the Shellcracker

FLORIDA CHAPTER OF THE AMERICAN FISHERIES SOCIETY ***http://www.sdafs.org/flafs***

July, 2009

President's Message:

"Summer Update"

I hope this issue of the summer newsletter finds all our chapter members well and either enjoying summer field work or some well deserved summer holidays. I will take this opportunity to update everyone on our chapter's activities since our annual chapter meeting.

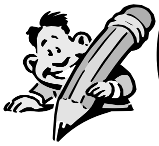
First, a request was issued by the Tennessee Chapter for financial support of the AFS annual meeting this year. Funding levels ranged from the "Smallmouth Bass" level of $15K to a "Crappie" level of $500 (their wording, not ours!). On behalf of the executive committee, I am pleased to report that our chapter provided a "Double-Crappie" donation based on a $500 donation from the chapter itself and a further $500 donation on behalf of our Florida Student Subchapter. Our chapter is student-strong, and it is important that we support our student subchapter unit in both funding when possible, and by also elevating their profile within the Southern Division. Hopefully this will encourage other chapters and their student subunits to also contribute to supporting the meeting.

Our "Local Arrangements Committee" has also been very busy lately getting information on potential venues for a future Southern Division Meeting, which we agreed to host in 2011. Many thanks to Eric Nagid (Chair), Kevin Johnson, Dennis Renfro, David Kerstetter, and John Galvez for spending a considerable amount of time in bringing the executive committee all the information needed to make a decision. Based on their footwork, it appears that Tampa will be the best choice of location, and the committee will be in negotiations with a couple of local hotels to get the best deal for all of us at the meeting. Remember, when we host the 2011 meeting we will not be holding our chapter meeting, so plan on attending the Southern Division meeting in 2011. We will also need many volunteers to work at the meeting, so please keep it on your sonar!

The AFS annual meeting themed "*Diversity, the foundation of fisheries and the American Fisheries Society; are we gaining ground?"* in Nashville is also just around the corner during 30 August – 3 September. It's not too late to make plans to attend. For those able to go this year, please feel free to send in tidbits of information about the annual meeting to Kevin for posting in the next newsletter.

The next newsletter in the fall will have more information on the timing of our next chapter meeting in the spring of 2010….we can all start planning early and set aside that date! As always, if you have any issues or concerns that you would like to be addressed by our chapter, please let me know.

Cheers, Deb Murie
FL Chapter President



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Upcoming Events

July 20 – 24: 6th International Fisheries Observer and Monitoring Conference. Portland, Maine. www.IFOMC.com

August 24 – 28: Fourth International Symposium on Fish Otolith Research and Application. Monterey, California.

August 30 – Sept. 3: American Fisheries Society 139th Annual Meeting. Nashville, Tennessee. www.fisheries.org/afs09

September 21 – 25: ICES 97th Annual Science Conference. Berlin, Germany.

Check out our Parent Society's calendar at http://www.fisheries.org/afs/calendar.html for other events not listed here!

New Titles

Eels at the Edge: Science, Status, and Conservation Concerns. John M. Casselman and David K. Cairns, editors. 449 pages, Symposium 58. Published by the American Fisheries Society. May 2009.

Interested in contributing something to the Shellcracker? Email Kevin Johnson at *kevin.johnson@myfwc.com* with any articles or information that you would like to be included in the next issue. The deadline for the next issue is September 30th, 2009, so start fishing...

Feature Article

Post-Stocking Mortality and Diet Composition of Hatchery Produced Advanced-Fingerling Largemouth Bass Stocked into Lake Seminole, Pinellas County, Florida

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Introduction

Supplemental stocking of largemouth bass *Micropterus salmoides* fingerlings with the intention of augmenting natural recruitment is a popular management tool (Boxrucker 1986). The size of fish at the time of stocking can affect the success of a supplemental stocking program (Olsen et al. 2000; Porak et al. 2002; Calvin et al. 2008; Mesing et al. 2008). Stocking advanced size largemouth bass (> 80 mm TL) may increase percent contribution (Mesing et al. 2008) and survival (Buynak and Mitchell 1999), and it is suggested that larger fish have greater prey availability and are less vulnerable to predation than smaller fish (Loska 1982; Wahl et al. 1995). Thus, the Florida Fish and Wildlife Conservation Commission (FWC) recently retooled their freshwater fisheries hatchery at Richloam, Florida to focus on the production of advanced-fingerling Florida largemouth bass *Micropterus salmoides floridanus*. Results from previous stockings in Florida using advanced size largemouth bass have been inconsistent yielding varying degrees of success (Porak et al. 2002; Mesing et al. 2008). Factors potentially affecting mortality of stocked largemouth bass included handling and stocking stressors, elevated water temperatures (> 25 ^{0}C) at time of stocking, vitamin C deficiencies and liver disease from being pellet reared, difficulty transitioning to natural prey, and angling mortality (Porak and Bonvechio 2007). FWC fisheries biologists have been challenged with developing an effective stocking program utilizing advanced-fingerling largemouth bass.

Hatchery-reared fish stocked in the wild must go through a critical period where the highest rate of mortality occurs (Diana 1995), which is generally directly following release (Brown and Laland 2001). These fish must develop feeding and anti-predator behaviors that are often not learned in the hatchery (Heggberget et al. 1992). Additional challenges occur when piscivorous fish species reared on pellet feed have to transition to natural prey (Larscheid et al. 1999; Olson et al. 2000; Porak et al. 2002). Reduced feeding may result in stress, which can lead to mortality via starvation or predation.

We investigated the success of supplemental stocking of pellet reared advanced-fingerling largemouth bass in a hypereutrophic system, which has historically displayed poor largemouth bass recruitment. The objective of the study was to compare survival and diet composition of stocked and wild age-0 largemouth bass within the first 90 days post-stocking (critical period). Results of this study may be used by hatchery managers to potentially increase the survival of pellet-reared hatchery fish in the wild.

Methods

Study Site and Stocking

Lake Seminole is a 289 ha hypereutrophic reservoir located in Pinellas County, Florida. The lake has had historic largemouth bass recruitment problems with low densities (11 largemouth bass/ha; Champeau et al. 2008). However, the lake supports an adequate forage base to support a much higher density of juvenile largemouth bass (Champeau et al. 2008).

Advanced-fingerling largemouth bass for this study were raised at the FWC Largemouth Bass Conservation Center at Richloam Hatchery. Brood fish were spawned in February 2008. The fry were placed in fertilized earthen ponds for 30 days and then returned to raceways where they were fed pellet feed. One week prior to stocking fish were transitioned from pellet feed to live prey (eastern mosquito fish *Gambusia Holbrooki*).

The lake was stocked on 28 May 2008 with 18,263 coded wire tagged (CWT) advanced-fingerling largemouth bass (50-96 mm TL; mean = 80 mm TL). All stocked fish were dispersed randomly along 3,000 meters of vegetated shoreline. A random sample of 60 stocked largemouth bass were placed into two cylindrical 1.83 m diameter by 1.22 m deep cages within the stocking zone to estimate stocking mortality. Cages were checked for moribund fish and water quality variables (temperature and dissolved oxygen) were measured at 24, 48, and 72 h post-stocking.

Mortality and Diets

To evaluate mortality and diets of stocked and wild age-0 largemouth bass the lake was divided into 12-750m transects and electrofishing was conducted at 7, 14, 30, 60, and 90 days post-stocking. For each sampling event, nine transects were sampled (6 fixed sites and three randomly selected sites) for 15 min of electrofishing pedal time. All largemouth bass collected were measured (mm TL), weighed (g) and checked for coded wire tags. A representative sample of stocked largemouth bass (N=35) were sacrificed for diet analysis, and if 35 fish were not collected the total number collected were sacrificed. We also sacrificed five wild largemouth bass per cm group ≤ 20 cm TL; otoliths were removed to differentiate age-0 and age-1 wild fish and stomachs were removed to determine diet composition.

Analysis

We constructed catch curves to estimate instantaneous mortality (Z) and total mortality ($A=1-e^{-(Z*90d)}$) of stocked and wild age-0 largemouth bass (Timmons et al. 1980). We used the percent occurrence of common prey categories (empty, fish, and invertebrates) to compare the diet composition of stocked and wild age-0 largemouth bass. Percent similarity index (PSI) was used to compare percent occurrence of diet items between stocked and wild age-0 largemouth bass at each sampling event (Krebs 1999). A z-test was used to compare the proportion of diets by prey category between stocked and wild age-0 bass. Significance was set at $P < 0.05$.

Results and Discussion

Mean stocking mortality (72 hour evaluation) was 20% ± 11%. At the time of stocking water temperature was 31.6º C which may have led to the high rate of stocking mortality during the initial 72 hours. Porak and Bonvechio (2007) suggest that stocking should be done when water temperatures are < 25º C to reduce stocking stress which can lead to mortality.

Mortality 90 days post-stocking for stocked fish was 88.5% compared to 45.4% for wild age-0 largemouth bass (Figure 1). When evaluating the slopes of the catch curve the highest rate of mortality for stock largemouth bass occurred in the first 30 days post-stocking and reaches a plateau at 60 to 90 days post-stocking. The cause for the high rates of initial mortality is difficult to determine but can likely be attributed to lack of habitat, predation, competition and foraging efficiency. Schlechte et al. (2005) suggested that the likely source of initial mortality for stocked fingerling (30-64 mm TL) largemouth bass was predation; however, other researchers have suggested that stocking larger fish should decrease mortality via predation (Loska 1982). The transition from pellet feed to natural prey items may have been difficult, which could have led to the high rate of initial mortality in stocked largemouth bass. Percent similarity index results indicated that at 7 days post-stocking diets were much more dissimilar between wild age-0 and stocked largemouth bass than at 14, 30, and 60 days post-stocking (Figure 2). At 7 days post-stocking stocked largemouth bass had 86% empty diets compared to 37% for age-0 wild fish. Additionally z-test results indicated that the proportion of wild age-0 largemouth bass diets that contained fish was significantly more ($P = 0.03$) than stocked largemouth bass and the proportion of empty diets in stocked largemouth bass was significantly higher ($P = 0.03$) than wild age-0 fish throughout the study period. These results suggest that stocked fish had a difficult time making the transition to natural prey. Similarly, Olsen et al. (2000) found reduced feeding behavior of pellet reared advanced-fingerling walleye *Stizostedion vitreum* within the first 4 weeks post-stocking and suggested introducing natural prey prior to stocking.

In this study stocked largemouth bass were fed mosquito fish five days prior to stocking. It was observed that stocked fish transitioned to natural prey quickly in the hatchery (Rick Stout FWC hatchery manager, personnel communication). However, these fish were fed prey in an enclosed system (i.e. raceways) with no habitat complexity. McKeown et al. (1999) found reduced survival of stocked muskellunge *Esox masquinongy* raised in troughs on natural prey and attributed the reduced survival to the rearing environment. These results suggest that a learned foraging behavior may not be developed in the hatchery. Fish weakened by hunger are more likely to fall victim to predation, and unlearned foraging behavior may indirectly contribute to the higher predator related mortality observed in hatchery-reared fish (Brown and Laland 2001).

Results from this study as well as others suggest that changes in fish rearing procedures prior to stocking may increase the survival of stocked fish. These would include increasing the time stocked fish are introduced to natural prey and the introduction of habitat complexity to raceways to mimic a natural environment. Additionally, the introduction of predators to raceways may help develop hatchery-reared advanced-fingerling largemouth bass anti-predator skills. Ongoing research at the Richloam hatchery is aimed at addressing these issues in order to develop an effective stocking program using hatchery produced largemouth bass advanced-fingerlings.

We gratefully acknowledge FWC Freshwater Research and Fisheries Management personnel for assisting with this project. We would also like to thank the staff at FWC, FWRI Port Manatee Stock Enhancement Research Facility in particular Chris Young for their assistance with stocking.

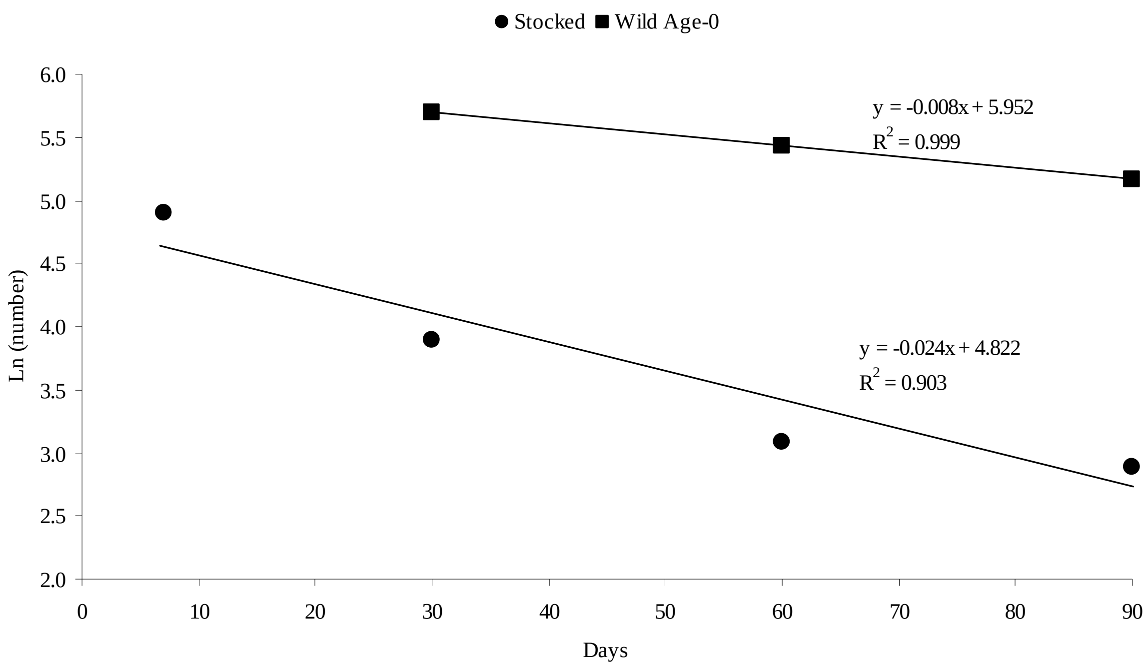

Figure 1. Catch curve for stocked and wild age-0 largemouth bass collected at 7, 14, 30, 60, and 90 days post-stocking from Lake Seminole, Florida. The descending limb of the catch curve was used to estimate mortality for wild age-0 largemouth bass (30, 60, and 90 days post-stocking) and stocked advanced-fingerling largemouth bass (7, 30, 60, and 90 days post-stocking). The sampling events at 7 and 14 days were excluded for wild age-0 bass because they had not fully recruited to electrofishing gear and the sampling event at 14 days was excluded for stocked bass because a different electrofishing boat was used, which changed the catchability coefficient.

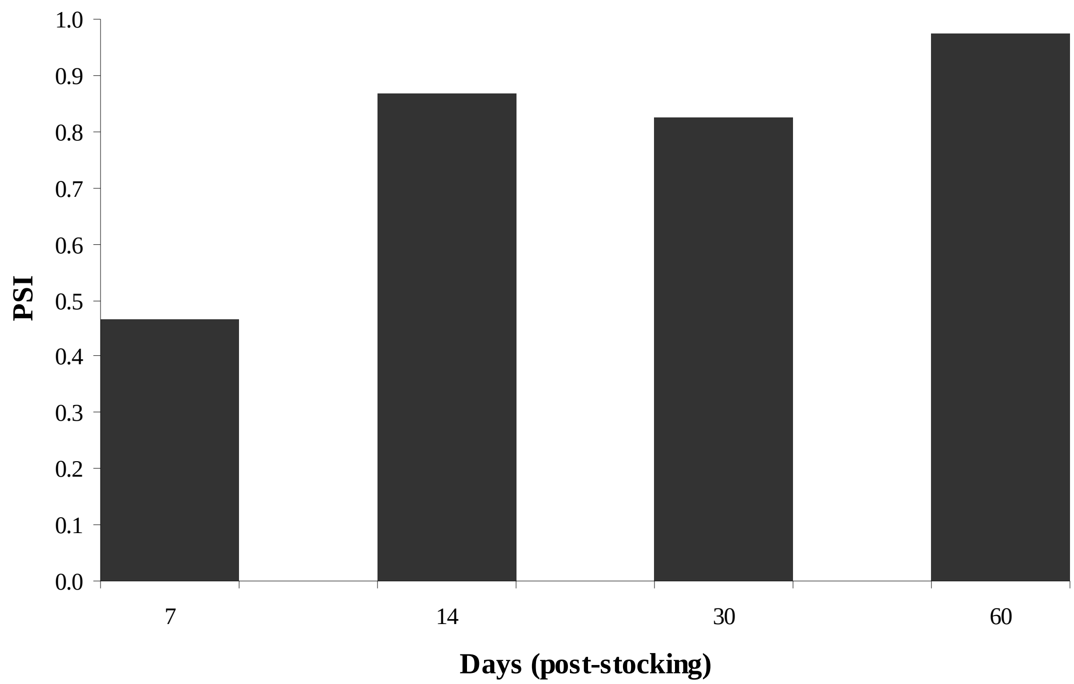

Figure 2. Percent similarity index (PSI) comparing percent occurrence of diet items (fish, invertebrates, and empty) found in the stomachs of stocked and wild age-0 largemouth bass at 7, 14, 30, and 60 days post-stocking. The similarity between wild age-0 largemouth bass and stocked largemouth bass diet composition is presented on a scale of 0 to 1 (y-axis), where 1.0 is identical and 0 is no similarity. The 90 day post-stocking PSI value was not used due to a small sample size of stocked bass.

References

Boxrucker, J. 1986. Evaluation of supplemental stocking of largemouth bass as a management tool in small im poundments. North American Journal of Fisheries Management 6:391-396.

Brown, C., and K. Laland. 2001. Review Paper: Social learning and life skills training for hatchery reared fish. Journal of Fish Biology 59:471-493.

Buynak, G.L., and B. Mitchell. 1999. Contribution of stocked advanced-fingerling largemouth bass to the population and fishery at Taylorsville Lake, Kentucky. North American Journal of Fisheries Management 19:494-503.

Champeau, T., and 6 coauthors. 2008. Southwest Florida Regional Fisheries Management: Annual Report. Florida Fish and Wildlife Conservation Commission, Division of Freshwater Fisheries Management, Tallahassee, Florida.

Colvin, N.E., C.L. Racey, and S.E. Lochmann. 2008. Stocking contribution and growth of largemouth bass stocked at 50 and 100 mm into backwaters of the Arkansas River. North American Journal of Fisheries Management 28:434-441.

Diana, J.S. 1995. Biology and ecology of fish. Cooper Publishing, Indiana.

Heggberget, T.G., M. Staurnes, R. Strand, and J. Husby. 1992. Smoltification in salmonids. NINA-Norsk-Institutt-for-Naturforskning-Forskningsrapport 31:3-42.

Krebs, C.J. 1999. Ecological Methodology, 2nd Ed.. Menlo Park, California: Addison-Welsey Educational Publishers, Inc. 620 pp.

Larscheid, J., J. Christianson, T. Gengerke, and W. Jorgensen. 1999. Survival, growth, and abundance of pellet-reared and minnow-reared muskellunge stocked in Northwestern Iowa. North American Journal of Fisheries Management 19:230-237.

Loska, P.M. 1982. A literature review on the stocking of black basses (*Micropterus* spp.) in reservoirs and streams. Georgia Department of Natural Resources, Game and Fish Division, Atlanta, Georgia.

Mesing, C.L., R.L. Cailteux, P.A. Strickland, E.A. Long, and M.W. Rodgers. 2008. Stocking advanced-fingerling largemouth bass to supplement year-classes in Lake Talquin, Florida. North American Journal of Fisheries Management 28:1762-1774.

McKeown, P.E., J.L. Forney, and S.R. Mooradian. 1999. Effects of stocking size and rearing method on muskellunge survival in Chautauqua Lake, New York. North American Journal of Fisheries Management 19:249-257.

Olson, M.H., T.E. Brooking, D.M. Green, A.J. VanDeValk, and L.G. Rudstam. 2000. Survival and growth of intensively reared large walleye fingerlings and extensively reared small fingerlings stocked concurrently in small lakes. North American Journal of Fisheries Management 20:337-348.

Porak, W.F., and 7 coauthors. 2002. Factors affecting survival of largemouth bass raised on artificial diets and stocked in Florida lakes. American Fisheries Society Symposium 31:649-665.

Porak, W.F., and K.T. Bonvechio 2007. Largemouth bass stocking workshop: Florida Bass Conservation Center (September 27-28, 2005), Florida Fish and Wildlife Conservation Commission, Eustis, Florida. 22pp.

Schlechte, J.W., R.K. Betsill, and D.L. Buckmeier. 2005. A laboratory evaluation of post stocking predatory losses for cultured largemouth bass. Transactions of the American Fisheries Society 134:141-148.

Timmons, L.T., W.L. Shelton, and W.D. Shelton. 1980. Sampling of reservoir sport fish populations with rotenone in littoral areas. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 32:474-484.

Wahl, D.H., R.A. Stein, and D.R. DeVries. 1995. An ecological framework for evaluating the success and effect of stocking fishes. American Fisheries Society Symposium 15:176-189.

Modeling Gulf Sturgeon Population Recovery in the Apalachicola River

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Introduction

The Gulf of Mexico sturgeon Acipenser oxyrinchus desotoi ("Gulf sturgeon") is a subspecies of the Atlantic sturgeon A. oxyrinchus oxyrinchus, historically found throughout much of the northern Gulf of Mexico. Gulf sturgeon were listed as "Threatened" under the Endangered Species Act (ESA) in 1991 and the current Gulf Sturgeon Recovery Plan (GSRP) outlines a variety of criteria that must be met before Gulf sturgeon populations can be considered recovered and delisting of this species proposed (U.S. Fish and Wildlife Service [USFWS] 1995). The GSRP's primary long-term goal is to establish self-sustaining population levels that could allow delisting of the species by 2023 with a secondary long-term goal of population recovery to a point at which they could sustain directed fishing (USFWS 1995).

In order to aid managers in setting realistic recovery targets, it is important to estimate population recovery rates using available data and techniques. For Gulf sturgeon in the Apalachicola River, for example, managers have expressed concern that the population is not recovering at a rate that will lead to delisting by the target recovery date of 2023. There is uncertainty whether this slow rate of recovery is real or perceived and what might be the cause. The Apalachicola River Gulf sturgeon population is of special concern because of ongoing water allocation disputes in the Apalachicola-Chattahoochee-Flint River basin (ACF). Additionally, the ACF is the largest Gulf sturgeon drainage, perhaps historically containing the largest population of Gulf sturgeon, and is unique because the Jim Woodruff Lock and Dam (JWLD) complex blocks upstream passage to approximately 78% of riverine habitat within the ACF (Wooley and Crateau 1985).

Methods

The GSRP suggested the use of population models to assess restoration and management options for Gulf sturgeon, identify future research needs, and forecast time to population recovery (USFWS 1995). In this study I used an age-structured population model to assess the recovery characteristics of the Apalachicola Gulf sturgeon population. The model in this study was the same as that used and described in detail in Flowers (2008) and Flowers et al. (*In Press*). Model parameter inputs were readily derived from available literature and data on the Apalachicola River Gulf sturgeon population.

In this study I specifically used the model to create estimates of the time that it would take for the Apalachicola Gulf sturgeon population to recover to pre-harvest levels from the stock's depleted state at the end of fishing in 1985. I evaluated the range of population recovery states by varying the population size at year 1985 (N_{1985}) based on a population estimates derived from Wooley and Crateau (1985). I also examined the effects of increasing total mortality (Z) on population recovery by simulating varying levels of anthropogenic mortality (F) potentially arising from sampling, management practices, and/or fisheries by-catch.

Results

Varying N_{1985} had a significant effect on the recovery rate of the Apalachicola Gulf sturgeon population, with higher N_{1985} values resulting in shorter recovery time than low N_{1985} values. Using the range of N_{1985} estimates from Wooley and Crateau (1985), abundance at the recovery goal date of 2023 varies by a factor of nearly two depending on whether the N_{1985} lower bound (N= 181) or upper bound (N= 645) is used for the initial population abundance. Extending the time interval of recovery until 2084 reduces the effect of different initial population starting values as populations are expected to reach 94-97% of the pre-exploitation levels by this time (Figure 1). The effects on the recovery rate of the population at shorter time intervals are driven by life history attributes such as late maturity combined with the impact on the reproductive potential of the population at low population sizes and the absence of large, older fish in the population.

Increasing Z after the closure of the directed fishery greatly affected recovery time in some instances. The base Z value of 0.13 was added to by using the anthropogenic mortality term F, simulating the effects of non-specific human-induced mortality. Increased total mortality had a strong negative effect on population recovery. With an annual F of 1% (total mortality of 14%), population size at the recovery goal years of 2023 and in 2084 was estimated at 27 and 84% of the historic population size, respectively (Figure 2). With F values of 5 and 10% (total mortality 18 and 23%), these recovery values become 15 and 7% in 2023 and 45 and 14% in 2084, respectively.

Discussion

The results show that the Apalachicola Gulf sturgeon population is likely limited by population size at the end of harvest and will not fully recover by the current long-term recovery date of 2023. Population recovery at this time may only be to around 25-30% of the historic population size while the time to full recovery may be in excess of 100 years. The biological reason for this slow recovery is the erosion of population age-structure, specifically the loss of older, more fecund individuals, caused by heavy fishing pressure. When these individuals are removed by the fishery more time is required for these highly exploited populations to rebuild their age-structure and related reproductive capacity (Walters et al. 2008) and the effects may be even more pronounced in slow growing and late maturing species such as sturgeons (Paragamian et al. 2005, Walters et al. 2008). The Apalachicola Gulf sturgeon population will begin to recover more rapidly once the number of older individuals present in the population increases. Regardless of the population's status, recovery will be slowed by any additional mortality added to the population. Gulf sturgeon populations are sensitive to harvest and small increases in mortality (Pine et al. 2001). For reference, model estimated sustainable harvest rates for Gulf sturgeon are in the 5-10% range.

Population models are a valuable tool in natural resource conservation. Effective management programs are those that successfully integrate modeling approaches with field research. Because of this, they are often required by the recovery plans of species of concern. In this study, a population model was used to evaluate population recovery for a threatened Gulf sturgeon population in the Apalachicola River. This was accomplished using existing data and more importantly, for any species of concern, without affecting or harming actual populations. The model in this study simulates what may actually be occurring in wild Gulf sturgeon populations so that resource managers will not be forced to make assumptions about the behavior of these populations and provides hypotheses against which future research and actions can be evaluated. Flowers (2008) and Flowers et al. (*In Press*) provide additional information on this model and more Gulf sturgeon recovery scenarios evaluated using the same model discussed here.

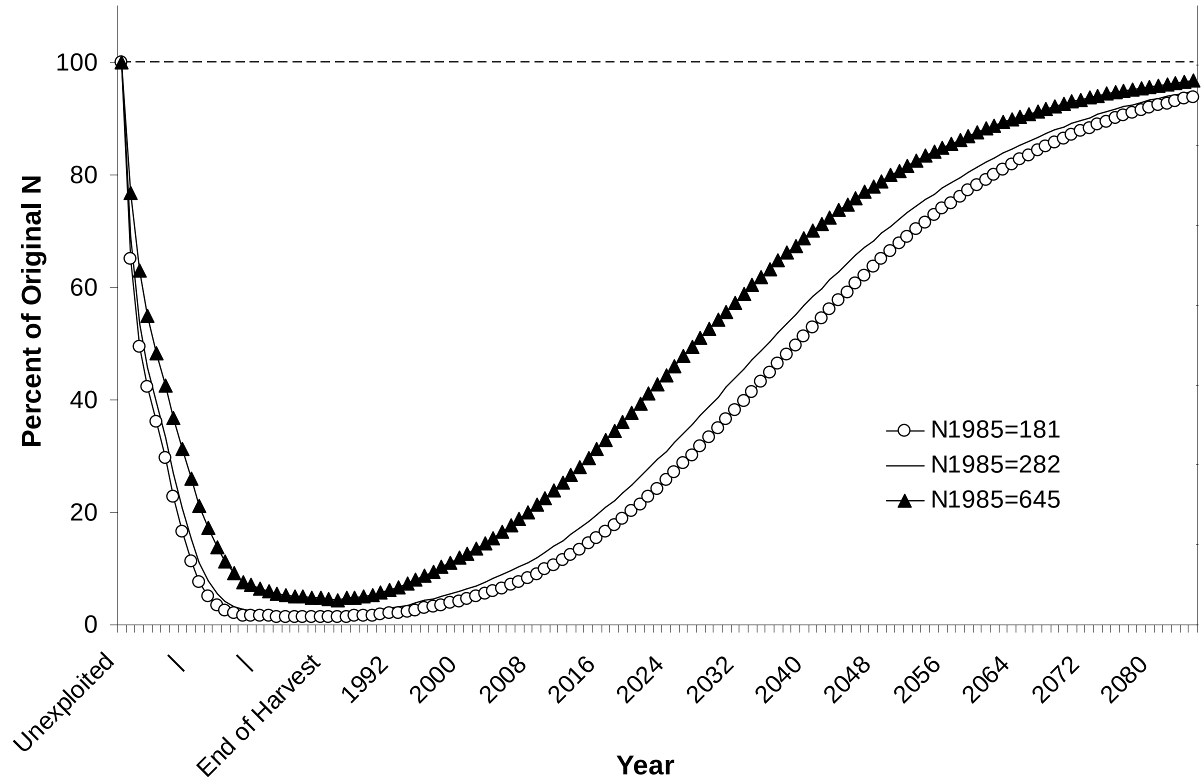

Figure 1. Apalachicola River Gulf sturgeon recovery rates based on the range of N_{1985} estimates. Percent of original pre-exploitation population on the y-axis, year of simulation on the x-axis.

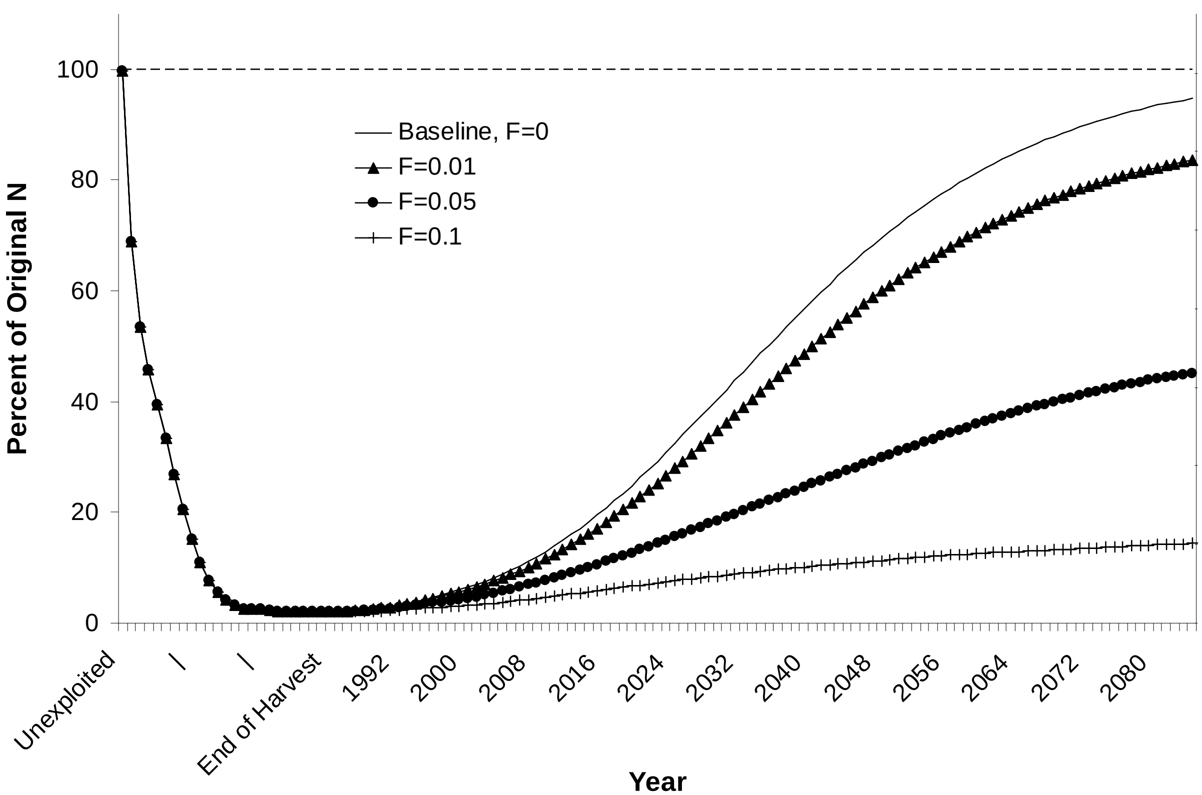

Figure 2. The effect of additional mortality on Apalachicola River Gulf sturgeon population recovery. Percent of original pre-exploitation population on the y-axis, year of simulation on the x-axis. The baseline is the N_{1985} = 282 simulation from Figure 1.

Literature Cited

Flowers, H.J. 2008. Age-Structured Population Model For Evaluating Gulf sturgeon Recovery On The Apalachicola River, Florida. Masters Thesis. University of Florida.

Flowers, H.J., W.E. Pine III, A,C, Dutterer, K.G. Johnson, J.W. Ziewitz, M.S.Allen, F.M. Parauka. *In Press*. Spawning site selection and potential implications of modified flow regimes on viability of Gulf sturgeon populations. Transactions of the American Fisheries Society.

Paragamian, V.L, R.C.P. Beamesderfer, and S.C. Ireland. 2005. Status, population dynamics, and future prospects of the endangered Kootenai River white sturgeon population with and without hatchery intervention. Transactions of the American Fisheries Society 134:518-532.

Pine, W. E. III., M. S. Allen, and V. J. Dreitz. 2001. Population viability of the Gulf of Mexico Sturgeon: Inferences from capture-recapture and age-structured models. Transactions of the American Fisheries Society 130:1164-1174.

USFWS. 1995. Gulf sturgeon recovery plan. U.S. Fish and Wildlife Service and Gulf States Marine Fisheries Commission.

USFWS. 2008. Biological opinion on the U.S. Army Corps of Engineers, Mobile District, revised interim operating plan for Jim Woodruff Dam and the associated releases to the Apalachicola River. U.S. Fish and Wildlife Service, Panama City, Florida.

Walters, C.J., R. Hilborn, and V. Christensen. 2008. Surplus production dynamics in declining and recovering fish populations. Canadian Journal of Fisheries and Aquatic Sciences 65:2536-2551.

Wooley, C. M. and E. J. Crateau. 1985. Movement, microhabitat, exploitation, and management of Gulf of Mexico sturgeon, Apalachicola River, Florida. North American Journal of Fisheries Management 5:590-605.