Final Report for Technical Assistance for an Ecological Evaluation of the Southwest Florida Feasibility Study

STRESSOR RESPONSE MODEL FOR THE SPOTTED SEATROUT, *CYNOSCION NEBULOSUS*

By Frank J. Mazzotti, Leonard G. Pearlstine, Tomma Barnes, Stephen A. Bortone, Kevin Chartier, Alicia M. Weinstein, and Donald DeAngelis

Joint Ecosystem Modeling Laboratory

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FINAL REPORT
for

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Introduction

A key component in adaptive management of Comprehensive Everglades Restoration Plan (CERP) projects is evaluating alternative management plans. Regional hydrological and ecological models will be applied to evaluate restoration alternatives and the results will be applied to modify management actions.

Objective

The purpose of this habitat suitability model for the C-43 West Basin Reservoir and Southwest Florida Feasibility Study projects is to portray species responses to changes in environmental variables resulting from restoration activities spatially and temporally to facilitate policy decisions. The intention of the habitat suitability model is not to simulate the life-cycles of the species. Rather, the intent is to estimate numbers of habitat units to serve as a relative basis for comparing management alternatives.

Southwest Florida Feasibility Study

The Southwest Florida Feasibility Study (SWFFS) is a component of the Comprehensive Everglades Restoration Plan (CERP). The SWFFS is an independent but integrated implementation plan for CERP projects and was initiated in recognition that there were additional water resource issues (needs, problems, and opportunities) within Southwest Florida that was not being addressed directly by CERP. The SWFFS identifies, evaluates, and compares alternatives that address those additional water resource issues in Southwest Florida. An adaptive assessment strategy is being developed that will create a system-wide monitoring program to measure and interpret ecosystem responses. The SWFFS provides an essential framework to address the health and sustainability of aquatic systems. This includes a focus on water quantity and quality, flood protection, and ecological integrity.

C43 West Reservoir

The purpose of the C43 Basin Storage Reservoir project is to improve the timing, quantity, and quality of freshwater flows to the Caloosahatchee River estuary. The project includes an above ground reservoir with a total storage capacity of approximately 197 million cubic meters (160,000 acre-feet) and will be located in the C-43 Basin in Hendry, Glades, or Lee Counties. The initial design of the reservoir assumed 8094 hectares (20,000 acres) with water levels fluctuating up to 2.4 meters (8 feet) above grade. The final size, depth and configuration of this facility will be determined through more detailed planning and design.

Forecasting Models

Forecasting models bring together research and monitoring to ecosystems of Southwest Florida and place them into an adaptive management framework for the evaluation of alternative plans. There are two principle ways to structure adaptive management: (1) *passive* by which policy decisions are made based on a forecasting model and the model is revised as monitoring data become available, and (2) *active* by which management activities are implemented through statistically valid experimental design to better understand how and why natural systems respond to management (Wilhere 2002).

In an integrated approach that includes both passive and active-adaptive management, a forecasting model simulates system response and is validated by monitoring programs to measure actual system response. Monitoring can then provide information for passive-adaptive management for recalibration of the forecasting model. Directed research, driven by model uncertainties, is an active-adaptive management strategy for learning and the reduction of uncertainties in the model.

The forecasting models for the C-43 West Reservoir Project and the Southwest Florida Feasibility Study consist of a set of stressor response (habitat suitability) models for individual species. These stressor response models have been developed principally with literature, expert knowledge, and currently available field data.

Habitat Suitability Indices

Habitat Suitability Indices (HSI) models were developed with each stressor variable portrayed spatially and temporally across systems of the study area at scales appropriate to the organism or community being portrayed. The HSI models have been incorporated into a GIS to portray responses spatially and temporally to facilitate policy decisions. That is, the model describes a response surface of habitat suitability values that vary spatially according to stressor levels throughout the estuary and temporally according to temporal patterns in stressor variables. Much of the temporal variation is a result of temporal cycling of important stressor inputs, such as water temperature and salinity. Temporal change for other important variables may not be cyclical, such as rising sea level and increasing land use and fresh water demands in the region. Areas predicted to be suitable and those predicted to be less suitable or disturbed should be targeted for additional sampling as part of the model validation and adaptive management process.

Species selected for modeling (focal species) are ecologically, recreationally or economically important and have a well established linkage to stressors of management interest. They may also make good focal species because they engage the public in caring about the outcome of restoration projects. The habitat suitability models (HSI) were developed by choosing specific life stages of each species with the most limited, restricted, or tightest range of suitable conditions, to capture the highest sensitivities of the organisms to the environmental changes associated with the planned restoration activities. Values used in the models are listed in Table 1.

The models calculate habitat suitability monthly as the weighted geometric mean of the environmental variables identified as important for each model. Because the geometric mean is derived from the product of the variables rather than the sum (as in the arithmetic mean) and has the appropriate property that if any of the individual variables are unsuitable for species success (i.e., the value of the variable is zero) then the entire index goes to zero.

Ecology of the Spotted Seatrout

The spotted seatrout, *Cynoscion nebulosus*, is a member of the Sciaenidae family of croakers and drums. It is an important estuarine species as it can serve as a long-term indicator of estuarine conditions because it is one of the few estuarine species that spends its entire life within the confines of a single estuarine system. The species occurs in all estuaries from North Carolina to Mexico along the Atlantic and Gulf of Mexico coasts. An added feature of this species is that it is highly prized by both commercial and recreational fishers, thus, it commands attention among the general public. These features of its basic biology and position with the public make it an ideal species as an indicator of estuarine conditions.

Seatrout are non-migratory fish (Tabb 1966) that are found in shallow bays, estuaries, bayous, canals, and along Gulf Coast beaches. Spotted seatrout usually live between seven and ten years, completing their entire life cycle in these inshore waters while utilizing different estuarine zones and habitats during different life stages (Helser et al. 1993). Adults can tolerate a wide range of salinities and temperatures (Tabb 1958, Simmons 1957, Vetter 1982, Killam et al 1992) and in South Florida are not commonly exposed to extremes that may be lethal (e.g. temperature <4°C (Tabb 1958)). Spawning is thought to occur throughout the summer (Brown-Peterson 2003, Brown-Peterson et al. 2001, McMichaels and Peters 1989) in South Florida estuaries in meso and polyhaline portions of the estuary and near passes (5 -30 ppt) but not in oligohaline areas (<5 ppt) (Holt and Holt 2003, Lassuy 1983). A depth requirement for spawning has been suggested as less than 5 m (Brown-Peterson 2003), in areas next to steep drop offs, near seagrass beds (Bortone pers. com). Eggs hatch in more saline marine to estuarine environments (25-40 ppt) which enables eggs to stay buoyant (Holt and Holt 2003, Alshith and Gilmore, 1994).

Juveniles and adult spotted seatrout are frequently associated with seagrass beds, a critical habitat for the species (Chester and Thayer 1990, Tolan et al. 1997, Rooker et al. 1998, Thayer et al. 1999, Baltz et al. 2003,). In colder months, they may move into deeper holes within the estuary (Tabb 1958).

The spotted seatrout is an opportunistic carnivore. Their diet changes with size/life stage and with seasonal abundance of food items (Peret et al 1980). Larvae feed primarily on zooplankton; post-larvae on larval shrimp, copepods, small fishes, and crabs (Lorio and Perret 1980). Juveniles feed predominately on fishes, shrimp (penaeids, mysids, and cardeans) copepods and other benthic invertebrates (McMichael and Peters 1989, Hettler 1989). Young adults prey on a variety of invertebrates, shifting almost entirely to smaller fish, when available, as mature adults (McMichaels and Peters 1989, Hettler 1989, Tabb 1958).

Spotted seatrout have permanently recorded growth features; growth rings or annuli on its otolith or ear stone. These rings reflect the growth conditions to which the fish had been subjected (Bedee et al. 2003). Therefore, the growth rate of each fish is essentially a permanent historical record that reflects the environmental conditions of a specific estuary.

HSI for the Spotted Seatrout

Environmental parameters used to determine habitat suitability of the adult spotted seatrout forage include salinity, temperature, and seagrass cover. Salinity, and proximity to seagrasses (SAV) and drop offs are used for the adult spawning habitat suitability component. SAV coverage is output from annual suitability models for seagrasses. Specific requirements that have been pulled from scientific literature are listed, along with their source, in Table 1 below.

A user interface for running coastal southwestern Florida HSI models is documented in Mazzotti *et al.* (2006).

Table 1. Habitat Requirements for the Spotted Seatrout

Variable	**Value**	**Source**
Larvae: Salinity	Eggs sink when exposed to salinity lower than when spawned	Holt, G.J., and S.A. Holt. 2003. Effects of variable salinity on reproduction and early life stages of spotted seatrout. Pages 135-145 In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida.
Adult Foraging: Salinity	18-32 in LA	Baltz, D.M., R.G. Thomas, E.J. Chesney. 2003. Spotted seatrout habitat affinities in Louisiana. Pages 147-175 In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida.
Adult Foraging: Temperature	20-24° C in Louisiana	Baltz, D.M., R.G. Thomas, E.J. Chesney. 2003. Spotted seatrout habitat affinities in Louisiana. Pages 147-175. In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida.
	15-27° C in Florida	Tabb, D. 1958. Differences in the estuarine ecology of Florida waters and their effects of populations of the spotted weakfish, Cynoscion nebulosus (Cuvier and Valenciennes). Twenty-third North American Wildlife Conference, 392-401 pp.
	<4° C lethal in Florida	Story, M. and Gudger, E.W. 1936. Mortality of fishes due to cold at Sanibel Island, Florida, 1886-1936. Ecology 17:640-648.
Adult Foraging: Seagrass cover	Essential	Baltz, D.M., R.G. Thomas, E.J. Chesney. 2003. Spotted seatrout habitat affinities in Louisiana. Pages 147-175. In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida. Chester, A.J., Thayer, G.W. 1990. Distribution of spotted seatrout (Cynoscion nebulosus) and gray snapper (Lutjanus griseus) juveniles in seagrass habitats of western Florida Bay. Bull. Mar. Sci. 46(2): 45-357. Tolen, J.M., Holt S.A., Onuf C.P. 1997. Distribution and community structure of ichthyoplankton in Laguna Madre seagrass meadows: potential impact of seagrass species change. Estuaries 20:450-465 Rooker, J.R.; Holt S.A.; Sota M.A.; Holt G.J. 1998. Postsettlement patterns of habitat use by sciaenid fishes in subtropical seagrass meadows. Estuaries 21:318-327. Thayer, G.W., Powell, A.B., Hoss, D.E.. 1999. Composition of larval, juvenile, and small adult fishes relative to changes in environmental conditions in Florida Bay. Estuaries 22:518-533. Thomas, P., Arnold, C.R., Muir, J.F., Roberts, R.J. 1993. Environmental and hormonal control of reproduction in sciaenid fish. Recent Advances in Aquaculture, vol. 4. :31-42.
Adult Spawning: Salinity	16-32 ppt in Florida & Texas	Holt, G.J., and S.A. Holt. 2003. Effects of variable salinity on reproduction and early life stages of spotted seatrout. Pages 135-145. In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida.

	18-33 ppt Florida east coast	Alshuth, S. and R.G. Gilmore. 1993. Salinity and temperature tolerance limits for larval spotted seatrout, Cynoscion nebulosus C. (Pisces: Sciaenidae). In ICES Council Meeting Papers, Denmark: ICES 19.
Adult Spawning: Temperature	21-34° C in Louisiana	Baltz, D.M., R.G. Thomas, E.J. Chesney. 2003. Spotted seatrout habitat affinities in Louisiana. Pages 147-175. In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida.
	21-34° C in Florida	Brown-Peterson, N.J. 2003. The reproductive biology of spotted seatrout. Pages 99-133. In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida.
Drop-offs	Essential	Lowe-Barbieri (FWRI, personal communication)
Seagrass Bed Distance	*Proximate*	Brown-Peterson, N.J. 2003. The reproductive biology of spotted seatrout. Pages 99-133. In: S.A. Bortone (ed.). Biology of the Spotted Seatrout. CRC Press. Boca Raton, Florida.

HSI for the Spotted Seatrout

HSI Formula

Forage Component Index = $(\text{Habitat}^{w}_{\text{Seagrass\%Cover}} * \text{Salinity}^{w} * \text{Temperature}^{w})$

Spawn Component Index = $(\text{Habitat}^{w}_{\text{Dropoff\&SeagrassProximity}} * \text{Salinity}^{w})$
Spawning is May - October

HSI = MAX(ForageComponent, SpawnComponent)

The HSI for any particular grid-cell is selected as the maximum of the forage component or the spawning component. The component values are not multiplied together because they occupied different places in the landscape.

Temperature values used in model are average monthly water temperatures and do not change with hydrologic alternatives.

HSI Graphs

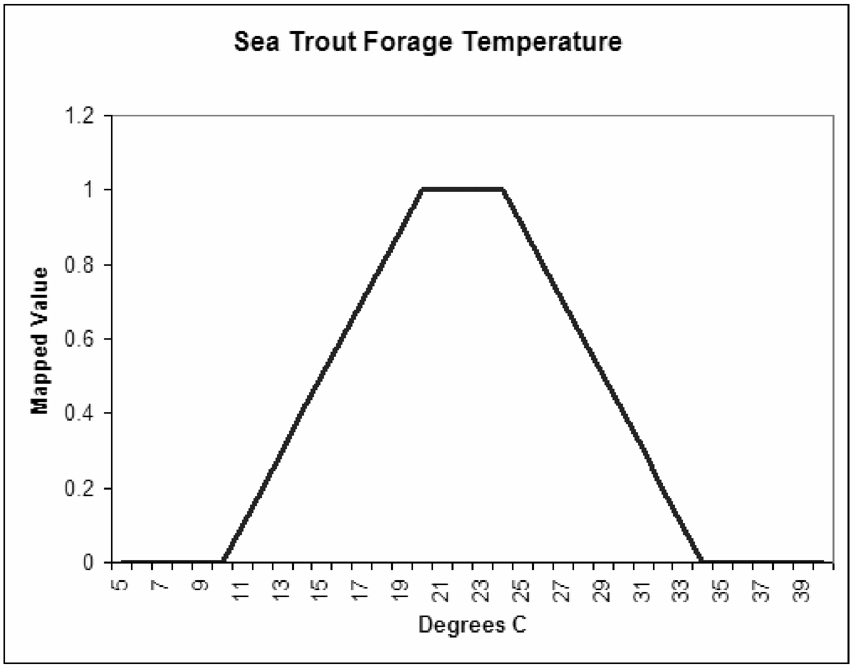

Figure 1. Index value for spotted seatrout forage response to temperature

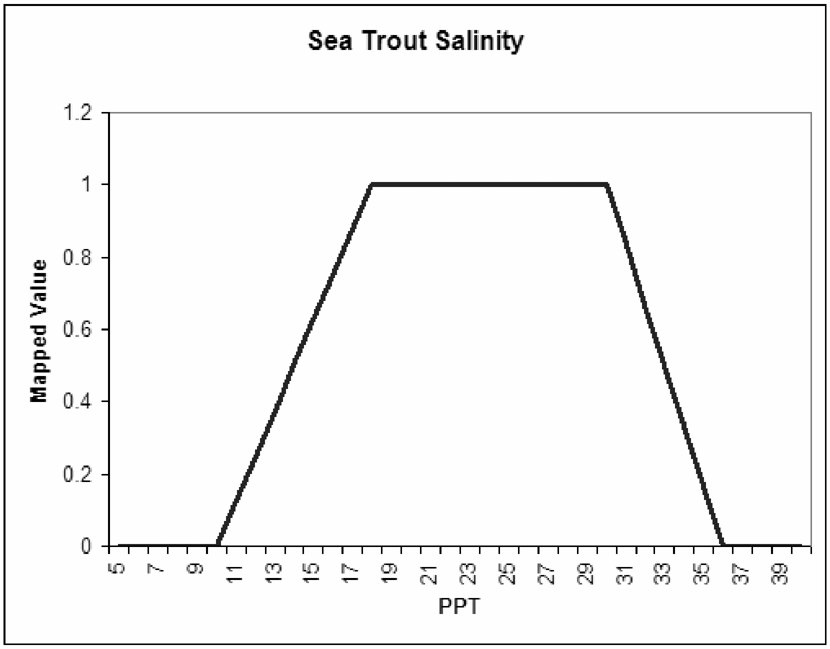

Figure 2. Index value for spotted seatrout adult response to salinity

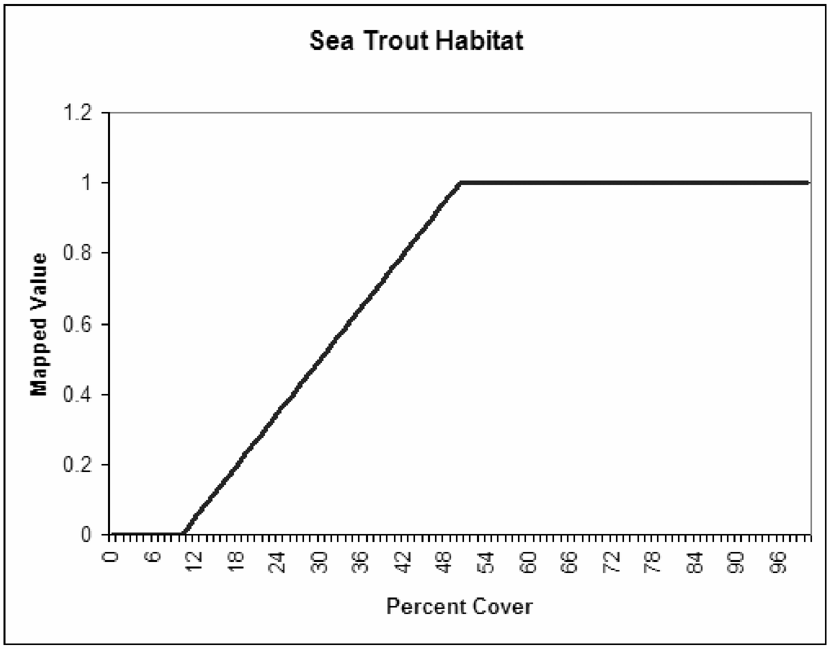

Figure 3. Relationship between the suitability index and % cover of seagrass for spotted seatrout foraging.

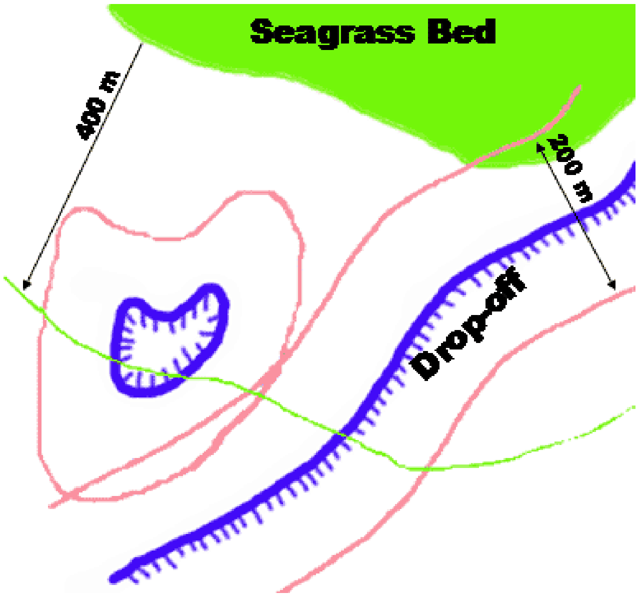

Figure 4a. Spotted seatrout spawning requirement for depth. Spawning is within a 100 m proximity to steep drop-offs and a 400 m proximity to seagrass beds.

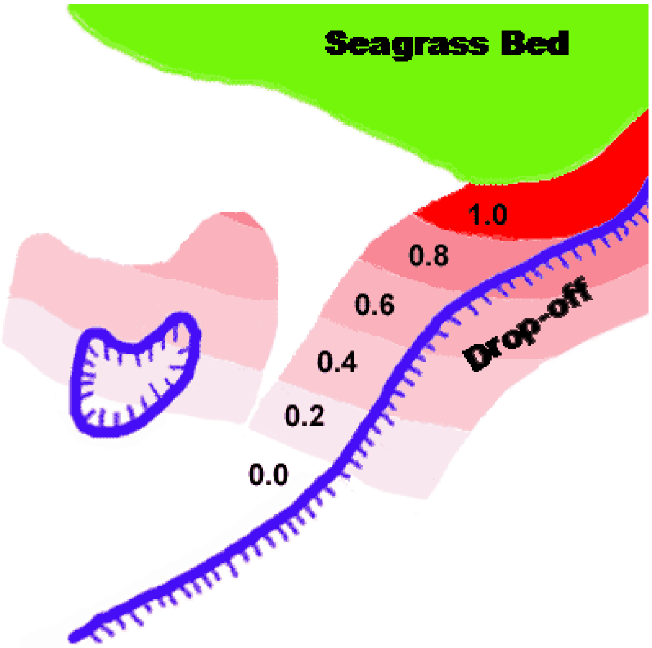

Figure 4b. Index value for spotted seatrout spawning response to depth The suitability value of the spawning habitat component decreases linearly as distance increases from a seagrass bed. The habitat suitability is illustrated here as a red gradient with values from 0.0 (white) to 1.0 (darkest red).

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