Storage Loss

Analysis and recomendations

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2022-07-16

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Introduction

- Need to find a fair method of compensating growers for actual storage loss
- Problem is complex and multi-factorial
- Previous attempts to use gross-loss have tended to also capture loss not related to storage
- Current approach is to analyse each defect/disorder in terms of trajectory during storage time
- The effect of ESP and Harvest Date specifically have been accounted for in the model

Extent of storage days

Summary of Rockit storage 2018 - 2022 (YTD)

season	packing start	first CA	last CA	CA min storage days	CA packing days	packing start to first CA
2018	2018-03-01	2018-07-09	2018-08-03	121	25	130
2019	2019-03-04	2019-07-16	2019-10-01	127	77	134
2020	2020-03-02	2020-08-11	2020-09-25	150	45	162
2021	2021-03-01	2021-08-16	2021-10-01	159	46	168
2022	2022-02-21	2022-06-27	2022-07-15	77	18	126

Pack-out performance

	pack-out		
season	CA	RA	mean uplift
2018	74.96%	69.79%	5.17%
2019	79.27%	79.57%	-0.30%
2020	73.79%	69.73%	4.06%
2021	70.23%	70.34%	-0.10%
2022	57.79%	69.03%	-11.24%

Calculated uplift

	regression coefficients					
	RA			CA		
season	`$\alpha$`	`$\beta$`	`$\theta$`	`$m$`	`$\mu$`	uplift
2018	22.69%	-0.053	63.56%	-3.01%	0.750	11.40%
2019	21.29%	-0.112	76.92%	-1.45%	0.793	2.35%
2020	26.29%	-0.105	67.69%	-5.27%	0.738	6.09%
2021	53.14%	-0.140	68.54%	2.80%	0.702	1.70%
2022	18.92%	-0.034	61.34%	13.19%	0.578	-3.55%

[a] `$m$` = slope in pack-out % per day. Note the none of the slopes were significant meaning that the hypothesis that the slopes are all zero (i.e. CA PO is constant) cannot be rejected

[b] `$\mu$` = the mean packout for all the CA batches from that season

[c] uplift = actual uplift, calculated as mean CA packout (μ) - `$\theta$`

Pack-out behaviour

Modeled pack-out

The pack-out can be modeled using a first order rate equation of the form

$$E[PO_i|SD_i] = \alpha e^{\beta SD_i} + \theta$$

where:

$E[PO_i|SD_i]$ = conditional estimate of pack-out given the i^{th} storage day
α = constant, $\alpha + \theta$ = initial pack-out at storage day zero
β = regression coefficient (rate constant)
θ = "steady state" pack-out

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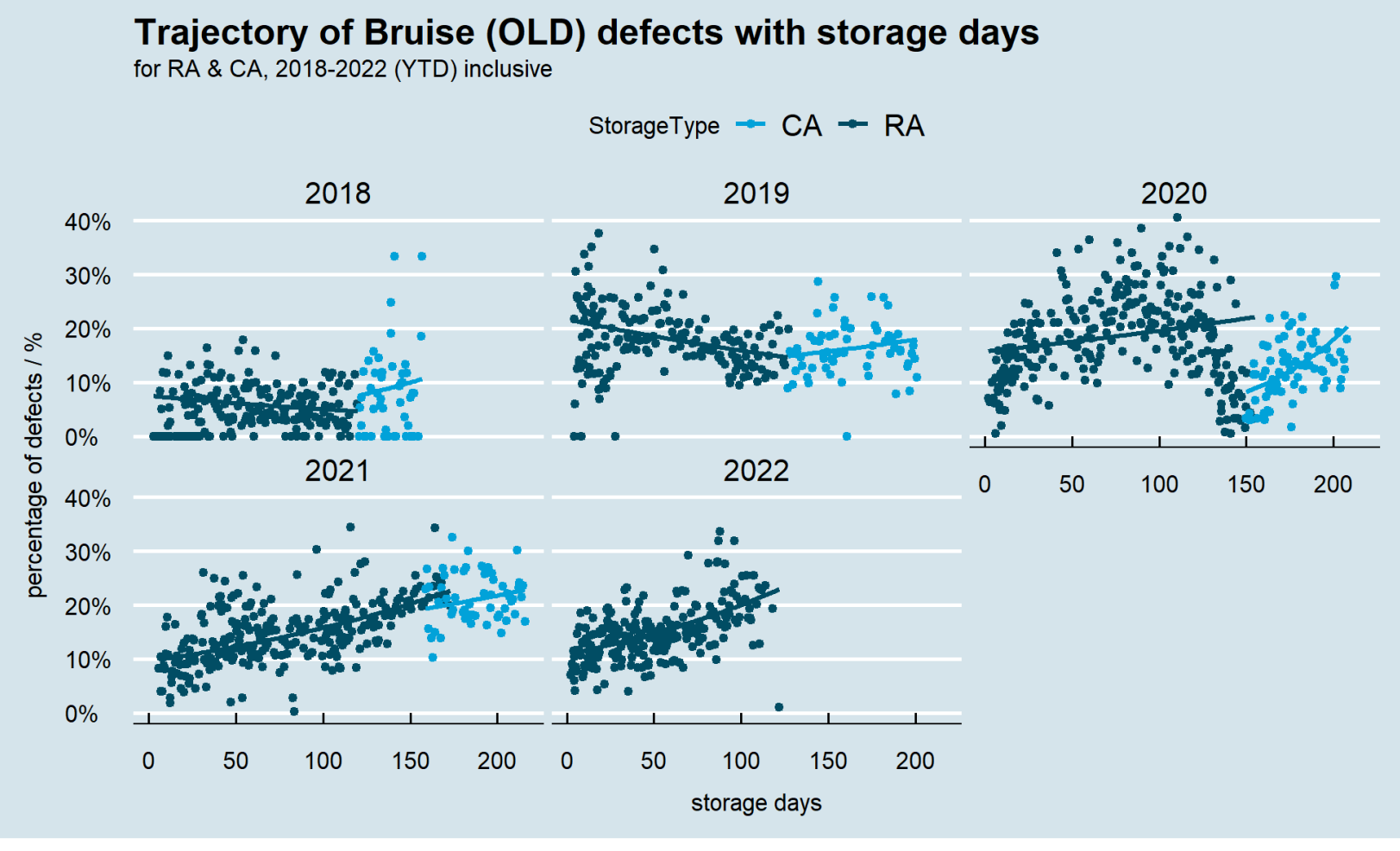
Examination of individual defects

- Curves above are the aggregation of individual defects
- Approach then is to examine the behaviour of individual defects as a function of storage time and storage type (i.e. RA or CA)
- Defects fall into three categories: directly related to storage, indirectly related to storage and independent of storage
- Shrivel is directly related to time in storage, undersize is independent, old bruising appears to be indirectly related.

Classification of defects

direct	indirect	indirect cont'd	independent	independent cont'd
Scald	Alternaria	Grey mould (Botrytis)	Bird Damage	Spray Residue
Shrivel	Black Rot	Lenticle Breakdown	Blotch	Stem Tear
Stem end browning	Black Spot	Lenticle Burn	Elongated	Sting
	Blemish Cosmetic	Lenticle Spot	Export fruit	Sunburn
	Blue mould (penicilin)	Major Bruise (spoilt)	Hail	Surfaces Deposits
	Bronze Beetle Damage	N.Alba	Insect Damage	Tree Damage
	Bruise (fresh)	Over Maturity	Leaves	Under Size
	Bruise (OLD)	Phytophthora	Low Colour	Variety Mark
	Calyx Split	Pit	Misshapen	Wrong Variety
	Cracking	Puncture	Noctuid Damage	
	Cuts	Rose Weevil Damage	Over Size	
	Dry Botrytis	Rot (Botrytis)	Parrot Beak	
	Eye Rot/Canker rot	Stem End Rot	Russet	
	Frost Damage	Stem Split	Scarf Skin	
		WHITE ROT		

Old Bruising vs storage days



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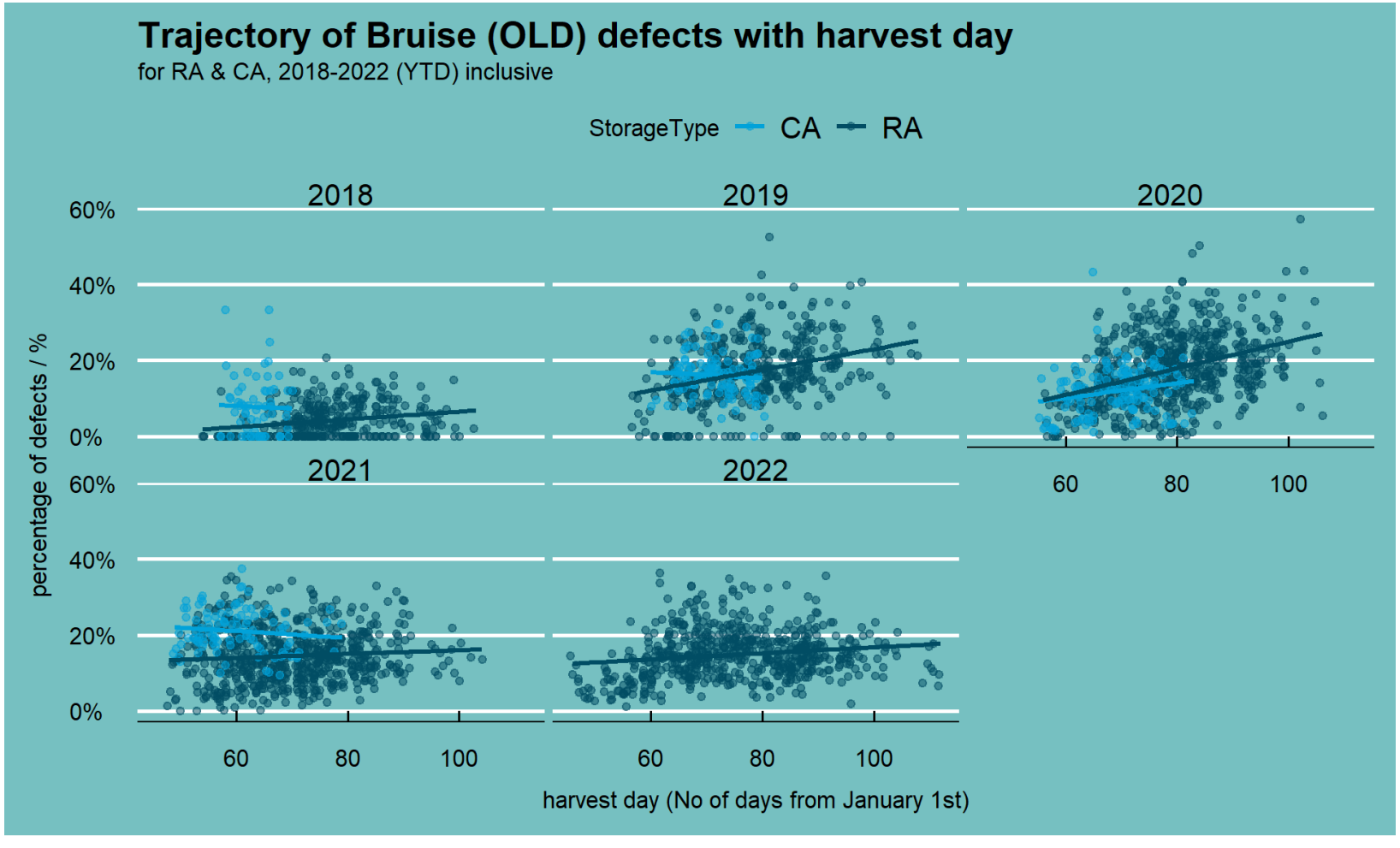
Old Bruising vs harvest day



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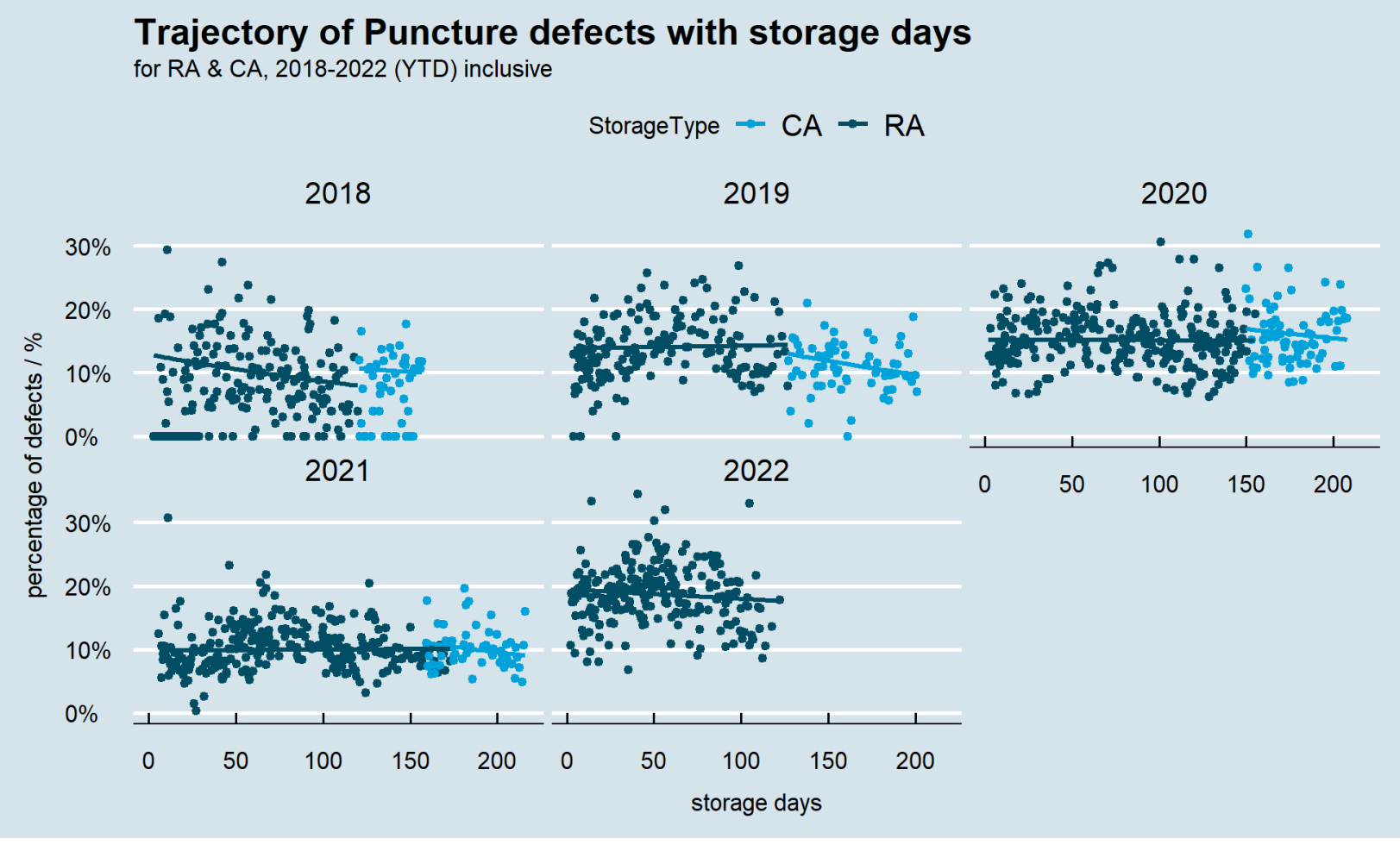
Puncture vs storage days



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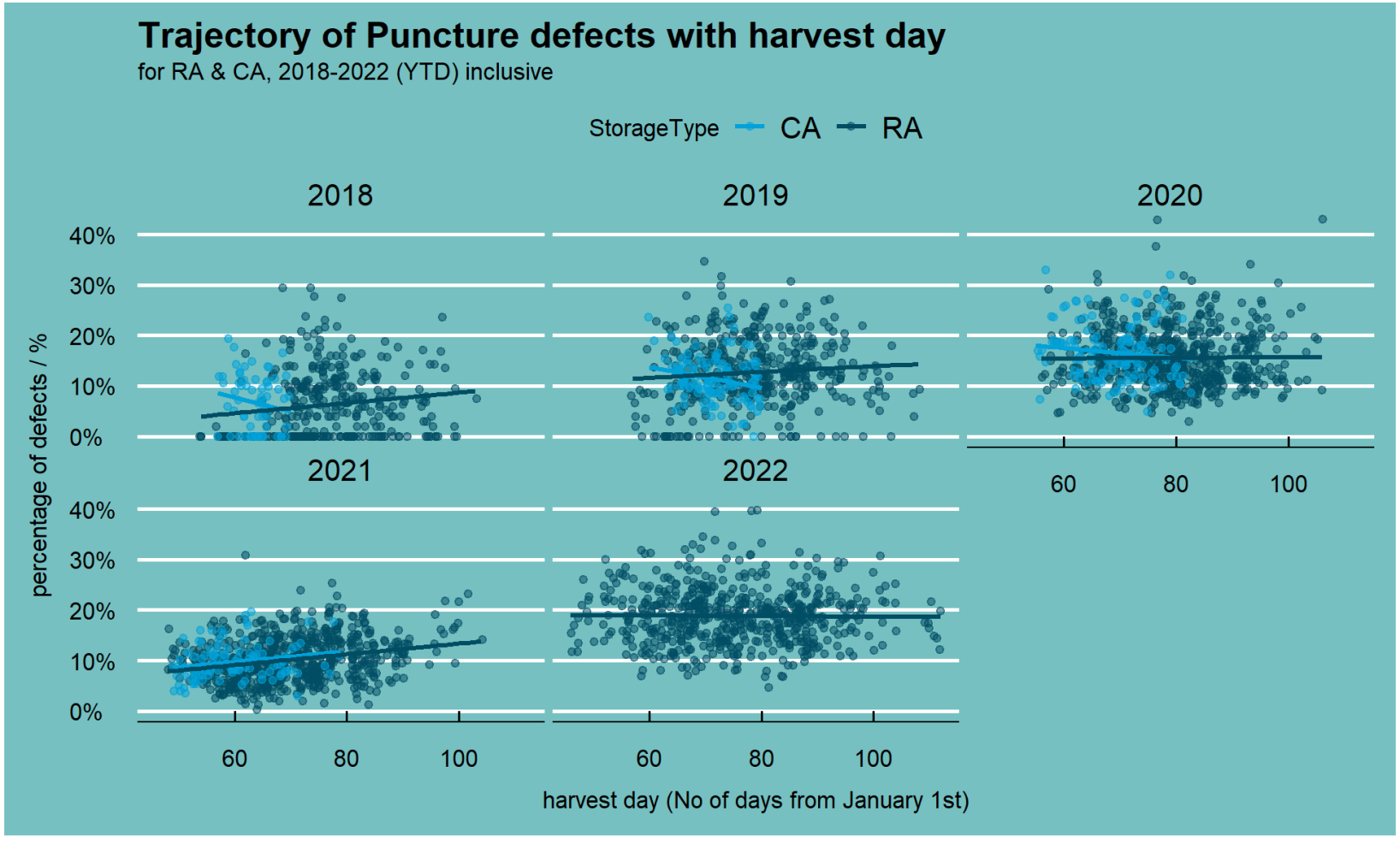
Puncture vs harvest day



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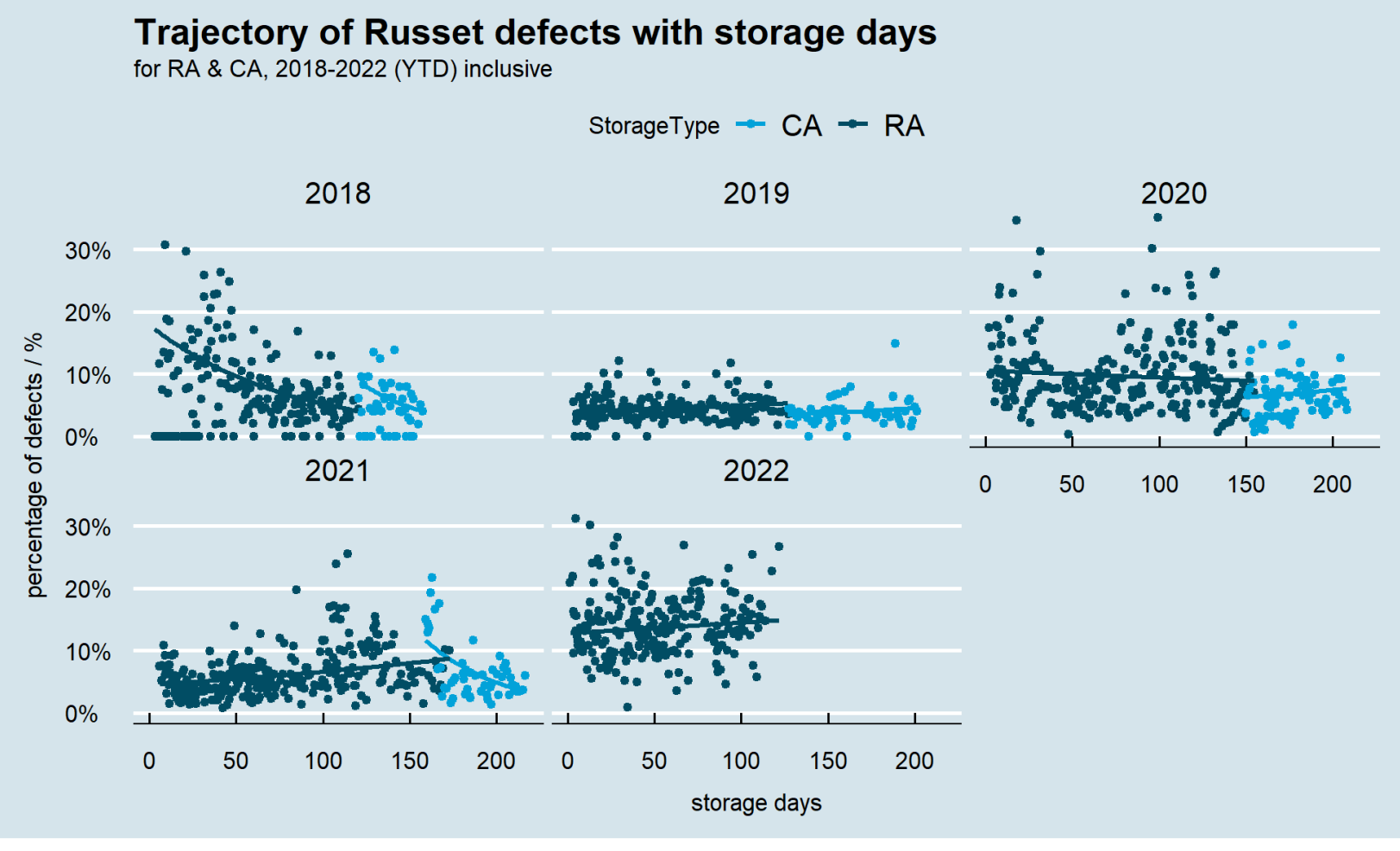
Russet vs storage days



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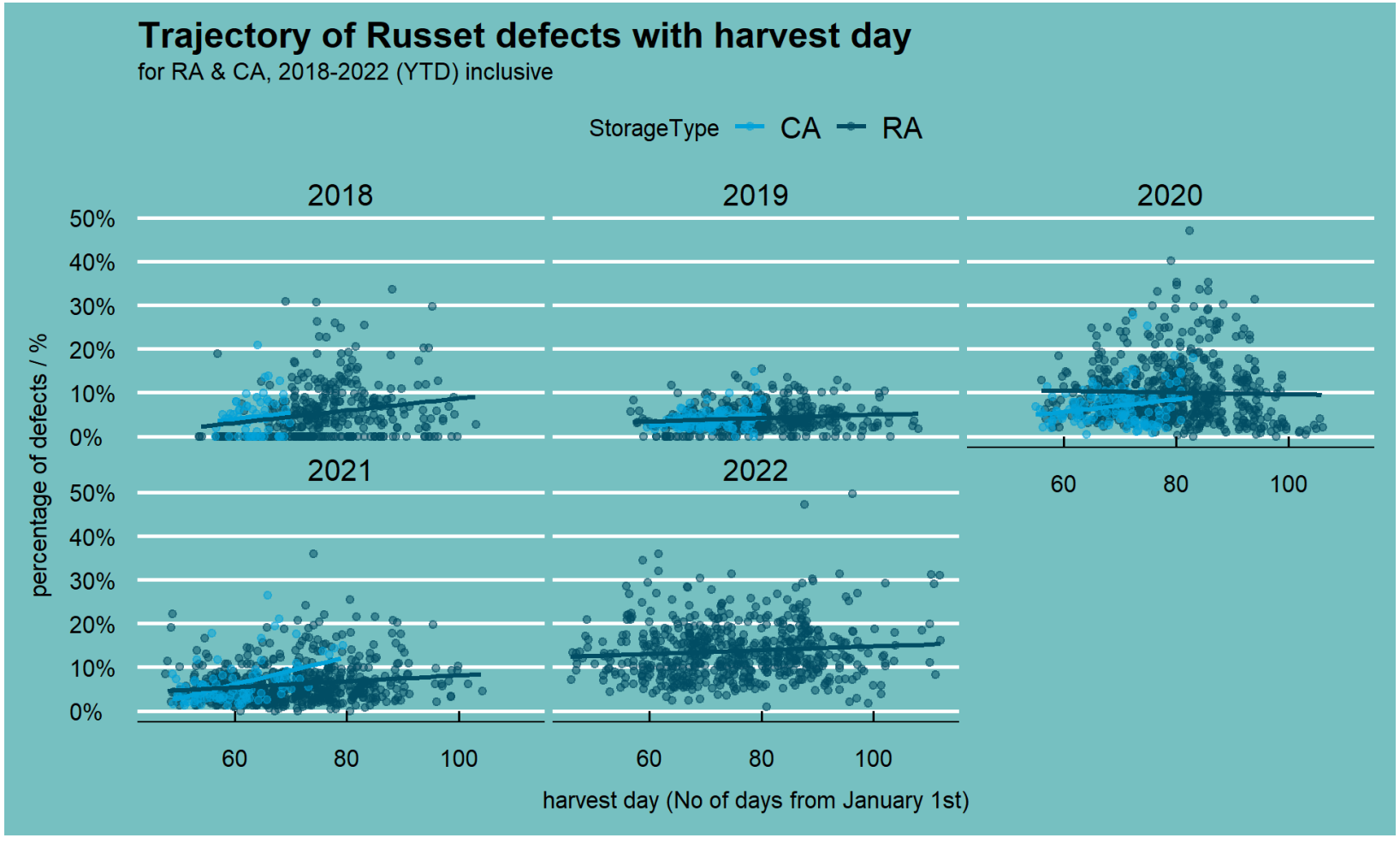
Russet vs harvest day



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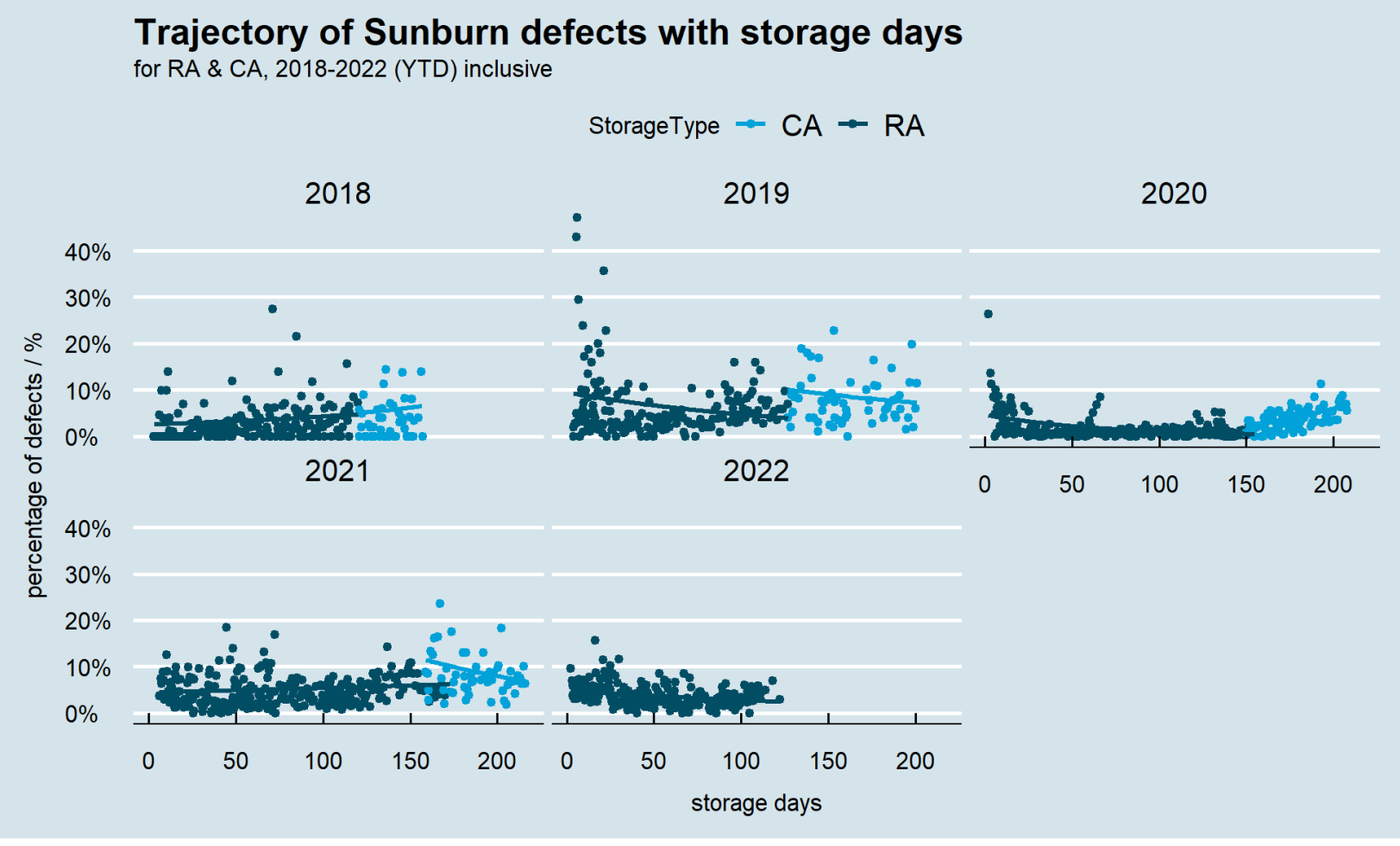
Sunburn vs storage days



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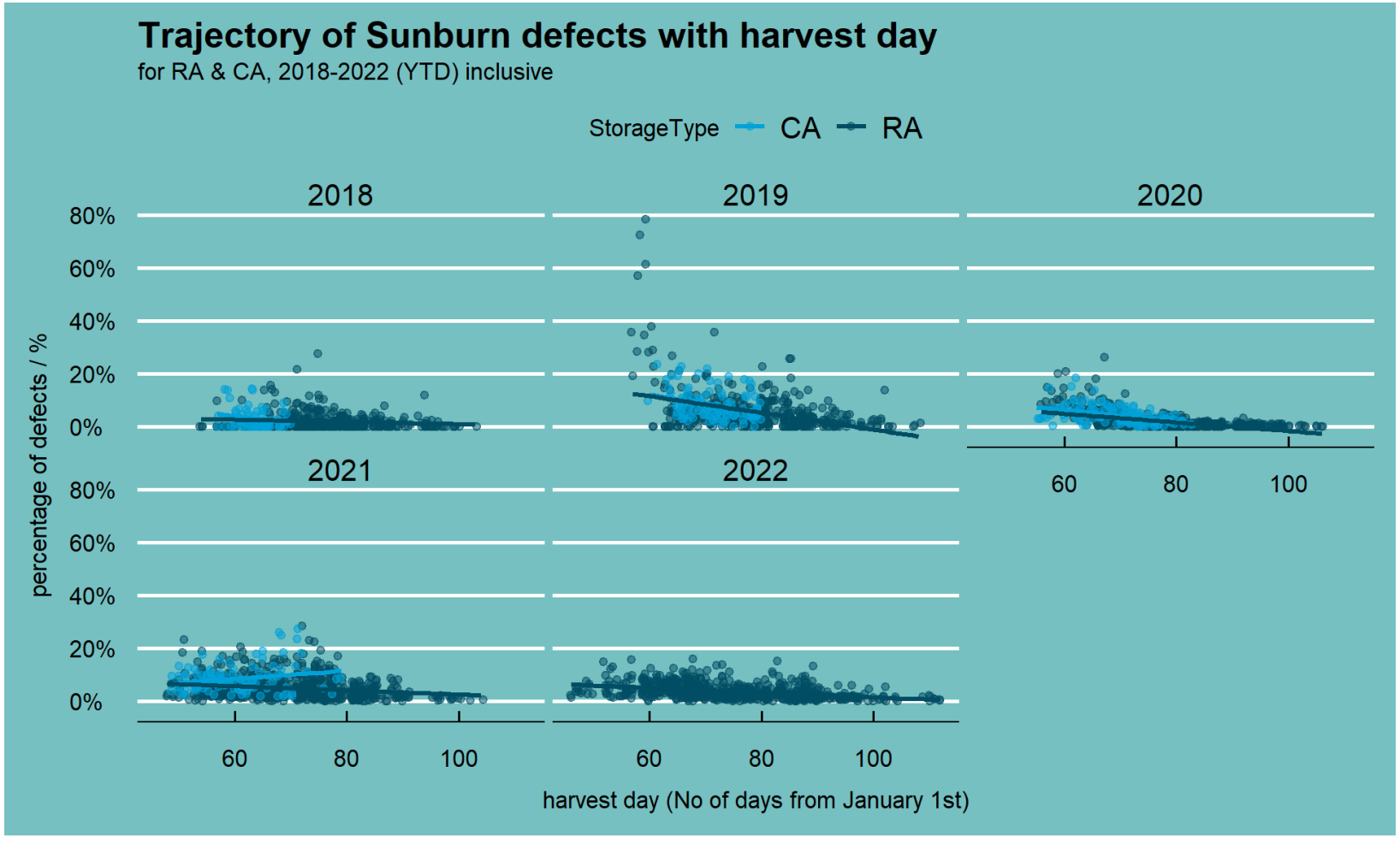
Sunburn vs harvest day



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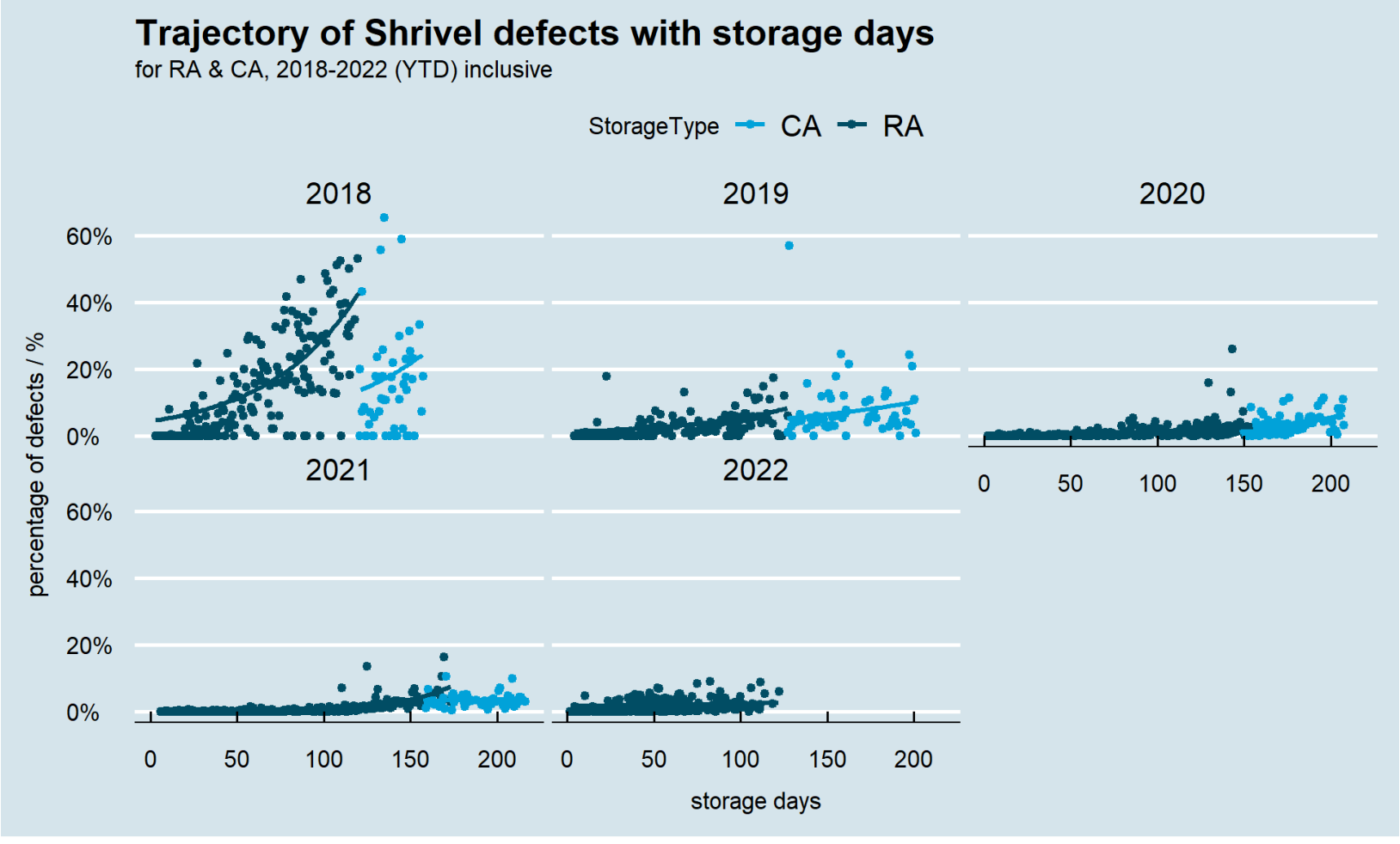
Shrivel vs storage days



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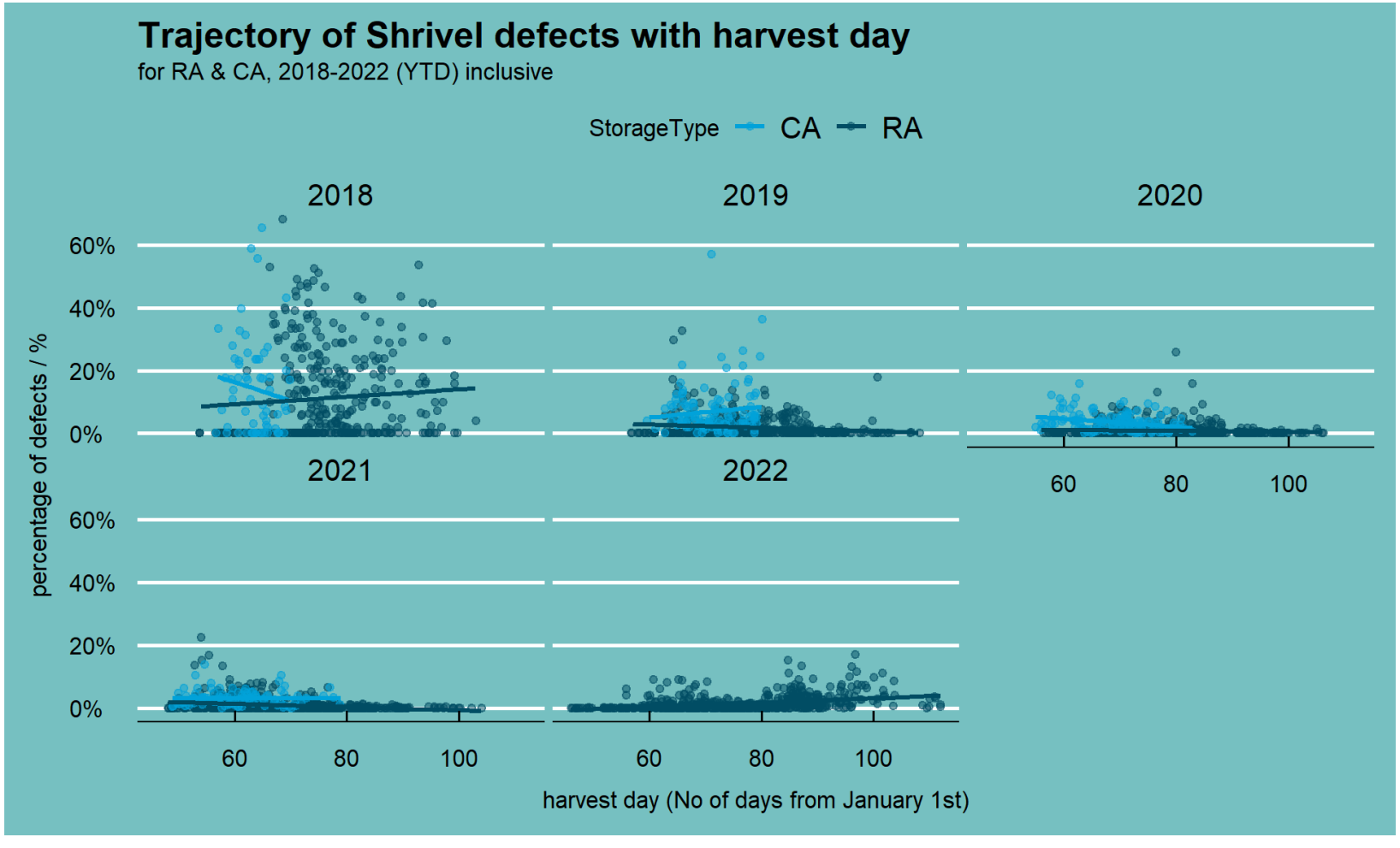
Shrivel vs harvest day



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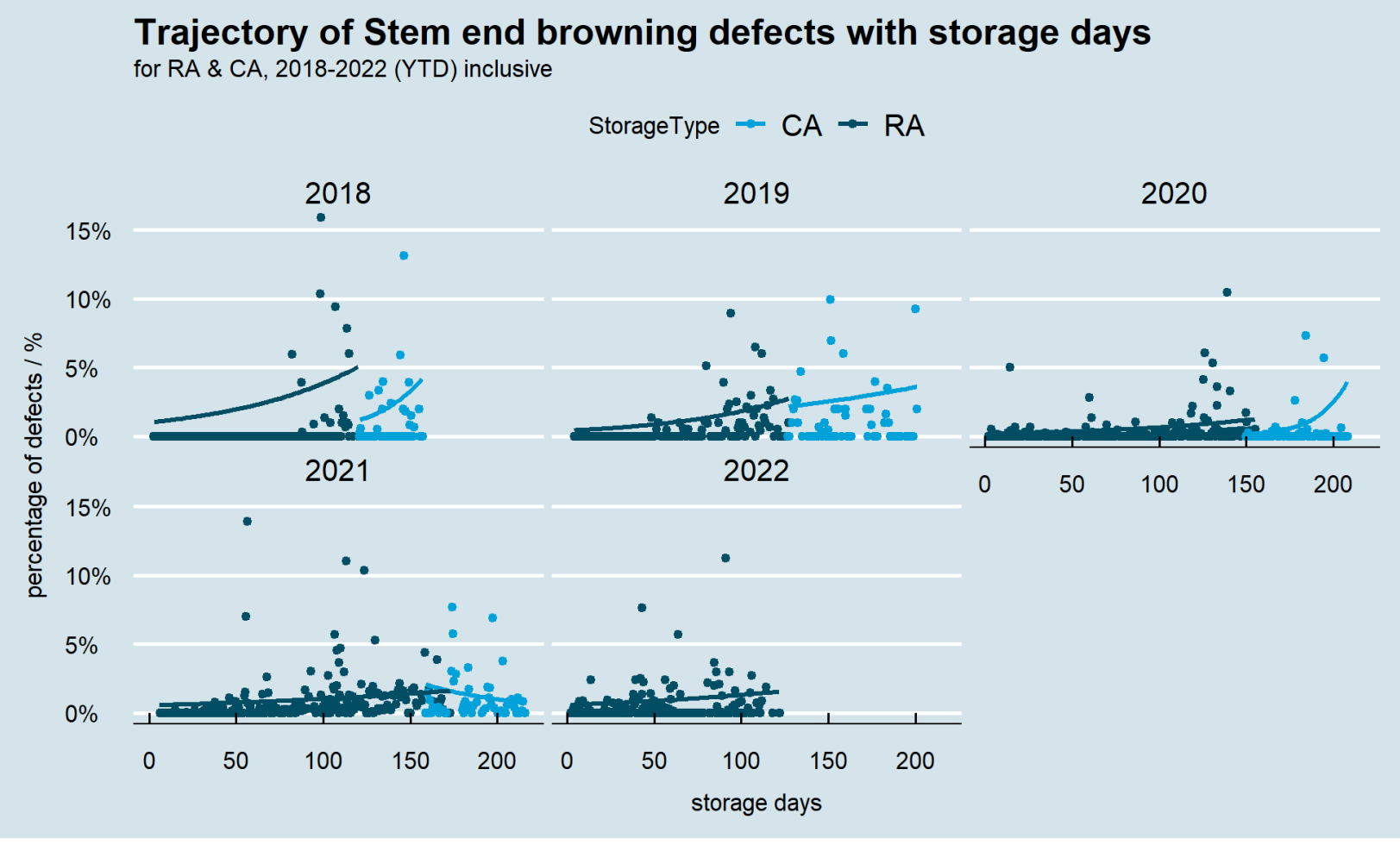
Stem end browning vs storage days



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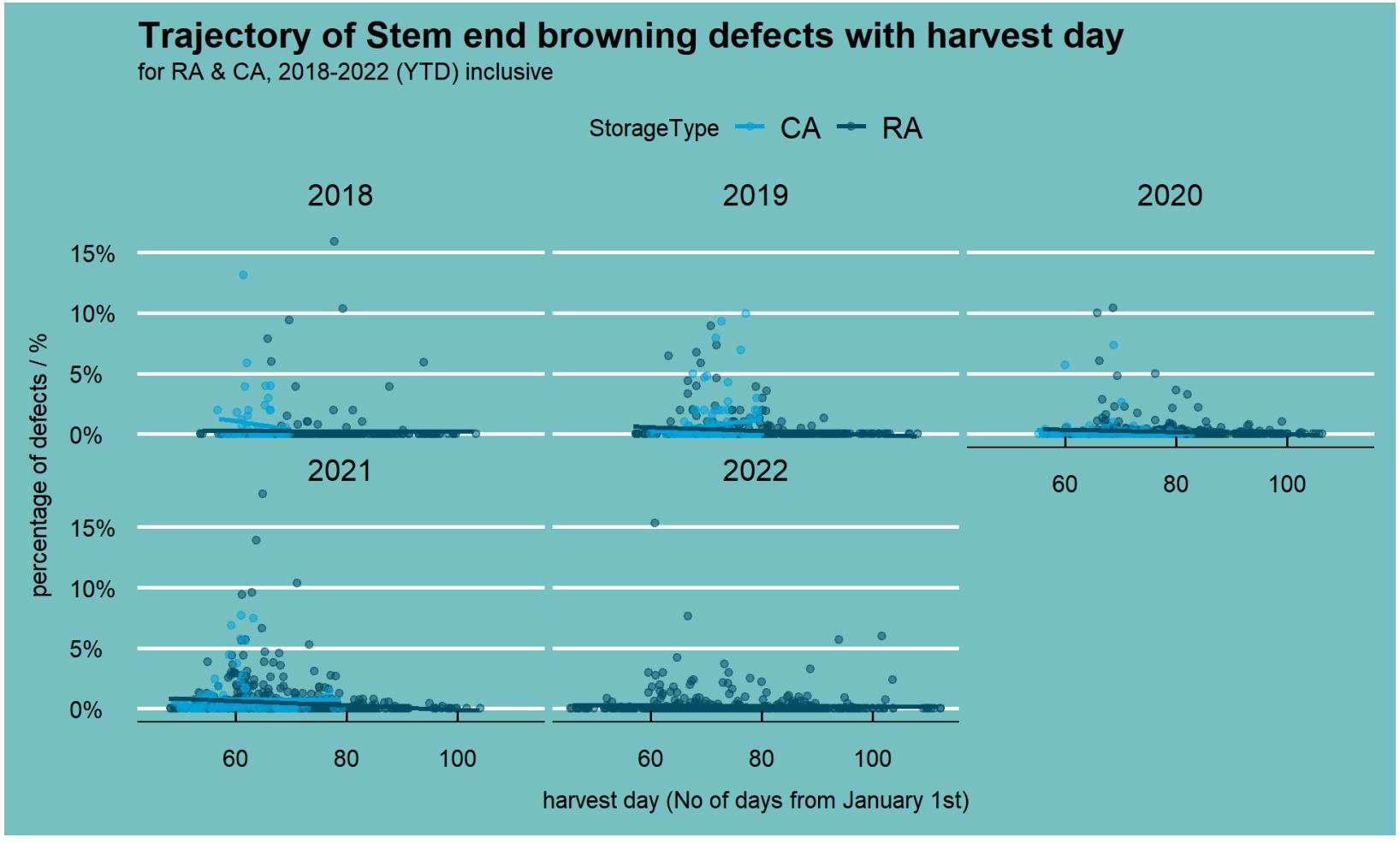

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Model development

- using poisson GLM regression (best suited to count/proportional data)
- tested a number of covariates - harvest date and ESP were the most influential
- significant interactions were observed between storage days and ESP (as expected)

$$log(E[DQ_i|SD_i, HD_j, ESP_k]) = \beta_0 + \beta_1 SD_i + \beta_2 HD_j + \beta_3 ESP_k + \beta_4 SD_i ESP_k + log(SQ_i)$$

where:

$E[DQ_i|SD_i, HD_j, ESP_k]$ = expected value of defect quantity given i^{th} storage day, j^{th} harvest day and k^{th} value of submission profile (ESP)
SQ_i = i^{th} value of sample quantity
$\beta_{0...4}$ = regression coefficients

The above equation can be reformulated into the more usable form:

$$\frac{E[DQ_i|SD_i, HD_j, ESP_k]}{SQ_i} = e^{\beta_0 + \beta_1 SD_i + \beta_2 HD_j + \beta_3 ESP_k + \beta_4 SD_i ESP_k}$$

Regression results

Storage days as single predictor variable

term	estimate	p-value
(Intercept)	-2.3467	p<0.001
storageDays	0.0050	p<0.001

Storage days, harvest day & ESP as covariates

term	estimate	p-value
(Intercept)	-2.7052	p<0.001
storageDays	0.0061	p<0.001
harvestDay	0.0035	p=0.030
MaturityCodeB	0.2461	p=0.002
MaturityCodeC	0.7661	p<0.001
storageDays:MaturityCodeB	-0.0033	p<0.001
storageDays:MaturityCodeC	-0.0103	p<0.001

Key Assumptions for model

- Storage will never improve the condition of the fruit
- Storage loss at day zero is zero
- Defects such as "colour", "undersize", "oversize", "export fruit", "elongated", "hail" etc are independent of storage time
- aggregate storage loss is the sum of the relevant individual defect loss curves i.e.

$$LF_i = \sum_{n=1}^{k} e^{(\beta_{0n} + \beta_{1n} SD_i)}$$

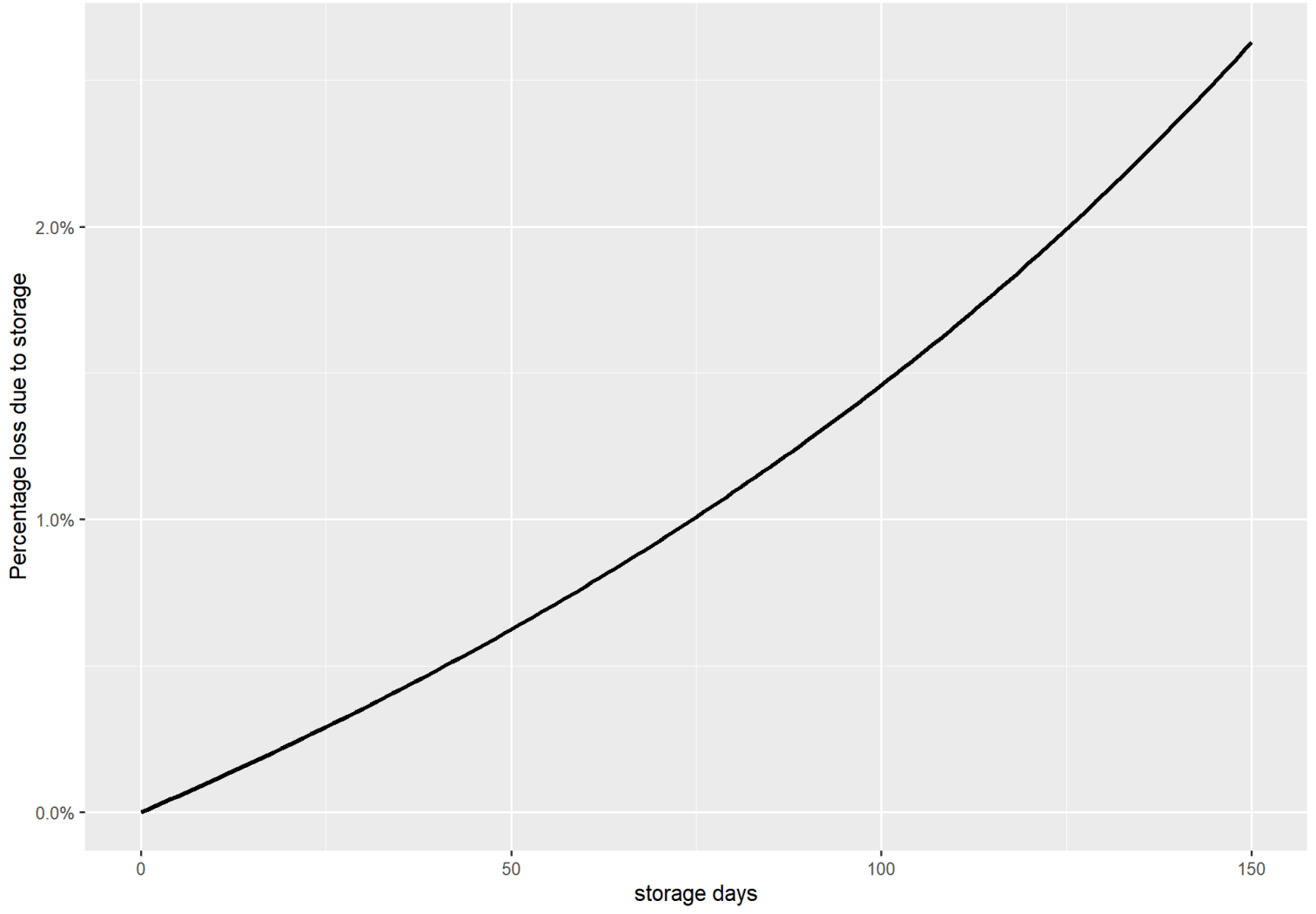
Where:

LF_i = loss function for the i^{th} storage day
k = number of defects in the defect set
β = average regression coefficient of the last four years losses

Defects contributing to storage loss

defect	$`e^{\beta_1}`$	$`e^{\beta_0}`$	$`e^{\hat{\beta}_1}`$
Bruise (OLD)	1.003	0.148	1.003
Puncture	1.001	0.127	1.001
Cuts	0.998	0.056	1.000
Bruise (fresh)	1.001	0.037	1.001
Stem Split	0.996	0.044	1.000
Shrivel	1.014	0.002	1.014
Blemish Cosmetic	0.993	0.031	1.000
Lenticle Spot	1.008	0.012	1.008
Stem end browning	1.008	0.003	1.008

Aggregate loss curve



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Conclusion

- Defect-by-defect approach to estimating storage loss was described in this presentation
- The relationship of each defect was examined with respect to storage days and harvest date for the last five years
- The defects were then classified as directly, indirectly or independent of time in storage.
- Each defect proportion was then modeled using Poisson GLM regression. . The last three years data were average to establish a mean initial rate and mean growth rate for each defect
- An aggregate loss curve was then formulated giving a total loss due to storage of 2.3% of the mass of fruit packed after 150 days.
- The aim is to refine the model with additional years data to establish a robust loss curve that can be used to compensate growers for fruit quality loss in storage.

Appendices

Historical defect summaries by storage days and harvest date

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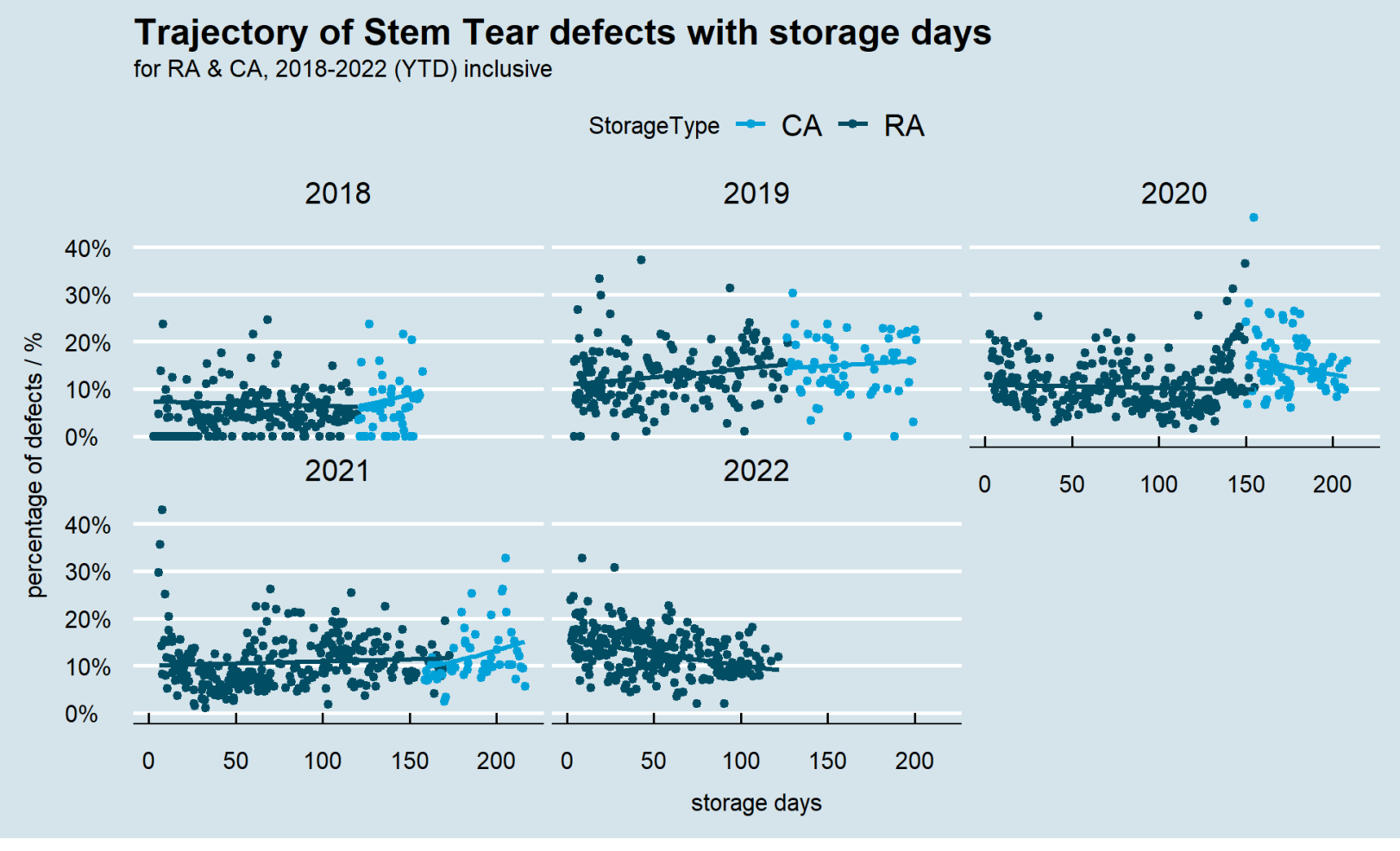
Stem tear vs storage day



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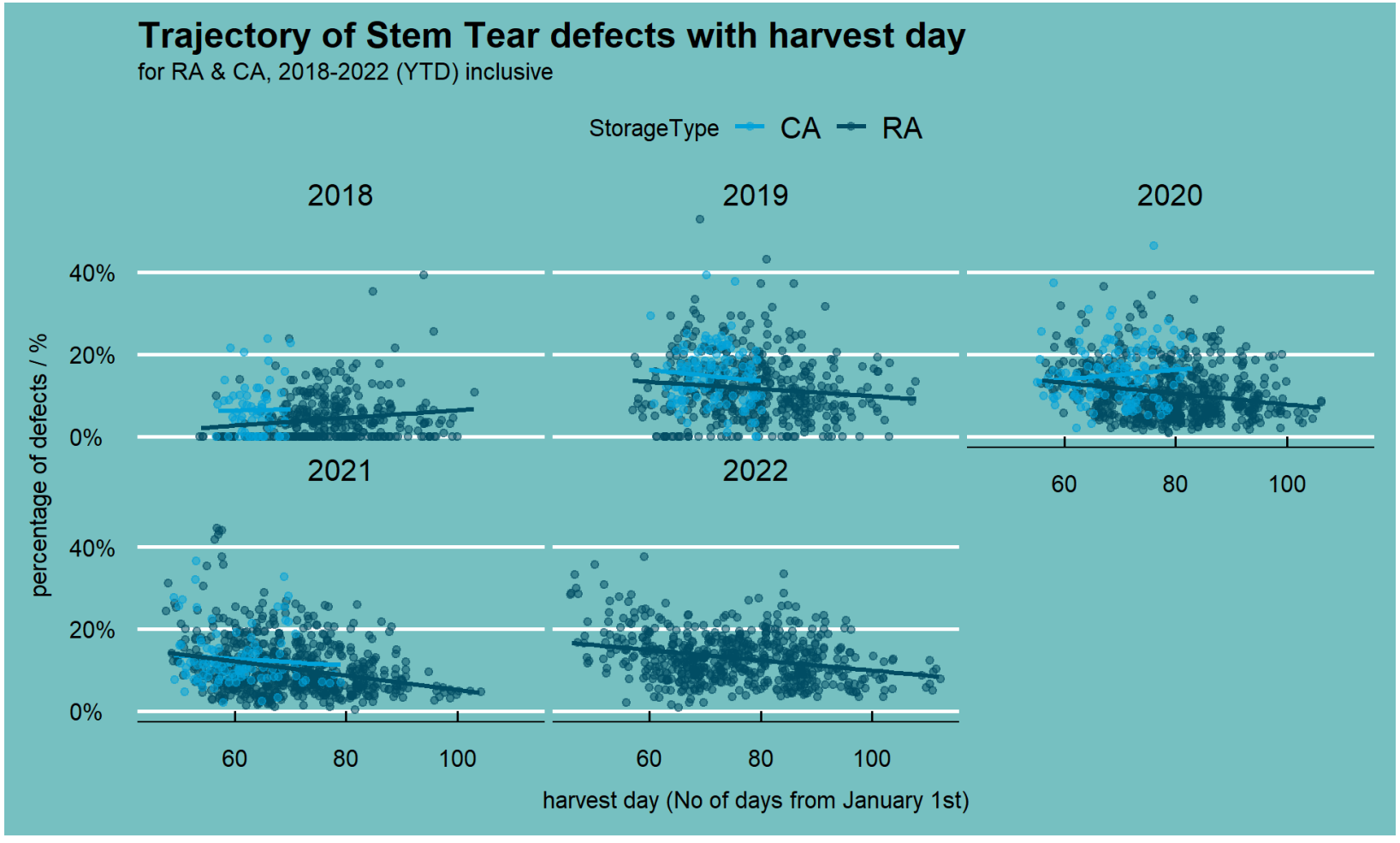
Stem tear vs harvest day



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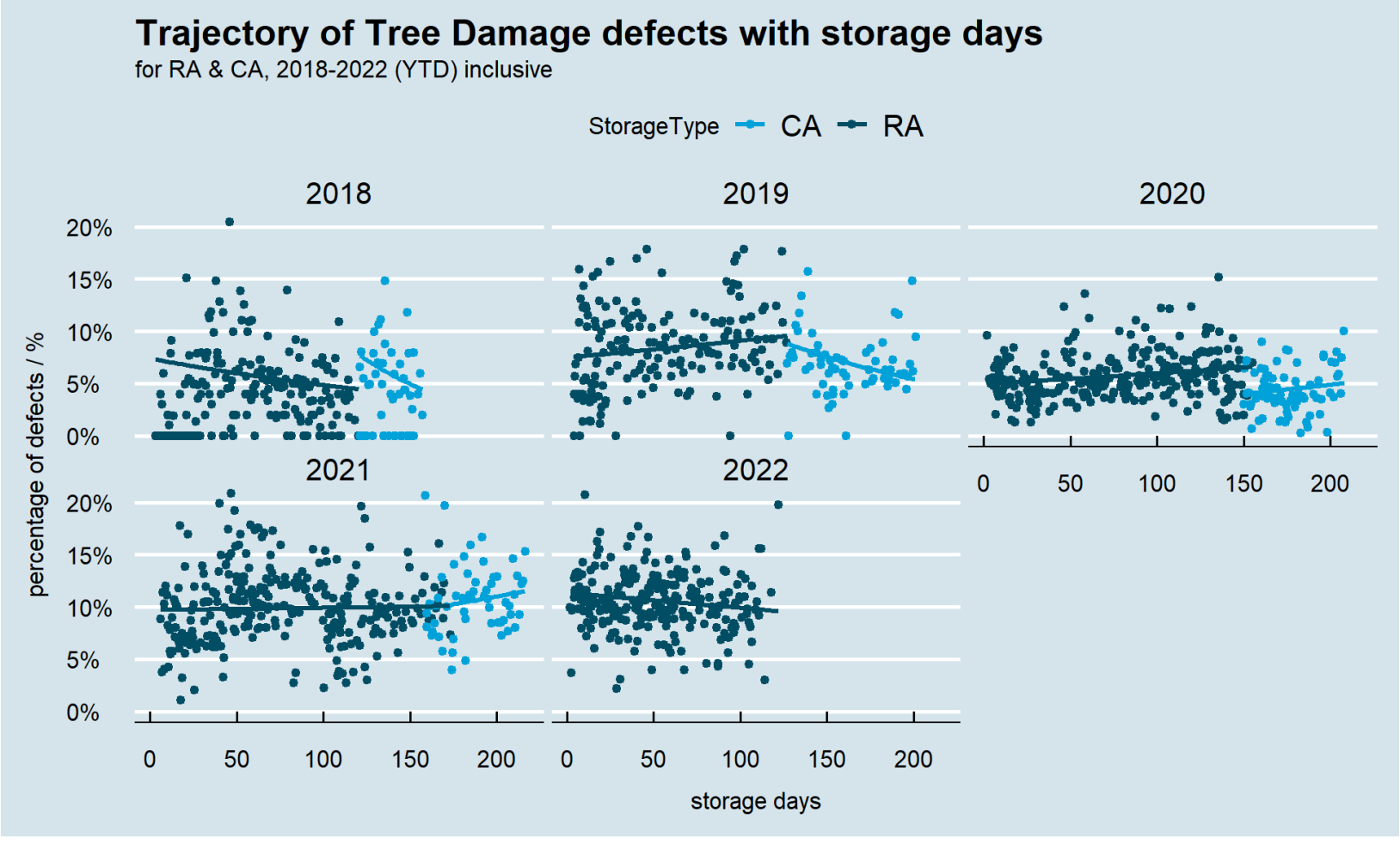
Tree damage vs storage days



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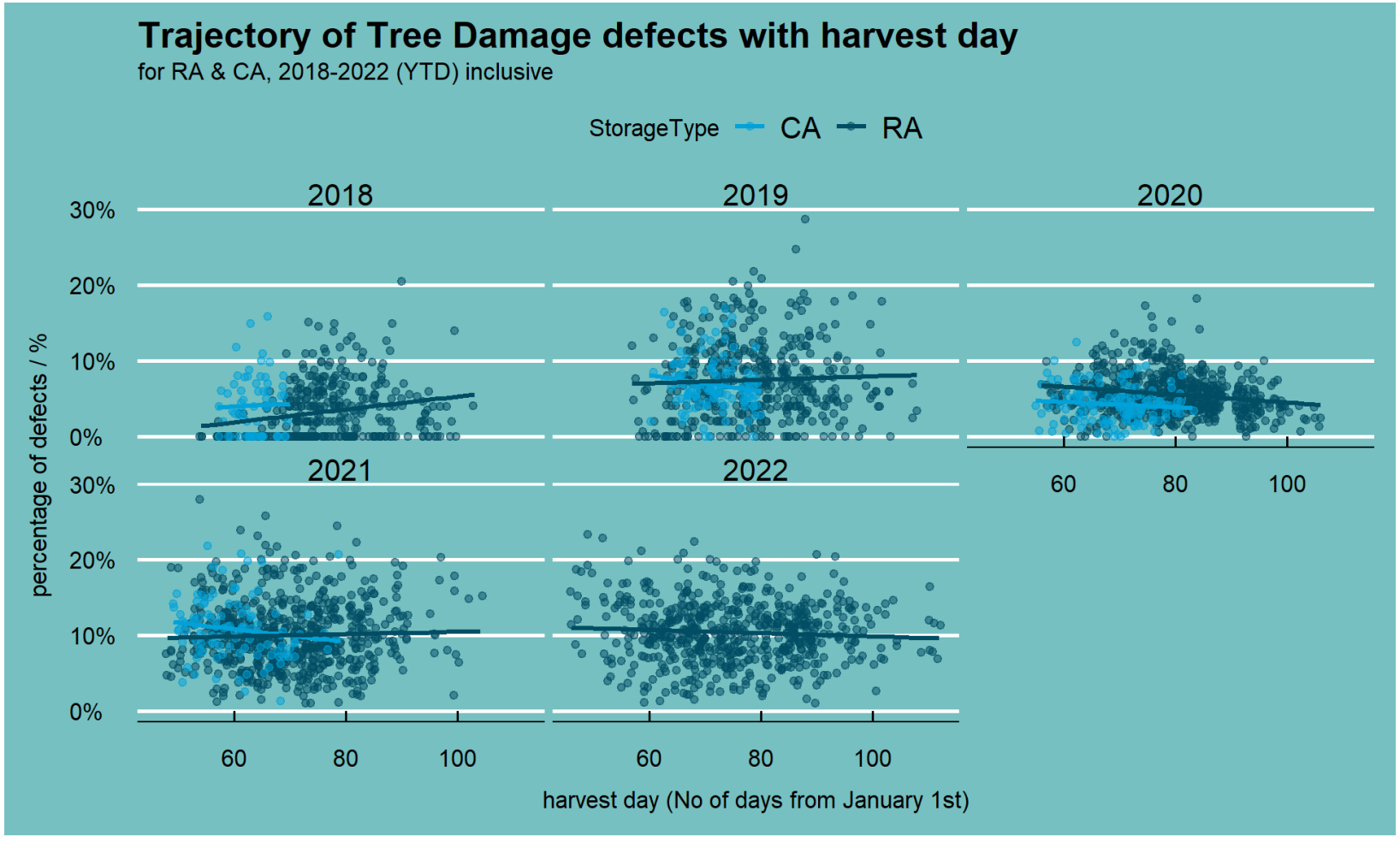
Tree damage vs harvest day



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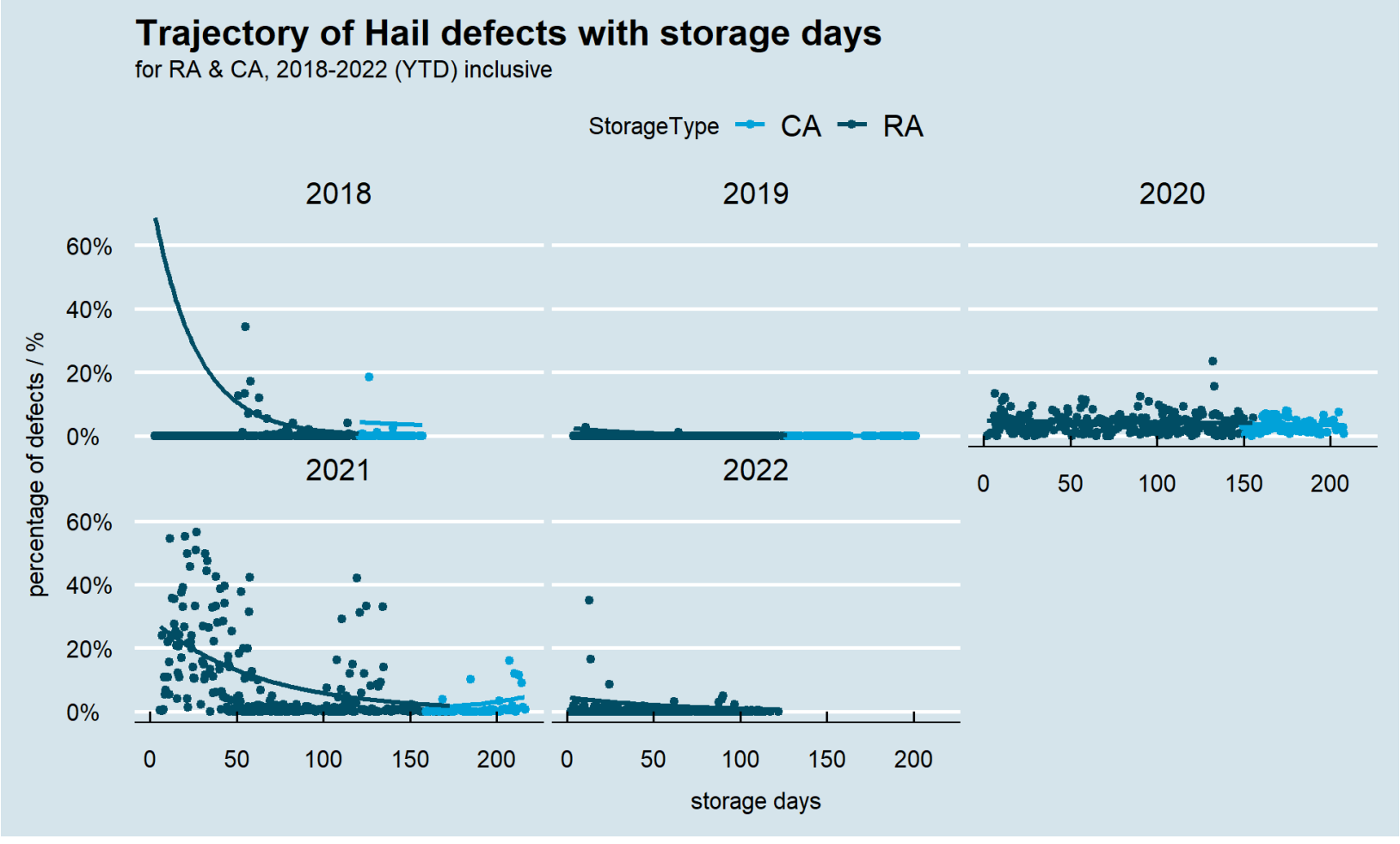
Hail vs storage days



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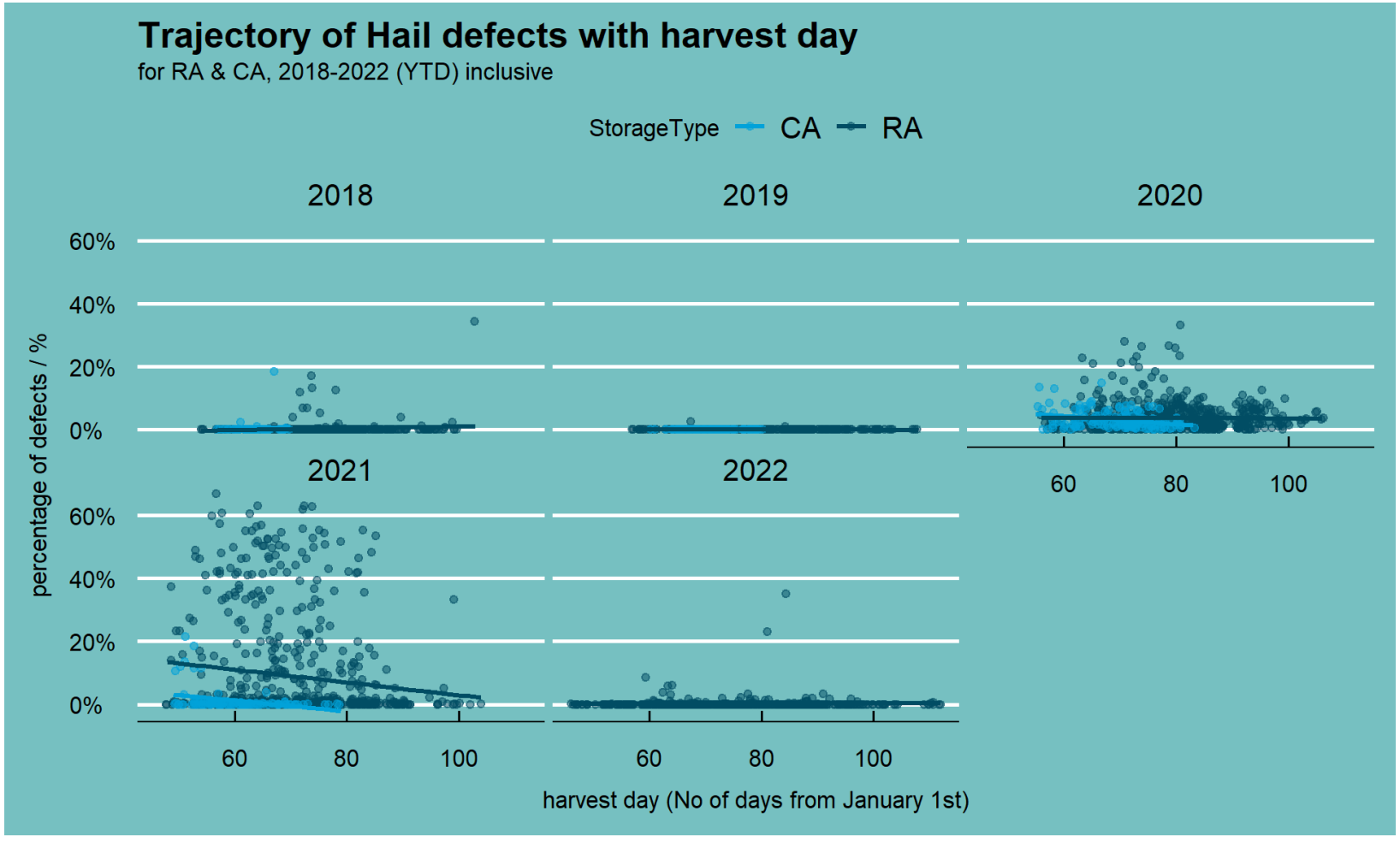
Hail vs harvest day



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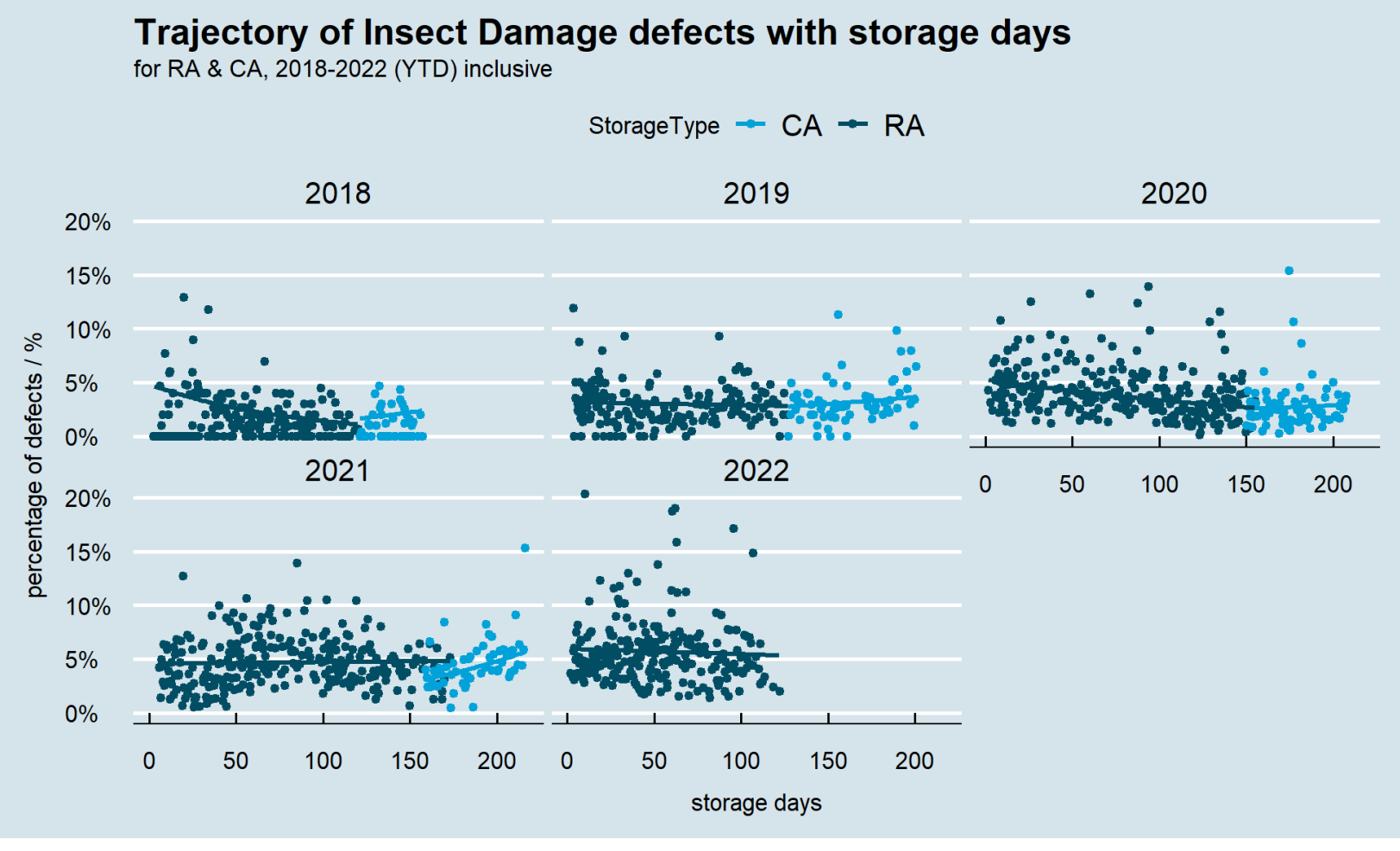
Insect damage vs storage days



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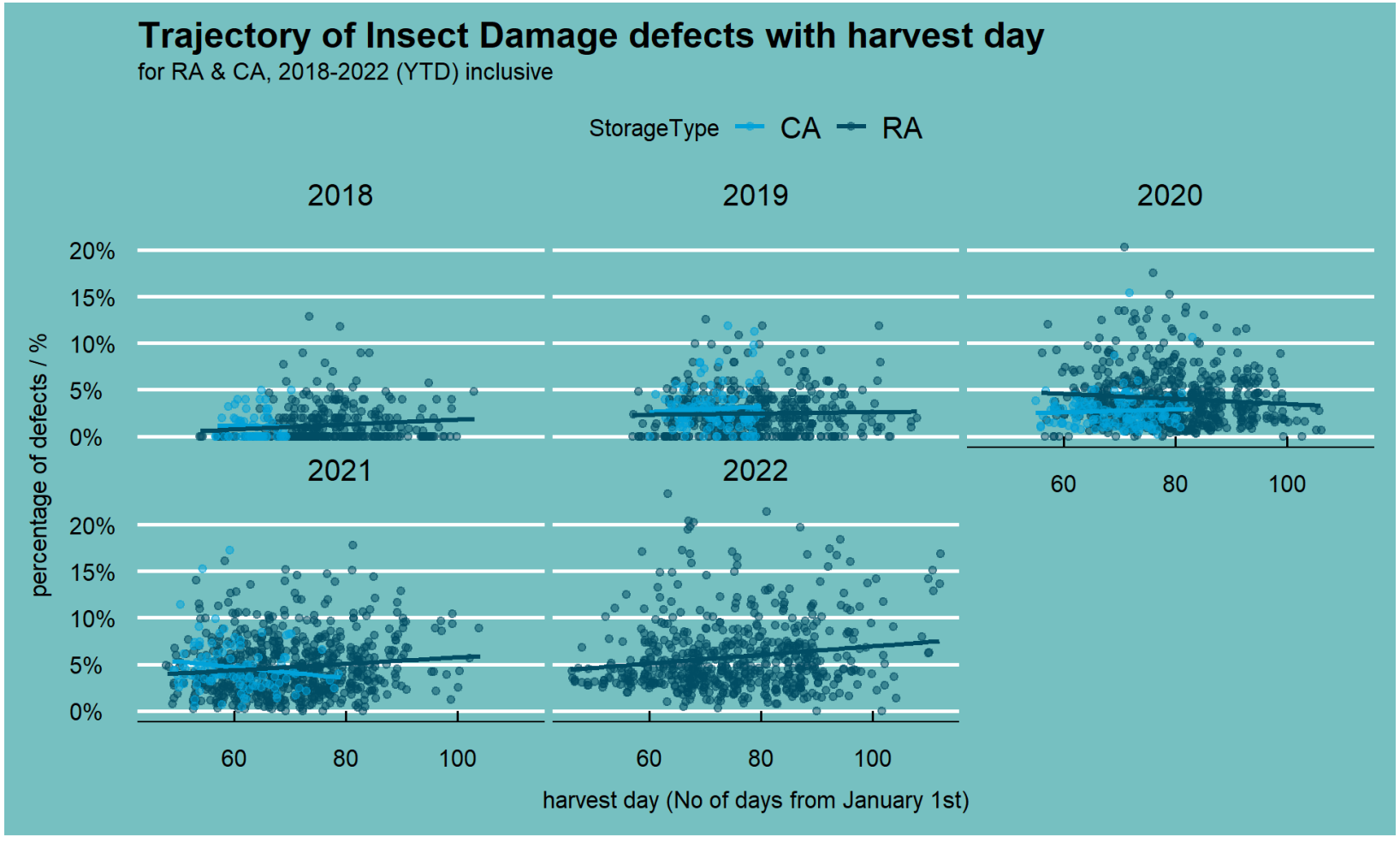

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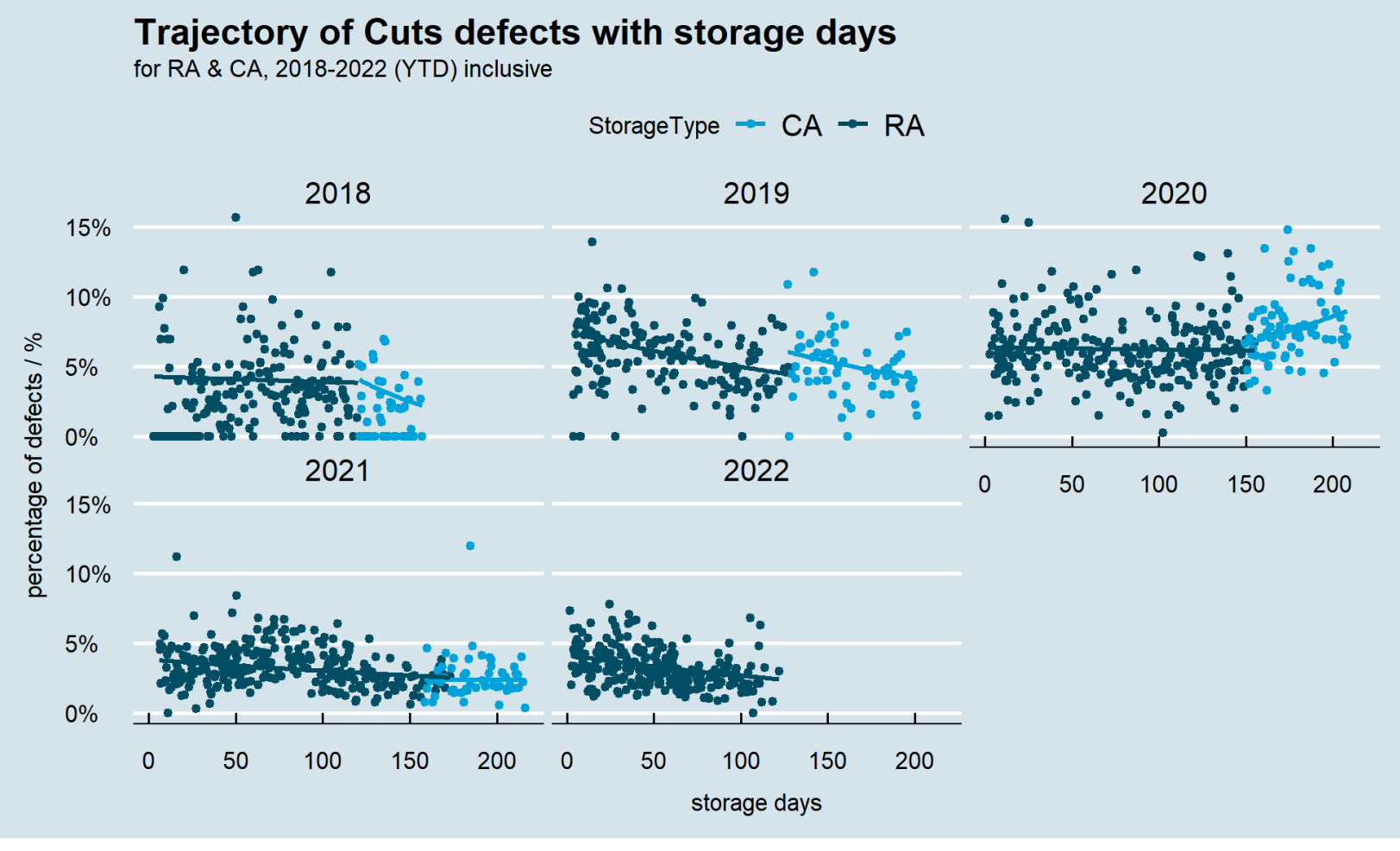
Cuts vs storage days



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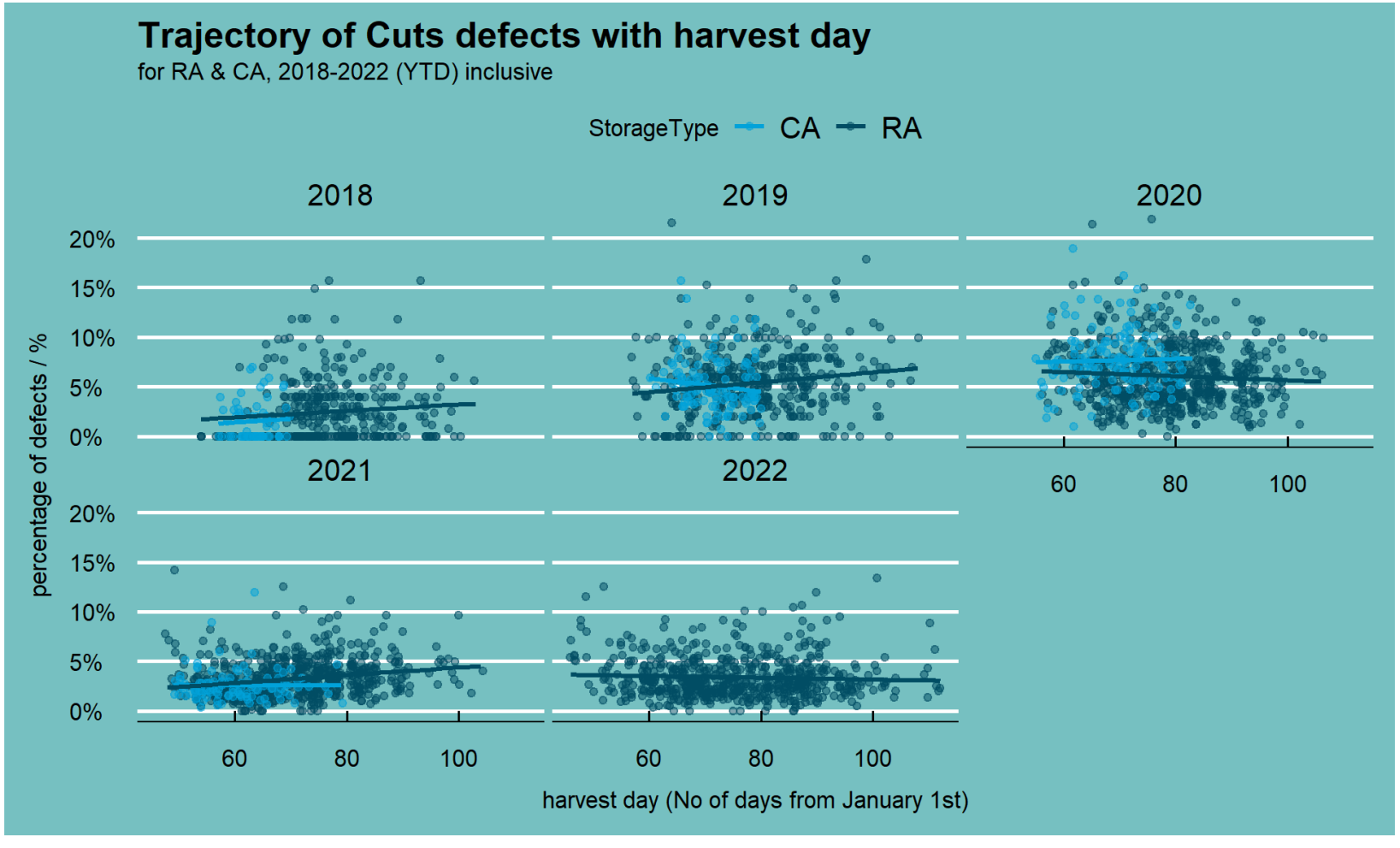

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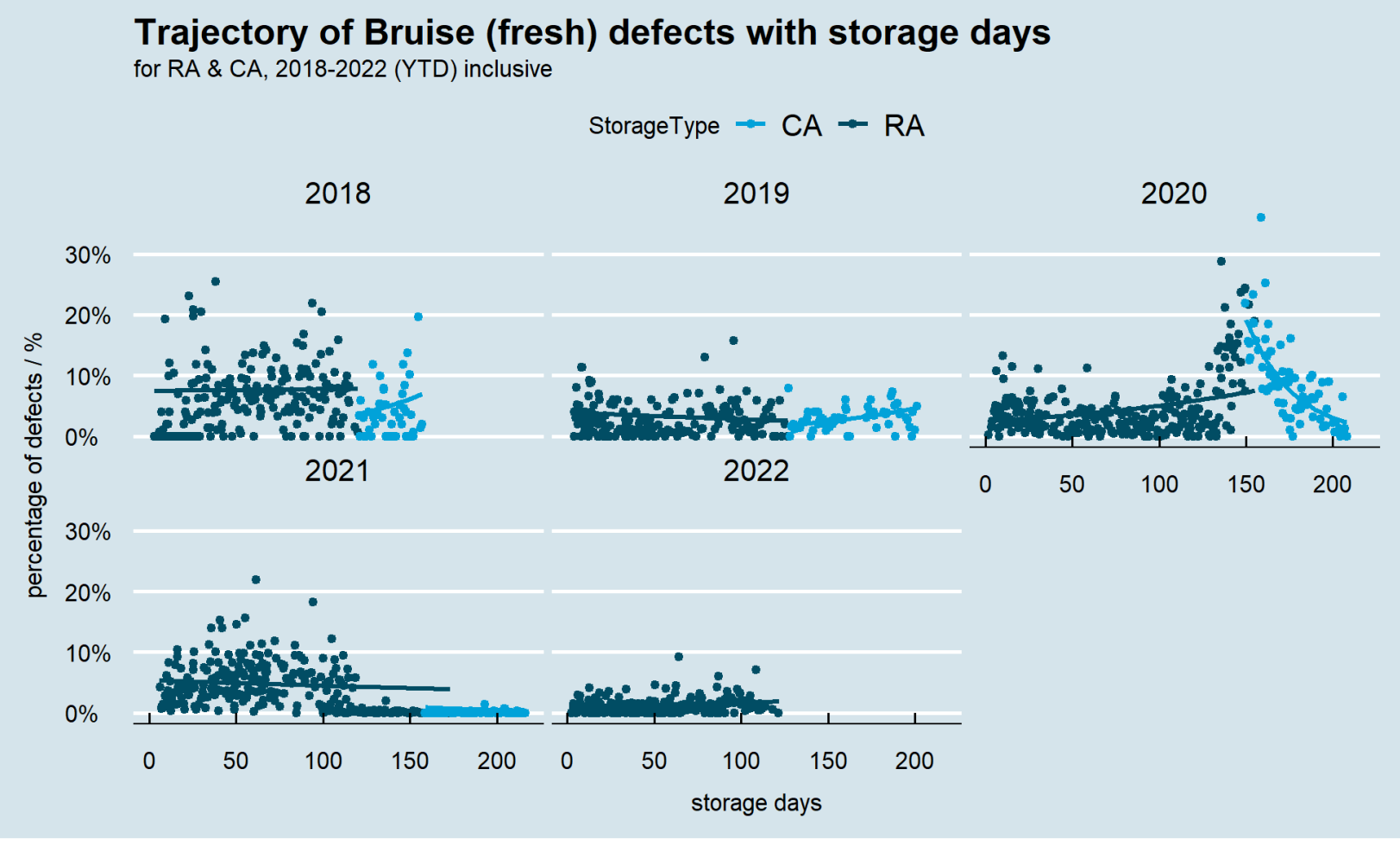
Fresh bruise vs storage days



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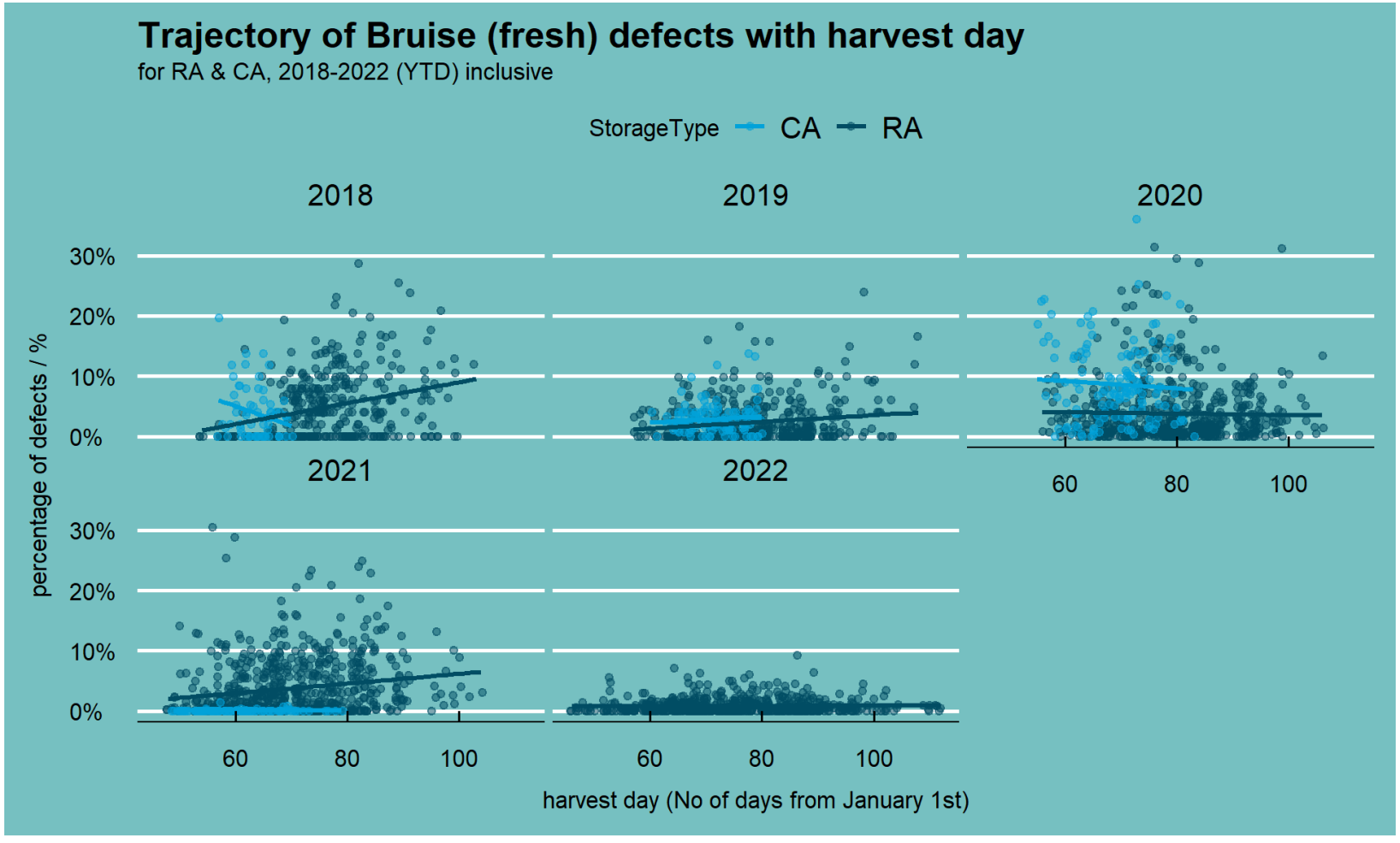

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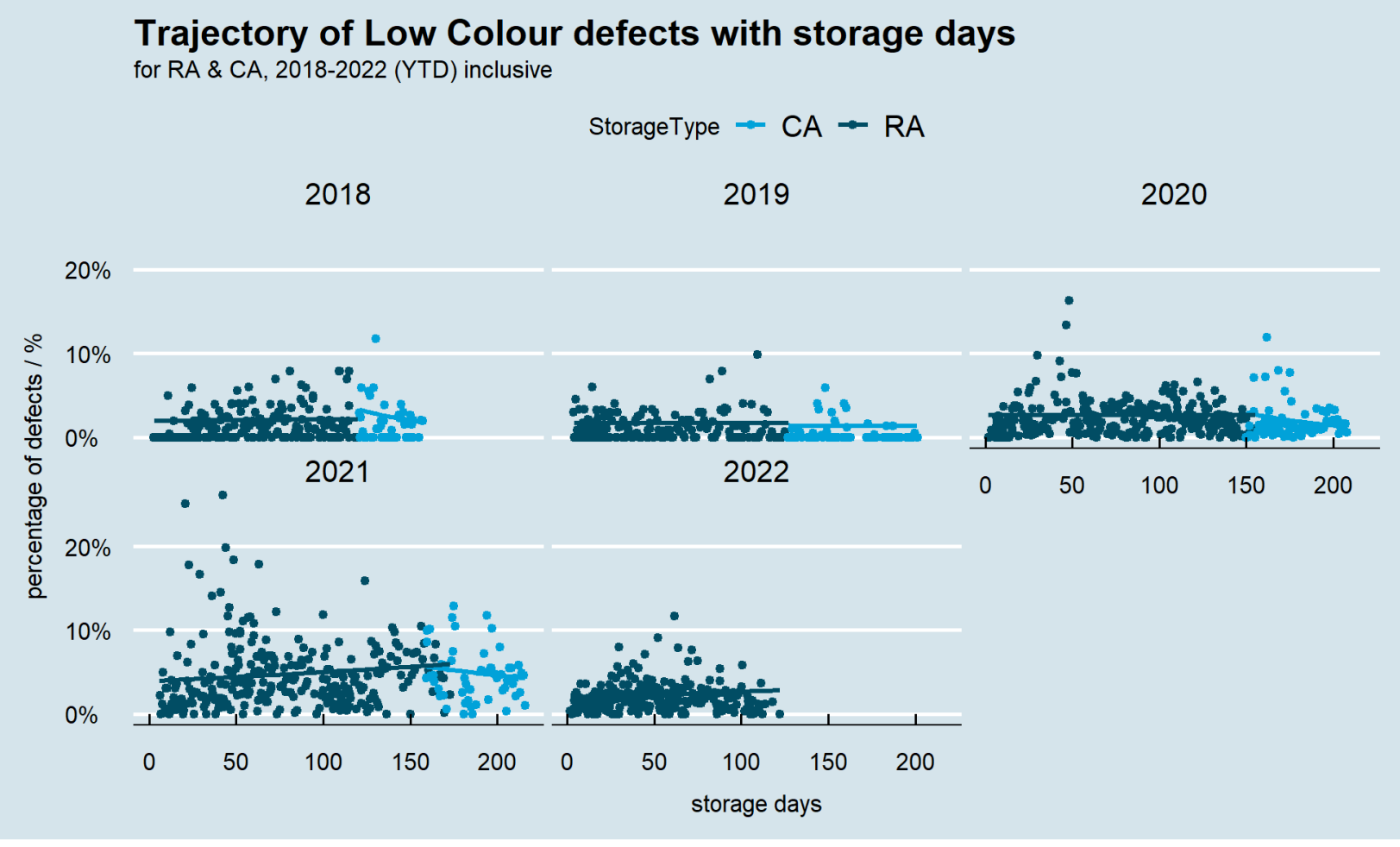
Low colour vs storage days



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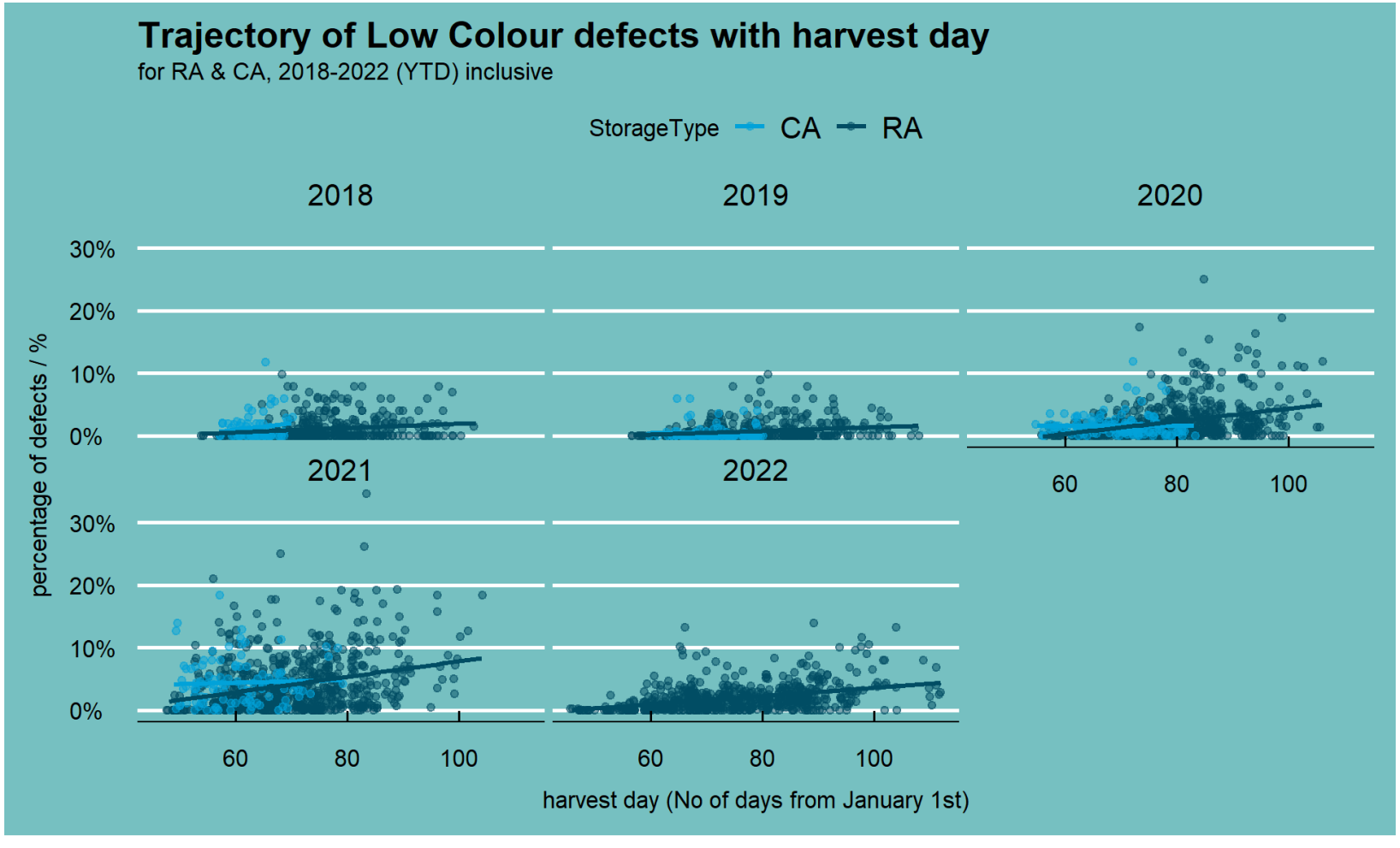

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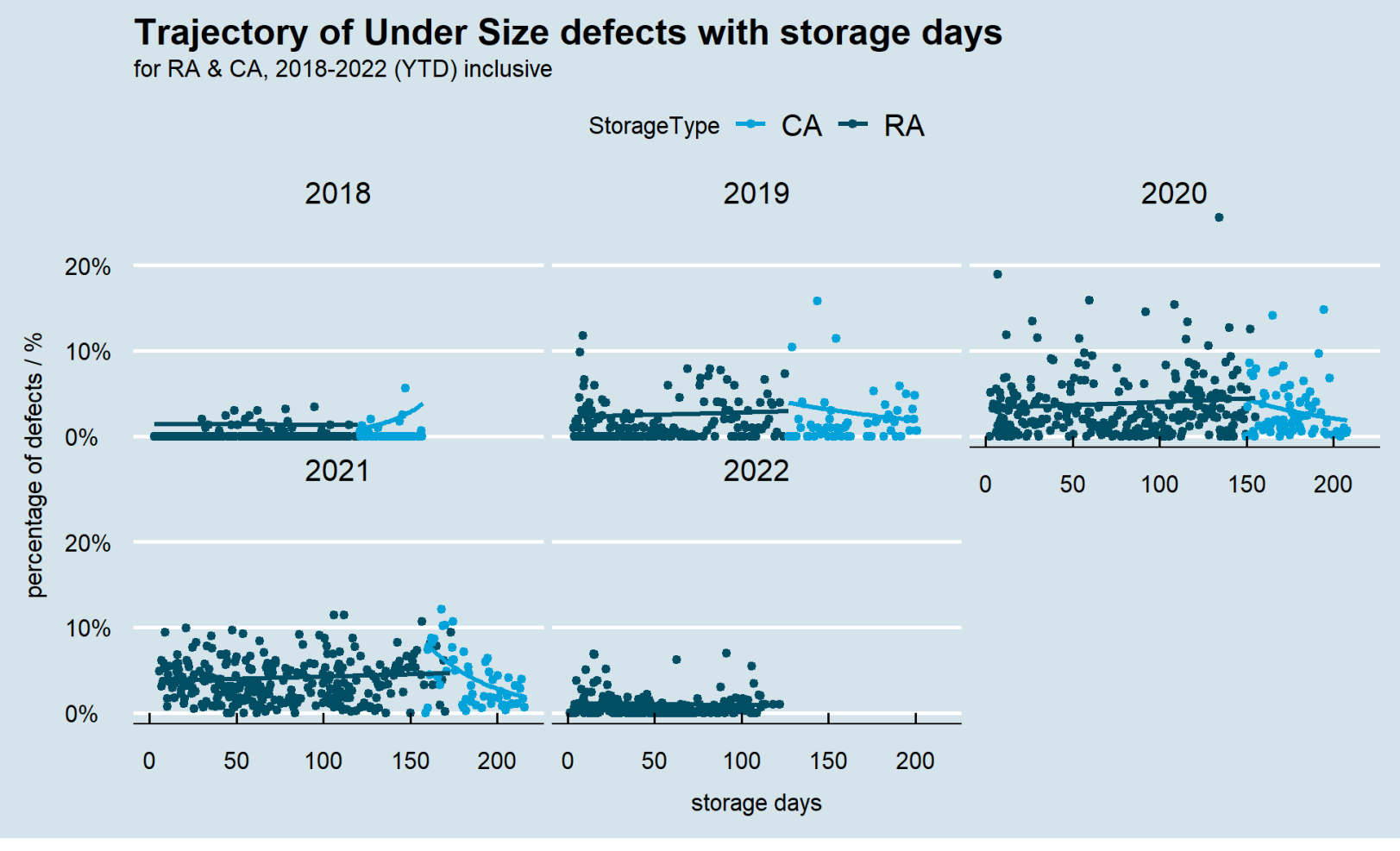
Undersize vs storage days



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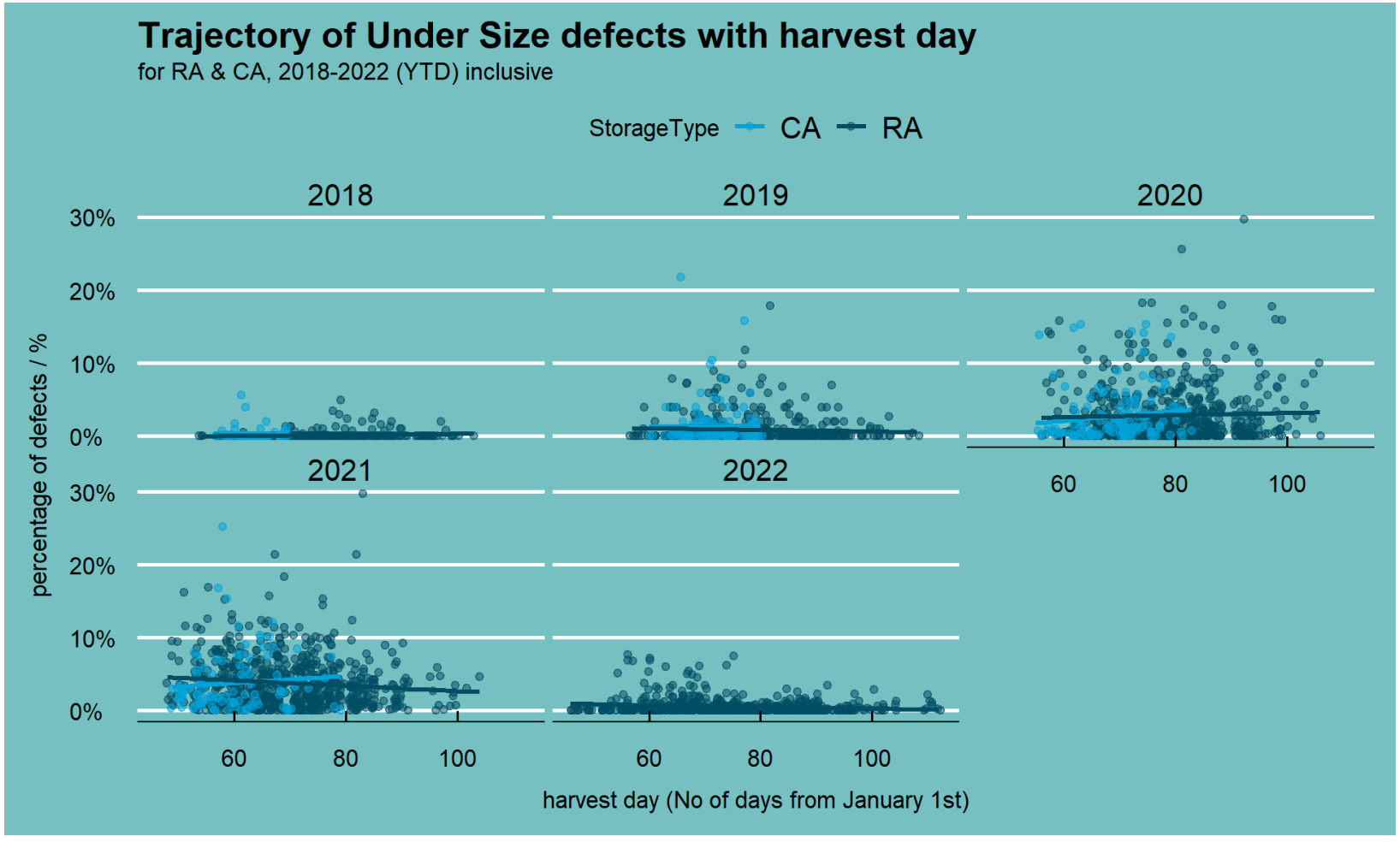

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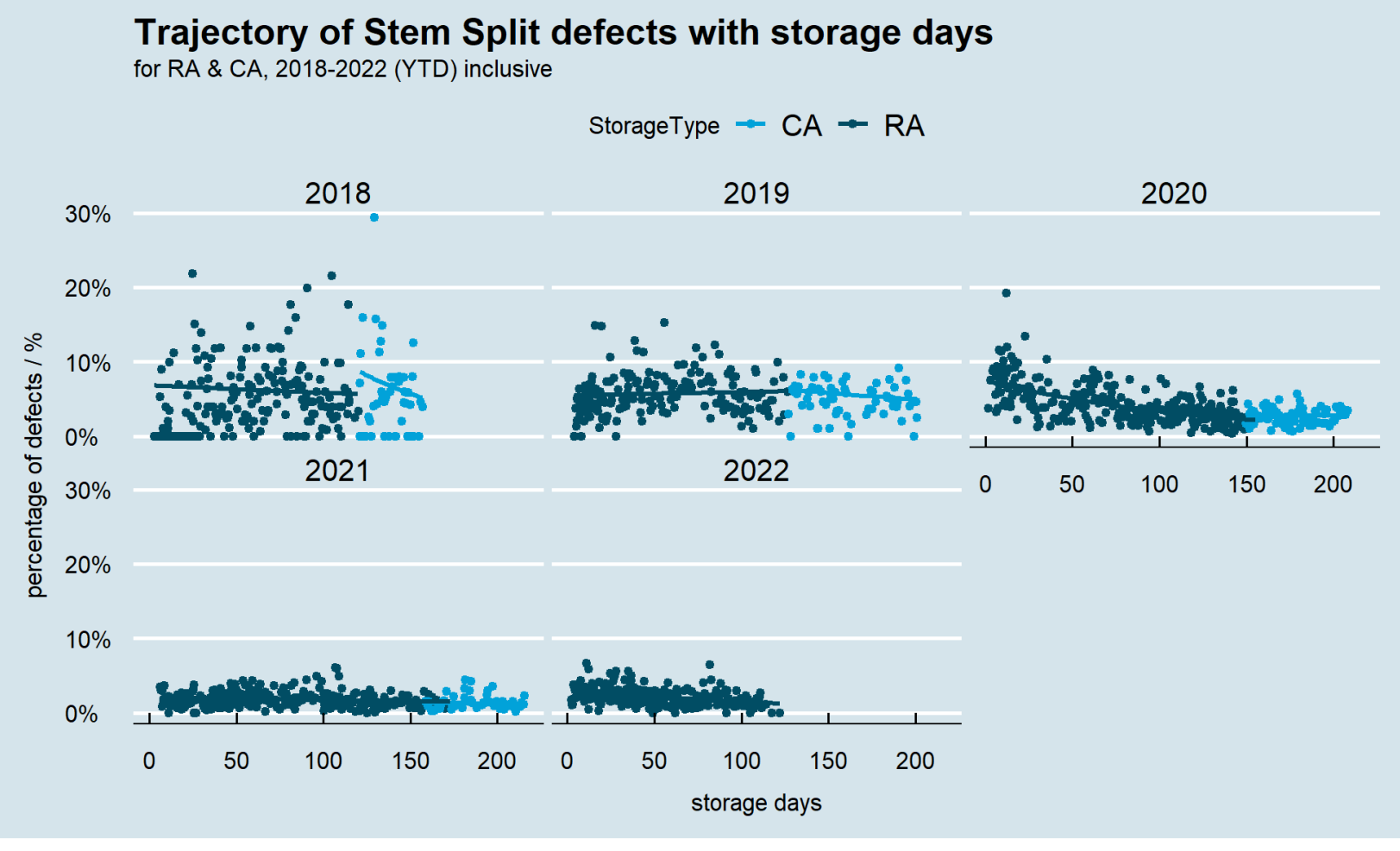
Stem split vs storage days



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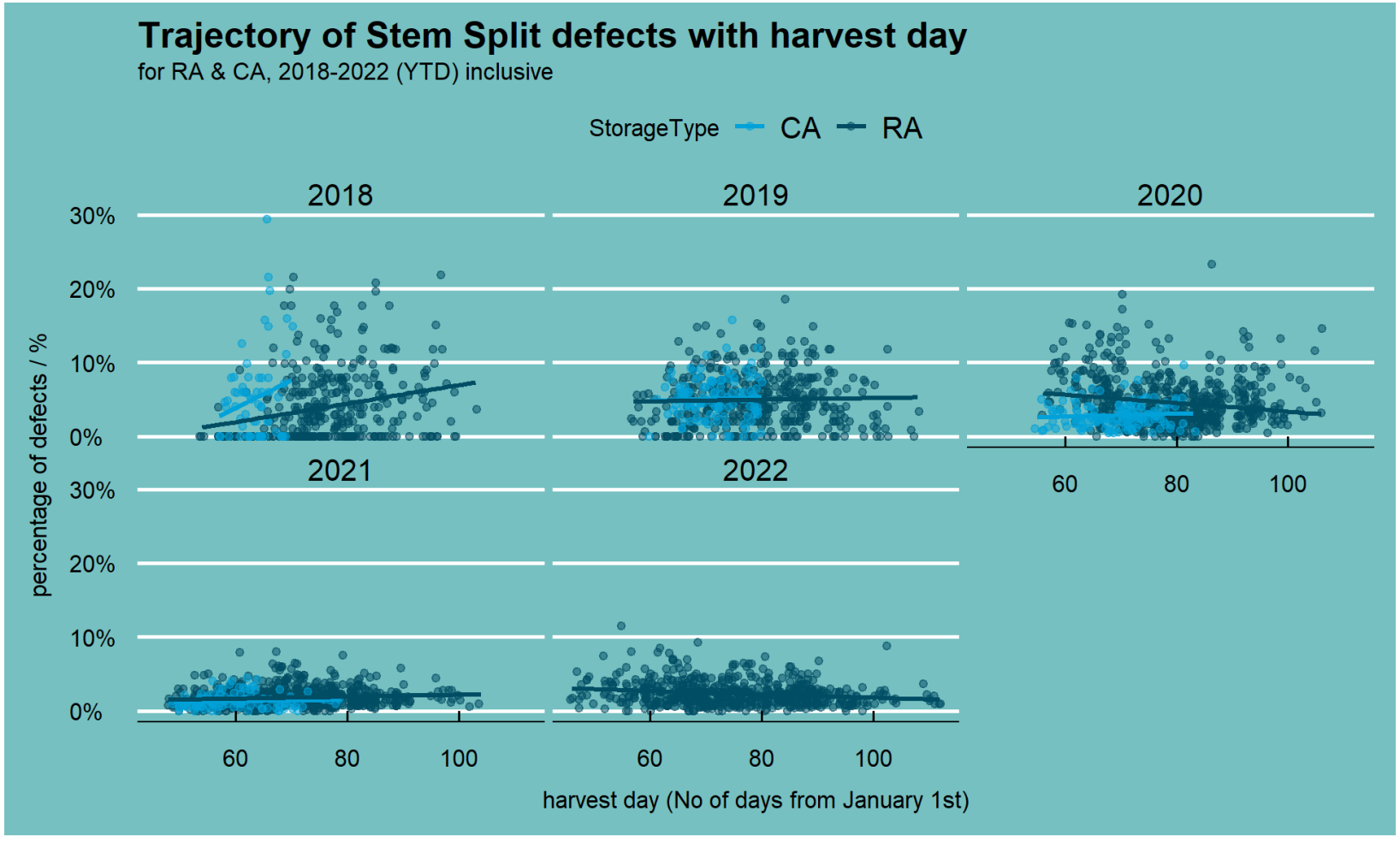

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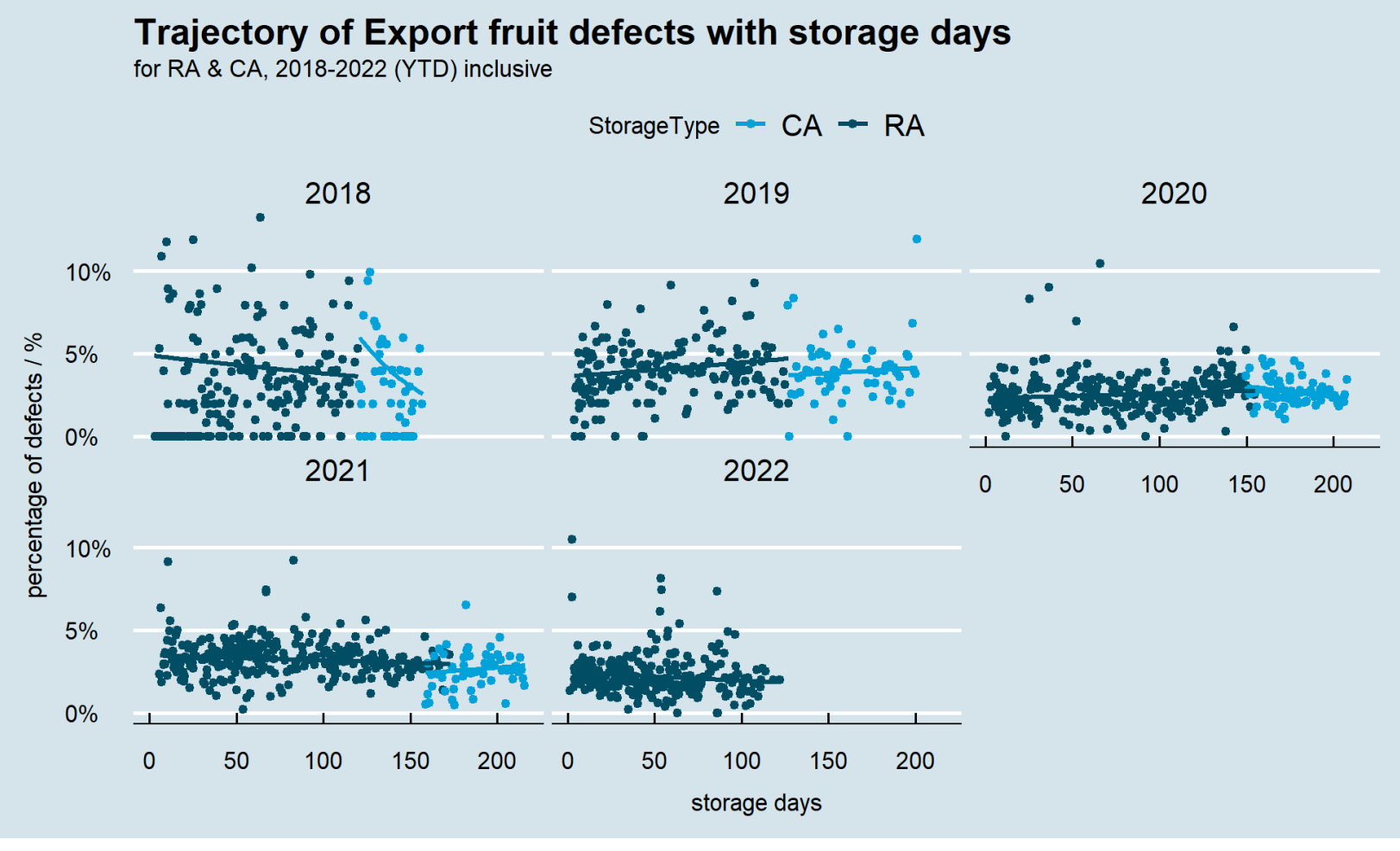
Export fruit vs storage days



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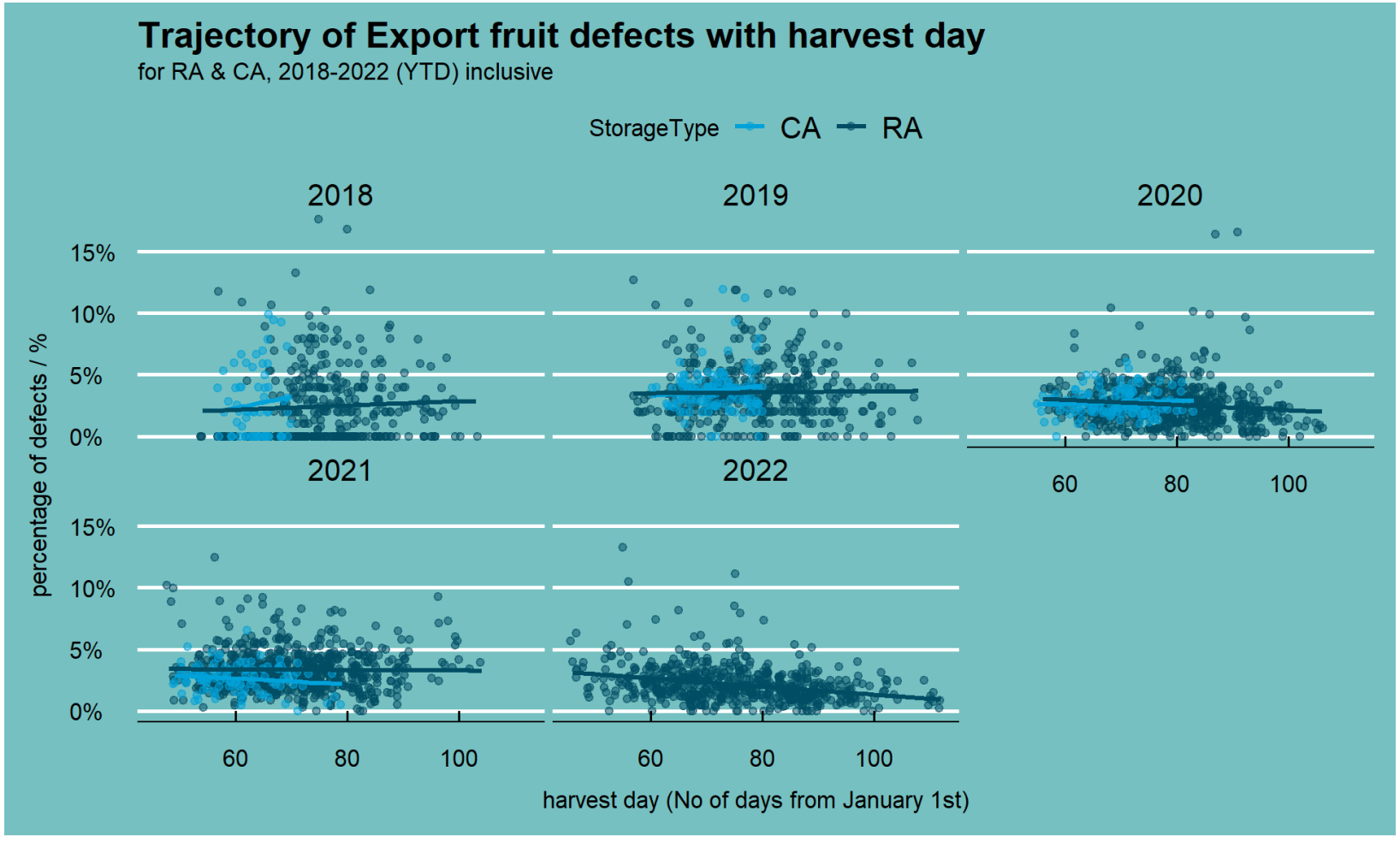

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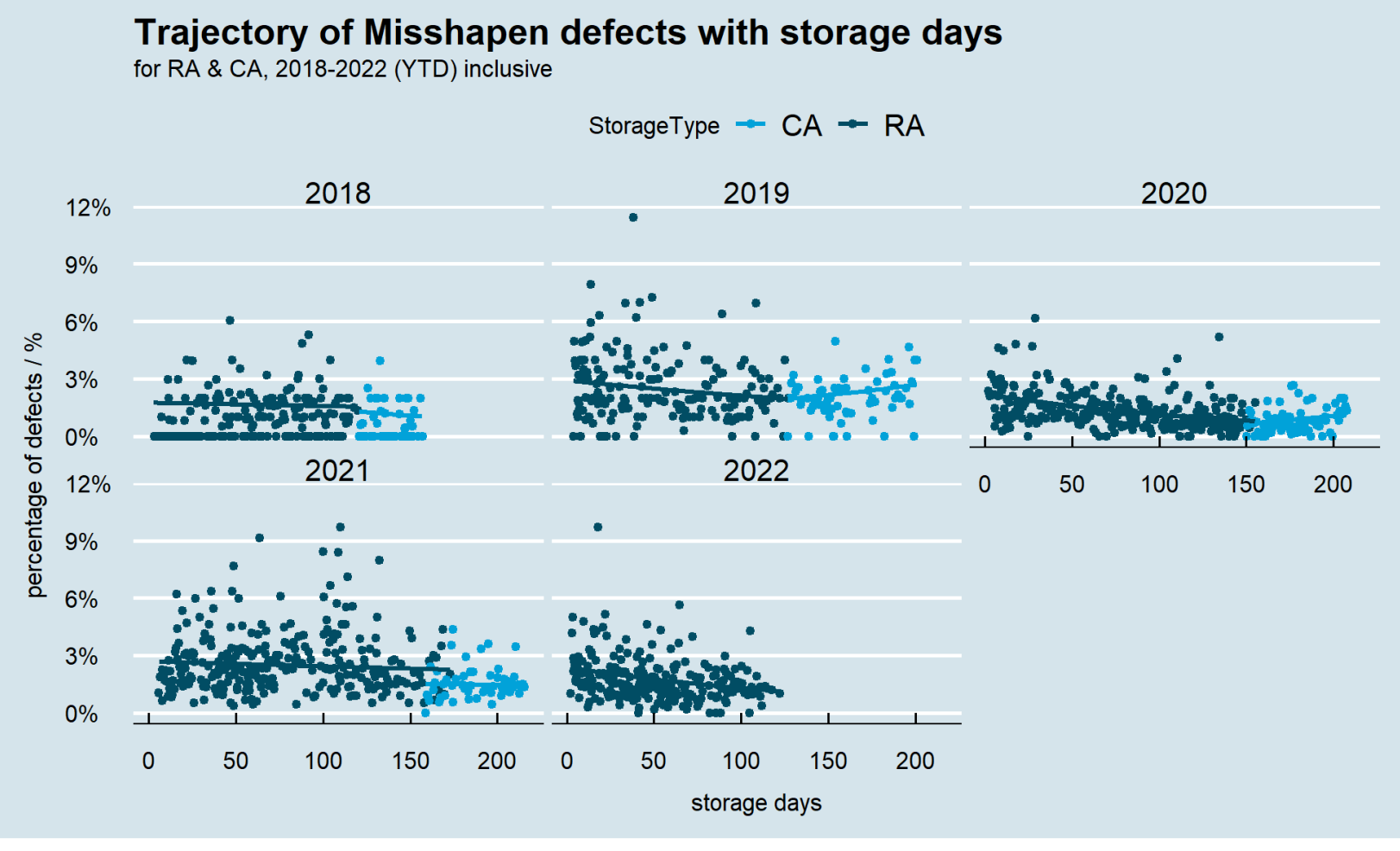
Misshapen vs storage days



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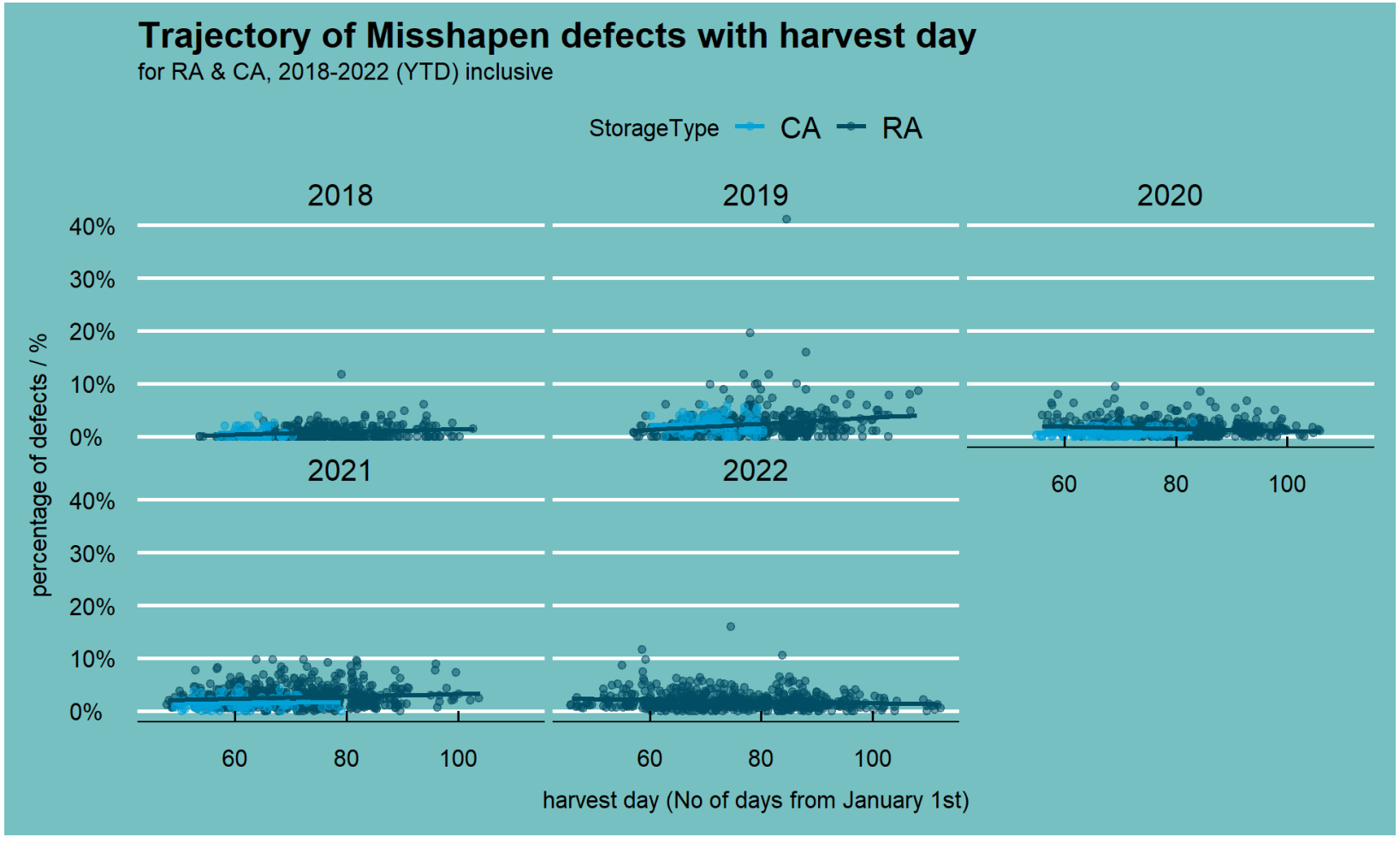

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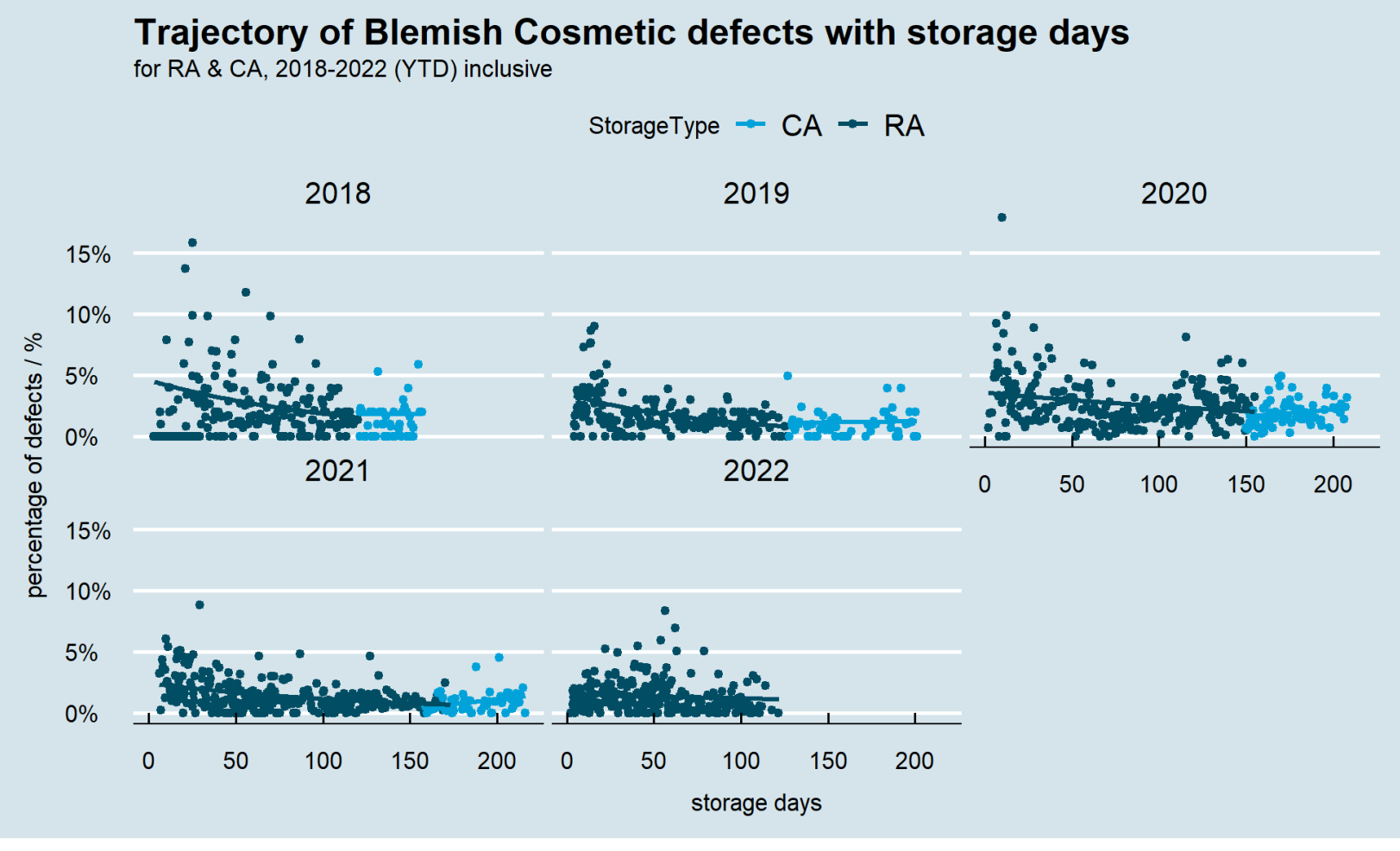
Blemish cosmetic vs storage days



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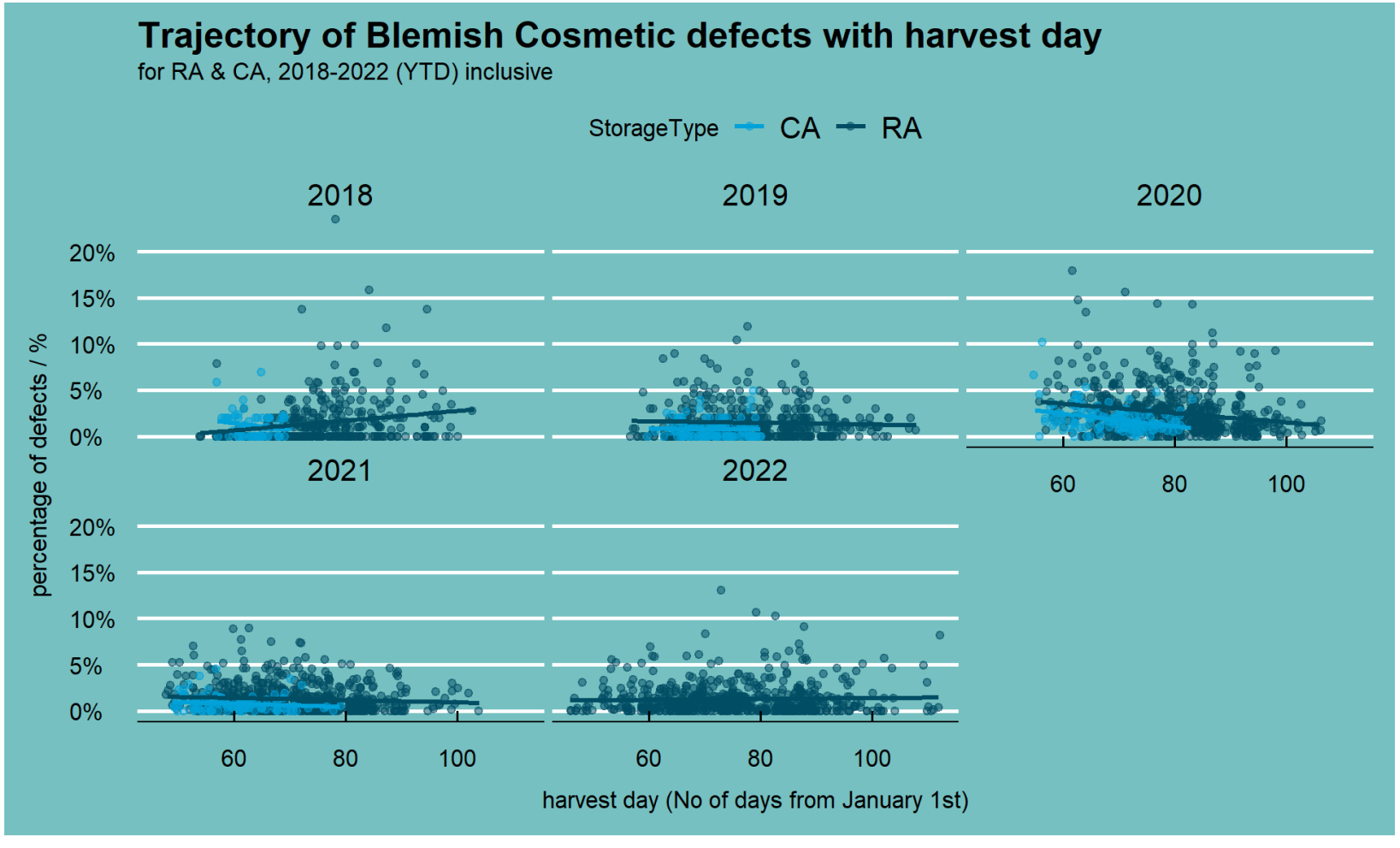

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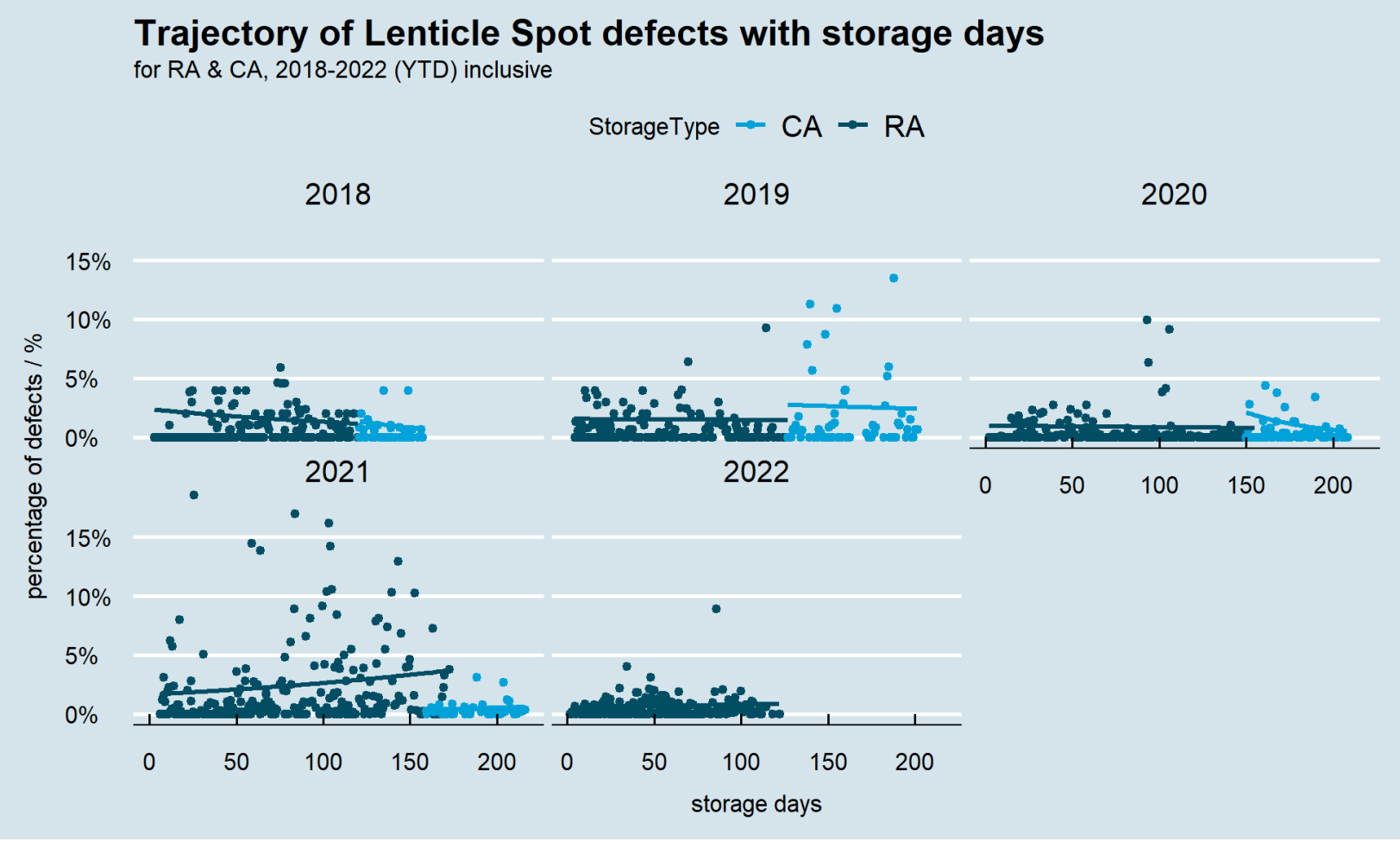
Lenticle Spot vs storage days



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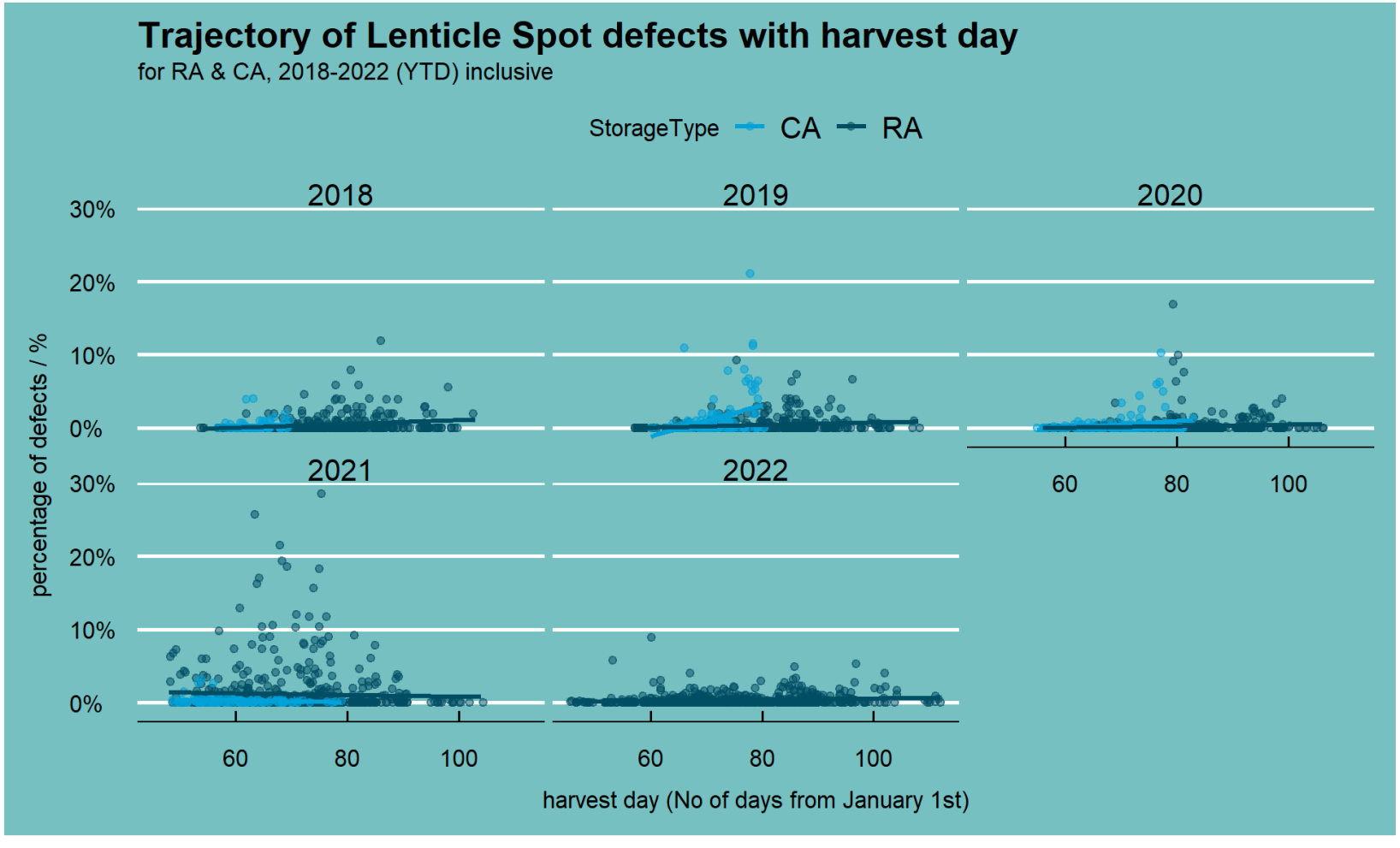

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