Penobscot Estuary Community Modeling Workshop
ABM Draft Spawning Function
August 6th, 2025

Spawning Behavior

Drafted By: Vanessa Quintana

Relevant Background Information

Term	Definition
Pairwise Spawning	A reproductive strategy where one male and one female must be in the same place to release and fertilize eggs through direct interaction.
Broadcast Spawning	A reproductive strategy where females release eggs into the water column and males fertilize them externally, often without direct contact.
Stress	A physiological response to suboptimal environmental conditions like high salinity or temperature, which can delay or prevent spawning.
Iteroparous	Fish that can spawn multiple times in their lifetime across different seasons or years.
Semelparous	Fish that spawn only once in their lifetime and die shortly afterward.
Homing	The ability of fish to navigate back to their natal or preferred spawning areas, often using environmental cues.

Model Objectives

Purpose: Simulate spawning based on individual fish condition and reproductive strategy once they reach homing habitat.

Objectives:

1. **Simulate spawning behavior**
   Trigger spawning when fish meet thresholds for energy, low stress, and reproductive capacity.
2. **Capture species-specific spawning strategies**
   Distinguish between broadcast spawners (e.g., alewife) and pairwise spawners (e.g., sturgeon) based on their reproductive mode and spawning interactions.
3. **Track reproductive outcomes**
   After spawning, fish either continue migration or enter a recovery phase depending on their energy, age, and mortality risk. This helps reflect realistic patterns like migration success or overwintering.

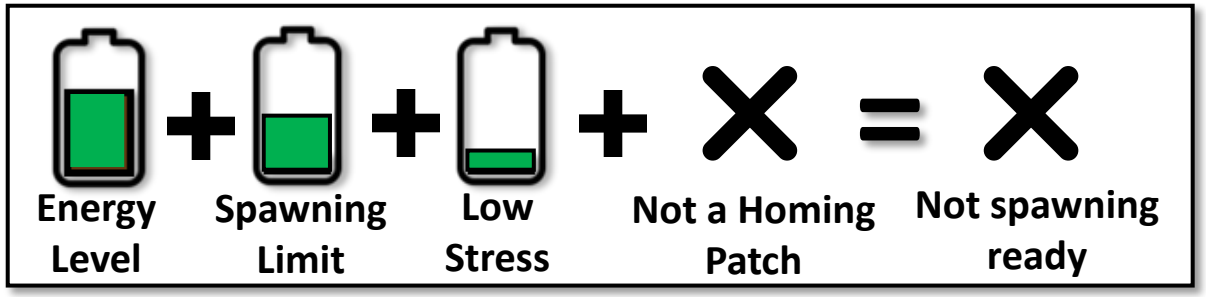
Conditions that Trigger Spawning

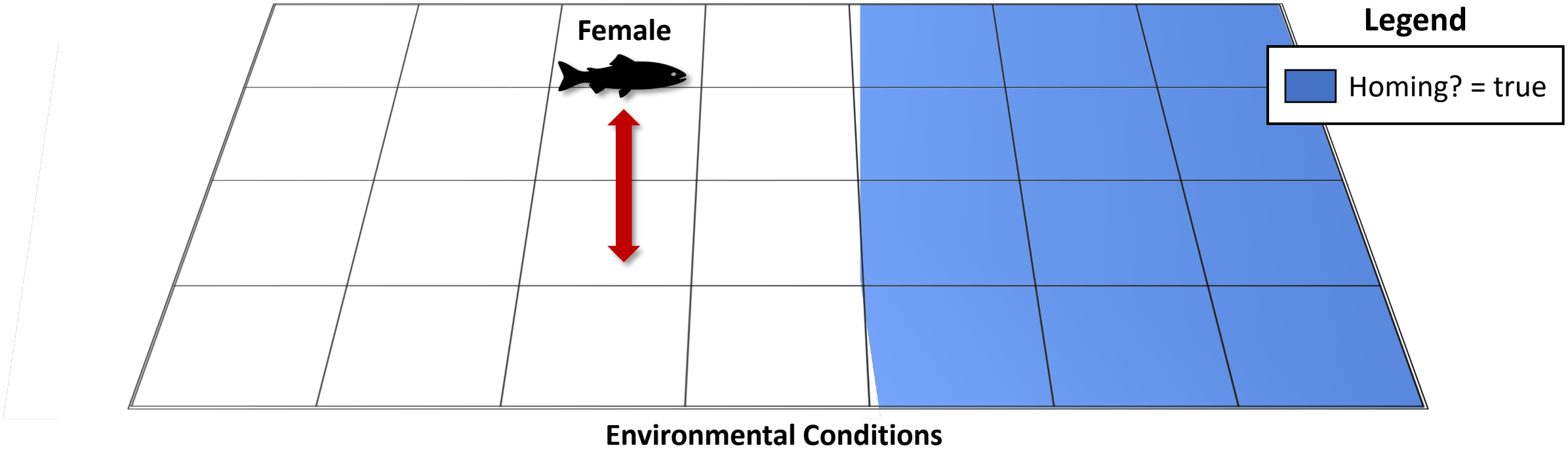
Condition	What it Means	Why it Matters
Homing? = True	The fish has reached its known spawning area.	Spawning should only happen in familiar reproductive zones.
Energy > Spawning Energy	The fish has enough energy to spawn.	Low energy can prevent successful reproduction
Stress < 3	The fish has low stress levels.	High stress reduces reproductive success
Spawns < Limit	The fish has not reached its maximum number of spawns for the migration.	Prevents unrealistic spawning frequency and accounts for fish that spawn several times in one migration

All of these conditions must be true for a fish to spawn.

Broadcast Spawners:

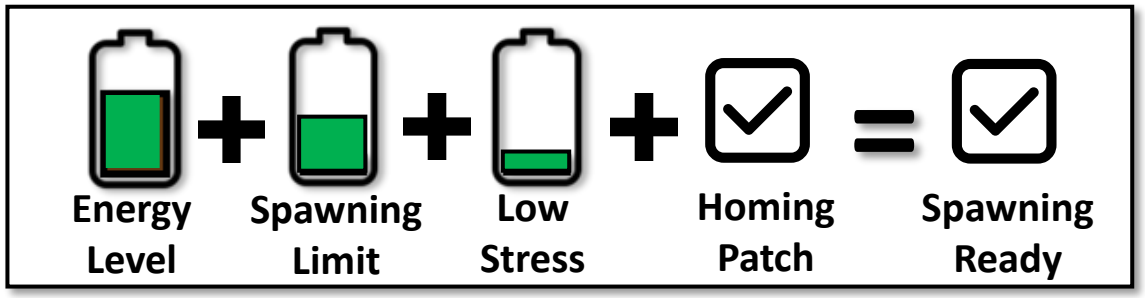
Female

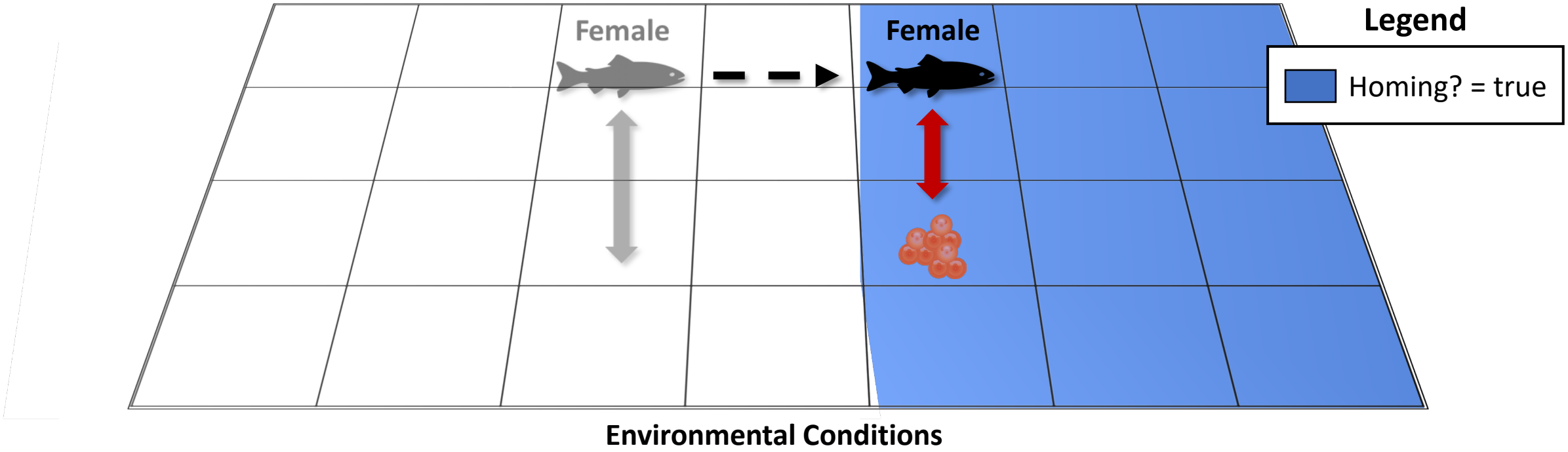




The female has enough energy and low stress but cannot spawn until she reaches her known spawning area.

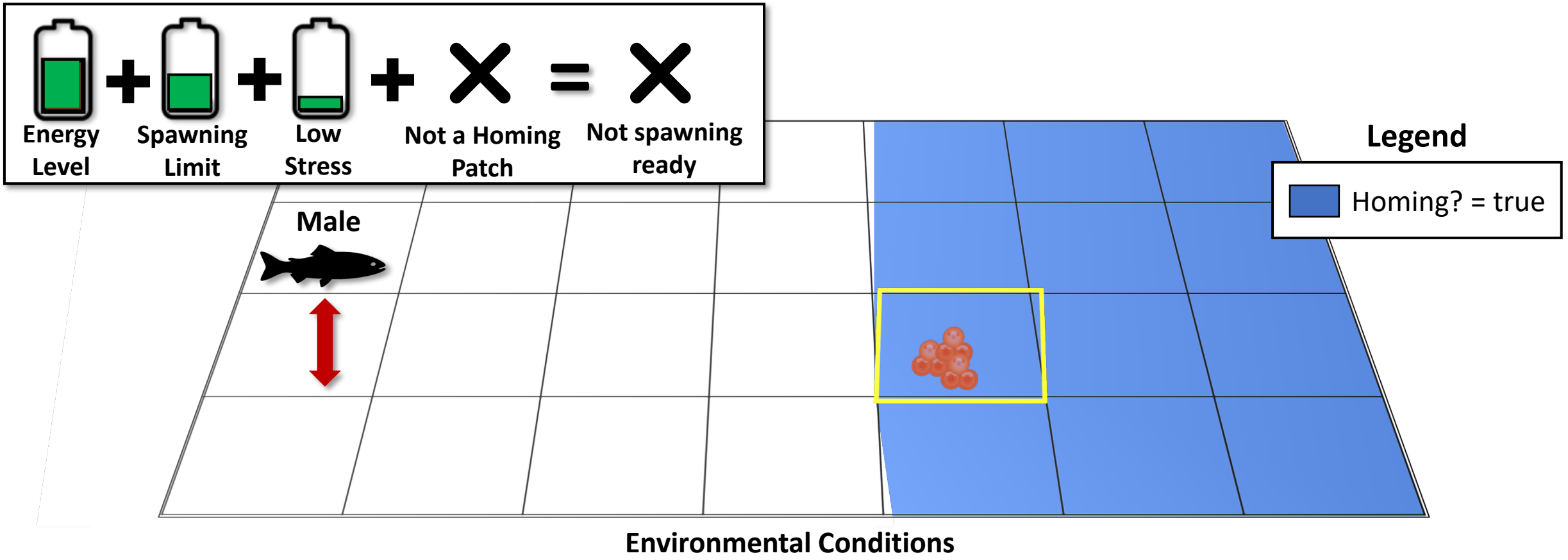
Broadcast Spawners: Female





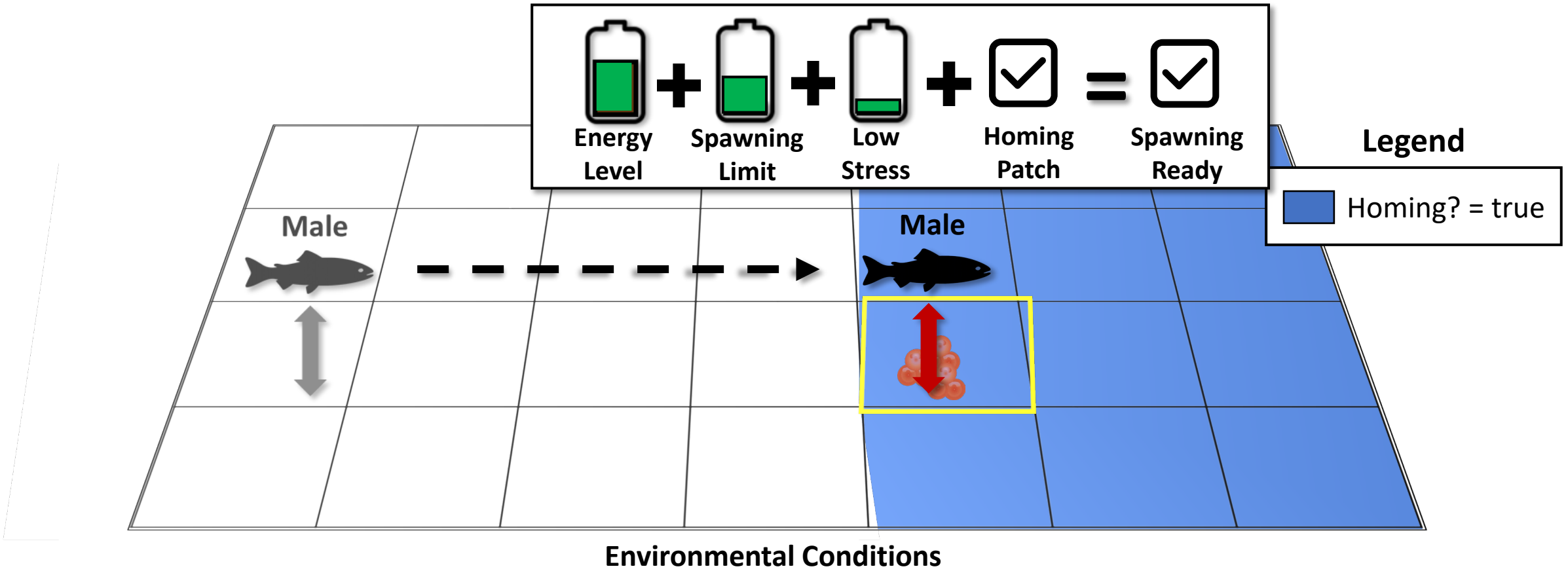
Once the female reaches a homing patch and conditions are right, she releases her eggs and spawning starts.

Broadcast Spawners:
Male



The male is in good condition but must locate a spawning patch with eggs before he can fertilize them.

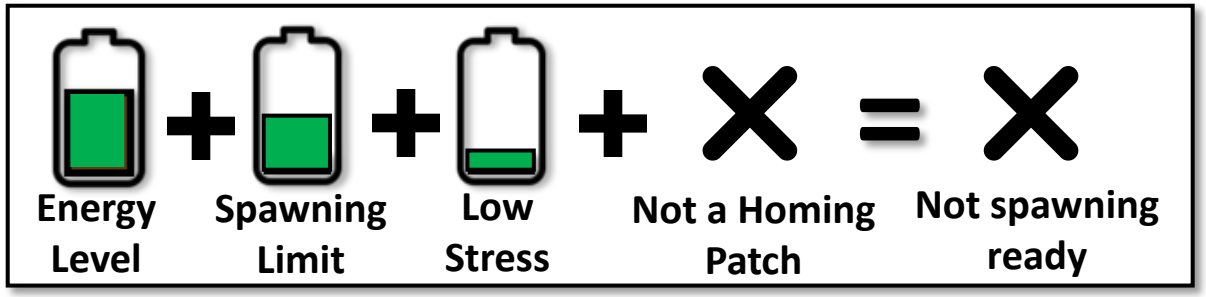
Broadcast Spawners: Male

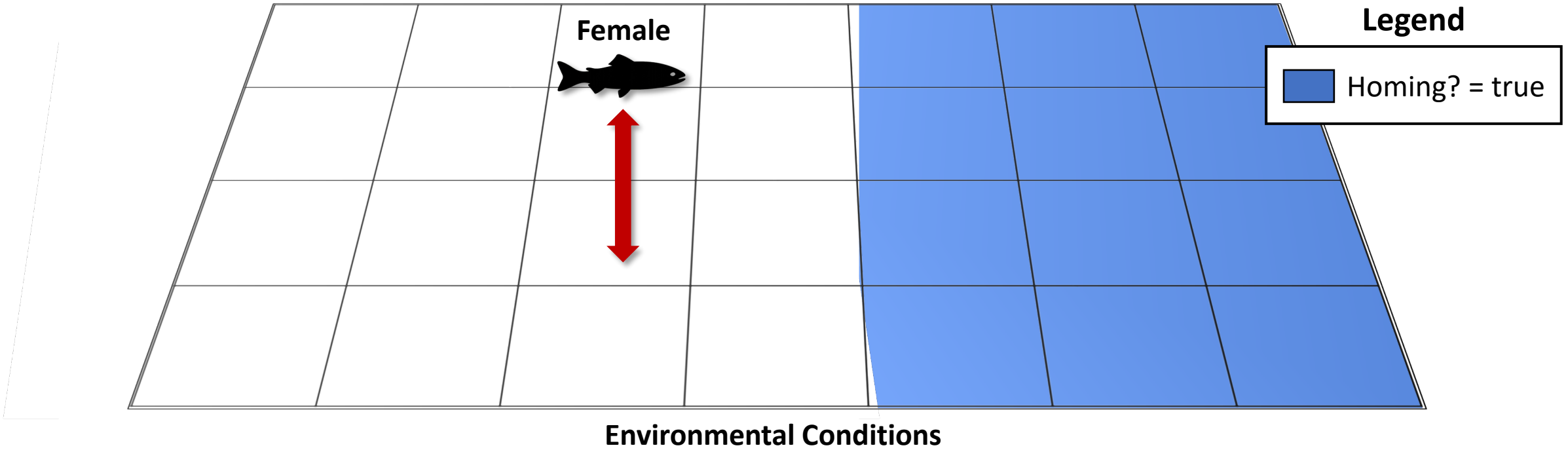


The male reaches a patch with eggs and fertilizes them, completing his role in the spawning process.

Pairwise Spawners:

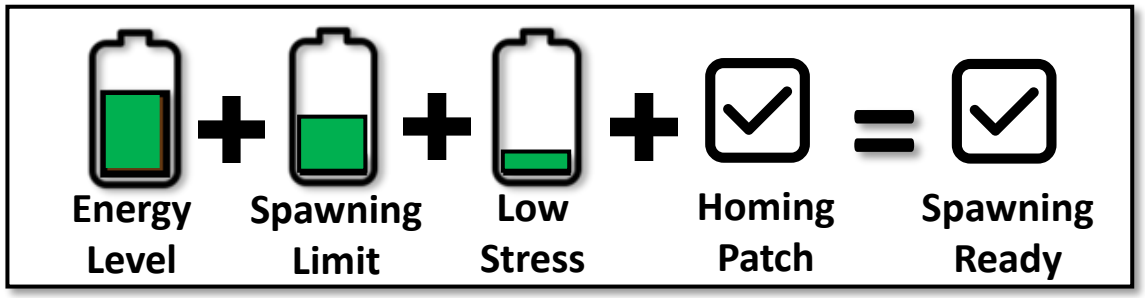
Female

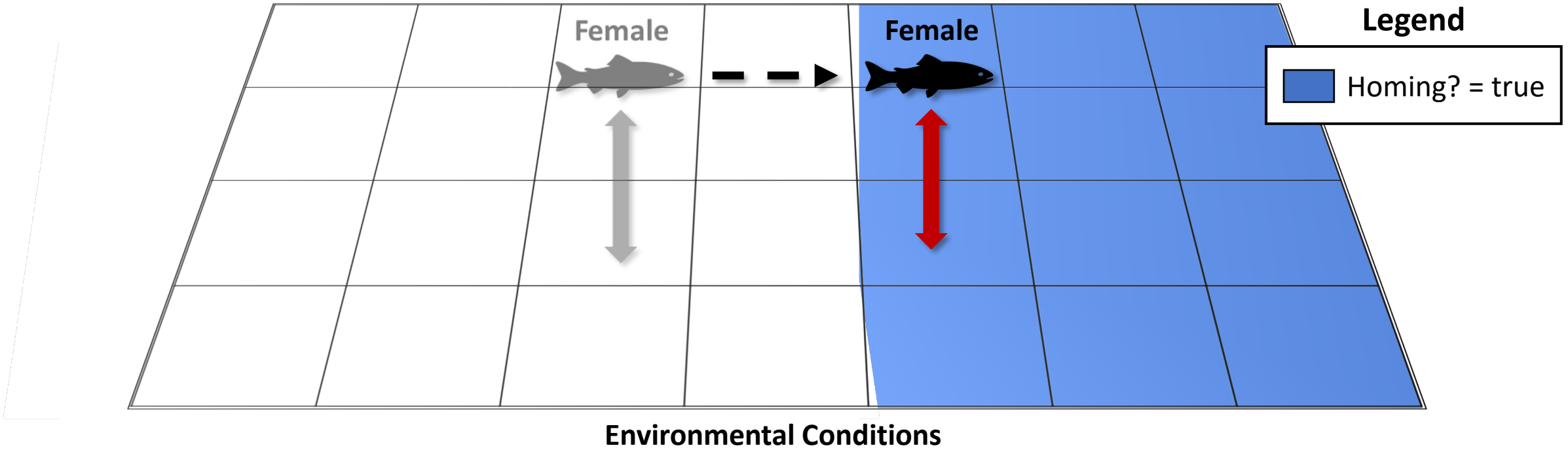




The female is not spawning-ready because she has not reached a known homing patch, even though her energy and stress levels are acceptable.

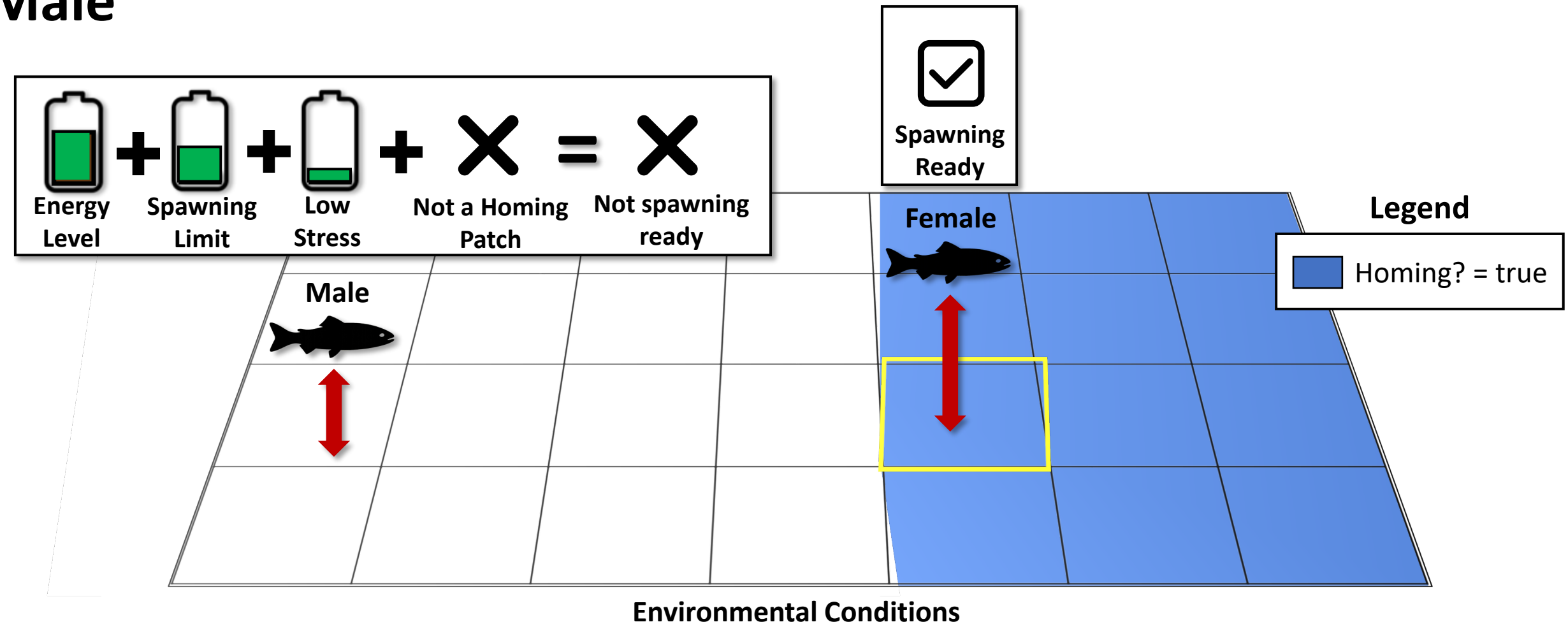
Pairwise Spawners:
Female





Once the female reaches a homing patch and meets all physiological conditions, she becomes spawning-ready and waits for a male.

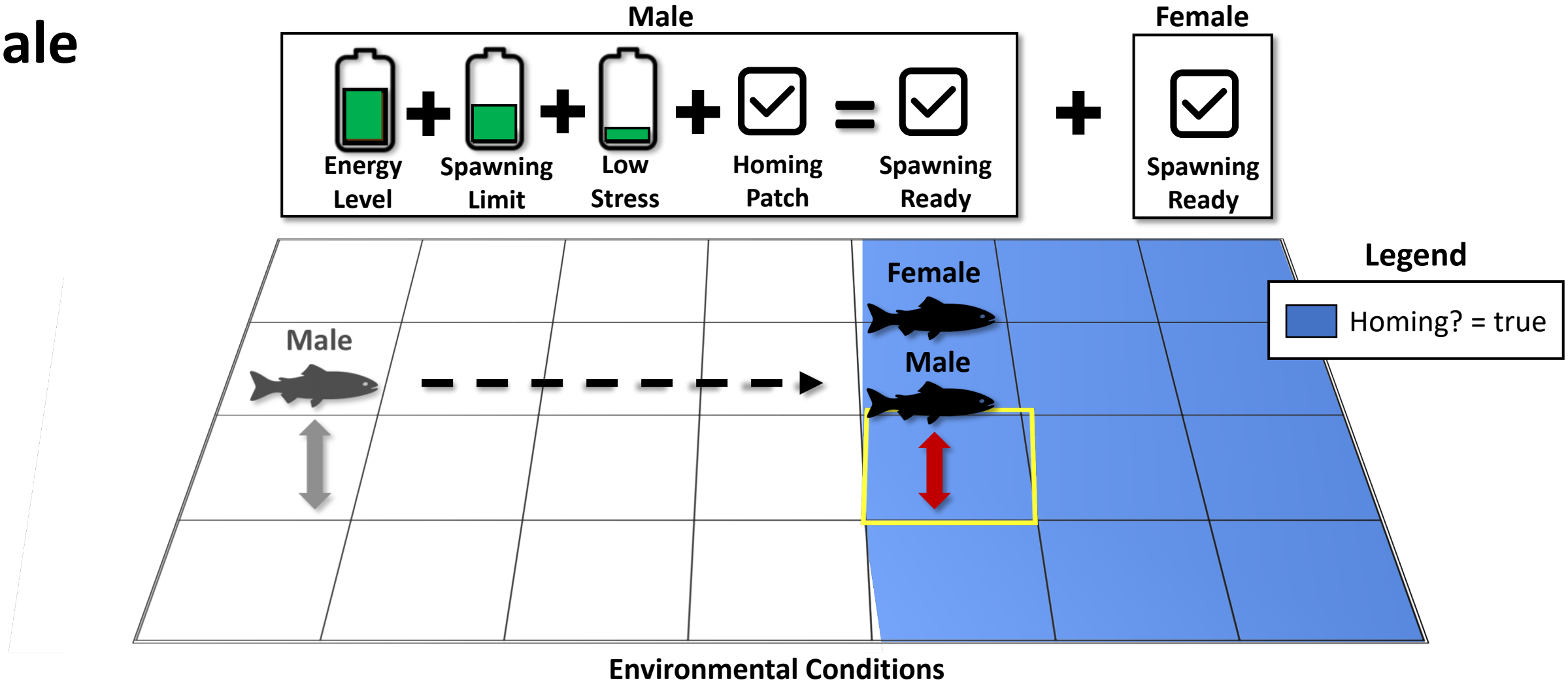
Pairwise Spawners:
Male



The male has good energy and low stress, but he cannot spawn unless he is in a homing patch with a ready female.

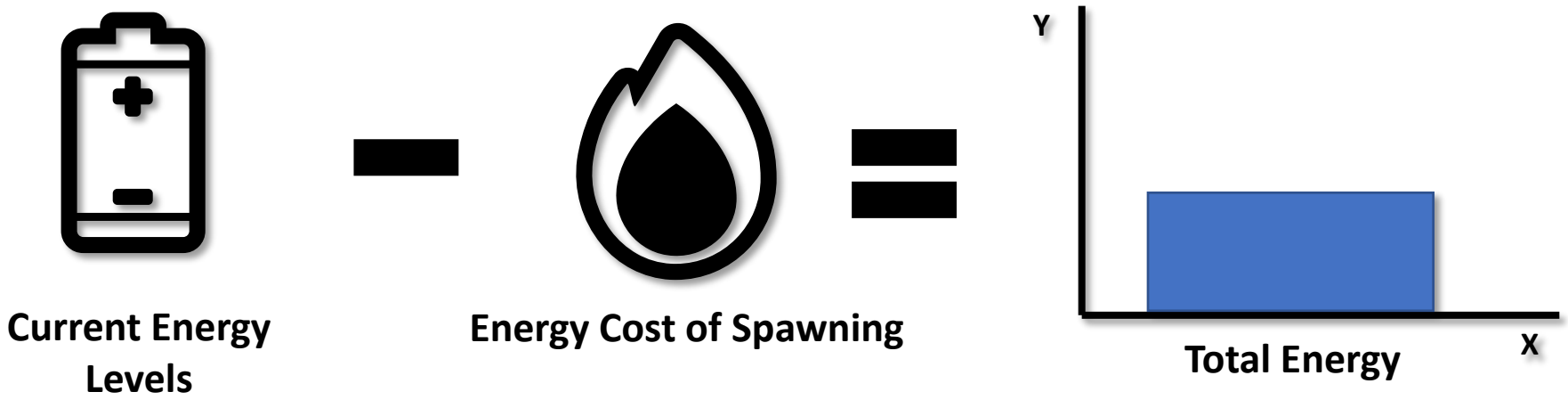
Pairwise Spawners:

Male



When both a male and female meet spawning conditions and are in the same homing patch, spawning occurs successfully.

Total Energy Balance



Total Energy: amount of energy a fish has left to complete migration.

A fish's total energy budget depends on how much it starts with minus what's spent on spawning.

Individual-Specific Traits

Trait Type	Generalization
Stress	Sensitivity to salinity and temperature changes that may delay or prevent spawning
Energy	Internal reserves required for gamete production and post-spawning recovery
Spawning Strategy	Depends on preferences of fish (broadcast vs pairwise)

Each fish's size, age, energy, stress, and reproductive strategy shape its ability and readiness to spawn.

Outputs of Interest

Type	Variable	What It Tells Us
Temporal	Spawned?	Indicates if and how many times a fish has spawned.
	Time-Since-Spawning	Tracks recovery and overwintering likelihood after each spawn.
	Overwintering Probability	Estimates likelihood that a fish will overwinter based on energy, age, and spawn timing.
Spatial	Spawning-Species	Location of patches repeatedly used for foraging.
	Spawning-Encounters	Which species have used a patch for reproduction.
	Overwintering Probability	Tracks the spawning areas with highest overwintering likelihood across agents.

The model tracks where, when, and how fish spawn to identify reproductive hotspots, timing bottlenecks, and recovery or overwintering risks.

Discussion Prompts

1. **Accuracy & Realism**

- Do species-specific spawning triggers (like homing and energy thresholds) reflect what you've observed in wild populations or your personal knowledge?
- Should the model allow for fallback spawning if fish fail to reach their natal site, and how might this influence reproductive success under fragmented or altered flow regimes?

2. **Missing Variables, Traits, or Parameters**

- Should traits like age at maturity, prior spawning experience, or sex ratio dynamics be included to better reflect reproductive success?
- Can flow velocity, temperature, or salinity gradients physically limit access to spawning sites even when fish are ready to spawn?

3. **Outputs of Interest**

- Which outputs (e.g., spawning frequency, location, post-spawn mortality, or overwintering probability) would best support conservation or management needs?
- Could outputs like spatial clustering of spawning events inform infrastructure planning to reduce disruption of reproductive corridors?