A Little Water Can Go a Long Way, Especially in a **Drought: The Focused Flow** Concept







### Effects of Altered Freshwater Inflow



Intercepted Continental Runoff: 3-6 times as much water in reservoirs as in natural rivers

Source: http://www.millenniumassessment.org



### Reduces nutrient and sediment flux and increases salinity

Source: Montagna et al. 1996, CCBNEP #8 http://cbbep.org/publications/virtuallibrary/ccbnep 08.pdf 2

# There is plenty of evidence that reduced inflows matter

### > Too many examples to list

- Australia
- North Africa
- South Africa
- North America
  - California, Gulf of California, Texas, and Florida reviewed in Montagna et al (2013)



🖄 Springer

### Droughts Cause Severe Problems in Lakes and Estuaries



California Lake Runs Dry: Reservoir in the Feather River Source: CBS - Sacramento News - 25 September 2015



Rincon Bayou, Nueces Delta, Corpus Christi, TX Source: Montagna et al. (2009)

### **US Environmental Flow Protection**

- Recognizing the need for environmental flow, some states have enacted laws to protect water quantities flowing to the coast
- TX 1985 & 2007, FL 1990, CA 2010
  Federal inter-state water projects are subject to the endangered species act
  A new field of study: Ecohydrology

### Inflow Effects (20<sup>th</sup> Century View)



### Inflow Has Indirect Effects "Domino Theory"



**Evolution of the idea:** 

- Alber, Estuaries (2002)
- Science Advisory Committee, Methodologies for Establishing a Freshwater Inflow Regime (2009)
- > Palmer et al., *Hydrobiologia*, 667:49-67 (2011)
- Montagna et al., Hydrological Change and Estuarine Dynamics (2013)

# Original Inflow Recommendations in Texas Bays (1994)

- Treated whole bay systems as one unit
- Estimated volumes needed to dilute whole bays

Volumes are large because the bays are large Sabine 9.5M ac-ft

Galveston 5.2M ac-ft

Matagorda 2.0 M ac-ft San Antonio 1.15M ac-ft Aransas 0.82M ac-ft

/Nueces 0.14M ac-ft

### **SB3 Regimes are Complicated**

Inflow Regime	Inflow Quantity (February) (af)	Inflow Quantity (March-May) (af)	Strategy Target Frequency	Inflow Regime	Inflow Quantity (June) (af)	Inflow Quantity (July-September) (af)	Strategy Target Frequency
Spring 1	N/A	550,000-	at least 12%	Summer 1	N/A	450,000-800,000	at least 12% of the years
Spring 2	N/A	375,000-	at least 12%	Summer 2	N/A	275,000- 450,000	at least 17% of the years
Spring 3	N/A	275,000-	N/A	Summer 3	N/A	170,000- 275,000	N/A
Spring 4	greater than	<u>375,000</u> 150,000-	N/A	Summer 4	greater than 40,000	75,000- 170,000	N/A
Spring 4	75,000 less than	275,000		Summer 5	less than 40,000	75,000- 170,000	N/A
Spring 5	75,000	275,000	N/A	Summer 6	N/A	50,000-	N/A
Spring 6	N/A	0- 150,000	than 9% of the years	Summer 7	N/A	0- 50,000	no more than 6% of the years
Spring 2 and Spring 3 combined	N/A	N/A	at least 17% of the years	Summer 2 and Summer 3 combined	N/A	N/A	at least 30% of the years
Spring 4 and Spring 5 combined	N/A	N/A	less than 67% of the total	Summer 4 and Summer 5 combined	N/A	N/A	Summer 5 no more than 17% of the

But, volumes can be zero during droughts, and average is still large

### But that is not how estuaries work!

Satellite image of turbidity plumes during a flood (6NOV2006) Hydrological Restoration Opportunities

 TX law (2007 SB3) now allows environmental flow as a benefit in a water permit application
 Lot's of restoration dollars "floating" around

### Focused Flows to Nursery Habitats

- Nursery habitats occur in areas that are smaller, so small volumes of fresh water will have big impacts
- These are the secondary and tertiary bays close to river mouths
- > Three case studies:
  - Rincon Bayou restoration
  - San Antonio Bay inflow needs study
  - San Antonio Bay Hurricane Harvey effects



Conceptual model of shrimp life cycle

### **Rincon Bayou Hydrological Restoration**





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### 1994 - Dug Overflow Channel



#### Salinity Before Channel



#### **Salinity After Channel**

Rincon Bayou

#### Nueces Overflow Channel

#### **Nueces River**

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### Added A Pipeline



> 2009 - City of Corpus Christi completed construction to pass-through the first 3,000 acre-ft (3,700,440 m<sup>3</sup>) per month from the Calallen Pool to Rincon Bayou

# **Calculating Optimal Salinity**



**Turner and Montagna (2016) Ecological Informatics 36: 118–125** 

Diversity peaks with salinity between 4 psu and 10 psu
 Diversity peaks with water depth around 10 cm

# Optimal Pumping Strategy to Enhance the Environment



Pumping controls salinity and water depth.
 Based on indicators, 0.41 m<sup>3</sup>/s (29 ac-ft/day), would maintain optimal salinity and depth for bioindicators

Leveraging Hydrological **Restoration Opportunities** > TX Environmental Flow Initiative Can we lease or purchase water for environmental benefit? But, water volumes available are small and very expensive

Can a small volume of water be leased or purchased to benefit the nursery areas?

> Hypothesis: small estuary volumes can be diluted with small inflow volumes in upper reaches that are nursery habitats



# Can Drive Water Quality in Smaller Estuaries



PC1 is an Inflow Index

Improve water quality with as little as 2000 ac-ft/month

### What about Fisheries?

Texas Parks and Wildlife Department collected monthly since 1977 using a baywide random sampling design

We created segments to convert data to a salinity gradient



### Shellfish Use Nursery Habitats

Blue Crab

#### White Shrimp



> Higher densities of smaller organisms in the upper reaches, thus there are nursery grounds that can be protected

# Hurricane Harvey (8/25/2017)



- Storm surge pushed salinities over 30. Salinity dropped to zero within 7 days of the storm
- Nutrients and organic matter loading enhanced respiration of blue carbon and DO declined to zero about 9 days after the storm. DO did not recover until 15 days after the storm

# Hurricane Harvey Recovery Led by Small Benthic Clams



- Typical bivalve abundance and size distribution prior to the storm
- Nearly nothing for the first five months after the storm
- > Bloom of small Mulinia lateralis and Rangia cuneata by April 2018.
- April recruits grew by July 2018, and a second bloom occurred.

### Conclusions

Volumes of fresh water available for hydrological restoration will be small, expensive, and difficult to deliver Focused flow concept is one tool for hydrological restoration because the upper reaches of estuaries near freshwater sources are nursery habitats, and they are smaller areas with smaller volumes

### Acknowledgements

- > Texas Water Development Board
- Coastal Bend Bays & Estuaries Program
- National Fish and Wildlife Foundation award 49317
- National Oceanic and Atmospheric Administration, Office of Education Educational Partnership Program award NA16SEC4810009. Its contents are solely the responsibility of the award recipient and do not necessarily represent the official views of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration

# **Questions**?

11.6.2002