Migration

Definitions:

Migration- The seasonal movement of fish between habitats to complete specific life stages, such as spawning, feeding, or overwintering.

Landward Migration- Movement from marine or estuarine waters into freshwater, often for spawning or juvenile development.

Seaward Migration- Movement from freshwater or estuarine habitats out toward marine environments, often for growth or oceanic life stages.

Flood Tide- The incoming tide that raises water levels and often aids landward movement of fish.

Ebb Tide- The outgoing tide that lowers water levels and can assist with seaward movement or dispersal.

Migration Timing- The seasonal or environmentally triggered window during which fish initiate and complete migration.

Description of Process:

Migration is a critical behavioral function for anadromous fish that move between freshwater and saltwater habitats to complete their life cycles. These annual migrations often follow environmental cues such as water temperature, salinity, flow direction, day length, and tidal phase.

In estuaries, fish use both landward and seaward migration strategies depending on their life stage. Adults may migrate landward on flood tides to spawn, while post-spawning adults, or adults who have completed their migration objective, may ride ebb tides seaward to reach sea or offshore habitats. These movements are often synchronized with selective tidal stream transport, behavioral staging, or energy conservation strategies (next round of break-outs).

Successful migration requires balancing internal conditions (e.g., energy, stress, readiness) with external forces (e.g., current velocity, tidal timing, salinity shifts). Barriers to movement, unfavorable hydrodynamics, or poor timing can result in delayed arrival, missed spawning, higher predation risk, or increased contaminant exposure. Juveniles are especially sensitive to energy costs and environmental mismatch.

In modeling, migration should capture directionality (landward vs. seaward), timing (seasonal and tidal), energetic cost, and behavioral decision-making. Individual migration

paths and durations can influence exposure risk, spawning success, and survival, making this a key integrative process in estuarine models.

Little Facts:

- Anadromous fish often migrate during high-discharge spring events, using flow to reach spawning habitat faster.
- Some species only move during specific tidal phases (e.g., flood tide for landward migration).
- Migration success depends on both physical conditions and internal cues like maturity and energy levels.
- Delayed migration can reduce reproductive success or lead to spawning in suboptimal habitats.
- Energetic cost of migration increases with distance, poor hydrodynamic conditions, or environmental stressors (e.g., salinity, contaminants).
- Younger and small-bodied fish may be more vulnerable during migration due to lower swimming capacity or navigation ability.

Discussion Objectives:

- Is this function accurate and realistic to your knowledge?
- What are the migration objectives of each species in the model (e.g., spawning, foraging, predation, sheltering).?
- Do all species in the model migrate using similar strategies, or are there key differences?
- What accounts for species-specific migration differences (e.g., timing, migration cues, destination, behavior, energy needs)?
- Where in the estuary would you expect the most challenging or high-risk migration zones?
- What kind of model outputs should reflect this process?
    - Are fish successfully reaching intended habitats (e.g., spawning grounds, nursery zones)?
    - Do tides and flow direction facilitate or hinder movement at different stages?
    - Are there hotspots of delayed migration or increased exposure due to timing mismatches or habitat fragmentation?