NOAA FISHERIES
Northwest Fisheries Science Center

A Bio-economic Model of Marine Recreational Fisheries off Washington and Oregon

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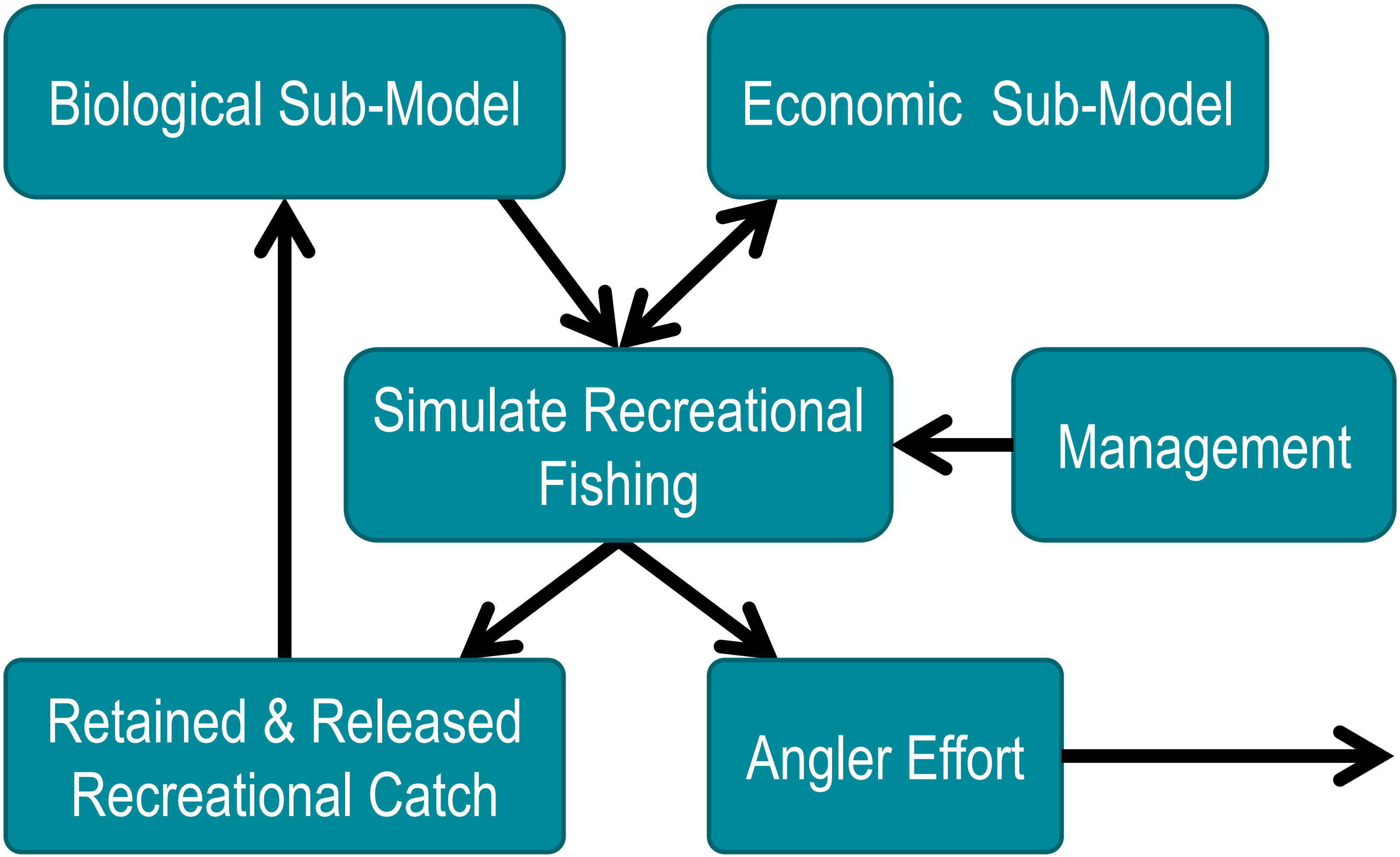
Motivation

- Off the West Coast in 2013, more than 1.7 million recreational anglers took part in an estimated 7.5 million fishing trips. These anglers spent about $1.9 billion on fishing trips and equipment, which supported over 21 thousand jobs
- Bring together biological and economic models to look at how management affects recreational fishing behavior and recreational fishing affects the stocks being fished
- Examine the effects of management on:
  - Staying within target population ranges
  - Economic value of the recreational fishery
  - The recovery of depleted populations

Related Research

- Bio-economic model of recreational cod and haddock fisheries in the Northeast U.S. (Steinback et al.)
- Bio-economic model looked at how changes in water quality may affect the Atlantic Coast summer flounder recreational fishery (Massey et al., 2006)
- Theoretical recreational bio-economic modeling work on the influence of fish life history, angler behavior, discard mortality, and non-compliance on optimal recreational fishery management (Johnston et al., 2010, 2013, and 2015)

Model Overview



Model Focus

- Oregon and Washington, not including Puget Sound
- Marine groundfish and salmon recreational fisheries
- Boat (private and charter) recreational fishing, not shore fishing

Economic sub-model

- Built on data from a discrete choice experiment survey conducted in 2007 in Washington and Oregon
- Simplified discrete choice experiment question:

	Trip A	Trip B	Trip C
Catch	1	1	2
Size	2 lb.	4 lb.	4 lb.
Cost	$15	$30	$30

  - Which trip do you prefer?
  - Would you prefer to take a trip or do something else?

C1 Suppose that you have the choice between two boat fishing trips in the Ocean area (Choice A or Choice B) or not taking a boat fishing trip in the Ocean area (Choice C). Below the table, indicate which of these three choices you like best and second best.

		Choice A		Choice B		Choice C
Area	Boat boarding area	Ocean area		Ocean area		**Do one of the following** (other than boat fishing in the Ocean area): • Inside area fishing • Saltwater shore fishing • WA freshwater fishing • Non-WA fishing • Do some activity other than fishing
Salmon	Catch (weight per fish)	2 hatchery kings (20 lb.) 1 wild king (10 lb.) 2 wild kings (20 lb.)		3 wild kings (20 lb.)		
Salmon	Legal daily limit	4 salmon (combined), release all kings		2 salmon (combined), no more than 1 king, release wild kings		
Cost	Fishing cost (per person per day) + Transportation cost + Lodging cost	**Private:** $80 + auto fuel / air + motel / camp	**Charter:** $175 + auto fuel / air + motel / camp	**Private:** $80 + auto fuel / air + motel / camp	**Charter:** $175 + auto fuel / air + motel / camp	

If you were presented these three choices (A, B, C), which one would you choose to do?
(mark only one)

- OCEAN Choice A ☐
- OCEAN Choice B ☐
- NO OCEAN Fishing Trip Choice C ☐

If your first choice was not available, what would be your second choice?
(mark only one)

- OCEAN Choice A ☐
- OCEAN Choice B ☐
- NO OCEAN Fishing Trip Choice C ☐

Economic sub-model

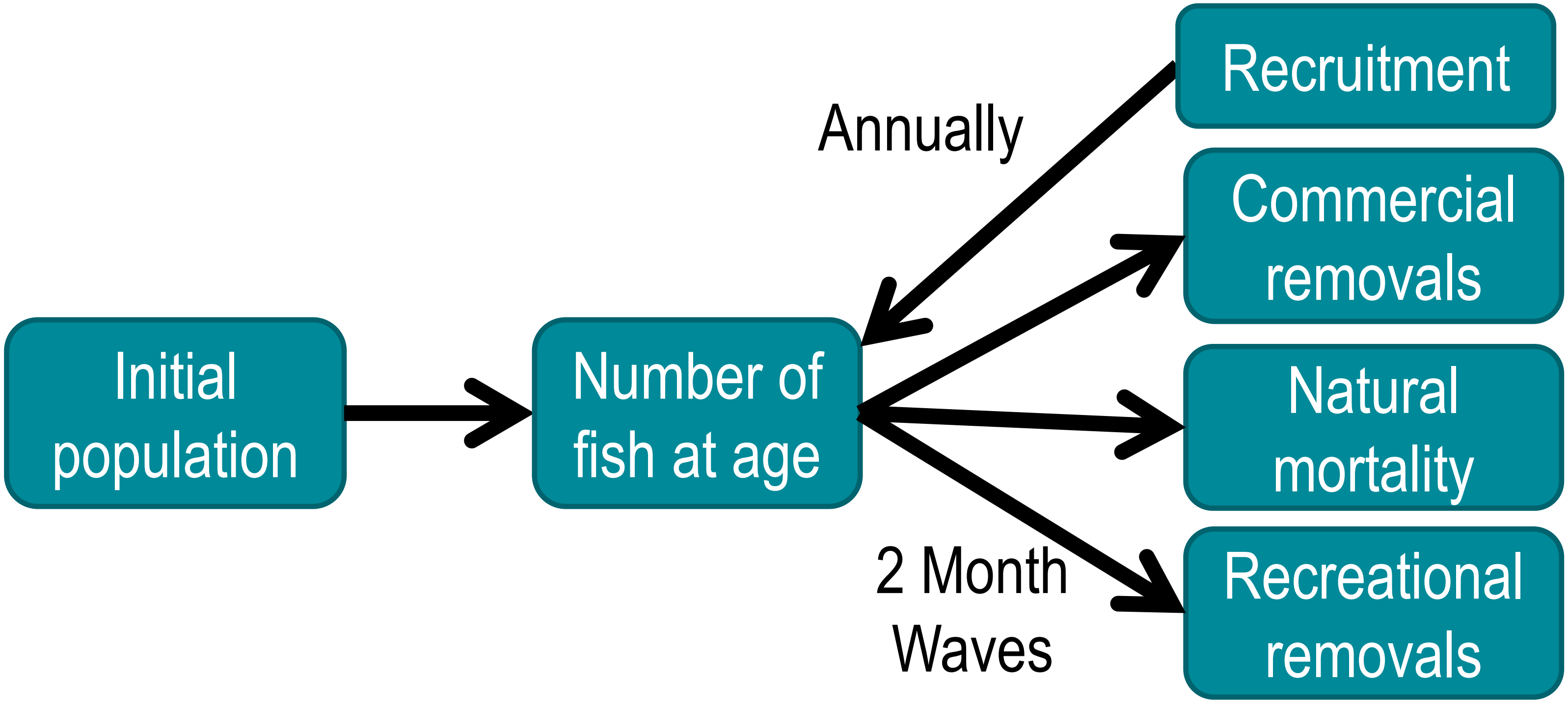
- Logit random utility model
  - Anderson and Lee (2013)
  - Anderson, Lee, and Levin (2013)
- Incorporates many of the trade-offs important to anglers:
  - Number of fish caught
  - Size of fish caught
  - Number of fish that can be kept
  - Cost

Economic sub-model

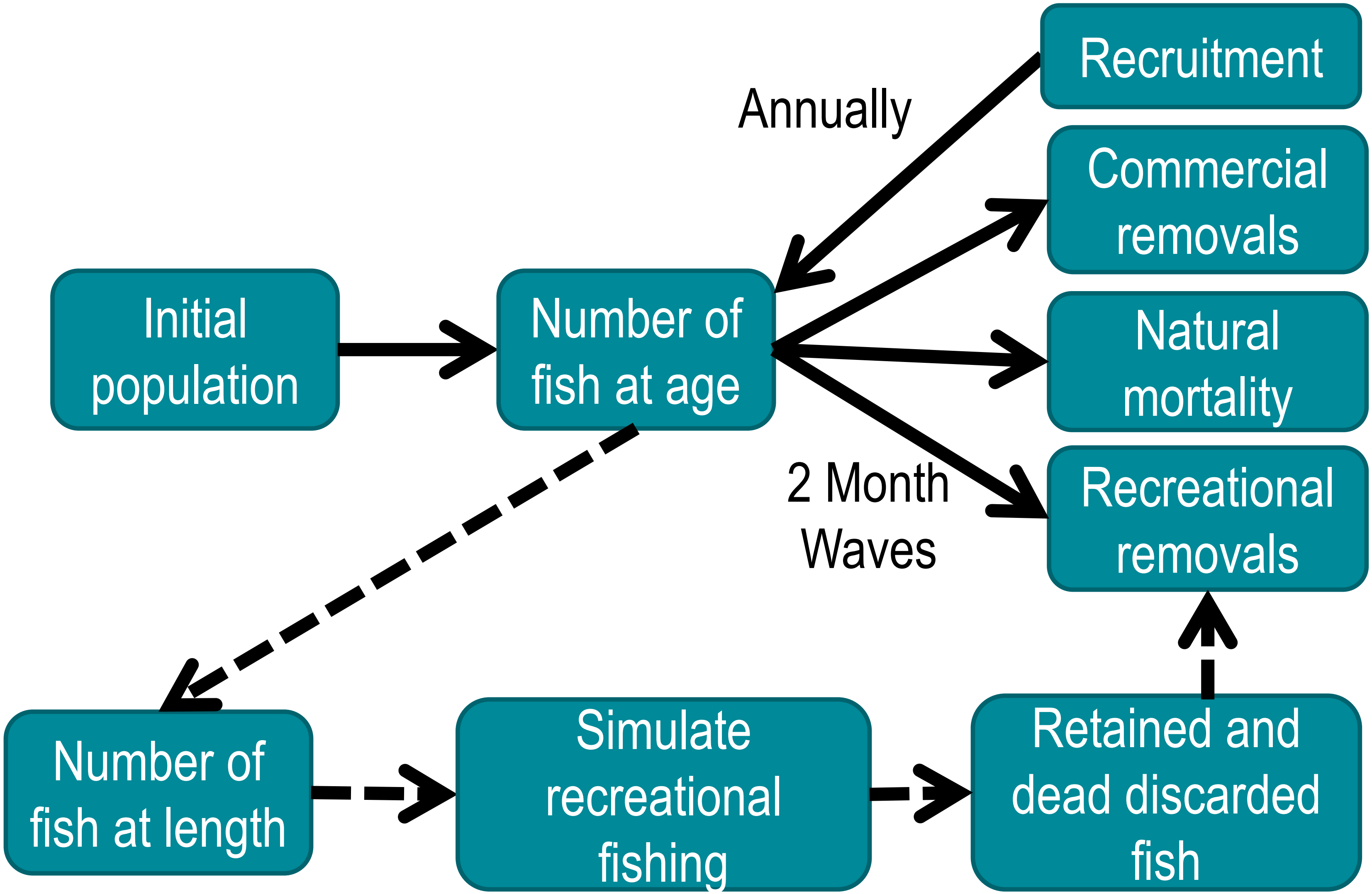
$$U_{nij} = \delta Price_{nij} + \sum_t \alpha_t Opt_{tnij} + \sum_s \sum_l \beta_{ls} \, Catch_{lsij} + \sum_s \rho_s Catch_{sij}^2 + \sum_s \gamma_s \, LbsRelease_{sij} + \sum_k \theta_k Type_{kij} + \epsilon_{nij}$$

Catch (β_{ls})	Halibut	
	Small	1.25866***
	Medium	1.50204***
	Large	1.77075***
	Rockfish	
	Small	0.106269***
	Medium	0.131425***
	Large	0.130522***
Catch^2 (ρ_s)	Halibut	–0.22859***
	Rockfish	–0.00334***
LbsRelease(γ_s)	Halibut	–0.0178***
	Rockfish	–0.00674

Biological sub-model



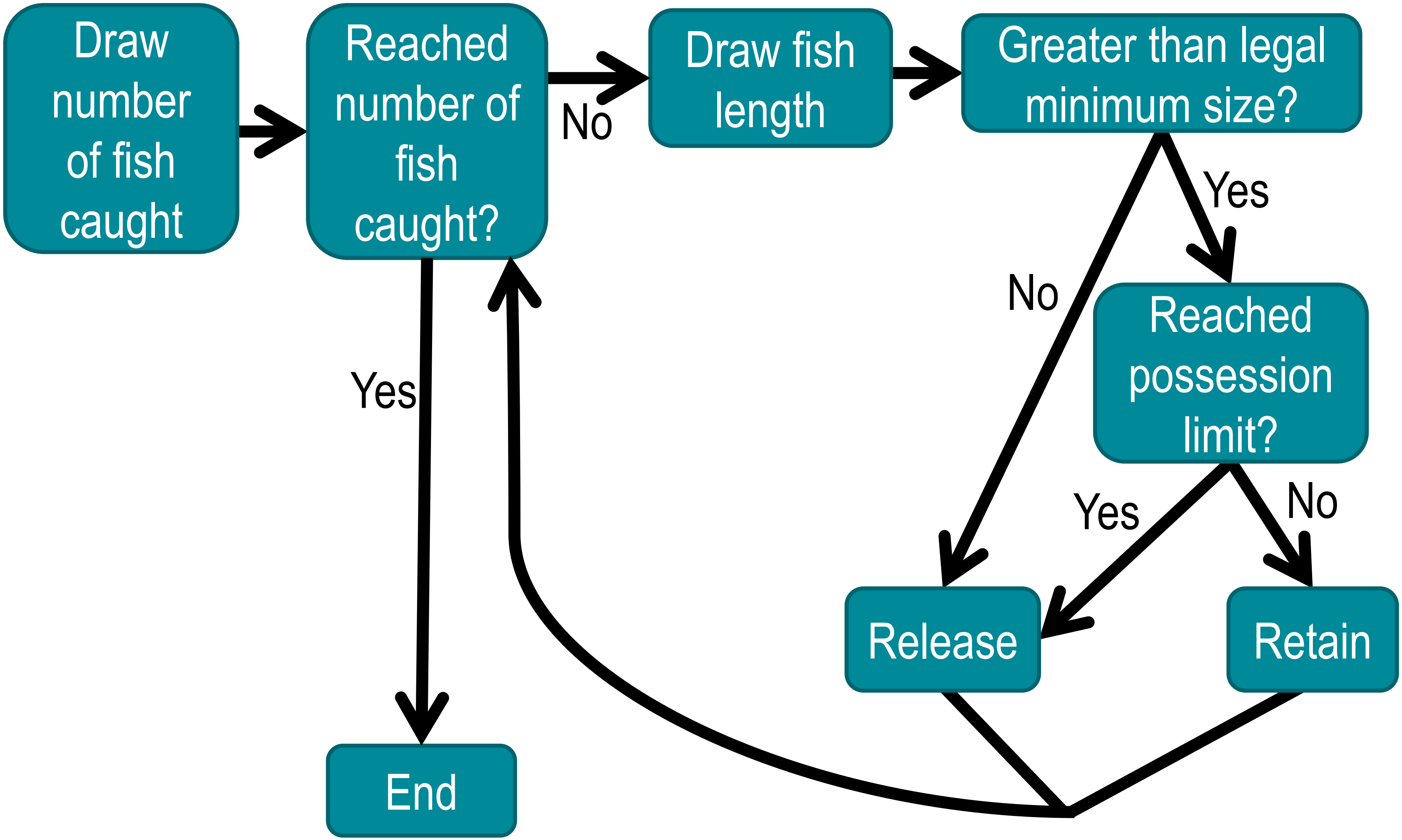
Biological sub-model



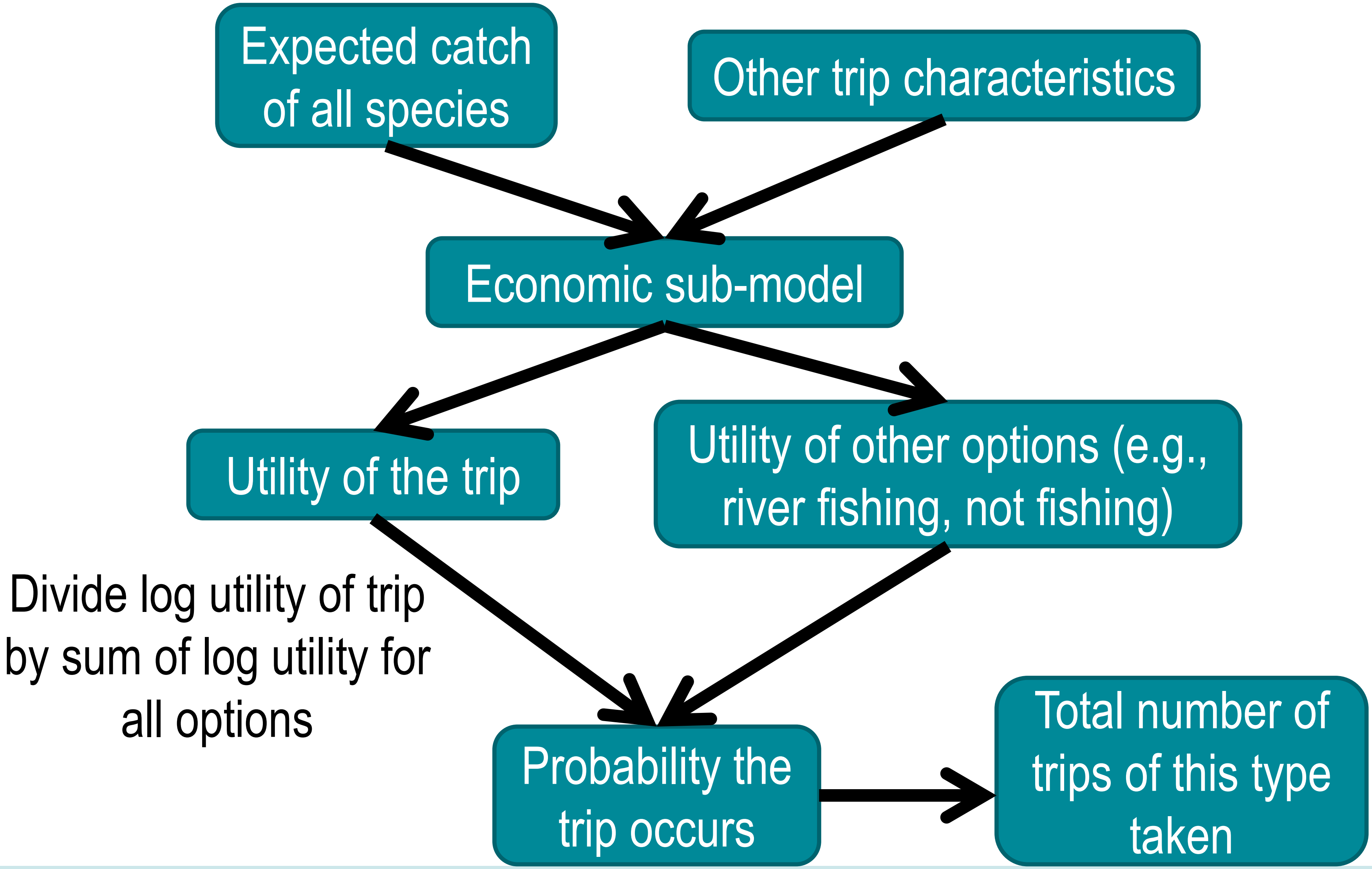
Biological sub-model

- Age-structured population dynamics model
  - Completed for lingcod
  - Planning to include black rockfish, yelloweye rockfish, and canary rockfish
- For additional species, only modeling the recreational catch based on catch from recent years
  - Wild and hatchery chinook and coho salmon
  - Pacific halibut
  - Other rockfish

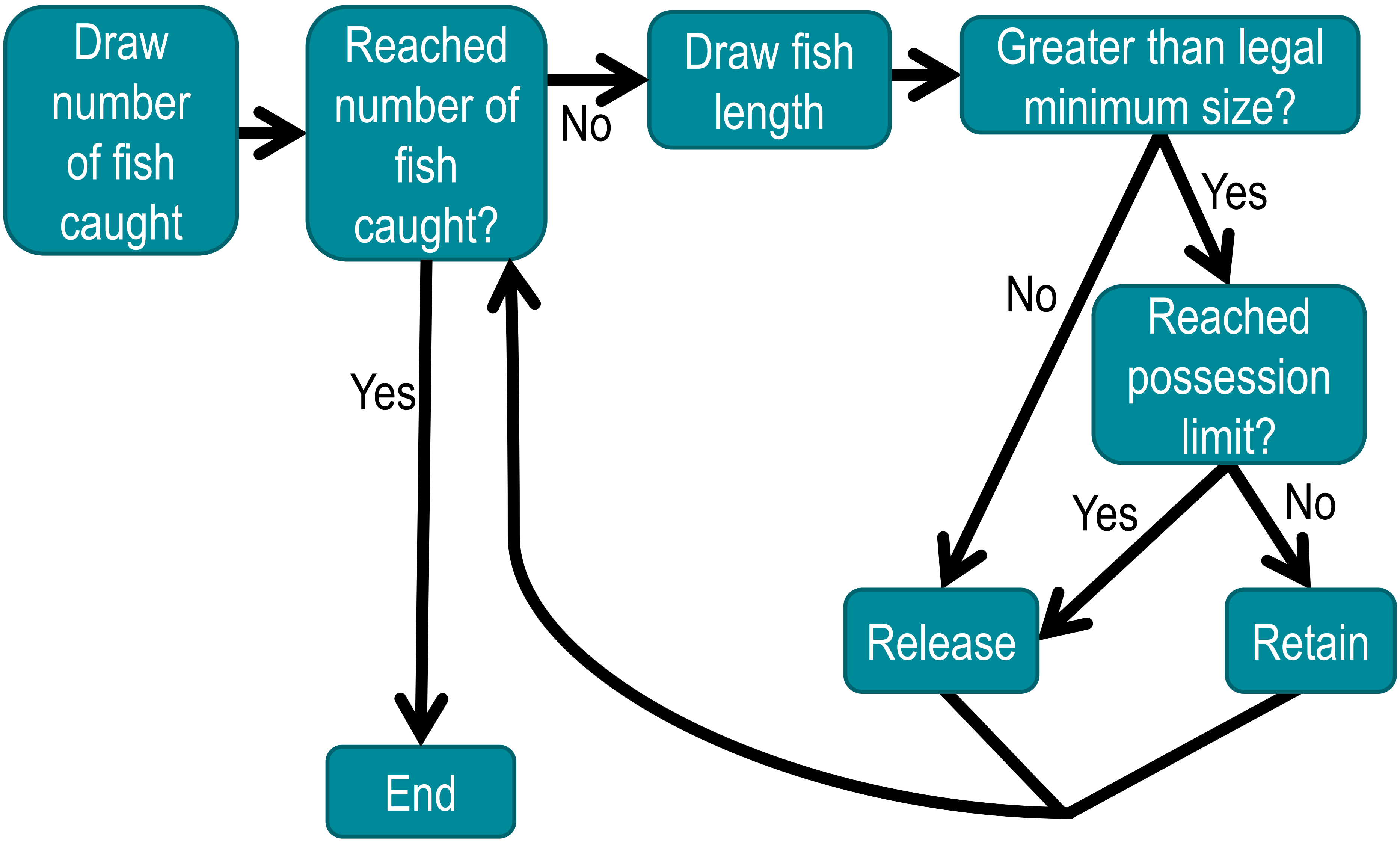
Simulating "expected" catch for a trip



How many fishing trips will occur?



Simulating "actual" catch for a trip



How many fish are caught per trip?

- Modeled the catch-per-trip based on data from observed recreational fishing trips
  - Modeled each species, trip type, and area separately
- Considered four possible models:
  - Poisson
  - Negative binomial
  - Zero-inflated Poisson
  - Zero-inflated negative binomial
- In most cases, the zero-inflated negative binomial was chosen as the best model

Zero-inflated negative binomial model of catch-per-trip

- Probability of an inflated zero is modeled as a binomial process with a logit link:

$$p = \frac{e^{(\alpha_{zi} + \boldsymbol{\beta}_{zi}\boldsymbol{X}_{zi})}}{1 + e^{(\alpha_{zi} + \boldsymbol{\beta}_{zi}\boldsymbol{X}_{zi})}}$$

  - α_{zi} is the intercept
  - $\boldsymbol{\beta}_{zi}$ is a vector of coefficients for the covariates $\boldsymbol{X}_{zi}$

Zero-inflated negative binomial model of catch-per-trip

- When there is not an inflated zero, catch is modeled as a negative binomial process with a log link, where the mean catch-per-trip is:

$$\mu = a \times e^{(\alpha_c + \boldsymbol{\beta}_c \boldsymbol{X}_c)}$$

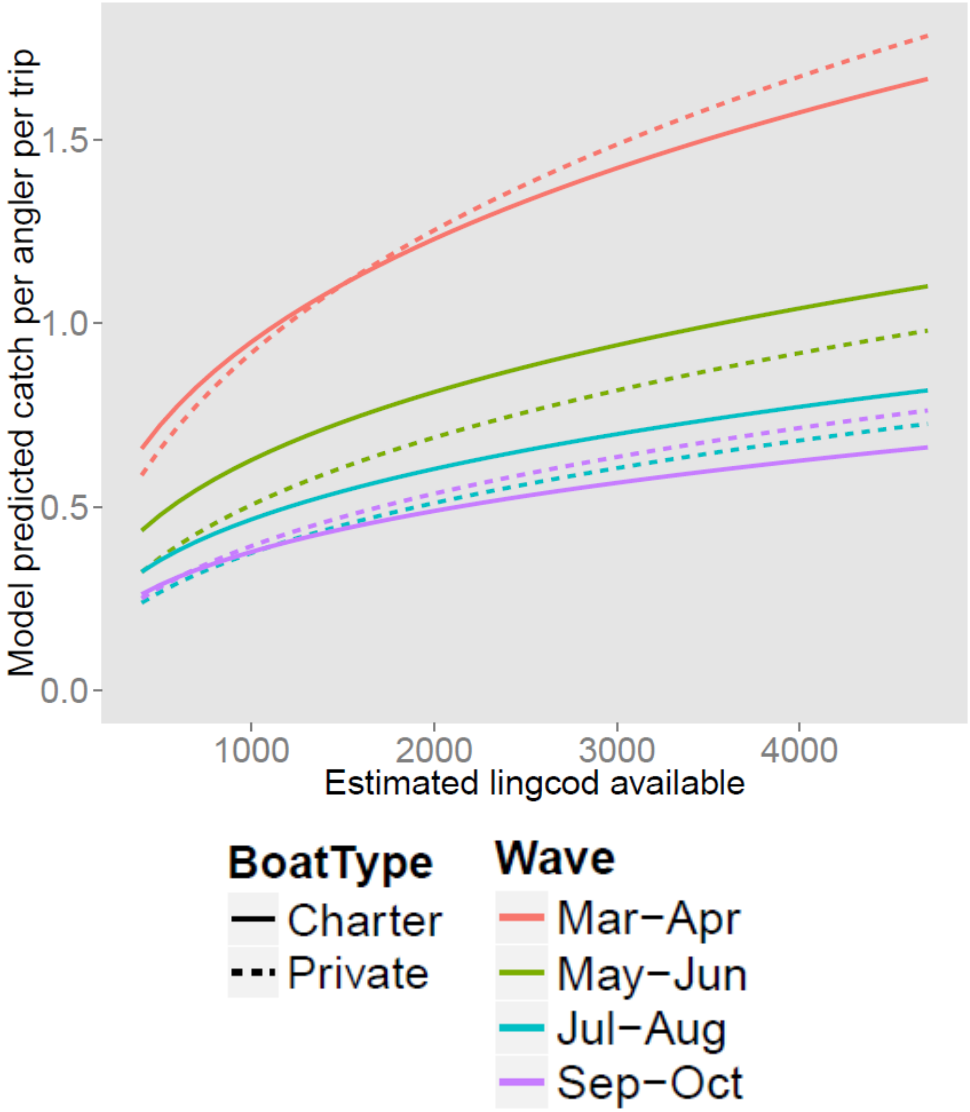
  - a is the number of anglers on the trip (constant offset)
  - α_c is the intercept
  - $\boldsymbol{\beta}_c$ is a vector of coefficients for the matrix of covariates $\boldsymbol{X}_c$

Zero-inflated negative binomial model of catch-per-trip

- Same covariates considered for both the zero-inflated and negative binomial portions of the model:
  - Estimated number of fish available to the recreational fishery
    - Only for stocks for which the population dynamics are modeled
    - Calculated based on the number of fish in the population and recreational selectivity by length
  - Boat type: charter or private
  - Two month “wave”
  - Estuary or ocean trip (Oregon only)
  - Two-way interactions of boat type, wave, and estuary/ocean

Washington bottomfish trip lingcod catch-per-trip model

Variable	Est.	S.E.
Zero-inflation model coefficients		
(Intercept)	1.672	0.146***
log(LingcodAvailable)	-0.502	0.021***
BoatTypePrivate	0.974	0.031***
Negative binomial model coefficients		
(Intercept)	-2.053	0.061***
log(LingcodAvailable)	0.312	0.008***
Wave3	-0.414	0.026***
Wave4	-0.712	0.028***
Wave5	-0.923	0.039***
BoatTypePrivate	0.179	0.030***
Wave3:BoatTypePrivate	-0.185	0.032***
Wave4:BoatTypePrivate	-0.187	0.035***
Wave5:BoatTypePrivate	0.073	0.050
Log(theta)	-0.157	0.013***



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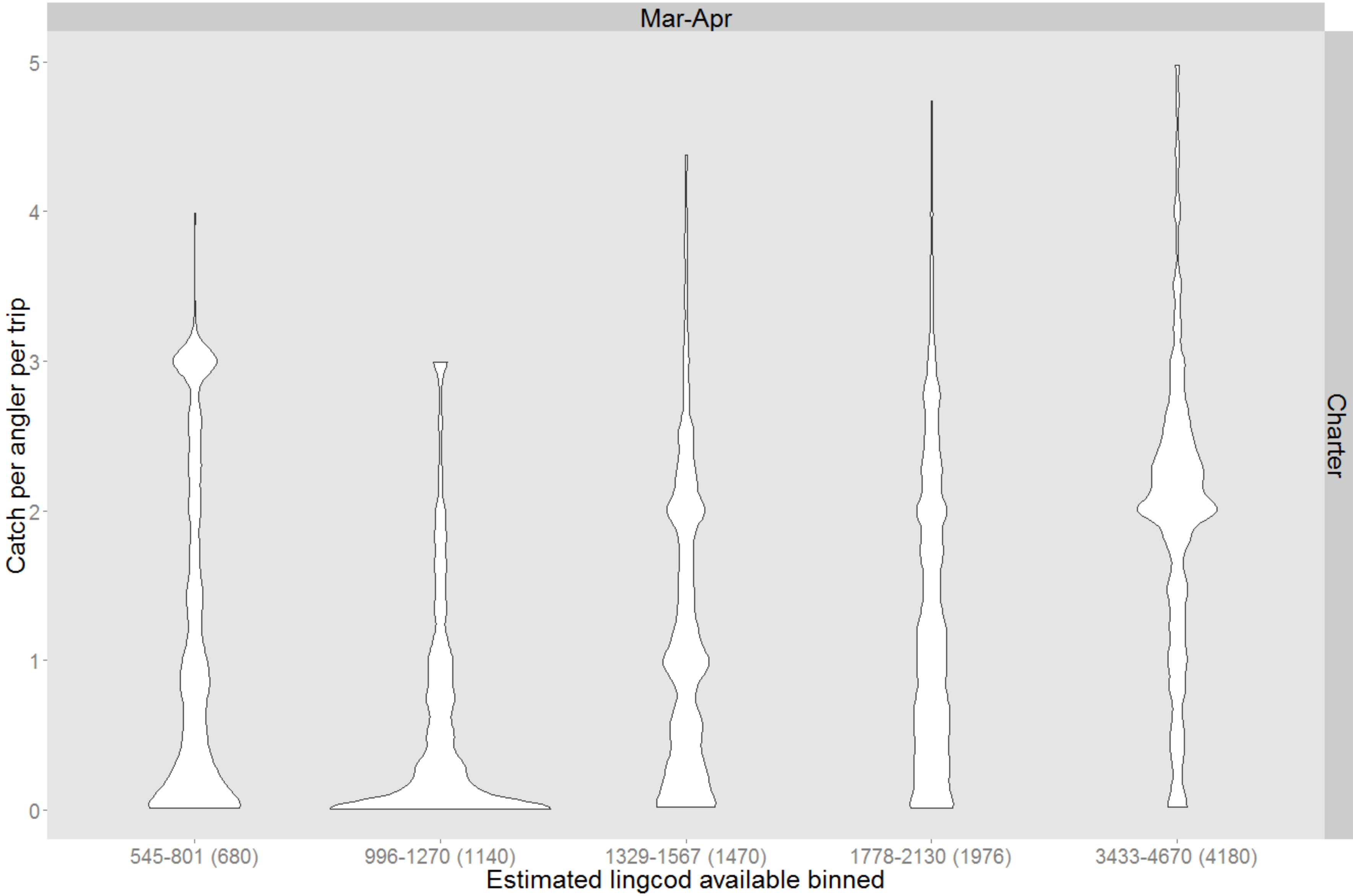

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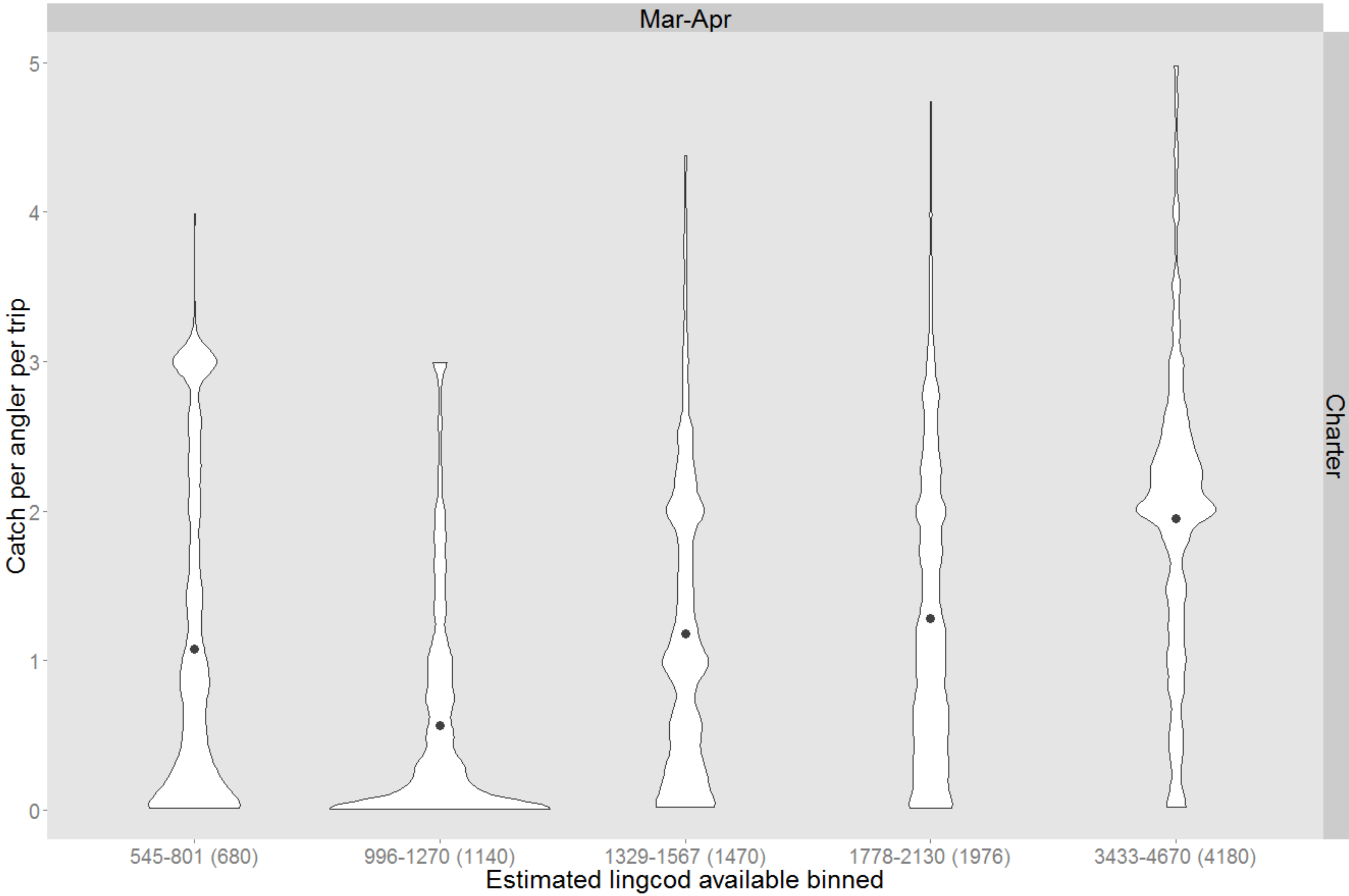

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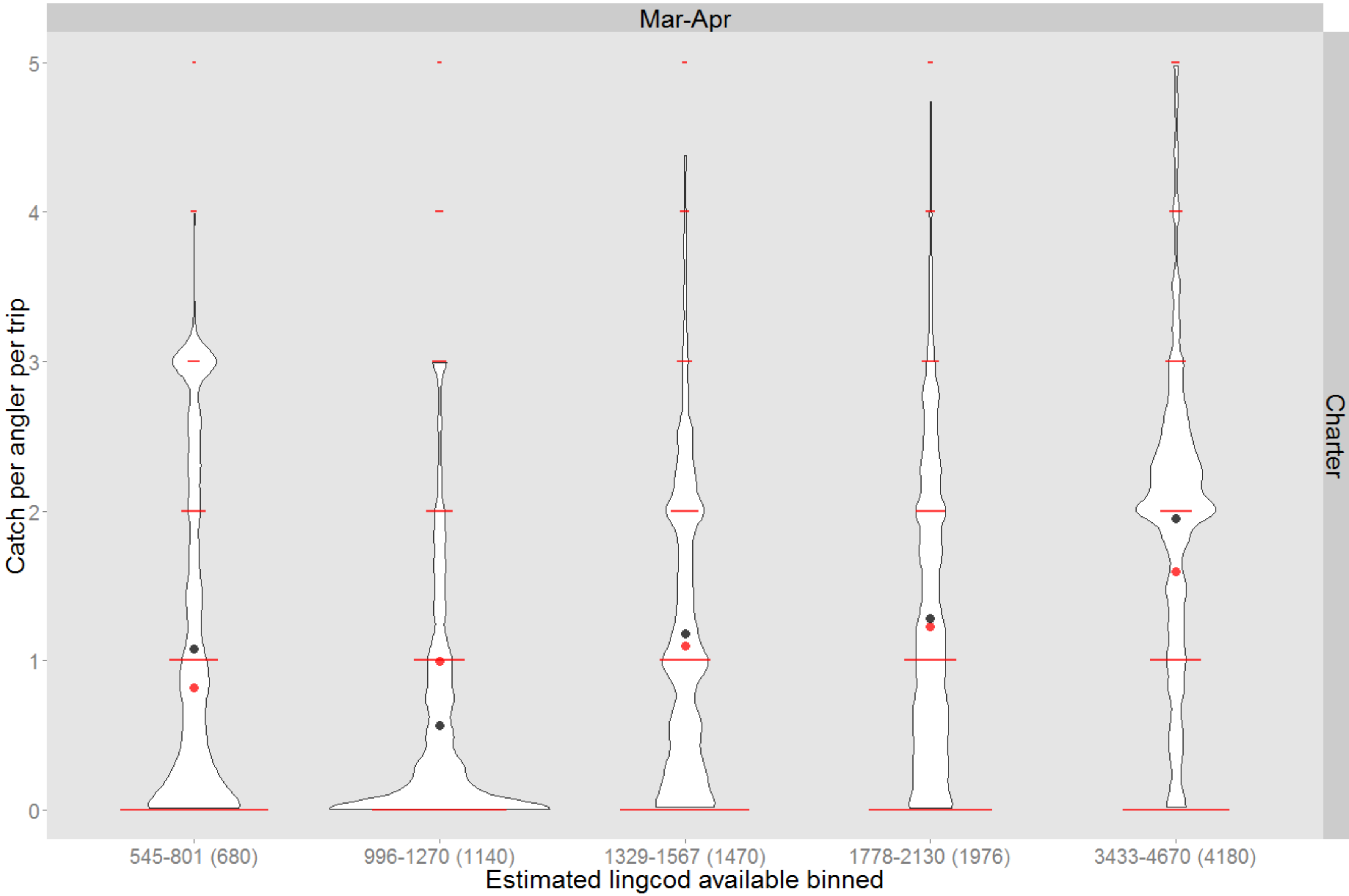

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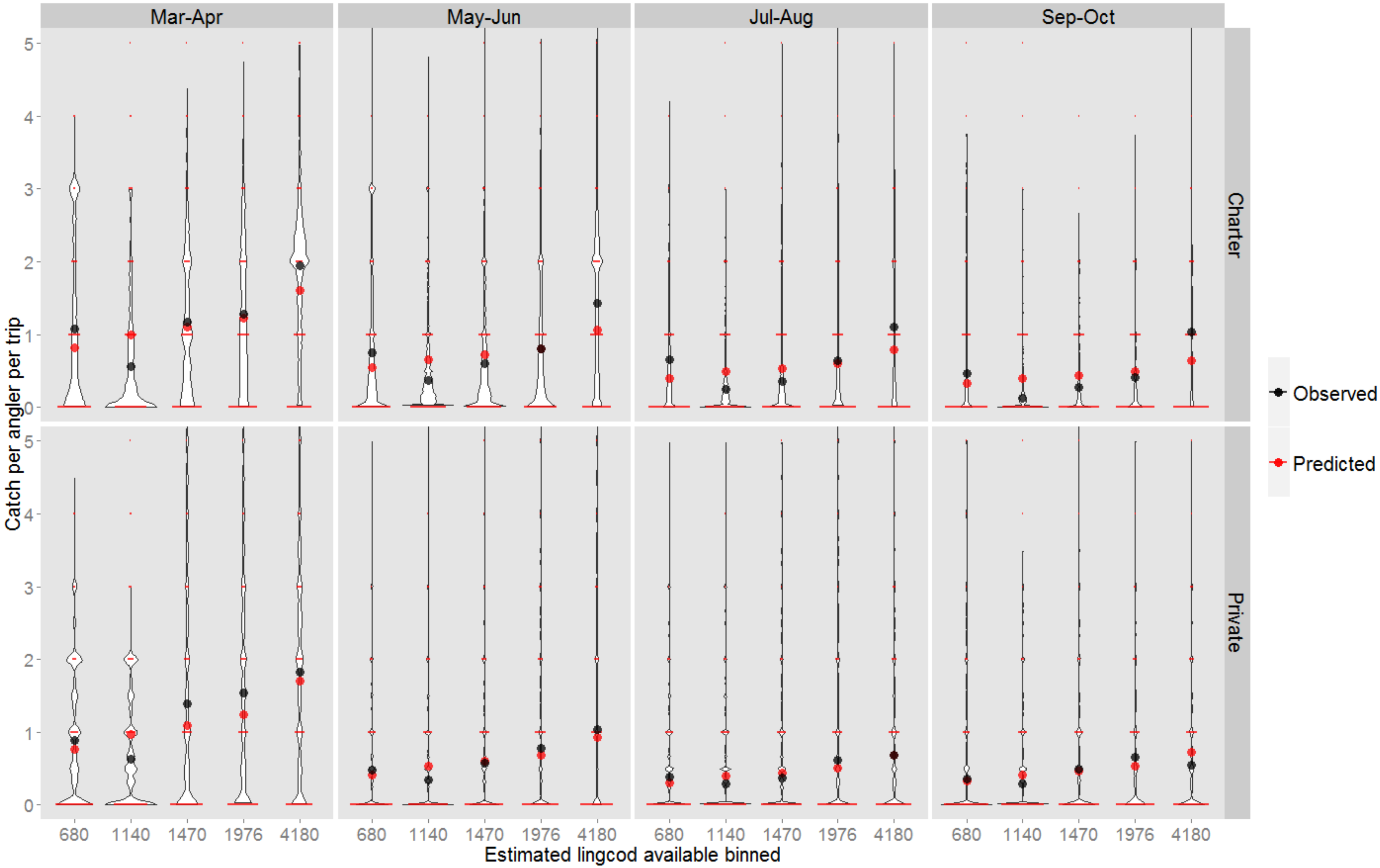

Next steps

- Finish incorporating the catch-per-trip modeling into the bio-economic model
- Incorporate the full age-structured model for additional stocks
- Calibrate the number of "potential" trips (angler choice occasions) so the number of model predicted trips taken is similar to what has been observed under similar conditions

Next steps

- Examine what occurs under different management measures
  - Bag limits
  - Size limits
  - Open/closed seasons
- Simulate changes in catch rates for stocks we are not modeling (e.g. poor salmon returns) and see how that affects angler effort and other stocks

Potential future improvements

- Include California stocks and fisheries in the model once information is available from an updated economic survey
- Incorporate information from fully observed fishing trips (Oregon onboard charter survey)
- Account for changes in behavior with changes in regulations in modeling catch-per-trip