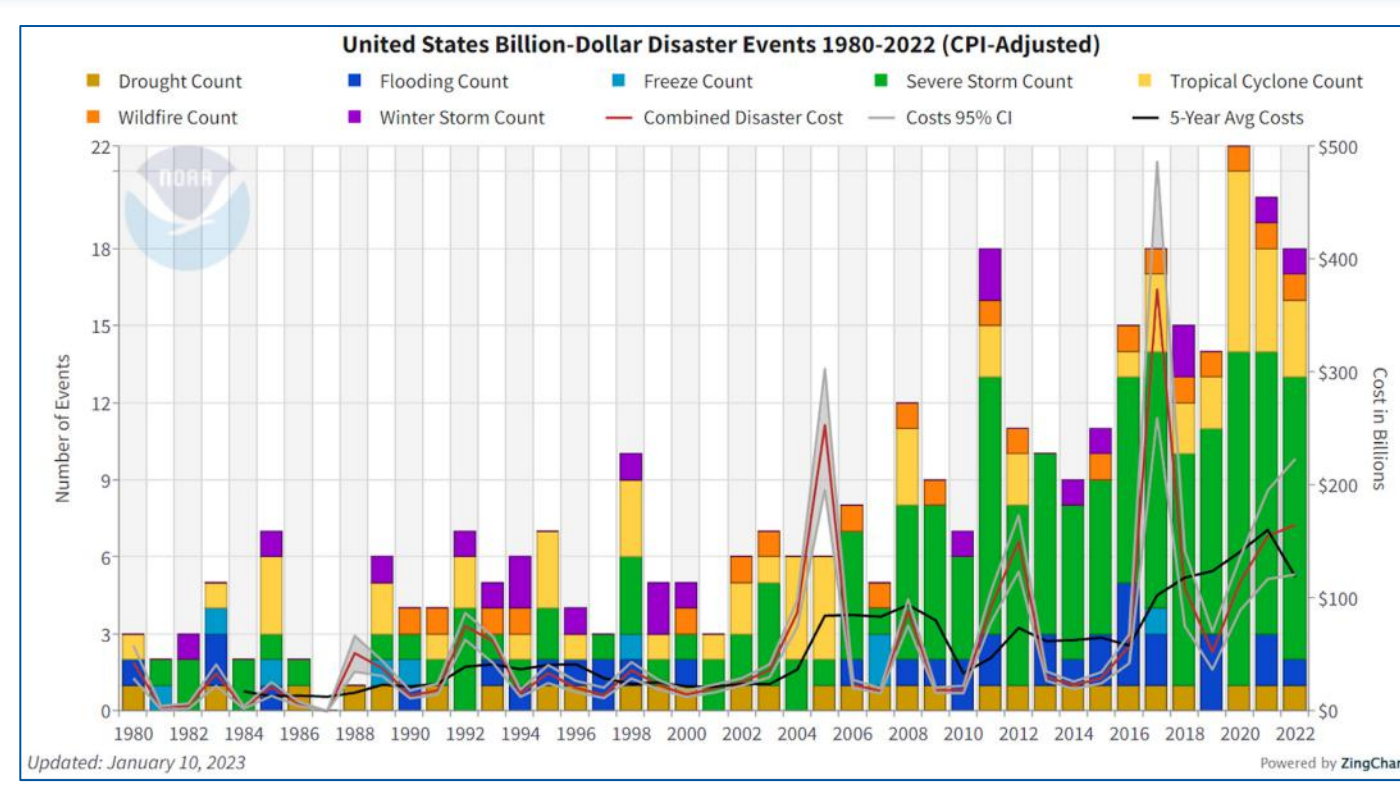


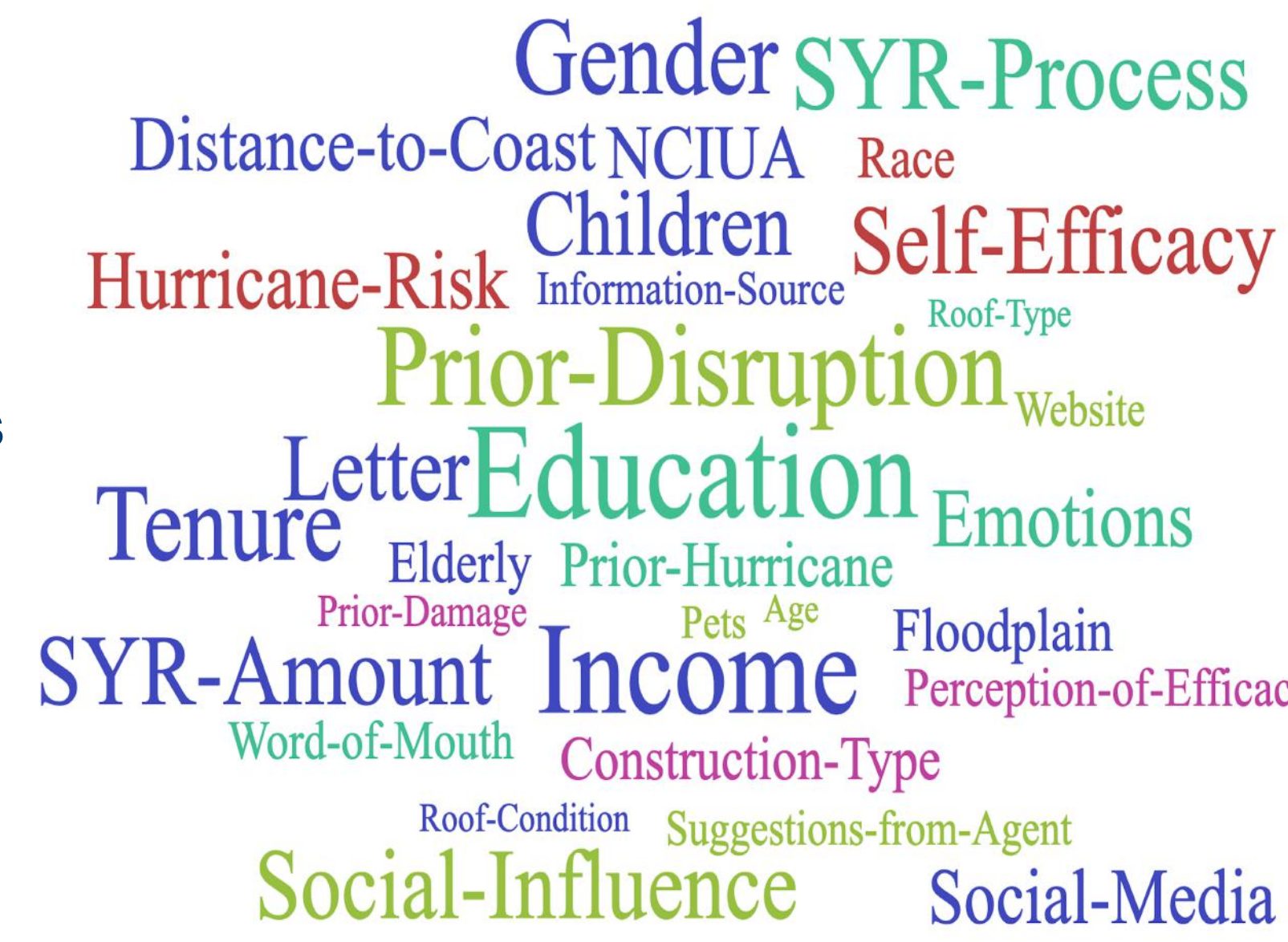
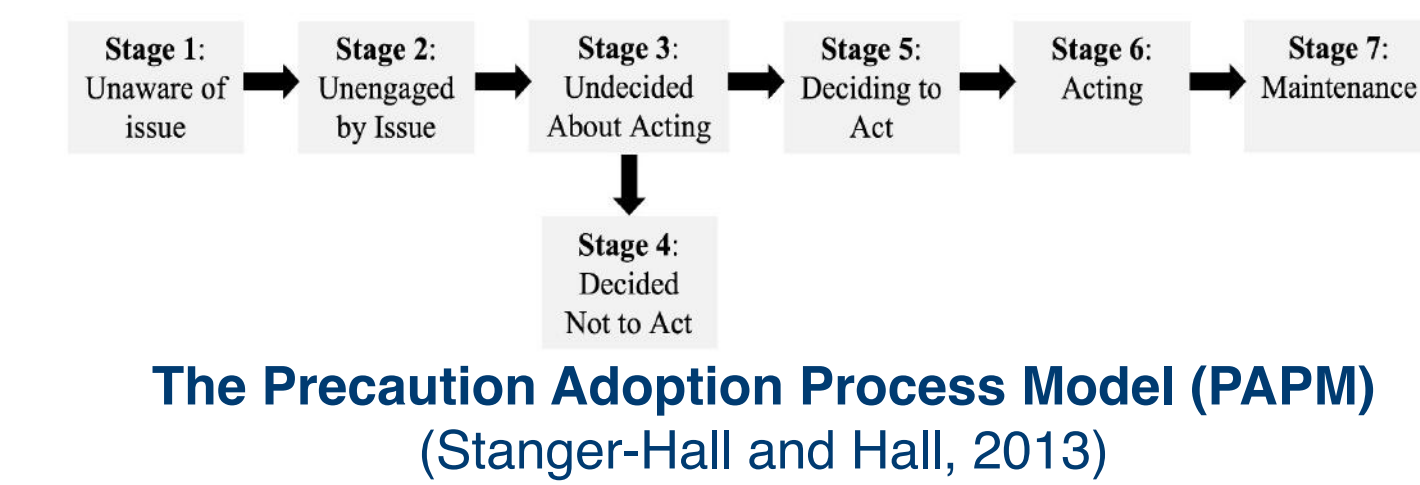
## Background

Increased hurricane activity alongside rapid coastal development has resulted in escalating hurricane-related losses in the US over the past 40 years. While federal and state programs have attempted to motivate homeowners to implement structural retrofits, Javeline and Kijewski-Correa (2019) observed that homeowners do not voluntarily take preventative protective action to strengthen their homes against hurricanes. Previous studies on homeowner mitigation decision-making assume homeowners are actively engaged in making protective action decisions. However, by utilizing the theory of the Precaution Adoption Process Model (PAPM), Stock et al. (2021) discovered that one-third of homeowners are unengaged in hurricane mitigation decision-making. This study applies the PAPM framework to the stages of a mitigation incentive program aimed at encouraging homeowners to take structural measures to strengthen their homes against future hurricane events.



## Methods and Data Collection

Surveys were deployed to 38,942 households between July and December 2022 consisting of two types of questions:  
 (1) PAPM stage of homeowner regarding their decision to apply for the SYR Grant  
 (2) information about the homeowner including, sociodemographics, household characteristics and homeowner beliefs regarding hurricanes and hazard adjustment behavior



## Multi-State Markov Model: Preliminary Results

Transition Probability Matrix ( $P_m$ ) for a Unit Step (1 day)

PAPM Stage	From	Application						Construction					
		Unaware	Unengaged	Undecided	Decide No	Decide Yes	Applied	Unengaged	Undecided	Decide No	Decide Yes	Selected Contractor	Complete
Application	Unaware 1	0.89	0.11	1.9E-04	0.0E+00	2.0E-07	1.2E-09	3.1E-12	9.0E-14	6.3E-17	6.4E-16	3.2E-18	4.2E-21
	Unengaged 2a	0	1.00	3.3E-03	8.2E-07	5.4E-06	4.3E-08	1.4E-10	4.7E-12	3.8E-15	3.9E-14	2.2E-16	3.3E-19
	Undecided 3a	0	0	1.00	4.9E-04	3.2E-03	3.8E-05	1.6E-07	6.9E-09	6.9E-12	6.9E-11	4.7E-13	7.8E-16
	Decide No 4a	0	0	0	1.00	0	0	0	0	0	0	0	0
	Decide Yes 5a	0	0	0	0	0.98	0.02	1.5E-04	8.4E-06	1.0E-08	1.0E-07	8.5E-10	1.7E-12
	Applied 6a	0	0	0	0	0	0.99	0.01	1.0E-03	1.7E-06	1.7E-05	1.8E-07	4.2E-10
Construction	Unengaged 2b	0	0	0	0	0	0	0.84	0.15	3.9E-04	3.9E-03	5.4E-05	1.6E-07
	Undecided 3b	0	0	0	0	0	0	0	0.95	4.8E-03	0.05	9.7E-04	3.8E-06
	Decide No 4b	0	0	0	0	0	0	0	0	1.00	0	0	0
	Decide Yes 5b	0	0	0	0	0	0	0	0	0	0.96	0.04	2.3E-04
	Selected Contractor 6b	0	0	0	0	0	0	0	0	0	0	0.99	0.01
	Complete 7	0	0	0	0	0	0	0	0	0	0	0	1.00

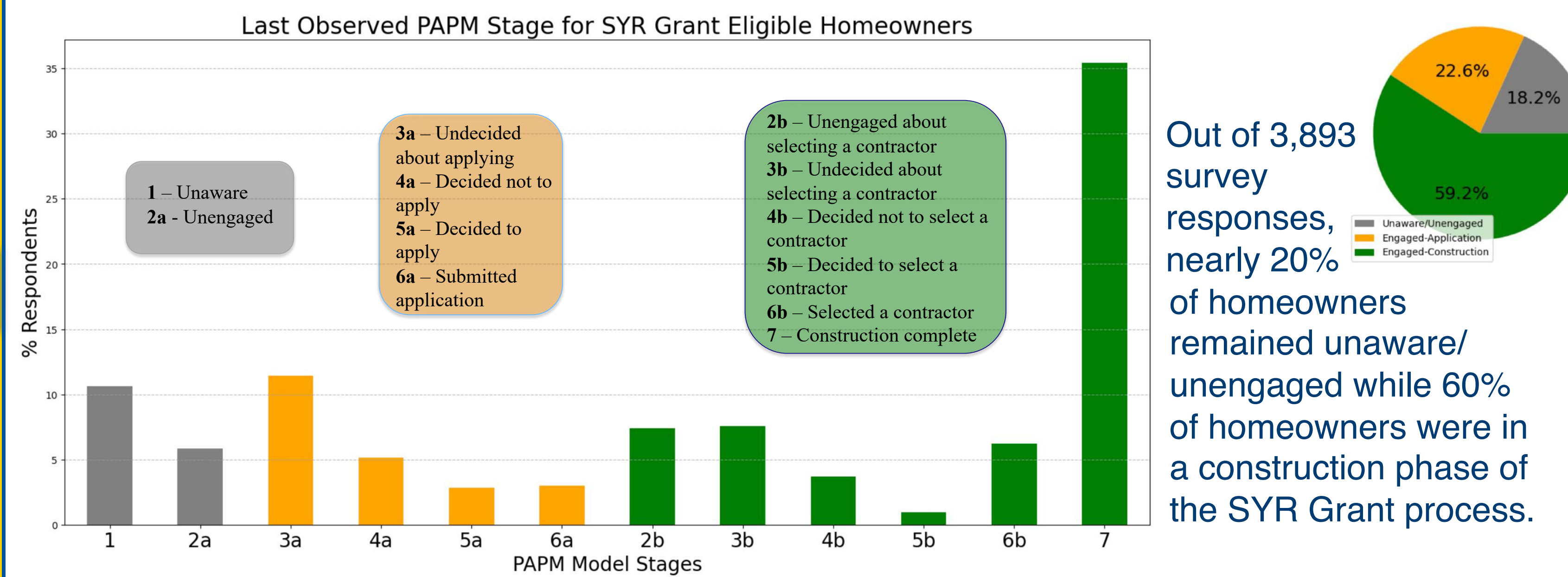
Mean Sojourn Times in Transient Stages (Days)

PAPM Stage	Days
Unaware 1	8.6
Unengaged 2a	300.2
Undecided 3a	266.2
Decide Yes 5a	41.9
Applied 6a	76.3
Unengaged 2b	5.8
Undecided 3b	18.4
Decide Yes 5b	24.7
Selected Contractor 6b	86.0

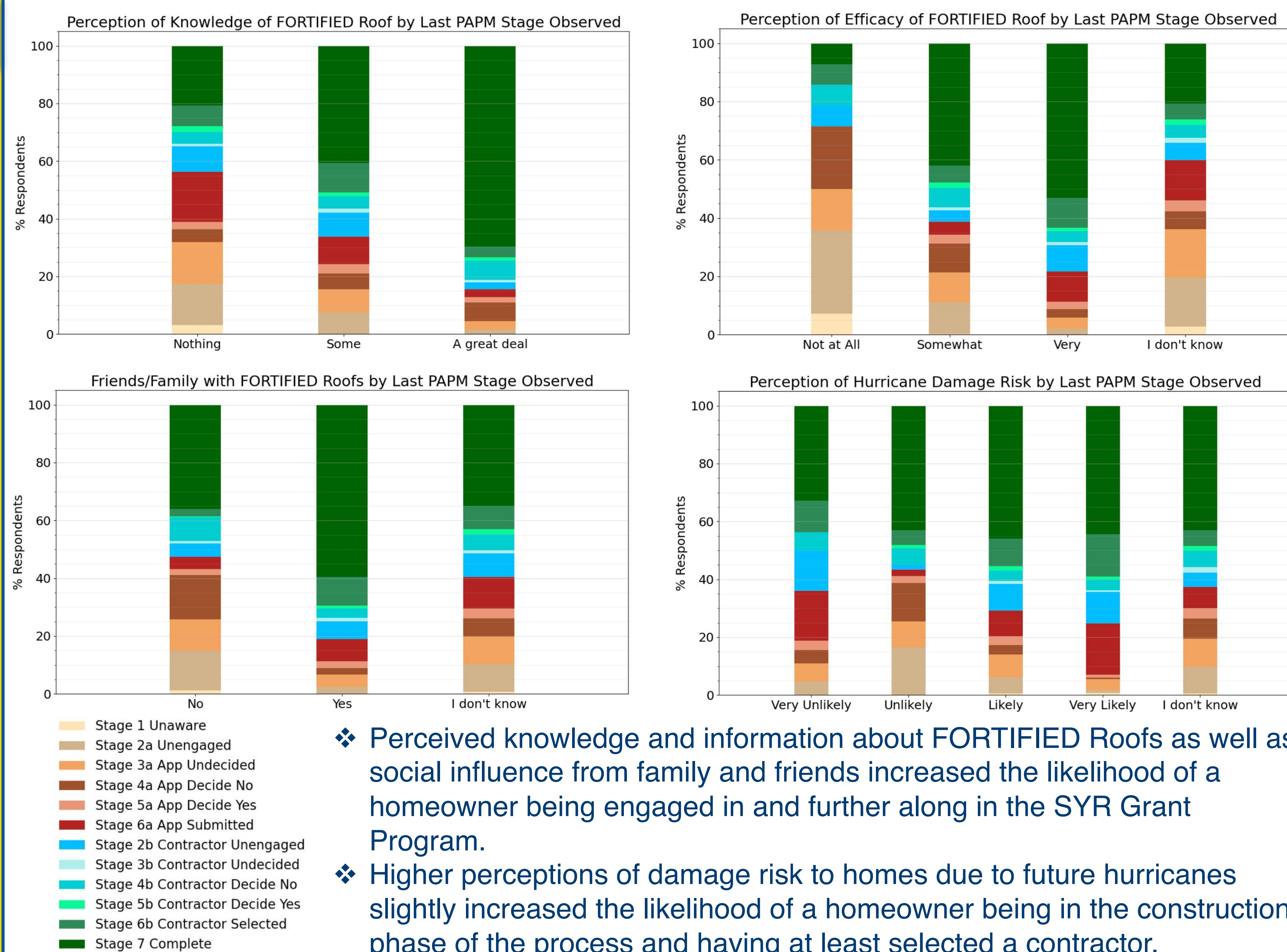
Transition probabilities are functions of the maximum likelihood transition intensities estimated by the multi-state model. Transition probabilities represent the probability that a homeowner moves from one PAPM stage to another in a given time period. Zero values indicate such a transition is not permitted for the defined model. The transition probability matrix suggests that the probability of transitioning from one stage to another stage in one day is slim for nearly all pairs of stages. Preliminary findings of mean sojourn times suggest homeowners spend at least three times as long not engaging in or being undecided about applying for the SYR grant program than in any other stage.

## Key Findings

At the close of the SYR 2022 application window, in what stage of the decision-making process to fortify their roofs through the SYR Grant Program were homeowners?



Which variables influenced the last PAPM Stage observed of each homeowner?



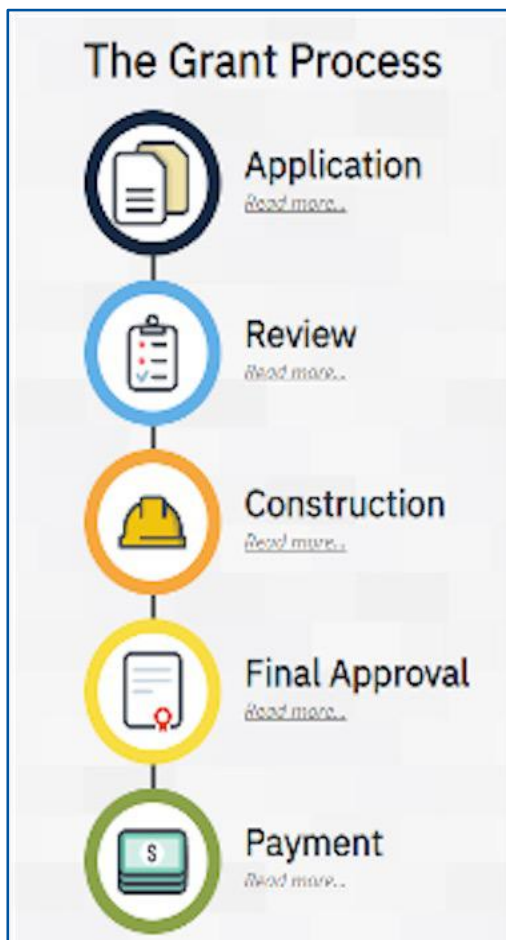
## Research Objectives

- To identify the factors that trigger homeowners to transition from one PAPM stage to another particularly those that drive homeowners from unengagement to engaging in mitigation decisions
- To operationalize the phases of PAPM using multi-state modelling to determine the probabilities of transitioning between stages and the length of time spent in each stage

## Case Study

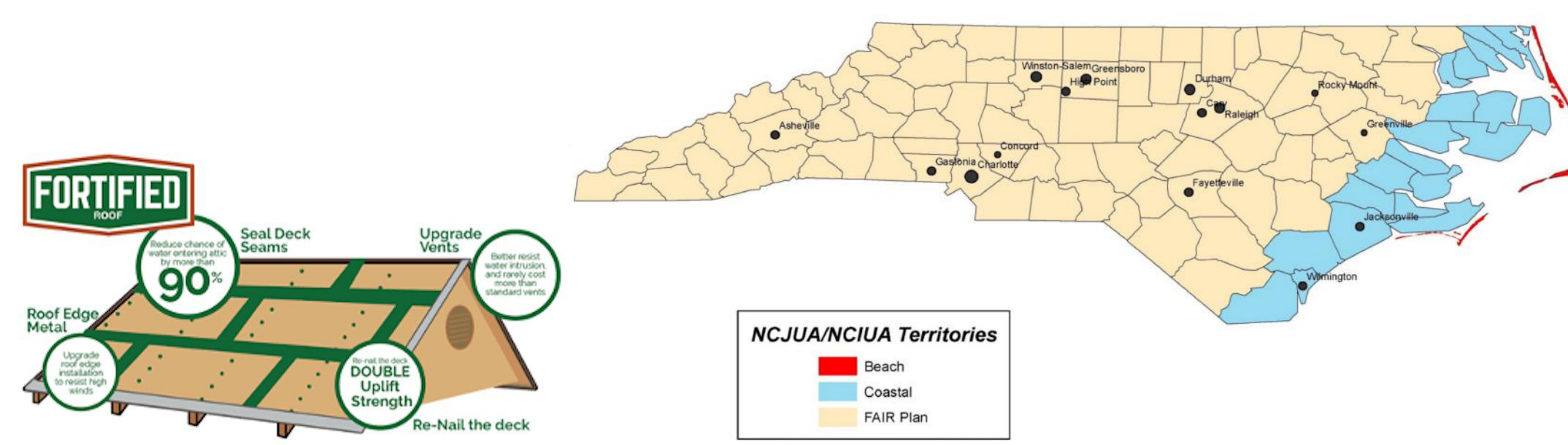
### Strengthen Your Roof (SYR) Grant Program

- Launched in 2019 by the North Carolina Underwriting Insurance Association (NCIUA) in conjunction with the Institute of Business and Home Safety (IBHS)
- Provides grants of up to \$6,000 to eligible policyholders in the barrier islands of North Carolina to replace existing roofs with IBHS FORTIFIED Roofs



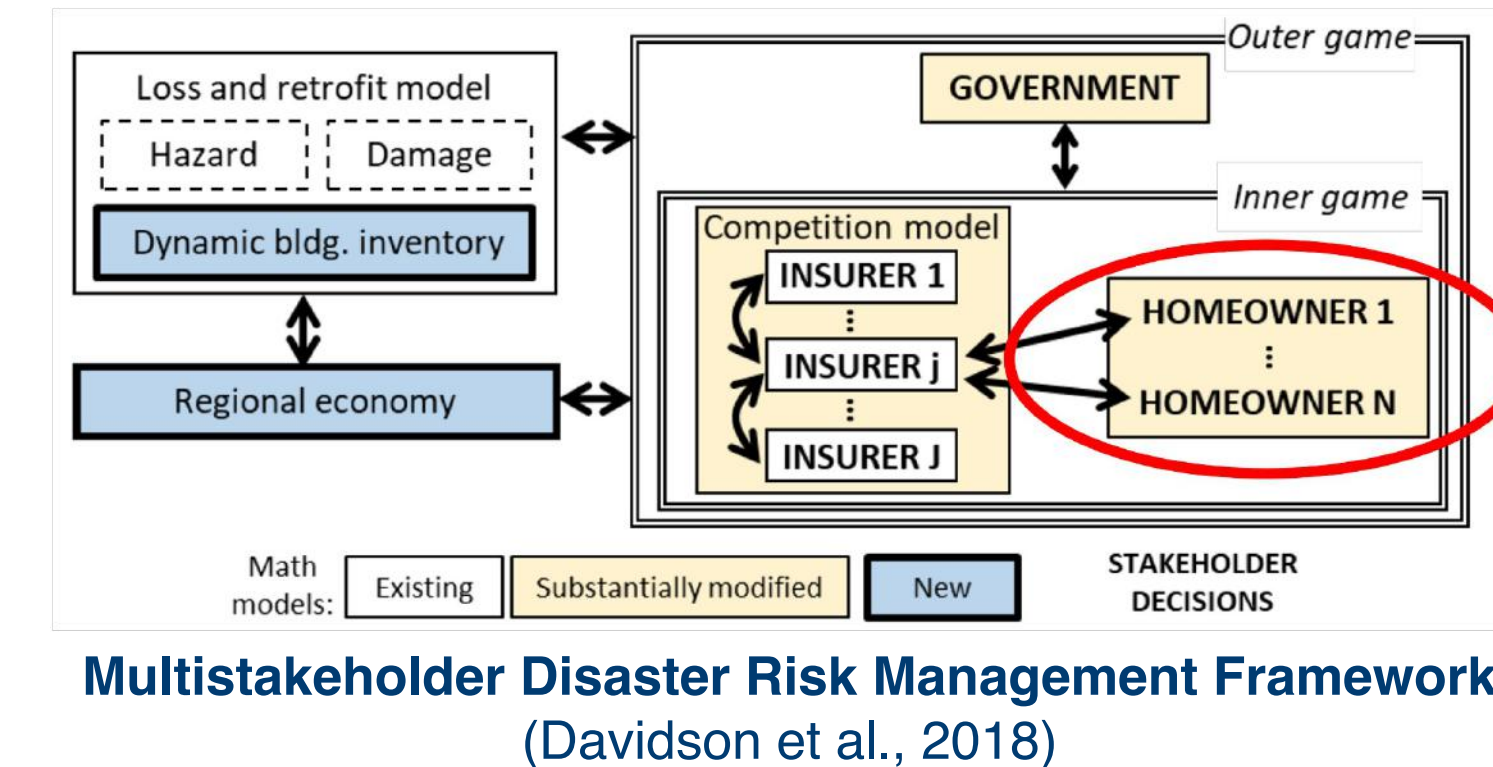
**Study Area**  
 NCIUA Beach Plan Territory

**Population**  
 Households with active wind damage insurance policies through NCIUA eligible for the Strengthen Your Roof (SYR) Grant Program between 2019 and 2022



## Future Research

The multi-state model will be modified to include a selection of explanatory variables collected from the survey data and supplemented by homeowner policy and claims data. New transition probabilities will be derived as a function of these variables. The results will highlight which factors facilitate or impede a homeowner's transition from one stage to another. Additional data is being collected through (1) the Strengthen Your Coastal Roof Grant Program which targets households with active wind policies in NCIUA's Coastal Territory and (2) the 2023 SYR Grant Program which will help refine and validate the current model. The proposed research will contribute to the Multistakeholder Disaster Risk Management Framework by informing current household decision-making models with probabilities that a household participates in a mitigation incentive program that better reflects actual household protective action behavior. A more accurate prediction of the number of households that engage in protective decision-making will result in a more realistic estimation of regional risk and expected future damage and losses.



## References

Javeline, D., & Kijewski-Correa, T. (2019). Coastal homeowners in a changing climate. *Climatic Change*, 152(2), 259–274.

Stock, A., Davidson, R.A., Trainor, J.E., Slotter, R., Nozick, L.K., & Kruse, J.B. (2021). What Makes Homeowners Consider Protective Actions to Reduce Disaster Risk? An Application of the Precaution Adoption Process Model and Life Course Theory. *International Journal of Disaster Risk Science*, 12, 312–325.

Davidson, R., Kruse, J., Nozick, L., Trainor, J., (2018) LEAP-HI: Embedding Regional Hurricane Risk Management in the Life of a Community: A Computational Framework. NSF Grant Proposal. Award Abstract #1830511.