 

Using vessel monitoring systems data to characterize movement patterns of the Pacific Salmon ocean troll fishery in response to variable oceanographic conditions

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Overview

Methods

- Transfer ecological methods to human systems to describe changes in:
    - Fishing locations of salmon fisheries
    - Associated behavioral states (e.g., fishing, searching)

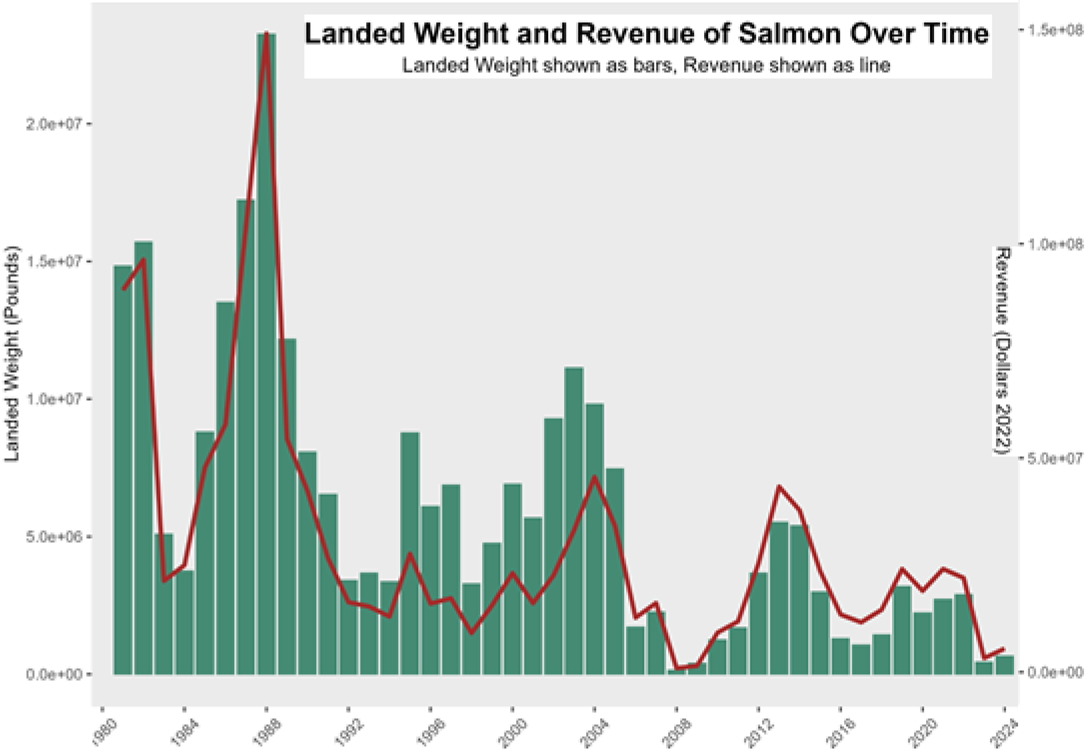
Preliminary Results:

- Methods were successfully validated by one independent data source
- Post marine heatwave (the”blob”), fishers spent more time searching for fish and less time fishing

Importance:

- Understanding this is useful for:
    - Conservation of threatened salmon stocks
    - Understanding how fishing costs change over time
    - Better estimates of CPUE

Rationale



- Climate change is projected to cause declines in landings revenue
    - Not felt evenly among geographic areas

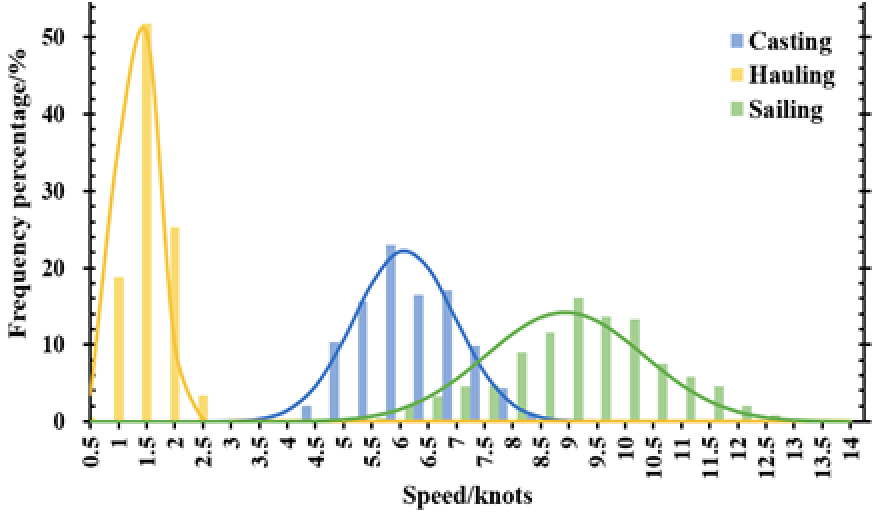
- Location of fishing activity can reveal areas of:
    - High fishing intensity
    - Potential space-use conflict
- Changes in these locations can reveal:
    - How fishers respond to environmental change
    - Adaptive capacity of a fleet

Data

- Pacific Salmon Ocean Troll Fishery (Chinook and coho)
  - Fishers who also fish for groundfish → ~20%
- Washington, Oregon, and California
- 2007 - 2023
- **Pacific Fisheries Information Network (PacFIN):**
  - Landings receipts data
  - Vessel monitoring systems (VMS) data
  - → New VMS-salmon landings "trip" data
- **Previous studies have used VMS data to assess:**
  - Spatial fishing behavior (Janette et al., 2010; O'Farrell et al., 2019; Li et al., 2022)
  - Fishing effort (Thoya et al., 2021; Zhao et al., 2021)
  - Fishing uncertainty (Ducharme-Barth & Ahrens 2017)

Characterizing Fisher Movement

- Can we assess how fisher movement behavior has changed in response to variable oceanographic conditions?
  - E.g., has time spent "searching" for fish increased over time as salmon shift their range into more suitable habitats and fishers adjust their behavior to find them?



Source: Li et al. (2022) - Yellow Sea prawn fishery

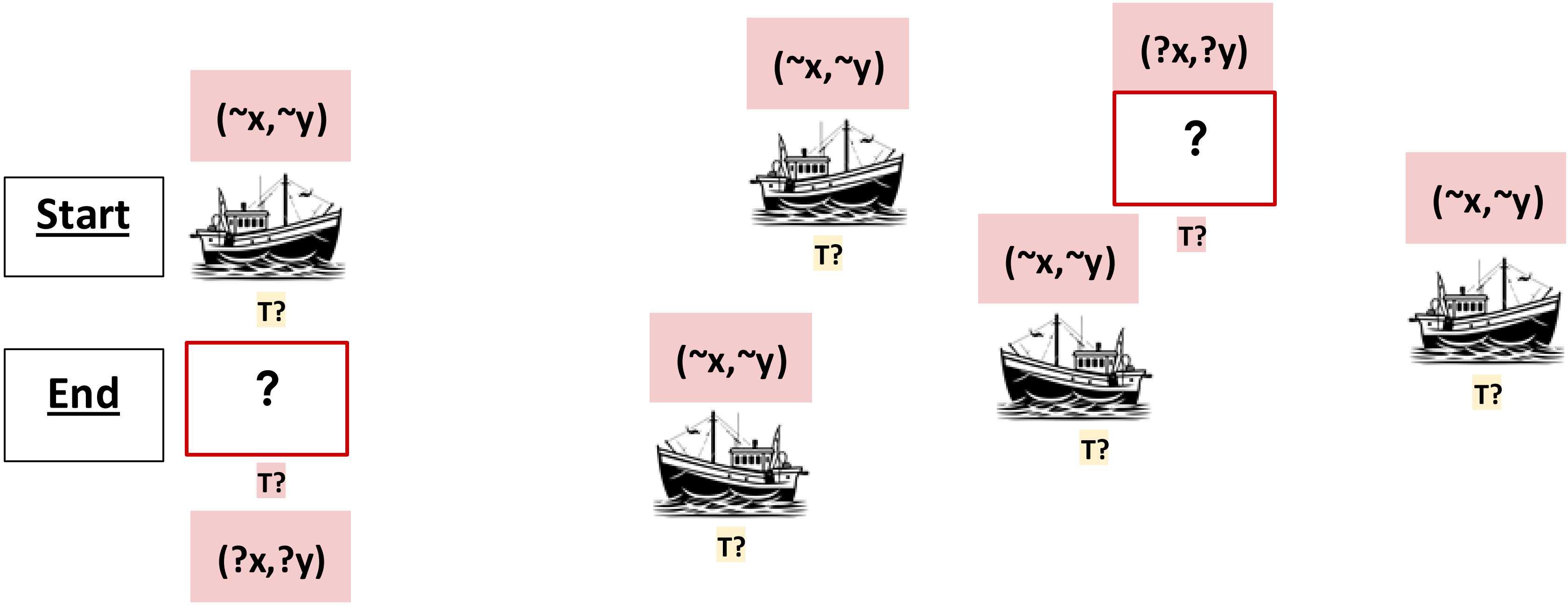
Characterizing Fisher Movement

- **1) Methods from fisheries economics:**
  - Artificial neural networks; random forest models
    - Shrimp, Yellow Sea (Li et al., 2022); Reef fish, Gulf of Mexico (O'Ferrell et al., 2024)

- **2) Methods from animal movement ecology:**
  - State-space models; hidden Markov models
    - Blue whales (Hucke-Gaete et al., 2018); Pumas (Wang et al., 2015)

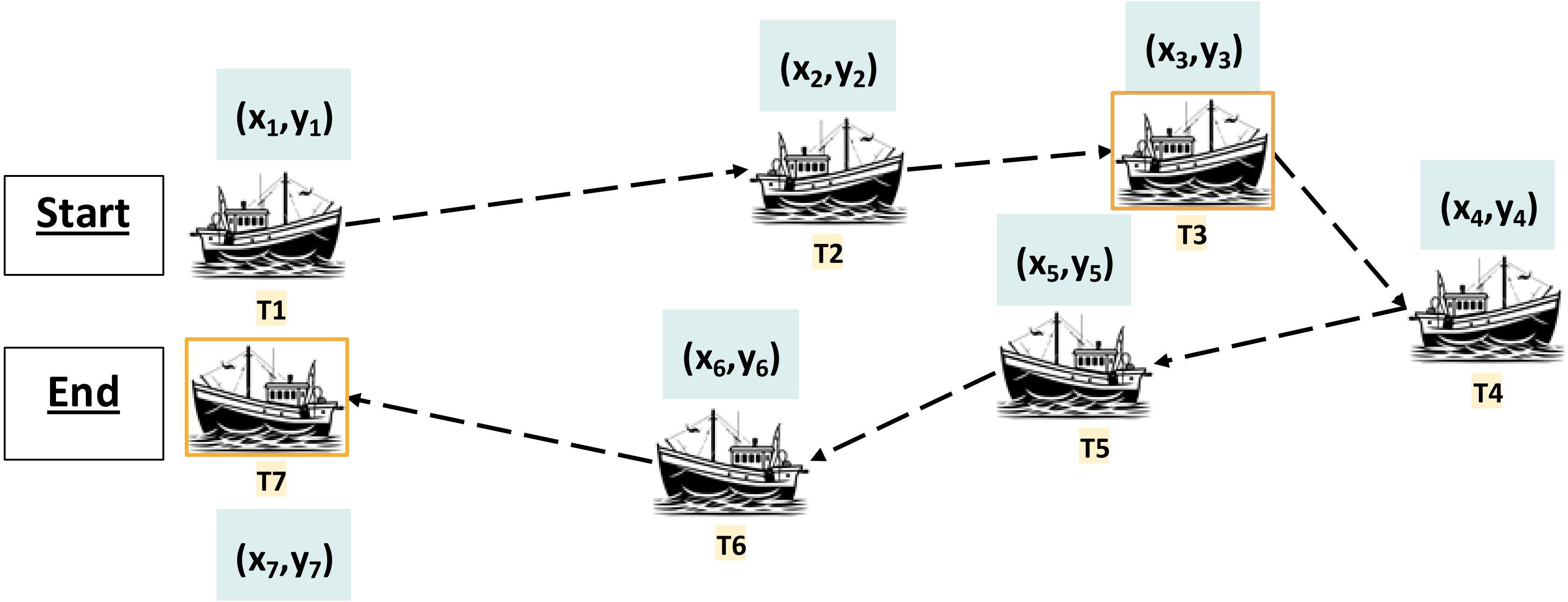
Methods - 1) State Space Model

- Data gives us...
  - Observed locations with measurement error



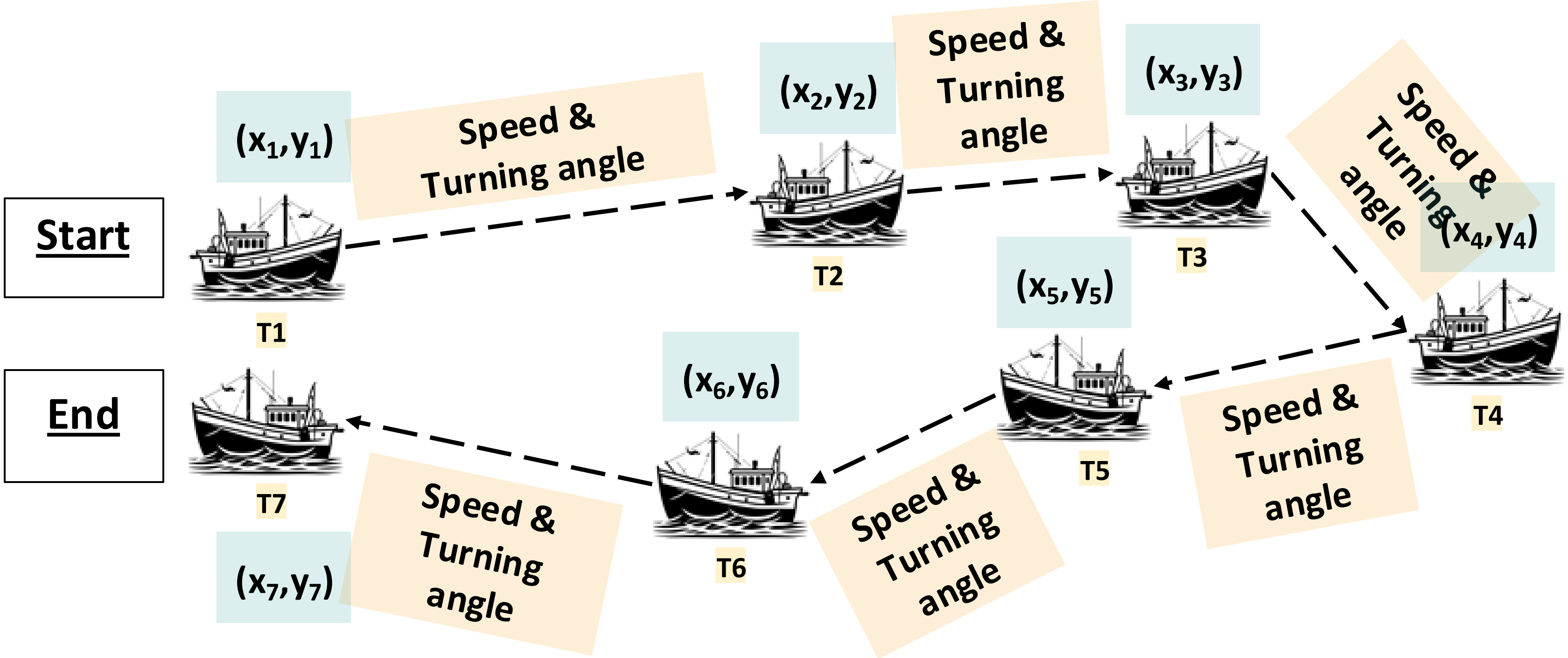
Methods - 1) State Space Model

- Fitting a SSM gives us unobserved true states:



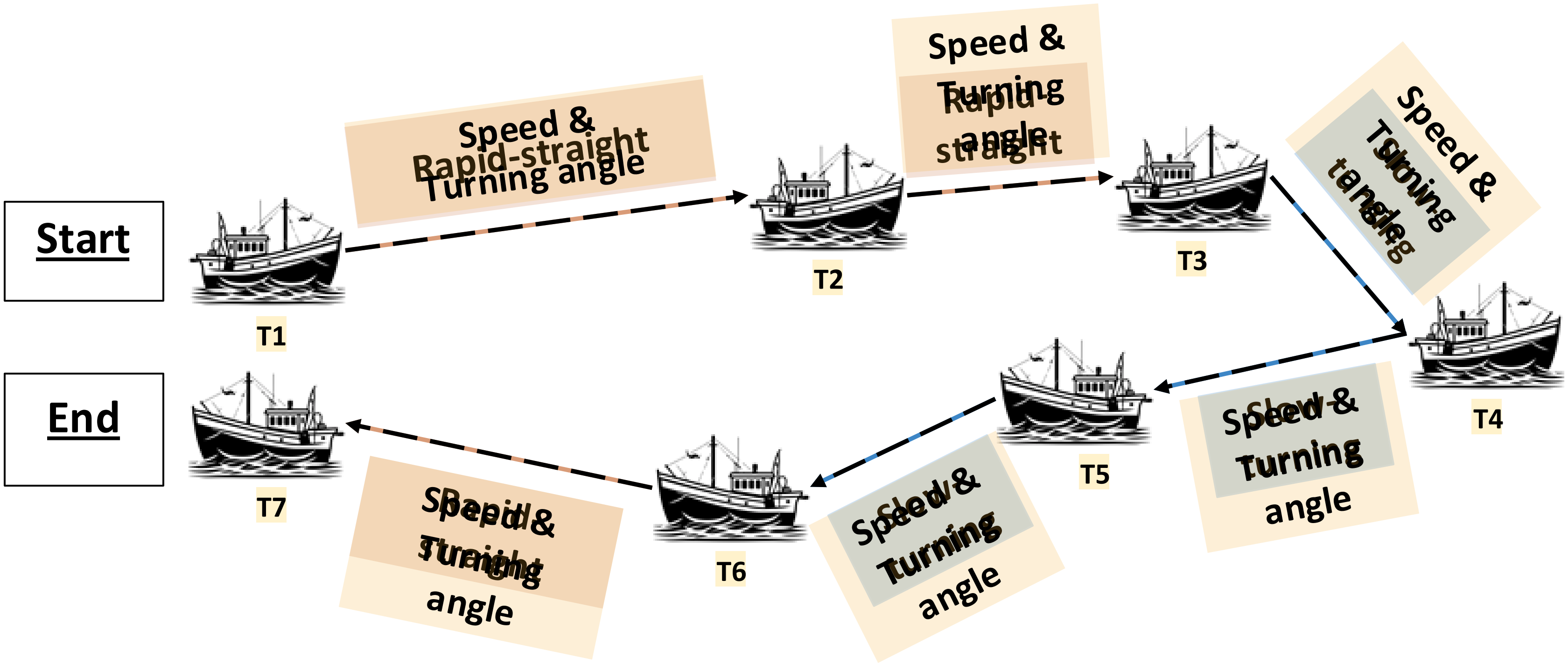
Methods - 1) State Space Model

- Fitting a SSM gives us unobserved true states:
  - 1) Estimated true locations with regularized data

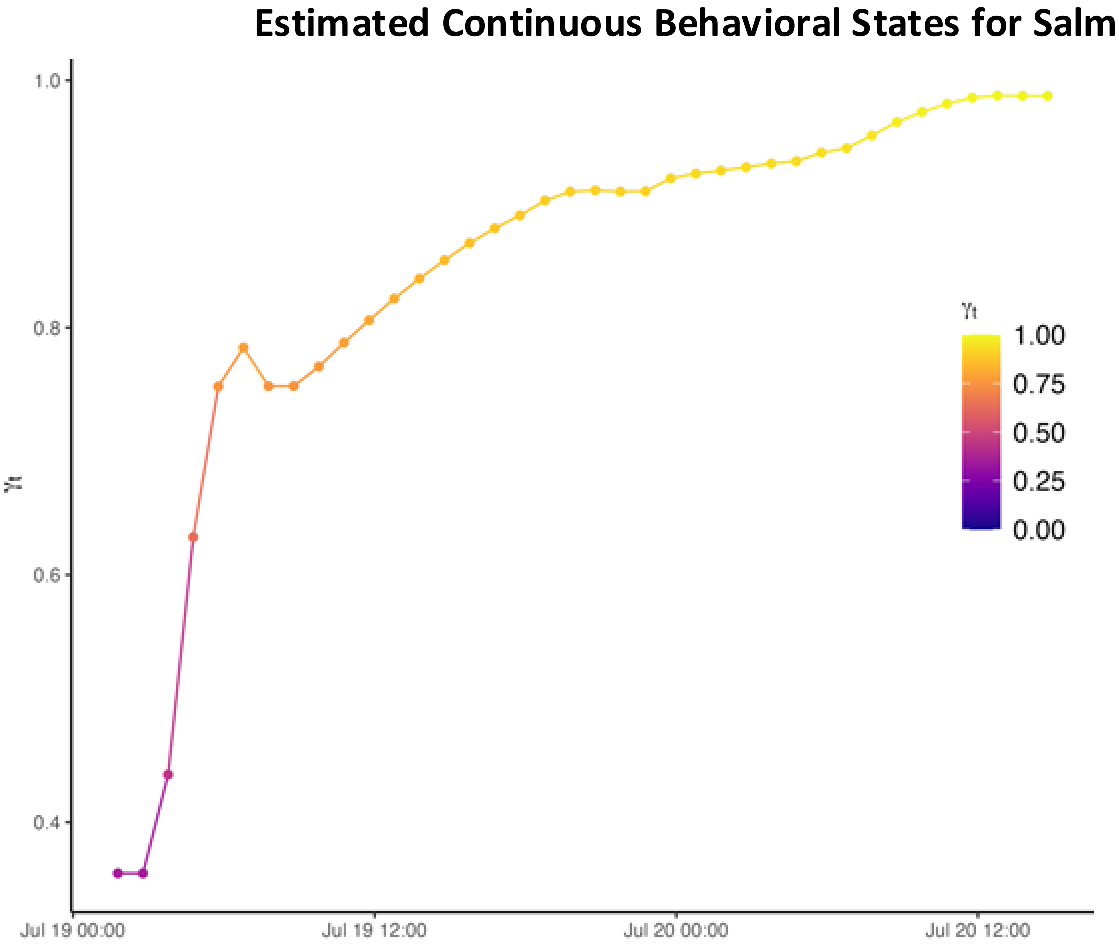


Methods - 1) State Space Model

- Fitting a SSM gives us unobserved true states:
  - 1) Estimated true locations with regularized data
    - → calculated movement metrics

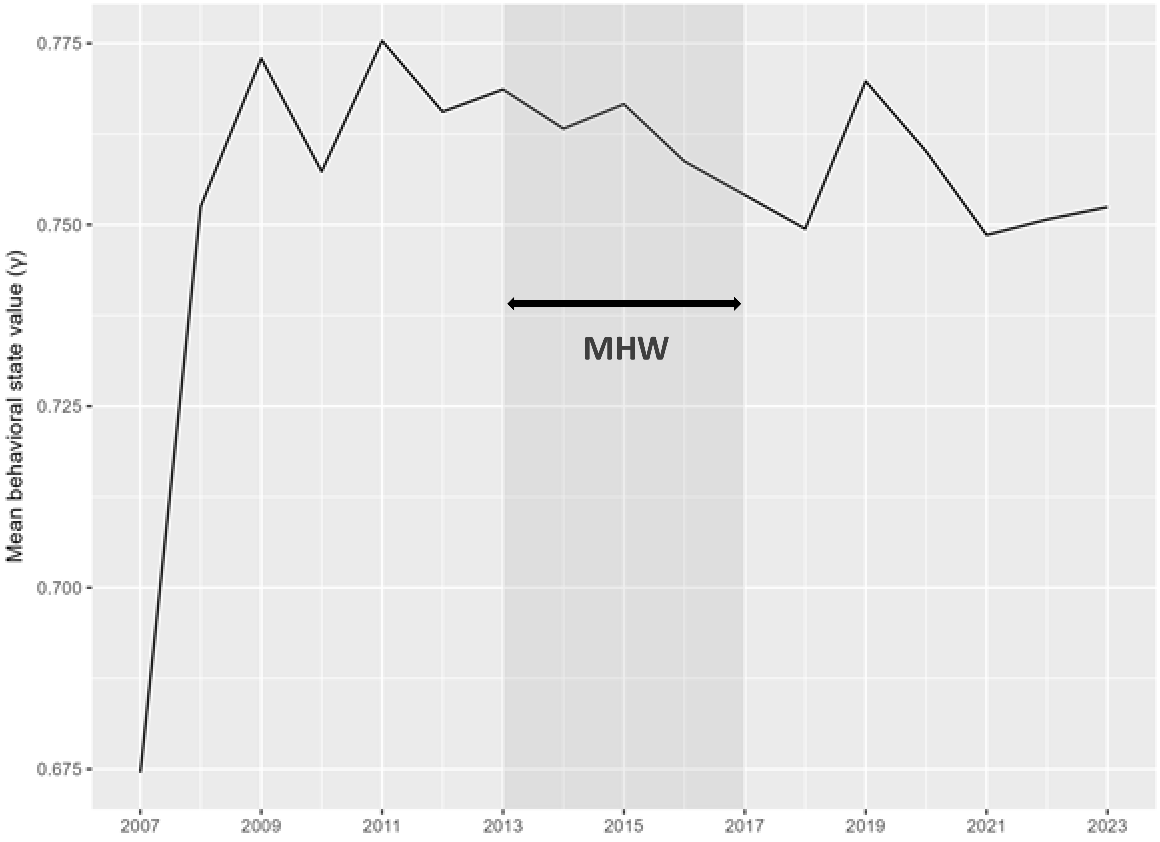


Preliminary Results - 1) State Space Model



- $\gamma = 0$
  → slow, turning movements
- $\gamma = 1$
  → fast, straight movements

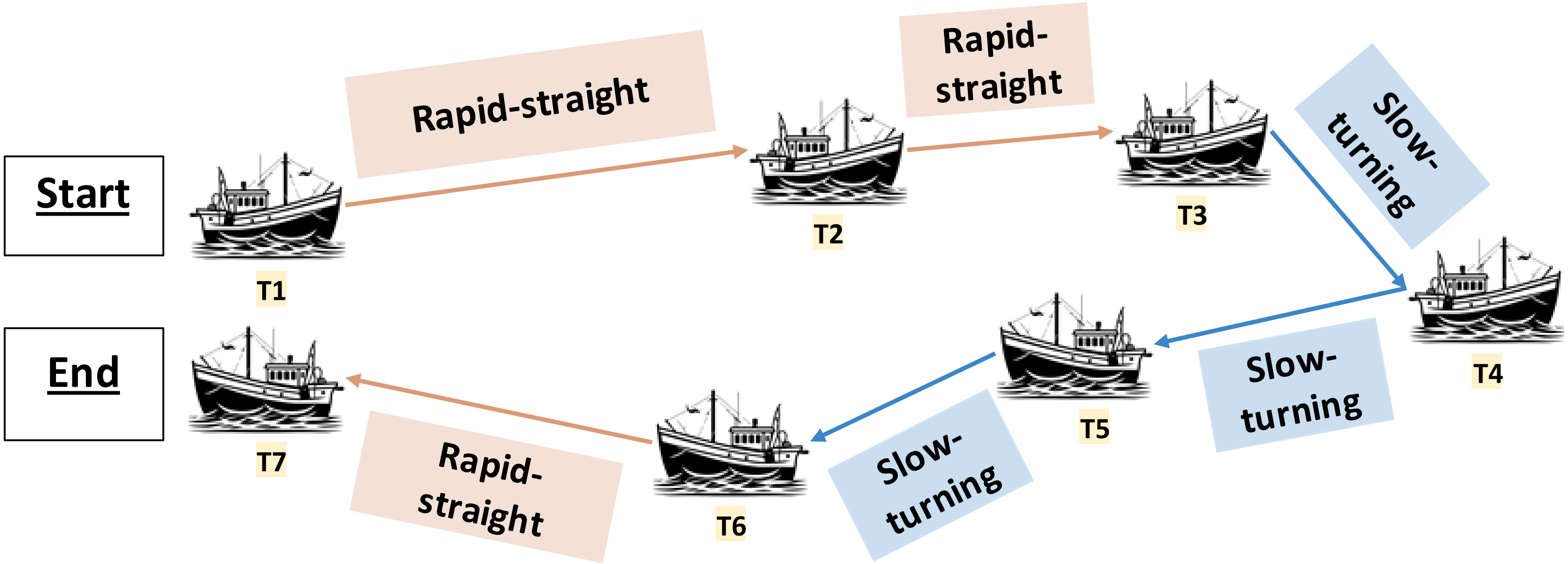
Preliminary Results - State Space Model



- Increasing time spent "foraging" during MHW years
- Does foraging mean "searching" or "fishing"?
- <u>**Issue**</u>: model does a poor job estimating distinct behaviors

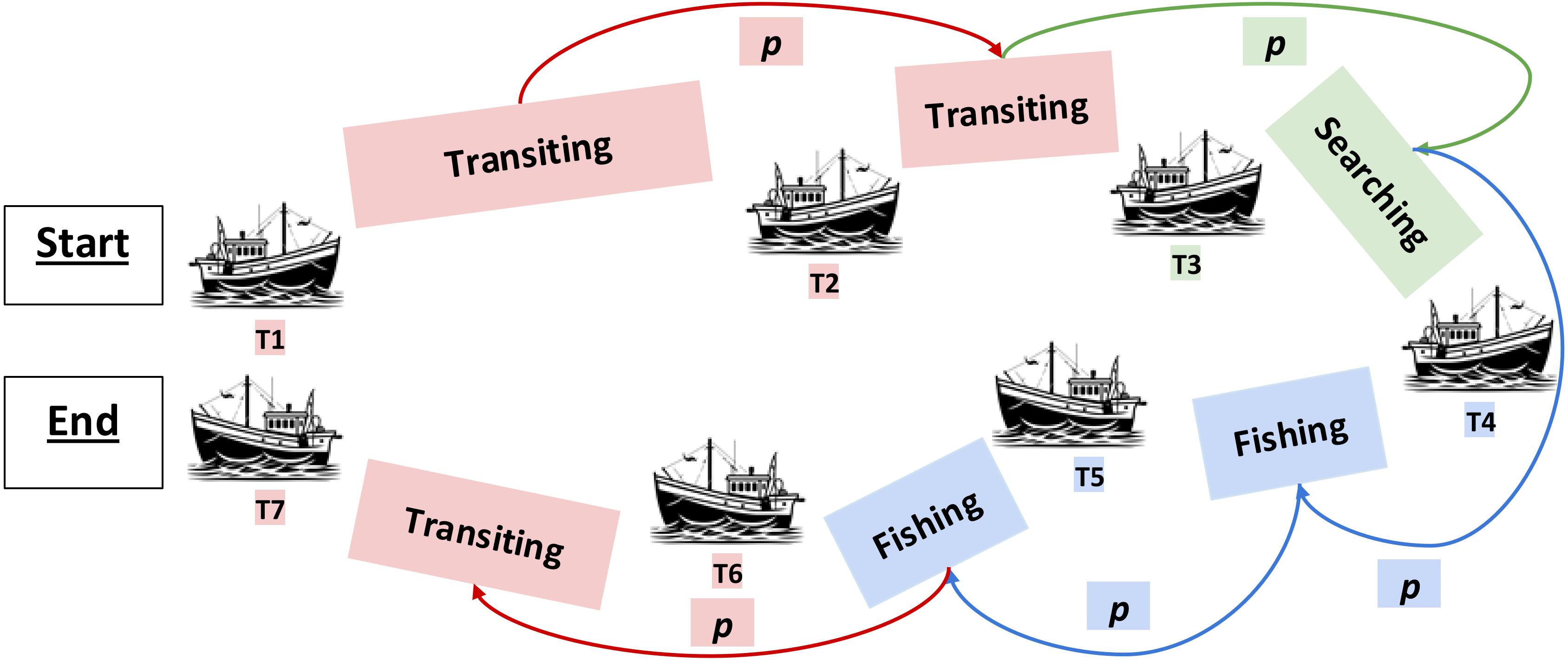
Methods - 2) Hidden Markov Model

- Previously, fitting a SSM gave us continuous estimated behavioral states at each timestep

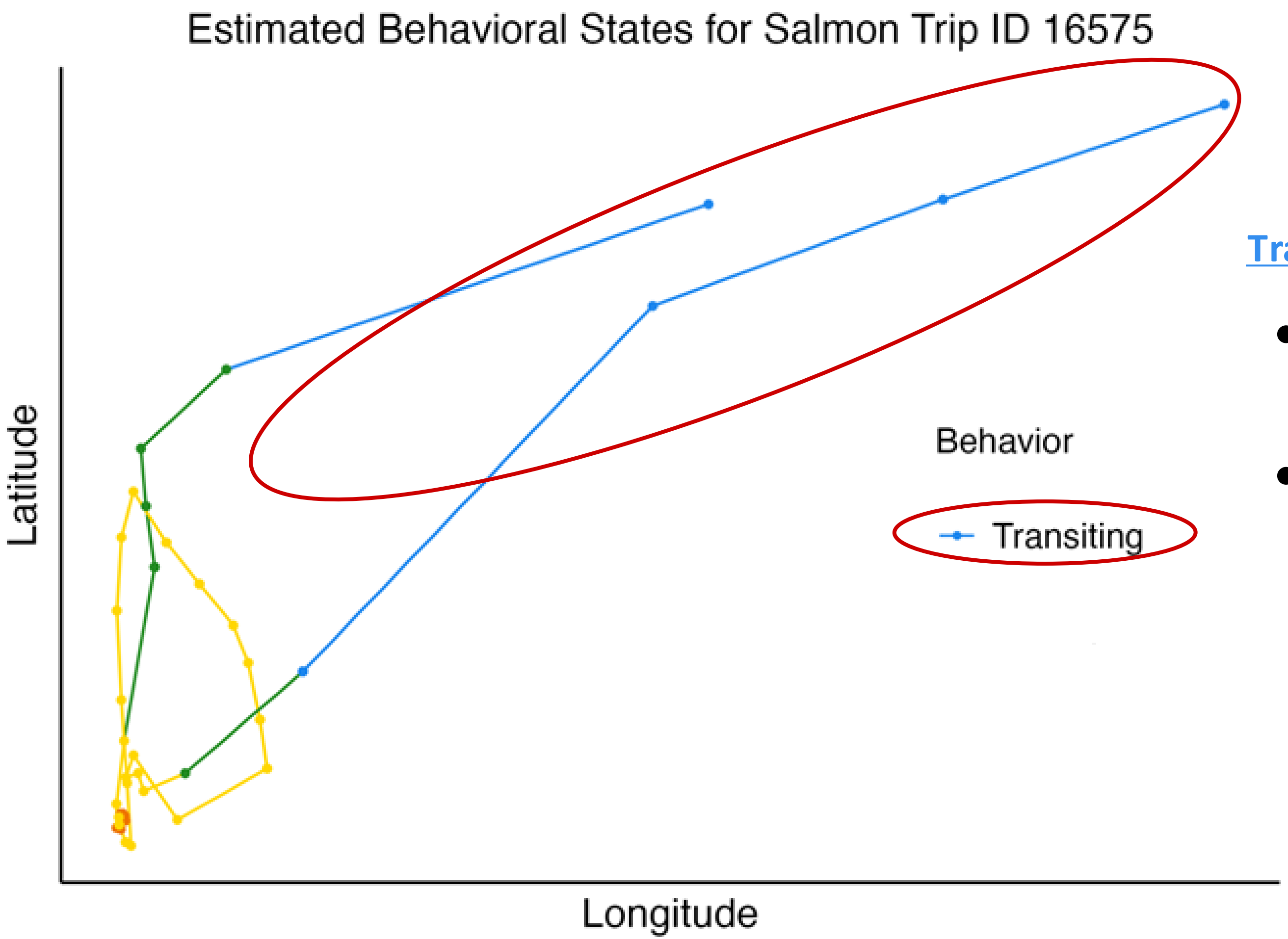


Methods - 2) Hidden Markov Model

- Now, fitting a HMM gives us…
  - Distinct estimated behavioral states at each time step
  - Probabilities of transitioning from one behavior to the other



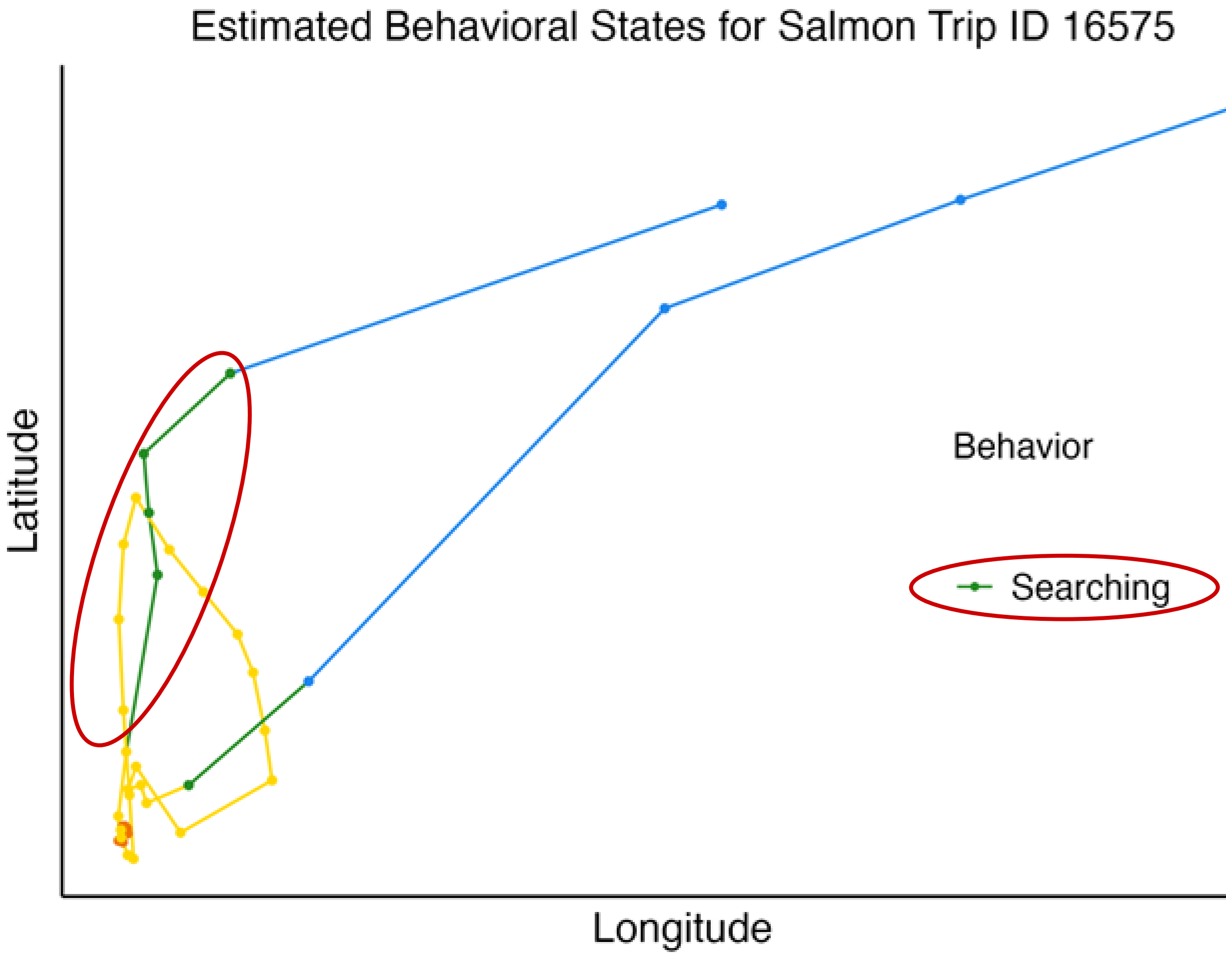
Preliminary Results - 2) Four State Hidden Markov Model



Transiting:

- Dots further apart
  - Faster
- Segments have few angles
  - Almost no turning

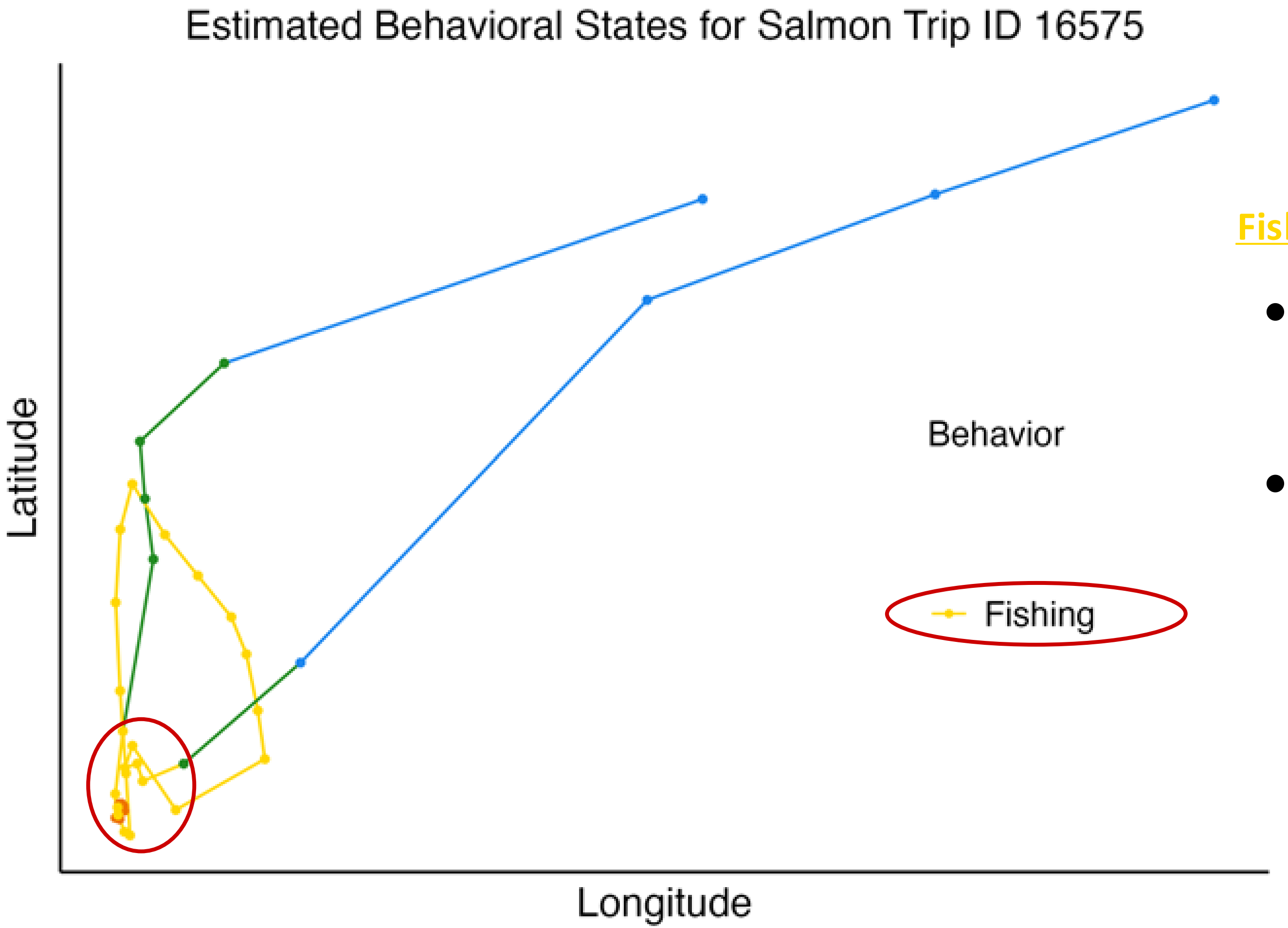
Preliminary Results - 2) Four State Hidden Markov Model



Searching:

- Dots less far apart
- Segments form more angles

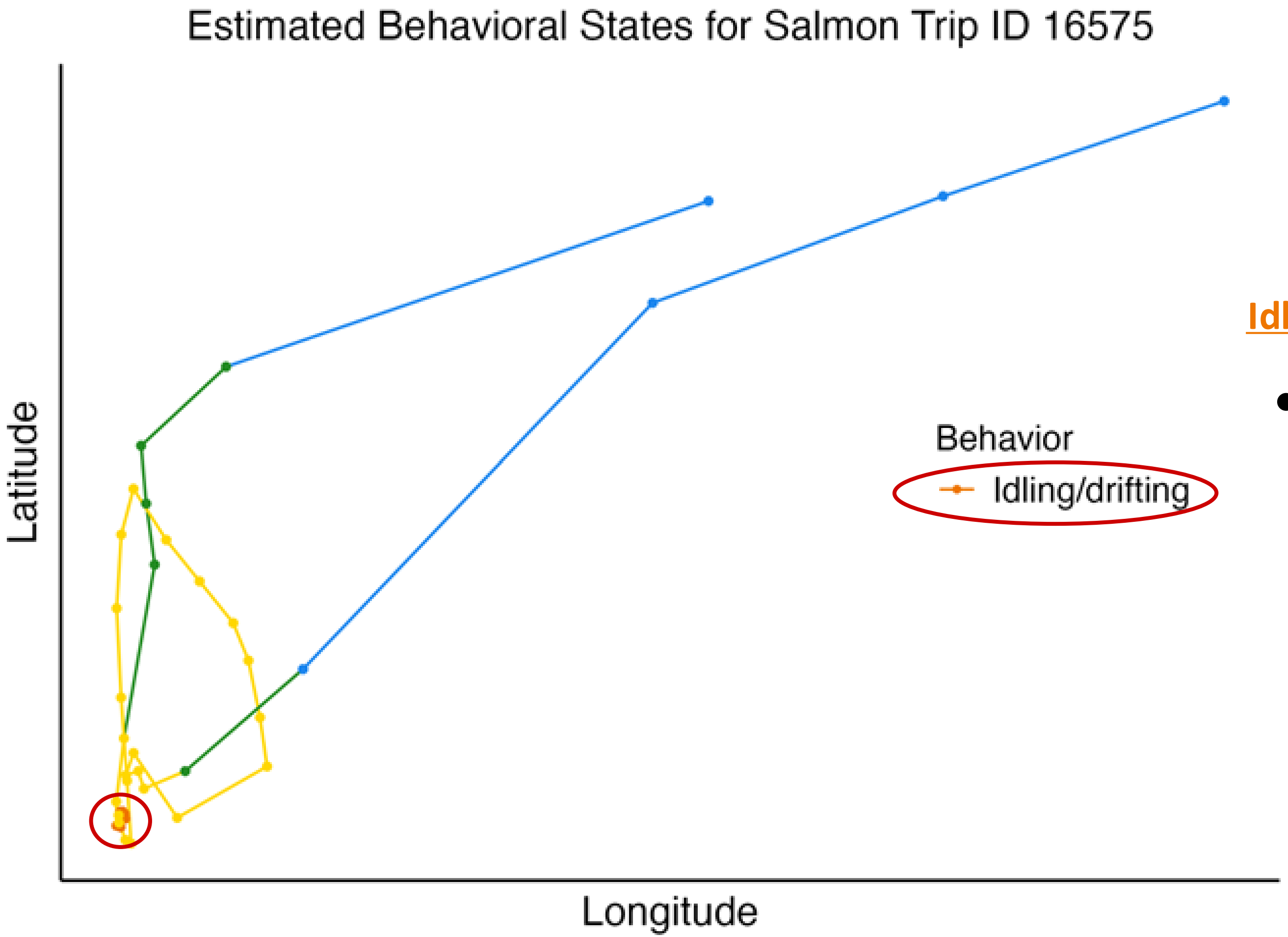
Preliminary Results - 2) Four State Hidden Markov Model



Fishing:

- Dots very close together
  - Slower
- Segments almost all angles
  - Lots of turning

Preliminary Results - 2) Four State Hidden Markov Model



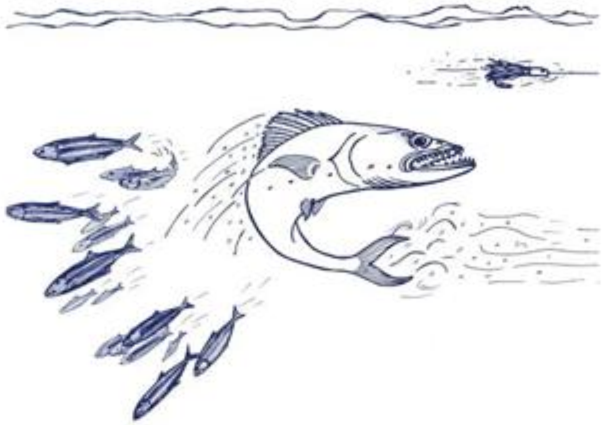
Idling/drifting:

- Dots highly clustered
  - No movement

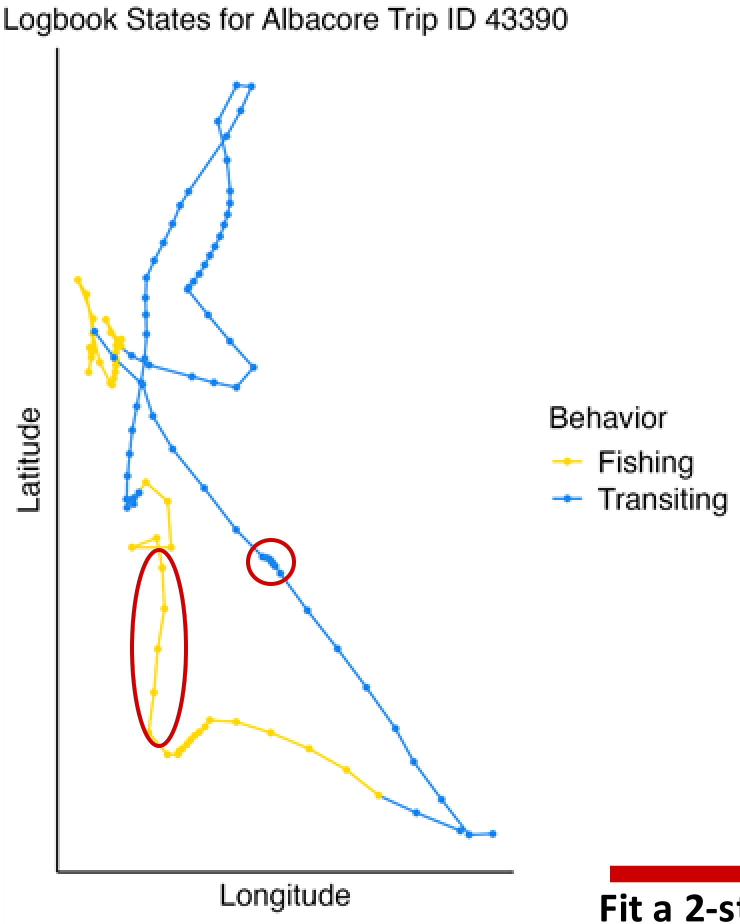
Methods - 3) Model Validation

- **Issue:** Pacific salmon ocean troll fishery has no available data with which to validate estimated fisher behaviors

- **Solution:** Validate estimated behaviors with independent data sources
    - 1) Logbook records from the Pacific albacore troll fishery
        - Similar to the salmon troll fishery
- **Methods:**
    - 1) Regularize data with a SSM
    - 2) Estimate behavioral states with a HMM
        - 2 state model
        - 4 state model

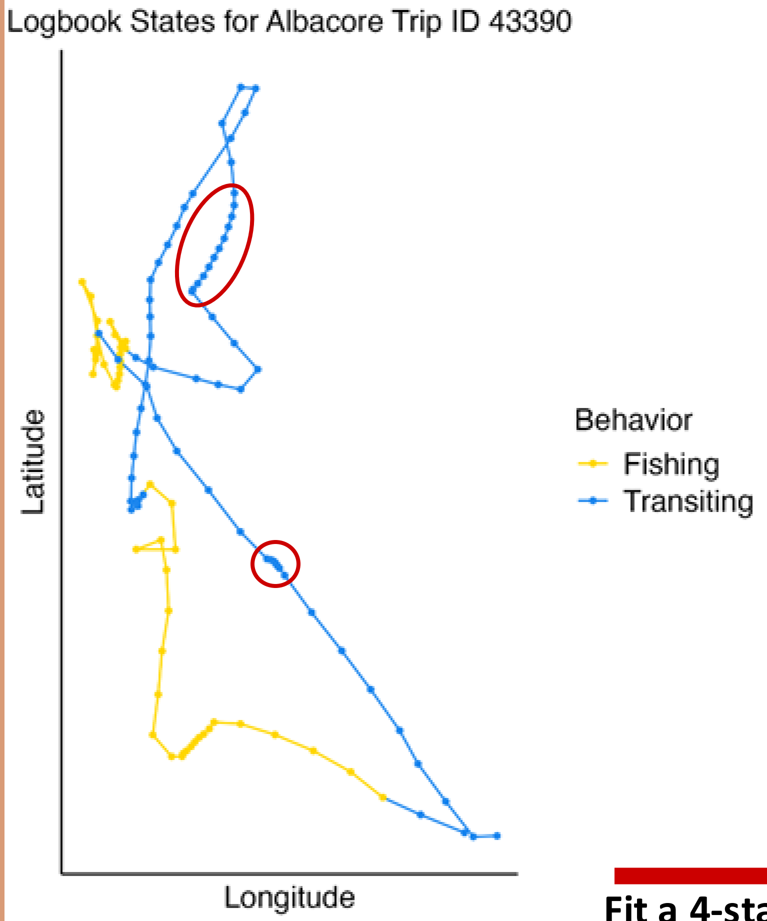


Preliminary Results - 3) Two State Model Validation



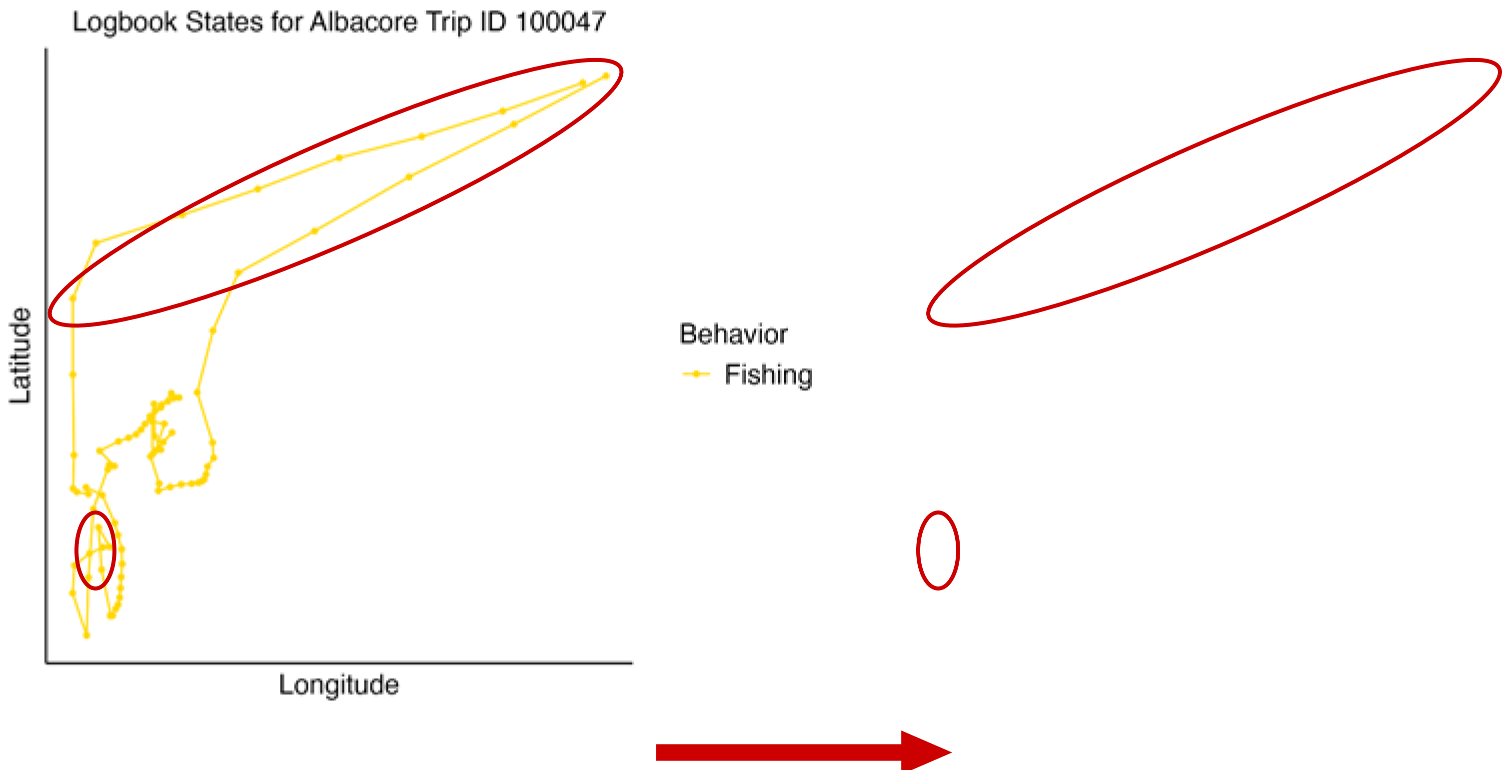
Fit a 2-state HMM

Preliminary Results - 3) Four State Model Validation



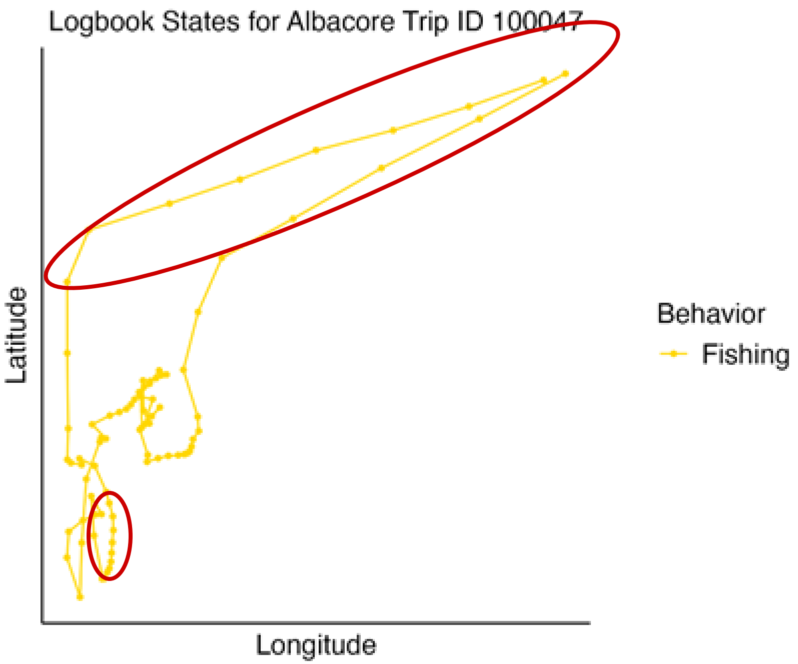
Fit a 4-state HMM

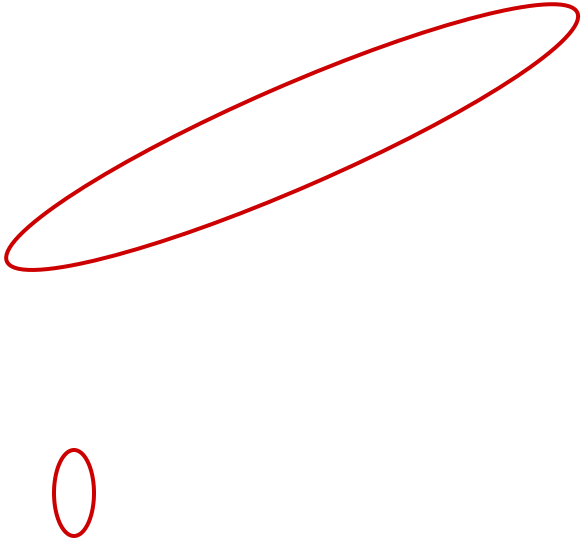
Preliminary Results - 3) Two State Model Validation



Fit a 2-state HMM

Preliminary Results - 3) Four State Model Validation





Fit a 4-state HMM

Preliminary Results - 3) Model Validation

- Reasons for discrepancies include:
    - Albacore logbook data is very noisy
        - Some trip data is more "useful" than others
        - Relies on fisher to note down activity and when it switches
    - Coarse characterization of trip activities:
        - Temporally (1 observation/day)
        - Per behavior

Concluding Thoughts

- **Methodological benefits:**
  - Uses less data
    - ~ 33% of federally managed fisheries have logbook data
  - Uses higher resolution data
    - 1 observation/hour as opposed to 1/day
  - Can be transferred to any fishery

- **Methodological challenges:**
  - Run time increases with the addition of behavioral states and covariate
  - Ability to differentiate between fishing and searching
    - Lack of variance in turning angle between the two behaviors

- Next steps:
  - 1) Interview commercial salmon fishers
  - 2) Use groundfish observer data



Thank you!

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