Project Title: SFERPM 2000: Linking Everglades Restoration and Enhanced Freshwater Flows to Elevated Concentrations of Mercury in Florida Bay Fish

Grantees: NOAA/NOS/NCCOS /Center for Coastal Fisheries and Habitat Research Beaufort and South Florida Water Management District

Award Period: From 08/01/00 To 07/31/02

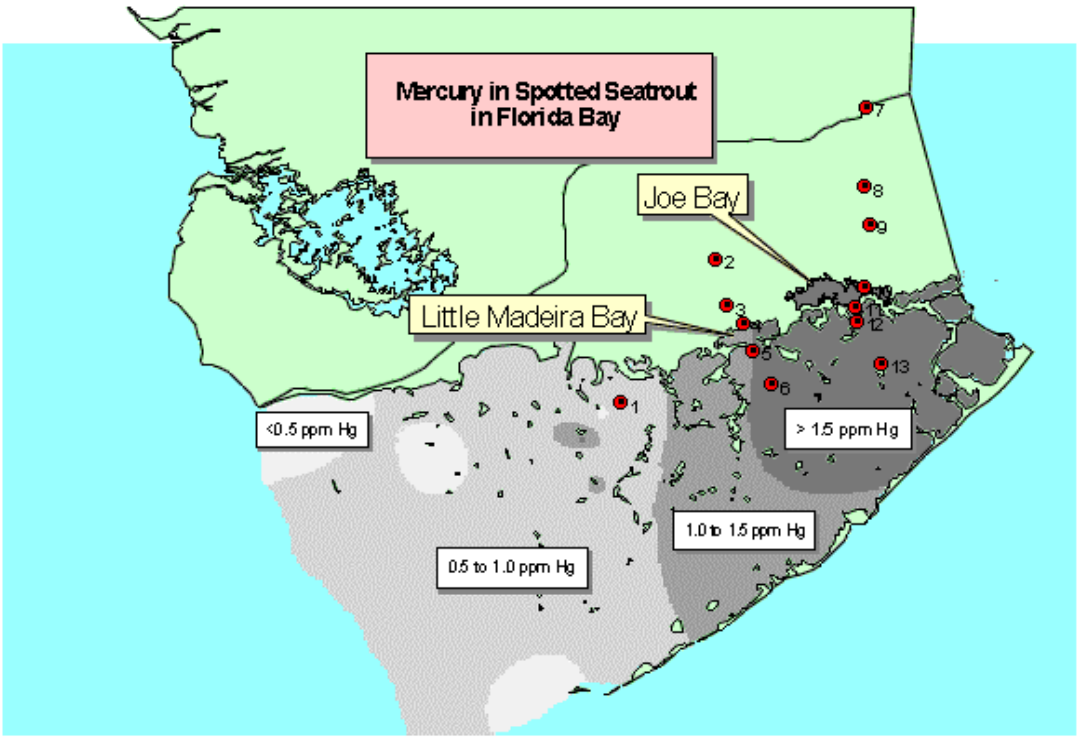
Period Covered by this Report: From 08/01/01 To 05/01/01

Summary of Progress:

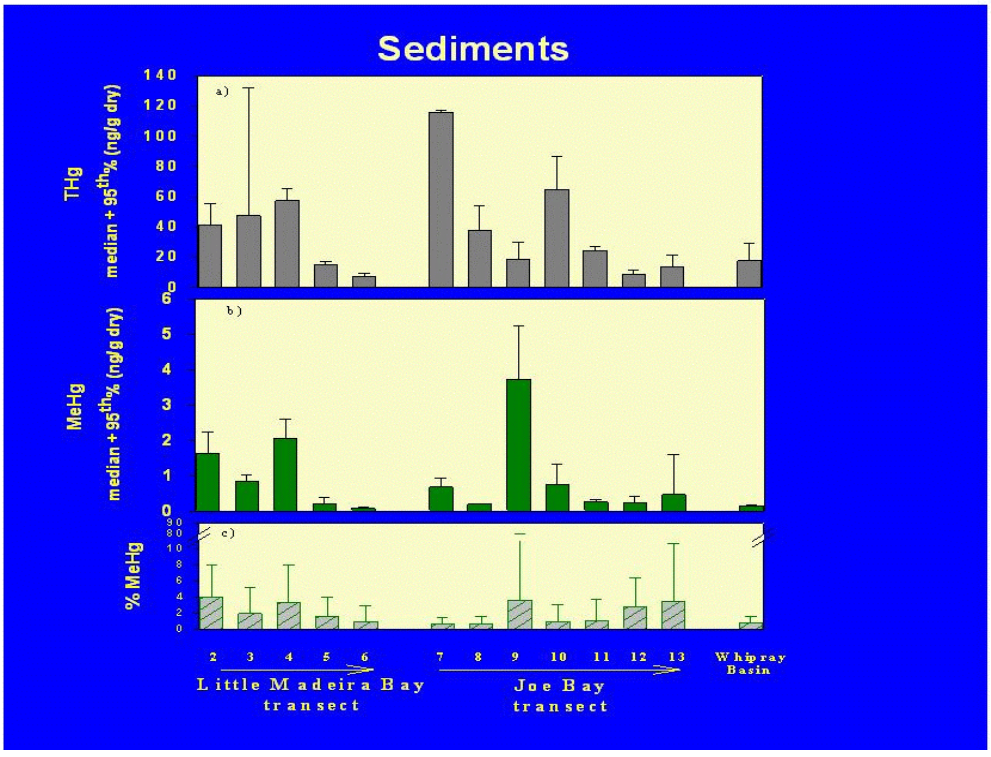
1. Work Accomplishments

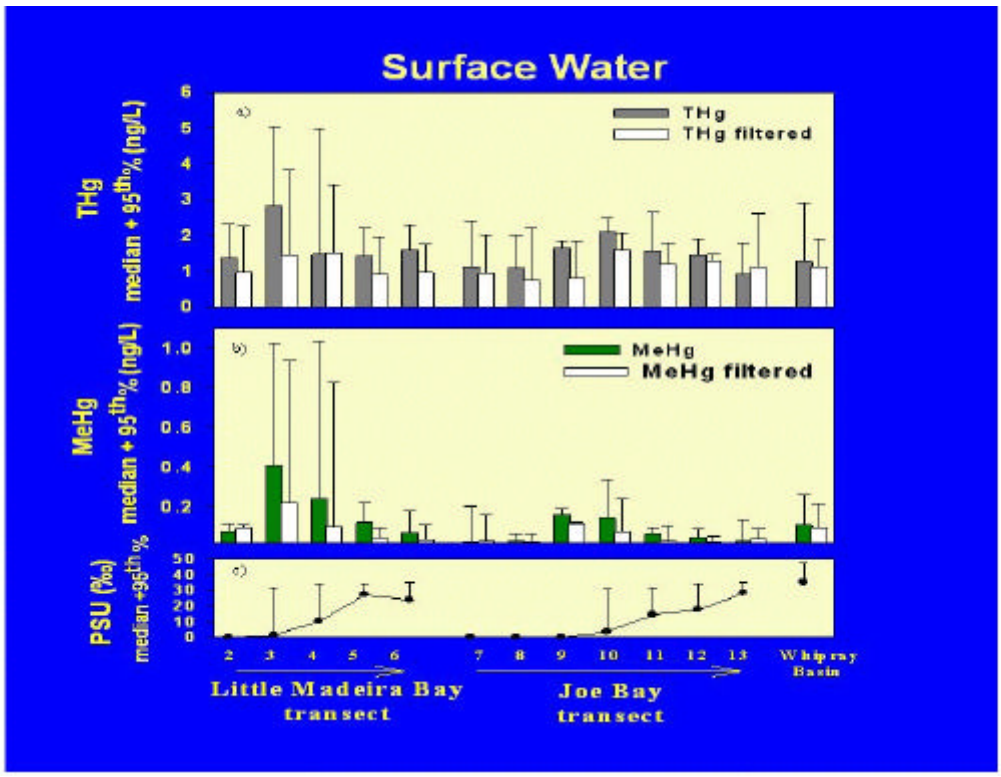
In south Florida, much of the Everglades and adjacent wetland areas are under consumption advisories because of elevated concentrations of mercury in fish that put humans, other mammals, birds, and reptiles at risk. Health advisories are now posted in eastern Florida Bay warning of elevated levels of mercury in some higher trophic level fish. Reduction in body burdens of mercury in top carnivores is one of the success criteria listed by the South Florida Ecosystem Restoration Task Force.

Elevated mercury concentrations in Florida Bay fish may originate from external sources of methylmercury carried by inflowing waters from the Everglades or by sources within the bay itself. Everglades restoration forecasts increased freshwater flows to eastern Florida Bay through Taylor Slough and C-111 canal. This increased flow might bring with it enhanced methylmercury deliveries. Our work is monitoring mercury concentrations in water, sediment and biota along two transects through Taylor River/Little Madeira Bay and C-111/Joe Bay and into eastern Florida Bay (Figure 1). We are measuring methylmercury production rates along these transects to infer the sources and sites of exposure of methylmercury to biota within eastern Florida Bay. Stable isotope tracers are being employed to determine the trophic pathways of methylmercury bioaccumulation.


Mercury in Spotted Seatrout in Florida Bay
Joe Bay
Little Madeira Bay
<0.5 ppm Hg
0.5 to 1.0 ppm Hg
1.0 to 1.5 ppm Hg
> 1.5 ppm Hg
1
2
3
4
5
6
7
8
9
12
13

1. **Progress to date**: Six sampling transects have been completed, December 2000, March, June, September, and December 2001, and March 2002. Water and sediment have been analyzed for methylmercury and total mercury and fish for total mercury from these transects. Combined with data from earlier transects of February and July of 2000, they reveal a pattern of elevated methylmercury concentrations in water and sediments in the mangrove transition zone of Little Madeira Bay (sites 3 and 4) and Joe Bay (sites 9 and 10) where the Everglades= runoff mixes with saline bay waters (Figures 2 and 3). This suggests a local source of methylmercury formation in this region. Florida=s prolonged drought has limited freshwater flows into this area and has also restricted sampling at site 2 in Taylor Slough and site 9 in the Joe Bay drainage which have been either dry or inaccessible by airboat.

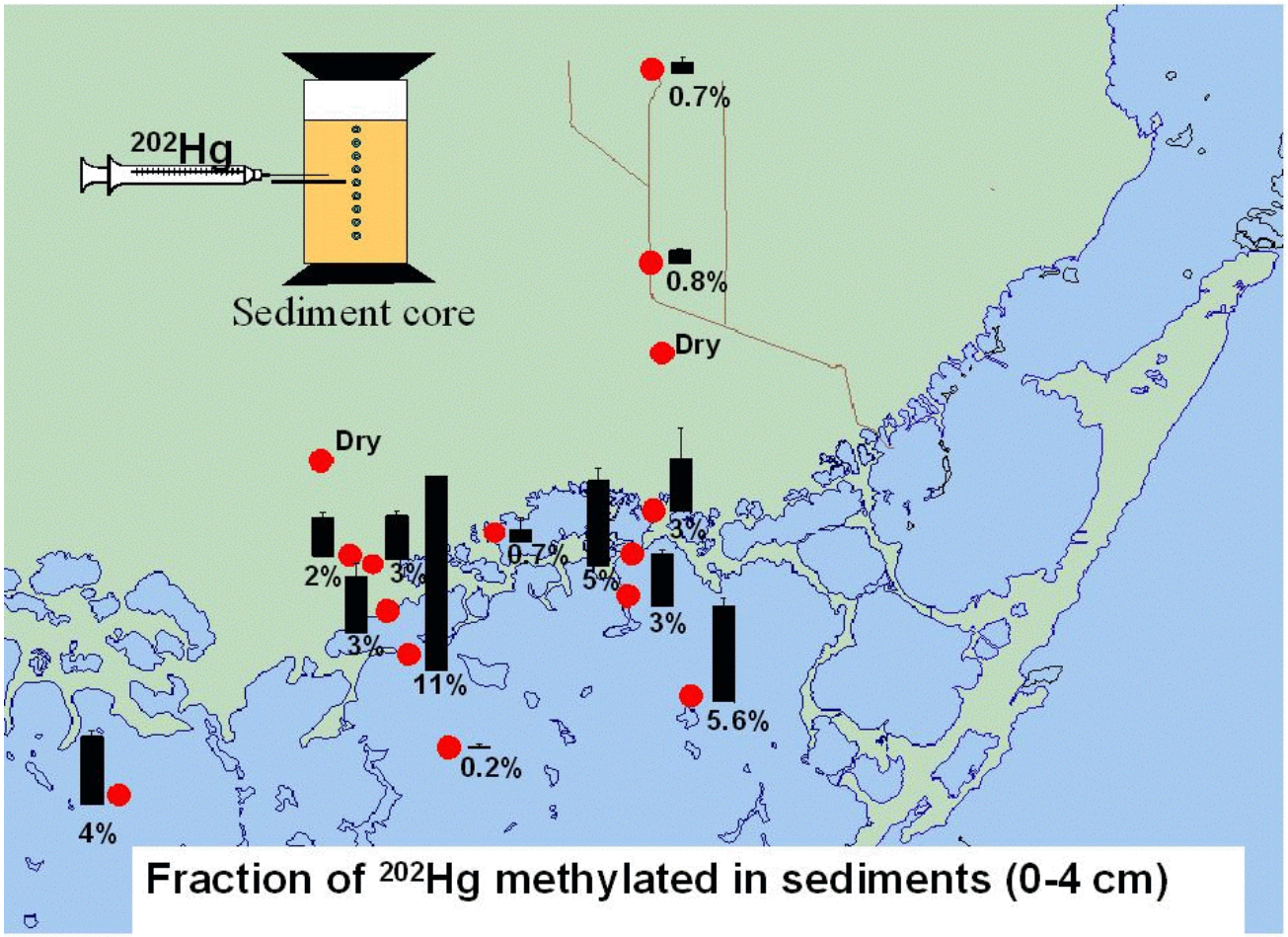




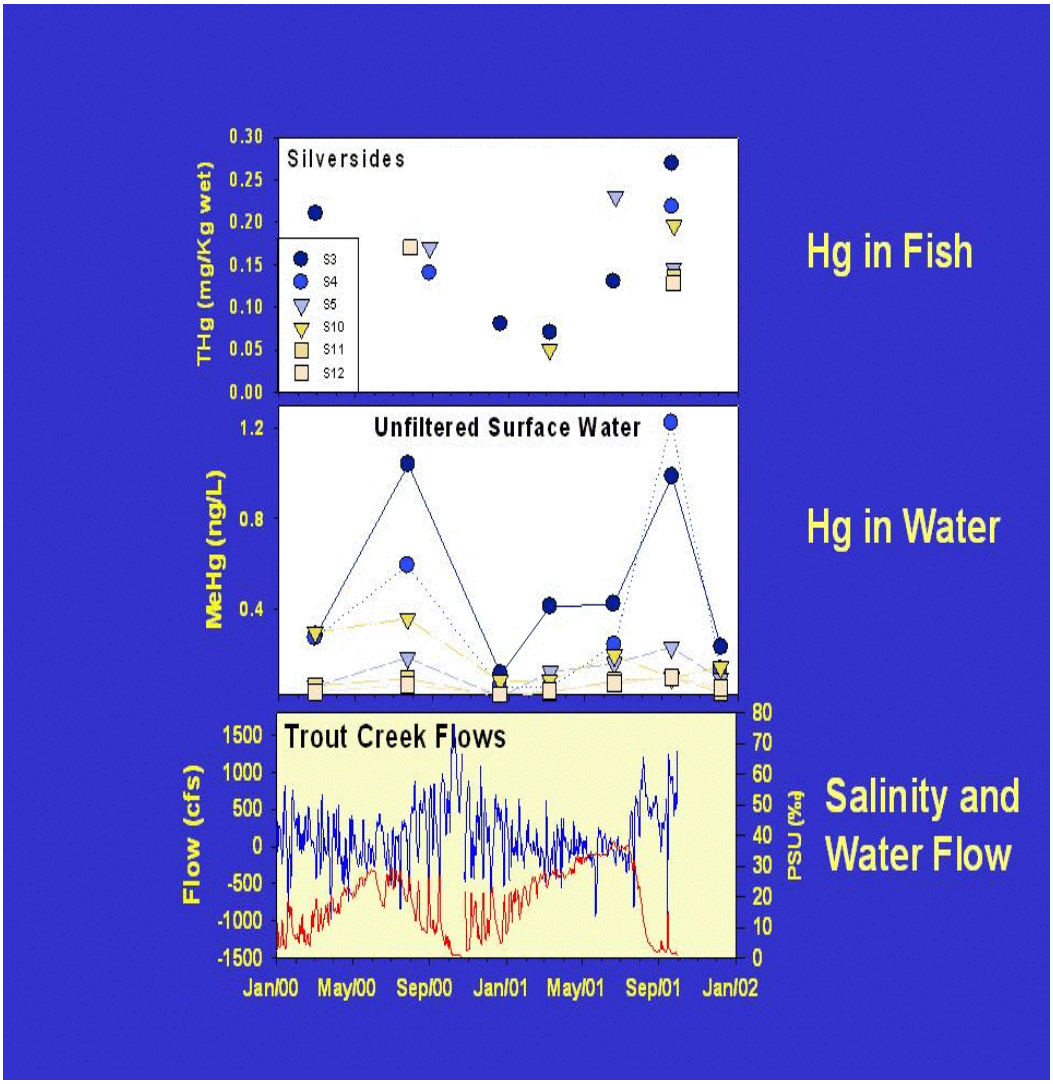
Mercury methylation rates have been measured to identify areas of active methylmercury production that could enter the food web. Intact sediment cores collected in November 2001 from 11 sites

were spiked with inorganic ^{202}Hg tracer and incubated to allow mercury to be methylated by resident microbes. The cores were frozen and shipped to the David Krabbenhoft at the USGS Mercury Research Laboratory in Wisconsin where they were analyzed for total and methylmercury by ICP-MS. The fraction of total mercury that was methylated is shown in Figure 4. Surprisingly, the degree of methylation was higher in many Florida Bay sites than in mangrove and freshwater wetlands sites. The total mercury concentrations in Florida Bay are lower than in the mangrove and freshwater sites, so that the rates of methylmercury formation are comparable. Greater water turbulence and dispersion and sediment resuspension in Florida Bay may keep methylmercury concentrations in the bay relatively low.

We have sampled often enough now to begin to see seasonal patterns in mercury concentrations. Lowest methylmercury concentrations occur in the dry season of mid winter. Methylmercury concentrations in water rise when freshwater flow increases in response to summer rains (Figure 5). Concomitantly, total mercury concentrations in silversides (*Menidia spp.*), a fast growing pelagic forage fish, also increase at this time, suggesting higher exposure of parts of the food web to methylmercury in the water. This linkage between methylmercury concentrations in water and total mercury concentrations in fish is strongest at sites in the mangrove transition



zone where we have observed highest methylmercury concentrations in water and sediments. We plan to extend these temporal observations backward in time by analyzing small forage fish collected from this zone during the period 1994 to 1998 by Jerry Lorenz and kindly provided to us. Further analyses of these patterns in relationship to summer rains, atmospheric deposition of mercury, and seasonal reflooding of Everglades marshes are planned.


Silversides
THg (mg/Kg wet)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
S3
S4
S5
S10
S11
S12
Unfiltered Surface Water
MeHg (ng/L)
1.2
0.8
0.4
Trout Creek Flows
Flow (cfs)
1500
1000
500
0
-500
-1000
-1500
PSU (‰)
80
70
60
50
40
30
20
10
0
Jan/00
May/00
Sep/00
Jan/01
May/01
Sep/01
Jan/02
Hg in Fish
Hg in Water
Salinity and Water Flow

Silversides are but a portion of the 324 fish samples we have analyzed for mercury to date. These fish include three other forage fish species, bay anchovy (*Anchoa mitchilli*), rainwater killifish (*Lucania parva*),and mojarra, (*Eucinostomus gula*) for which we have baywide mercury data.. Three gamefish species, spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*) and gray snapper (*Lutjanus griseus*), included in that earlier study have also been analyzed for the period 2000 to 2002. In addition jack crevalle (*Caranx hippos*) have also been sampled and found to have high mercury concentrations, generally exceeding 1 $\mu g\ g^{-1}$. Freshwater species have been added to infer methylmercury exposure in upstream sites. These include mosquitofish (*Gambusia spp*.) Mayan cichlid (*Cichlasoma urpophthalmus*), largemouth bass (*Micropterus salmoides*), and Peacock bass (*Cichla ocellaris*). Other species have been collected opportunistically. An additional twelve fish samples, from earlier studies, have been analyzed to establish the validity of our mercury analyses in comparison with analyses by the Florida DEP=s mercury analytical laboratory. Mercury concentrations for any single species are spatially consistent with average concentrations observed during the period 1996 to 2000.

Silversides are the only fish found across a wide salinity gradient that seem to have higher mercury concentrations at sites of lower salinity (Figure 6), at the sites of highest methylmercury concentrations in sediment and water in the mangrove transition zone (sites 3, 4, 9, and 10). Other species show either no relation (jack crevalle, gray snapper, and anchovy) of mercury concentrations with salinity or an increase in mercury with increasing salinity (killifish and mojarra).

Analysis of the stable carbon and nitrogen isotope concentration of these fish continue and should allow us to characterize both their position in the food web and relative importance of terrestrial/freshwater and estuarine sources of their food and, by inference, of their mercury content. A plot of mercury concentrations in some fish species against the stable carbon isotope signature shows that these estuarine fish derive their nutrition from both the mangrove or terrestrial food web ($d^{13}C$ *ca* -30 ‰) and from the seagrass or microalgal dominated food web ($d^{13}C$ *ca* -14 ‰) of the open bay (Figure 7). Surprisingly, we do not observe higher mercury concentrations in fish with a strong mangrove or terrestrial stable carbon isotope signature in their diet. Because methylmercury is acquired by fish through feeding, this suggests that

methylmercury has entered the lower trophic levels of the food web throughout eastern Florida Bay, not just in the mangrove transition zone where we find highest methylmercury concentrations in water and sediments.

Stable nitrogen isotope signatures serve as a measure of relative trophic level as well as a potential indicator of the trophic base of the food web. Higher $d^{15}N$ values are found in the gamefish (gray snapper and jack crevalle) than in the four forage fish, consistent with their higher trophic position. Higher mercury concentrations in these gamefish are consistent with methylmercury biomagnification up food chains. The two pelagic feeding forage fish, anchovies and silversides, have higher mercury concentrations than the two more benthic feeding forage fish, killifish and mojarra, despite similar $d^{15}N$ values. This might indicate preferential accumulation of methylmercury by the pelagic food web where its lower trophic levels are exposed to surface water methylmercury rather than the benthic food web which are be exposed to sediment methylmercury.

2. **Work planned for the next year**: We plan to continue quarterly monitoring of water, sediment, and biota. We hope for at least one sampling transect that will capture a period of high runoff from the Everglades. The next sampling effort in June occurs during the rainy season, and should improve this probability.

We anticipate a second sampling of sediments for determination of mercury methylation rates, this time during a period of high freshwater flow. These measurements will be performed again through a cooperative arrangement with the USGS Mercury Research Laboratory in Wisconsin. These samples should inform us if high rates of mercury methylation are associated with the high methylmercury concentrations in water and sediments of the mangrove transition zone, if high rates of methylation are found upstream in the Everglades wetlands hypothesized to provide methylmercury to the watershed, or if high rates are found in eastern Florida Bay itself which would implicate a new methylmercury source more closely linked in space to the high mercury concentrations found in fish.

We have begun work on the separation of methylmercury from fish tissues for subsequent stable carbon isotope analysis of the methyl carbon. This should allow us to identify the source of methylmercury in fish and complement the studies of sediment mercury methylation rates described above.

We have acquired samples of forage fish collected by Jerry Lorenz of the National Audubon Society since 1994 in the mangrove transition zone. These will be analyzed for mercury. They will allow us to capture any patterns associated with seasonal freshwater flows over an extended period of time that includes drought and high freshwater flow periods. They should also capture the signal resulting from recent water diversions into the Taylor Slough and Joe Bay drainages and thereby anticipate changes in mercury flows and bioaccumulation that can be expected from planned water diversions during the Everglades restoration.

2. Applications
    1. Publications, Presentations and Workshops
        1. Rumbold, D., L. Fink, S. Niemczyk, and K. Laine. 2001. Appendix 7-12: Florida Bay Mercury Screening Study. 2001 Everglades Consolidated Report. A7-12-1 to A7-12-12.
        1. Evans, D.W. and P.H. Crumley. 2000. Origin of elevated mercury concentrations in fish from Florida Bay. Poster presented at the Greater Everglades Ecosystem Restoration Conference, Naples Florida.
        2. Evans, D.W., P.H. Crumley, D. Rumbold, S. Niemczyk, and K. Laine. 2001. Linking Everglades Restoration and Enhanced Freshwater Flows to Elevated Concentrations of Mercury in Florida Bay Fish. Poster presented at Florida Bay Science Conference, Key Largo, Florida.
        3. Evans, D.W., P.H. Crumley, D. Rumbold, S. Niemczyk, and K. Laine. 2001. Linking Everglades Restoration and Enhanced Freshwater Flows to Elevated Concentrations of Mercury in Florida Bay Fish. Poster presented at Workshop on the Fate Transport, and Transformation of Mercury in Aquatic and Terrestrial Environments, West Palm Beach Florida.
        4. Rumbold, D. G. and D. W. Evans. 2002. Linking Everglades Restoration and Enhanced Freshwater Flows to Elevated Concentrations of Mercury in Florida Bay Fish. Presentation to the Florida Academy of Sciences annual meeting.
        5. Evans, D.W. and Rumbold, D. G. 2002. Linking Enhanced Mercury Bioaccumulation in Coastal Fish to Everglades Restoration. Presentation at the Healthy Ecosystems, Healthy People Conference in Washington D.C.
    2. Applications to management or research
        1. We provided input to the Comprehensive Everglades Restoration Plan (CERP) through participation in C-111 N. Spreader Canal Project and Florida Bay and Florida Keys Feasibility Study to include mercury flux and bioaccumulation information in Everglades restoration decision making.
        2. We provided input on mercury and food web structure to the synthesis report and presentation on Higher Trophic Levels at the Florida Bay Science Conference, April 23 to 26, 2001 at Key Largo, Florida.
        3. We provided data on mercury concentrations in gamefish and forage fish to Marnie Billie. She is working on a mercury risk analysis for ospreys in Florida Bay as part of a masters thesis at Florida International University.
    3. Data or information products: none
    4. Partnerships established with other agencies
        1. Collaboration with USGS in determination of mercury methylation rates in Everglades and Florida Bay sediments
        2. Sharing of fish samples for pesticide analysis with NOAA/NOS/NCCOS Center for Coastal Environmental Health and Biomedical Research, Charleston.

3. Mercury analysis of archived samples of fish collected by Jerry Lorenz of the National Audubon Society in the mangrove transition zone.