scenarios suggest that smalltooth sawfish still can recover despite the potential for shrimp trawl fishing mortality, key input variables for these optimistic scenarios is the initial population size and the true level of fishing mortality. This uncertainty highlights the importance of improving our understanding of sawfish life history, captures in fisheries and their associated post-release mortality.

1. Introduction

The incidental capture or bycatch of non-targeted species in fishing gear is widely recognized as an important threat to the conservation status of many animal populations (Read et al., 2006; Gilman et al., 2010; Reeves et al., 2013). Bottom trawling is a relatively non-selective fishing method, and in many cases, bycatch often comprises a much higher proportion of the total catch than the target species (Saila, 1983; Andrew and Pepperell, 1992). Bottom trawl impacts on elasmobranchs have been widely documented globally in various fisheries and areas (see review in Molina and Cooke, 2012; Oliver et al., 2015). For example, elasmobranch bycatch in the shrimp trawl fishery in Pacific waters off Costa Rica comprised 25 species and 13 families (Clarke et al., 2016). In Australia's Northern Prawn Fishery, 56 species of elasmobranchs have been documented in this fishery and these species comprise around 4 % of the bycatch by weight (Stobutzki et al., 2001).

Globally, all five species of sawfish populations face significant threats from fishing and habitat loss. Sawfish are among the most threatened families of elasmobranchs (Dulvy et al., 2014, 2016). All species in the Family are now listed as Critically Endangered under

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Population Viability Model

- ✓ An age-structured Leslie matrix model using data in the form of a post-breeding census with inputs of fecundity and survivorship
- ✓ Three fishery mortality sources identified
  - Commercial shark bottom longline
  - Recreational rod and reel
  - Commercial shrimp trawl fishery
- ✓ Initial population size based on density and genetic information

Leslie Matrix and Projections

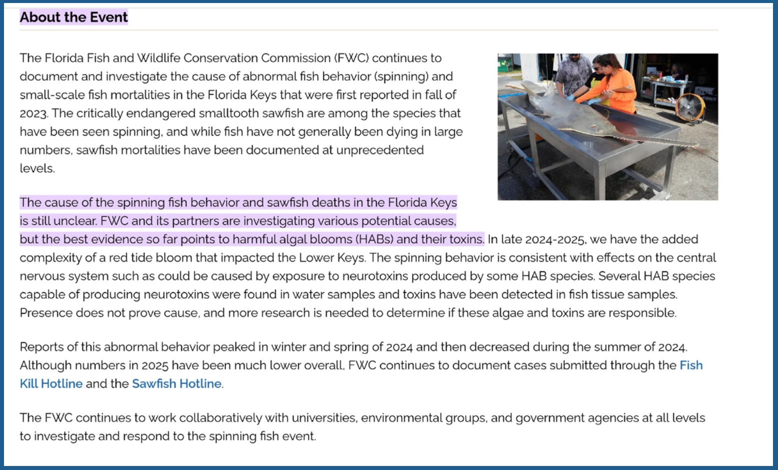
- ✓ An age-structured Leslie matrix model using data in the form of a post-breeding census with inputs of fecundity and survivorship
- ✓ Smalltooth sawfish (depending on assumed life history parameters) may have moderate productivity vs. other elasmobranchs (Cortes 2016)
- ✓ The population size (specified as a vector of abundance by age) from one time step (N(t)) to the next (N(t+1)) was given by: N(t +1)= L(t)N(t) and the population was projected forward in time

Leslie Matrix

$$L = \begin{bmatrix} F_0 & F_1 & F_2 & F_3 \\ S_0 & 0 & 0 & 0 \\ 0 & S_1 & 0 & 0 \\ 0 & 0 & S_2 & 0 \end{bmatrix}$$

Updated PVA Inputs

- ✓ **Updated shrimp bycatch estimates** (2015–2023) using Bayesian generalized linear models (Babcock and Peterson 2025)
- ✓ **Population size:** New genetic close-kin-mark-recapture study suggests **small population size** (<2000; Swift and Portnoy, in prep.)
- ✓ **Mortality event**: During the winter and spring of 2024 in the lower Florida Keys, a **mortality event** occurred with ~230 reports of smalltooth sawfish exhibiting abnormal behavior (spinning) with documented mortalities exceeding 50 individuals



About the Event

The Florida Fish and Wildlife Conservation Commission (FWC) continues to document and investigate the cause of abnormal fish behavior (spinning) and small-scale fish mortalities in the Florida Keys that were first reported in fall of 2023. The critically endangered smalltooth sawfish are among the species that have been seen spinning, and while fish have not generally been dying in large numbers, sawfish mortalities have been documented at unprecedented levels.

The cause of the spinning fish behavior and sawfish deaths in the Florida Keys is still unclear. FWC and its partners are investigating various potential causes, but the best evidence so far points to harmful algal blooms (HABs) and their toxins. In late 2024-2025, we have the added complexity of a red tide bloom that impacted the Lower Keys. The spinning behavior is consistent with effects on the central nervous system such as could be caused by exposure to neurotoxins produced by some HAB species. Several HAB species capable of producing neurotoxins were found in water samples and toxins have been detected in fish tissue samples. Presence does not prove cause, and more research is needed to determine if these algae and toxins are responsible.

Reports of this abnormal behavior peaked in winter and spring of 2024 and then decreased during the summer of 2024. Although numbers in 2025 have been much lower overall, FWC continues to document cases submitted through the Fish Kill Hotline and the Sawfish Hotline.

The FWC continues to work collaboratively with universities, environmental groups, and government agencies at all levels to investigate and respond to the spinning fish event.

Updated PVA Inputs

Parameter	Value	Source
Age-at-maturity	8 years	Carlson (2023)
Maximum age	30 years	Scharer et al. (2012)
Litter size (yr)	2.62 (0.504)	Brame et al. (2019); Carlson (2023)
Survivorship		
Age 0	0.87 (0.208)	Carlson and Simpfendorfer (2014)
Age 1	0.87 (0.131)	
Age 2	0.89 (0.104)	
Age 3	0.90 (0.093)	
Age 4	0.91 (0.087)	
Age 5-6	0.92 (0.082)	
Age 7-11	0.93 (0.080)	
Age 12-30	0.94 (0.080)	
Population Size		
Initial total population size (N_{init})	1255 females 1695 females	Breeders: (Feldheim et al. 2017); Smith et al. (2021) N_B: (Smith, 2021; Chapman, unpublished)
Carrying capacity	45,000 females	Carlson and Simpfendorfer (2014)

Inputs identical to Carlson (2023); however, only 2 of 4 N_{init} scenarios evaluated as preliminary CKMR results suggest the higher N_{init} values considered in Carlson (2023) are unlikely.

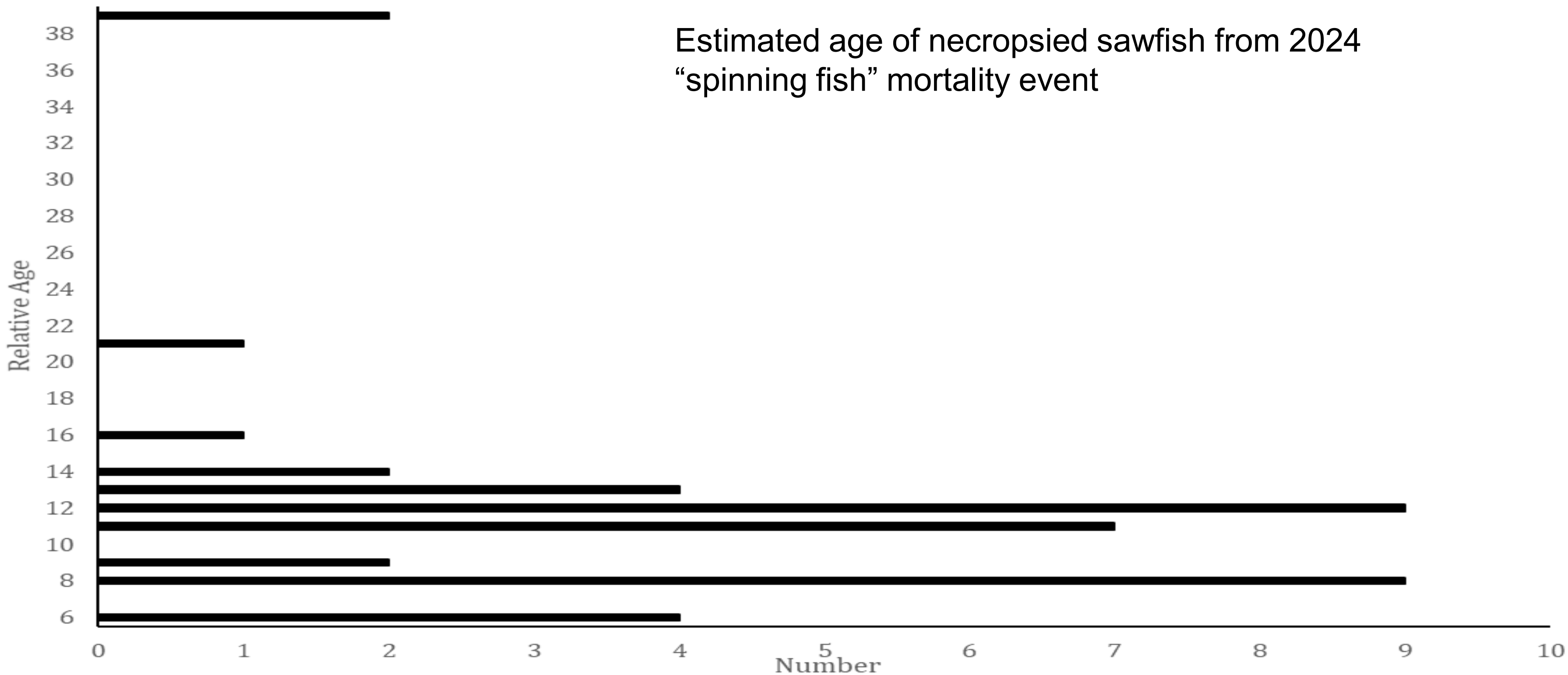
Year	Initial population size	Recreational Fishing Mortality	Shark Bottom Longline	Shrimp Trawl Removals	Sawfish Spinning Mortality Event
2009	1255 or 1695	10.9	1.0	65	
2010	1255 or 1695	10.9	1.0	48	
2011	1255 or 1695	10.9	1.0	52	
2012	1255 or 1695	10.9	1.0	51	
2013	1255 or 1695	10.9	1.0	26	
2014	1255 or 1695	10.9	1.0	60	
2015	1255 or 1695	10.9	1.0	53	
2016	1255 or 1695	10.9	1.0	67	
2017	1255 or 1695	10.9	1.0	72	
2018	1255 or 1695	10.9	1.0	72	
2019	1255 or 1695	10.9	1.0	72	
2020	1255 or 1695	10.9	1.0	94	
2021	1255 or 1695	10.9	1.0	82	
2022	1255 or 1695	10.9	1.0	62	
2023	1255 or 1695	10.9	1.0	24	
2024	1255 or 1695	10.9	1.0	60 or 72	38 or 182
2025-2044	1255 or 1695	10.9	1.0	60 or 72	

- **Commercial shrimp trawl bycatch:** Ages 6–30 based on observer data
- **Recreational fishery bycatch:** All ages
- **Shark bottom longline bycatch:** Ages 6–30 based on observer data
- **“Spinning Fish” Mortality:** Ages and sex ratio (0.51) based on FWRI data

Two scenarios for spinning fish mortality were evaluated:

(1) Total deaths = observed, necropsied individuals and

(2) Total deaths = necropsied + reported symptomatic individuals



Source: FWRI

Updated Population Viability Model Results

Scenarios						Percentiles of Terminal Abundance				
	Ninit	Rec. Fishery	Shark BLL	Shrimp Trawl	Spinning Fish	5th	25th	50th	75th	95th
1	1255	10.9	1.0	60	38	**0**	**0**	**0**	2,062	25,903
2	1255	10.9	1.0	60	182	**0**	**0**	**0**	628	20,671
3	1255	10.9	1.0	72	38	**0**	**0**	**0**	***25***	23,929
4	1255	10.9	1.0	72	182	**0**	**0**	**0**	**0**	21,646
5	1695	10.9	1.0	60	38	**0**	**0**	10,457	26,025	43,658
6	1695	10.9	1.0	60	182	**0**	**0**	2,981	20,156	39,286
7	1695	10.9	1.0	72	38	**0**	**0**	7,037	20,560	41,505
8	1695	10.9	1.0	72	182	**0**	**0**	4,401	20,138	37,905

- Inclusion of the 2024 “spinning fish” mortality event led to substantially more pessimistic PVA results than those presented in Carlson (2023)
- All scenarios → at least a 25% probability of population extinction
- Scenarios 1–4 → median (50%) predicted outcome was population extinction
- Scenario 4 → >75% likelihood of extinction
- Scenarios 5–8 → population slowly recovers from mortality event (>5 years), with faster recovery at lower bycatch levels

Sources of Uncertainty

LIFE HISTORY PARAMETERS

- High variability in life history parameters leads to uncertainty in PVA outcomes
- Age0 survivorship estimate is 0.87 (with high standard deviation)
- Age at maturity and maximum age still need refinement

Less productive species leads to delayed recovery

INITIAL POPULATION SIZE

- Population size estimates based on three genetic approaches: (1) effective genetic population size (Ne), (2) number of breeders (NB), and (3) close-kin mark recapture (CKMR)
- All approaches suggest small population size, confirmed by independent methods in Farmer et al. (In Review) for Charlotte Harbor
- Some evidence of small populations in less sampled areas

Remote area sampling to strengthen CKMR estimates

SHRIMP BYCATCH MORTALITY

- All scenarios assumed bycatch 60-72/yr.
- 72/yr met or exceeded 5 of past 9 years.
- Bycatch in 2024 was the lowest on record (post-Hurricane Ian)
- As the industry in southwest Florida recovers, effort could increase, resulting in more frequent bycatch.

Increased bycatch would lead to worse outcomes

EPISODIC MORTALITY EVENTS

- Only a single episodic mortality event is modeled (2024 spinning fish)
- Some evidence of other events: (1) Cold shock 2010, (2) Mortality event 2021, (3) “Spinning Fish” mortality event 2025
- In 2025, at least 37 “spinning fish” reports and 6 confirmed dead

Future mortality events (including 2025) would lead to worse outcomes

Conclusion

- **Model outcomes suggest the U.S. DPS of smalltooth sawfish is on the brink; the next few years will be critical to the viability of this endangered species.**
- **PVA projections clearly indicate that the 2024 mortality event had a substantial impact on population viability.**
- **If future mortality events are minimal in scope and scale, and if shrimp bycatch remains at or below the reduced 2023 level, there is cause for optimism that the population has the capacity to recover.**

Credit: WFTX

Ways forward to advance PVA

- ✓ Refine bycatch estimates, particularly size/age of bycatch
  - ✓ Improve observer coverage and total effort for shrimp fishery
    - ✓ Potential for EM (Moncrief-Cox et al. 2020) and electronic logbooks
  - ✓ Opportunity for industry involvement

- ✓ Continue to improve life history, post release mortality data and population size information
    - ✓ Close-kin mark recapture study with Texas A&M University
      - ✓ Requires large sample size
      - ✓ Can industry assist in collecting samples
        - ✓ Tissue samples and tagging sawfish

QUESTIONS?

This is a sawfish