Informing Gulf Sturgeon Population Status and Trends as a Baseline to Evaluate Restoration Deepwater Horizon Project ID 203

Executive Summary Report

September 2024

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Project Highlights and Outcomes

"*Informing Gulf Sturgeon Population Status and Trends as a Baseline to Evaluate Restoration*" ("Gulf sturgeon status and trends") was a Deepwater Horizon Natural Resource Damage Assessment Open Ocean Trustee Implementation Group Monitoring and Adaptive Management Activity intended to support evaluation of regional restoration outcomes within the Open Ocean Restoration Area; perform data aggregation and data management; resolve critical information gaps and uncertainties for restoration planning and informing restoration decision-making; and perform monitoring to inform the design and implementation of future restoration projects. The approved project budget was $910,000 for implementation, with a goal of assessing Gulf sturgeon stock status and population viability to inform restoration priorities and develop a standardized data collection and storage program to evaluate Gulf sturgeon population responses to restoration actions. The project team successfully completed all components, and the major findings are listed below.

- Reviewed and compiled available Gulf sturgeon capture-recapture information (several million contacts) and developed a unified database to establish a baseline for river, region, and Gulf-wide populations to evaluate restoration.
- Developed and implemented a standardized data collection and storage program for Gulf sturgeon using electronic logbooks.
- Used available tagging and life-history data to build a series of age-structured mark-recapture models to estimate Gulf sturgeon survival for each river system and potential management unit in the Gulf of Mexico. These models were also used to evaluate the overall rate of population change for different rivers and management units of interest.
- Developed an individual-based population viability analysis (PVA) model (females only) to evaluate "what-if" scenarios (e.g., high baseline mortality, frequent mortality events) related to the viability of Gulf sturgeon populations. This information provides a better understanding of extinction risk for each of the seven Gulf sturgeon populations under a variety of scenarios.
- Identified priority river populations and restoration actions based on modeling results: estimated mortality; population change; and extirpation risk.

Introduction

On or about April 20, 2010, the mobile offshore drilling unit *Deepwater Horizon,* which was being used to drill a well for BP Exploration and Production, Inc. (BP) in the Macondo prospect (Mississippi Canyon 252 – MC252), exploded, leading to a fire and its subsequent sinking in the Gulf of Mexico (GoM). This incident resulted in discharges of oil and other substances into the GoM from the rig and the submerged wellhead, and resulting response actions, affecting multiple natural resources, which provide a number of important ecological and human use services.

In the Deepwater Horizon (DWH) Oil Spill Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement (PDARP/PEIS;

DWH NRDA Trustees, 2016a), the Trustees selected a comprehensive, integrated ecosystem approach to restoration in the Gulf of Mexico. The restoration portfolio allocates up to $8.8 billion (including funds already spent for Early Restoration) paid out over fifteen years for natural resources restoration across the five Gulf States and the open ocean. One of the programmatic goals established in the PDARP/PEIS is to "Provide for Monitoring, Adaptive Management, and Administrative Oversight to Support Restoration Implementation" to ensure that the portfolio of restoration projects provides long-term benefits to natural resources and services injured by the spill (Appendix 5.E of the PDARP/PEIS). In May 2019, the Open Ocean Trustee Implementation Group (OO TIG) released the Open Ocean TIG MAM Strategy (see http://www.gulfspillrestoration.noaa.gov), which describes the TIG's approach to MAM, responsibilities, and goals for the use of the Open Ocean Restoration Area MAM allocation. The "*Informing Gulf Sturgeon Population Status and Trends as a Baseline to Evaluate Restoration*" ("Population Status and Trends") was a Monitoring and Adaptive Management Activity approved by the OO TIG in 2019 according to the process identified in their MAM Strategy.

The Gulf sturgeon (*Acipenser oxyrinchus desotoi*) is a fish that inhabits coastal and estuarine waters in the northern Gulf of Mexico and rivers from the Pearl River in Louisiana/Mississippi to the Suwannee River in Florida. After spending the first 2 to 3 years in the river in which it hatched, Gulf sturgeon becomes anadromous, spending fall and winter in the Gulf of Mexico and spring and summer in the rivers where it spawns. The Gulf sturgeon is listed as threatened under the federal Endangered Species Act (56 Federal Register [FR] 49653), and critical habitat has been designated (68 FR 13370). The focused assessment of potential injuries to Gulf sturgeon conducted by the DWH Trustees found that between 1,100 and 3,600 Gulf sturgeon were potentially exposed to DWH oil in the nearshore areas of the northern Gulf of Mexico. Although a direct kill of Gulf sturgeon from the oil was not observed, the Trustees found evidence of physiological injury, including exposure biomarkers for DNA damage and immunosuppression, to exposed Gulf sturgeon compared with Gulf sturgeon that were not exposed to the oil. Considering the protected status of Gulf sturgeon, the DWH Trustees decided to focus restoration on approaches that are consistent with those identified in the federal Gulf Sturgeon Recovery Plan (USFWS & GSMFC 1995). Therefore, the restoration approaches identified in the PDARP/PEIS emphasize spawning habitat and reproductive success.

It is necessary to organize Gulf sturgeon monitoring data in order to effectively estimate the status of the overall population and individual river populations. Further, as additional monitoring data is collected it must also be organized in a format that is compatible with past monitoring data. Thus, the early objectives of this project were to collate all available Gulf sturgeon capture-recapture data (1976-2022) in one database and develop a standardized method for collection and entry of capture-recapture data. With that accomplished, four metrics estimating status and trends of Gulf sturgeon by river population and overall population were estimated: 1) survival (2010-2022); 2) survival over a loner period (1990-2022); 3) population growth (1990-2022); and 4) population viability into the future. These metrics were then used by managers to identify priority river populations and restoration actions.

Contents of this Report

The following report provides a summary of the major components of this project. The discussion below provides a summary of field work conducted during 2021, 2022 and 2023 (under two other related DWH MAM and Sturgeon activities - Portal IDs 182 and 206) and a summary discussion of the Gulf sturgeon observed. For more detailed project information visit this project's page on the Gulf Spill Restoration website: https://www.gulfspillrestoration.noaa.gov/project?id=203. Here you will find the Pine 2024 'Summary of Project Results' document detailing:

1. Gulf Sturgeon Database Development and Standardized Data Collection
2. Survival Estimation Models and Transition Probabilities
3. Population trends- Lambda Pradel Estimation and Population Viability Analysis

Gulf Sturgeon Database

It was necessary to organize Gulf sturgeon capture-recapture into one database prior to initiation of all subsequent components of this project (e.g., collection of new Gulf sturgeon monitoring data, data analysis). This entailed building off of past Gulf sturgeon data archiving and database efforts to organize all physical and virtual capture-recapture information from both electronic and paper sheet formats into one MS Access database.

A standardized data collection and import process was developed and implemented early in the first year of Gulf sturgeon fieldwork (2020) to minimize data recording error and allow rapid sharing of data among multiple scientists Gulf-wide. This included development of a standardized datasheet for recording and importing capture-recapture data of Gulf sturgeon to the Gulf sturgeon database (database), and development of a process for importing tag detection data from automated acoustic receivers to the database. Additionally, a subset of scientists used an electronic tablet for recording data in the field to the cloud; these tablets were ultimately adopted by all partners in the projects allowing for near real-time import of standardized data to the database.

Survival Estimation and Transition Probabilities

Active acoustic tags have been implanted in adult Gulf sturgeon ($\geq$1350 mm total length [TL]) and detected by automated acoustic hydrophones (receivers) in Gulf rivers since approximately 2010. This is the most consistent Gulf sturgeon capture-recapture data available and was used in a multistate model to estimate adult Gulf sturgeon survival by river population from 2010-2021. Survival of adult Gulf sturgeon over a longer time period (1990-2021) was also estimated by river population with a Barker model which involved capture-recapture records of Gulf sturgeon tagged with passive integrated transponders (PIT tags) since 1990 along with information from the acoustic tags and receivers described above. Transition probabilities between river systems, or likelihood of an adult sturgeon tagged in riverine habitat to be detected in a different river, were also estimated using information from acoustic tags and receivers described above.

Population Trends and Population Viability Analysis

The capture-recapture data described above was also used in a Lambda Pradel estimation of the rate of population change for adult Gulf sturgeon by river population over three decades, and the relative contributions of adult survival and recruitment (number of new adults per adult entering the population per year) on these population trends. This information helped inform the PVA which estimated the probability of river population extirpation under the mortality scenarios listed in Table 1, below.

Conclusions

This project successfully met all of its objectives. Gulf sturgeon capture-recapture information was collected in a unified database and a standardized data collection and storage program for Gulf sturgeon was implemented using electronic logbooks. Available tagging and life-history data was used to estimate Gulf sturgeon survival for each river system and also used to evaluate the overall rate of population change for different rivers. Finally, an individual-based PVA model was to evaluate the viability and extirpation risk of Gulf sturgeon populations.

The complete database included capture-recapture information on almost 22,000 individual Gulf sturgeon and several million capture-recapture records from 1976 to 2022. The database was used in all components of this study, and multiple other analyses funded by DWH NRDA and other sources. Results from the multi-state survival models indicated the lowest survival in the Pearl River adult Gulf sturgeon population and the western region (Pearl and Pascagoula river) populations from 2010-2021 (Table 2). Lowest adult Gulf sturgeon survival was also estimated in the Pearl River and Pascagoula River, respectively, in the Barker model over a longer time period from 1990-2021 (Table 3). Analysis of transition probabilities of adult Gulf sturgeon showed extreme western (Pearl River) and eastern (Suwannee River) populations were only present in riverine habitat in their presumed natal rivers and adjacent rivers (Table 4). Conversely, adult Gulf sturgeon tagged in the Pascagoula River were the only non-Pearl River origin detected in the Pearl River (Table 4).

Results of the population trends analysis suggested positive population growth (λ) in most Gulf sturgeon river populations ($\lambda > 1$) and time periods (5-year intervals) from 1990-2021 (Table 5). In the most recent time period, the Pearl and Pascagoula populations had positive population growth while three river populations (Escambia, Apalachicola, and Suwannee) had negative population growth (λ values < 1) i(Table 5). This recent positive population growth in the western region is somewhat divergent from the low estimated adult survival in the region. Pine (2024), however, noted that recent trend data may be difficult to interpret due to current sampling efforts focused on juvenile Gulf sturgeon. This shift in sampling likely resulted in lower numbers of adult captures and recaptures (especially in rivers with historically intensive adult sampling) and potentially decreased recent estimates of adult relative abundance and population growth in larger river populations. Results of the Gulf sturgeon PVA were more consistent with survival estimates and general assumptions on the species' biology; scenarios involving smaller river populations with low estimated survival and low adult female populations

(Scenario No. 9 in Tables 1 and 6) had some probability (11.3%) of extirpation within 50 years (Table 6). Furthermore, scenarios involving low adult female populations with frequent episodic mortality events (Scenario No. 21 in Tables 1 and 6) also had some probability (11.8%) of extirpation within 50 years (Table 6).

Recommendations

The results of Gulf sturgeon status and trends report were used to complete the final component of this project which was to identify priority Gulf sturgeon river populations and restoration actions. The Pearl River population had consistently high adult mortality in multiple models. This is true to a lesser degree for the Pascagoula River population. The Pearl River population also appeared to be the most isolated population in the transition analyses with only adults from the Pascagoula River detected in low numbers in potential Pearl River spawning habitats.

Results of recent population trends information is less clear. Negative population growth in seemingly healthy populations (i.e., Suwannee River) may have been influenced by changes in sampling methods over time. The PVA indicated extirpation risk in river populations with low adult female abundance and high baseline or episodic mortality, which could involve populations in the western region where sturgeon populations are less abundant, or populations that experience more frequent or intense episodic mortality events (e.g., Apalachicola River and the 2018 Hurricane Michael mortality). Notably, estimated baseline annual adult mortality rates on the Pearl River (0.19; Table 2) were well in excess of the highest mortality scenario in the PVA (0.15; Table 1).

From both the results of the PVA and observations of consistent juvenile recruitment across all populations and seemingly high production of juveniles in the Pearl River, it does not appear that juvenile recruitment is a limiting factor for Gulf sturgeon. Conversely, all the components of the Gulf sturgeon status and trends analysis indicate high adult baseline mortality and potentially high frequency of episodic mortality as a major factor influencing Gulf sturgeon population dynamics. Thus, areas occupied by the western region populations that have the highest baseline mortality, or populations that have experienced documented episodic mortality events should be the focus of restoration actions. Actions that reduce adult mortality (e.g., improvements to water quality and quantity in holding habitats during summers and fall months) or improve recruitment of subadults to the adult population (e.g., ameliorating point sources of pollution and spills in estuarine habitats) should be the priority based on these results. Outside of restoration, conservation of natural riparian and estuarine habitats will accomplish some of the water quality recommendations described above. Further, reducing interactions between humans and sturgeon in commercial (e.g., bycatch, ship strikes) and potentially a research context could also be relevant as management actions that reduce adult and subadult mortality.

New developments in Gulf sturgeon research and timing and feasibility of restoration actions should also be considered in prioritizing actions. River populations outside of the western region could also be candidates for restoration actions; relatively high mortality was estimated in one analysis in the Yellow, Escambia, and Apalachicola rivers. Furthermore, abundance of the river populations in all rivers (notably adult female abundance) is not known and a presumably stable population may be vulnerable to extirpation if it is determined that there are few females. Efforts should be made to generate the adult female abundance metric for the PVA by estimating ratios of female to male sturgeon in river habitats with genetic samples, and applying these ratios to abundance estimates to continue identification of future restoration projects.

Tables

Table 1. Modified from Pine 2024. A summary of the various mortality scenarios evaluated using population viability analysis simulations including the average frequency of occurrence for episodic events. The mortality rate is applied with this frequency on average.

Scenario No.	Threat Definition	Adult Mortality	Vulnerable Abundance	Mean Freq.
1	Chronic mortality – baseline conditions	0.11	100	–
2	Chronic mortality – baseline conditions	0.11	500	–
3	Chronic mortality – baseline conditions	0.11	1,000	–
4	Chronic mortality – baseline conditions	0.11	10,000	–
5	Chronic mortality – creeping baseline	0.13	100	–
6	Chronic mortality – creeping baseline	0.13	500	–
7	Chronic mortality – creeping baseline	0.13	1,000	–
8	Chronic mortality – creeping baseline	0.13	10,000	–
9	Chronic mortality – creeping baseline	0.15	100	–
10	Chronic mortality – creeping baseline	0.15	500	–
11	Chronic mortality – creeping baseline	0.15	1,000	–
12	Chronic mortality – creeping baseline	0.15	10,000	–
13	Additional 35% episodic mortality	0.11	100	1/50 years
14	Additional 35% episodic mortality	0.11	500	1/50 years
15	Additional 35% episodic mortality	0.11	1,000	1/50 years
16	Additional 35% episodic mortality	0.11	10,000	1/50 years
17	Additional 35% episodic mortality	0.11	100	1/25 years
18	Additional 35% episodic mortality	0.11	500	1/25 years
19	Additional 35% episodic mortality	0.11	1,000	1/25 years
20	Additional 35% episodic mortality	0.11	10,000	1/25 years
21	Additional 35% episodic mortality	0.11	100	1/10 years
22	Additional 35% episodic mortality	0.11	500	1/10 years
23	Additional 35% episodic mortality	0.11	1,000	1/10 years
24	Additional 35% episodic mortality	0.11	10,000	1/10 years
25	Recruitment failure	0.11	100	1/10 years
26	Recruitment failure	0.11	500	1/10 years
27	Recruitment failure	0.11	1,000	1/10 years
28	Recruitment failure	0.11	10,000	1/10 years
29	Recruitment failure	0.11	100	1/5 years
30	Recruitment failure	0.11	500	1/5 years
31	Recruitment failure	0.11	1,000	1/5 years
32	Recruitment failure	0.11	10,000	1/5 years

Table 2. Modified from Pine 2024. Survival probabilities for adult Gulf sturgeon (≥1350-mm TL) with upper (UCL) and lower (LCL) 95% confidence limits from Models 1–4.

Model number	Area or time	Estimate	LCL	UCL
	Range-wide			
1	Constant	0.89	0.88	0.9
	Region			
2	West	0.83	0.79	0.87
2	Pensacola Bay	0.87	0.84	0.89
2	Choctawhatchee	0.93	0.91	0.94
2	East	0.88	0.86	0.9
	River			
3	Pearl	0.71	0.61	0.79
3	Pascagoula	0.87	0.83	0.9
3	Escambia	0.86	0.82	0.9
3	Yellow	0.87	0.84	0.9
3	Choctawhatchee	0.93	0.91	0.94
3	Apalachicola	0.86	0.82	0.89
3	Suwannee	0.89	0.87	0.92
	Year			
4	2010	0.91	0.85	0.95
4	2011	0.92	0.88	0.95
4	2012	0.89	0.85	0.92
4	2013	0.76	0.71	0.8
4	2014	0.89	0.84	0.92
4	2015	0.72	0.66	0.78
4	2016	0.76	0.7	0.81
4	2017	0.95	0.91	0.98
4	2018	0.93	0.89	0.95
4	2019	0.97	0.94	0.98
4	2020	0.96	0.93	0.98
4	2021	0.97	0.93	0.98

Table 3. Modified from Pine 2024. Gulf sturgeon survival estimates, standard errors (SE) and associated 95% confidence intervals (lower confidence limits [LCL] and upper confidence limits [UCL] from a Barker model (Model 3) estimating river-specific survival (S), river-specific PIT tag capture probability (p), and a constant rate of acoustic tag detection (R). Specific parameter definitions can be found in Table 3.2 of Pine 2024.

Parameter	River	Estimate	SE	LCL	UCL
S	Pearl	0.77	0.03	0.71	0.82
S	Pascagoula	0.87	0.01	0.84	0.89
S	Escambia	0.9	0.01	0.87	0.92
S	Yellow	0.91	0.01	0.9	0.93
S	Choctawhatchee	0.93	0.01	0.92	0.94
S	Apalachicola	0.9	0.01	0.88	0.92
S	Suwannee	0.9	0.01	0.89	0.91
p	Pearl	0.09	0.02	0.06	0.13
p	Pascagoula	0.07	0.01	0.05	0.09
p	Escambia	0.05	0.01	0.04	0.06
p	Yellow	0.05	<0.01	0.05	0.06
p	Choctawhatchee	0.03	<0.01	0.03	0.04
p	Apalachicola	0.05	<0.01	0.04	0.06
p	Suwannee	0.03	<0.01	0.02	0.03
R	Pearl	0.86	0.04	0.78	0.92
R	Pascagoula	0.97	0.01	0.94	0.98
R	Escambia	0.81	0.02	0.77	0.85
R	Yellow	0.65	0.02	0.62	0.68
R	Choctawhatchee	0.79	0.01	0.77	0.81
R	Apalachicola	0.82	0.02	0.78	0.86
R	Suwannee	0.89	0.01	0.86	0.91
R'	Constant	0	<0.01	0	0
r	Constant	0	<0.01	0	0
F	Fixed	1	–	–	–
F'	Fixed	0	–	–	–

Table 4. Modified from Pine 2024. Transition probabilities of adult Gulf sturgeon (≥1350-mm TL) movement between rivers with 95% confidence intervals (CI) in parentheses. Columns indicate the river occupied in a given sampling occasion, and rows denote possible destinations in the following sampling occasion. Estimates along the diagonal represent river fidelity rates. An "×" represents an unobserved transition during the study.

	Pearl	Pascagoula	Escambia	Yellow	Choctawhatchee	Apalachicola	Suwannee
Pearl	0.89 (0.81, 0.96)	0.02 (0.01, 0.05)	×	×	×	×	×
Pascagoula	0.11 (0.06, 0.21)	0.95 (0.93, 0.98)	0.01 (0.00, 0.03)	0.01 (0.00, 0.02)	0 (0.00, 0.01)	×	×
Escambia	×	0.02 (0.01, 0.04)	0.63 (0.57, 0.69)	0.11 (0.09, 0.13)	0.03 (0.02, 0.04)	0.01 (0.00, 0.02)	×
Yellow	×	0 (0.00, 0.03)	0.24 (0.19, 0.30)	0.8 (0.77, 0.83)	0.05 (0.03, 0.06)	0.01 (0.01, 0.04)	0 (0.00, 0.01)
Choctawhatchee	×	0 (0.00, 0.03)	0.1 (0.07, 0.14)	0.08 (0.06, 0.11)	0.91 (0.89, 0.93)	0.03 (0.02, 0.05)	×
Apalachicola	×	×	0.01 (0.00, 0.04)	0 (0.00, 0.01)	0.01 (0.01, 0.02)	0.93 (0.91, 0.96)	0.01 (0.00, 0.02)
Suwannee	×	×	×	×	×	0.02 (0.01, 0.04)	0.99 (0.98, 1.00)

Table 5. Modified from Pine 2024. Population growth estimates from the top ranked temporal symmetry model by river system and time period. Confidence intervals (95% CI) are provided in parentheses next to each estimate. Values above 1.0 indicate positive population growth and values below 1.0 indicate negative population growth.

River	Parameter	**1990–1994**	**1995–1999**	**2000–2004**	**2005–2009**	**2010–2014**	**2015–2021**
Range-wide	Population growth (λ)	0.97 (0.97–0.97)	1.36 (1.34–1.39)	0.93 (0.91–0.94)	1.10 (1.08–1.12)	1.00 (0.99–1.02)	1.04 (1.03–1.06)
Pearl	Population growth (λ)	–	–	1.10 (0.99–1.21)	1.30 (1.19–1.41)	0.82 (0.82–0.82)	1.19 (1.11–1.28)
Pascagoula	Population growth (λ)	–	2.34 (2.02–2.71)	0.71 (0.71–0.71)	0.53 (0.46–0.60)	2.16 (1.87–2.51)	1.20 (1.11–1.30)
Escambia	Population growth (λ)	–	–	1.29 (1.21–1.37)	0.99 (0.99–0.99)	1.14 (1.09–1.19)	0.90 (0.86–0.94)
Yellow	Population growth (λ)	–	2.47 (1.94–3.14)	0.99 (0.94–1.04)	1.18 (1.14–1.23)	0.95 (0.92–0.99)	1.19 (1.15–1.23)
Choctawhatchee	Population growth (λ)	–	1.70 (1.60–1.80)	0.86 (0.86–0.86)	1.14 (1.12–1.17)	0.95 (0.95–0.95)	1.20 (1.17–1.23)
Apalachicola	Population growth (λ)	1.23 (1.06–1.42)	1.51 (1.39–1.66)	1.17 (1.11–1.24)	1.02 (0.98–1.07)	1.10 (1.05–1.15)	0.94 (0.91–0.97)
Suwannee	Population growth (λ)	0.99 (0.99–0.99)	1.28 (1.25–1.31)	0.97 (0.94–1.00)	1.04 (1.00–1.08)	1.20 (1.16–1.25)	0.94 (0.91–0.97)

Table 6. Modified from Pine 2024. Extirpation probabilities associated with 50-year, 100-year, and 200-year time horizons for all 32 simulated population viability scenarios. Scenario No. is defined in Table 1.

Table 6. Modified from Pine 2024. Extirpation probabilities associated with 50-year, 100-year, and 200-year time horizons for all 32 simulated population viability scenarios.

Scenario No.	50-year Probability	100-year Probability	200-year Probability
1	0%	0%	0.50%
2	0%	0%	0%
3	0%	0%	0%
4	0%	0%	0%
5	0.10%	18.50%	90.50%
6	0%	0%	58.20%
7	0%	0%	46.20%
8	0%	0%	27.40%
9	11.30%	90.80%	100%
10	0%	47.20%	100%
11	0%	26.20%	100%
12	0%	3.80%	99.60%
13	0.10%	1.30%	15.90%
14	0%	0%	0.60%
15	0%	0%	0.30%
16	0%	0%	0%
17	0%	9%	64.10%
18	0%	0.10%	20.40%
19	0%	0%	14.10%
20	0%	0%	6.40%
21	11.80%	78.90%	100%
22	0.50%	38.50%	99.90%
23	0%	25.70%	99.70%
24	0%	5.30%	99.10%
25	0%	0.30%	10.20%
26	0%	0%	0.10%
27	0%	0%	0.10%
28	0%	0%	0%
29	0%	4.40%	64.60%
30	0%	0%	21.20%
31	0%	0%	13.90%
32	0%	0%	5.30%