A mechanistic model and web-based tool for estimating the potential impact of water, sanitation, and hygiene interventions, accounting for contextual and intervention factors

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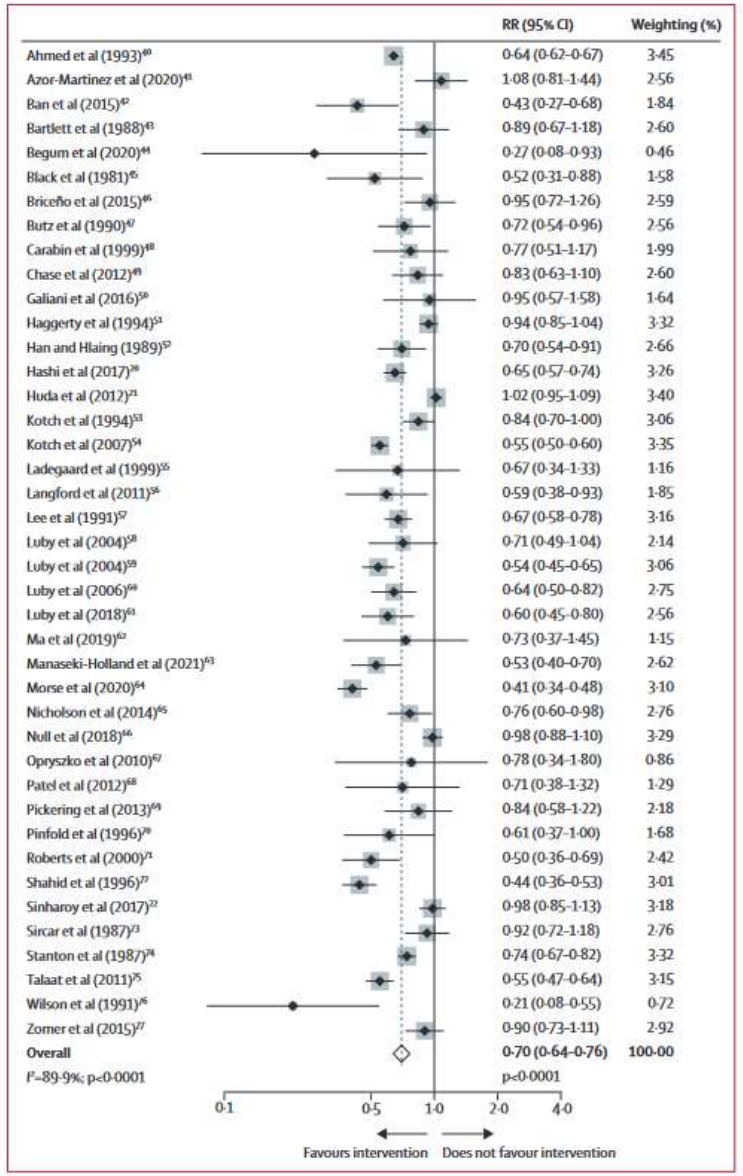
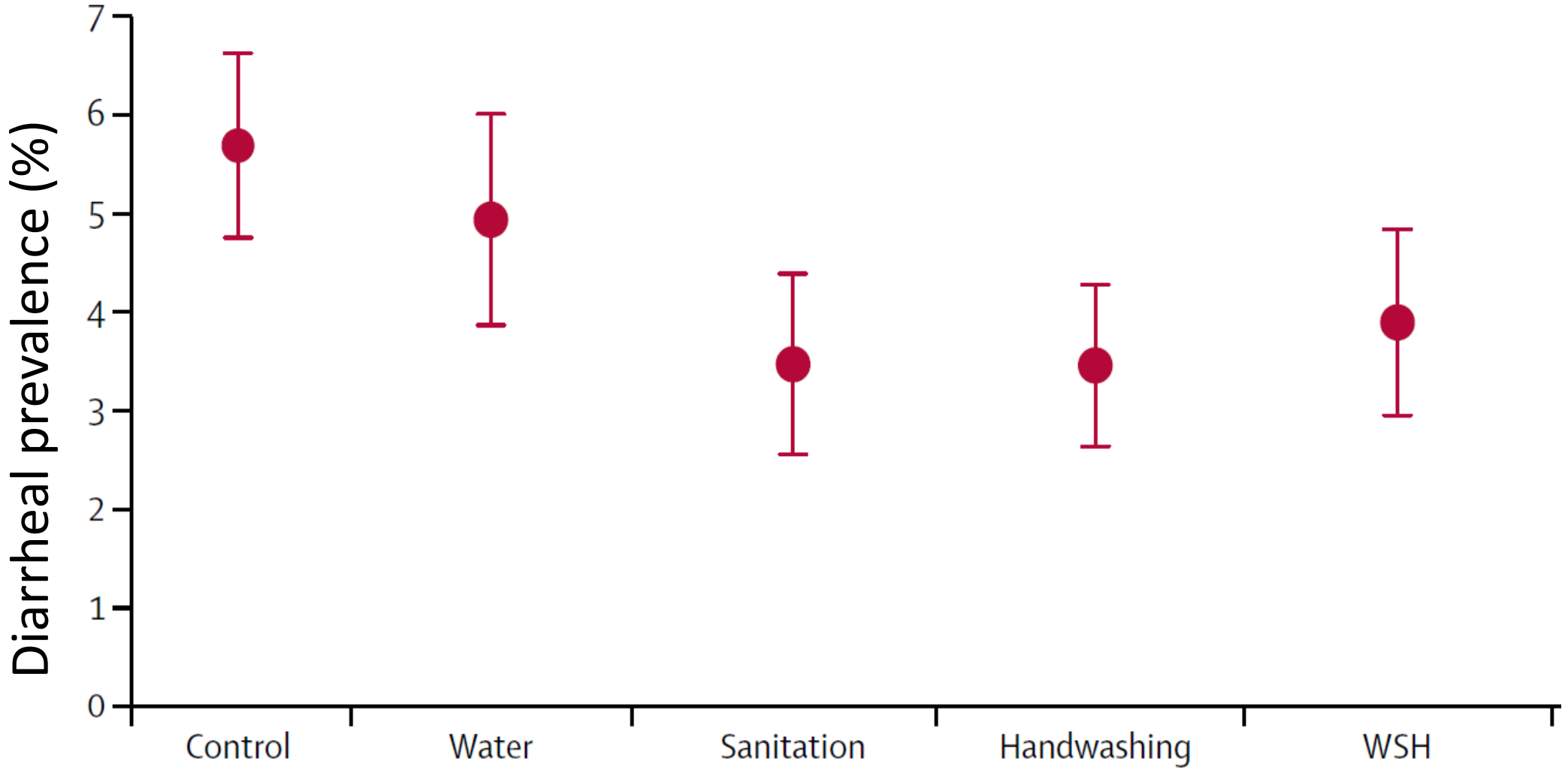
Water, sanitation, and hygiene (WASH) interventions have the potential to reduce the burden of diarrheal disease…

… but there has been substantial heterogeneity and multiple large trials with modest-to-null results.



Wolf et al., 2022. *The Lancet*.
Meta-analysis of the effectiveness of hygiene interventions

For example, the WASH Benefits Bangladesh trial found…



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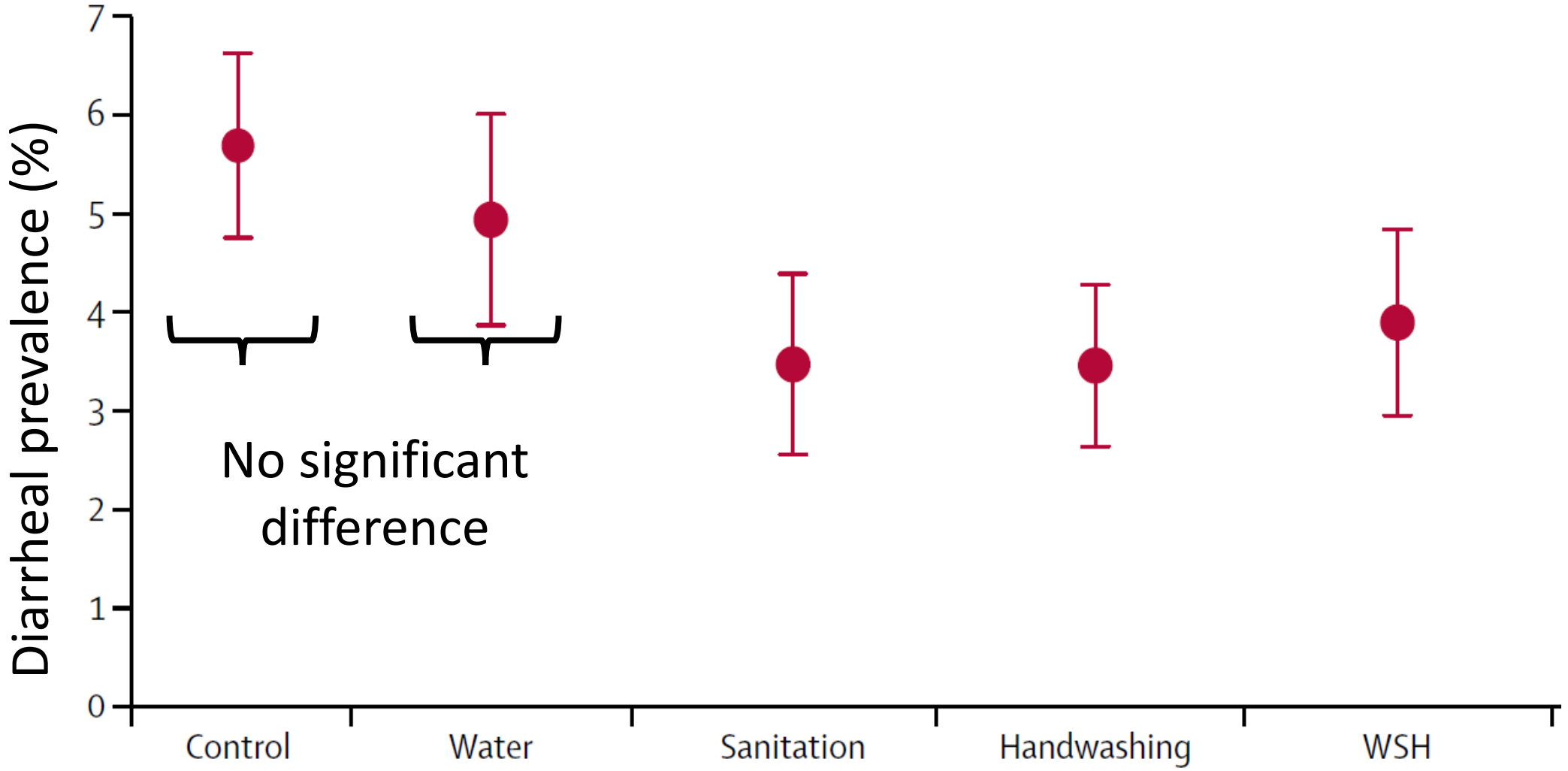

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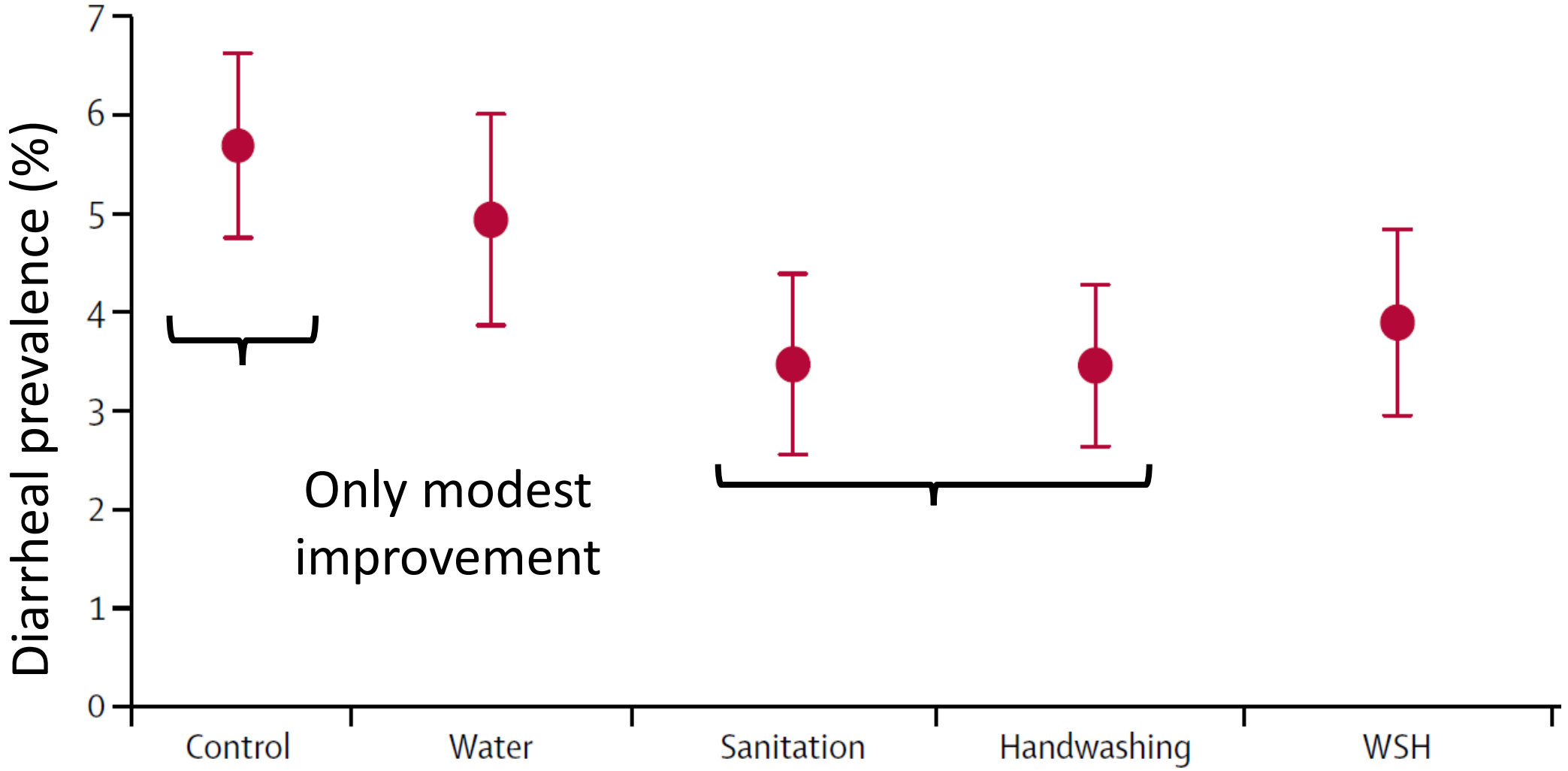

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Magnitude of transmission pathways

Water

Hands & Fomites

All other

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Baseline disease conditions	Does the effectiveness depend on the disease burden?

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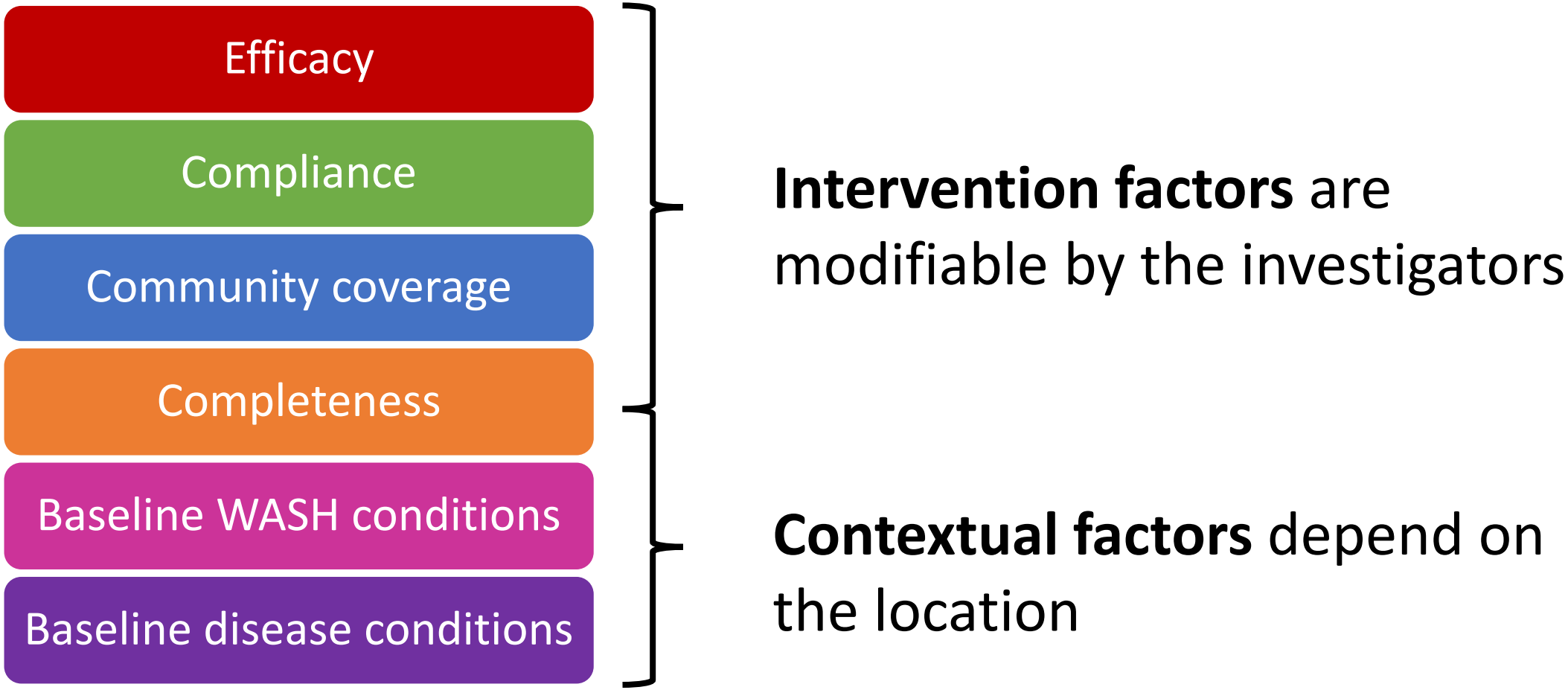

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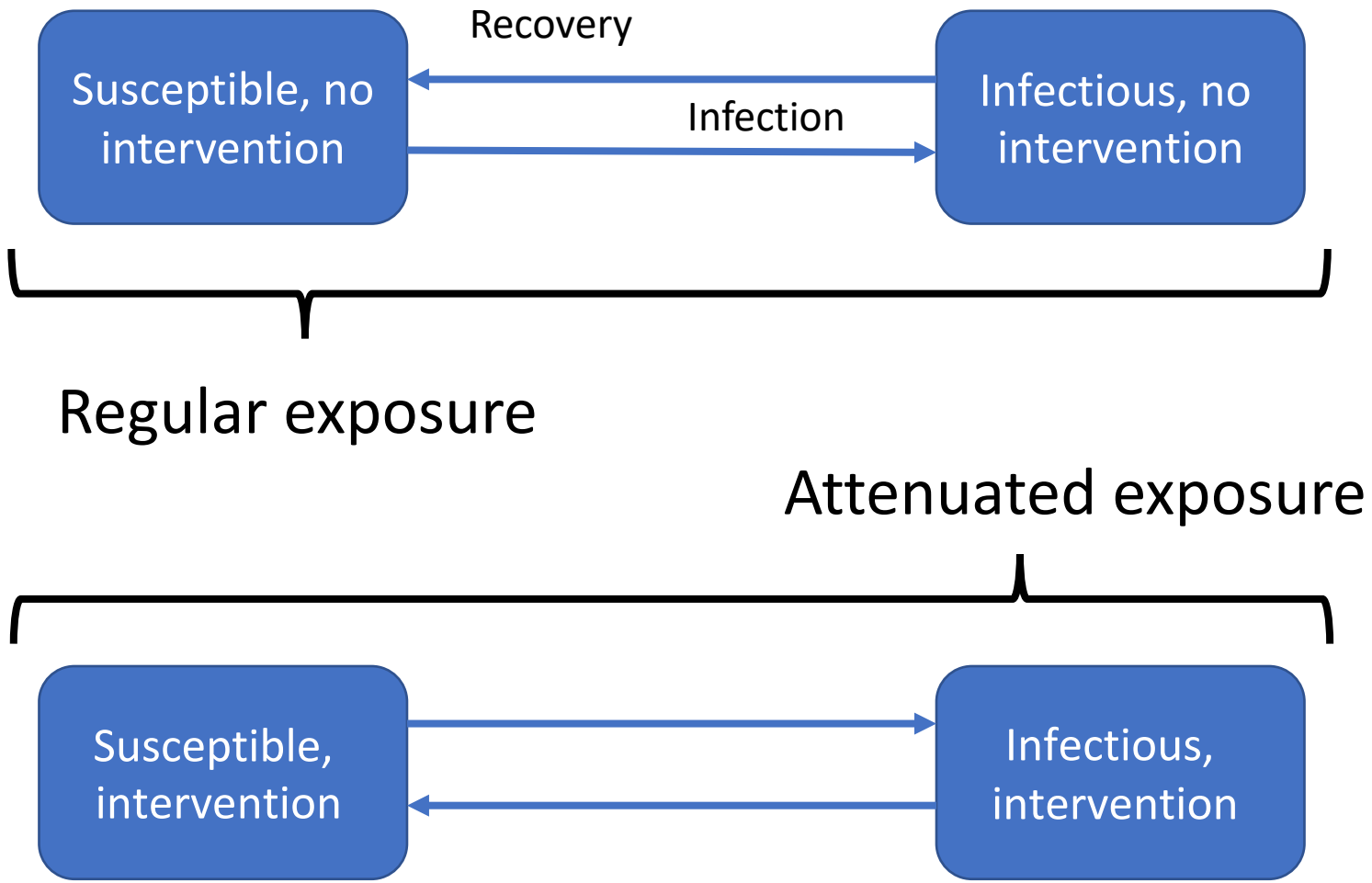
	Basse, The Gambia	Mirzapur, Bangladesh	Karachi (Bin Qasim Town), Pakistan
0–11 months			
Number of case-control pairs	258	293	284
Rotavirus	23·0% (18·8–29·1)	23·4% (18·9–28·7)	27·0% (22·7–33·5)
Adenovirus 40/41	9·6% (4·9–15·9)	8·3% (4·7–13·9)	7·2% (0·9–10·6)
Cryptosporidium spp	11·5% (4·6–16)	1·2% (0·1–2·7)	10·4% (5·1–16·1)
Shigella spp or EIEC	7·5% (3·9–12·9)	15·8% (12–20·4)	13·8% (9·7–19·7)
C jejuni or *C coli*	*	12·3% (7·6–19·8)	7·0% (0–17·1)
ST-ETEC	5·5% (1·8–9·7)	2·0% (0·5–3·9)	12·2% (8·9–17·6)
Norovirus GII	4·4% (1·8–11·1)	1·8% (0·2–5·3)	2·7% (0–6·2)
tEPEC	2·7% (0–5·7)	0·3% (0–2·6)	2·1% (0–5·1)
Sapovirus	1·0% (0–5·4)	1·1% (0–3·4)	4·4% (0·2–11·1)
Astrovirus	0·7% (0–4·4)	1·4% (0–3·9)	3·3% (0·1–7·6)
V cholerae	*	0·6% (0–1·7)	5·6% (2·3–8·8)

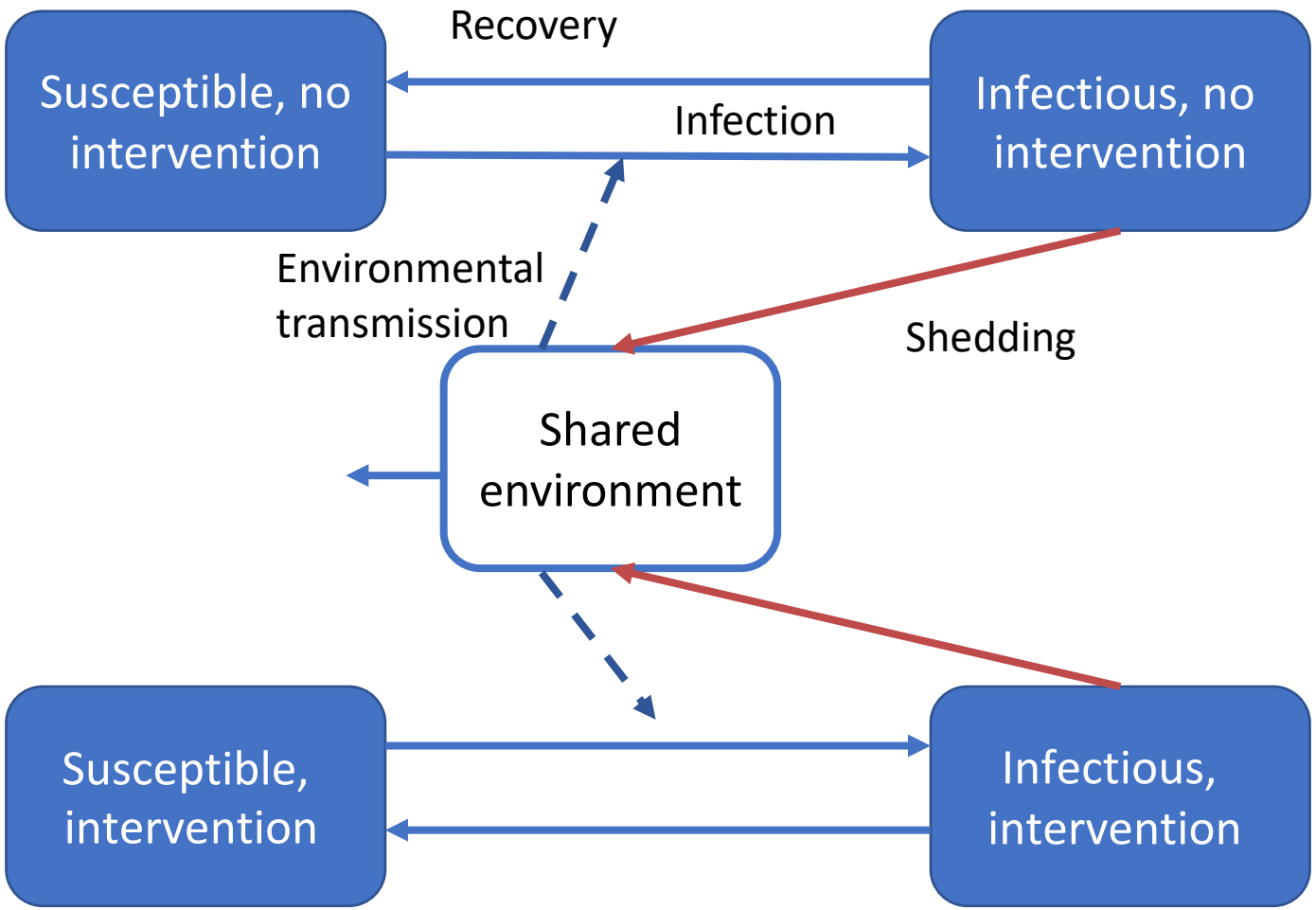
The Global Enteric Multicenter Study found substantial differences in the distribution of pathogens at different sites.

Mechanistic transmission modeling can aid in predicting and generalizing WASH trial outcomes.

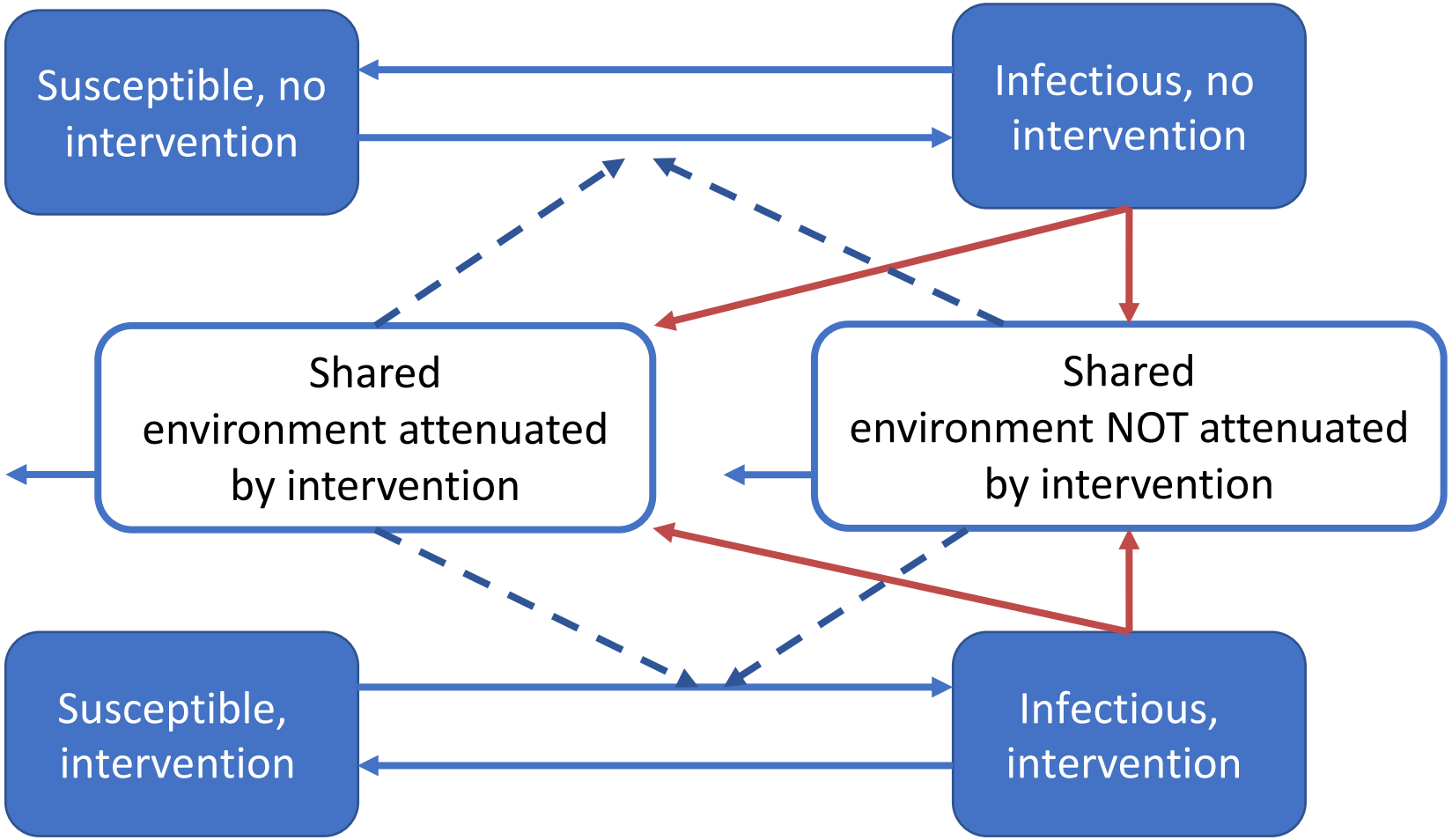
Our transmission model accounts for people using and not using interventions…



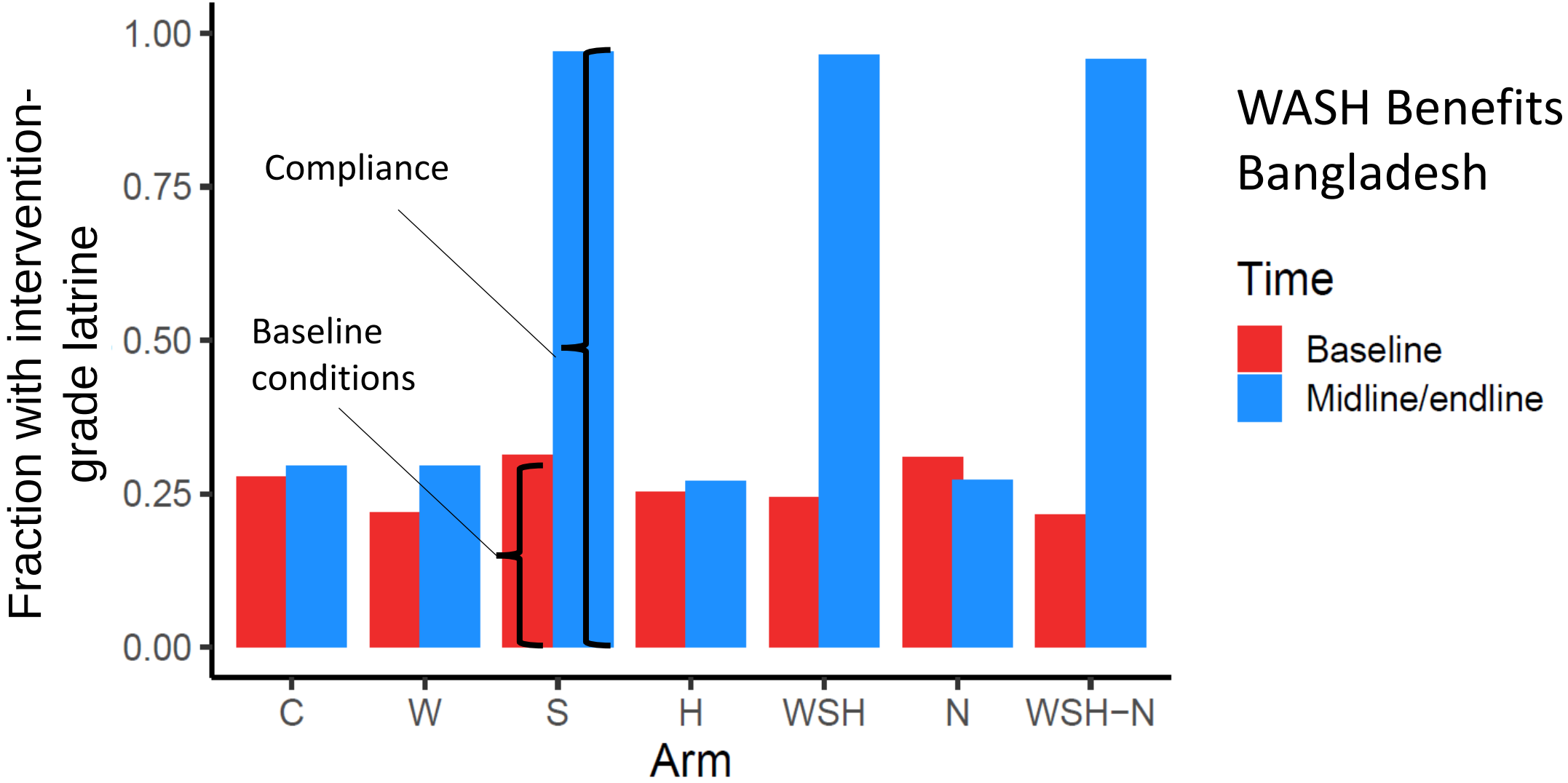
… a shared environment …



… and multiple transmission pathways.



We also account for intervention compliance and baseline WASH conditions.

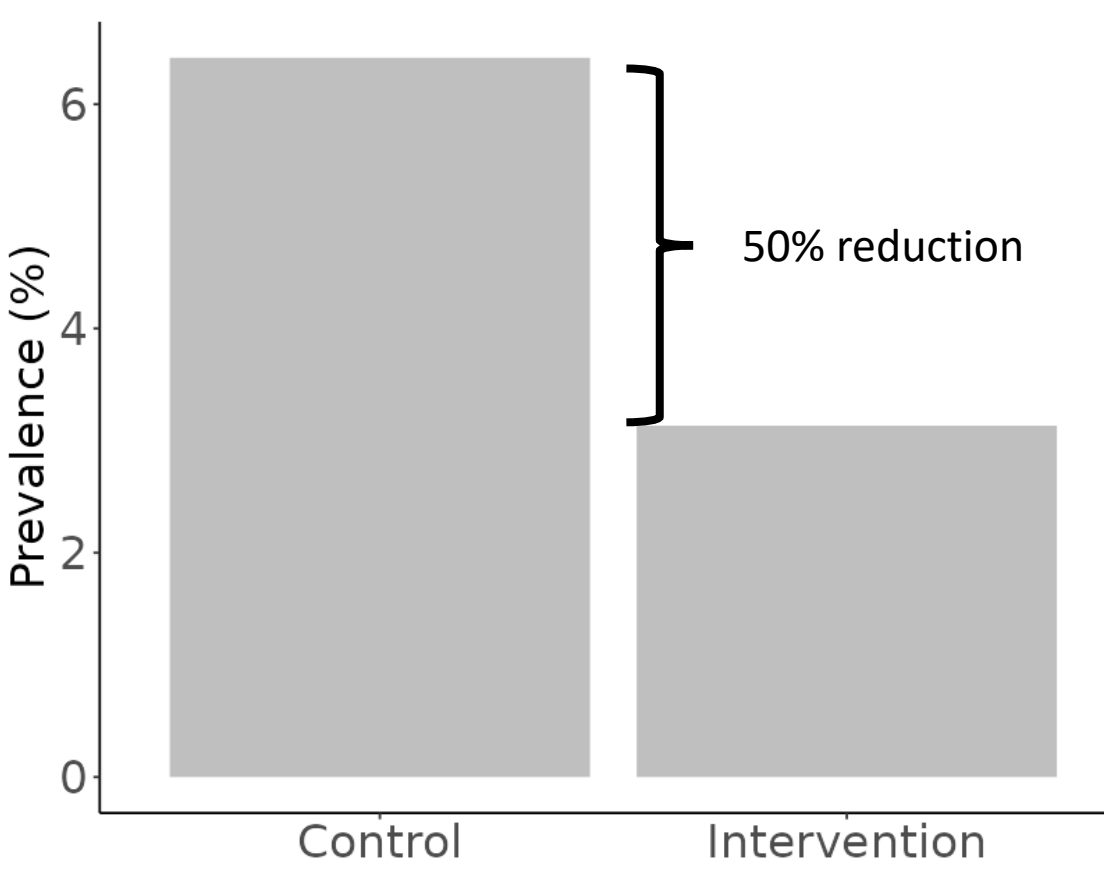


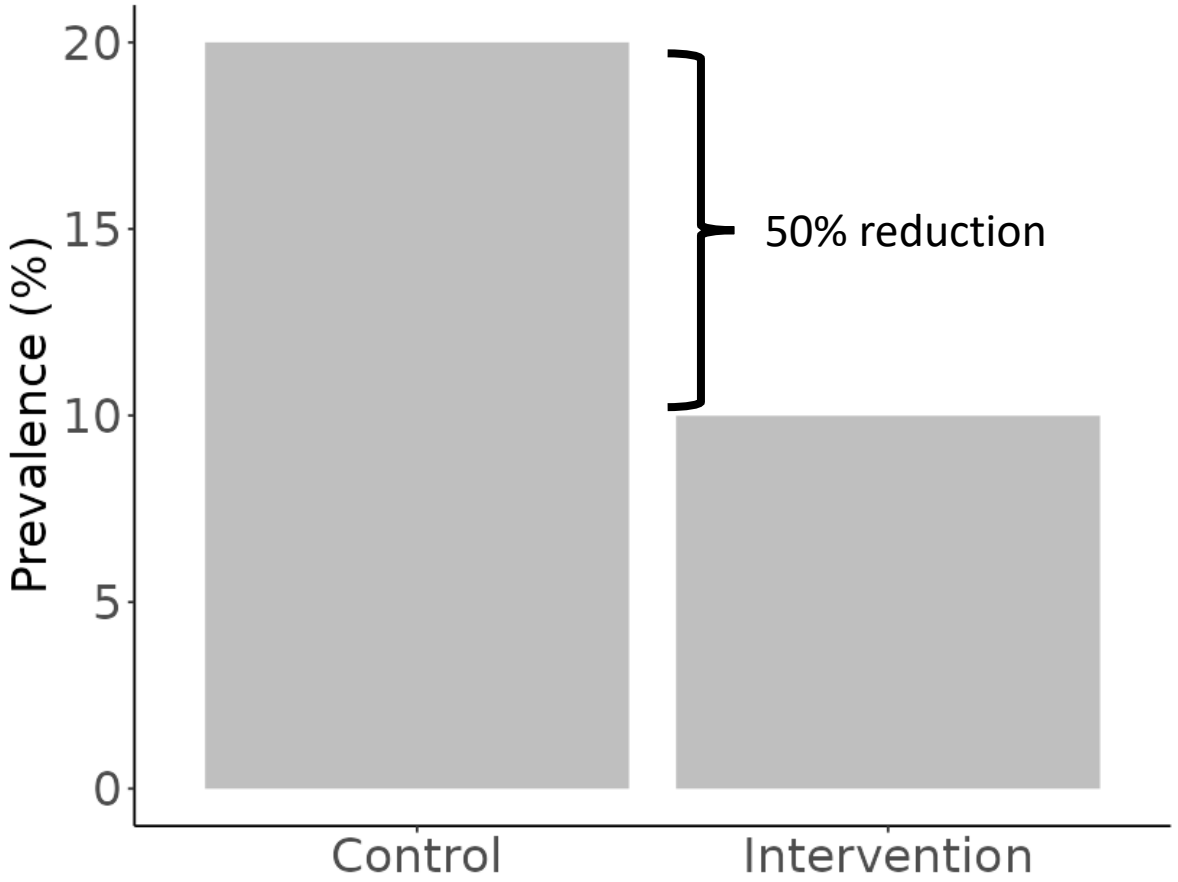
We illustrated the sensitivity of intervention effectiveness to intervention and contextual parameters in two scenarios.

- Efficacy
- Compliance
- Community coverage
- Completeness
- Baseline WASH conditions
- Baseline disease conditions

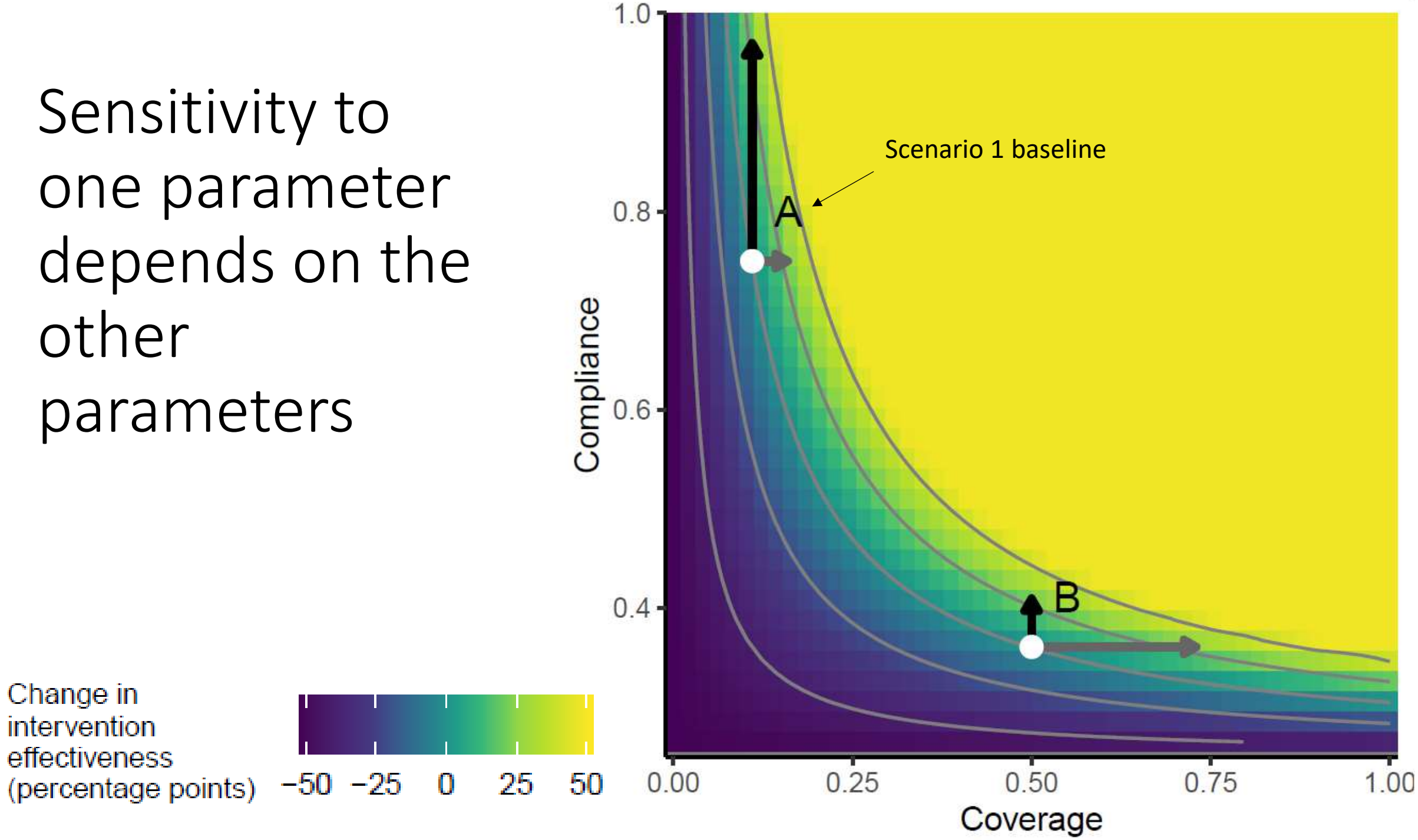
Scenario 1	Scenario 2
Lower (75%)	Higher (83%)
Higher (75%)	Lower (50%)
Lower (11%)	Higher (75%)
Higher (75%)	Lower (35%)
Higher (25%)	Lower (0%)
Lower (6.4%)	Higher (20.0%)

These scenarios were chosen to have 50% effectiveness.

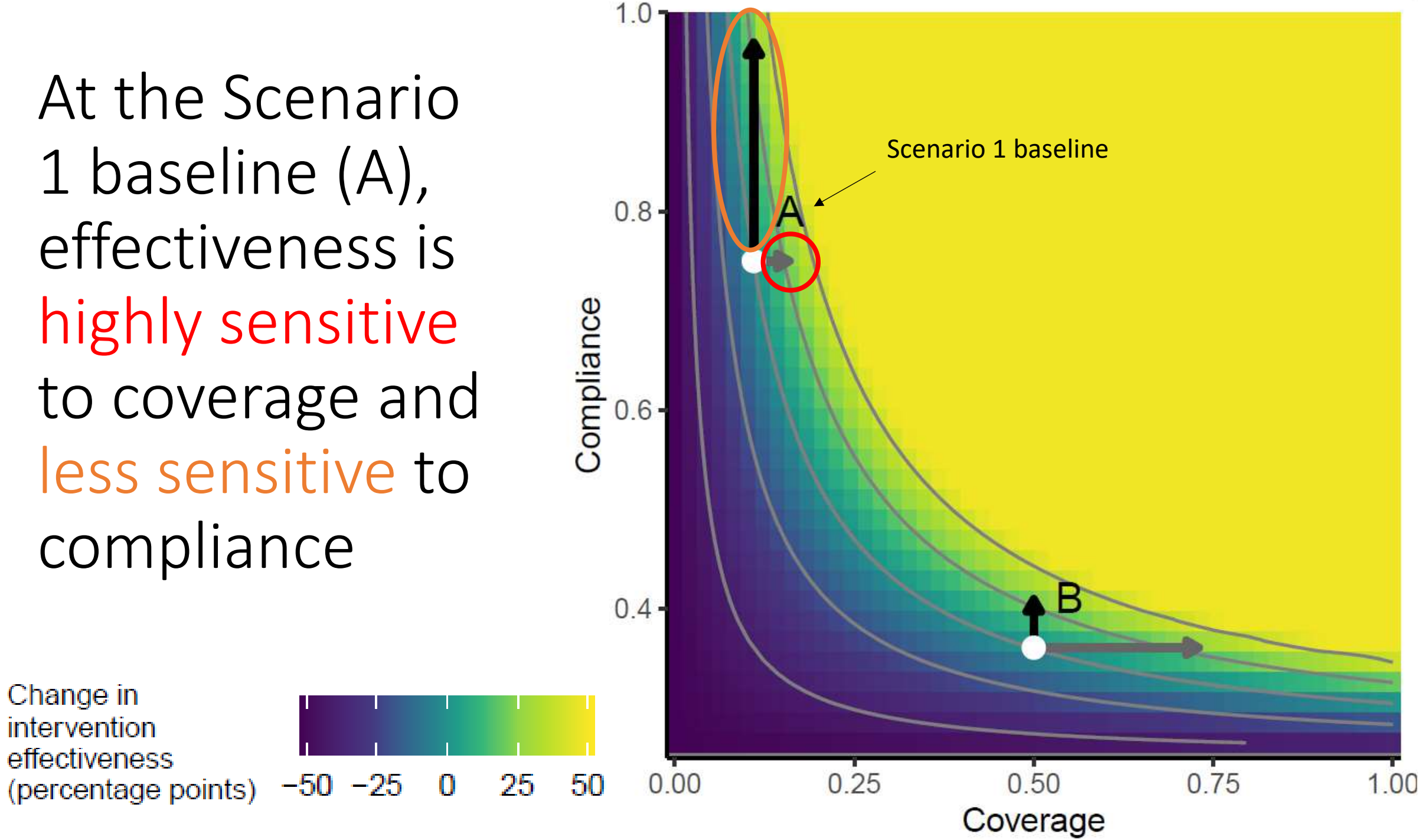




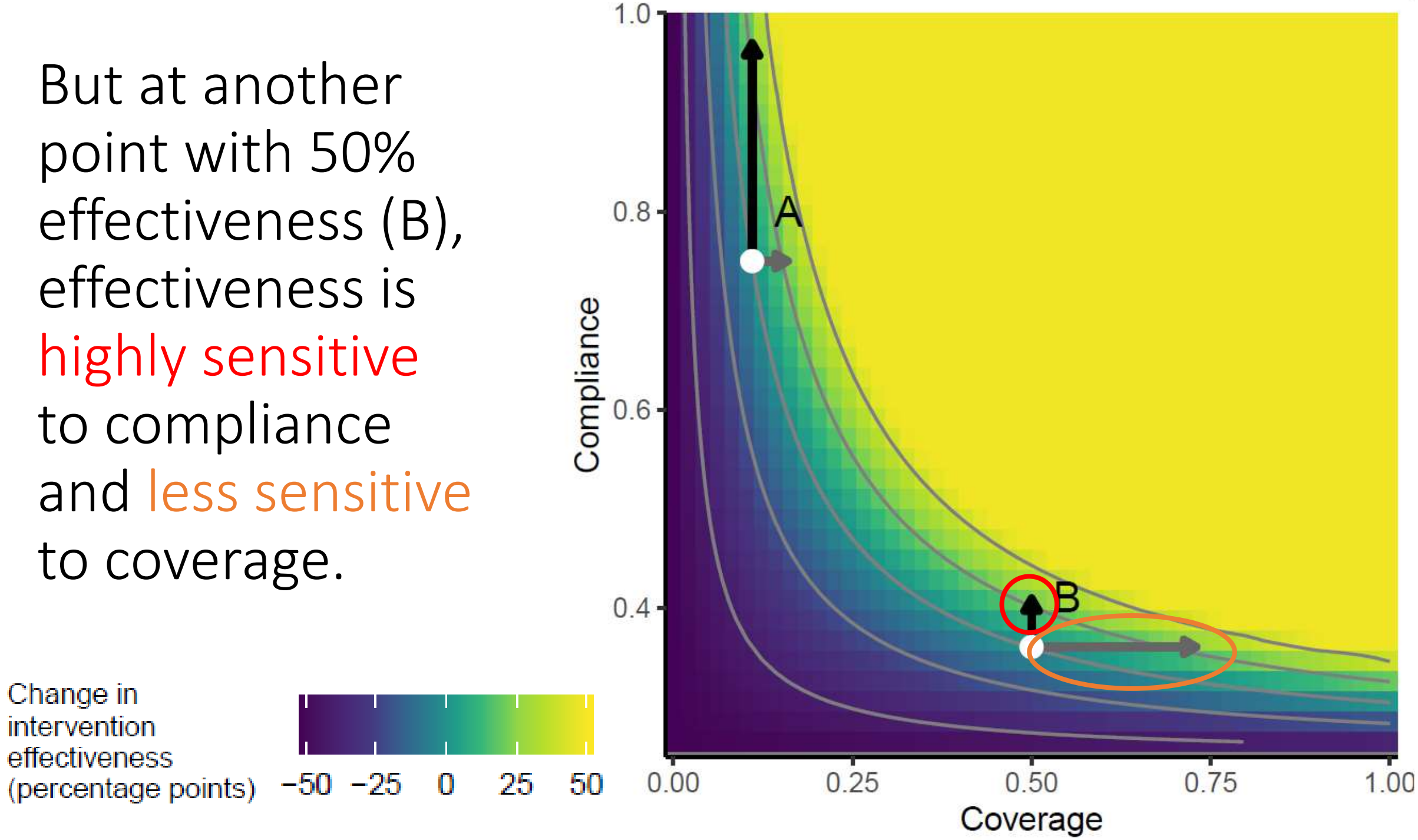
Sensitivity to one parameter depends on the other parameters



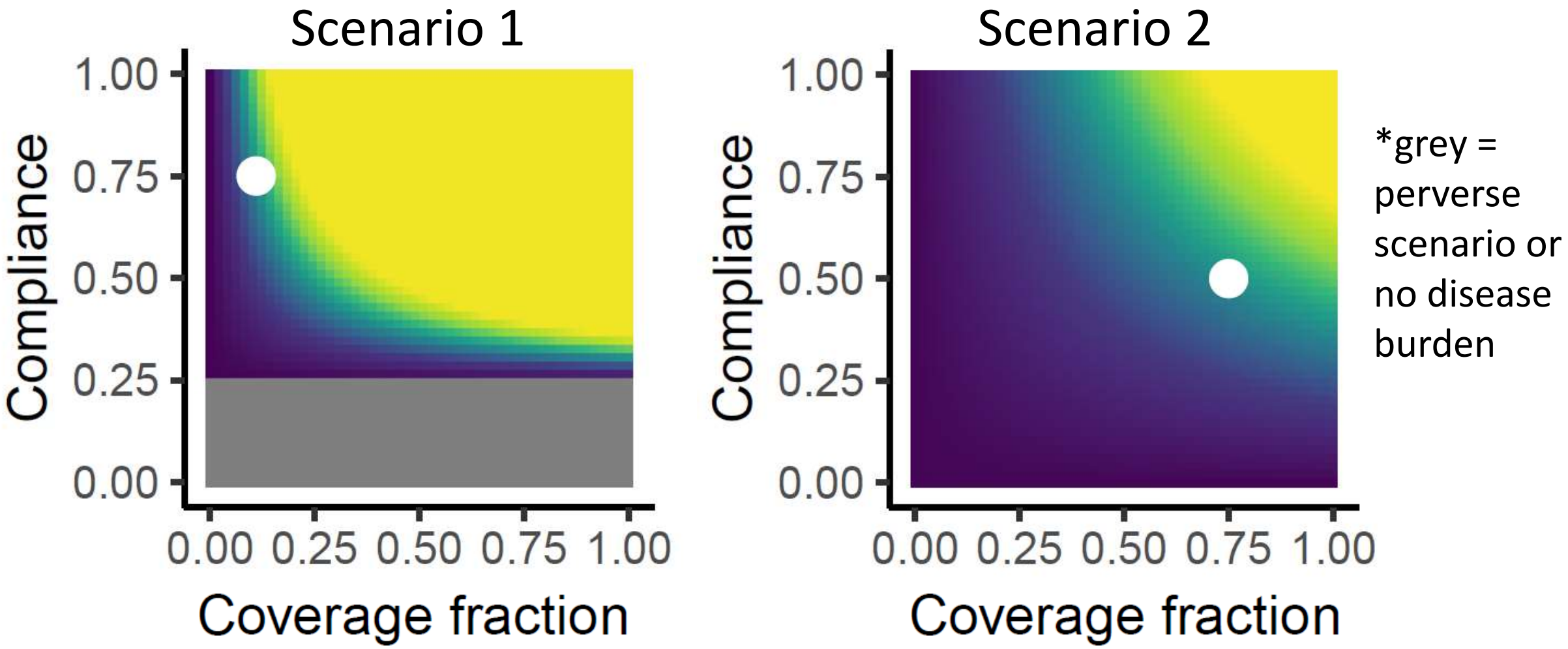
At the Scenario 1 baseline (A), effectiveness is highly sensitive to coverage and less sensitive to compliance



But at another point with 50% effectiveness (B), effectiveness is highly sensitive to compliance and less sensitive to coverage.



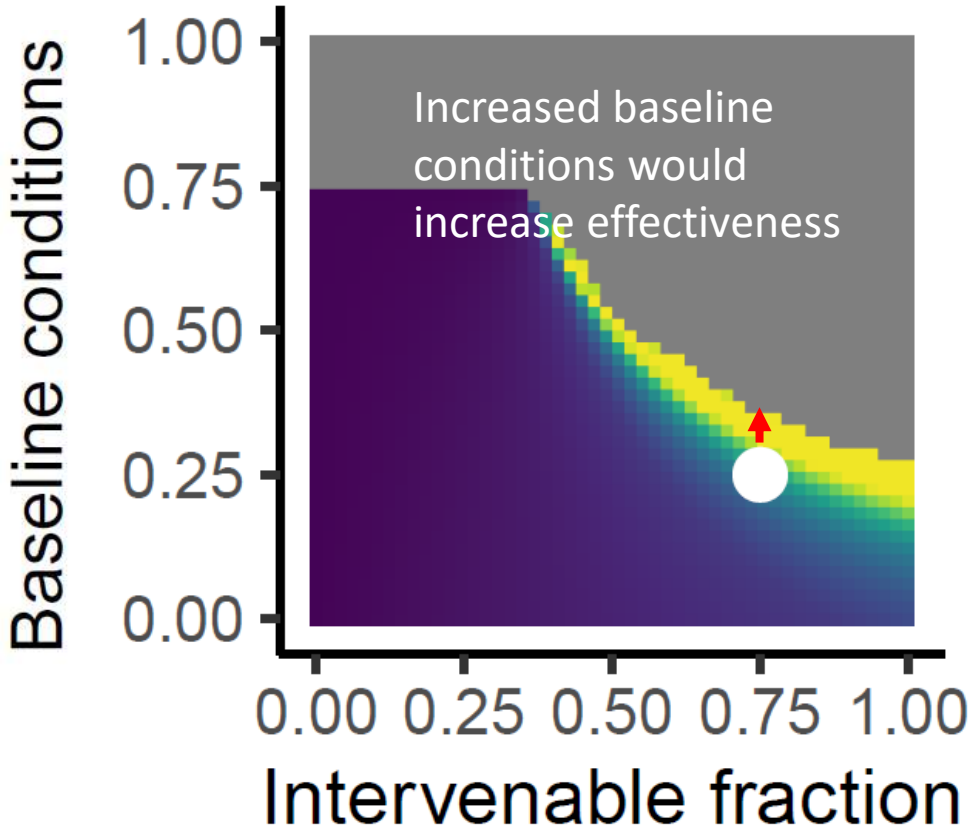
And these sensitivities further depend on the other intervention and contextual factors.



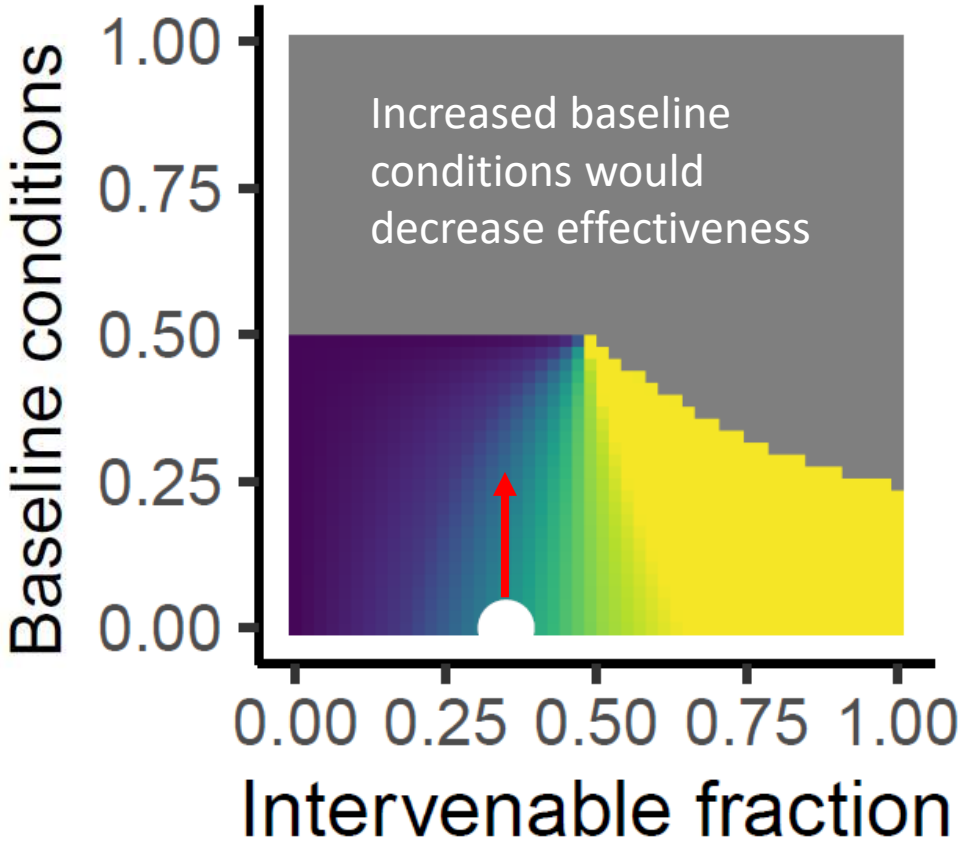
*grey = perverse scenario or no disease burden

Indeed, in some cases, a combination of factors could increase effectiveness in one scenario but *decrease* it in another.

Scenario 1



Scenario 2



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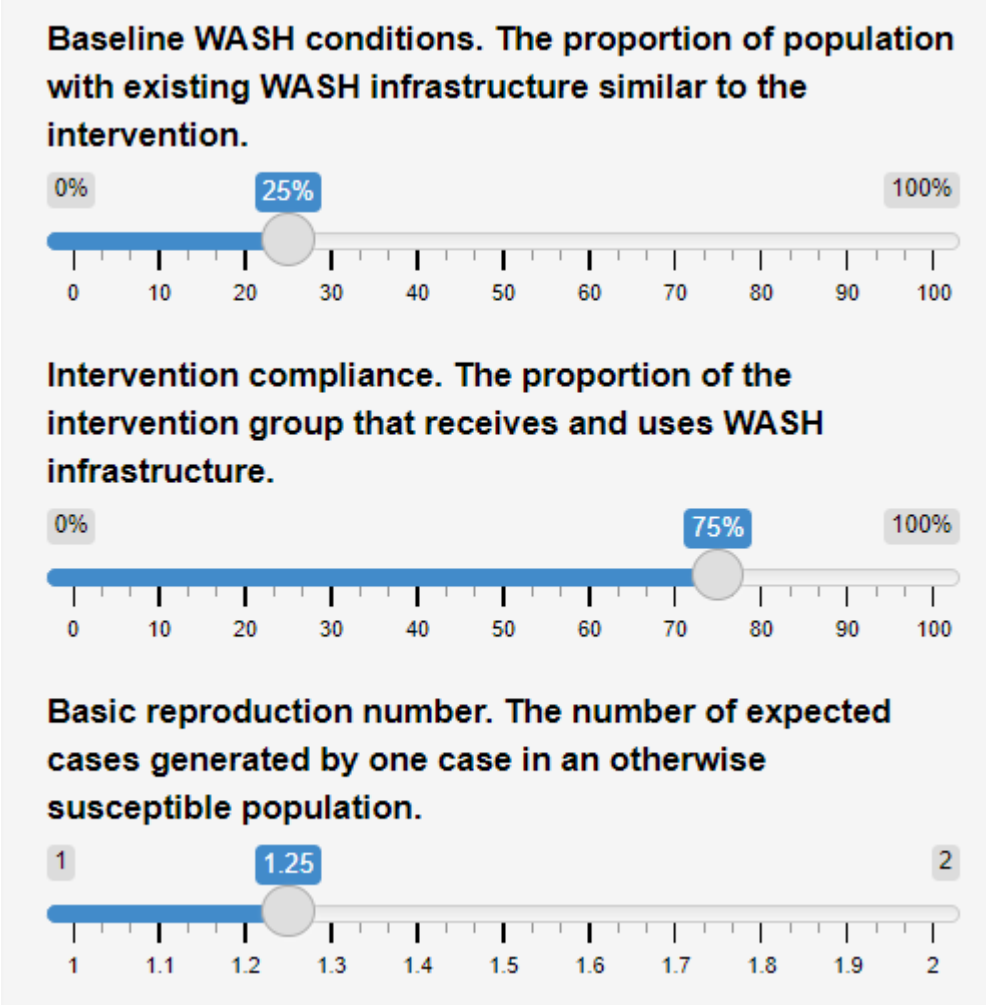
Thus, it is important project an intervention's effectiveness in a specific context.

We have created a **public-use tool** to facilitate intervention planning for *local contexts.*

https://umich-biostatistics.shinyapps.io/sise_rct/

Set your intervention and contextual factors



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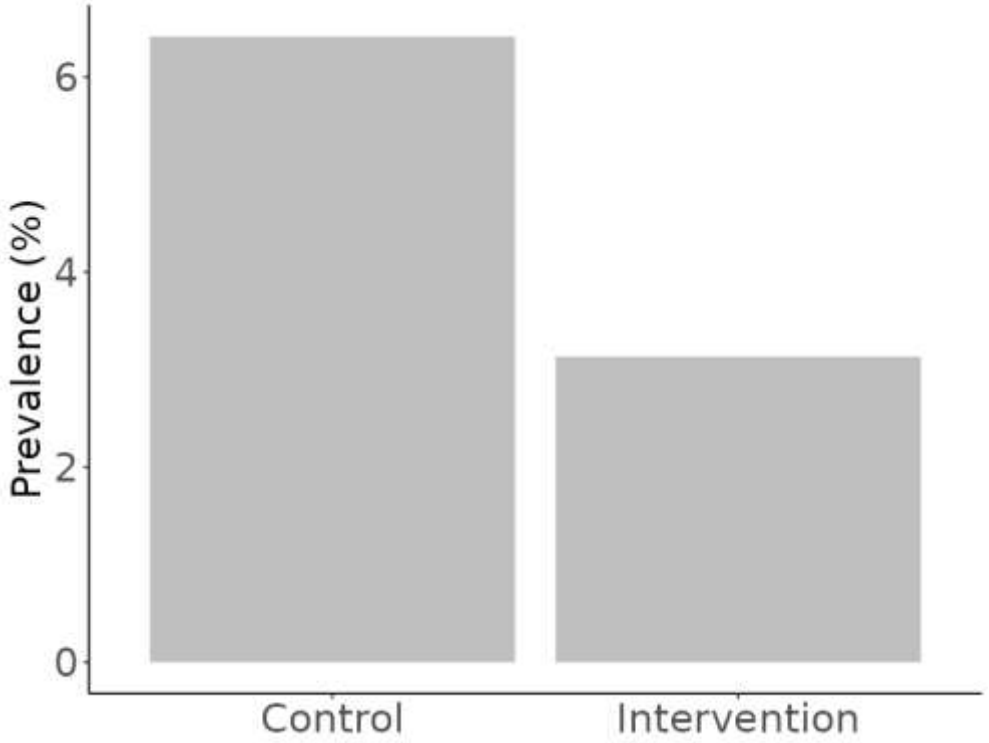
Estimate the baseline prevalence and intervention effectiveness



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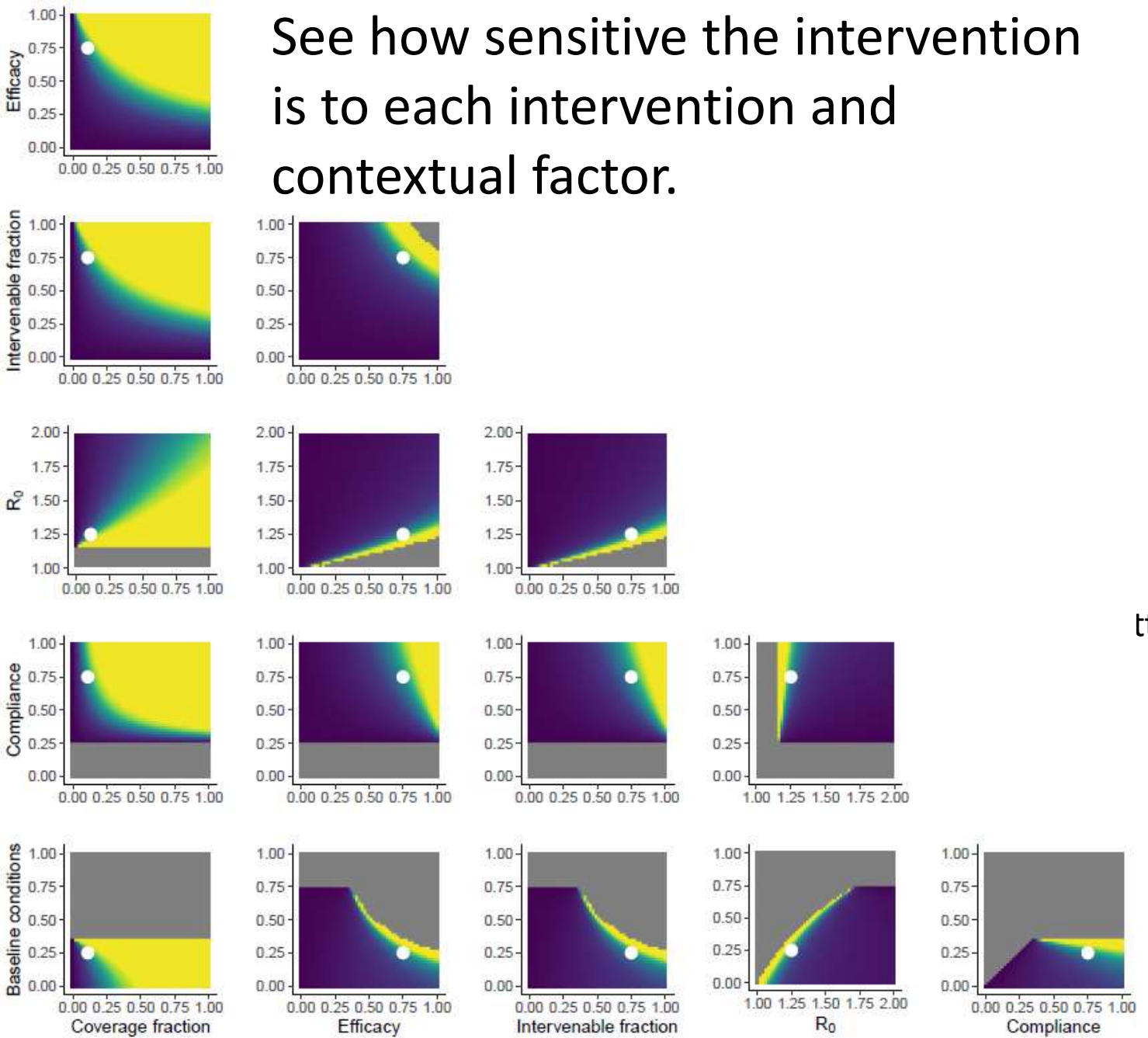
Prevalence in control arm	Prevalence in intervention arm	Non-intervenable prevalence	Intervention effectiveness
6.4	3.1	0	51.2%



See how sensitive the intervention is to each intervention and contextual factor.

ttps://umich-biostatistics.shinyapps.io/sise_rct/

Conclusions

- Not surprisingly, the sensitivity of intervention effectiveness to an intervention or contextual factor is highly sensitive to the other factors.
- These factors likely underly the heterogeneity in trial outcomes.
- Local contextual factors must be accounted for when developing priorities for interventions.
- Mechanistic modeling can both aid in this intervention planning and help to estimate how the results of an intervention in one location will translate to another location.

Acknowledgments

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Questions?

Shiny app tool

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Preprint paper

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