

# Evaluating Surfing Dynamics Using a Monte Carlo Simulation

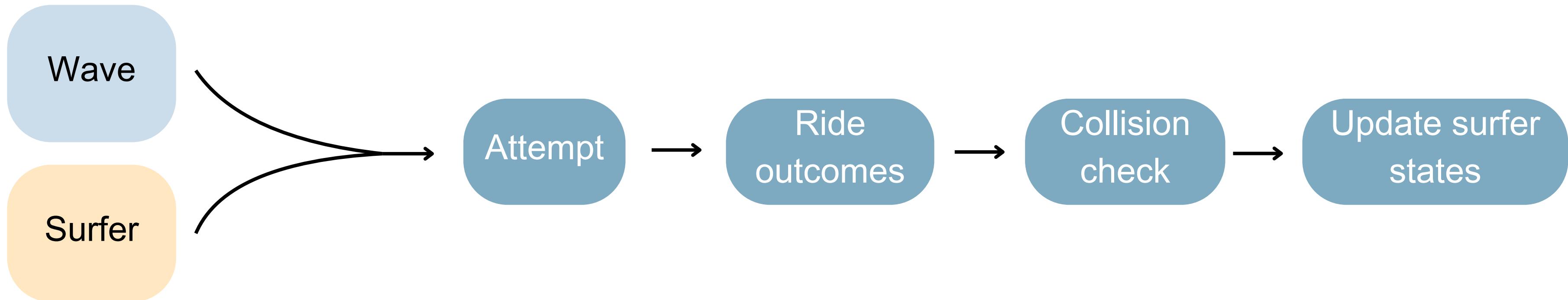
Hsin-Ya Chien

# Introduction

- What really happens when a lineup is full of beginners?
- Does adding rules actually help make things safer or fairer?



# Model



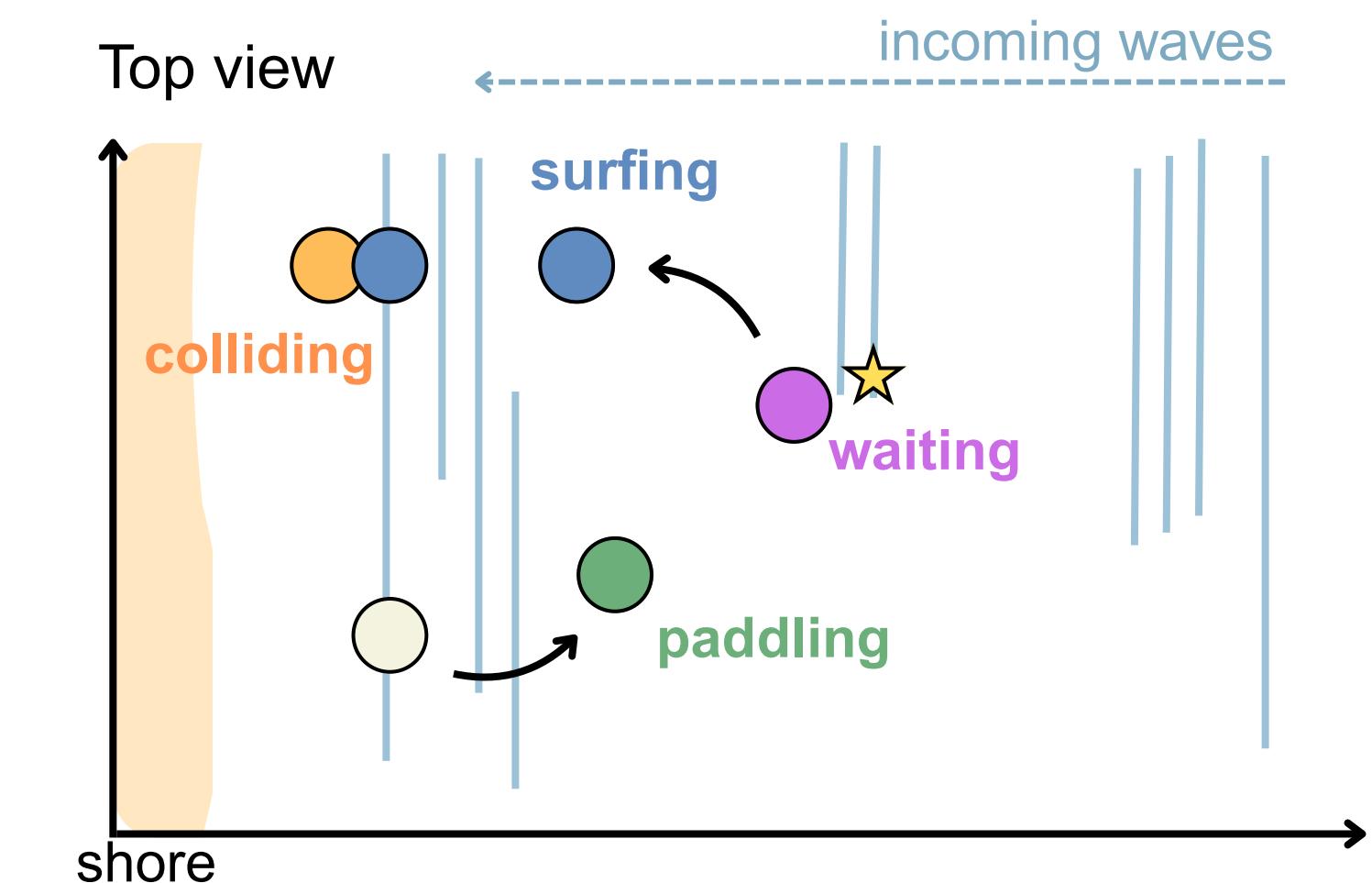
Each wave has its own height, speed, and moves horizontally toward the shore

Each surfer behaves as an agent with position, velocity, best take-off point, and state transitions

## Surfer States

Each surfer transitions through several states during the simulation:

- Waiting — watching for waves
- Paddling — moving toward best takeoff point
- Riding — moving along the wave toward shore
- Wipeout — fails at riding stage
- Collision — triggered when riders/floater get too close



# Assumptions

- Beginners have lower success probability & slower paddling due to lower skill levels
- Collisions happen when surfers ride the same wave or when riders get too close to a floater
- Fairness measured by a wave-distribution Gini index
- Surfers behave differently depending on the rule:
  - Free-for-all: chase any wave they think they can catch
  - Safe-distance rule: only take the wave if riders on the same wave are  $>10$  meters away



# Variables

## Inputs (Parameters)

- Spot level
- Number of surfers
- Lineup rule (free-for-all vs distance rule)
- Beginner ratio (Experiment)
- Wave-height distribution (Experiment)

## Outputs (Metrics)

- Avg Ride Count
- Avg Collision Count
- Average waiting time
- Fairness (Gini index)

# Key Variable Definitions

- **Spot level**

How difficult the surf environment is

Higher levels = larger, faster waves and more skilled surfers

- **Success**

A clean ride of at least 10 meters without wiping out or colliding

- **Collisions**

When a riding surfer gets too close to:

- (a) another rider on the same wave
- (b) a floater in the wave path

- **Avg Success Count**

Average number of successful rides per surfer

- **Avg Collision Count**

Average number of collisions per surfer

- **Fairness**

How evenly waves are shared

0 = equal sharing; 1 = one surfer dominates

- **Average waiting time**

Time between two successful rides for each surfer



BEGINNER

MIXED

ADVANCED

$$\text{Success Rate} = \frac{\text{Total Number of Successful Rides}}{\text{Total Number of Surfers}}$$

$$\text{Collision Rate} = \frac{\text{Total Number of Collisions}}{\text{Total Number of Surfers}}$$

$$\text{Fairness (Gini)} = \frac{\text{Mean Absolute Difference of Rides}}{2 \times \text{Average Number of Rides}}$$

$$T_{avg} = \frac{\text{Total Adjusted Waiting Time}}{\text{Total Number of Successes}}$$

# Hypothesis

## Hypothesis 1 — Spot-level effect

Advanced spots run smoother under free-for-all → lower waiting time & lower Gini  
Beginners  create far more chaos → longer waits & more inequality

## Hypothesis 2 — Rule-type effect

Safe-distance-rule reduces inequality and collisions ▼ ( $\approx 20\%$  lower Gini, 30% fewer collisions vs free-for-all)

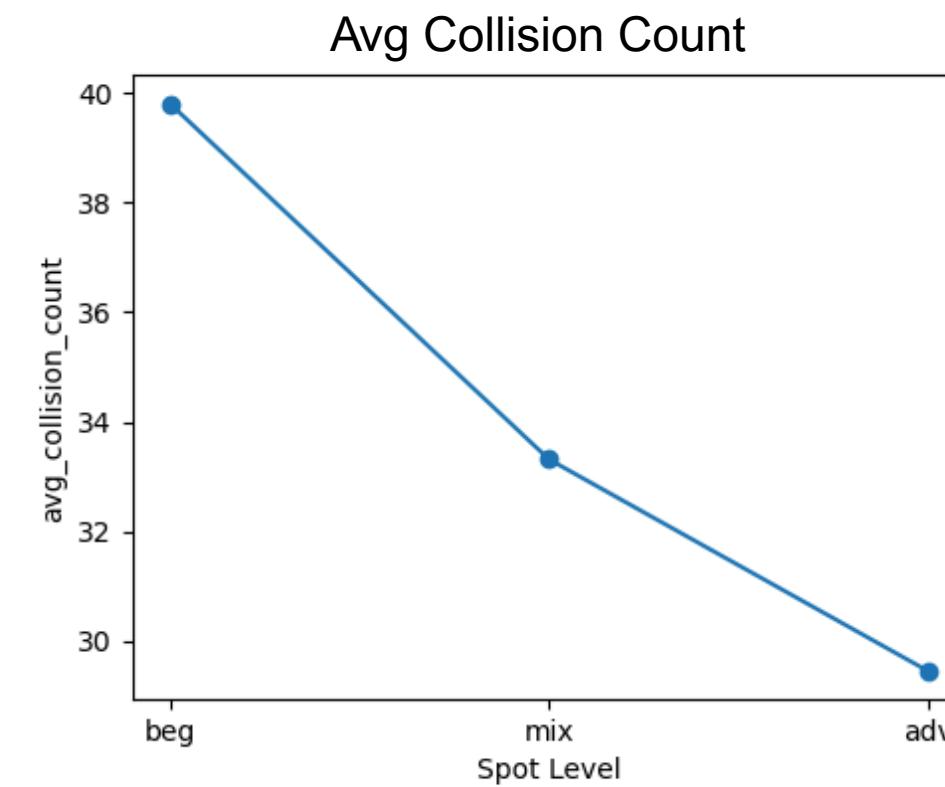
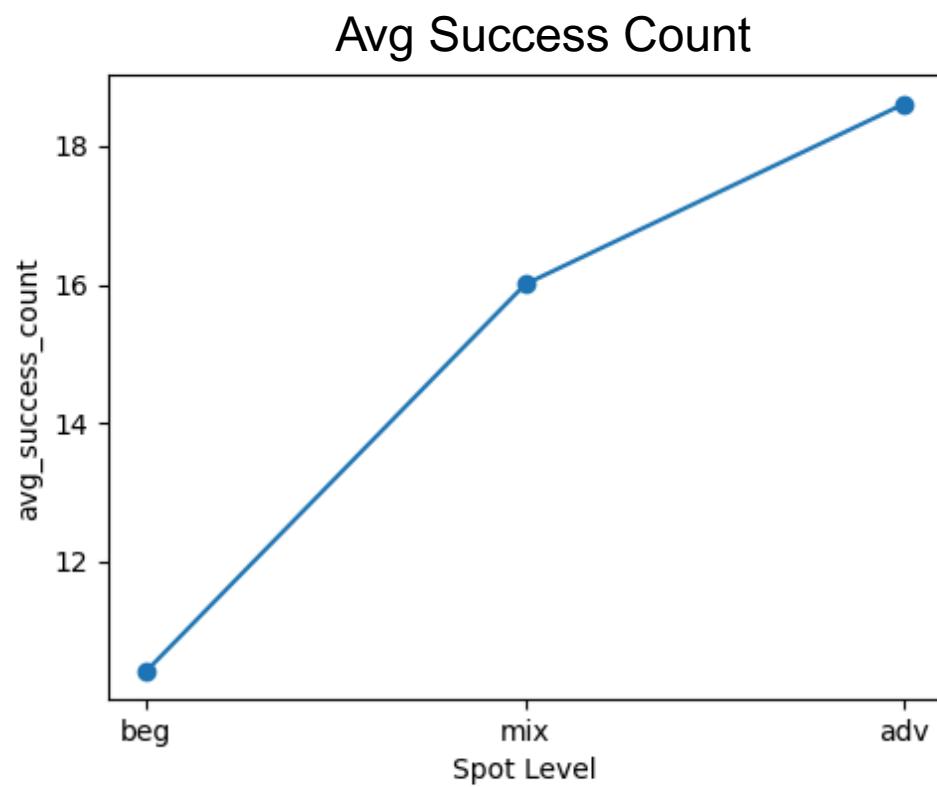
## Hypothesis 3 — Wave-height effect

Bigger waves  increase waiting time; beginners struggle the most  
Success drops sharply in beginner-heavy spots, but skilled surfers remain stable

# Results

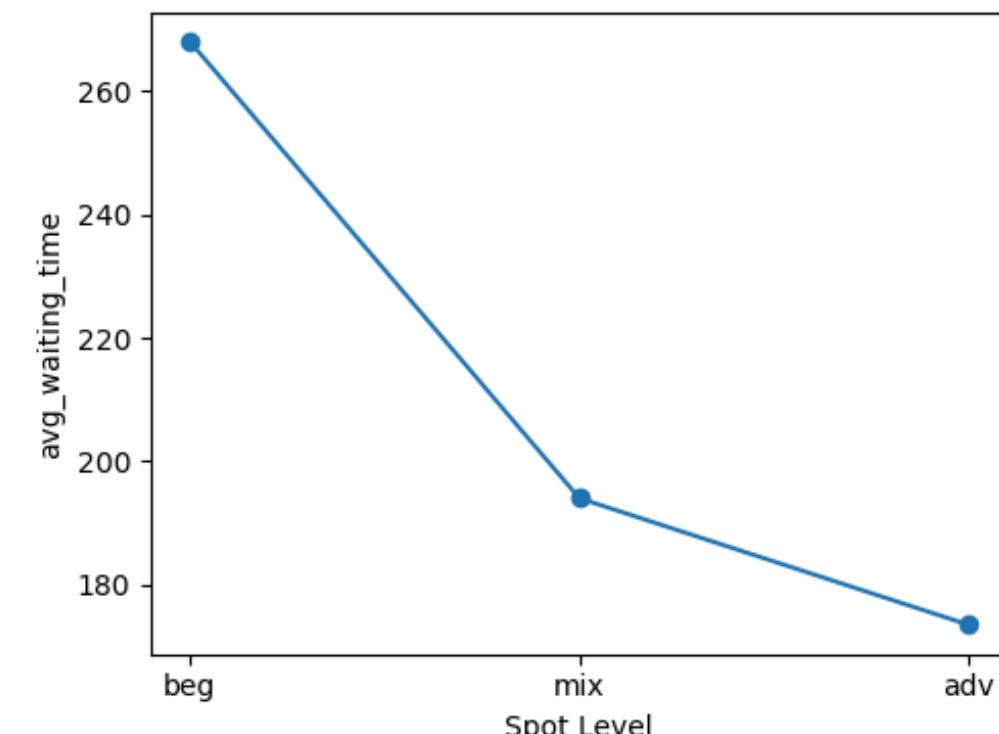
## Hypothesis 1 — Spot-level effect

Advanced spots run smoother under free-for-all → lower waiting time & lower Gini.  
Beginners create far more chaos → longer waits & more inequality.

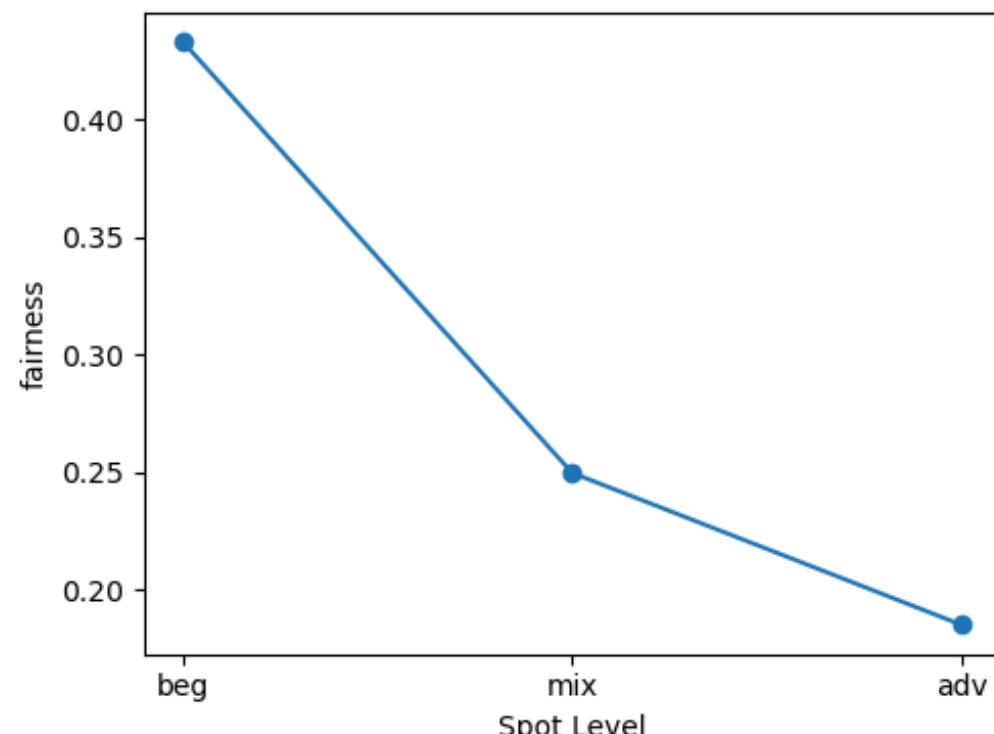


→ Spot level ↑ Success ↑ collision ↓

Avg Waiting Time



Inequality (Gini)

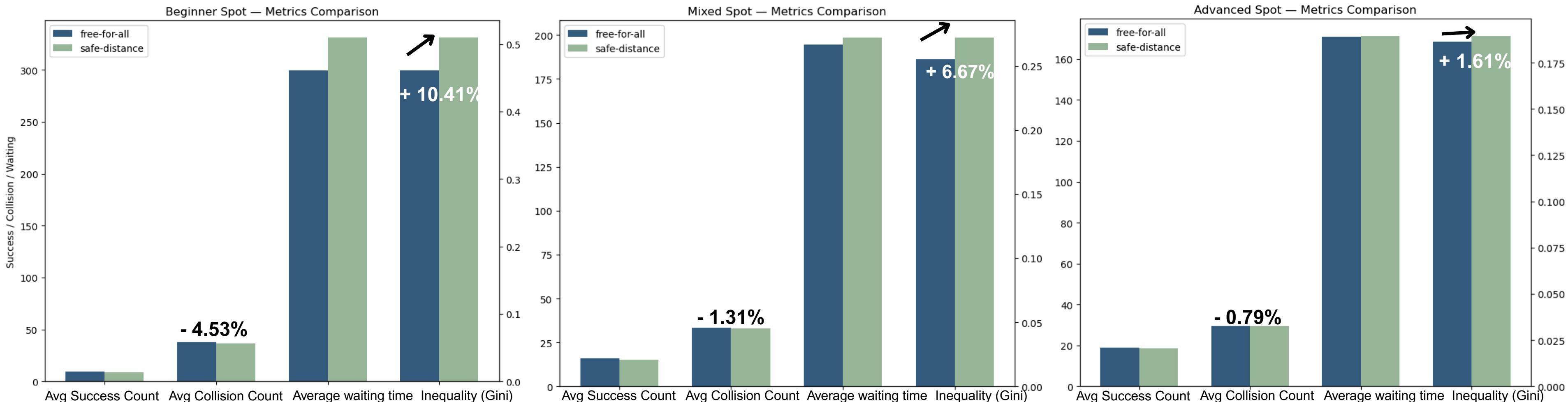


Spot level ↑ Waiting time ↑ Inequality (Gini) ↓ ←

# Results

## Hypothesis 2 — Rule-type effect

Safe-distance rule reduces inequality and collisions ( $\approx 20\%$  lower Gini, 30% fewer collisions vs free-for-all).



Across all spot levels, both rules behave similarly:

- Success and collision rates show minimal differences
- A free-for-all ends up being fairer — likely because safe-distance reduces ride opportunities

# Results

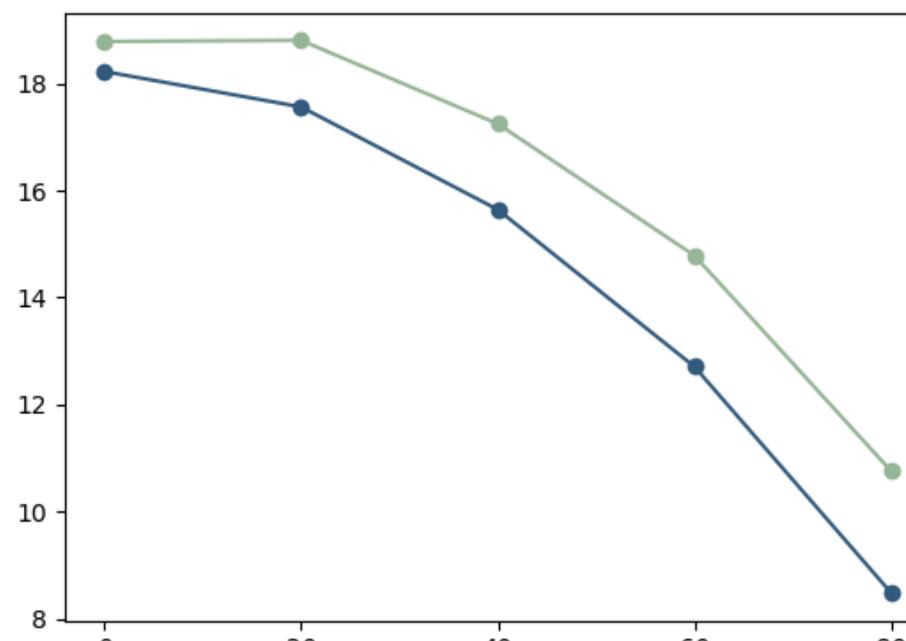
## Hypothesis 3 — Wave-height effect

Bigger waves  increase waiting time; beginners struggle the most.

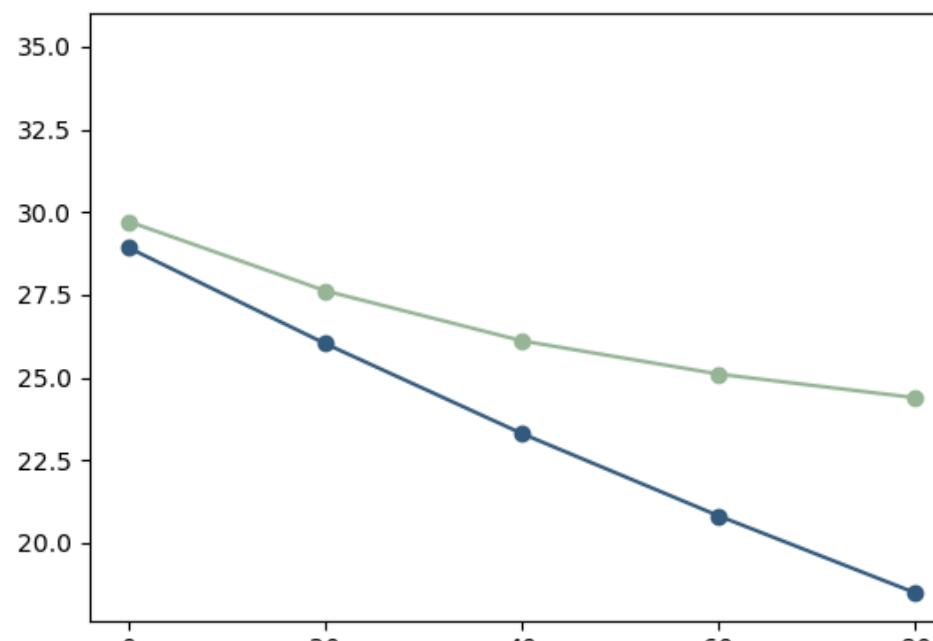
Success drops sharply in beginner-heavy spots, but skilled surfers remain stable.

★ spot\_level: advanced

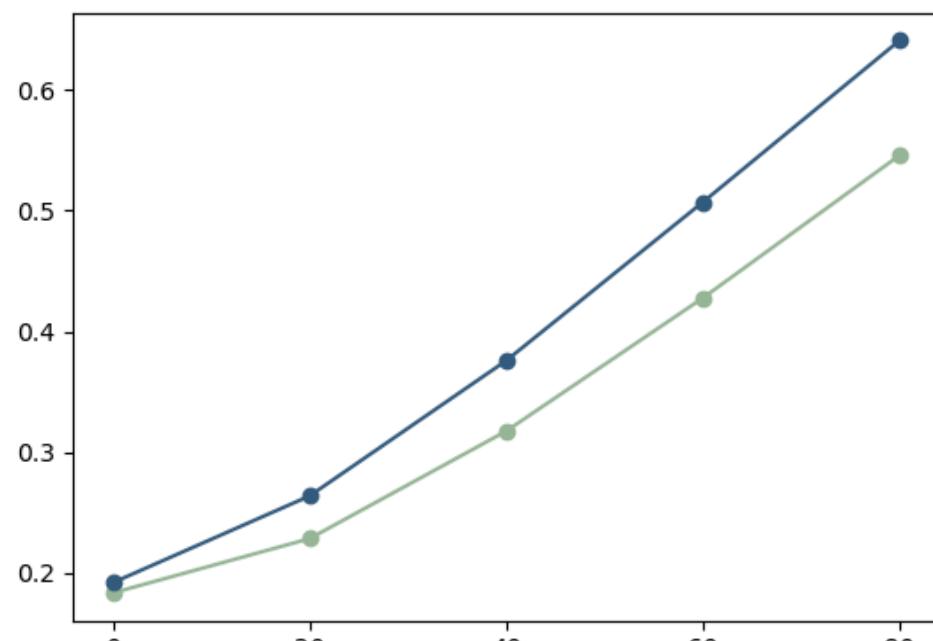
Avg Success Count



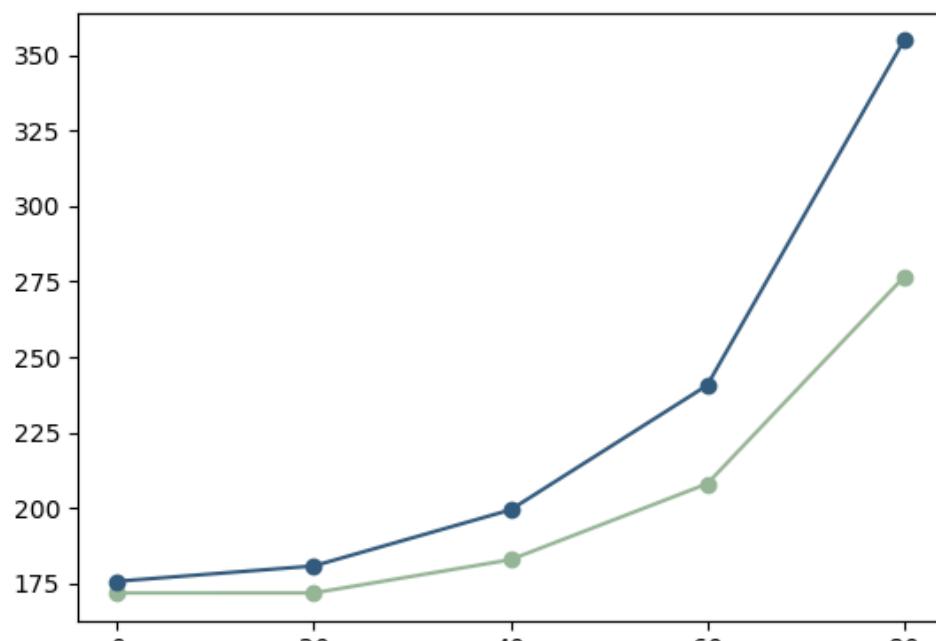
Avg Collision Count



Inequality (Gini)



Average waiting time



Beginner ratio ↑

Avg Waves: Success ↓

Bigger waves: Success ↓ ↓

Beginner ratio ↑

Avg Waves: Collision ↓

Bigger waves: Collision ↓ ↓ ↓

Beginner ratio ↑

Avg Waves: Inequality ↑

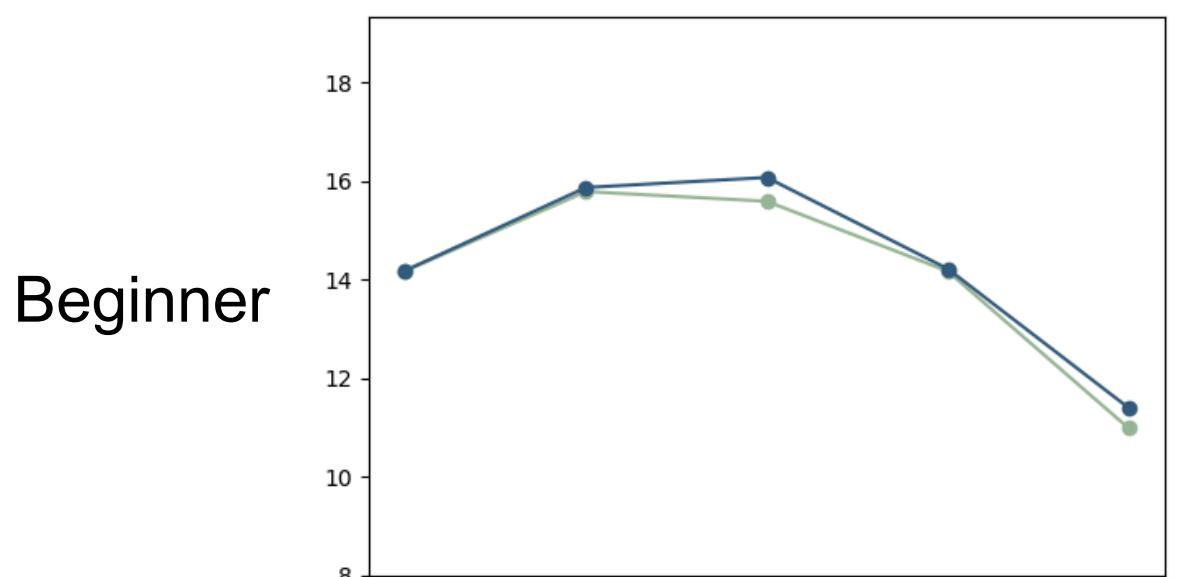
Bigger waves: Inequality ↑ ↑

Beginner ratio ↑

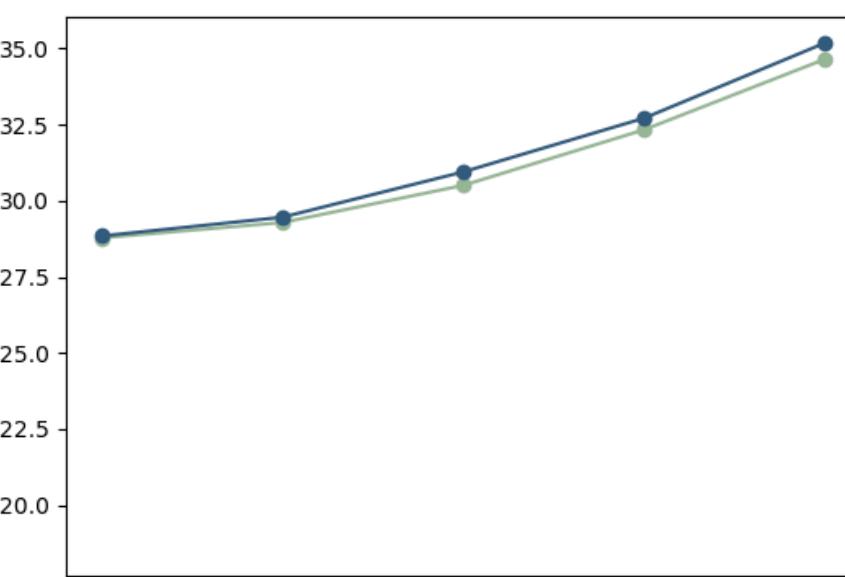
Avg Waves: Waiting ↑

Bigger waves: Waiting ↑ ↑ ↑

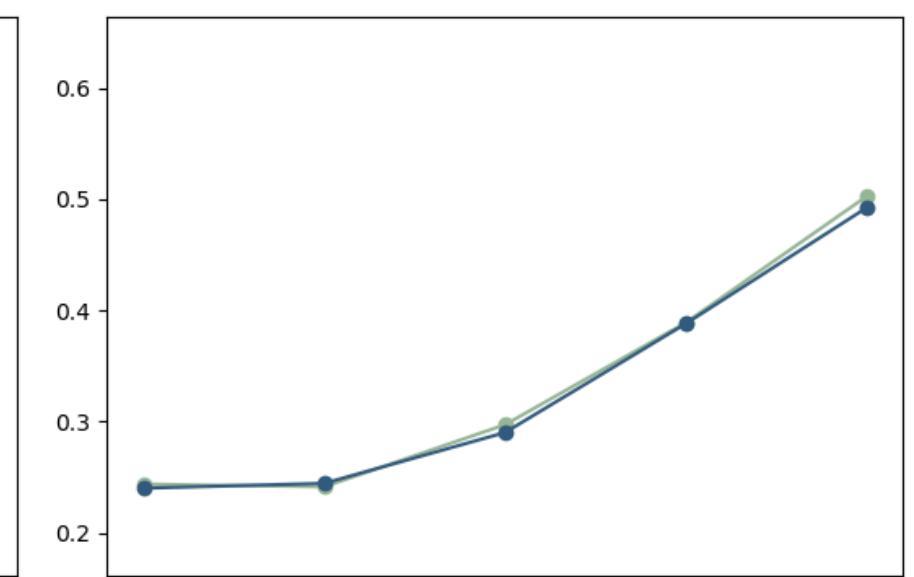
### Avg Success Count



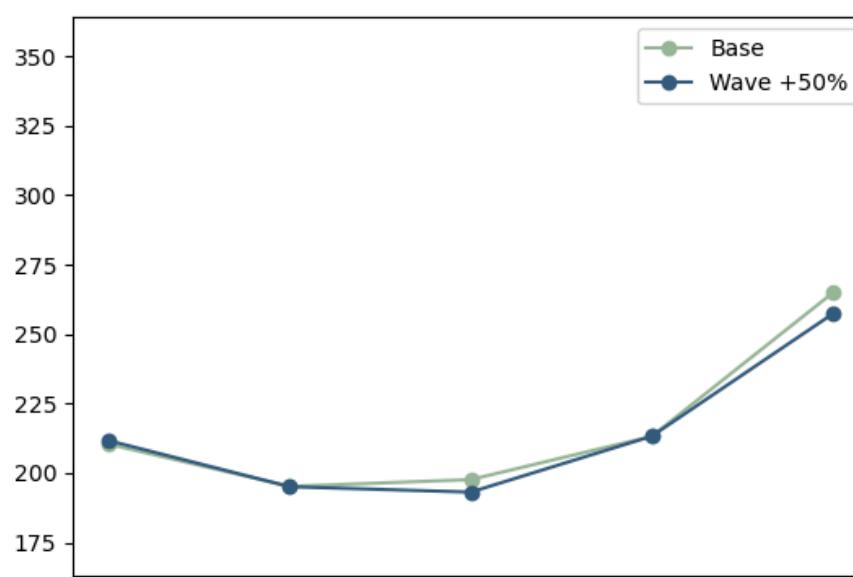
### Avg Collision Count



### Inequality (Gini)



### Average waiting time



Beginner

Mixed

Advanced

Beginner ratio

Beginner ratio

Beginner ratio

Beginner ratio

Q & A

# THANK YOU

