Tidal migratory fishes, shrimps, and crabs: behavior, geomorphological determinants of habitat use in tidal creek basins, and recommendations for management

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North Inlet Estuary

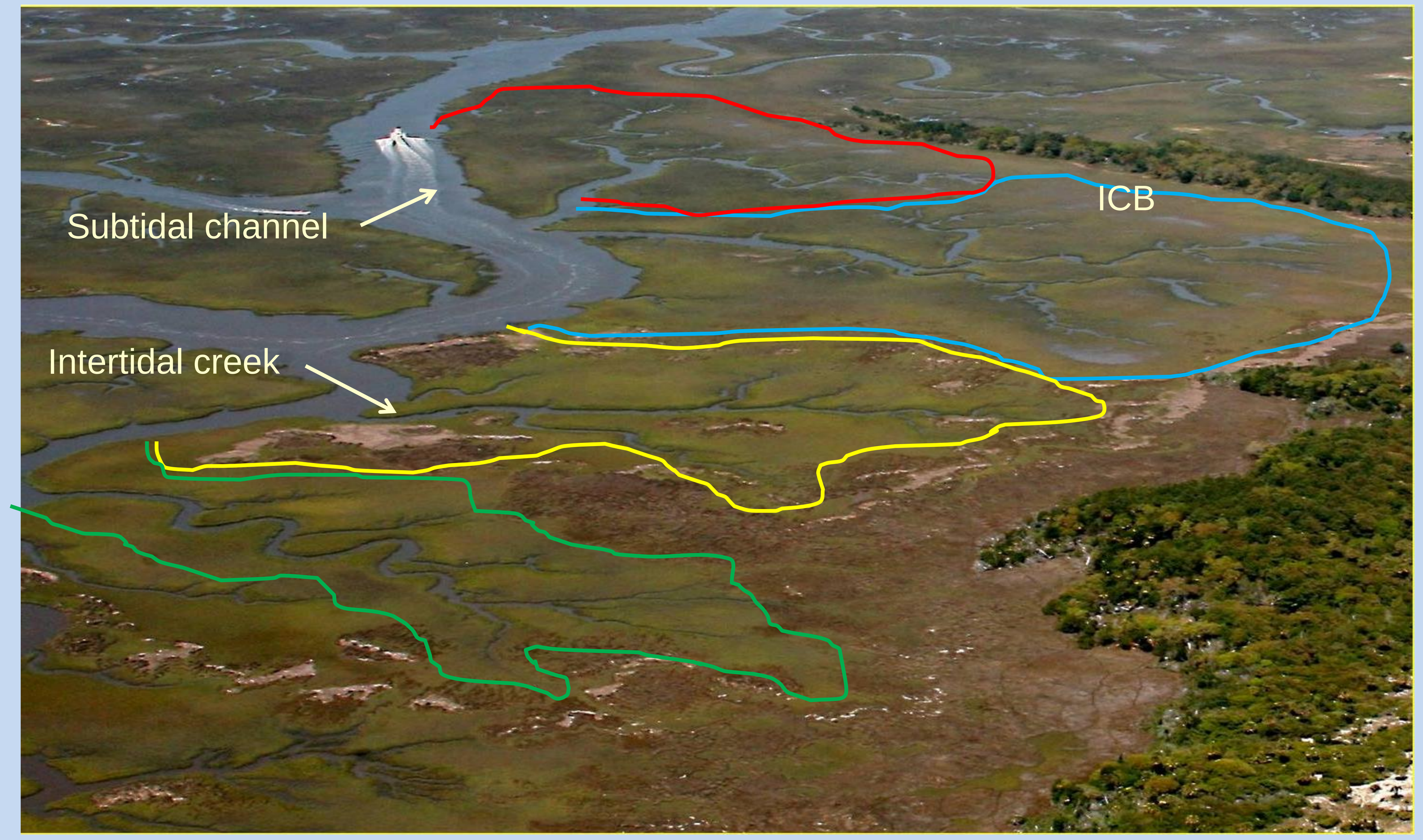
1650 ha (4100 acres)
71% *Spartina alterniflora*
16% open water
13% flats, reefs, and intertidal creeks

1.4 m mean tide range

~ 50% volume exchange with ocean each cycle

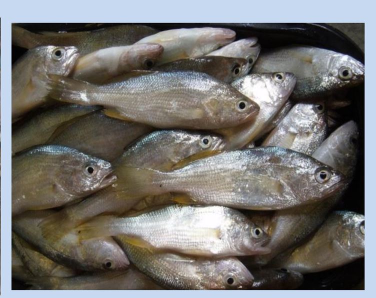
salinities mostly >30

>90% of watershed in natural condition



The intertidal landscape can be thought of as a mosaic of Intertidal Creek Basins (ICBs) which consist of an intertidal creek (main trunk and branches) and an area of surrounding marsh that is flooded and emptied through the mouth of that intertidal creek. ICBs include the creek bed, associated slopes, flats, and oyster reefs, banks, and all vegetated and open areas within the upper intertidal drainage basin.

- more than 1500 ICBs are located within a 17 km^2 area
- average intertidal drainage area is about 2.8 acres
- <10% of the ICBs are located adjacent to upland ridges or forests
- creeks range in length from 3 to >11,000 m
- creek bottom areas range from 127 to >650,000 m^2
- depths of flooded creeks range from <50 cm to >200 cm (in pools) within & among creeks

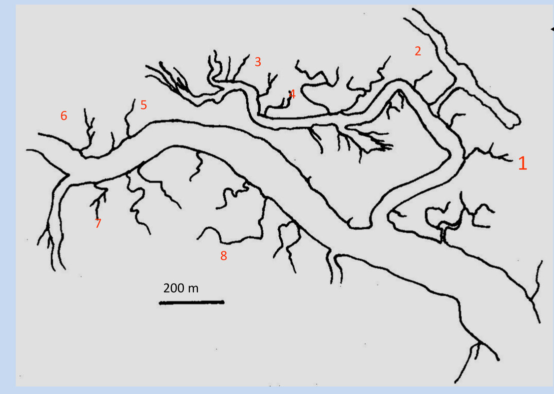


Intertidal creek basins serve as Essential Nekton Habitat

Intertidal creeks are:
- conduits for animal movements to and from subtidal channels
- access points to tidal migratory animals that feed and/or seek refuge on the marsh
- final destinations of other species that feed or seek refuge within the creek
- 142 species (80% of all species recorded in North Inlet estuary) have been captured in ICBs
- 40 species are year-round occupants; spawn, grow, and never leave these habitats
- >70% of all species are transient or temporary nekton; arrive from ocean, grow, and leave
- huge abundance differences: spring and summer are10 to 100 times greater than winter
- a wide range of feeding modes among nekton: from herbivores to top predators

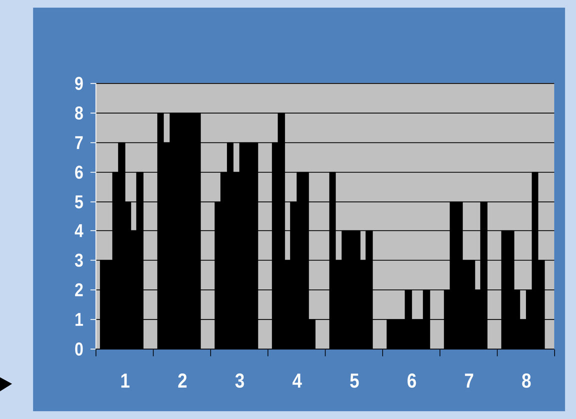
What we know about creeks and the nekton that use them in North Inlet Estuary

Habitat quality varies among creeks



Left: 8 intertidal creeks were sampled each season for 2 yrs. Creeks all 2-6 m wide.

Right: ranks for all 8 creeks; each vertical cluster of 8 shows the rank for each of 8 seasons. Rank of 8 is highest biomass

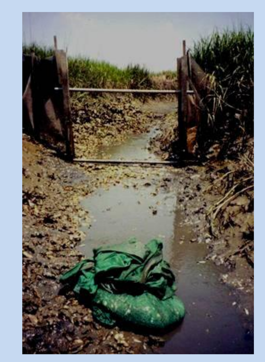


Four out of 28 geomorphology features were most important for nekton use:

1. **steepness of lateral (cross-creek) profile**: gentler slopes are better
2. **mean depth when flooded:** shallower is preferred
3. **rate of flooding and ebbing (flow):** slower exchange is preferred
4. **creek location**: closer to an upland ridge and/or larger subtidal channel are important

VS

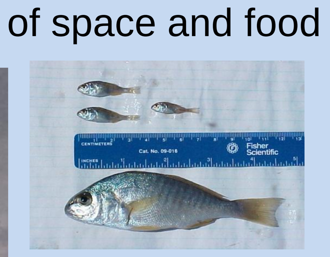
Less important features:
- creek size (e.g. length, width, volume, bottom area)
- amount of oyster reefs
- complexity (bottom roughness, bends, branching)
- linear measure of marsh edge
- area of marsh in the surrounding basin



Summary:
Creeks that were shallow, broad, filled and emptied slowly, and closest to upland ridges and/or larger subtidal channels consistently supported the greatest amount of nekton use during all seasons over two years. These types of intertidal creeks support up to 10 times as many fishes, shrimps, and crabs per square meter (or cubic meter) than others.
Functionally, these features are ones that favor higher benthic infauna densities (meiofauna and macrobenthos) and provide the best conditions for bottom foraging behavior by small nekton.

Nekton Behavior in ICBs

High abundance and diversity in tidal migratory nekton assemblages is possible because species partition the timing of use of space and food resources in creeks.



Ordered tidal movements or migrations
- different species and size classes enter creeks at different times in the tide cycle
- small resident species (e.g. mummichogs and grass shrimps) enter first and leave last
- a high proportion of residents remain in residual pools within the creek at low tide
- the size of the animals entering increases with depth
- the order or succession is predictable and similar among creeks
- the presence of predators can alter the patterns
- not all nekton go with the flow; at any tide stage some are moving against the tide

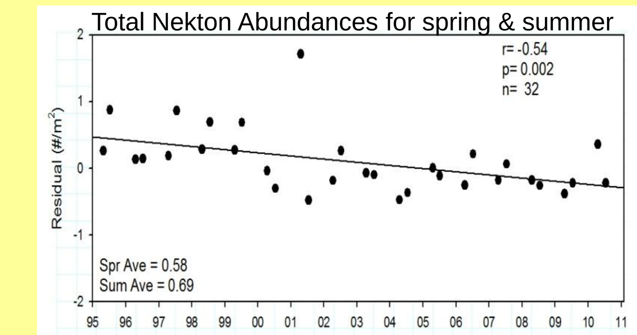
Tendency to establish local residency (Site Fidelity)
- tagging experiments have shown that individuals of both resident and transient species use the same ICB tide after tide even though low tide forces most individuals into a common subtidal channel
- high site fidelity by mummichogs, grass shrimps, striped mullet, spot, silver perch, and pinfish
- some individuals were recaptured in the same creek multiple times over several months

Ecosystem engineers
- nekton mobilize sediments while feeding and affect sediment composition and bathymetry
- nekton excrete ammonium and orthophosphate which can stimulate primary production
- nekton sequester biomass and nutrients in ICBs and export these to the ocean

Long-term changes in nekton use of ICBs; impacts of climate change

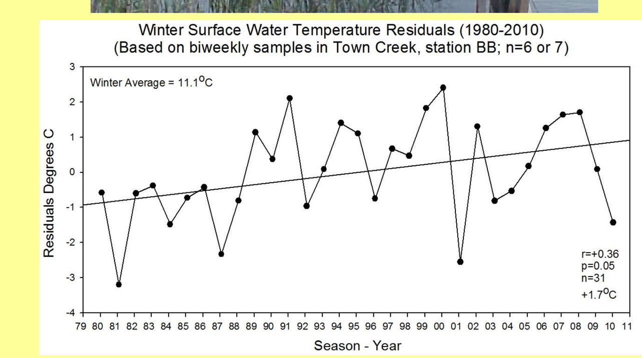
Oyster Landing Basin nekton monitoring, North Inlet, SC 1984 - present:

1) Abundance and biomass of nekton have decreased significantly over the past 15 years.
2) Decreases occurred for 8 of the 15 top species; no species increased in abundance.
3) No change in diversity, richness, and evenness; community composition today is similar.
4) The long-term change might best be described as a downsizing in the extent of nekton use of the intertidal creek basin.
5) Arrival time of juvenile life stages from the ocean has changed for some species: earlier arrival dates have been correlated with increasing water temperatures in the winter/spring.
6) Juveniles arriving earlier have been smaller with size being inversely correlated with temperature.



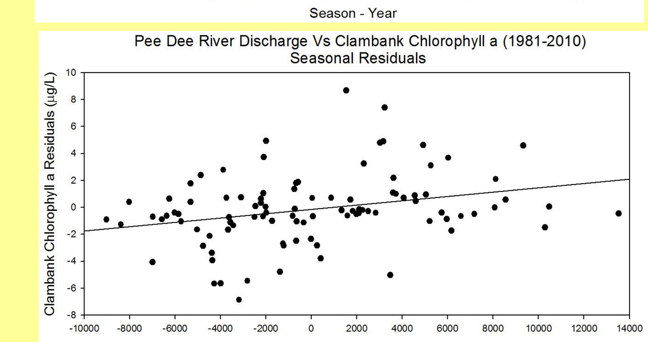
Local Environmental Changes

1) Water temperature has increased significantly over the past 30 years by about 0.9°C for all seasons and 1.7°C for winter.
2) Salinity has increased significantly in the past 15 years as a function of drought and reduced freshwater discharge by major rivers in northern SC.
3) Temperature and salinity changes cannot explain the general decrease in nekton abundance.



Other relevant changes & demonstrated relationships among ecosystem components

1) Chlorophyll in the water column has declined; related to decrease in freshwater discharge.
2) Mesozooplankton has declined; related to chlorophyll.
3) Spartina primary production in Oyster Landing Basin has declined.



Management Recommendations

1. Recognize that intertidal creeks vary considerably in their capacity to support nekton use.
2. Identify intertidal creeks with the highest potential for nekton use and production using key hydrogeomorphological features (shallow, wide, gently sloped bank to bank profiles) and protect them from disturbances that could change their hydrology and geomorphology such as:
   a) atypical patterns of freshwater inflow (e.g. volume, periodicity, sediment load, contaminants)
   b) placement of pilings, docks, and other hard structures in the creek bed and surrounding intertidal basin
   c) physical disturbances of the creek bed or at the confluence of the creek with the subtidal channel (e.g. dredging) that could modify flow dynamics or bathymetry.
3. The presence of oyster reefs within intertidal creeks did not enhance nekton use and because reefs change morphology and hydrology as they develop, the placement of shell and other devices to enhance or restore living reefs within intertidal creeks might adversely impact habitat quality for nekton.
4. Minimize disturbance from April through October when intertidal creek use by fishes, shrimps, and crabs is at the highest level.

Research Recommendations

1. Comprehensive effort to understand temporal and spatial dynamics of nekton diets, prey populations (mostly benthos), and behavioral aspects of trophic interactions at every level.
2. Develop food web network models for creeks to determine relationships between food web structure, biomass, creek geomorphology, and the impacts of climate and anthropogenic disturbances.

Tidal creek research collaborators since 1978:
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