# The Influence of Freshwater on Fishery Production on Continental Shelves: The Mississippi River

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# Nutrient enrichment processes

1. Coastal upwelling
2. Tidal mixing
3. Land-based runoff, especially river discharge

**Biological processes**

Primary and secondary production

Larval fish production

**Physical oceanography**

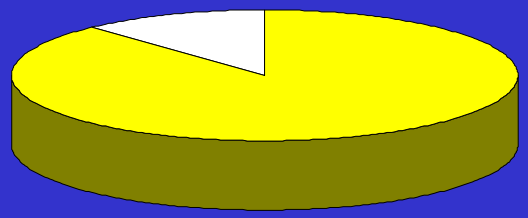
convergence upwelling

transport retention

stratification

# U.S. Gulf of Mexico Catches from Areas Influenced by the Mississippi River Discharge

***Commercial***

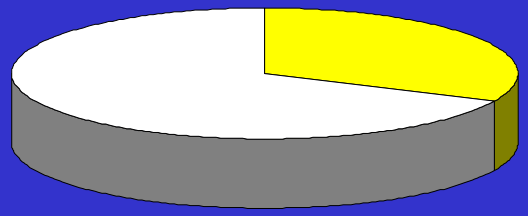


**88% of 726,000 MT**

**Discharge**

**Non-discharge**

***Sport***



**32% of 42,000 MT**

# Circumstantial Evidence of the Importance of River Discharge

***Disruption***

• Filling of the Aswan Dam 1965-69 reduced flow by 90% with attendant decline in Egyptian fishery landings from 37,800 MT in 1962 to 7,142 MT in 1976 and simplified community structure (Bebars and Laserre 1983)

•Colorado River diversion eliminated spawning and nursery areas for *Totaba macdonaldi* in the Gulf of California, eventually resulting in a population decline that destroyed important commercial and sport fisheries leading to listing as endangered species in 1976 (Barrera-Guevara 1990)

# *Restoration*

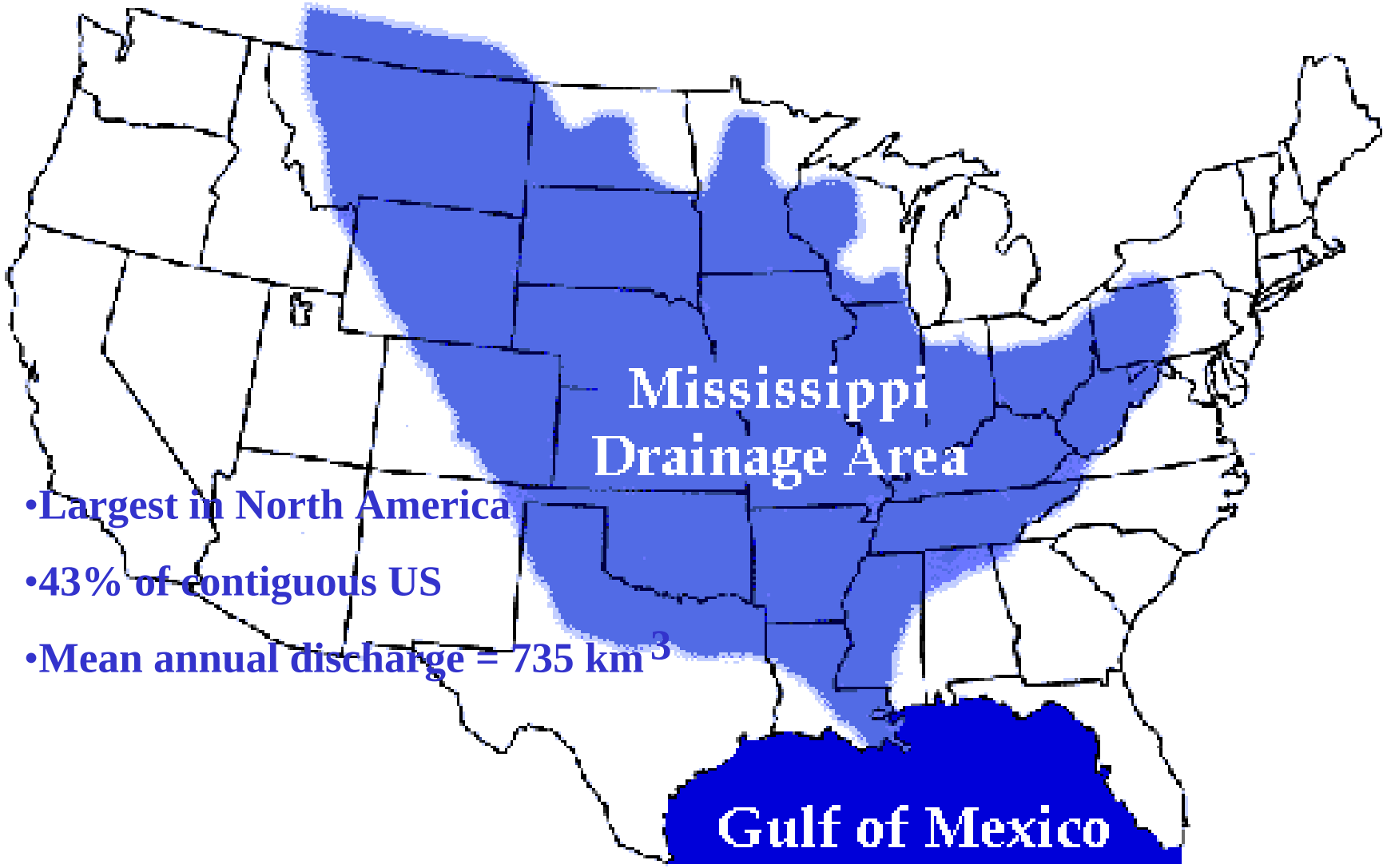
- On the Ganga River in India in 1975 fresh water flow was restored to the Hooghly distributary doubling fishery landings in the estuary (Sinha, et al. 1996).

- When Nile River flow was restored after the Aswan Dam was filled and releases of water from the dam restored river flow, Egyptian fishery landings recovered to one-third the pre-dam level (Smetacek 1986) and had fully recovered by 1989, although with different community structure (Lasserre, et al. 1997).

# Principle Ecological Groups of Fishes in Gulf of Mexico Catches

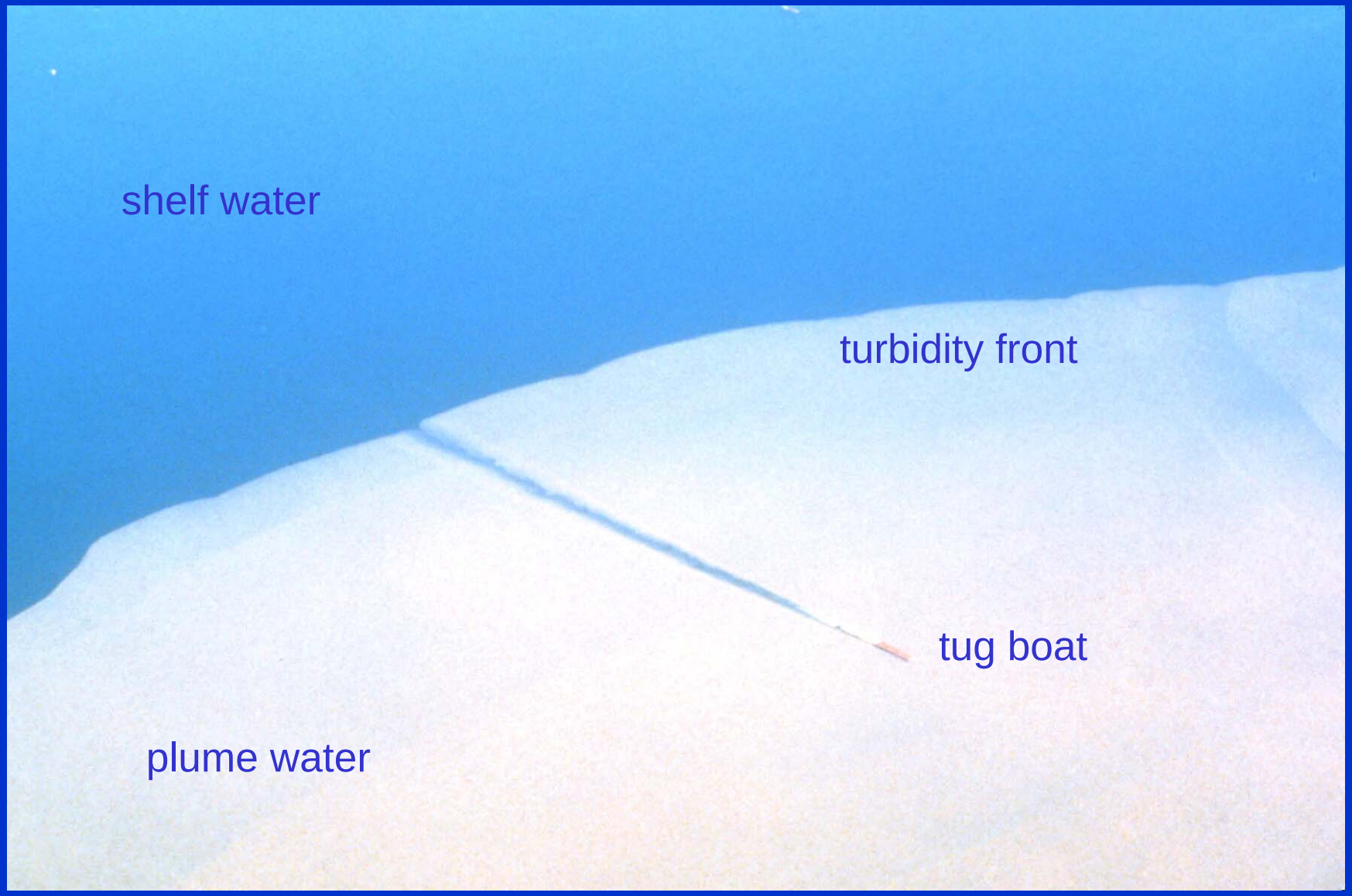
- ***Oceanic pelagic species***, e.g., tunas and billfishes, that complete life history in oceanic waters
- ***Reef species***, e.g., snapper and grouper, associated with hard substrata away from the turbid waters of Mississippi River discharge.
- ***Estuarine dependent species***, e.g., menhaden, mullet and croakers, drums and seatrout, spawn in nearshore waters with transport of larvae and juveniles to estuarine nursery grounds for rearing.
- ***Coastal species***, e.g., mackerels, bluefish, coastal herrings and jacks that complete life cycles pelagic continental shelf waters

# Mississippi River Drainage Basin

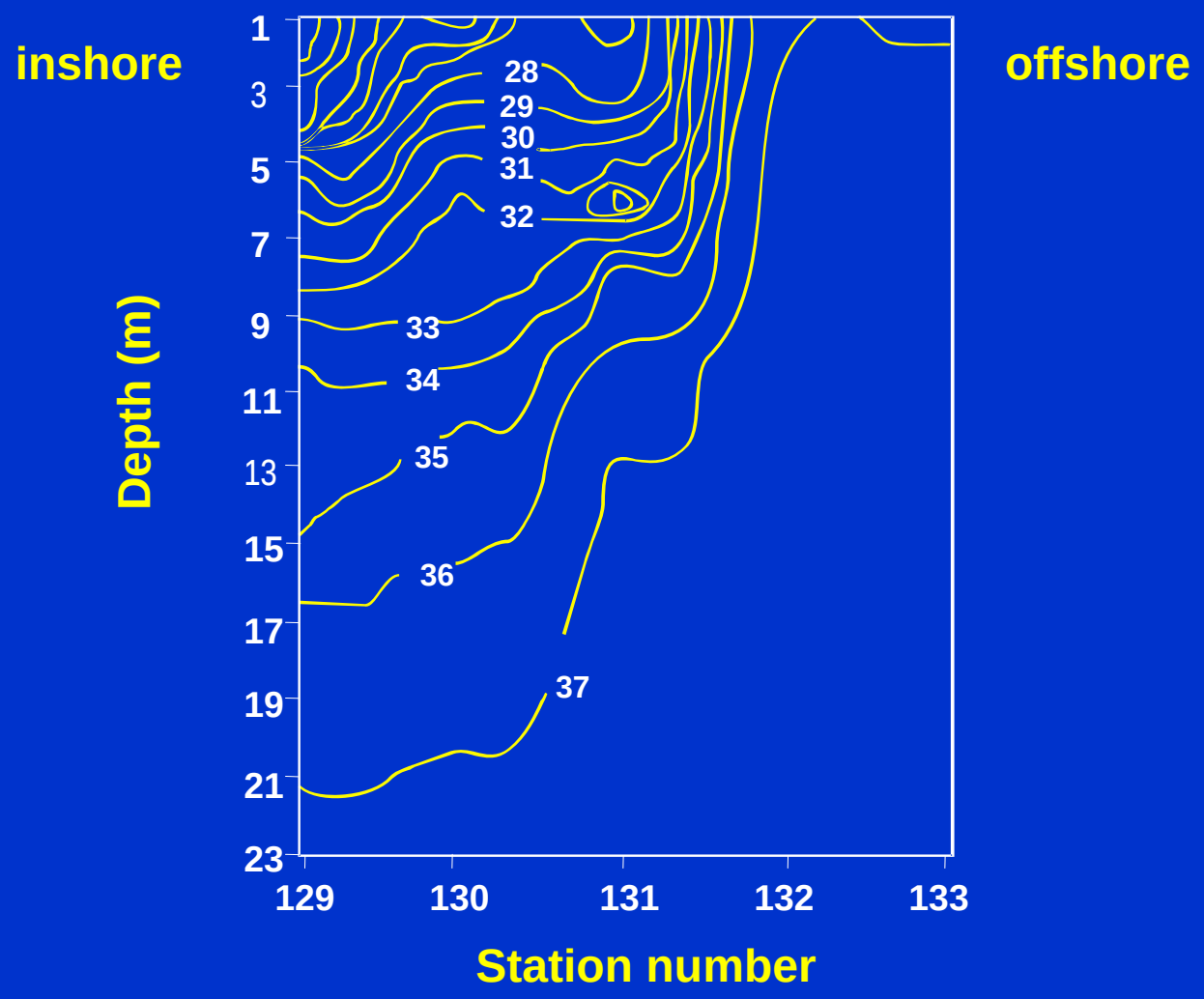



- Largest in North America
- 43% of contiguous US
- Mean annual discharge = 735 $km^3$

# Mississippi River Discharge into the Gulf of Mexico

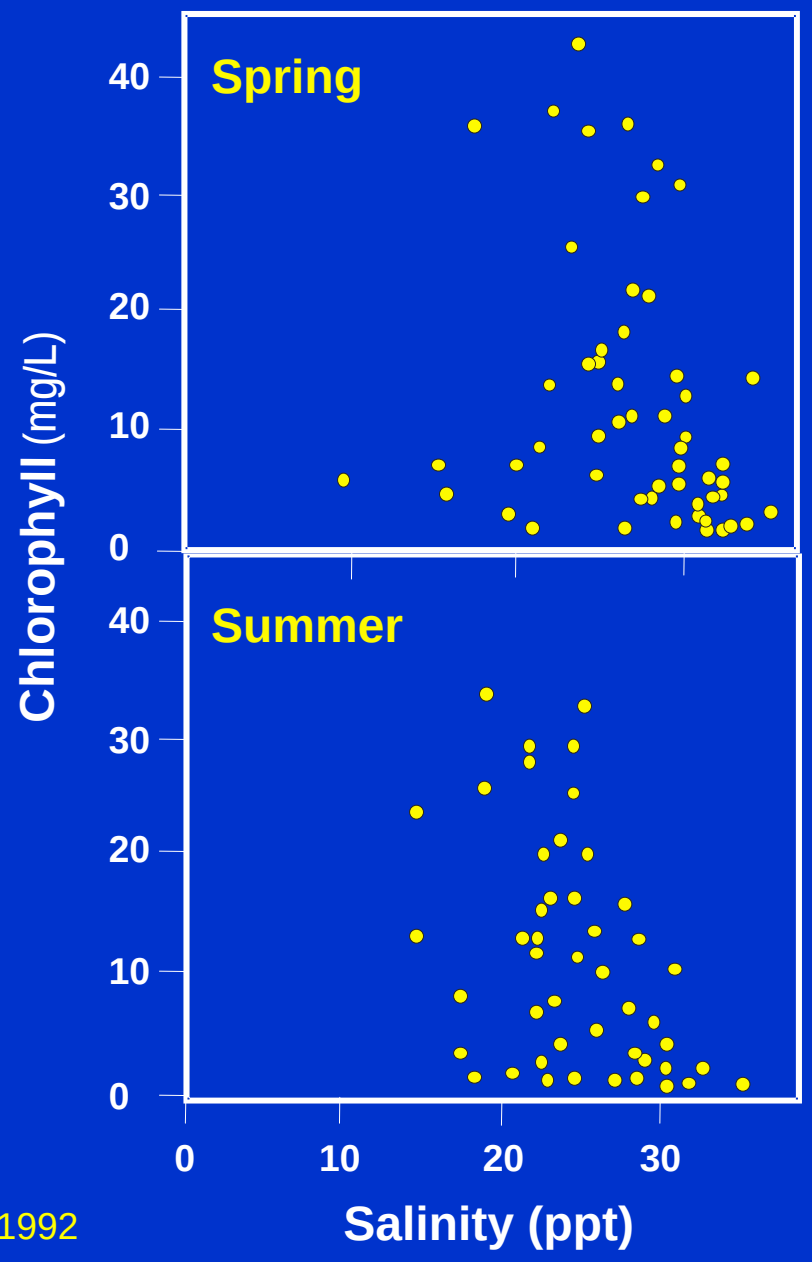


# Salinity (ppt) Profile Along Transect of the Plume



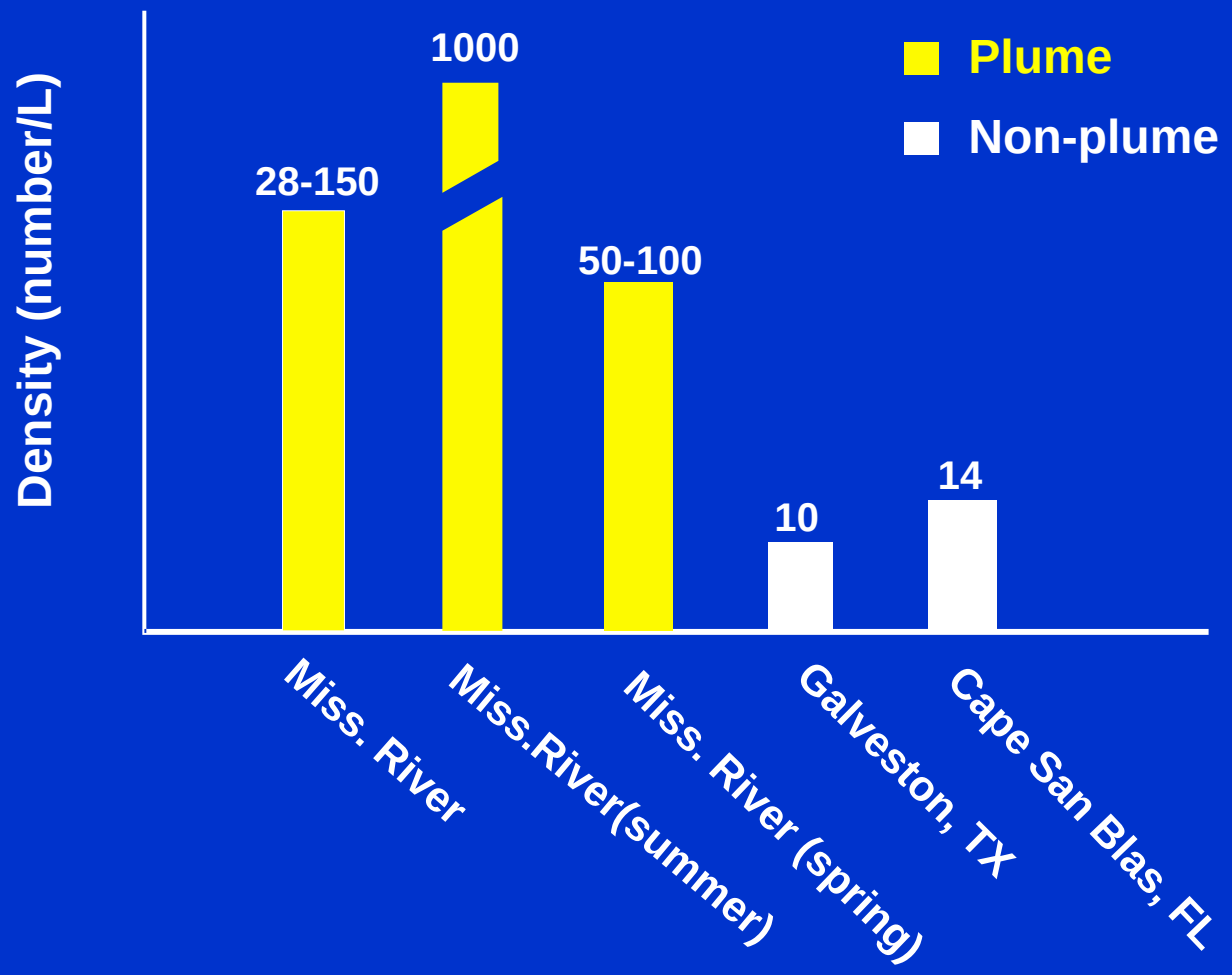

From Grimes 2001

# Distribution of Phytoplankton Biomass with Surface Salinity



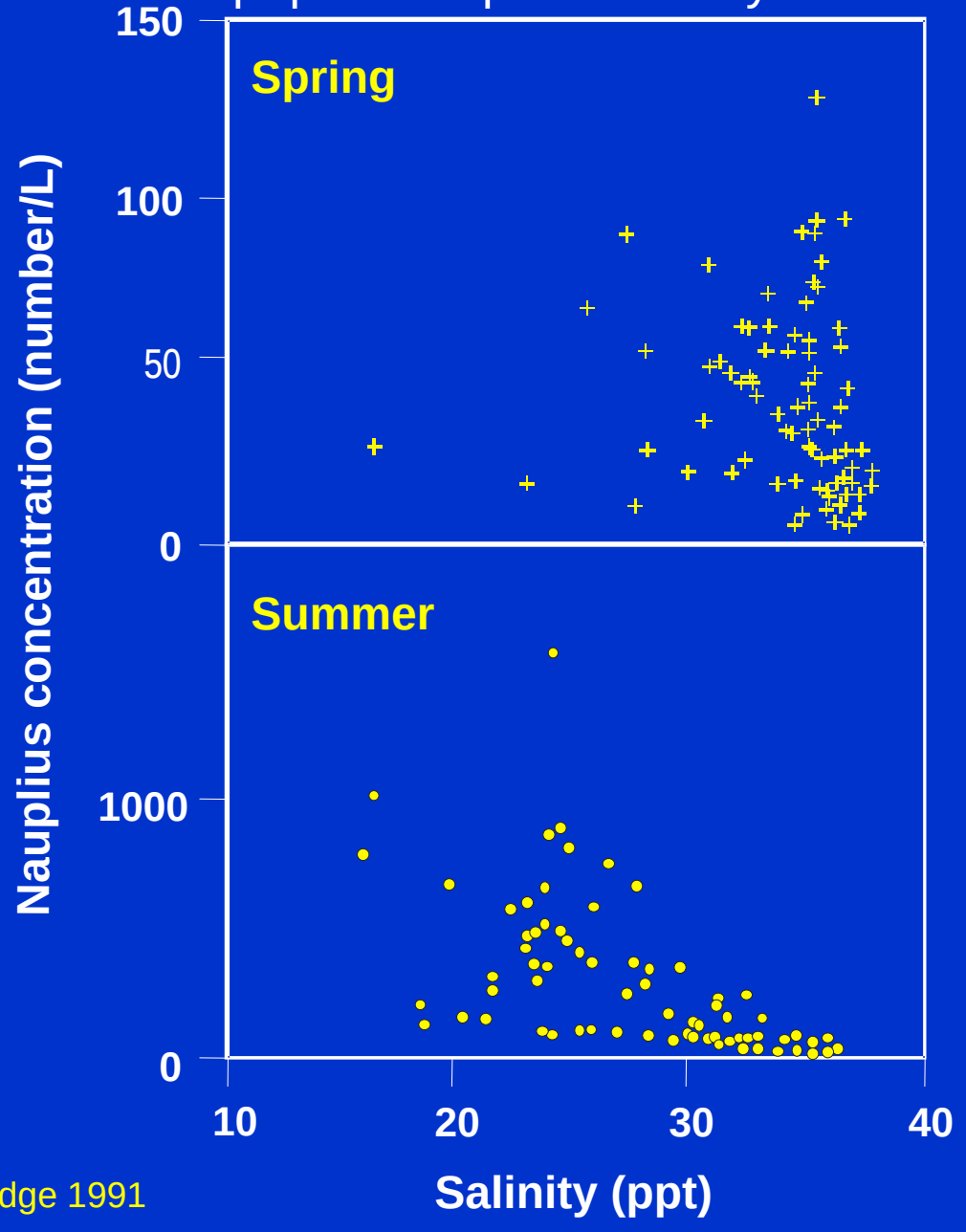

From Dortch and Whitledge 1992

# Mean Copepod Nauplius Densities in and Away from the Mississippi Discharge Plume



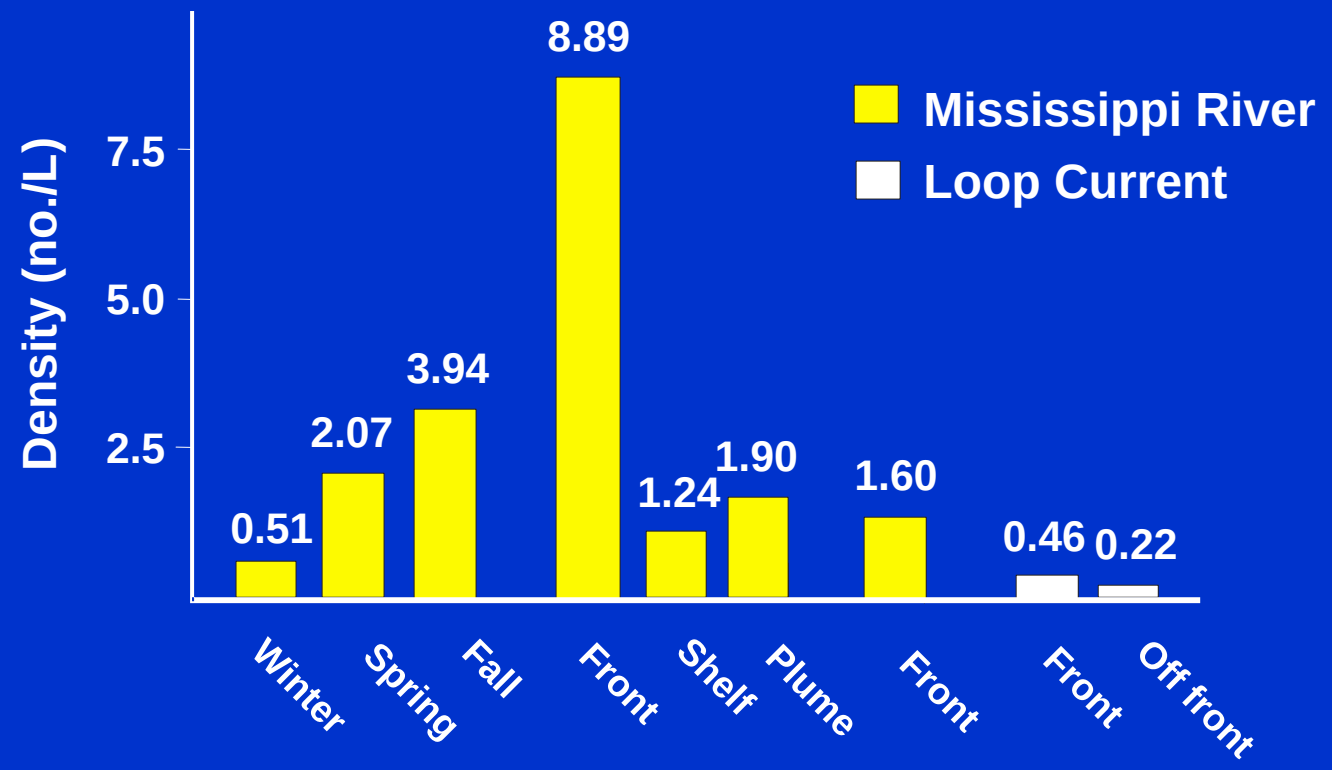

From Dagg et al. 1987 and
Dagg and Whitledge 1991

# Distribution of Copepod Nauplius Density with Surface Salinity



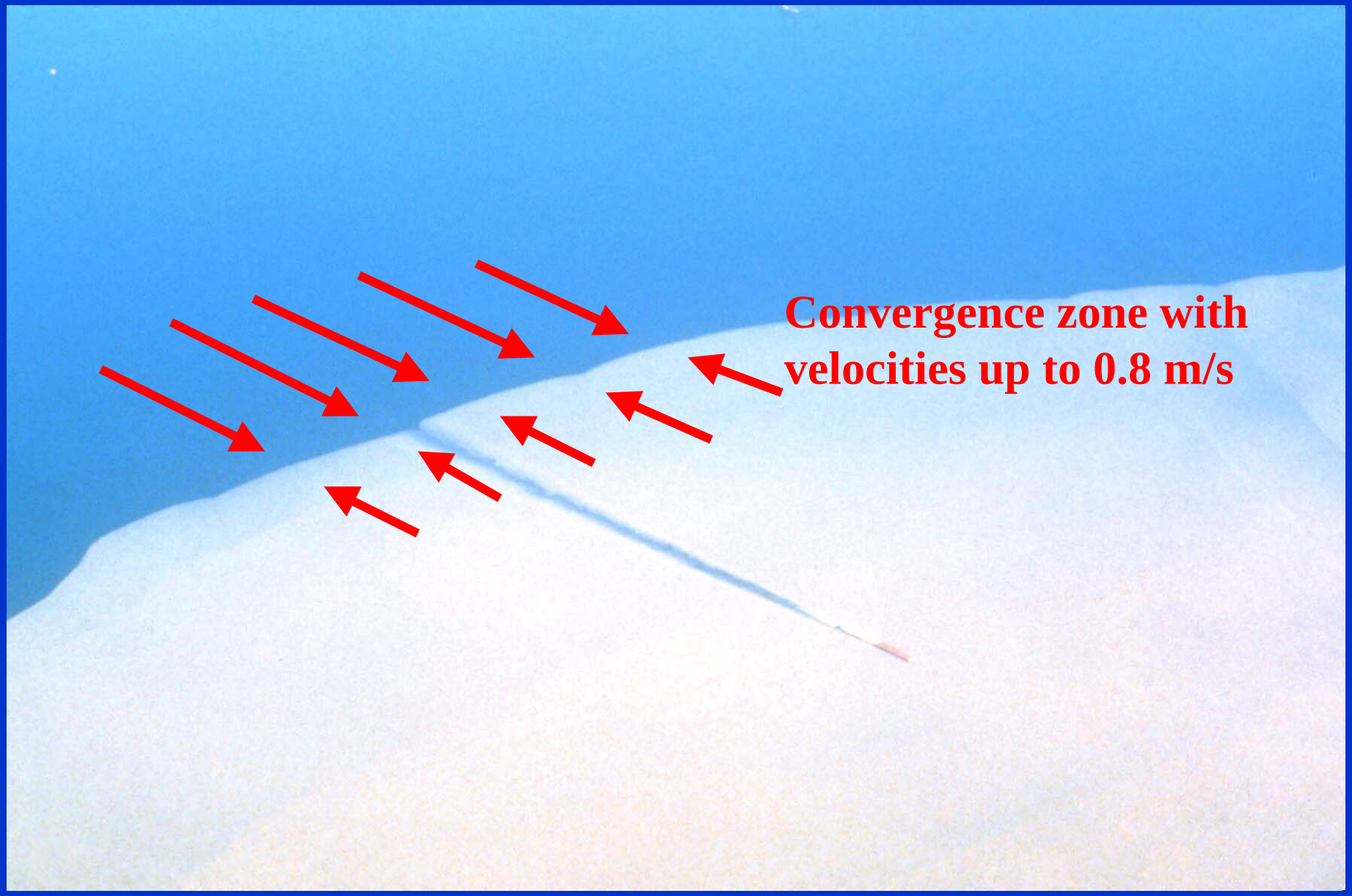

From Dagg and Whitledge 1991

# Densities of Fish Larvae in the Vicinity of the Mississippi Discharge Plume and Away from the Plume

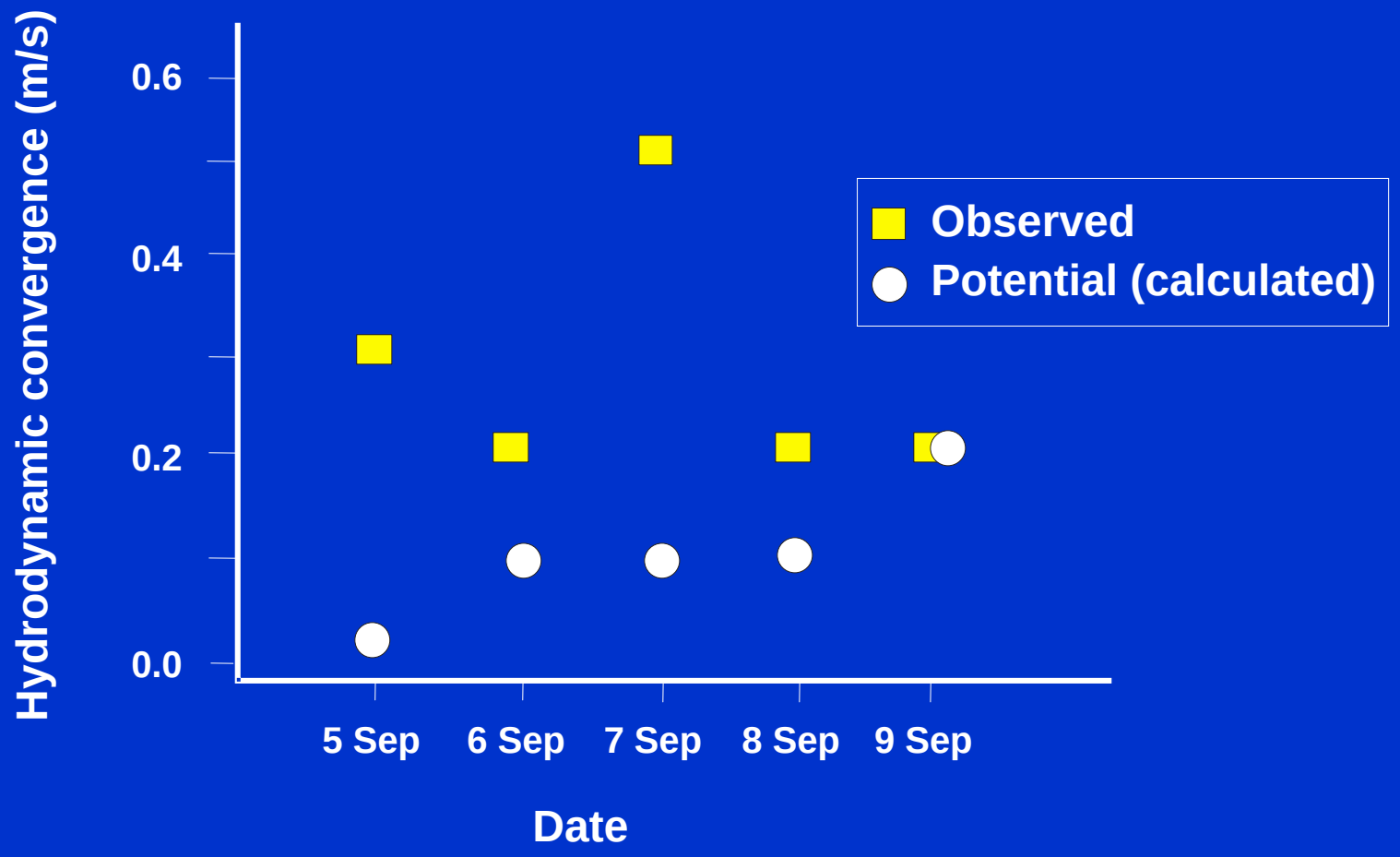



From Ditty 1986, Govoni et al. 1989, Richards 1989 and Grimes and Finucane 1991

# Hydrodynamic Convergence Along the Plume Front



# Observed and Potential (Calculated) Convergence Velocity at Mississippi River Turbidity Fronts




from Grimes 2001

Fishery production = (G+R)-(F+M)

where:

G = growth,

R = recruitment,

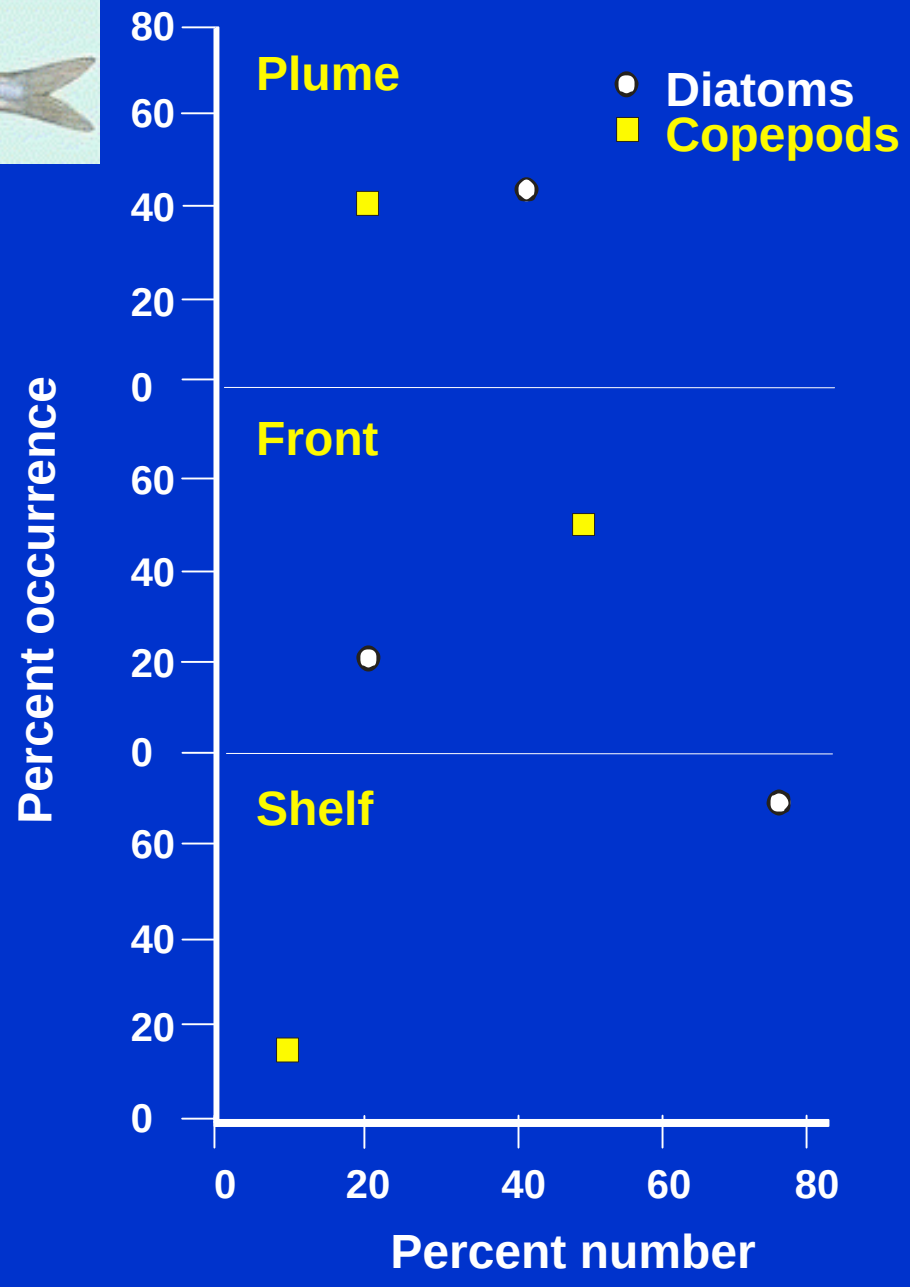
F = fishing mortality and

M = natural mortality

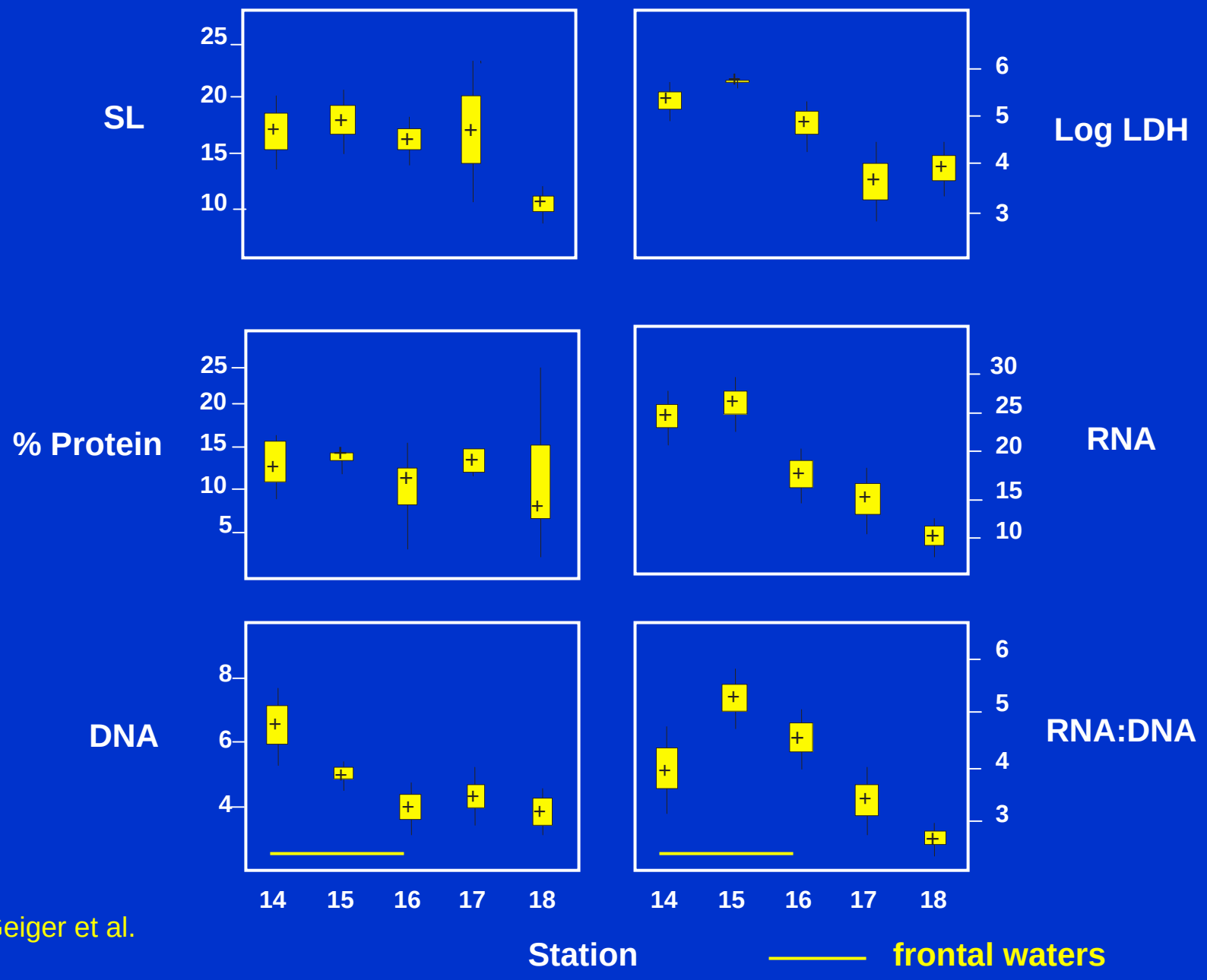
# Short Food Chain Hypothesis

Fish larvae in the vicinity of the riverine discharge in general, and the frontal region in particular, (1) take advantage of abundant food and consume a superior diet, (2) grow faster and (3) have shorter larval stage duration and experience better survival.

# Frequency of Occurrence and No. of Food Items in Anchovy Larvae

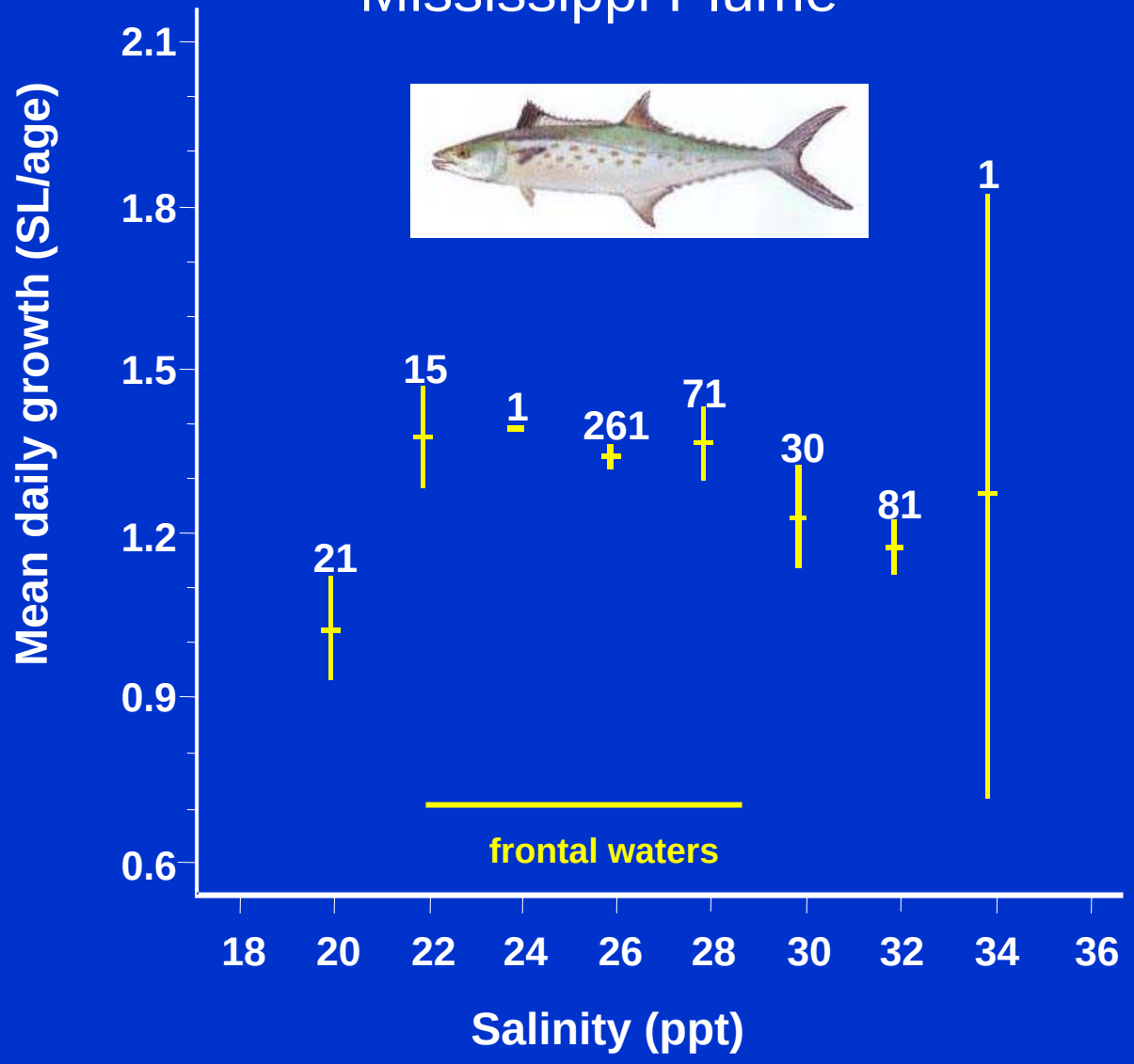


# Measures of Physiological Condition in Larval Anchovy




From Geiger et al.
in prep

# Mean Daily Growth of Spanish Mackerel Larvae in the Mississippi Plume



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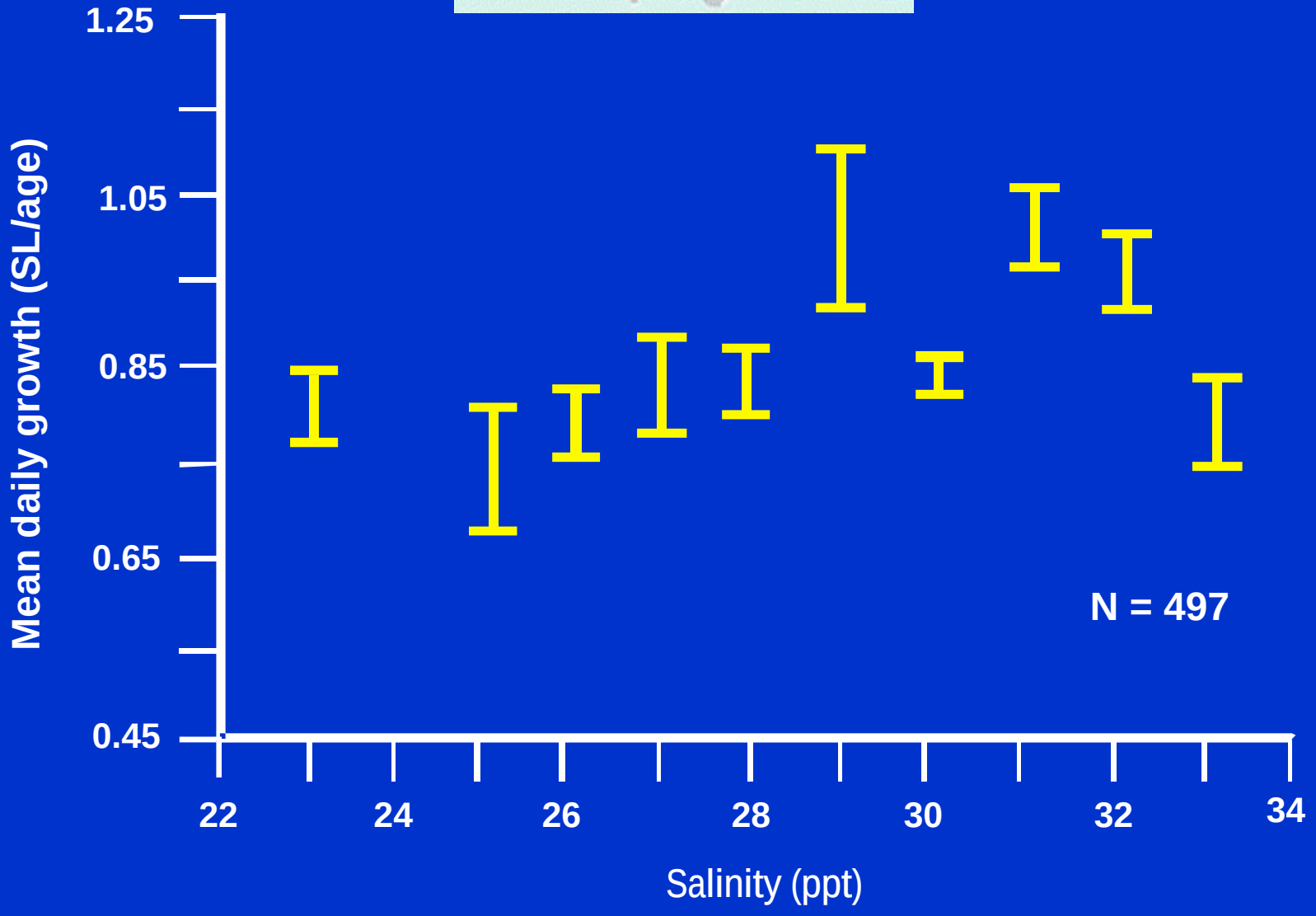
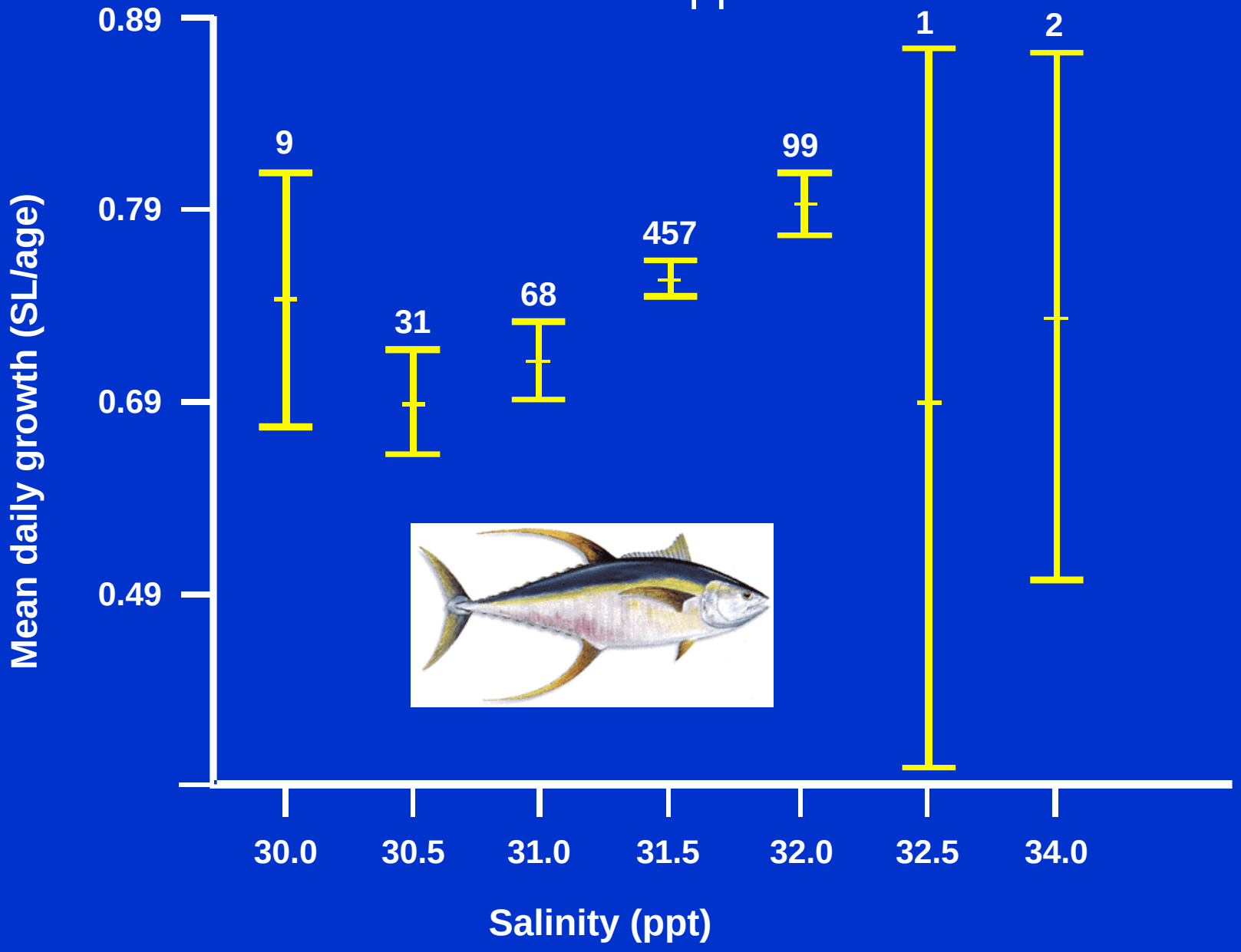
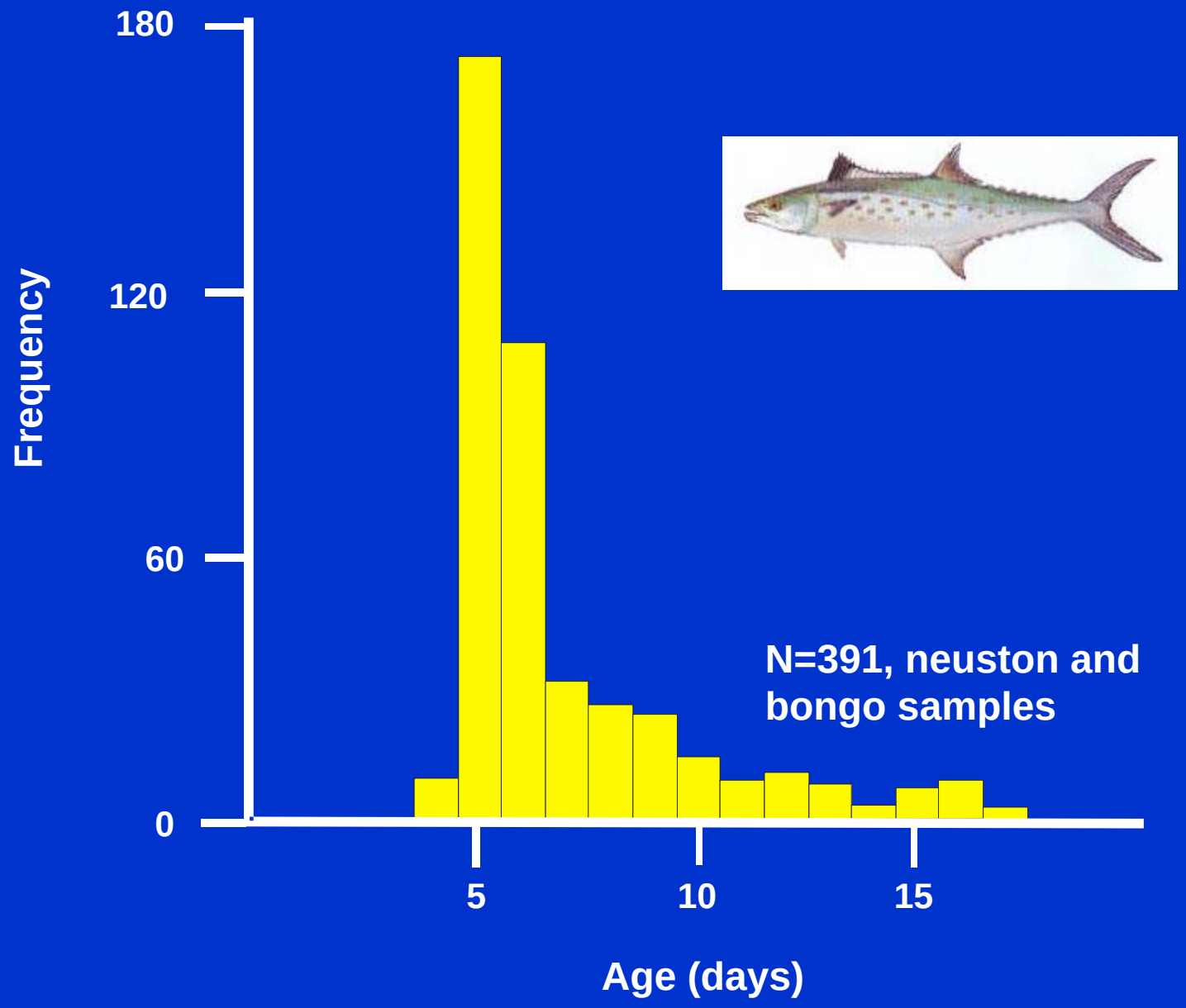


# Mean Daily Growth of Yellowfin Tuna Larvae in the Mississippi Plume



# Survivorship Curve for Spanish Mackerel



# Instantaneous Daily Mortality Rates

| Spanish mackerel | z | N | Ages(d) | Gear |
|---|---|---|---|---|
| plume (fall) | 0.60 | 155 | 11 - 19 | N & T |
| plume (spring) | 0.68 | 47 | 12 - 18 | N & T |
| non-plume (PC) | 0.32 | 391 | 5 - 17 | N & B |
| non-plume (SEAMAP) | 0.20 | 25 | 6 - 16 | N |
| **King mackerel** | | | | |
| plume | 0.23 | 49 | 6 - 17 | N |
| non-plume | 0.17 | 30 | 6 - 20 | N |
| non-plume (SEAMAP) | 0.83 | 360 | 4 - 10 | B |
| **Striped anchovy** | | | | |
| plume | 0.23 | 120 | 7 - 15 | N & T |
| front | 0.13 | 132 | 7 - 17 | N & T |
| shelf | 0.09 | 245 | 7 - 20 | N & T |
| **Yellowfin tuna** | | | | |
| front | 0.16 | ~200 | 3 - 12 | N & T |
| shelf | 0.43 | ~200 | 3 - 12 | N & T |

# Summary of Results Relevant to Short Food Chain Hypothesis

- Some species of larvae are conferred a trophic advantage.
- Some species grow faster.
- Mortality rates appear to be higher.

- So, validity of the hypothesis depends upon relative magnitude of growth and mortality.

# A simple model for the effects of growth and mortality on a population of larval fish:

$$N_t = N_0 \exp(-z L_c / g), \qquad (1)$$

Where $N_t$ is the number of fish surviving the larval period, $z$ is the instantaneous daily mortality rate, $L_c$ is the length that fish leave the larval stage and $g$ is the daily growth rate. Thus, survival through the larval period, $s = N_t / N_0$.

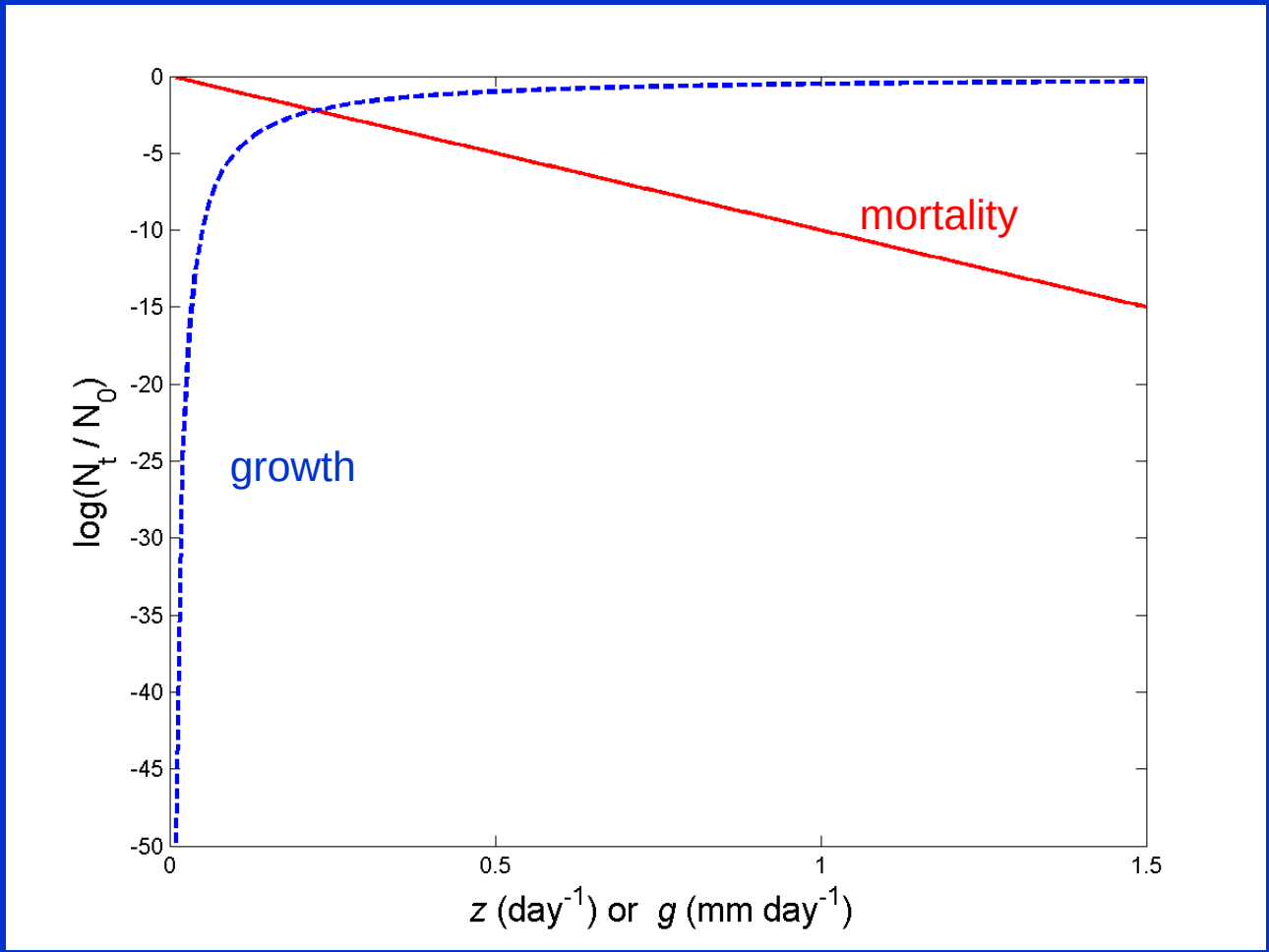
To evaluate the relative importance of changes in growth and mortality on $s$, let $f = \log(N_t / N_0) = -z L_c / g$. The effect of an incremental change in growth or mortality on $s$ can be determined by examining the first derivatives of $f$ with respect to $z$ and $g$:

$$\partial f / \partial z = - L_c / g \qquad (2)$$

$$\partial f / \partial g = z L_c / g^2. \qquad (3)$$

By examination of **2** and **3**, we see that the sensitivity of $s$ to changes in $z$ and $g$ depends upon the particular values of $z$, $g$ and $L_c$, and that sensitivity of $s$ to changes in $g$ is nonlinear.

# Sensitivity of Survival ($N_t$ / $N_0$) to Changes in Growth (g) and Mortality (z)




At small **g**, **s** is highly sensitive to changes in **g**. Over the ranges of **g** and **z** we observed (**z ~ 0.1 – 0.6 / d and g ~ 0.3 – 0.9 mm/d**), an incremental increase in **z** has a stronger effect on **s** than an incremental increase in **g**.

**Conclusion:** If physical and biological conditions in the vicinity of the discharge aggregate prey for larval fish that results in a trophic advantage and faster growth, but also aggregates predators and increases mortality rate of larvae, the disadvantage of increased mortality may well outweigh the advantage of faster growth, and increased survival and recruitment may not be the result.

# Alternative Hypotheses

- Total larval production Ho: Trophic conditions support such high total larval production that negative effects of unfavorable dynamics are overridden.

- Retention Ho: Physical dynamics and circulation facilitate retention of larvae within the area influenced by the riverine discharge.

- Downstream Ho: Specific dynamics of the farfield area of the discharge do favor enhanced recruitment, I.e., slightly enhanced feeding conditions subtly increase growth and diminished predator field allows lower mortality.

# Conclusions

- Circumstantial evidence worldwide that river discharges enhance fishery production in coastal shelf waters, and that is so for the Mississippi River into the Gulf of Mexico
- While the enhancing effect of riverine input seems clear, the exact mechanisms by which it occurs is not, but it is by affecting recruitment that fishery production can be influenced the most
- Coastal shelf waters receiving riverine input are a rich environment where both physical and biological dynamics may favor processes that regulate recruitment

# Fishery production = (G + R) – (F + M)

where:

G = growth,

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