Statistical Power for Trend Detection Under Alternative Panel Designs for Surveys over Time

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Options for Trend Estimation

- Simple and weighted linear regression models
  - Based on annual designed-based estimates of status
- Linear mixed model(s)
  - does not incorporate weights from design (Urquhart et al 1993, Piepho & Ogutu 2002, Urquhart 2012)
- Probability-Weighted Iterative Generalized Least Squares (PWIGLS)
  - Simple fixed- and random effect models applied in design-based setting (Pfeffermann et al. 1998)
- Regional Kendall Tau nonparametric trend detection (Helsel and Frans 2006)
  - Requires all sites be sampled on each sampling occasion. (more general approach by van Belle and Hughes 1984)

Panel/Revisit Designs

- Panel designs are basis for monitoring over time
- Names for panel designs are not consistent in literature but McDonald (2003) provides a naming structure that is helpful

- Always revisit: [1-0] is traditional revisit same sites every time period
- Never revisit: [1-n] is never revisit the same site
- Rotating panel: [3-n] is revisit same site for three years, then never again (rotating panel or sampling with partial replacement)
- Serially alternating: [1-3] is visit site in year one, skip three years and then repeat that pattern in future years
- Split panel: [1-0, 1-4] split panel design with always revisit and serially alternating panels
- Complex rotating panel: [1-3-1-3-1-n] panel design: panel 1 - visit site in years one, five and nine and then never visit again

[1-0] Panel Design: Always Revisit

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	ETC
Panel 1	150	150	150	150	150	150	150	150	150	150	
Cum#	150	150	150	150	150	150	150	150	150	150	Etc

- **Visit same 150 sites in all years.**
- **No additional site evaluation after first year**
- **Landowners may begin to deny access**
- **Sites may be impacted by sampling**
- **Sites may be "treated" differently by owner or by environmental agency.**

[1-n] Panel Design: Never Revisit

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	ETC				
Panel 1	150										
Panel 2		150									
Panel 3			150								
Panel 4				150							
Panel 5					150						
Panel 6						150					
etc											
Cum#	150	300	450	600	750	900	1050	1200	1350	1500	etc

- **New sites every year**
- **Same level of site evaluation effort each year**
- **Landowners only asked for permission for one time**
- **Impact due to sampling or being "treated" differently by owner or by environmental agency not an issue**

[3-n] Panel Design: Rotating Panel

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	ETC		
Panel 1	50	50	50								
Panel 2		50	50	50							
Panel 3			50	50	50						
Panel 4				50	50	50					
Panel 5					50	50	50				
Panel 6						50	50	50			
etc											
Cum#	50	100	150	200	250	300	350	400	450	500	etc

- **Visit sites for three years in row and then never again, i. e., drop 50 sites each year and add new 50 sites.**
- **Number of unique sites increases each year but not as fast as when never revisit a site.**
- **Landowner only has three visits to site which may impact whether they give permission to sample more than once.**
- **Note that if want to always sample 150 sites each year, then will have a set of "start up" panels that add additional sites in first 2 years.**

[1-3] Panel Design: Serially Alternating

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	etc
Panel 1	150				150				150				
Panel 2		150				150				150			
Panel 3			150				150				150		
Panel 4				150				150				150	
Cum#	150	300	450	600	600	600	600	600	600	600	600	600	etc

- **Visit 150 sites in year 1, again in year 5 and again in year 9 and continue this serially alternating pattern. Other panels same except start in year 2, 3 and 4.**
- **Reduces issue with landowner access by not sampling every year**
- **Likely reduces impact on site**
- **Potential of "improving" sites sampled if they are in poor condition either by landowners or environment agency**

[1-3-1-3-1-n] Panel Design

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14
Panel 1	50				50				50					
Panel 2		50				50				50				
Panel 3			50				50				50			
Panel 4				50				50				50		
Panel 5					50				50				50	
Panel 6						50				50				50
etc														
Cum#	50	100	150	200	250	300	350	400	450	500	550	600	etc	

- **Visit 50 sites in year 1, year 5 and year 9 and never again; etc for other panels**
- **Cumulative number of sites increases over time so that visit more unique sites over time.**
- **Maximum number of times a site is visited is three.**
- **Reduces issue with landowner access, impact on site, and potential of "improving" just sites sampled if they are in poor condition.**
- **Note that if want to always sample 150 sites each year, then will have a set of "start up" panels that add additional sites in first 9 years.**

Considerations: Panel Design Choice

- Power to detect trends in status over time
- Monitoring organization's time/cost to complete site evaluations required each year
- Likelihood landowner will give permission to sample a site when asked to give permission for multiple visits
- Impact sampling has on a site by returning to the same site multiple times
- Potential for landowner to impact site (positively or negatively) when they know site will be sampled multiple times
- Potential for environmental agency to improve a site given that they know its current condition

Power to Detect Trends in Status

Mixed linear model

$$y_{ijk} = \beta_0 + w_j\beta_1 + T_j + S_i + w_jB_i + C_{ij} + \varepsilon_{ijk}$$

$i = 1,\ldots,s$ number of sites
$j = 1,\ldots,t$ number of years
$k = 1,\ldots,r$ number of replications within site and year
w_j - location shifted year variable representing jth year
β_0 and β_1 – fixed intercept and slope of linear trend in time
T_j - random effect of *j*th year
S_i and B_i - random effects of *i*th site intercept and trend slope
C_{ij} - random effect of *i*th site and *j*th year interaction
ε_{ijk} - unexplained error

- y may be Benthic macroinvertebrate MMI, total nitrogen, etc.
- Focus is on determining the power when testing null hypothesis that β_1, the overall linear trend in the population, is equal to 0
- Need estimates for variance components T_j , S_i , B_i , C_{ij} and ε_{ijk}
- Can simplify model: drop B_i (variation adsorbed into C_{ij}); drop ε_{ijk} if no replications

Variance Components Required

$$\sigma^2_{Tot} = \sigma^2_{Site} + \sigma^2_{Year} + \sigma^2_{Site*Year} + \sigma^2_{SiteTrend} + \sigma^2_{Error}$$

$\hat{\beta} = (X'\Sigma^{-1}X)^{-1} X'\Sigma^{-1}Y$ and $cov(\hat{\beta}) = (X'\Sigma^{-1}X)^{-1}$

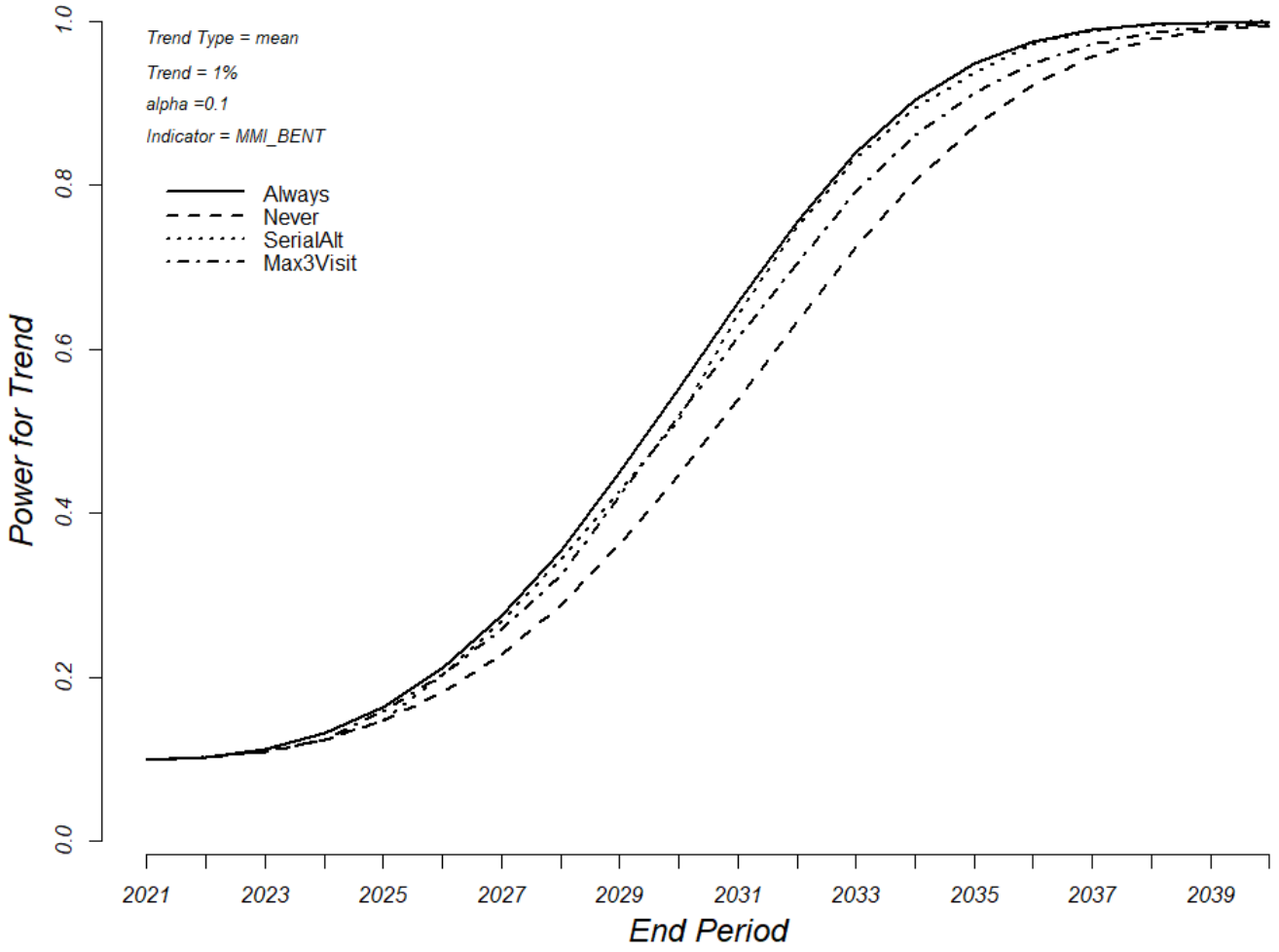
X is matrix with column of ones and column containing time period variable for year, w_j, and

Σ is cov(Y) where Y is vector of responses Y_{ij} and includes information on panel designs and variance components

$\hat{\beta}_1$, second element of $\hat{\beta}$, is estimated population trend and its standard error is the square root of the second diagonal element of $cov(\hat{\beta})$, β_1^0 is assumed true trend, Φ is cumulative normal distribution, and power is expected power given true trend, panel design and sample size.

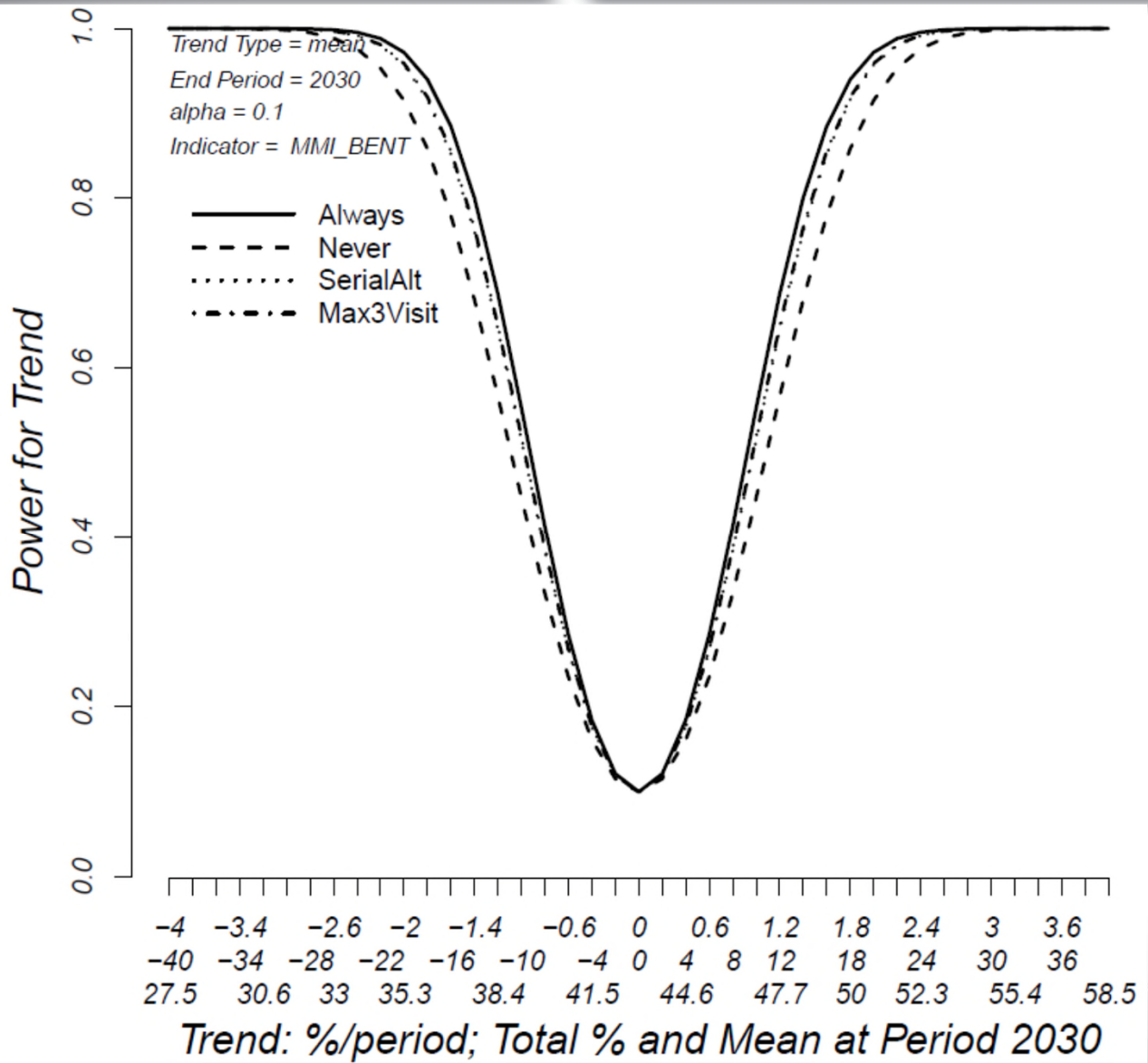
$$\text{Power}(\beta_1^0) = \Phi\left(-1.645 - \frac{\beta_1^0}{\sigma_{\hat{\beta}}}\right) + 1 - \Phi\left(1.645 - \frac{\beta_1^0}{\sigma_{\hat{\beta}}}\right)$$

Power Four Panel Designs



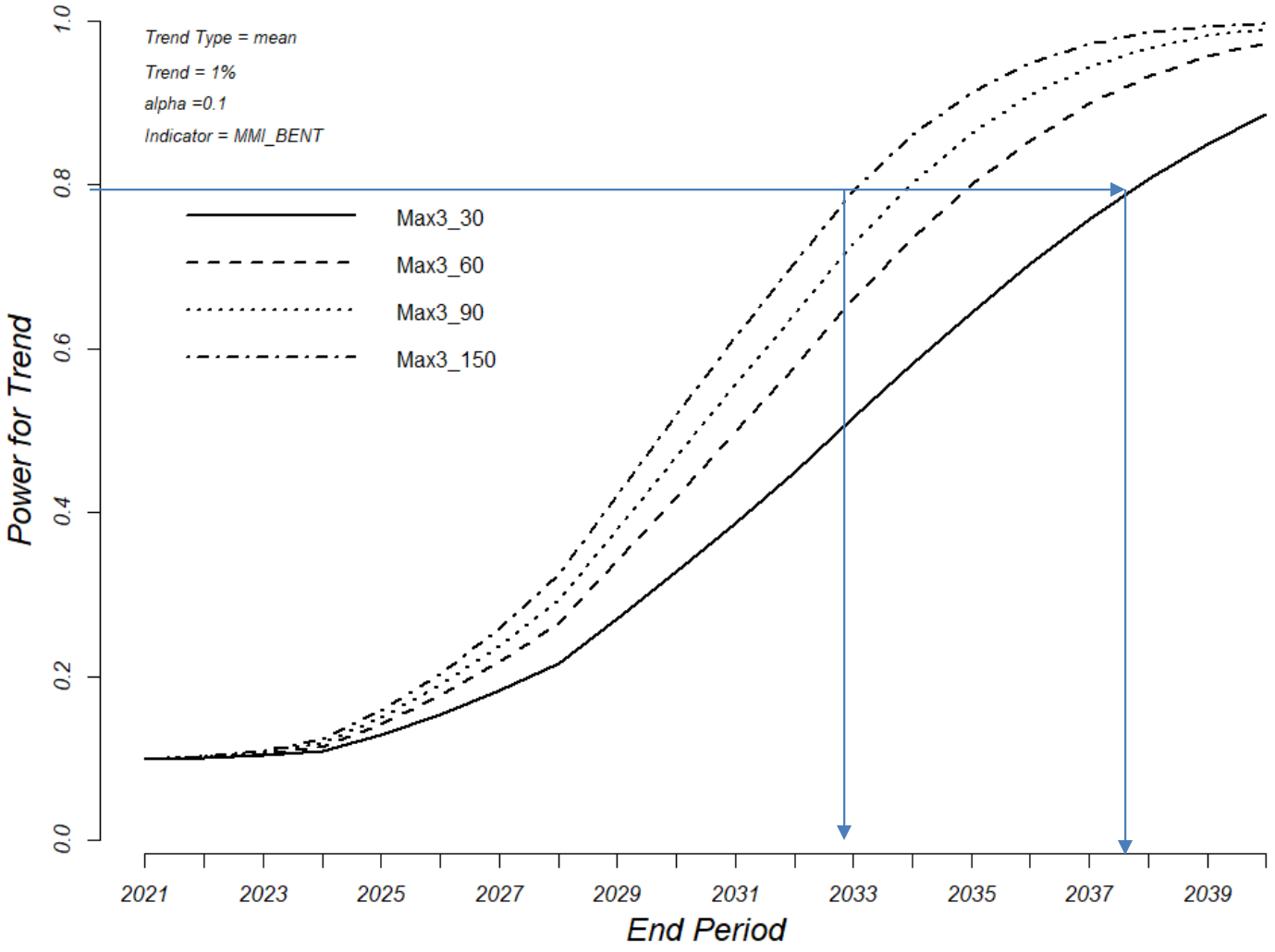
- **Four panel designs**
  - **Always [1-0]**
  - **Never [1-n]**
  - **SerialAlt [1-4]**
  - **Max3Visit [1-3-1-3-1-n]**
- **Sample size 150 with Trend 1%/Year**
- **Power by year**
- **Power is similar for all panel designs but Never revisit panel design has lowest power**

Power Four Panel Designs



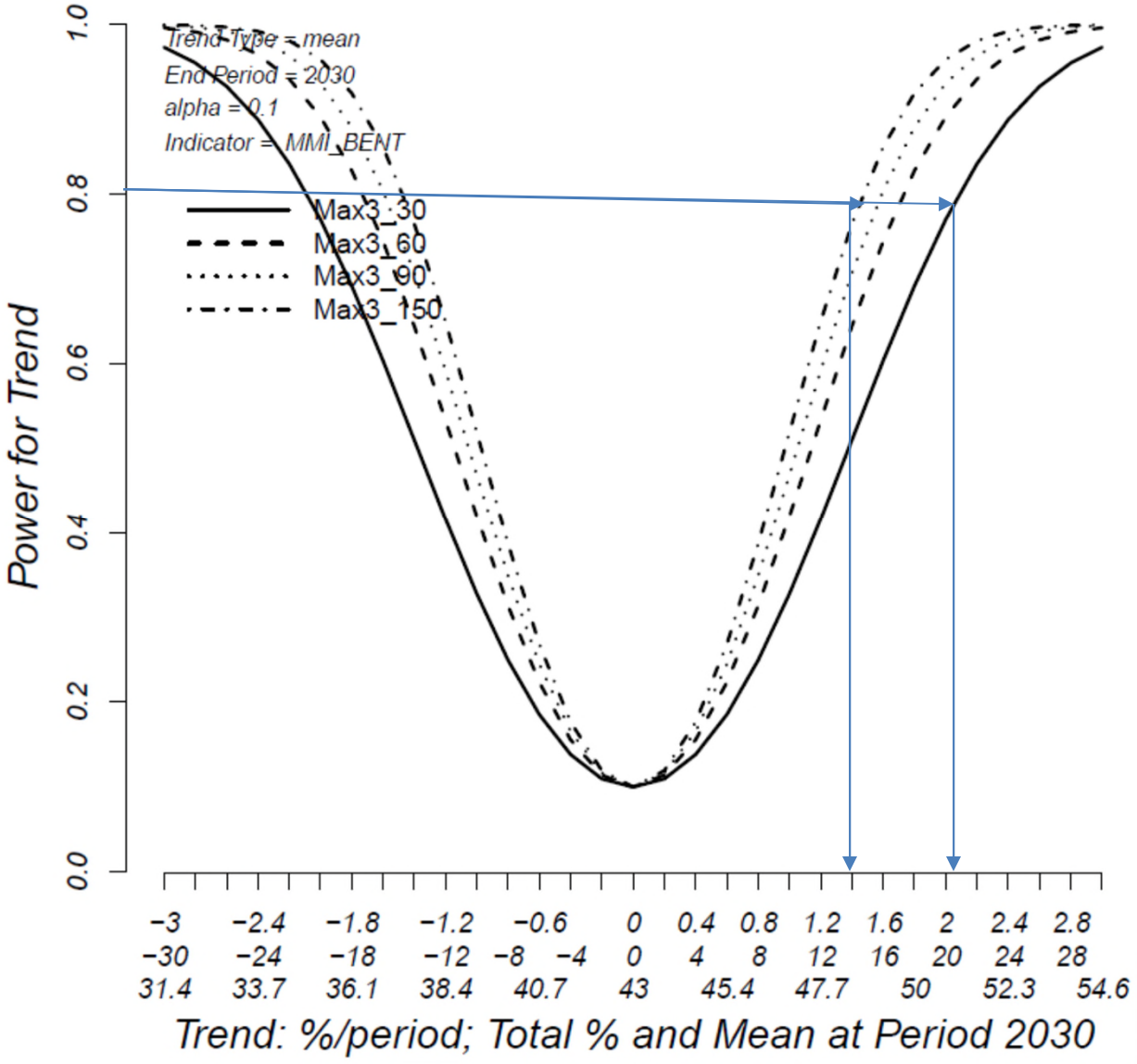
- **Four panel designs**
  - **Always [1-0]**
  - **Never [1-n]**
  - **SerialAlt [1-4]**
  - **Max3Visit [1-3-1-3-1-n]**
- **Sample size 150**
- **Power after 10 years**
- **Power is similar for all panel designs but Never revisit panel design has lowest power**
- **Panel design choice may depend on other factors**

[1-3-1-3-1-n] Power Sample Size



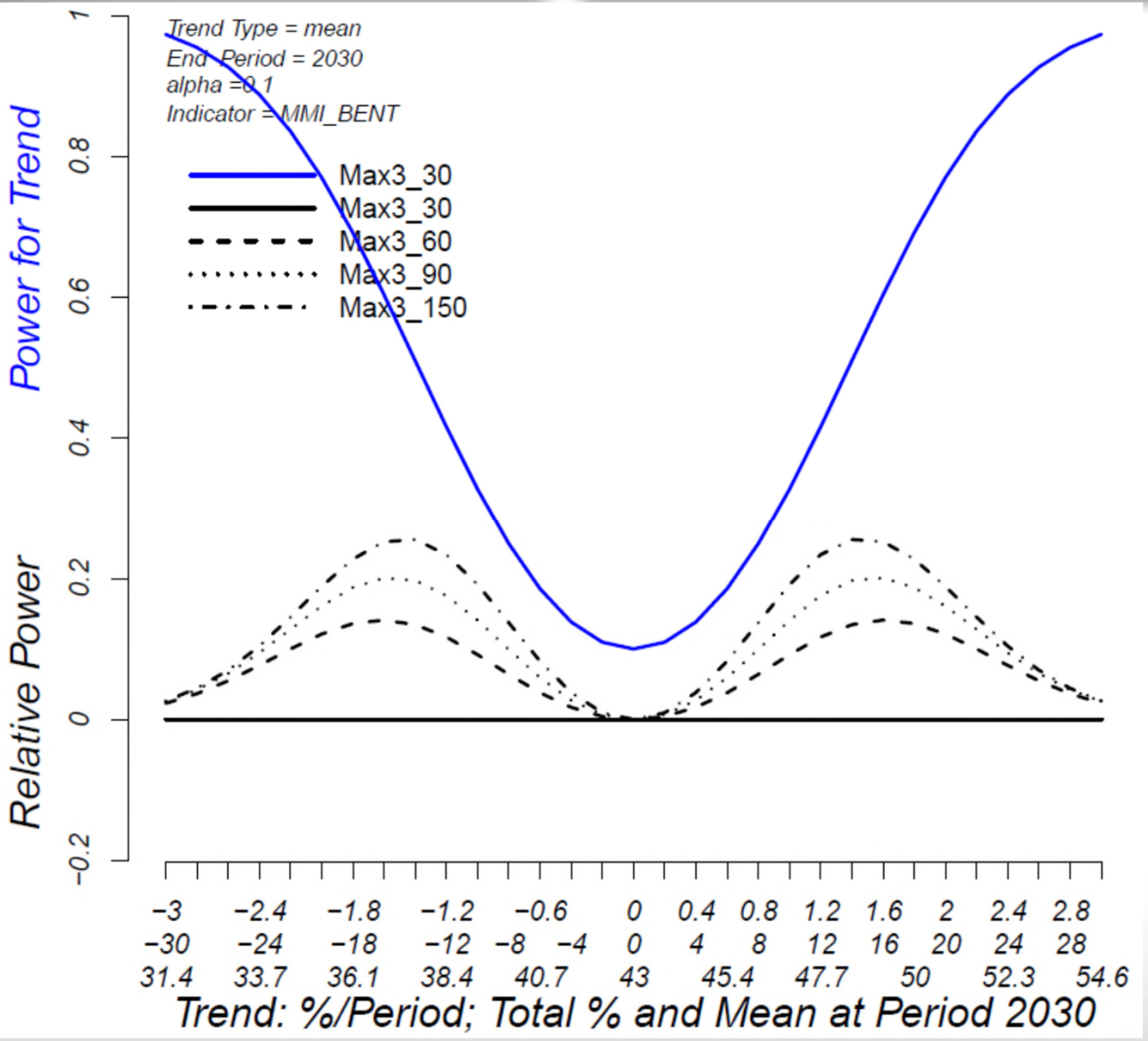
- **Power by years monitored for sample sizes of 30, 60, 90 and 150**
- **Trend: 1%/year. After 10 years a total change of 10%**
- **Power > 0.8 in 2033 if n = 150 and Power > 0.8 in 2038 if n = 30**

[1-3-1-3-1-n] Power Sample Size: 10 Years



- **After 10 years (2030), power is >0.8 for all sample sizes if trend is >2%/year (or <-2%/year). At 10 years total % change is 20% (or -20%) and MMI changes to ~51 (or ~35) from base of 43.**
- **If sample size is 150/year, then power >0.8 if trend is >1.4% or total % change 14% with MMI change to ~49 from base of 43.**

[1-3-1-3-1-n] Relative Power Sample Size



- **If use panel design with 30 sites as base, then increase in power if increase sample size to 60, 90 and 150 is shown in black.**
- **If increase sample size by factor of five (to 150), then largest power increase is ~0.2 when %/year is ~1.5%**
- **Can see on prior plot but this makes explicit comparison.**

Power Computation Alternatives

- **Power Based on Variance Components**
  - **Alternative panel design alternatives included**
  - **Assumes survey design is simple random sample, i.e., complex survey design structure not accounted for in computation**
  - **Requires estimating variance components based on existing data**
  - **Assumes estimated variance components are known for power analysis**
  - **Power calculations simple to compute given R functions**
- **Power Based on Simulations**
  - **Alternative panel design alternatives included**
  - **Complex survey design structure included in simulation**
  - **Requires creating response values for entire sampling frame under hypothesis of no trend as well as set of alternative trends. Created response values may be based on a model.**
  - **Requires selecting samples large number of times (~1,000) and estimating trend for each**
  - **Power is simply proportion of simulations where null hypothesis of no significant trend is rejected**

R functions for Power

- **Revisit_dsgn: Create panel designs**
  - **Creates a revisit design for panels in a survey that specifies the time periods that members of each panel will be sampled using panel naming convention of McDonald (2003).**
  - **Three basic revisit design structures may be created: always revisit panel, serially alternating panels, or rotating panels**
  - **revisit_bibd and revisit_rand are additional alternatives**
  - **panel_summary: summarizes characteristics of a revisit design**
- **power.dsgn: Compute power for trend detection**
  - **Based on Urquhart (2012) mixed linear model**
  - **power for trend detection for one or more variables, for one or more panel designs, for one or more linear trends, and for one or more significance levels**
- **plot.powerpaneldesign: Plot power based on results from power.dsgn**
  - **Multiple options for creating power plots**
- **All soon to be added to spsurvey**