ASSESSMENT OF SALINITIES AND BIO-ABUNDANCES RESULTING FROM RUNOFF INTO FAKA UNION BAY FOR PICAYUNE STRAND RESTORATION PROJECT SCENARIOS

John D. Wang
Atmospheric and Marine Processes
Rosenstiel School of Marine and Atmospheric Science
Cooperative Institute for Marine and Atmospheric Sciences
4600 Rickenbacker Causeway
Miami, Florida 33149

Joan A. Browder
NOAA Fisheries
National Marine Fisheries Service
Southeast Fisheries Center
75 Virginia Beach Drive
Miami, Florida 33149

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INTRODUCTION

From July 1982 to June 1984 we made a physical and biological study of Faka Union, Fakahatchee, and Pumpkin Bays on the southwest coast of Florida in the Ten Thousand Island area (Wang and Browder 1986). The study examined the flows and salinity variations in the bays and the influence of the Faka Union Canal (FC) discharges on these physical characteristics. Extensive biological samples were also collected and analyzed. Based on the observations, a salinity prediction model and abundance models for several individual species were developed. The abundance models related (explained variance of 46 to 74%) monthly abundance to the percent area within certain salinity bands within the bays (Browder and Wang 1988).

The objective of the present report is to apply these earlier developed models to assess the downstream effects in Faka Union Bay of alternative CERP project plans (http://www.evergladesplan.org). For this purpose, the salinity prediction model was updated and its validity was reassessed in view of new data of FC discharges and salinities at one point of the Bay. These data, consisting of continuous records at one point from 2000 to 2002 were provided by the SFWMD and M. Shirley (Rookery Bay National Estuarine Reserve, pers. comm.), as summarized by M. Savarase (Florida Gulf Coast University, pers. comm.). The reestablished models were then used to predict salinity patterns and species abundances for Faka Union Bay.

REVIEW OF 1986 MODEL IN LIGHT OF RECENT DATA

The 1986 model (Wang and Browder 1986) developed regression relationships between FC discharges and observed salinities at 5 locations in FU Bay and 4 locations in the channel leading from the west Florida Shelf to the mouth of the Bay, Fig. 1. The established regressions assumed a hyperbolic relationship between discharge and salinity at each station and were crucial to the prediction of salinity in the bay. It was therefore important to check the validity of these relationships with newer data for the Bay. Fig. 2 shows salinity at location XX plotted against the recorded FC discharge from July 13, 2000 to December 31, 2002. Along with these observations are also plotted the hyperbolic relationships for stations 17 and 19, the two stations closest to the point of observation of the more recent salinity data. The graph depicts an obvious shift such that the more recent data shows a higher salinity for the same discharge as compared to the 1986 data.

Based on information that the canals had accumulated substantial live and dead vegetation, which was cleaned out starting 1992 (A Nath, personal communication), there was reason to believe that a redistribution of flows between the canal and the culverts under the Tamiami Trail (US 41) had taken place. An investigation was made to determine whether the shift in the discharge salinity relationship was due to a change in the proportion of total runoff discharged through the canal (as opposed to through the culverts beneath the Trail) between the two observation periods. For this purpose, a more detailed mass balance analysis of rainfall and discharge from 1985 to 2002 (18 years) was made. Although it would have been desirable to go back farther, the data previous to 1985 was of poor quality or incomplete.

A change in slope is noticeable in the plot of cumulative rainfall from 1985 to 2002 against cumulative discharge. This change in slope indicates that indeed a change in the discharge per unit of rainfall took place some time around 1995, a change that has led to a big increase of discharge for the same rainfall (Fig. 3). Appendix 1 describes the data and analysis more detail. To establish precise regression lines of discharge *vs*. rainfall before and after cleaning is difficult because of the apparent effect of partial canal blocking developing in the early 90's. Regression before 1990 would have too few points to be significant. Because of these data problems, it is not possible to precisely determine how much the recorded canal discharge per unit of rainfall increased after ca 1995 compared to pre-1995. However, based on regression from 1985 to 1992 and from 1993 to 2002, the increase is approximately 50% of the post-1995 discharge (100% of the pre-1995 discharge).

Since observations and model simulations show that flows in the canal in the later years very nearly represent 100% of flows to the Bay (DHI model data, A. Nath, personal communication), we conclude that when developing the hyperbolic relationships between FC discharge and bay salinity, the canal was only carrying approximately half of the total flow to the bay, and a similar flow was reaching the bay through local streams fed by the culverts. When the discharges in 2000 to 2002 are reduced by 50%, the resulting data points fall very closely to the hyperbolic relationships (Fig. 4). We, therefore, divided the total flows to the bay in half and used the hyperbolic relationships of the 82-84 work, which provided salinity predictions for 5 stations in the Bay, in contrast to the single station of the 2000-2002 study, to predict the boundary salinities in the present simulations. In other words, when the total flow to the Bay was Q, a value of 0.5*Q was used in the 82-84 regression relationships to determine the corresponding salinities at the boundaries.

DETERMINATION OF SALINITY WITHIN FAKA UNION BAY

The hydrodynamic and salinity model developed in Wang and Browder (1986) was re-established for Faka Union Bay in such a way that different discharge values could be easily simulated. The hydrodynamic model with the grid shown if Fig. 5 was forced by the total discharge to the Bay (the sum of FU#1 and Merritt at US 41), as obtained from DHI simulations. The hyperbolic regression relationships were used to specify the salinities at boundaries as described in the previous section. Diffusion coefficients were set to 25 m^2/sec as in previous runs. These values included the diffusive effects from tides, which were not simulated. Although the model is a full 2-D hydrodynamic model it was here applied primarily as a tool to interpolate between the specified salinities at 6 locations of the Bay. The effect of advection towards the ocean due to freshwater inflows was represented by the model through the computed hydrodynamic velocity fields. Ultimately, the model interpolation was constrained by the salinities at the 6 locations in the bay where the calibrated hyperbolic relationships between discharge and salinity were used.

The hydrodynamic model was run at a time step of 10 sec to preserve stability, while the salinity solution was only carried out every 10th time step. Salinity solutions were saved every 100,000 sec. Several tests showed that for a constant discharge a steady state was reached after approximately 300,000 sec (3.5 days) when starting the model from rest with zero velocities, water surface at a horizontal mean water level, and salinities equal to 36 psu everywhere. The simulation runs were therefore run for 400,000 sec and a comparison between calculated salinities after 300,000 sec and 400,000 sec was made to ascertain that a steady state had been reached. In order to efficiently evaluate a number of alternatives and to allow simulations of monthly averaged flows for 12-year periods, a number of basis runs were made for discharges of 0.1, 0.5, 1.0, 2.0, 3.0, 5.0, 7.5, 10.0, 15.0, 20.0, 25.0, 30.0, 40.0, 50.0,and 75.0 m^3/sec. Runs with discharges of 40 m^3/sec and greater were run at a time step of 5 sec to preserve stability. Instead of running every distinct discharge value, an interpolation method was then used in which the salinities at each node for an arbitrary discharge were obtained by linearly interpolating the results of the basis run at grid nodes. Model grid and nodes are shown in Fig. 5.

ANALYSIS OF SALINITY MODEL RESULTS

The computed salinities for each month of every simulation were used to calculate the area of the Bay within every 1 psu salinity band. The mean salinity and coefficient of variation (standard deviation divided by mean) at each grid point were also calculated for each simulation run. Finally, the salinity time series at 10 arbitrarily chosen points (nodes 3, 13, 23, ... , 93) were also saved to be used in connection with a shrimp model. The basis run using 15 different discharge values were also used to generate the area of the Bay contained within a 1 psu salinity band as a function of salinity (abscissa) and discharge (ordinate) (Fig. 6). The computed salinity fields are illustrated in Figs. 7, 8, and 9 for discharges of 10, 25, and 50 m^3/sec.

For use with the biological models (Browder and Wang 1988), the percent area within required salinity bands was calculated for each month of every simulation. A list of all the simulations made with the model is provided in Table 1.

Table 1. Scenarios of inflow used to predict salinities and biological effects in Faka Union Bay.

Time series	Scenario	1-ppt salinity zones	10 salinity points
Jan 1994-Dec 2000			
	Existing	Yes	Yes
	Natural system	Yes	Yes
	Alternative 3D	Yes	Yes
Jan 1989-Dec 2000			
	Existing	Yes	
	2050 without	Yes	
	Natural system	Yes	
	Alternative 3D	Yes	
	Alternative 6	Yes	
	Alternative 12	Yes	

The average year (1994) simulations and the long-term (12-year) 1989 to 2000 simulations were treated somewhat differently in the biological model. For 1994, the antecedent abundances were assumed to be zero, and the model was run 100 years repeating the salinity fields every year. The period of 100 years was chosen to assure that a quasi-stationary result for the year was obtained, *i.e.*, the month by month values of abundances repeated year after year. The abundance results from the last year were then used.

For the long-term runs, the biological models were initialized using the quasi-stationary results, and the models were simply run for the 12-year duration. Although results from the DHI model were available for 1988, results from that year were possibly influenced by DHI model initialization and were therefore not used in our simulations.

RESULTS WITH THE BIOLOGICAL MODELS

The four validated statistical models from the 1986 study were used to predict biological effects of alternative flow scenarios. The models were based on the area of Faka Union Bay within certain 3-ppt salinity bands (i.e., 9-12, or 18-21). The models also contained autoregressive relationships. The models predicted abundance indices in the form of the natural log. The models were for the following four species: bay anchovy (*Anchoa mitcilli*), pinfish (*Lagodon rhomboides*), silver perch (*Bairdiella chrysoura*), and silver jenny (*Eucinostomus gula*). Model equations are in Appendix 2. Two sets of simulations were made to predict the biological effects of alternative flow scenarios in Faka Union Bay:

(1) six scenarios were compared for 1994:
    existing

2050 without
natural system
alternative 6
alternative 12
alternative 3D

(2) three scenarios were compared for the period 1989-2000:

existing
natural system (NS)
alternative 3D

The 1-year simulations with the six flow scenarios (Fig.10) showed monthly differences; but, abundance indices for two of the species, the pinfish and the Gulf pipefish, were higher with freshwater inflows and resultant salinities from the three design alternatives (**alternatives 6, 12,** and **3D**) and **the natural system** than with those from **existing** or **2050-without** scenarios. For one species, the silver perch, existing and 2050-without outperformed the alternatives during the winter and spring (months 1-5), but **the alternatives** and **the natural system** outperformed the **existing** and **2050-without** during the summer and fall. The silver jenny was favored by **existing** and **2050-without** conditions. **Alternative 3D** outperformed the other alternatives except for the silver perch, for which **alternative 12** outperformed all others and **alternative 6** was most similar to the natural system. The results in Figure 1 have the shortcoming of being confined to only one year, and every year is different.

The 12-year simulations with the three flow scenarios also varied (Fig.11), although simulations with the **alternative 3D** scenario were almost identical to that of **the natural system**. For three of the four species (bay anchovy, silver perch, and pinfish), **alternative 3D** and **the natural system** yielded consistently higher abundances than **existing**. For the fourth species, the silver jenny, **existing** yielded higher abundances than **alternative 3D** or **the natural system**. Averages of the predicted monthly abundance indices from the simulations (Fig.12) showed the cumulative magnitude of the differences among scenarios.

Thus three of the four species are expected to become more abundant in Faka Union Bay when flows and salinity patterns are made more similar to that expected from a natural hydrologic system (a system unaltered by canals and levees). All four species spend all or a part of their time in estuaries, where salinities are less than sea water strength (35 ppt) because of the influence of fresh water; however the silver jenny may be more tolerant of low salinities because it is known to enter South Florida’s calcium-rich fresh waters (Robins et al. 1986). A brief review of readily available information about the habitat and salinity requirements or preferences of these four species is given in Appendix 2.

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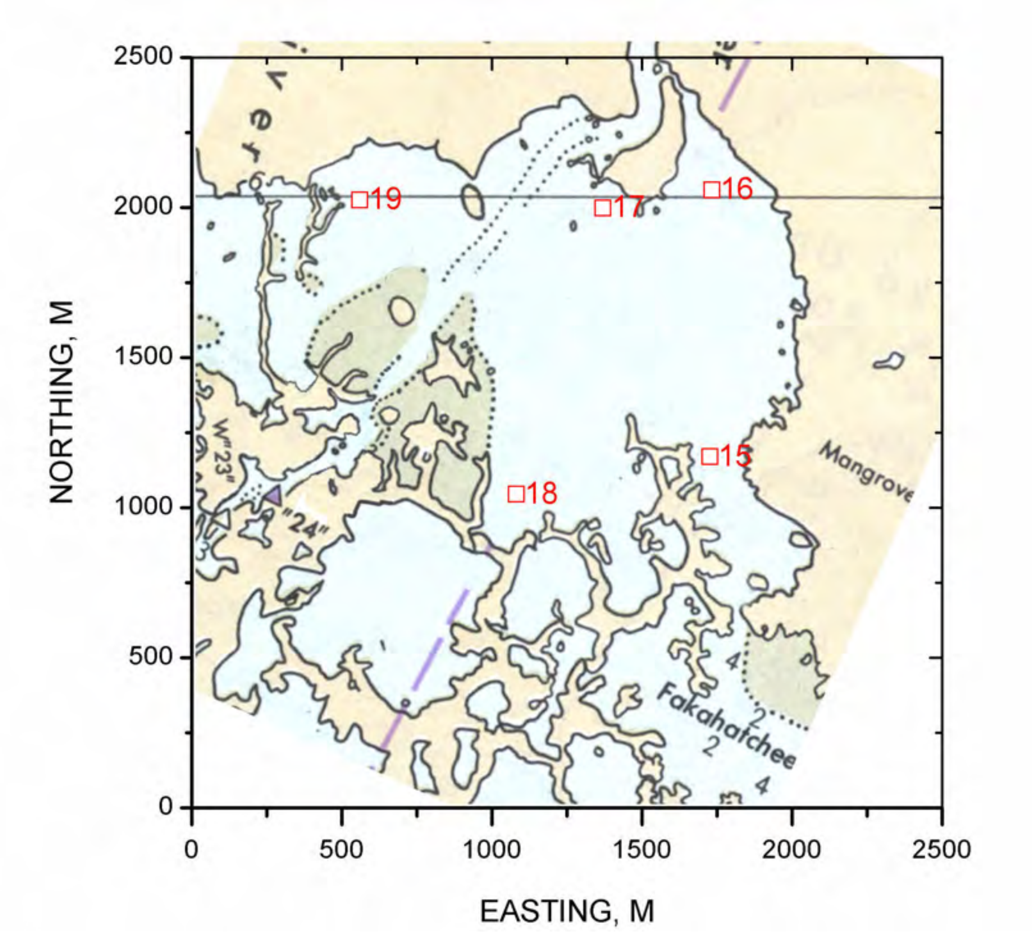


Fig. 1. Chart of Faka Union Bay with station locations.

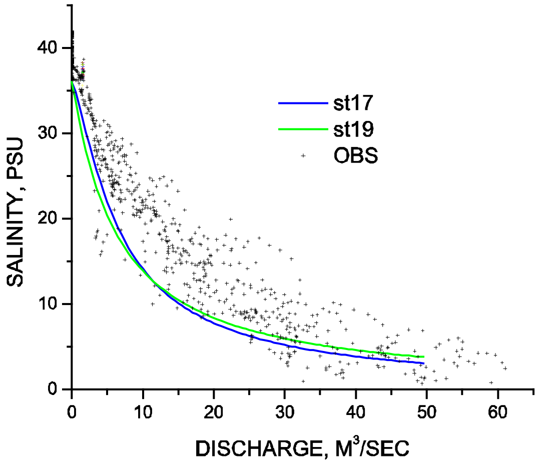


Fig. 2. Faka Union discharge and salinity from 2000 to 2002 study with 1982 to 1984 regression relationship for nearby stations 17 and 19.

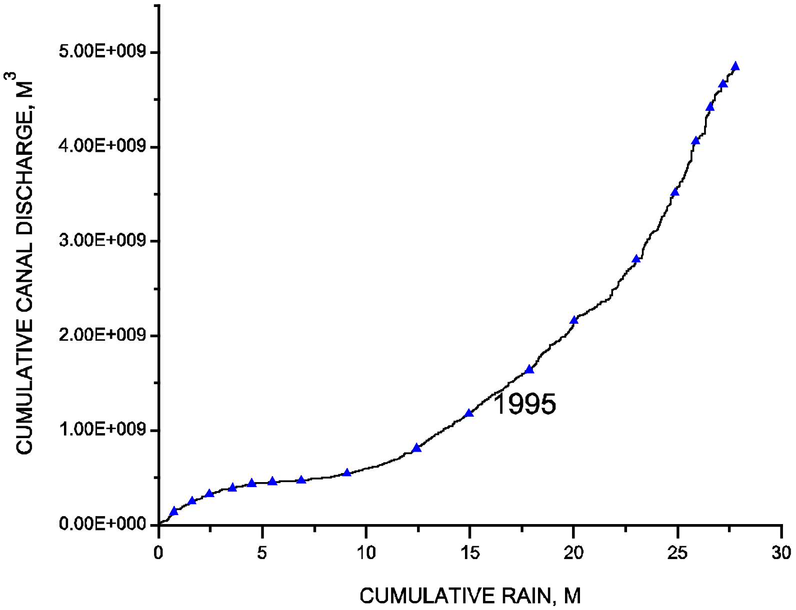


Fig. 3. Mass balance of cumulative rain vs cumulative Faka Union Canal discharge for year 1985 to 2002. The end of each year is indicated with a triangle.

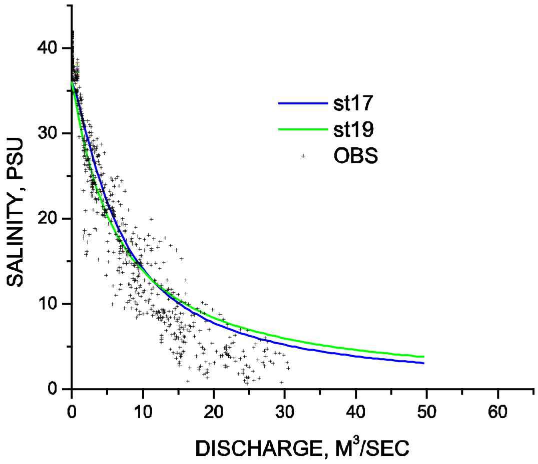


Fig. 4 Discharge and rainfall data with revised regression relationships.

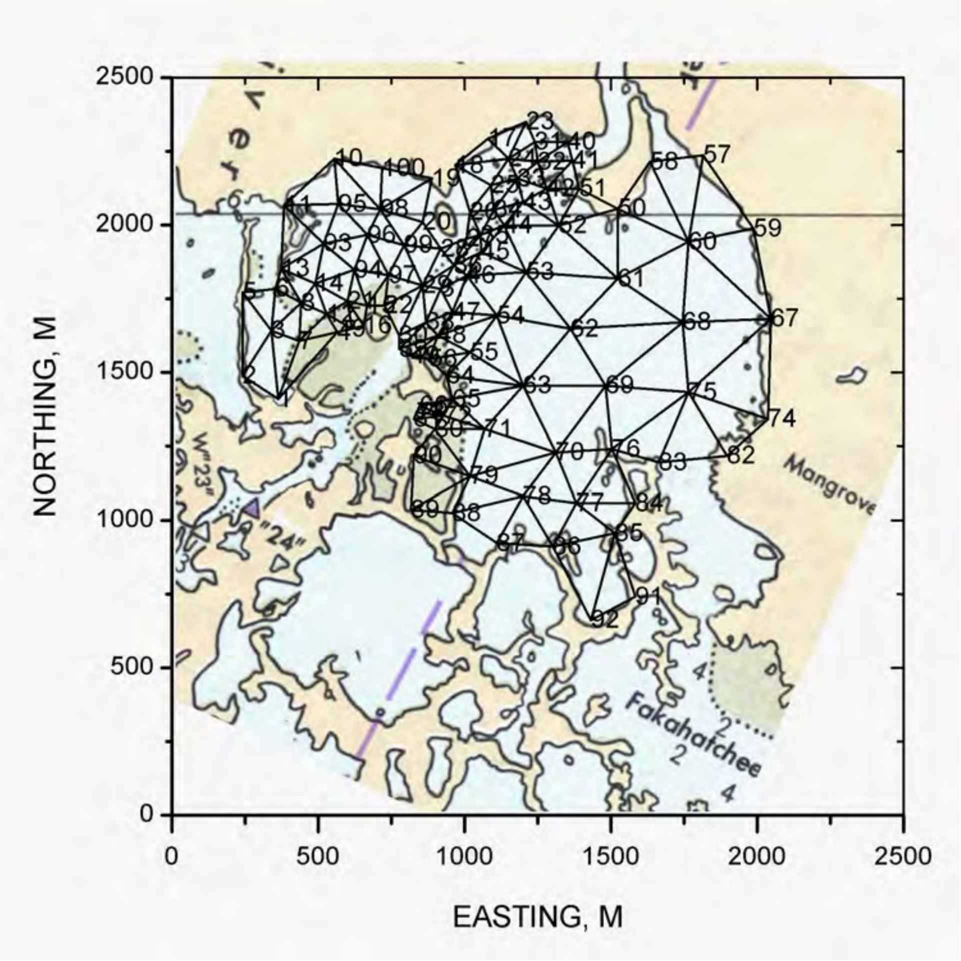


Figure 5. Model grid.

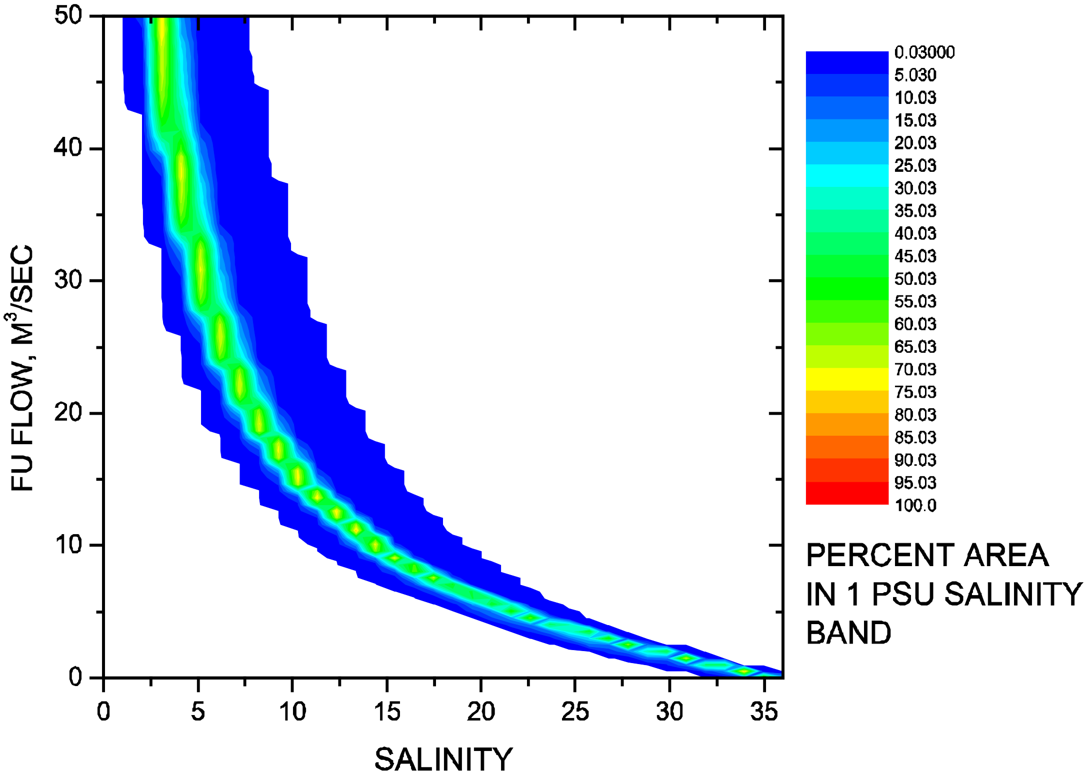


Figure 6. The percent of Faka Union Bay area with indicated salinity for given canal discharge.

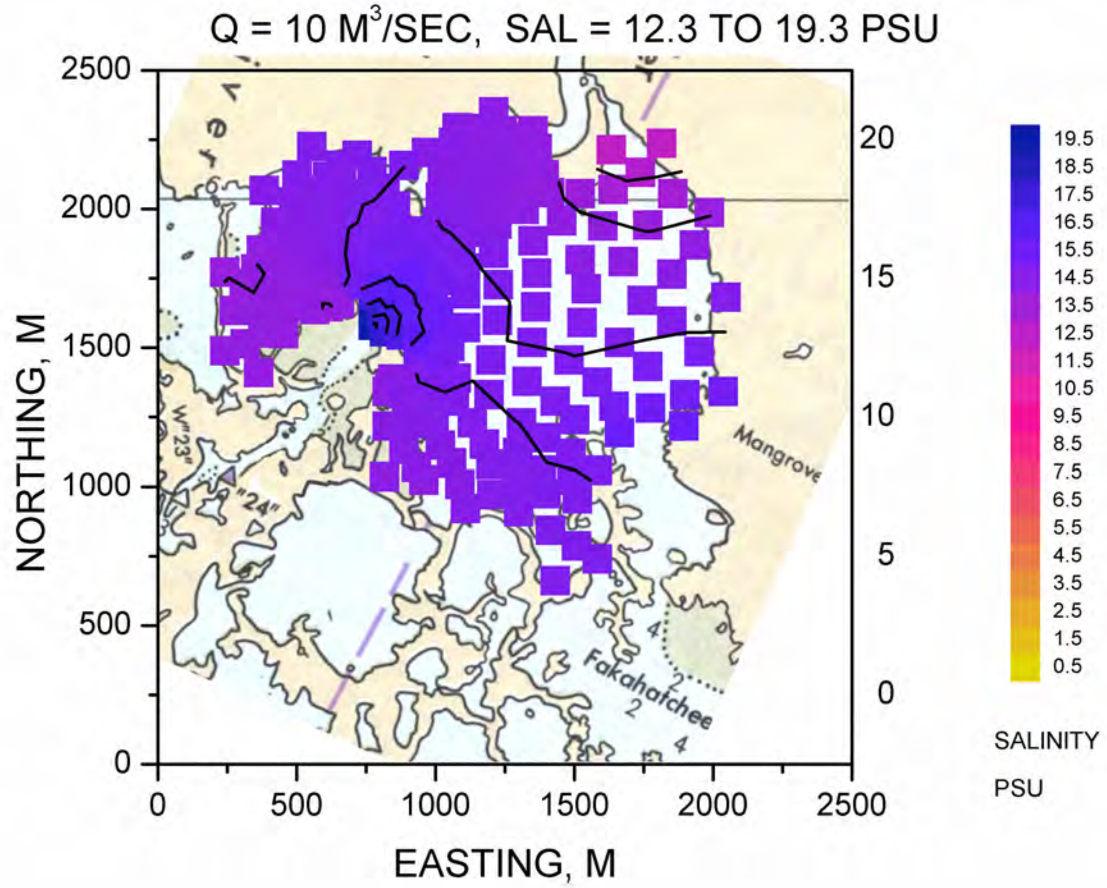


Figure 7. Model-computed salinity field for freshwater inflow of 10 m^3/s.

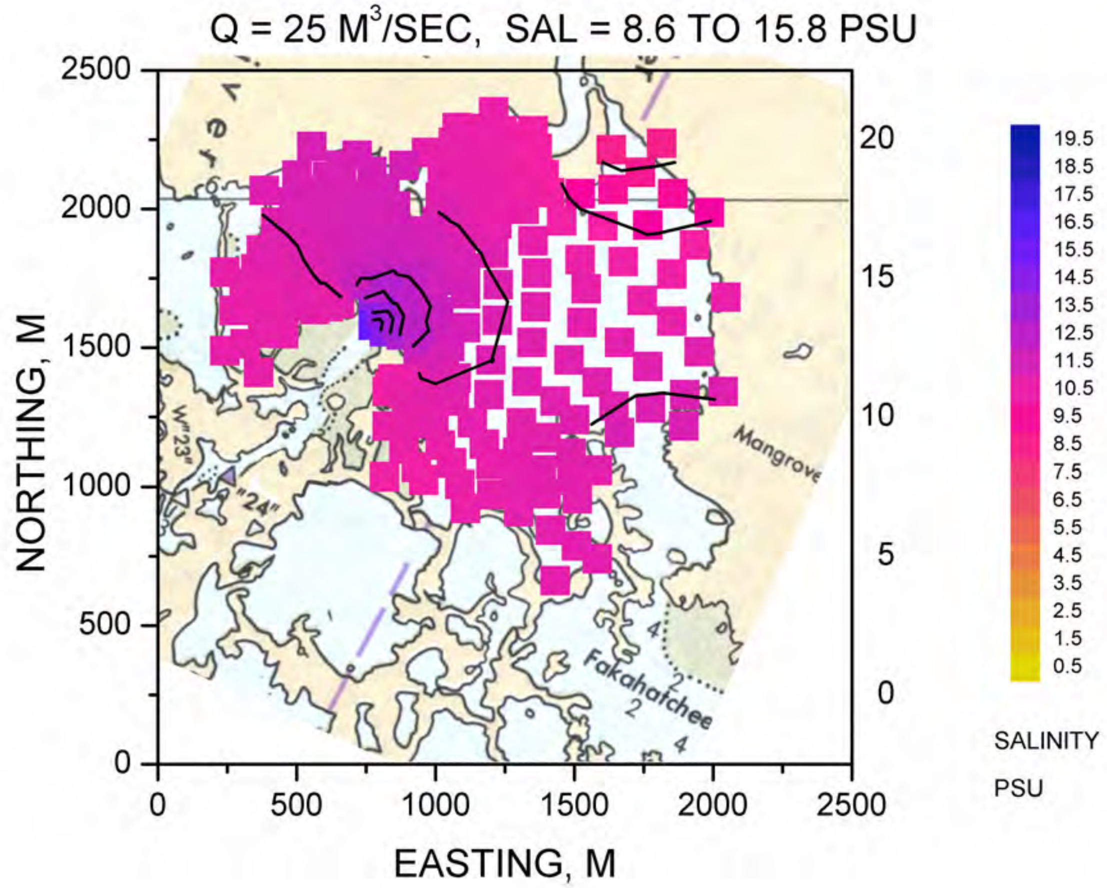


Figure 8. Model-computed salinity field for freshwater inflow of 25 m^3/s.

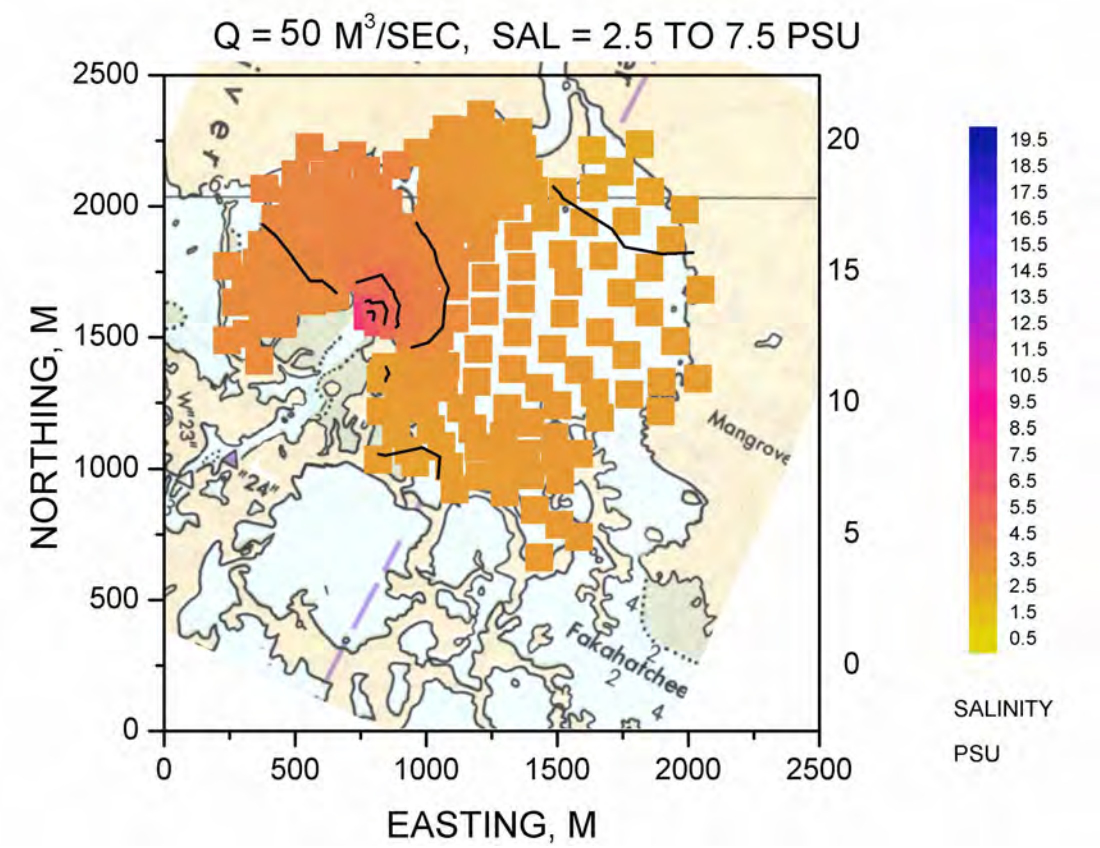
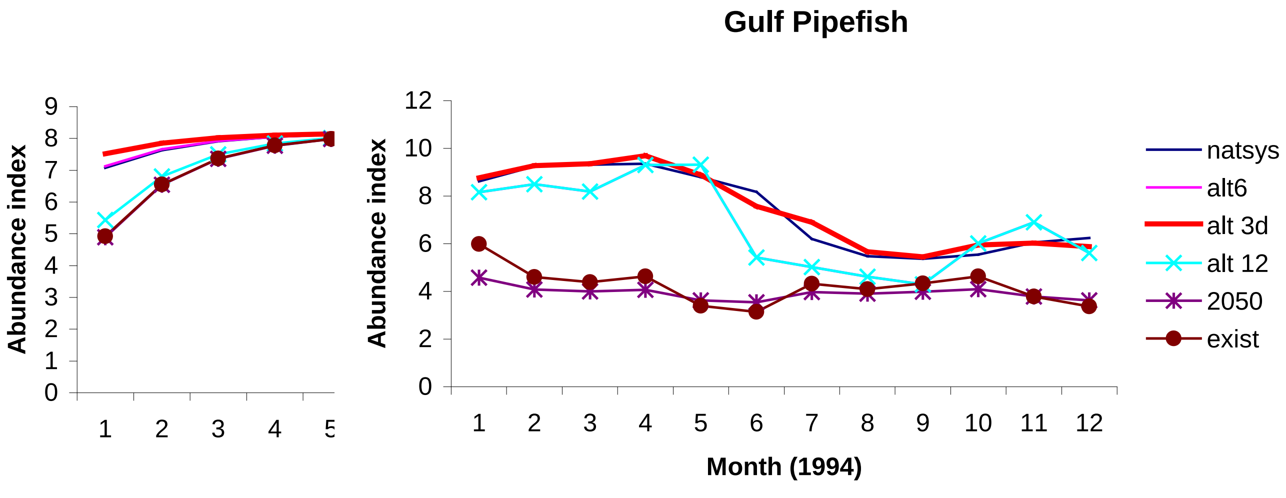


Figure 9. Model-computed salinity field for freshwater inflow of 50 m^3/s.



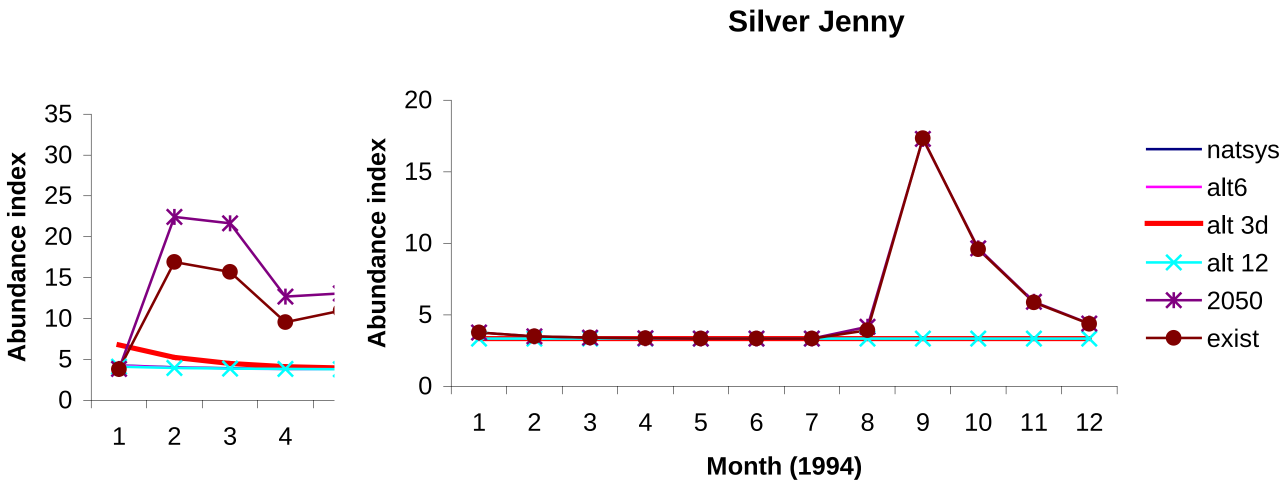


Figure 10. Monthly predictions of the index of abundance of four species in Faka Union Bay under six scenarios (natural system, existing, 2050 without, alternative 3D, alternative 6, and alternative 12) of predicted inflows and resultant salinity patterns, 1994.

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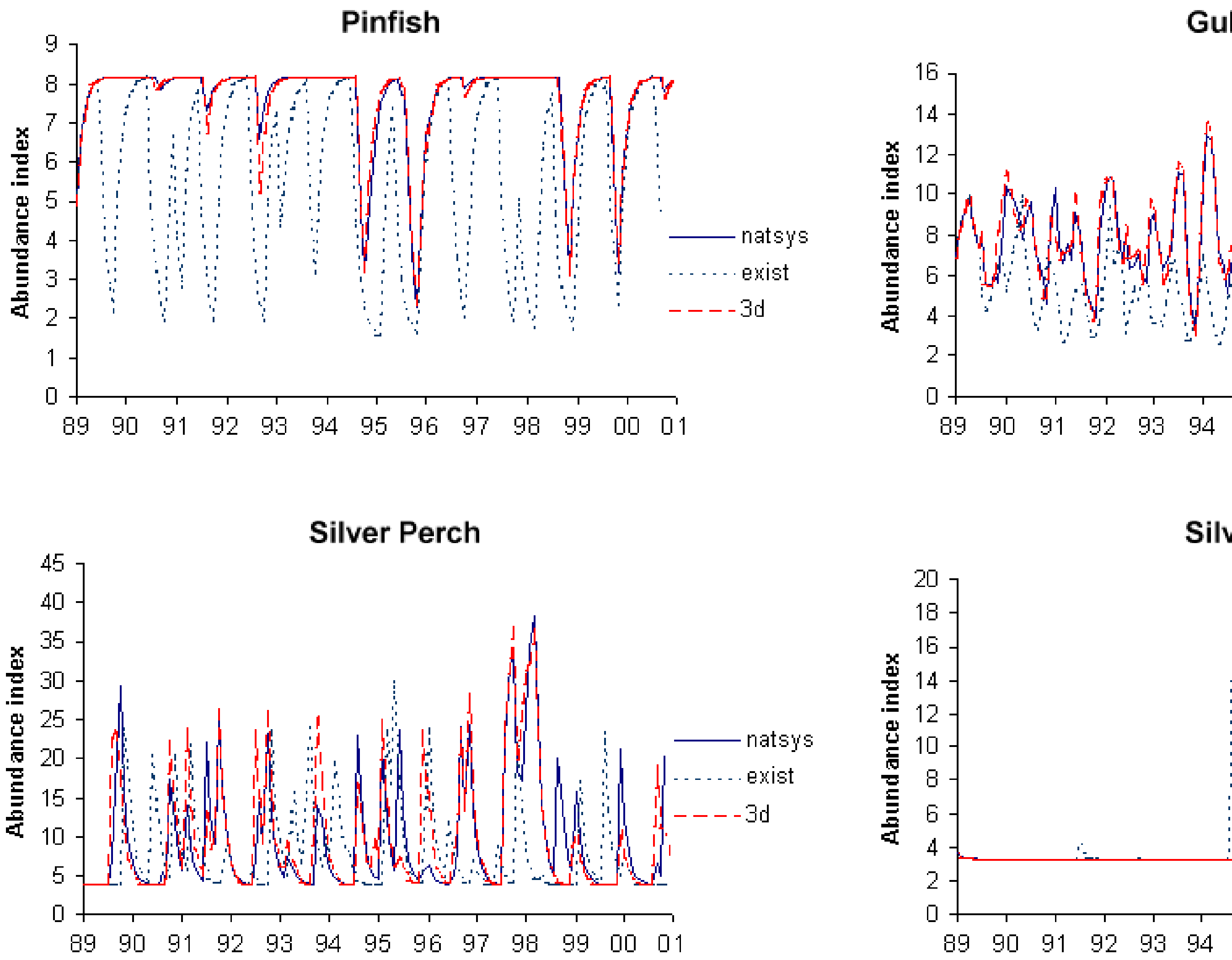

Figure 11. Monthly predictions of the index of abundance of four species in Faka Union Bay under three scenarios (natural system, existing, and alternative 3D) of predicted inflows and resultant salinity patterns, 1989-2000.

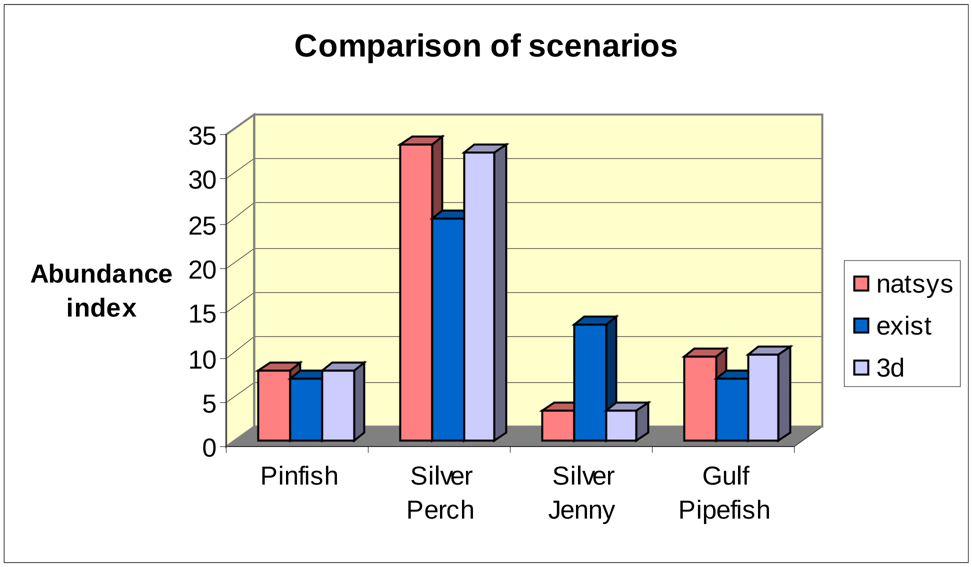

Figure 12. Average of the predicted monthly abundance index for each of four species in Faka Union Bay under three scenarios (natural system, existing, alternative 3D) of predicted inflows and resultant salinity patterns, 1989-2000.

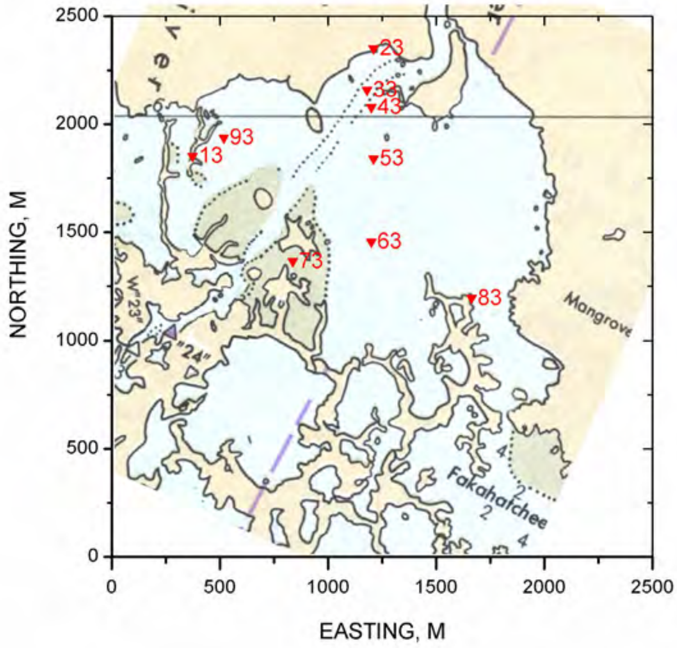

Figure C.1. Faka Union Bay with the 10 locations of salinity simulation indicated (with triangles) and numbered in red.

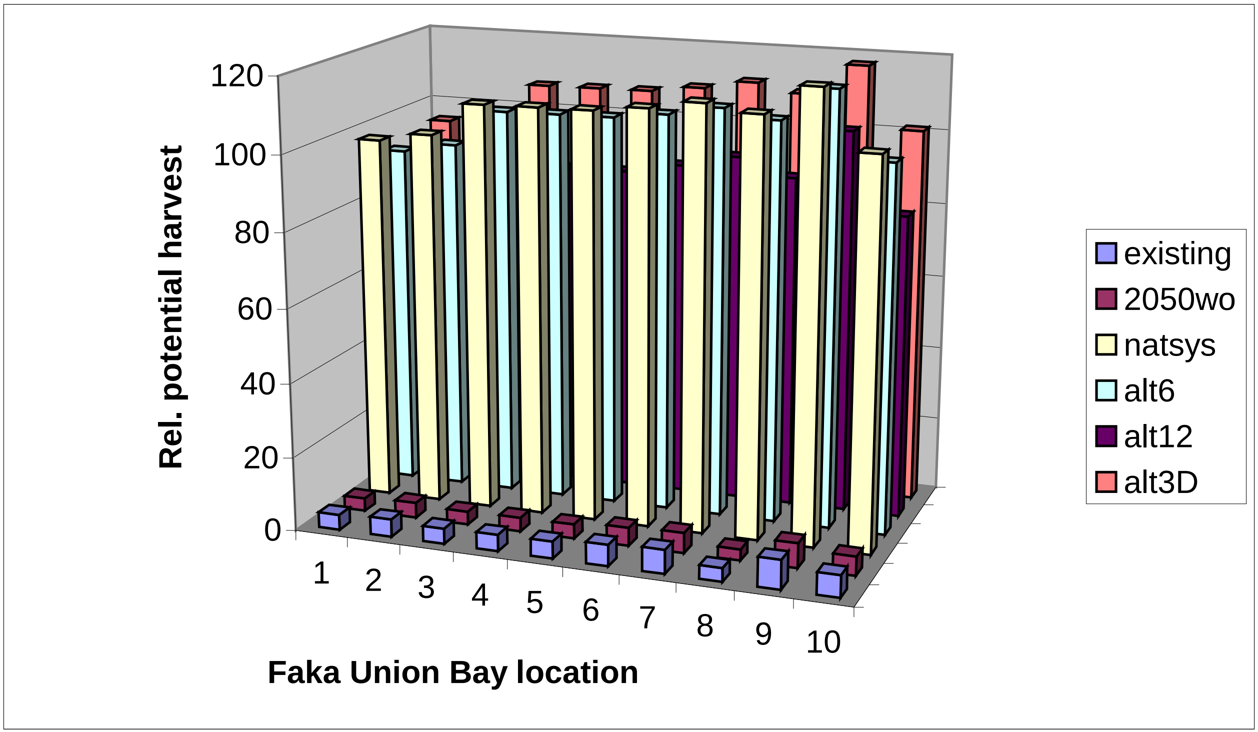

Figure C.2. Pink shrimp simulation model results: comparison of scenarios (relative potential harvest from July 1994 cohort).

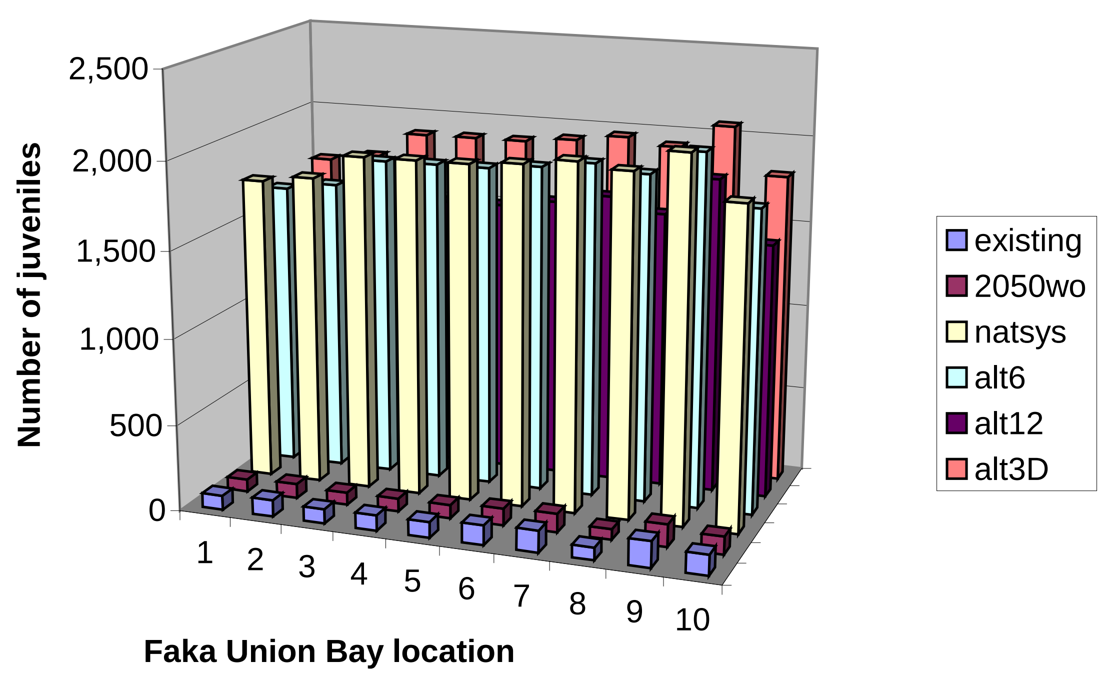

Figure C.3. Pink shrimp simulation model results of comparison of scenarios (relative number of juveniles in July 1994 cohort at 121 days from first settlement).

APPENDIX 1

Analysis of Freshwater Discharge at Faka Union Bay and Rainfall at Immokalee Time series in the Period 1985—2002

R. Garcia, J.D. Wang

RSMAS/AMP
University of Miami
4600 Rickenbacker Cswy.
Miami, FL 33149 USA

1. Introduction

Located in southwest Florida, Faka Union Bay receives high discharges from the Golden Gate Estates network of drainage canals [1]. In a previous study [2] the relationship between physical conditions in Faka Union Bay and canal discharges was analyzed. These authors analyzed in 1982-1984 the salinity distribution in the Bay as a function of Faka Union Canal discharges and derived regression relationships between canal discharge and salinity for several points in Bay. In recent years 2000 to 2003 additional data have been collected.

In this report, time series of daily values of freshwater discharge into the Faka Union Bay and rainfall at Immokalee in the period 1985-2002 are analyzed to determine whether the relationship between recorded canal discharge and Bay salinity has changed. The source of the data analyzed here are available from the South Florida Water Management District (SFWMD) webpage www.sfwmd.gov. Rainfall data, measured in inches, were taken at IMMOKA 2_R station (DBkey: 06082), from January 1, 1985 through December 31, 2002. Immokalee station appeared to provide the most complete dataset among the stations of the area. It also provides the only rainfall records available in the last three years. Discharge data, in cubic feet per second, were obtained at Faka Union Canal (DBkey: 05362) at weir #1 (U.S. 41 near Copeland), during the same period of rainfall data.

2. Analysis

Figure A1.1 depicts annually averaged daily discharge and rainfall time series for the period 1985 to 2002. A least squares fit to these data is performed and represented by the black curves. It represents the sums of the mean value plus annual and semiannual harmonics, with the 5-parameter model in the form

$$A+B*\cos(wt-Fi1)+C*\cos(2wt-Fi2)$$

Here t is the day of the year, and 2pi/w is equal to one year. The values of these parameters for the rainfall data are: A=.4225, B=.3115, C=.1113, Fi1=-2.8045 and Fi2=1.0378. For the annually averaged daily discharge these parameters are: A=8.5394, B=9.379, C=2.8596, Fi1=-1.7822 and Fi2=2.3312.

The shaded area around the black curves represent a one standard deviation uncertainty which only accounts for the goodness of the fit (it does not include data errors or other sources of random errors [3]). The annually averaged daily discharge record shows a clear seasonal cycle (the explained variance of the fit is about 95 %). The variance explained by the fit of annually averaged daily rainfall data is much smaller (about 45 %).

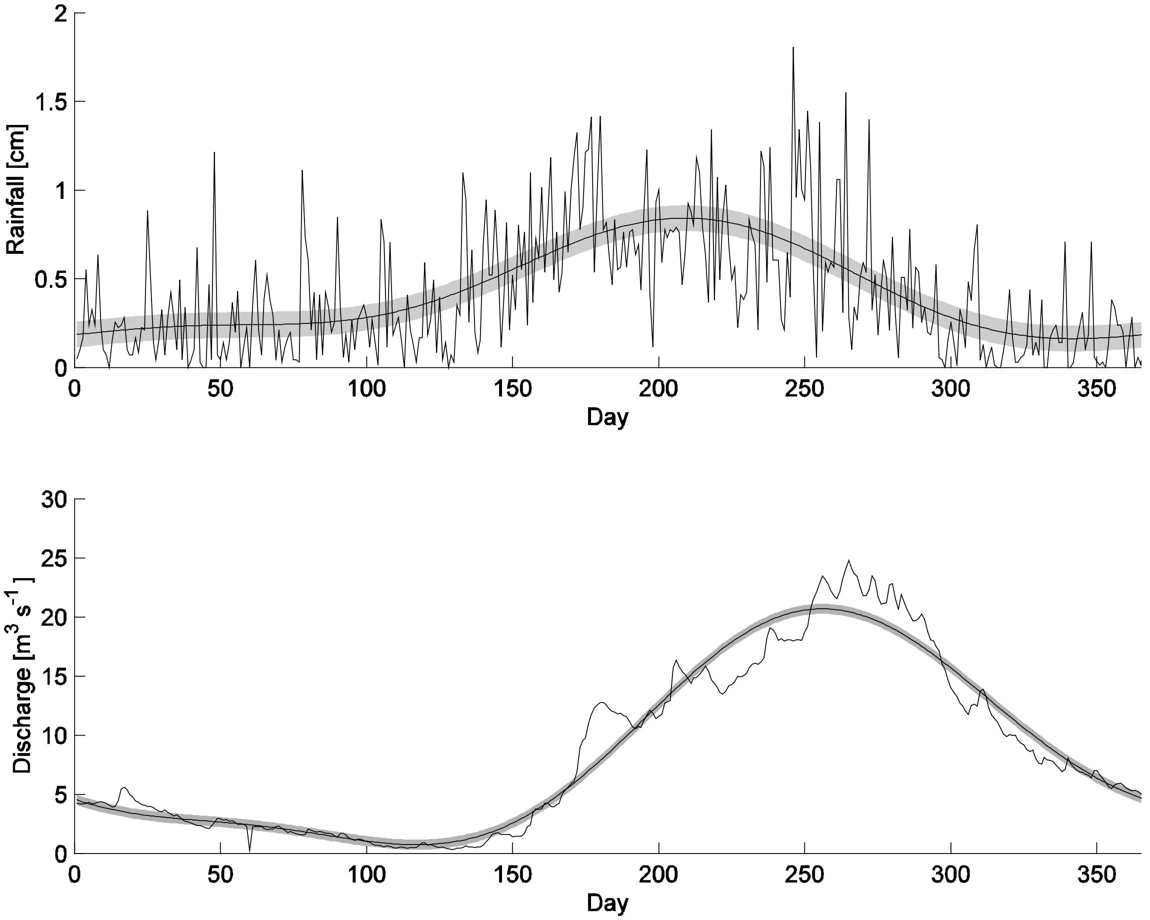

Figure A.1.1. Annually averaged daily discharge (upper panel) and rainfall (lower panel) time series for the period 1985 to 2002

Figure A1.2 depicts time series of annual average rainfall and discharge. The figure is interesting because it shows the tendencies over time of the variables considered in this study, indicated by dashed line in both panels. These tendencies were obtained by fitting a straight line, y = ax + b, to the data in a least-squares sense.

The discharge record (lower panel) shows oscillations superimposed on a linear trend with positive slope. For this clear tendency of the discharge to increase over time, we obtain: a=.3126 and b=-614.2917.

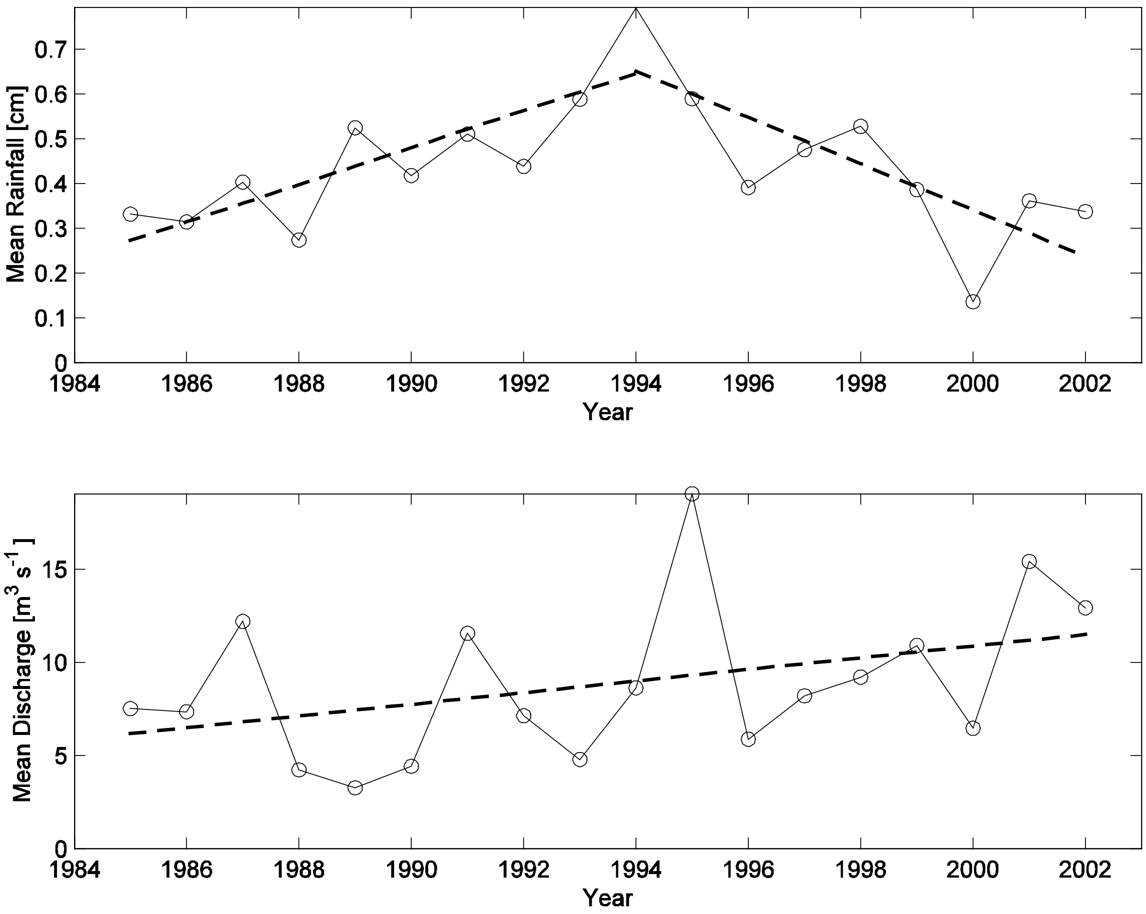

Figure A1.2 depicts time series of annual average rainfall (upper panel) and discharge (lower panel).

Another way to test whether the canal discharge has been altered during the selected period is showed in Figure A1.3, where cumulative discharge vs. cumulative rainfall is presented. The year 1995 again is observed to separate two different regimes. The tendency of the data, after fitting a straight line, y = ax + b, is indicated by the dashed lines in the figure. In this case the coefficients of the fitting line before 1995 are: a= 1.2538, b= 246.4860, and after 1995 are: a= 2.20, b= -141.85. x is in cm, and y is in million m3.

The slopes of these two lines allow us to quantify the relationship between cumulative rainfall and cumulative discharge as follows: In the period 1985-1995 approximately 125x10^6 m^3 of freshwater discharged into the Faka Union Bay per 100 cm of precipitation. In contrast, from 1995 through 2002, approximately 220x10^6 m^3 of freshwater was observed to discharge into the bay per 100 cm of precipitation. This represents a 43 % increase in discharge when normalized by the amount of rainfall.

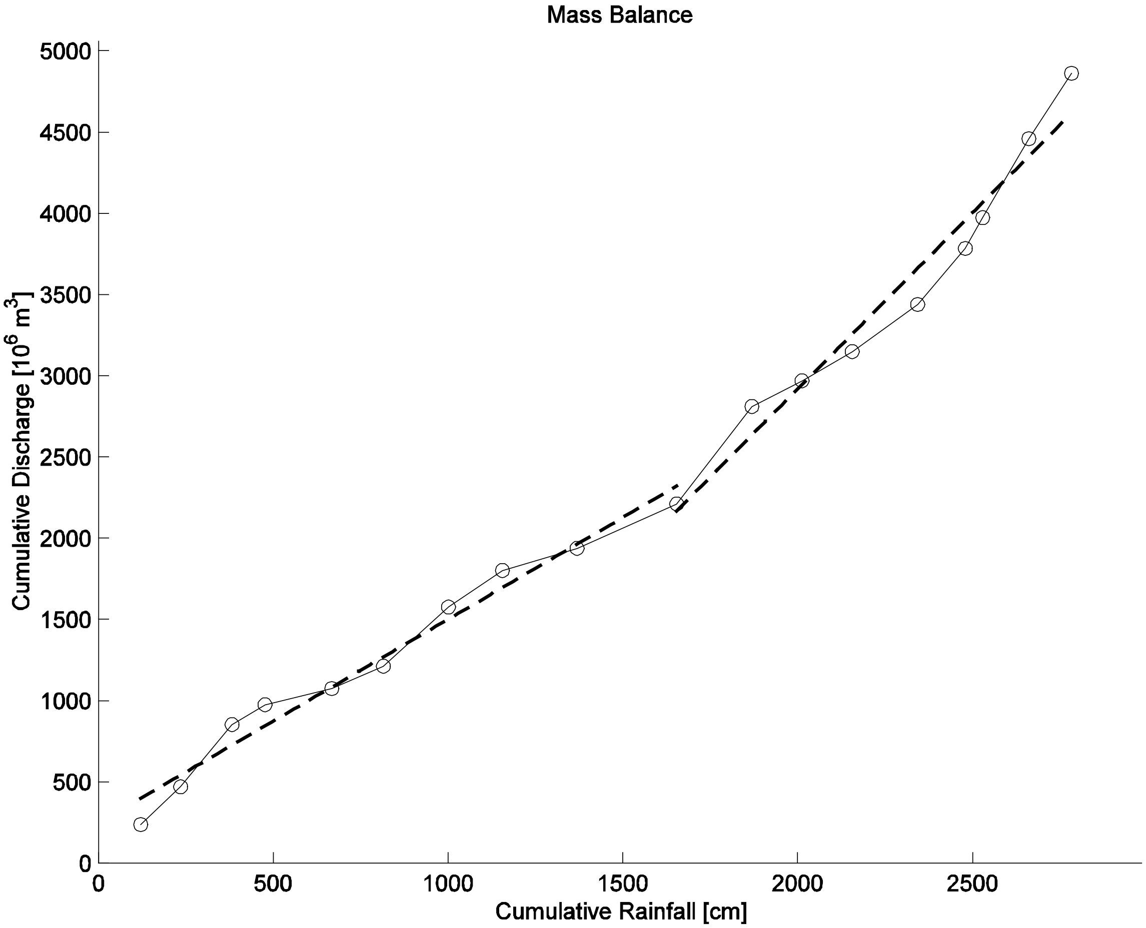

Figure A1.3. Mass balance curve (cumulative discharge vs. cumulative rainfall).

3. Conclusions

The data analyzed here confirm the previously observed tendency of the discharge of the Faka Union Canal into the Faka Union Bay to increase. This increase, however, cannot be explained with available rainfall data only.

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APPENDIX 2
A2.1. Biological Models
Joan A. Browder

The biological models used to conduct the analysis were developed by Browder and Wang (1988) based on biological data from Browder et al. (1986). Abundance indices for Faka Union Bay were developed for each month as a function of catches at the five stations, as follows: $AI = \Sigma \ln(C_i)$, where C is the station catch and i goes from 1 to 5. The catch at each station was from four tows, two surface tows and two bottom tows. The tows were standardized (3.7 km/hr for 2 min). The time series was for 21 months (the first three months of data were excluded because of insufficiencies in the initial sampling gear).

Monthly AI was analyzed in relation to the area of the bay within each 3 ppt salinity band (from 0-3 ppt through 33-36 ppt), as predicted by the Wang hydrodynamic model (Wang and Browder 1986). Salinity bands were used in models one at a time to avoid collinearity. One or more autoregressive terms (time lags of AI) were included in the model to account for seasonal factors or density dependent effects. One model for each species was selected from the series of models that were tested. Selection was based on the coefficient of determination (r2) and other criteria of reliability. Generally the model with the highest r2 was selected unless another model with relatively high r^2 had fewer autoregressive terms.

Nine models were developed, five for fish species (bay anchovy, *Anchoa mitcilli*; pinfish, *Lagodon rhomboides*; silver perch, *Bairdiella chrysoura*; and silver jenny, *Eucinostomus gula*; and gulf pipefish, *Syngnathus scovelli*), and four for macroinvertebrate taxa (pink shrimp, *Farfantepenaeus duorarum*; blue crab, *Callinectes sapidus*; grass shrimp, *Palaemonetes* spp.; and the Texas mud crab, *Neopanope texana*. The selected models explained 17-85% of variation in AI. From 11-49% of variation in AI was explained by salinity-band-area alone.

Models for four of the five fish species (pinfish, silver perch, silver jenny, and gulf pipefish) were validated with independent data from Pumpkin Bay, and one of these was also validated with independent data from Fakahatchee Bay. The validation exercise was handicapped by the lack of hydrodynamic models for Fakahatchee and Pumpkin bays to establish isohalines for estimating salinity-band areas at the time that biological samples were collected. As a substitute, observed data from the five stations in each of the bays (measured by Browder et al. 1986) were used to approximate isohalines from which salinity-band areas were calculated. For Fakahatchee Bay, isohalines in Carter et al. (1973) were used to help construct likely isohaline configurations. Using these salinity-band-areas, an AI was predicted for each month with the models that had been developed for Faka Union Bay. The predictions were then compared, by means of correlation analysis, to the AI in the observed data. Significant correlation ($p<0.1$) between the two data sets, indicating that they varied similarly over time, was taken as validation. Results for these same four models also were consistent with results from Browder et al. (1986) and Colby et al. (1985). These four models (Table A2.1.1) were used to make predictions concerning Southern Golden Gate scenarios. See Browder and Wang (1988) for more details of the models.

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II.B. Habitat and Salinity Relationships of the Four Faka Union Species with Models

Joan A. Browder and Darlene R. Johnson

A brief review of the literature was conducted to determine the known information about the habitat and salinity affinities of the four species that were the subject of the Faka Union models. The purpose was to provide background and perspective on model structure (especially the salinity band included as an independent variable in the model) and predictions. We relied heavily on the NOAA species synopsis by Pattillo et al. (1996) for pinfish and silver perch and consulted the wider literature for information on Gulf pipefish and silver jenny, which were not included in the NOAA synopsis.

Pinfish (*Lagodon rhomboides*)

The pinfish (*Lagodon rhomboides*) is an estuarine dependent species that is numerically dominant in the shallow subtidal seagrass communities of the Gulf of Mexico. It is typically non-schooling but has been reported in aggregations. It is a voracious predator on amphipods, but also feeds on plants and detritus. Other reported food items include fish eggs, insect larvae, decapod crabs, bivalve mollusks, and polychaetes. Pinfish are an important prey species of spotted seatrout (*Cynosion nebulosus*), ladyfish (*Elops saurus*), red drum (*Sciaenops oscellatus*), Gulf flounder (*Paralichthys albigutta*), southern flounder (*Paralichthys lethostigma*), and bottlenose dolphin (*Tursiops truncatus*) (Pattillo et al. 1996).

Pattillo et al. (1996) provided an overview on the seasonality of spawning and salinity and habitat affinities of this species. Spawning is thought to take place in the fall and winter. Eggs are marine and neritic. The distribution of larvae suggests offshore spawning. Larval pinfish occur in the Gulf of Mexico from October through April with peak abundance in December through February. Larvae move into estuaries when they reach a total length of 11 mm. Larval development is complete by 12 mm SL. Juveniles move up the estuary during spring and summer, while growing from 15 mm TL (12 mm SL) to 100 mm TL. They are common over seagrass. Sexual maturity occurs between 80 mm and 100 mm TL. This is a euryhaline species. Pinfish as a group (without regard to life stage) are said to tolerate salinities from 0 to 43.8 psu. There may be ontogenetic changes in salinity preference, with juveniles at lower salinities than adults, which may prefer euhaline conditions. Heavy rains reducing salinities to 4 psu have been reported to decrease the abundance of pinfish in a seagrass bed. A study by Subrahmanyam and Coultas (1980) positively correlated pinfish abundance with salinity. The oxygen-carrying capability of pinfish blood is affected by salinity and is greater at higher salinities.

Pinfish are commonly caught in recreational fishing and are a bycatch of some commercial fisheries (e.g., bait shrimp, hook and line, cast net). Although excellent eating, the species is not widely consumed because of its relatively small size (to 35 cm TL but usually less than 20 cm TL).

Silver Perch (*Bairdeilla chrysoura*)

The silver perch (*Bairdeilla chrysoura*) is an estuarine-dependent species, and most spawning occurs in estuaries. Eggs and larvae are pelagic, juveniles and adults are demersal. Abundant in some estuaries, this smaller drum (sciaenid) species consumes a diet largely of crustaceans (with some polychaetes and nematodes) and probably is an important food source of many predators. Reported predators include spotted seatrout and king mackerel (*Scomberomorus cavalla*). Juveniles occur mostly in estuaries in a variety of habitats, including backwater areas, tidal tributaries, and bare bottom areas, but they appear to prefer shallow seagrass areas. Adults, although most common in bays and quiet lagoons, also can be found in the Gulf of Mexico at depths up to 18 m.

According to Pattillo et al. (1996), all life stages appear to prefer polyhaline to euhaline conditions. Eggs have been collected at 14.3 to 26 psu. Larvae have been collected in salinities from <1 to 37.4, although most occurred at salinities <10 psu. Juveniles have been taken in salinities as low ask 0 psu, but they are most abundant at >20 psu. Adults have been found in salinities ranging from 0 to 48 psu but appear to prefer those parts of the estuary characterized by moderate to high salinities.

Adults move to deeper bay waters and offshore in winter and return t o coastal lagoons in the spring to spawn. Juveniles move into the shallow inner bays and then, as they grow, move back to deeper waters, especially during winter. Some year-round spawning seems to occur in South Florida. Spawning peaks may occur in spring and late summer. The juvenile stage is attained at 10-12 mm TL. By 15 mm, fin rays are fully developed. By 30 mm SL, juveniles have the body form of adults. Silver perch reach sexual maturity in the first year in South Florida. Maturity in males and females occurs by 95 mm SL. Maximum size is about 240 mm TL. This species may live up to 6 years.

Gulf pipefish (Syngnathus scovelli)

Pipefish are extremely slender and elongated fish with armored bodies and are related to the seahorses. The Gulf pipefish is a short-snouted species that grows to 175 mm (7 inches). It is found primarily in shallow inshore waters but also at depths of up to depths to 345 m (1135 ft) (Robins et al.1986). This species also enters fresh water. The gulf pipefish is the most common pipefish along the Gulf of Mexico and eastern Florida (Brown 1972). It is the commonest pipefish in Tampa Bay (Springer and Woodburn 1960) and the Indian River (Brown-Peterson and Eames 1990). It is also common in Florida Bay, along with other pipefish species (Matheson et al. 1999, Thayer et al. 1999). It is common as far north as Georgia (Targett 1984). Spawning is thought to occur primarily in summer and fall (Dokken et al. 1984). Gulf pipefish are most abundant in catches in spring and summer (Sheridan 1997, Tremain and Adams 1995, Brown-Peterson et al. 1993).

Brook (1977) reported that gulf pipefish in Card Sound fed mainly on amphipods, isopods, and tanaids. In Tampa Bay, Motta et al. (1995) reported that amphipods were the main food source, and Tipton and Bell (1988) reported that Gulf pipefish eat amphipods, crustacean eggs, harpacticoid copepods, and shrimp.

The usual habitat for this species is shallow seagrass beds. Highest densities in the Laguna Madre (Texas), Indian River, and Florida Bay have been reported in *Syringodium* and *Halodule* (Tolan et al. 1997; Stoner 1983; Sheridan 1997). Several studies in the Indian River have found them positively associated with drift algae biomass (Snelson 1980; Kulczychi et al. 1981). A shift in habitat may occur seasonally or with life stage. Tolan et al. 1997 found that densities in winter and fall were higher in *Syringodium*-dominated/mixed seagrass beds compared to *Halodule* or unvegetated sites, but, in the summer, highest numbers were in *Halodul*e. They are also found in *Thalassia* and are caught in mud habitats (Sheridan 1997). They were reported absent in mangrove areas of Florida Bay (Sheridan 1992; Lorenz 1999). Ley et al. (1999) reported catching them in the northeast part of the Bay, but they were not one of the dominant species of this habitat. A breeding population exists in a Georgia salt marsh habitat with no seagrasses (Targett 1984).

The pipefish is a euryhaline species that regularly utilizes freshwater areas (Whatley 1962, Targett 1984). The species has been reported common in fresh water to hypersaline waters up to 45 psu (Simmons 1957; Whatley 1962; Roessler 1967). An isolated population has been reported from Lake St. John, a freshwater lake 150 miles inland from the Louisiana coast (Whatley 1962, 1969) and has been found in the St. Johns River in northern Florida (McLane 1955). In the Ten Thousand Islands/Fakahatchee Strand, Carter et al. (1973) found gulf pipefish in four habitats--beaches and adjacent water, bays, tidal streams, and tidal canals, although not in freshwater lakes or canals.

Like the related seahorse, the female pipefish lays her eggs in the brood pouch of the male, where the eggs are fertilized and incubated. Quast and Howe (1980) reported that brood pouch osmolality is regulated near osmolality of the father through incubation, perhaps to protect developing embryos from osmotic extremes. This allows the larvae to develop efficiently in any aquatic environment acceptable to the adults.

Snodgrass (1992) reported that gulf pipefish density in the Indian River was determined by (in order of importance) vegetation biomass, depth, dissolved oxygen, pH, and salinity. Rydene and Matheson (2003) reported that, in the Little Manatee River, density was highest in a seagrass habitat with moderate seagrass cover, followed by a drift algae habitat with moderate algae biomass. Temperature and salinity were also factors influencing density. Clark (1970) reported that abundance was higher in higher salinity areas of Whitewater Bay in Everglades National Park and that the most important variables in predicting abundance were runoff, temperature, rainfall, and vegetation.

Silver Jenny (*Eucinostomus gula*)

The silver jenny is one of the most abundant mojarras in the waters of Florida (Reid 1954; Springer and Woodburn 1960; Tabb and Manning 1961; Christensen 1965; Gunter and Hall 1965; Roessler 1967; and Low 1973). This is a species of shallow water habitats that is especially abundant over mud bottoms in mangrove-lined lagoons or creeks (Roessler 1967, Aiken et al. 2000, Froese and Pauly 2004). Larger individuals may also occur on vegetated sand grounds in marine areas (Froese and Pauly 2004). A member of the family Gerreidae, the silver jenny grows to 180 mm (7 inches) and sometimes occurs in aggregations.

The silver jenny feeds on small benthic organisms. Aiken et al. (2000) described the silver jenny as a zoobenthivore. In Biscayne Bay, the diet of this species was primarily polychaete worms (54%) and peracaridean crustaceans (25% amphipoda, tanaidacea, isopoda) (Charles 1975). Smaller individuals fish fed on harpacticold copepods. Brook (1977) reported similar food sources—ampipods, copepods, and polychaetes—in Card Sound. Schmidt (1993) found that the silver jenny in Whitewater Bay fed on polychaetes (44%), crustaceans (47%, consisting of isopods, amphipods, and tanaids), and mollusks (24%). Fish <29 mm in length consumed mostly hydroids and copepods, and fish >29 mm in length fed heavily on polychaetes. Silver jenny use their extremely protrusible mouths to bite or suck their benthic prey from the substrate. They have also been observed burying their mouths in the sand, spouting sediment through the mouth and gills, to obtain their prey (Cyrus and Blader 1982; Zahoresak et al. 2000).

Silver jenny are found year-round in South Florida estuaries (Roessler 1967), Brown-Peterson and Eames 1990, Schmidt 1993, Tremain and Adams 1995). They may be most abundant in the summer and fall (Roessler 1967, Charles 1975, Brown-Peterson et al. 1993, Tremain and Adams 1995), when smaller individuals dominate the catch (Clark 1970, Weinstein et al. 1977). On the other hand, Fraser (1997) reported they were most abundant in Charlotte Harbor in the fall and early winter and least abundant from late winter through summer. A major spawning peak is thought to occur in the spring (Charles 1975; Yokel 1975). Another spawning peak may occur in the late fall (Charles 1975, Weinstein et al. 1977). Larger individuals (e.g., >70 mm) may leave the estuary to spawn (Hildebrand 1955, Clark 1970, Charles 1975, Yokel 1975).

The habitat of this species includes mangrove prop-roots and mud, *Halodule*, *Syringodium*, and mud and algae. Sheridan (1992) found that silver jenny were associated with mangroves in Rookery Bay. In Jamaica, this species is associated with areas near mangrove prop-roots and mud (Aiken et al. 2000). Kerschner et al. (1985) reported that the species was most frequently taken in *Halodule* (size range 10-109 mm) in the Indian River. Smaller fish were more abundant in seagrass, and larger fish were more abundant near the inlet. Sheridan (1997) found highest densities in Florida Bay in *Halodule*, followed by mud and algae habitats, and lowest densities in *Thalassia.* In the Indian River, Stoner (1983) found highest density associated with *Halodule*, followed by *Syringodium*, and lowest density in *Thalassia*. Rydene and Matheson (2003) reported that the density of silver jenny in Little Manatee River was highest in seagrass of moderate density. Clark (1970) reported that differences in catch rates appeared associated with vegetation density. Stoner (1983) reported that the density of silver jenny was not correlated to seagrass biomass in Apalachee Bay. In Charlotte Harbor, distribution was linked to dense algal concentrations (Wang and Raney 1971).

The silver jenny is tolerant of extreme low salinity, as the species is known to enter fresh water in limestone regions (Robins et al 1986). Fraser (1997), using principal component analyses, found silver jenny density in Biscayne Bay was related to dissolved oxygen/temperature, lunar cycle, and freshwater flow/salinity. He found that the lower the salinity, the higher the abundance of silver jenny. On the other hand, other available information does not suggest that this species is particularly favored by low salinity. Peaks in the abundance of Marco Island fish coincided with maximum salinity and water temperatures (Weinstein et al. 1977). The density of silver jenny in Florida Bay was reduced by one third in the 1990s, when salinities were reduced by 4 ppt, compared to the 1980s (Thayer et al. 1999), and Sogard et al. (1987) found the highest densities in parts of Florida Bay nearest to the Gulf of Mexico and the Atlantic Ocean. Serafy et al. (2004) found no difference in Biscayne Bay densities between mainland sites and barrier island sites for 3 of the 4 seasons, even though large differences in mean seasonal salinities (mainland always lower) and salinity variation were evident. However, barrier island sites had larger fish (>60 mm) than mainland sites (20-60 mm). Clark (1970) reported that there was little relation between catch rates of silver jenny in Whitewater Bay and changes in environmental conditions. Waldinger (1968) found that silver jenny catches in the Buttonwood Canal were related to rainfall and water levels in two wells (surrogates of freshwater inflow), however the direction of the relationships was mixed (ie., positive with rainfall and negative with well level (possibly confounded by inclusion of these three likely correlated independent variables in the same equation).

Other environmental factors may also affect the density of the species. Fraser (1997) noted that the silver jenny was rarely caught below 3.1-4 mg/liter of dissolved oxygen. Rydene and Matheson (2003) found density in the Little Manatee River was related to temperature.

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