An Update to the Population Viability Model for Giant Manta Ray for the Northwest Atlantic based on new estimates of Bycatch from the Southeast Shrimp Trawl Fishery

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Background

On April 26, 2021, the Southeast Regional Office (SERO) completed a biological opinion on the effects of the implementation of the sea turtle conservation regulations applicable to shrimp trawling and the authorization of southeast U.S. shrimp fisheries in federal waters on threatened and endangered species and designated critical habitat, in accordance with Section 7 of the ESA. The biological opinion was the result of an intra-agency consultation; SERO was both the action agency under our authorities to conserve sea turtles under the ESA and to manage federal shrimp fishing under the Magnuson-Stevens Act (16 U.S.C. §1801 et seq.) and the consulting agency.

On June 2, 2023, SERO's Sustainable Fisheries Division (SFD) (serving as the action agency) requested the Protected Resources Division (PRD) (serving as the consulting agency) reinitiate the subject consultation. Regulations at 50 C.F.R. § 402.16 require reinitiation of formal Section 7 consultation under the ESA if discretionary involvement or control over the action has been retained (or is authorized by law) and: (1) the amount or extent of the incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not previously considered; or (4) if a new species is listed or critical habitat designated that may be affected by the identified action. The subject fisheries have exceeded the anticipated incidental takes of giant manta ray (i.e., trigger #1) and SERO has received new smalltooth sawfish and giant manta ray bycatch information, which may trigger #2. In their reinitiation request, SFD summarized the last biological opinion on the subject action, documented why reinitiation is required, and outlined how SFD and PRD would need to work together to prepare a complete reinitiation package.

In March 2024, SERO request data and analyses to support the reinitiation of ESA Section 7 consultation on the Southeast U.S. shrimp fisheries in federal waters under the Magnuson-Stevens Act to address bycatch of giant manta rayand smalltooth sawfish and compliance with the terms and conditions of the 2021 biological opinion's incidental take statement.

Specifically, SERO requested the following:
To the extent practicable, provide a population viability analysis (PVA) for giant manta ray within the Western North Atlantic Ocean off the United States (e.g., Farmer et al. 2022), evaluating the population's ability to recover in the context of new bycatch estimates and considering uncertainty in initial population size, reproductive periodicity, bycatch mortality, and other key parameters.

This report, to the extent practical provides data and analysis to meet this request.

Overview

Population viability analysis (PVA) is a modeling tool that estimates the future size and risk of extinction for populations of organisms (Coulson et al., 2001). A wide range of modeling approaches are used in PVA, from simple models based on abundance trends to complex individual-based habitat models (Beissinger and McCullough, 2002). Software to conduct PVAs is widely available (e.g., RAMAS and Vortex), but models developed specifically for a given species have also been utilized (e.g., Legault, 2005). Whatever approach is taken, the purpose is to predict the probability of the population persisting into the future, as population size has been shown to be the best predictor of extinction risk (O'Grady et al., 2004). Population viability analysis is also a useful tool to explore potential consequences of management actions in the light of uncertain data and an ambiguous future.

Methods

A Leslie matrix was updated from Carlson (2023) based originally on that for female giant manta ray following Caswell (2001). Inputs were derived from data available in Dulvy et al. (2014) and Marshall et al. (2020 and references therein) (Table 1). Natural mortality was estimated as the maximum of three indirect estimates using longevity (Hoenig 1983), age at maturity (Jensen 1997), and as the reciprocal of average lifespan: M = 1/ù where average lifespan ù is (ámat + ámax)/2) (Pardo et al. 2016).

The Leslie matrix was input into a commercially available software package (RAMAS Metapopulation; Akçakaya, 2005) to project and examine population responses to conditions set in the models. This model implements a standard Leslie matrix (*L*) that provides age-specific inputs of fecundity (*Fx*) and survival (*Sx*). 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:

$$N_{(t+1)}= L_{(t)}N_{(t)}$$

The population was projected forward for 20 years for each scenario (~ 1 generation). Stochasticity was incorporated into new abundance vectors ($N_{(t+1)}$) by randomly drawing values specified in the Leslie matrix. At each time step, a random variable was drawn for each vital rate (i.e. survival and fecundity) based on a lognormal distribution and the standard deviation assigned to each vital rate in the matrix. Standard deviations were determined based on the variability in the estimates of survivorship calculated through all indirect mortality methods and fecundity from all values provided in the literature and unpublished data (see previous). Each time step was replicated 500 times. RAMAS introduced variation in initial population size and carrying capacity (*K*) by randomly sampling a single deviate at each time step based on the estimated standard deviation. Density dependence was assumed to follow a Beverton-Holt stock recruitment relationship:

$$R(t)=\frac{R_{max}*K}{R_{max}*N(t)-N(t)+K}$$

where *R(t)* is the population growth rate at time *t*, R_{max} is the maximum population increase rate, *N(t)* is the abundance vector at time *t*, and *K* was the carrying capacity. RAMAS models density dependence by modifying the select matrix elements at each time step so that the dominant eigenvalue (λ) of the matrix was equal to the growth rate. Further details on the sequence of calculations carried out by RAMAS during each simulation are provided in Akçakaya (2005).

Initial population size was based on estimates from Farmer (unpublished) from an approach used to generate a relative index of abundance for giant manta rays in the northwestern Atlantic Ocean in the area covered by Southeast Fisheries Science Center (SEFSC) aerial surveys from 2010–2019 (see Farmer et al. 2022). Based on this approach and assuming giant manta rays are available for detection 14.4% (median) of the time they are at the surface, the population size is 47,802 (median; total individuals) or 23,901 females. Carrying capacity (K) was estimated following Mangel (2006) and solving for K using the differential equation:

$$\frac{dN}{dt} = rN(1 - \frac{N}{K})$$

where r is the intrinsic rate of increase and N is the initial population size.

Scenarios were developed based on differences in age at maturity (see previous) and based on a combination of the average current fishing mortality for the southeast shrimp trawl fishery from 2019-2022 based model-based estimates from Babcock and Peterson (2024; see previous) (Table 2). As there is no information on the sex ratio or age of captured animals, it was assumed that females were equally captured at a rate of 1:1 to males and all ages of manta rays were subjected to fishing mortality.

Results and Discussion

Under the revised levels of giant manta ray bycatch for the commercial shrimp trawl fishery, in all scenarios the population of giant manta decreased 10% to 29% over 20 years (Figure 1; Table 3). From the initial population size of ~23,000 females estimated by Farmer (unpublished), the population was reduced to a low ~17,000 females. However, there was a high level of uncertainty associated with the ending population size (Figure 2).

The results presented herein are preliminary. There is still a high degree of uncertainty in life history and population size for giant manta ray in the northwest Atlantic, as well as the estimated level of take from observer data from the shrimp trawl fishery. There is a paucity of life history information for giant manta ray and in many cases information on fecundity, age at maturity, and longevity is based on information from animals in aquariums, sightings data, or inferred from conspecifics (Dulvy et al. 2014; Marshall et al. 2020). Indeed, in some life history scenarios when estimating the maximum rate of population increase (R_{max}), if survivorship was not assumed to be greater then 95%, the population would go extinct in the absence of any fishing mortality (Carlson and Cortes, unpublished). This combined with the high level of uncertainty in shrimp trawl bycatch (i.e., 155.4-527.2 animals in the Gulf of Mexico, and 68-598 animals in the South Atlantic) suggests results should be interpreted with caution. Further studies on giant manta ray life history are required as well as improved estimates of bycatch through increased observer coverage and improved estimates of shrimp total effort.

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Table 1. Female life history and baseline parameters used in development of giant manta population viability model.

Parameter	Value	Source
Age-at-maturity:	8-12 years	Marshall et al. (2020) Rambahiniarison et al. (2018)
Maximum age:	45 years	Marshall et al. (2020)
Litter size:	0.5 females per year (±0.2 st. dev.)	White et al. (2006) Rambahiniarison et al. (2018)
Reproductive periodicity	4 years	Marshall et al. (2020)
Survivorship:	0.9636 per year	Pardo et al (2016)
Initial female population size:	23,901 (UCL 80,902; LCL 4,103)	Farmer (unpublished)
Carrying capacity:	39,162 (±14,693 st. dev.)	Carlson (2023)

Table 2. Summary of scenarios for giant manta ray population viability analysis.

Scenario	Initial population size (females)	Age at maturity (yrs)	Average removals for the southeast Atlantic based on Babcock and Peterson (2024)	Average removals for the southeast Atlantic based on Babcock and Peterson (2024)	Average removals for NW Atlantic	Average removals of female giant manta for NW Atlantic
1	23,901	8	361.5	405.1	766.6	383.3
2	23,901	9	361.5	405.1	766.6	383.3
3	23,901	10	361.5	405.1	766.6	383.3
4	23,901	11	361.5	405.1	766.6	383.3
5	23,901	12	361.5	405.1	766.6	383.3

Table 3. Ending population sizes for all scenarios including the proportional change from initial abundance.

Scenario	Ending Population Size (females)	Standard deviation (±)	Mean proportional change
1	20,892	16,531	-0.13
2	21,570	13,382	-0.10
3	19,861	14,786	-0.17
4	18,877	12,712	-0.21
5	17,025	12,224	-0.29

Figure 1. Projections of the manta ray population exploring the current authorized take. Blue circles=the mean abundance at time t for scenario 1, red circles =scenario 2, green circles =scenario 3, yellow circles = scenario 4 and black circles =scenarios 5. Solid lines represent the ±1 standard deviation of the population mean at time t with the colors corresponding to the mean abundance symbols.

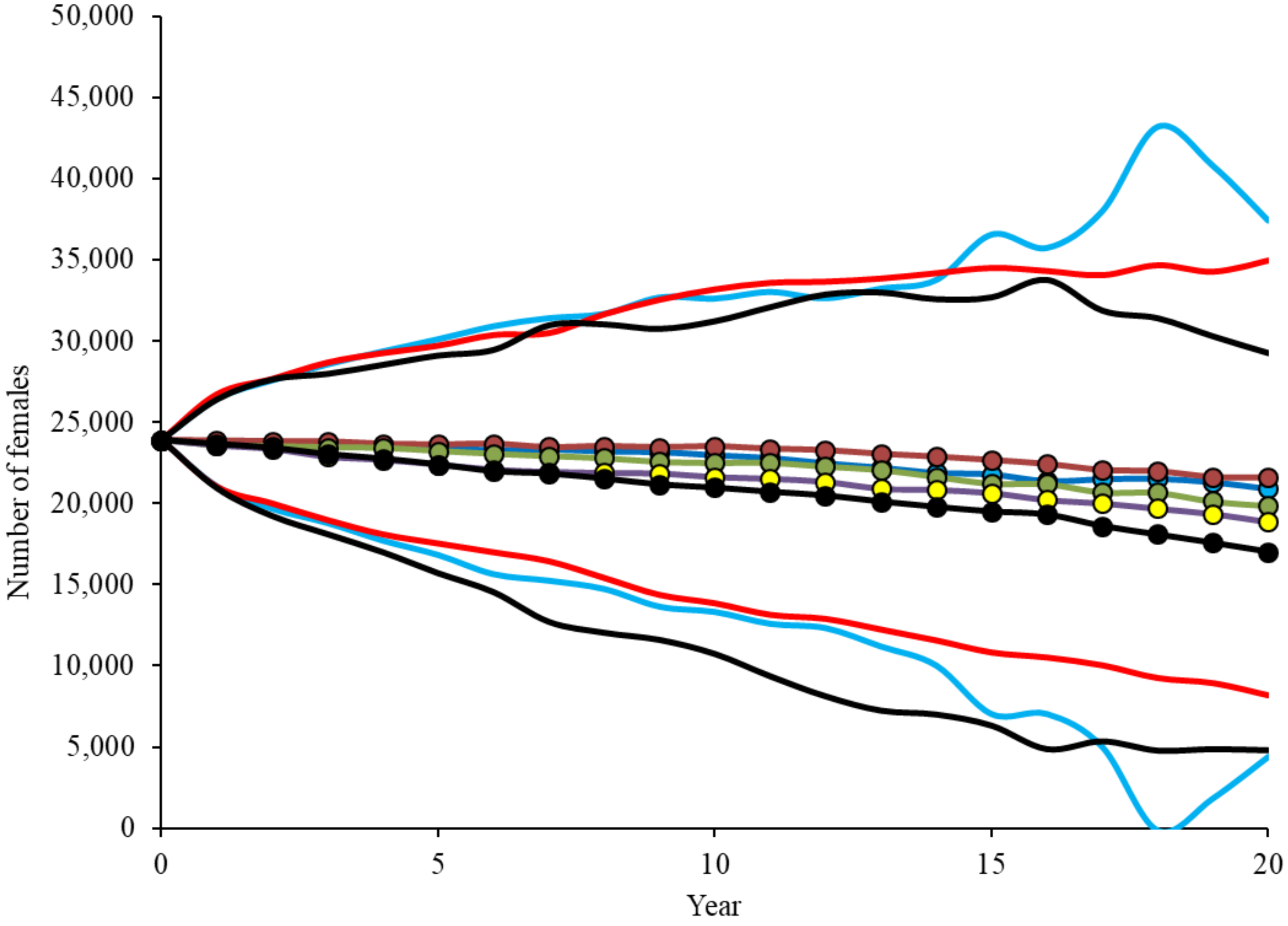

Figure 2. Change in abundance (number of females) from initial population size (solid bar) to ending population size (open bar). Error bars are ±1 standard deviation.