Power analysis to detect trends in haul-out counts of Harbour seals (*Phoca vitulina vitulina*) in Ireland

Cóilín Minto[1*] and Maria Rakka[1]

March 23rd 2015

[1]Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology, Dublin Road, Galway, Ireland.

[*]Contact email: coilin.minto@gmit.ie

GMIT
INSTITIÚID TEICNEOLAÍOCHTA NA GAILLIMHE-MAIGH EO
GALWAY-MAYO INSTITUTE OF TECHNOLOGY

MARINE AND FRESHWATER RESEARCH CENTRE
LÁRIONAD TAIGHDE MARA AGUS FÍORUISCE

Executive summary

Purpose

A central measure of the performance of animal monitoring programmes is the ability to detect changes in the abundance of observed species. We define the power as the probability of correctly identifying underlying trends in animal counts. Here we determined the power to detect changes in harbour seal haul-out counts from the National Parks and Wildlife Service's annual monitoring programme.

Procedure

Animal counts are influenced by environmental, behavioural and population-level effects. Using models estimated in Phase 1 of the current project, we developed comprehensive simulation routines to generate site-specific simulated datasets with the same properties as those of the observed data. Effects included: measured environmental variables, within-season variability and inter-annual variability. Rates of population change were then introduced, resulting in simulated datasets with the same environmental and inter-annual variability as those observed but, importantly, with known underlying trends. We then tested the ability of a suite of monitoring programme designs, as well as various summary statistics (yearly mean/maximum, model-based), to recover the true trend. Further modelling of power as a function of the design settings enabled the identification of the most important programme design settings determining power at the location and across-location levels.

Results

We found that the power to detect changes in the land-based counts was most determined by: (1) the number of years the population is monitored (more years corresponds to increased power); (2) the magnitude of the annual rate of change (larger rates of change correspond to increased power); (3) the magnitude of the inter-annual variability of counts unrelated to trends or measured environmental variables (high inter-annual variability corresponds to decreased power); and (4) the monitoring frequency, with annual counts achieving higher power than biennial counts.

For the land-based counts, achieving a power of 0.8 required that the number of years monitored was greater than 6 years, the annual rate of change was greater than 10% and that the inter-annual variability unrelated to trend or measured environmental variability had a CV<30%. For fewer years, lower rates of change and or greater inter-annual variability, the power was often considerably lower than 0.8. The power to detect trends was typically higher for the boat-based counts, albeit with simpler environmental variability simulation models, but there the number of monitoring years and inter-annual variability also had similar effects on power to detect trends as was found via the land-based power analyses.

The effect of inter-annual variability manifested itself in differing power to detect changes by location, with some locations such as Ballysadare Bay and Mannin Bay having increased power to detect trends relative to others such as Emlagh Point and Westport Bay. Similarly, for the boat-based surveys, low inter-annual variability unrelated to trend or measured environmental variables resulted in higher power to detect trends in the Inner Bantry Bay and Kenmare River counts, relative to that of Roaringwater Bay and Dunmanus Bay. These findings point to some locations being of specific importance to monitoring, particularly those with low inter-annual variability such as Ballysadare Bay, Mannin Bay, Bantry Bay and Kenmare River. These findings are further discussed in the Recommendations below.

The method used to derive the trend (mean or maximum yearly count or model-derived mean estimate) can affect the power, particularly for shorter monitoring time series and also for lower annual rates of change in relative abundance, with the modelling approach typically conferring increased power than un-modelled approaches, i.e. raw yearly mean or maximum. This is further discussed in the Recommendations below.

Design settings which had noticeably smaller effects on the power to detect trends were (1) the number of tidal states counted (a minimum of three versus five) and (2) whether the minimum number of visits per annum was two or three. While these variables may have affected the absolute counts and thus influenced perception of the total population size they were of relatively lower importance in determining the power to detect trends in the counts compared with: the number of monitoring years, the magnitude of the rates of change and inter-annual variability.

Recommendations

(1) Given the primacy of the number of monitoring years in determining the power to detect all rates of change (from low to high), we recommend that the conferred value of the continuation of time series to the power to detect trends across all locations be taken into consideration.

(2) The power to detect changes in the population must be placed in the context of the population definition and structure as well as agreed monitoring targets, specifically in terms of power to detect a specified population change over a given period of time. The development of these specified targets is recommended.

(3) If the population is defined at the location level, the present monitoring programme requires specific conditions to achieve acceptable power to detect trends, i.e., a long number of monitoring years, high rates of change, and low inter-annual variability. Aggregating the counts across putative sub-components of the population may reduce the high inter-annual variability component thus conferring increased power to detect trends at an aggregated level. We therefore recommend some focus on understanding connectivity among component/sub-populations such that an aggregative power analysis may be conducted.

(4) While modelling the counts typically confers increased power to detect trends, this analytical method may not be feasible on an annual basis. We have found that the yearly mean count has some increased power over the yearly maximum as would be expected statistically. We recognize however that information on absolute counts is

present in the maxima and thus recommend, where additional modelling is not possible, that trends be derived from the mean count (within a year) with additional reporting of the maxima to indicate absolute levels of the counts. In addition, where modelling is not possible, the distribution of the observation/environmental variables under which the counts were obtained should be monitored with respect to the variables having a significant influence on the count data, as seen in Phase 1 of the project. This would assist in the identification of outlying raw counts.

(5) To support decision making on the design of the monitoring program, we recommend that power to detect trends at an appropriate and agreed-upon level be treated as the gain function and the cost of given design settings be treated as the loss function for an appraisal of the optimum power gained versus the cost implication.

(6) Though some areas constitute a minor proportion of the total animals counted and have low power to detect trends (e.g., Emlagh Point, Dunmanus Bay), we recommend that an investigation of the potential to combine these counts as part of local/regional sub-populations be conducted in line with Recommendation 3.

Abstract

The power to detect trends in the abundance of wild animal populations is central to monitoring their status whether for conservation or other management purposes. Here we investigate, via a biologically and operationally realistic simulation framework, the power to detect trends in harbour seal haul-out counts from the National Parks and Wildlife Service's annual monitoring programme for the species in Ireland. A factorial monitoring design setup enabled the investigation of design settings to recover trends of naturally varying counts gathered during each moult season from 2009 to 2013. Within-season, between-visit and inter-annual variability were all included in the power analysis performed in 2014. Post-hoc analyses of the power determined which design settings had the greatest influence on the power to detect trends of varying scales. Within-location and across-location power analyses highlighted the importance of (1) the number of monitoring years and (2) the magnitude of the rate of change in determining statistical power. Monitoring locations differed in their power to detect a given trend, reflecting different within-season and inter-annual variability. Locations with low inter-annual variability in the count data acquired in the field (e.g., via land-based monitoring: Ballysadare Bay and Mannin Bay; via boat-based monitoring: Bantry Bay and Kenmare River) demonstrated higher levels of power to detect trends over shorter monitoring periods. Modelling methods such as GLMs and GLMMs typically offered gains in power where covariates and random variability influenced the counts; this was particularly the case among the land-based locations which are monitored differently and more extensively in time to those sites monitored by boat surveys. Power curves for each design setting are provided by location. Further enhancement of the power to detect trends via the investigation of regional site groupings is suggested by the analysis undertaken of this extensive 5-year dataset.

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Introduction

In accordance with their obligations under the EC Habitats Directive (92/43/EEC) EU member states are required to report periodically on the status of certain listed or protected species including harbour seal (*Phoca vitulina vitulina*). Aspects of the reporting parameters used to describe a species' conservation status (e.g., population, habitat, range, future prospects) include among other things the assessment of population size, population trends, population distribution and the identification of threats to and pressures acting on the species. Compliance with the Habitats Directive also requires the surveillance of such listed species to be undertaken. Therefore it requires the design of scientific monitoring programmes which can in time successfully detect statistically significant temporal variations in species populations, especially where the latter are known to be associated with sharp population declines or threats that could have population-level consequences (e.g., Phocine Distemper Virus [PDV] for harbour seal). In this regard the established International Union for Conservation of Nature (IUCN) criteria denote that declines exceeding 50% of the population over 50 years (with known reasons) or 30% over 10 years or 3 generations (with unknown reasons, whichever period is longer), raise serious conservation concerns and potentially flag a species as Vulnerable (IUCN Standards and Petitions Subcommittee, 2014).

Due to the inherent difficulty in estimating the absolute abundance of harbour seals (Cronin & Ó Cadhla, 2007) monitoring programmes typically rely on the use of indices, such as the minimum/maximum number of individuals at haul-out sites, in order to detect and assess population trends (Thompson *et al*., 2005). The ability to distinguish scientifically valid population trends from indices (e.g., counts of *x*% of the population ashore) depends on a range of critical factors on which adequate knowledge is required including: animal behaviour and life history, environmental and ecological variables influencing behaviour, the magnitude of the numerical trend and the underlying intrinsic variability in the population, but also factors associated with the monitoring programme's design such as sample number and the number of monitoring years, for example.

Investigation of the ability to detect biologically meaningful population trends is an important component of species management and monitoring, providing quantitative information that is useful in the assessment of the monitoring design and of its suitability to the species and its conservation status, and enabling its modification where necessary (e.g., to suit the particular characteristics of a location or species community/group). Statistical power analyses are important tools that can be used to perform such investigations (e.g., Fryer and Nicholson, 1993; Thompson *et al*., 1997; Teilmann *et al*., 2010).

The annual site-based programme for monitoring harbour seals in Ireland, which is conducted annually by the National Parks & Wildlife Service (NPWS) of the Department of Arts, Heritage and the Gaeltacht, has provided an extended dataset of harbour seal counts across 14+ coastal locations for more than 5 years. Data collected between and 2009 and 2013 were analysed extensively in Phase 1 of the current project in order to examine and describe on a site by site basis the influence of environmental and observational covariates on the numbers of harbour seals detected, and to evaluate where possible the trajectory of harbour seal numbers at each monitoring location. In this Phase 2 of the project the same 5-year dataset, along with the statistical models generated under Phase 1, were used to perform more detailed location-specific power analyses in order to:

1) Test the ability of various programme designs to accurately detect specific trends in haul-out count data;
2) Evaluate the most appropriate summary statistics to use in the description of harbour seal population size (i.e., relative abundance).

The results of these investigations provide practical suggestions for the ongoing design of the NPWS harbour seal monitoring programme, in order to assist in the achievement of national and regional surveillance objectives for the species.

Materials and Methods

This section first introduces the concept of simulation testing of statistical power. This is followed by a detailed description of the power scenarios tested during Phase 2 of the project and the methods used to estimate power. Finally, methods to synthesise and display the power analysis results are presented.

Statistical Power

Hypothesis testing includes two possible types of errors: Type I error, which refers to the probability of incorrectly rejecting a true null hypothesis (α, i.e., the significance level of a test), while Type II error refers to a failure to reject the null hypothesis when it is false. Statistical power is the probability of correctly rejecting the null hypothesis when it is false: (Power=1-β, where: β is the probability associated with Type II error).

In trend analysis, statistical power describes the probability of detecting a significant trend. Traditionally, power analysis was limited to mathematically tractable hypothesis testing frameworks of increasing complexity. More recently, computer simulation has allowed for increased biological realism (e.g., multiple levels of variability) to be incorporated into computational simulations, which are then used to assess the power of methods to recover the true trend from the simulated data (Bolker, 2008).

Simulation scenarios

Population change (trend)

If the population changed by a consistent annual rate of growth/decline *r*, the deterministic number of individuals in the next year, given a starting population size of N_0 is given by

$$N_1 = N_0(1 + r) \quad (1)$$

And the number of individuals in year *t* is given by

$$N_t = N_0(1 + r)^t \quad (2)$$

We simulated a suite of populations with r={-0.05,-0.1,-0.2}, corresponding to a consistent population decline of 5%, 10% and 20% per annum respectively. Note that the population numbers are bounded below ($N_t \geq 0$), whereas the population is unbounded above in Equation 2 so that a consistent 5% per annum decline results in a 40% decrease over 10 years (i.e., N_0(1-0.05)^10), whereas a 5% growth per annum results in a 63% increase over the same time period (i.e., N_0(1+0.05)^10). This observation implies that for a given time period the power to detect a given rate of increase in population size may be greater than the power to detect an equivalent rate of decline. Biologically, populations of wild animals are normally bounded above in terms of density-dependent processes. Given the relatively short time-series of count data available to this project (5 years) and the Habitats Directive objective of maintaining or restoring populations to a 'favourable conservation status' we don't attempt to formulate density-dependent models but rather treat the power to detect population declines as a lower bound on the power to detect increases. That is, a finding of a power of 0.7 to detect a 5% per annum decrease over 10 years is interpreted as a lower bound on the power to detect the equivalent increase in a geometrically increasing simulated population.

In general accordance with the 6-year reporting cycle for the EC Habitats Directive, we carried out power simulations over monitoring periods spanning 2-10 years in order to capture the statistical likelihood of detecting trends at sites within 1-2 reporting cycles. As set out below, this analysis involved the use of real field data from a wide range of harbour seal haul-out sites in Ireland and gathered under a standardised set of survey conditions (i.e., a survey protocol) that takes account of the optimal time of day, weather conditions, etc for surveying the species (NPWS, 2012).

Programme design

The principal goal of the statistical power analysis undertaken in this phase of the project was to test the power of the given monitoring programme design to detect trends in harbour seal haul-out counts. In order to achieve that, a set of **programme design variables** were considered:

- Inter-annual frequency of surveys (every year; every second year)
- Number of survey visits per year (1, 2 or 3 visits per location)
- Tidal range (i.e. counts only in: neap tides; spring tides; or randomly in accordance with their proportion in the 2009-2013 data)
- For land-based monitoring data only: Number of counts with respect to Tidal State:
    - Three counts at one-hour intervals before and after the local time of Low Water (-1,0,1);
    - Five counts at one-hour intervals before and after the local time of Low Water (-2,-1,0,1,2).

Combinations of all possible monitoring programme design and population change scenarios generated a set of 108 (land-based) and 54 (boat-based) possible scenarios per count location, respectively (Table 1).

Table 1. Simulation design scenarios. Each half-row corresponds to a simulation design setting implemented per monitoring location. *Visits* corresponds to the number of visits per annum; Tidal Range "*Data*" corresponds to the sampling from the observed proportion of spring and neap tides observed for a given location. Boat-based analyses did not include the two Tidal State scenarios.

Scenario	Monitoring	Visits	Tidal Range	Tidal States	%Change	Scenario	Monitoring	Visits	Tidal Range	Tidal States	%Change
1	Every year	1	Data	-2,-1,0,1,2	5	55	Every two years	1	Data	-2,-1,0,1,2	5
2	Every year	1	Data	-2,-1,0,1,2	10	56	Every two years	1	Data	-2,-1,0,1,2	10
3	Every year	1	Data	-2,-1,0,1,2	20	57	Every two years	1	Data	-2,-1,0,1,2	20
4	Every year	1	Data	-1,0,1	5	58	Every two years	1	Data	-1,0,1	5
5	Every year	1	Data	-1,0,1	10	59	Every two years	1	Data	-1,0,1	10
6	Every year	1	Data	-1,0,1	20	60	Every two years	1	Data	-1,0,1	20
7	Every year	1	Neap	-2,-1,0,1,2	5	61	Every two years	1	Neap	-2,-1,0,1,2	5
8	Every year	1	Neap	-2,-1,0,1,2	10	62	Every two years	1	Neap	-2,-1,0,1,2	10
9	Every year	1	Neap	-2,-1,0,1,2	20	63	Every two years	1	Neap	-2,-1,0,1,2	20
10	Every year	1	Neap	-1,0,1	5	64	Every two years	1	Neap	-1,0,1	5
11	Every year	1	Neap	-1,0,1	10	65	Every two years	1	Neap	-1,0,1	10
12	Every year	1	Neap	-1,0,1	20	66	Every two years	1	Neap	-1,0,1	20
13	Every year	1	Spring	-2,-1,0,1,2	5	67	Every two years	1	Spring	-2,-1,0,1,2	5
14	Every year	1	Spring	-2,-1,0,1,2	10	68	Every two years	1	Spring	-2,-1,0,1,2	10
15	Every year	1	Spring	-2,-1,0,1,2	20	69	Every two years	1	Spring	-2,-1,0,1,2	20
16	Every year	1	Spring	-1,0,1	5	70	Every two years	1	Spring	-1,0,1	5
17	Every year	1	Spring	-1,0,1	10	71	Every two years	1	Spring	-1,0,1	10
18	Every year	1	Spring	-1,0,1	20	72	Every two years	1	Spring	-1,0,1	20
19	Every year	2	Data	-2,-1,0,1,2	5	73	Every two years	2	Data	-2,-1,0,1,2	5
20	Every year	2	Data	-2,-1,0,1,2	10	74	Every two years	2	Data	-2,-1,0,1,2	10
21	Every year	2	Data	-2,-1,0,1,2	20	75	Every two years	2	Data	-2,-1,0,1,2	20
22	Every year	2	Data	-1,0,1	5	76	Every two years	2	Data	-1,0,1	5
23	Every year	2	Data	-1,0,1	10	77	Every two years	2	Data	-1,0,1	10
24	Every year	2	Data	-1,0,1	20	78	Every two years	2	Data	-1,0,1	20
25	Every year	2	Neap	-2,-1,0,1,2	5	79	Every two years	2	Neap	-2,-1,0,1,2	5
26	Every year	2	Neap	-2,-1,0,1,2	10	80	Every two years	2	Neap	-2,-1,0,1,2	10
27	Every year	2	Neap	-2,-1,0,1,2	20	81	Every two years	2	Neap	-2,-1,0,1,2	20
28	Every year	2	Neap	-1,0,1	5	82	Every two years	2	Neap	-1,0,1	5
29	Every year	2	Neap	-1,0,1	10	83	Every two years	2	Neap	-1,0,1	10
30	Every year	2	Neap	-1,0,1	20	84	Every two years	2	Neap	-1,0,1	20
31	Every year	2	Spring	-2,-1,0,1,2	5	85	Every two years	2	Spring	-2,-1,0,1,2	5
32	Every year	2	Spring	-2,-1,0,1,2	10	86	Every two years	2	Spring	-2,-1,0,1,2	10
33	Every year	2	Spring	-2,-1,0,1,2	20	87	Every two years	2	Spring	-2,-1,0,1,2	20
34	Every year	2	Spring	-1,0,1	5	88	Every two years	2	Spring	-1,0,1	5
35	Every year	2	Spring	-1,0,1	10	89	Every two years	2	Spring	-1,0,1	10
36	Every year	2	Spring	-1,0,1	20	90	Every two years	2	Spring	-1,0,1	20
37	Every year	3	Data	-2,-1,0,1,2	5	91	Every two years	3	Data	-2,-1,0,1,2	5
38	Every year	3	Data	-2,-1,0,1,2	10	92	Every two years	3	Data	-2,-1,0,1,2	10
39	Every year	3	Data	-2,-1,0,1,2	20	93	Every two years	3	Data	-2,-1,0,1,2	20
40	Every year	3	Data	-1,0,1	5	94	Every two years	3	Data	-1,0,1	5
41	Every year	3	Data	-1,0,1	10	95	Every two years	3	Data	-1,0,1	10
42	Every year	3	Data	-1,0,1	20	96	Every two years	3	Data	-1,0,1	20
43	Every year	3	Neap	-2,-1,0,1,2	5	97	Every two years	3	Neap	-2,-1,0,1,2	5
44	Every year	3	Neap	-2,-1,0,1,2	10	98	Every two years	3	Neap	-2,-1,0,1,2	10
45	Every year	3	Neap	-2,-1,0,1,2	20	99	Every two years	3	Neap	-2,-1,0,1,2	20
46	Every year	3	Neap	-1,0,1	5	100	Every two years	3	Neap	-1,0,1	5
47	Every year	3	Neap	-1,0,1	10	101	Every two years	3	Neap	-1,0,1	10
48	Every year	3	Neap	-1,0,1	20	102	Every two years	3	Neap	-1,0,1	20
49	Every year	3	Spring	-2,-1,0,1,2	5	103	Every two years	3	Spring	-2,-1,0,1,2	5
50	Every year	3	Spring	-2,-1,0,1,2	10	104	Every two years	3	Spring	-2,-1,0,1,2	10
51	Every year	3	Spring	-2,-1,0,1,2	20	105	Every two years	3	Spring	-2,-1,0,1,2	20
52	Every year	3	Spring	-1,0,1	5	106	Every two years	3	Spring	-1,0,1	5
53	Every year	3	Spring	-1,0,1	10	107	Every two years	3	Spring	-1,0,1	10
54	Every year	3	Spring	-1,0,1	20	108	Every two years	3	Spring	-1,0,1	20

Simulation routine

For controllable programme design settings (i.e., the number of visits, tidal range during visits, tidal states observed and monitoring frequency) settings were given by the scenarios (Table 1). The number of visits was used in order to randomly sample from a theoretical survey date occurring within 3 days either side of the following target survey dates: 10th August, 24th

August, and 7th of September. On a given survey day, the theoretical earliest and latest hours of first count were set at 10:00hrs and 16:00hrs local time, respectively. For environmental covariates (i.e., weather, wind direction, wind speed, disturbance presence), by-visit data per survey location were generated by sampling to reflect the proportions in the observed data. For example, if 90% of observed wind directions for a given location were westerly, approximately 90% of the simulated wind directions associated with the simulated count data would also be westerly. For categorical covariates, contrast was ensured by including at least two categories in each sample generated. This approach allowed for the generation of random but realistic values for the covariates at each location.

Statistical analysis of the 5-year NPWS dataset in Phase 1 of the project resulted in a set of best-fitting Poisson generalized linear models (GLM) for the boat-based locations and Poisson generalized linear mixed effects models (GLMMs) for the land-based locations. The model coefficients/effects (see Phase 1 report Appendix 3) for each location were used to predict the mean count per tidal state (i.e., mean rate λ) for the given simulated covariate dataset.

Both trend and inter-annual variability unrelated to the trend were included in the simulation framework (Fryer and Nicholson, 1993; Thompson *et al*., 1997; Teilmann *et al*., 2010). To include the inter-annual non-trend natural variability, a linear model was fitted to the log year effects from the best-fitting models per location from Phase 1 and the standard deviation of the residuals was taken as the inter-annual non-trend variation (Figures 1a,1b). Alternative formulations (i.e., additive models) for separating sources of variation (Fryer and Nicholson, 1993) were not considered given that five years of standardised count data were available from which to estimate the variability.

The location haul-out counts were simulated as

$$N_{i,t} \sim \mathrm{Pois}(\hat{\lambda}_i (1+r)^{\mathrm{t}} e^{\eta_t}) \quad (3)$$

where $N_{i,t}$ is the (see Phase 1 report) simulated haul-out count for observation *i* in simulation year *t*, $\hat{\lambda}_i$ is the mean rate predicted for the set of simulated covariates for observation *i*, *r* is the annual proportion/percentage change and η_t is the inter-annual non-trend deviation, assumed to be normally distributed $\eta_t \sim \mathrm{N}(-\sigma_\eta^2/2, \sigma_\eta^2)$ where σ_η is the inter-annual non-trend variability. The non-zero mean is a bias correction.

For each distinct survey location a set of 250 simulated count datasets was generated per design scenario (Table 1) and the trend (i.e., rate of change) was estimated per dataset using the following criteria:

1) Continuous trend in raw yearly mean counts;
2) Continuous trend in raw yearly maximum counts;
3) Continuous trend estimated from a GLMM fit to the simulated data.

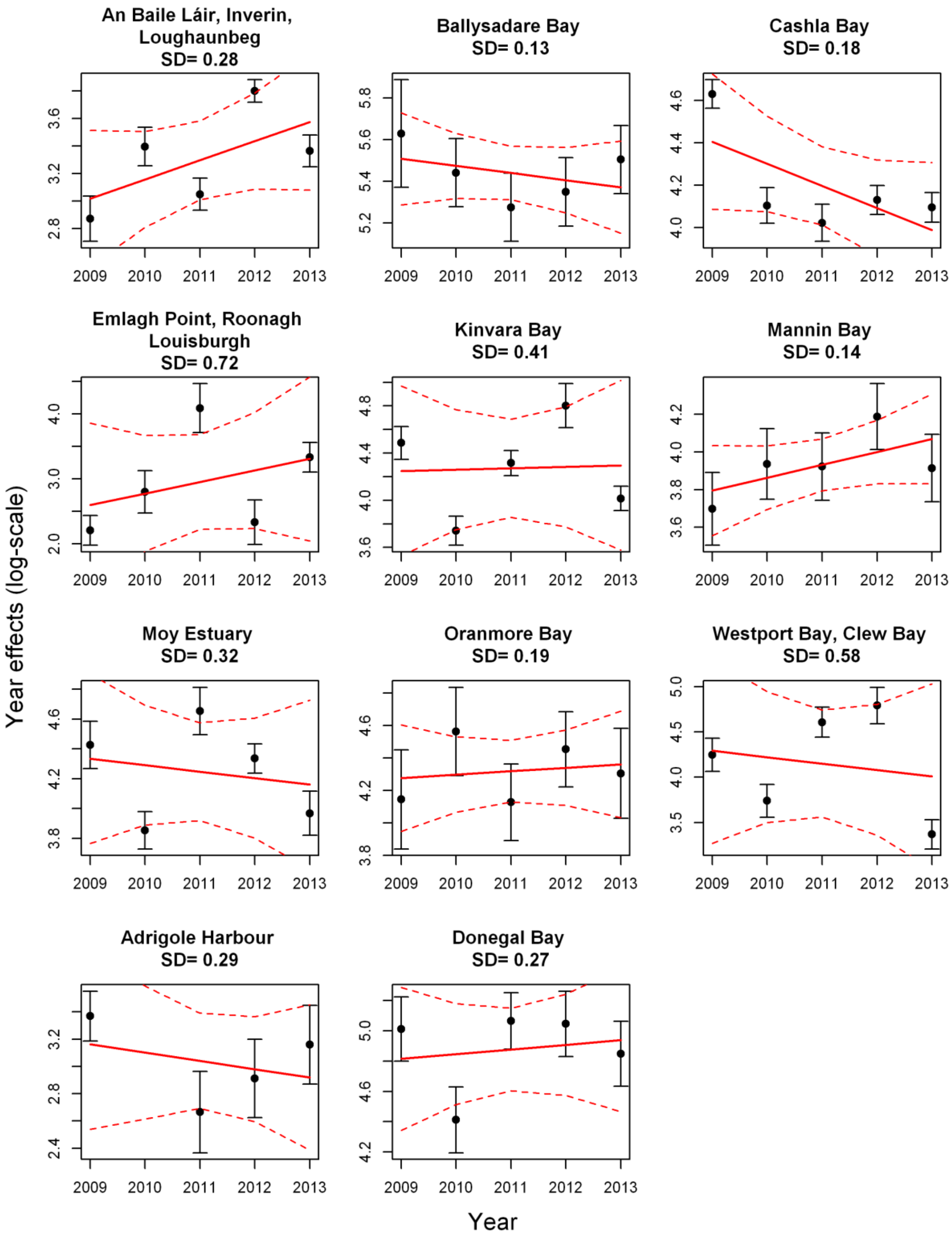

Figure 1a. Linear fits to the estimated year effects (black points with 95% *Confidence Intervals (CI)*) from the best fitting GLMMs for all land-based monitoring locations analysed in Phase 1 of the project. Red solid and dashed lines are the mean fitted linear trend and 95% CI on the trend, respectively. The residual standard deviation (*SD,* which approximates the CV on this scale) is shown above each panel. Note that in some cases the year effects are well estimated (small CIs) but there is a lot of inter-annual variability shown in the year effects (e.g., Westport Bay, Clew Bay, Kinvara Bay).

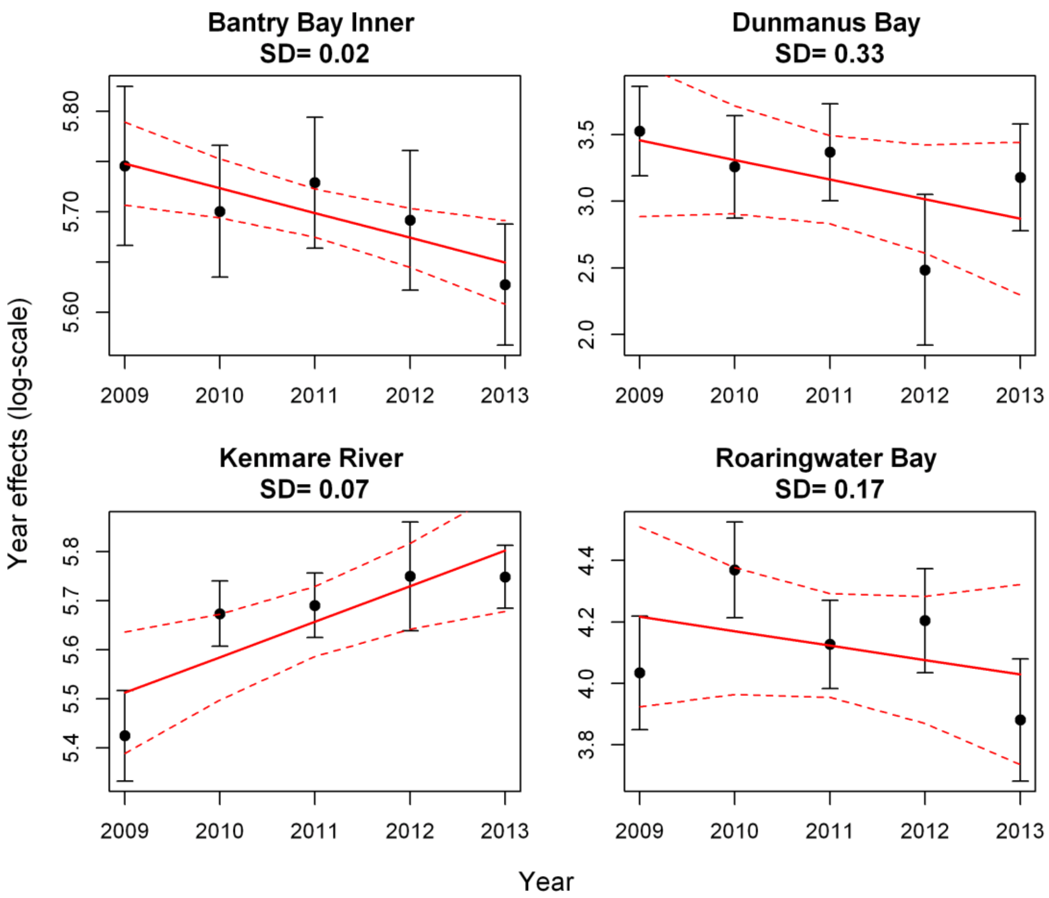

Figure 1b. Linear fits to the estimated year effects (black points with 95% CI) from the best fitting GLMs for all boat-based monitoring locations analysed in Phase 1 of the project. Further legend details are provided in the caption for Figure 1a.

For each survey location, the proportion of 250 replicates from which significantly changing trends (in the direction simulated) were estimated at a α=0.05 level formed the power to detect the trend. For example, if 125 out of 250 simulations successfully described a statistically significant annual decrease, the power to detect that trend would be 50%. The simulation design is summarised in Figure 2.

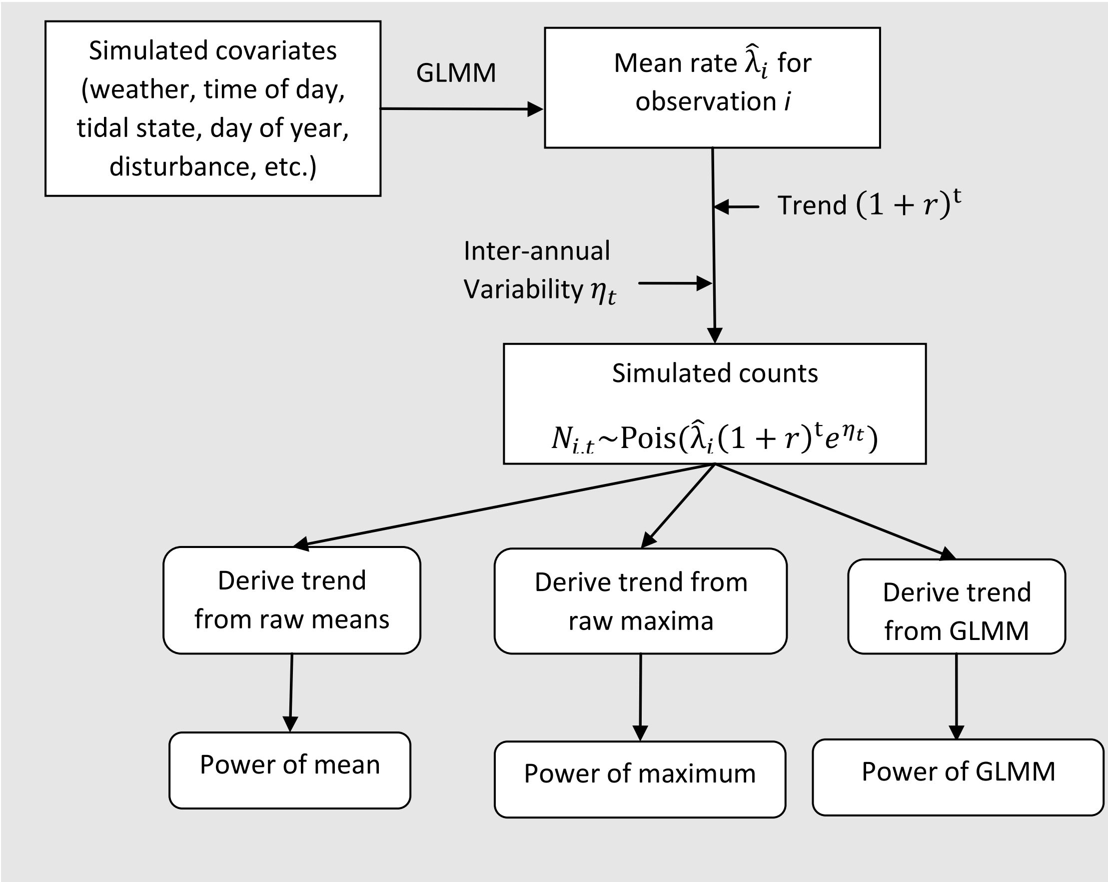

Figure 2. Flowchart of the simulation framework for a given design scenario setting (from Table 1).

Power summaries

The many combinations of simulation scenarios (Table 1) resulted in many power curves per location (108 land-based; 54 boat-based). These are of considerable use to by-location survey design in that they demonstrate the importance of specific design settings on the power to detect change with a high degree of confidence. To further summarise these results we fitted regression trees (De'ath and Fabricius, 2000) to the power analysis results thereby modelling power as a function of the monitoring programme design. Regression trees make no parametric assumption on the distribution of the response (here power is bounded from zero to one) and they allow for the quick appraisal of the most important design variables and the directional influence on the power to detect trends, including the magnitude of the trend itself (Equation 2). We set the complexity parameter of the 'by-location' regression trees at 0.05 and 'across-locations' at 0.03. The lower complexity parameter for the 'across-location' analysis was chosen because setting it at 0.05 led to trees with few branches.

Results

By-location power

Appendix 1 shows plots of the 108 (land-based) and 54 (boat-based) power scenarios by survey location, respectively. Note that for some single visit land-based data analysis no power curves are plotted owing to the GLMM failing to converge for that combination. This failing was largely restricted to the low power single visit scenarios (Appendix 1).

The power of the modelling approach (GLM and GLMMs) was typically higher than that of the yearly count mean or maxima, reflecting the importance of within-year variability (i.e., covariate effects) and between-visit (random effects) variability in response to environmental and observational variables which are ignored when using the mean or maxima (Appendix 1). In addition, there is only one yearly value contributing to the trend in each of the mean and maxima cases whereas all the data influence the trend in the models, which must also estimate covariate effects. The fact that the simulation and fitting model have the same structure must be noted, however. This effectively assumes that the correct model structure was identified. An approach that finds the best-fitting model structure for each simulated dataset instead of assuming it is known would address this. For the present study, we assumed that the best fitting model could be identified per simulation.

Regression trees by location (Appendix 2) typically showed the primary importance of the number of monitoring years with (i) longer time periods (>6.5 years) having considerably higher power to detect trends in relative abundance. In addition, (ii) the magnitude of the annual change and (iii) the summary statistic (mean, max, or model-derived trend) showed important effects on the statistical power by location (Figure 3). Some locations described considerably higher power for trend detection than others (e.g., Figure 4a: compare Mannin Bay or Ballysadare Bay with Emlagh Point). This outcome reflects the natural variability in counts at some sites both at the within-year and between-year levels.

Two of the boat-based survey locations (Bantry Bay and Kenmare River) displayed a high level of power to detect trends (Figure 4b), reflecting low inter-annual variability unrelated to the trend in these boat-surveyed locations (Figure 1b).

Across-location power

For a given programme design scenario, survey locations clearly differed in the power to detect a given trend (Figures 4a,4b). These differences were evident both in terms of the influence of environmental and observational covariates on the counts (see Phase 1) but also in the amount of non-trend inter-annual variability (Figure 1). When the power to detect trends was analysed across all land-based locations, the inter-annual variability was of considerable importance with those locations describing a lower inter-annual variability typically having a higher power (Figure 5a).

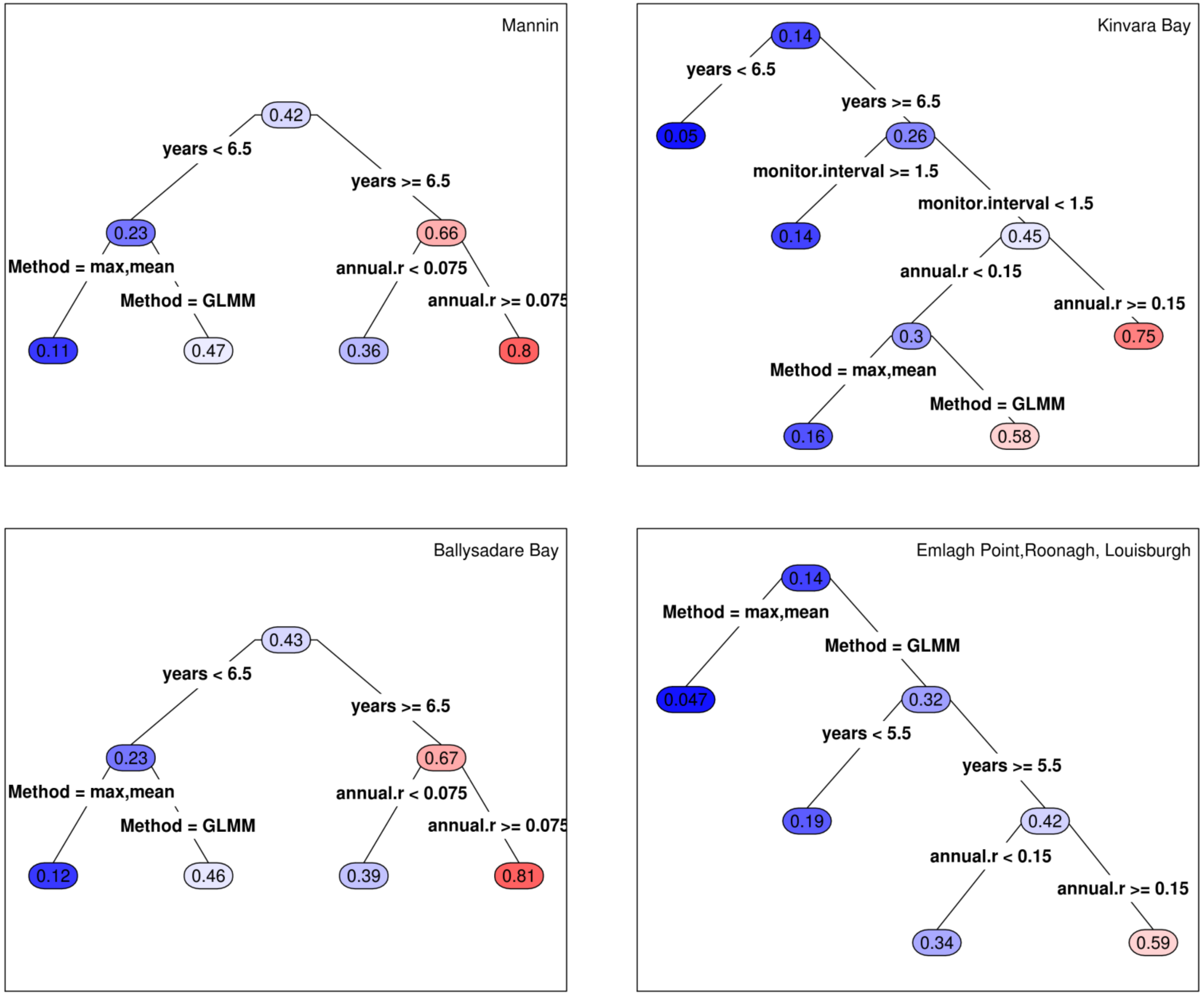

Figure 3. Example of regression trees showing the hierarchy of influence of key programme design elements (e.g., *monitor.interval* the inter-annual frequency of surveys, trend estimation method *mean, max*, *GLMM*) on the power to detect a given rate of change in the sampled population (i.e., *annual.r*) for a set of four land-based monitoring locations. The shaded oval-shaped nodes display the statistical power computed for a given combination of circumstances as relevant to each location. Similar plots for all locations are provided in Appendix 2.

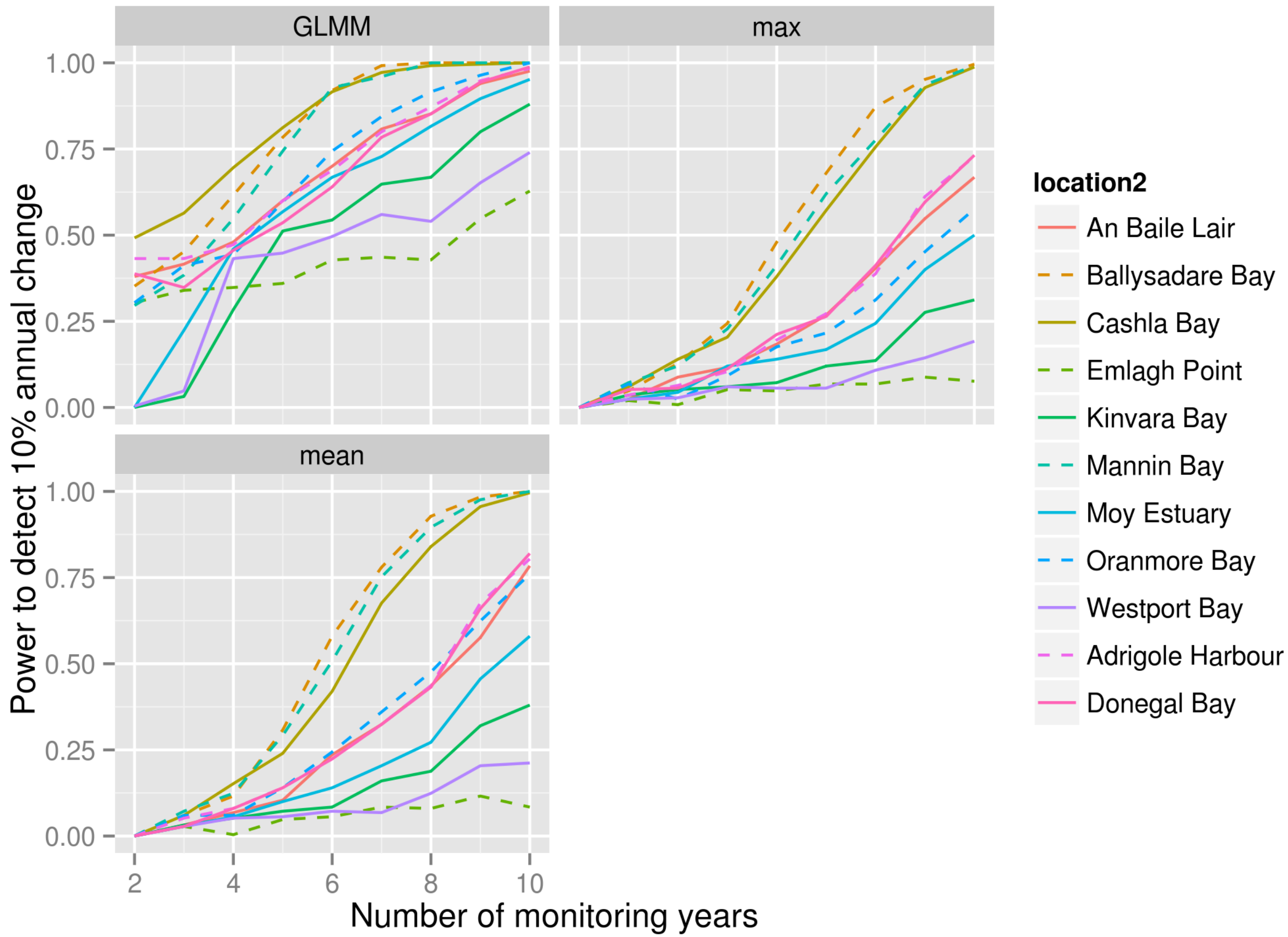

Figure 4a. Comparison of the power to detect a 10% annual change with three visits of 5 counts each per annum across land-based survey locations. Sub-plot headings refer to the method of trend estimation: *GLMM* refers to the modelling method, *mean* to using the yearly mean count, and *max* to using the yearly maximum count.

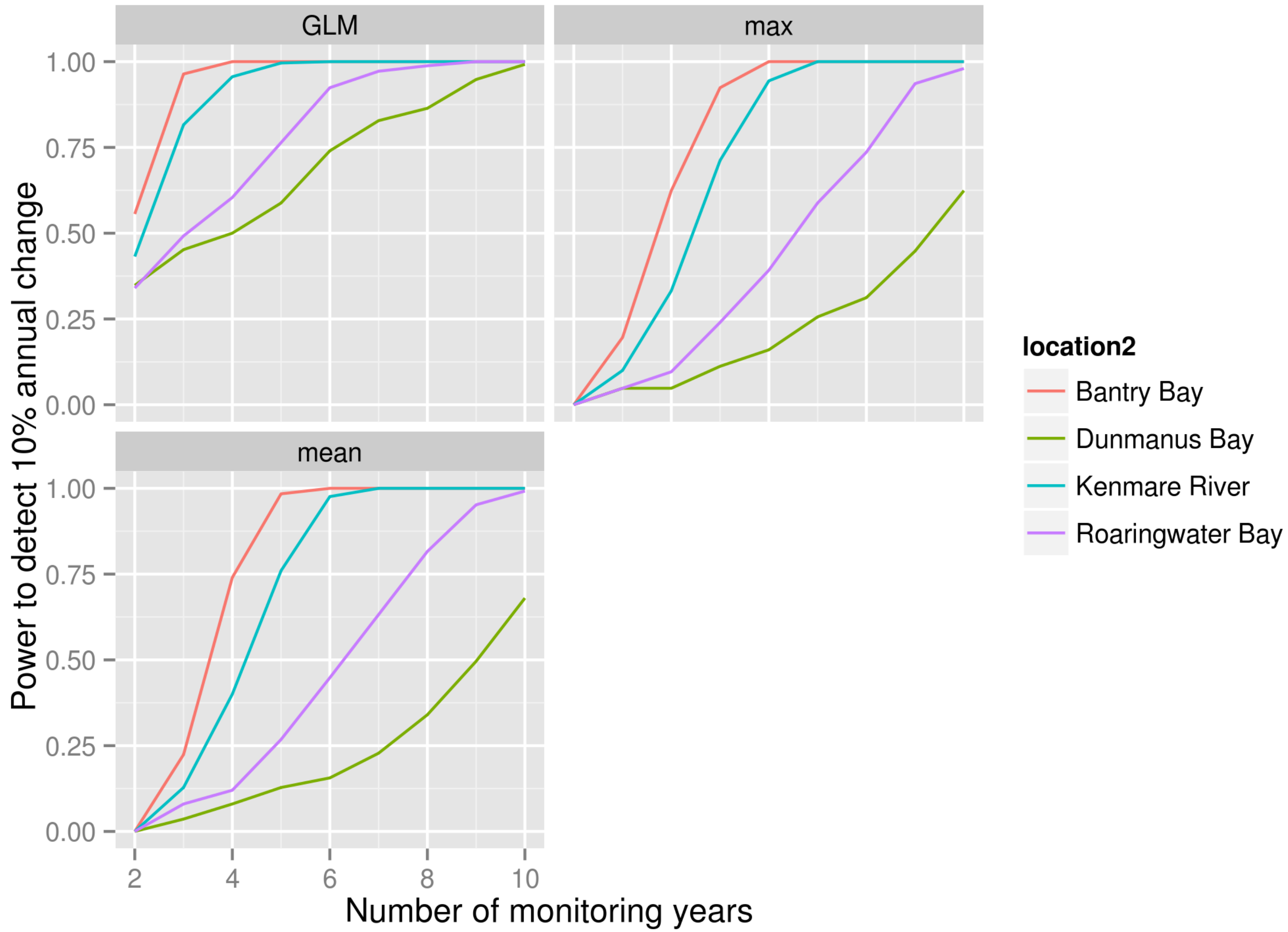

Figure 4b. Comparison of the power to detect a 10% annual change with three surveys per annum across boat-based survey locations. Sub-plot headings refer to the method of trend estimation: *GLM* refers to the modelling method, *mean* to the mean count per year, and *max* to the maximum count per year.

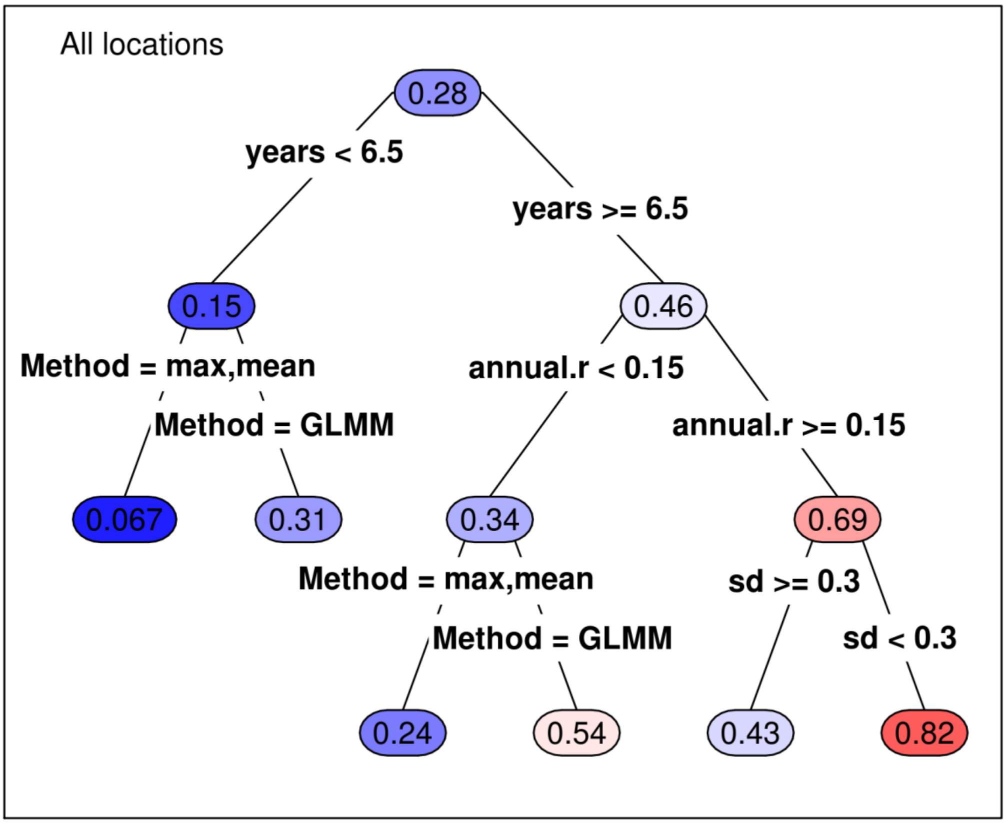

Figure 5a. Regression tree displaying the hierarchy of influence of key programme design elements on the power to detect trends in harbour seal haul-out counts across all land-based monitoring locations. *years* refers to the number of monitoring years, *method* to the summary statistic, *annual.r* to the annual rate of change and *sd* to the inter-annual non-trend variability (see also Figure 1a, Appendix 2). The shaded oval-shaped nodes display the statistical power computed for a given combination of circumstances as relevant to each location.

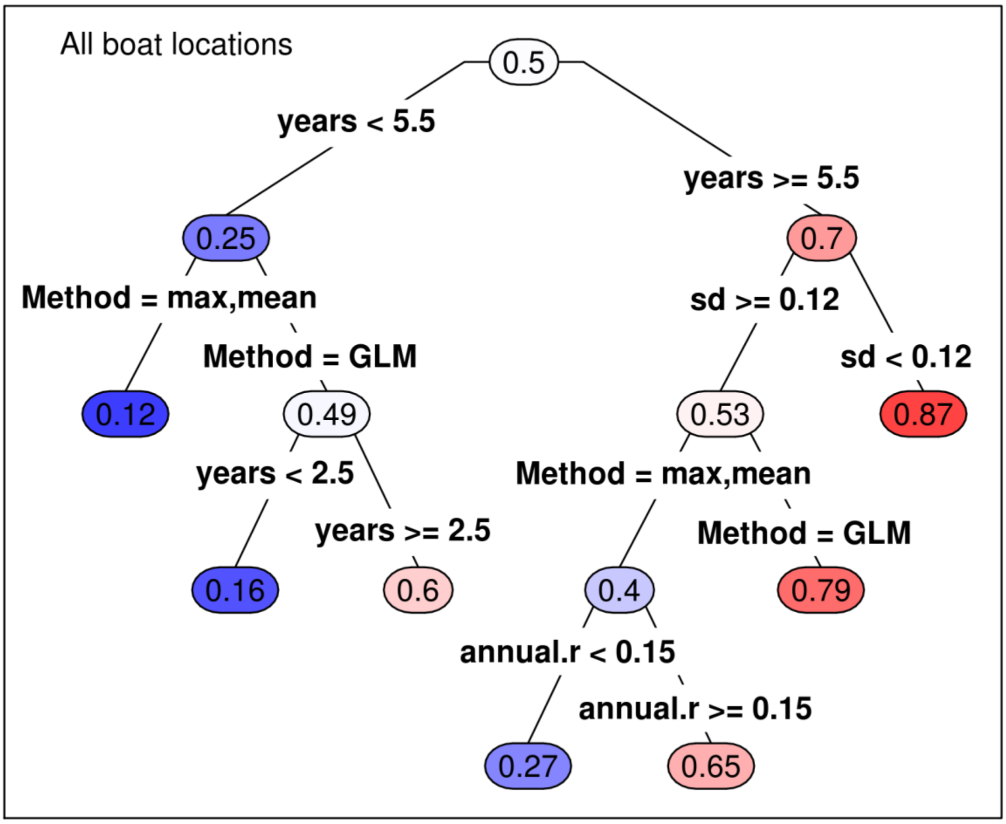

Figure 5b. Regression tree displaying the hierarchy of influence of key programme design elements on the power to detect trends in harbour seal haul-out counts across all boat-based monitoring locations. The shaded oval-shaped nodes display the statistical power computed for a given combination of circumstances as relevant to each location. Further legend details are given in the caption for Figure 5a.

Discussion

Overall findings

Detailed by-location power analyses are provided in graphical format in Appendix 1. These are of considerable importance in evaluating the performance of the analysis undertaken in Phase 2 by individual survey location and for comparing across locations.

Overall we found that, across locations, the power to detect statistically significant changes in harbour seal numbers (via haul-out counts) depended on:

1. The number of years the population was monitored for;
2. The magnitude of the rate of change in the population;
3. The method used to derive the trend;
4. The inter-annual variability unrelated to trend.

By location within the 5-year dataset provided for this analysis, factors such as the monitoring frequency were often important (e.g., Cashla Bay, Kinvara Bay, Moy Estuary, Westport Bay) with considerably lower power to detect trends shown in biennial surveys when compared to annual survey effort (Appendix 2). A general increase in power from one to two survey visits per year was immediately apparent (Appendix 2) and the power to detect a given trend was often strongly influenced by the number of visits per annum (e.g., Appendix 2: Westport Bay, Moy Estuary, Bantry Bay, Dunmanus Bay, Kenmare River). This, along with the higher performance of the modelling method over the mean and maxima counts, highlights the importance to address within-location and between-visits variability both in respect to sampling, by maintaining a high number of visits per year, and in respect to statistical analysis.

Across locations, the power to detect trends for a monitoring period greater than 6.5 and 5.5 years averaged at 46% (land-based locations) and 70% (boat-based locations), respectively (Figures 5a,5b). The power to detect trends from land-based monitoring locations was notably low considering the rate of population changes implemented (Table 1). However the power investigation did include within-year variability in covariate effects, random visit-level effects and between-year variability unrelated to trend. As such, we view the simulation framework as a realistic method for appraising the power to detect trends based on real data collected among diverse field locations, in comparison to more traditional power derivations that must make assumptions, for example, concerning factors influencing the count data used in the analysis and their ability to represent true observations. The simulations we have implemented are in line with the operating model component of management strategy evaluations (Kell *et al.,* 2007) which are widely gaining use in fisheries management procedure evaluations.

The finding that inter-annual variability unrelated to trend is of importance to trend detection points towards methods to address this in order to improve power. Of primary consideration is the option to potentially pool counts from individual land-based survey locations where there is biological evidence that the individuals at given locations may mix or undergo some exchange (e.g., within the same enclosed bay, such as Galway Bay or Clew Bay for example). To analyse the power in that manner would require similar generation methods to those presented here except the inter-annual variability in counts unrelated to trend would be correlated within the region/bay (i.e., by grouping locations) and the results from the estimating models would be combined when estimating the overall trend. The proportion of the animals from a region/bay found in a given survey location would thus vary inter-annually. Such an approach extends to dynamic factor analysis (Zuur *et al*., 2003, Holmes *et al.*, 2012) but this is considered beyond the scope of the present investigations.

A further option in this regard would be to consider modifying or eliminating the involvement of certain land-based or boat-based monitoring locations in the overall monitoring programme where (a) the intrinsic variability in the count data yielded over the previous five years do not provide statistical confidence that substantial trends can realistically be determined in the future, and/or (b) where the numbers of harbour seals observed at such locations are a small proportion of the overall population being monitored. Examples of such locations could be Emlagh Point, Westport Bay (land-based locations) and Dunmanus Bay (boat-based location), all of which displayed comparatively low levels of power to detect significant annual rates of change irrespective of the estimation method used.

It is important to note that both methodological approaches outlined above may improve the power to detect trends within the harbour seal population being monitored without altering the present monitoring programme design, thereby avoiding breaking the time series of survey data and the integrity of the overall monitoring programme for the species.

Acknowledgements

This work was initiated and funded in 2014 by the National Parks & Wildlife Service of the Department of Arts, Heritage and the Gaeltacht under the project "Statistical modelling and power analysis of NPWS Harbour seal monitoring data". We wish at the outset to thank all National Parks & Wildlife Service observers and external personnel who carried out the very substantial survey effort and data entry that contributed to this project, namely Dermot Breen, Carl Byrne, Helen Carty, Cameron Clotworthy, Pat Dawson, Pascal Dower, Leonard Floyd, Emma Glanville, Patrick Graham, Clare Heardman, Gerry Higgins, Tara Keena, James Kilroy, Emer Magee, Lee McDaid, Eoin McGreal, Frank McMahon, Jacinta Murphy, Louise O'Boyle, Irene O'Brien, Oliver Ó Cadhla, Aonghus O'Donaill, Declan O'Donnell, Ger O'Donnell, Barry O'Donoghue, Danny O'Keeffe, Michael O'Sullivan, Tim Roderick, Andrew Speer, Raymond Stephens, Rebecca Teesdale and Fiona Wheeldon. Also thanks to all NPWS District Conservation Officers and senior line management who oversaw regional implementation of the harbour seal monitoring programme in 2009-2013. We are also grateful to Dr Oliver Ó Cadhla, Dr Ferdia Marnell and Dr Eamonn Kelly of the Department of Arts, Heritage and the Gaeltacht and Dr Ian O'Connor and Dr Rick Officer of GMIT for their support towards all stages of the project.

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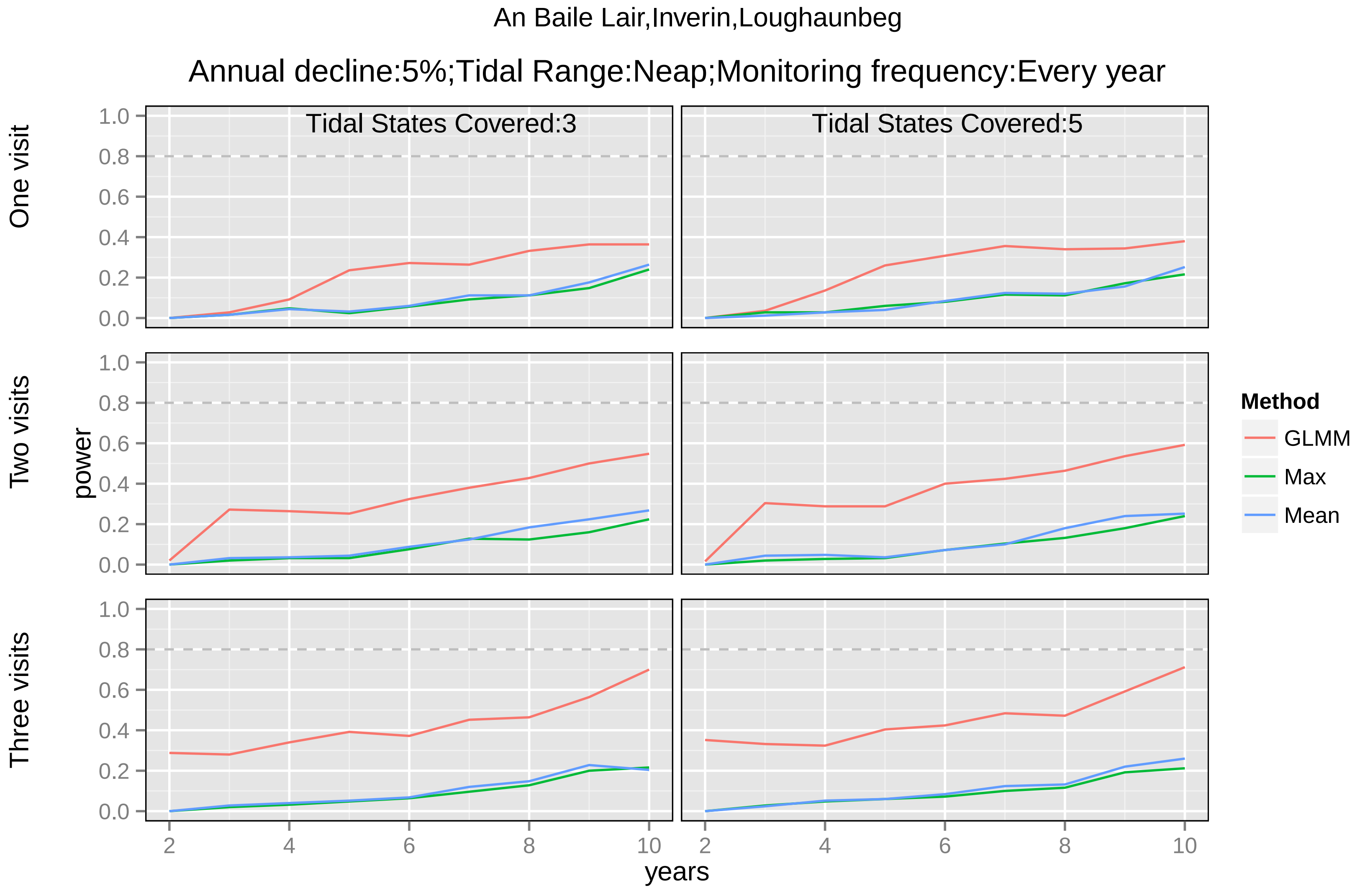
Appendices

Appendix 1

By-location and simulation scenario power curves. Note that for some single visit land-based data analysis no power curves are plotted owing to the GLMM failing to converge for that combination.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Tidal States Covered:5
One visit
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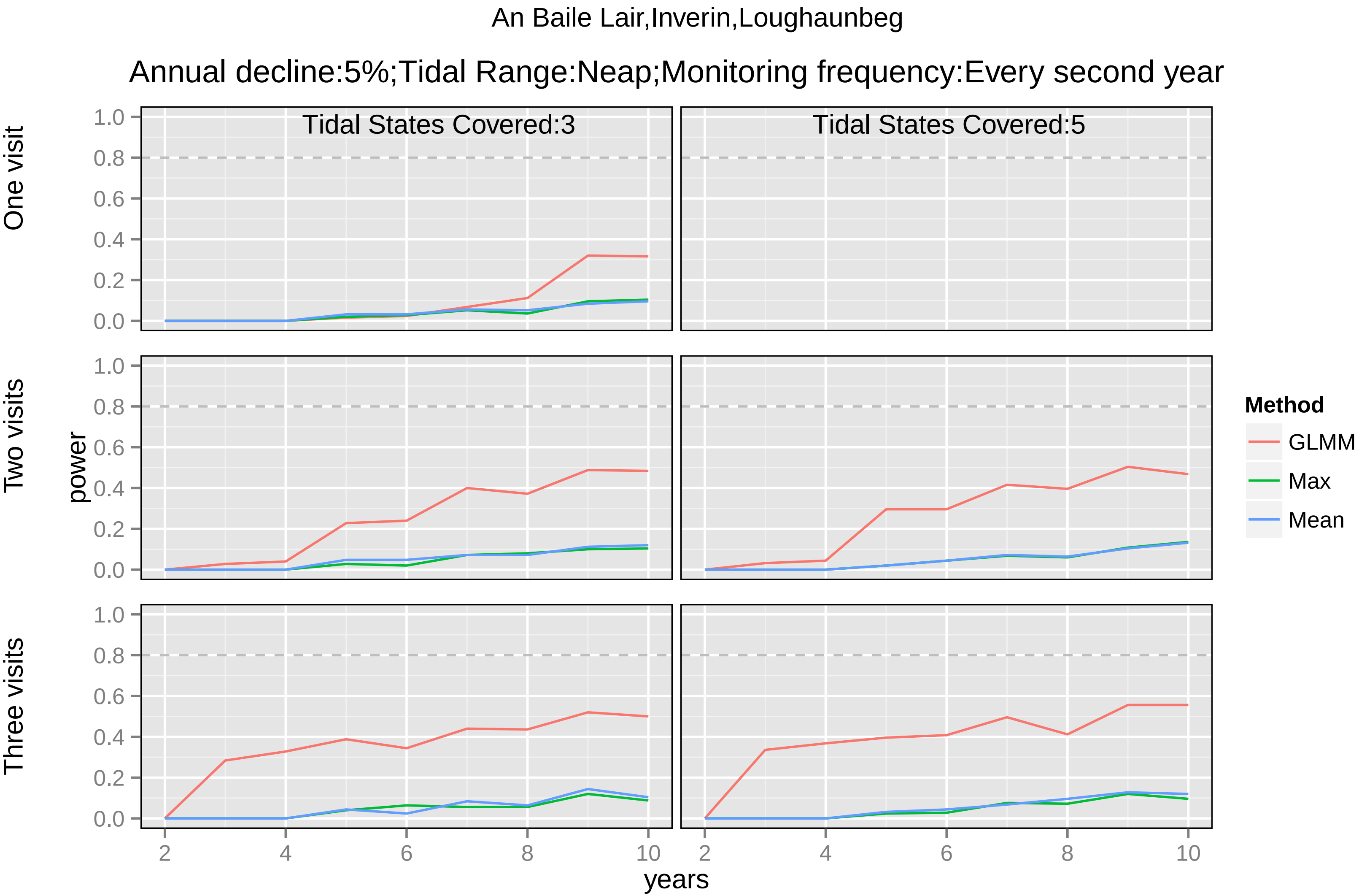

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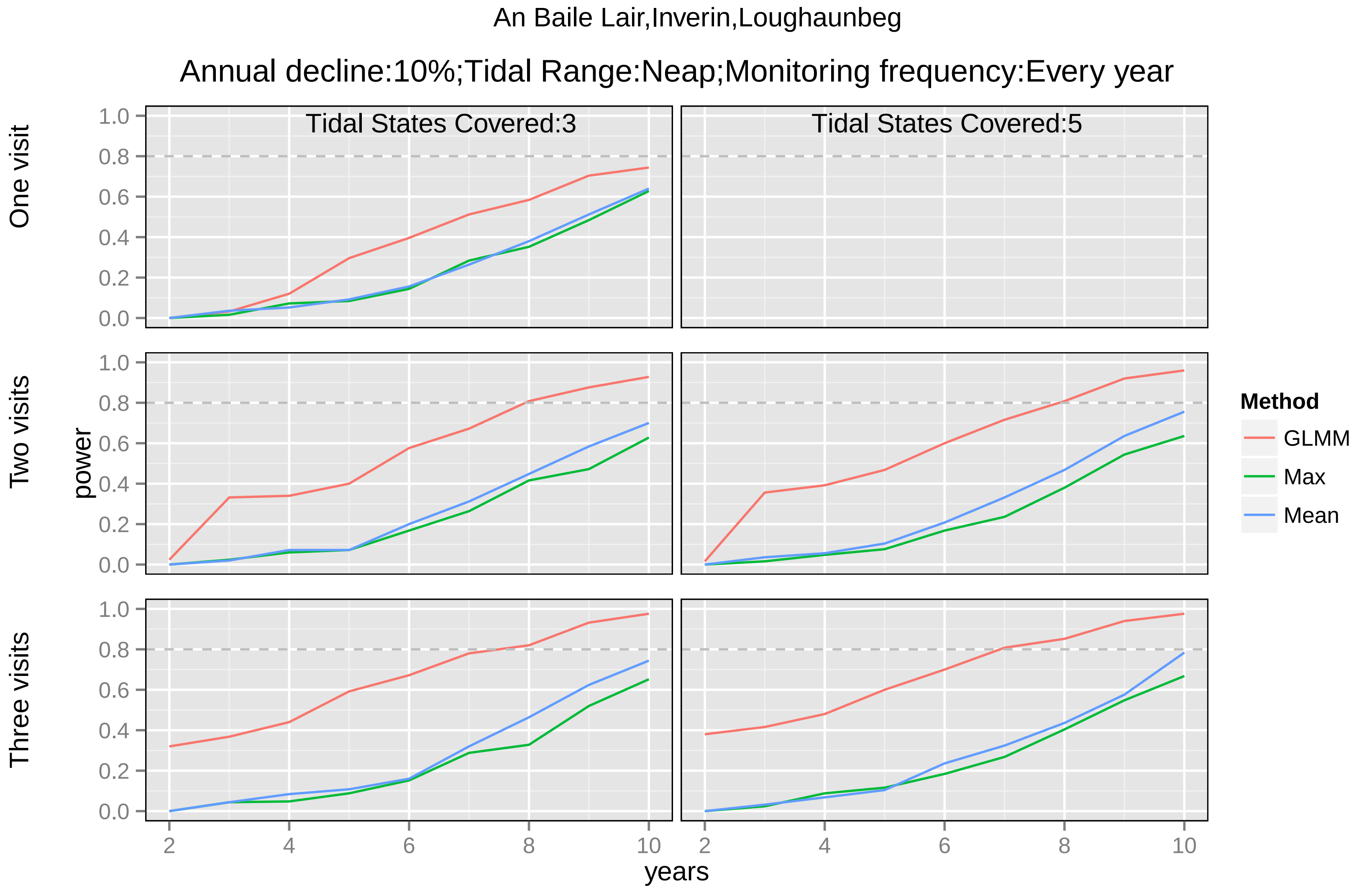

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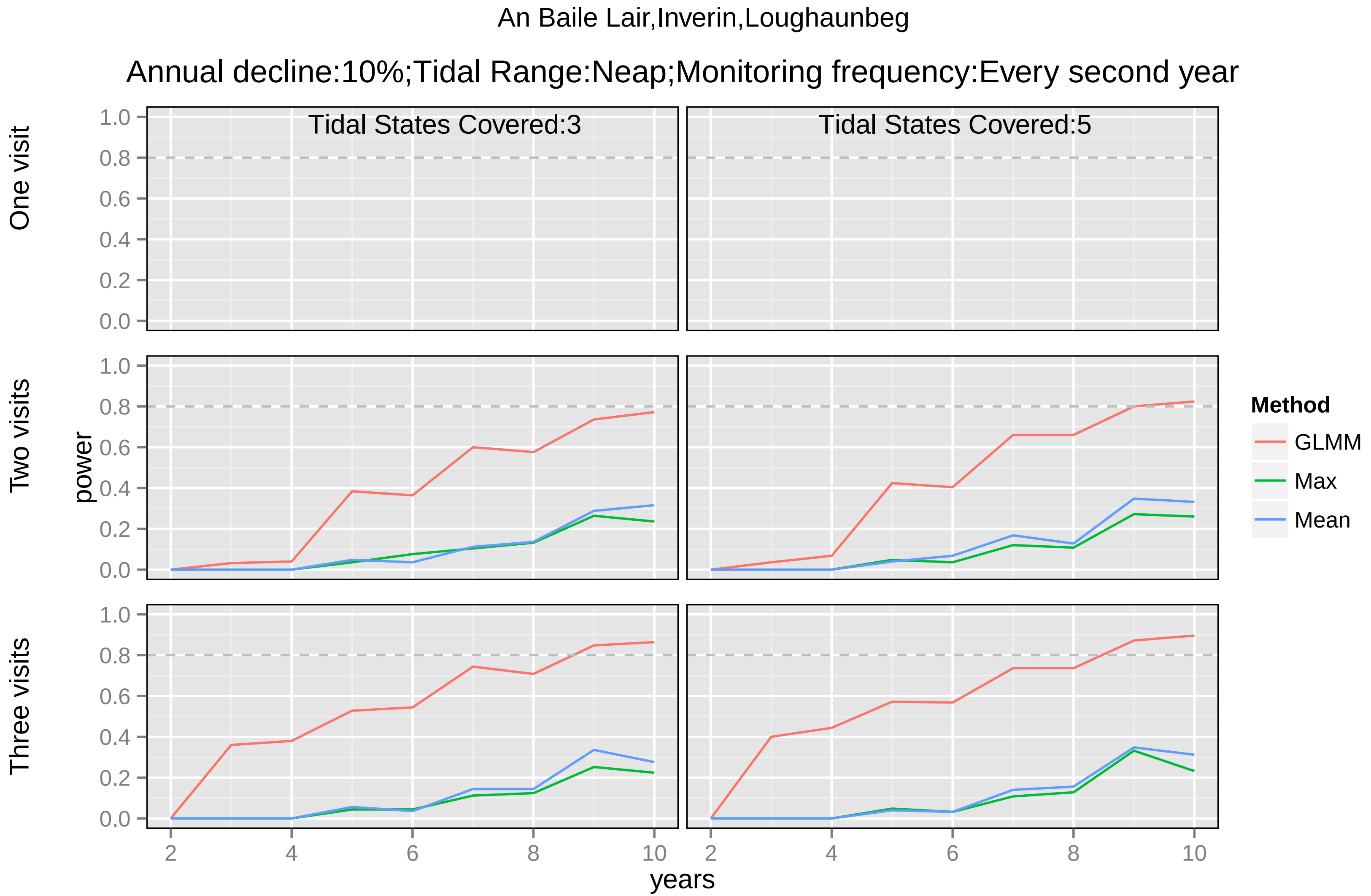
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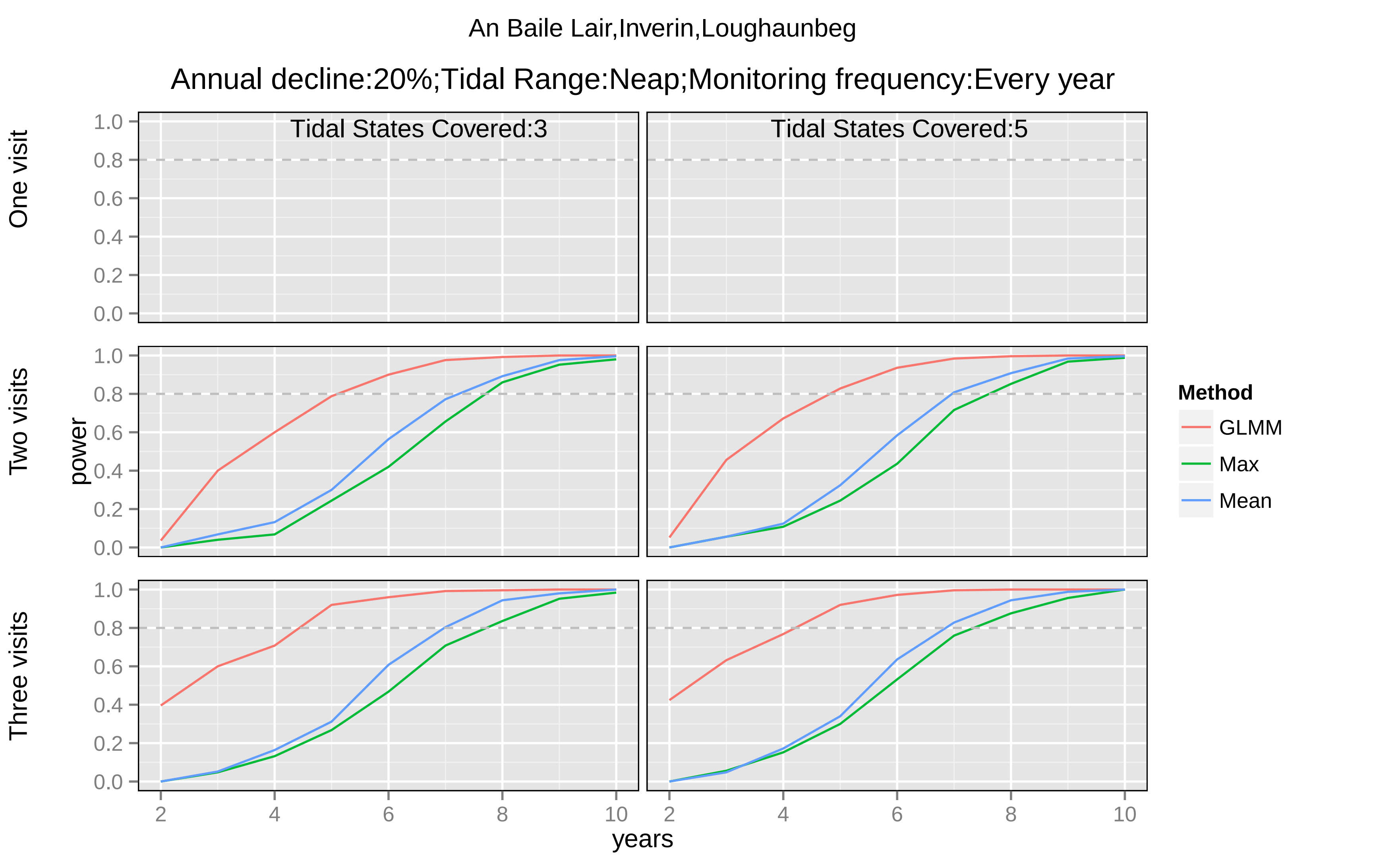

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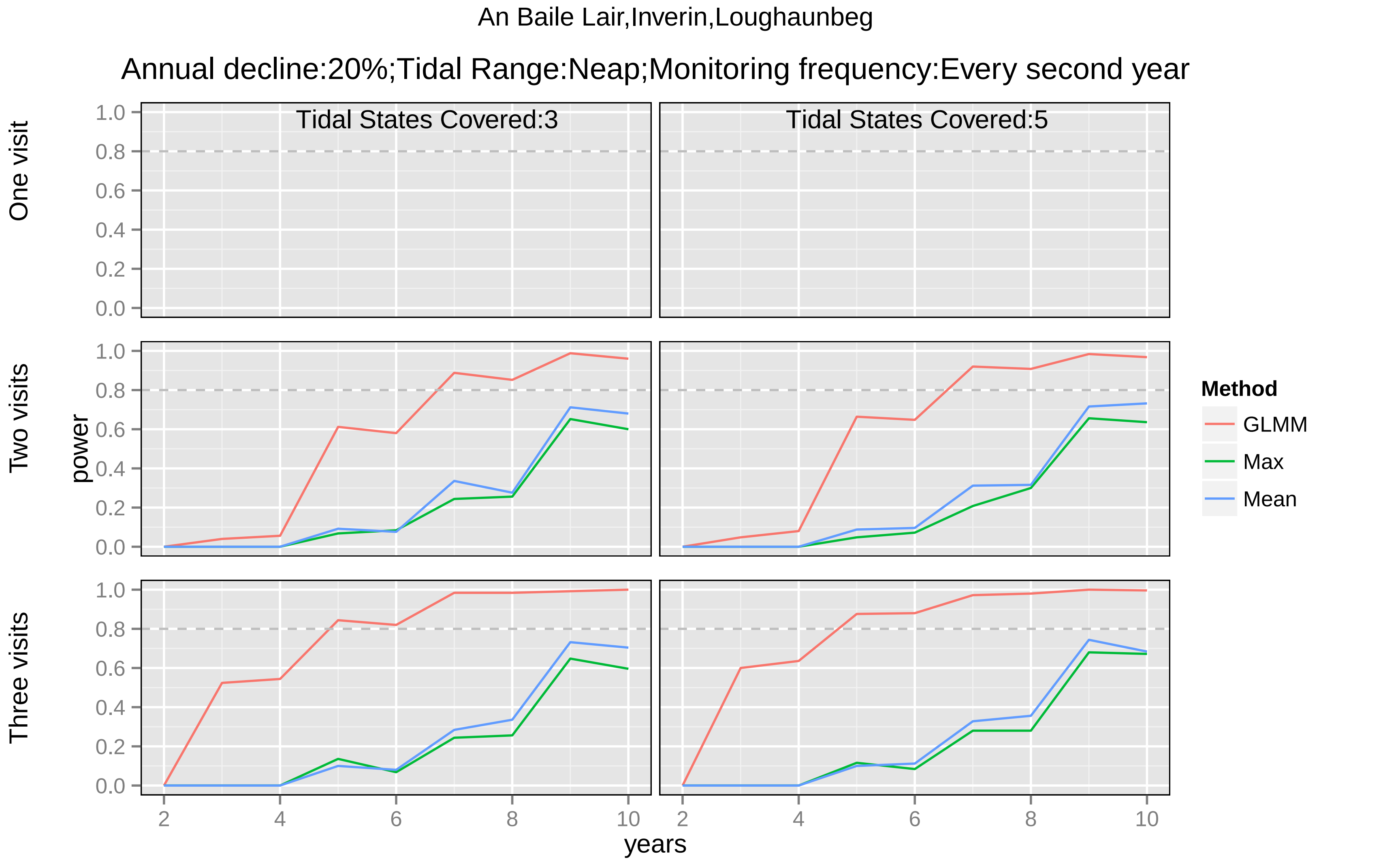
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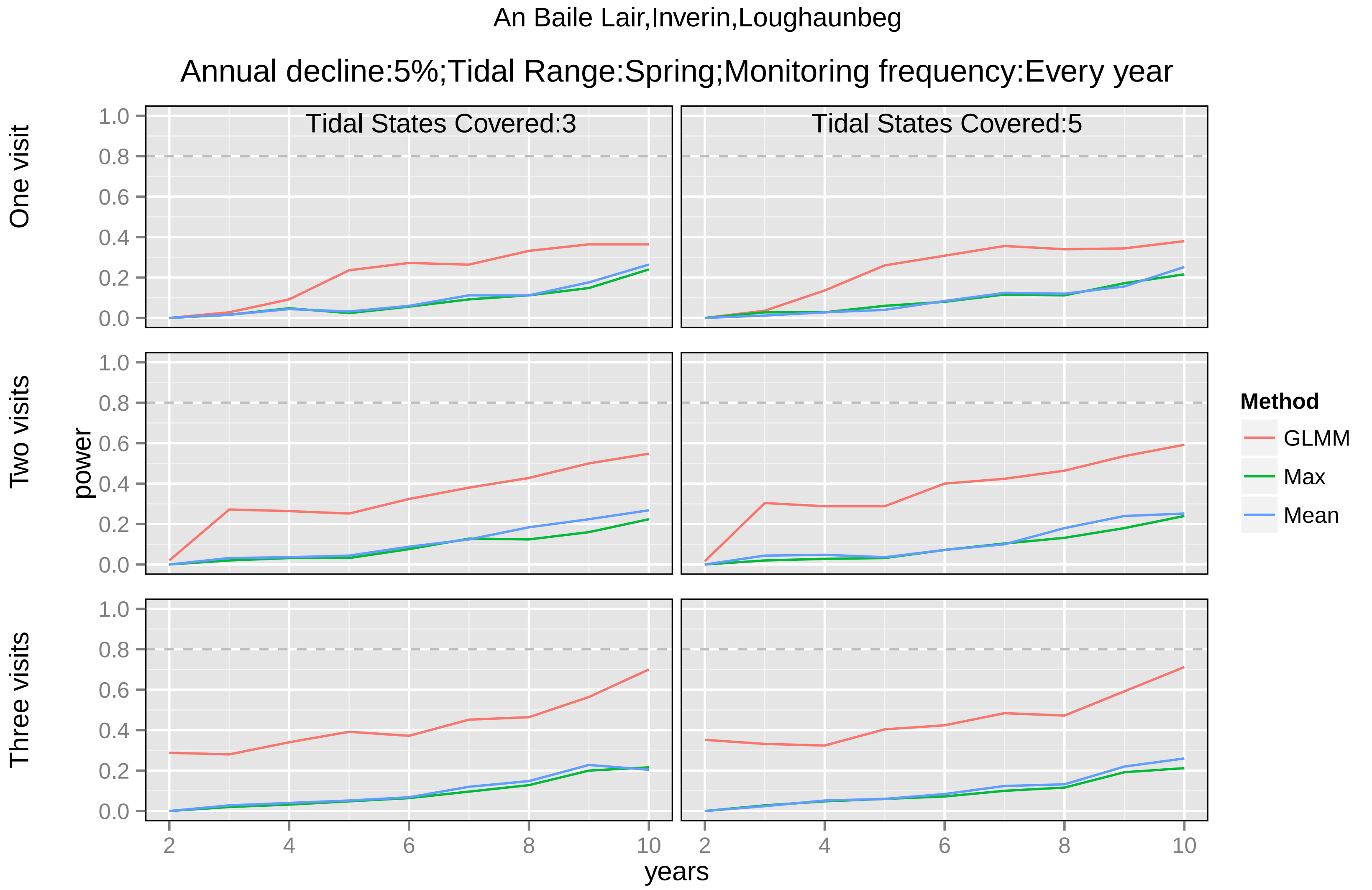

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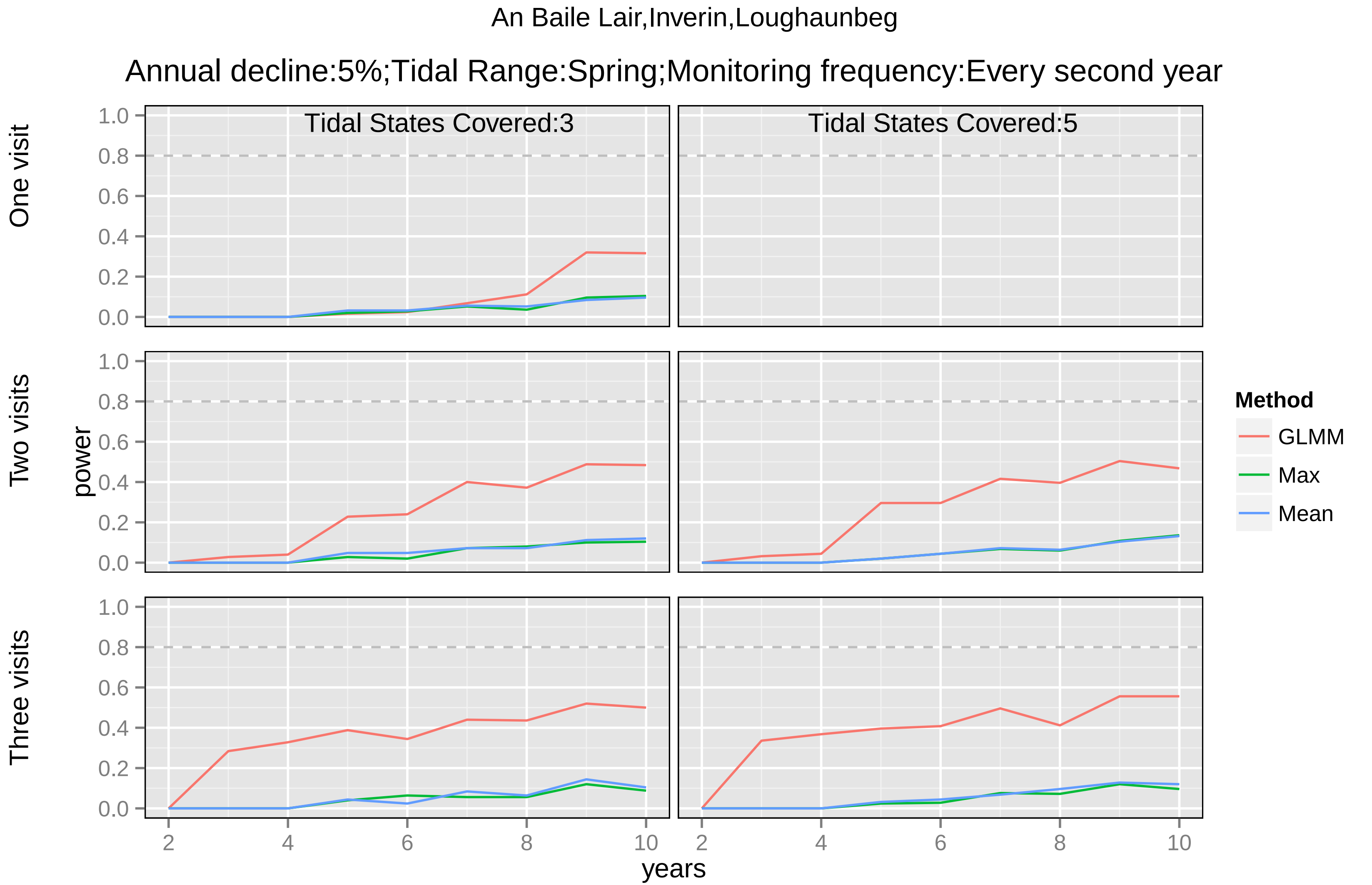

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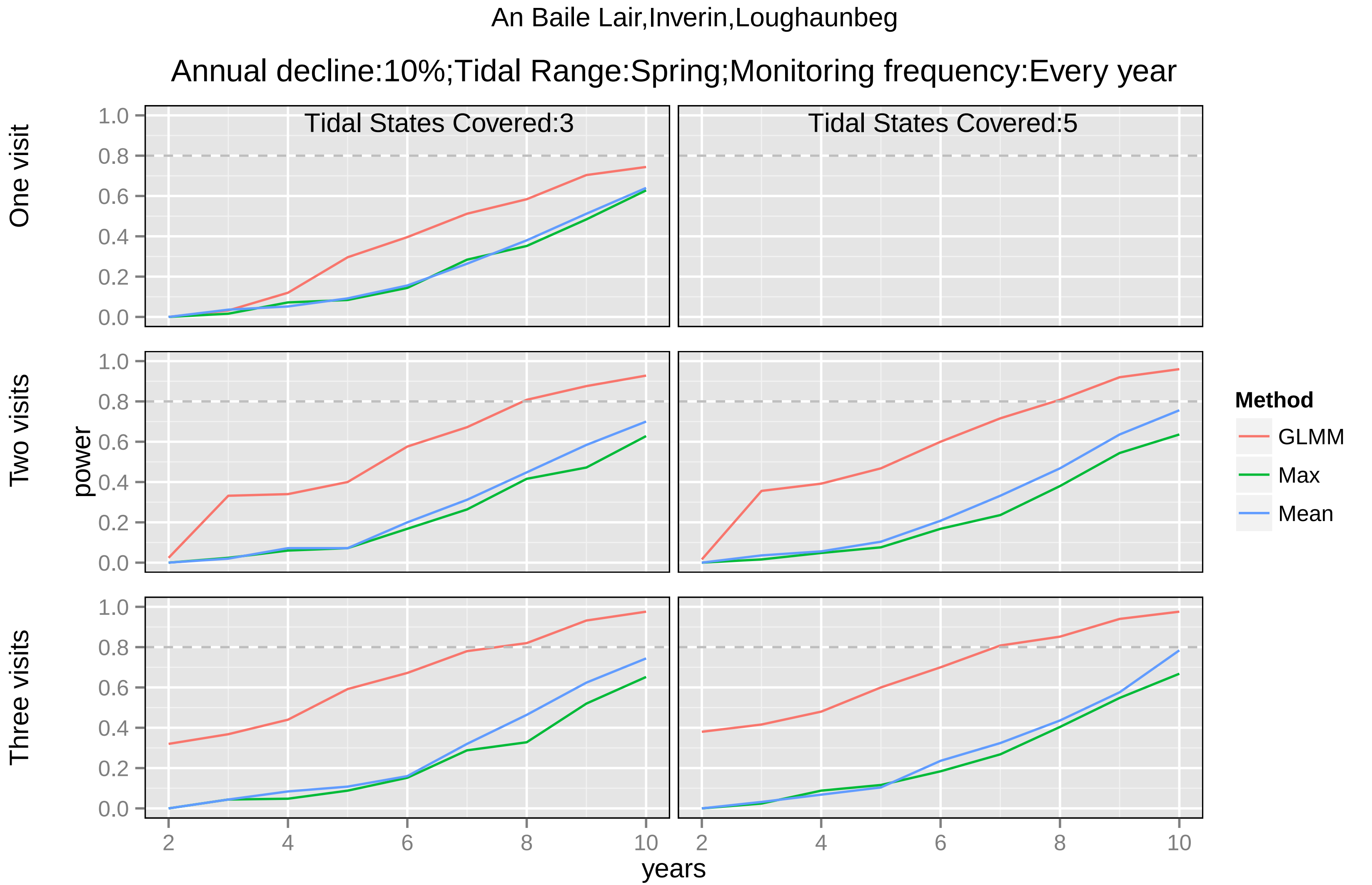

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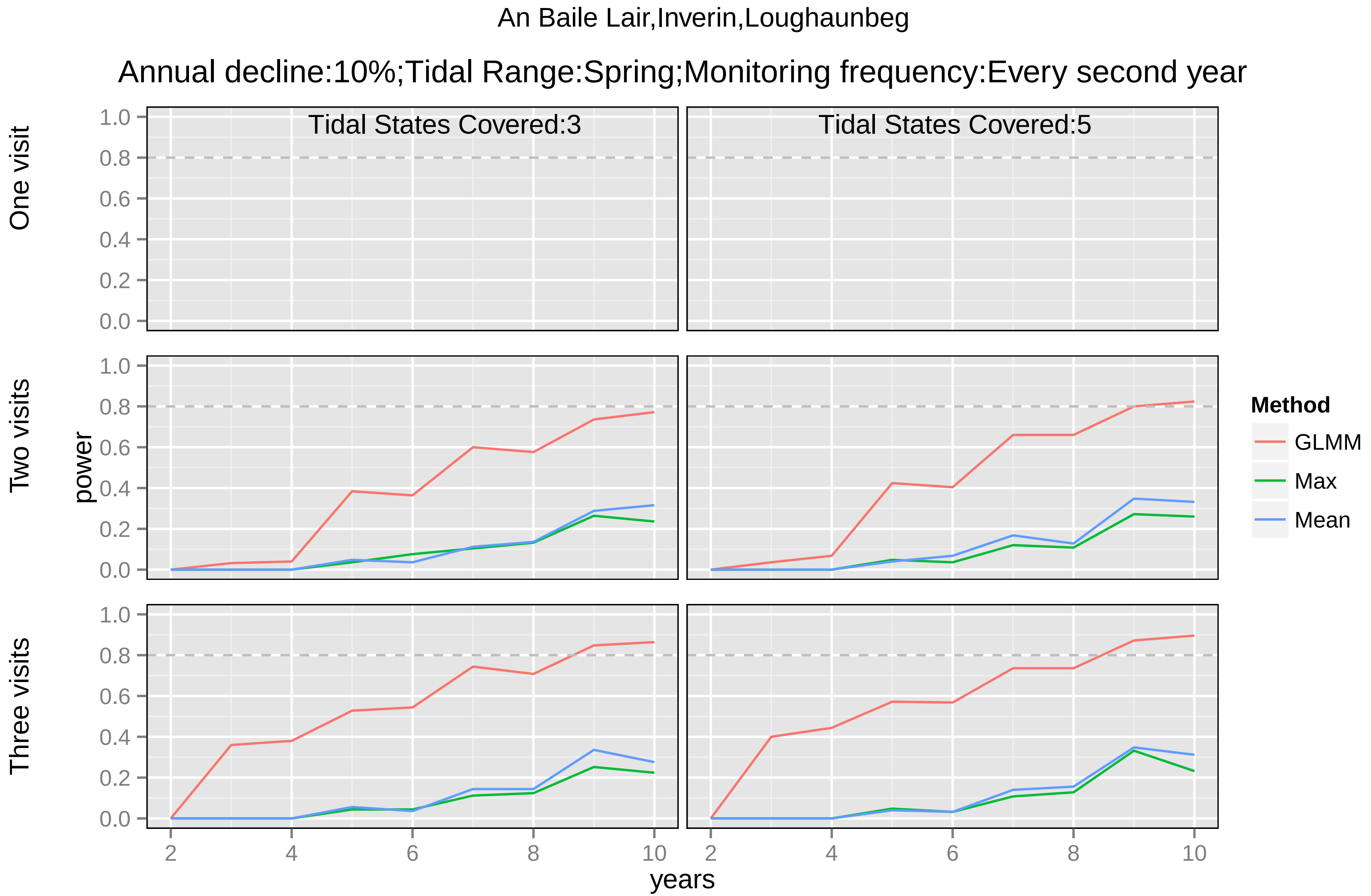
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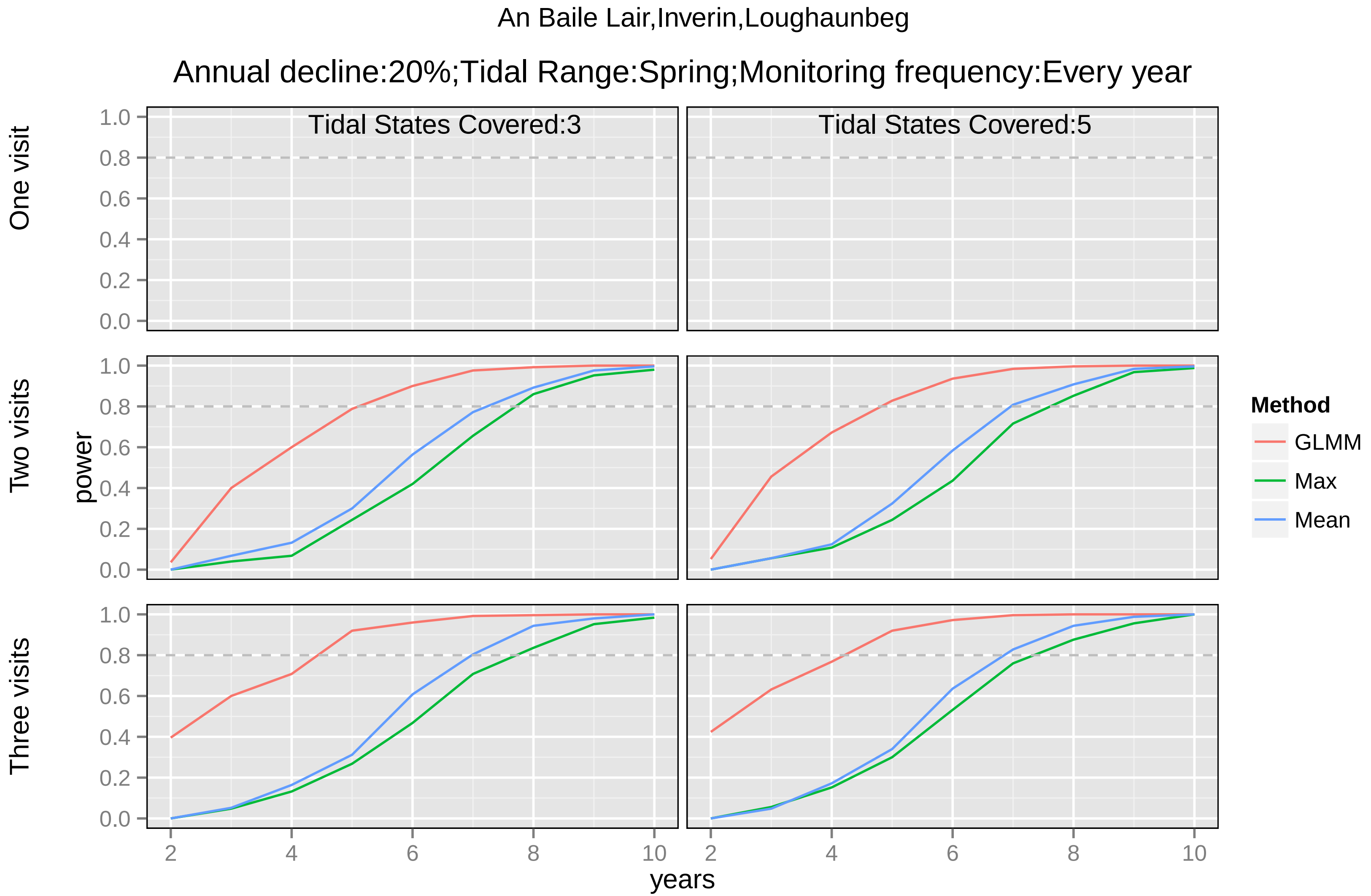
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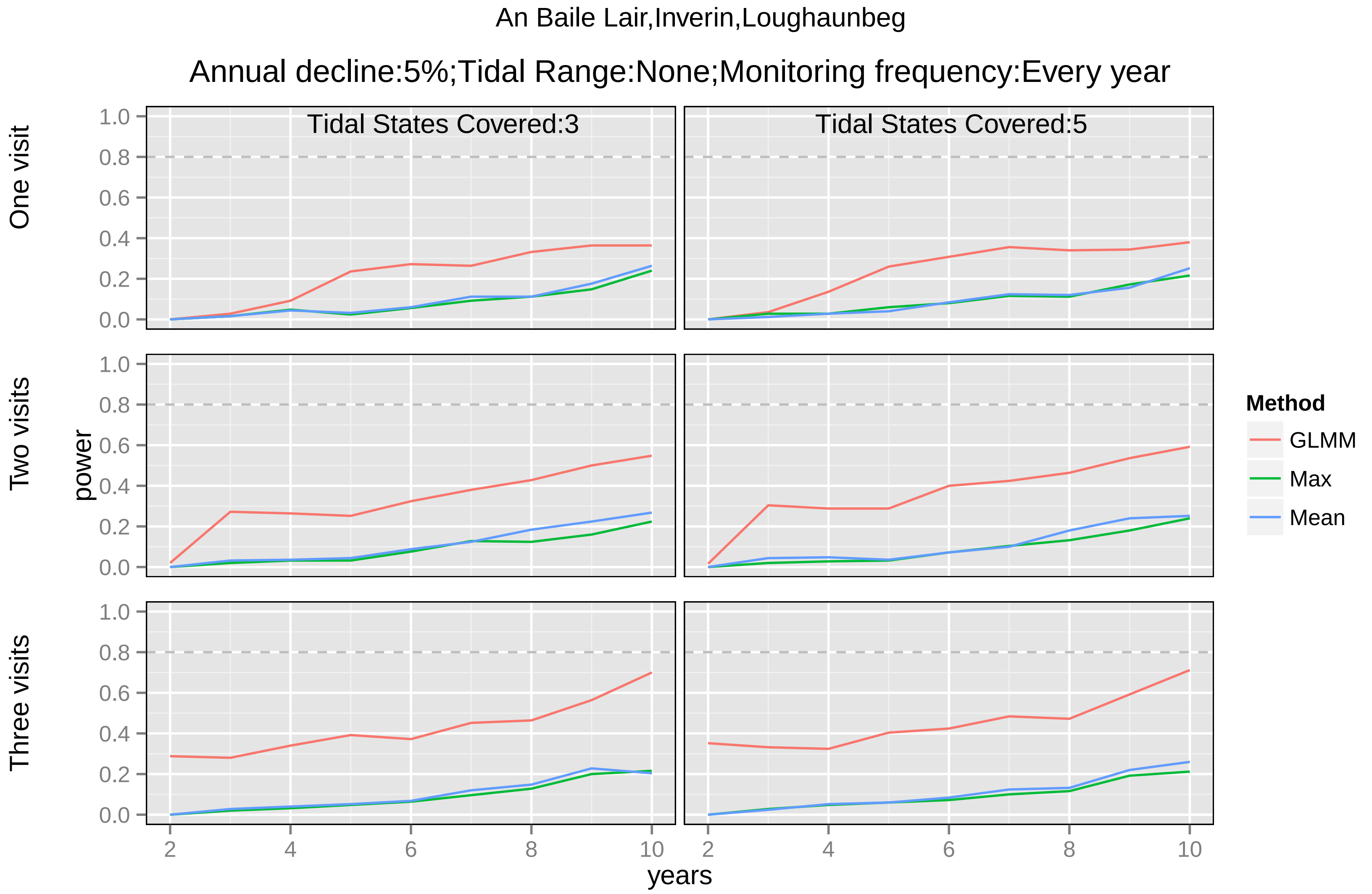

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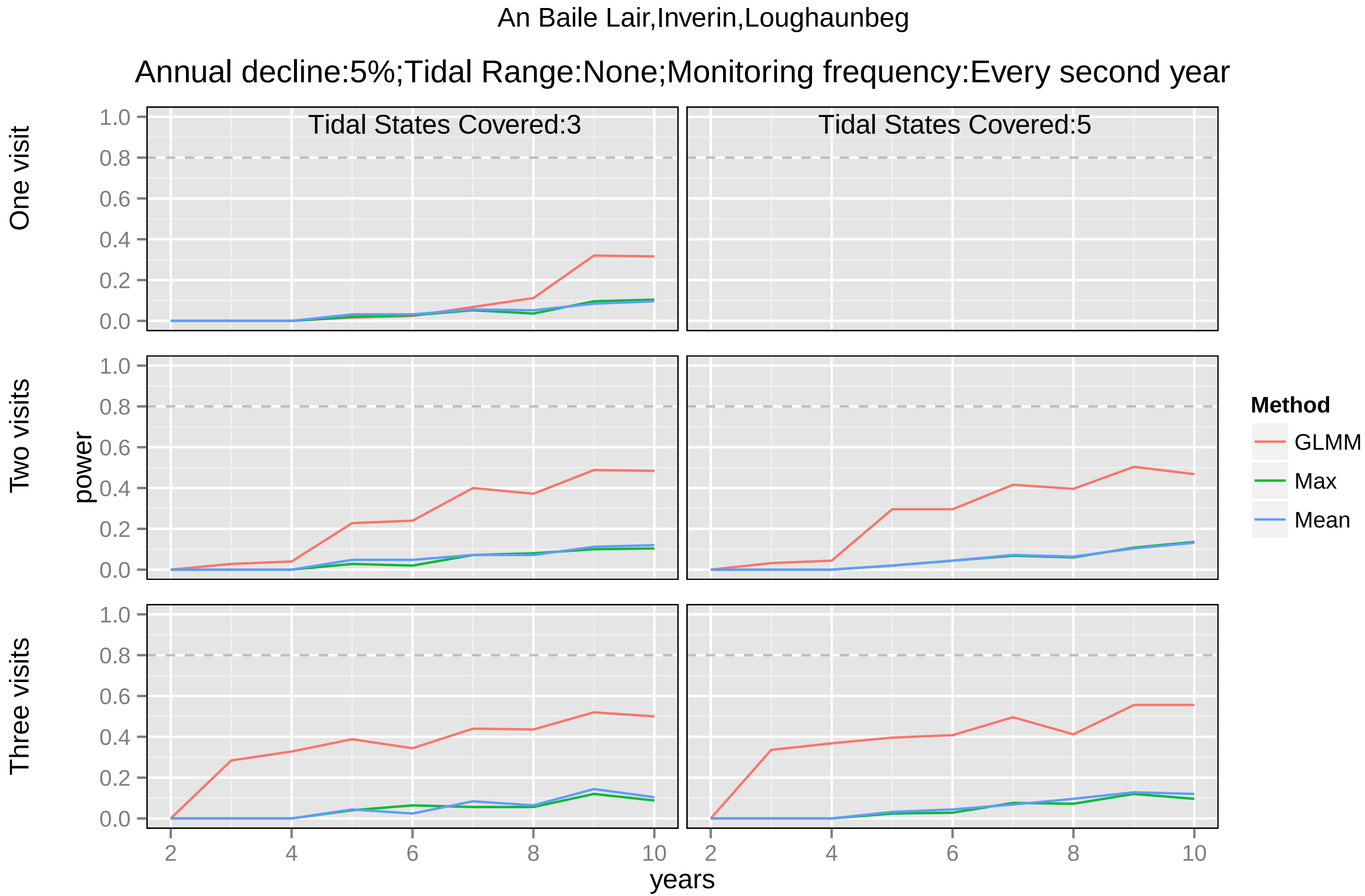
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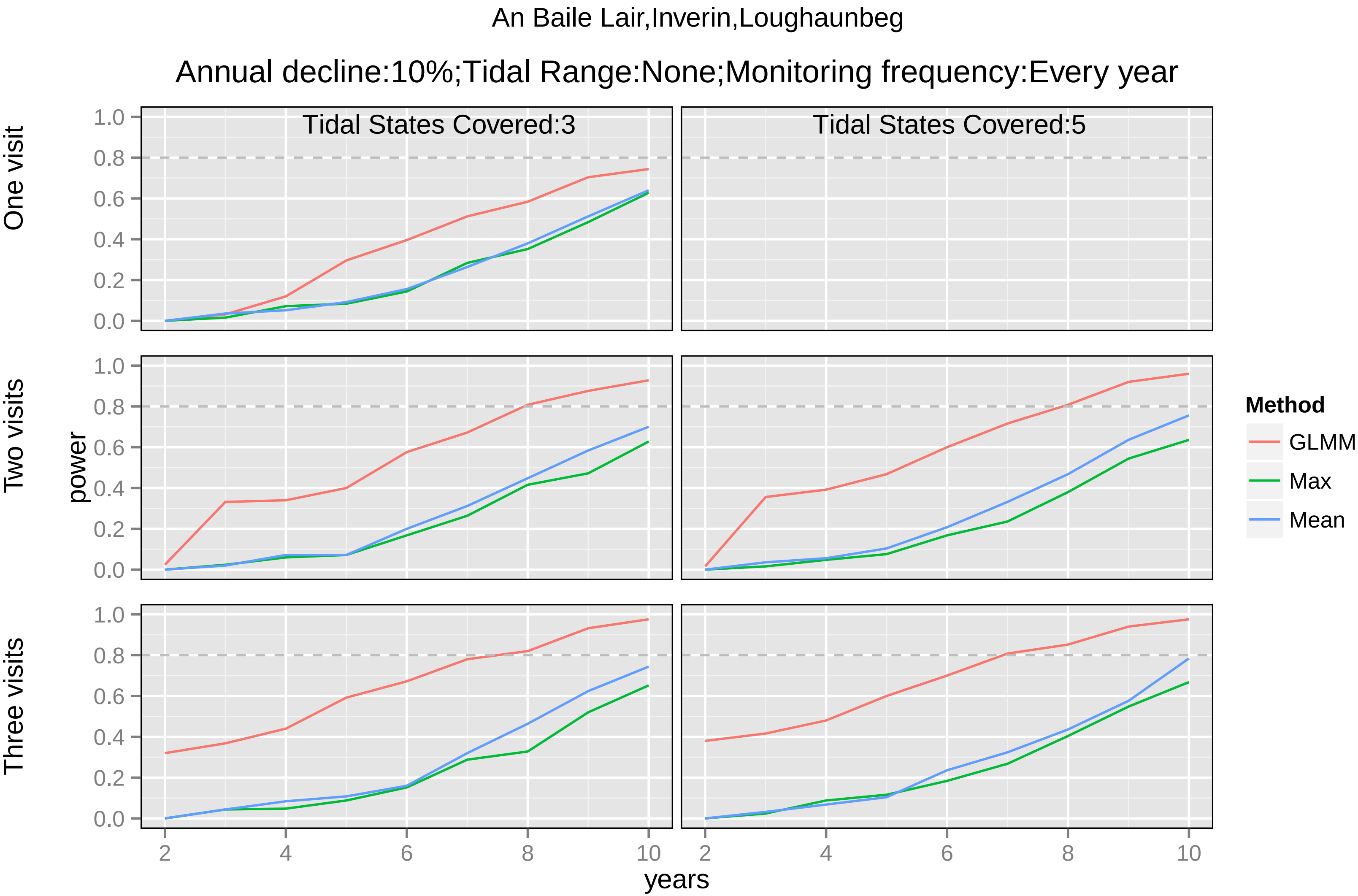
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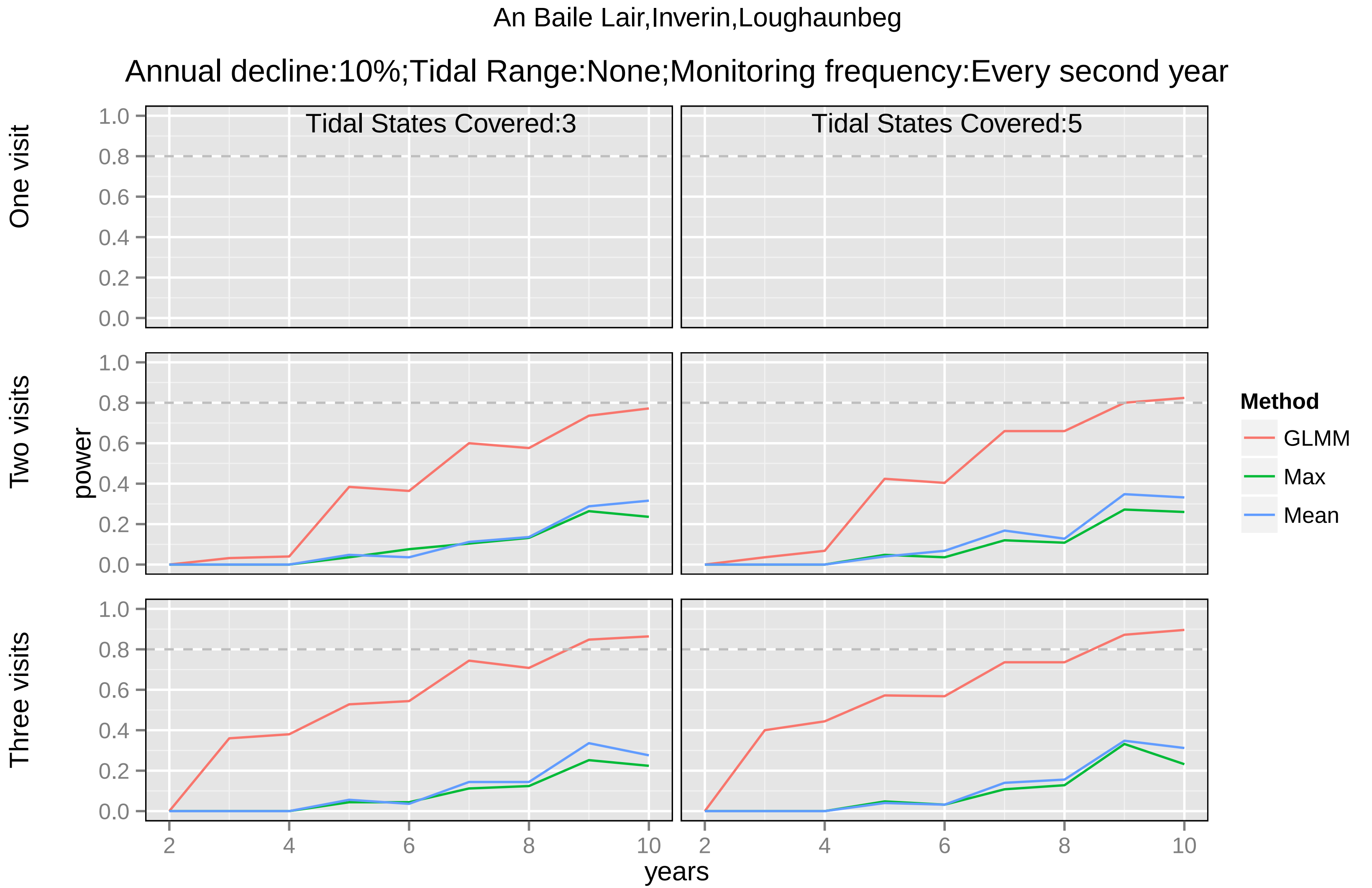
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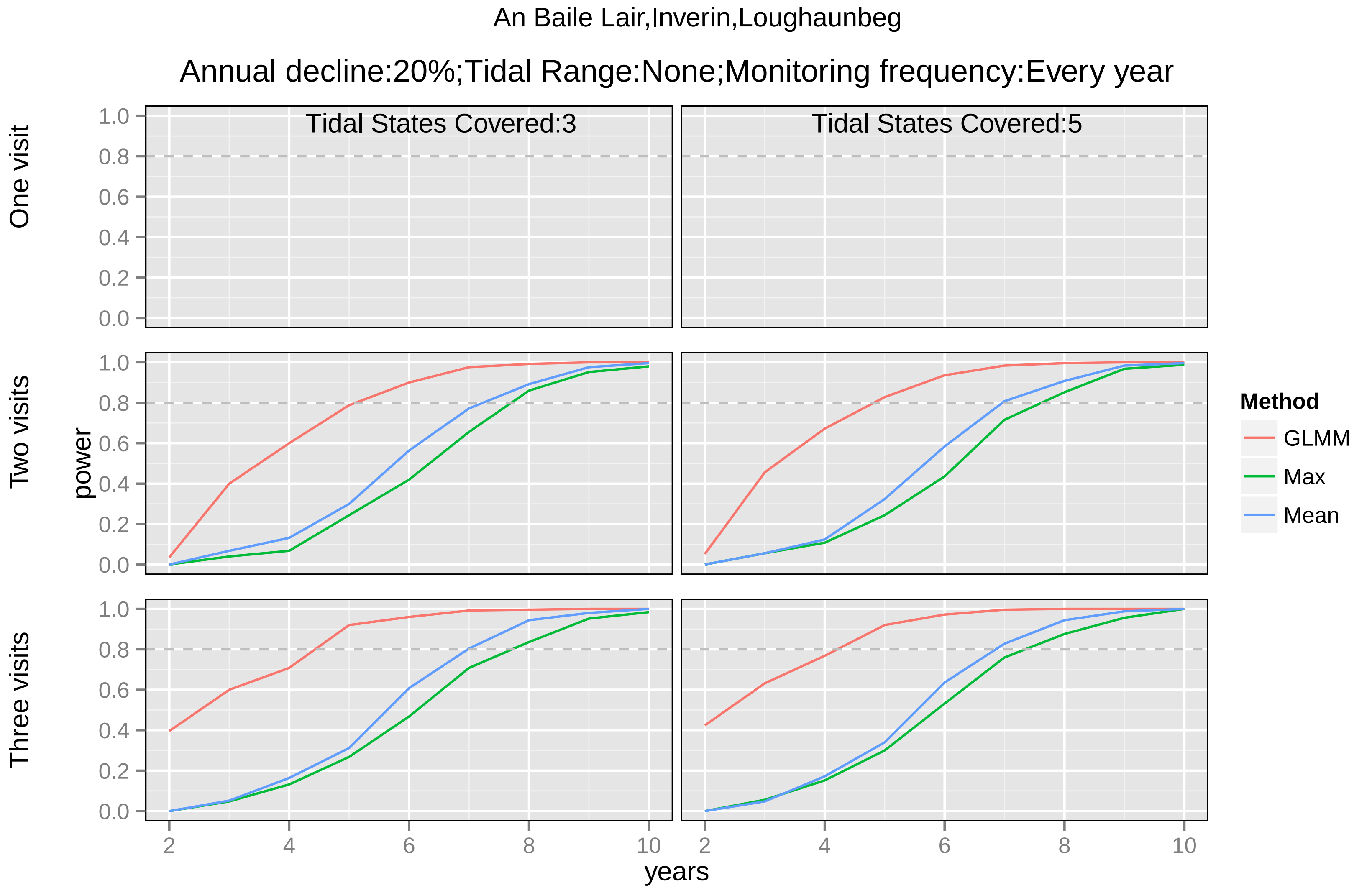
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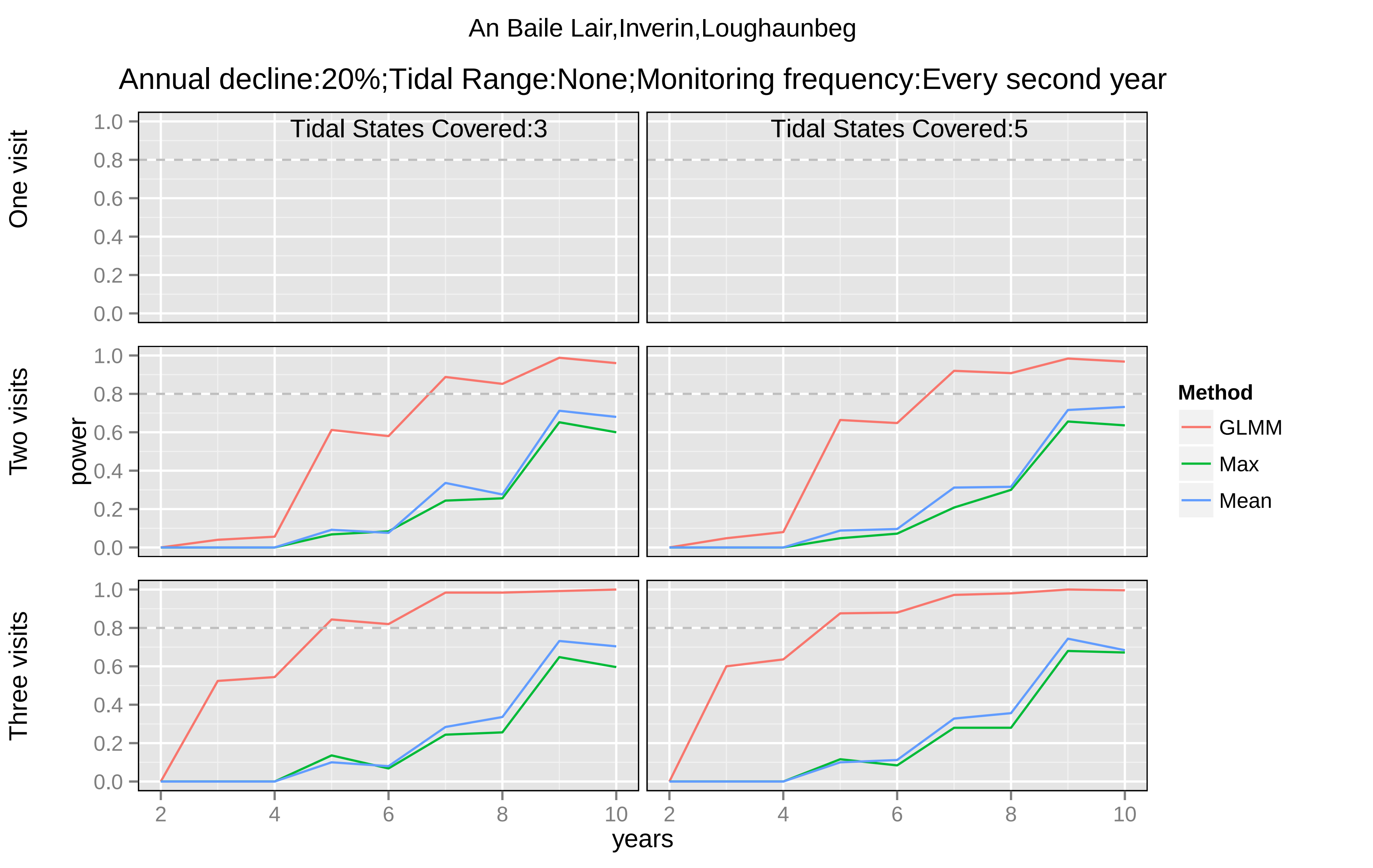
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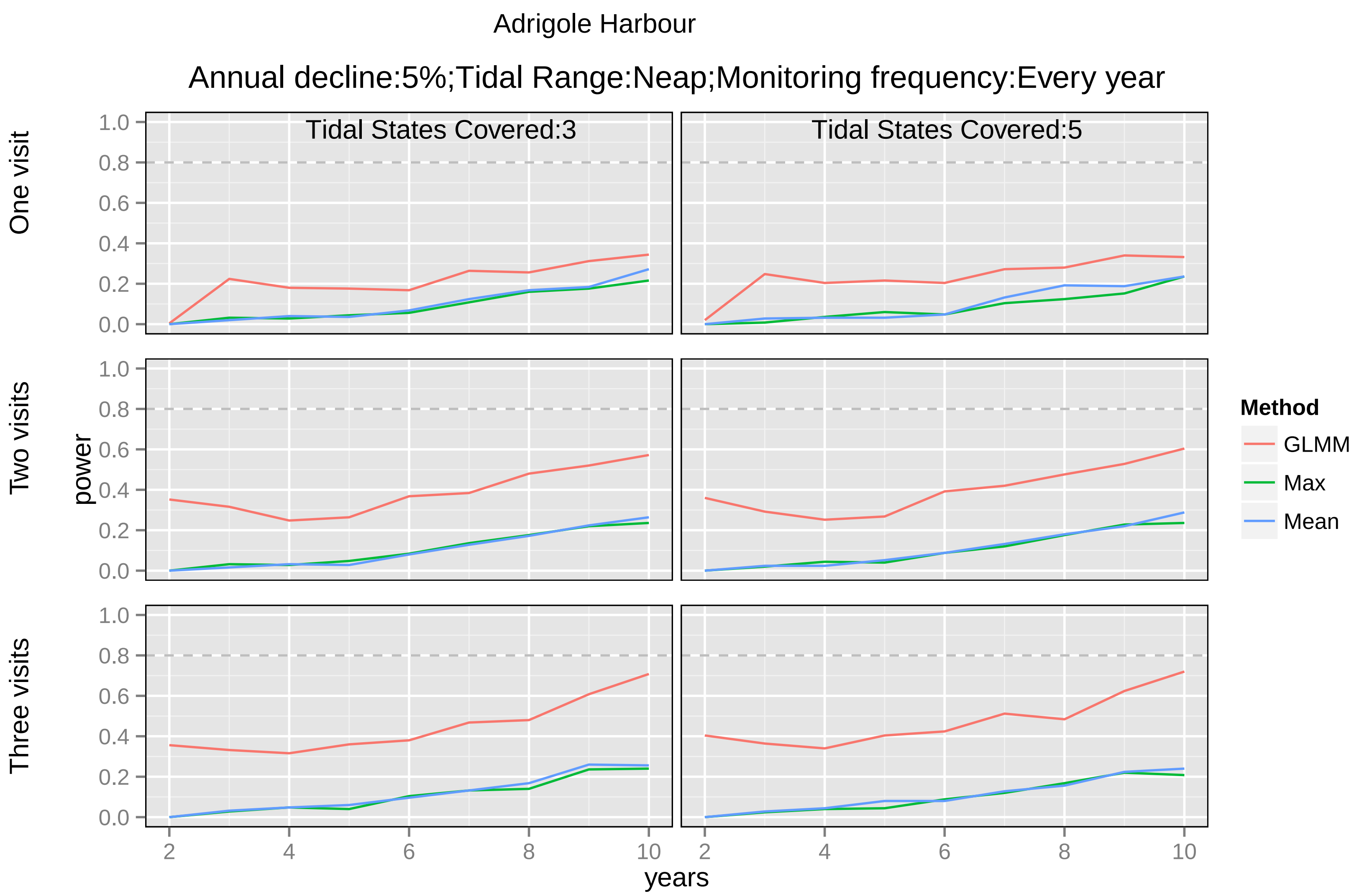
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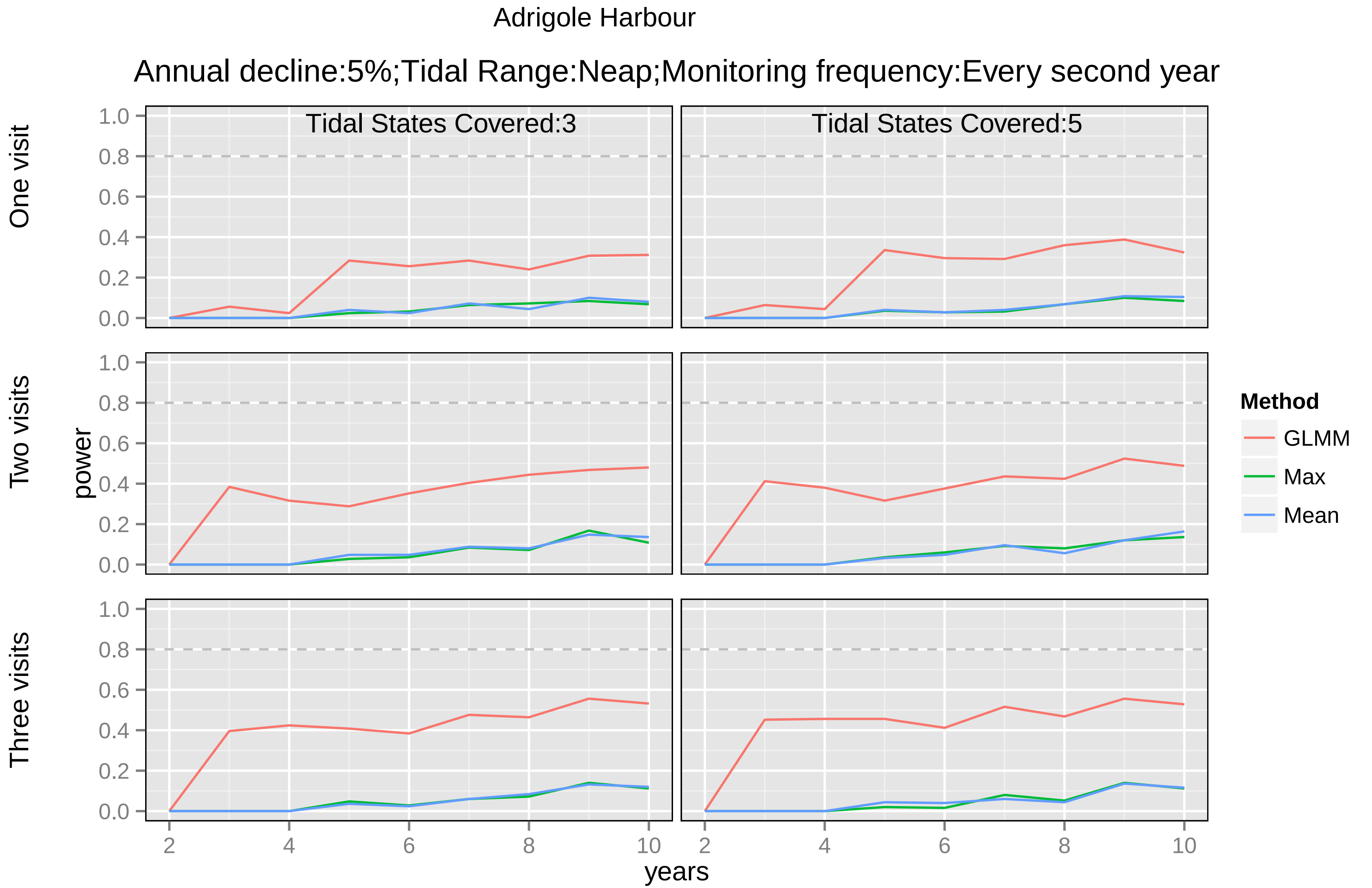
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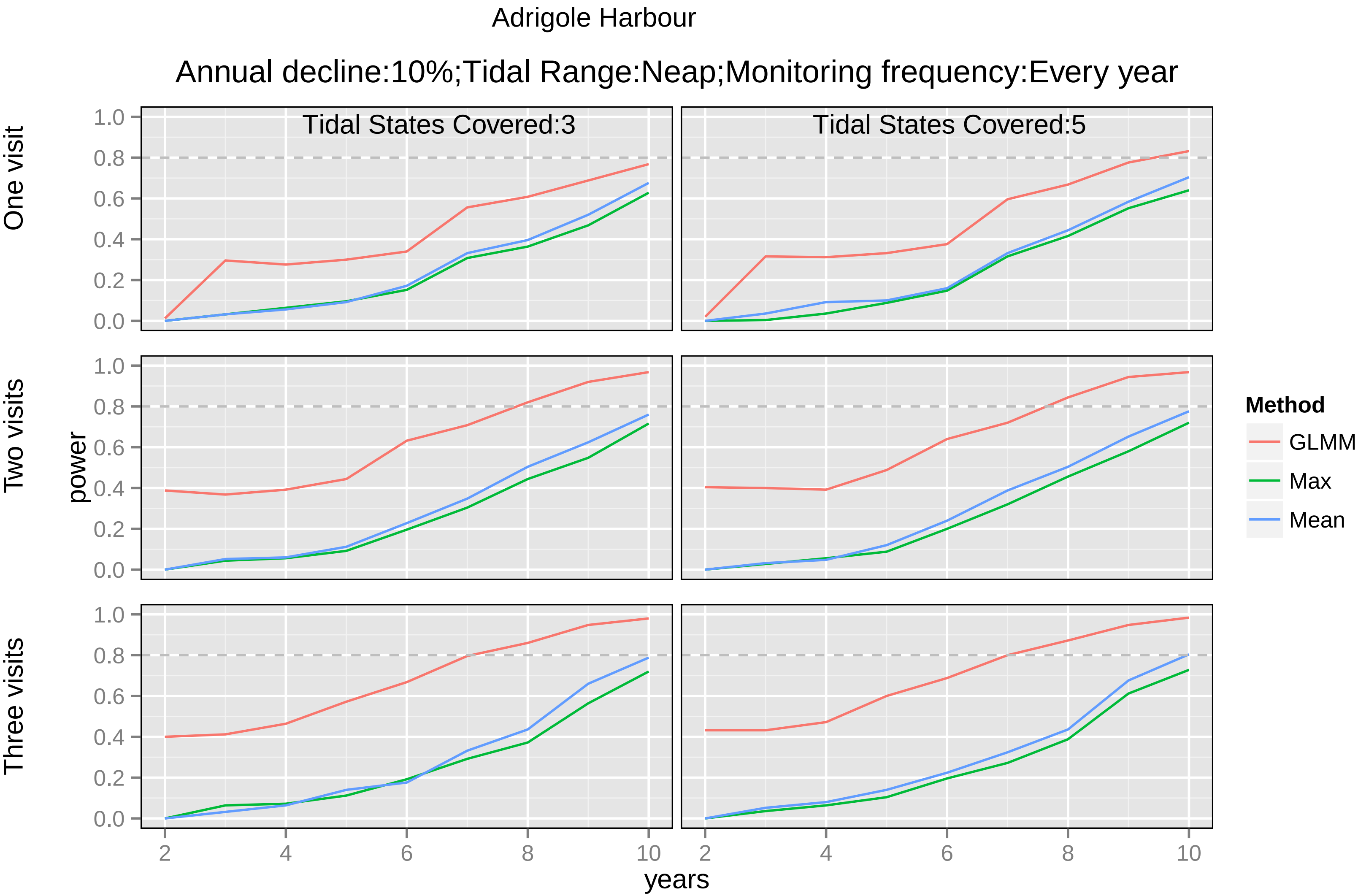
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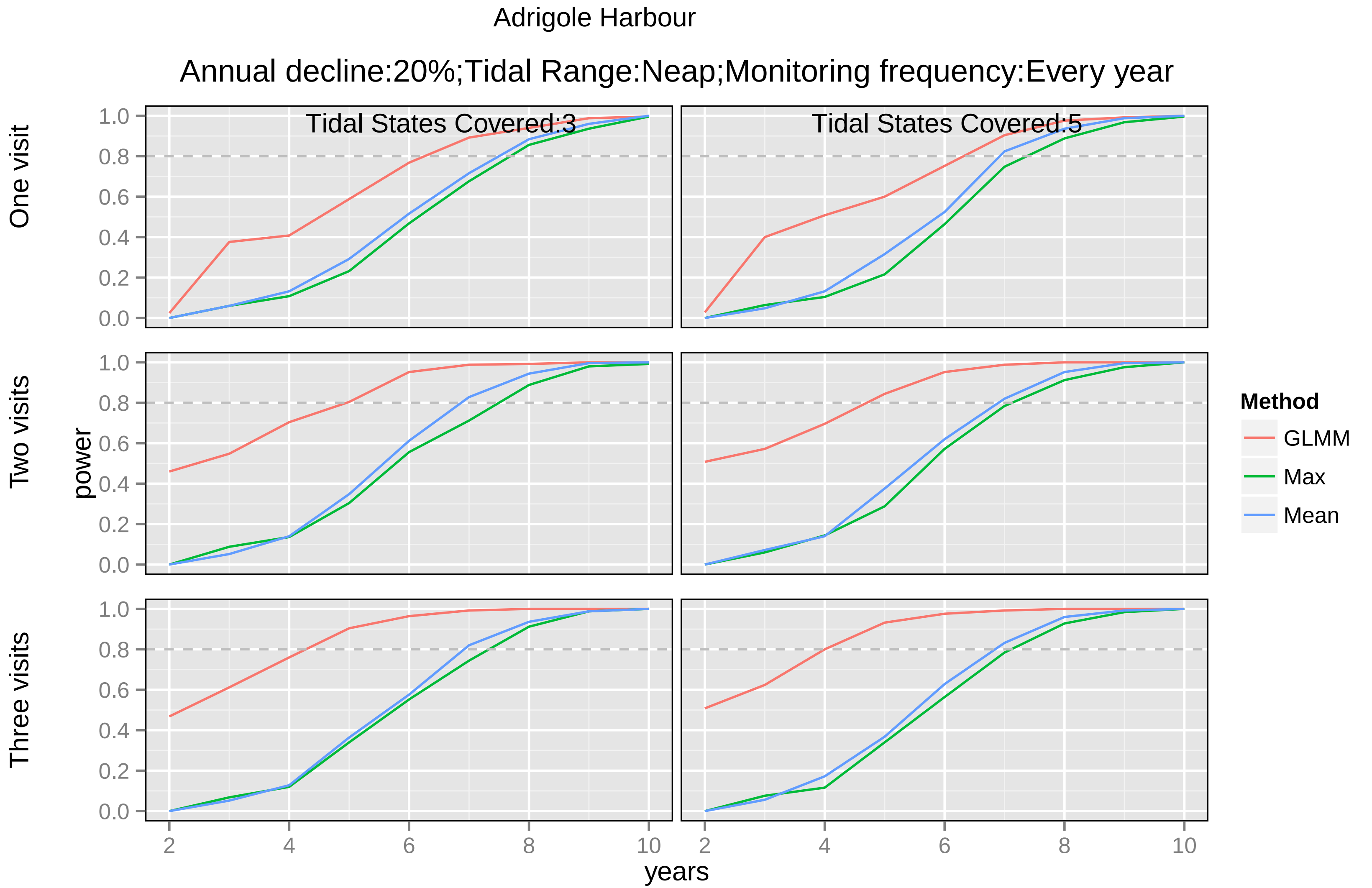
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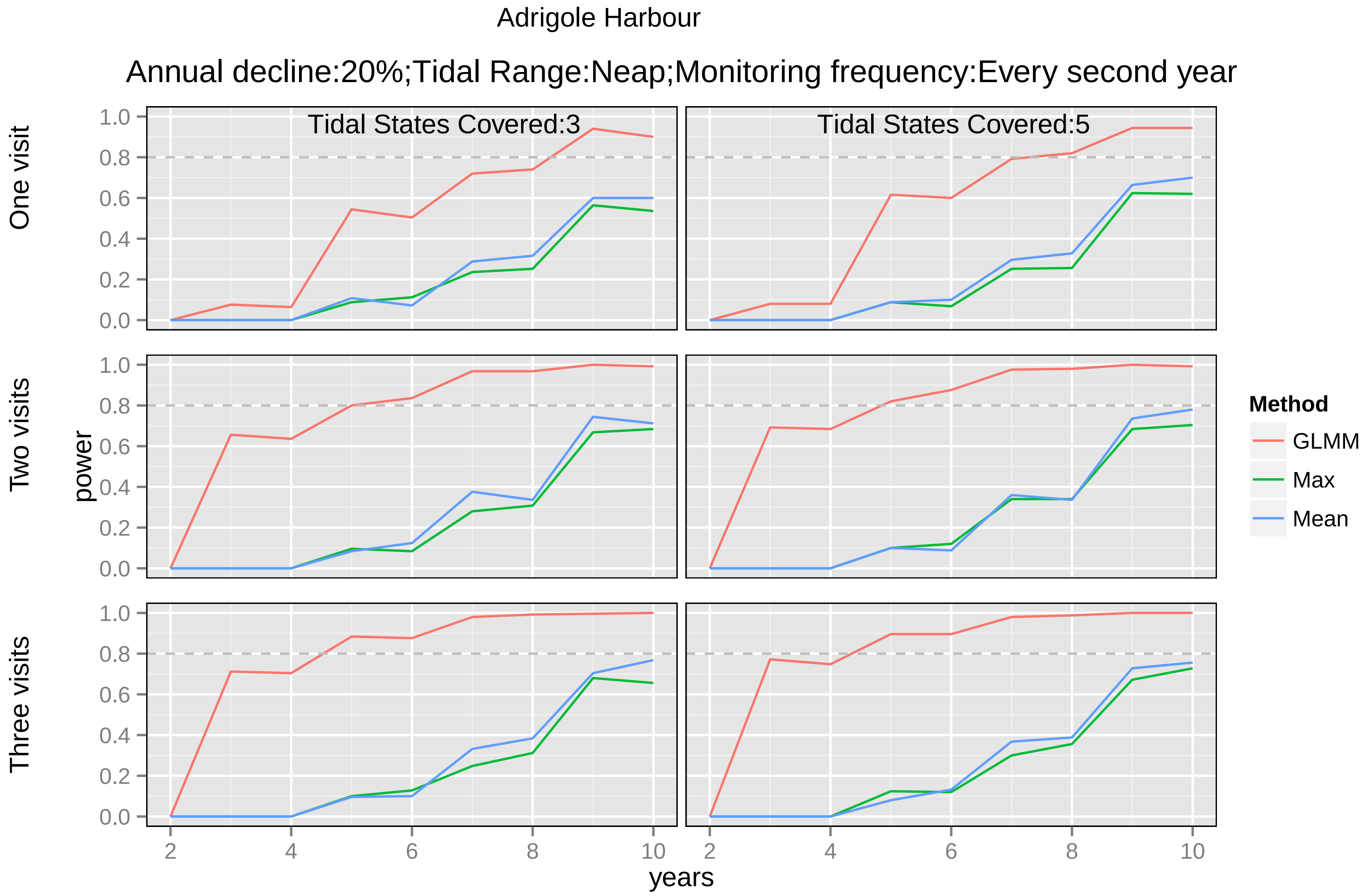

Adrigole Harbour
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
0.0
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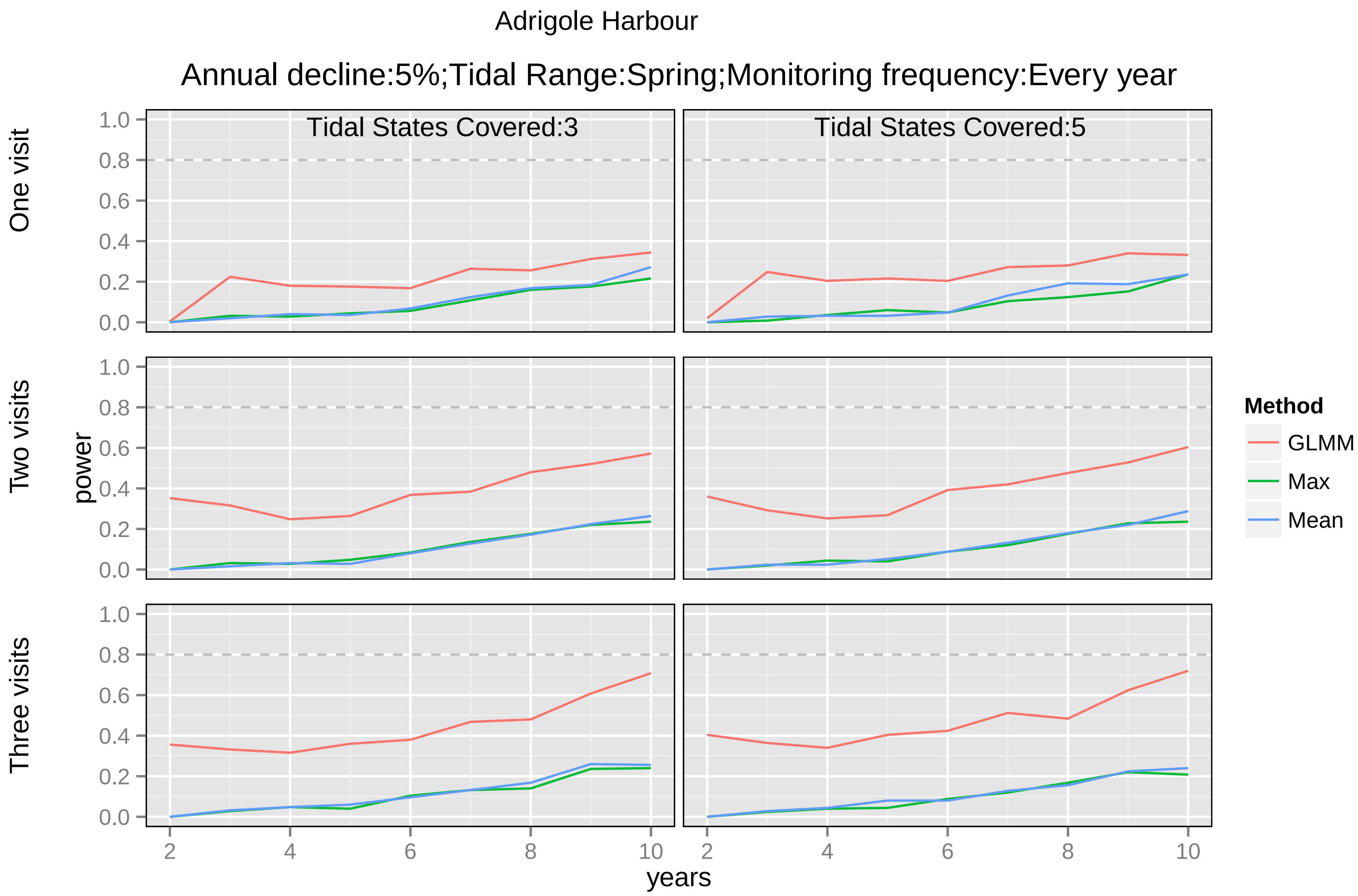
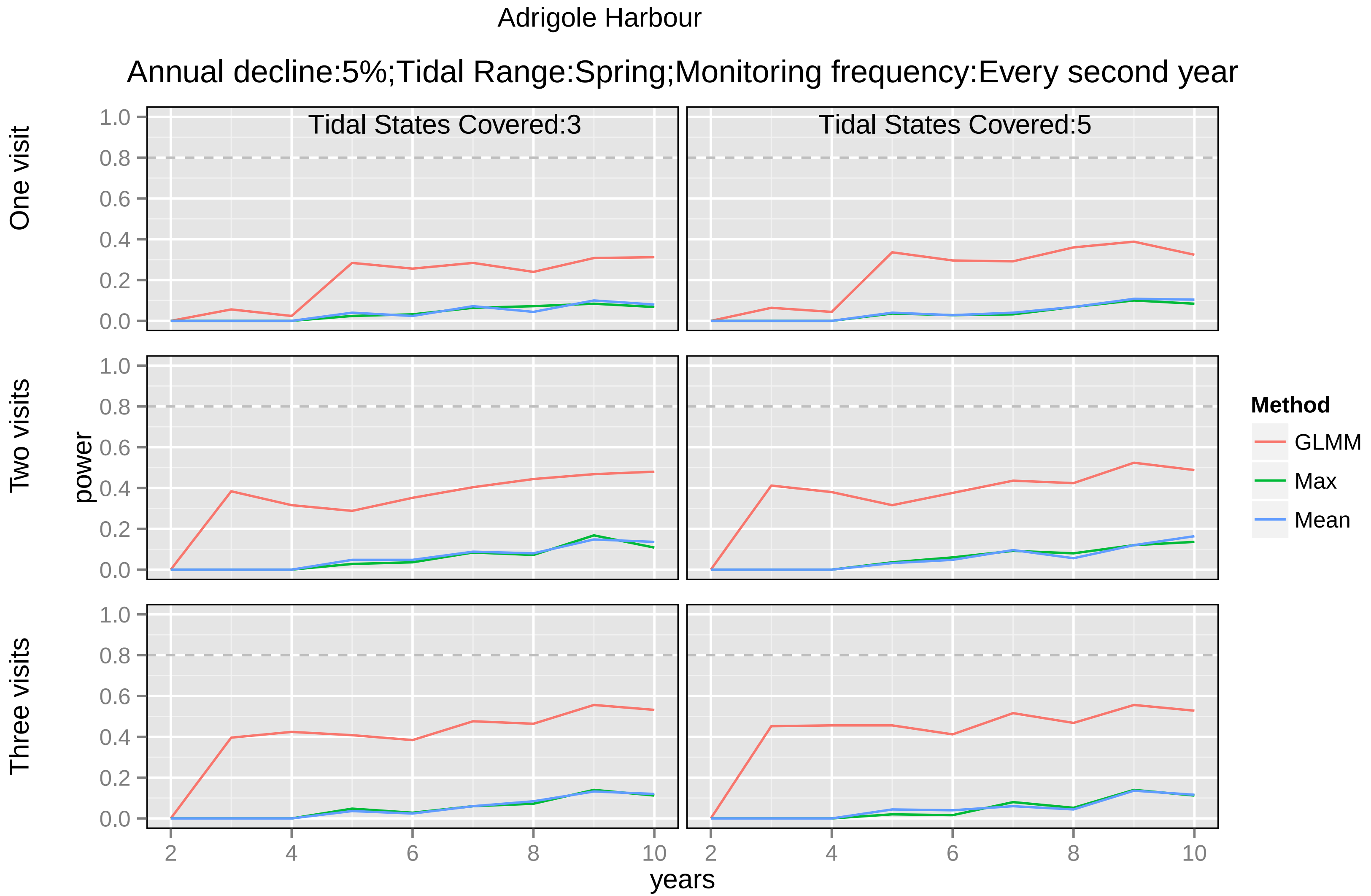

Adrigole Harbour
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean


Adrigole Harbour
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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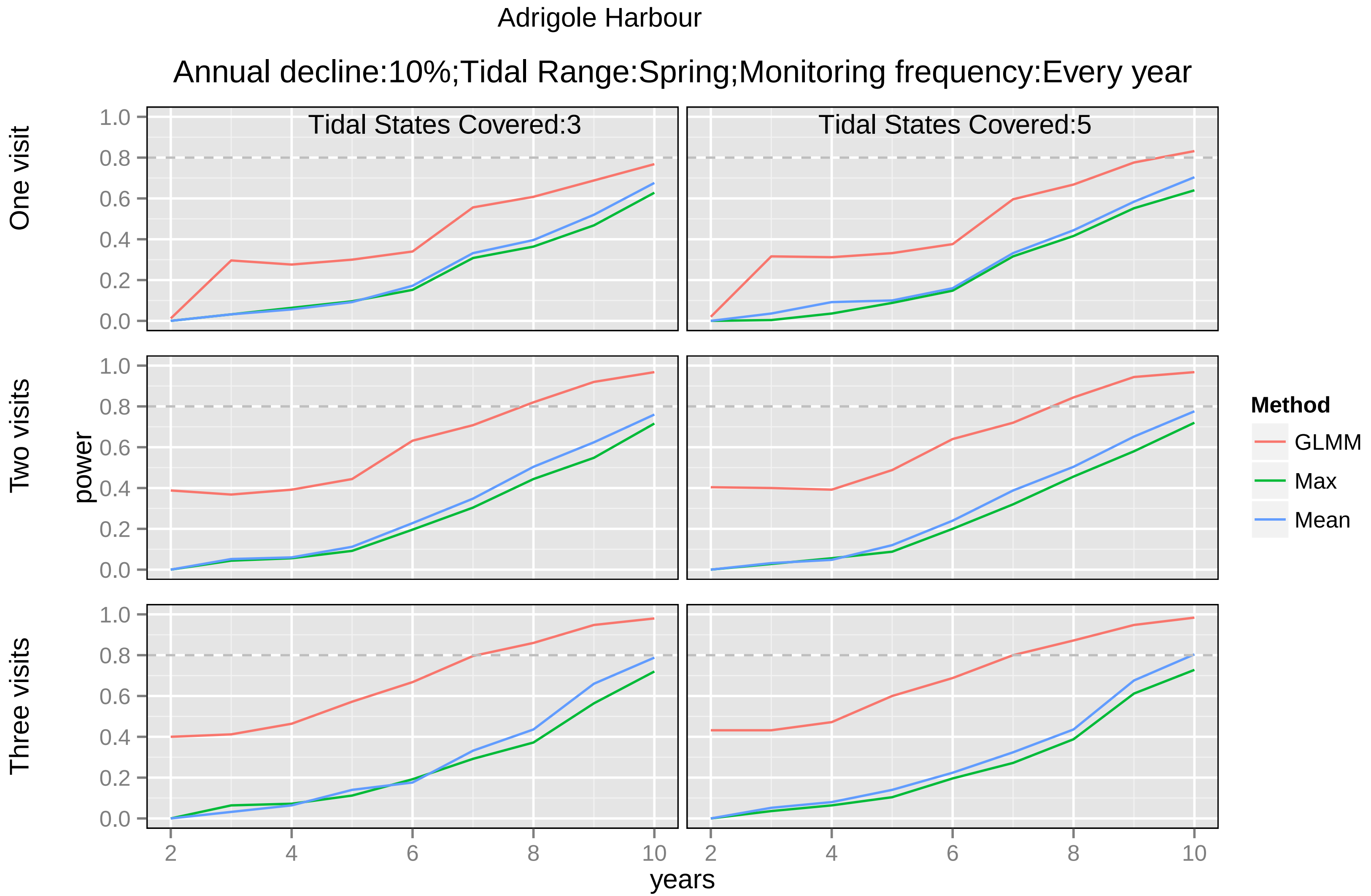
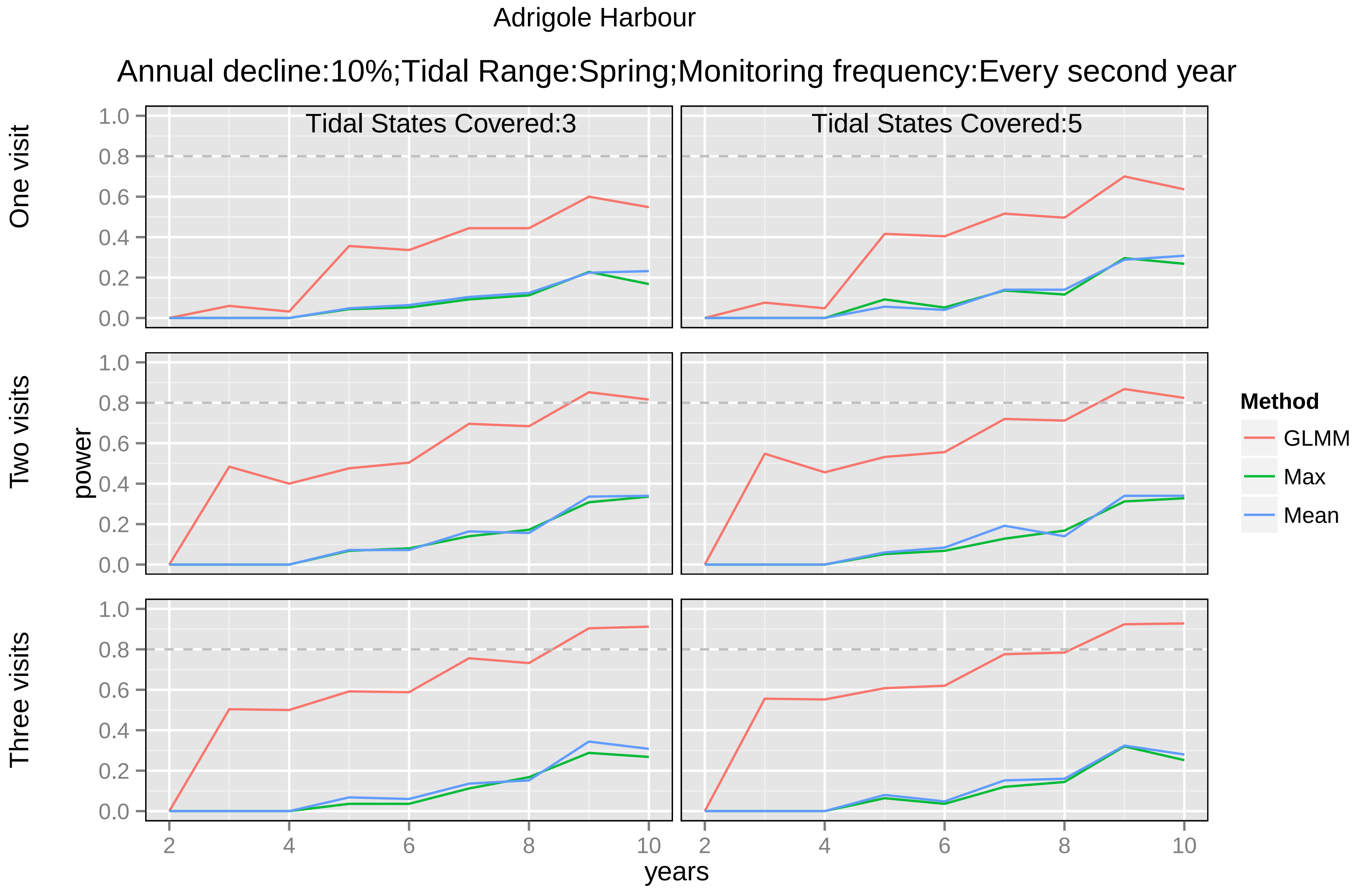
Method
GLMM
Max
Mean



Adrigole Harbour
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean



Adrigole Harbour
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
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Three visits
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years
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Adrigole Harbour
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every year
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One visit
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Method
GLMM
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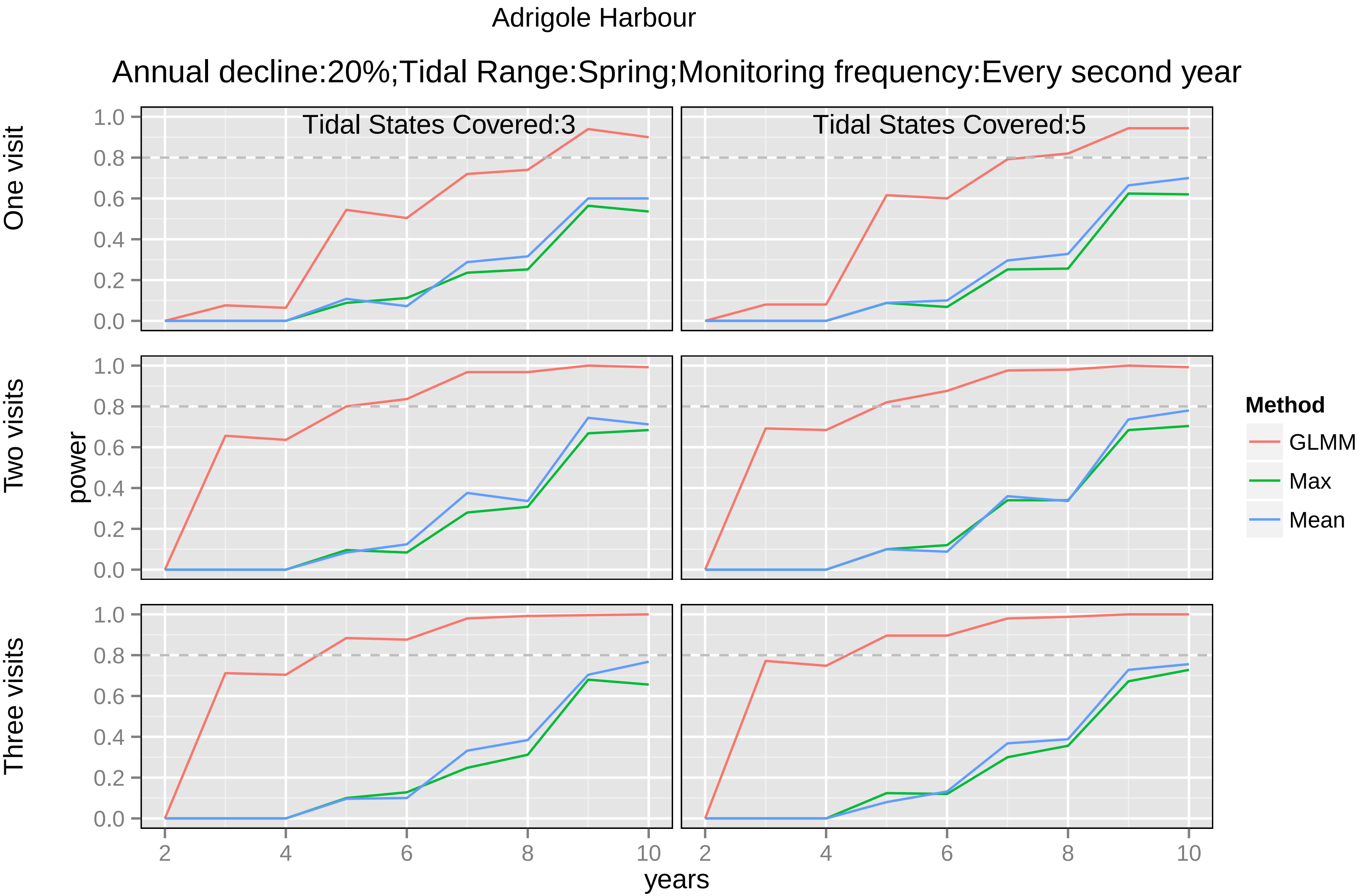
Mean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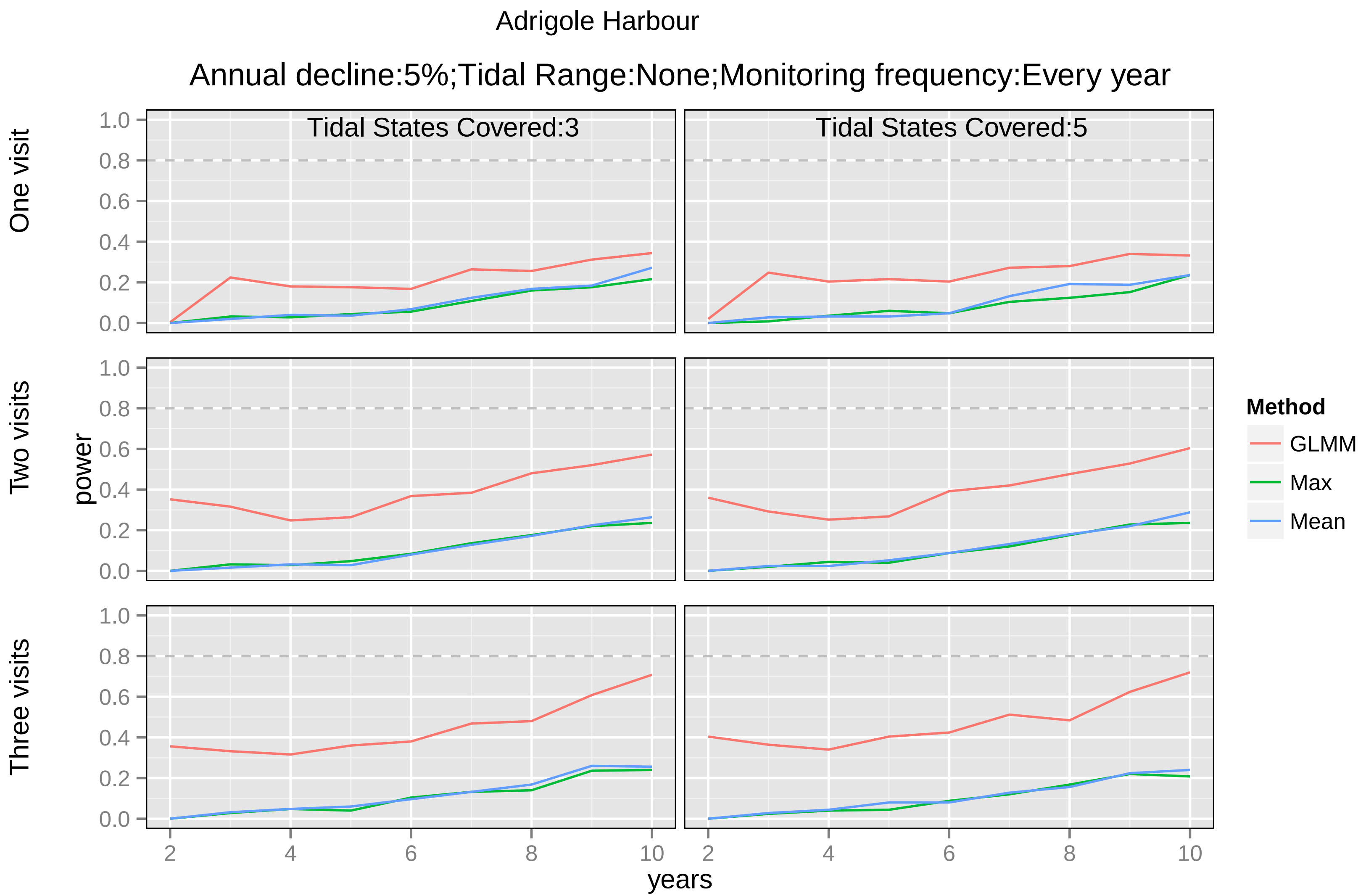

Adrigole Harbour
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
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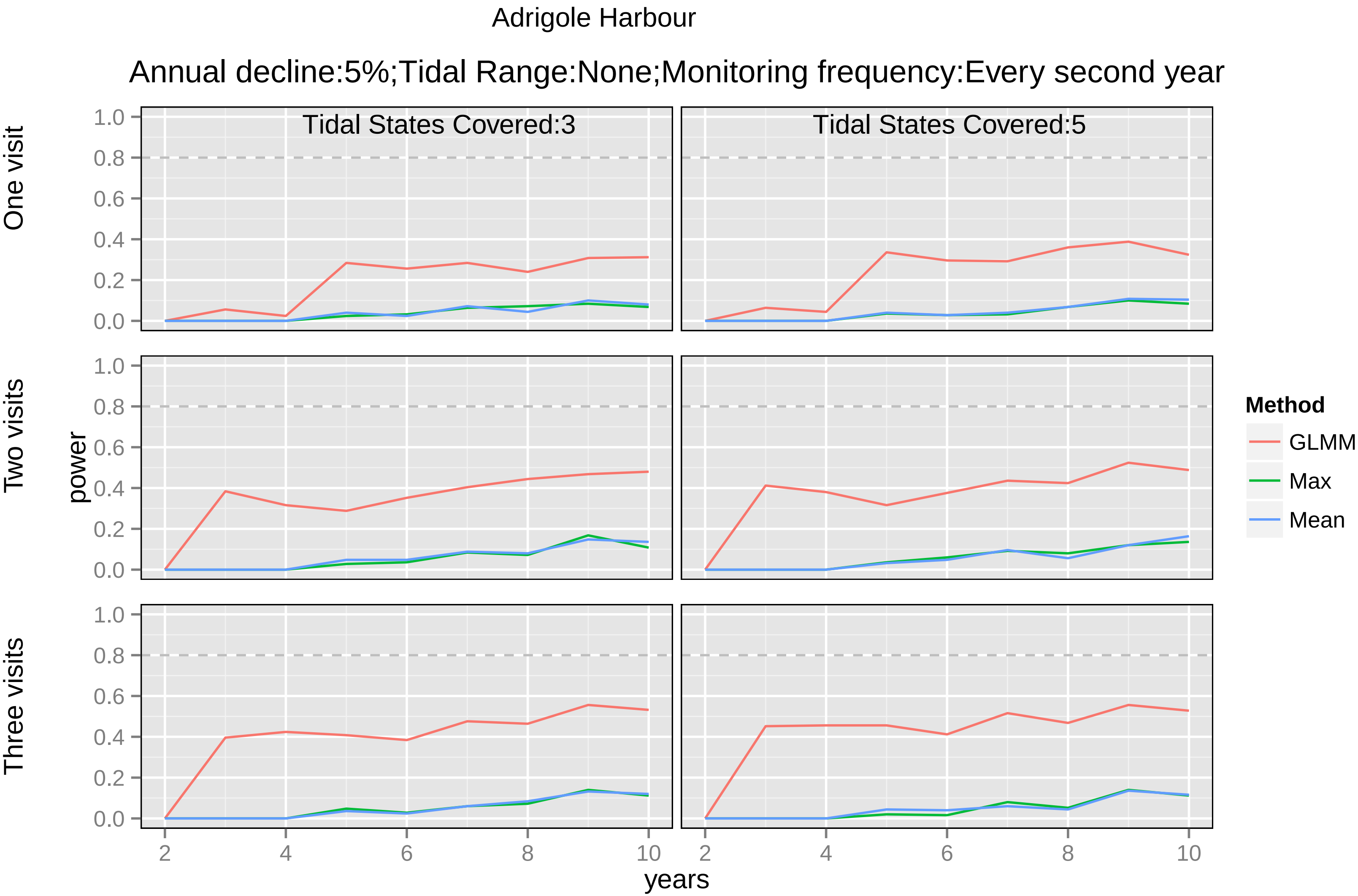

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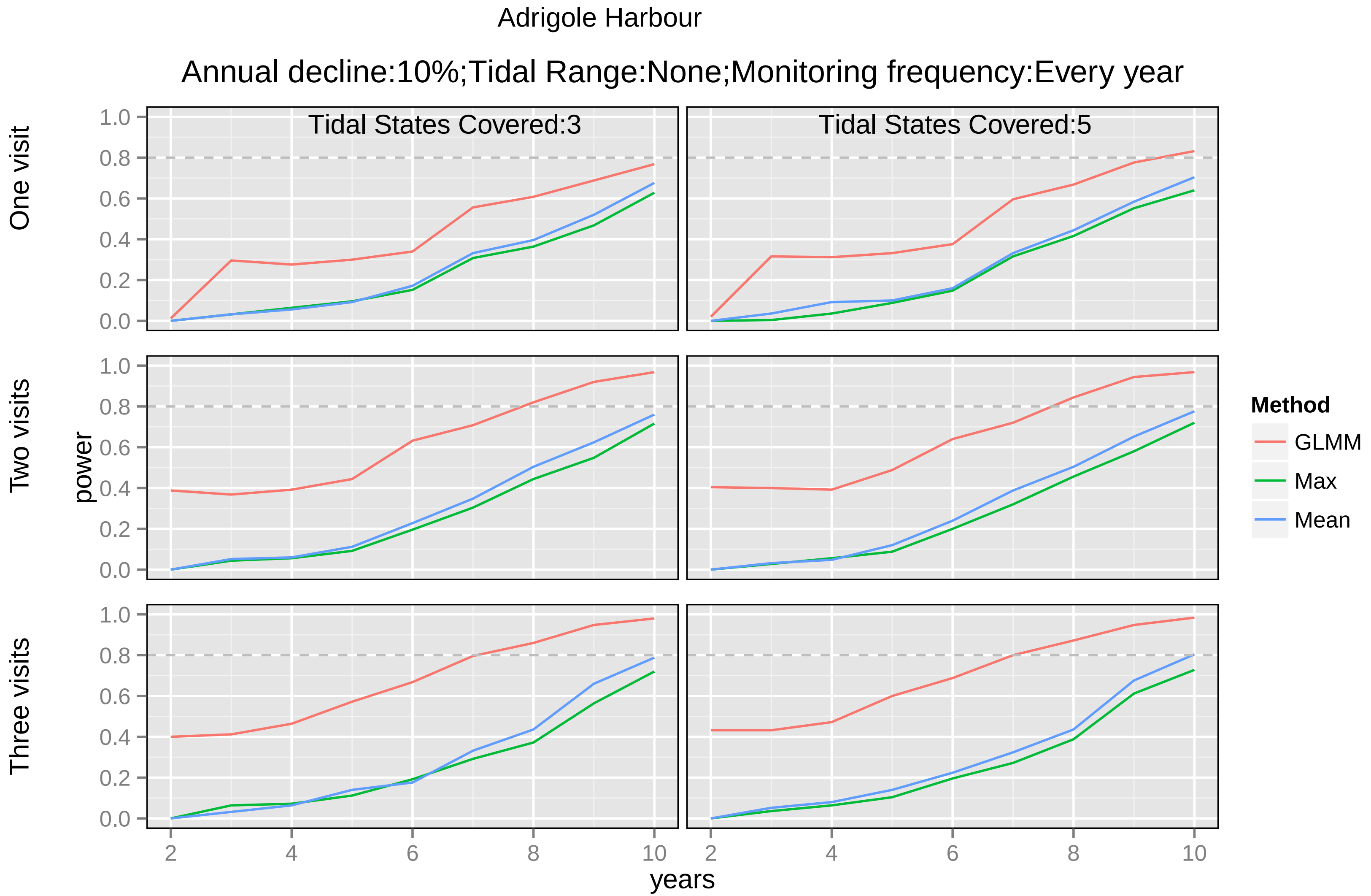

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Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
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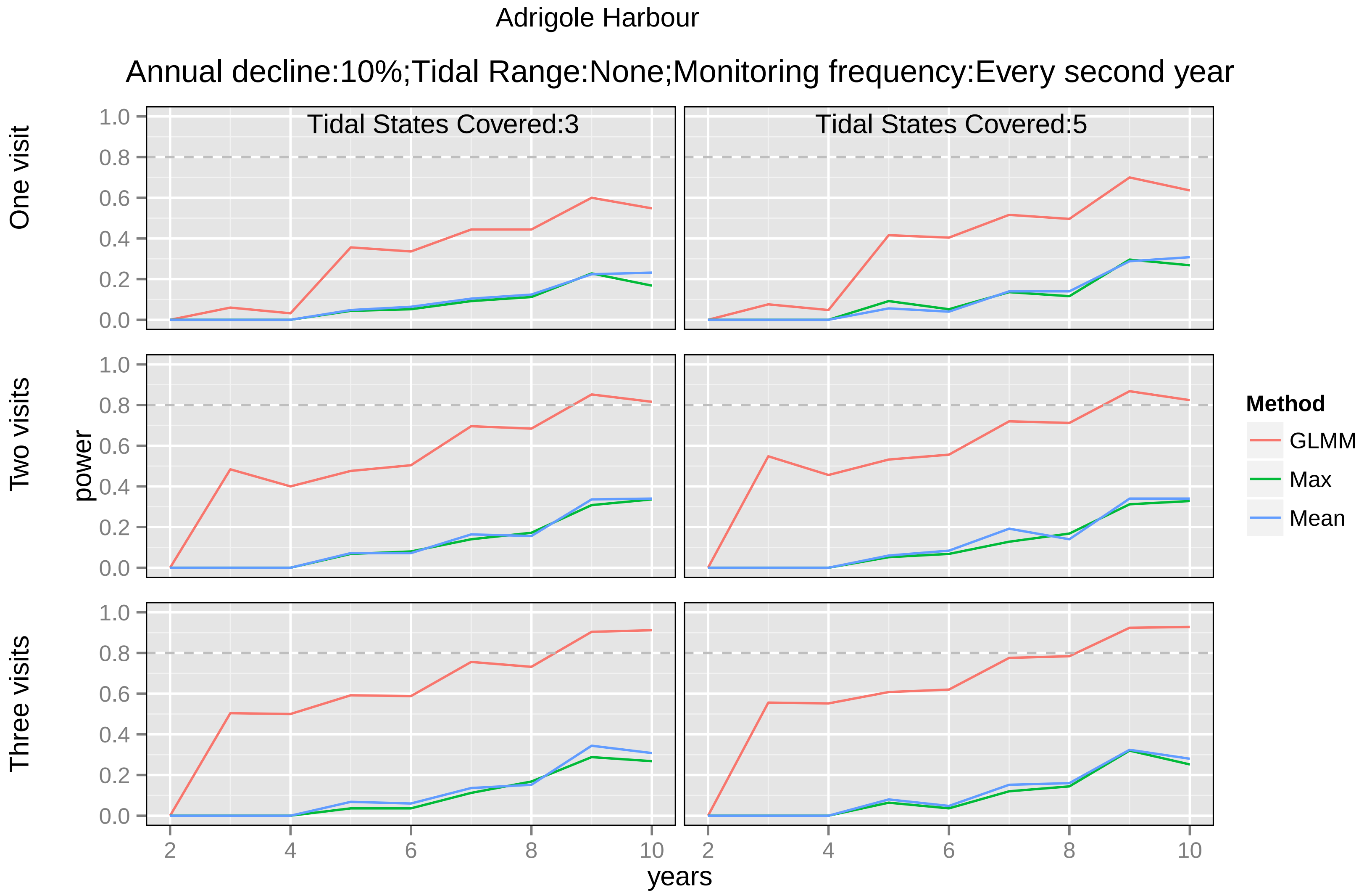
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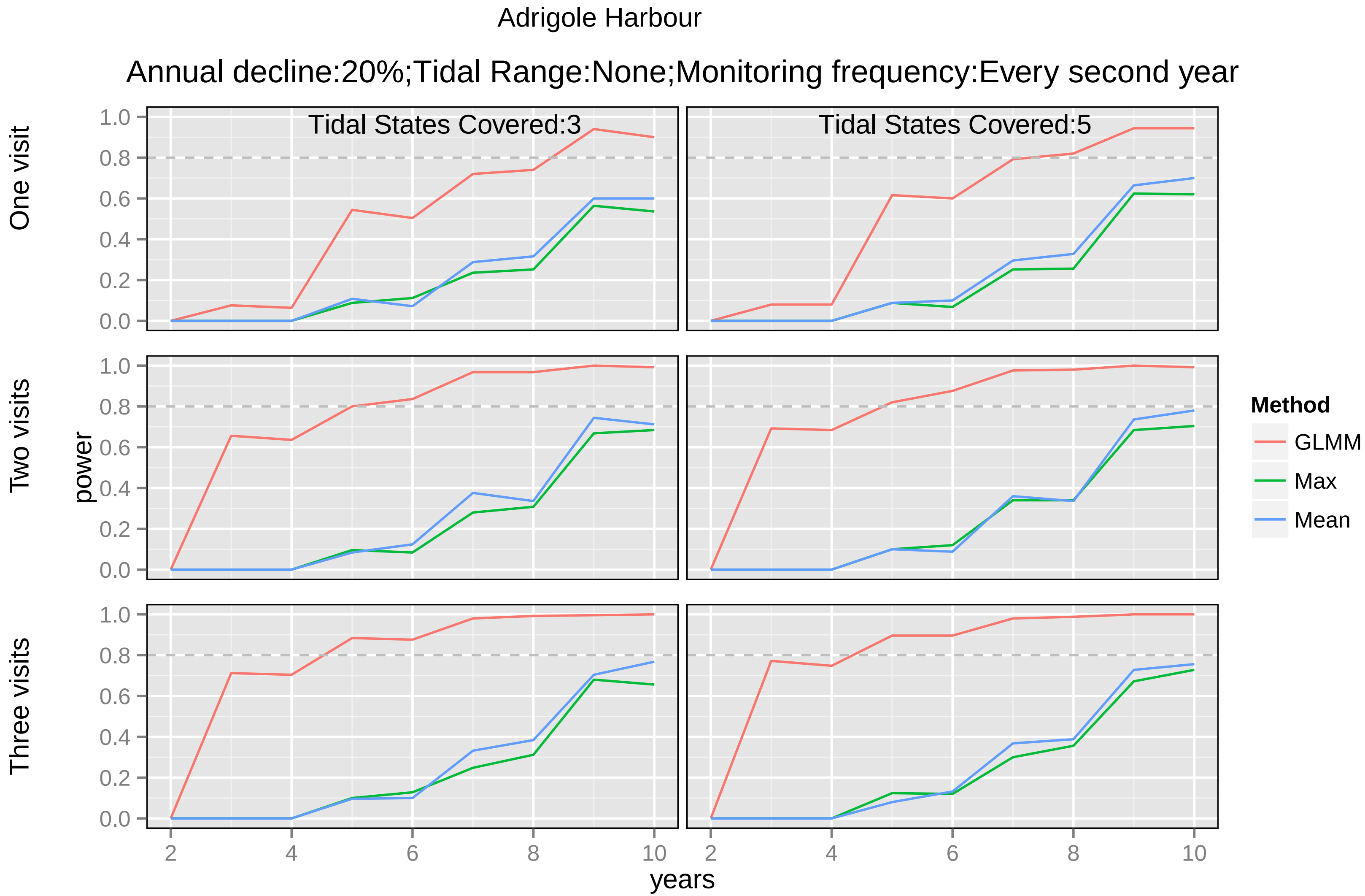

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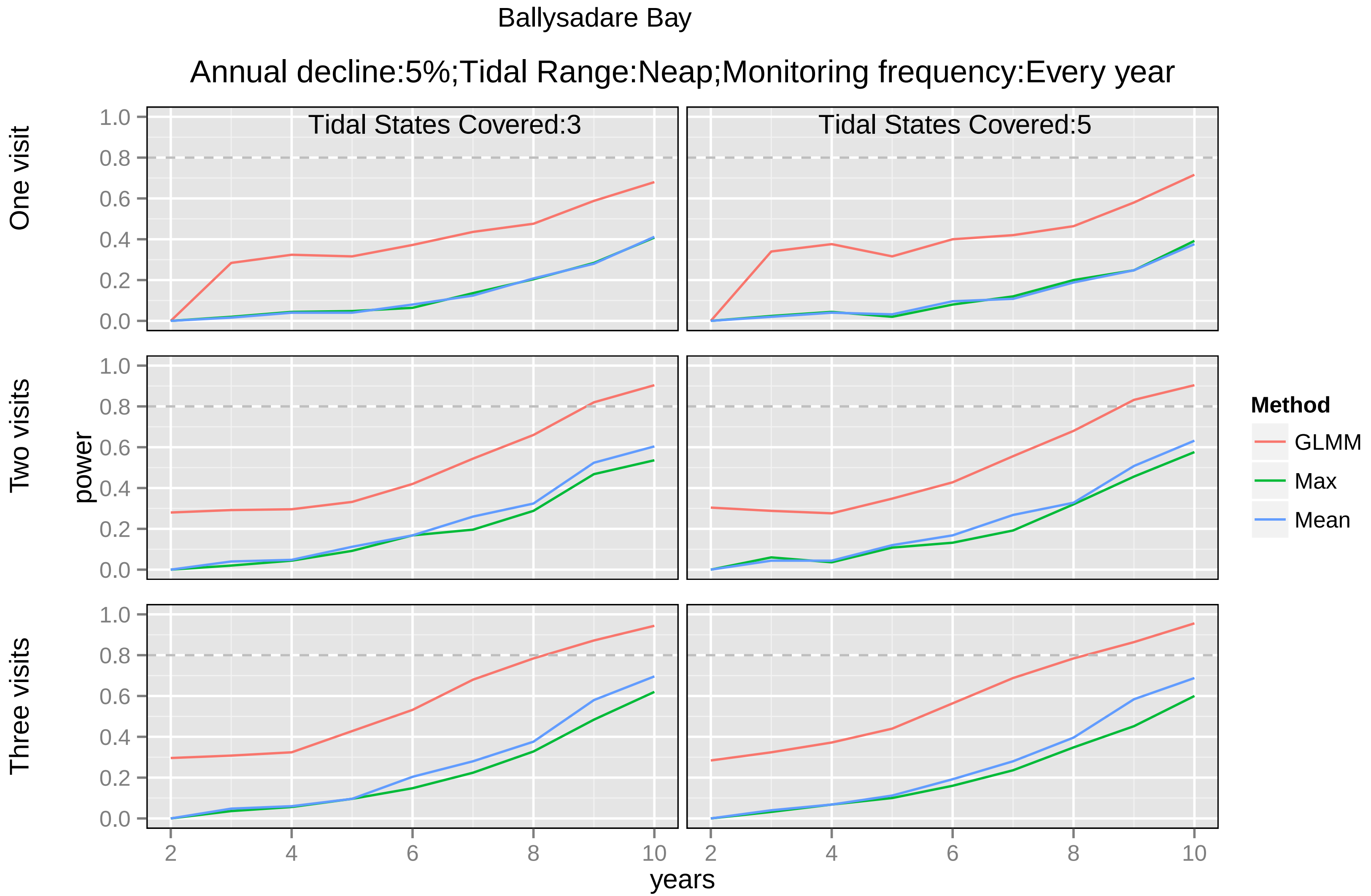
Ballysadare Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
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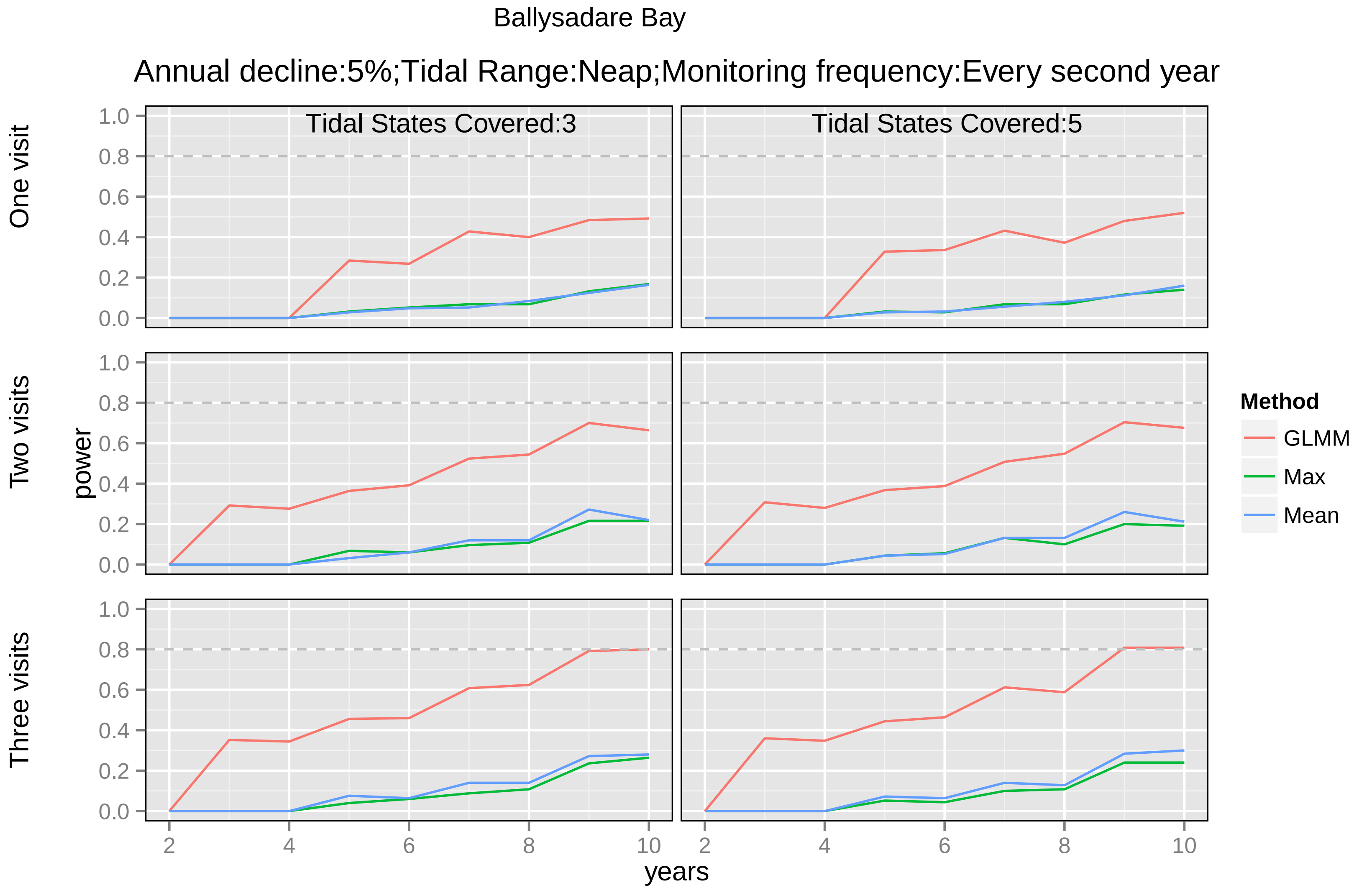
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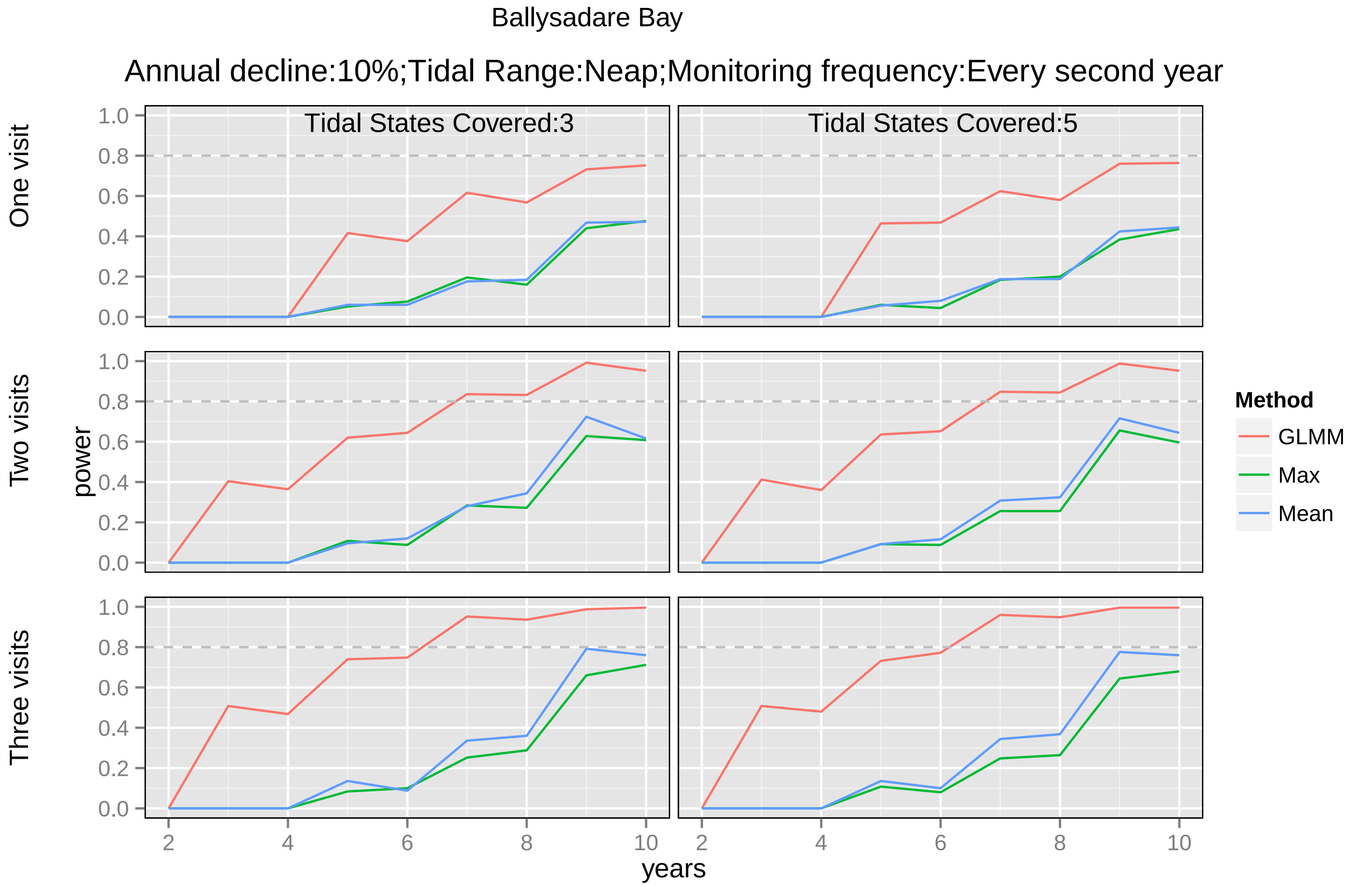
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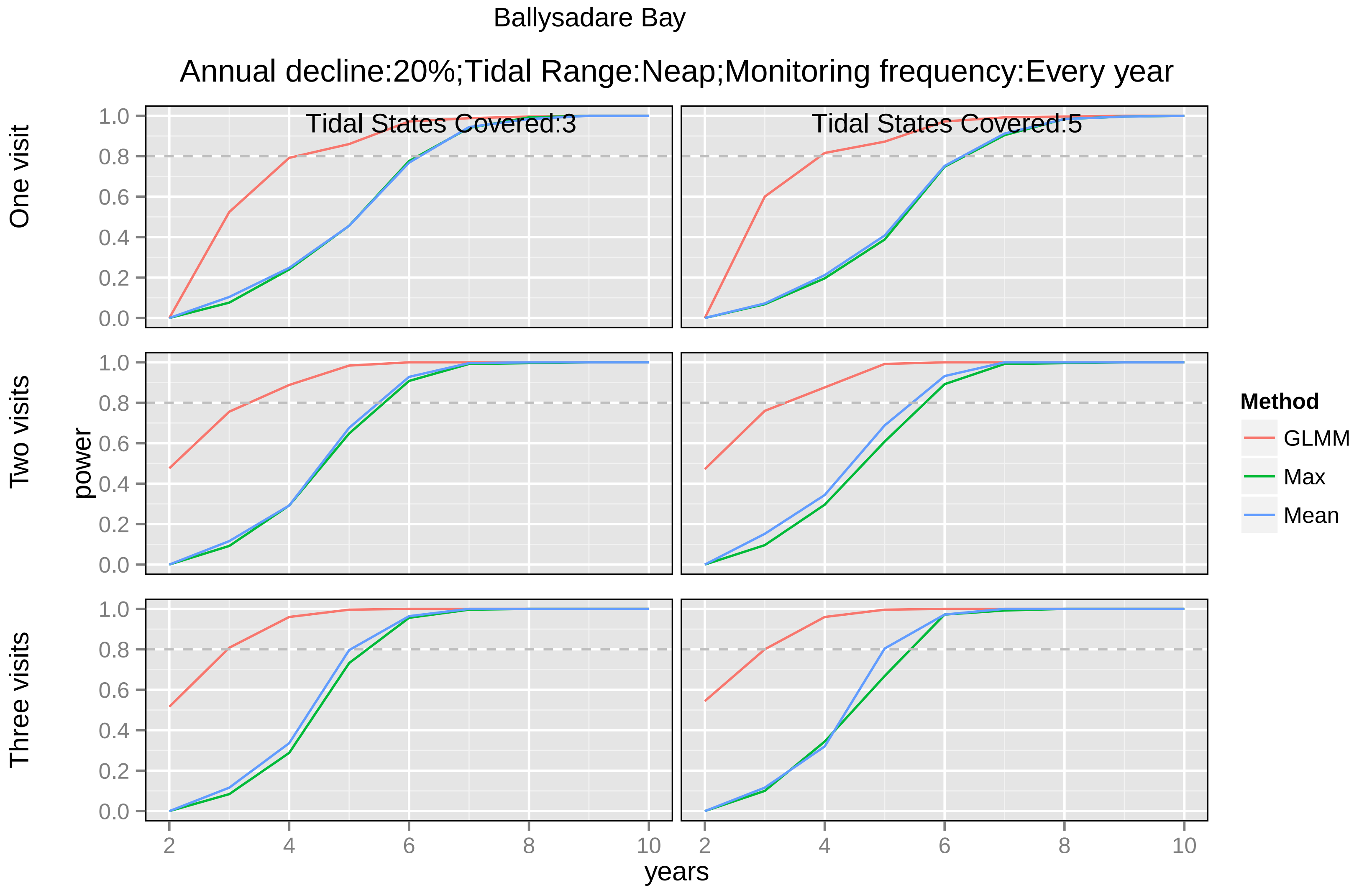
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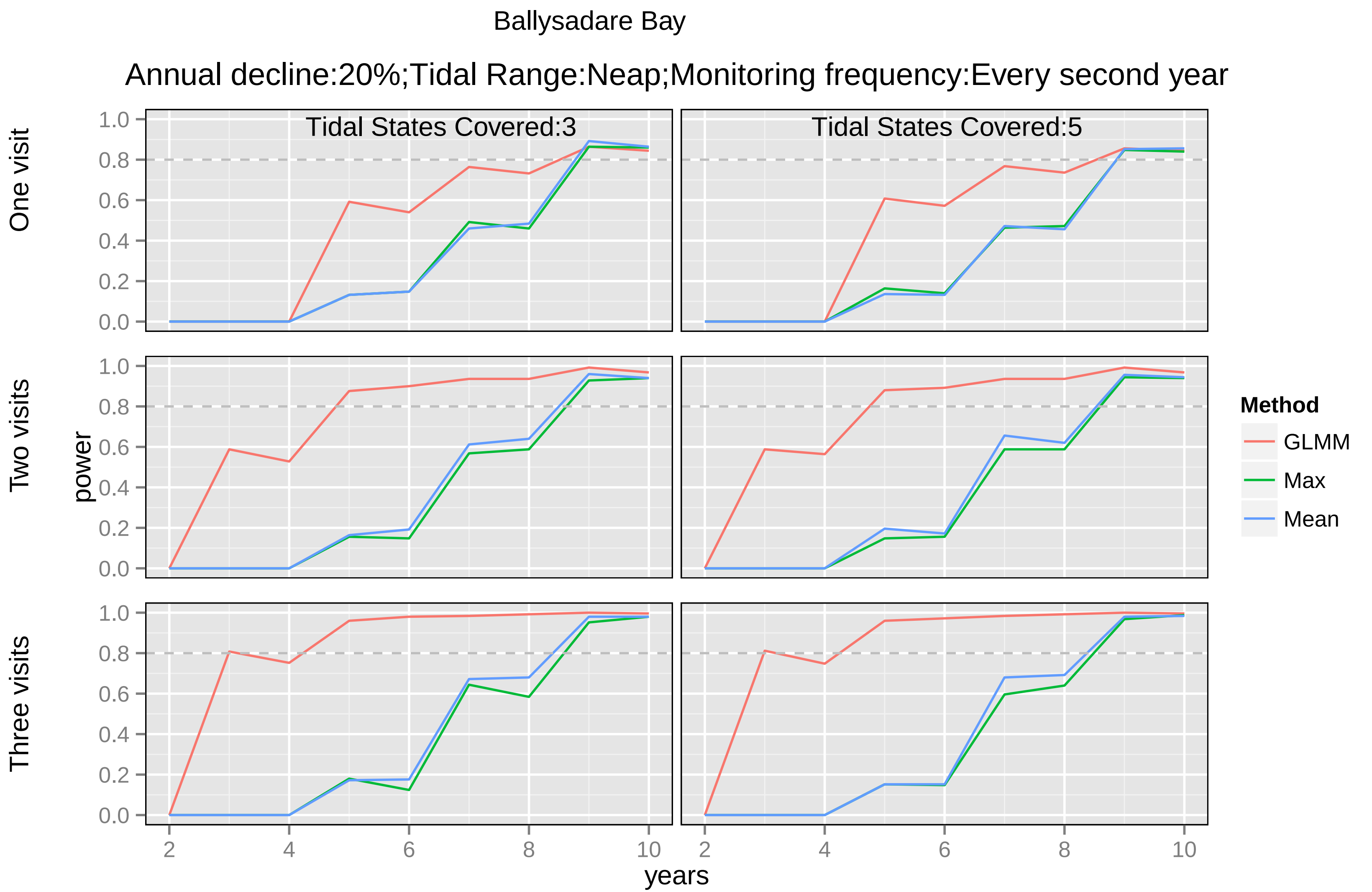

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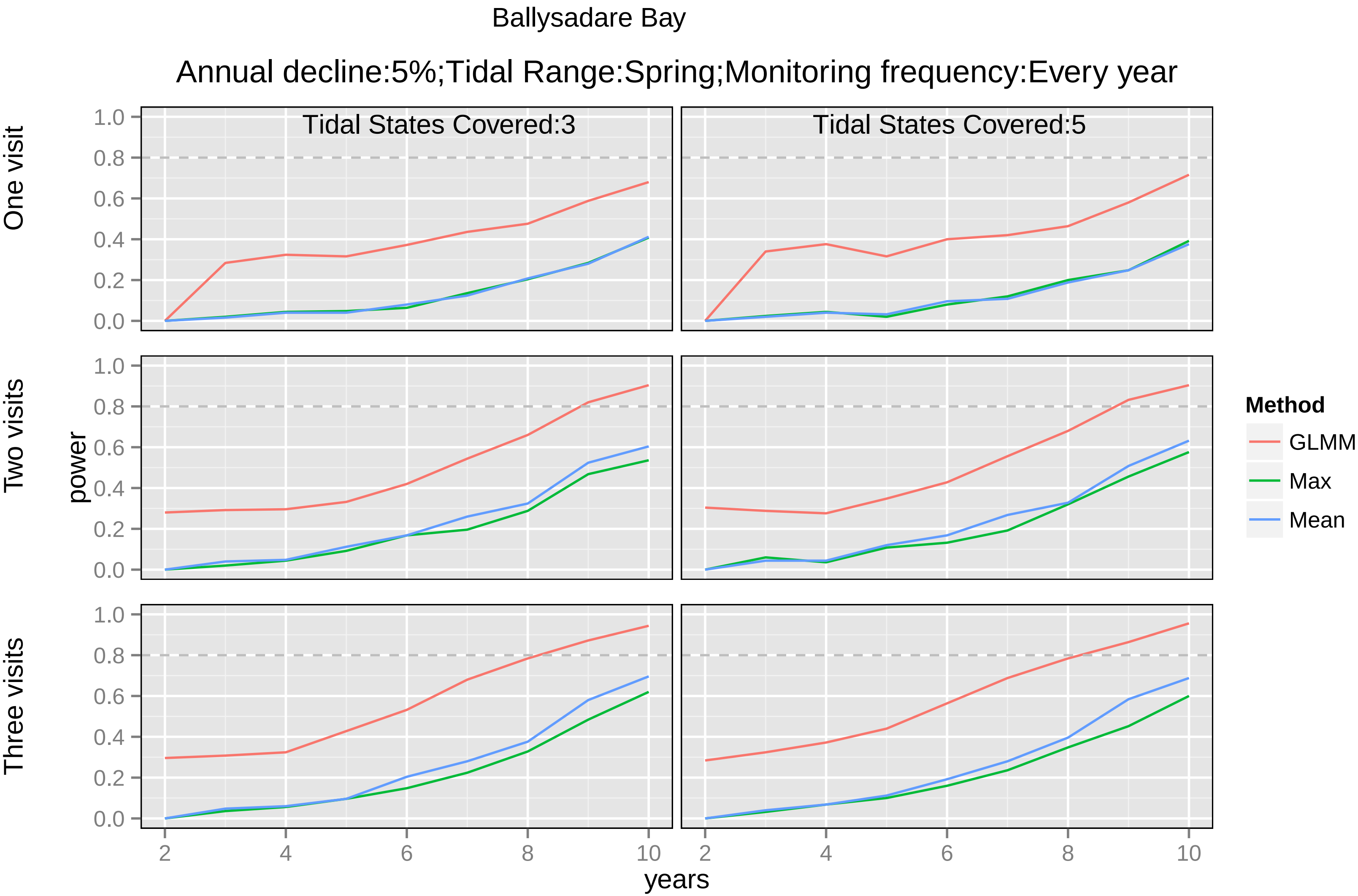
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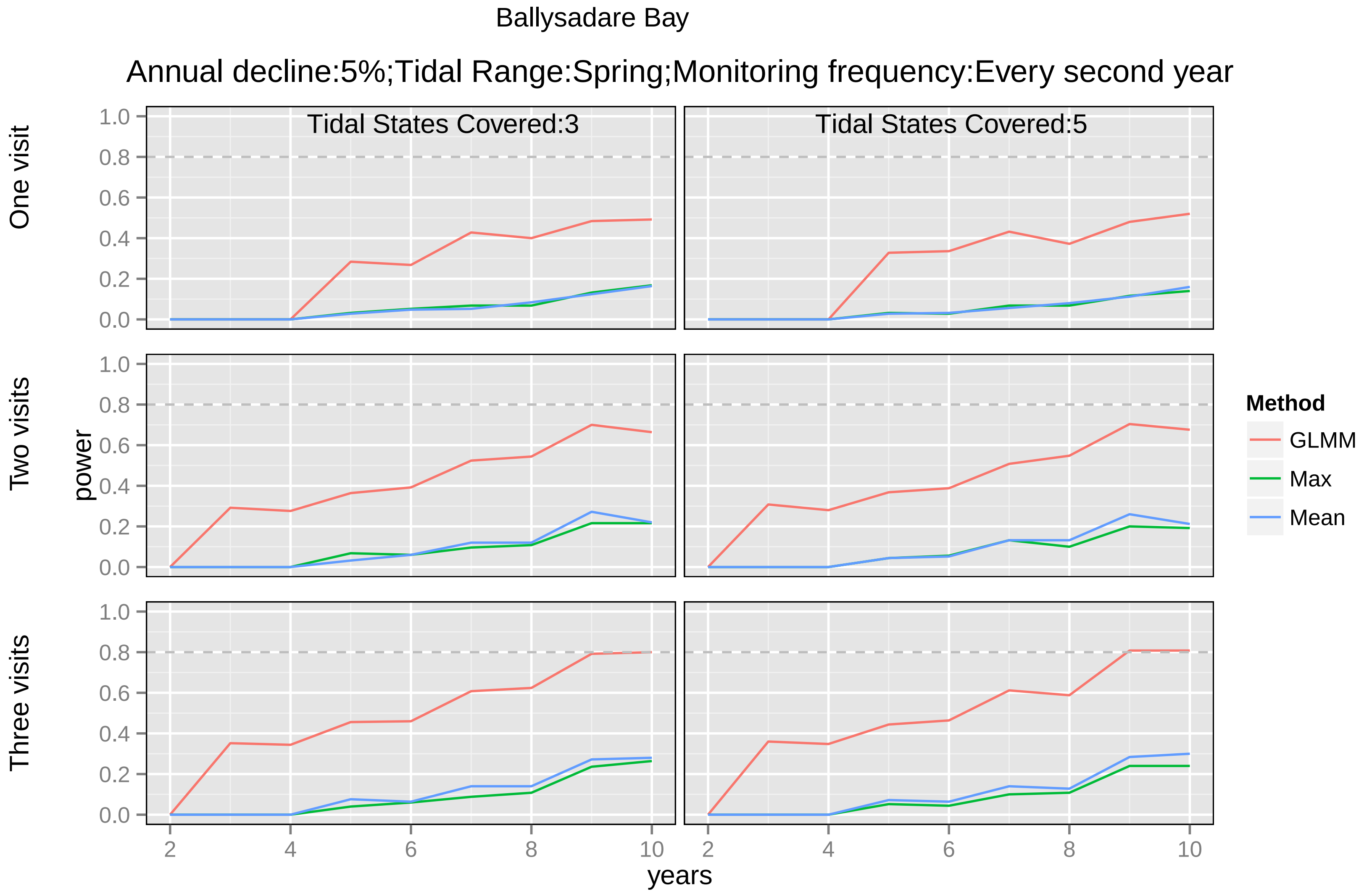
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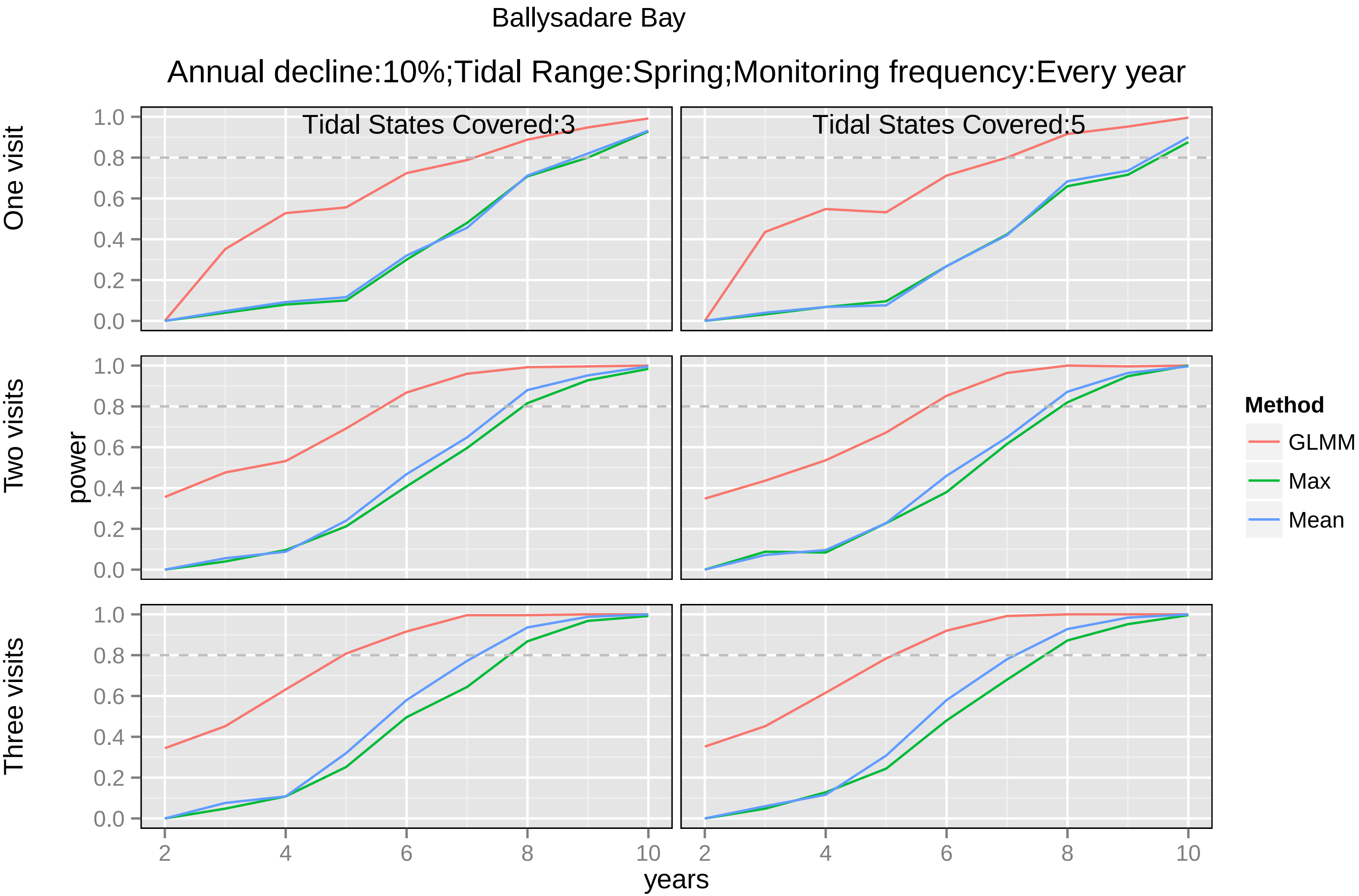

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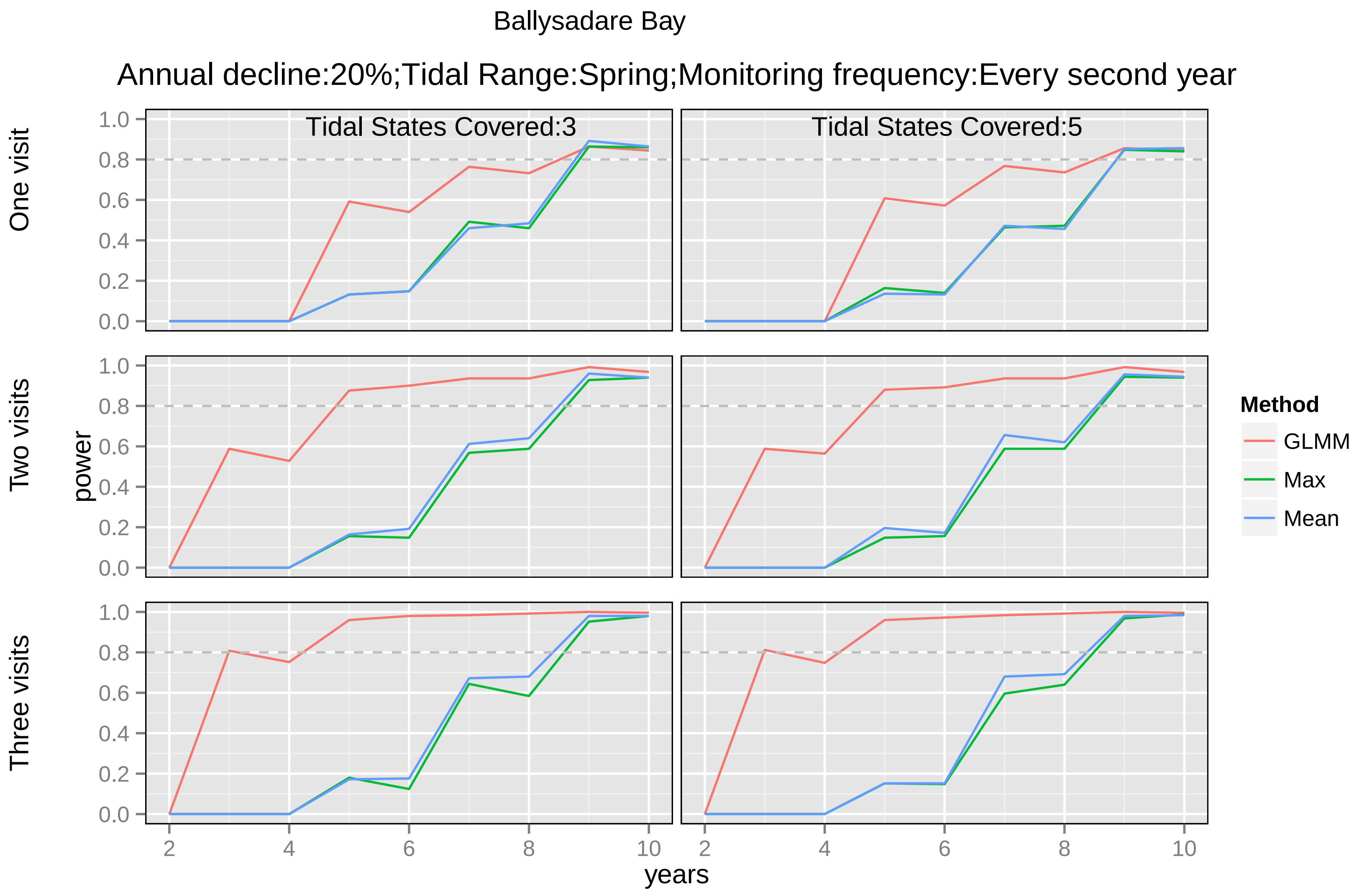
Ballysadare Bay
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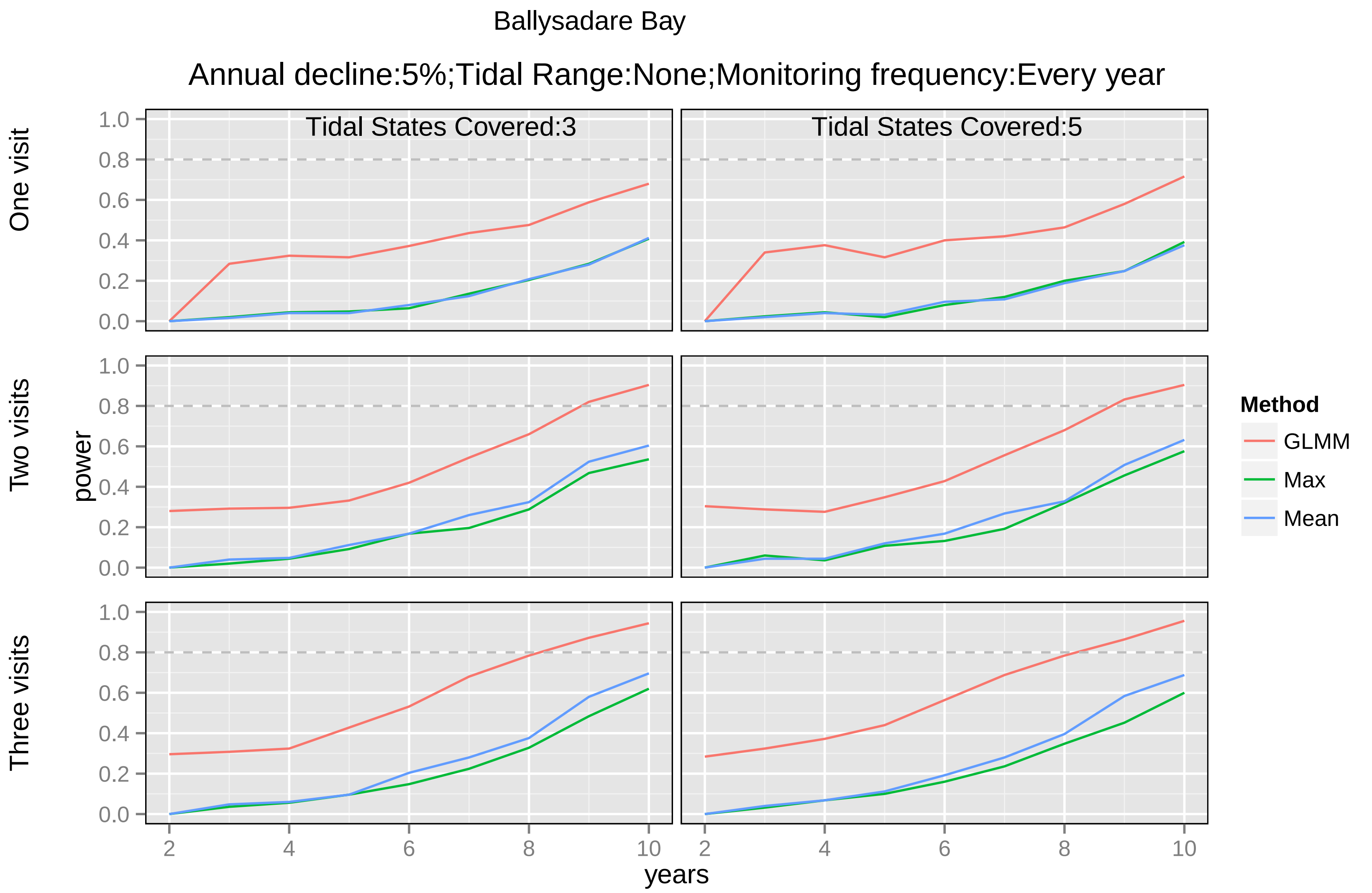
Ballysadare Bay
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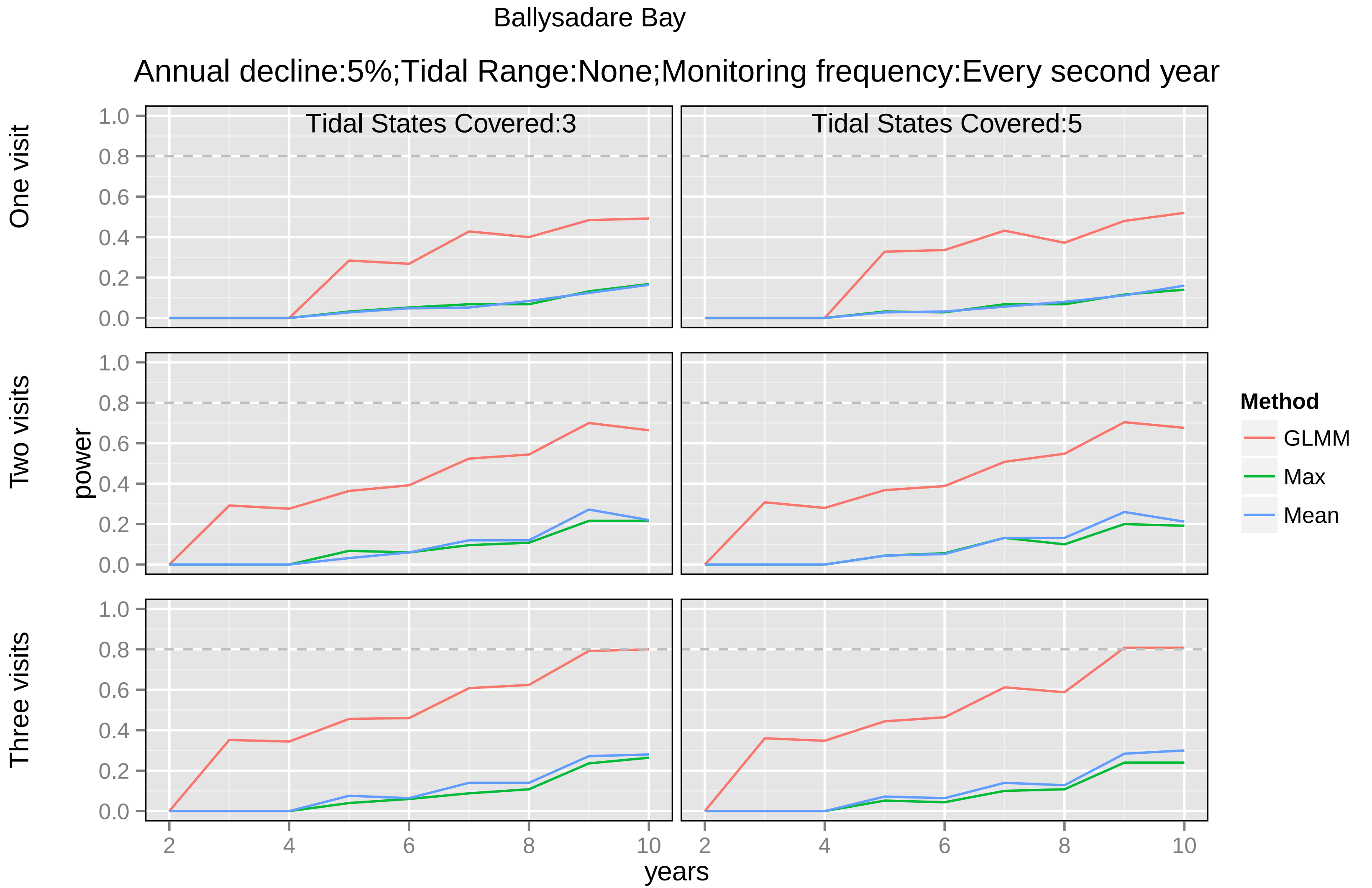
Ballysadare Bay
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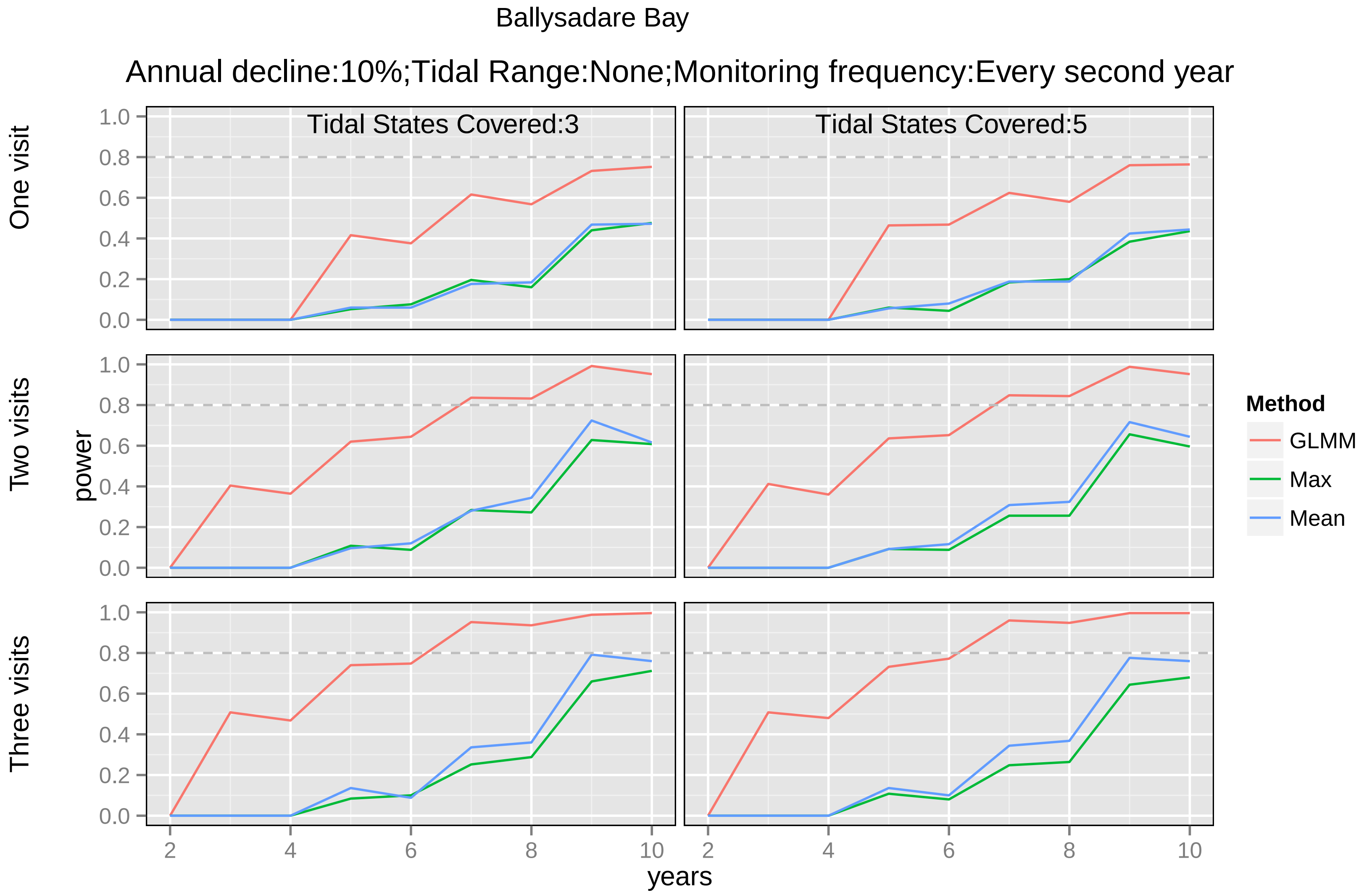
Ballysadare Bay
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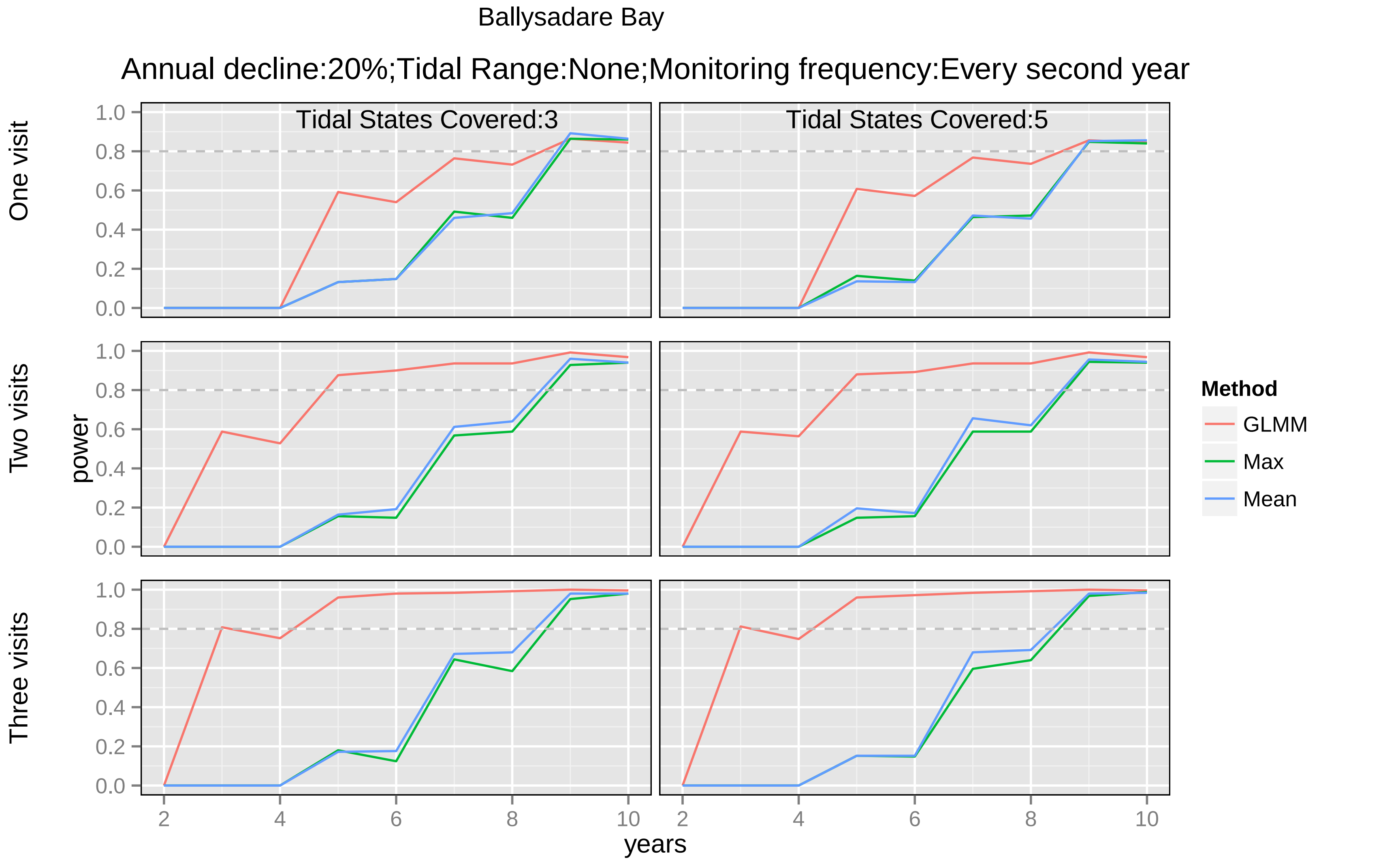
Ballysadare Bay
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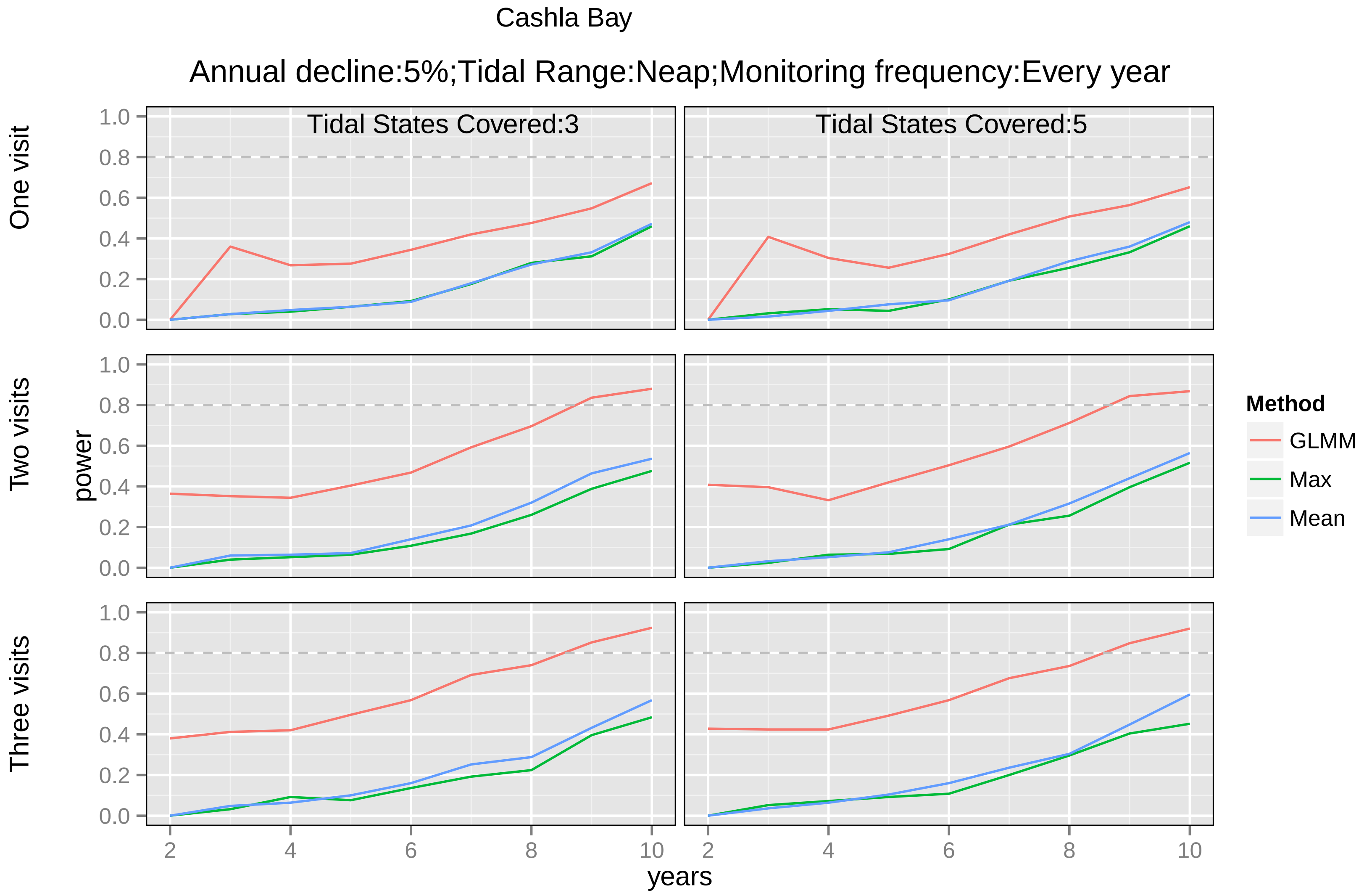
Cashla Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
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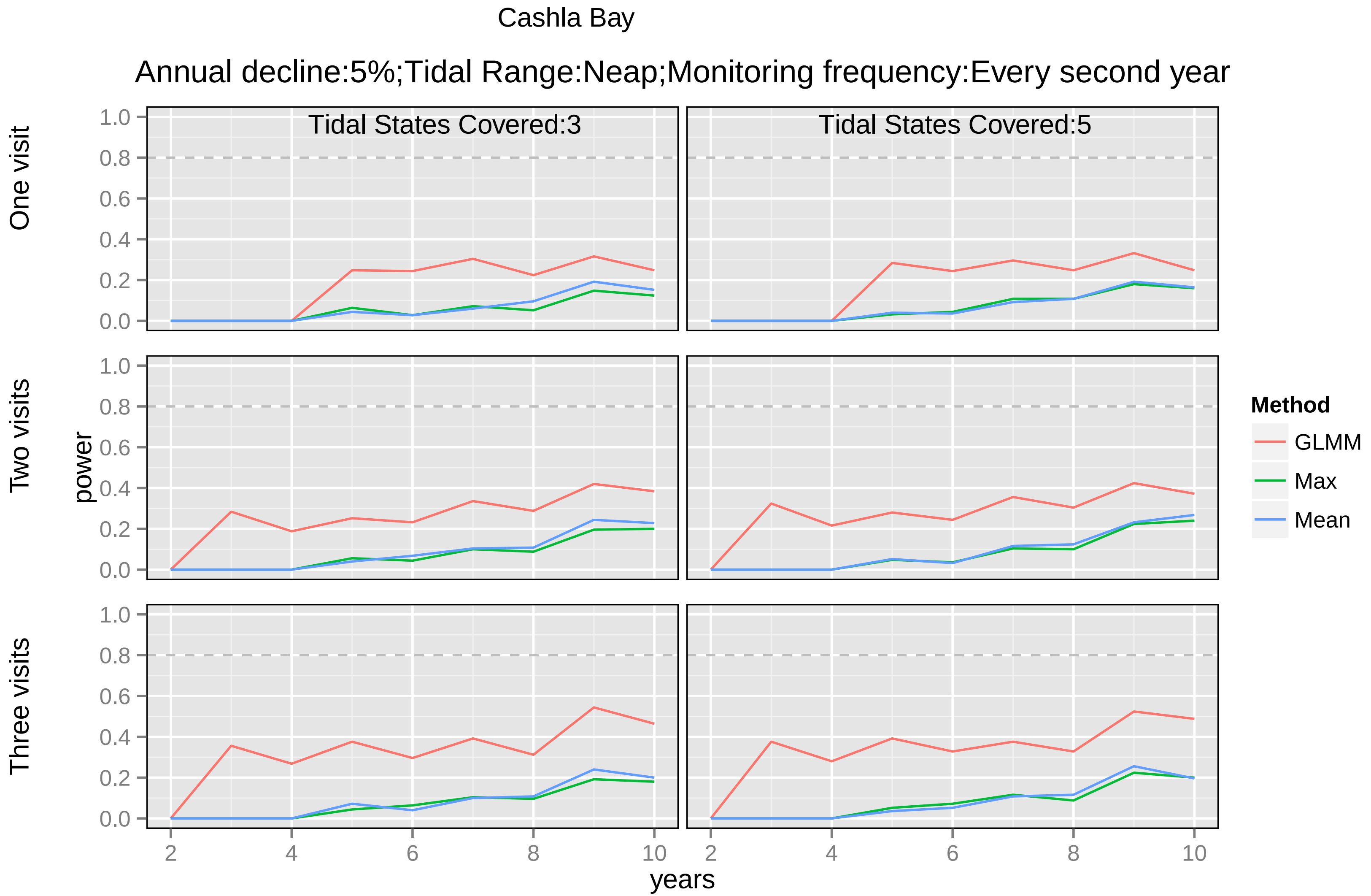

Cashla Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
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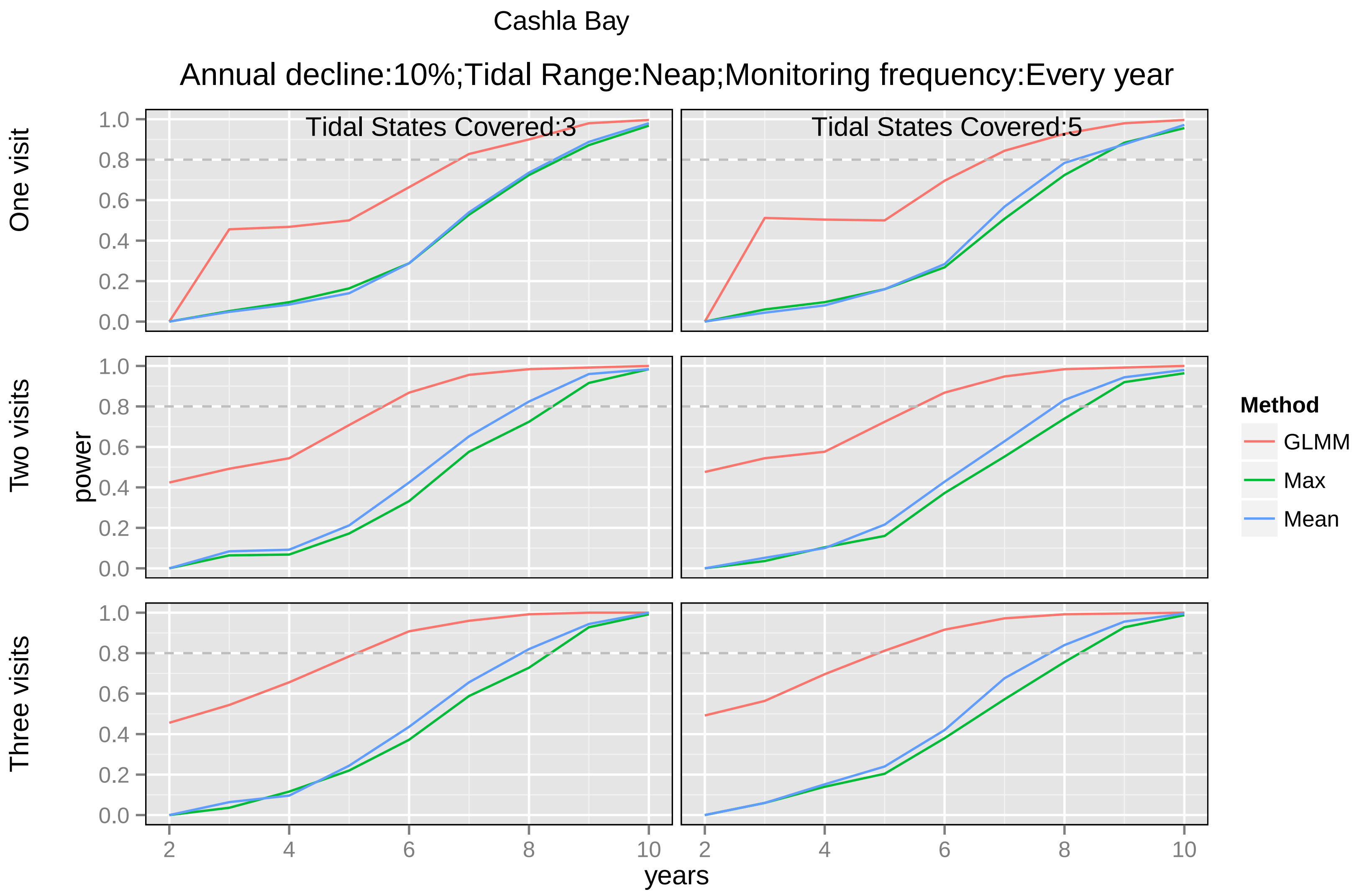
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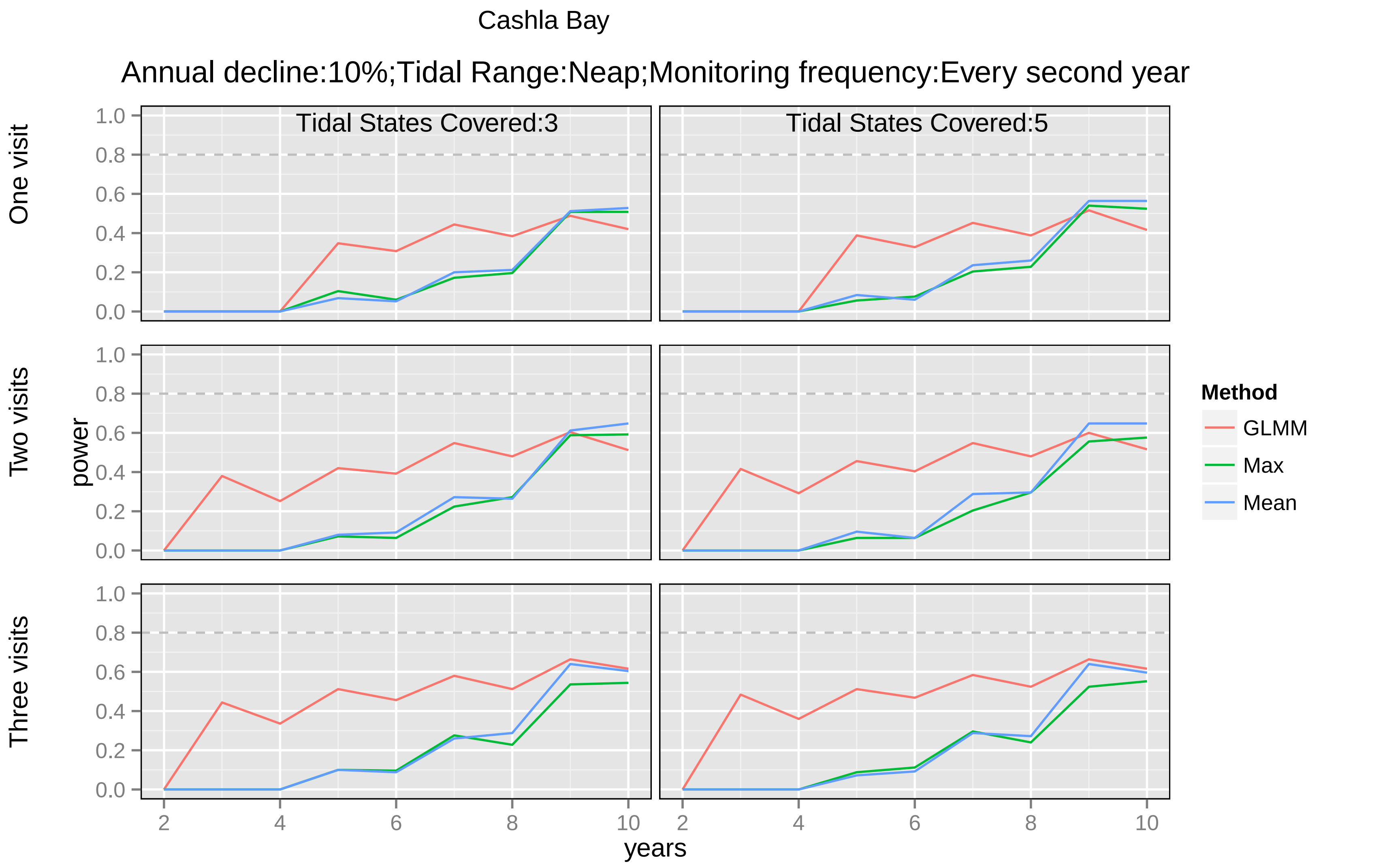

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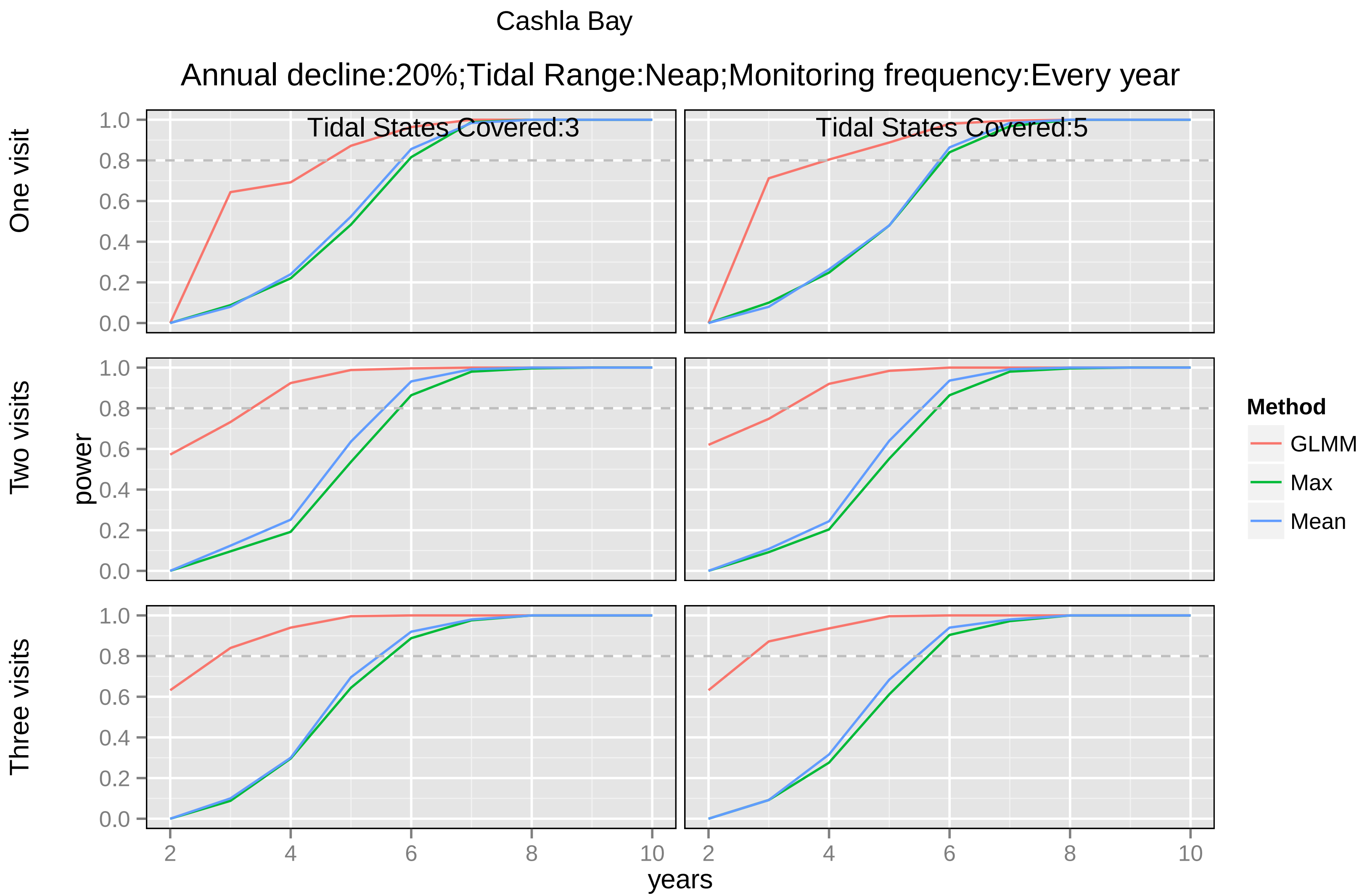
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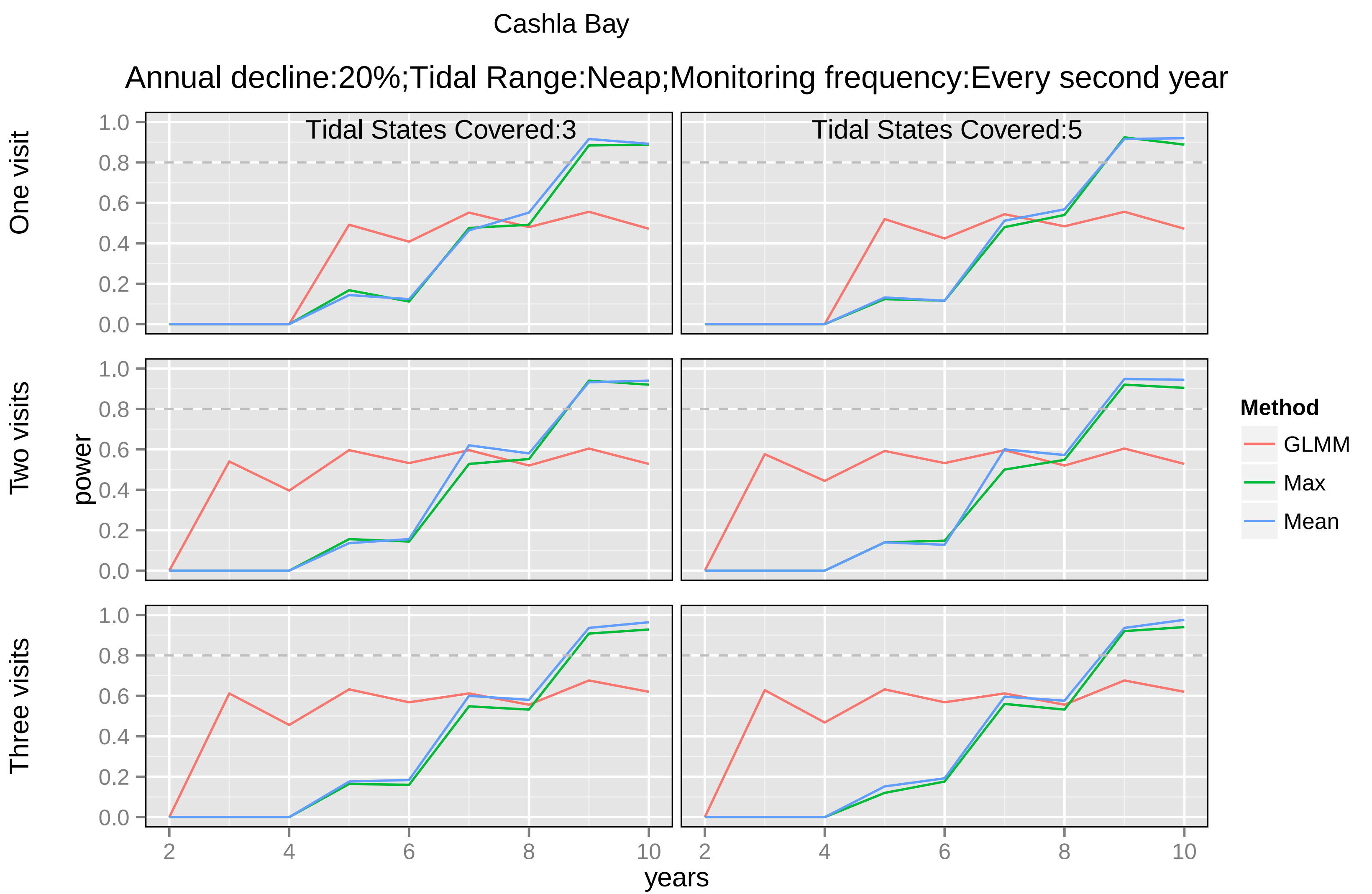
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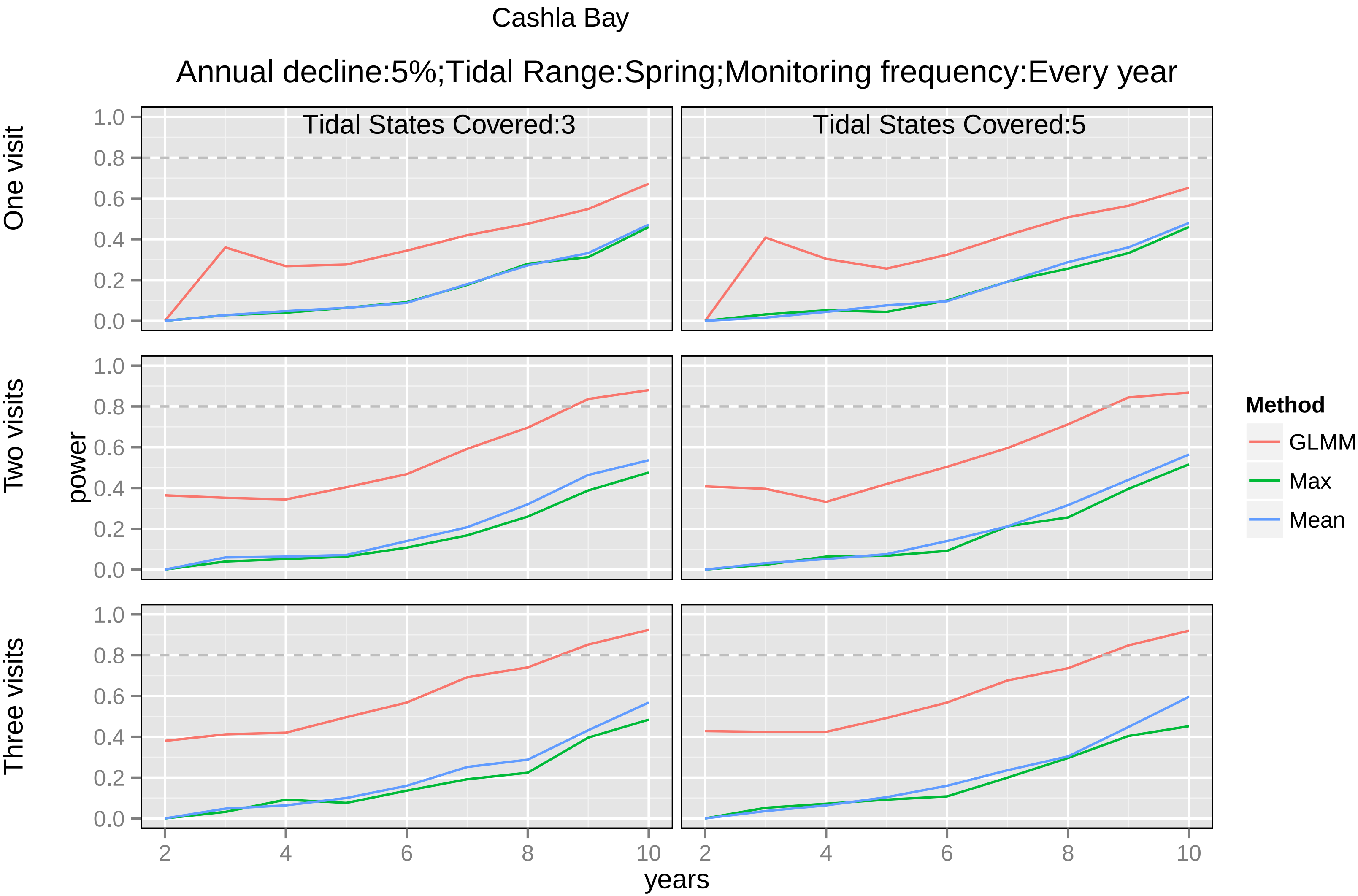
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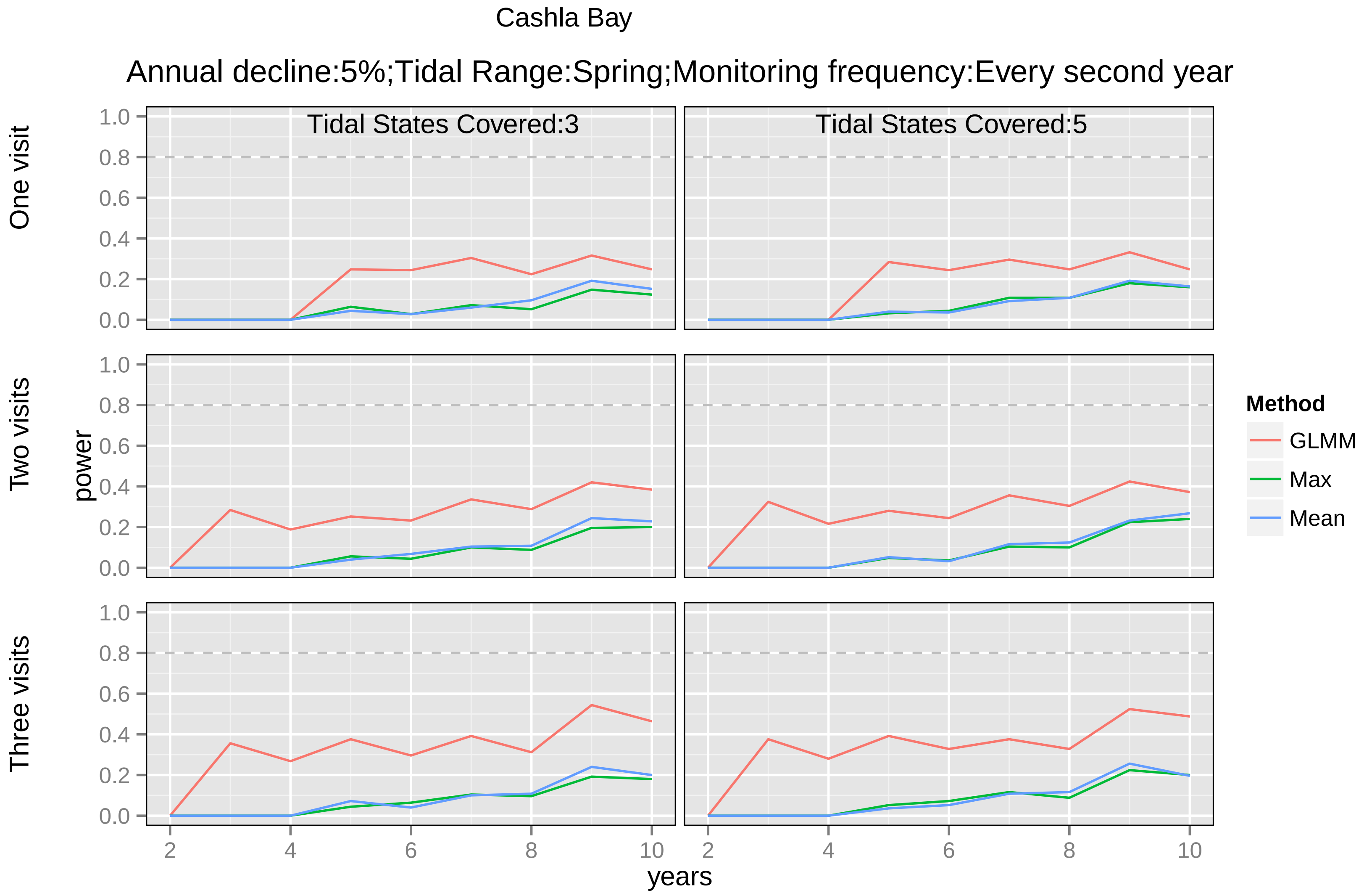
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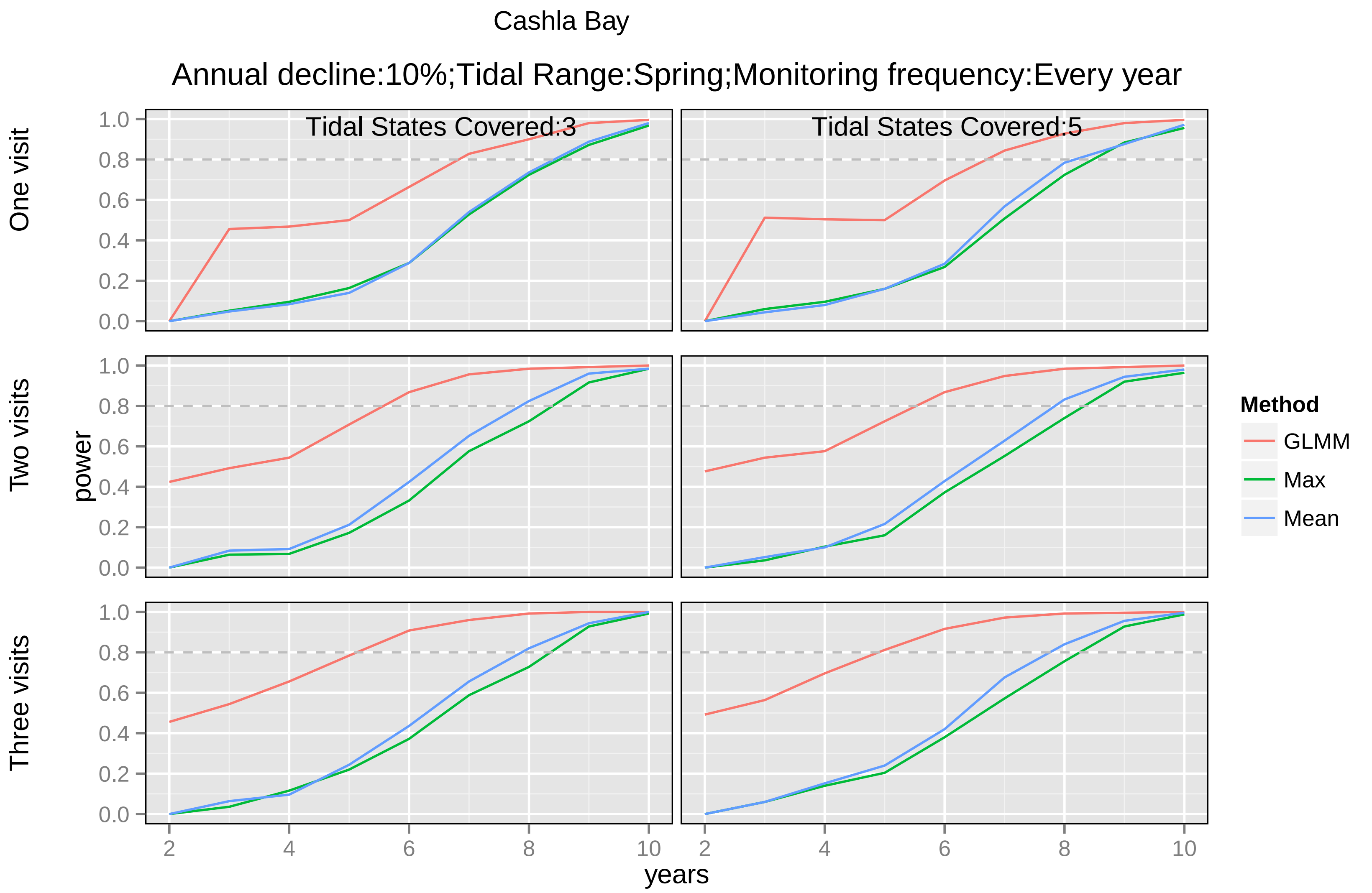
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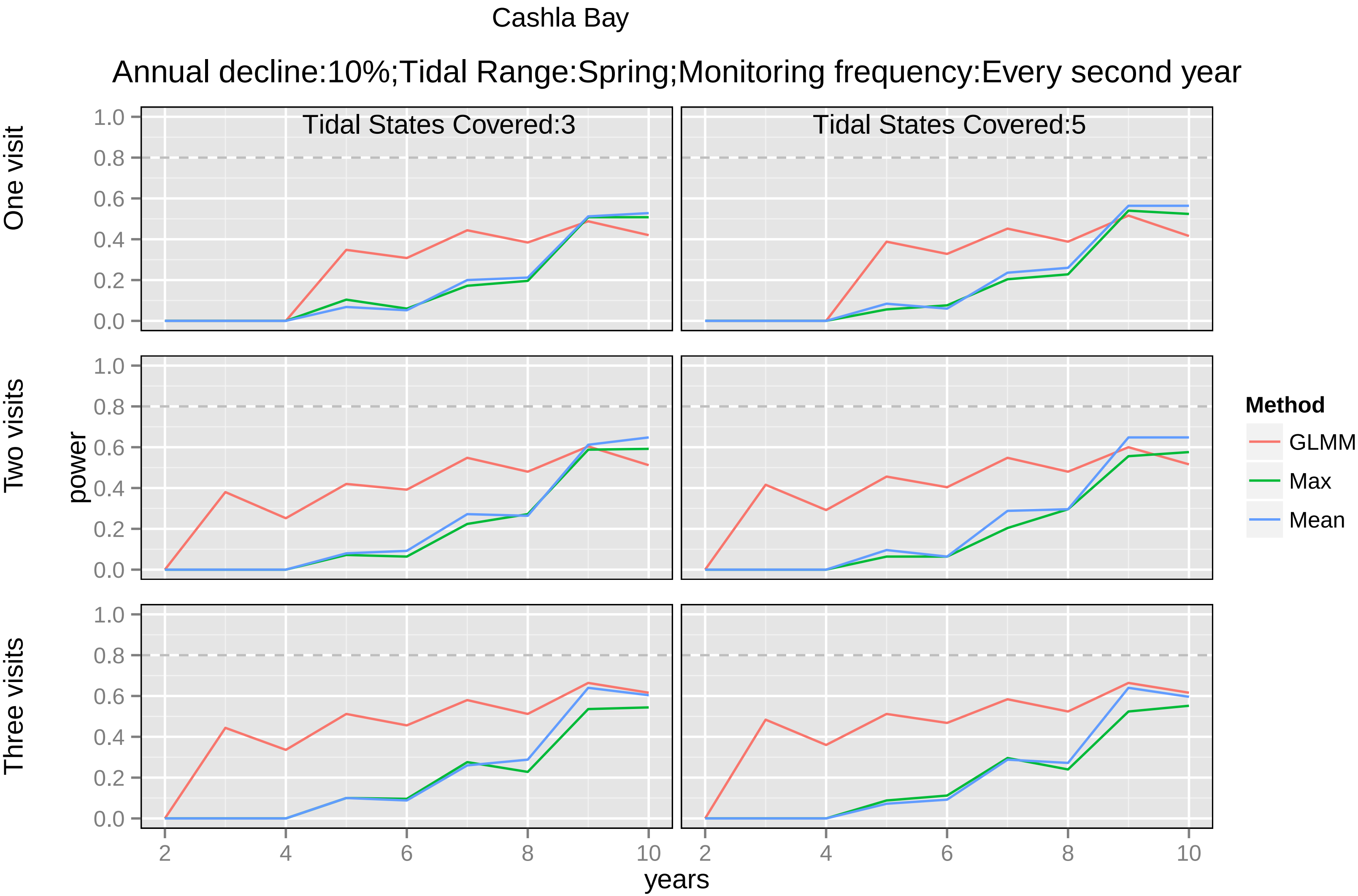
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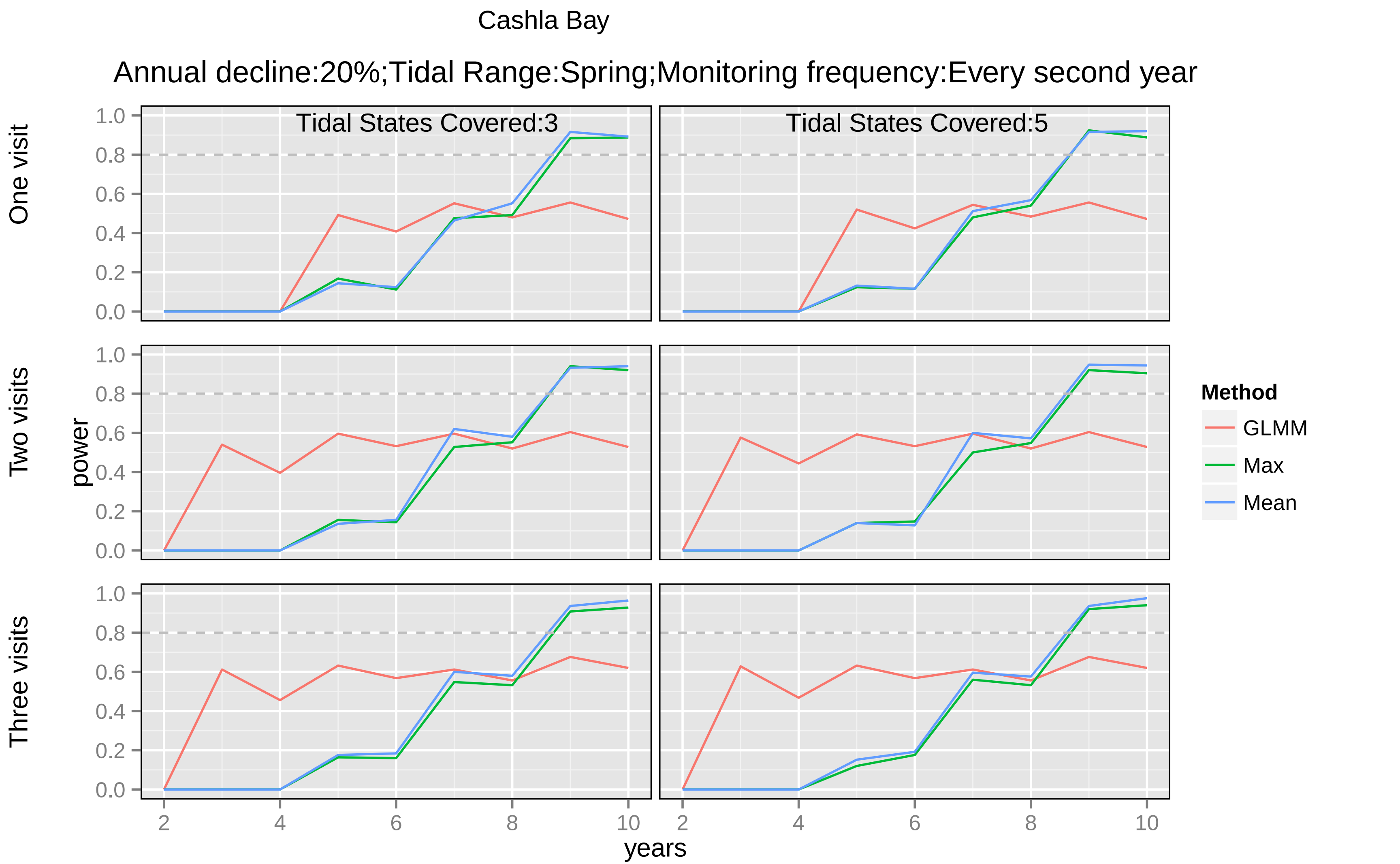
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One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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0.6
0.8
1.0
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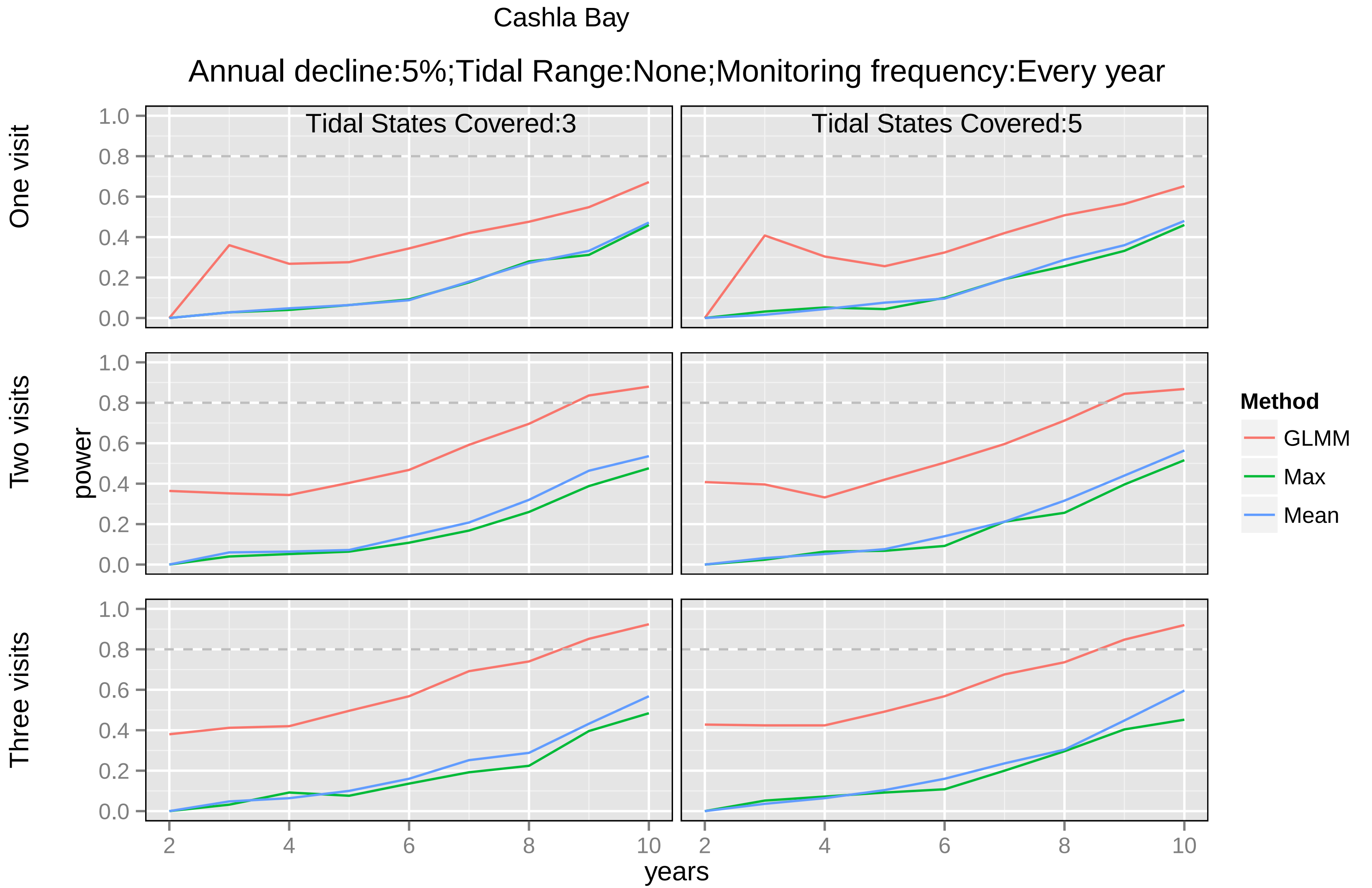
Cashla Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
1.0
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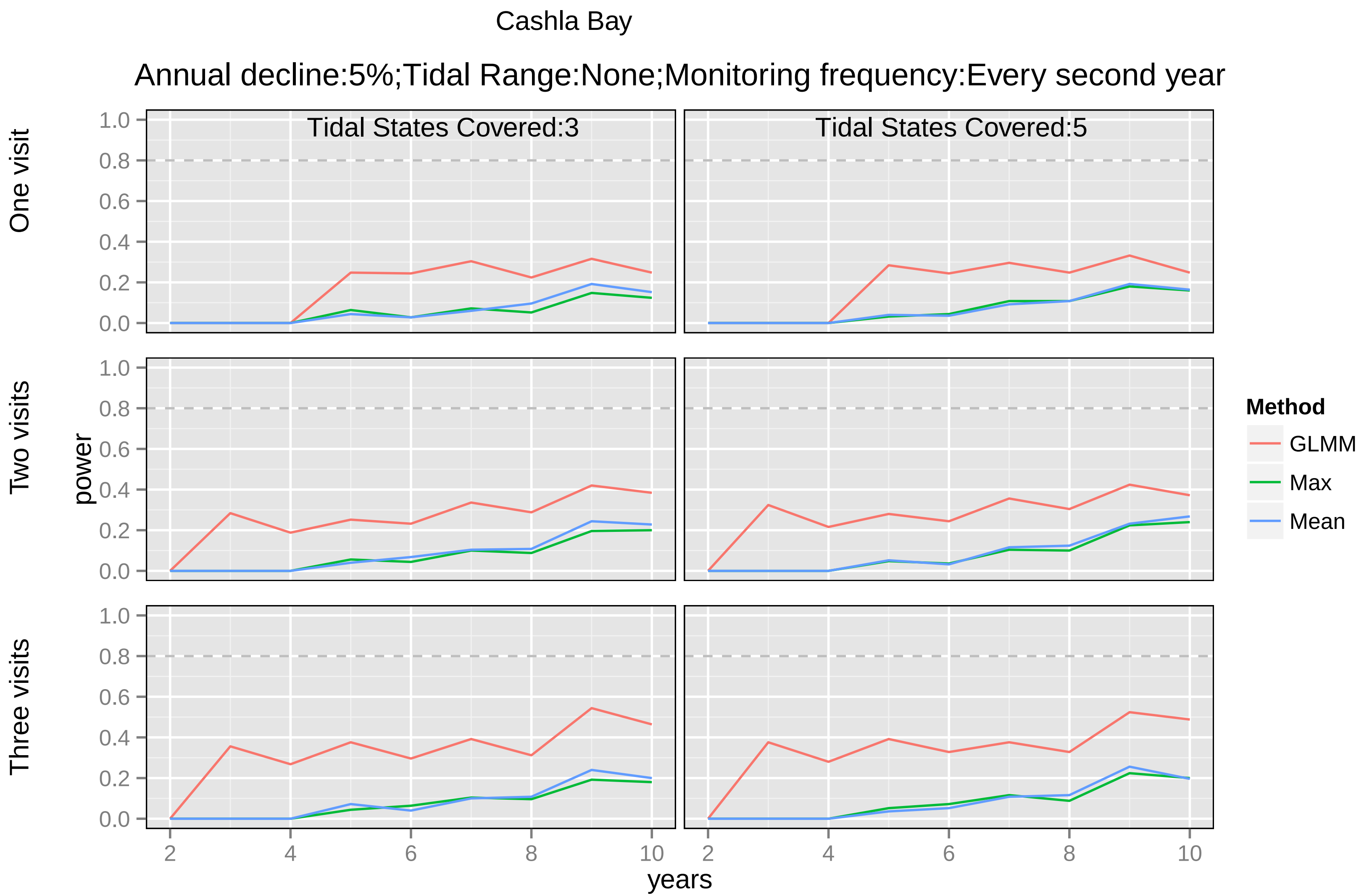

Cashla Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean

Cashla Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
1.0
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0.6
0.4
0.2
0.0
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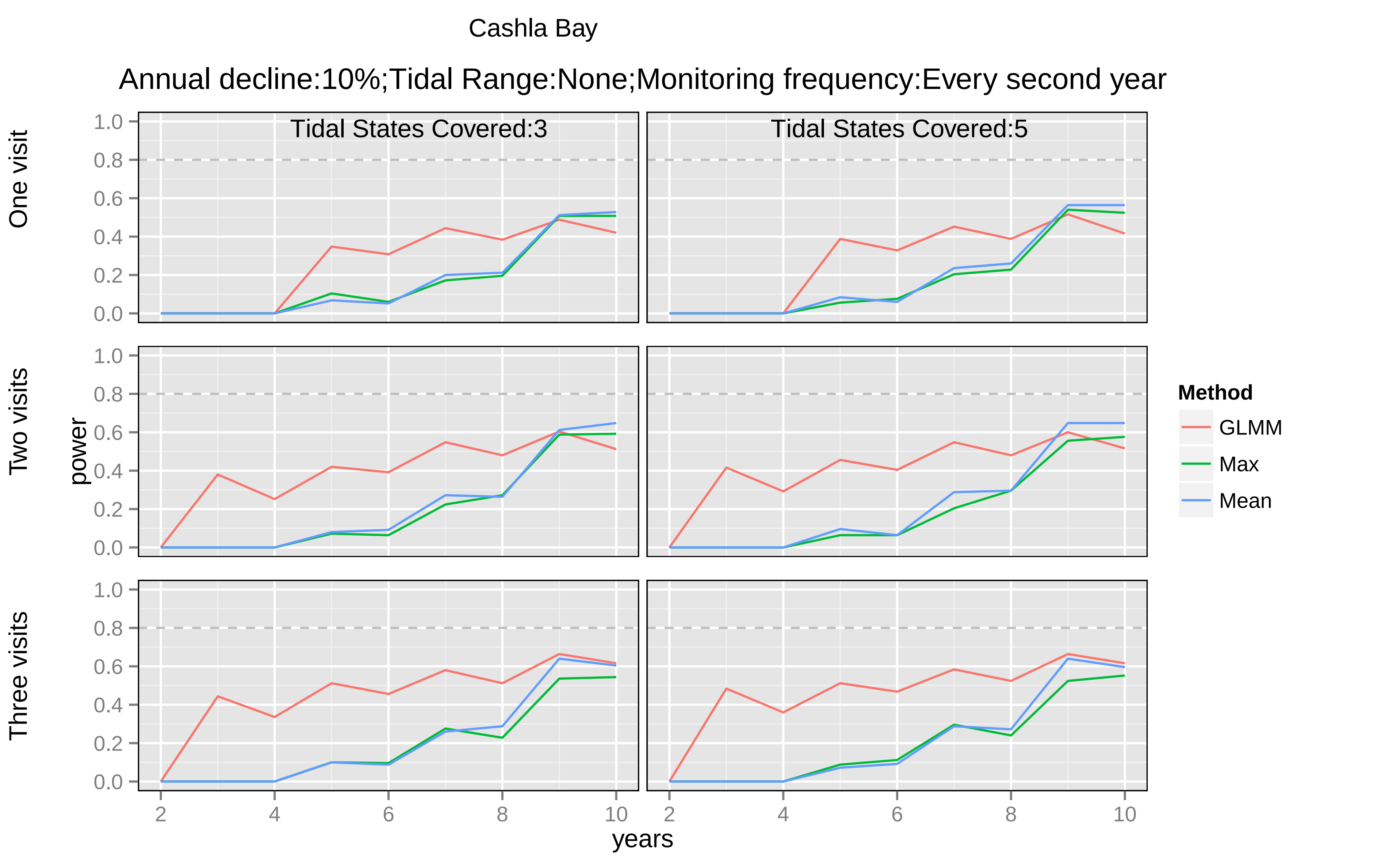
4
6
8
10
Method
GLMM
Max
Mean



Cashla Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
1.0
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6
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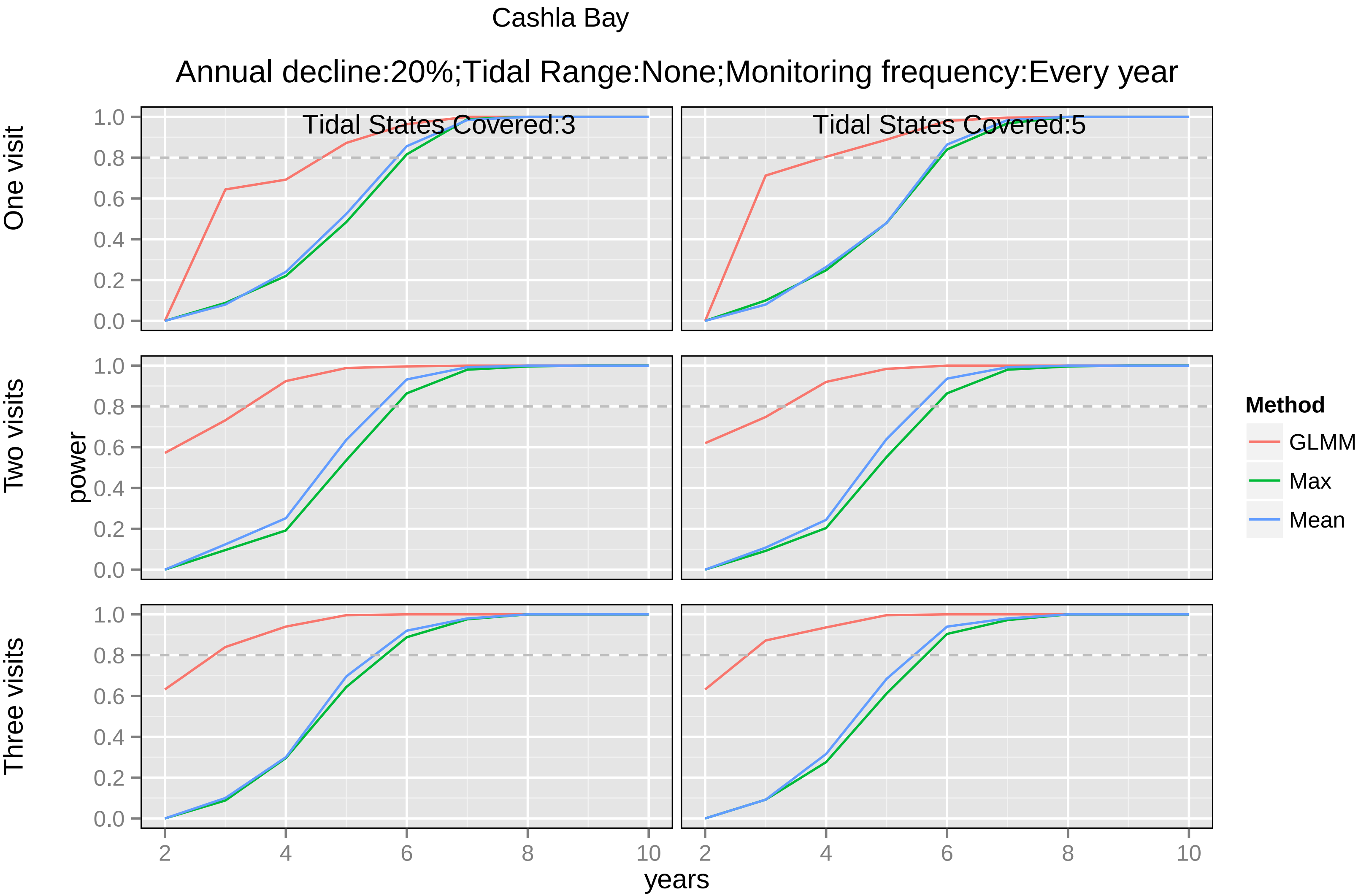
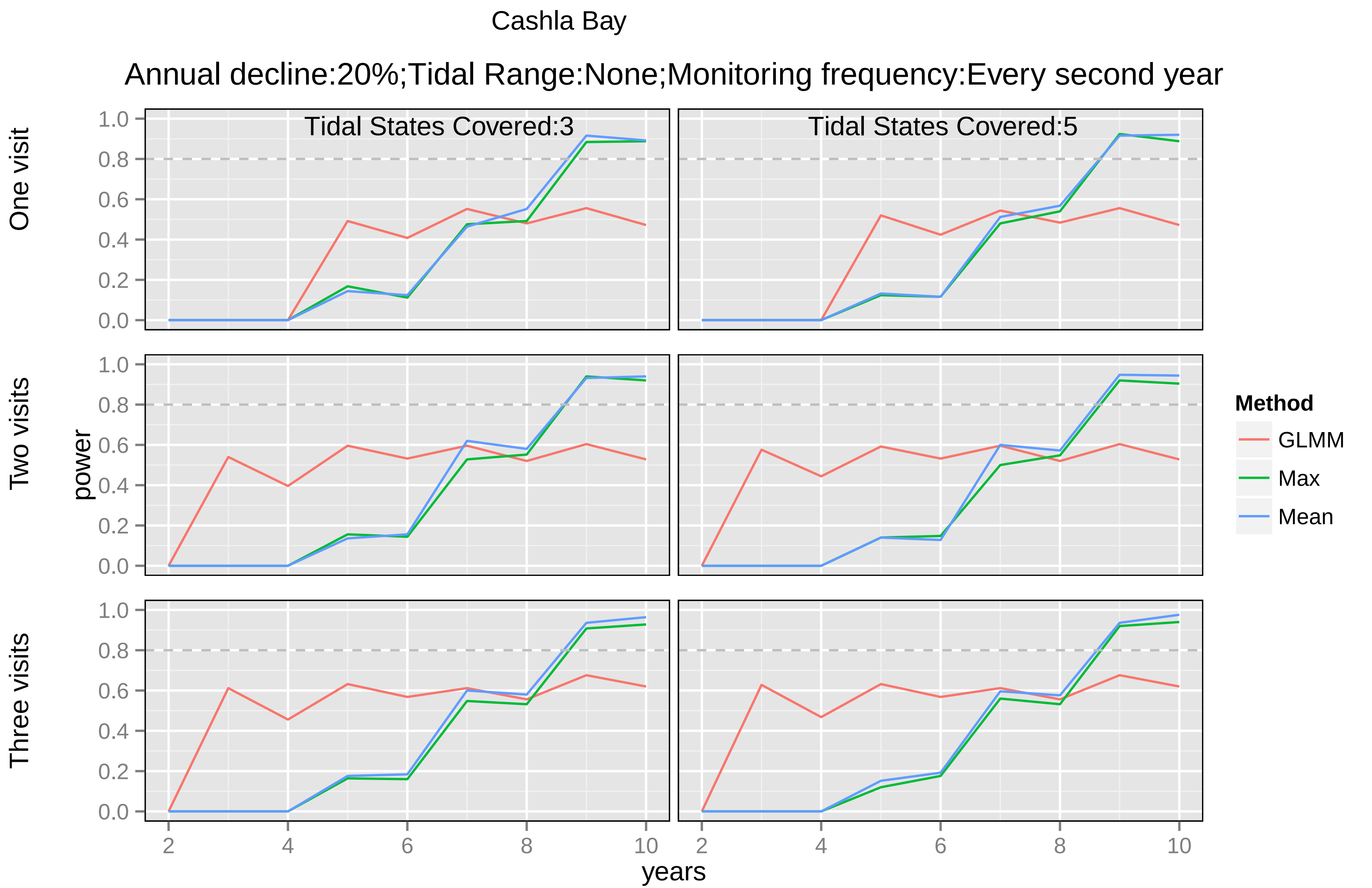
10
Method
GLMM
Max
Mean


Cashla Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean


Cashla Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
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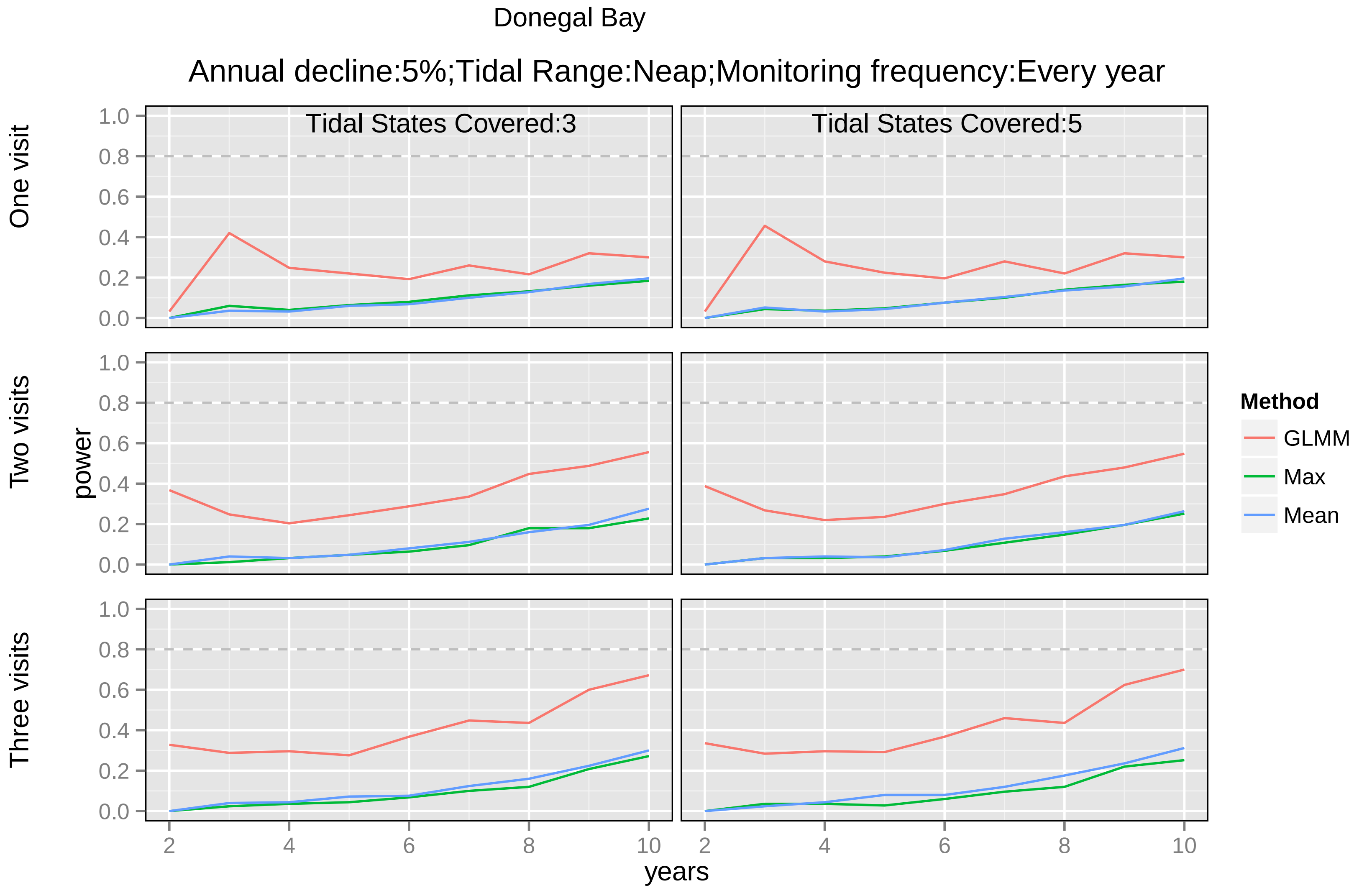
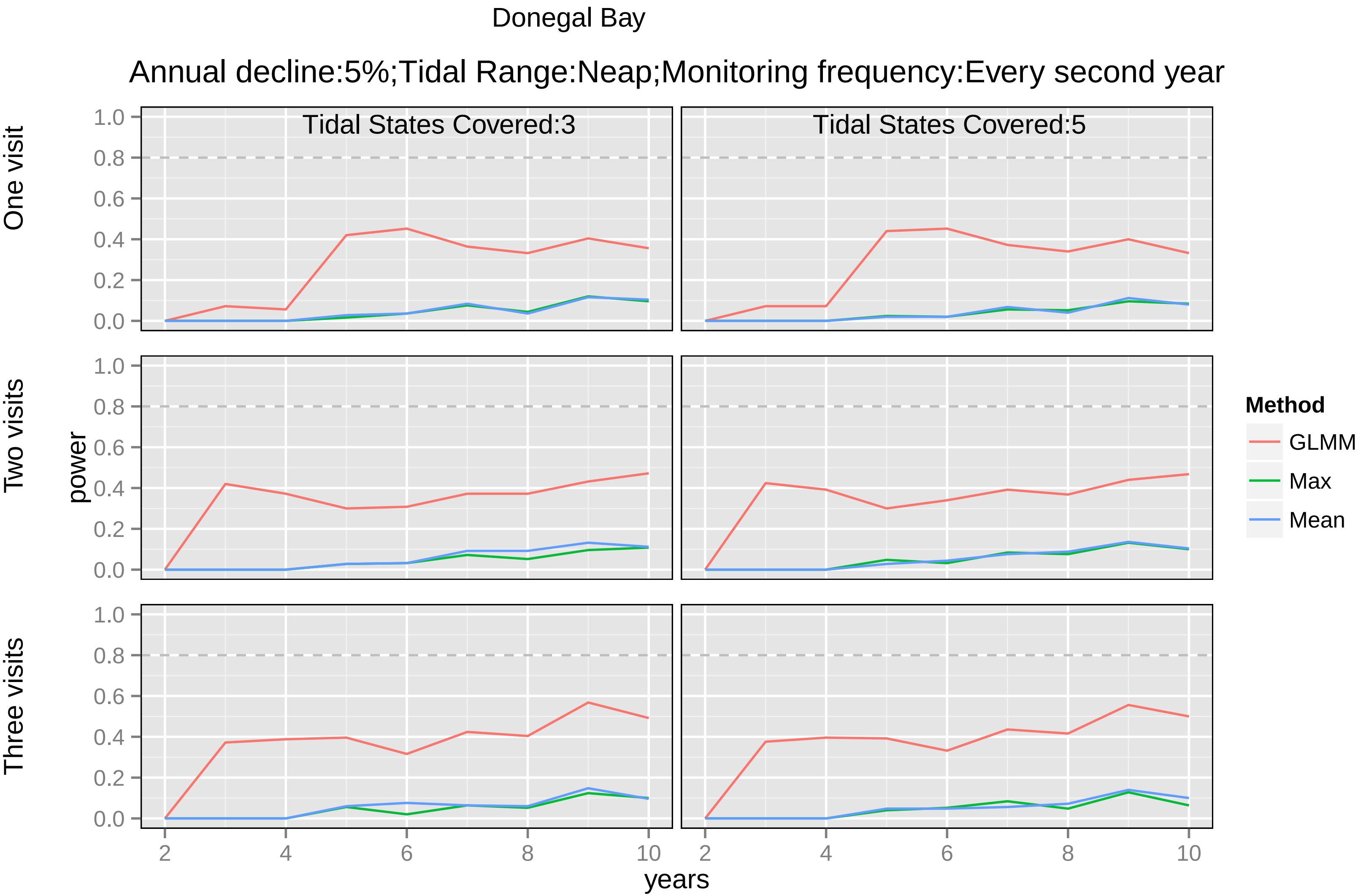


Donegal Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean


Donegal Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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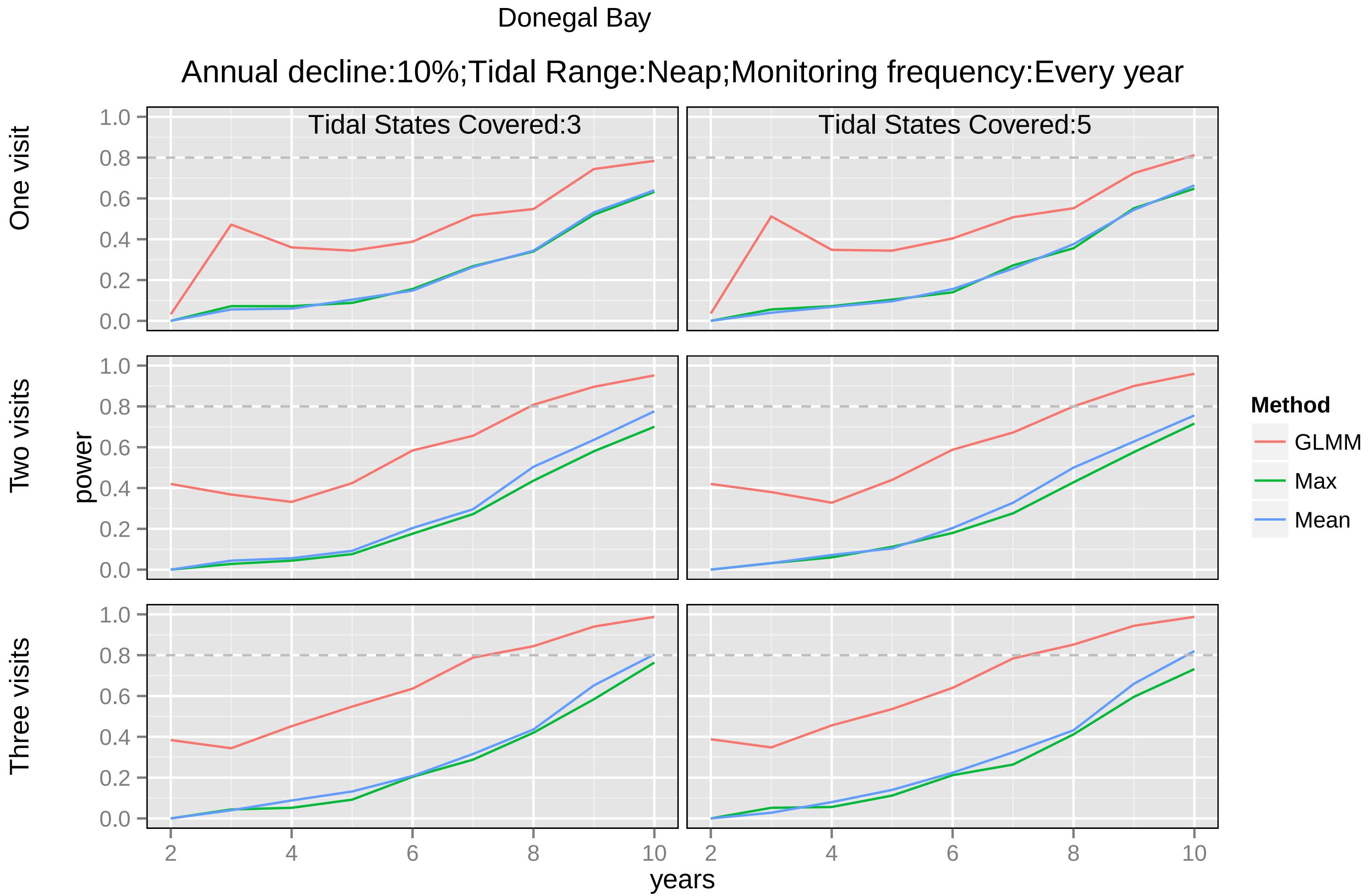
Method
GLMM
Max
Mean


Donegal Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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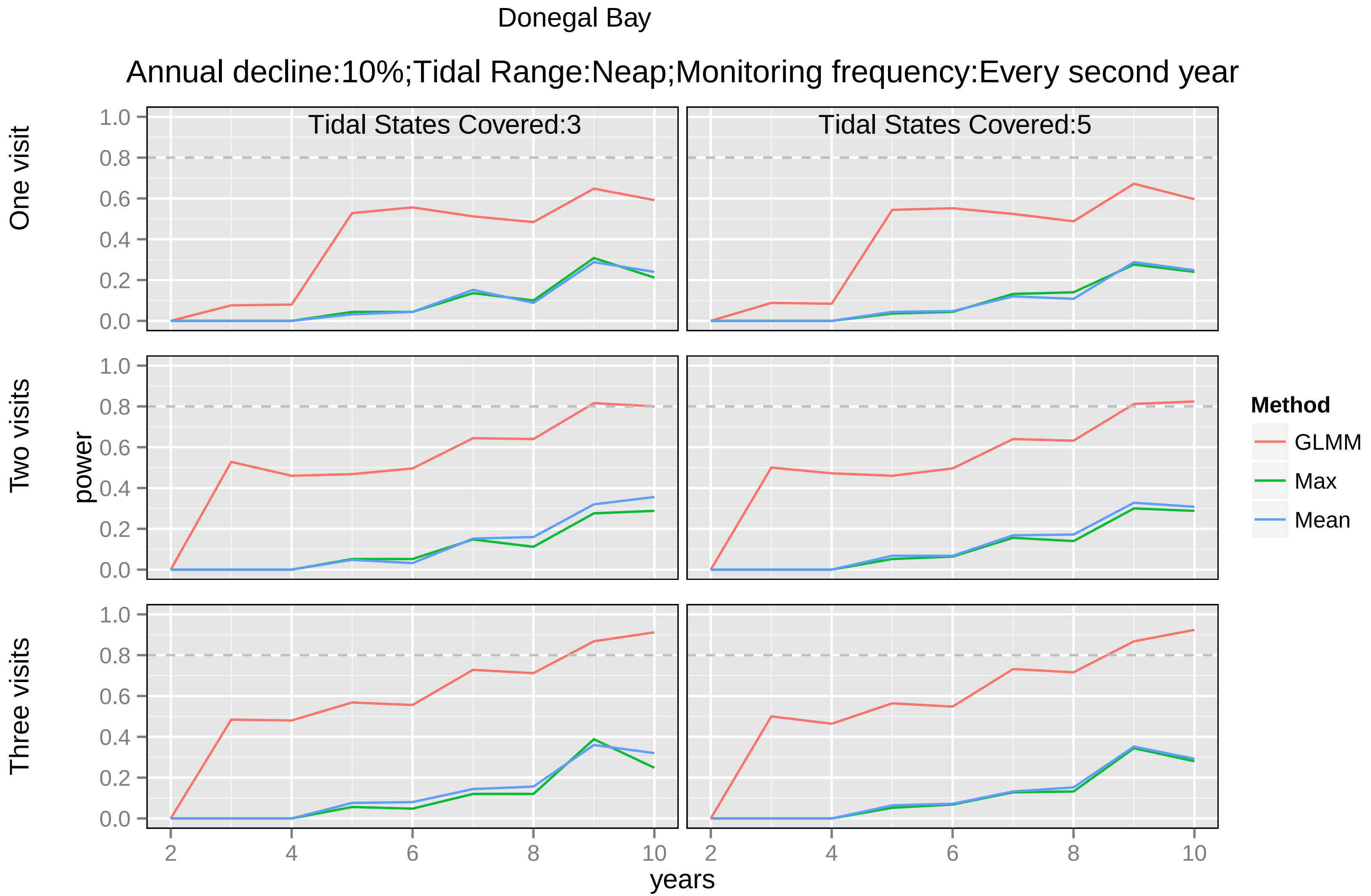
Donegal Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
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Mean


Donegal Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
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Mean
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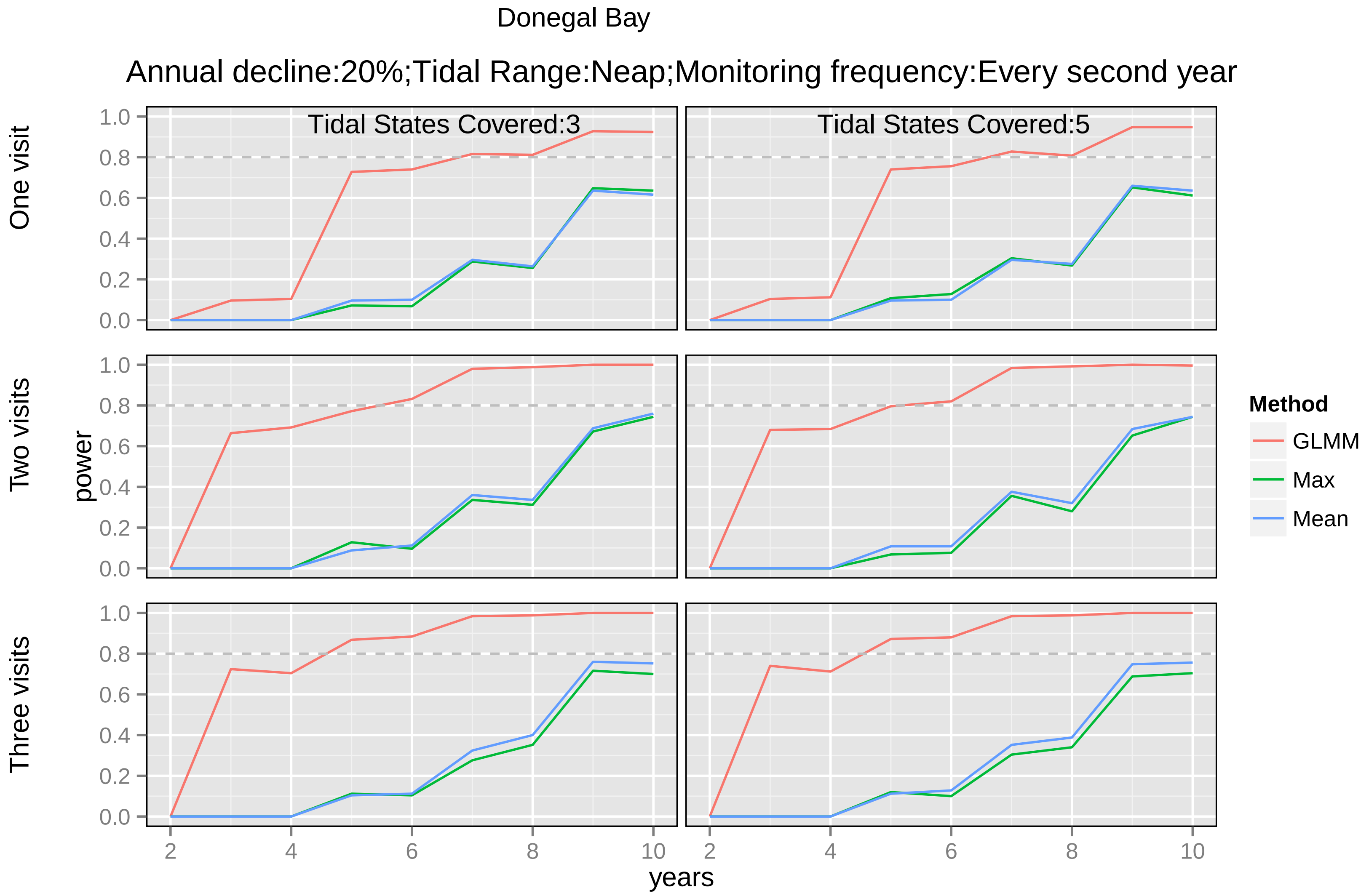

Donegal Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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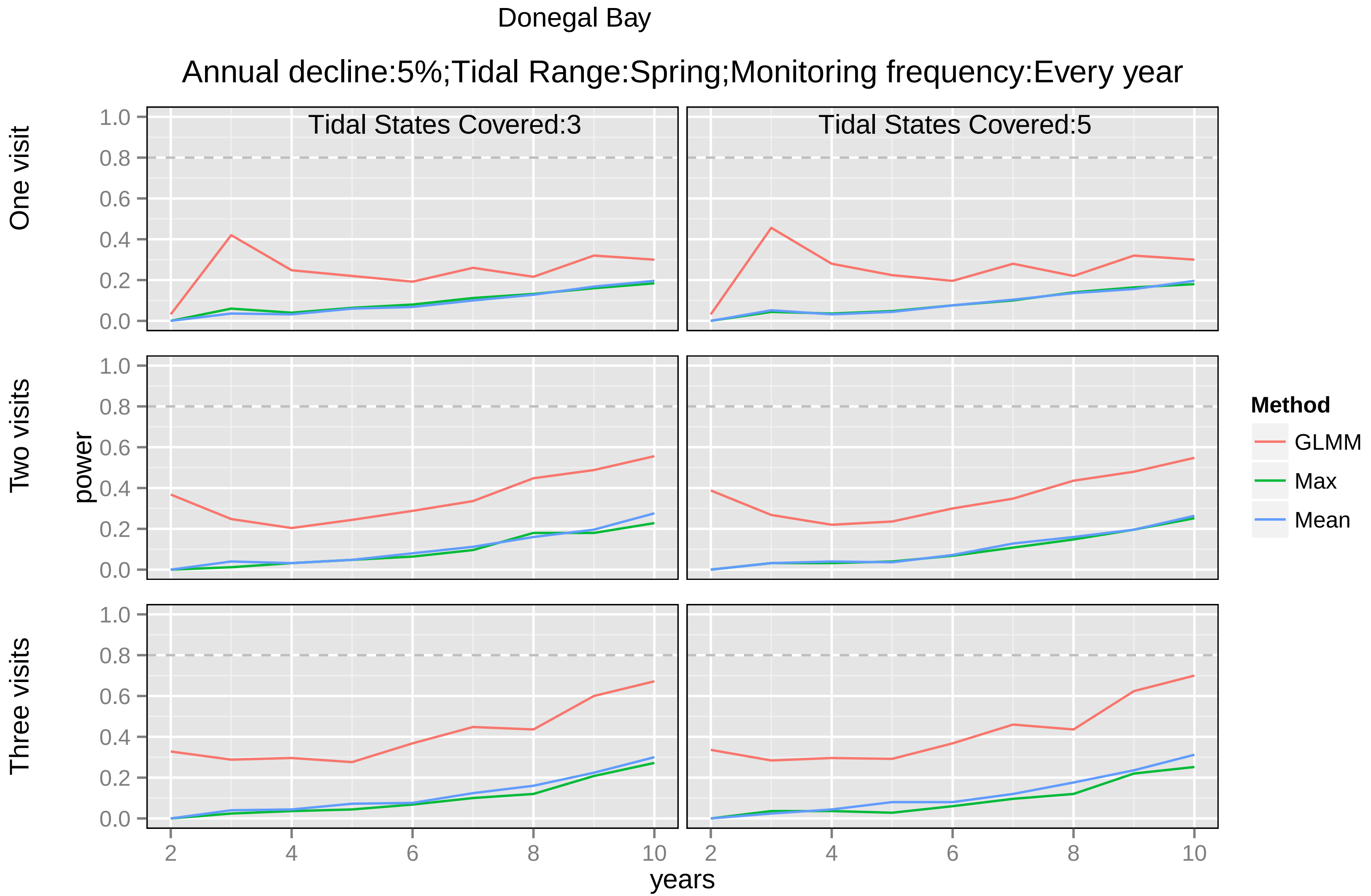
Donegal Bay
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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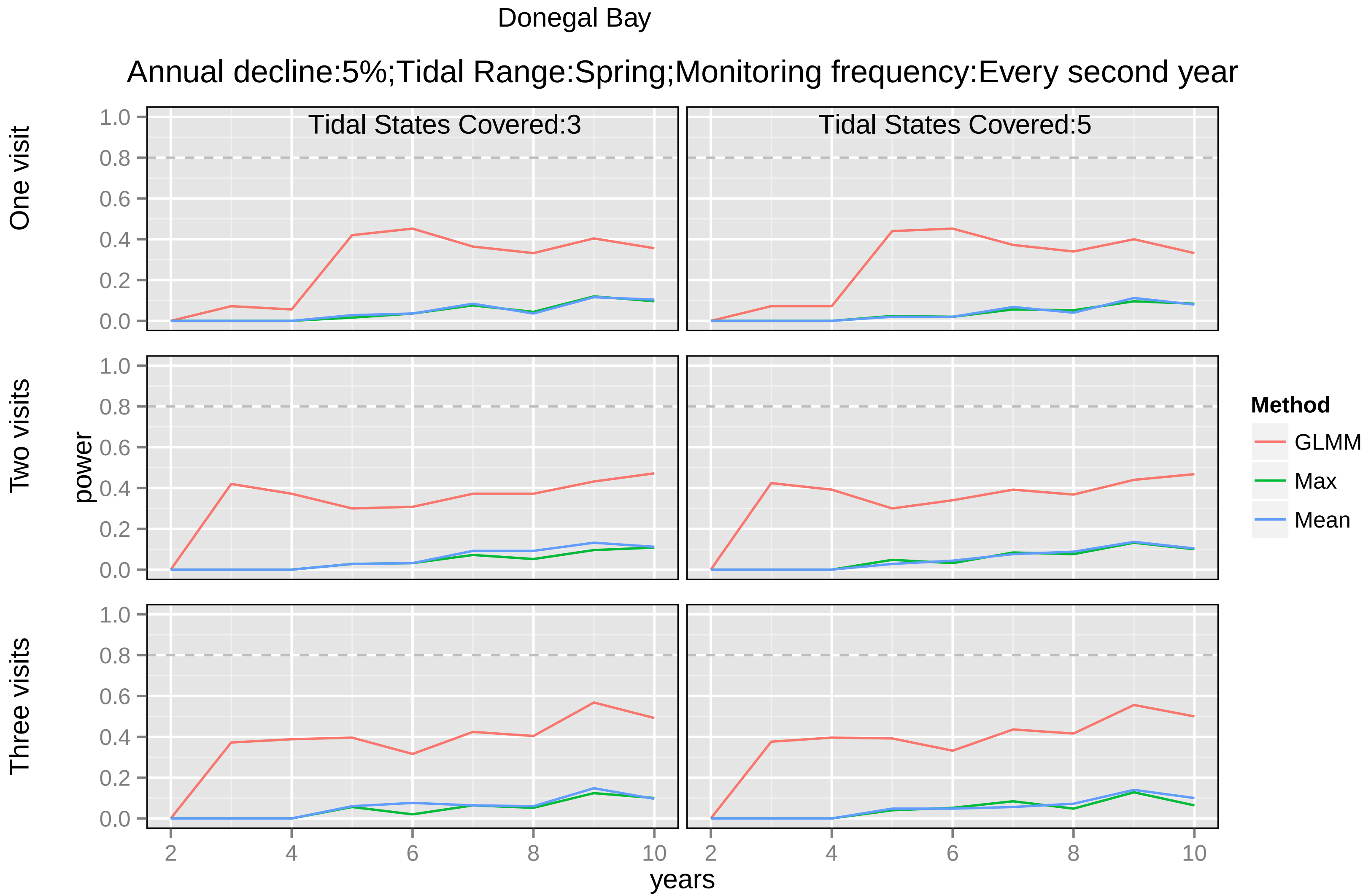

Donegal Bay
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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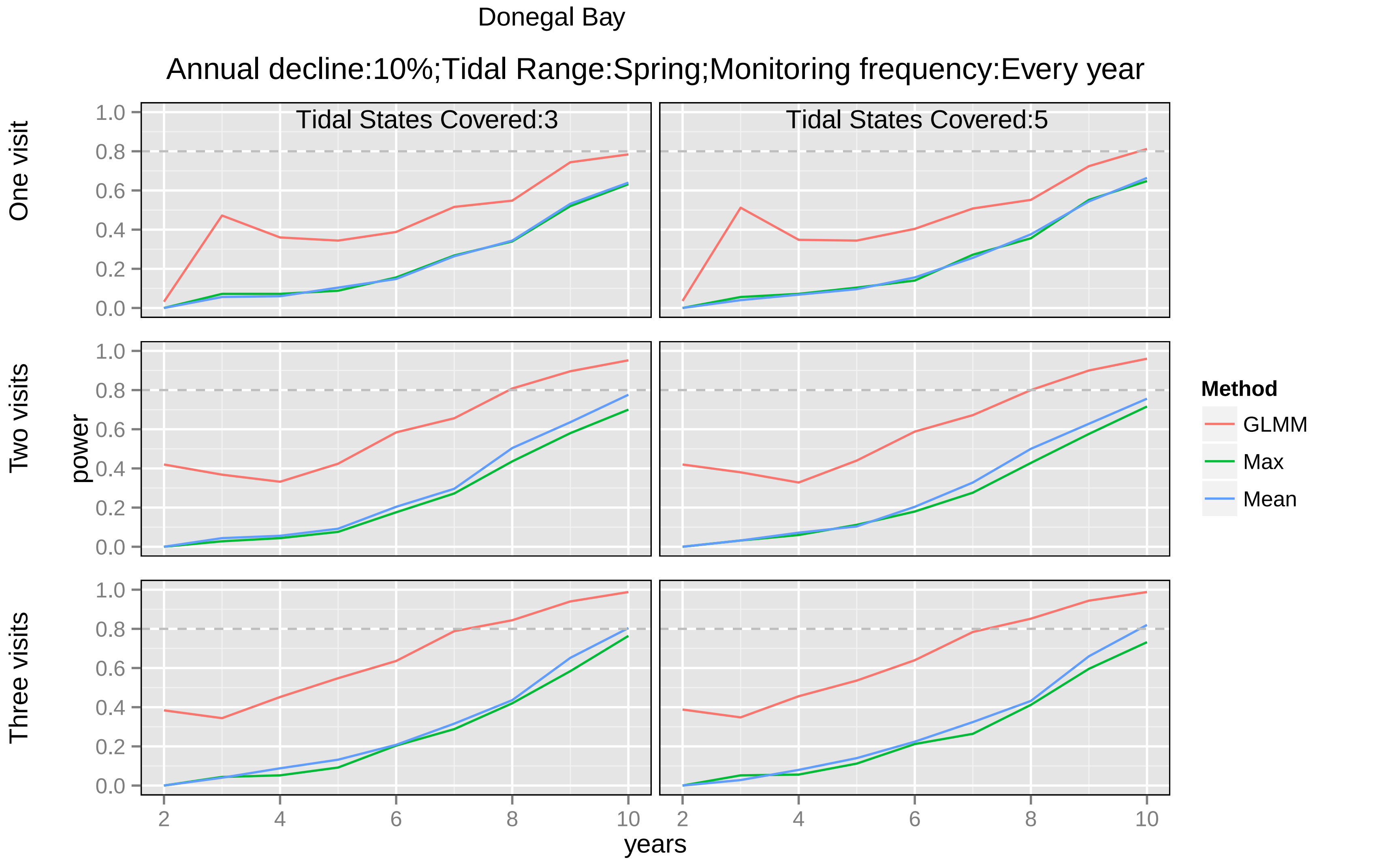
Method
GLMM
Max
Mean



Donegal Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
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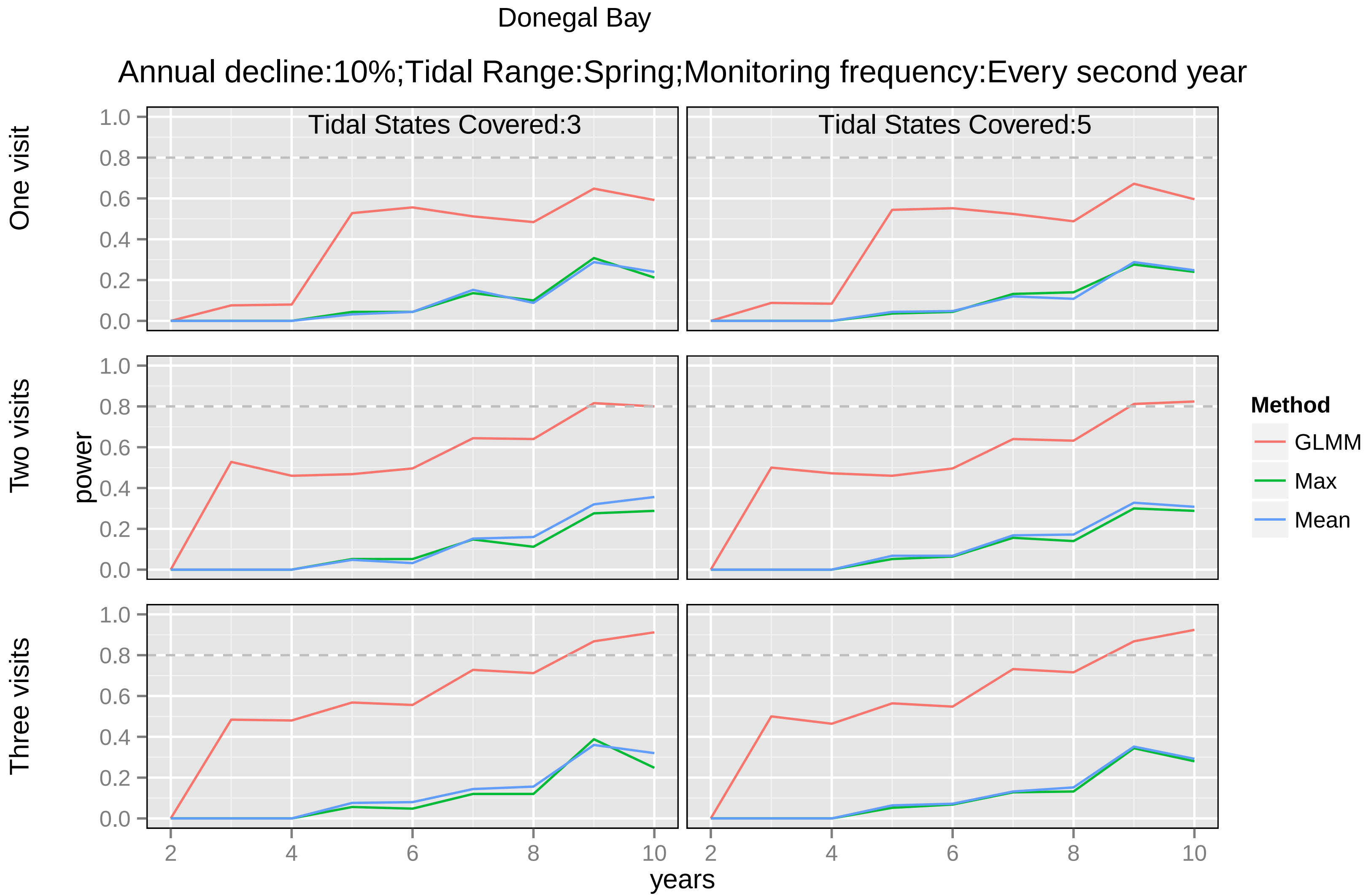
Donegal Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
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Donegal Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
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years
Method
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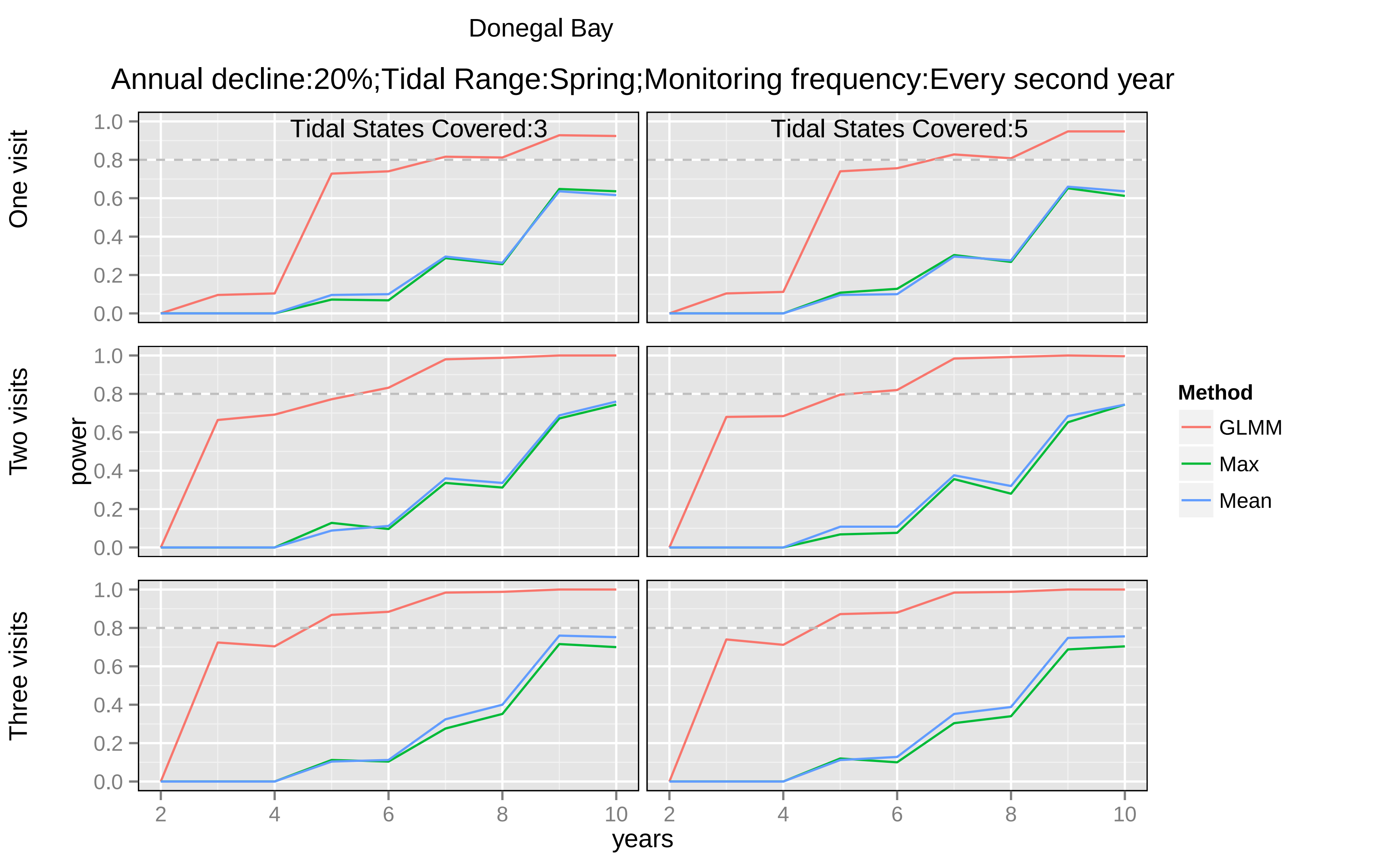
Max
Mean


Donegal Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
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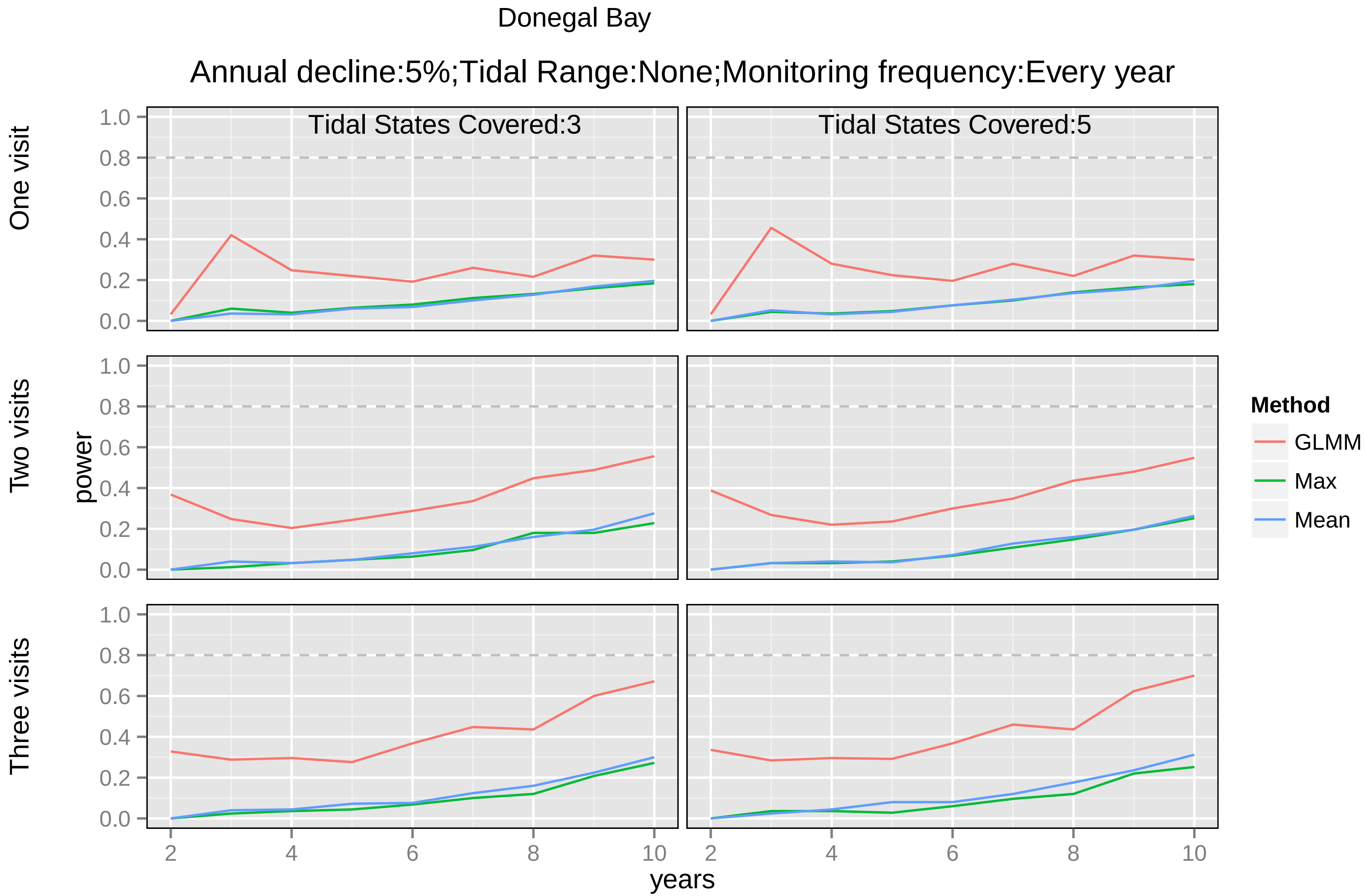
Donegal Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
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Tidal States Covered:5
One visit
Two visits
Three visits
power
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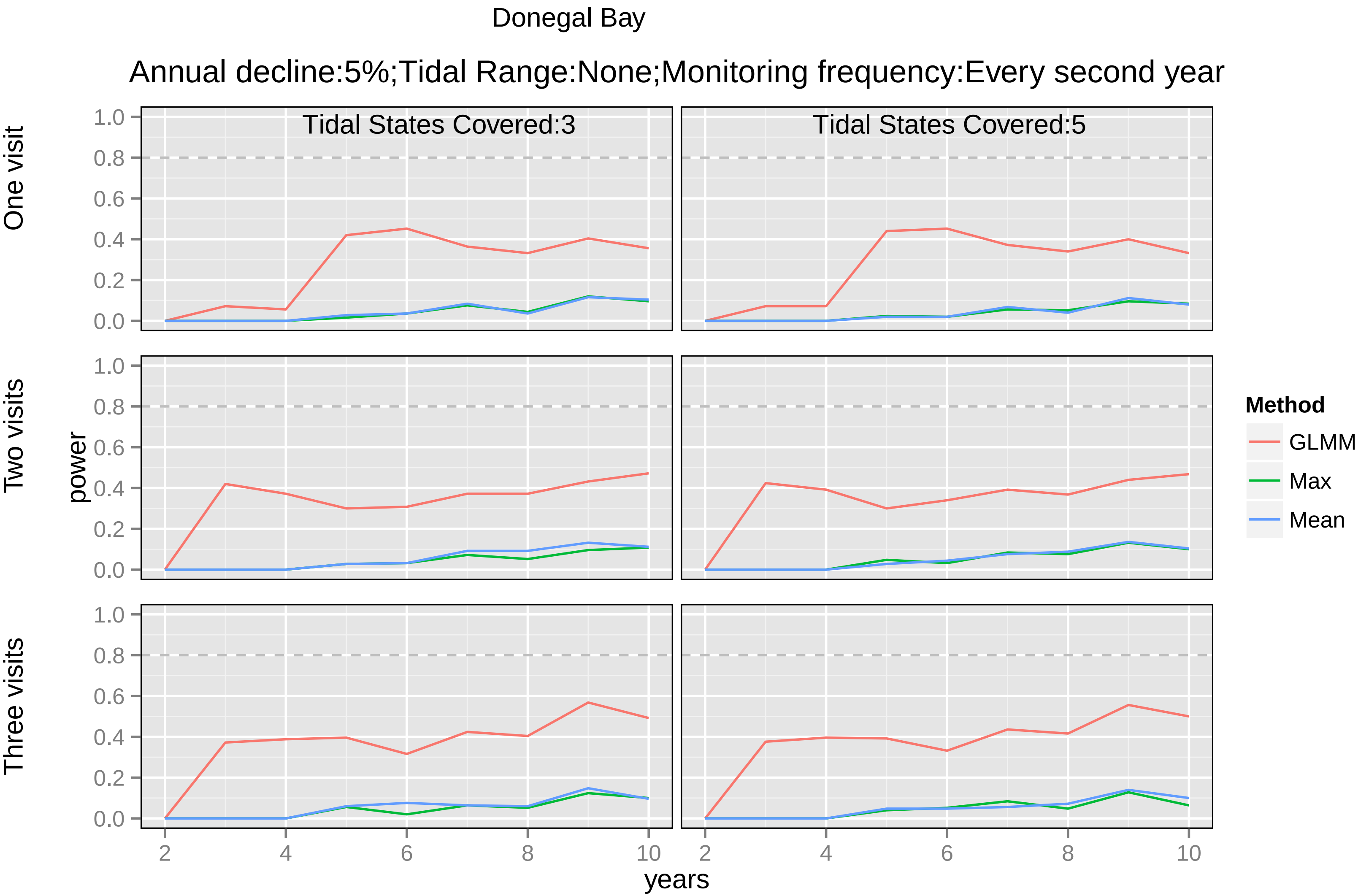
Method
GLMM
Max
Mean


Donegal Bay
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Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
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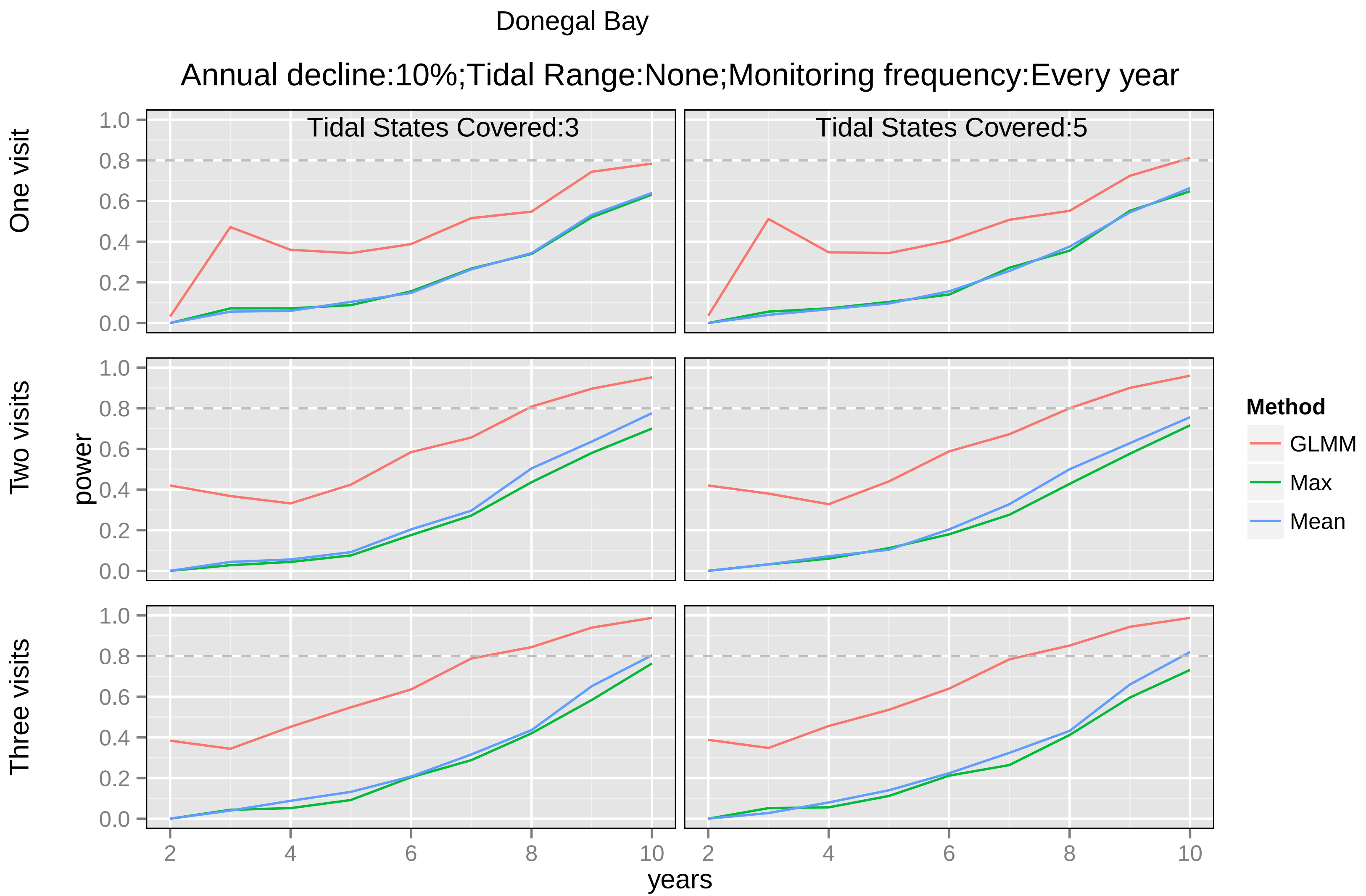
Method
GLMM
Max
Mean


Donegal Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
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Method
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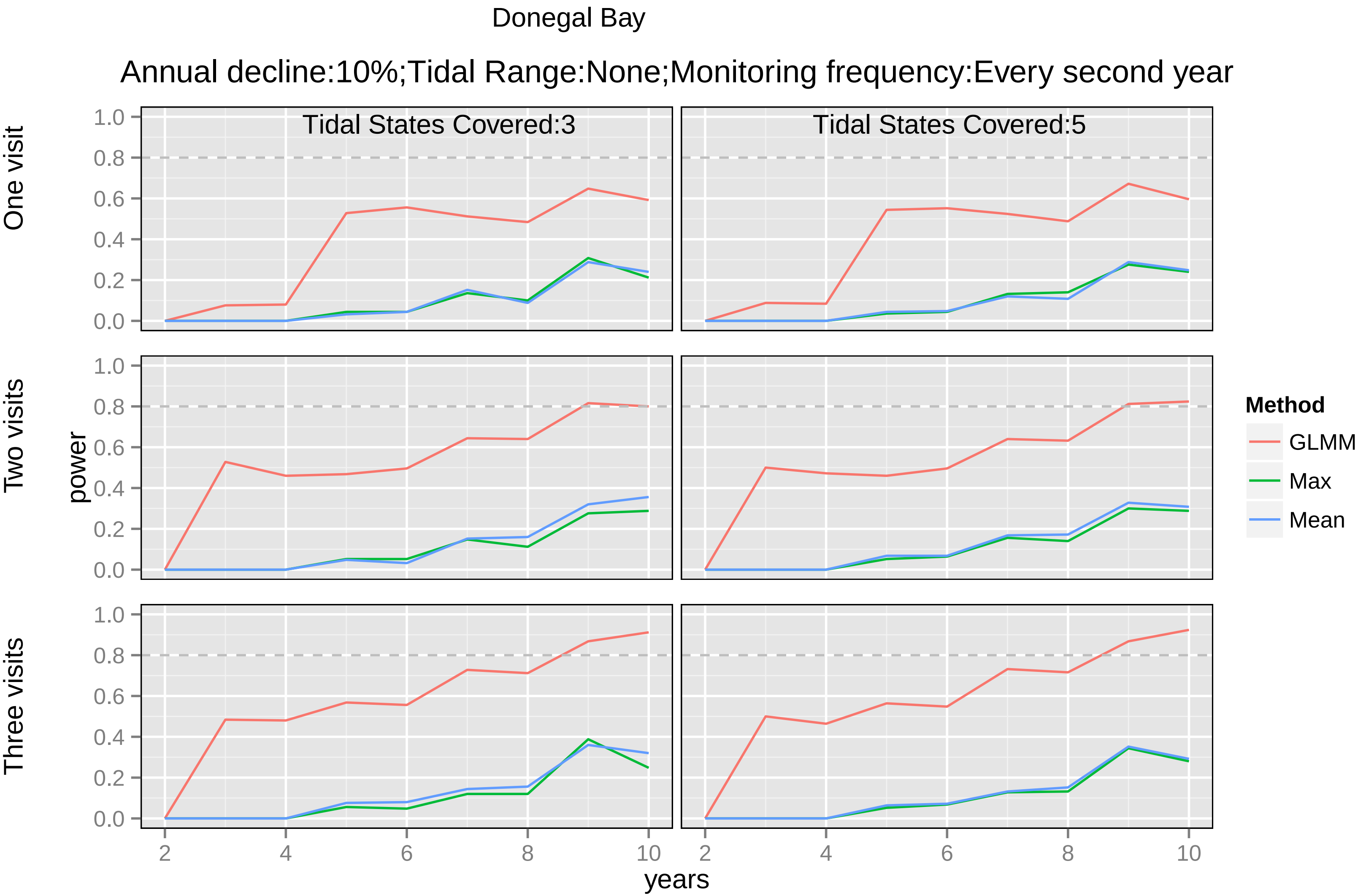

Donegal Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
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One visit
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Three visits
power
years
Method
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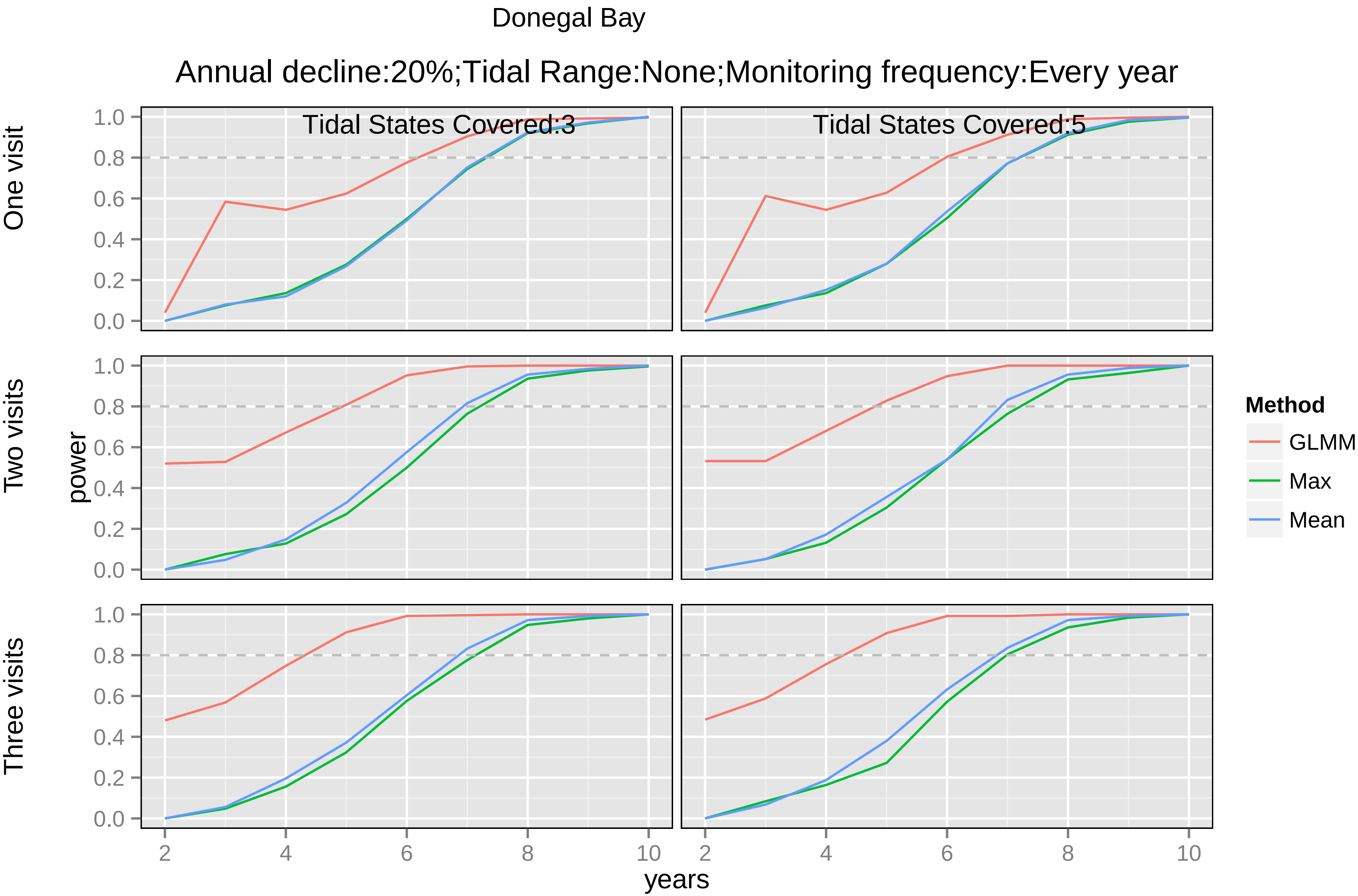
Max
Mean


Donegal Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every year
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Tidal States Covered:5
One visit
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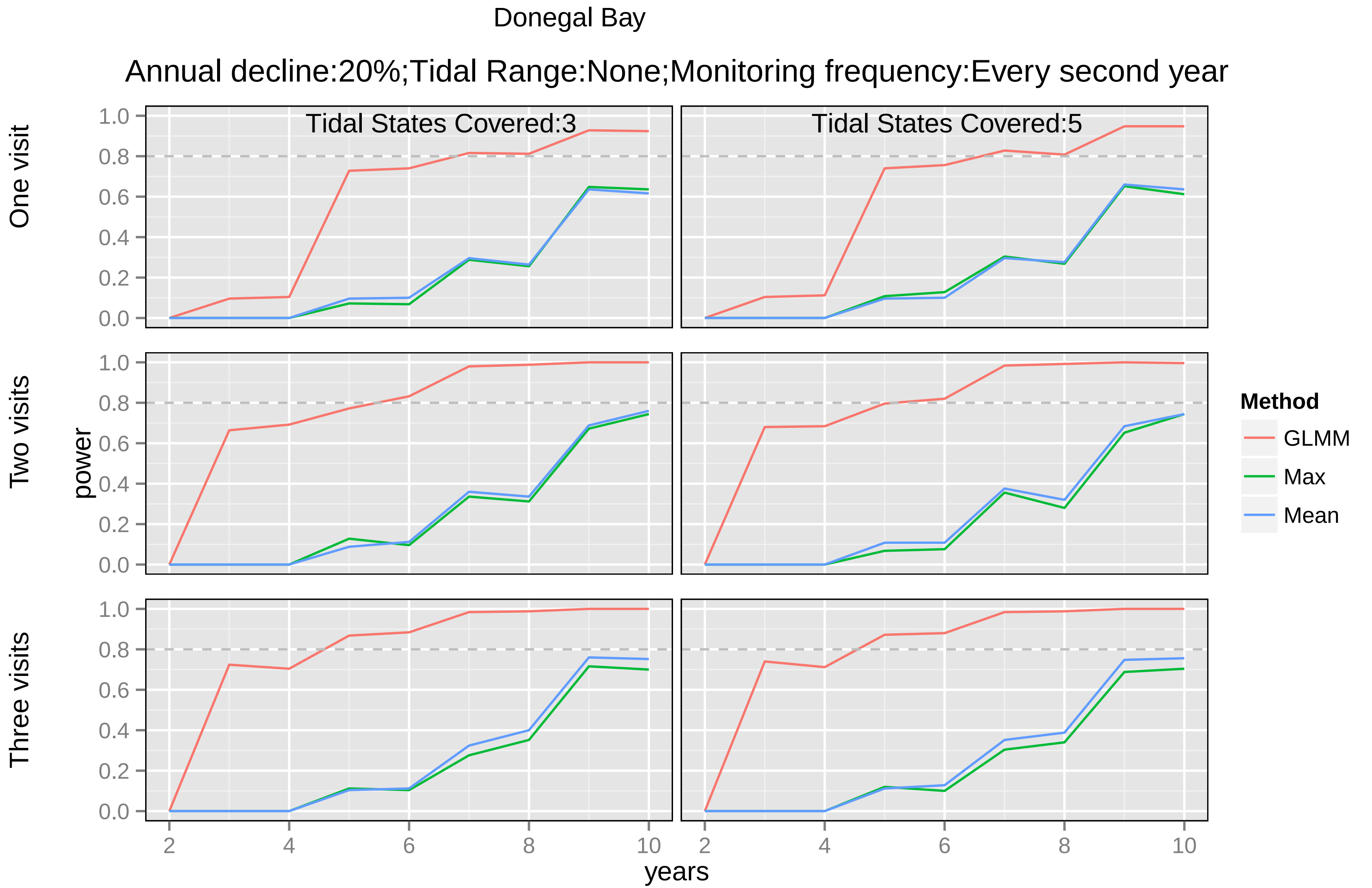
Three visits
power
years
Method
GLMM
Max
Mean



Donegal Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
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Method
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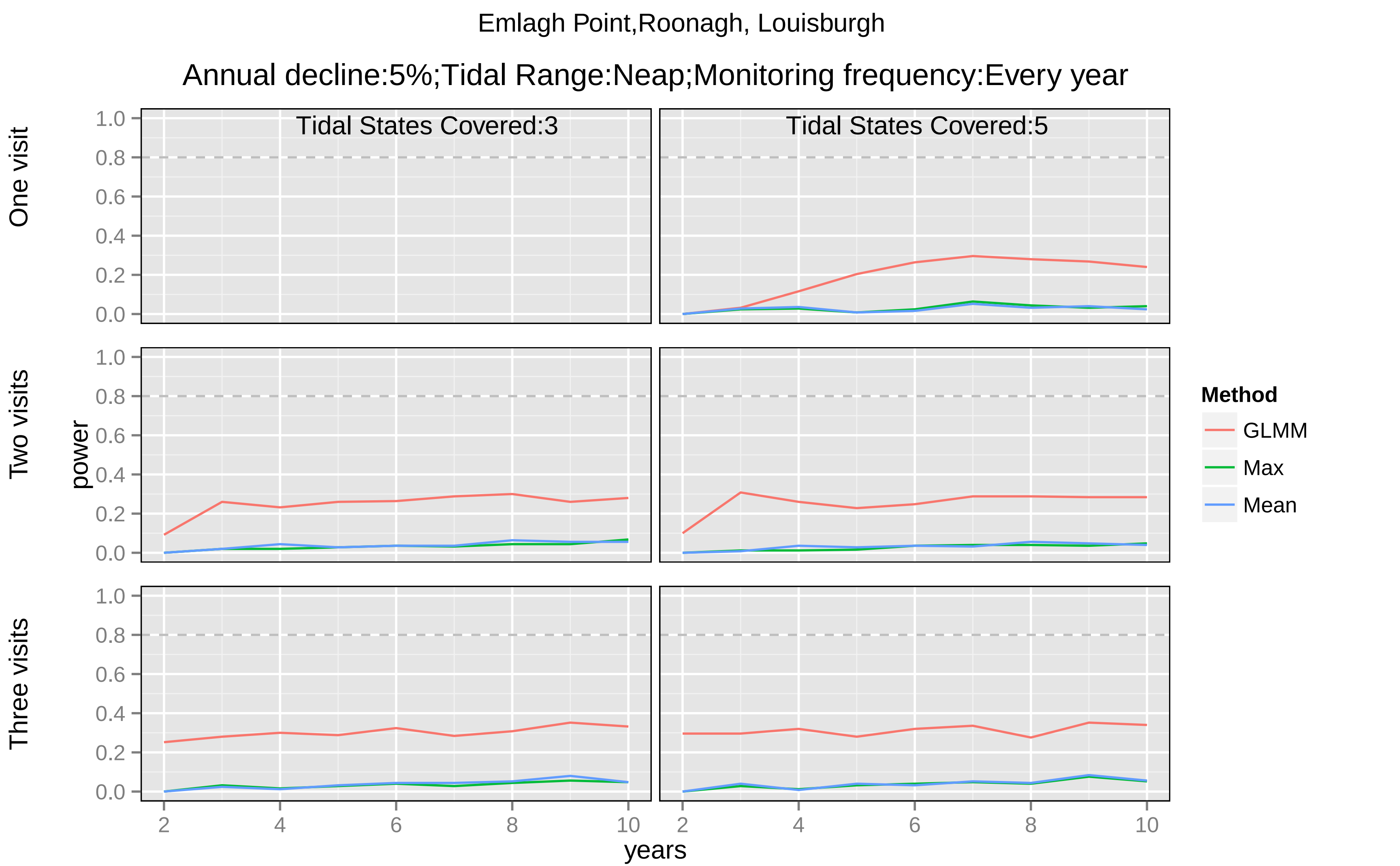

Emlagh Point,Roonagh, Louisburgh
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
1.0
0.8
0.6
0.4
0.2
0.0
2
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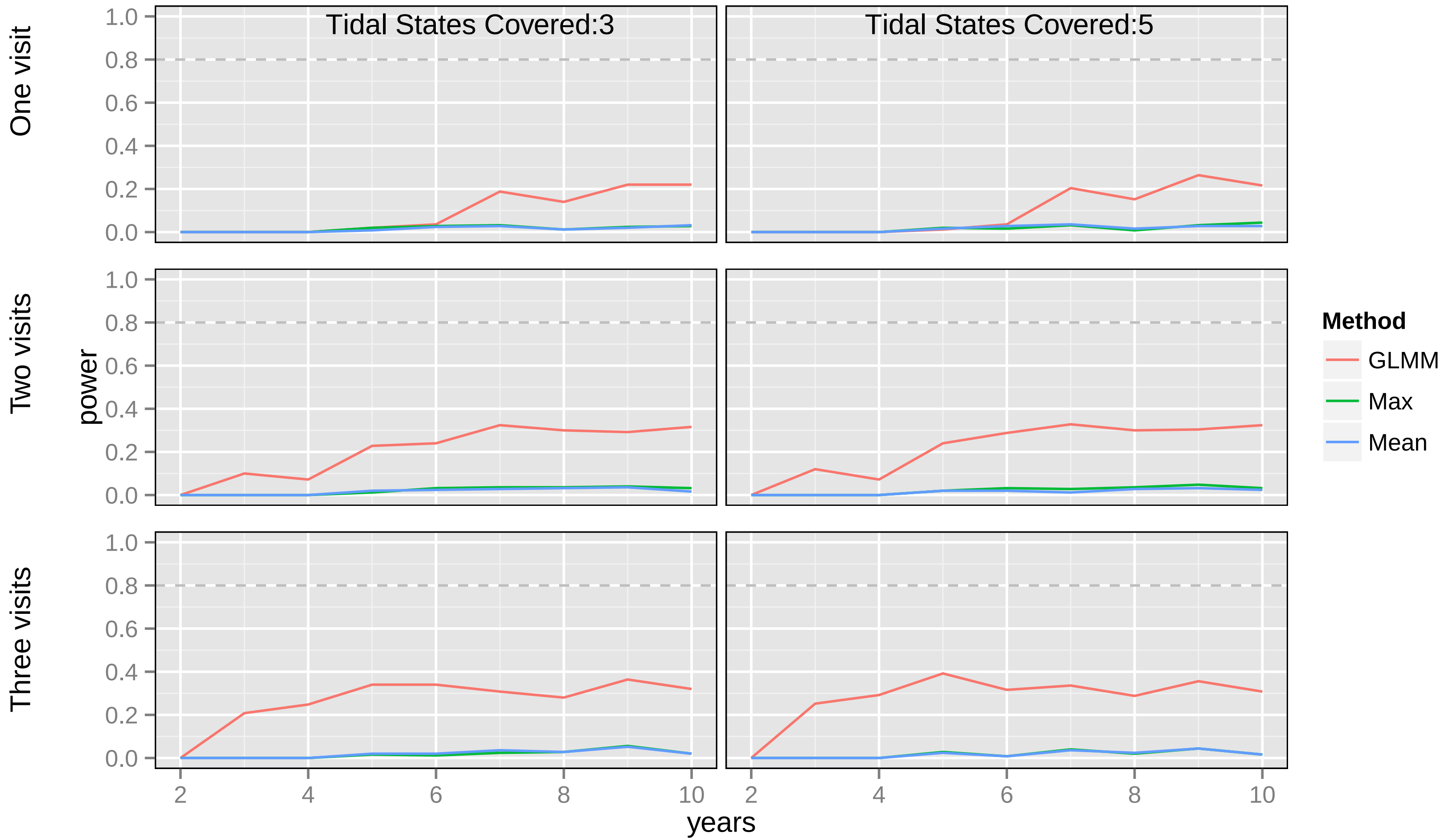
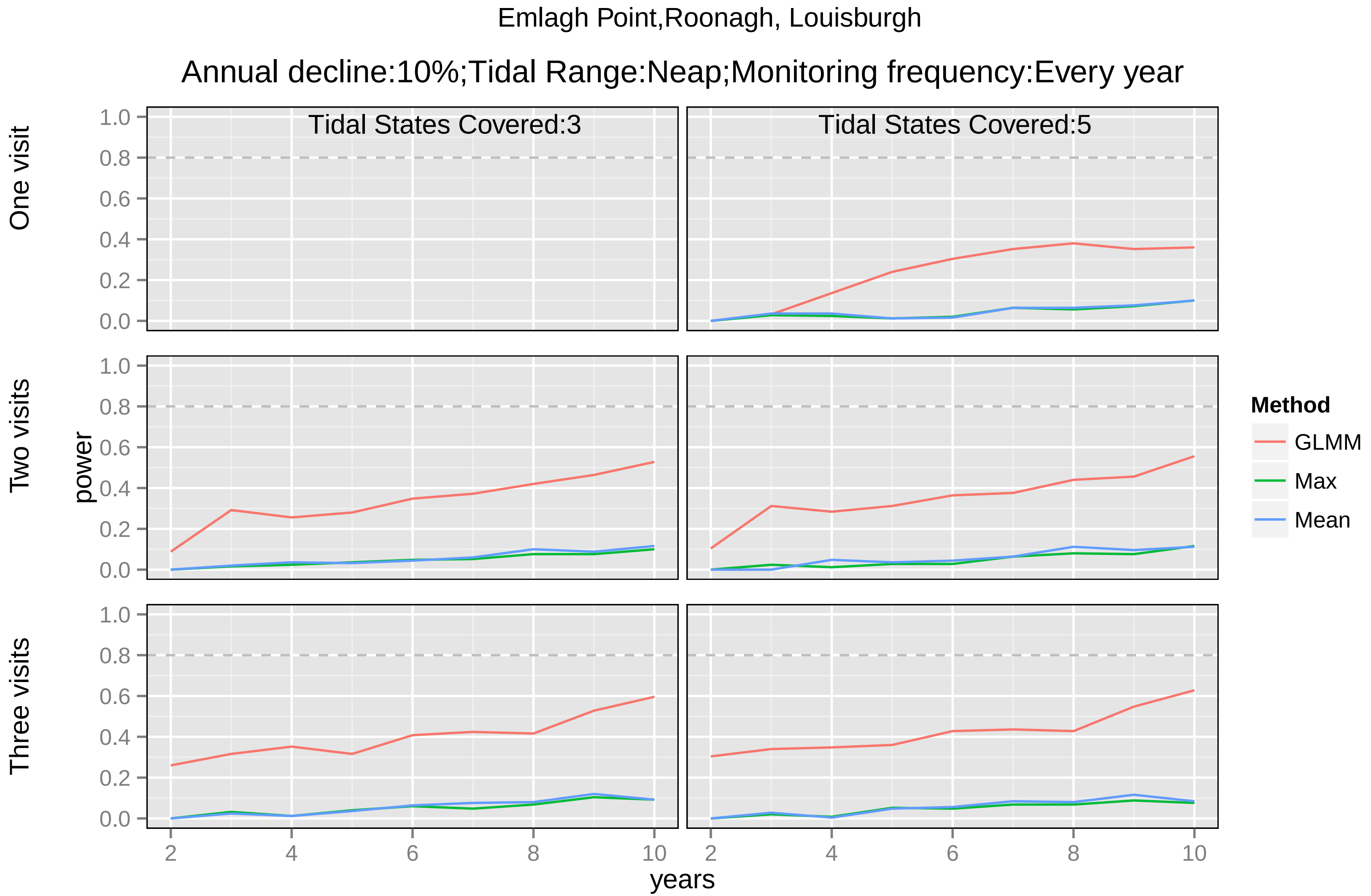
6
8
10
Method
GLMM
Max
Mean

Emlagh Point,Roonagh, Louisburgh

Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year





Emlagh Point,Roonagh, Louisburgh
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
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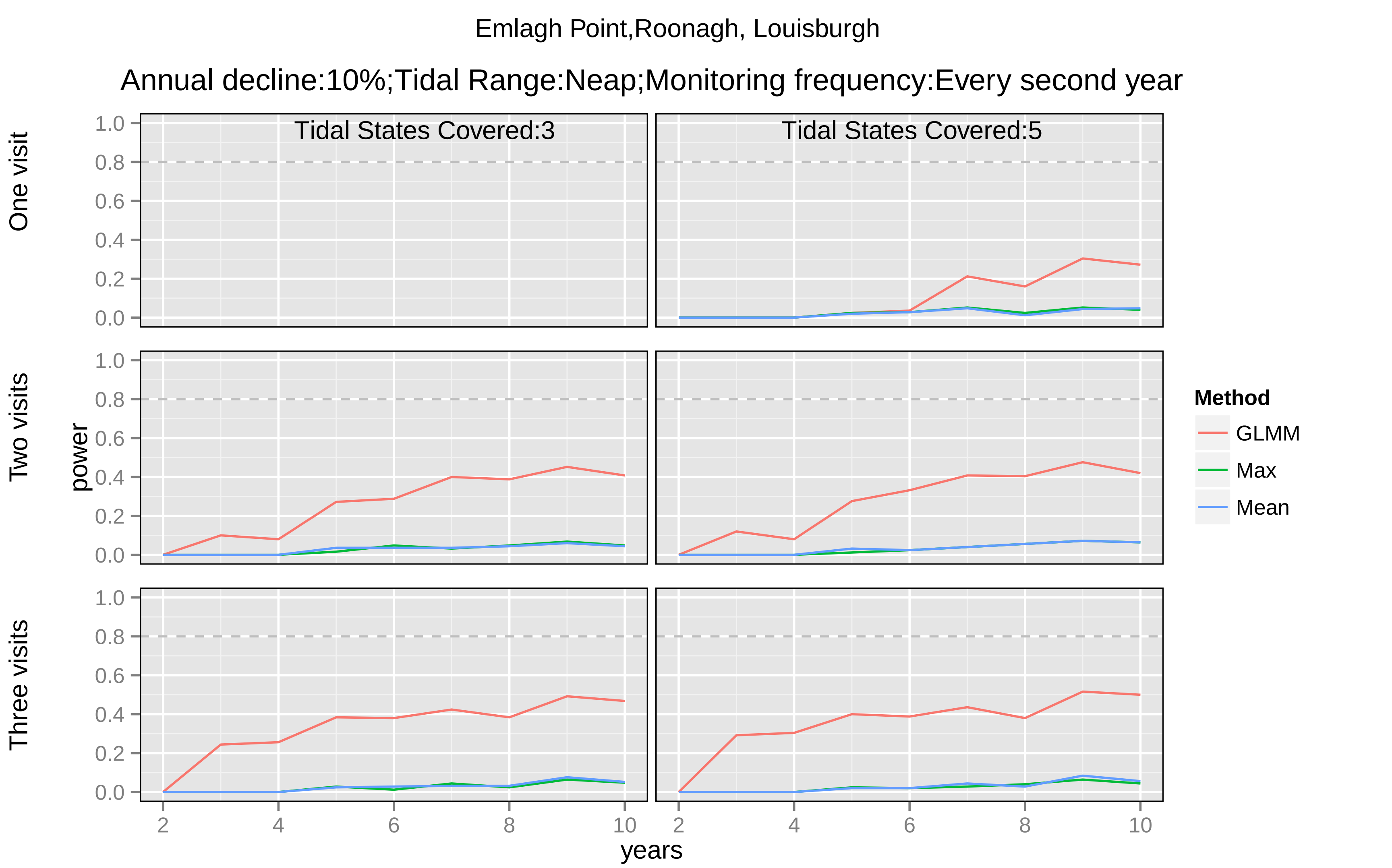

Emlagh Point,Roonagh, Louisburgh
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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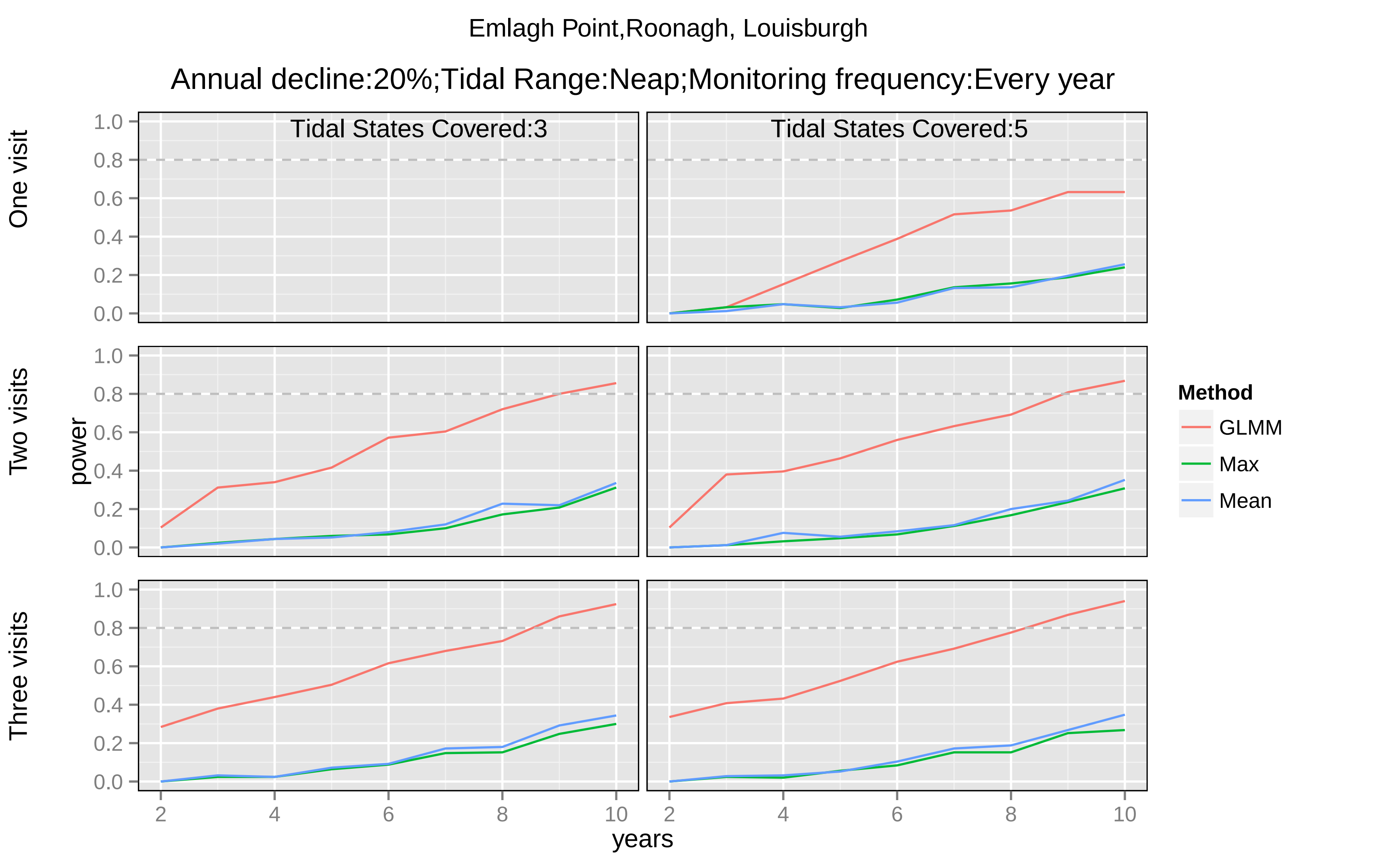
Method
GLMM
Max
Mean


Emlagh Point,Roonagh, Louisburgh
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
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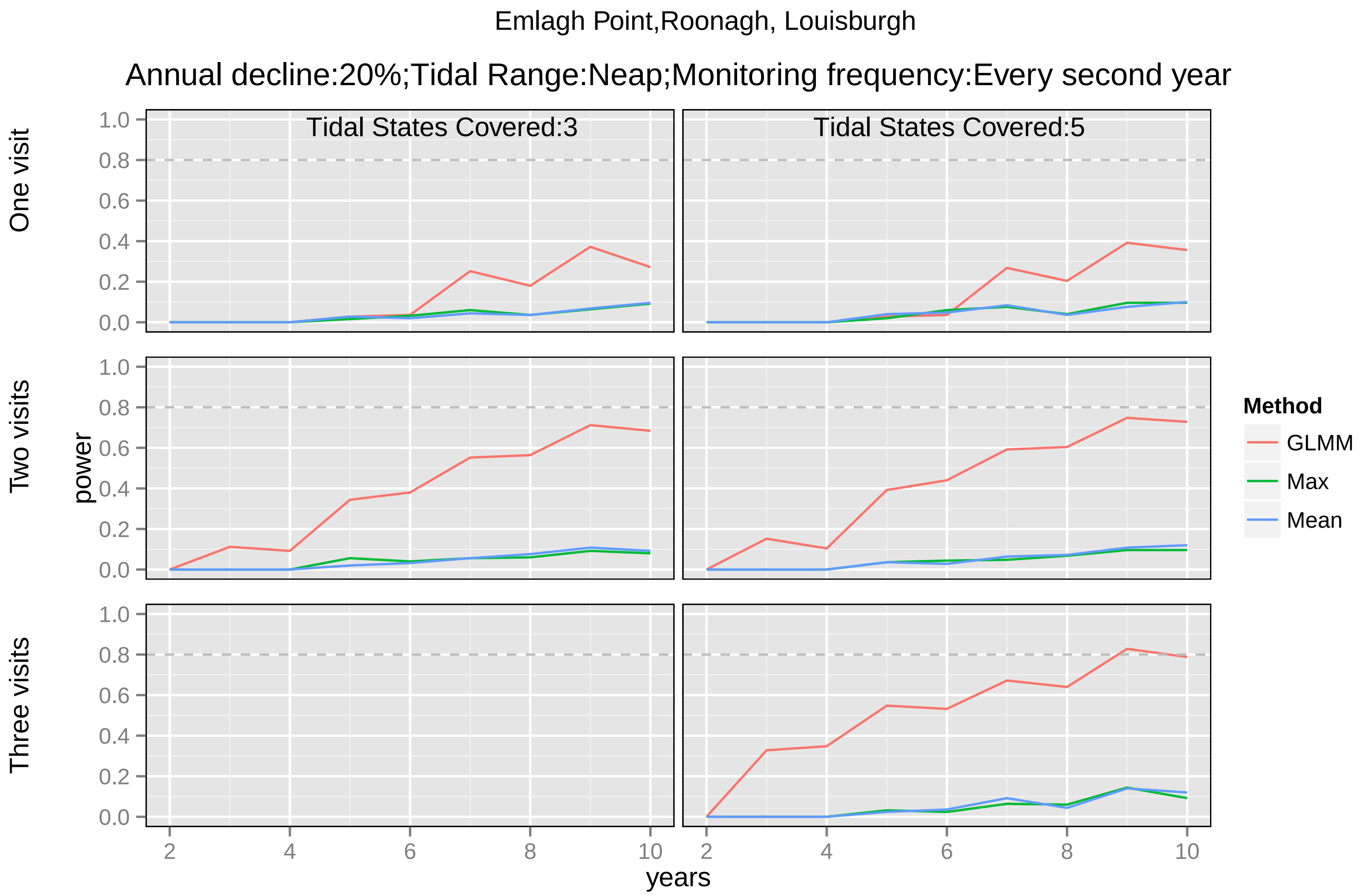
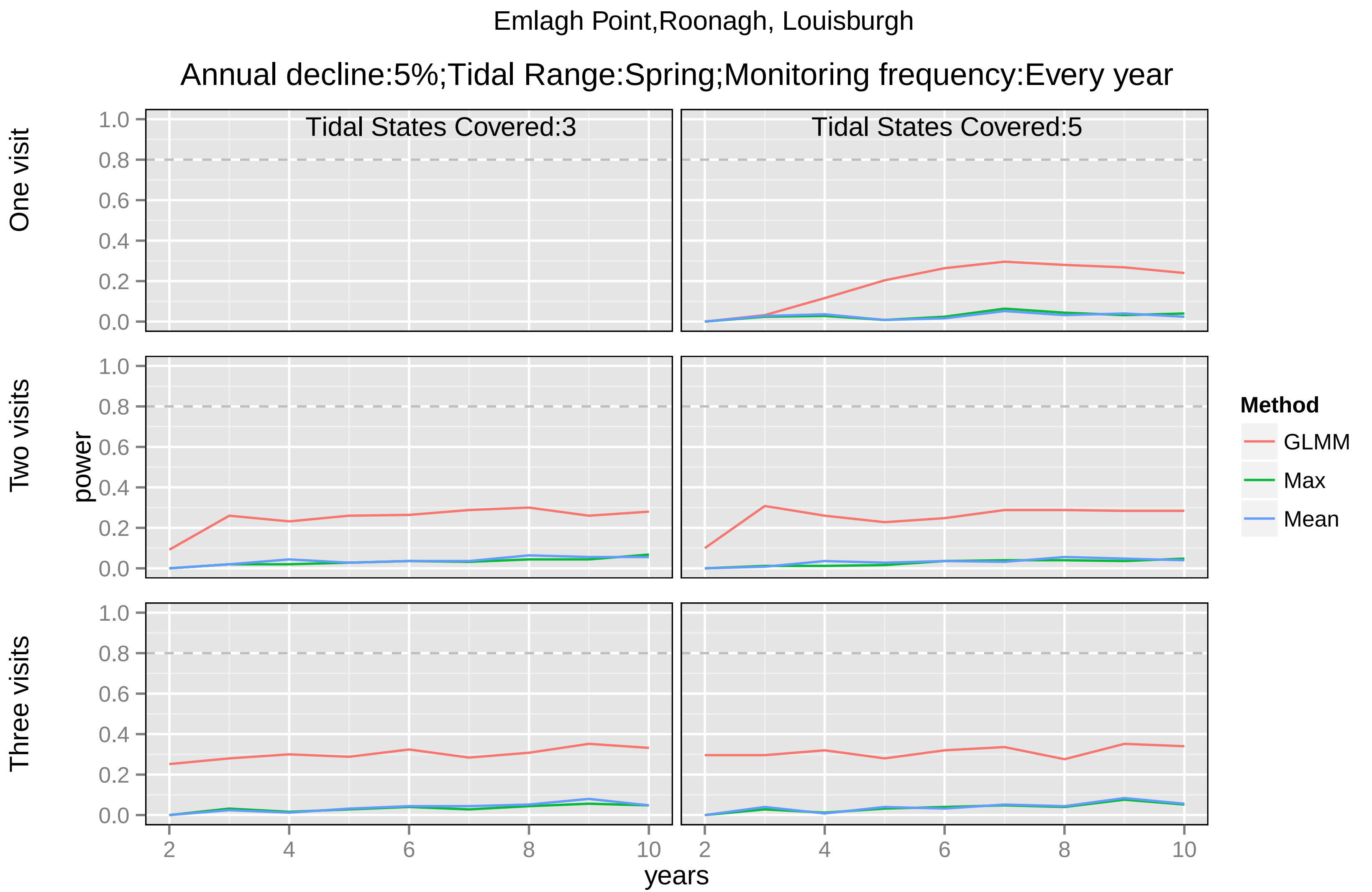


Emlagh Point,Roonagh, Louisburgh
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean



Emlagh Point,Roonagh, Louisburgh
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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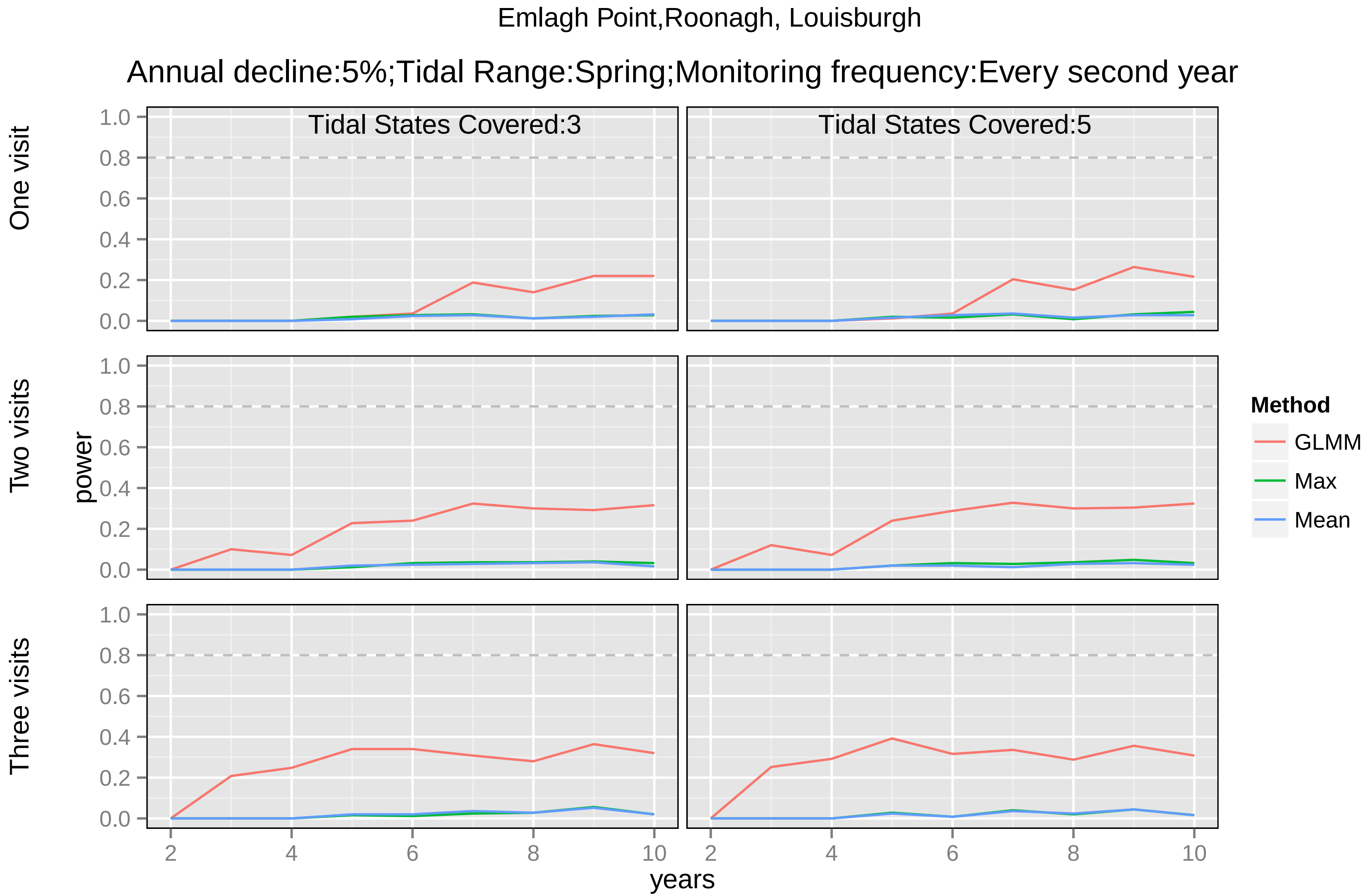

Emlagh Point,Roonagh, Louisburgh
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
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Method
GLMM
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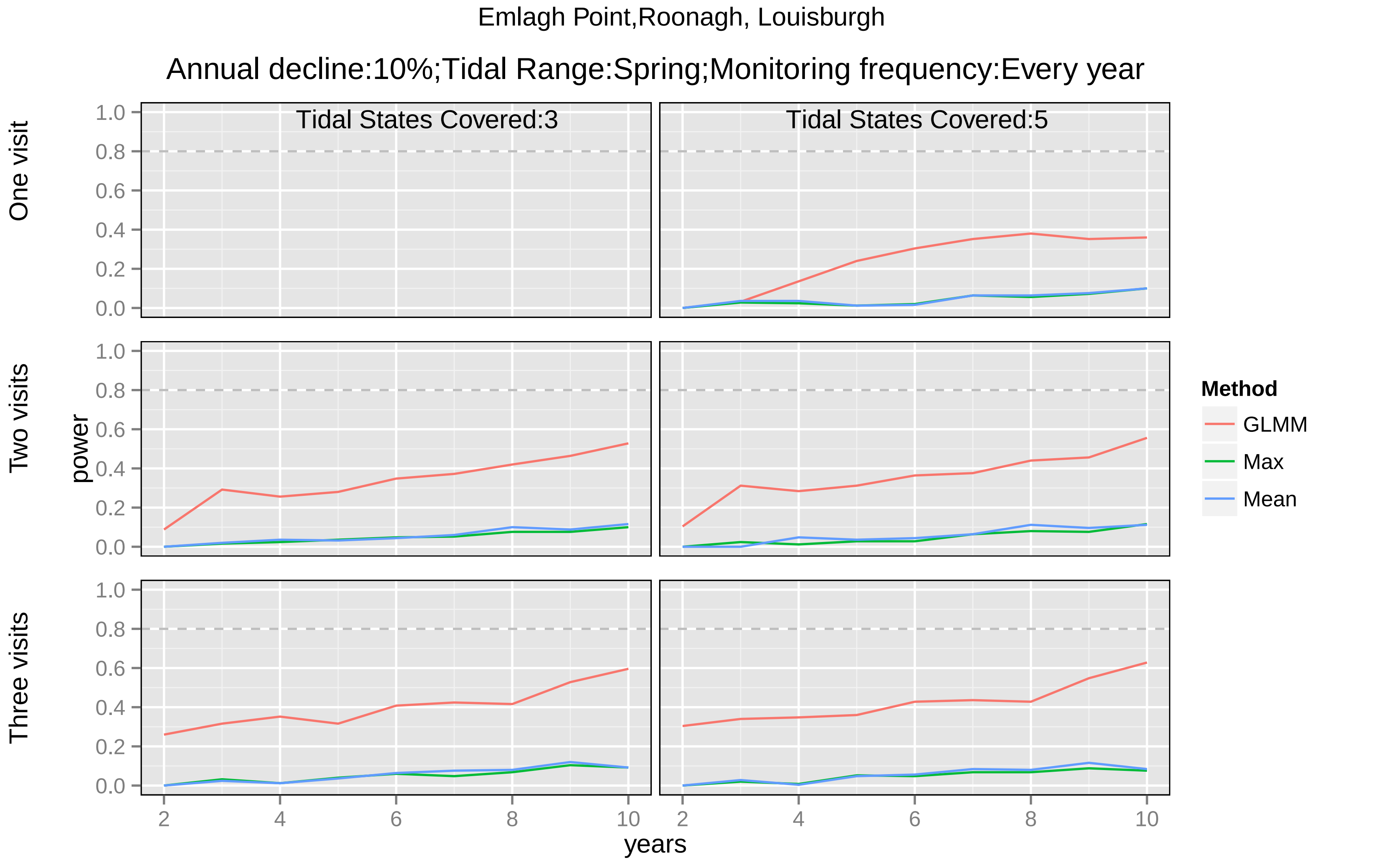
Mean



Emlagh Point,Roonagh, Louisburgh
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
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One visit
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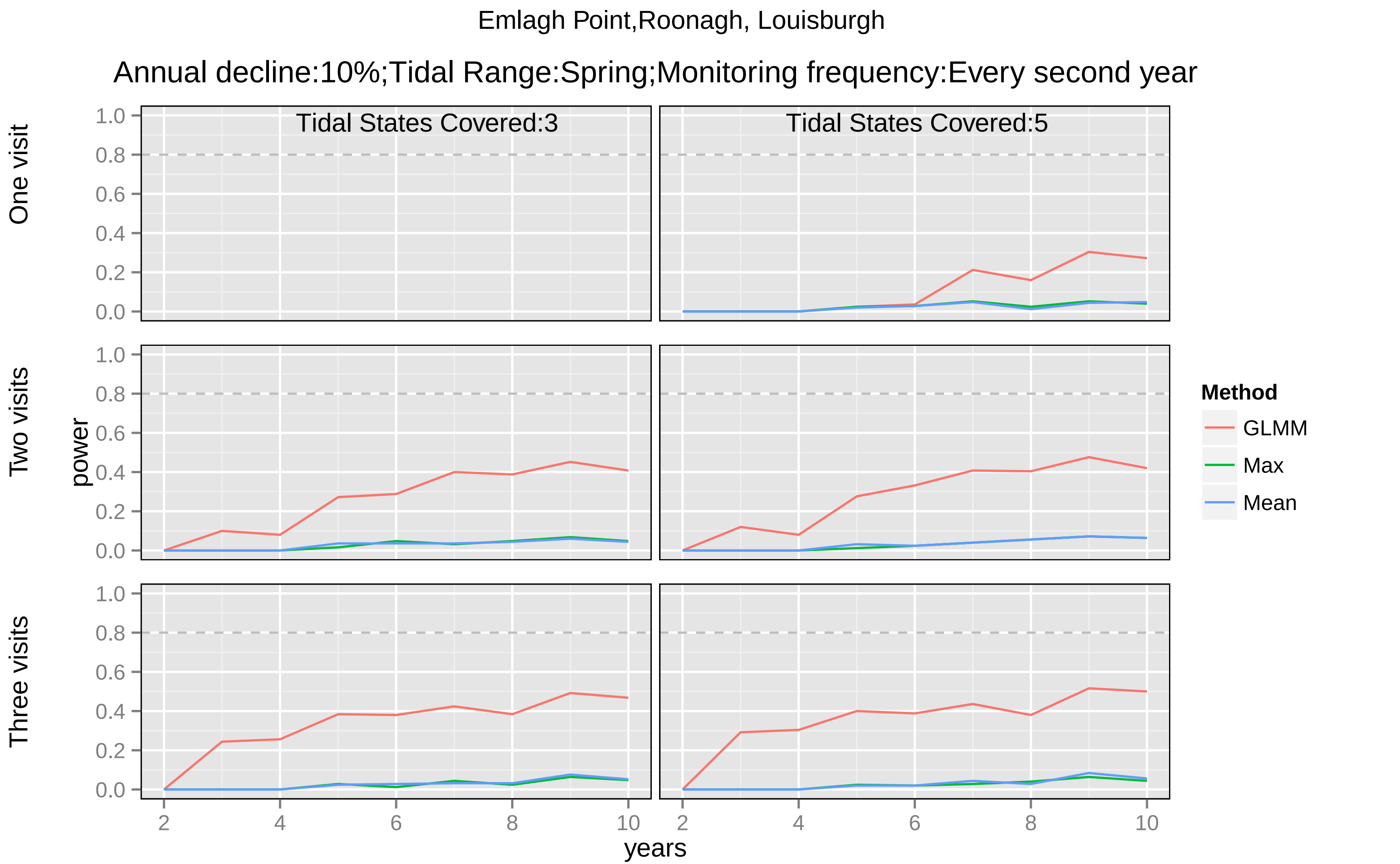
Emlagh Point,Roonagh, Louisburgh
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
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One visit
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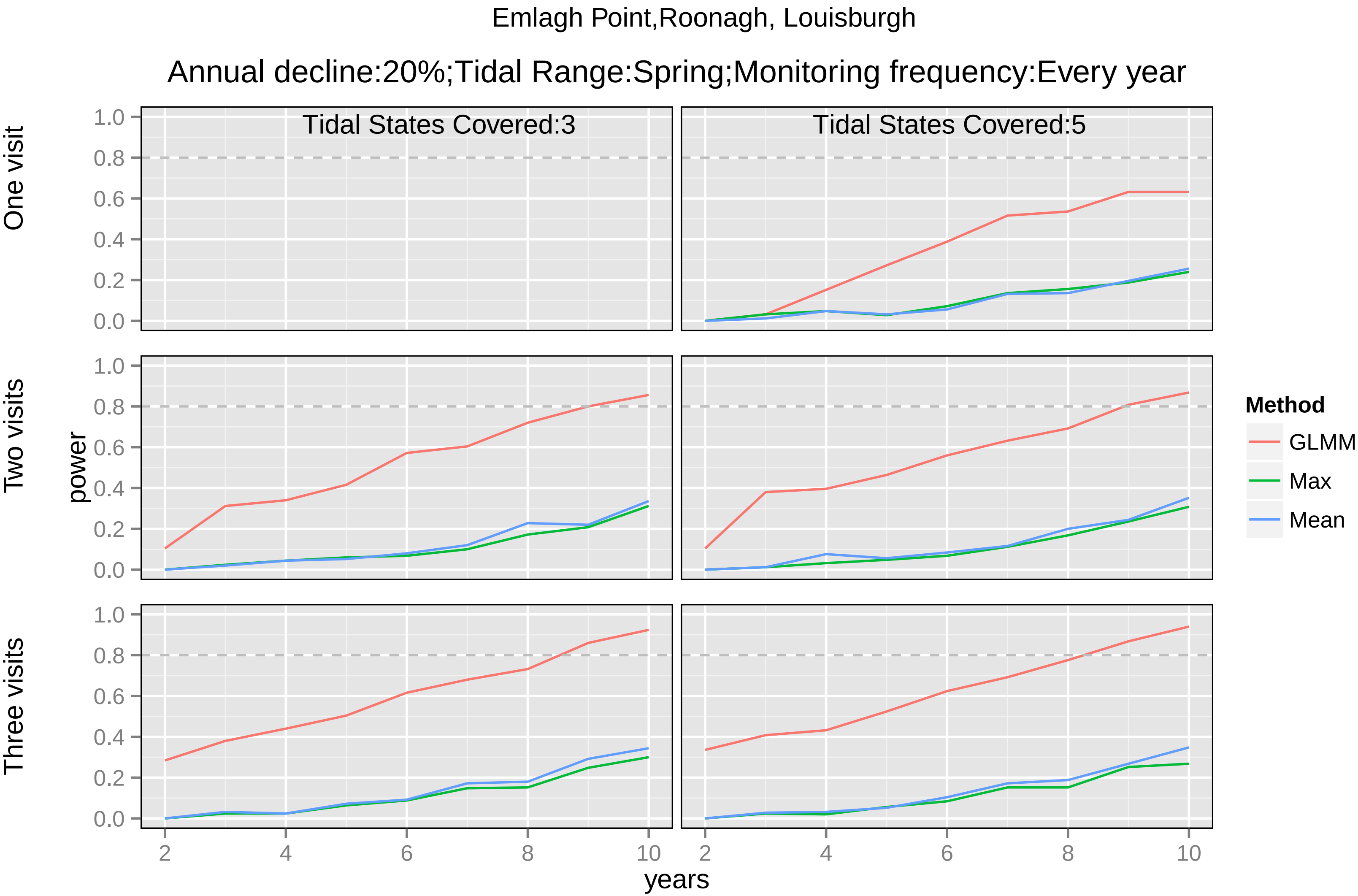
Emlagh Point,Roonagh, Louisburgh
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every year
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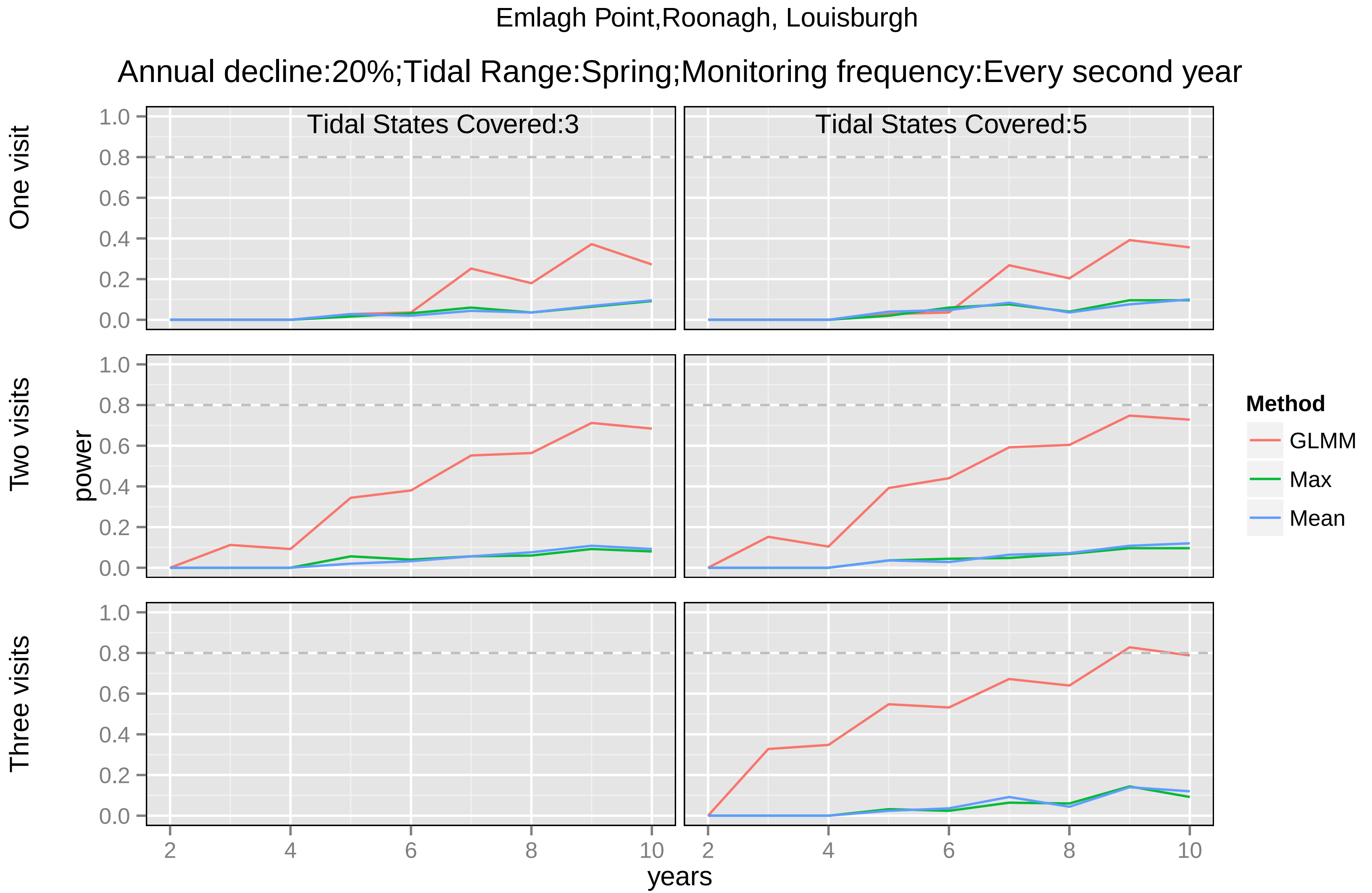
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean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Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
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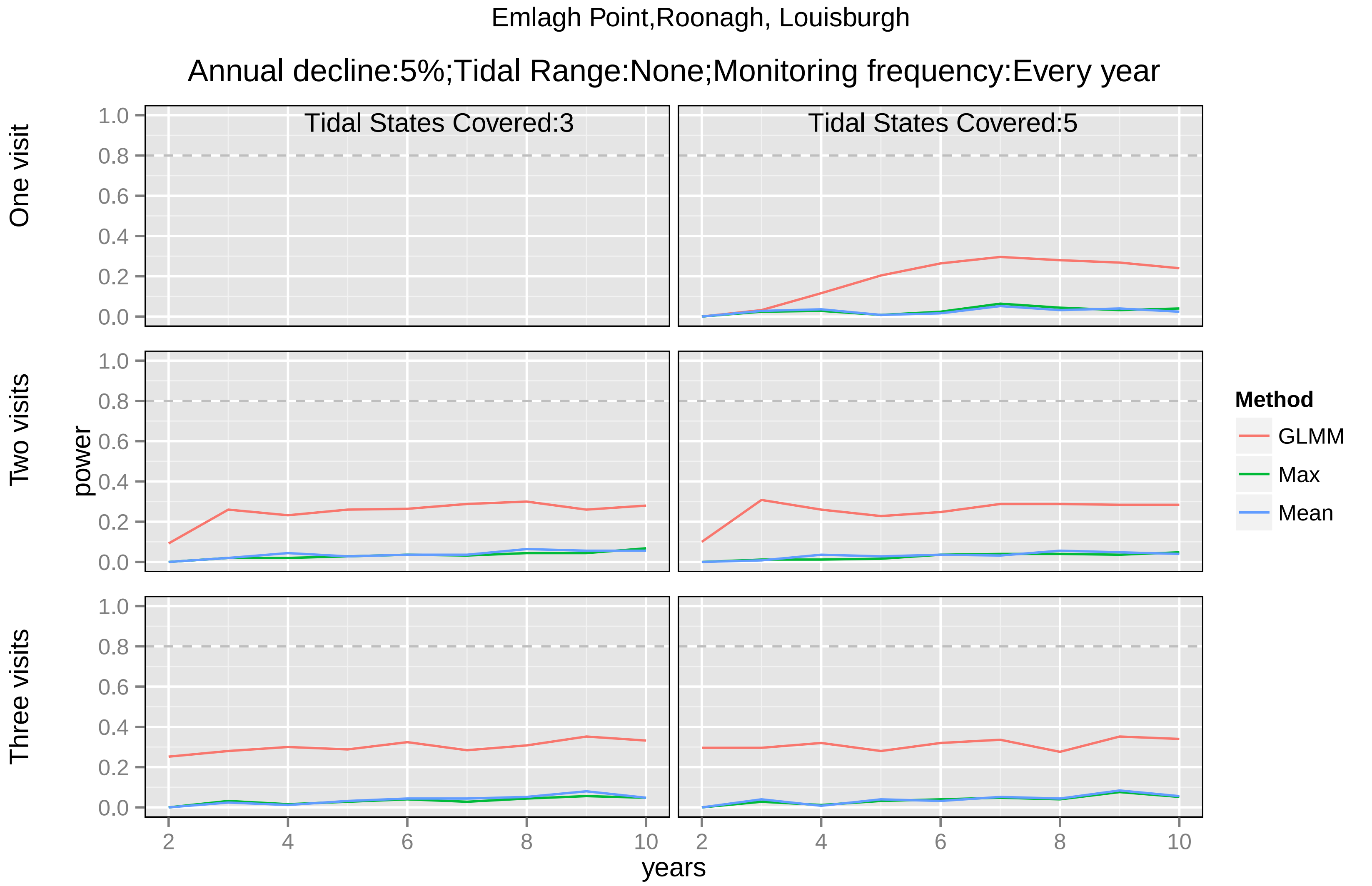

Emlagh Point,Roonagh, Louisburgh
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
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power
years
Method
GLMM
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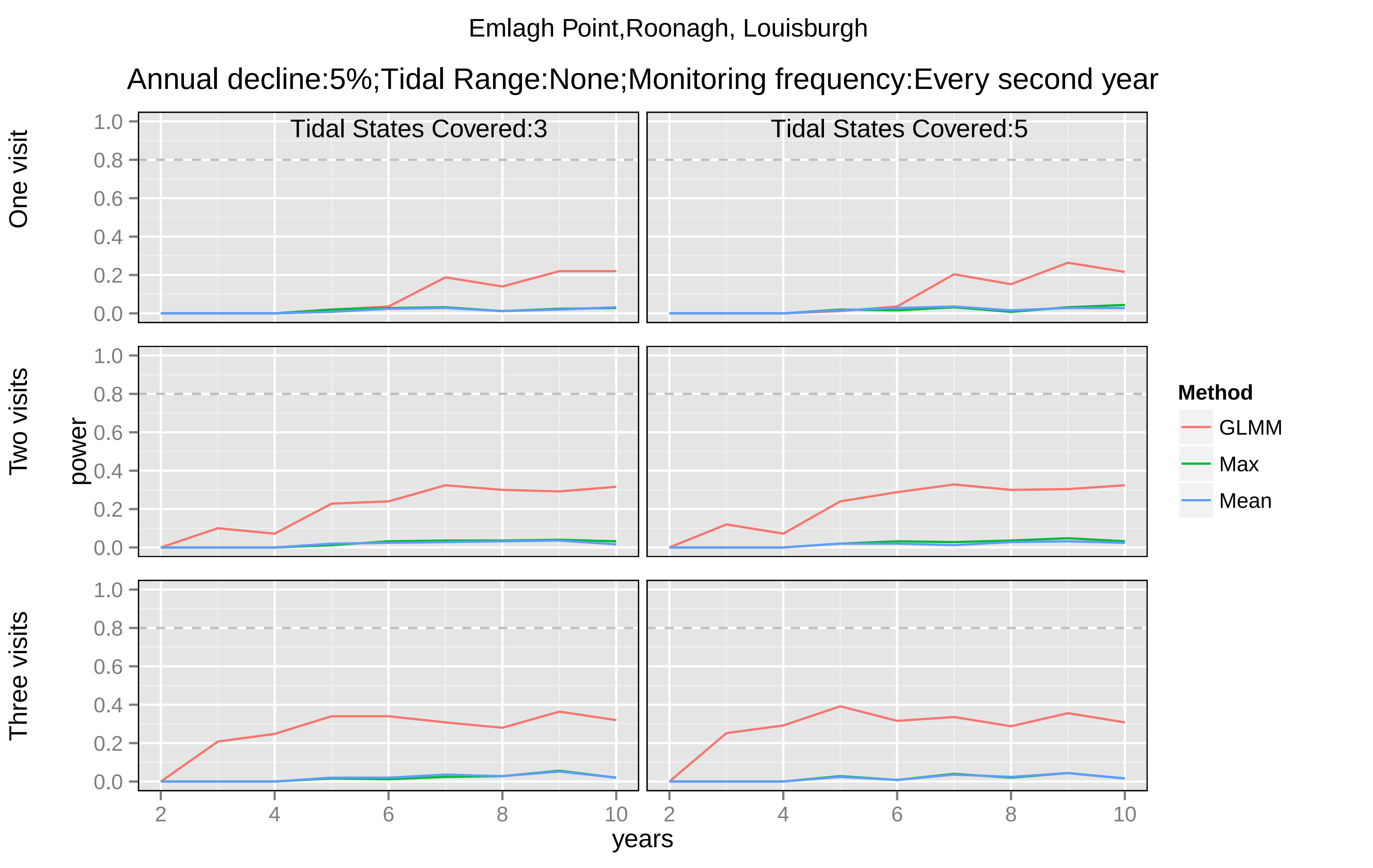

Emlagh Point,Roonagh, Louisburgh
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
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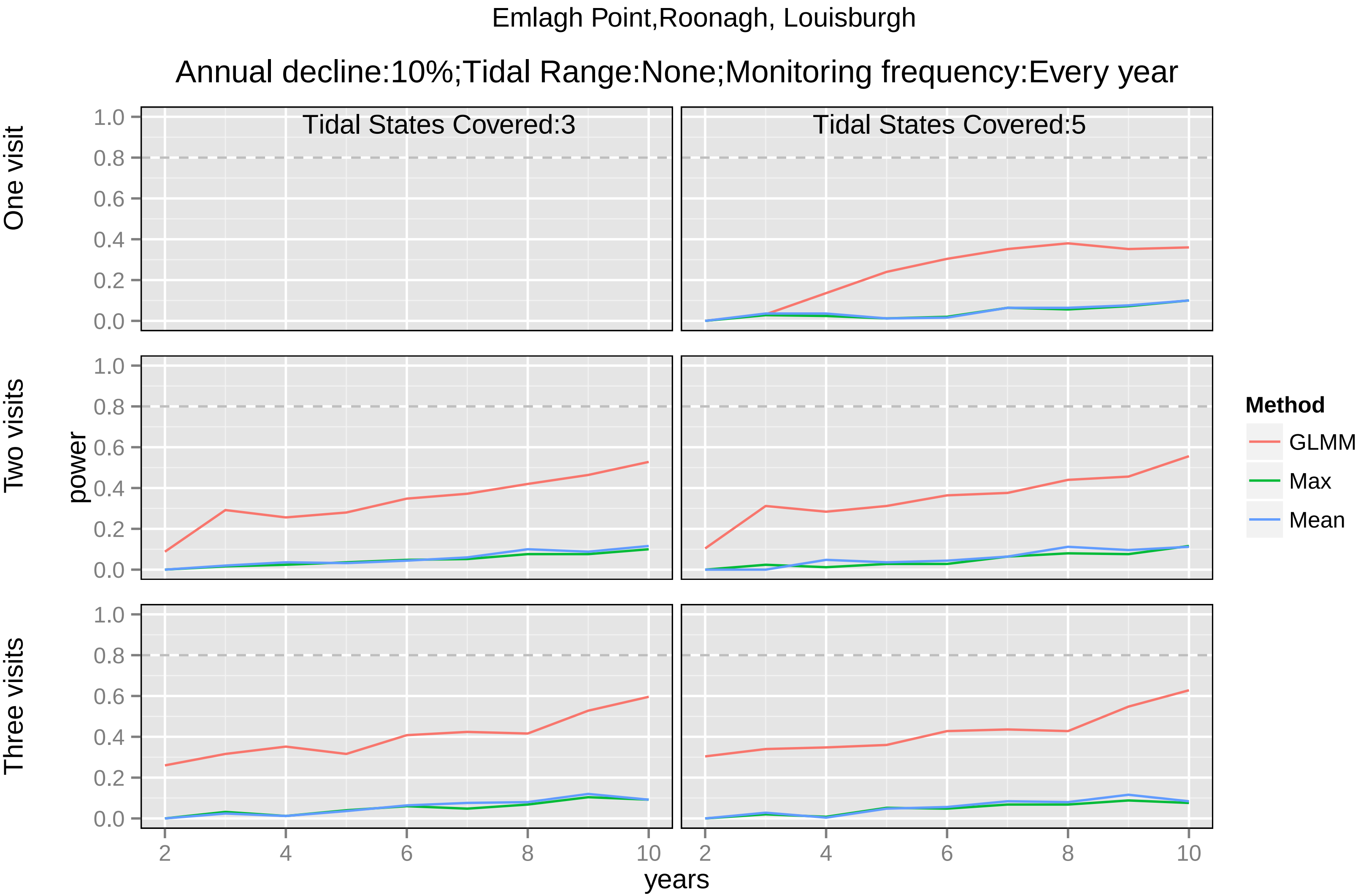

Emlagh Point,Roonagh, Louisburgh
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
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Method
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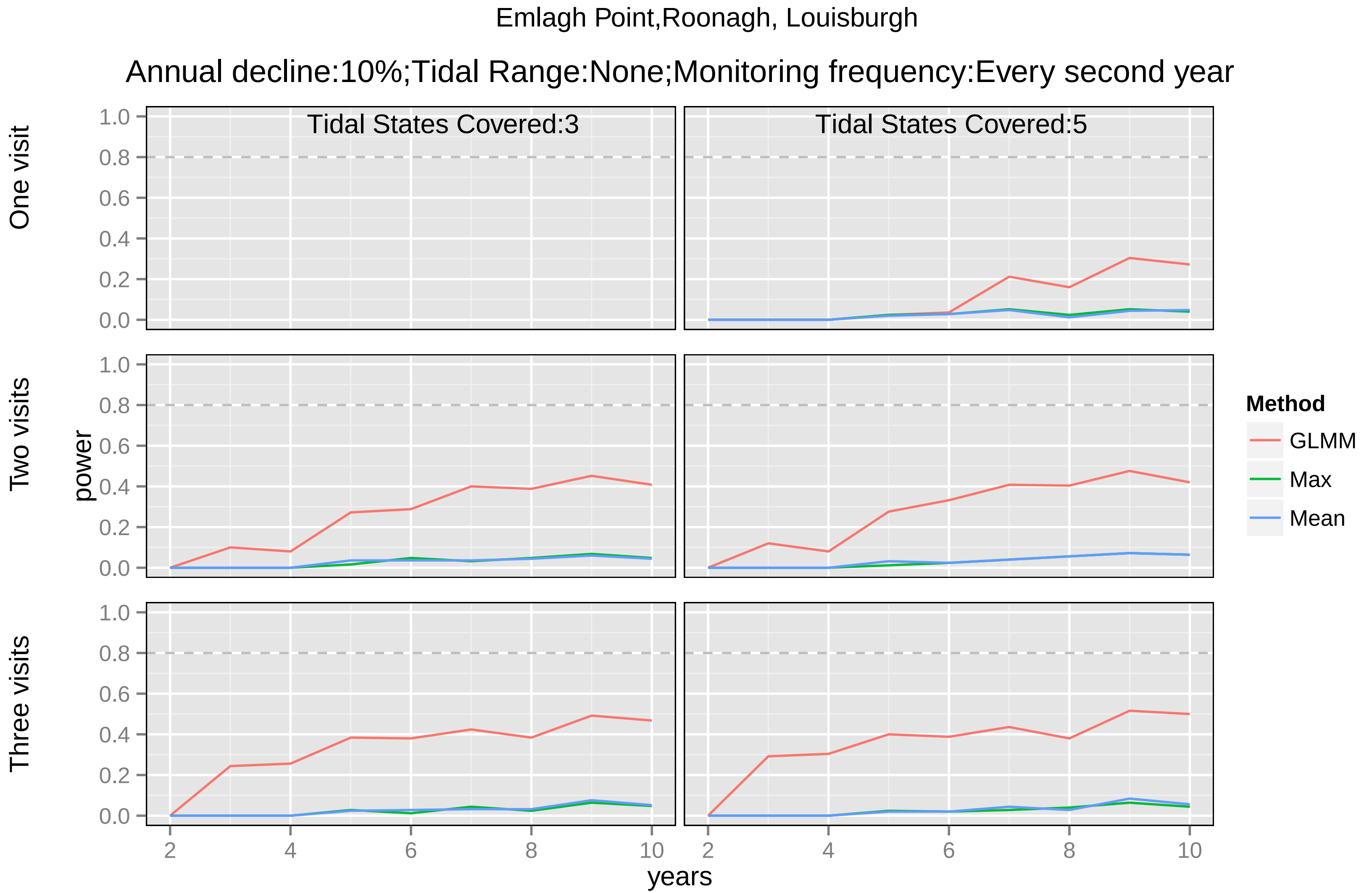
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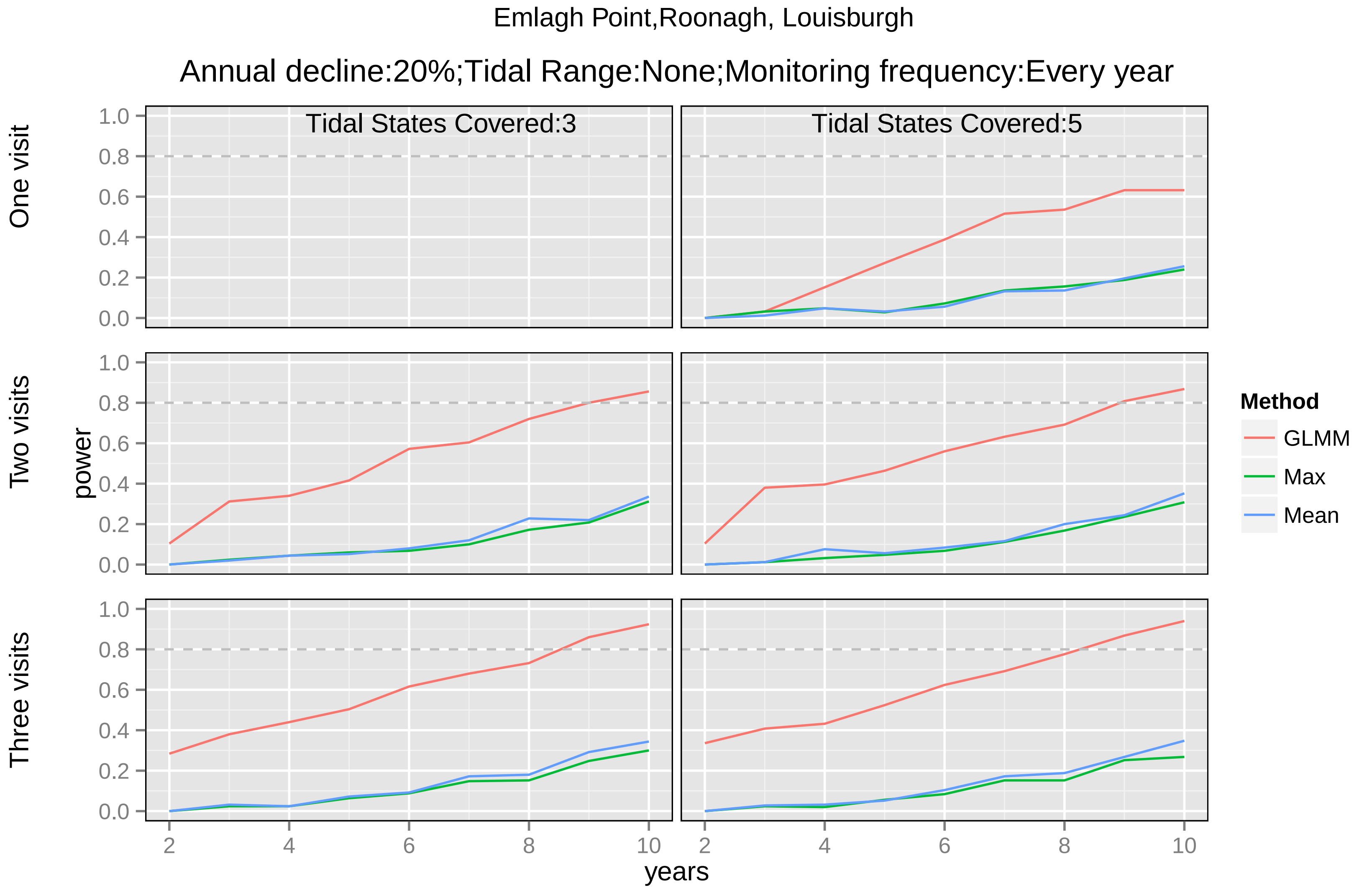

Emlagh Point,Roonagh, Louisburgh
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
0.0
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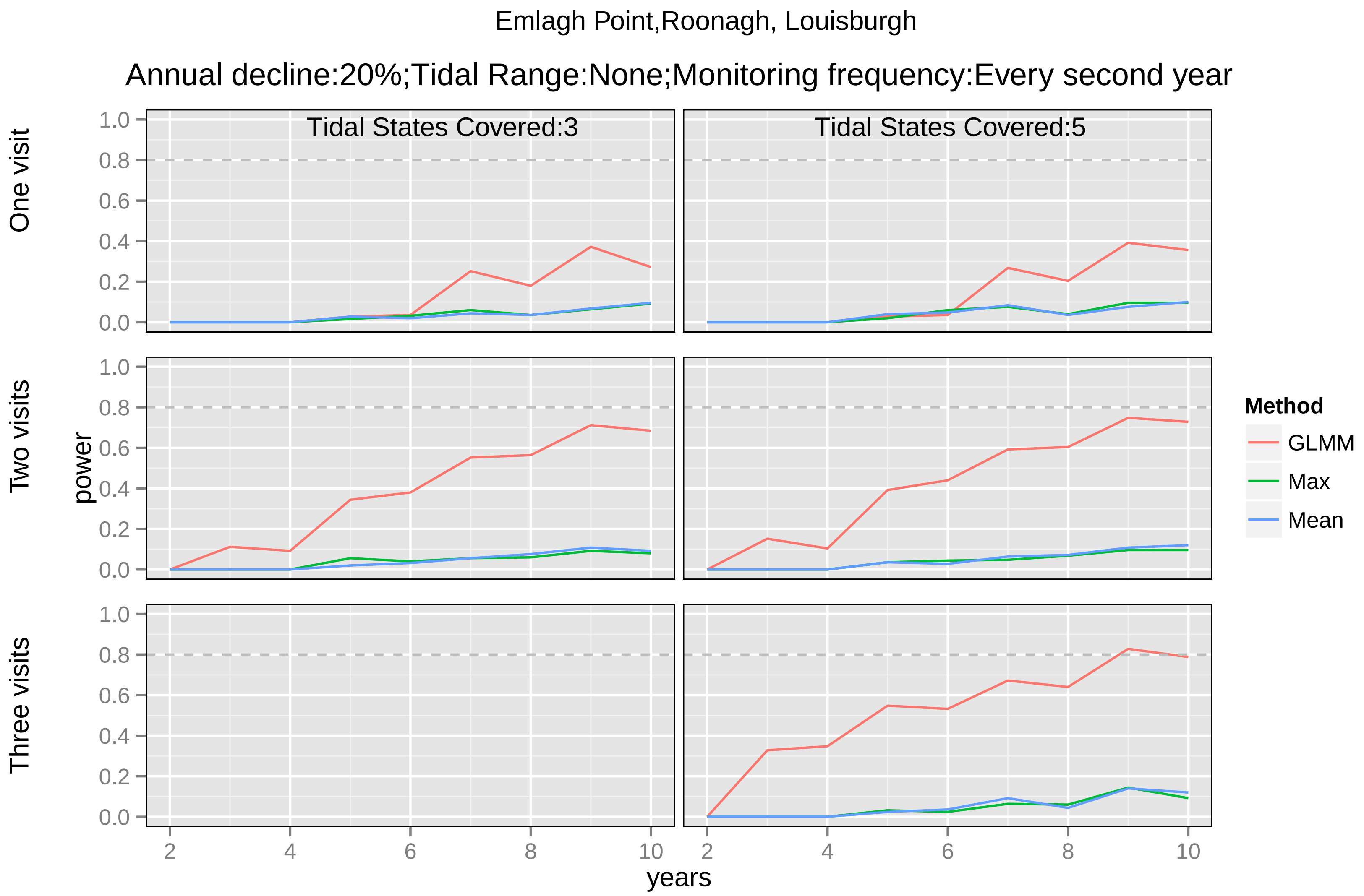
Emlagh Point,Roonagh, Louisburgh
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
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Three visits
power
years
Method
GLMM
Max
Mean
0.0
0.2
0.4
0.6
0.8
1.0
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4
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8
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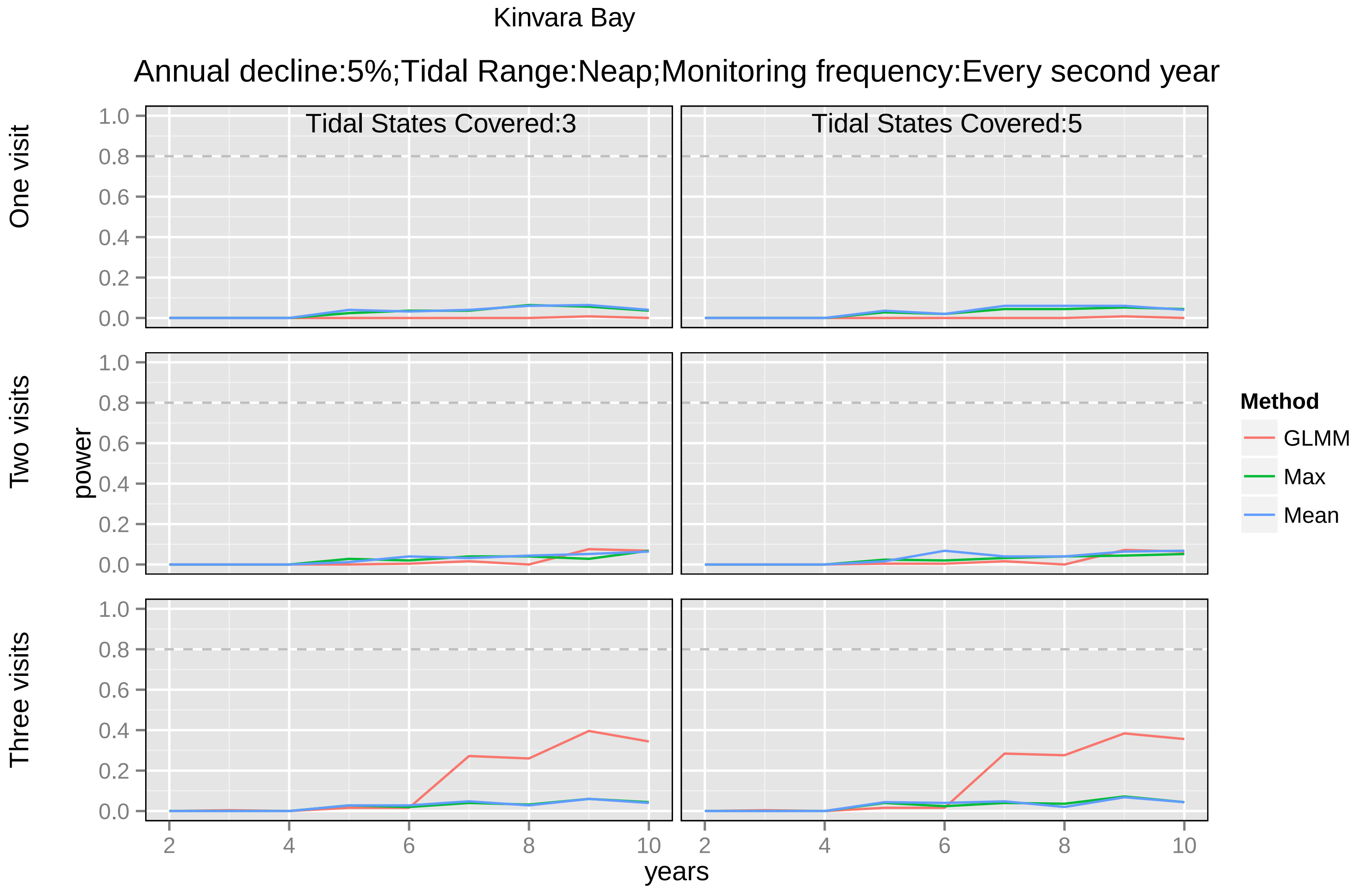
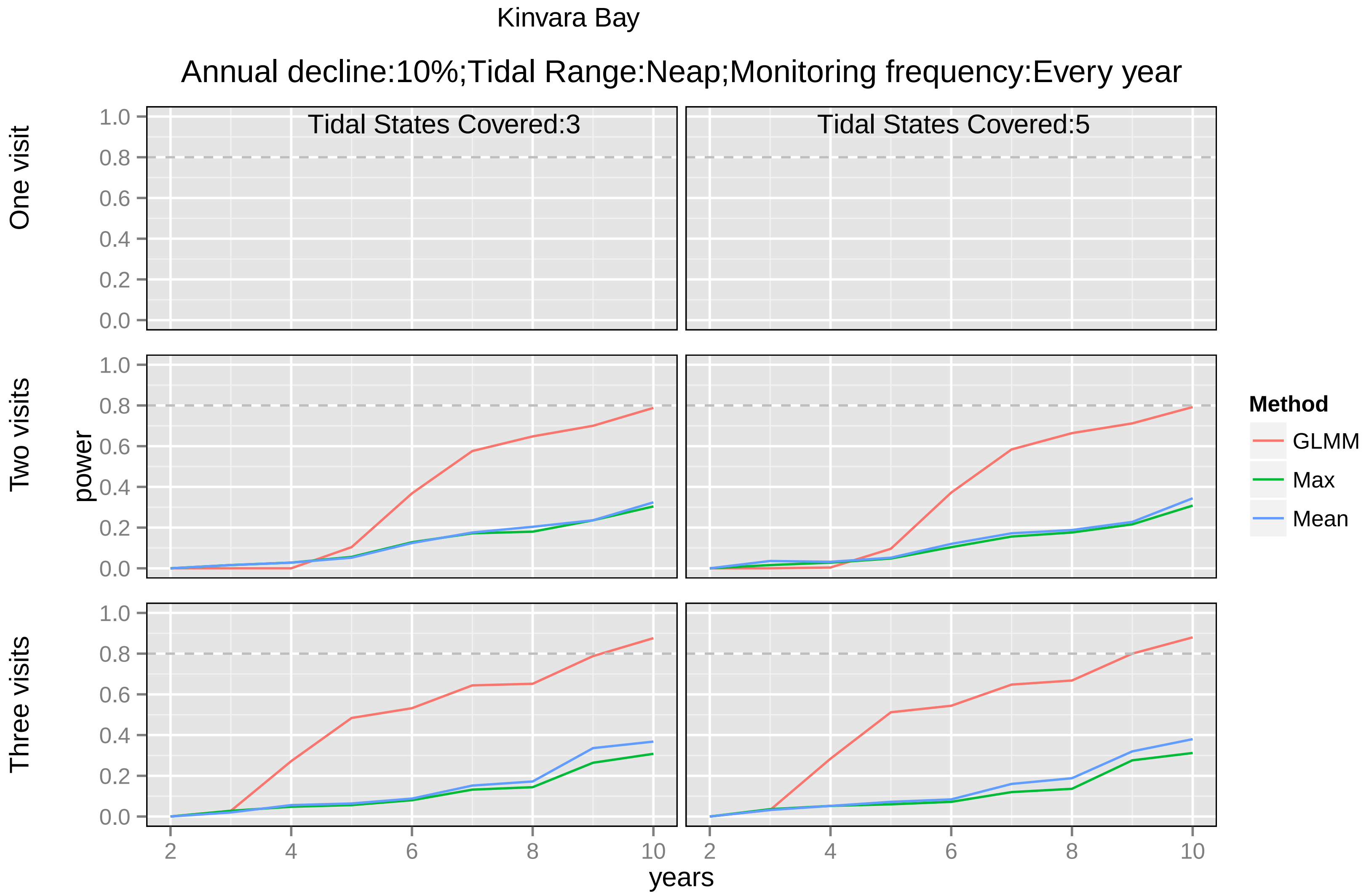
Kinvara Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean


Kinvara Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean



Kinvara Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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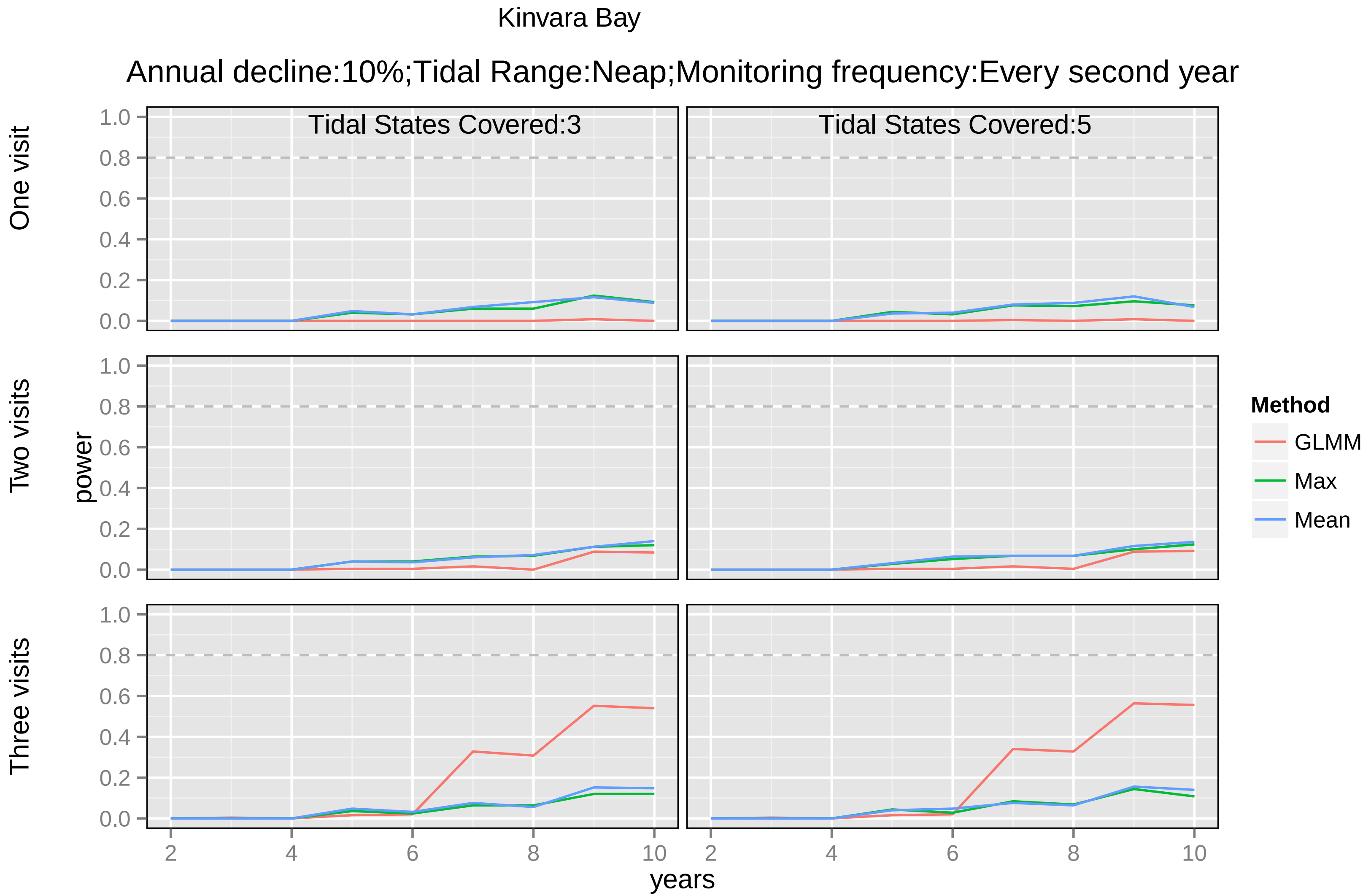
Kinvara Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every second year
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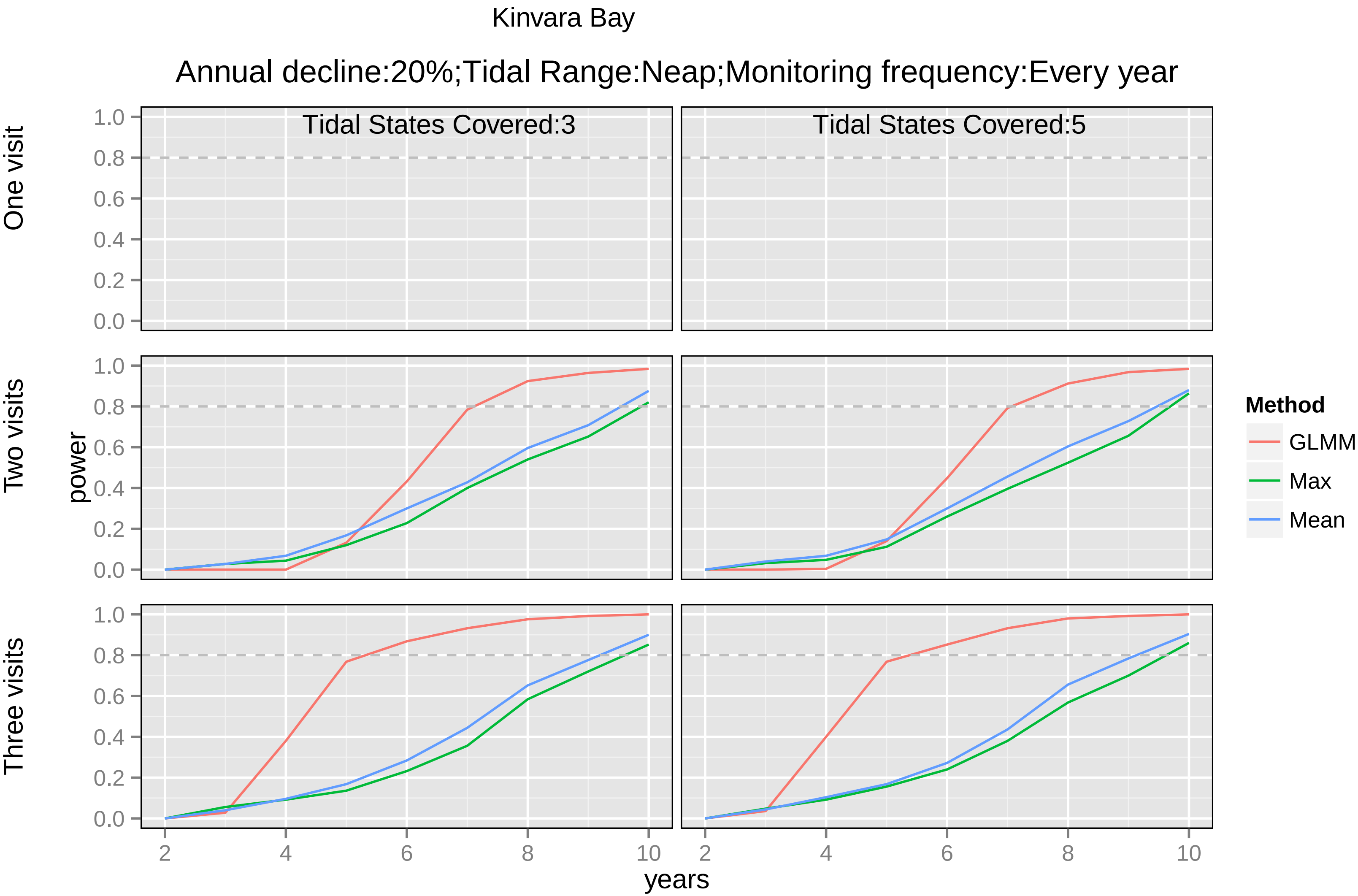
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Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
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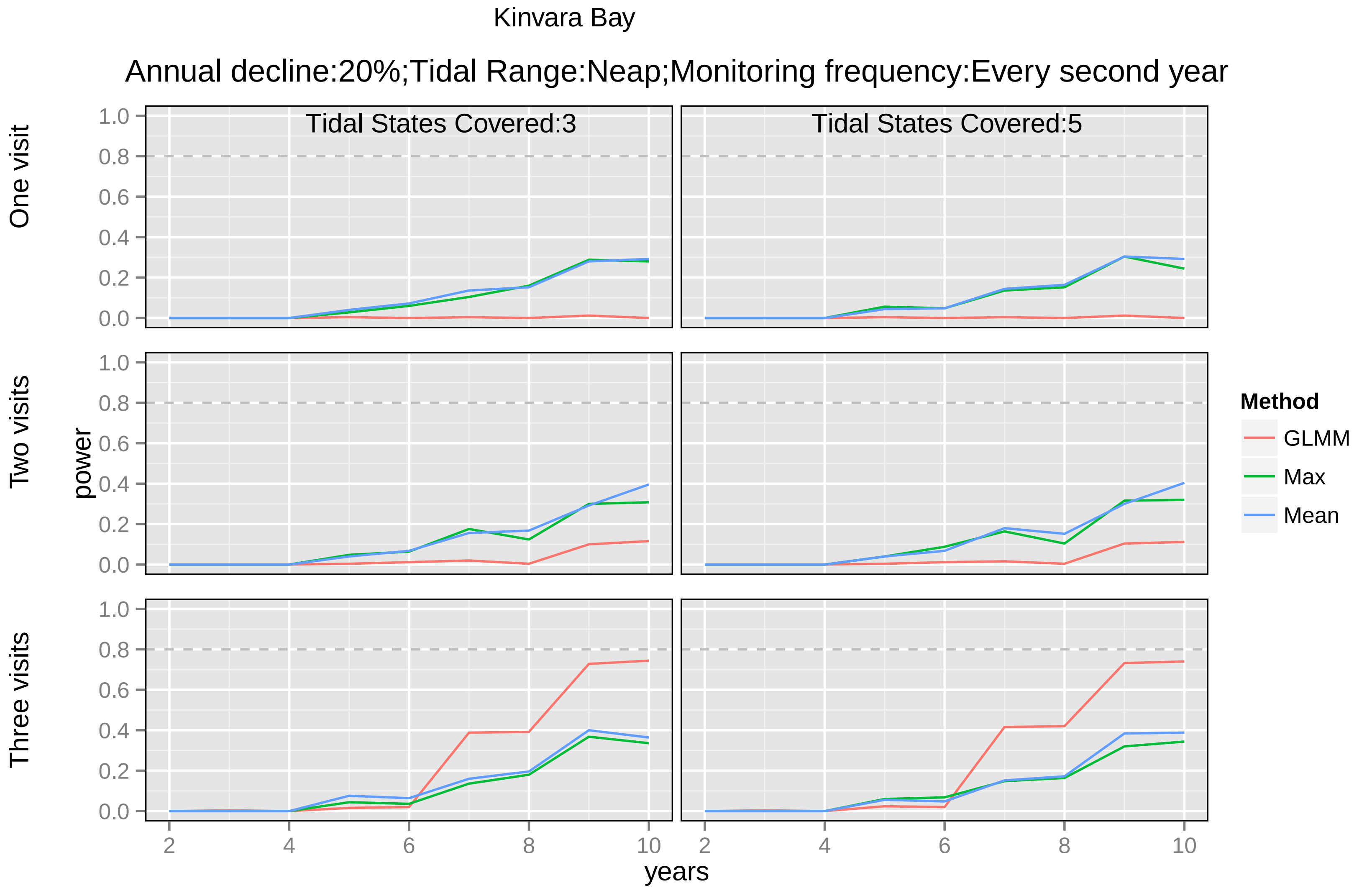

Kinvara Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
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Method
GLMM
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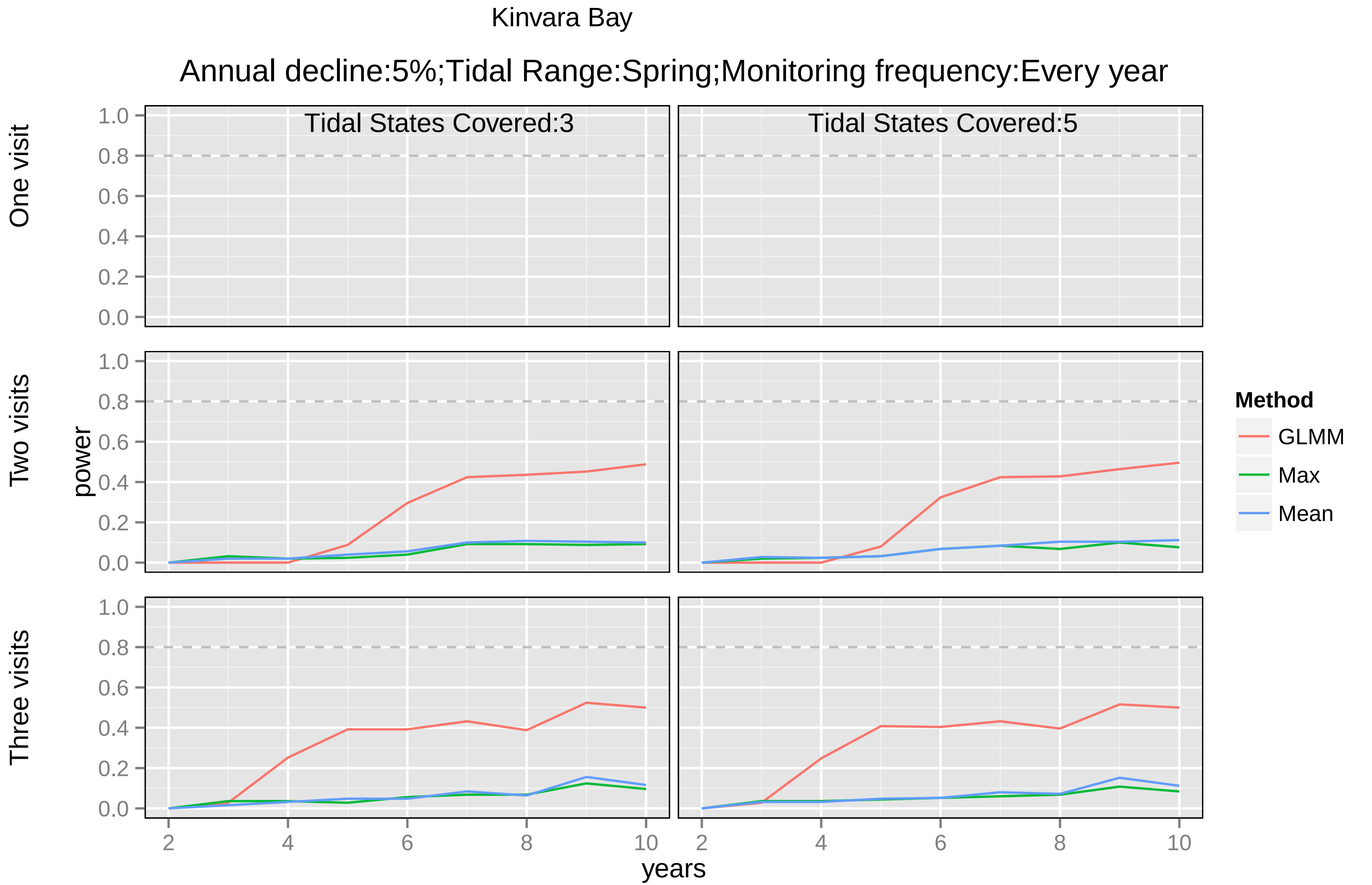
Mean


Kinvara Bay
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every year
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Tidal States Covered:5
One visit
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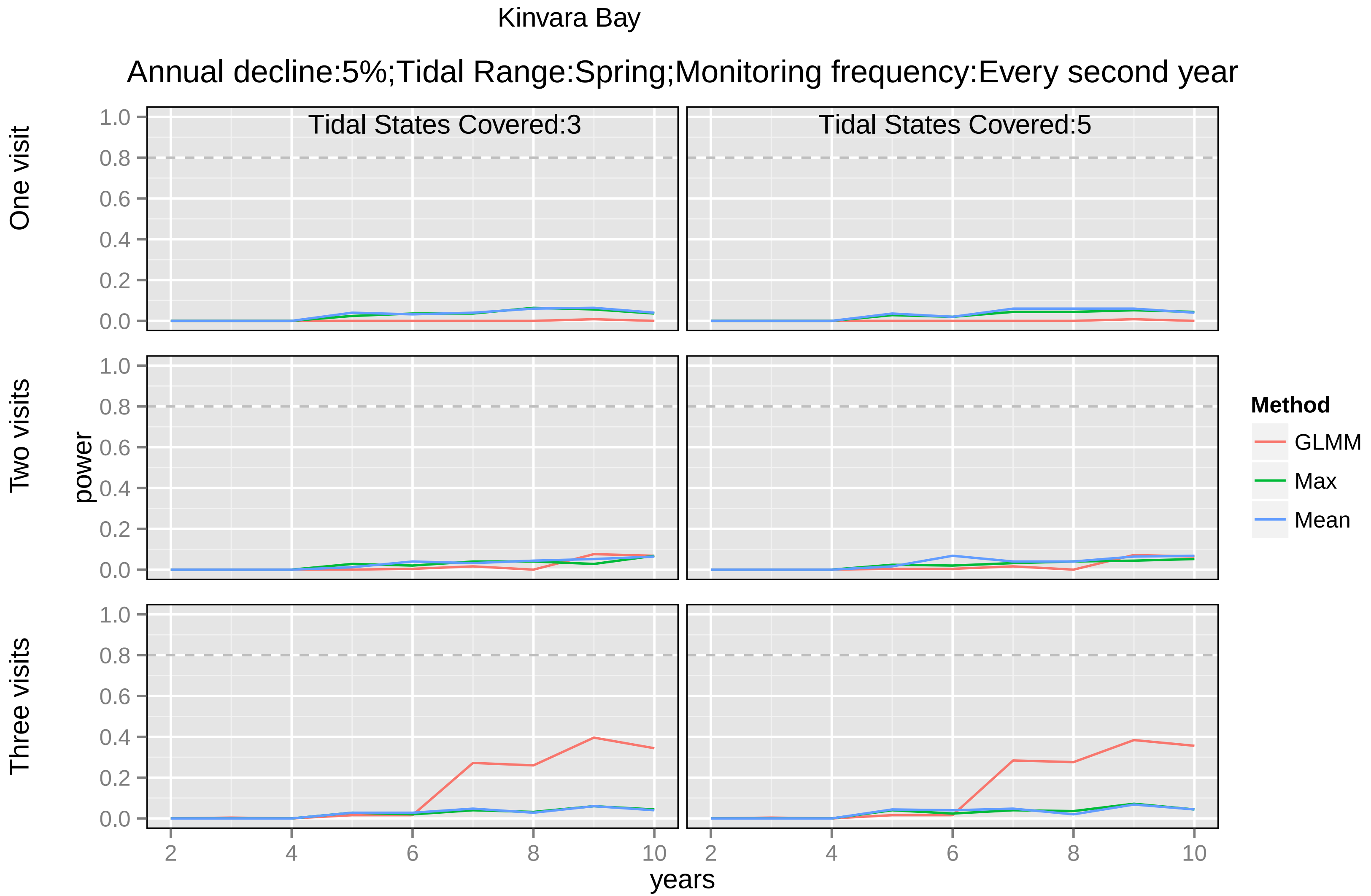

Kinvara Bay
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every second year
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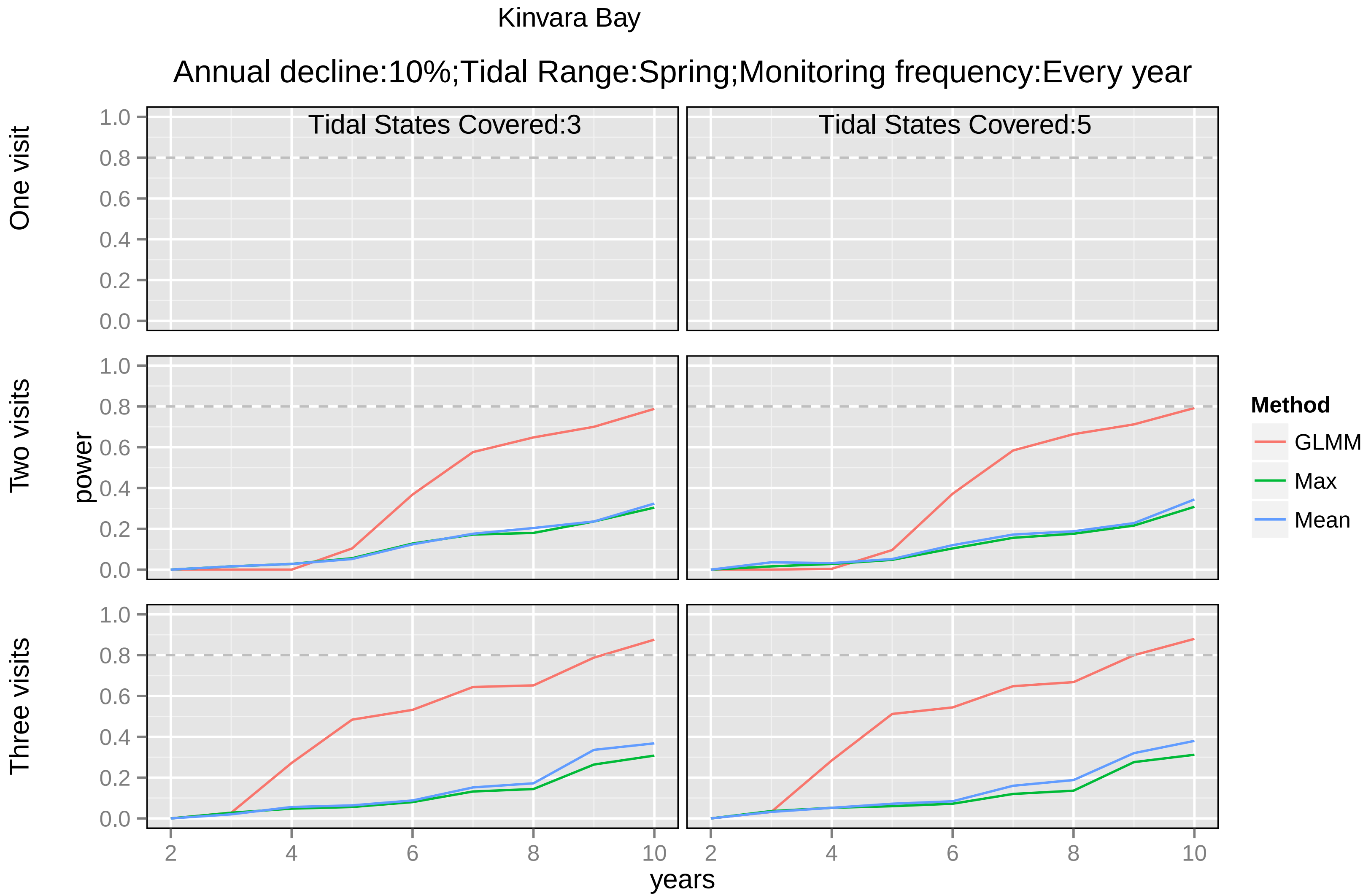
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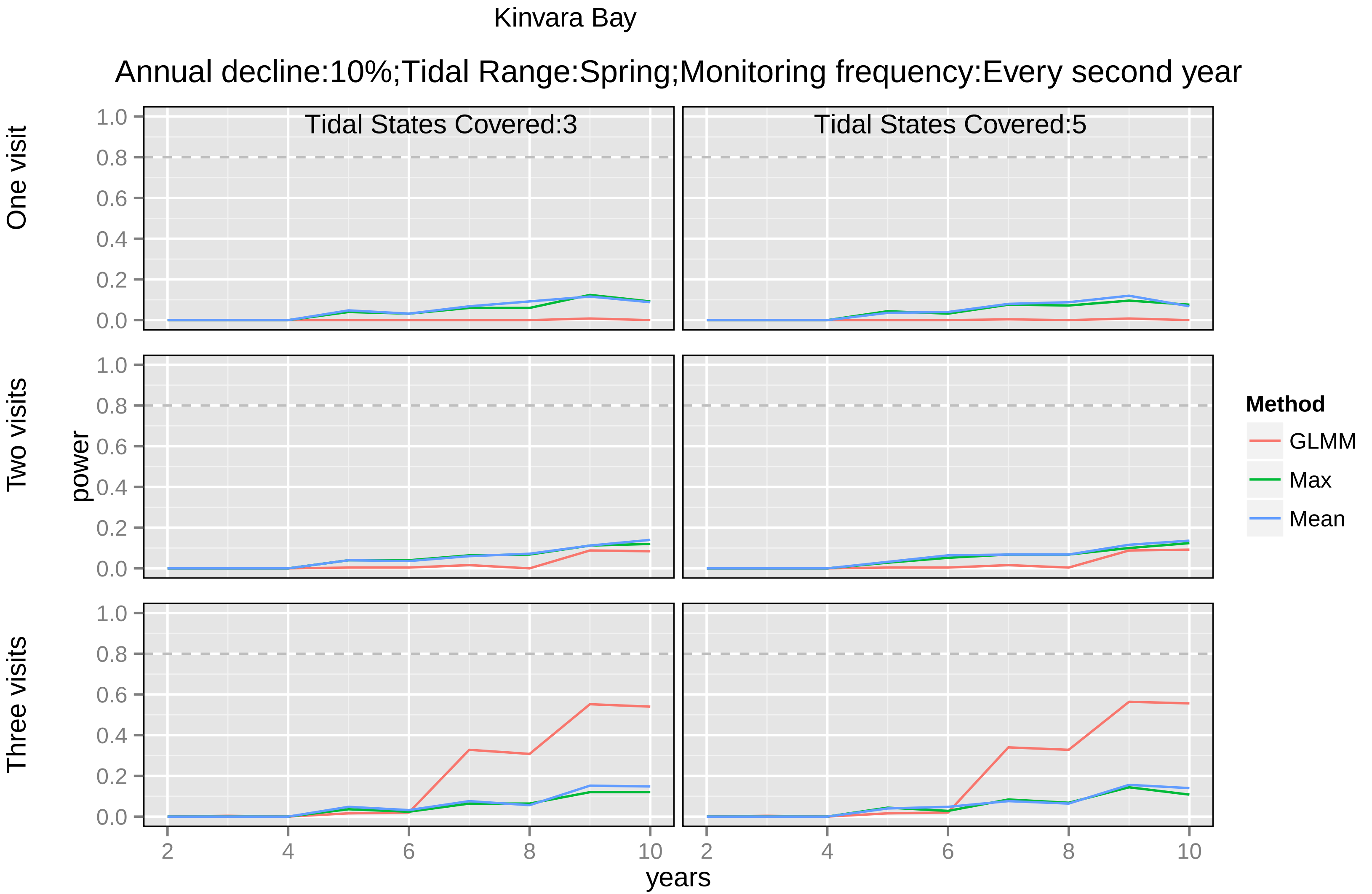
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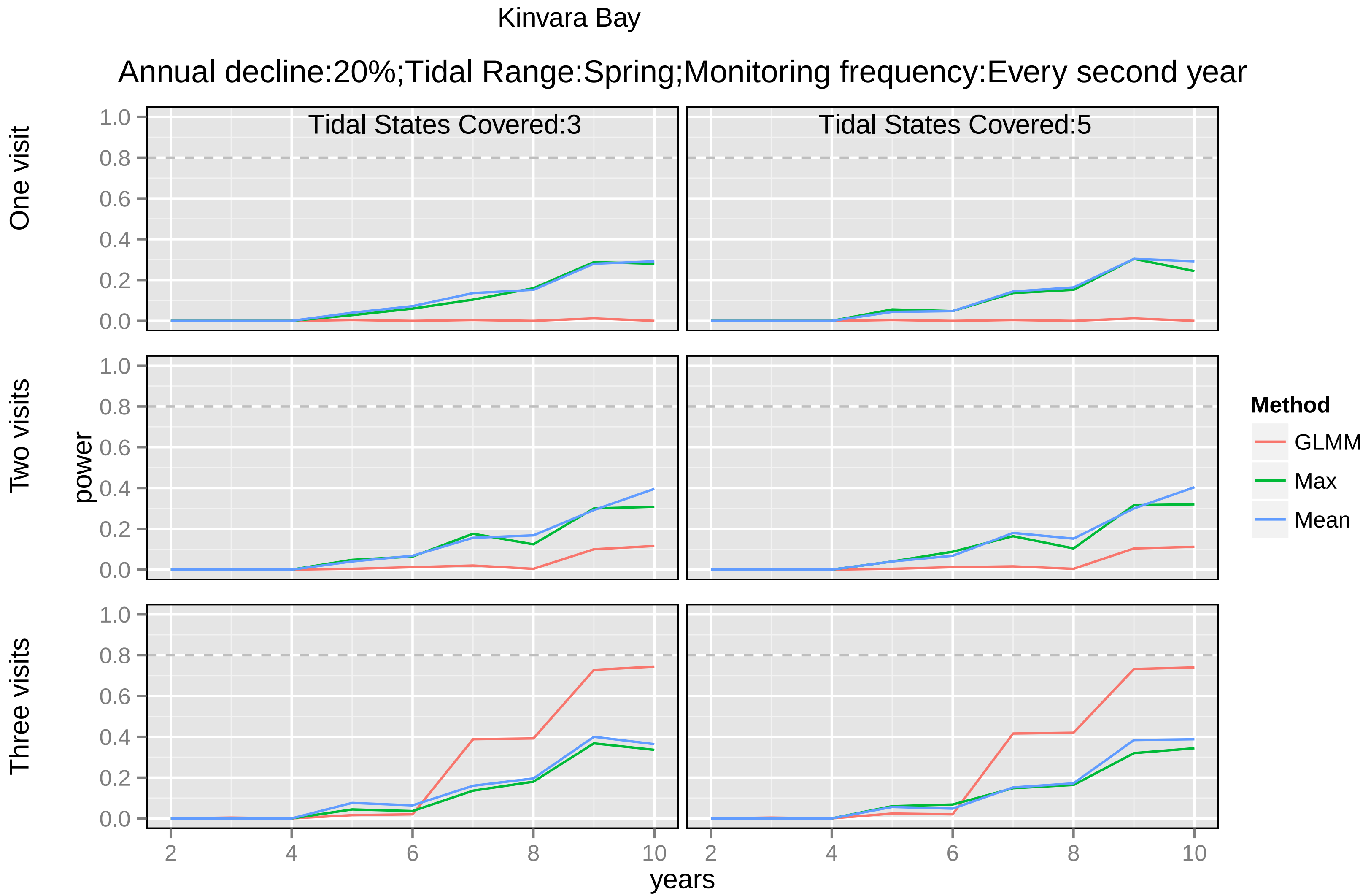

Kinvara Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
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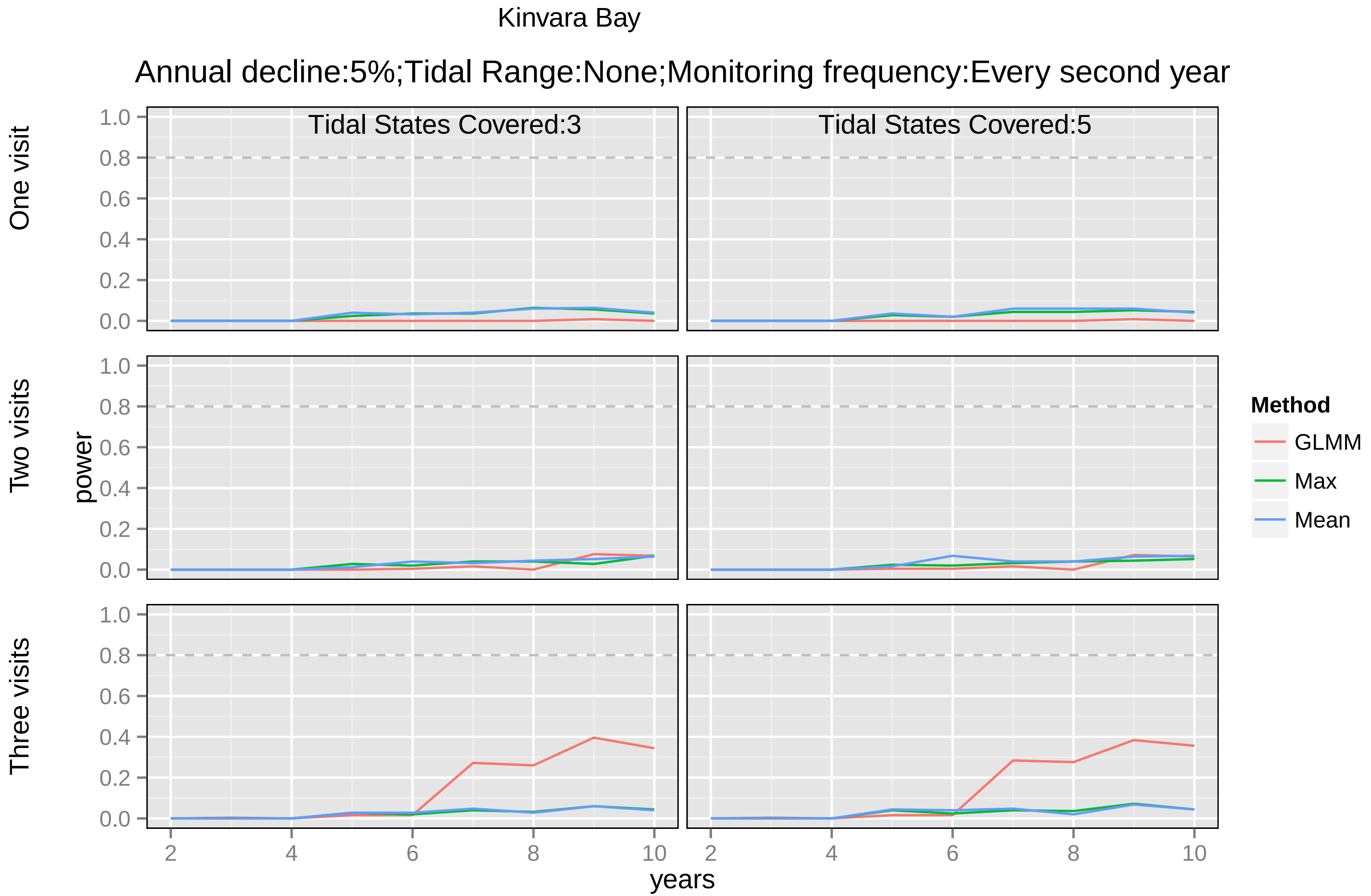

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Annual decline:5%;Tidal Range:None;Monitoring frequency:Every second year
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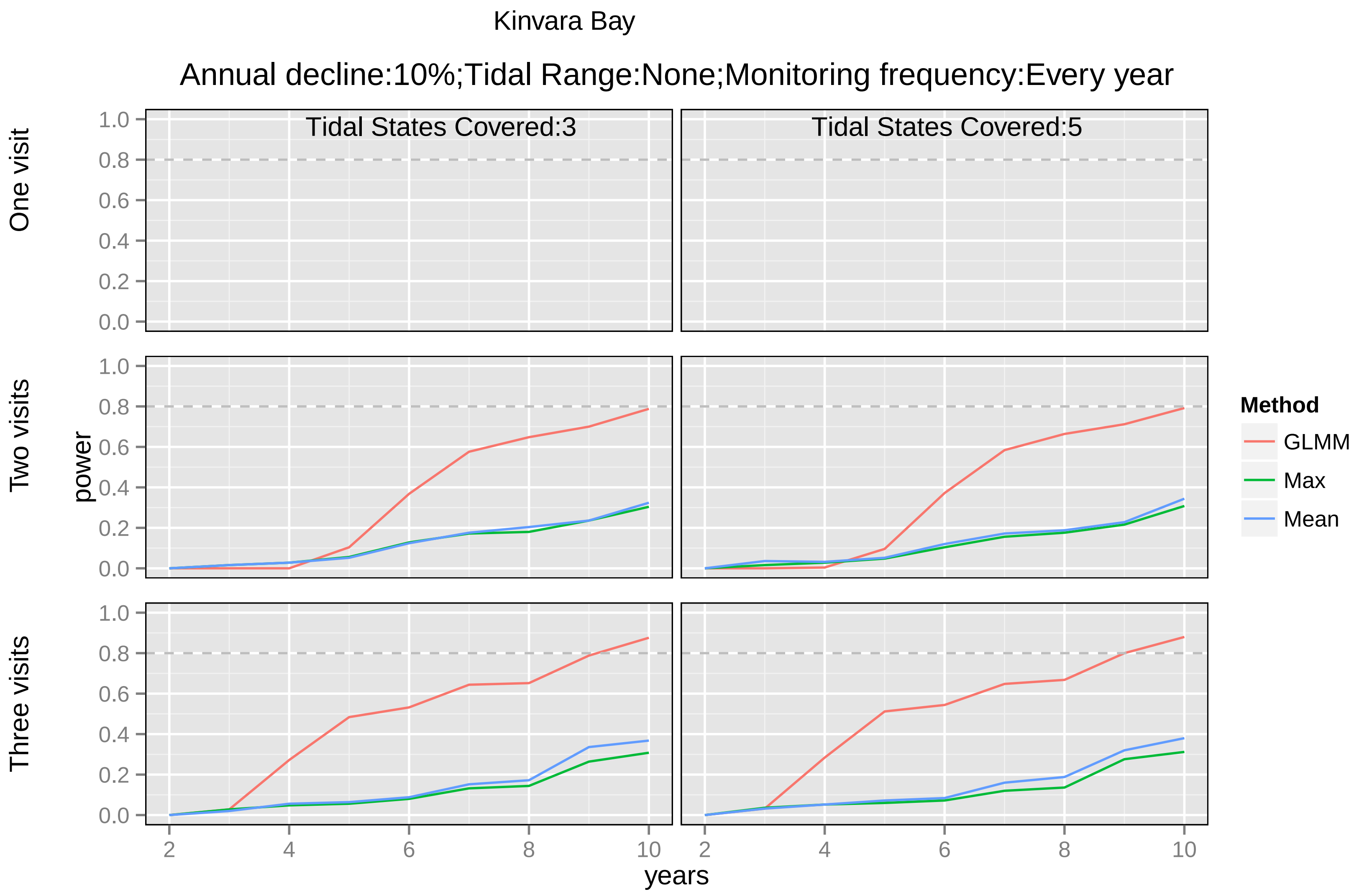

Kinvara Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
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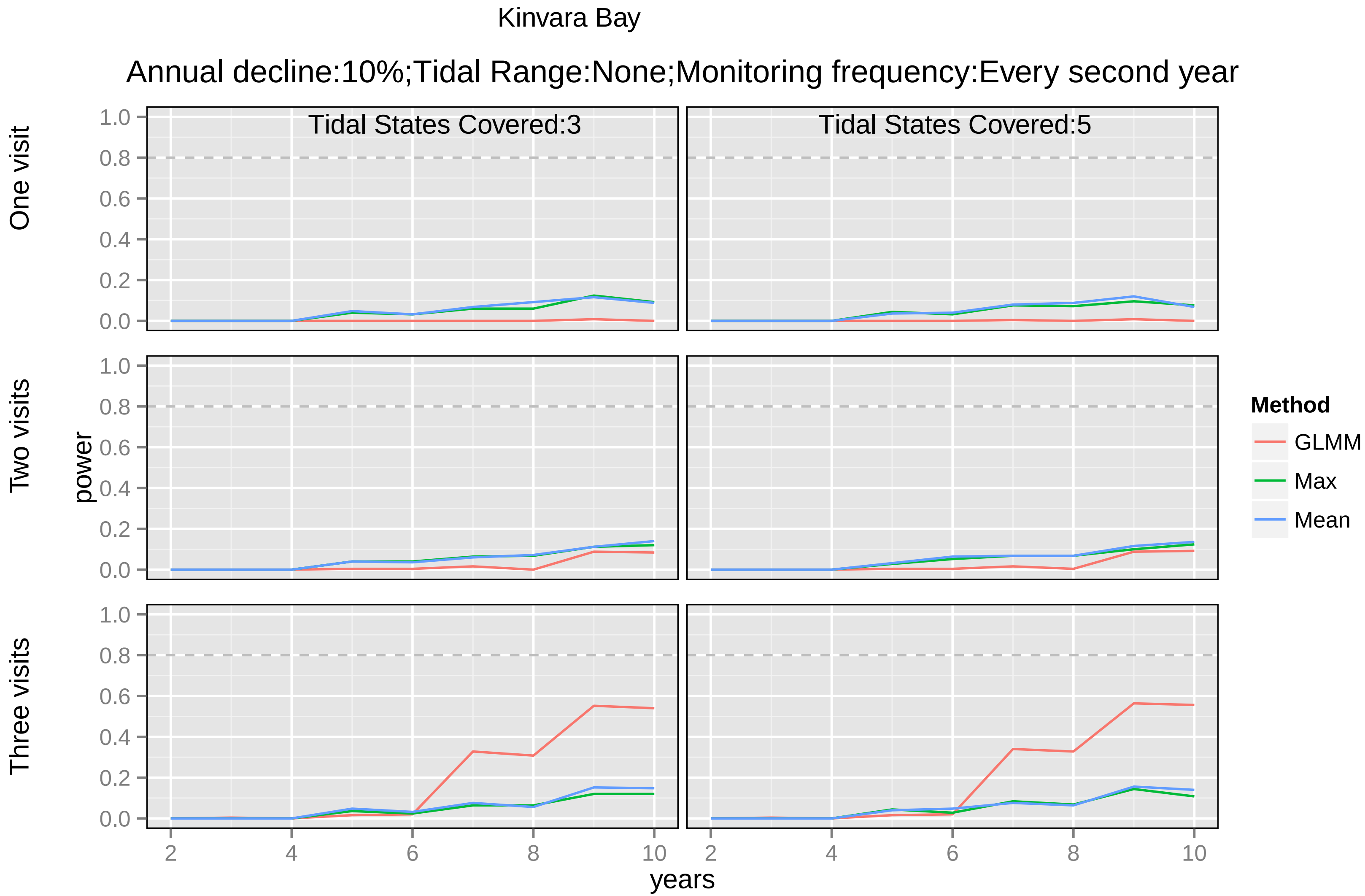
Kinvara Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
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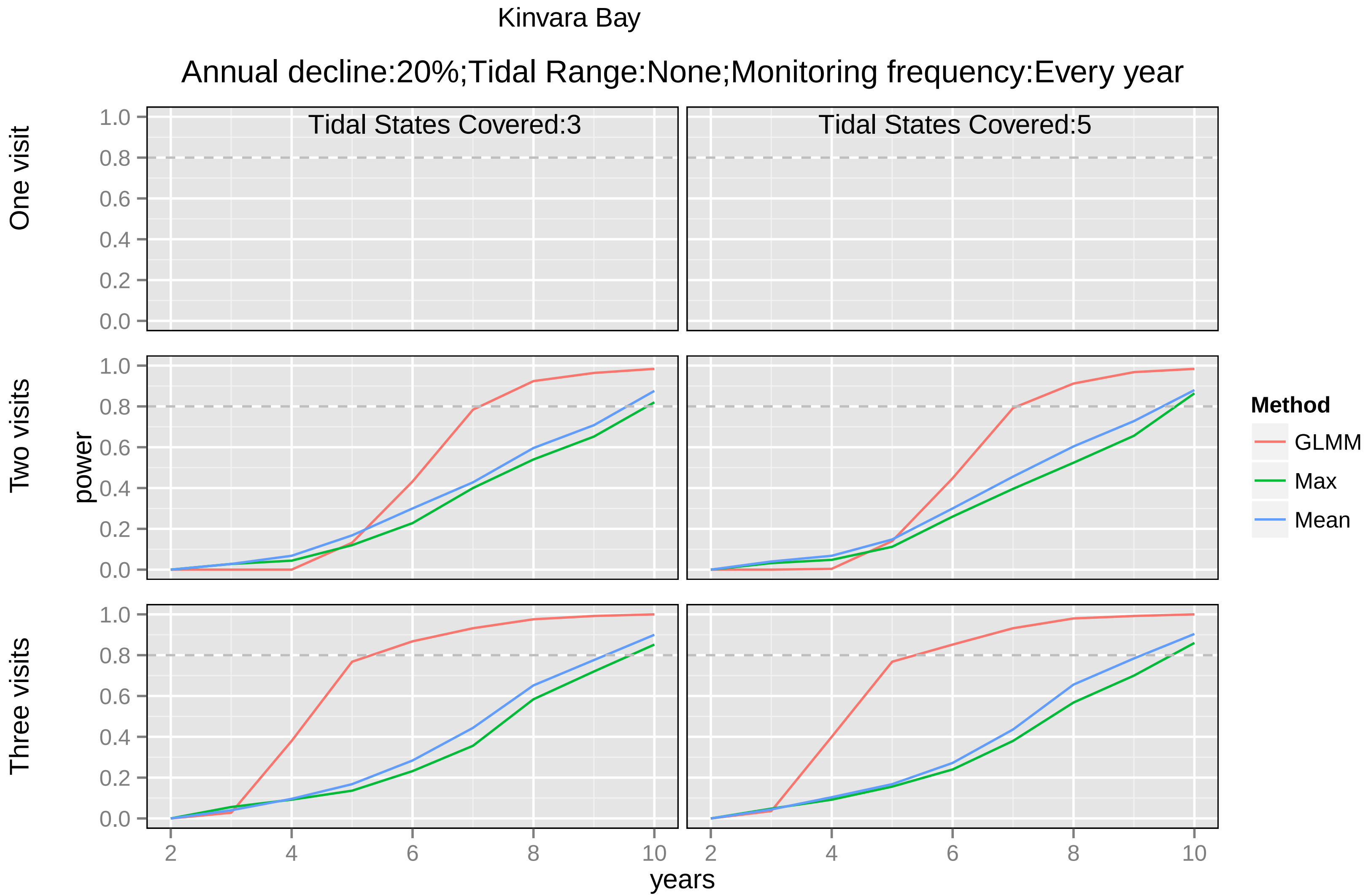
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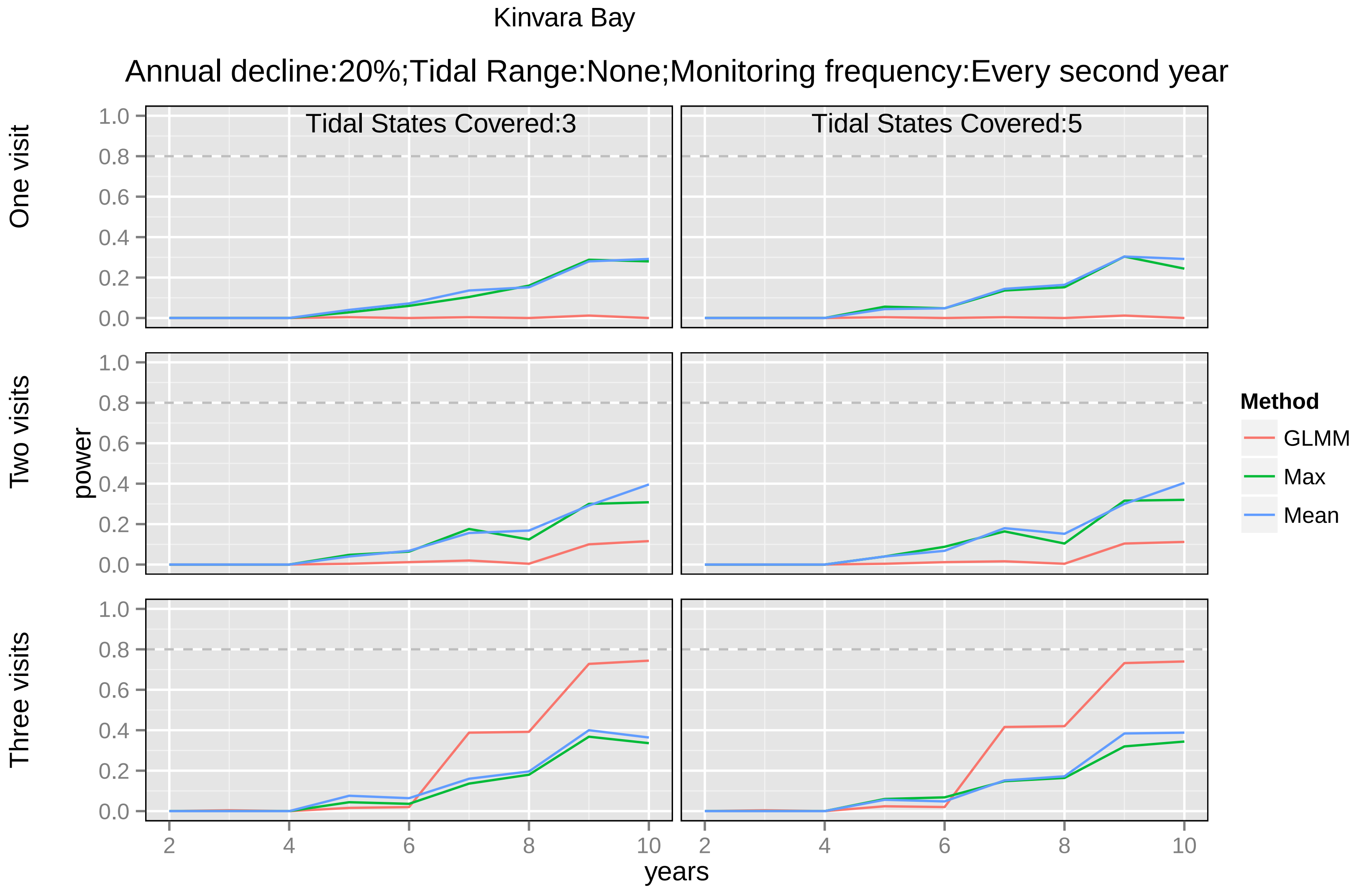
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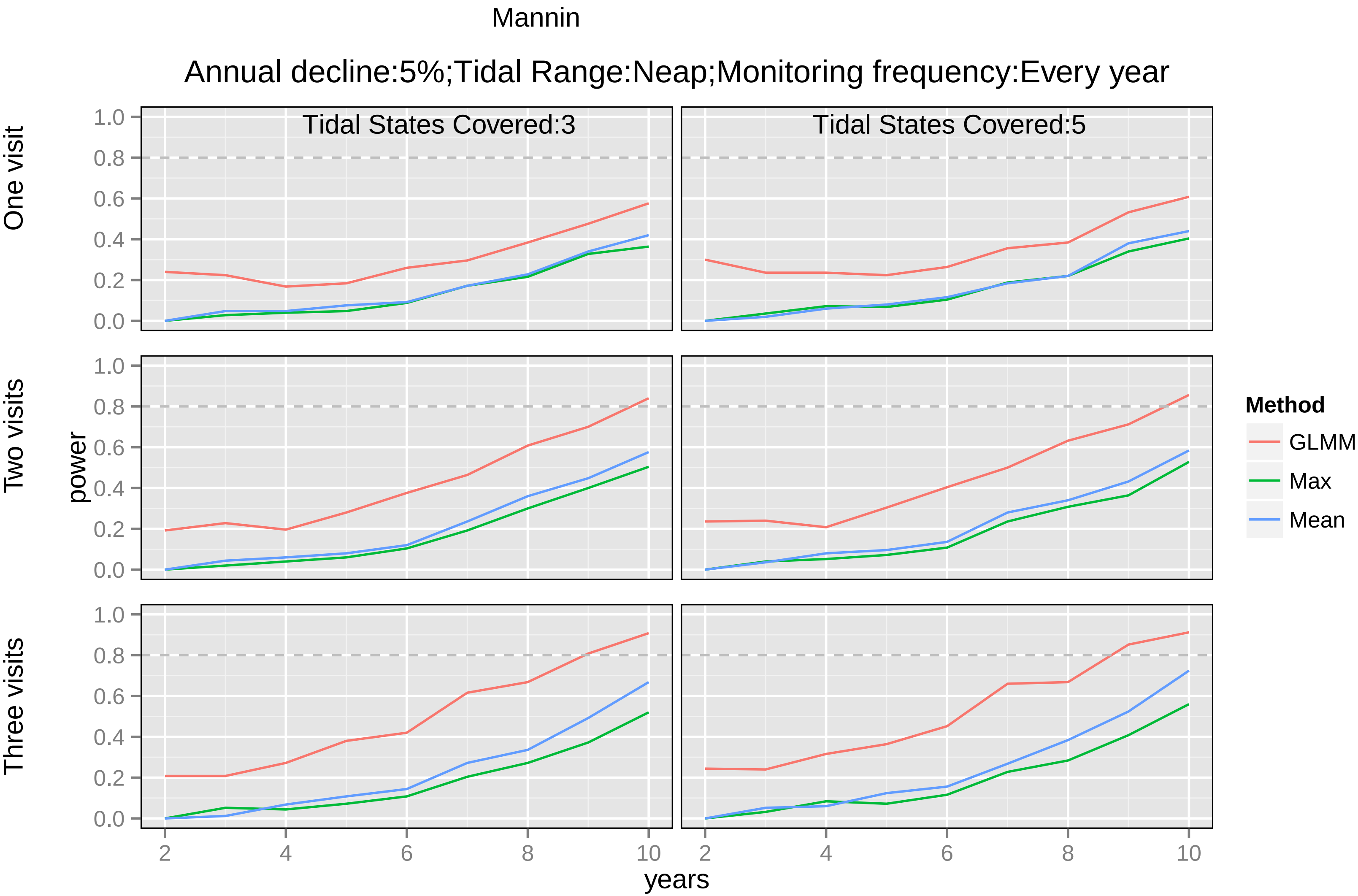
Mannin
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
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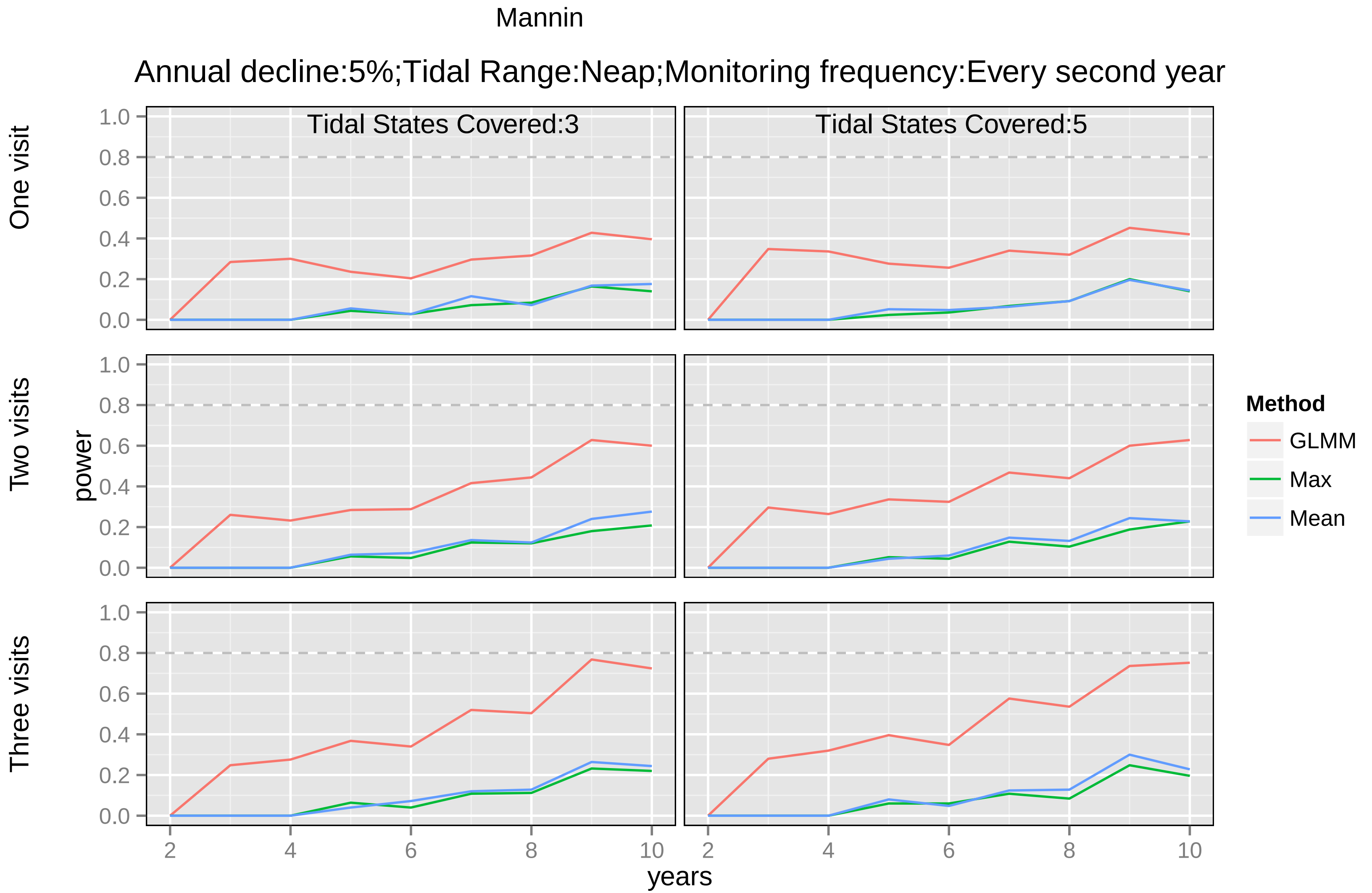
Mannin
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
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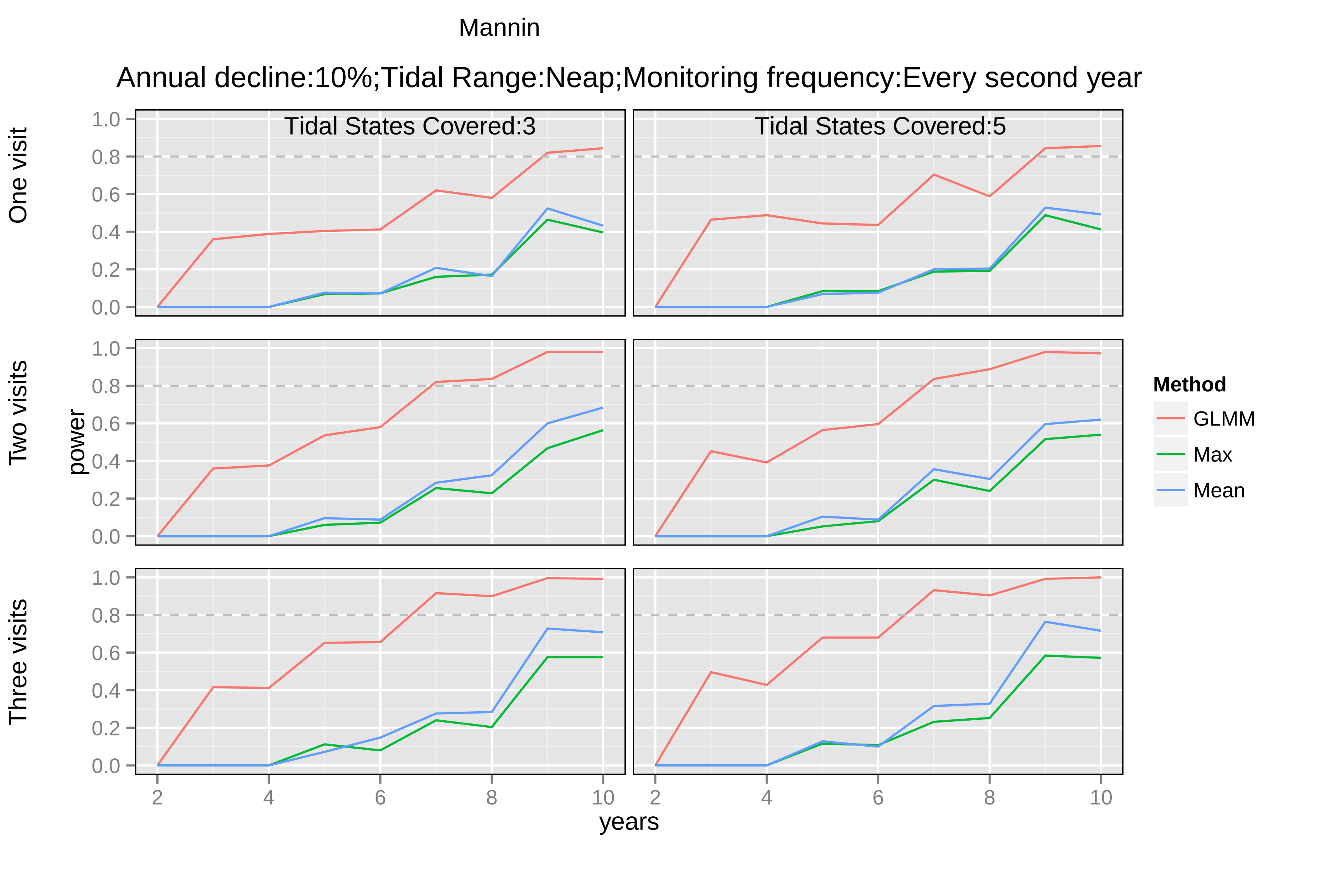
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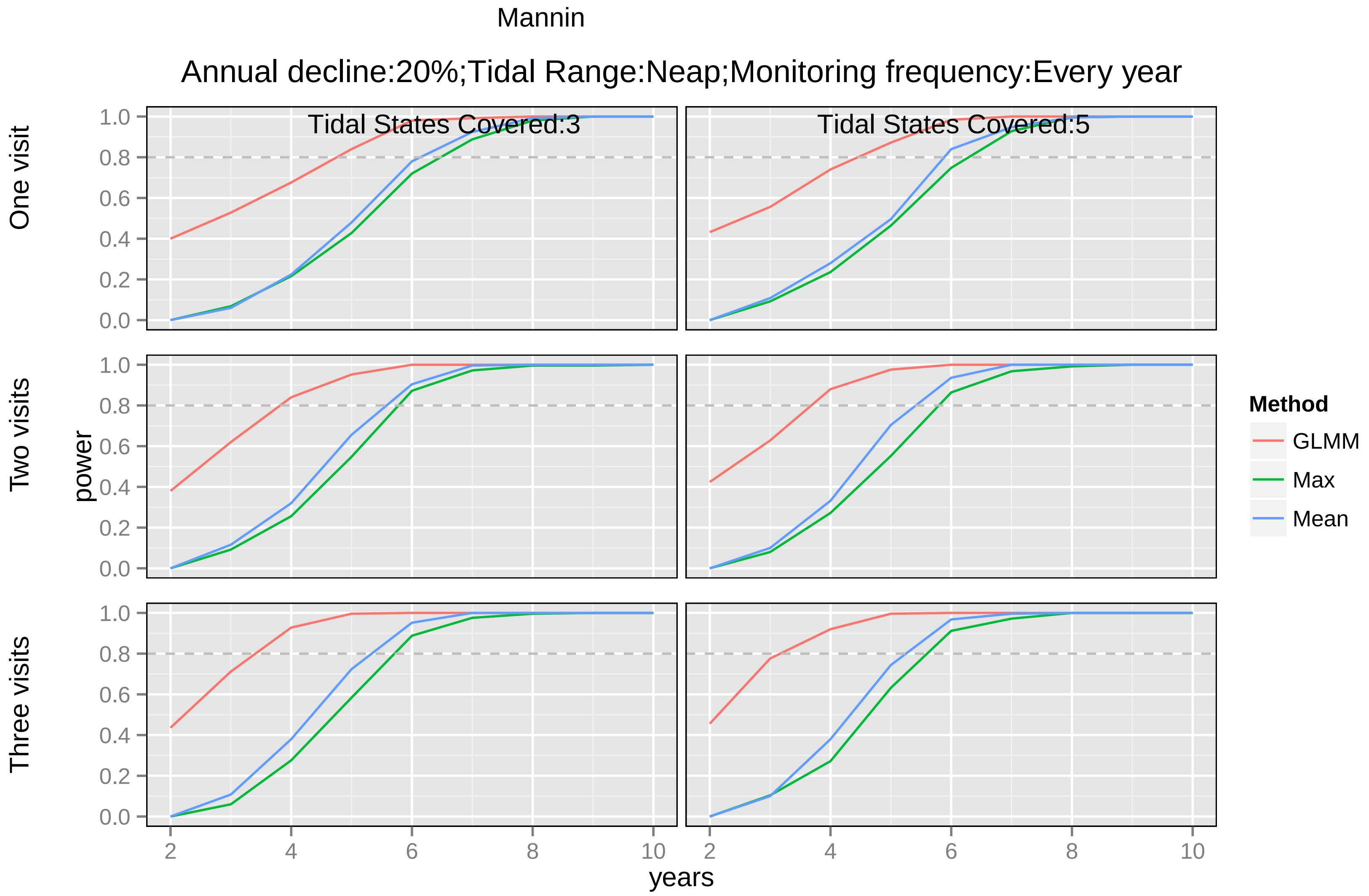

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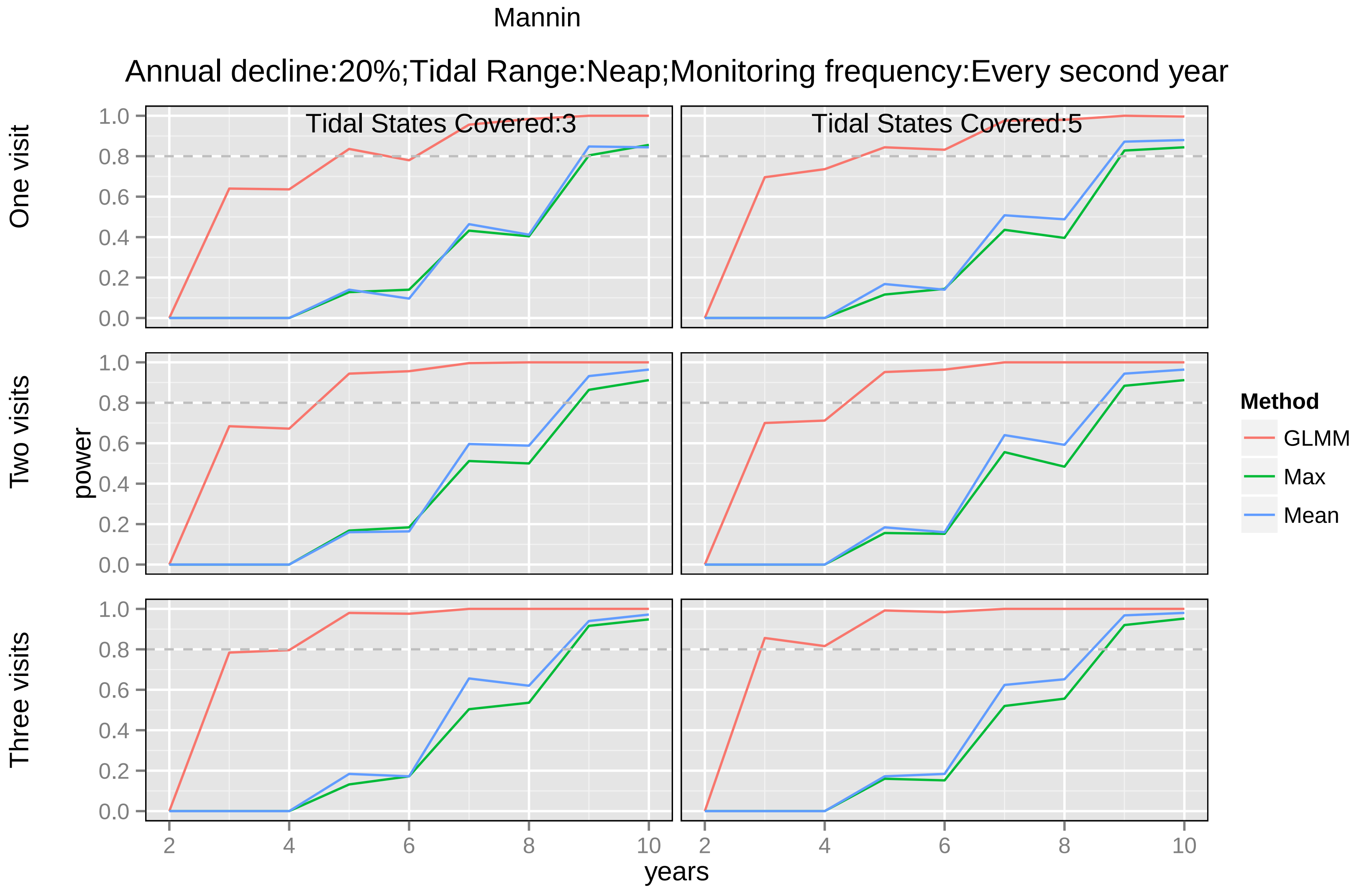
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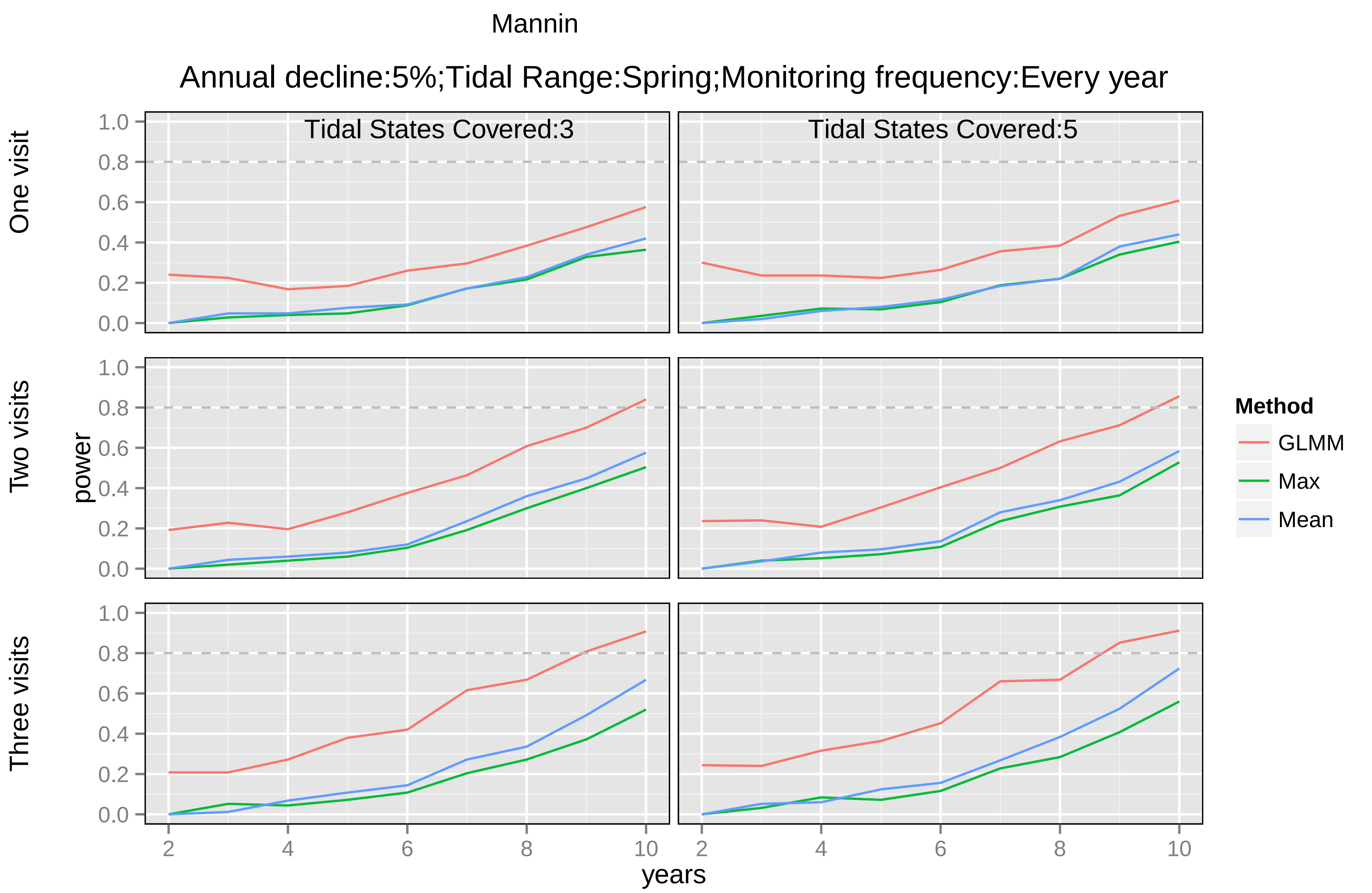
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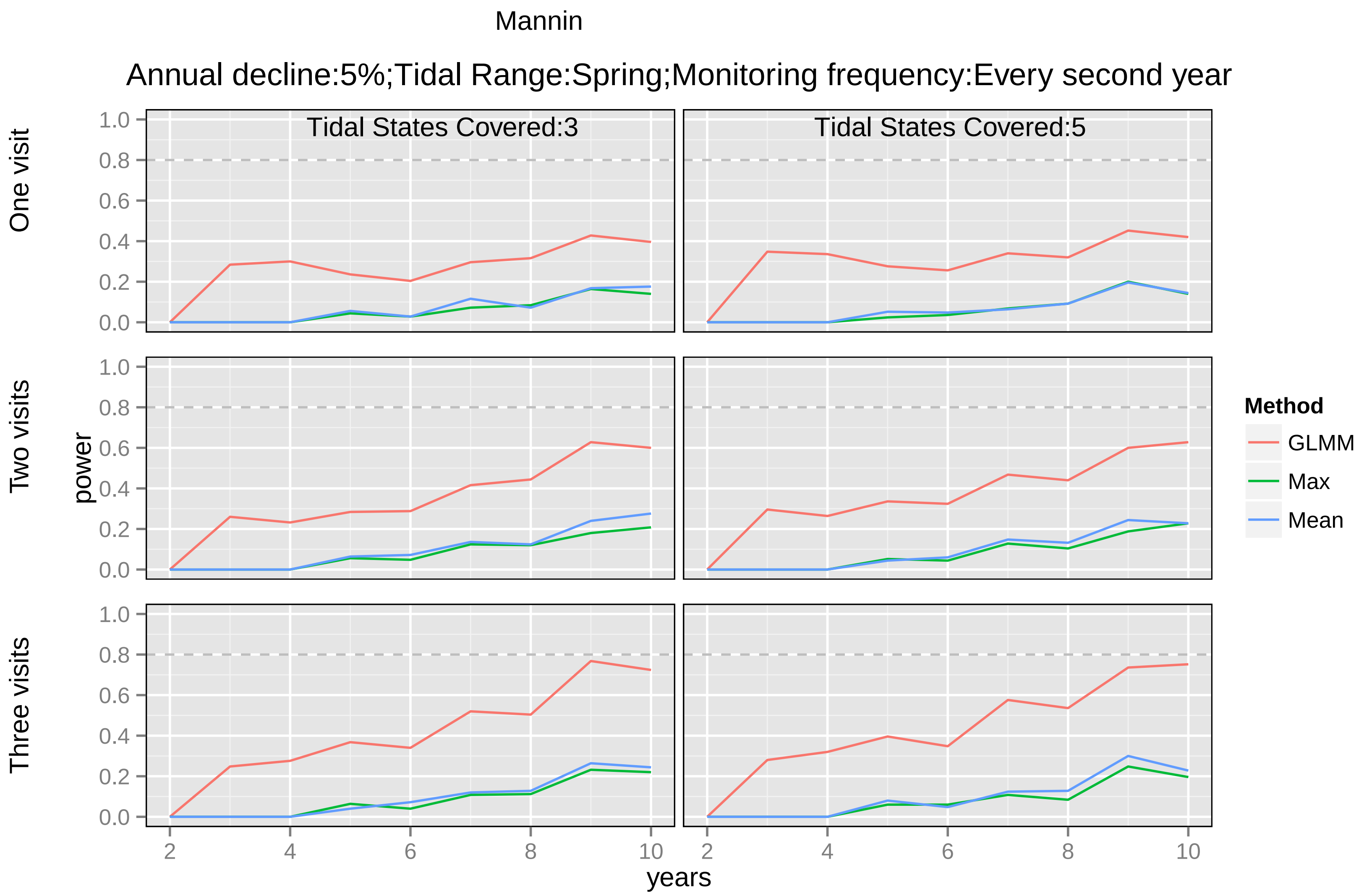
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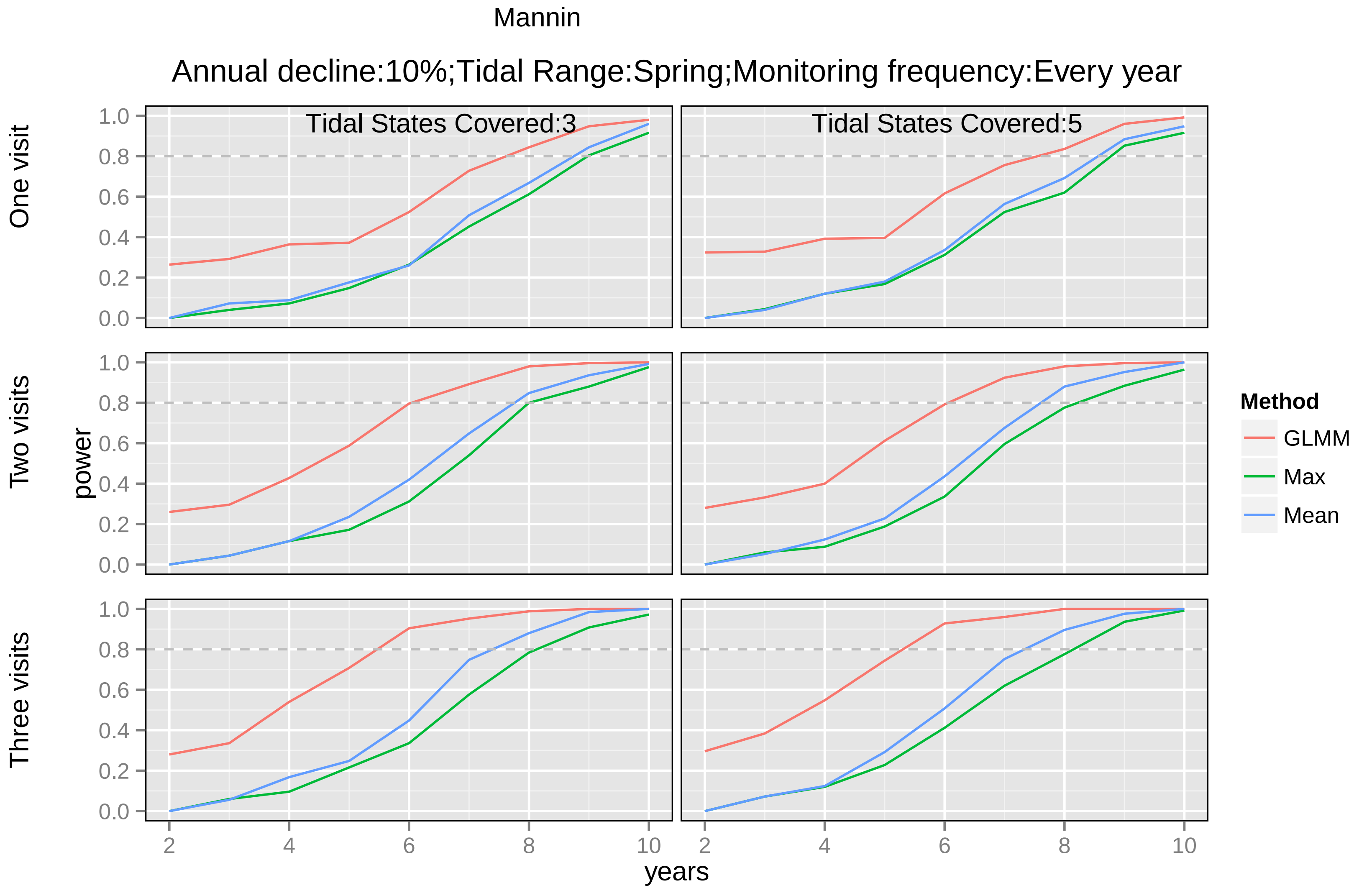

Mannin
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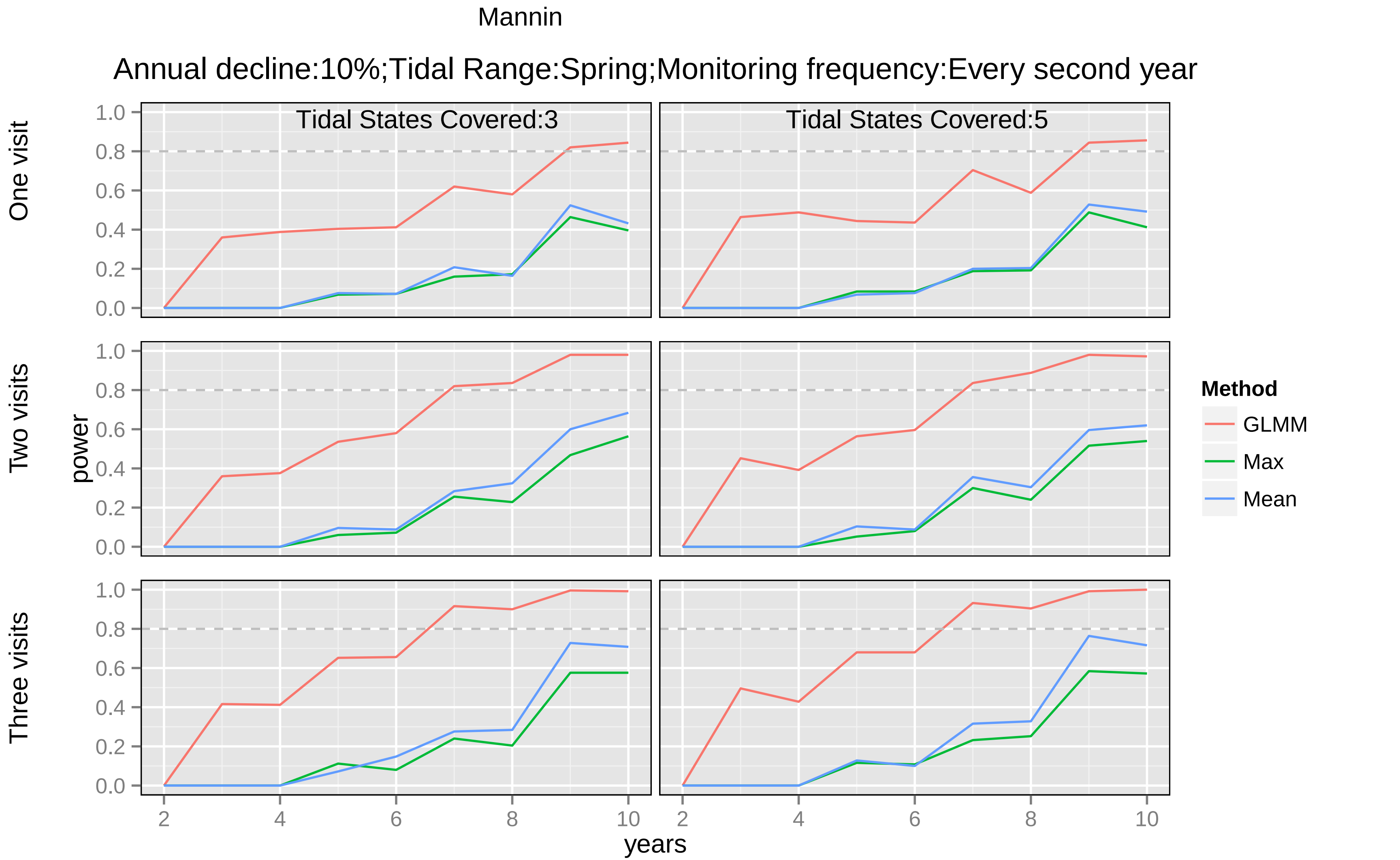
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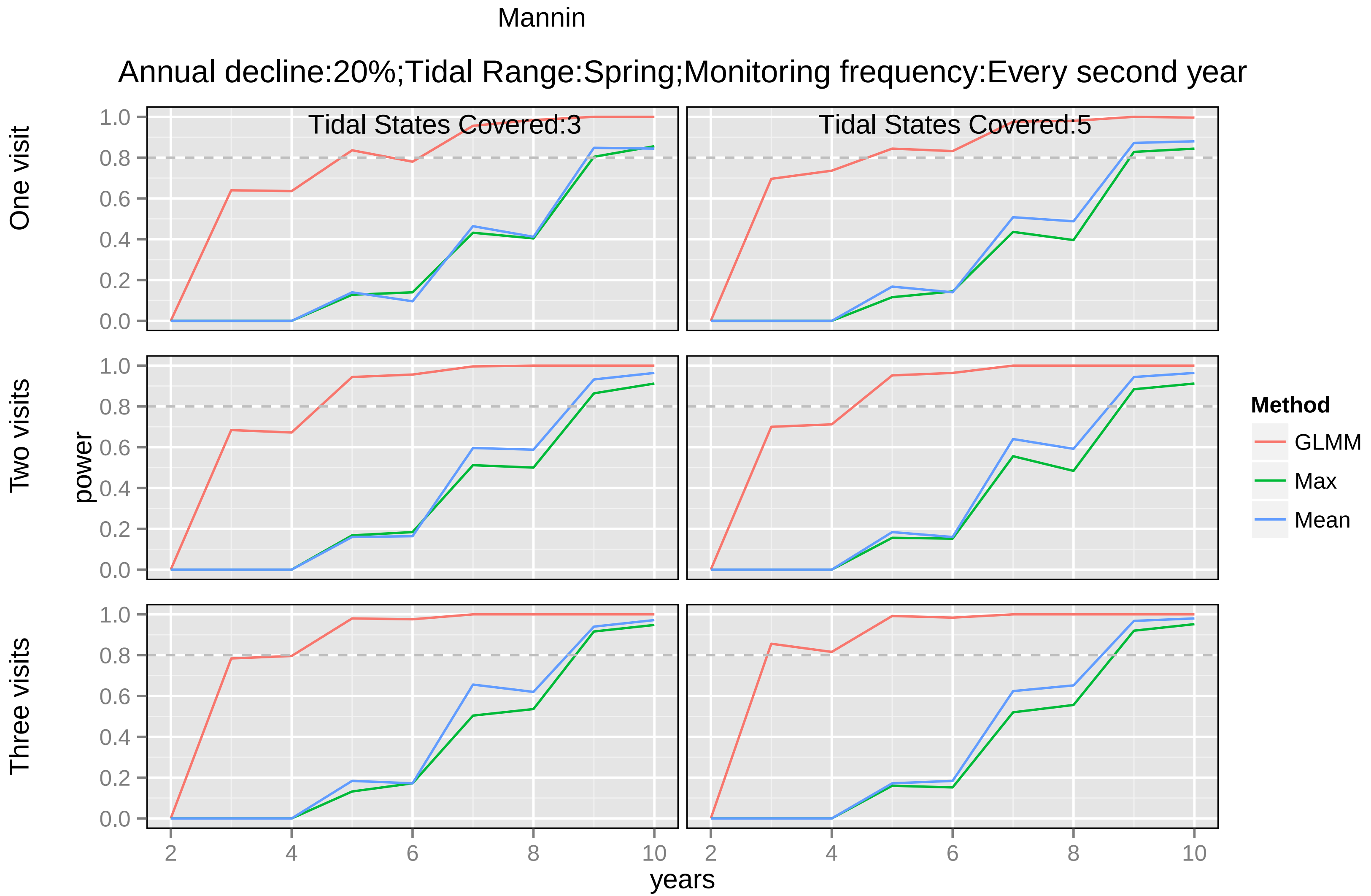
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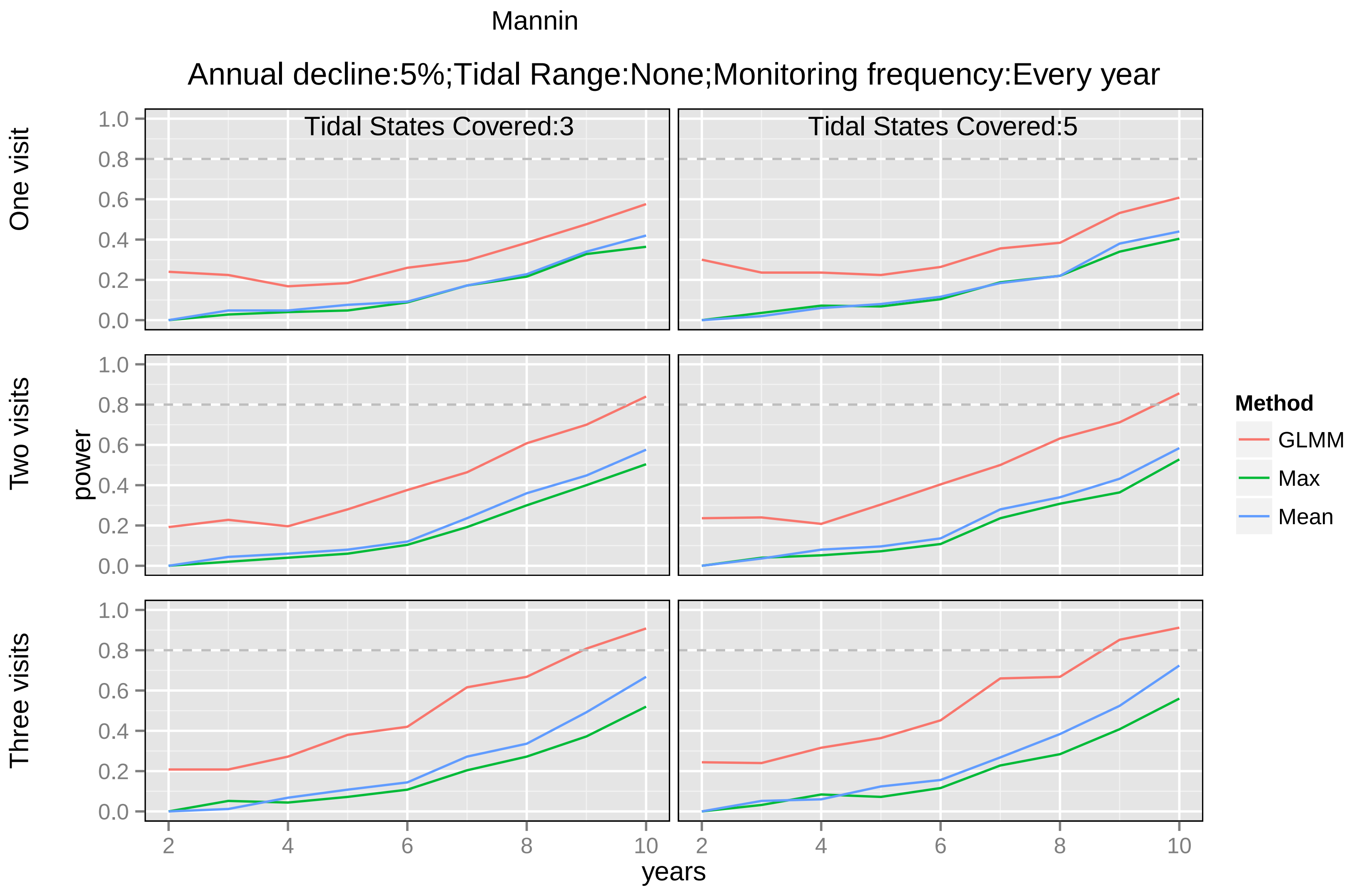

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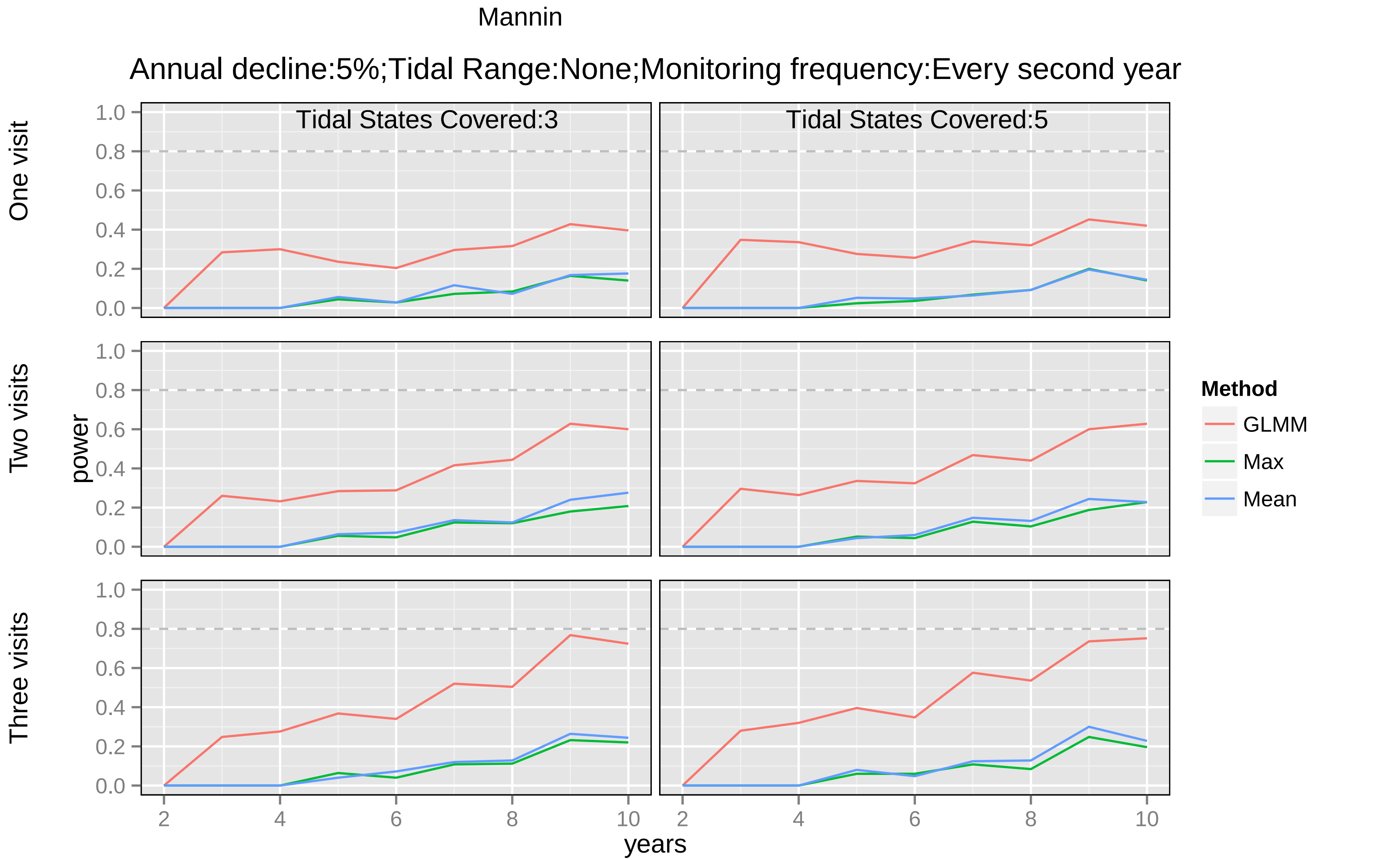
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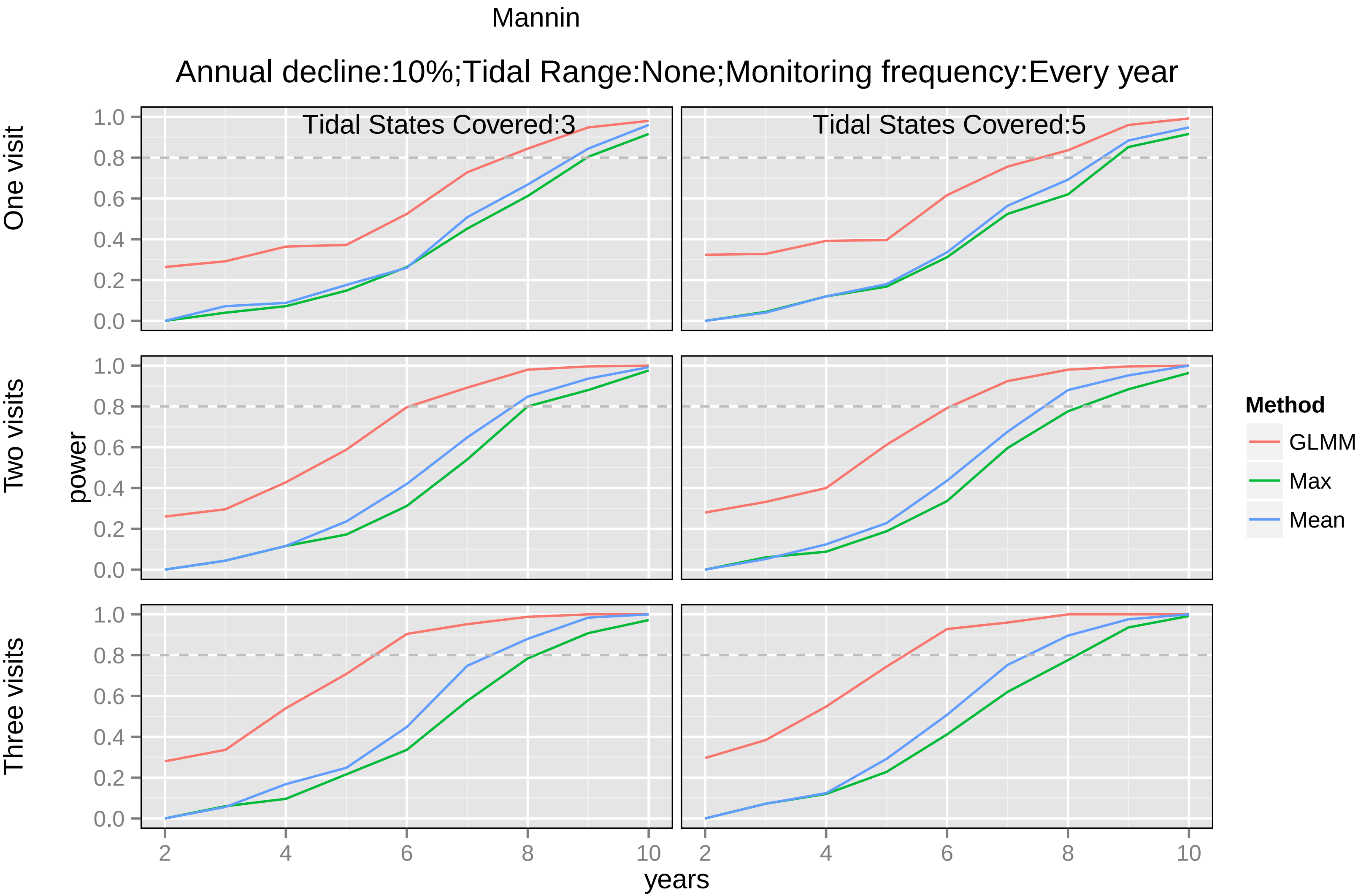

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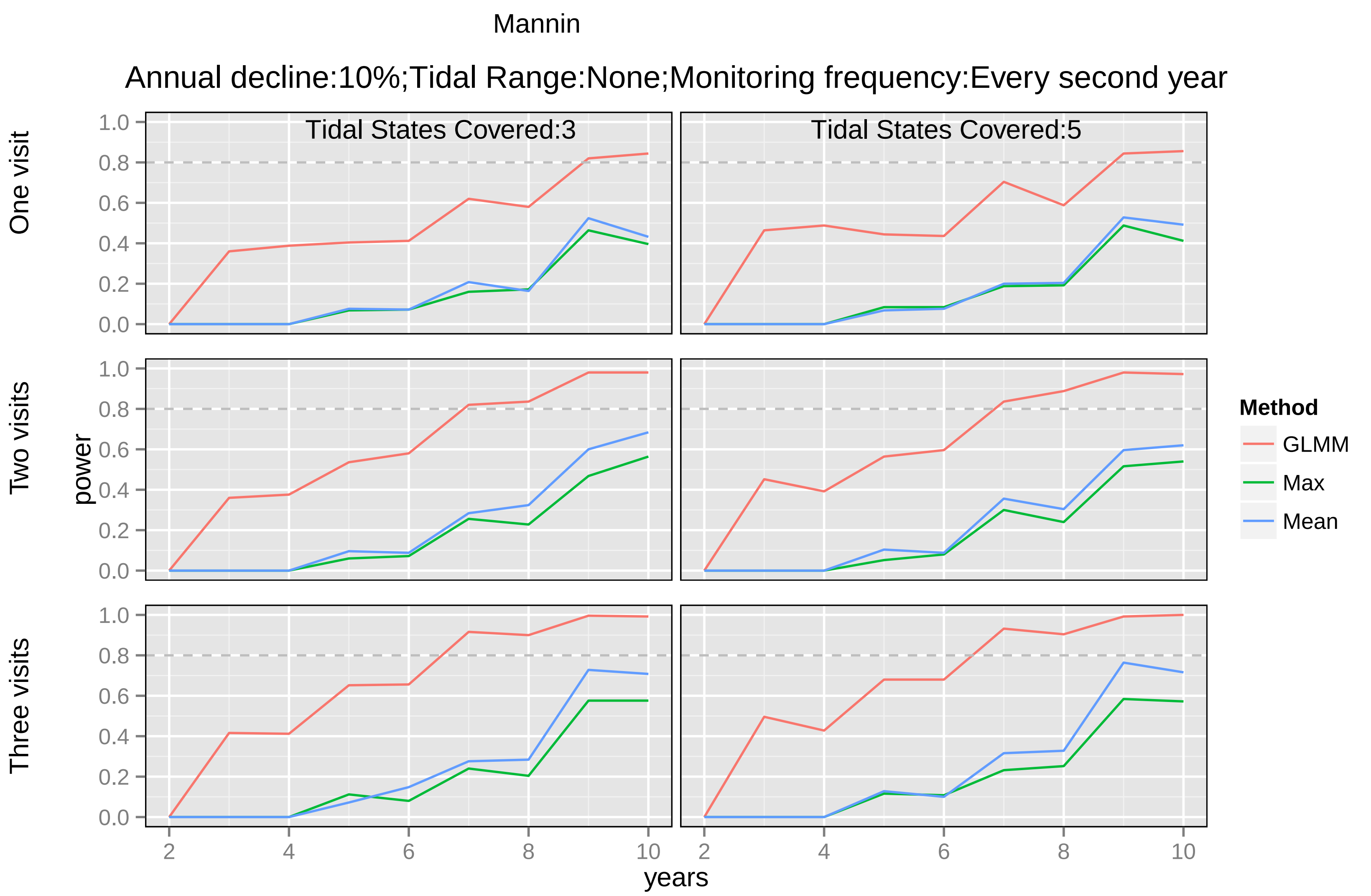
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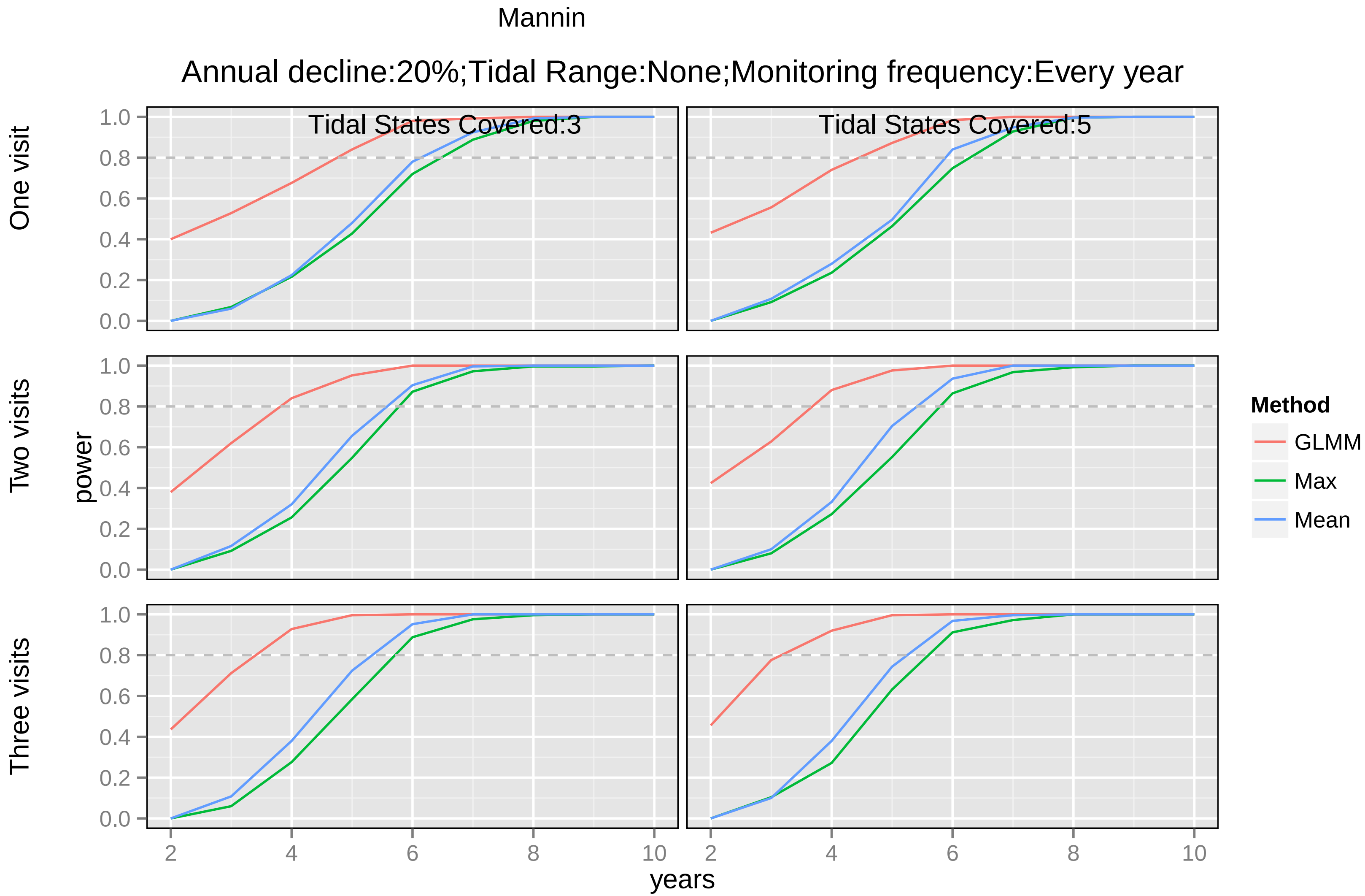
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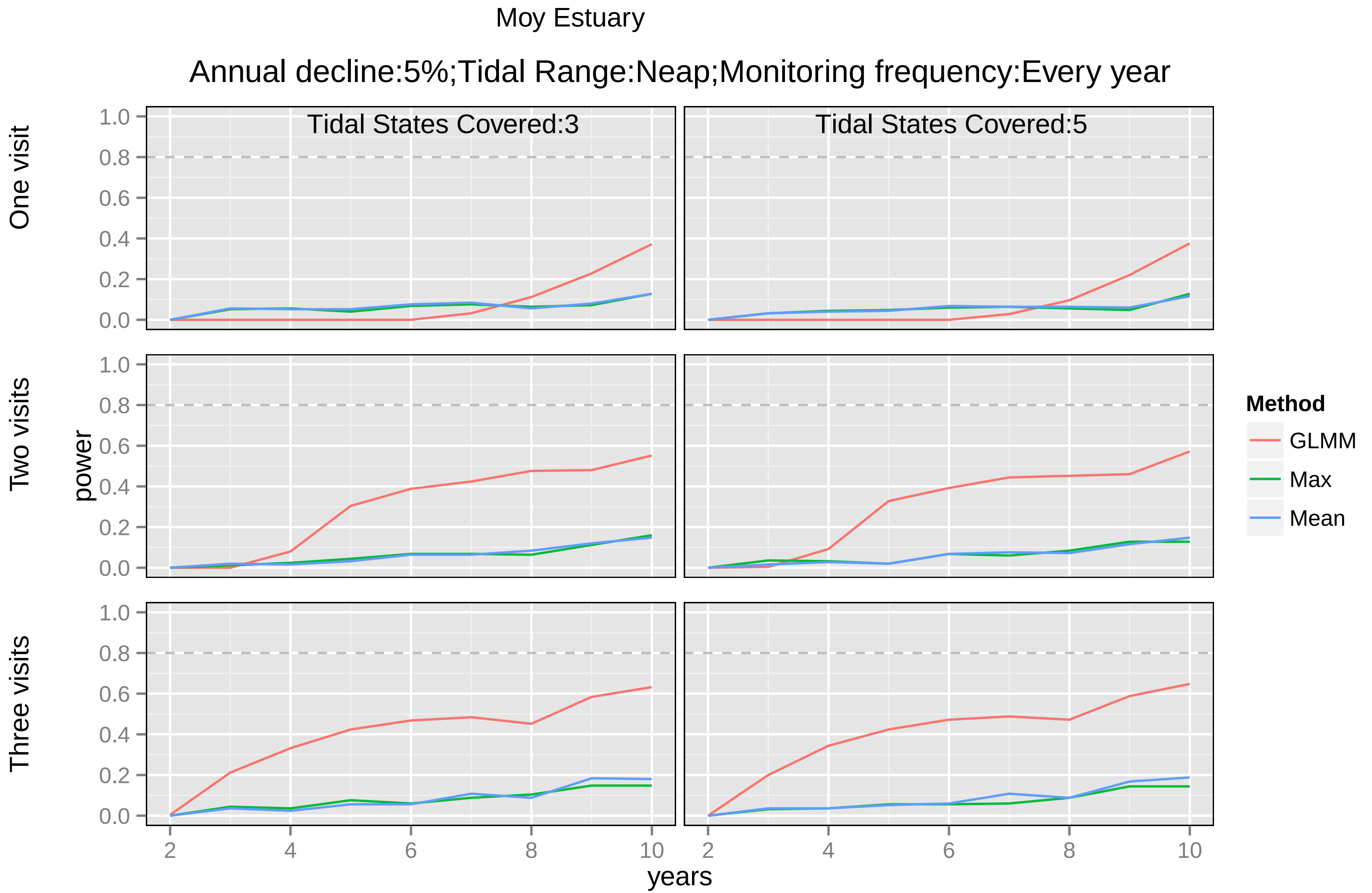

Moy Estuary
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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Method
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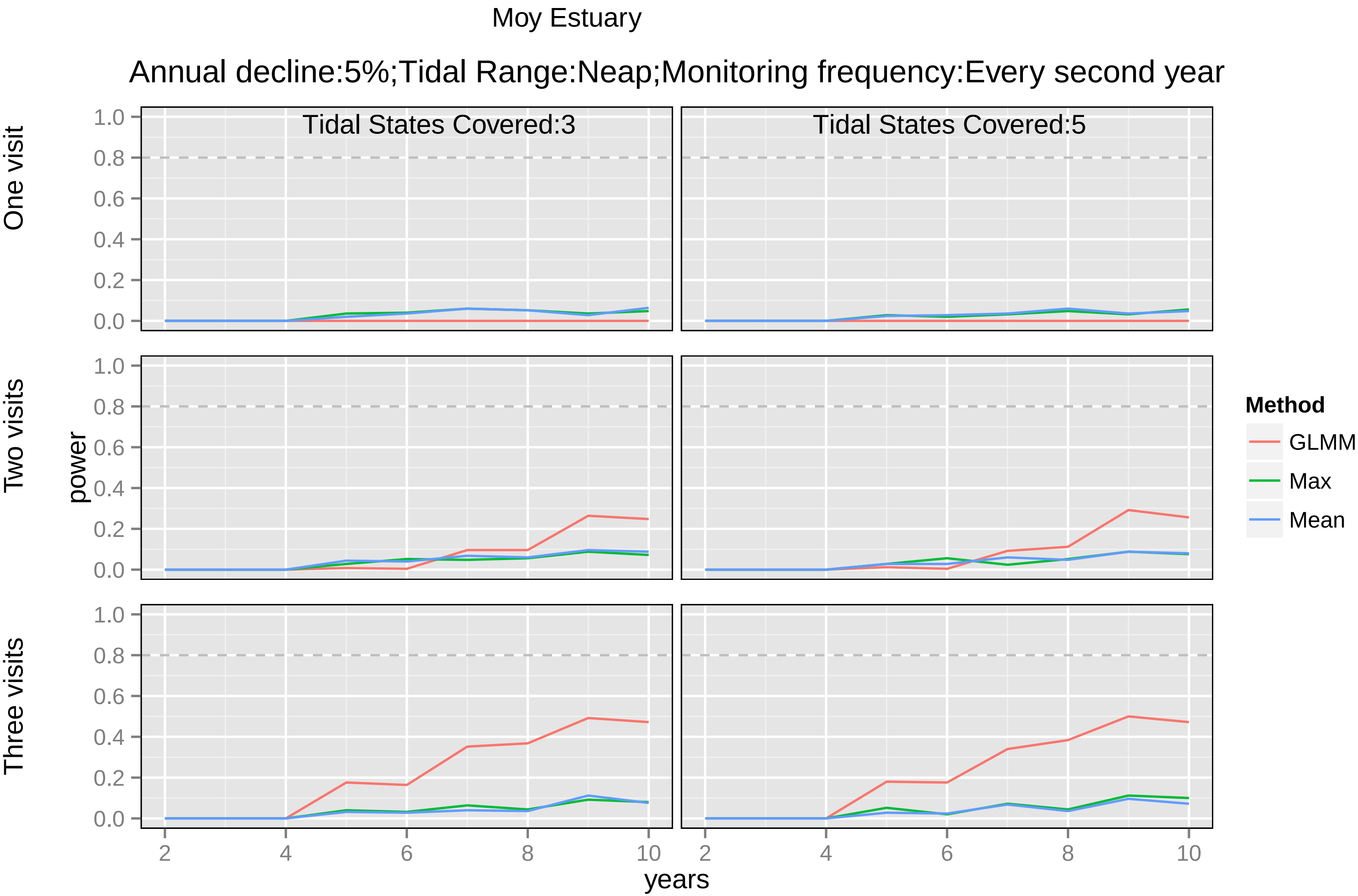

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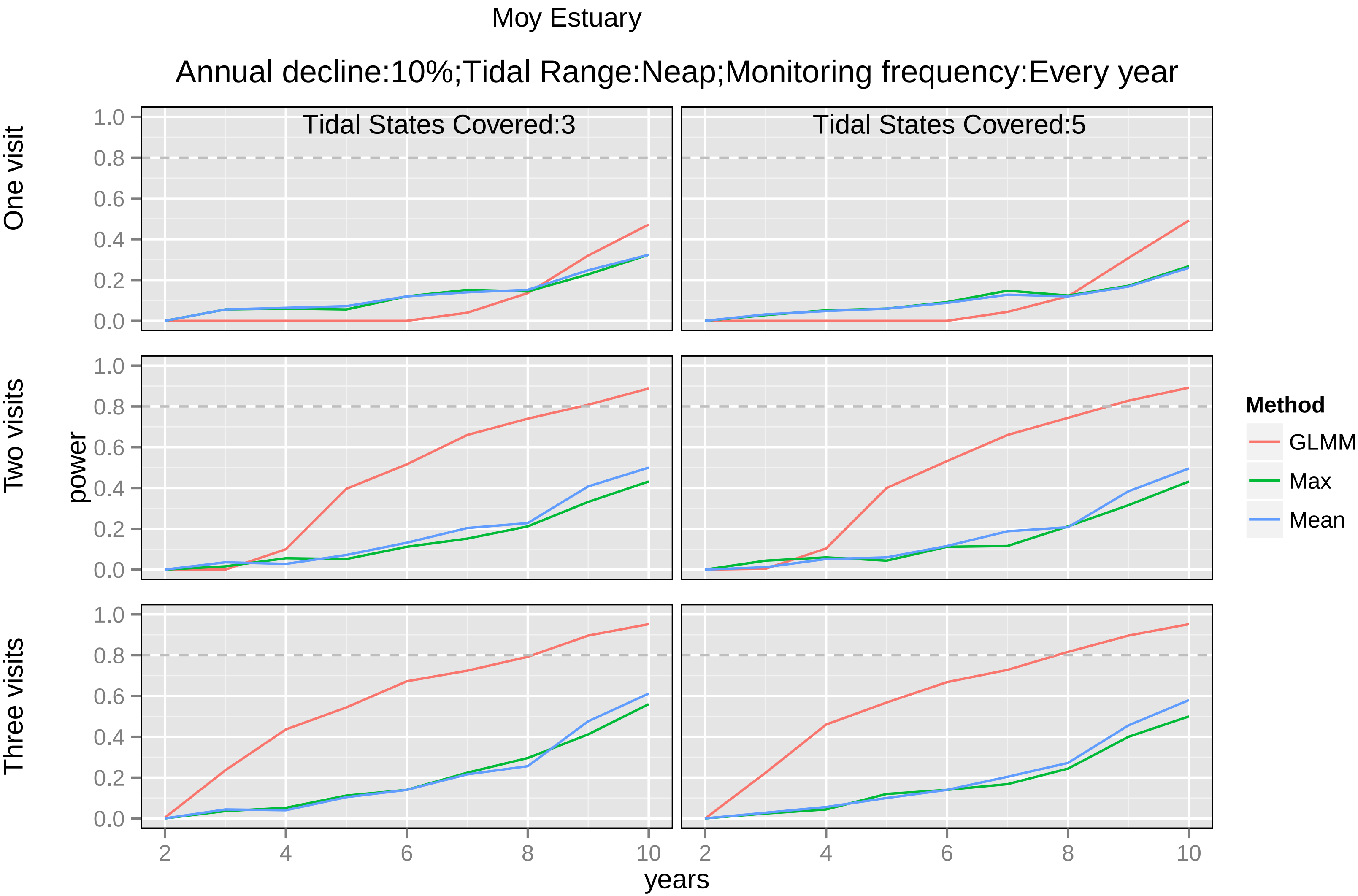

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Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every year
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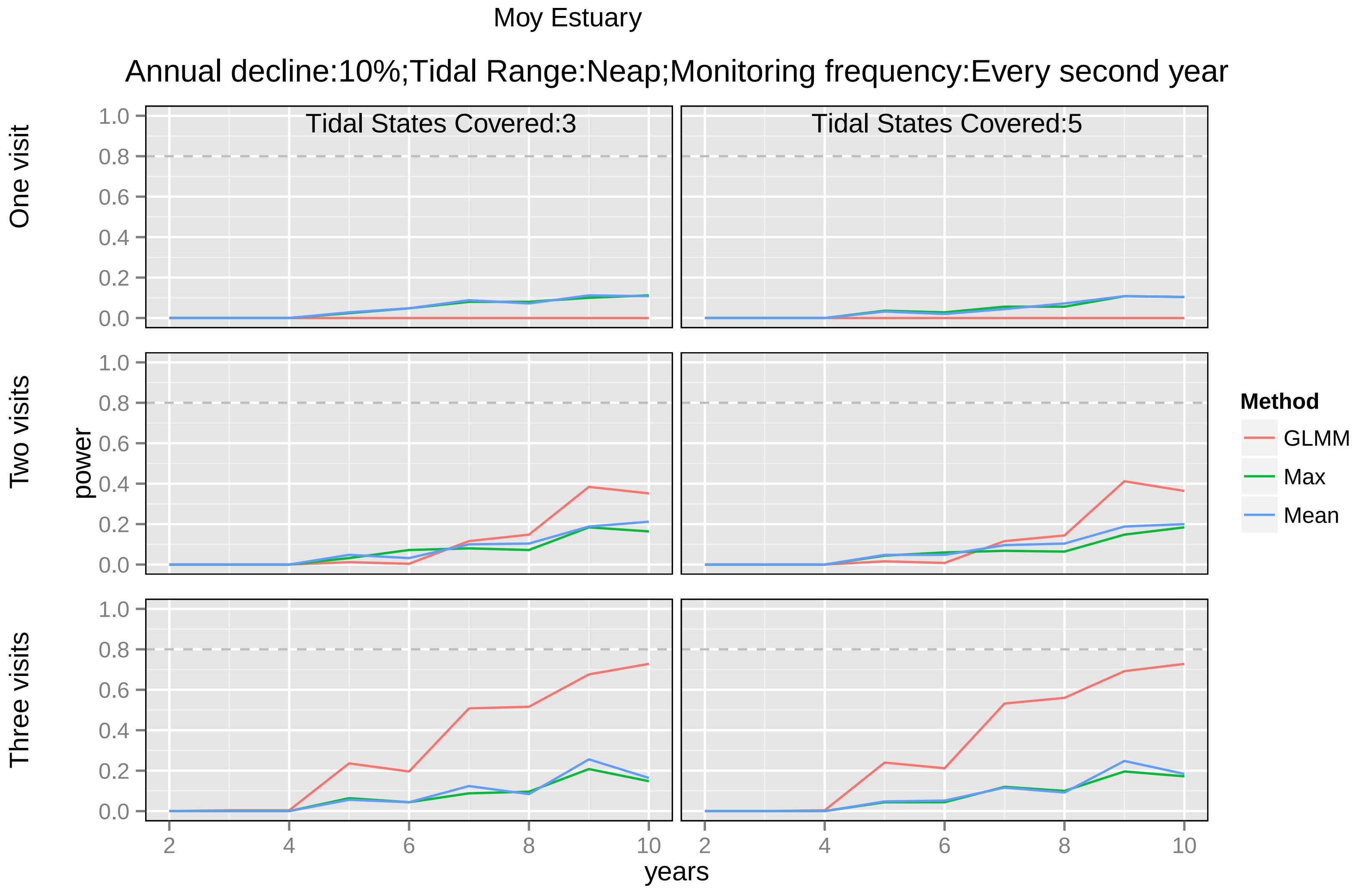

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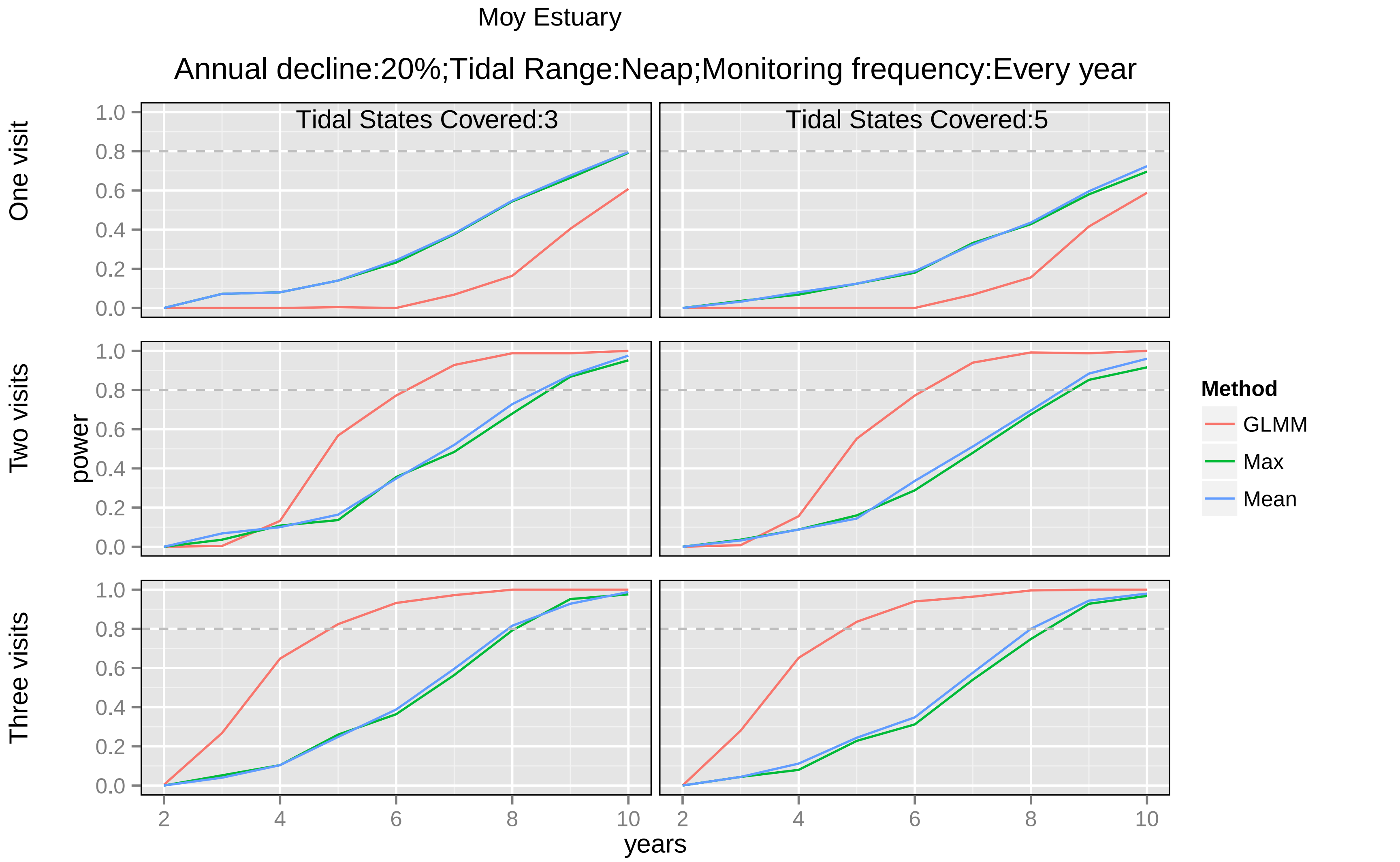
Max
Mean


Moy Estuary
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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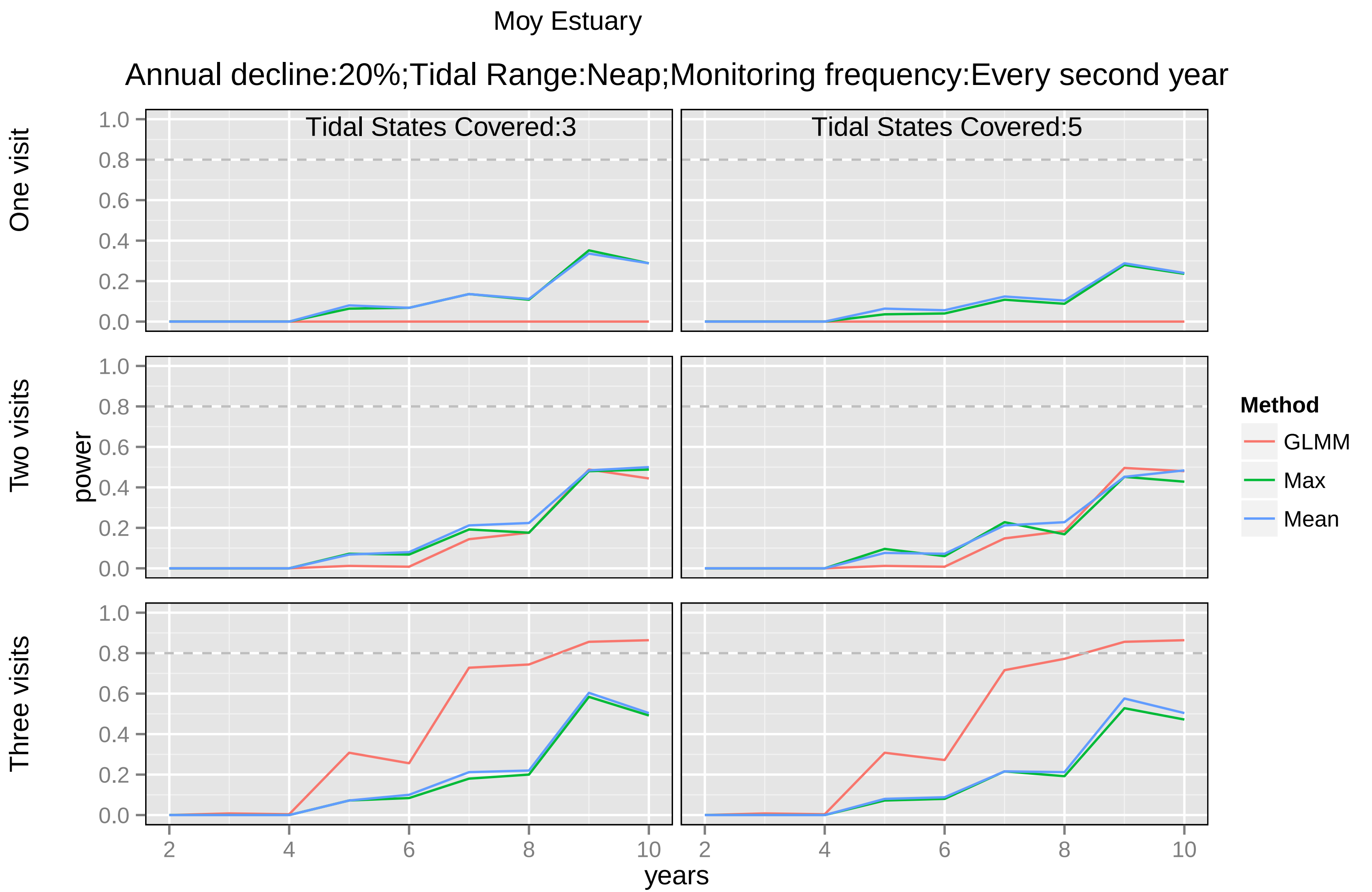

Moy Estuary
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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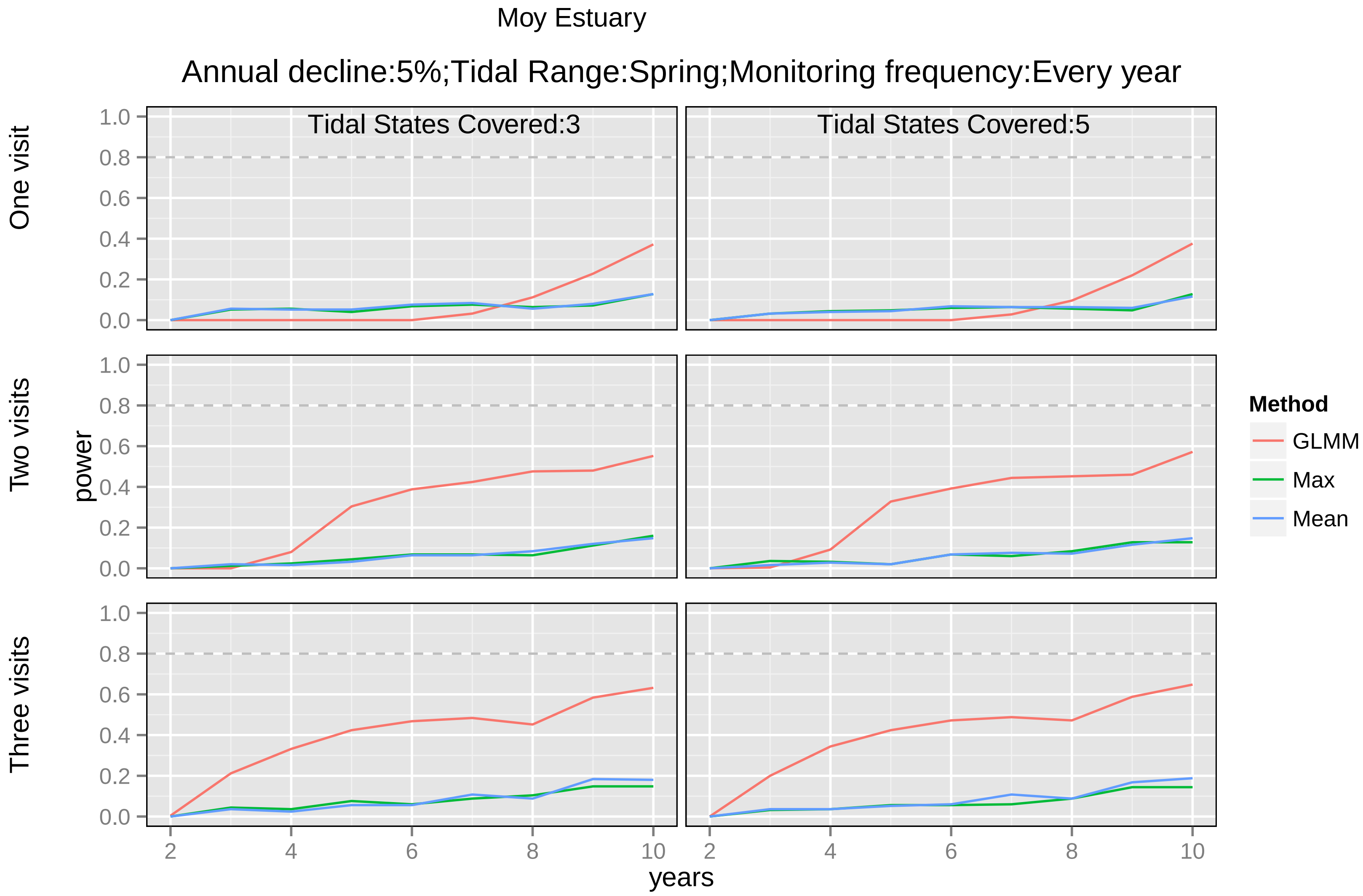

Moy Estuary
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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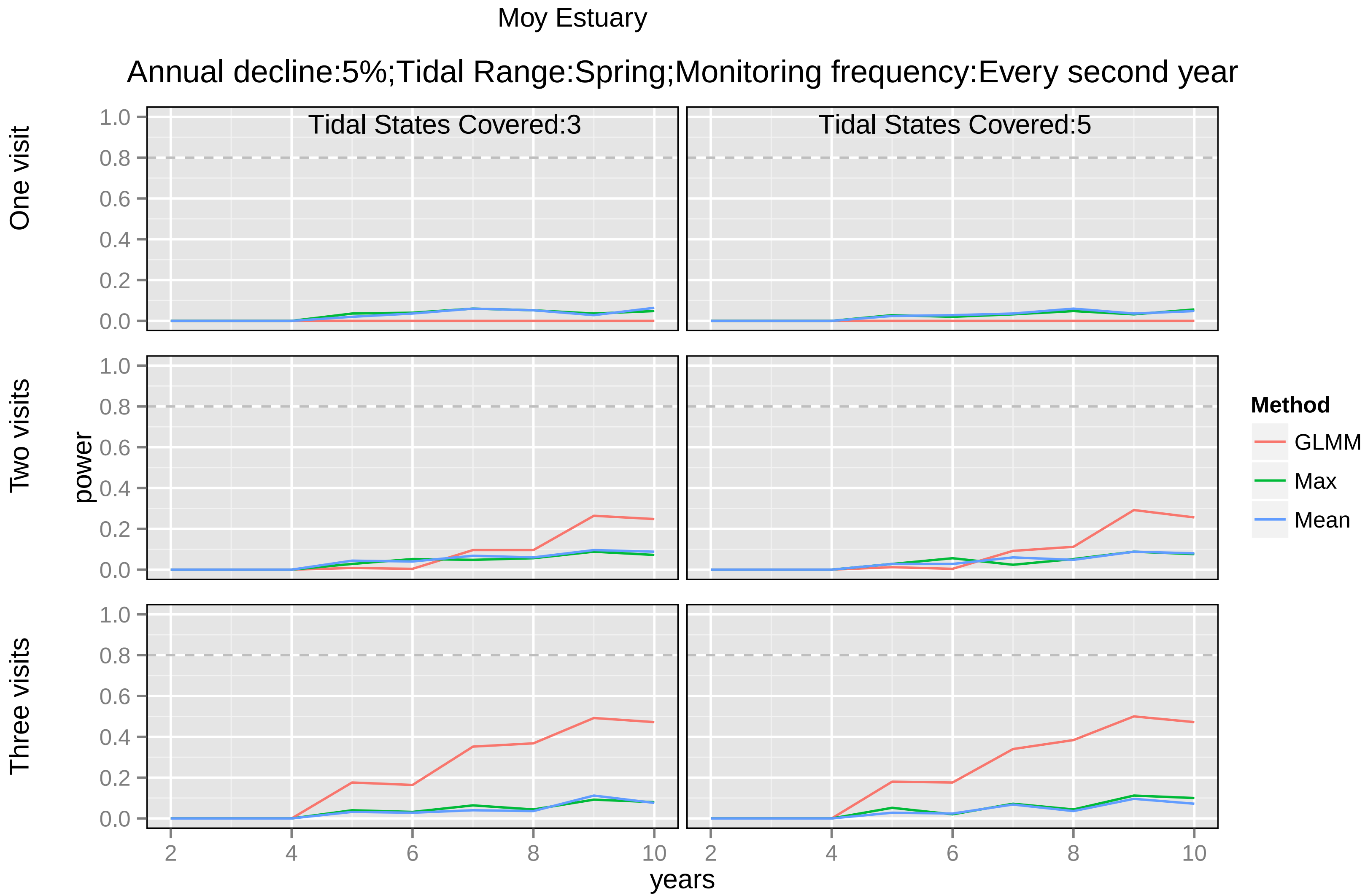
Method
GLMM
Max
Mean



Moy Estuary
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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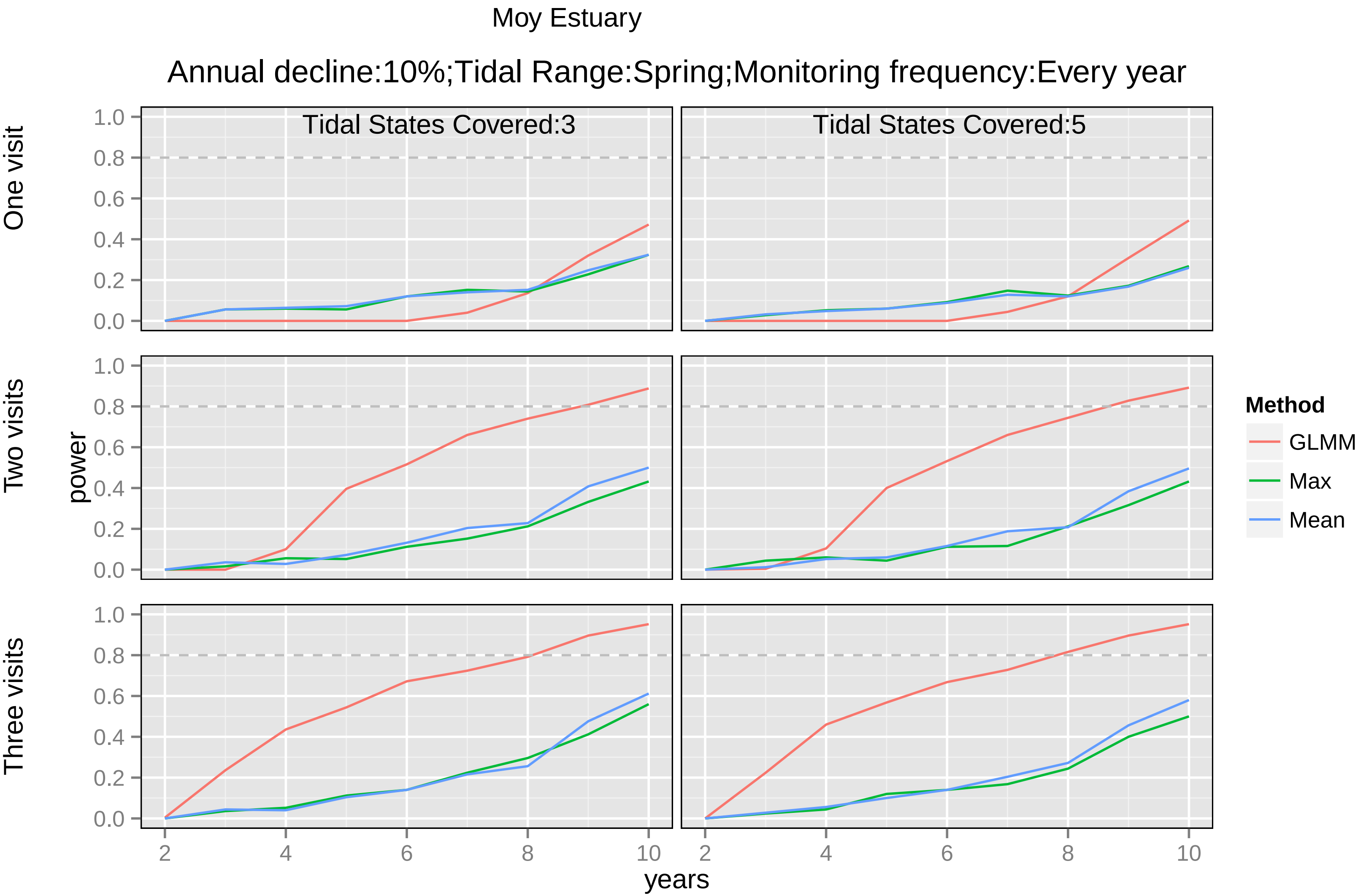
Method
GLMM
Max
Mean


Moy Estuary
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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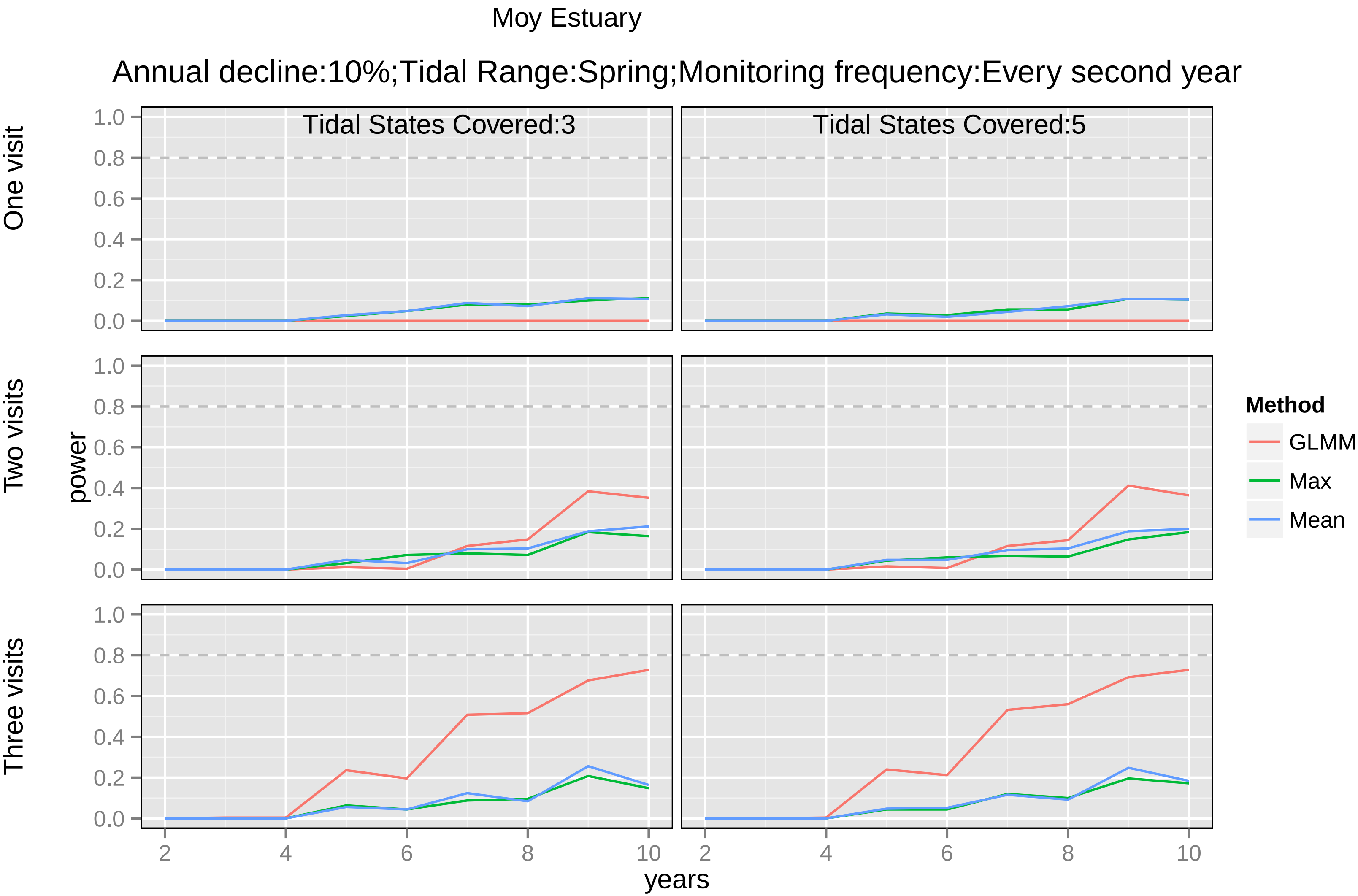
Method
GLMM
Max
Mean


Moy Estuary
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
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Moy Estuary
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every year
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Tidal States Covered:5
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Three visits
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GLMM
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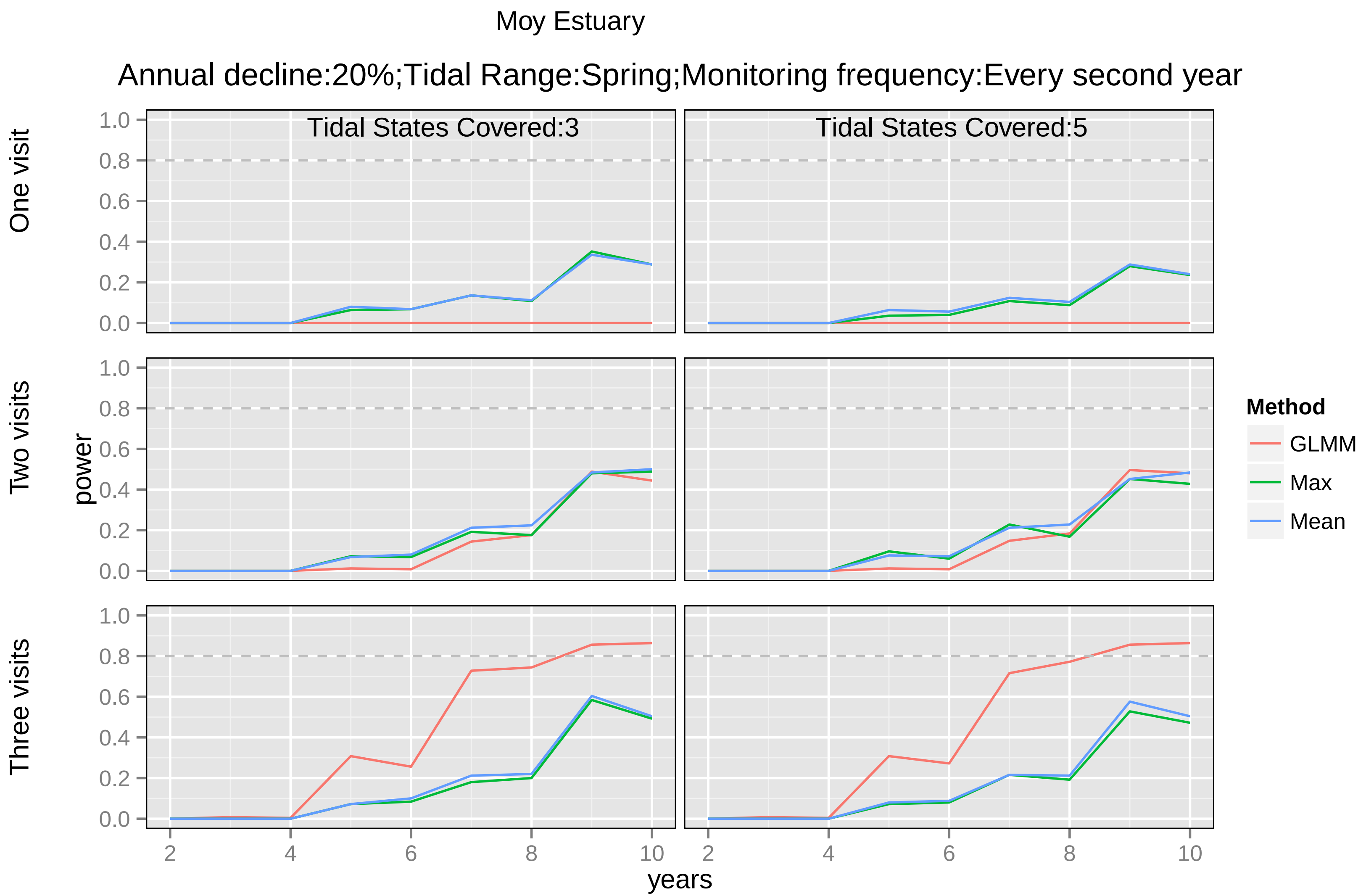
Moy Estuary
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
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Tidal States Covered:5
One visit
Two visits
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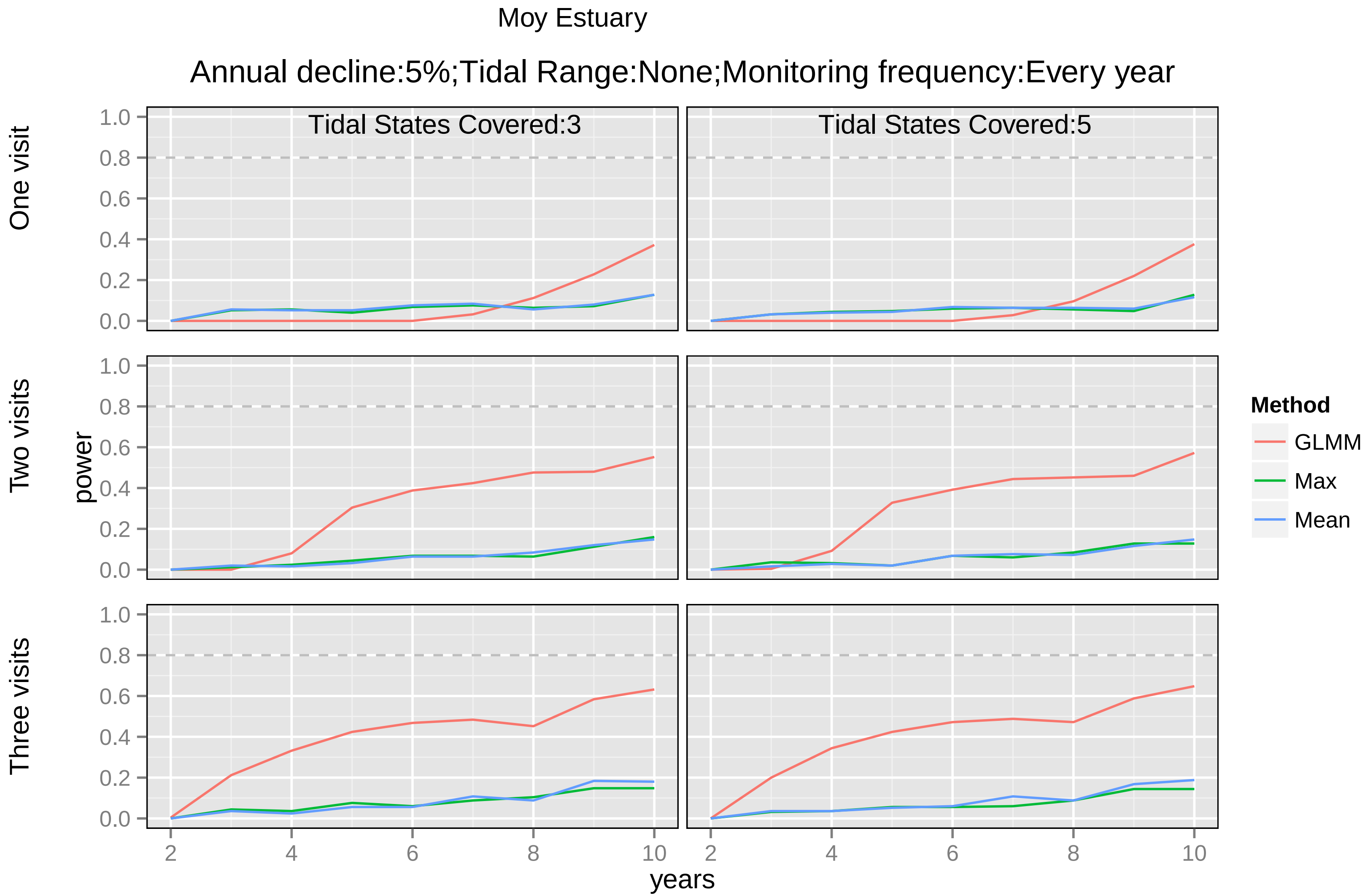
Moy Estuary
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
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Method
GLMM
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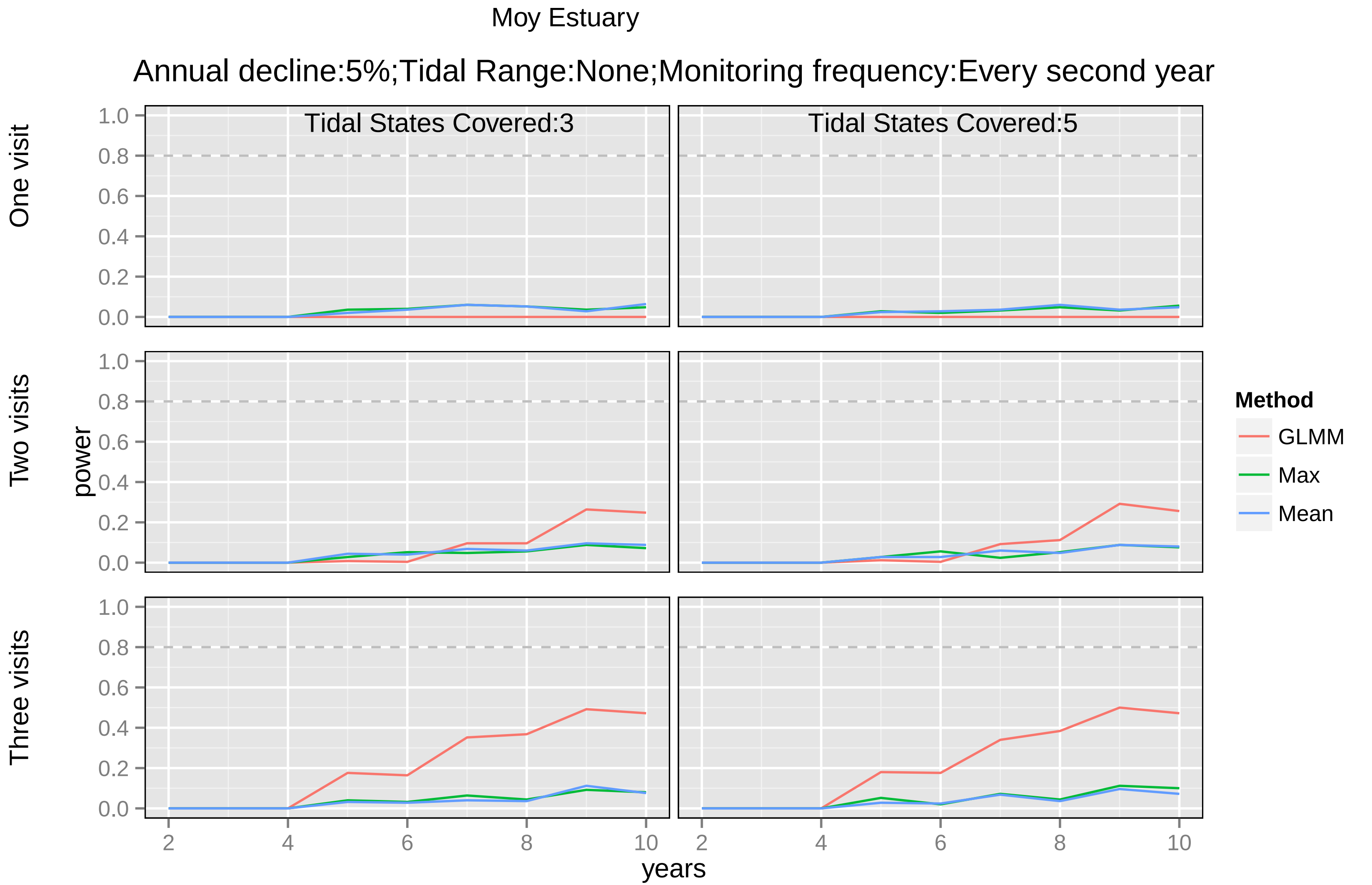
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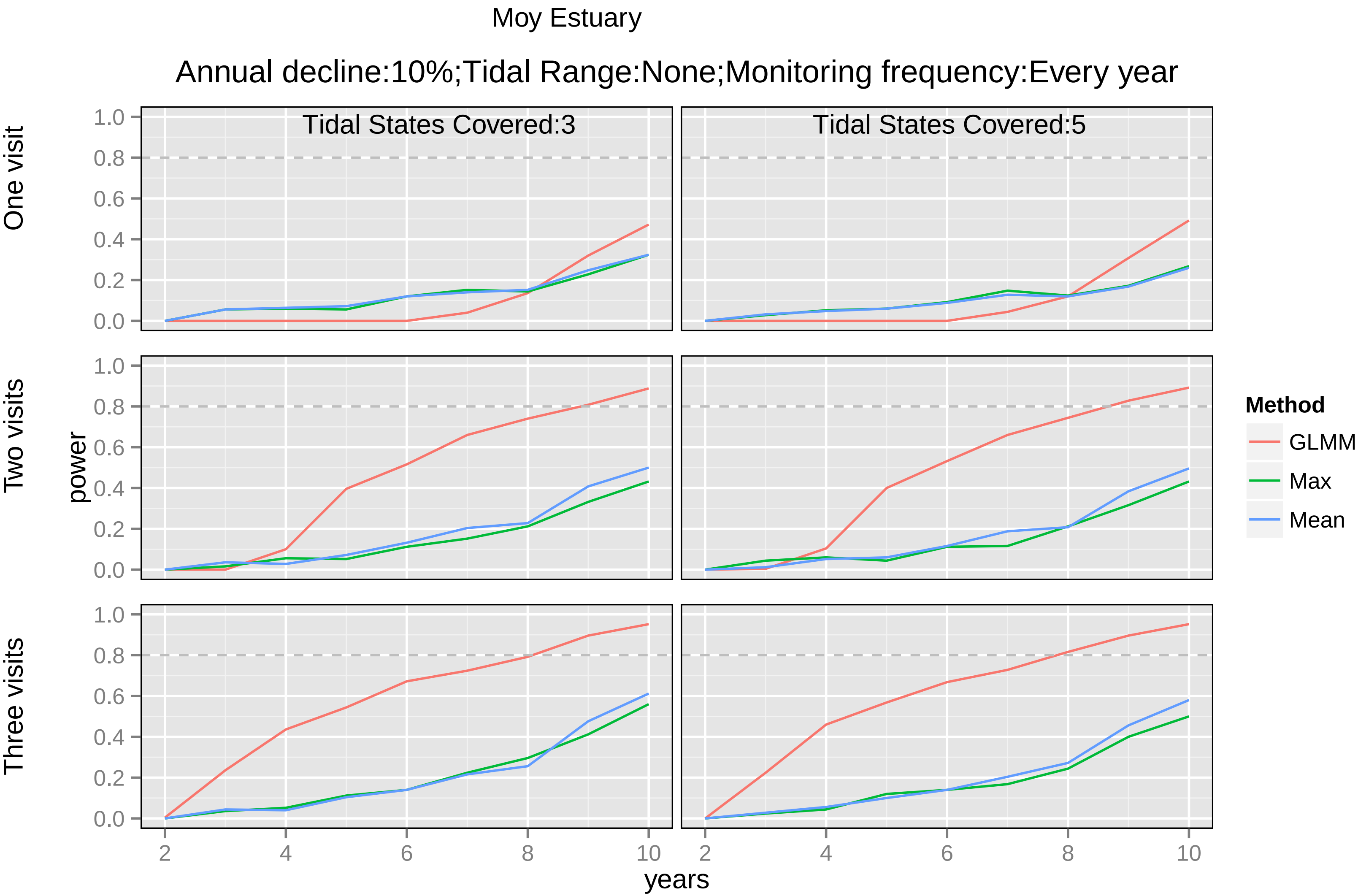
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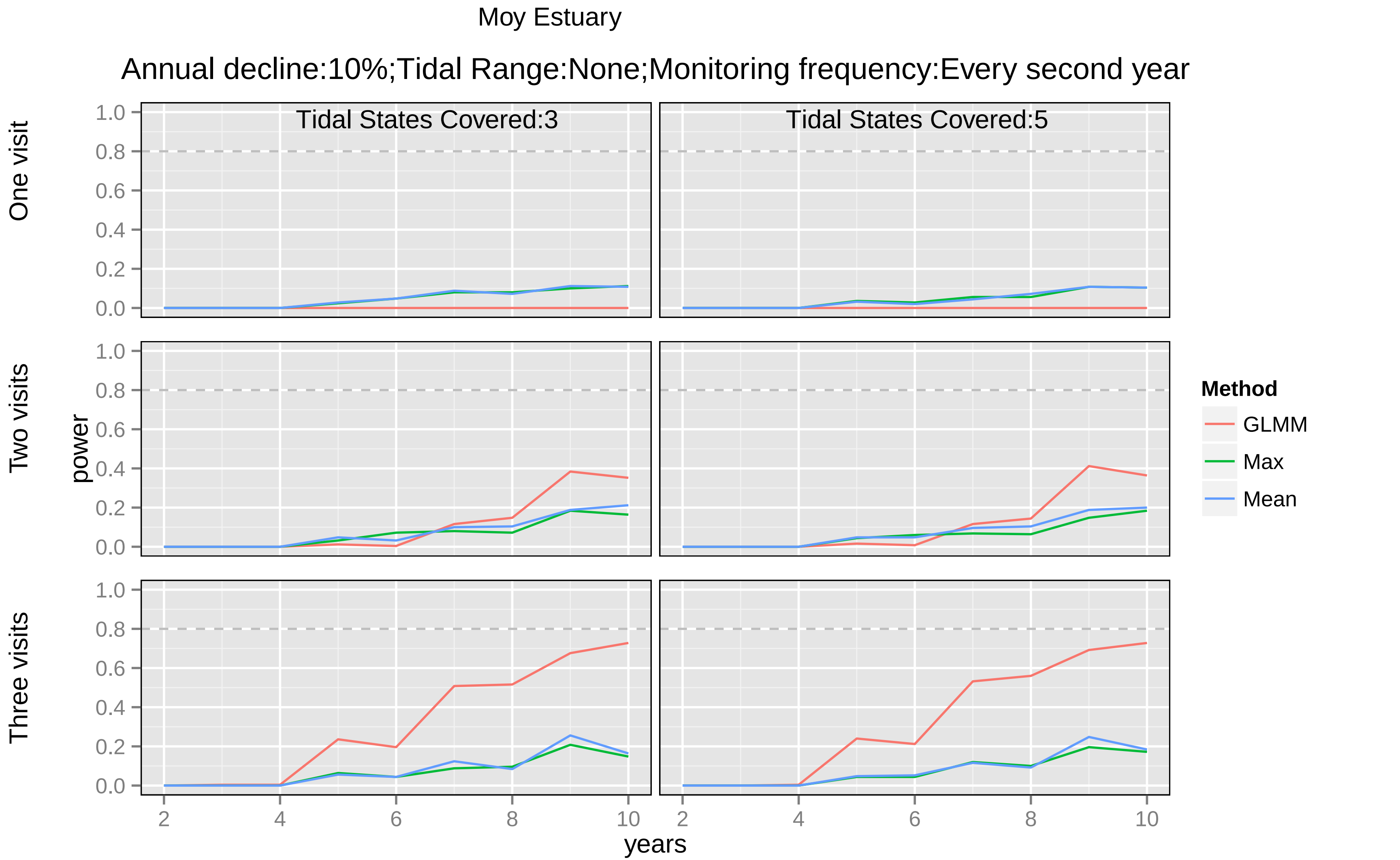

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Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
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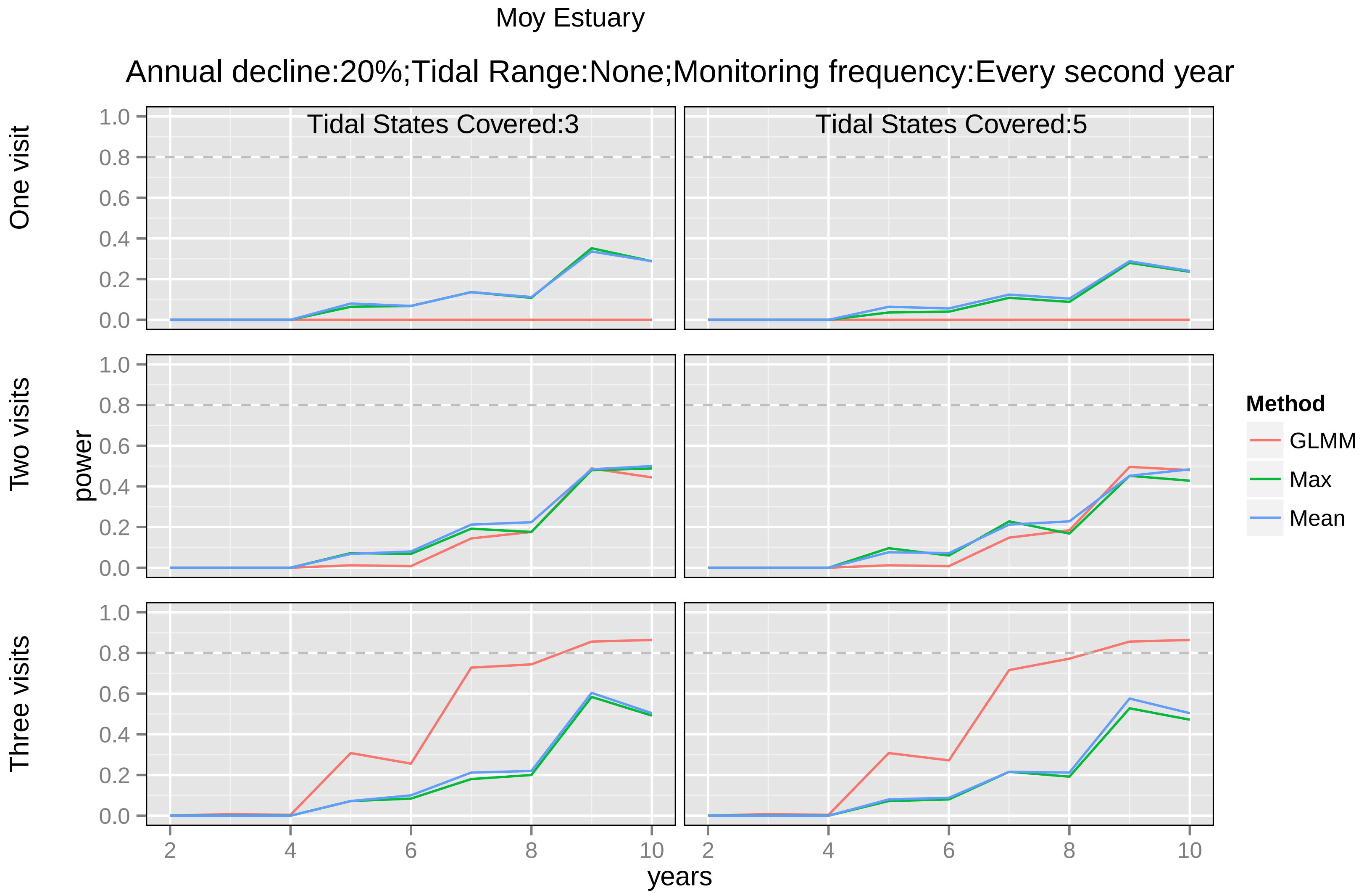
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Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
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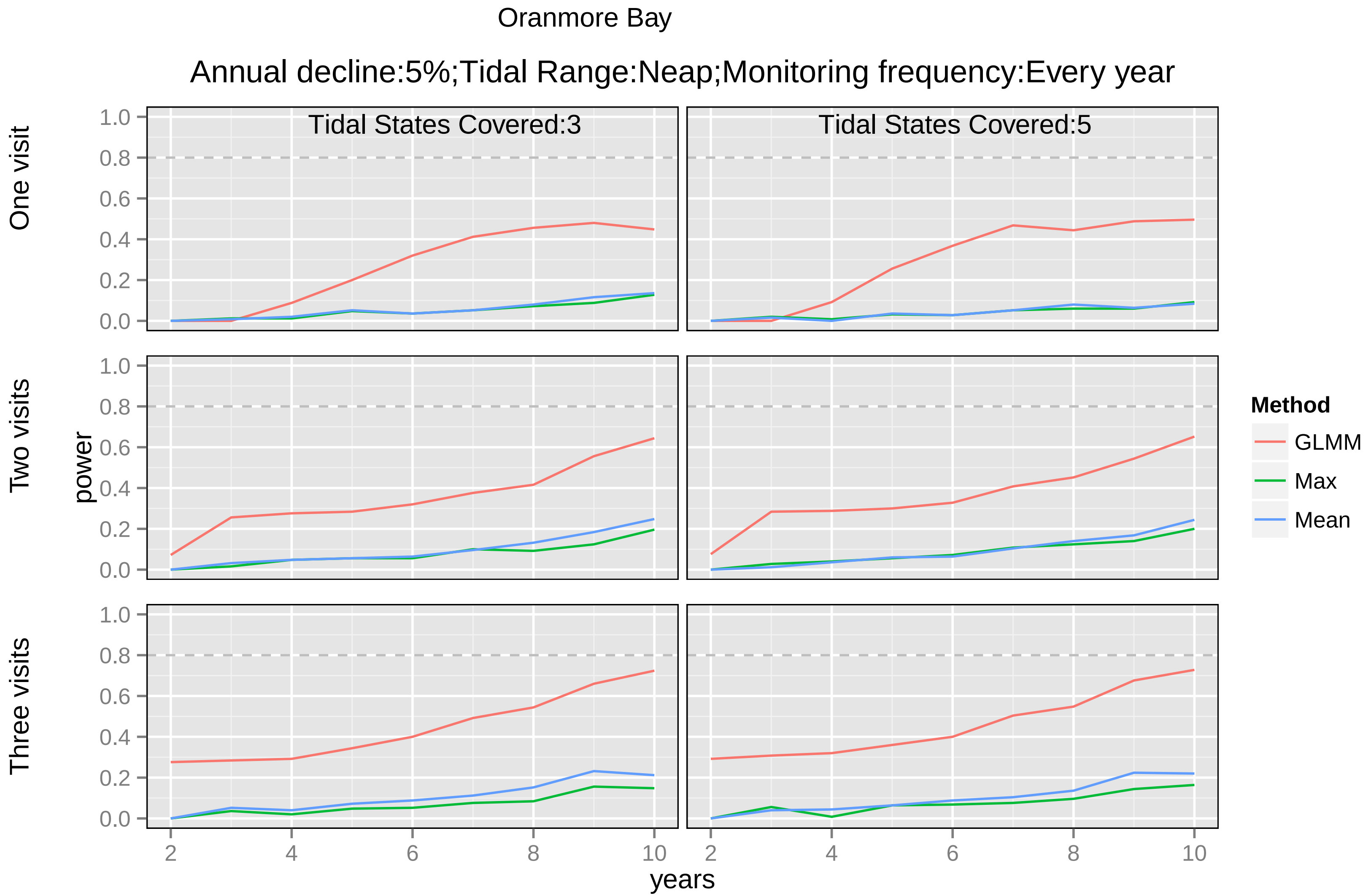

Oranmore Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
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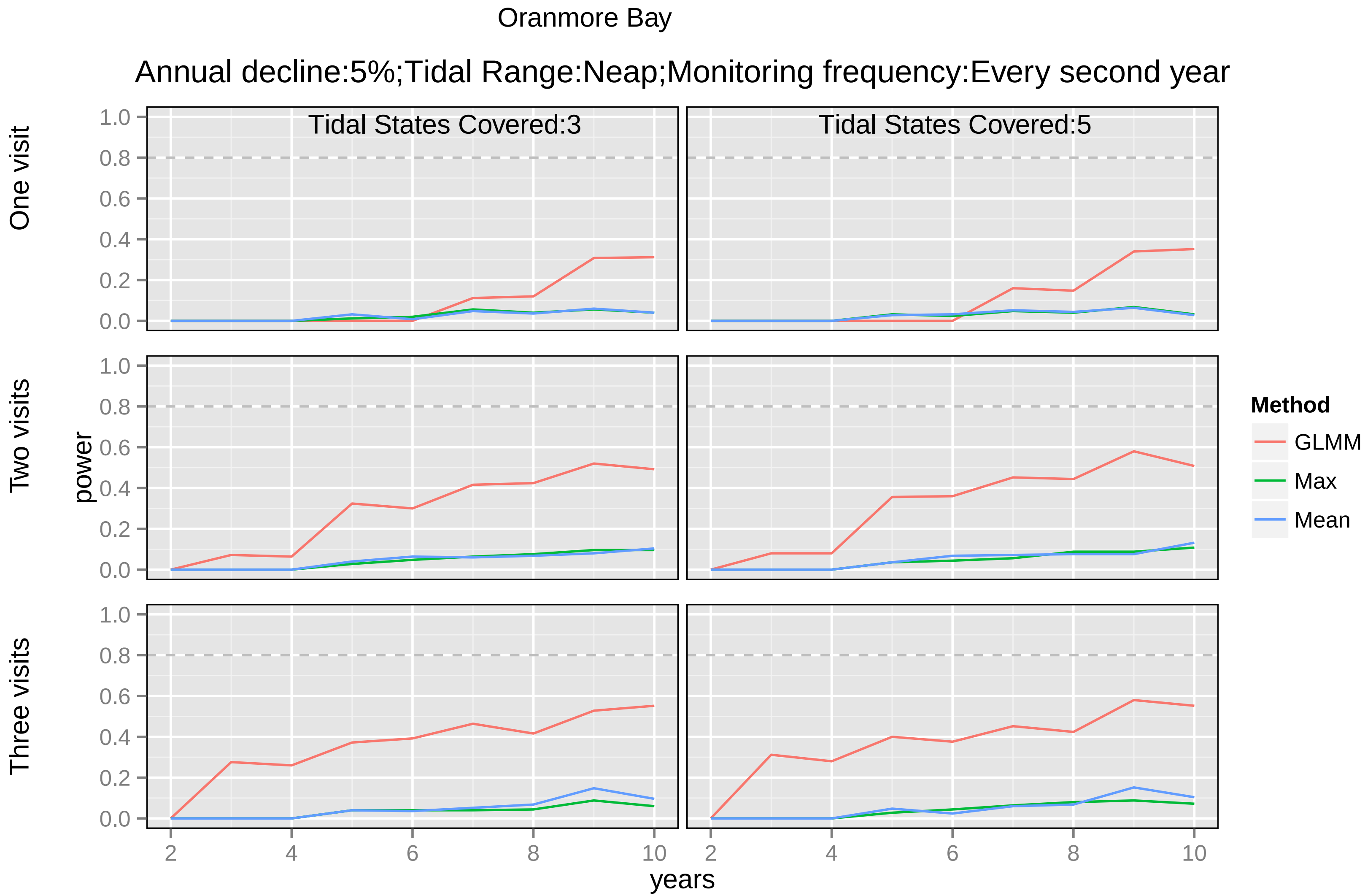
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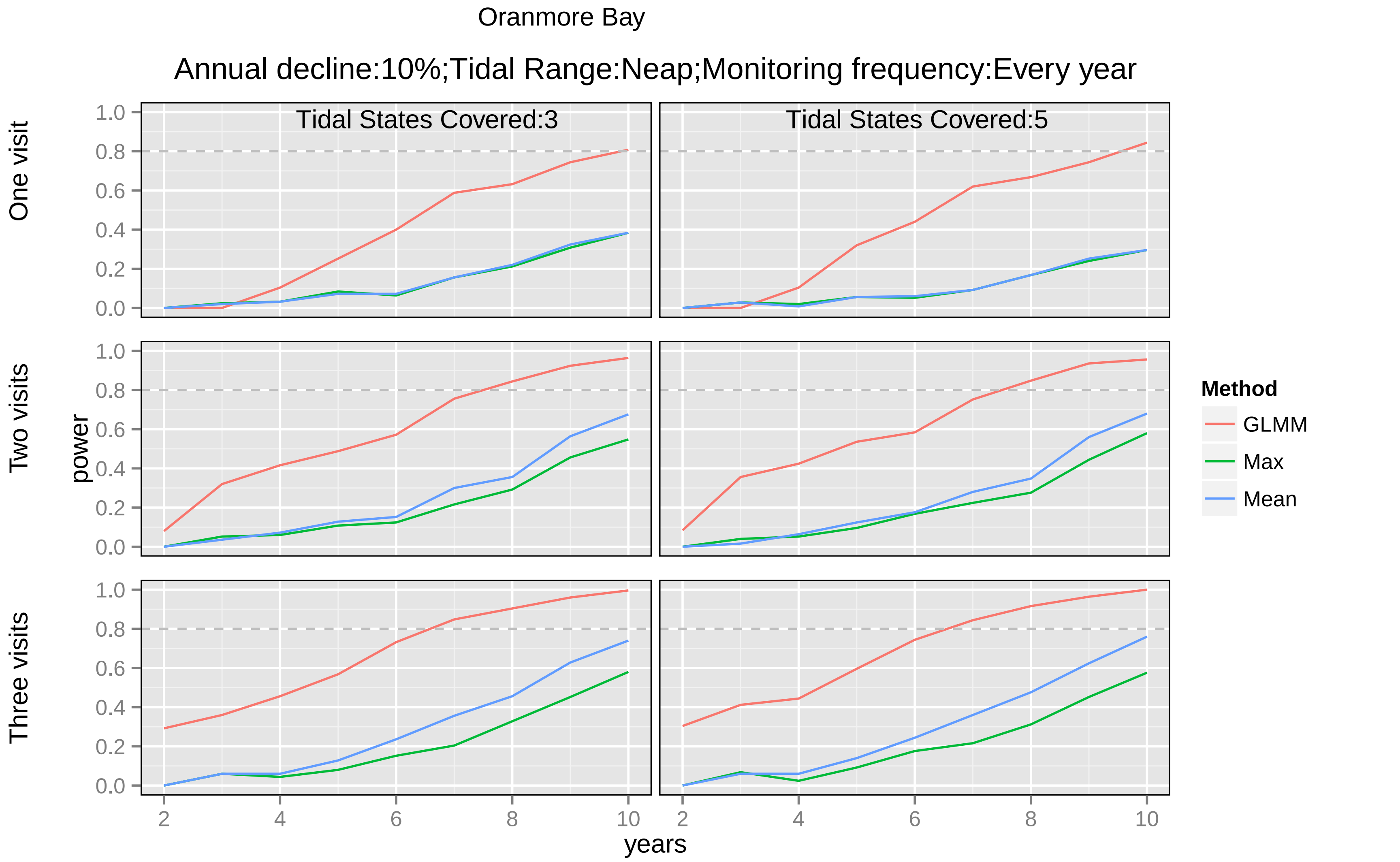
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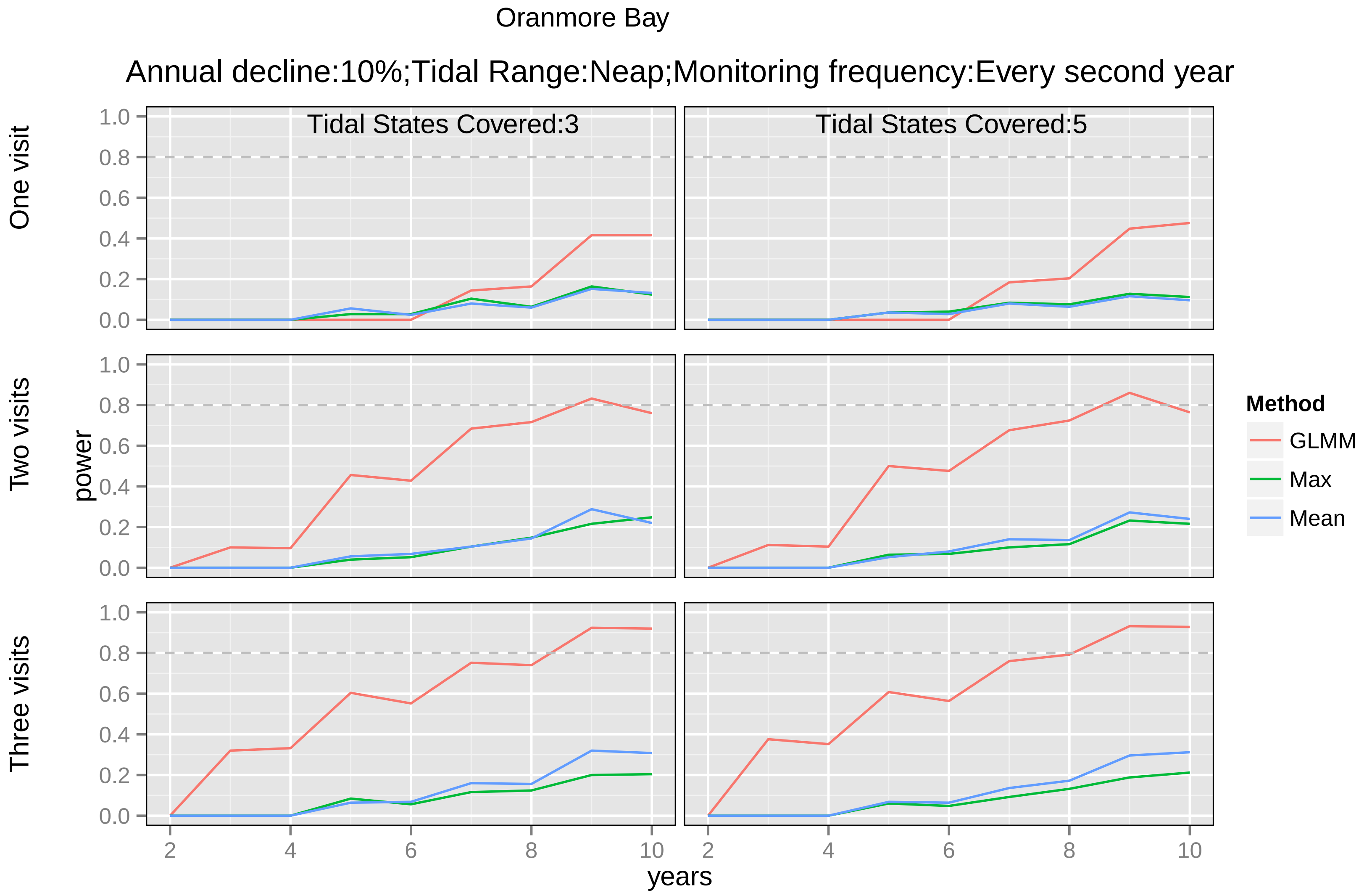

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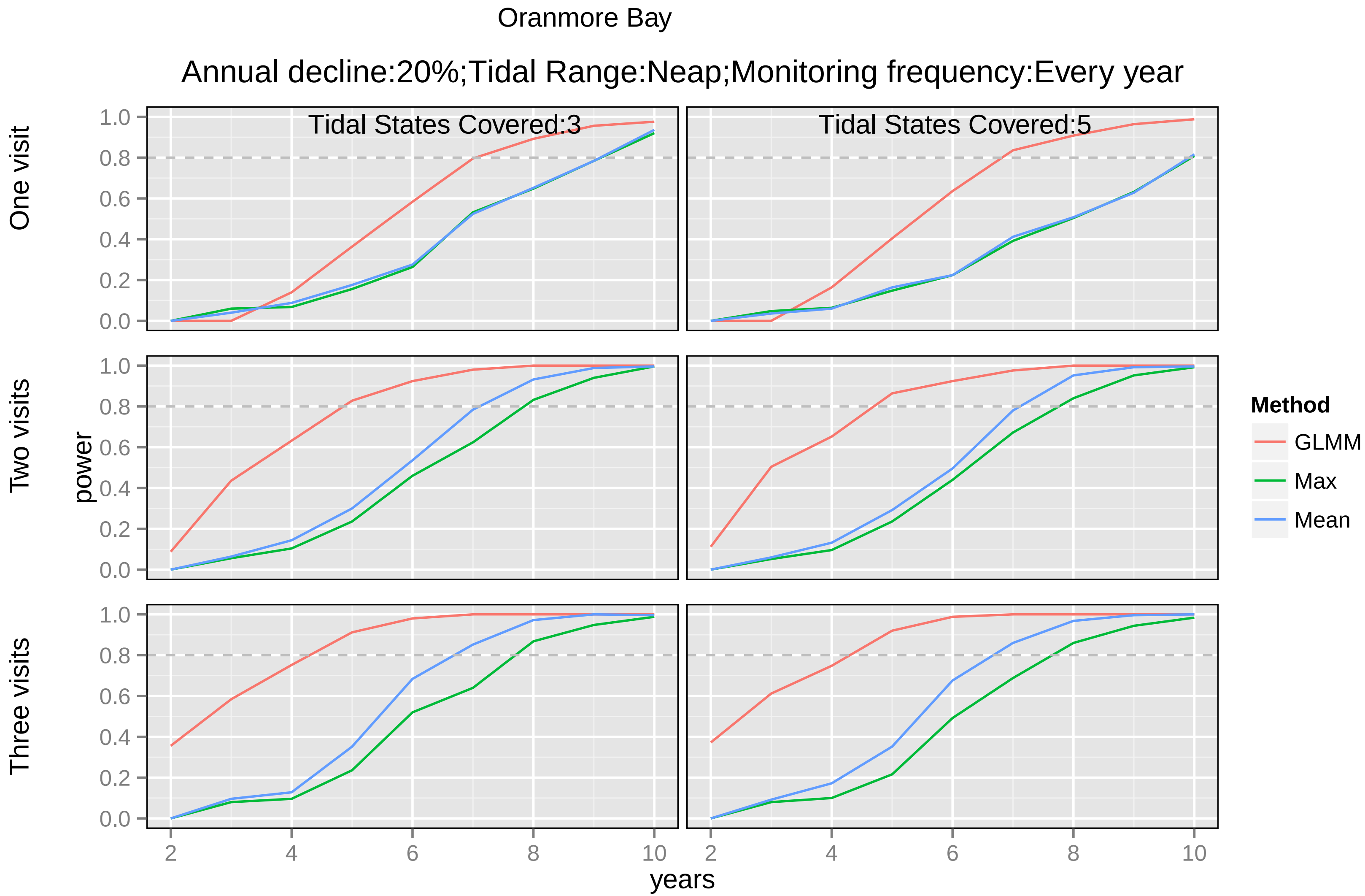
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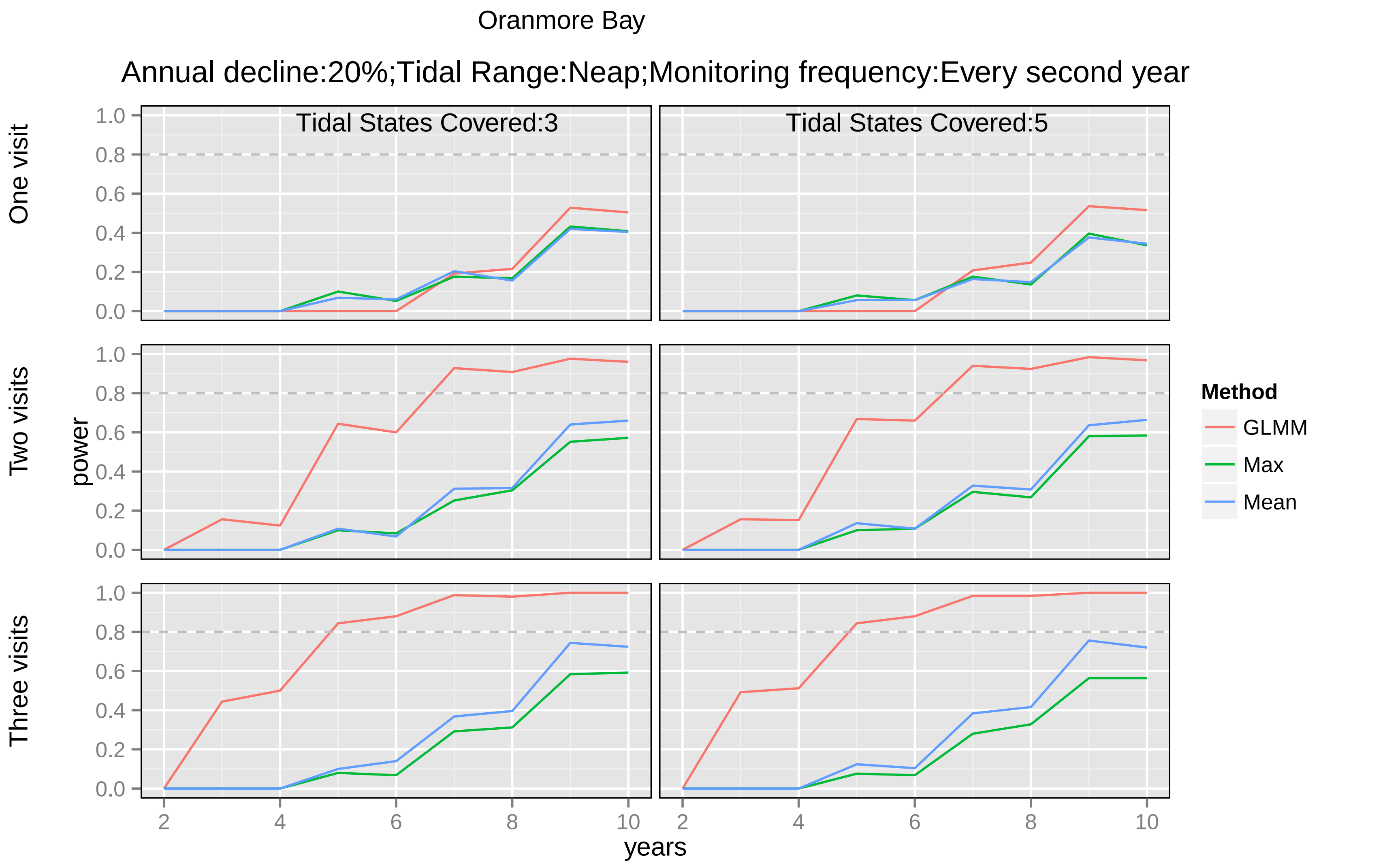
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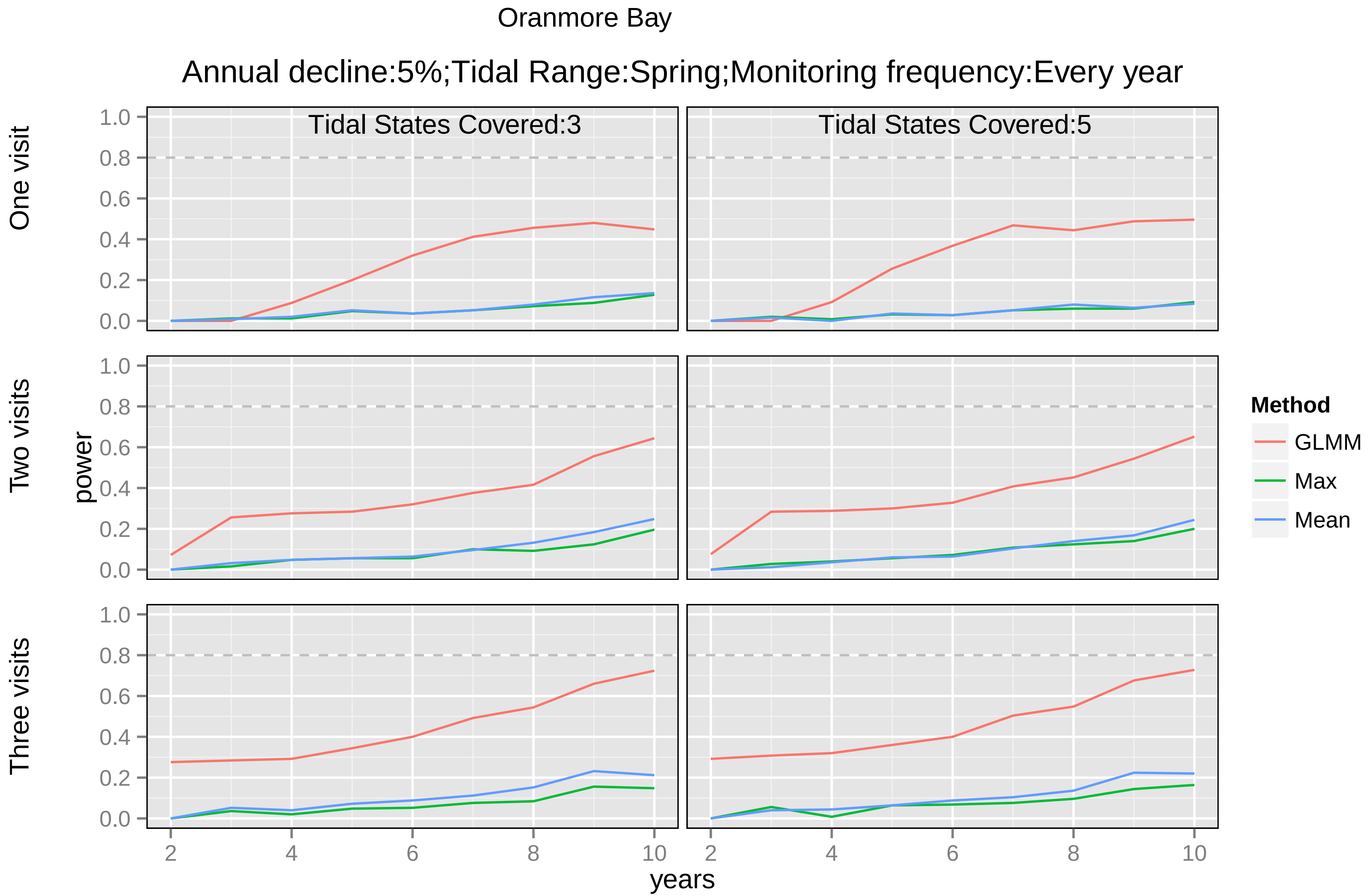
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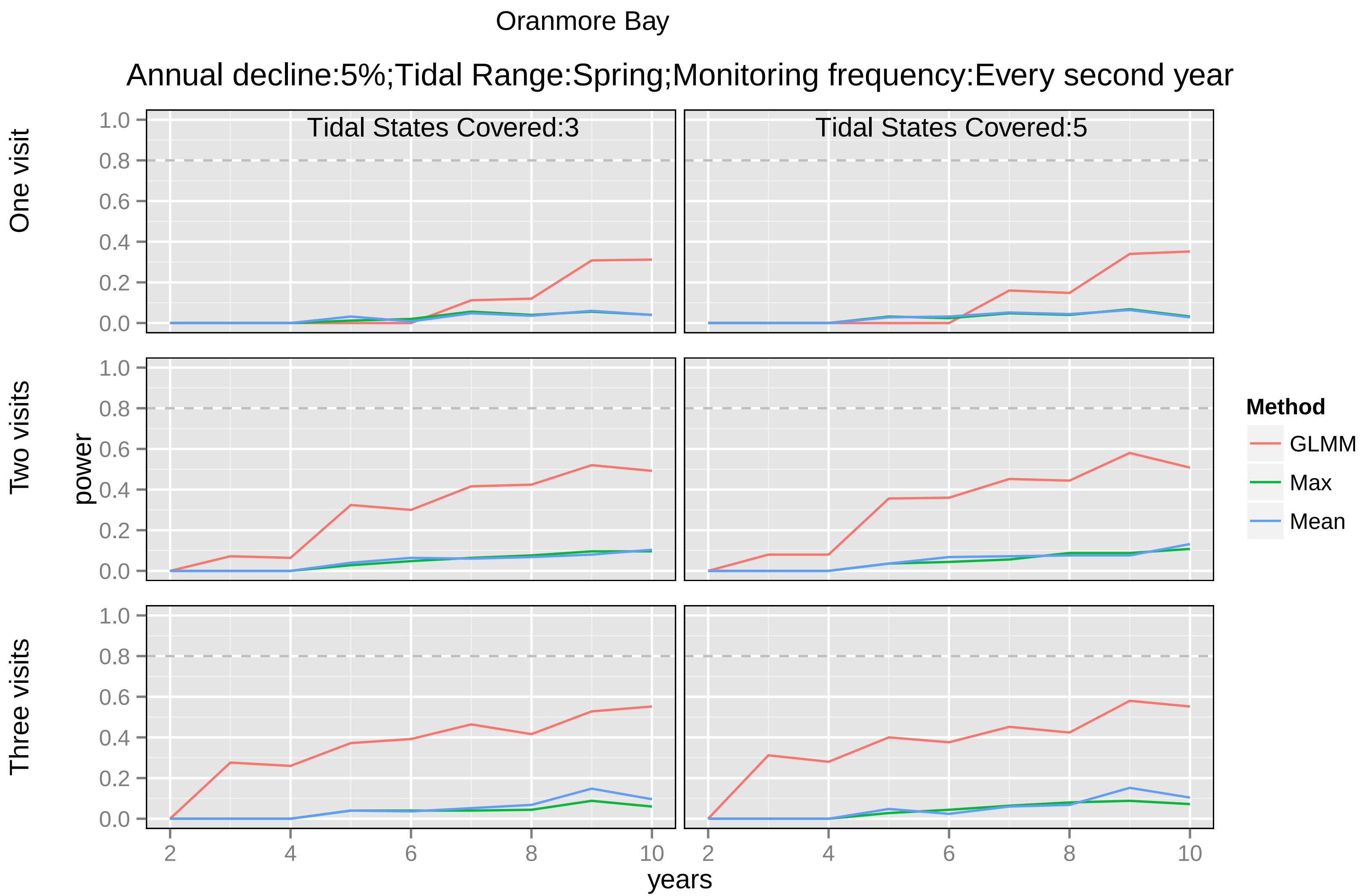
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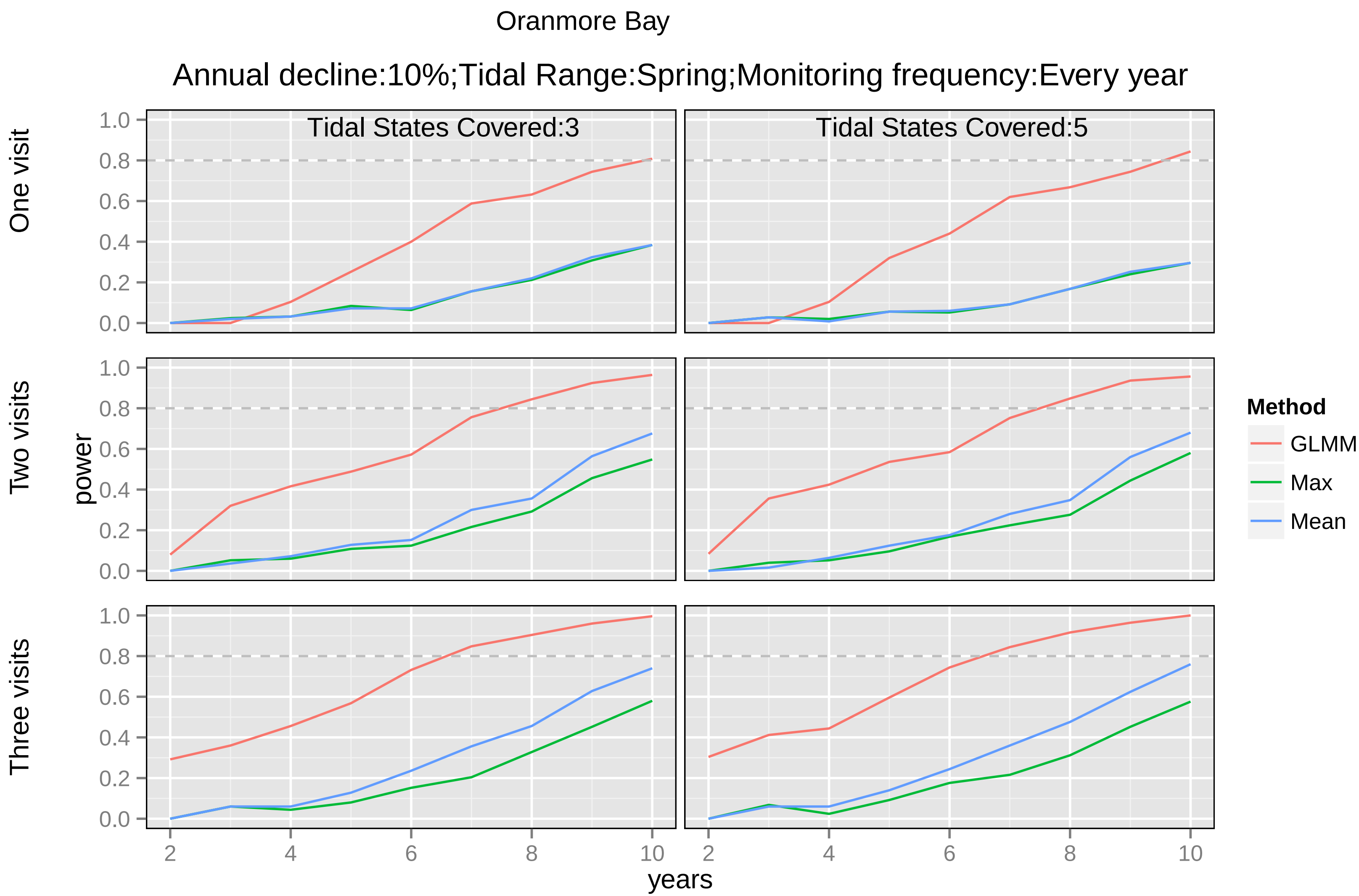

Oranmore Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
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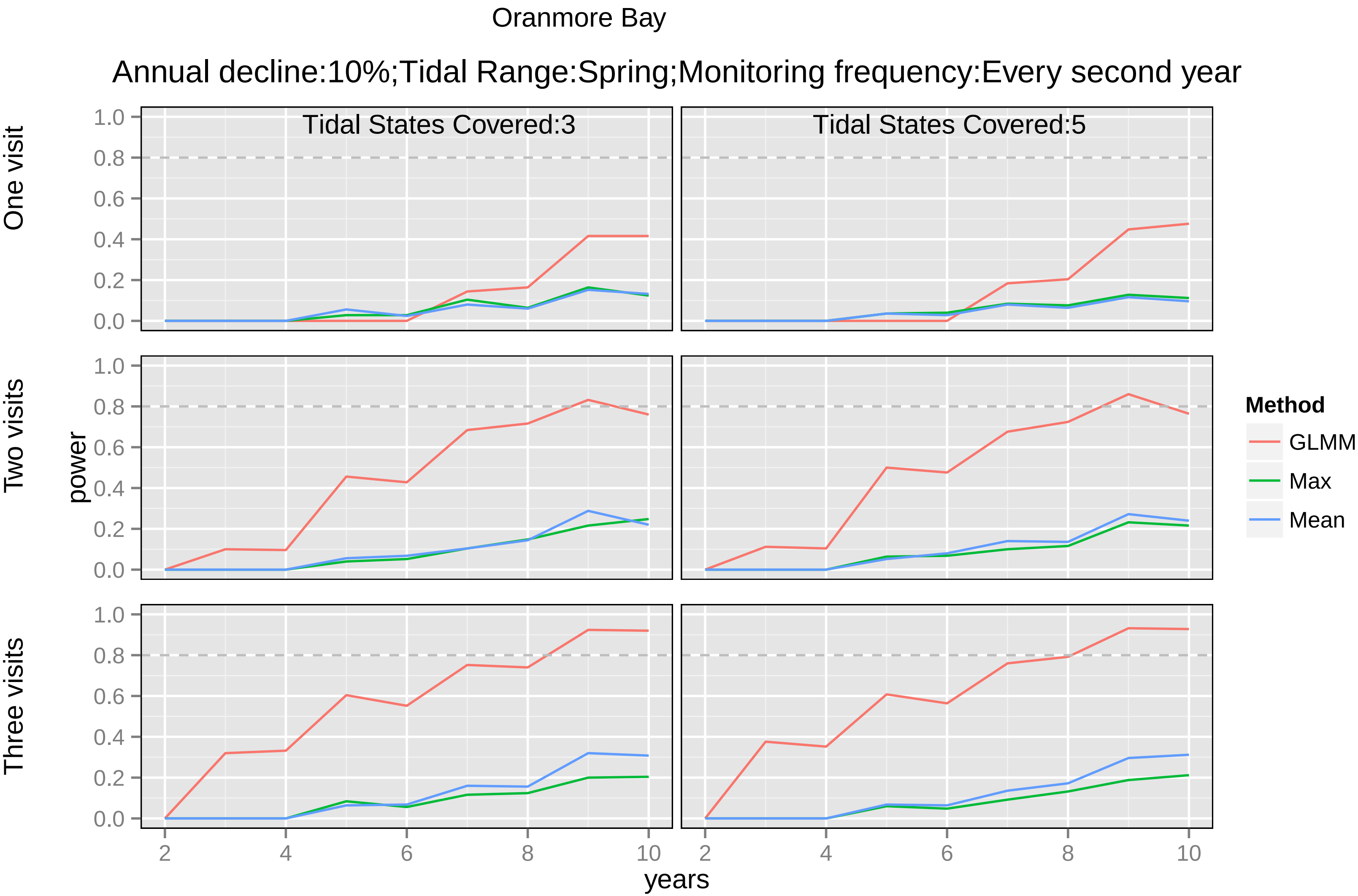

Oranmore Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every second year
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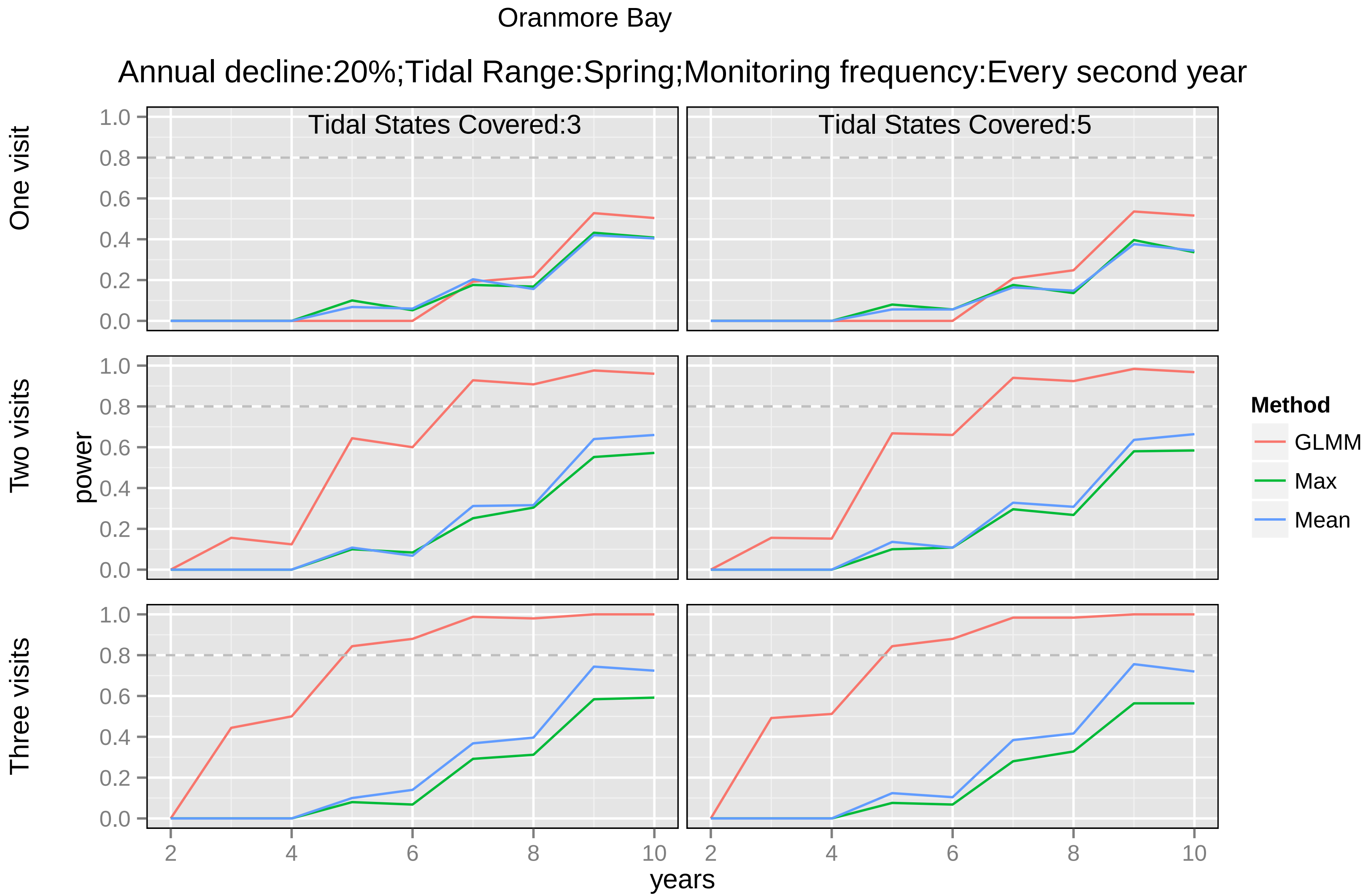
Oranmore Bay
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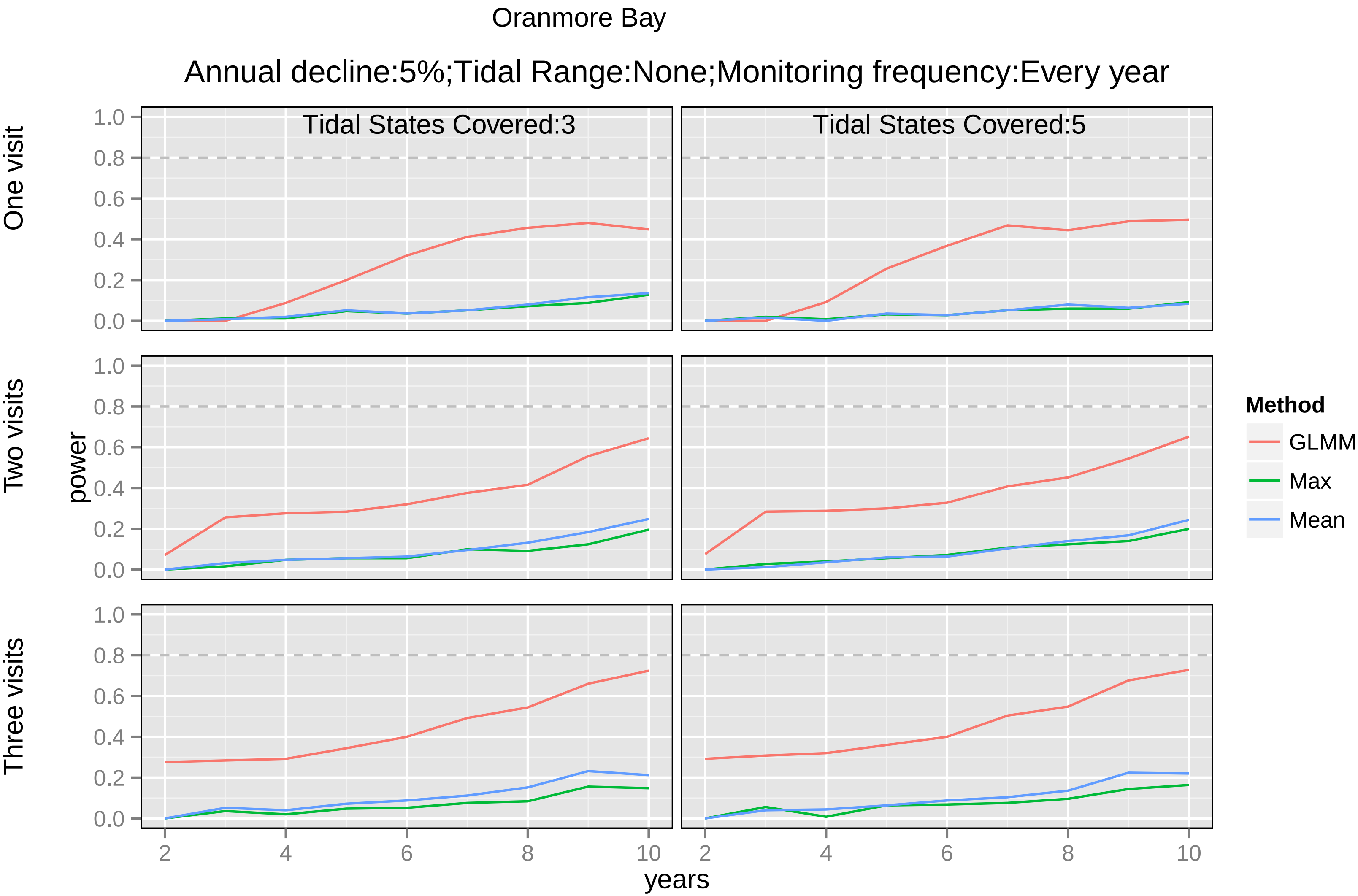
Oranmore Bay
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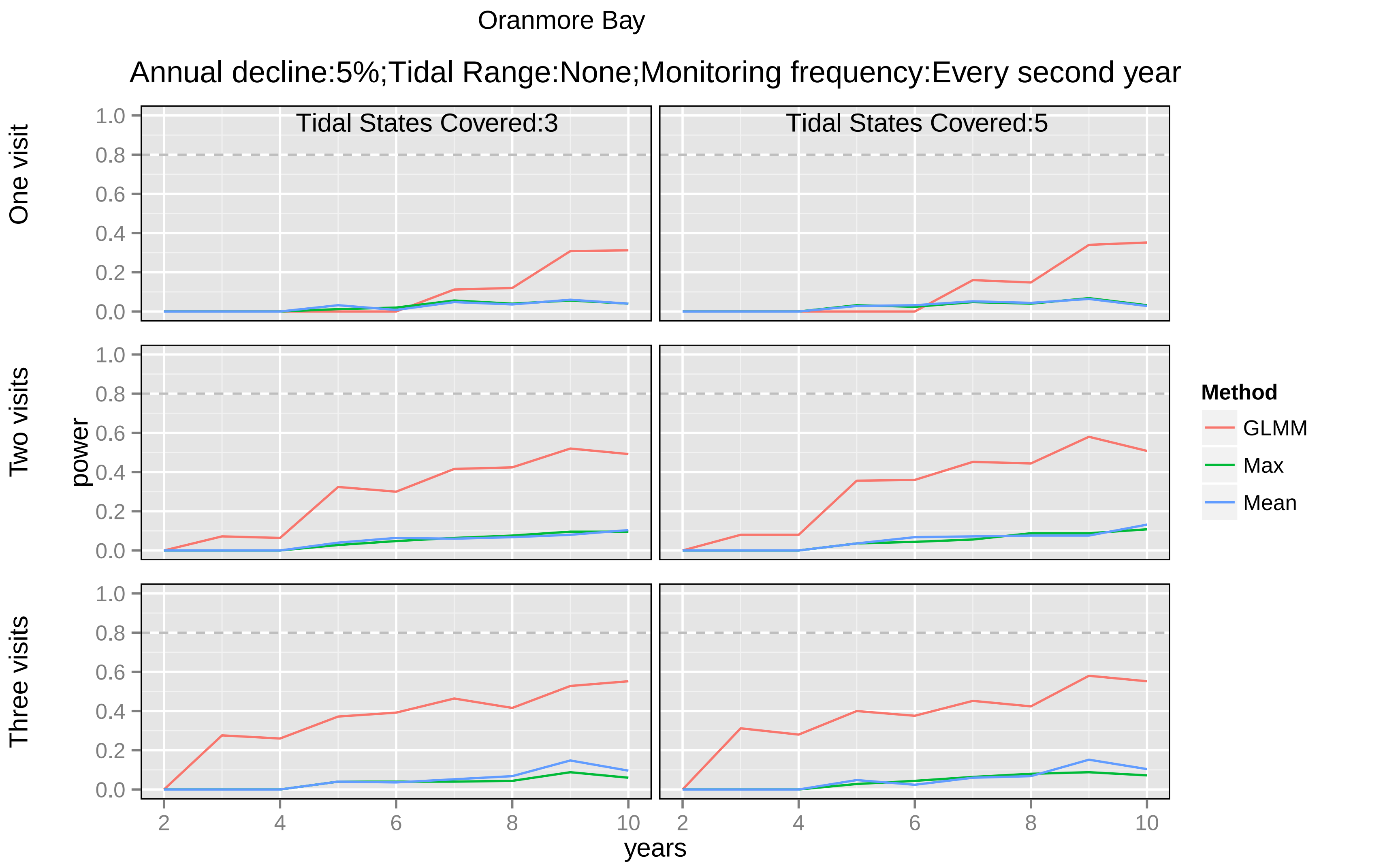
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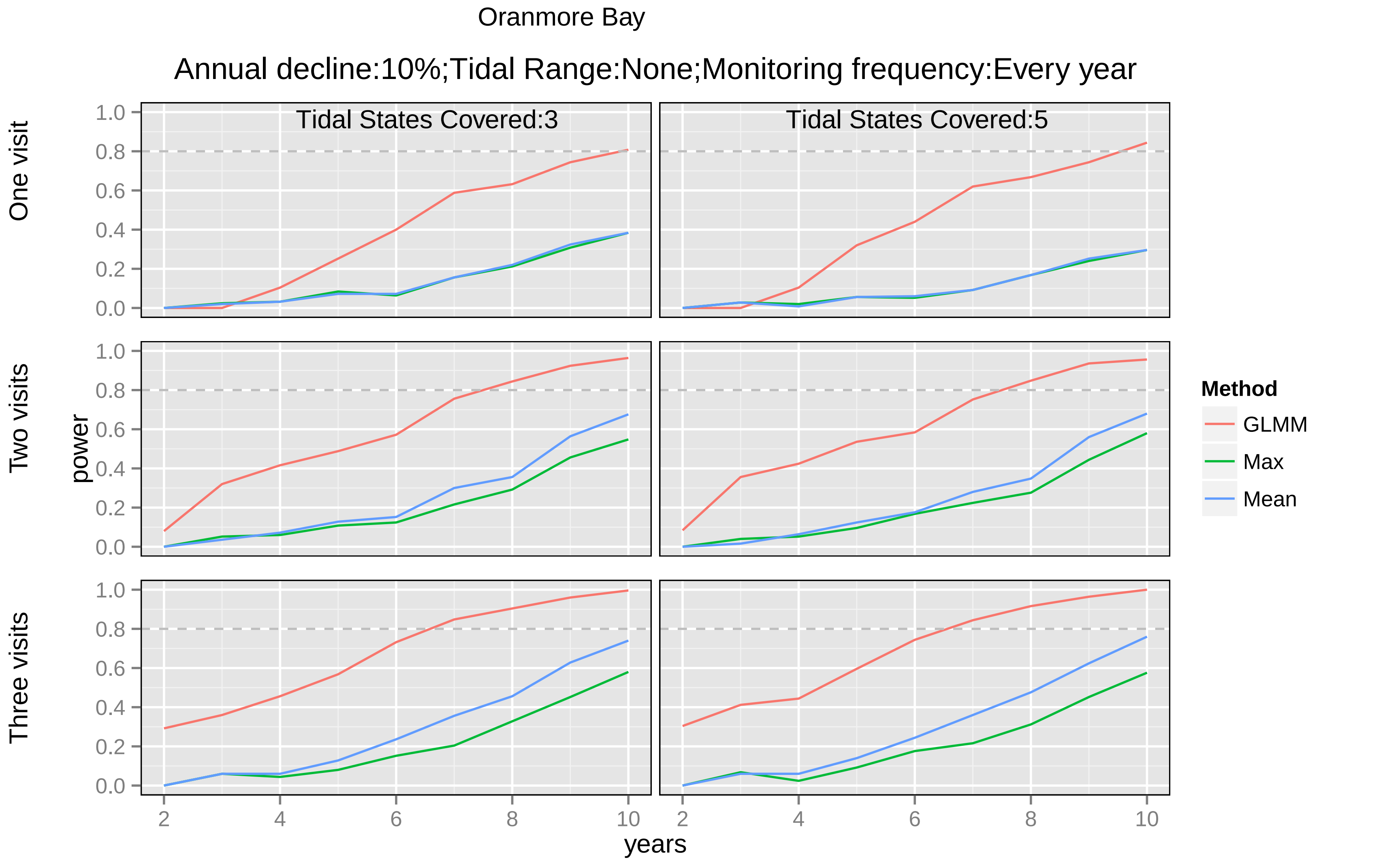
Oranmore Bay
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GLMM
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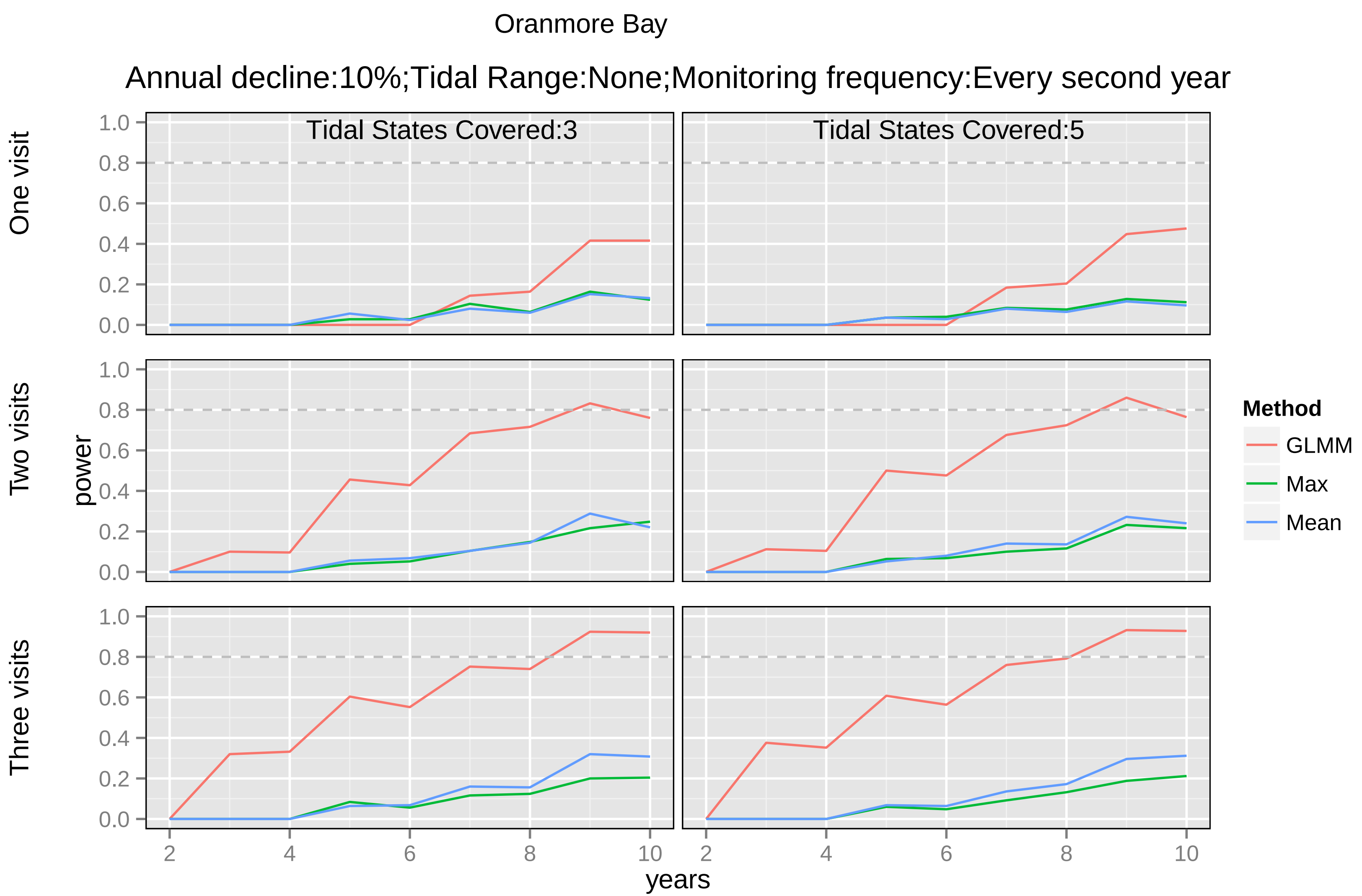
Mean



Oranmore Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
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One visit
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Annual decline:20%;Tidal Range:None;Monitoring frequency:Every year
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Method
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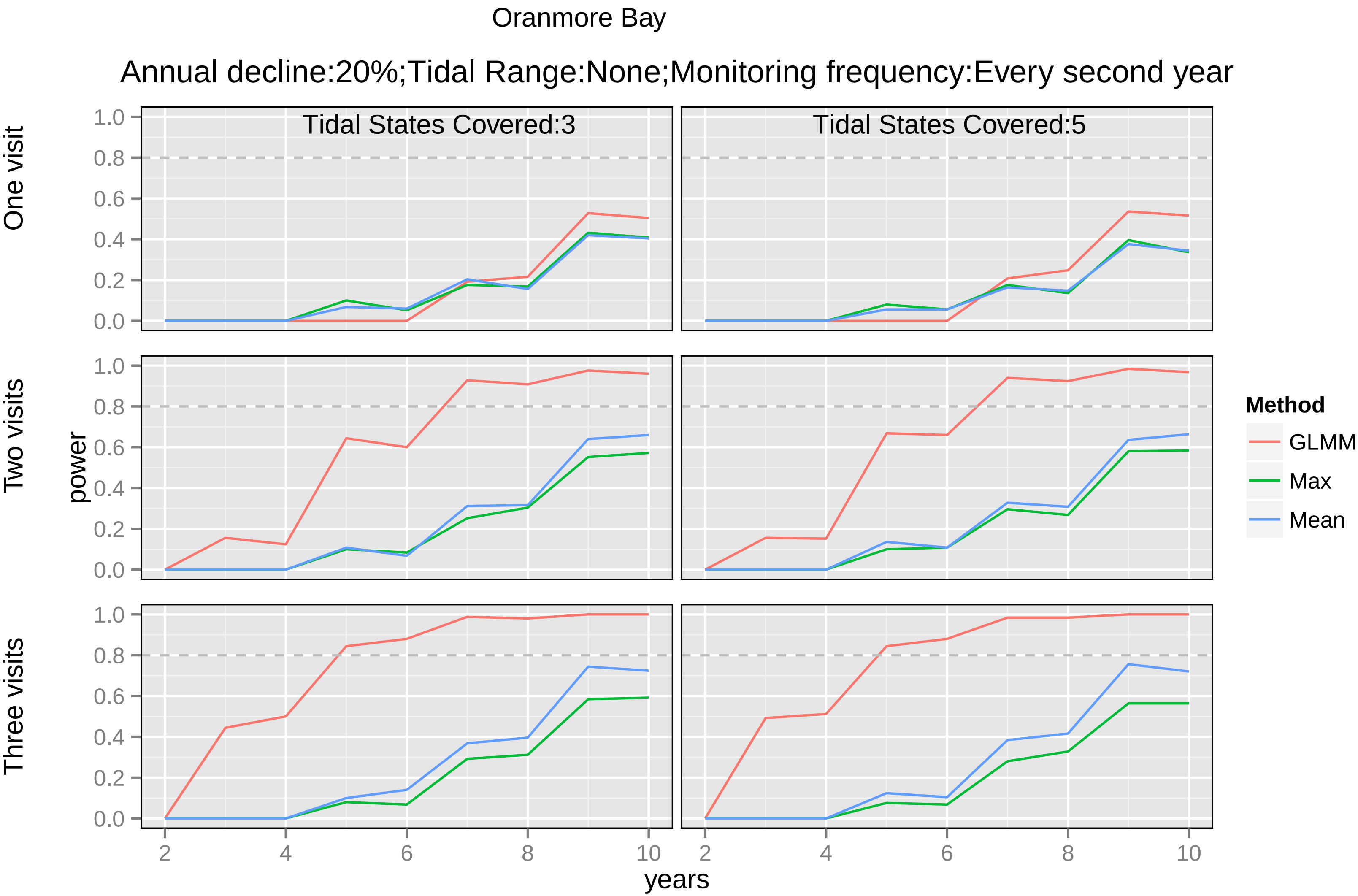
Oranmore Bay
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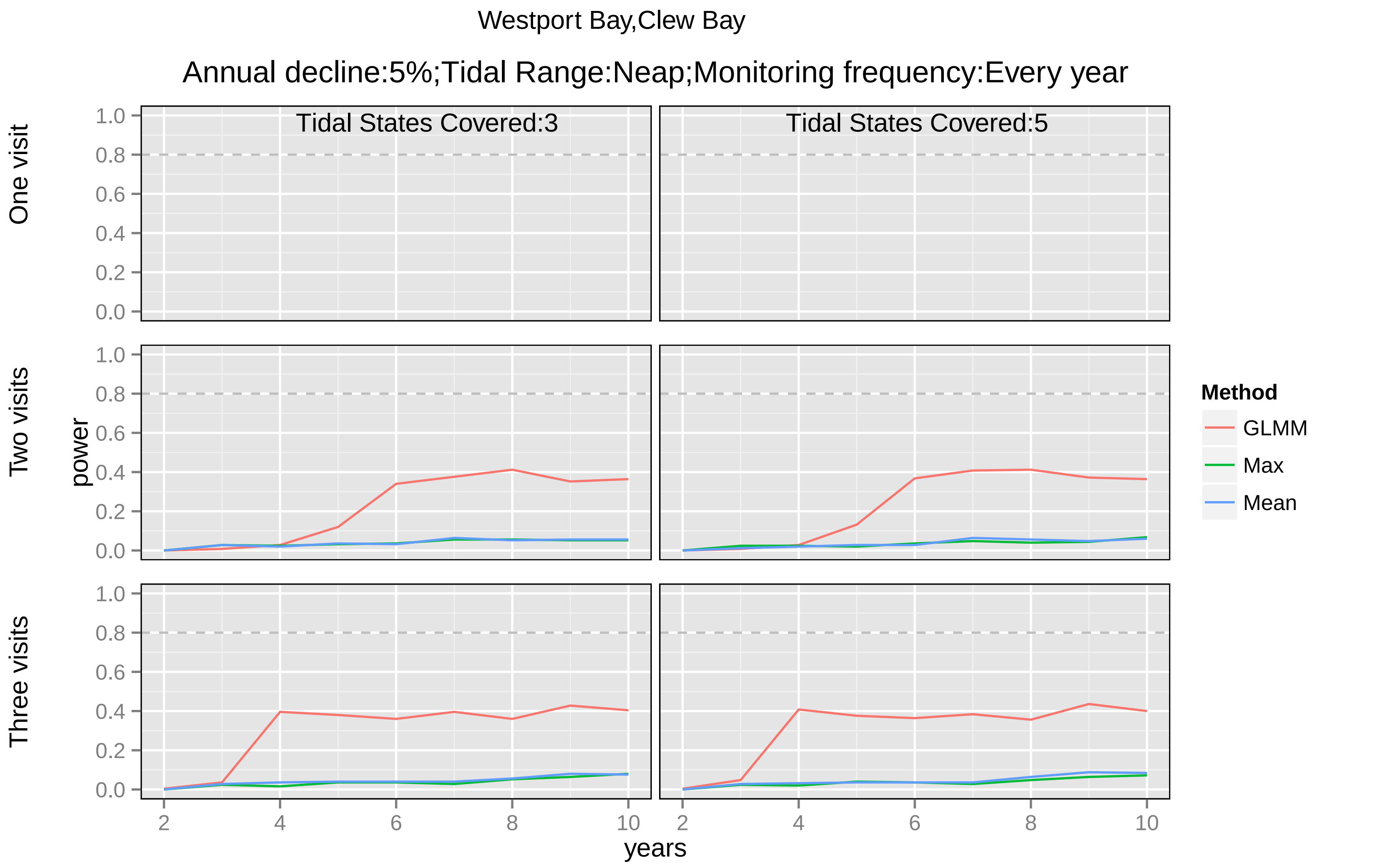
Westport Bay,Clew Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
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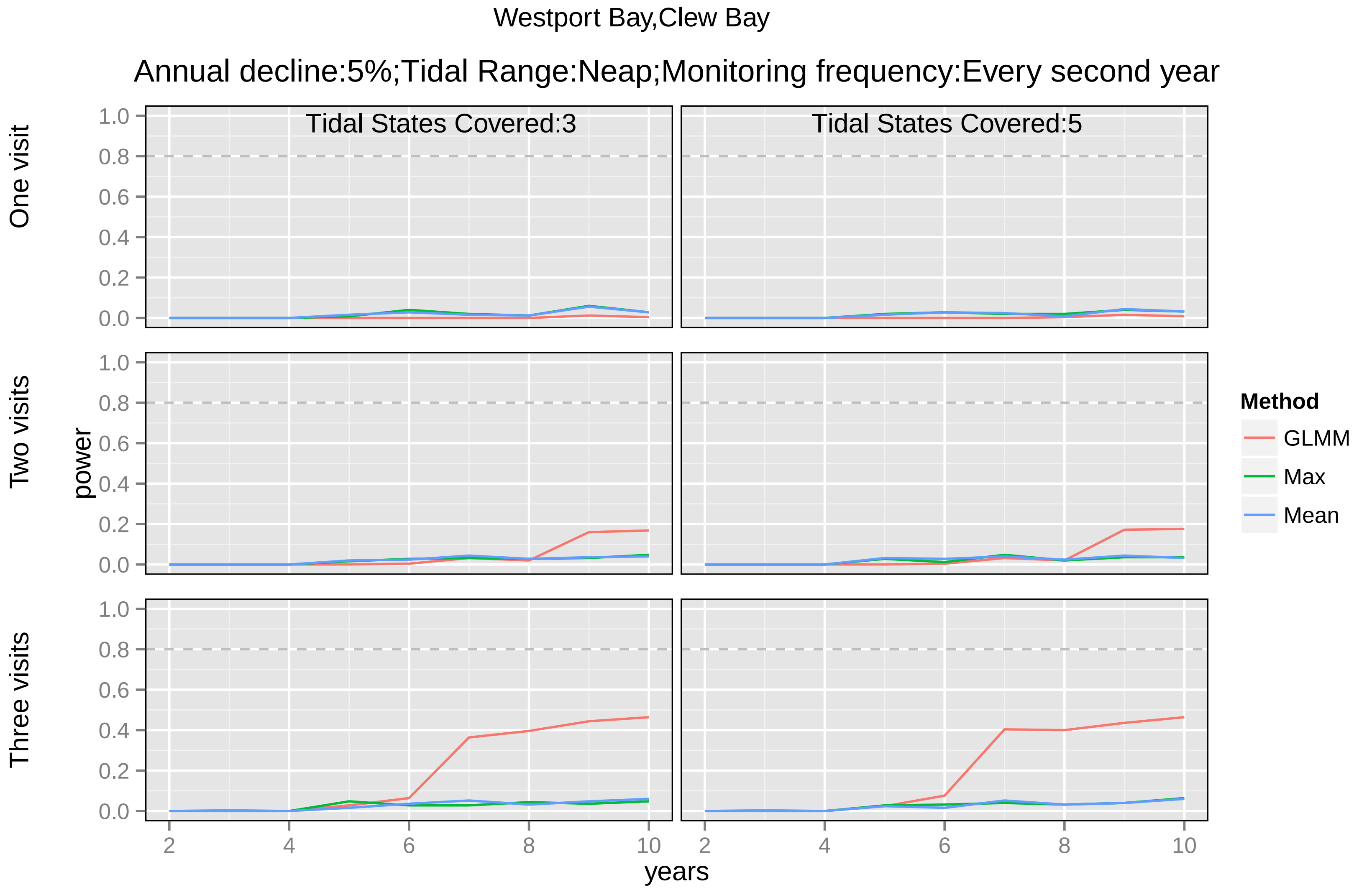

Westport Bay,Clew Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
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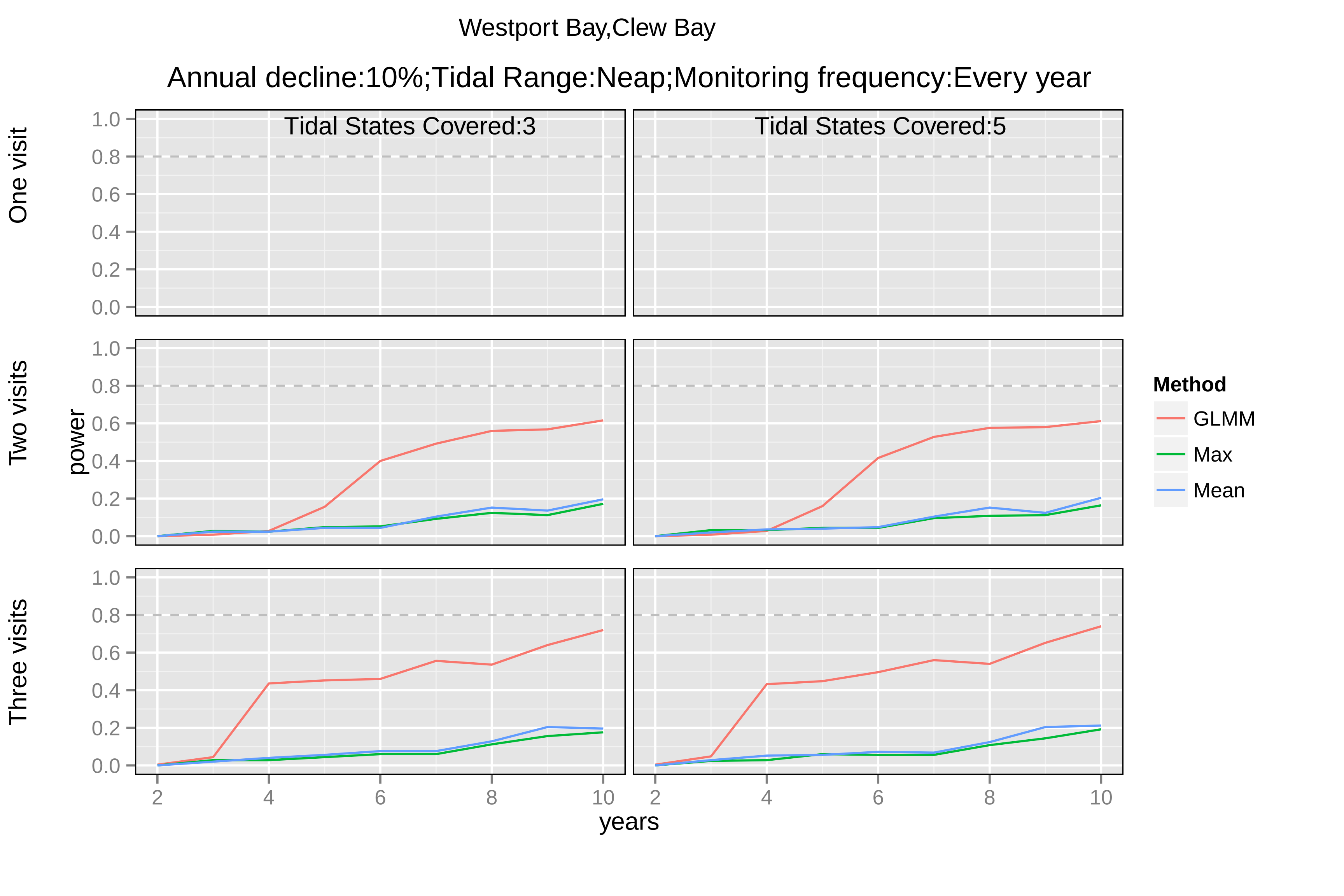
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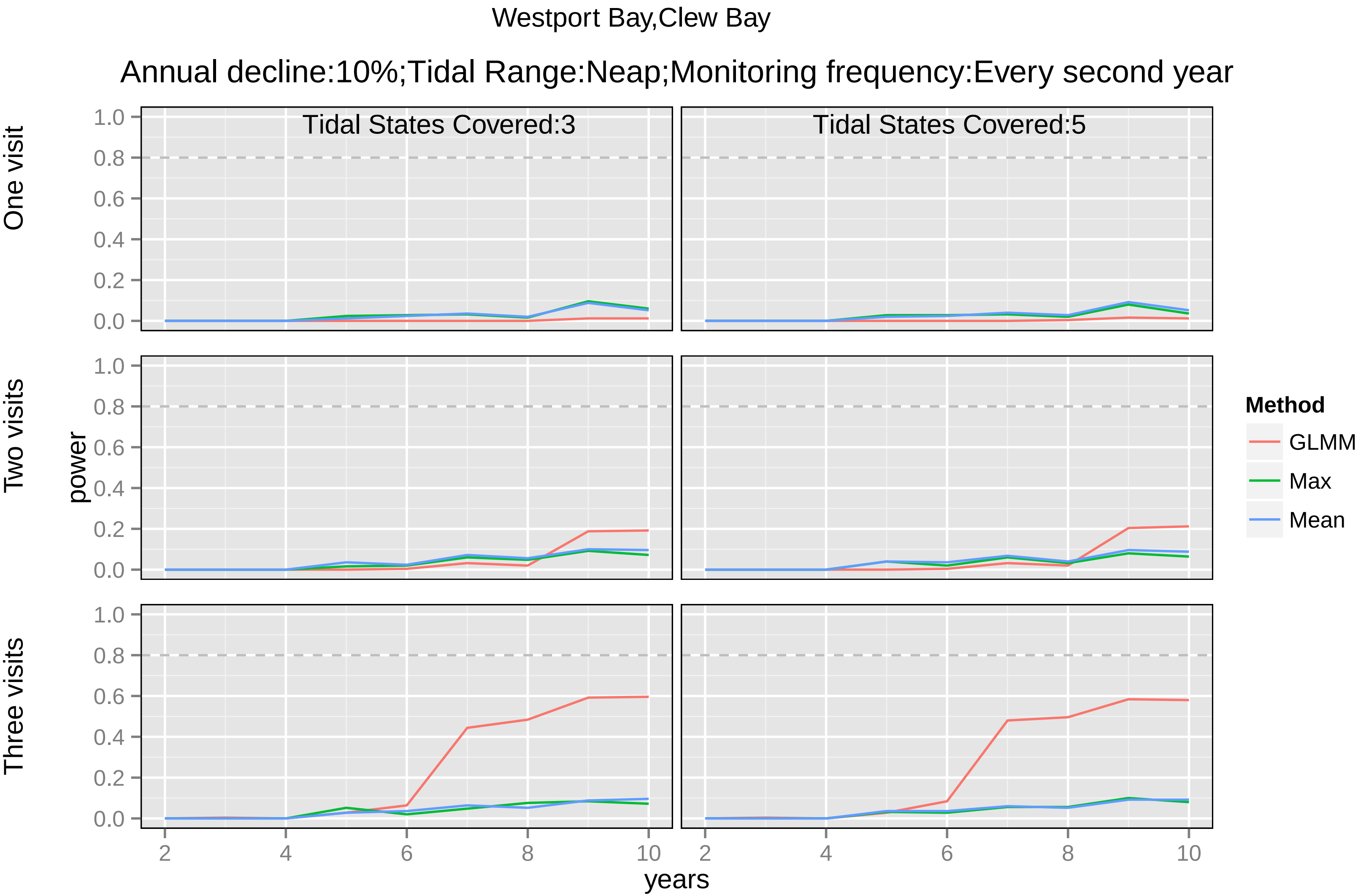

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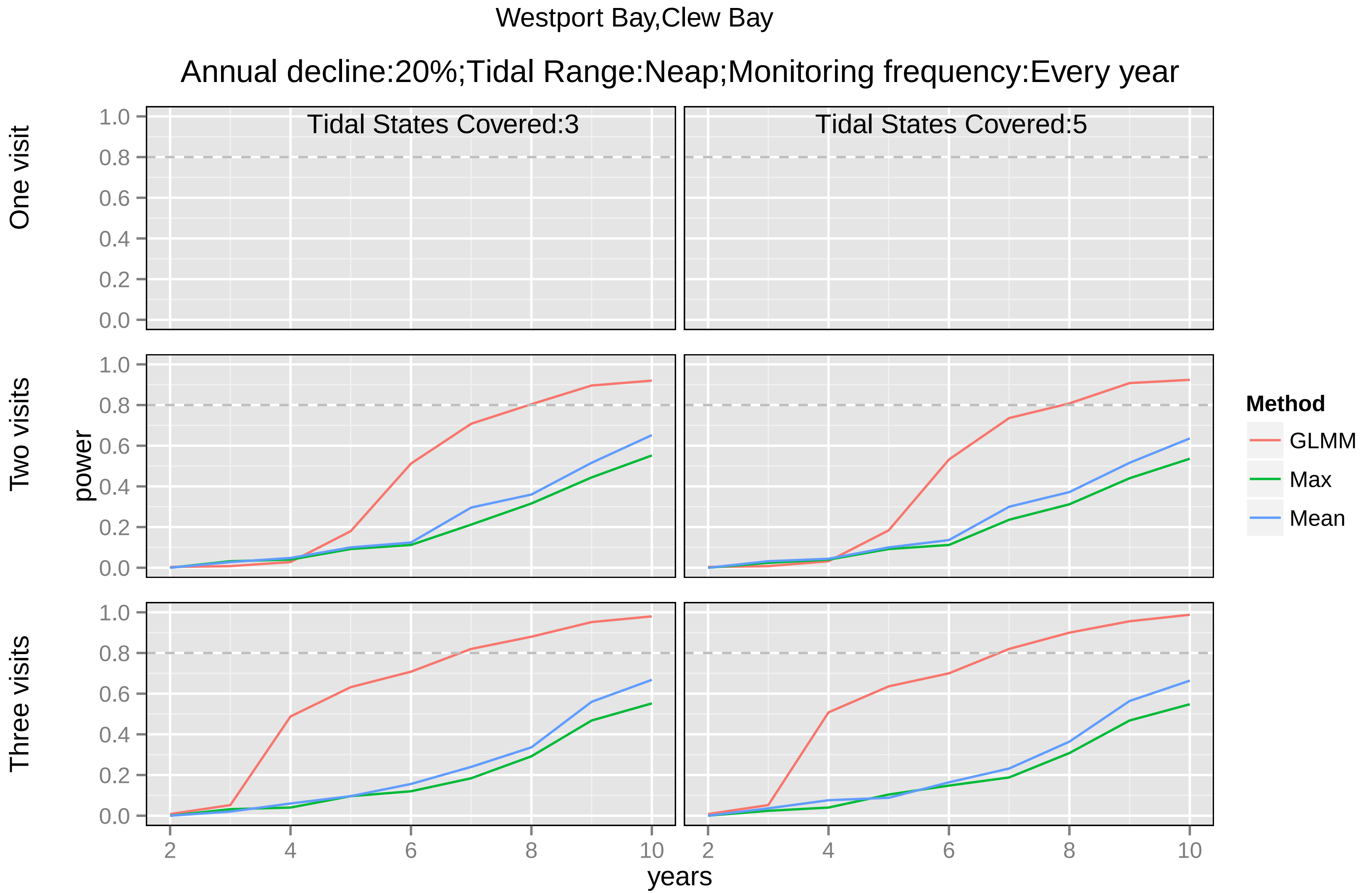
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Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
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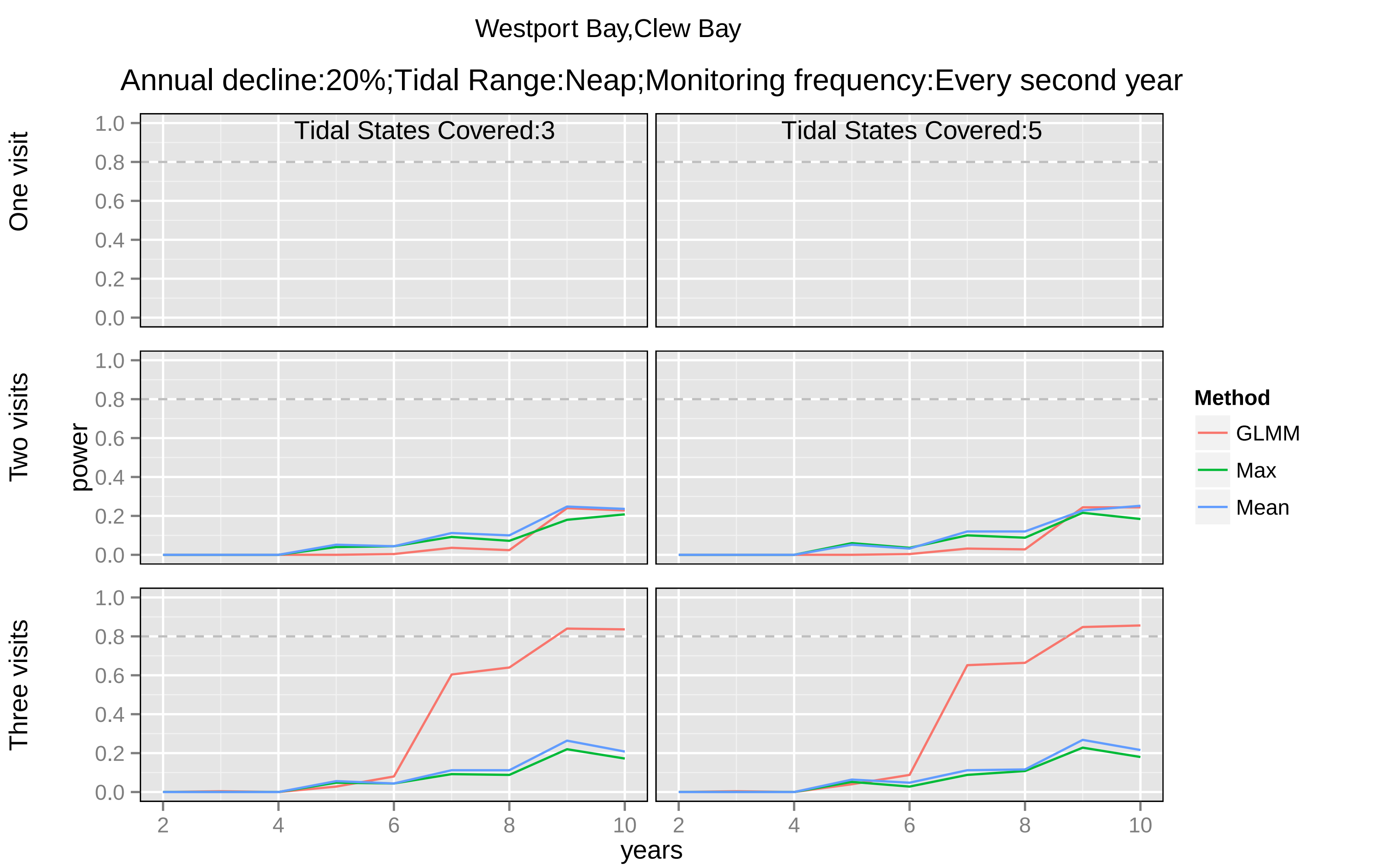

Westport Bay,Clew Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
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Tidal States Covered:5
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Two visits
Three visits
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Method
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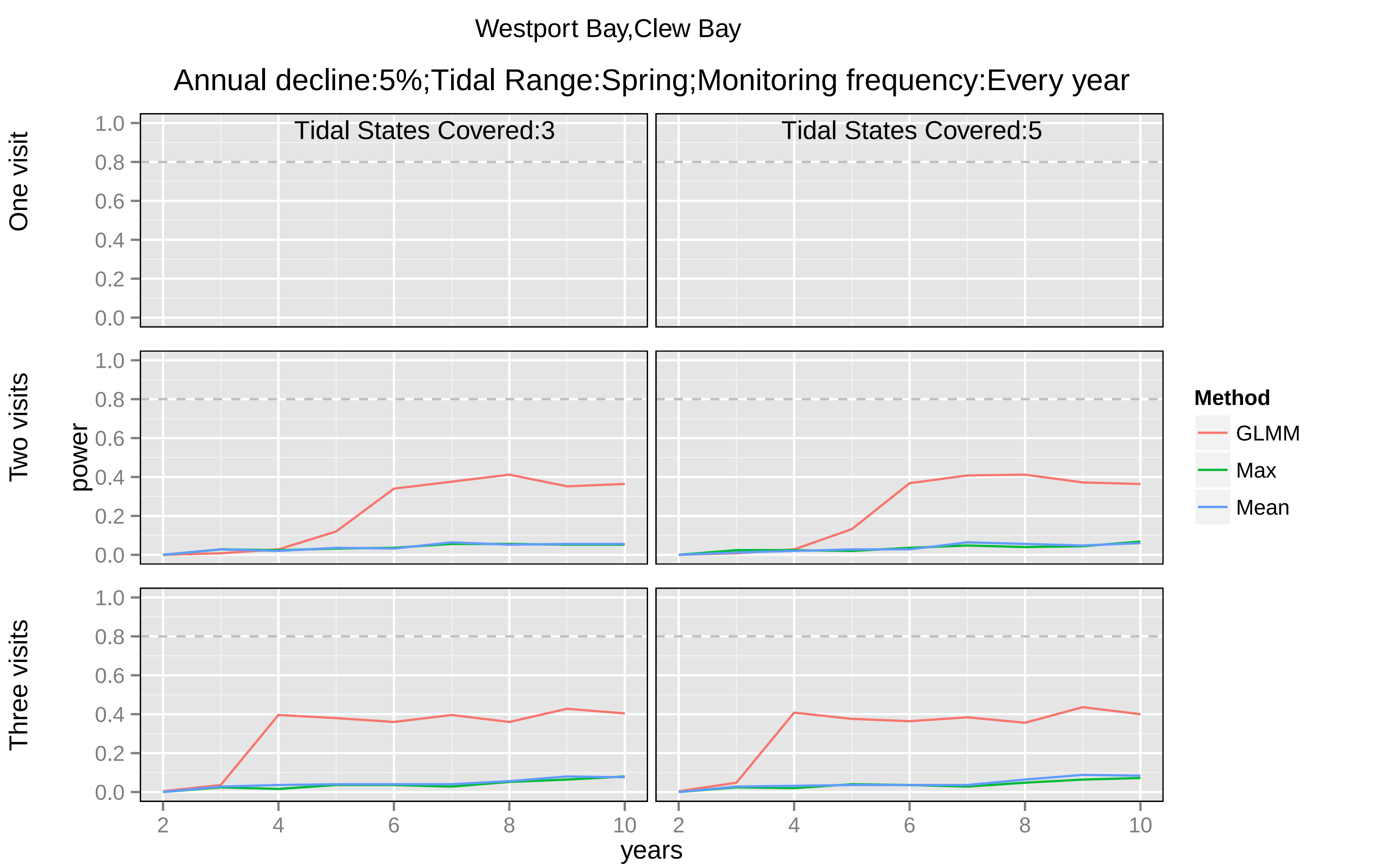
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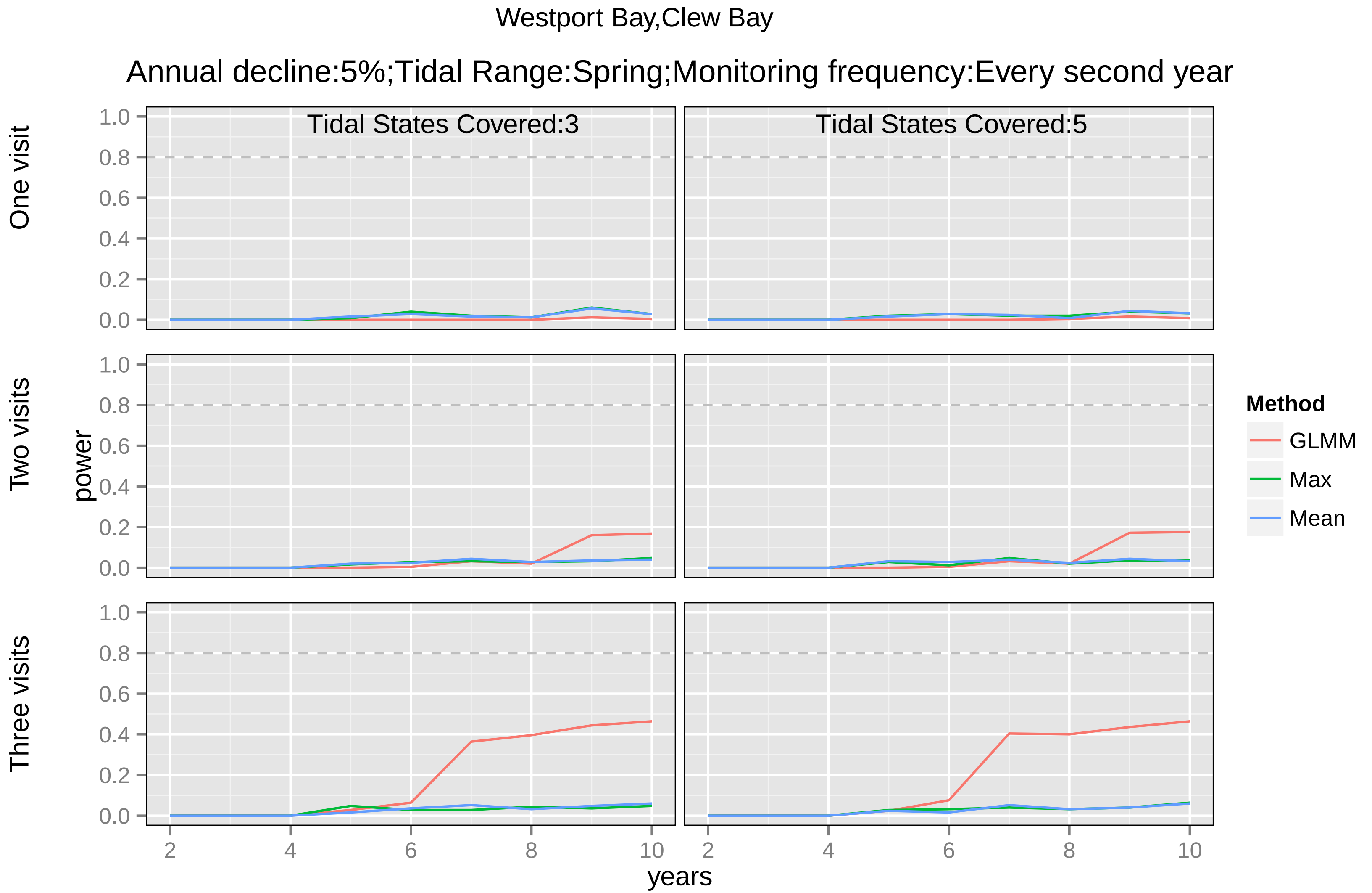
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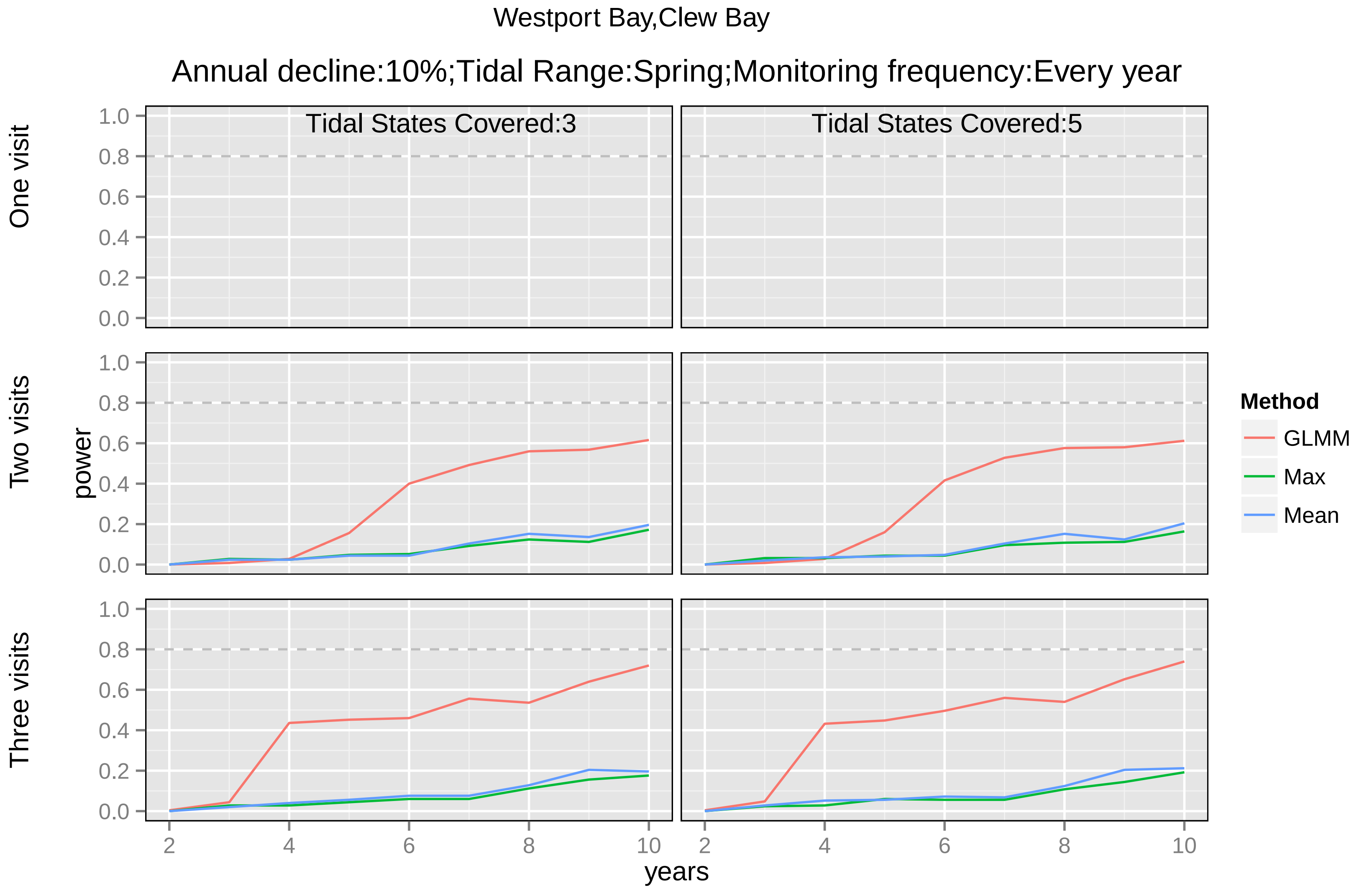
Westport Bay,Clew Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
0.0
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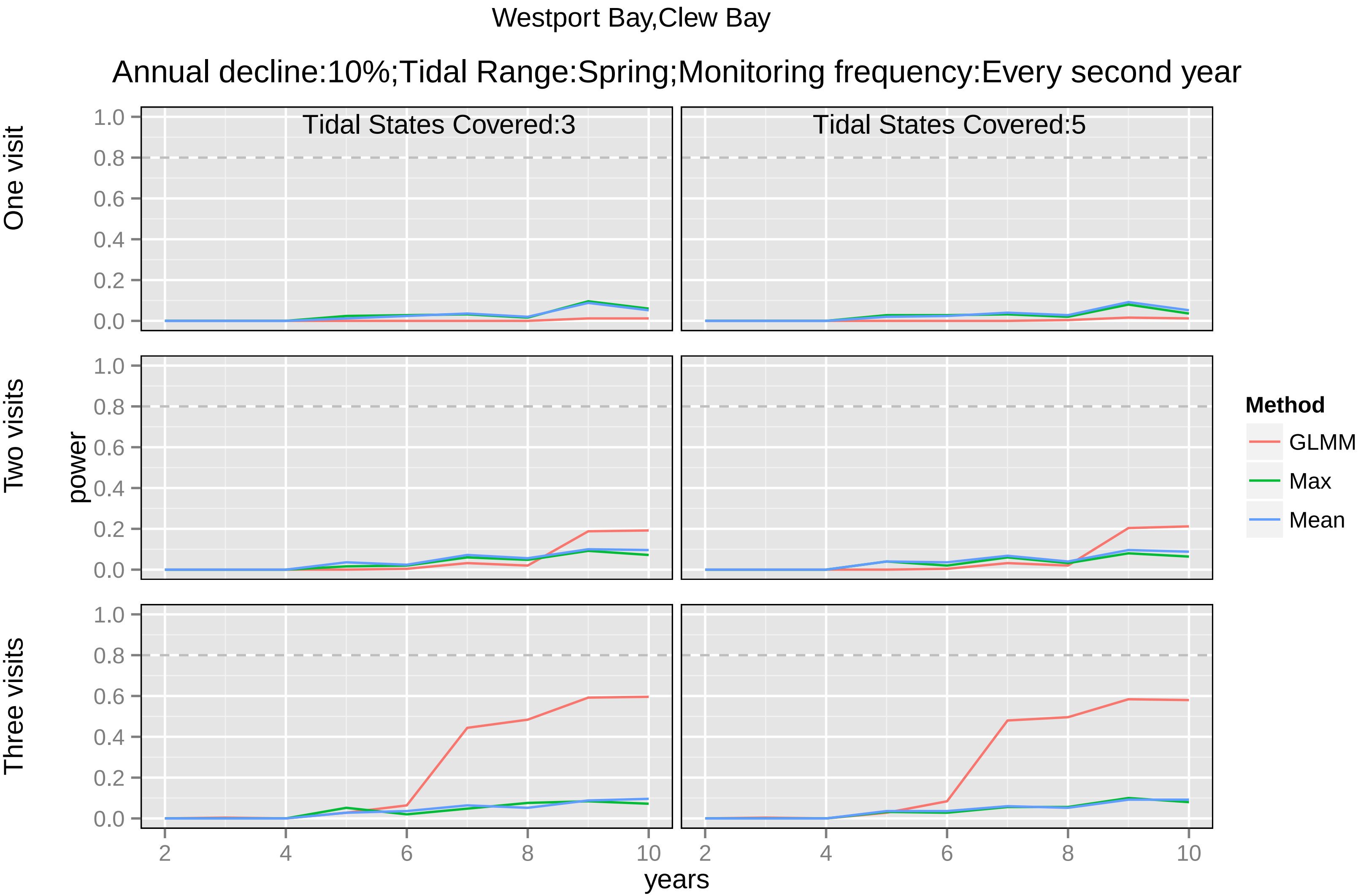

Westport Bay,Clew Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
1.0
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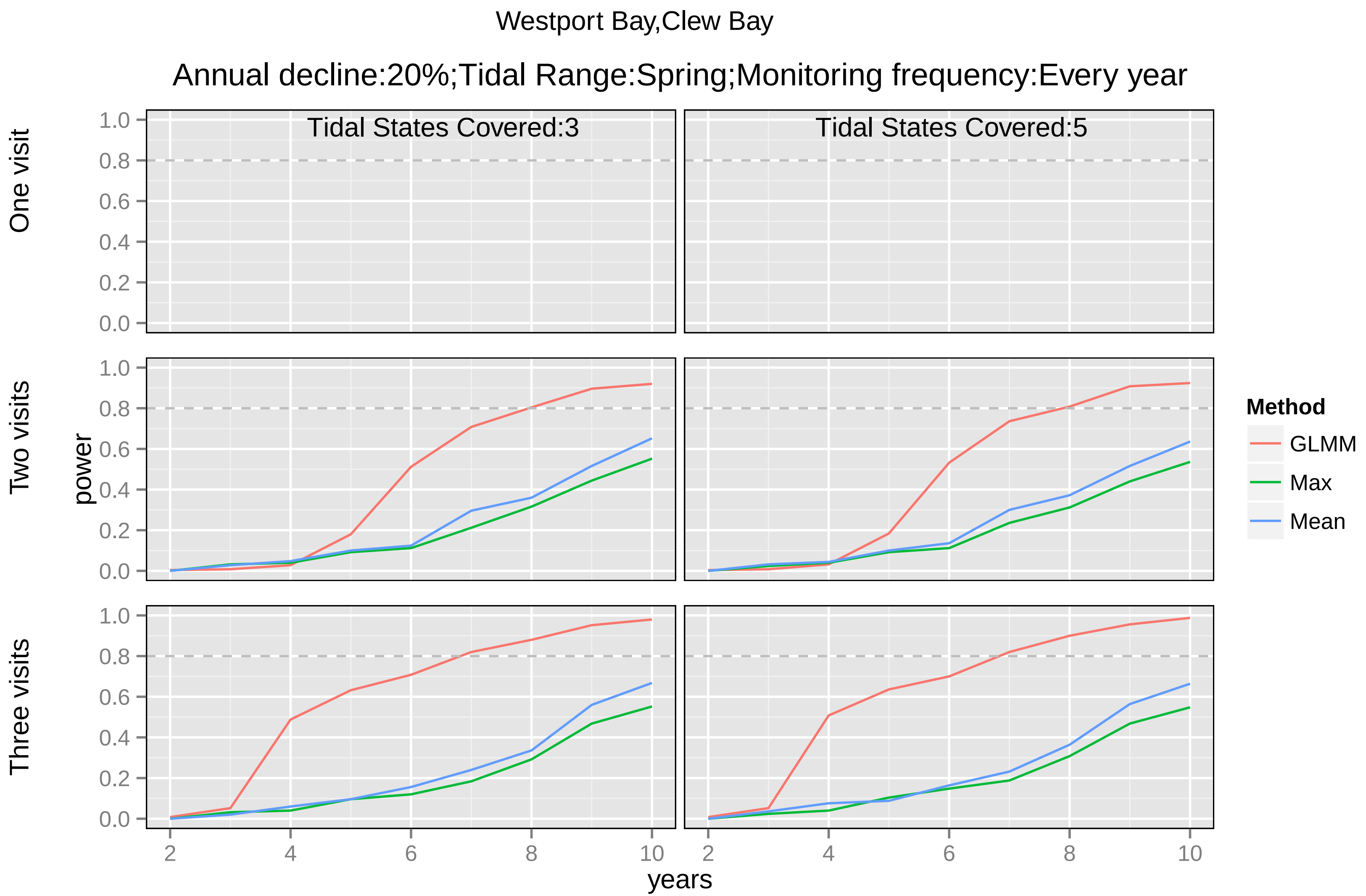
Method
GLMM
Max
Mean



Westport Bay,Clew Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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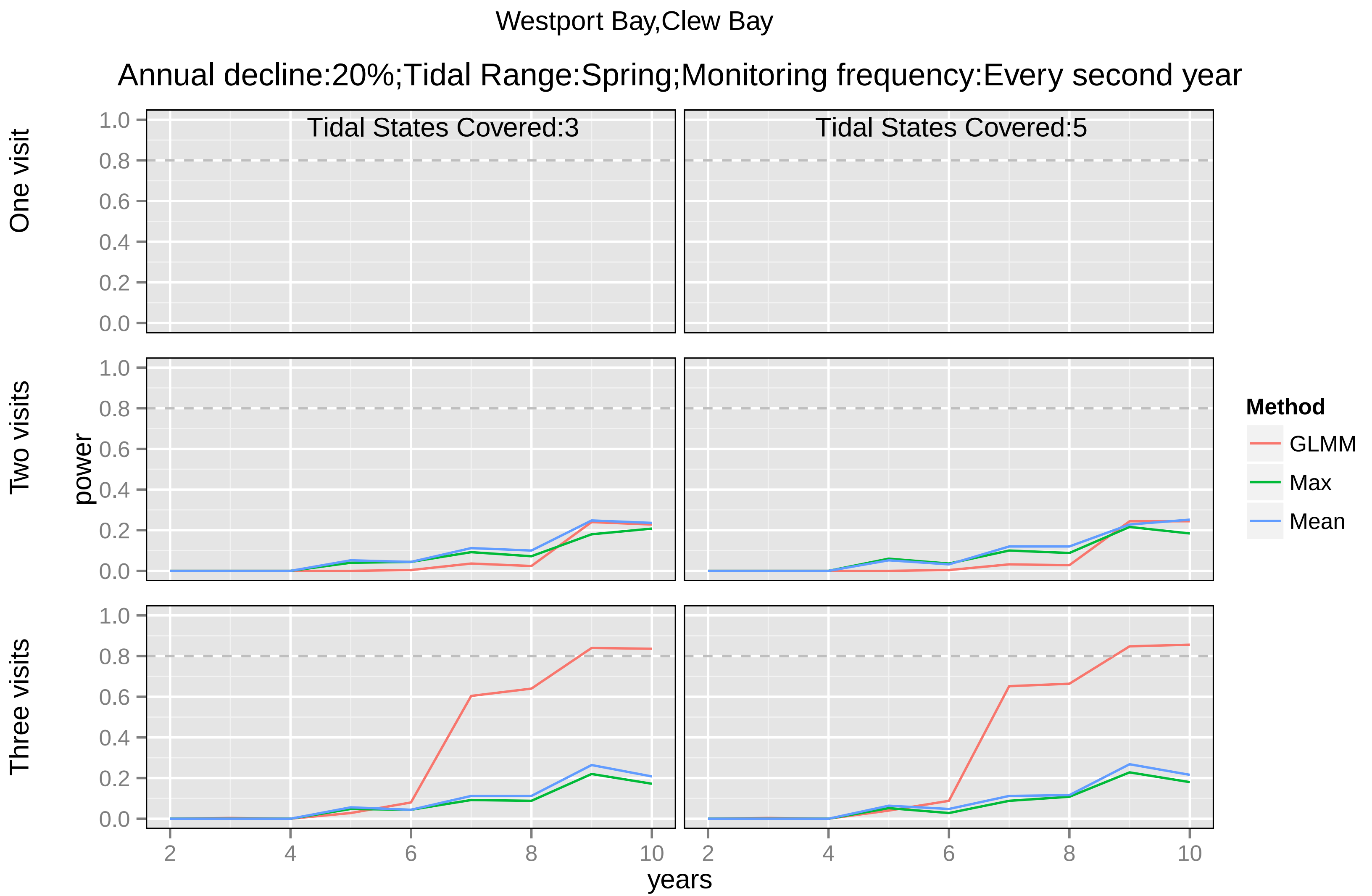
Westport Bay,Clew Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean
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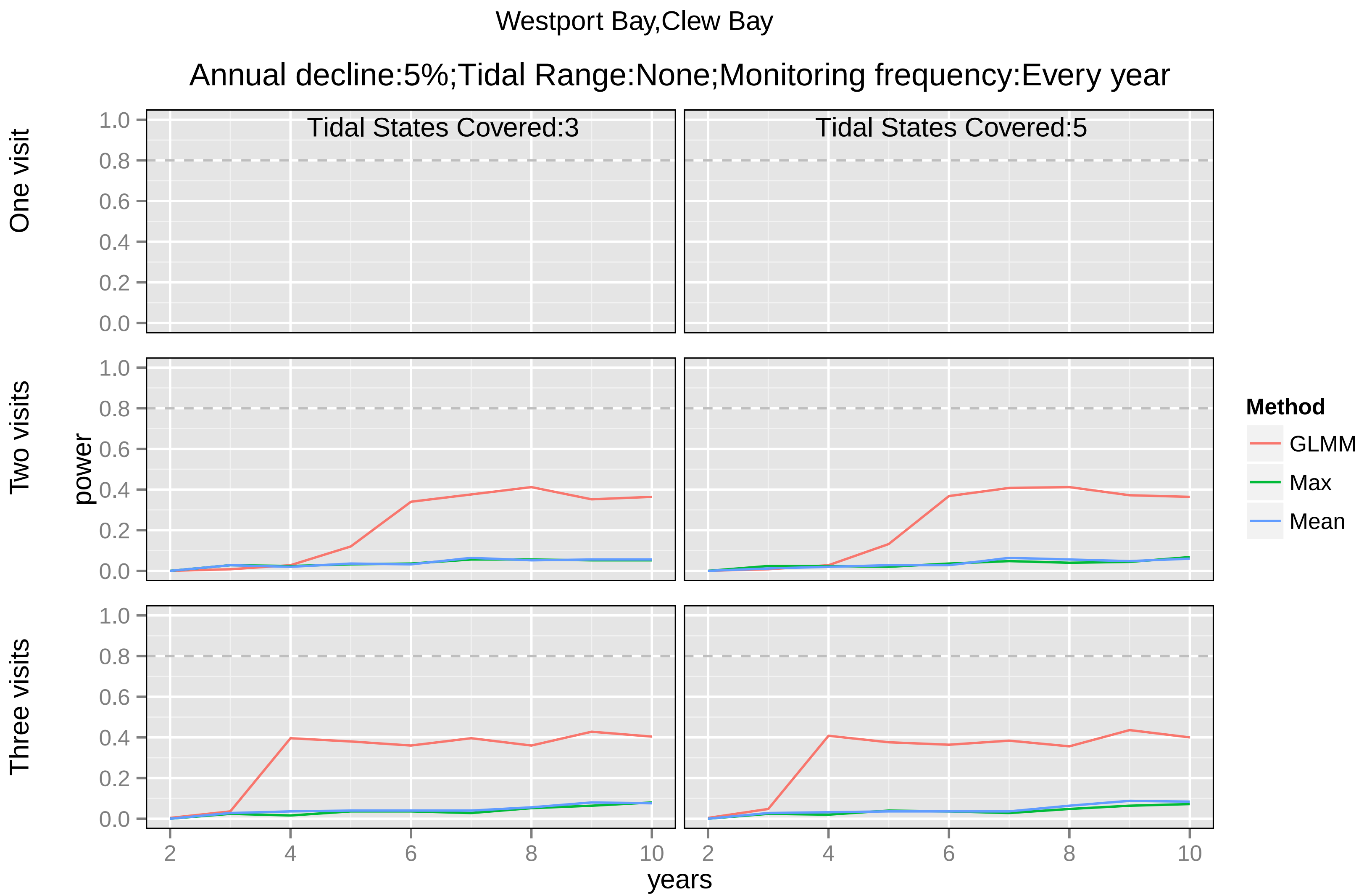

Westport Bay,Clew Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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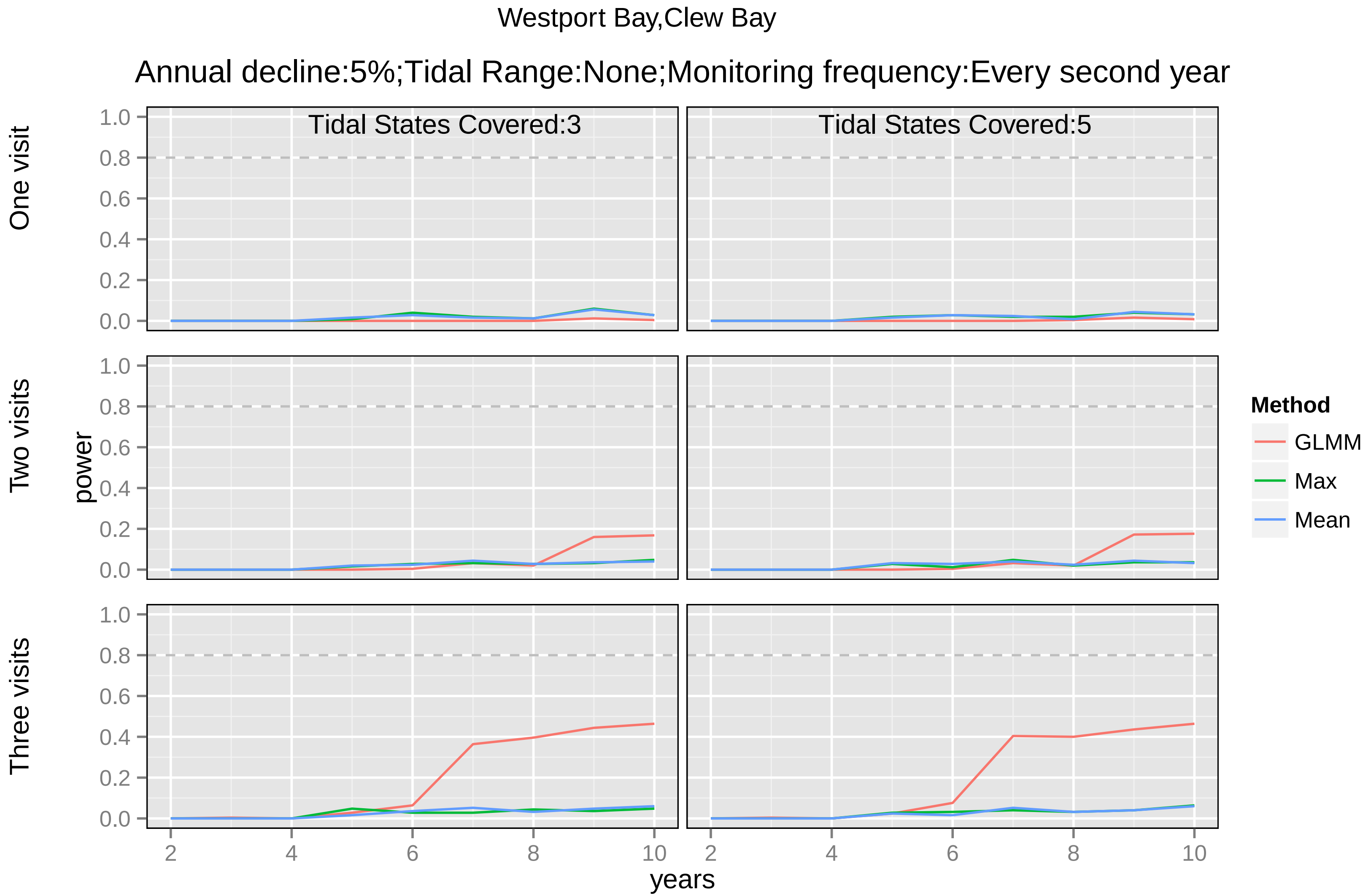
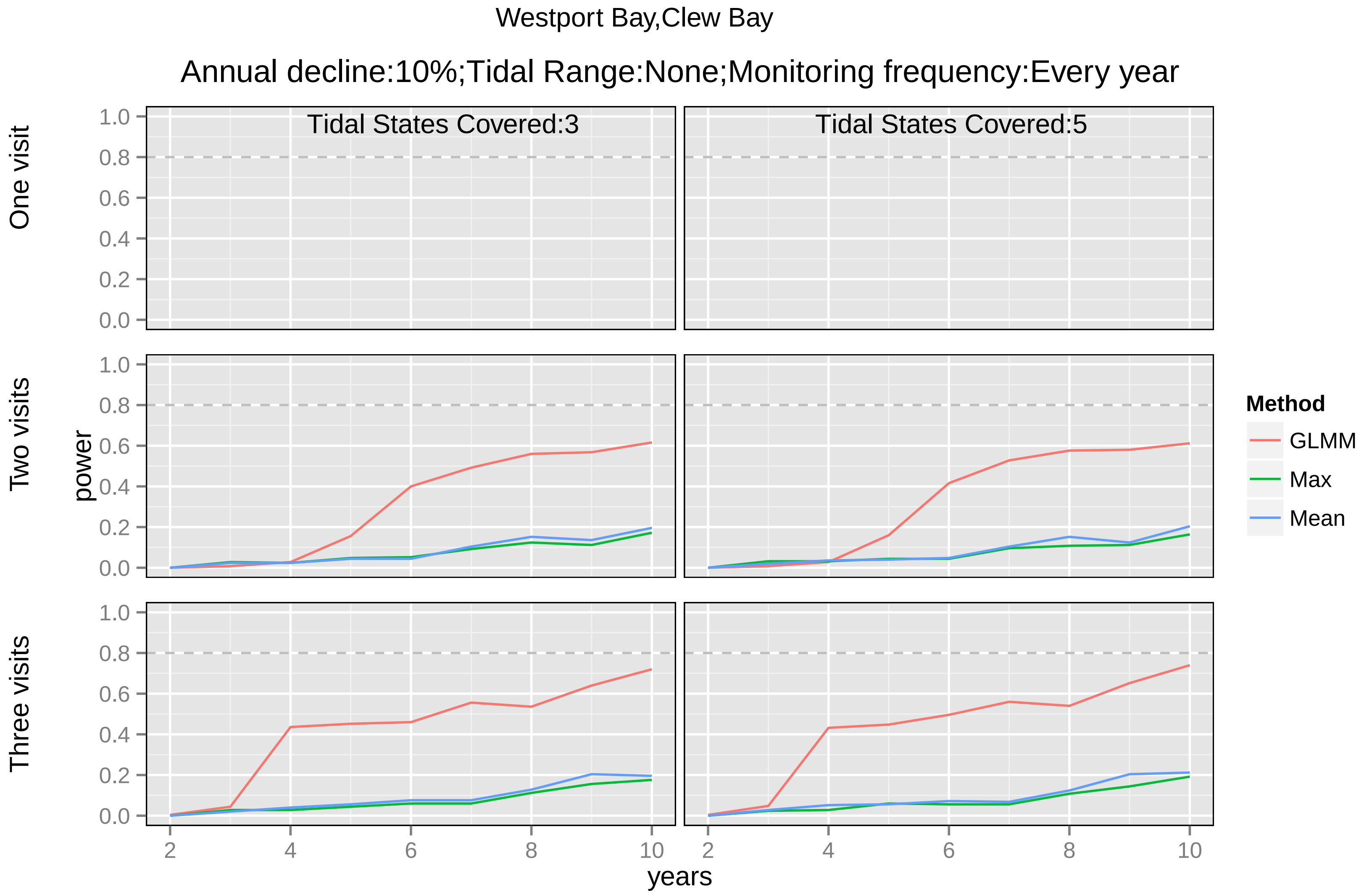
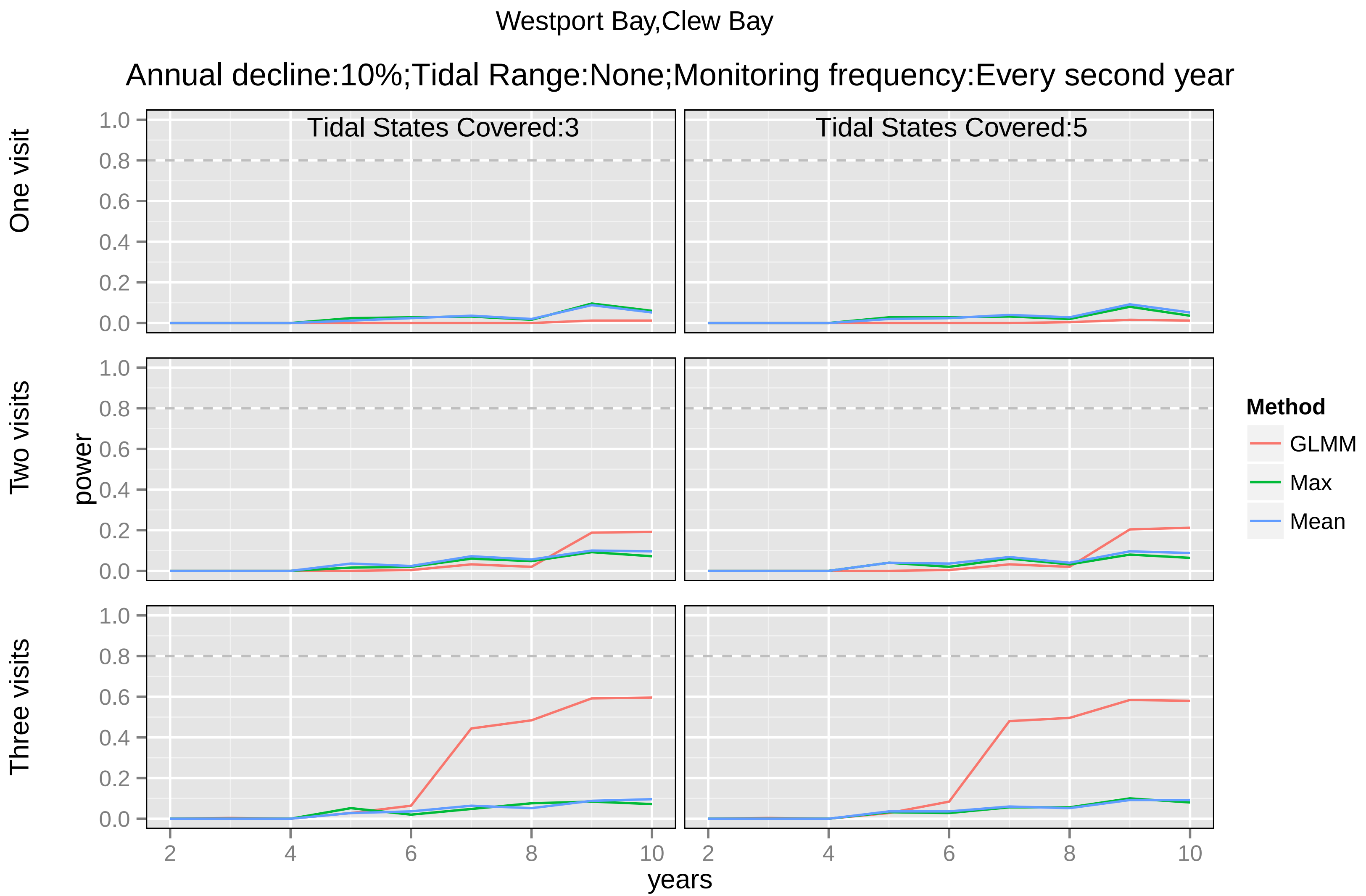
Method
GLMM
Max
Mean



Westport Bay,Clew Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean



Westport Bay,Clew Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
Max
Mean



Westport Bay,Clew Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
Method
GLMM
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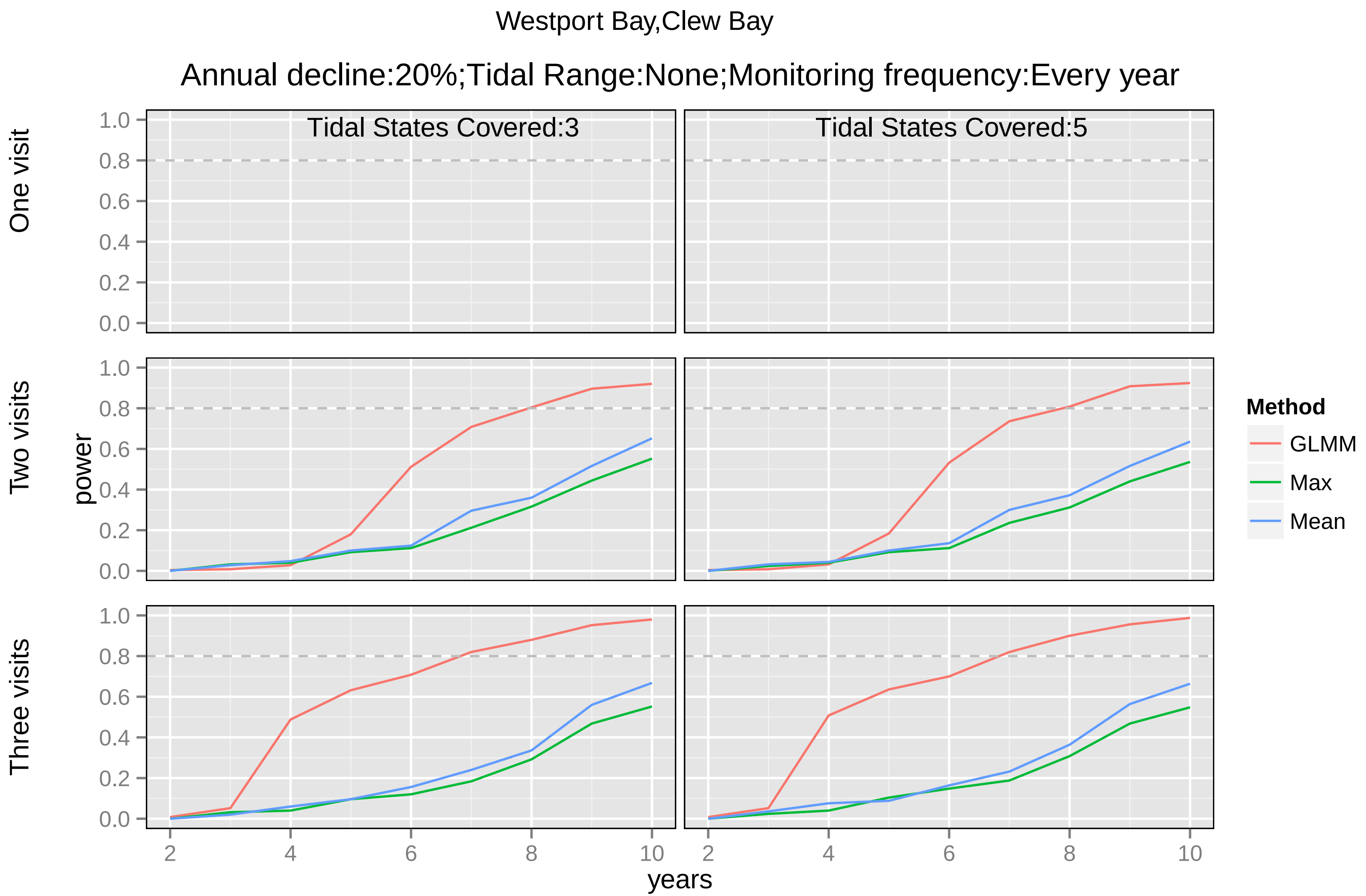
Westport Bay,Clew Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
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Method
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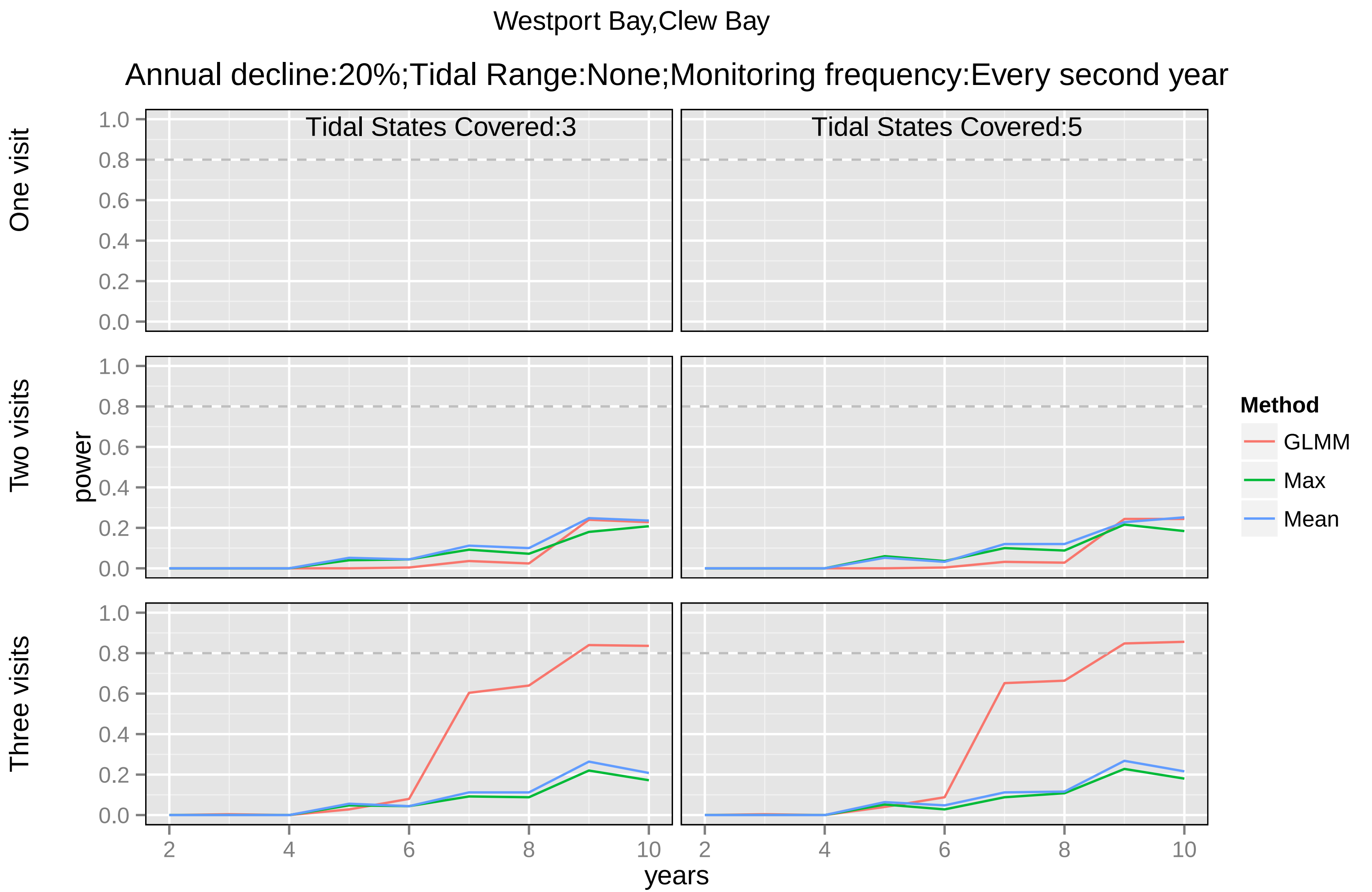

Westport Bay,Clew Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
Tidal States Covered:3
Tidal States Covered:5
One visit
Two visits
Three visits
power
years
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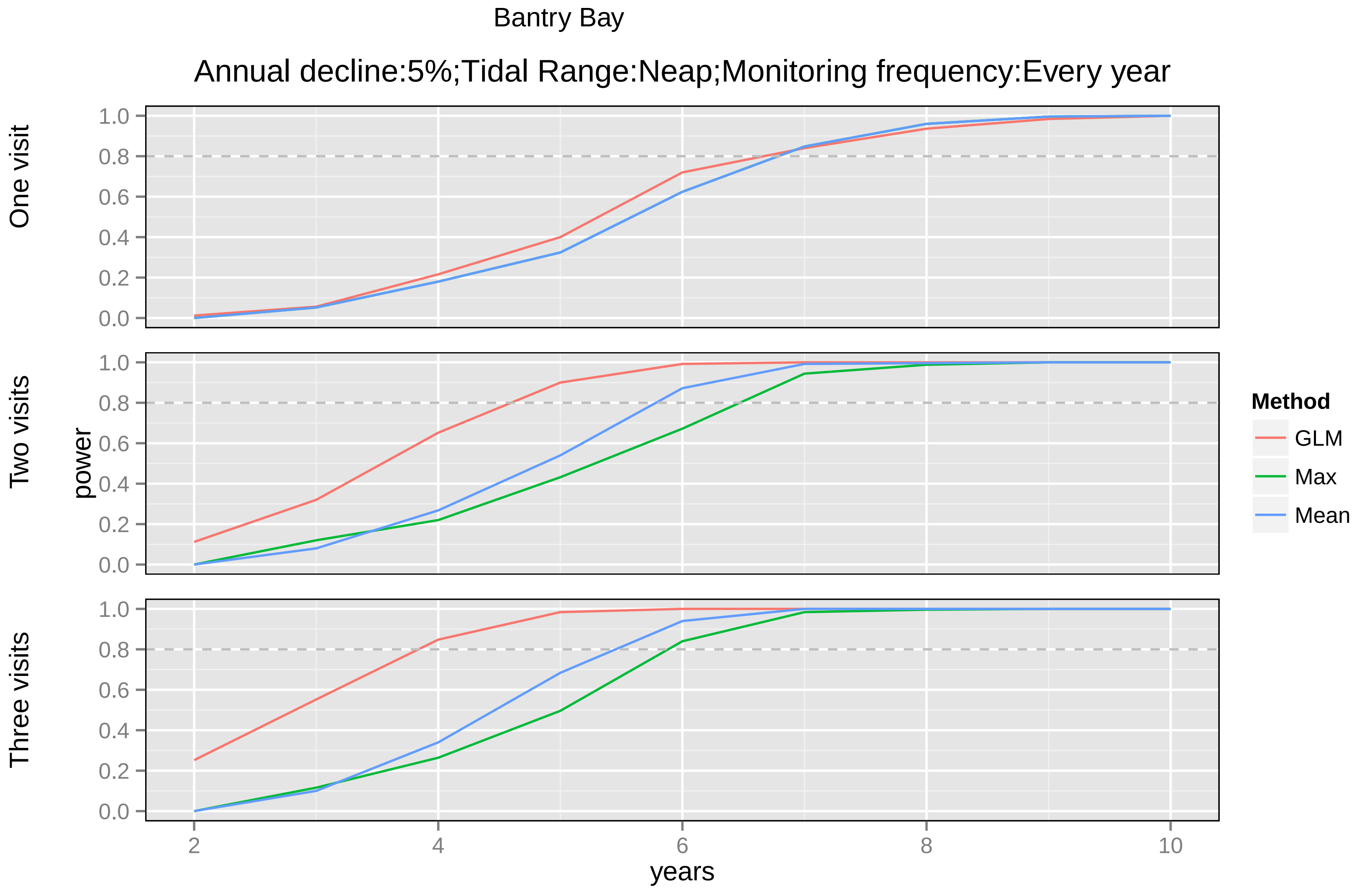
Method
GLMM
Max
Mean


Bantry Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
years
Method
GLM
Max
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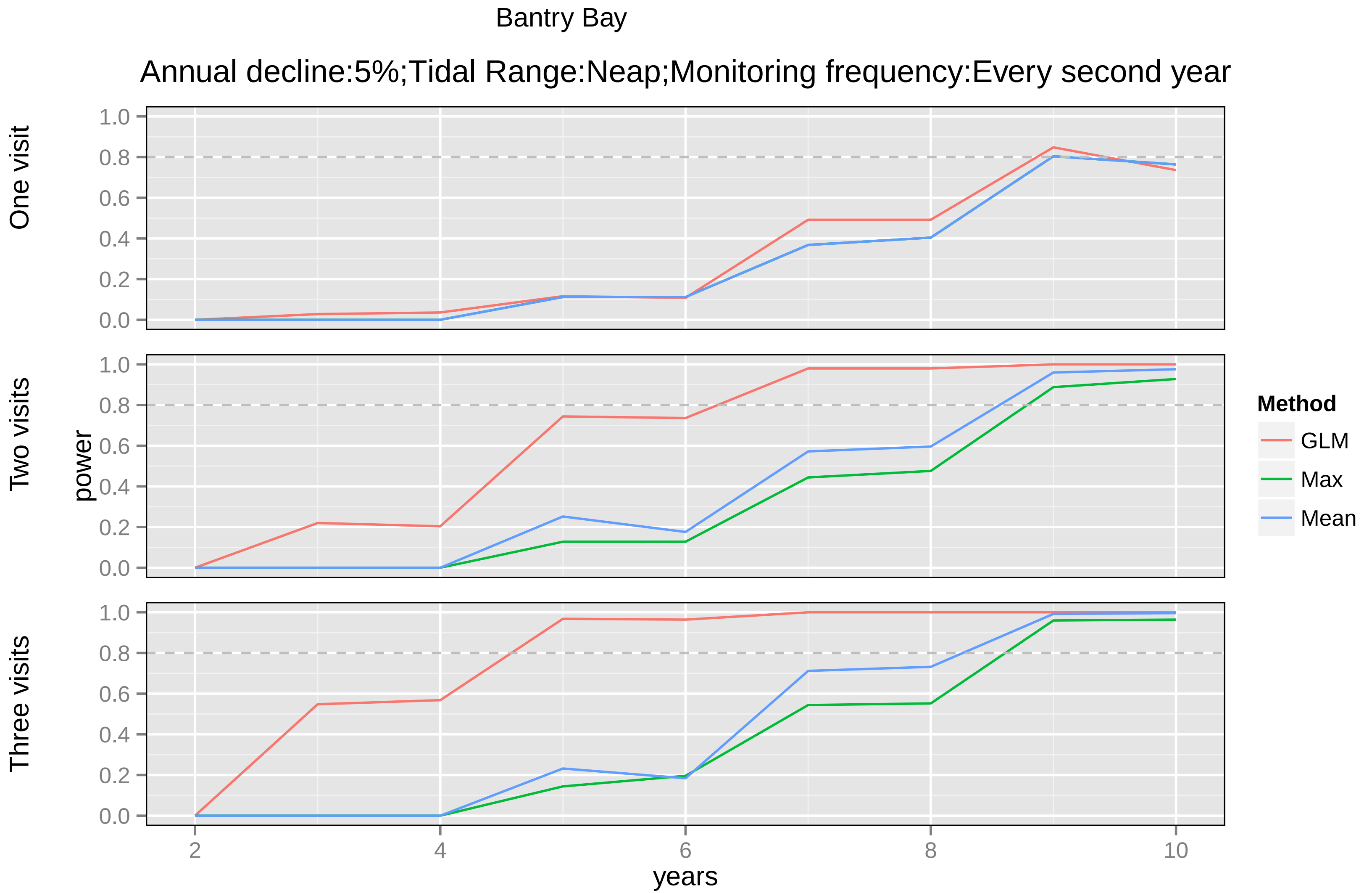
Bantry Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
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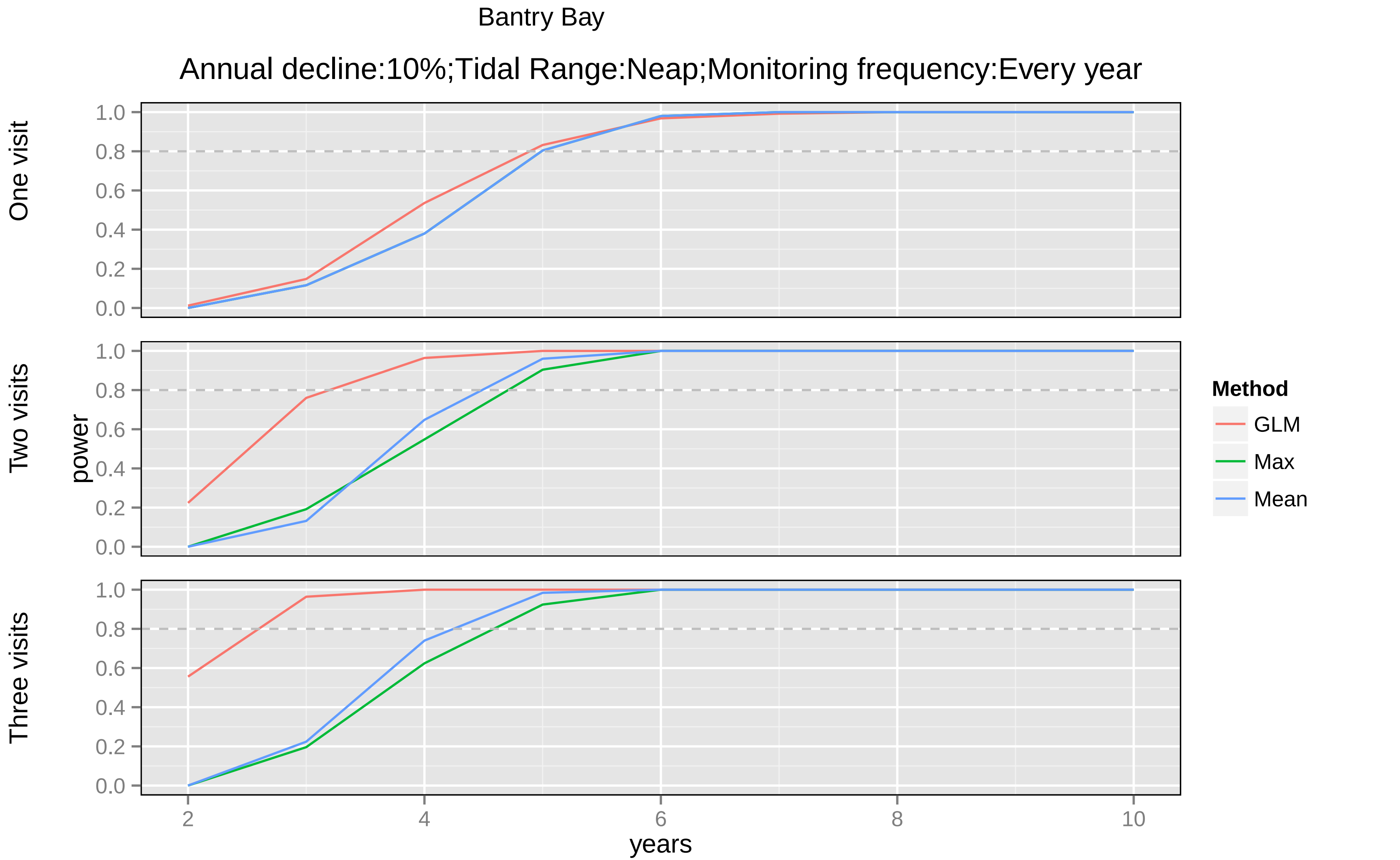
years
Method
GLM
Max
Mean


Bantry Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
Two visits
Three visits
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Method
GLM
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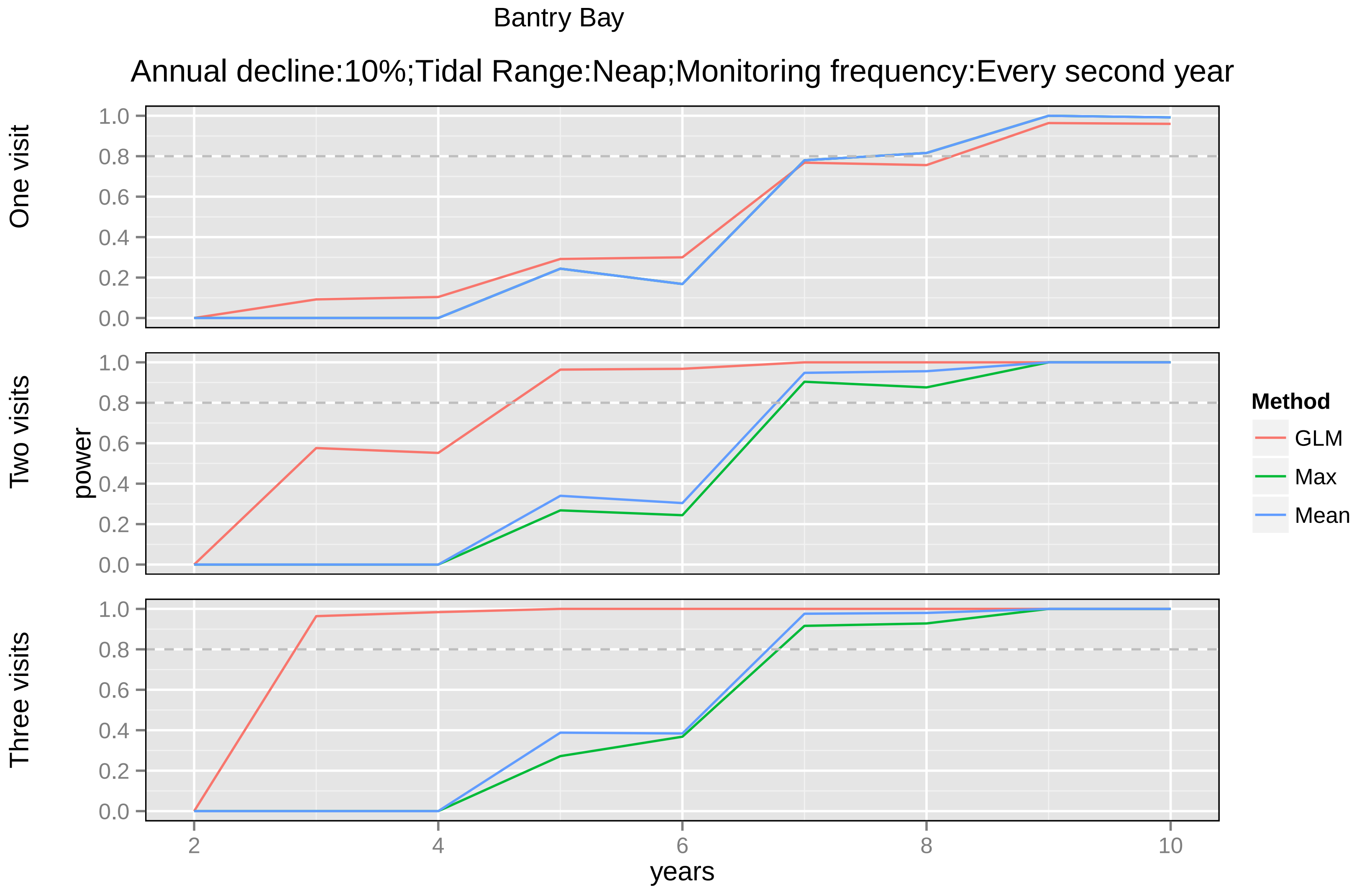
Mean


Bantry Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every second year
One visit
Two visits
Three visits
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Method
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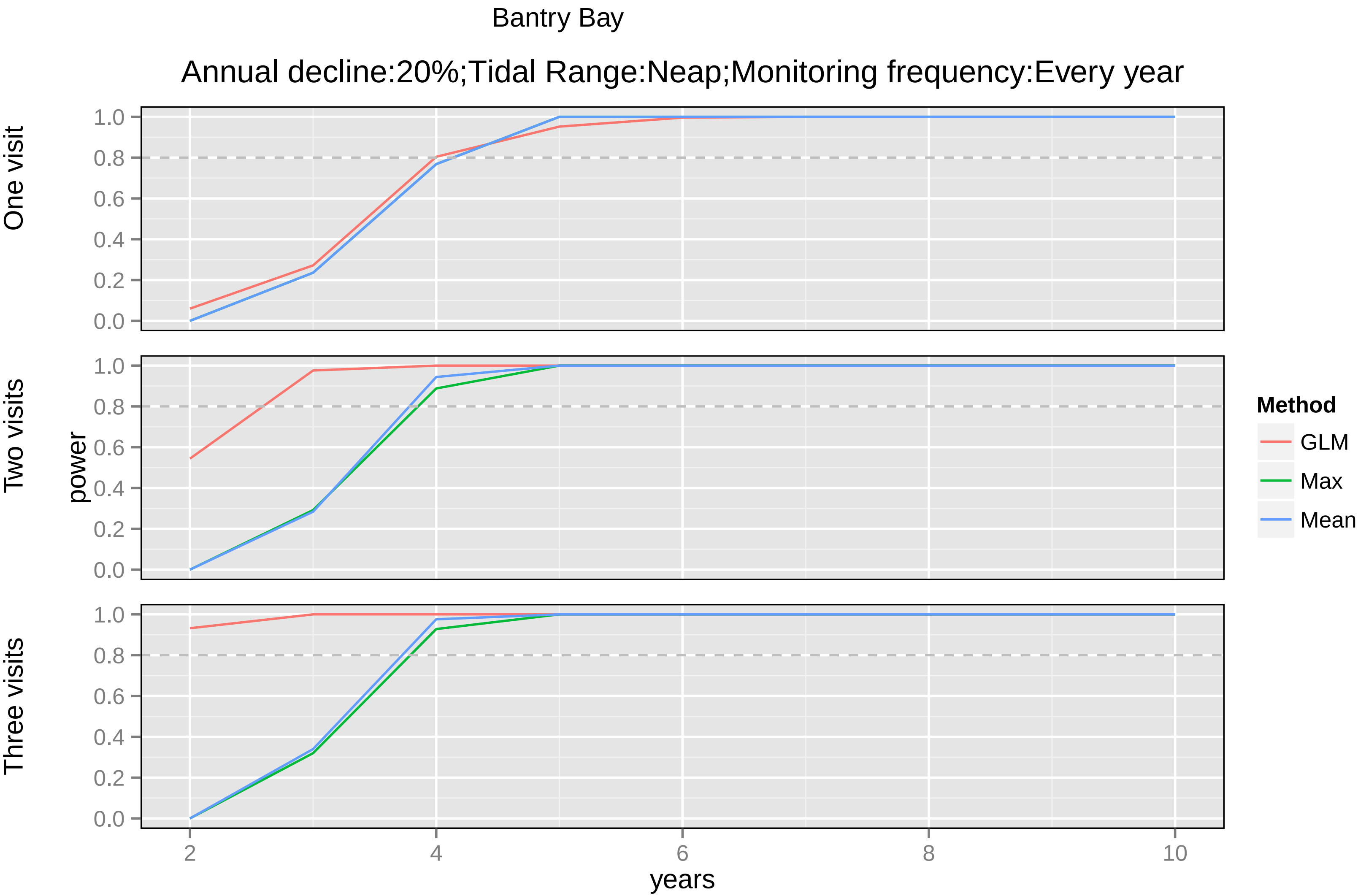
Bantry Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
Two visits
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Method
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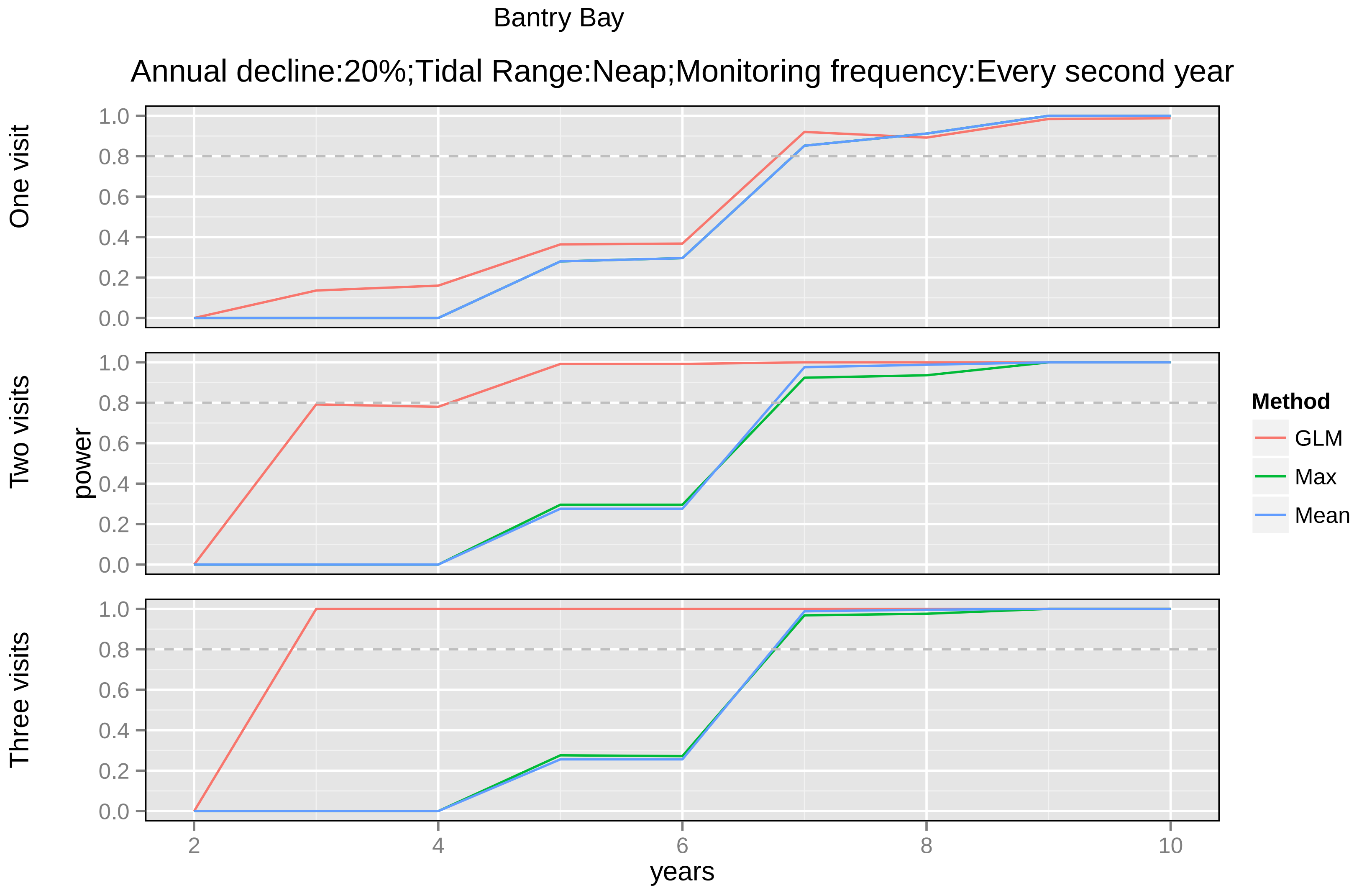

Bantry Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
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Method
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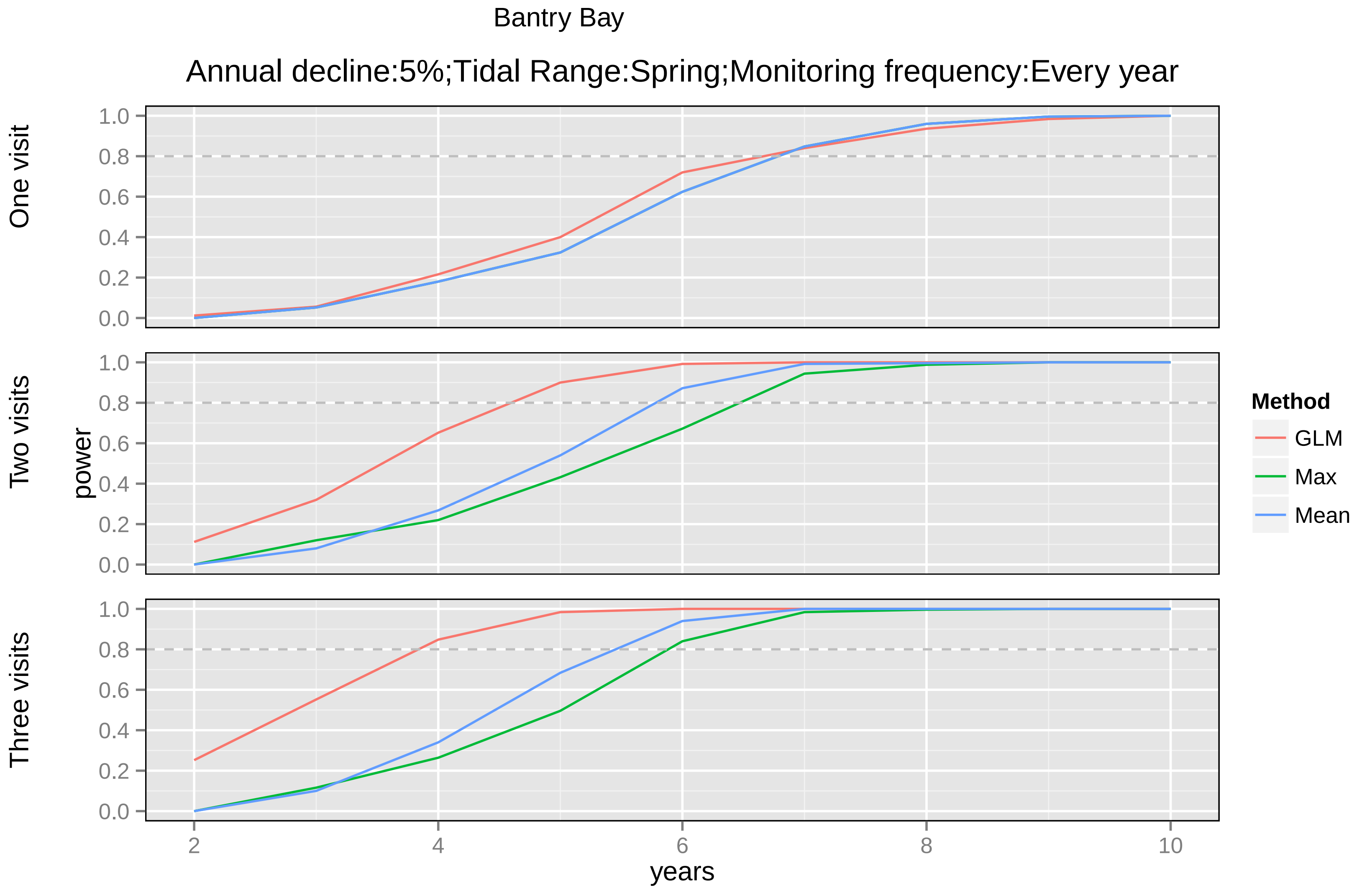
Mean


Bantry Bay
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every year
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Three visits
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Method
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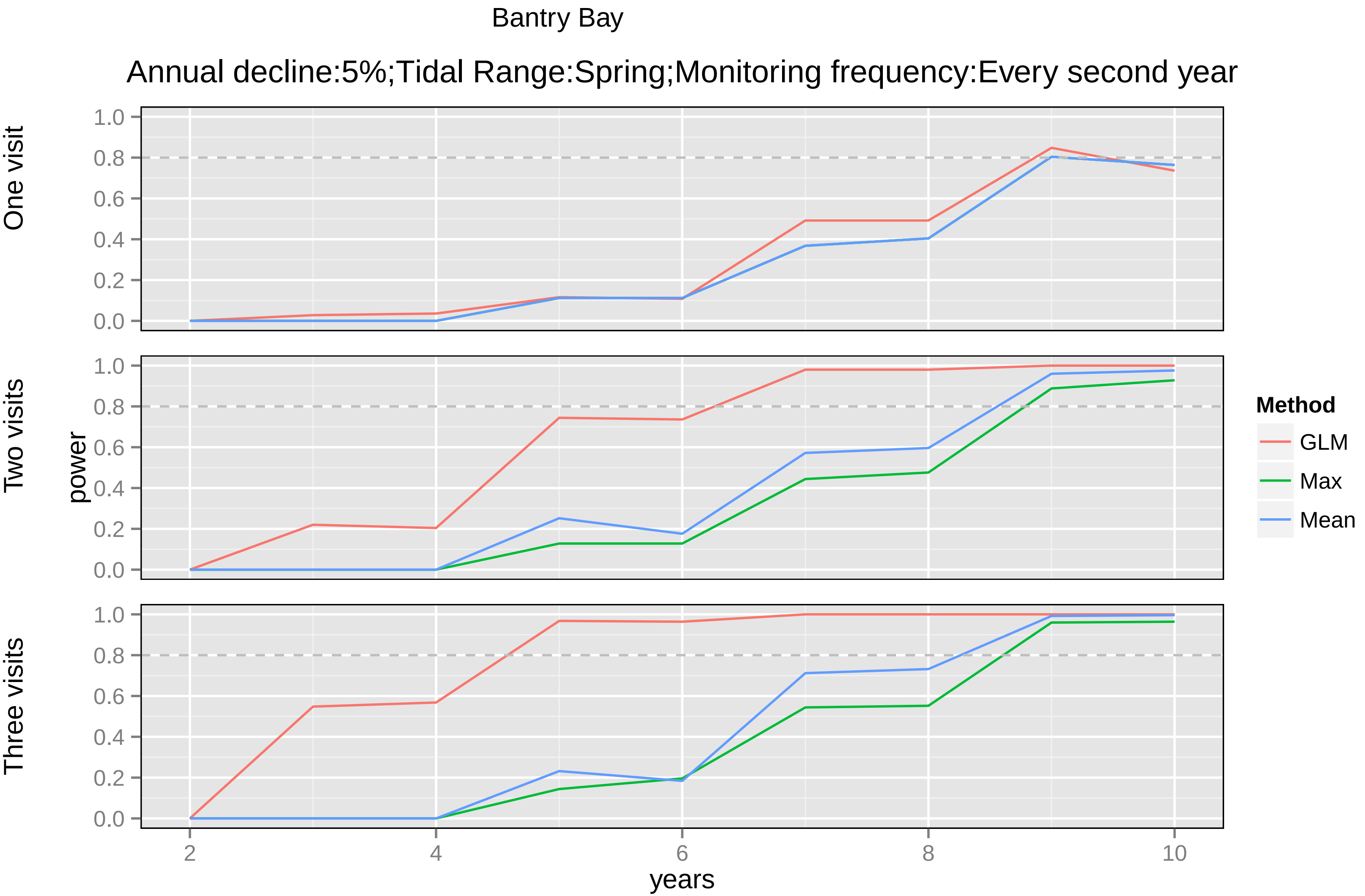

Bantry Bay
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every second year
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Two visits
Three visits
power
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Method
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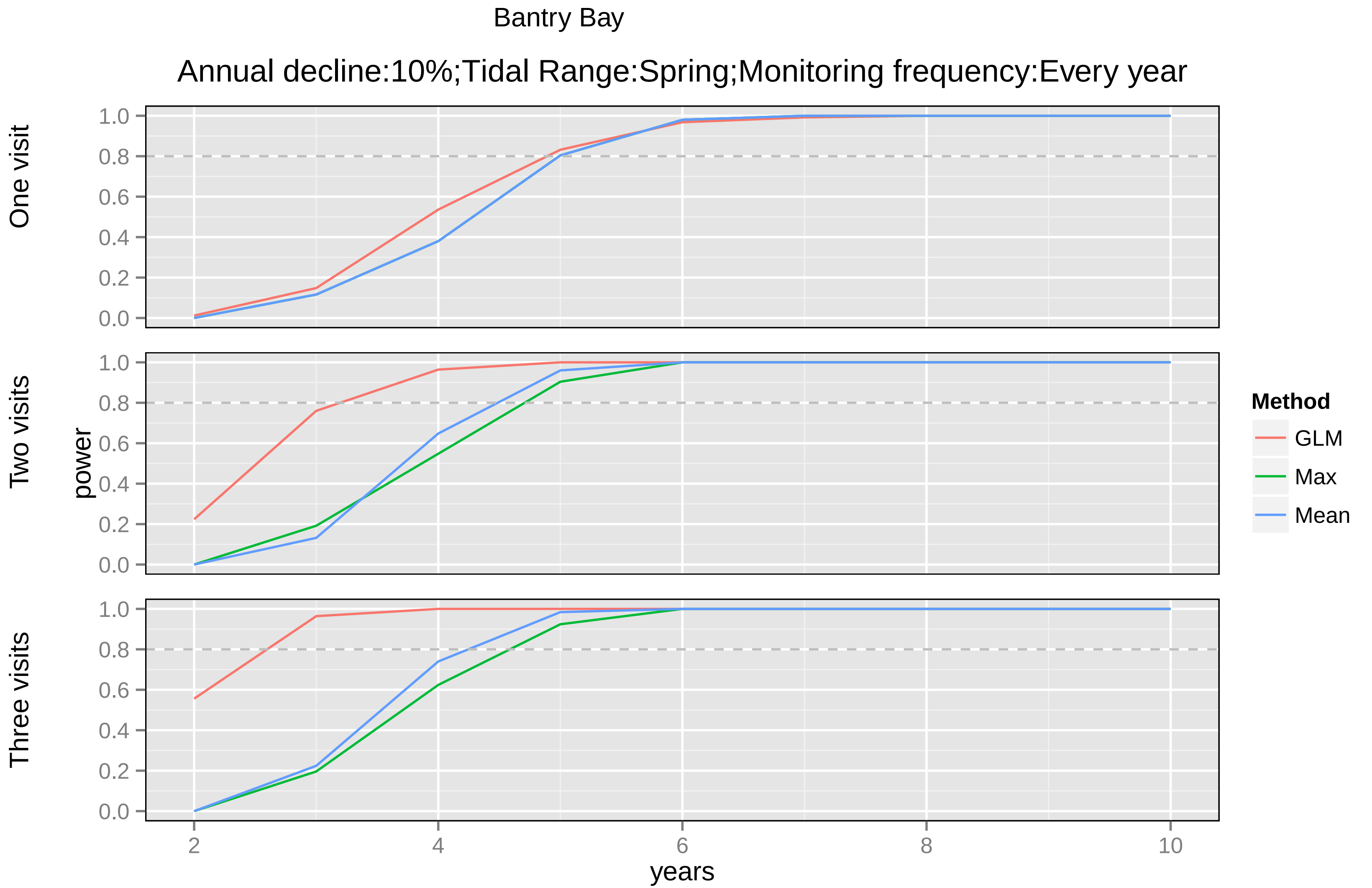
Max
Mean


Bantry Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
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Method
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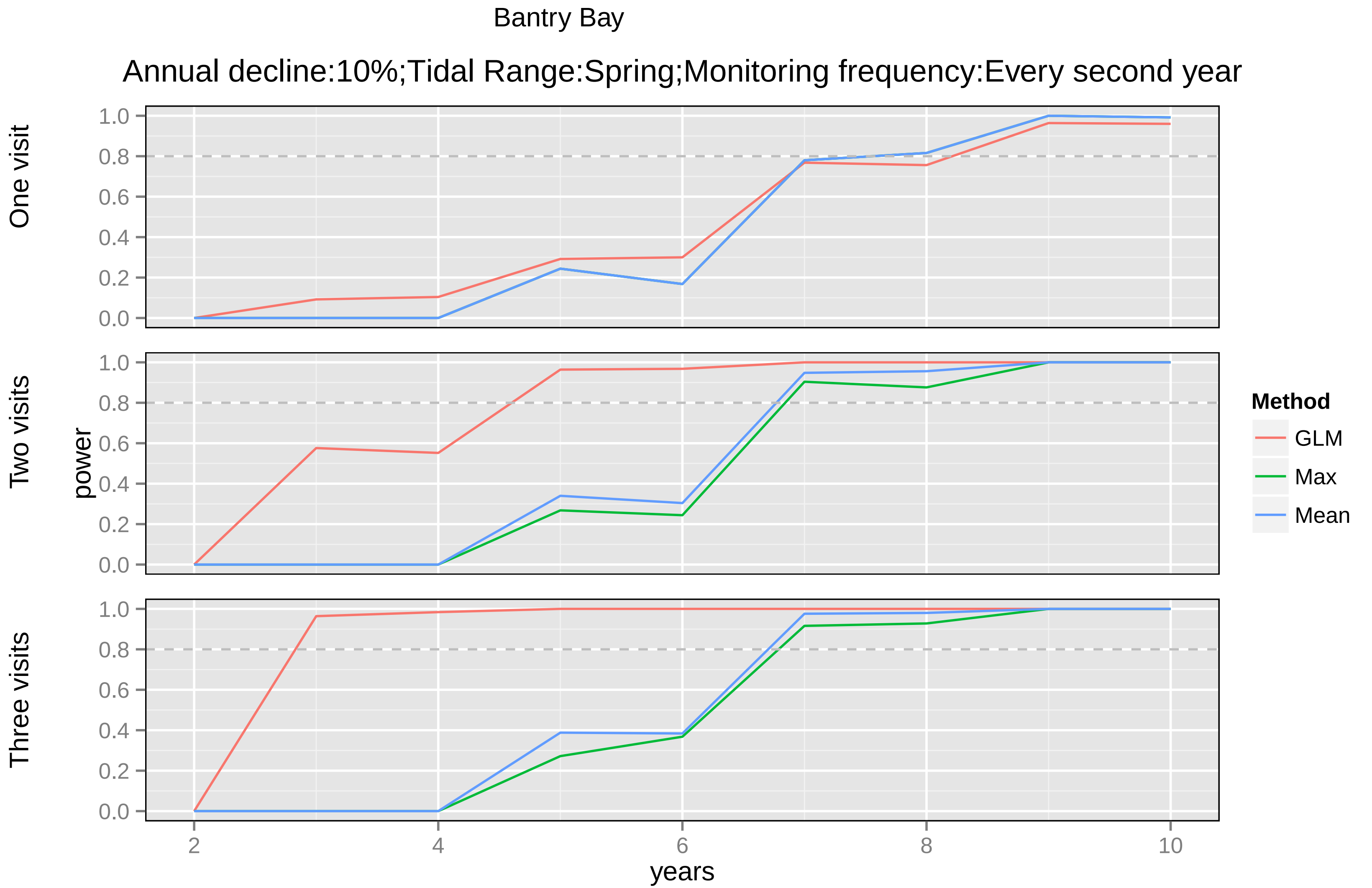

Bantry Bay
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every second year
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Two visits
Three visits
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Method
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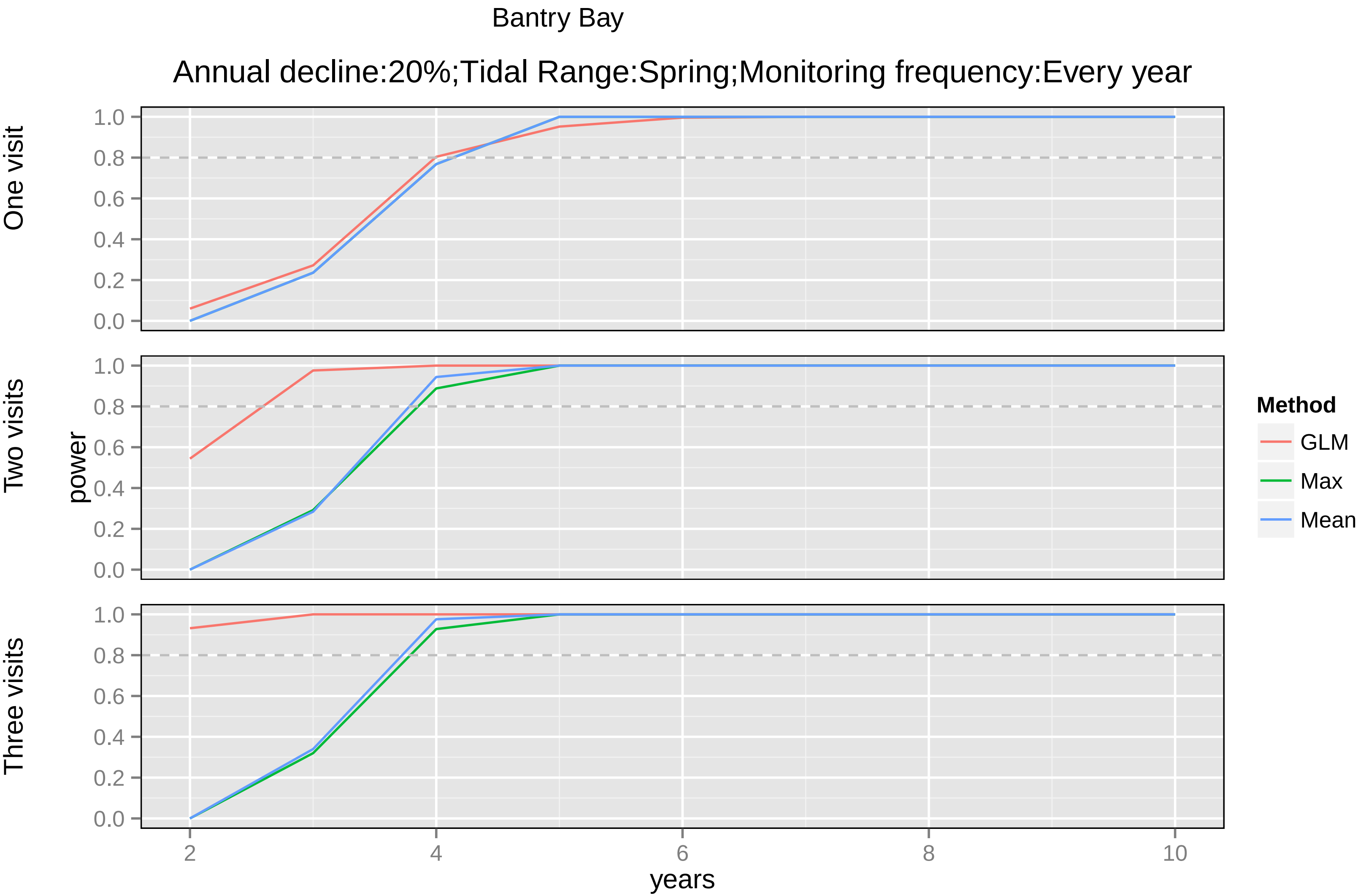
Bantry Bay
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Two visits
Three visits
power
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Method
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Max
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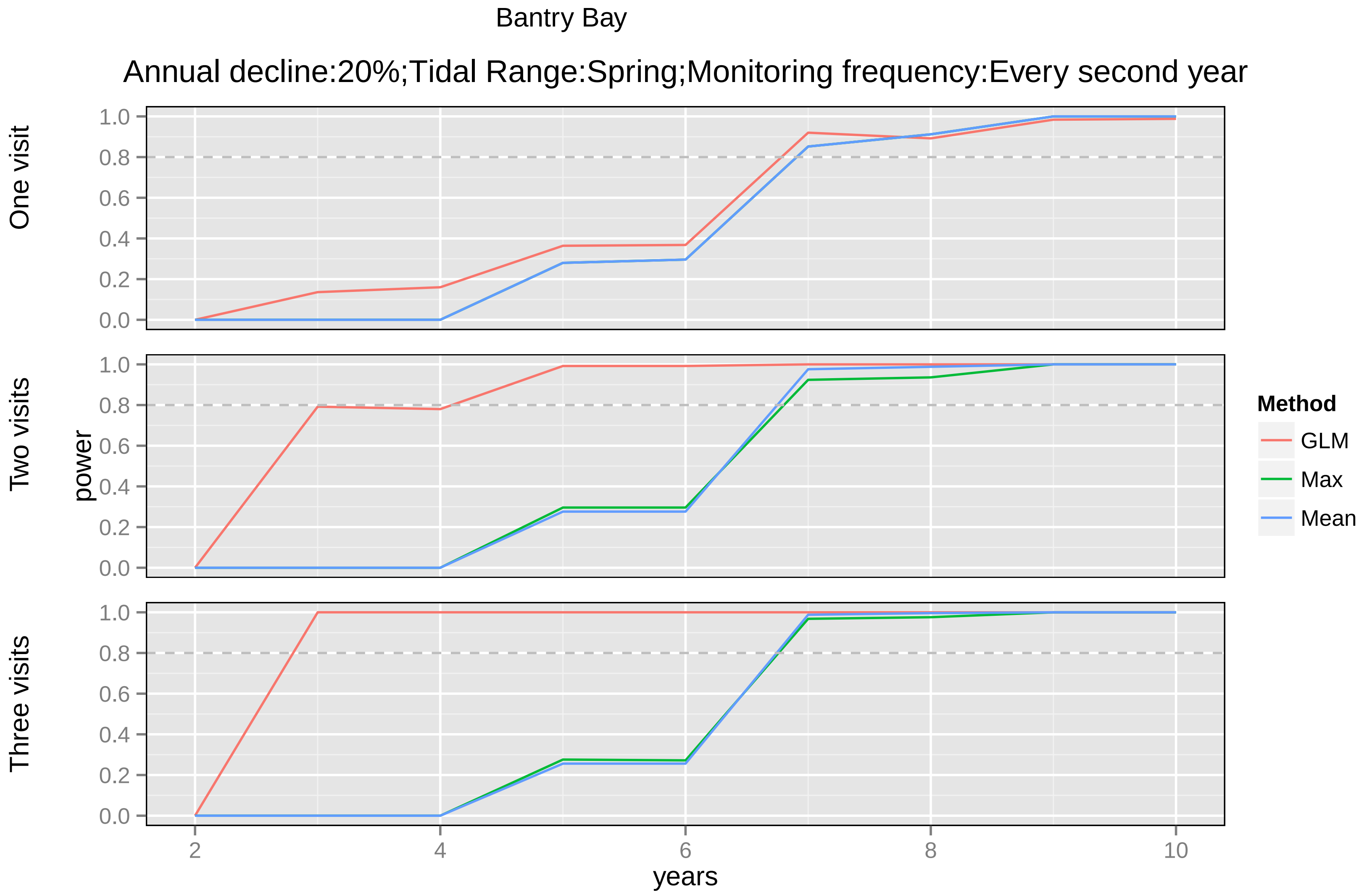

Bantry Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
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Two visits
Three visits
power
years
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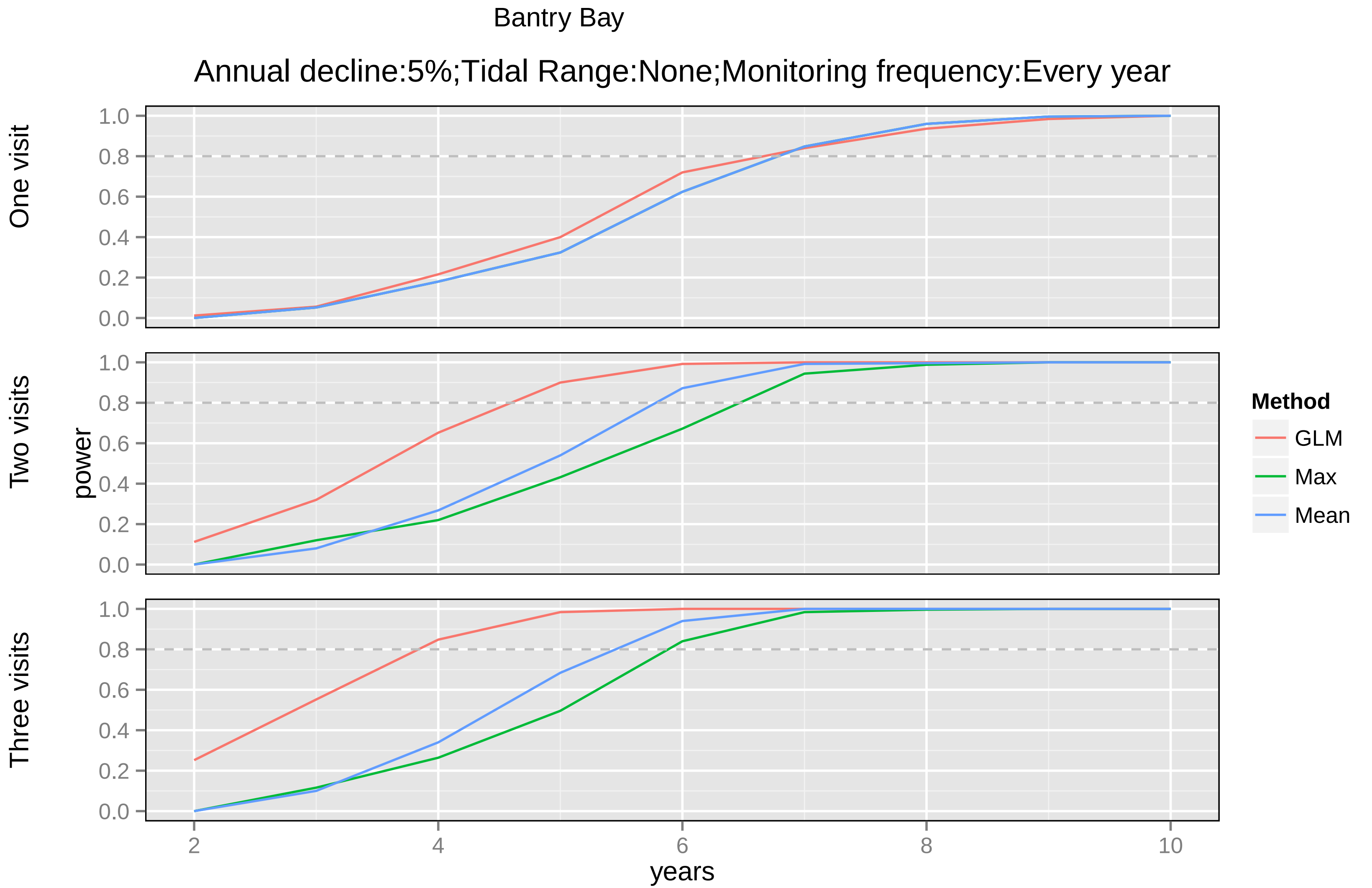
Method
GLM
Max
Mean


Bantry Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
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Two visits
Three visits
power
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Method
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Max
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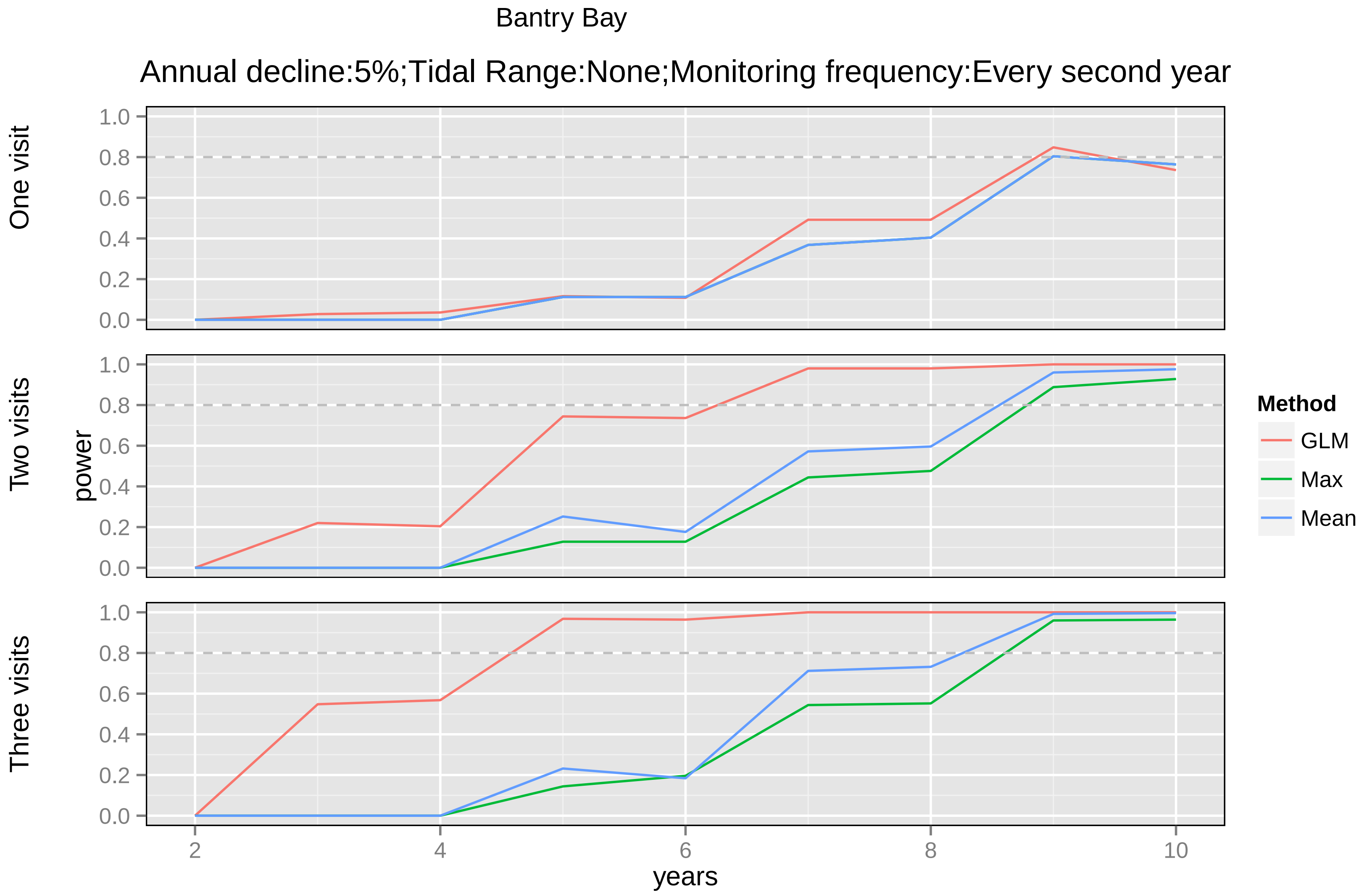
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power
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Method
GLM
Max
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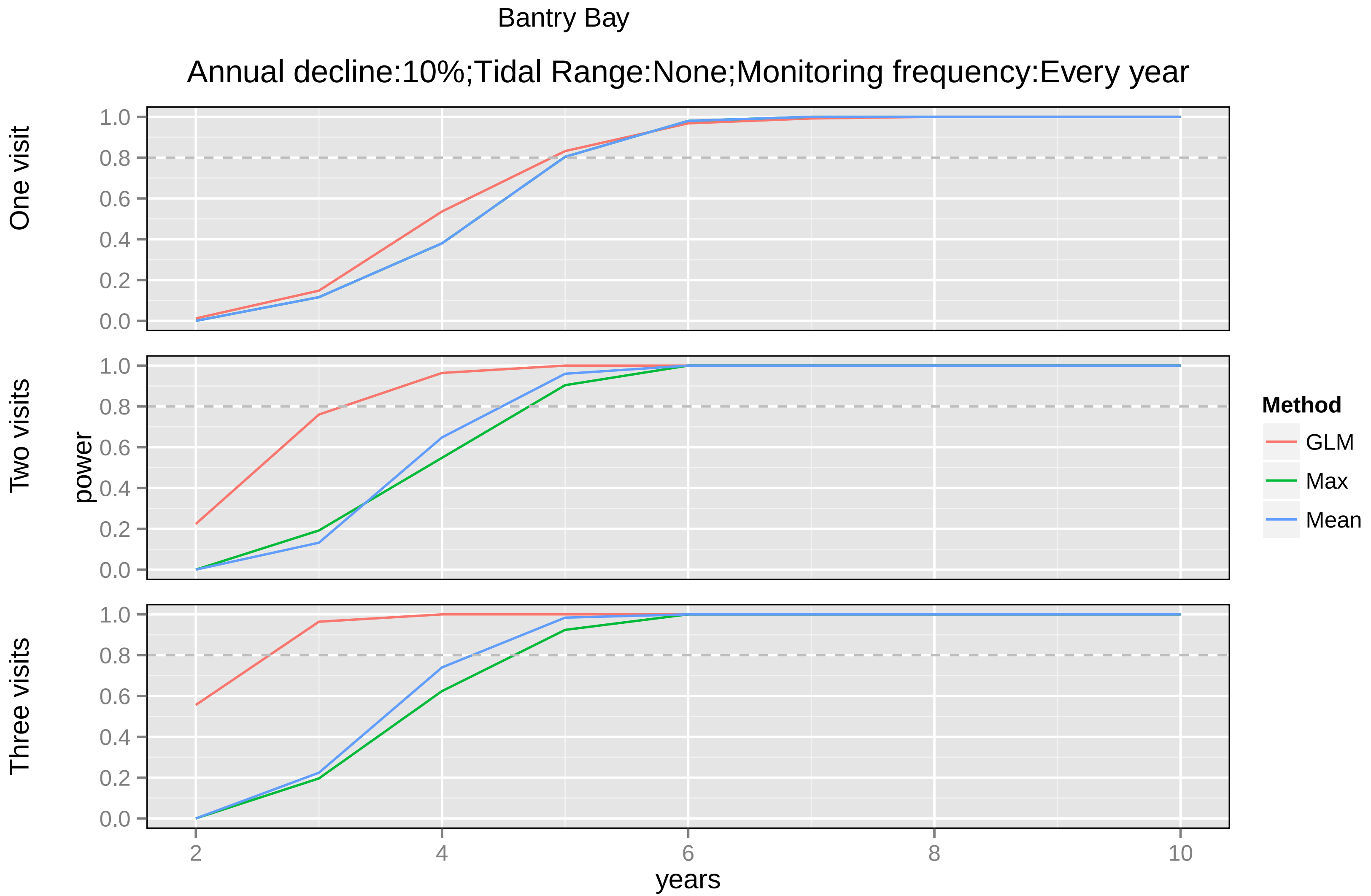

Bantry Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
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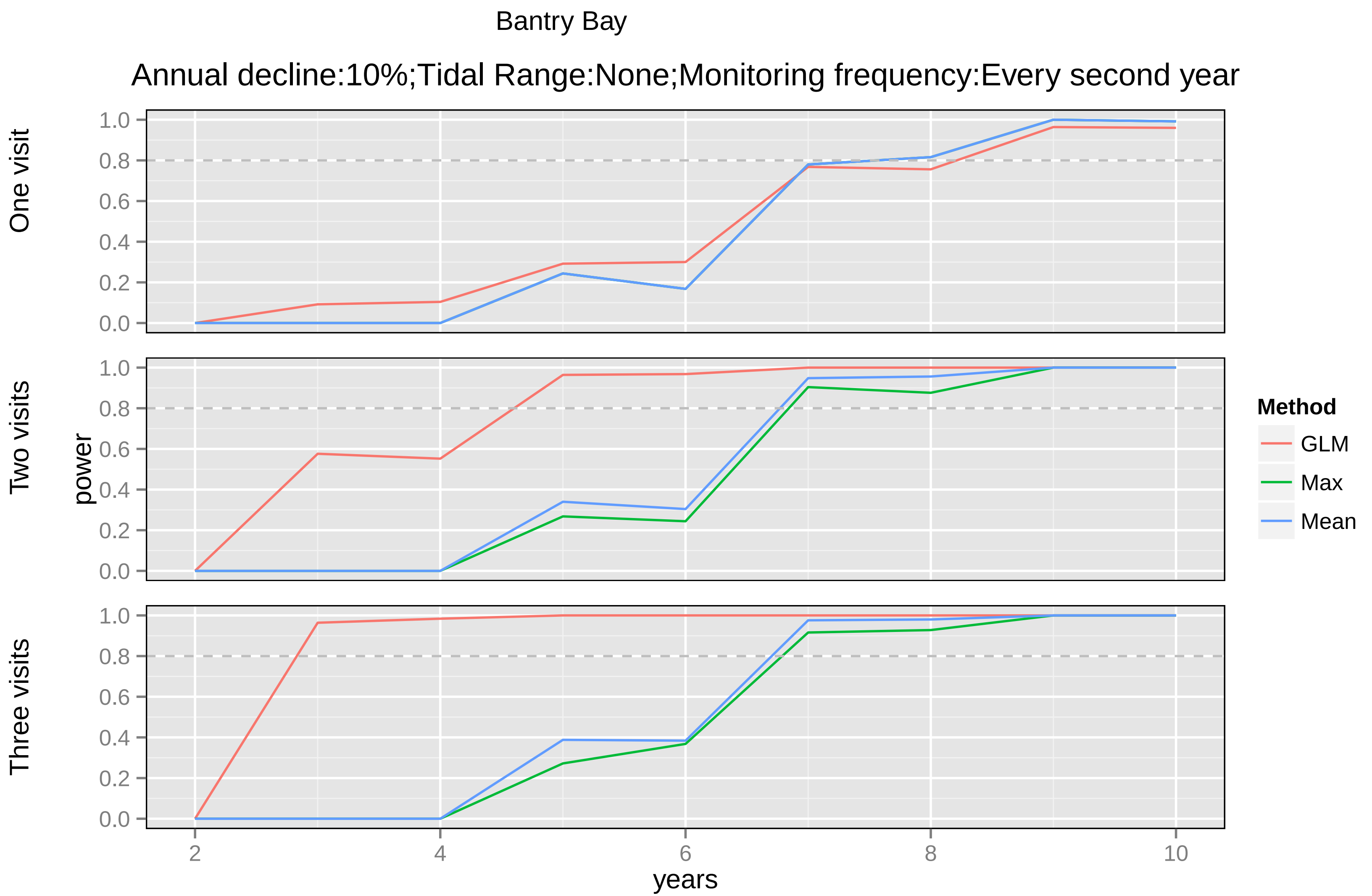
Method
GLM
Max
Mean



Bantry Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
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years
Method
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Max
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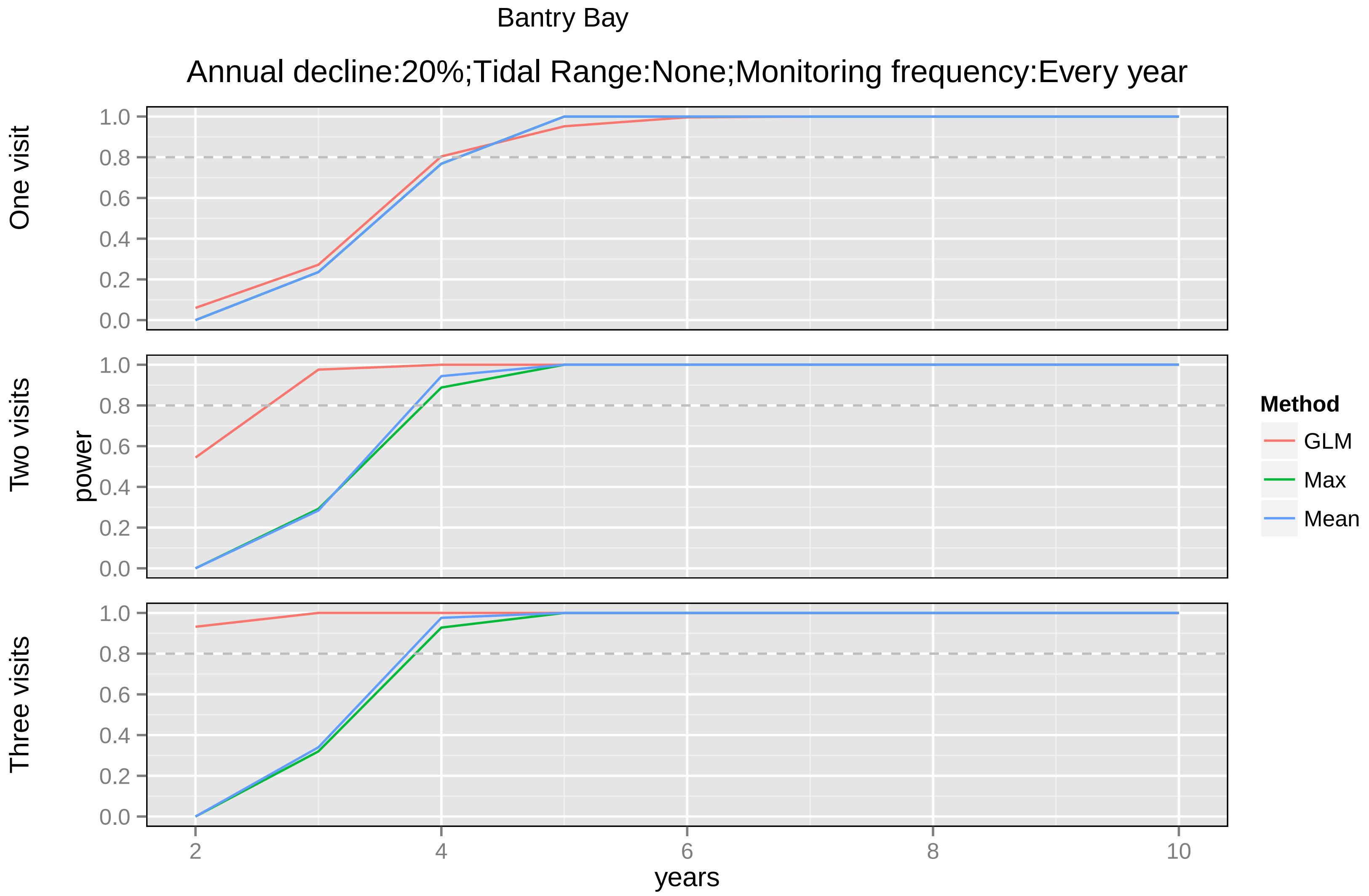
Bantry Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every year
One visit
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Three visits
power
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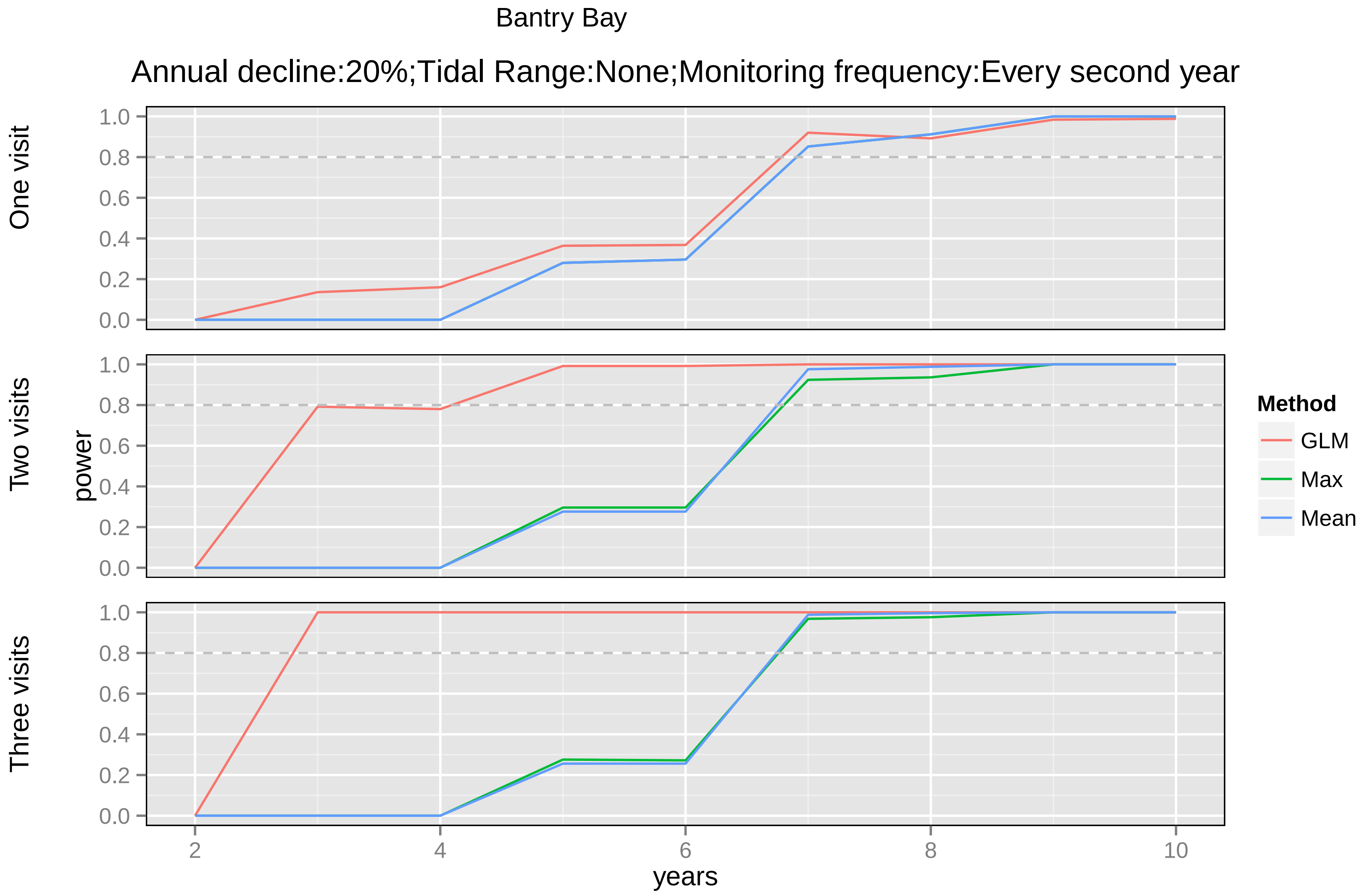
Method
GLM
Max
Mean


Bantry Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
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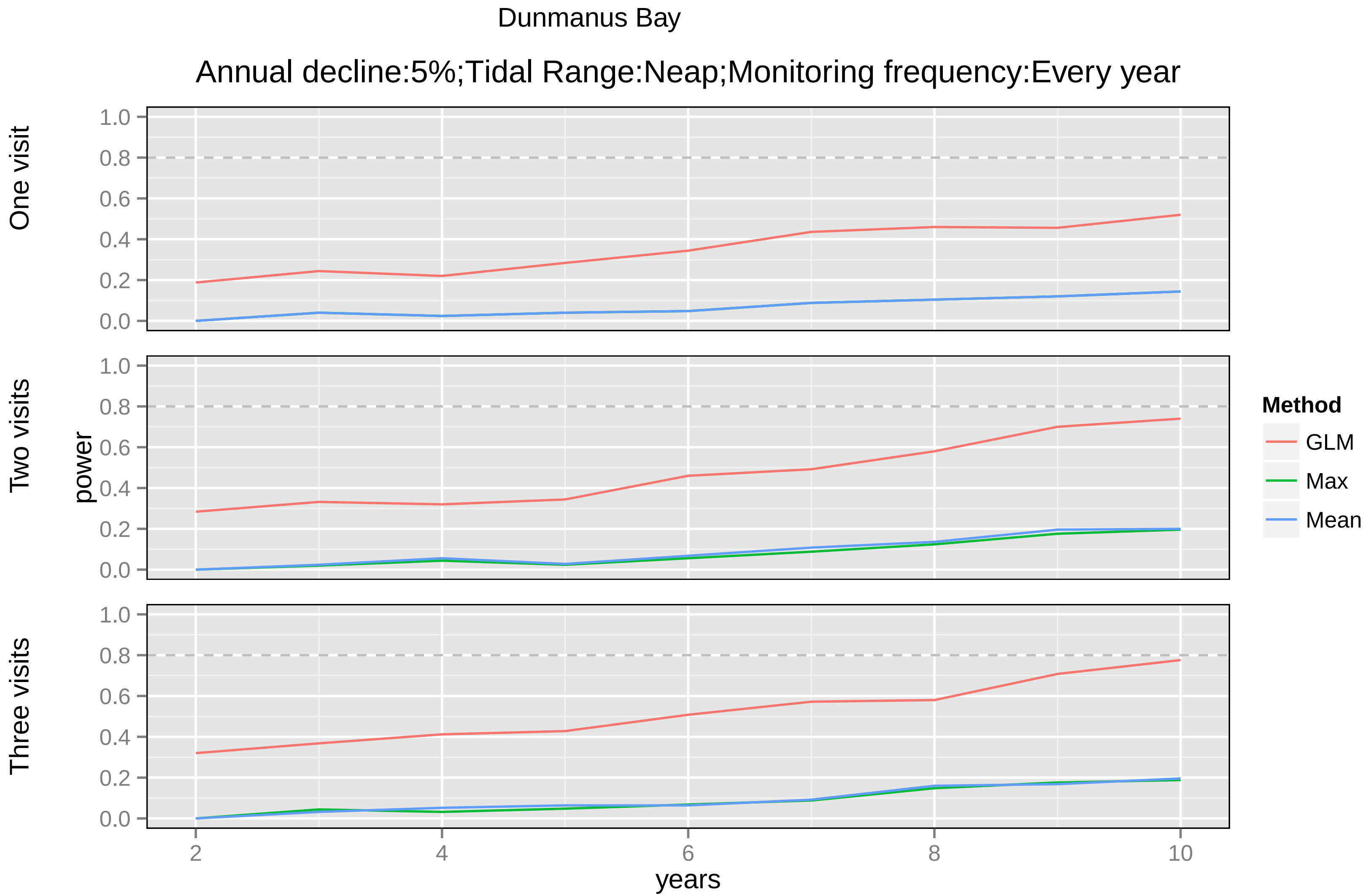
years
Method
GLM
Max
Mean


Dunmanus Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
years
Method
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Mean
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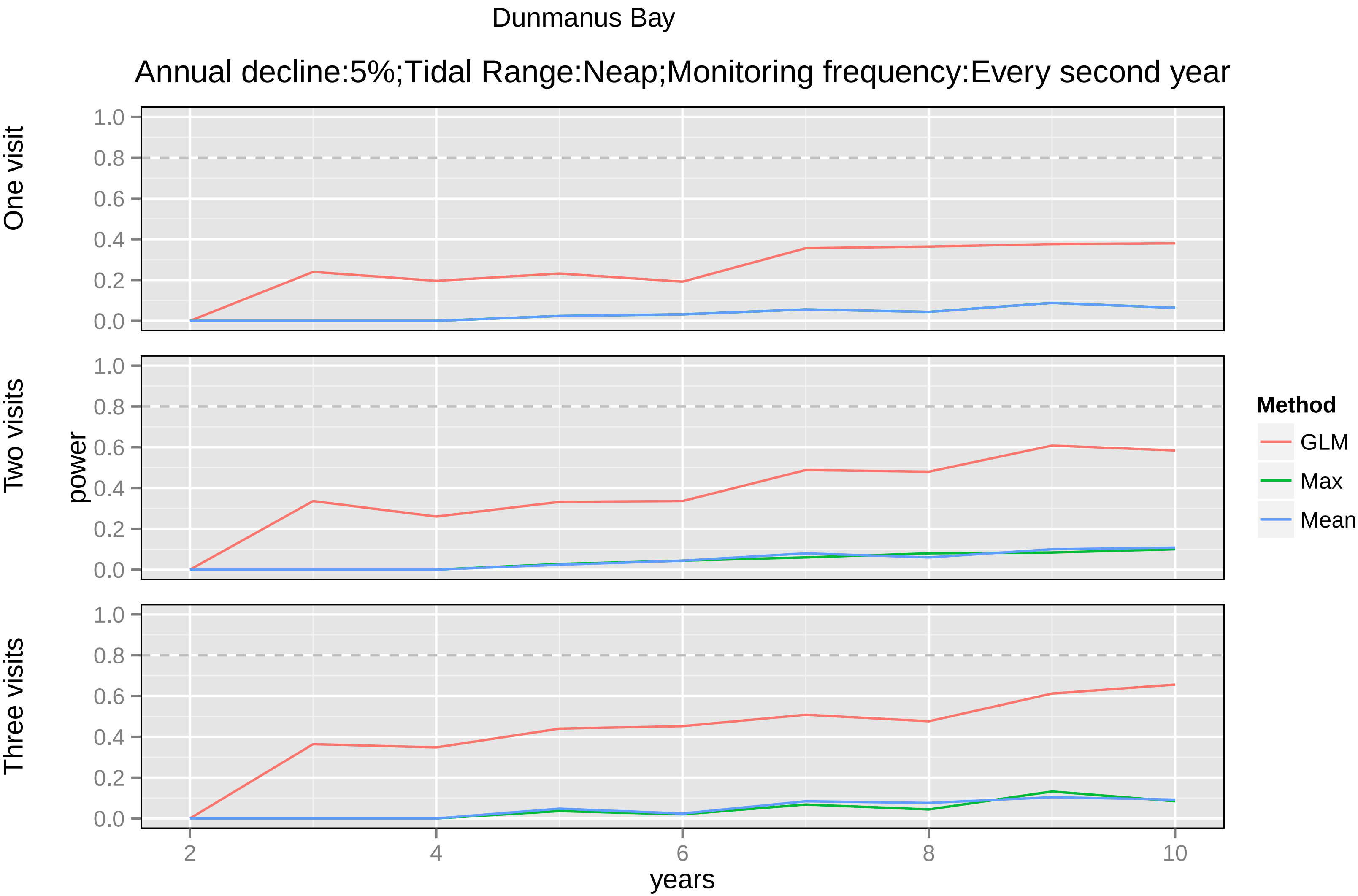
Dunmanus Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
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Two visits
Three visits
power
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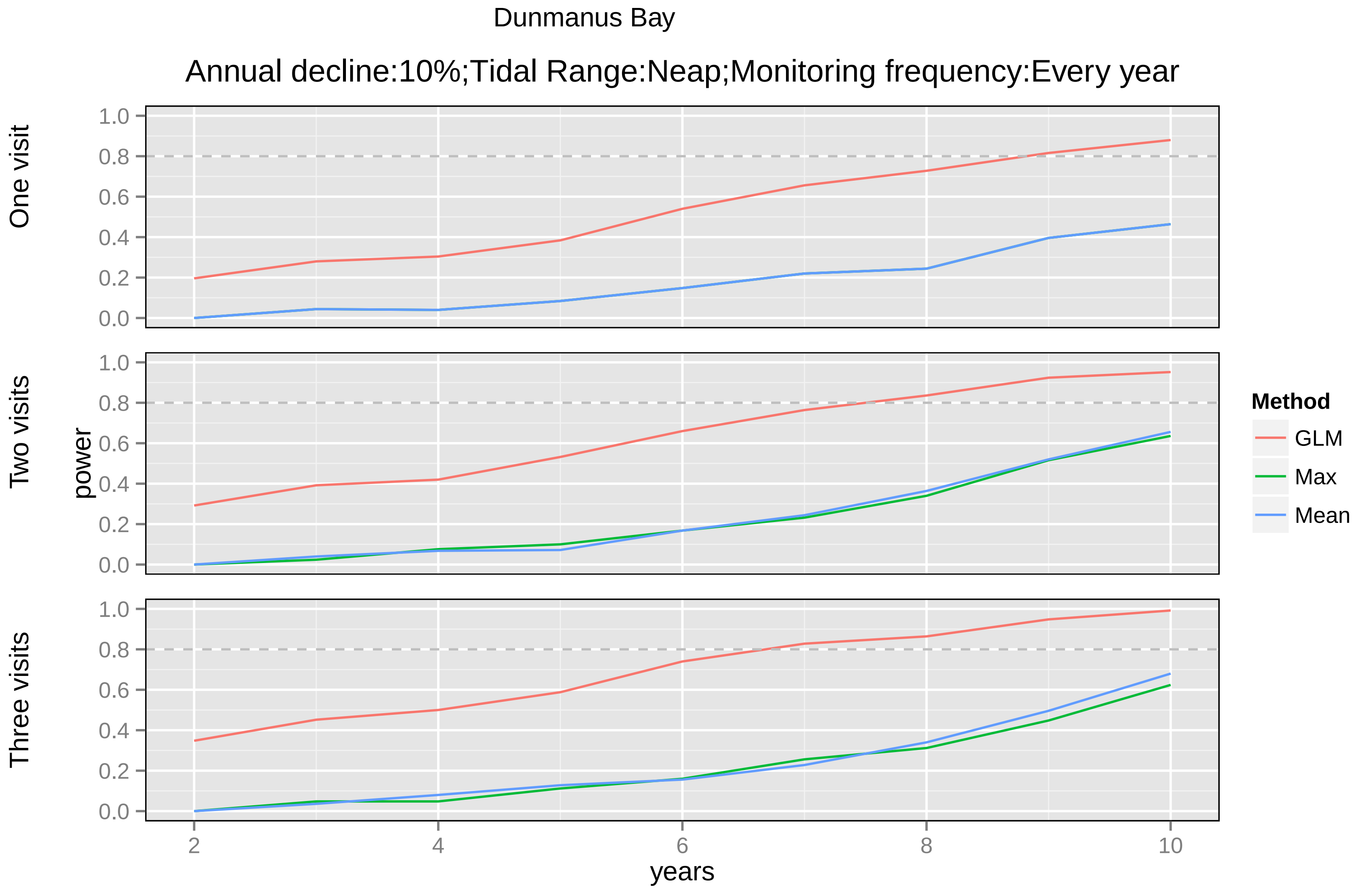

Dunmanus Bay
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One visit
Two visits
Three visits
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Method
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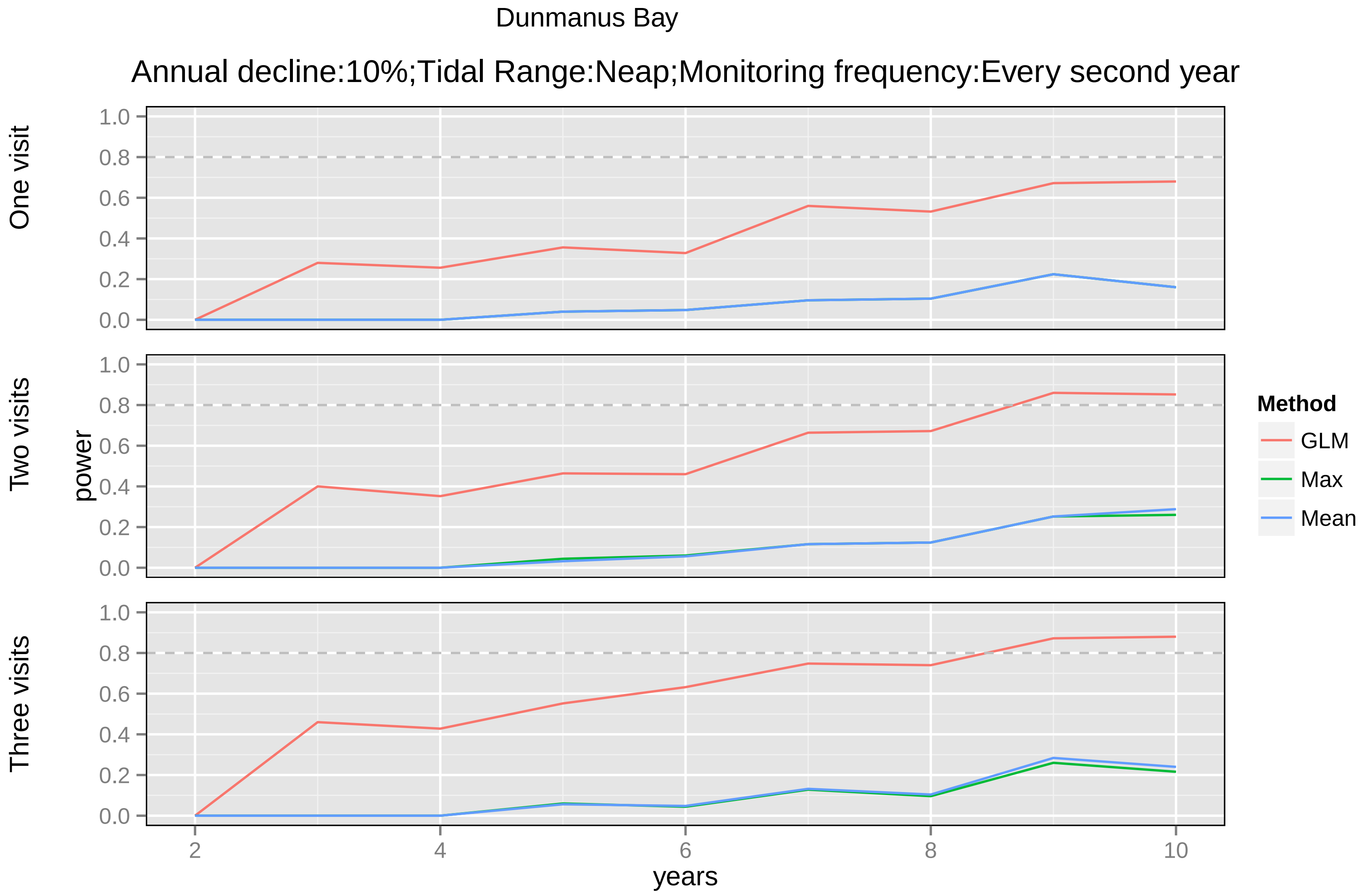

Dunmanus Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every second year
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Three visits
power
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Method
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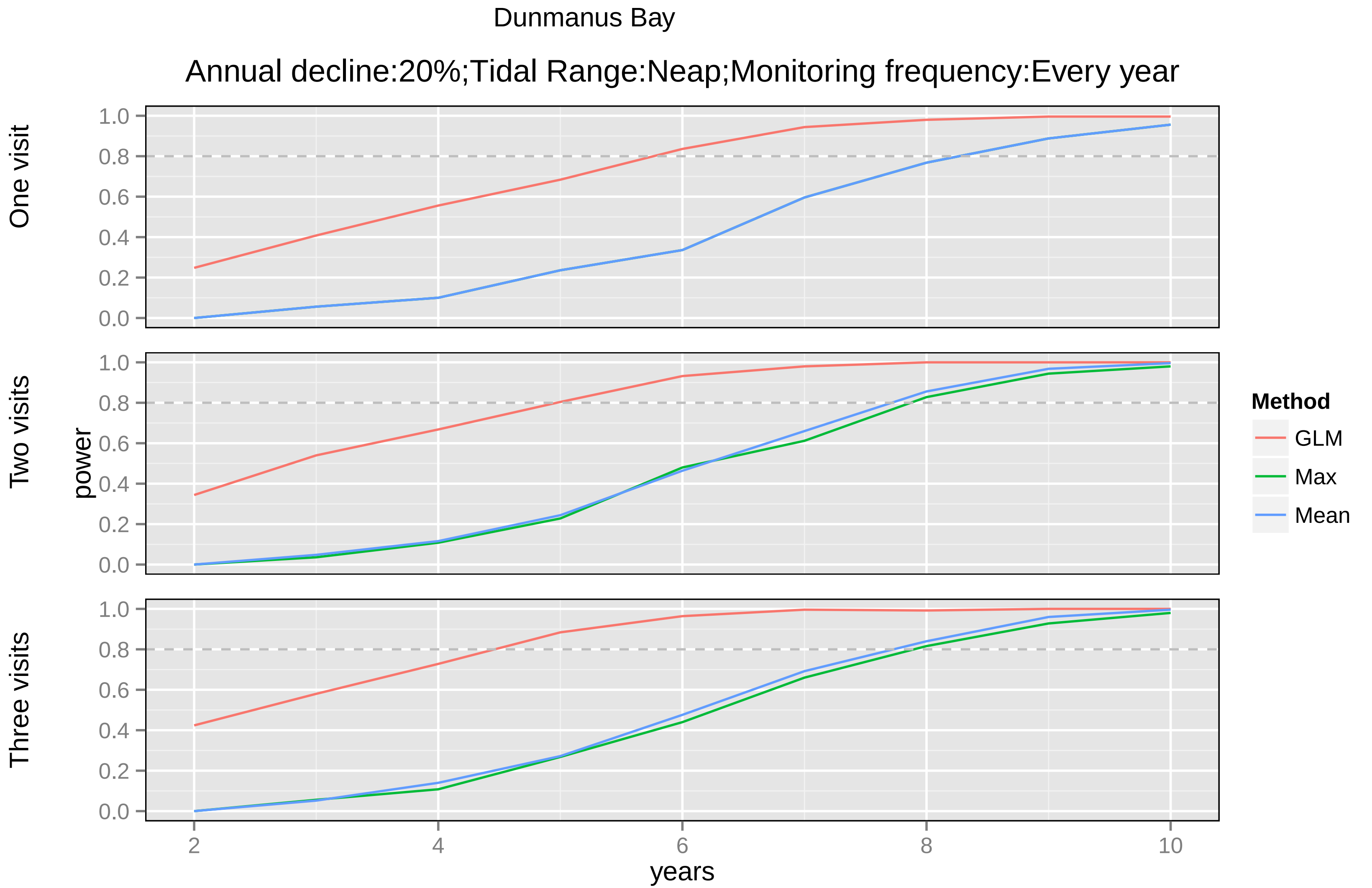
Max
Mean



Dunmanus Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
Two visits
Three visits
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Method
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Max
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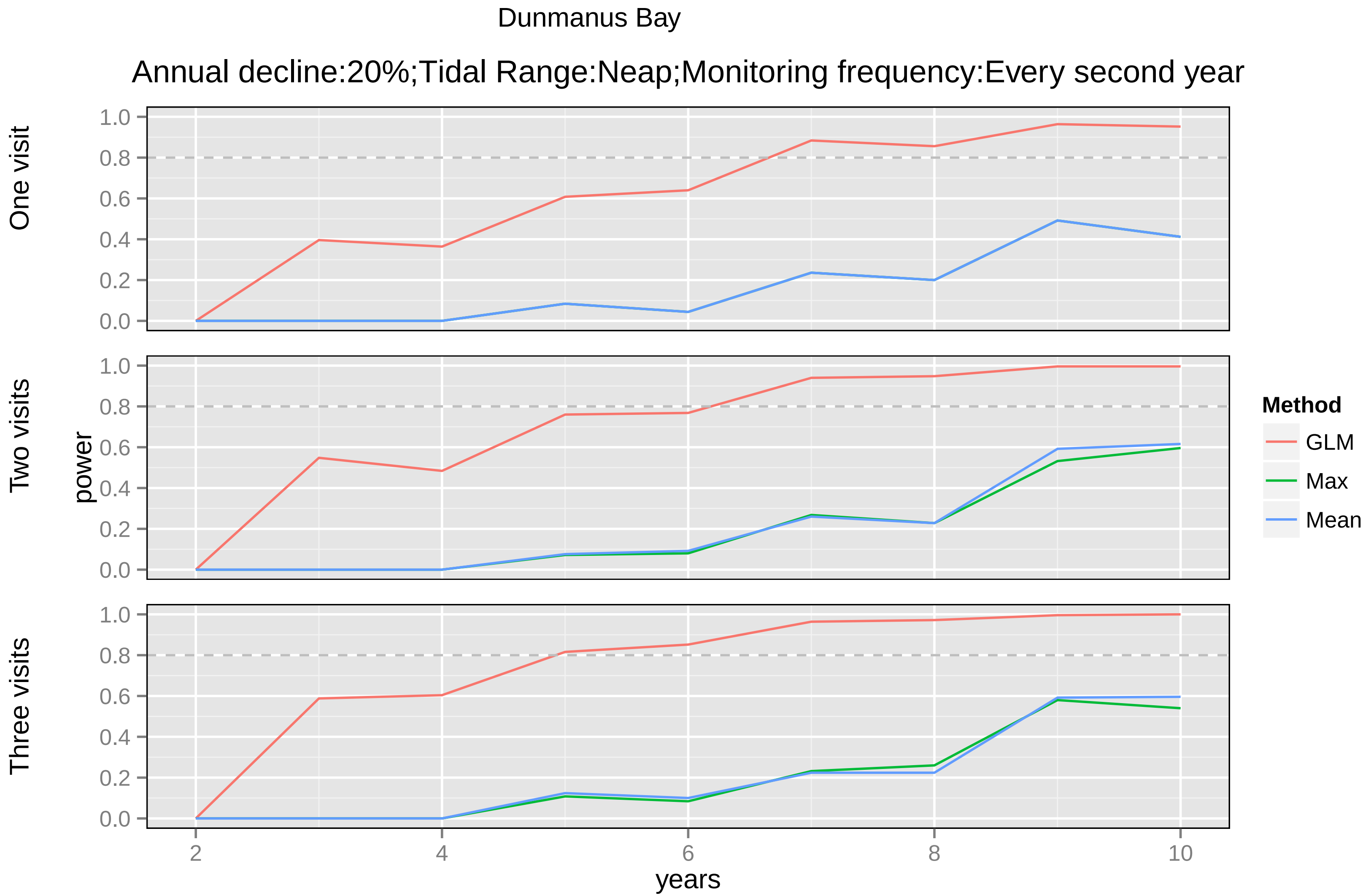
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Three visits
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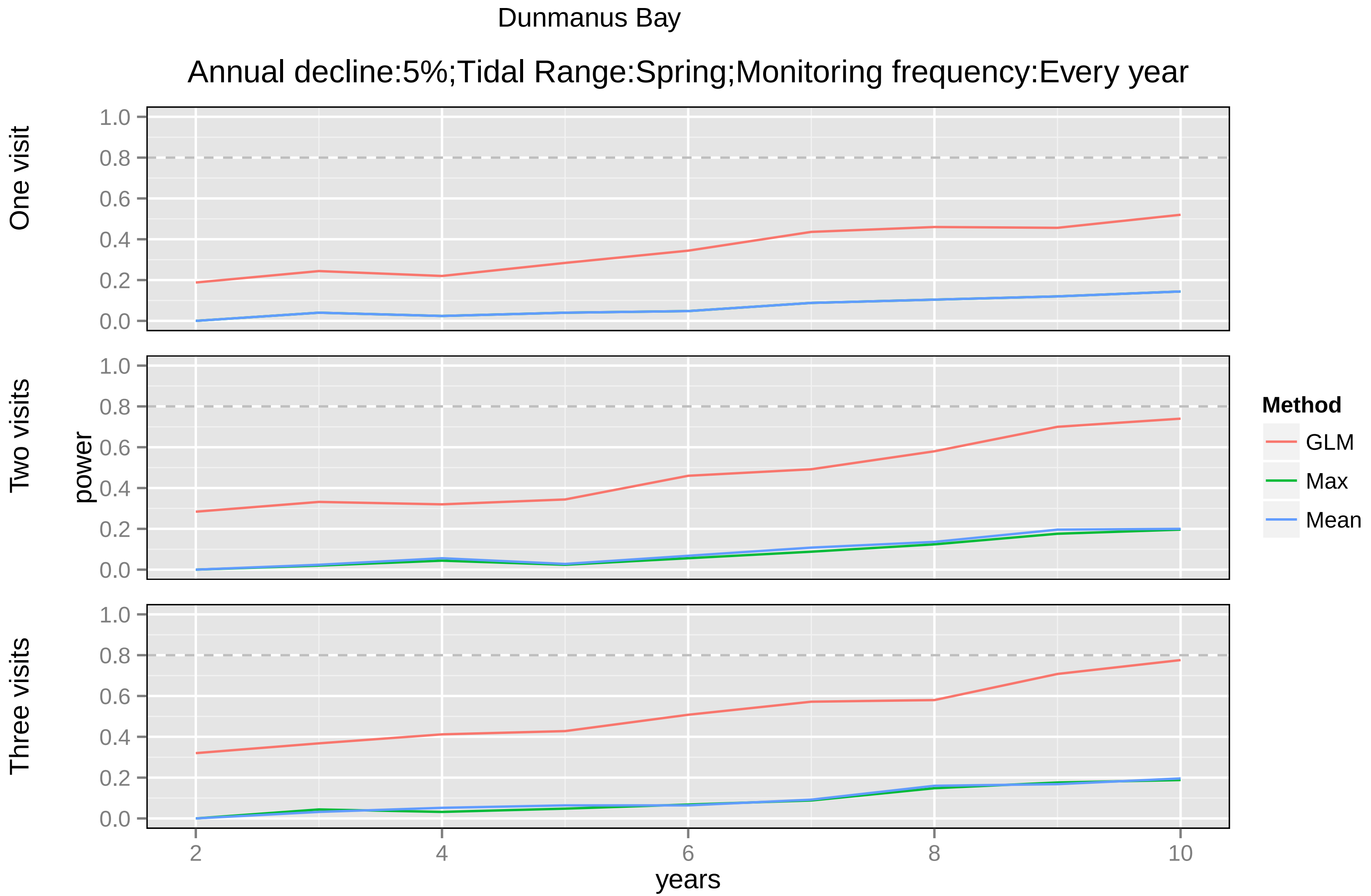

Dunmanus Bay
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Three visits
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Method
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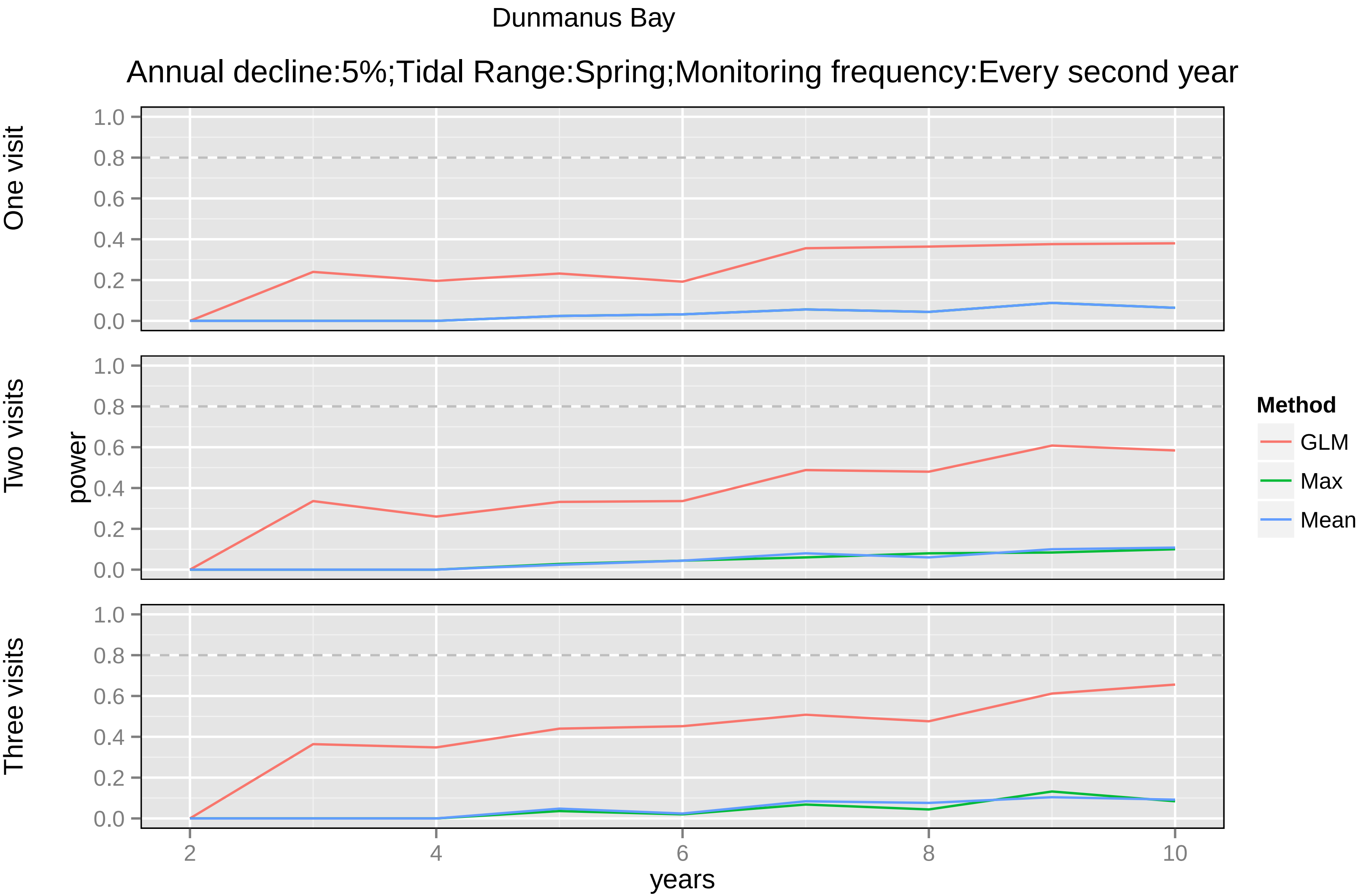
Mean


Dunmanus Bay
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years
Method
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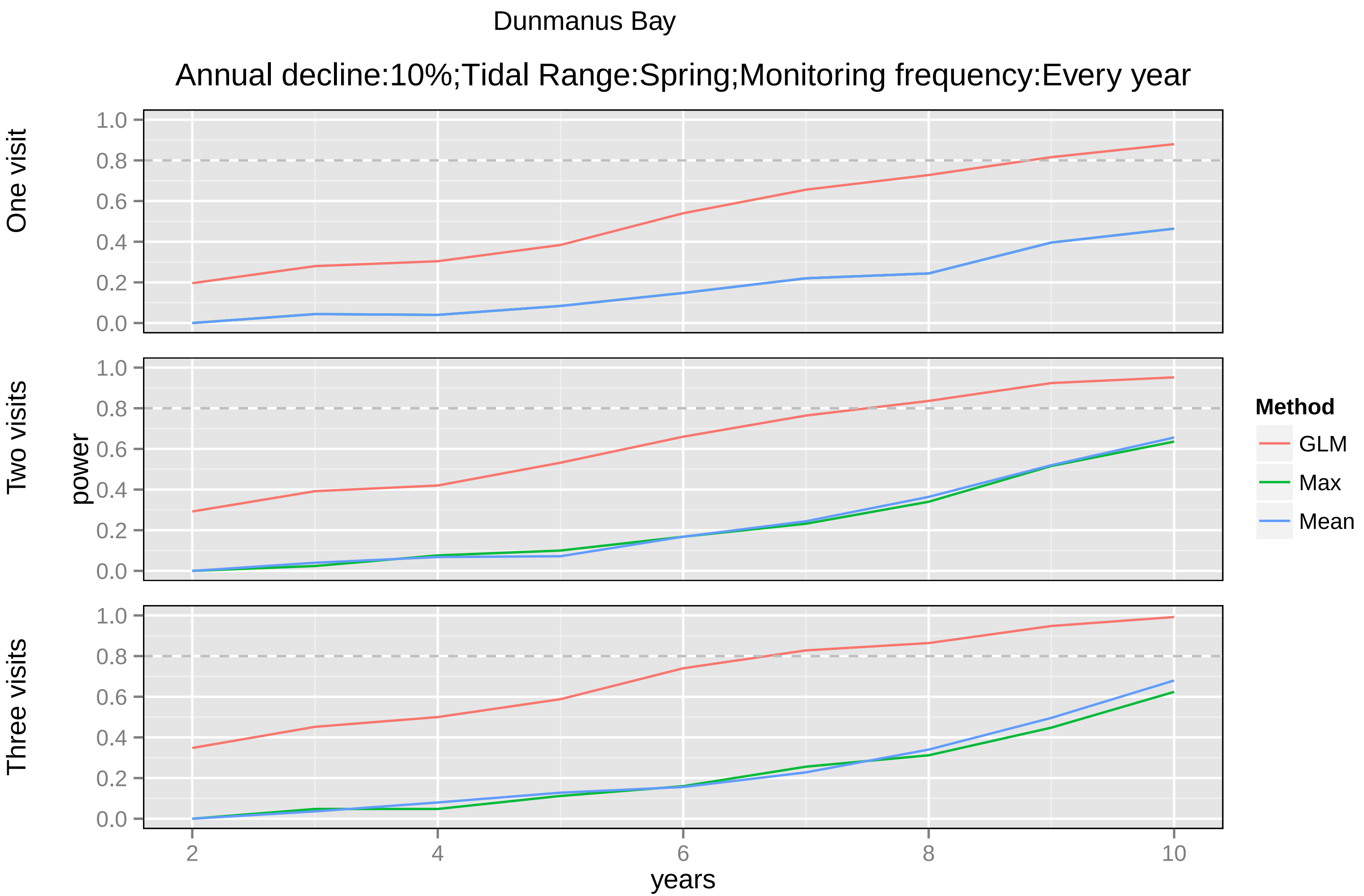
Mean


Dunmanus Bay
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Three visits
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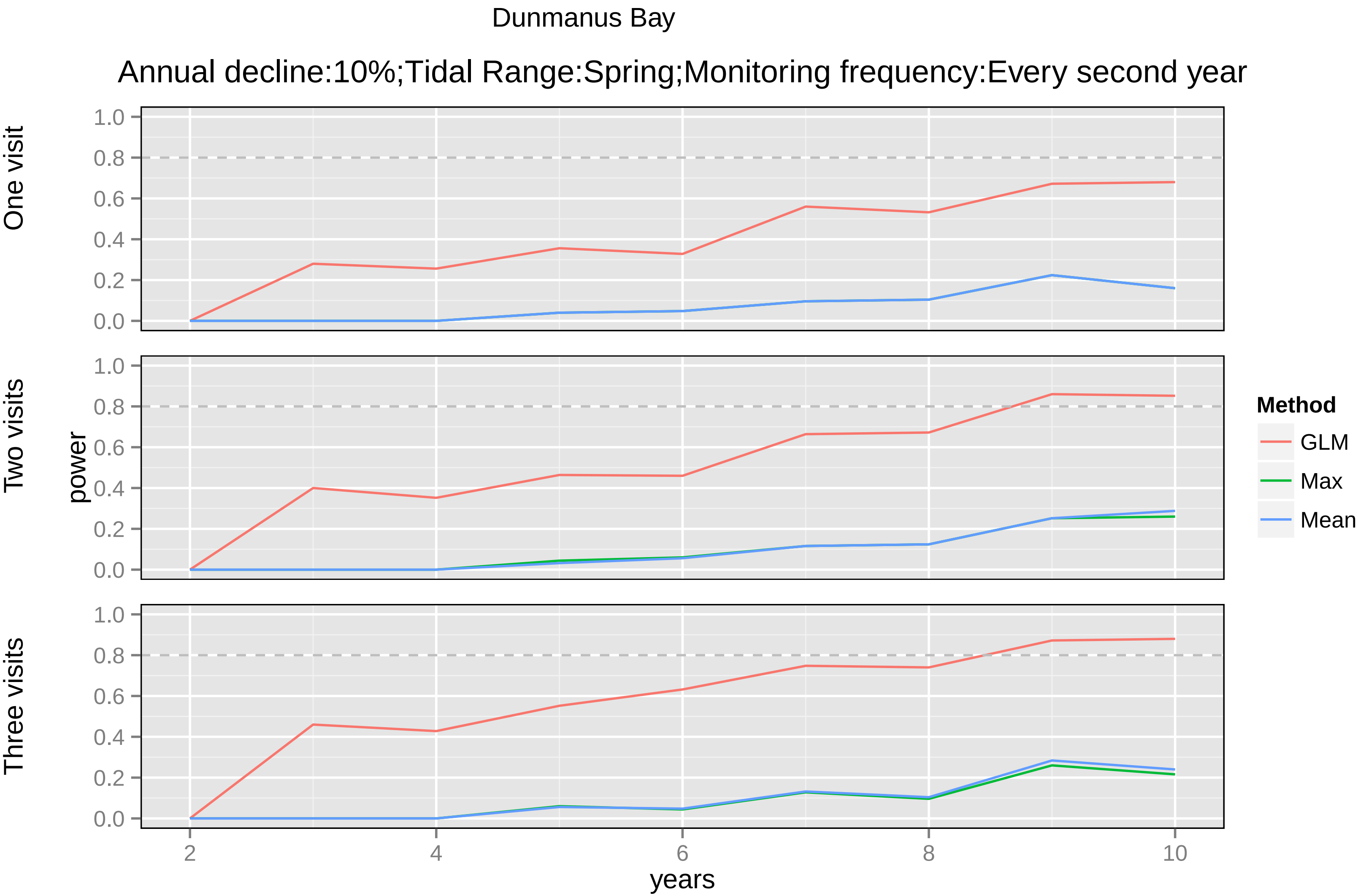

Dunmanus Bay
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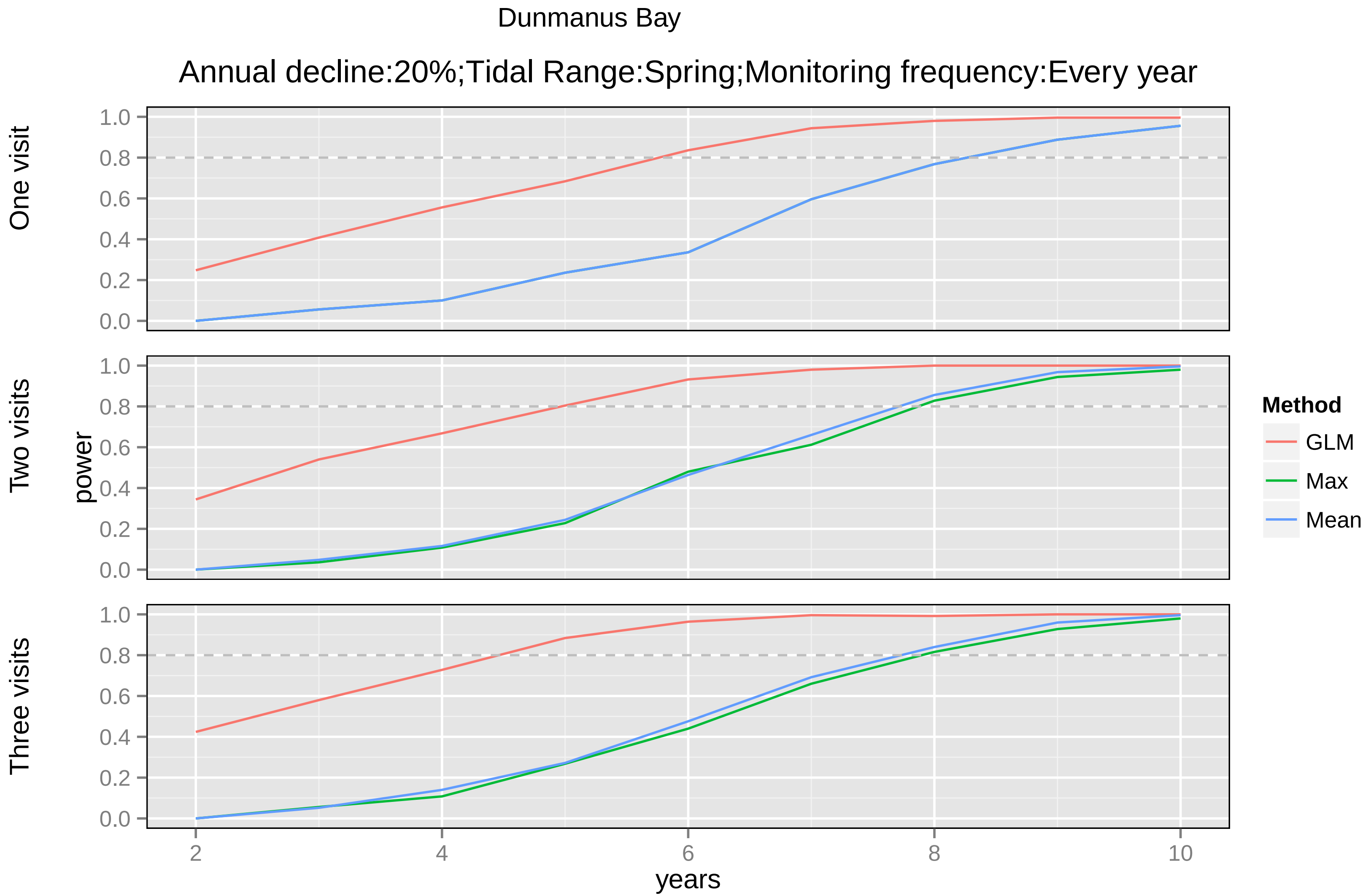
Dunmanus Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every year
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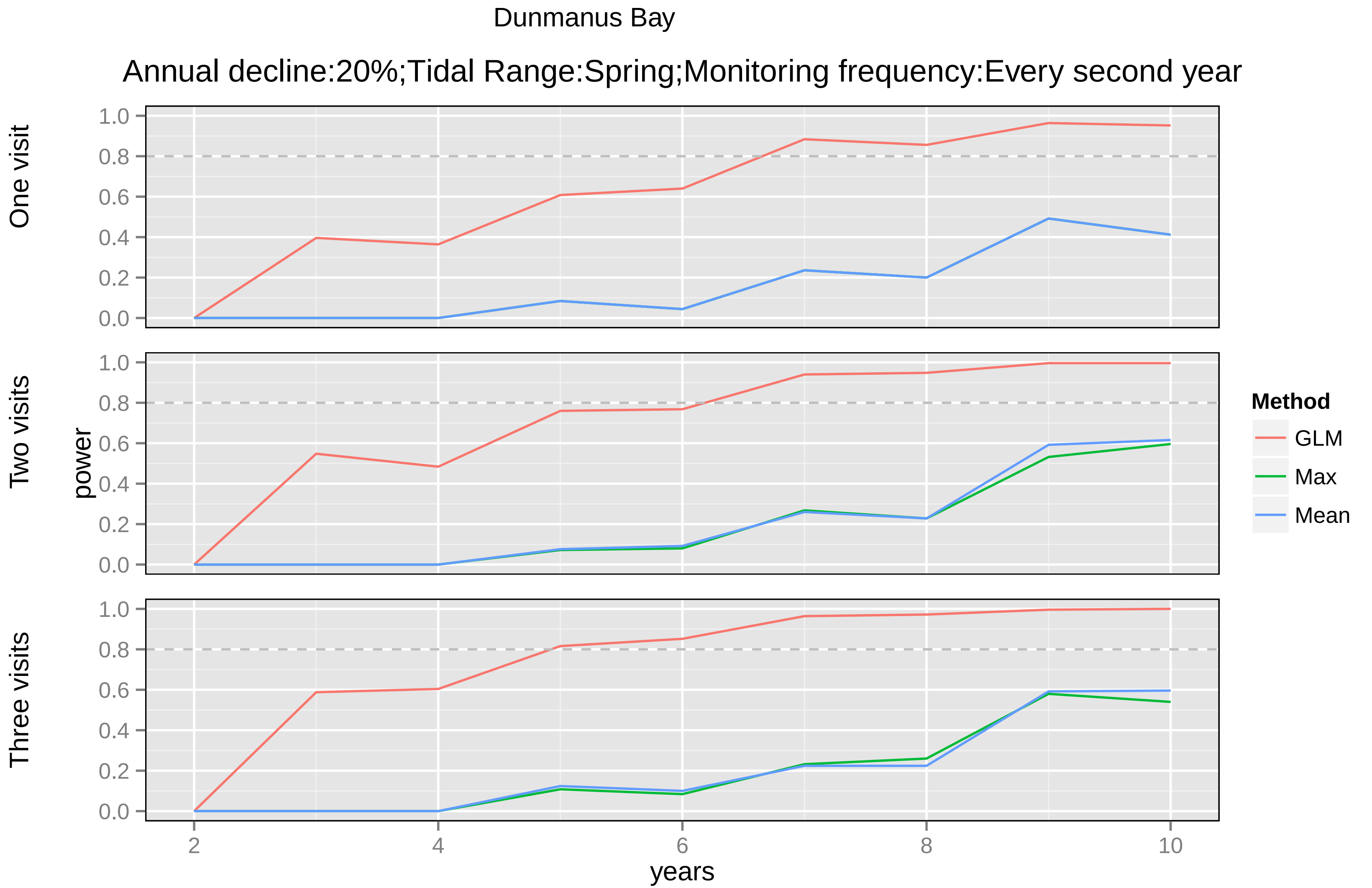
Max
Mean


Dunmanus Bay
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
years
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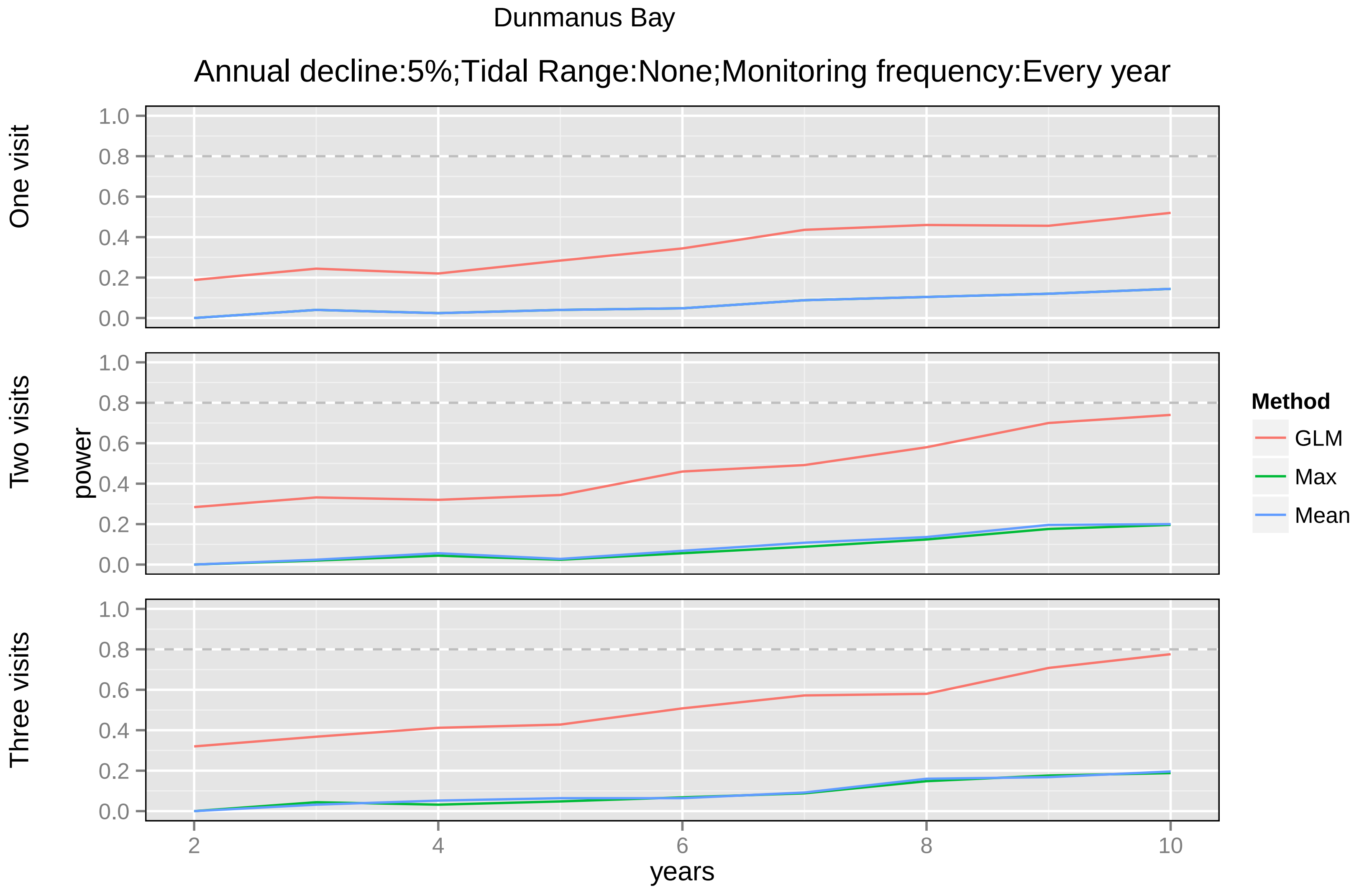
0.6
0.4
0.2
0.0
2
4
6
8
10
Method
GLM
Max
Mean


Dunmanus Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
years
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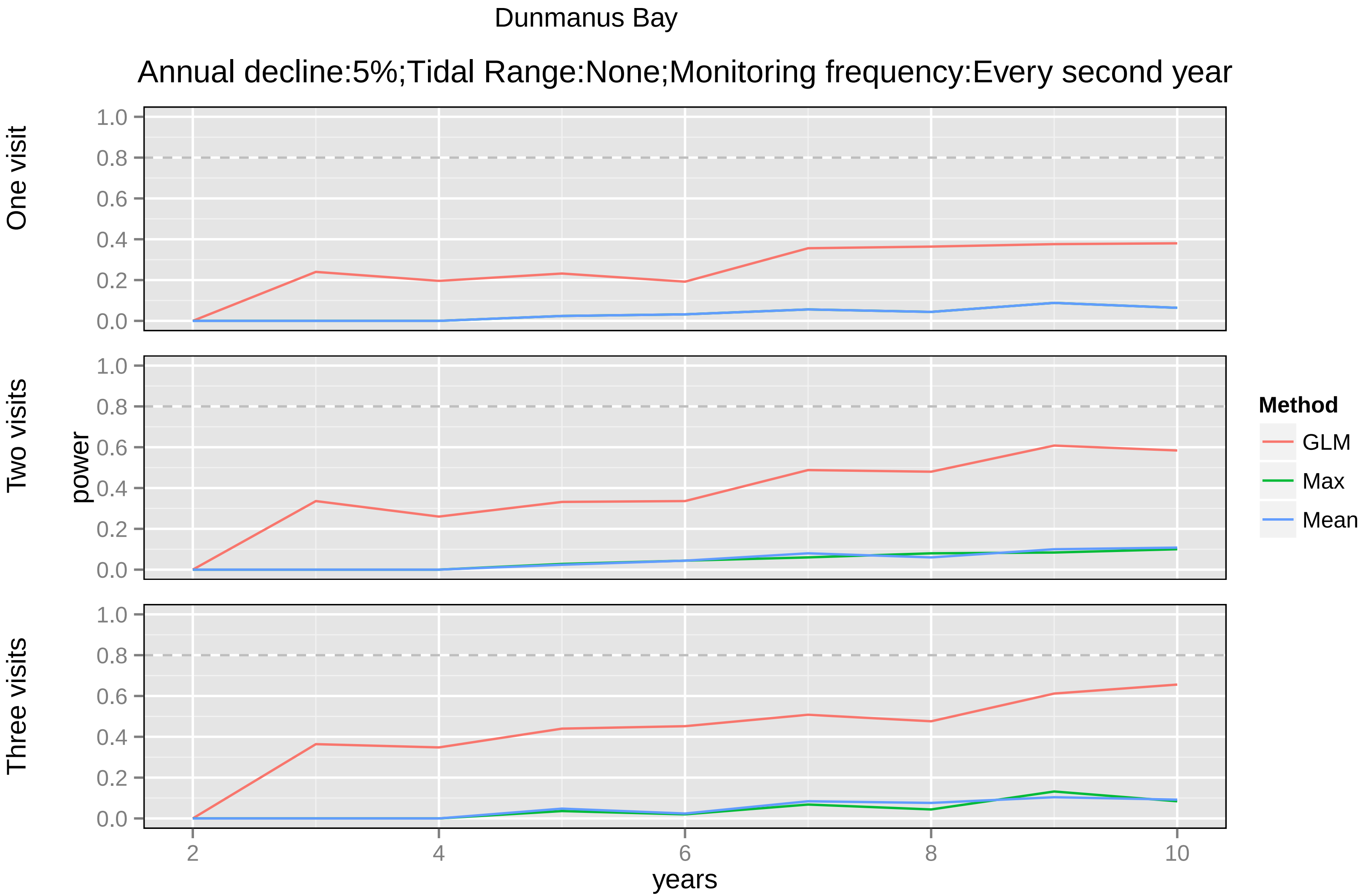
4
6
8
10
Method
GLM
Max
Mean


Dunmanus Bay
Annual decline:5%;Tidal Range:None;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
years
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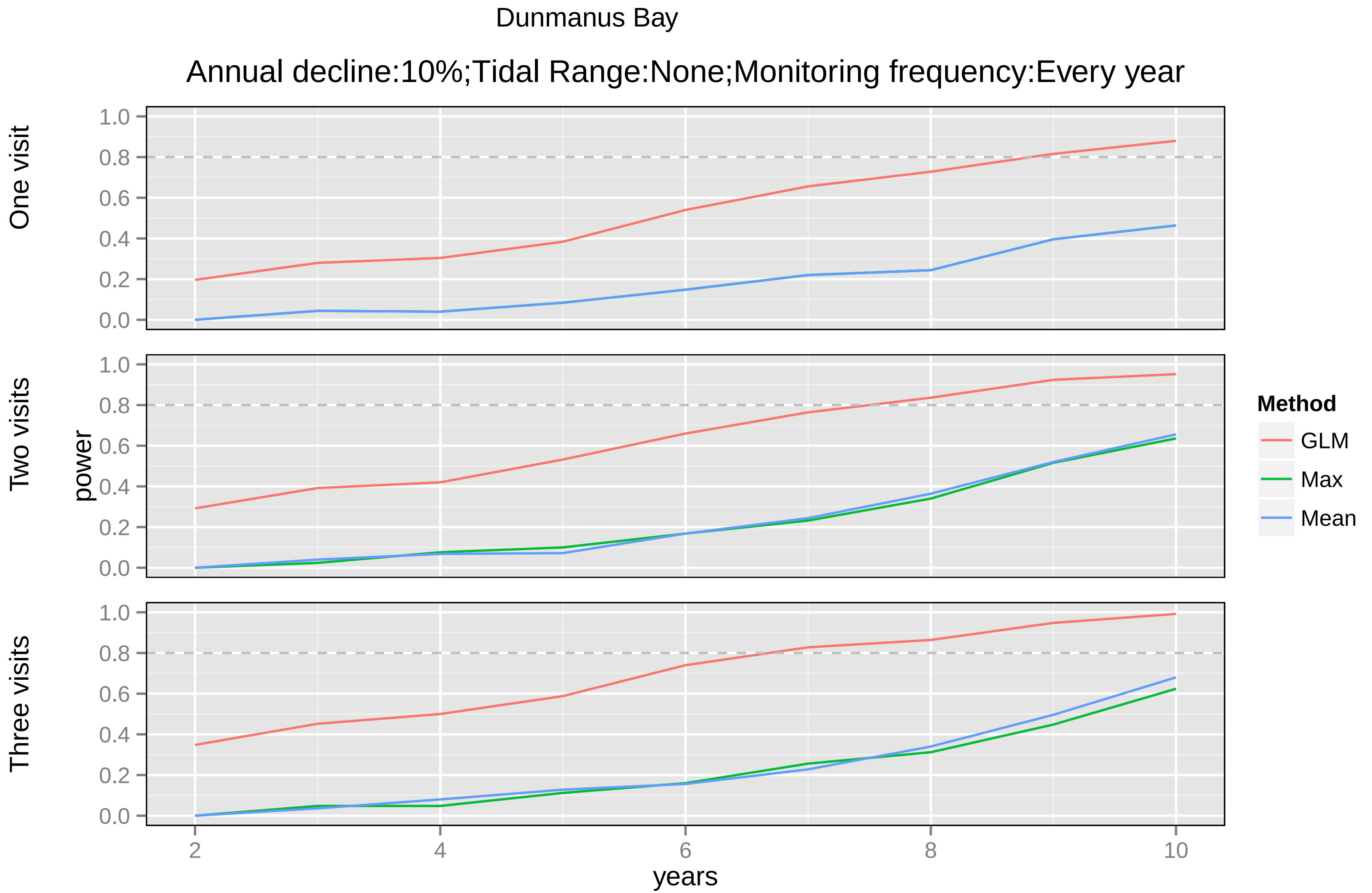
Method
GLM
Max
Mean


Dunmanus Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
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8
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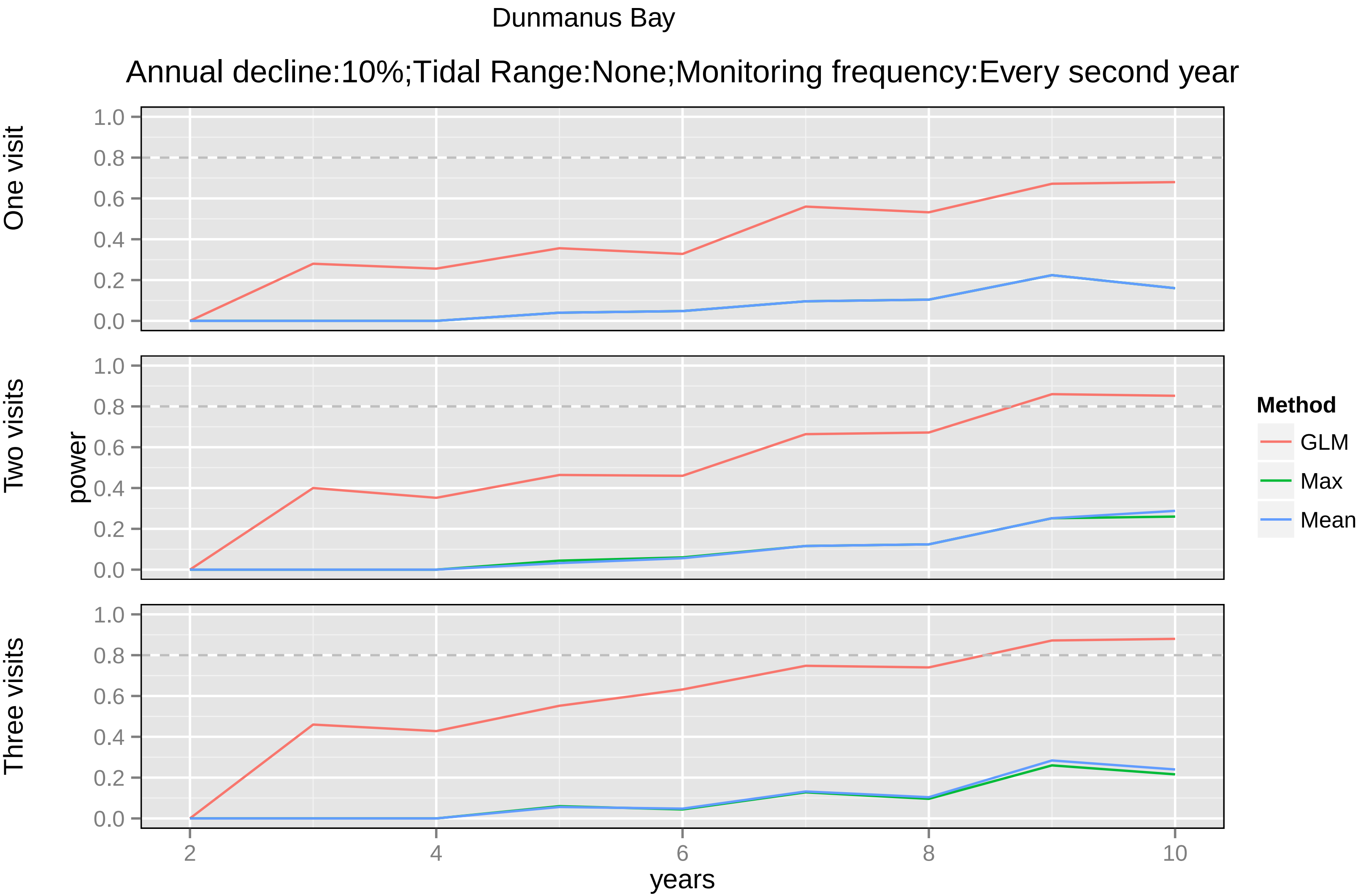
years
Method
GLM
Max
Mean


Dunmanus Bay
Annual decline:10%;Tidal Range:None;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
years
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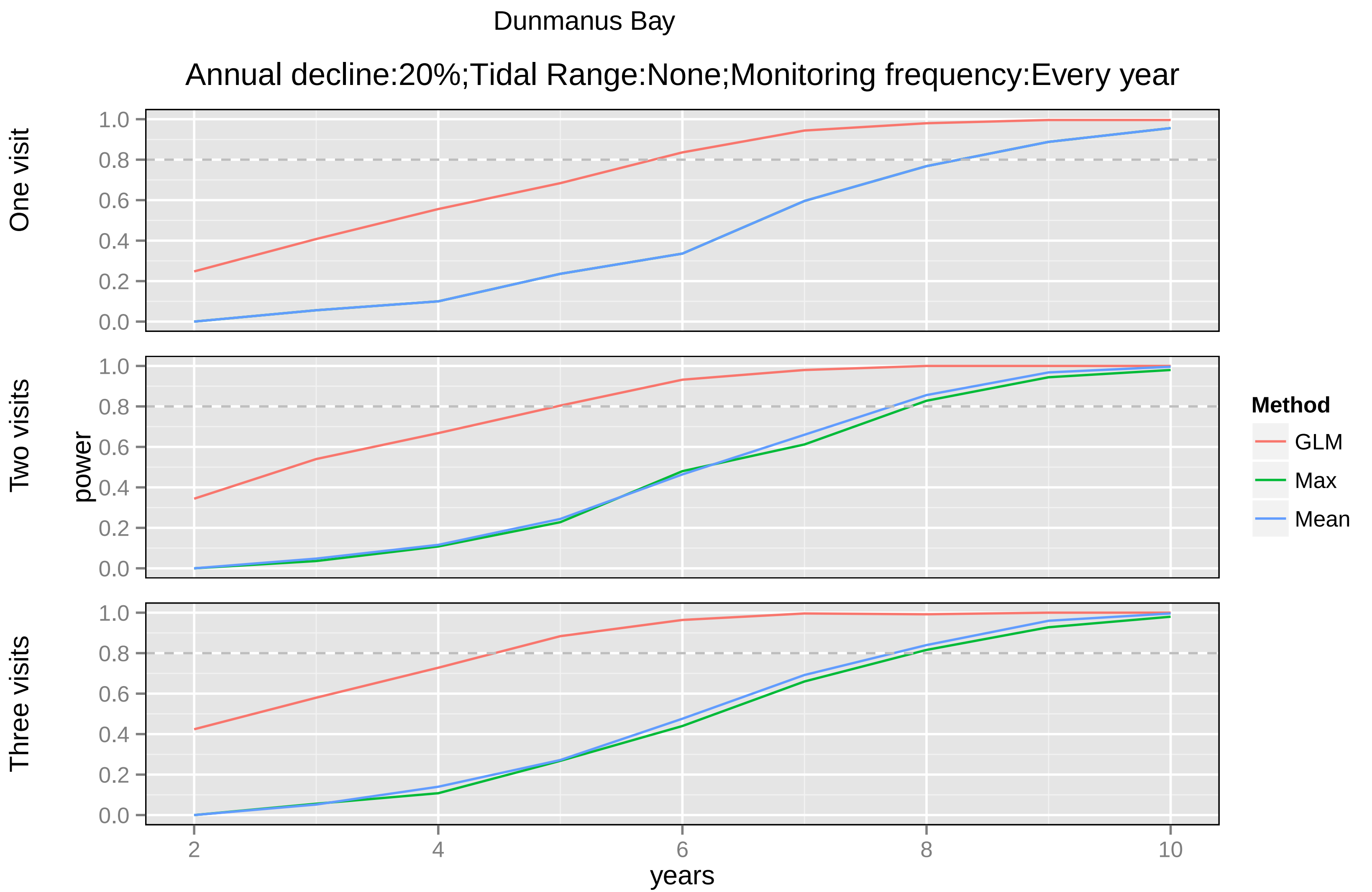
Method
GLM
Max
Mean


Dunmanus Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
years
Method
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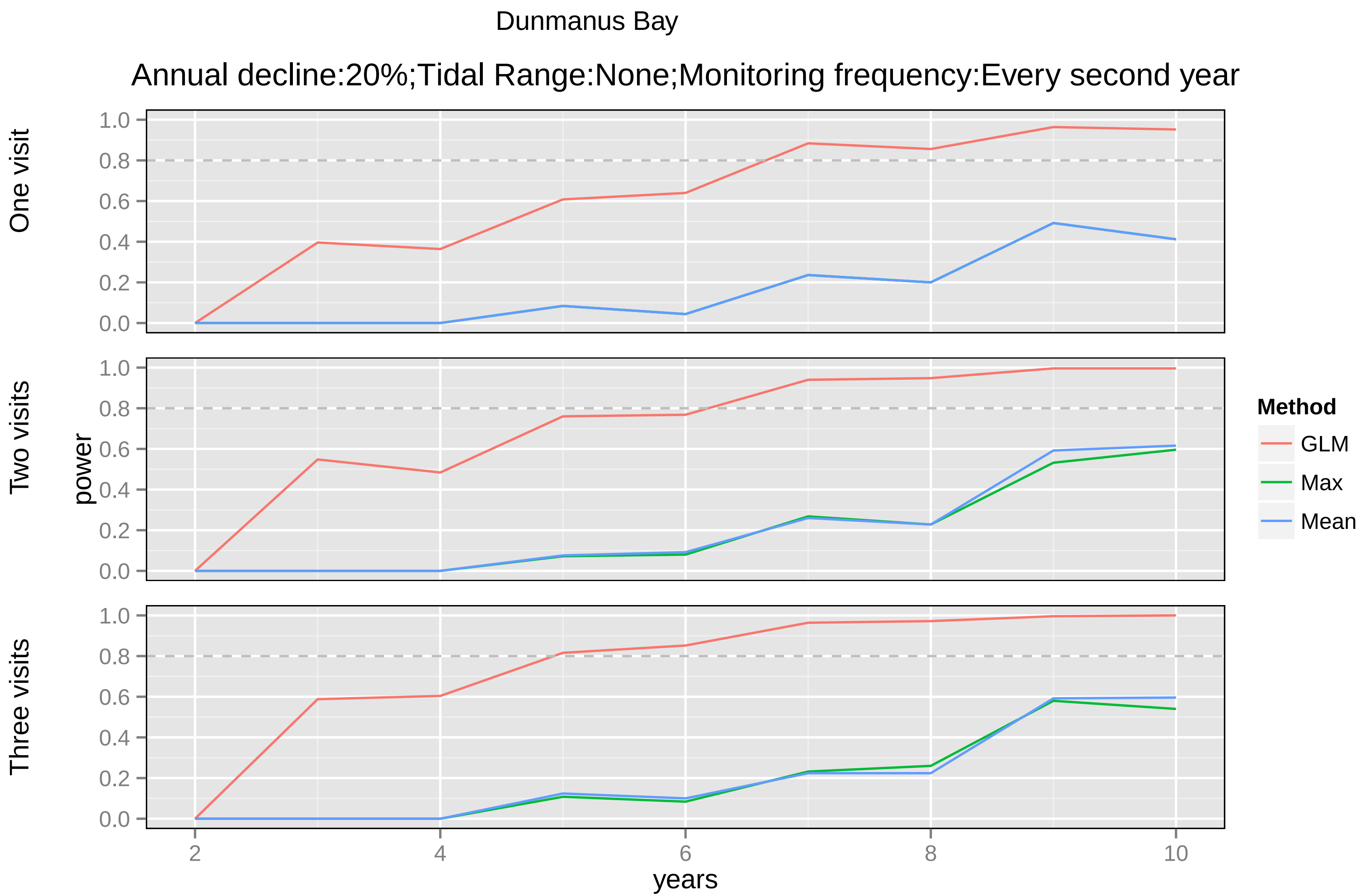
Dunmanus Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
One visit
Two visits
Three visits
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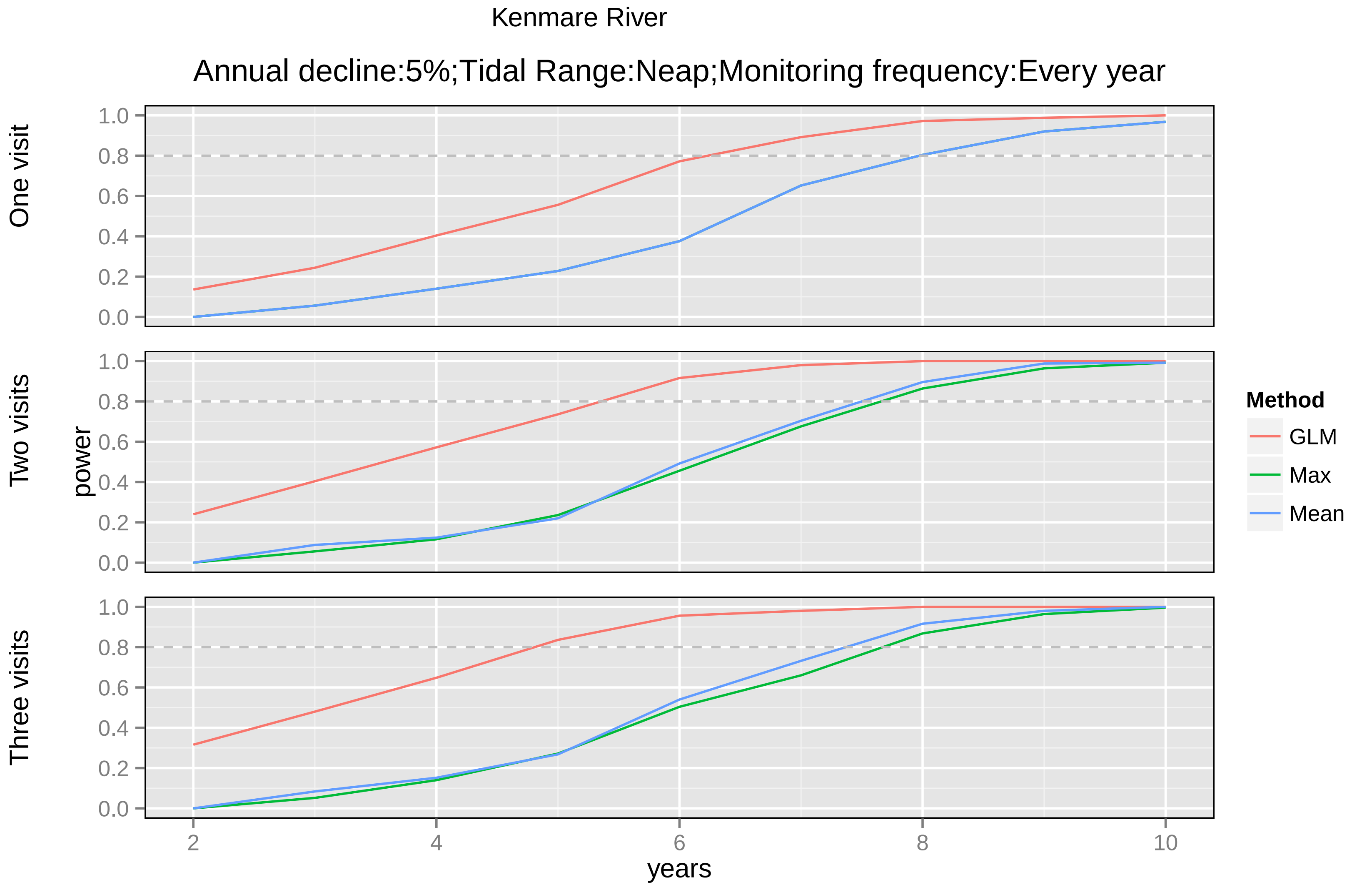
Mean


Kenmare River
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
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years
Method
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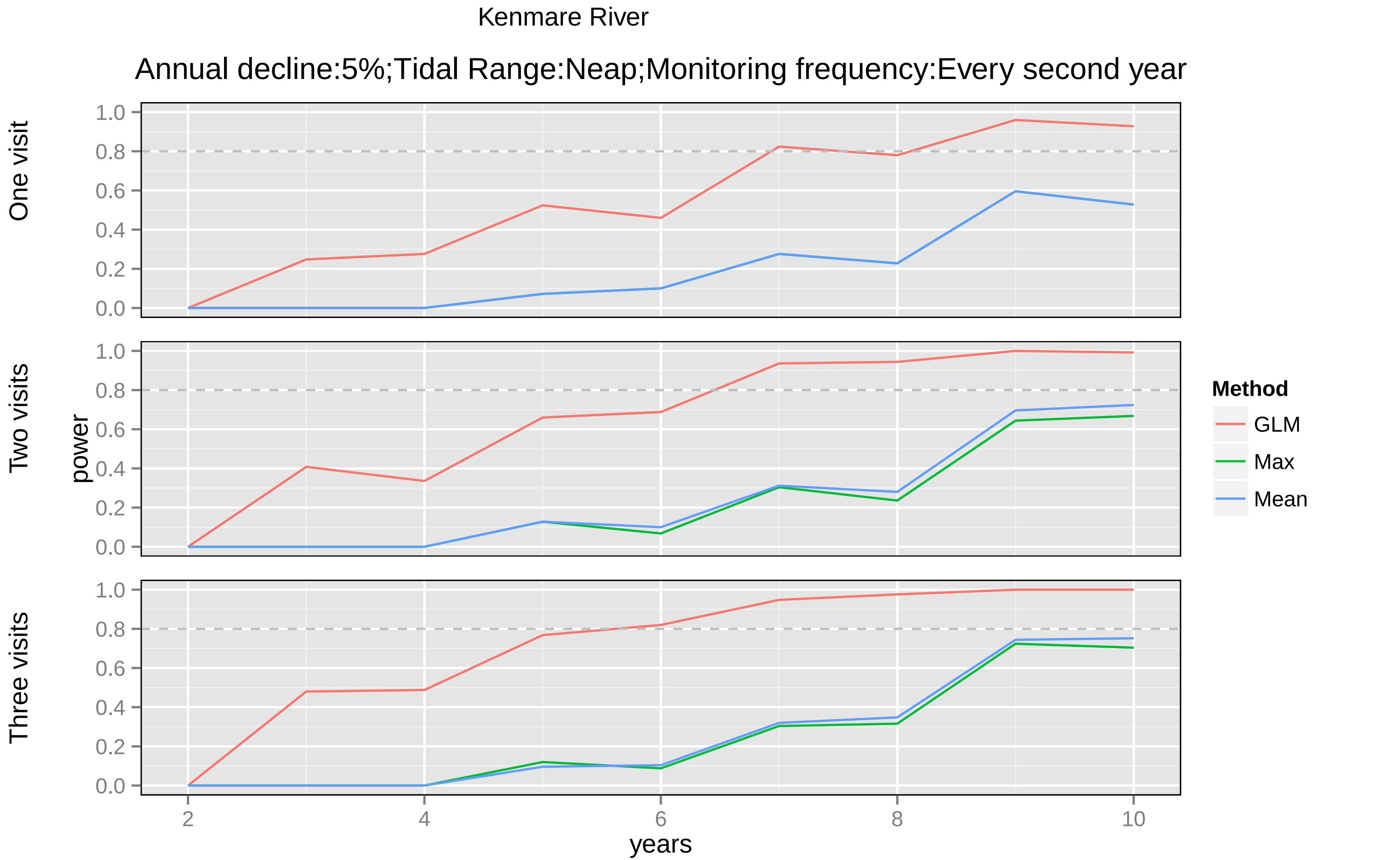
Max
Mean



Kenmare River
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
One visit
Two visits
Three visits
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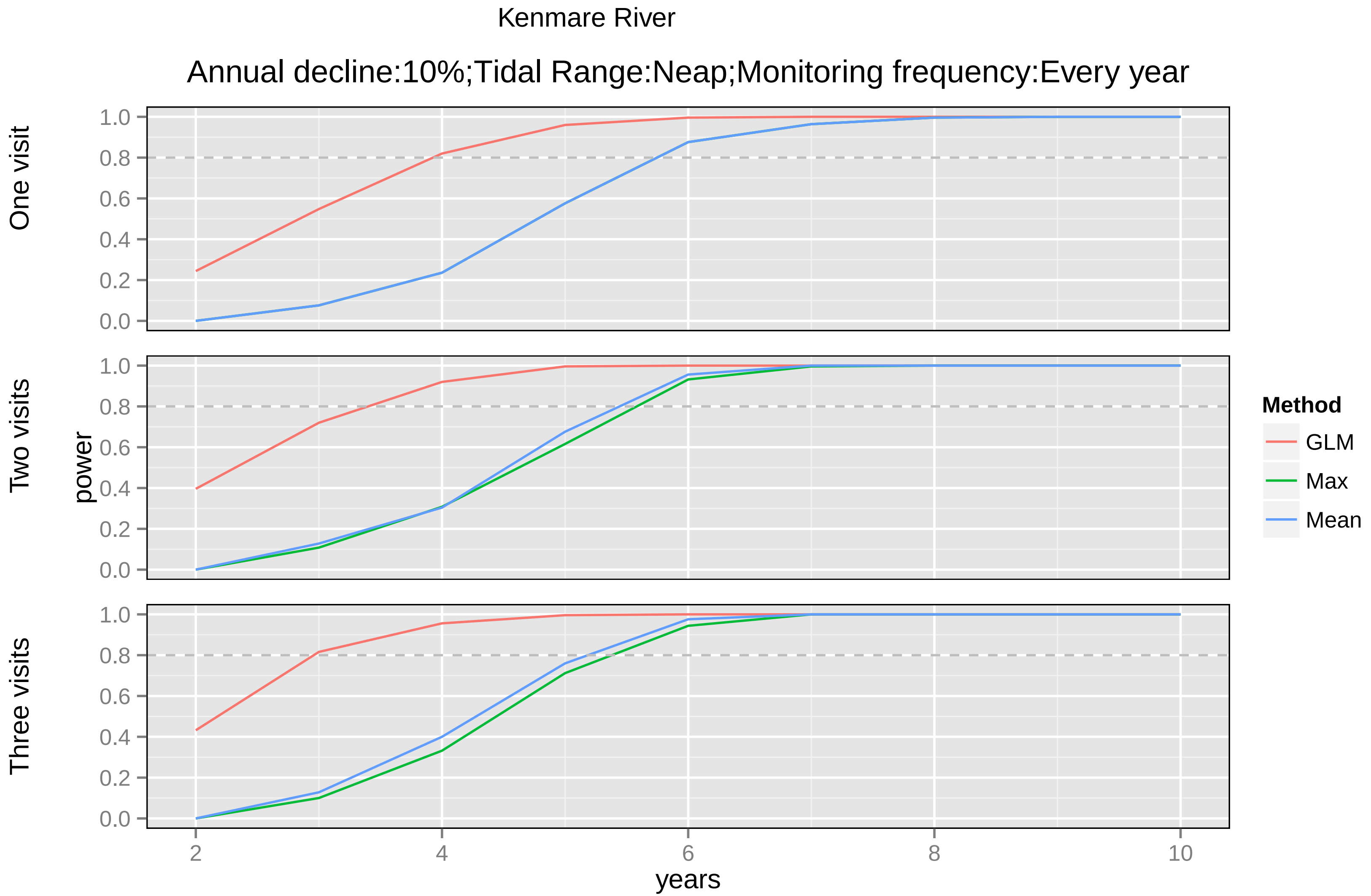
Kenmare River
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
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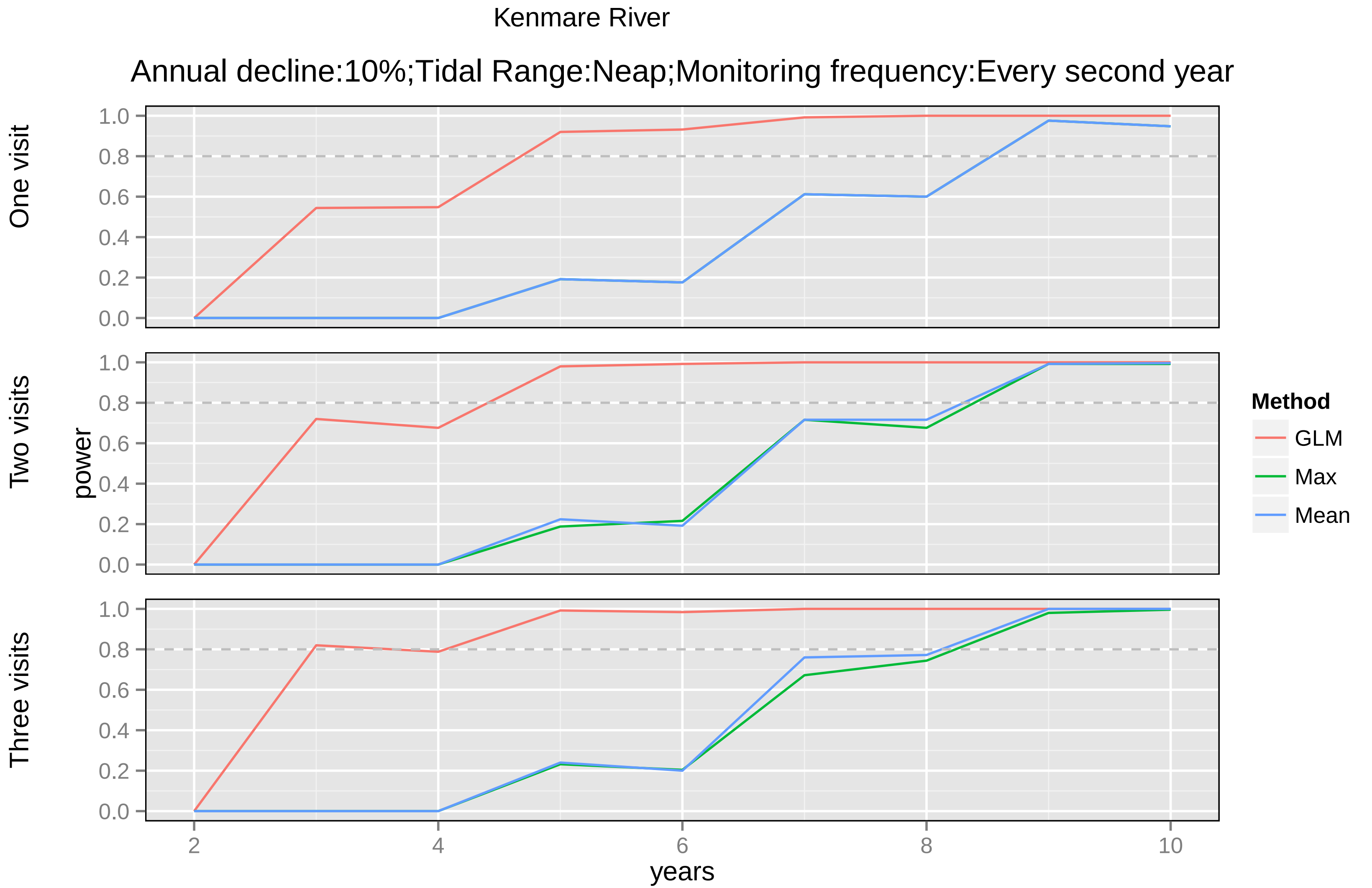

Kenmare River
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every second year
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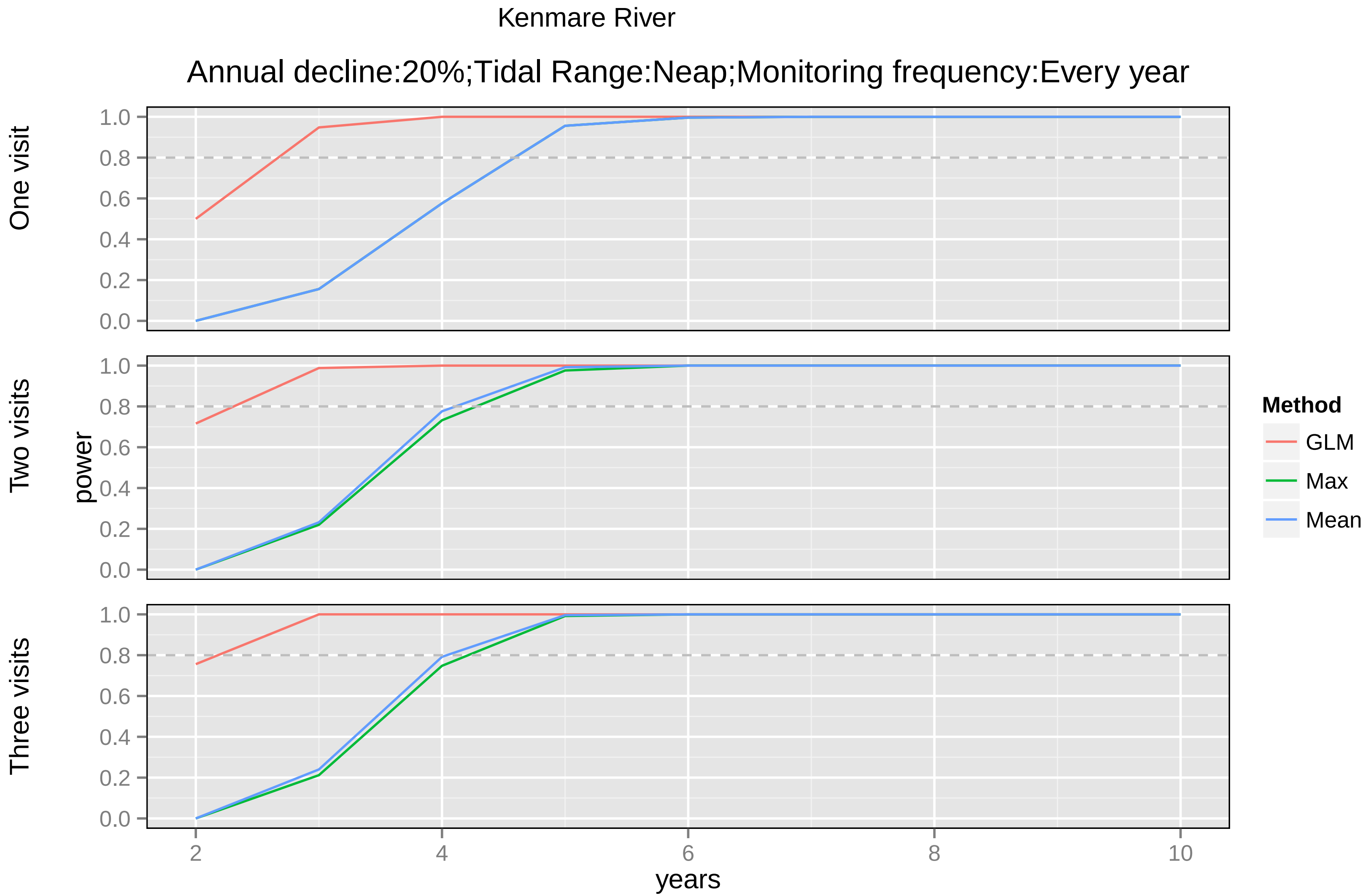
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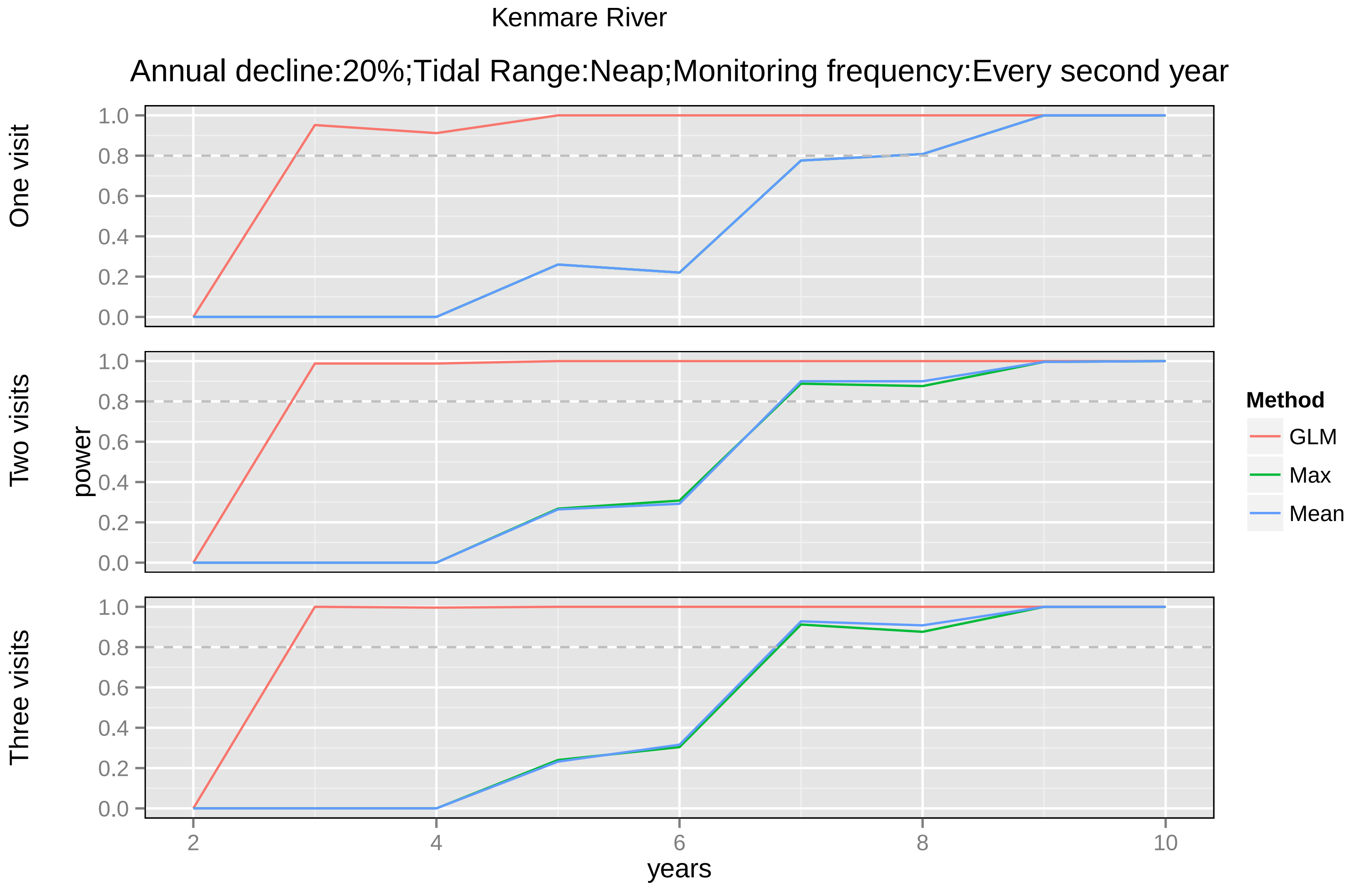
Kenmare River
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
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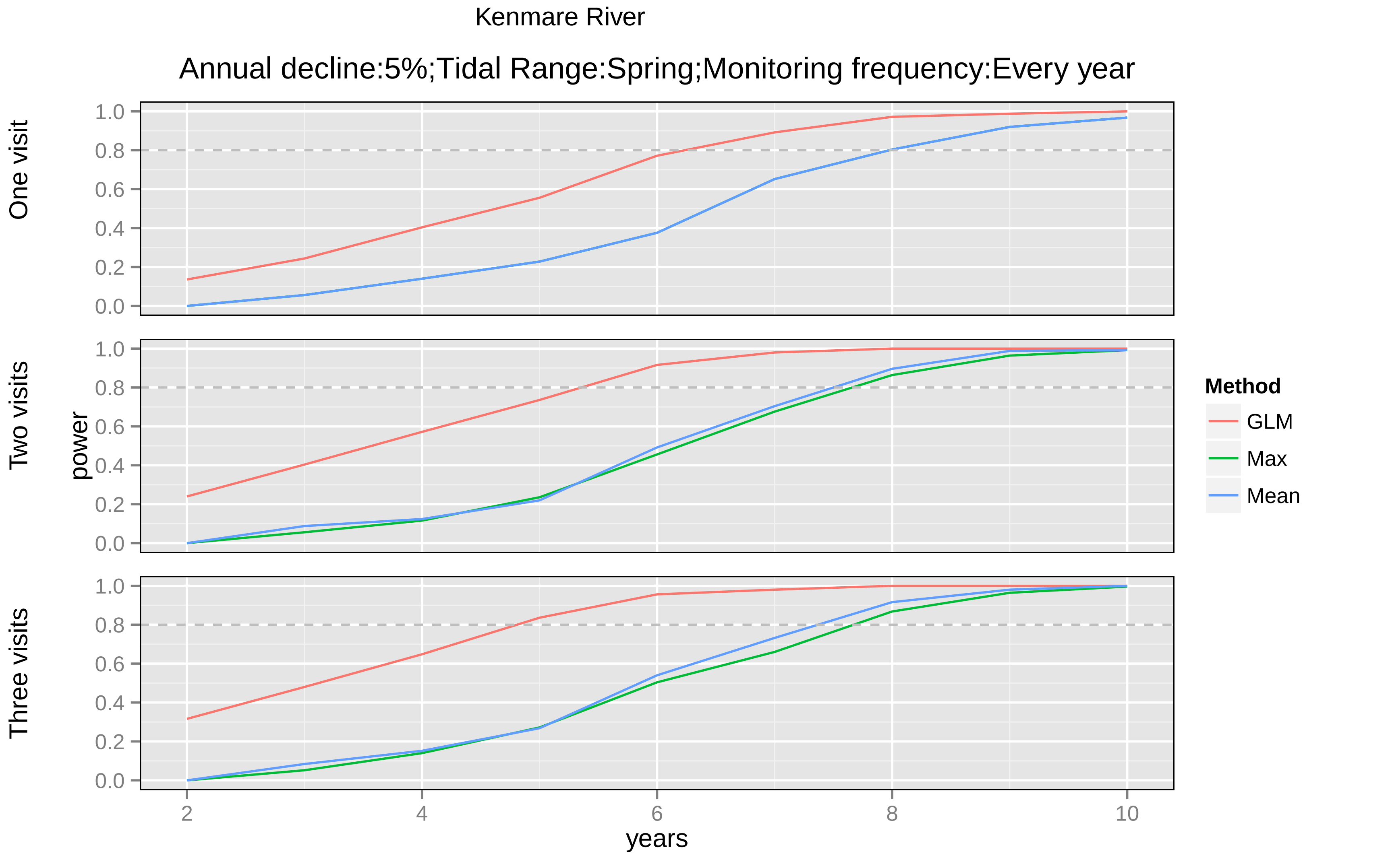
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Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every year
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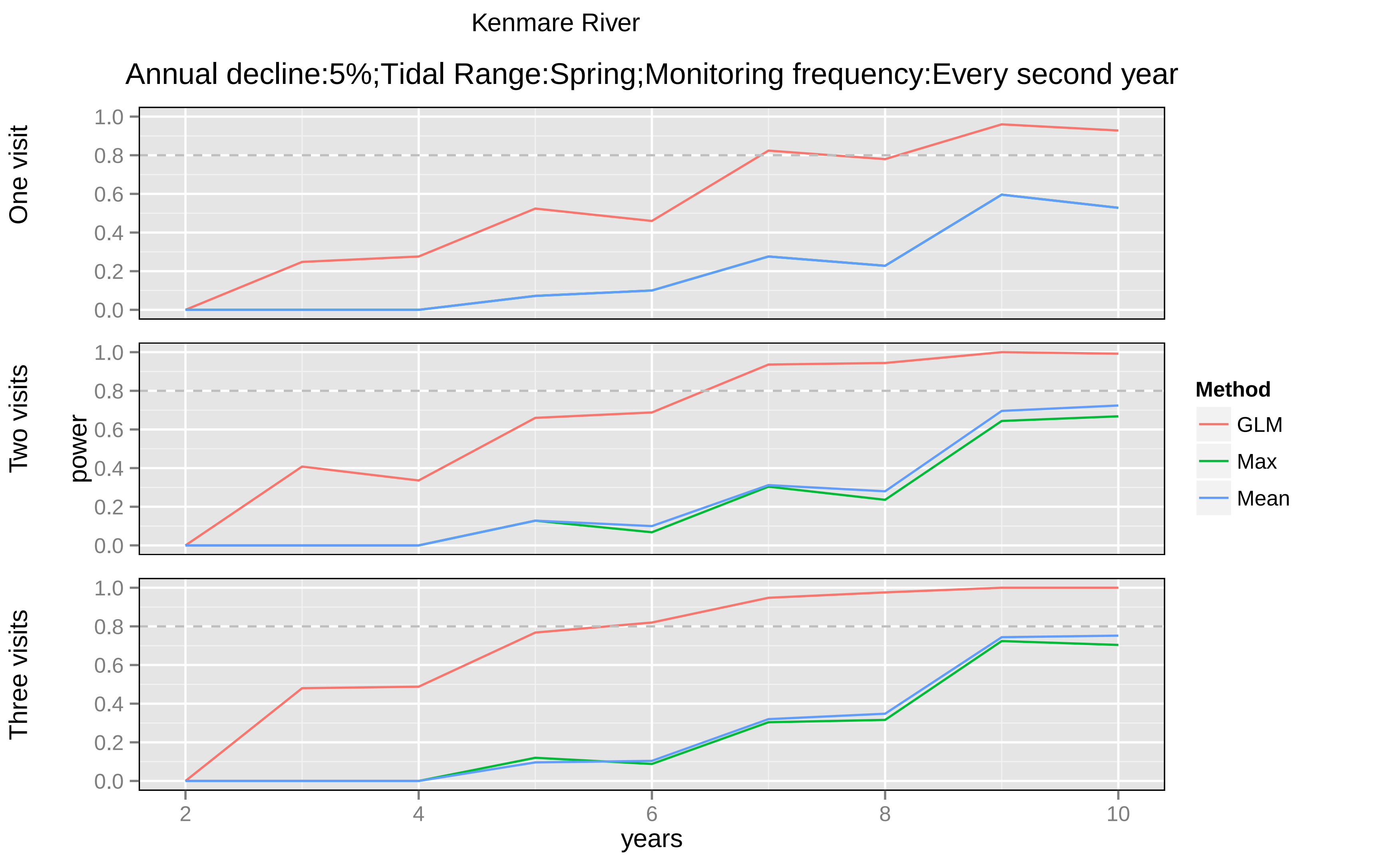
Kenmare River
Annual decline:5%;Tidal Range:Spring;Monitoring frequency:Every second year
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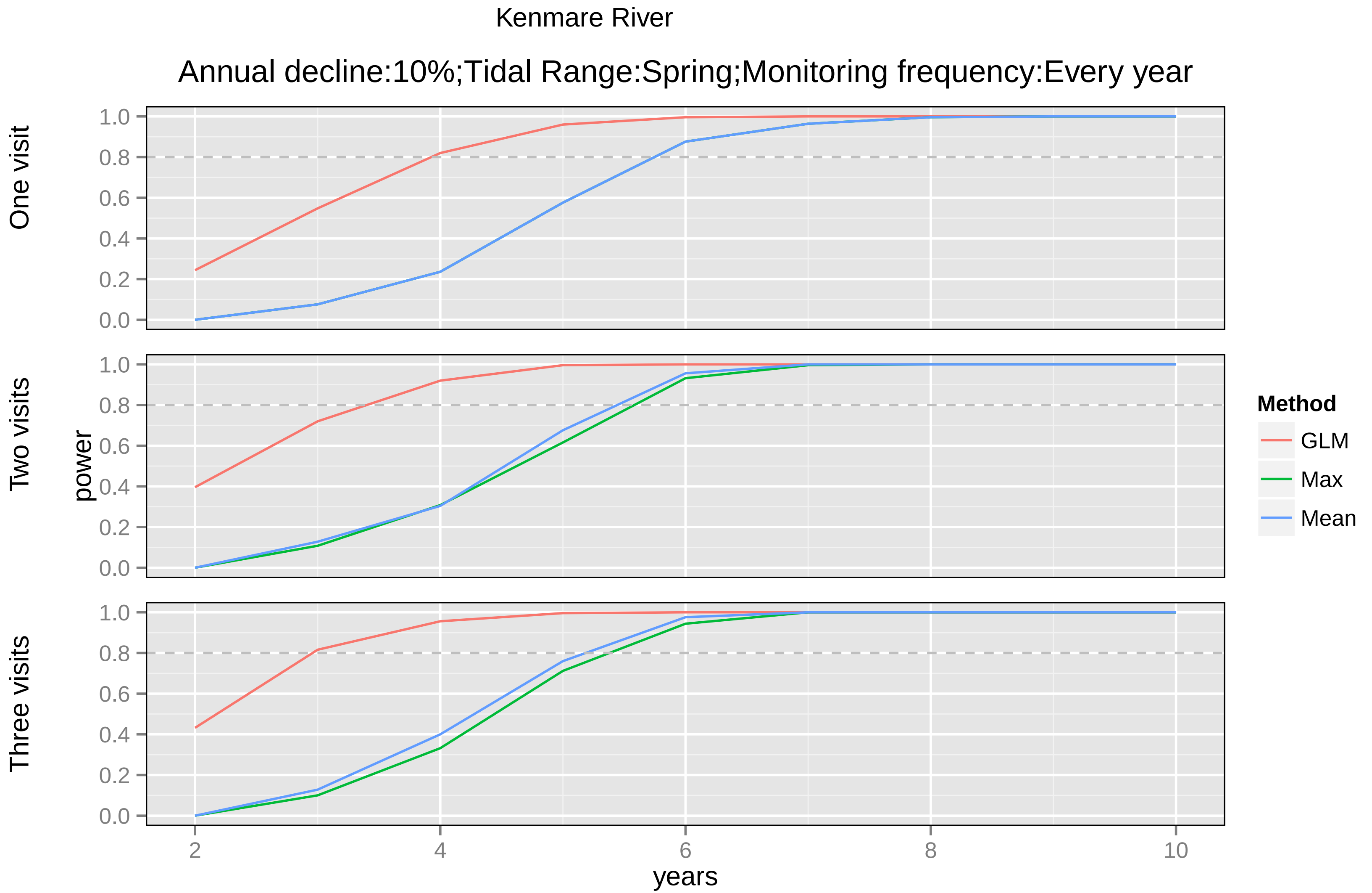

Kenmare River
Annual decline:10%;Tidal Range:Spring;Monitoring frequency:Every year
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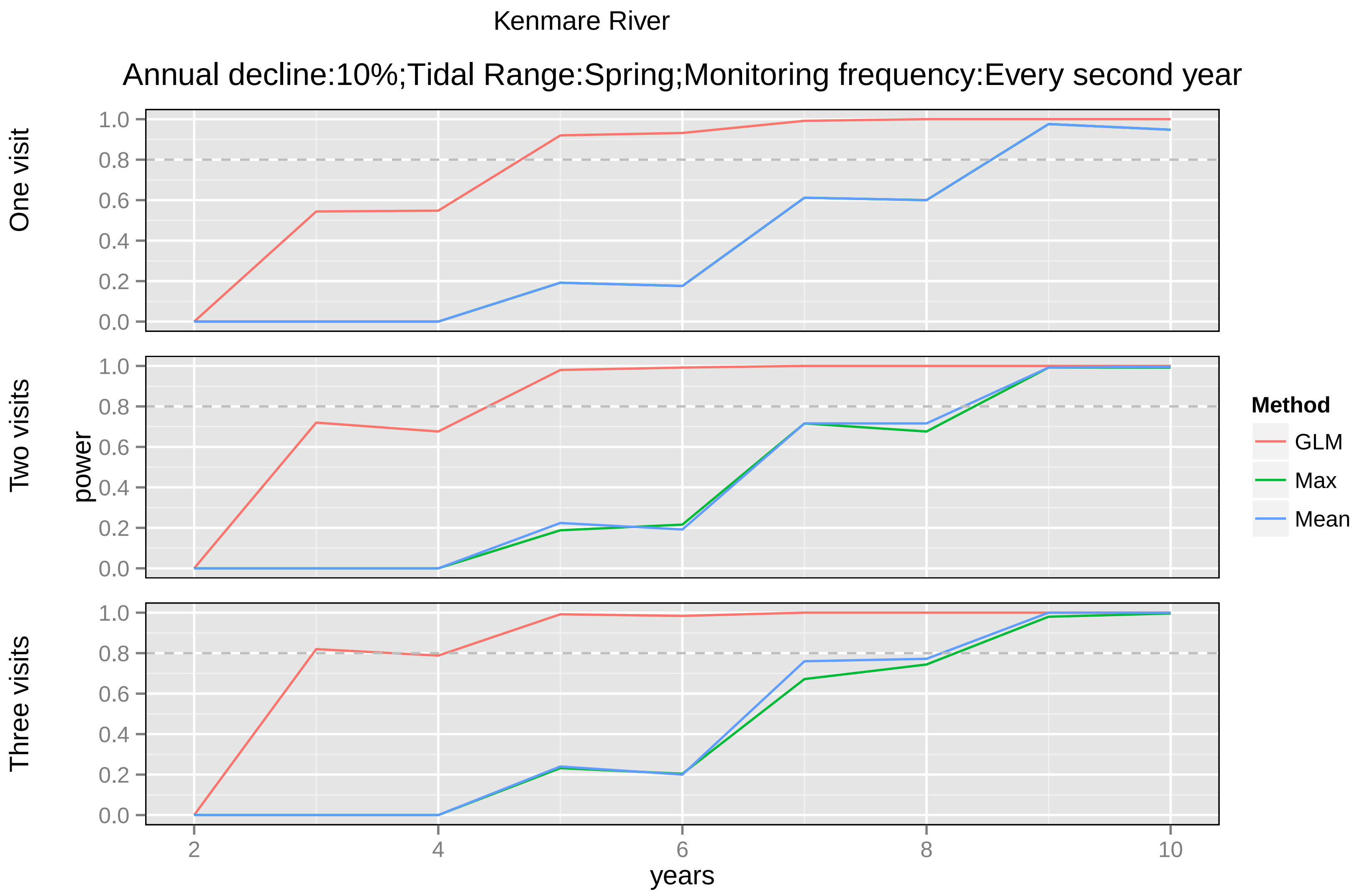
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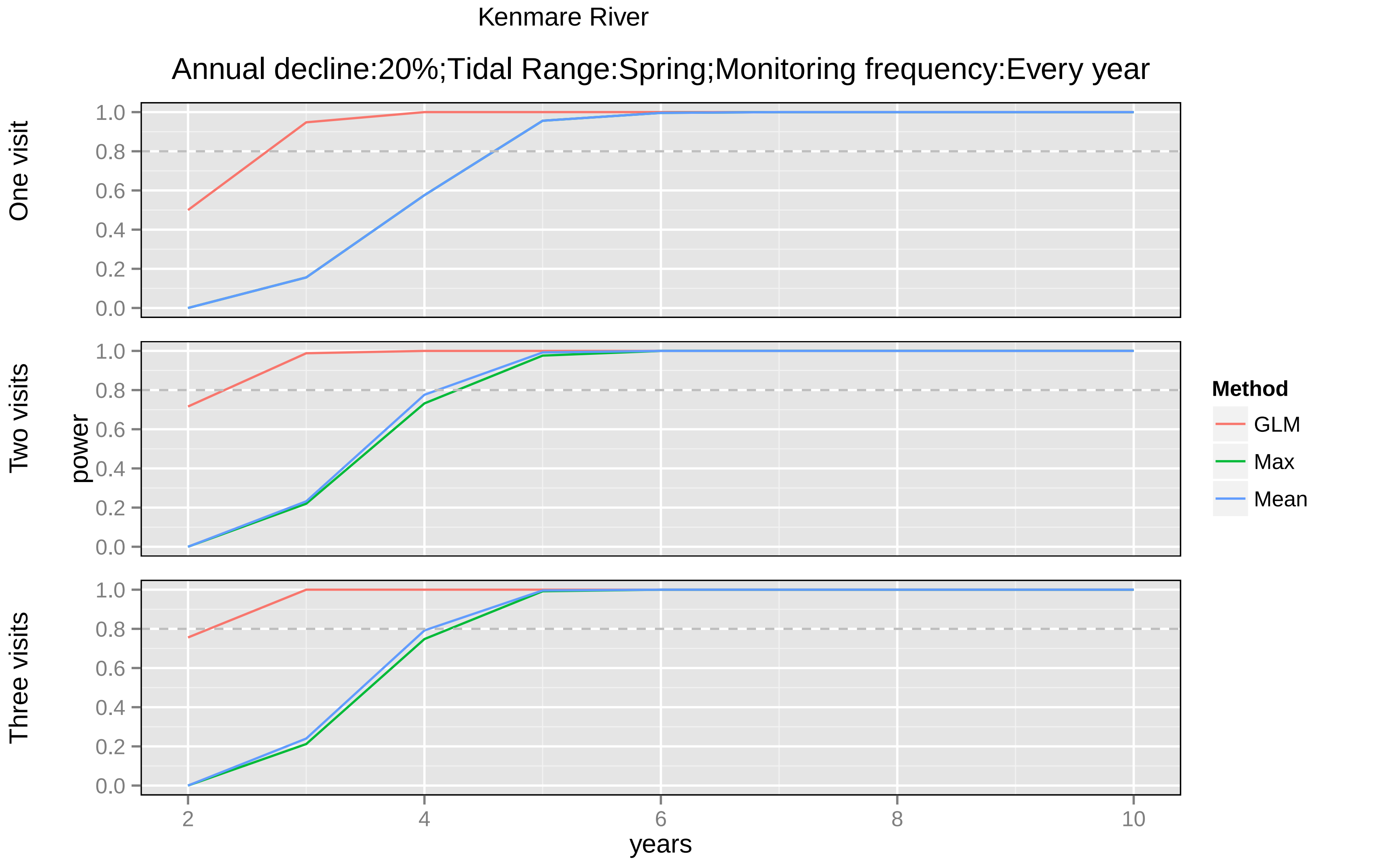

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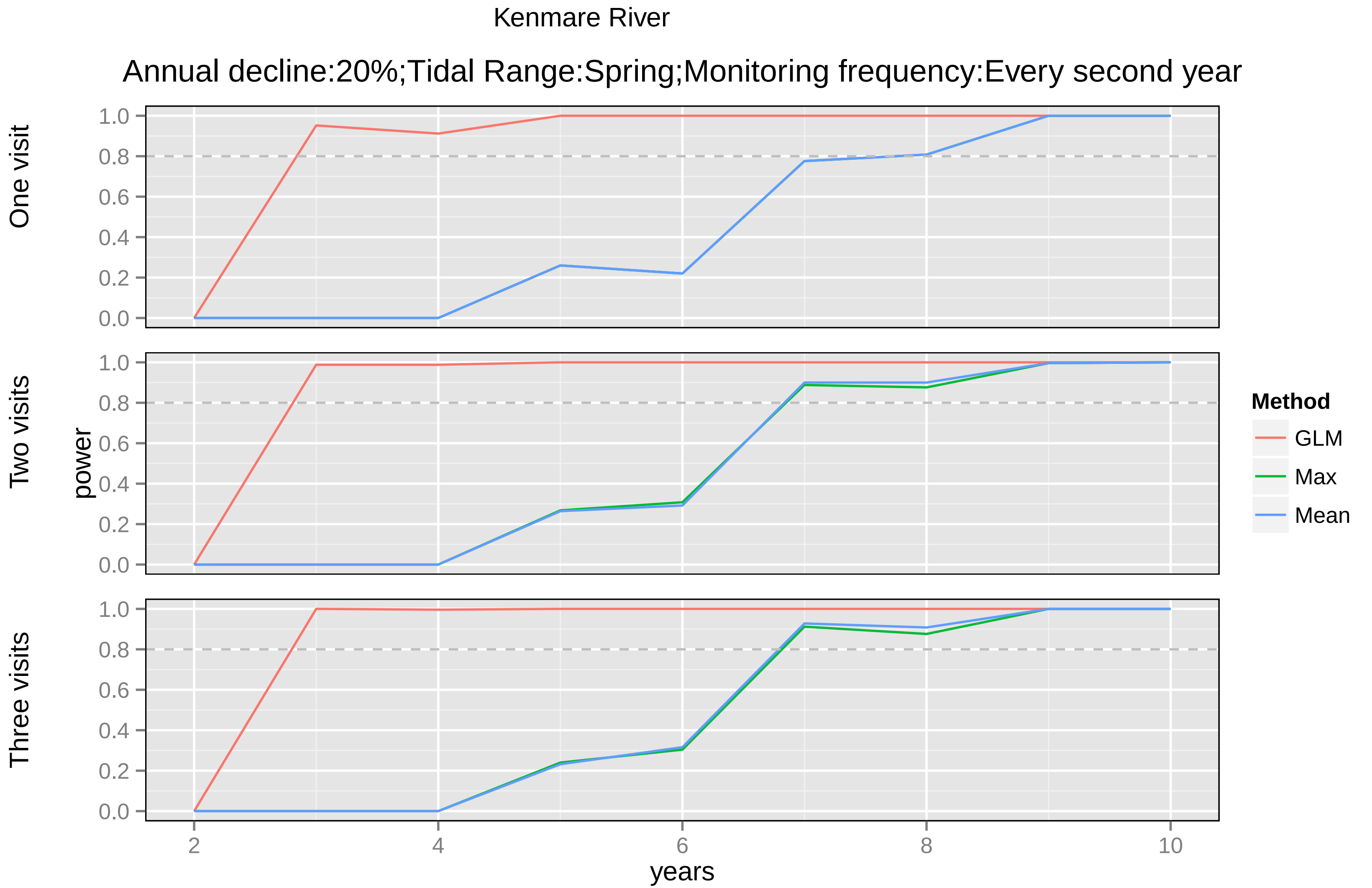
Kenmare River
Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
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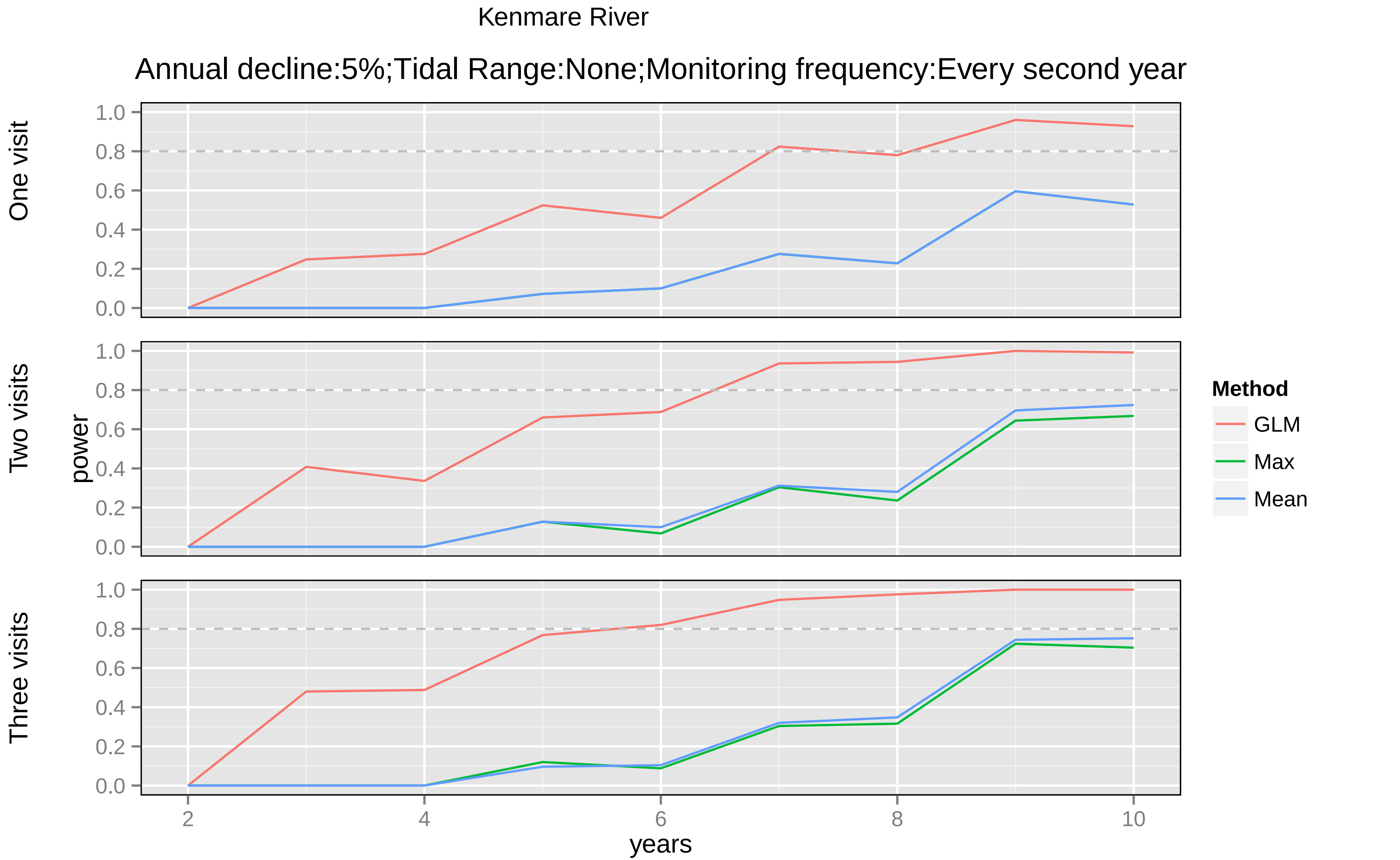
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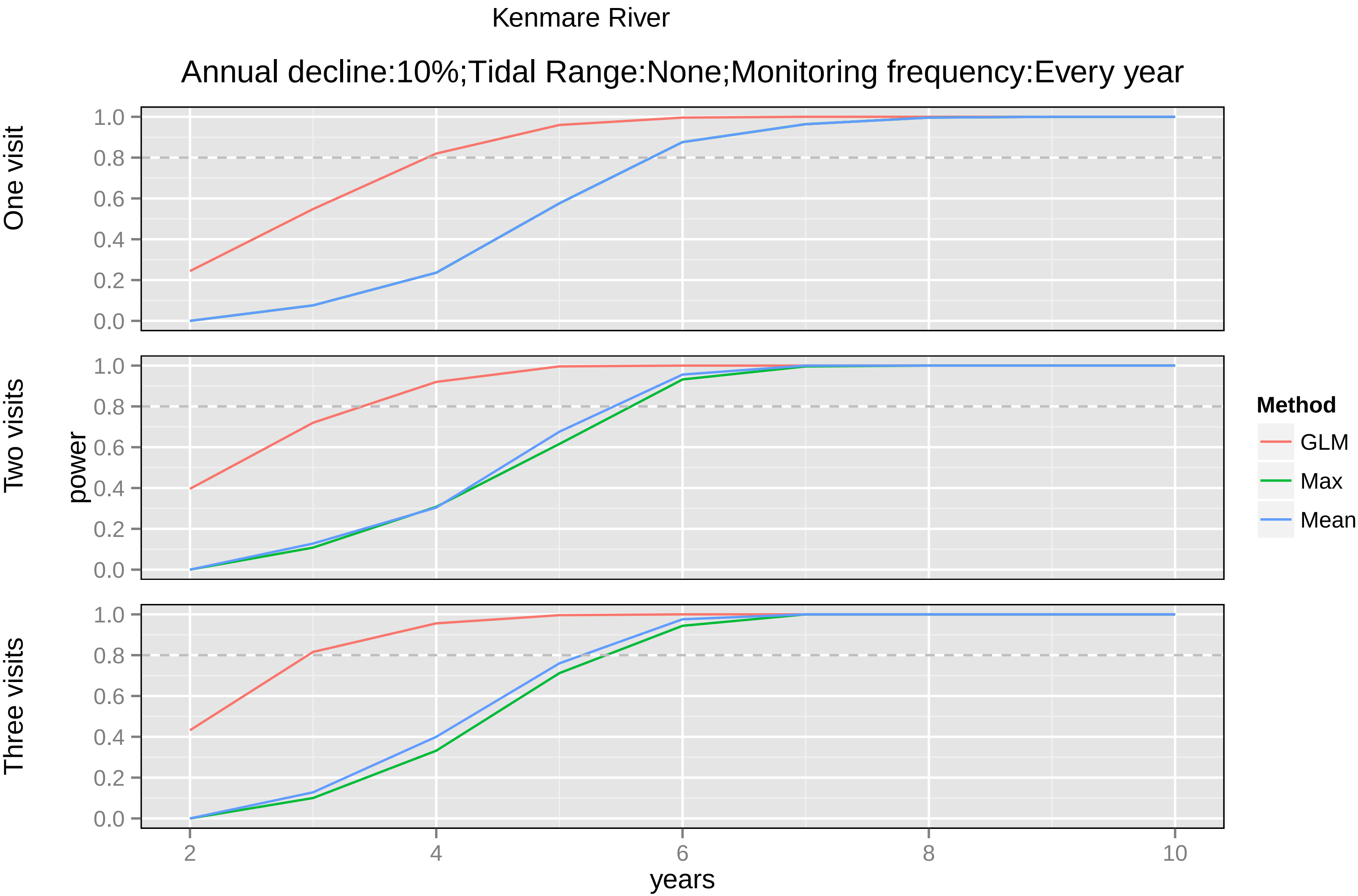

Kenmare River
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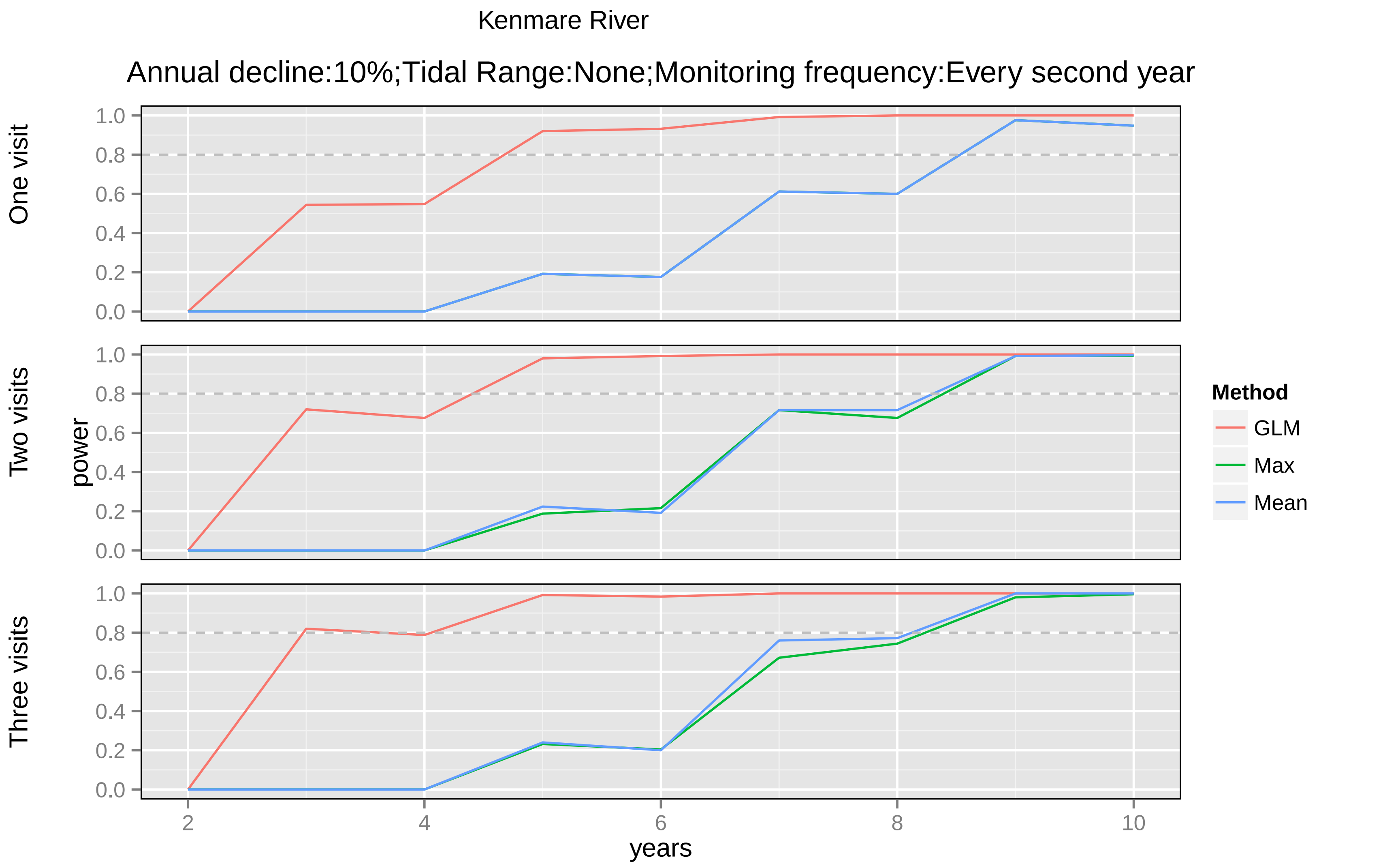
Kenmare River
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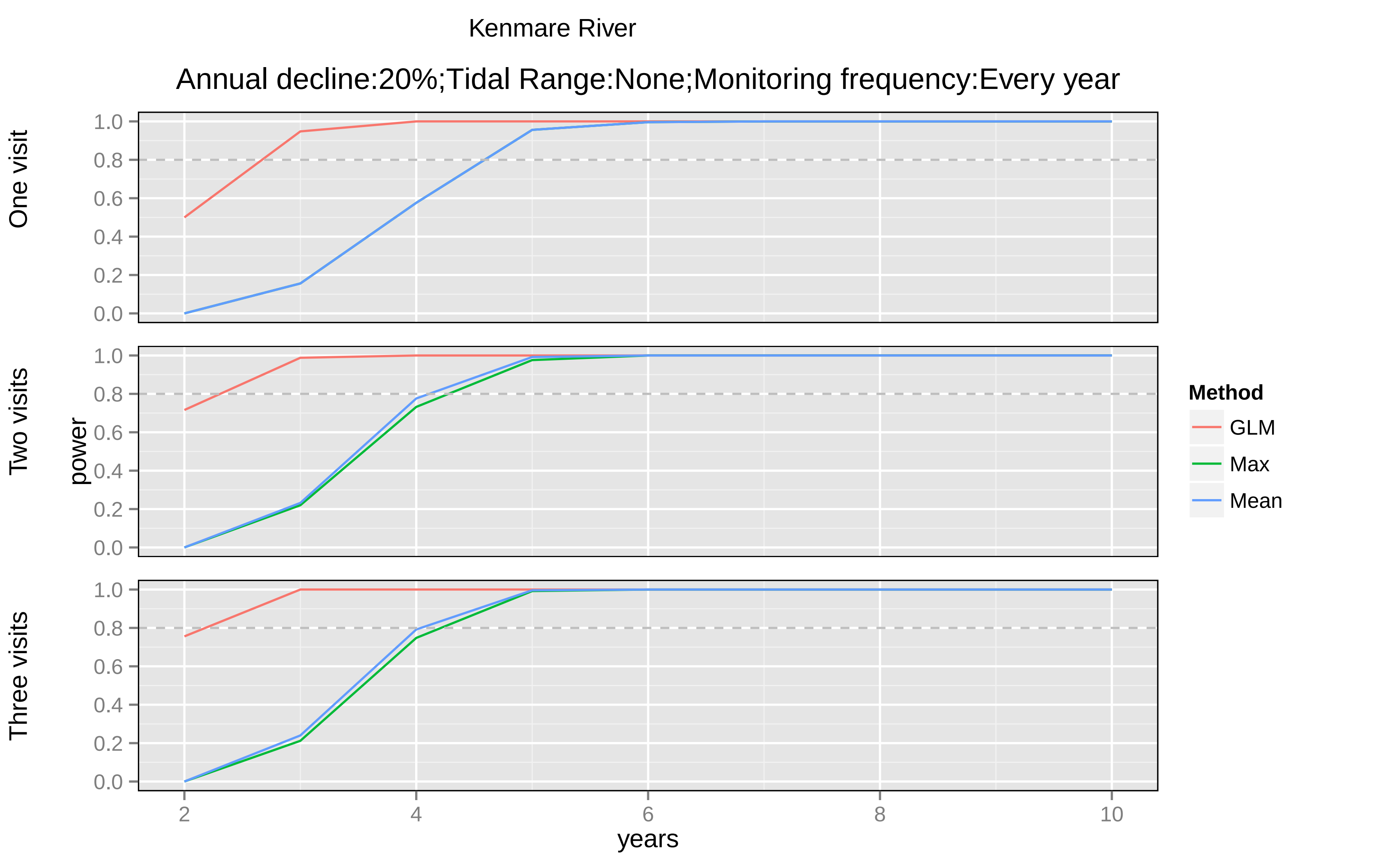
Kenmare River
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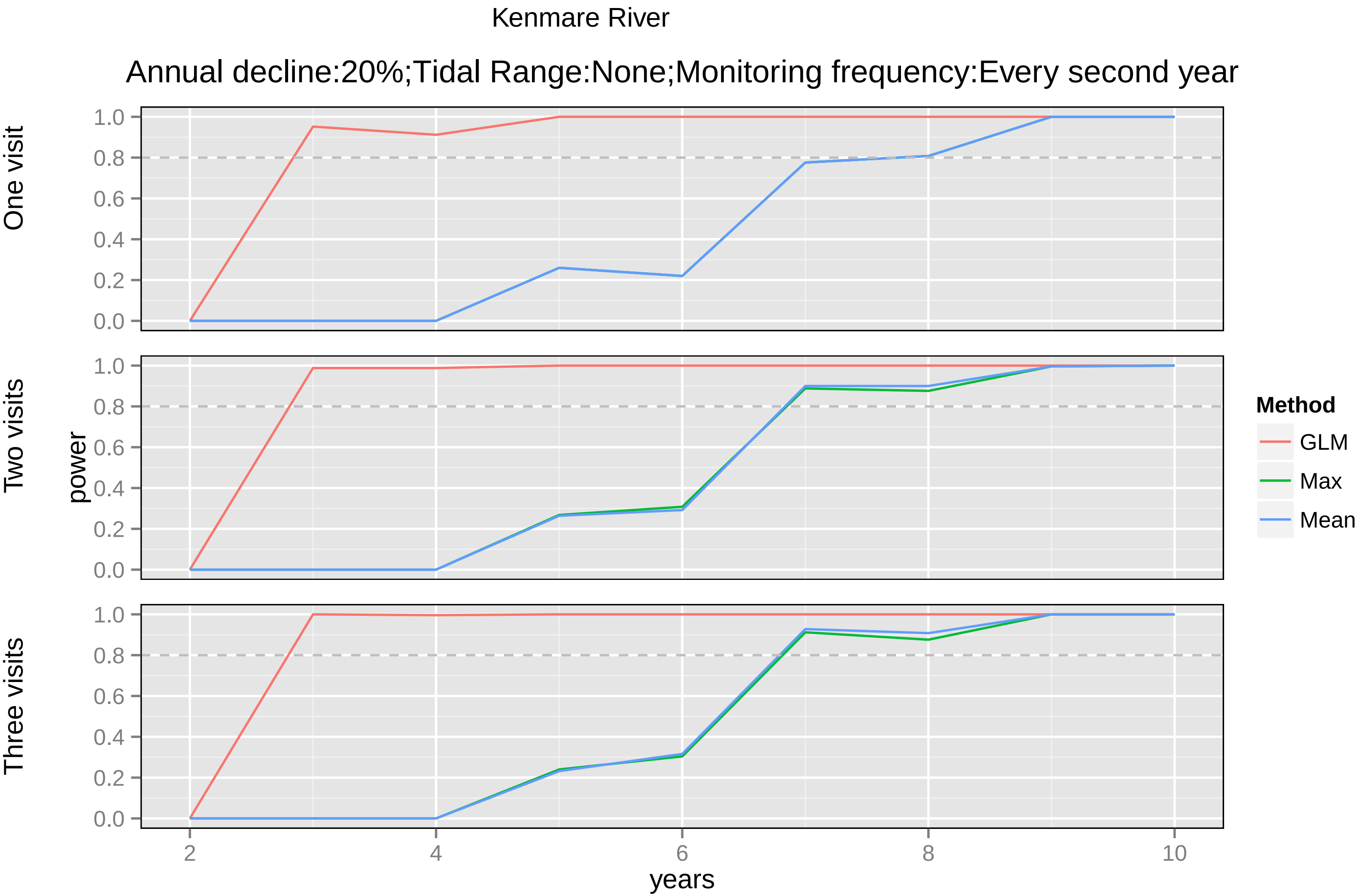
Kenmare River
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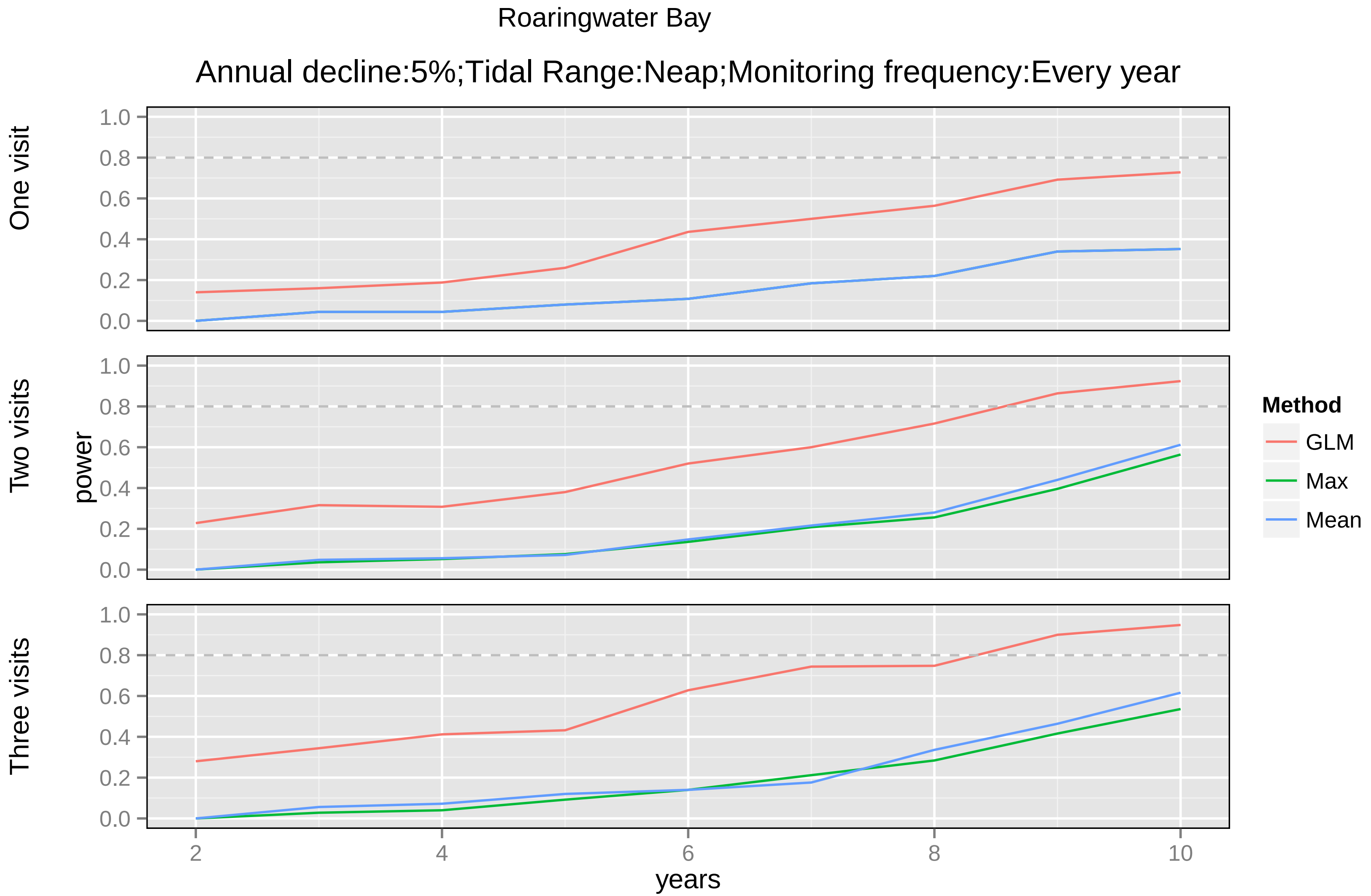

Roaringwater Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every year
One visit
Two visits
Three visits
power
years
Method
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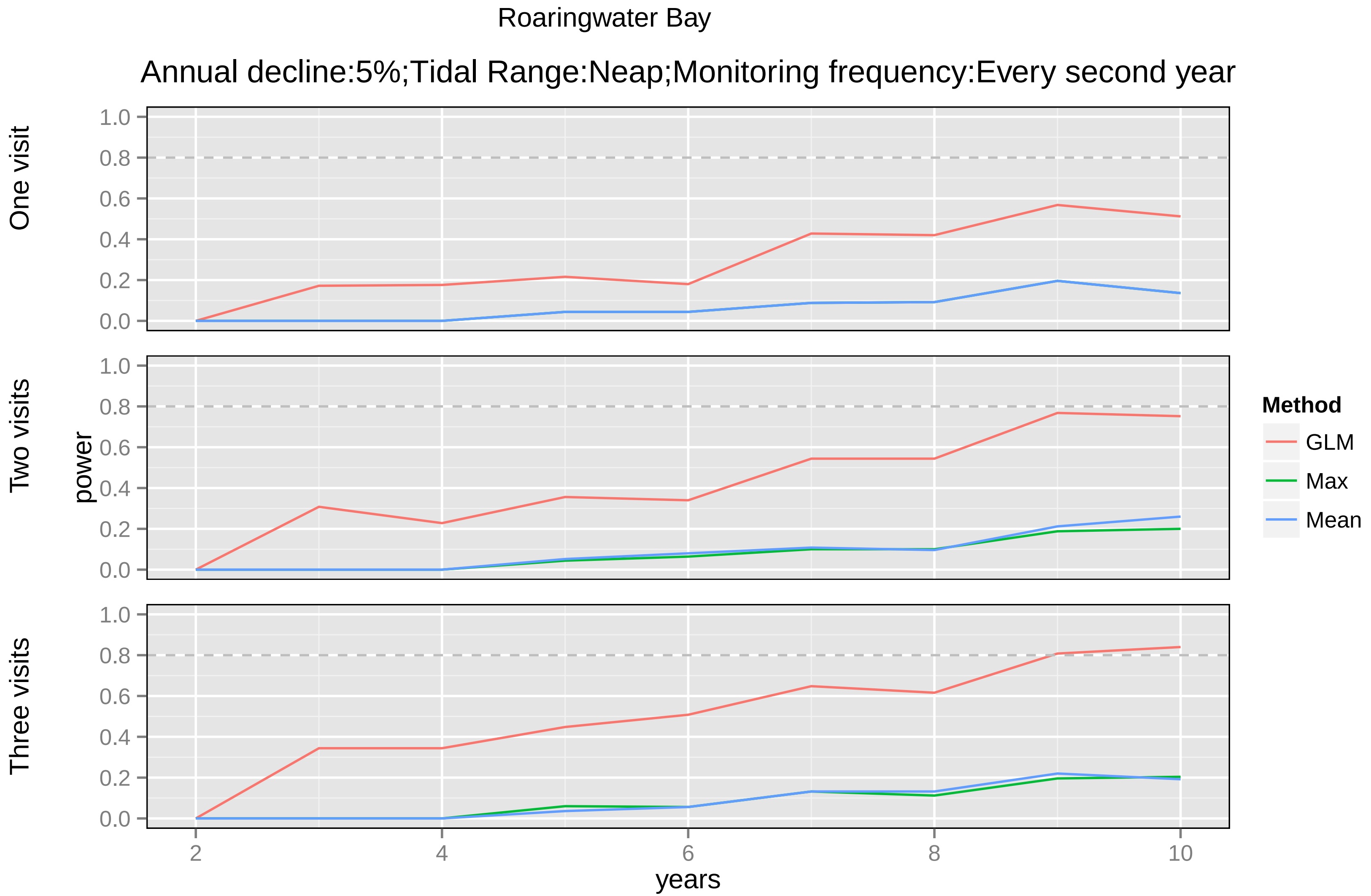

Roaringwater Bay
Annual decline:5%;Tidal Range:Neap;Monitoring frequency:Every second year
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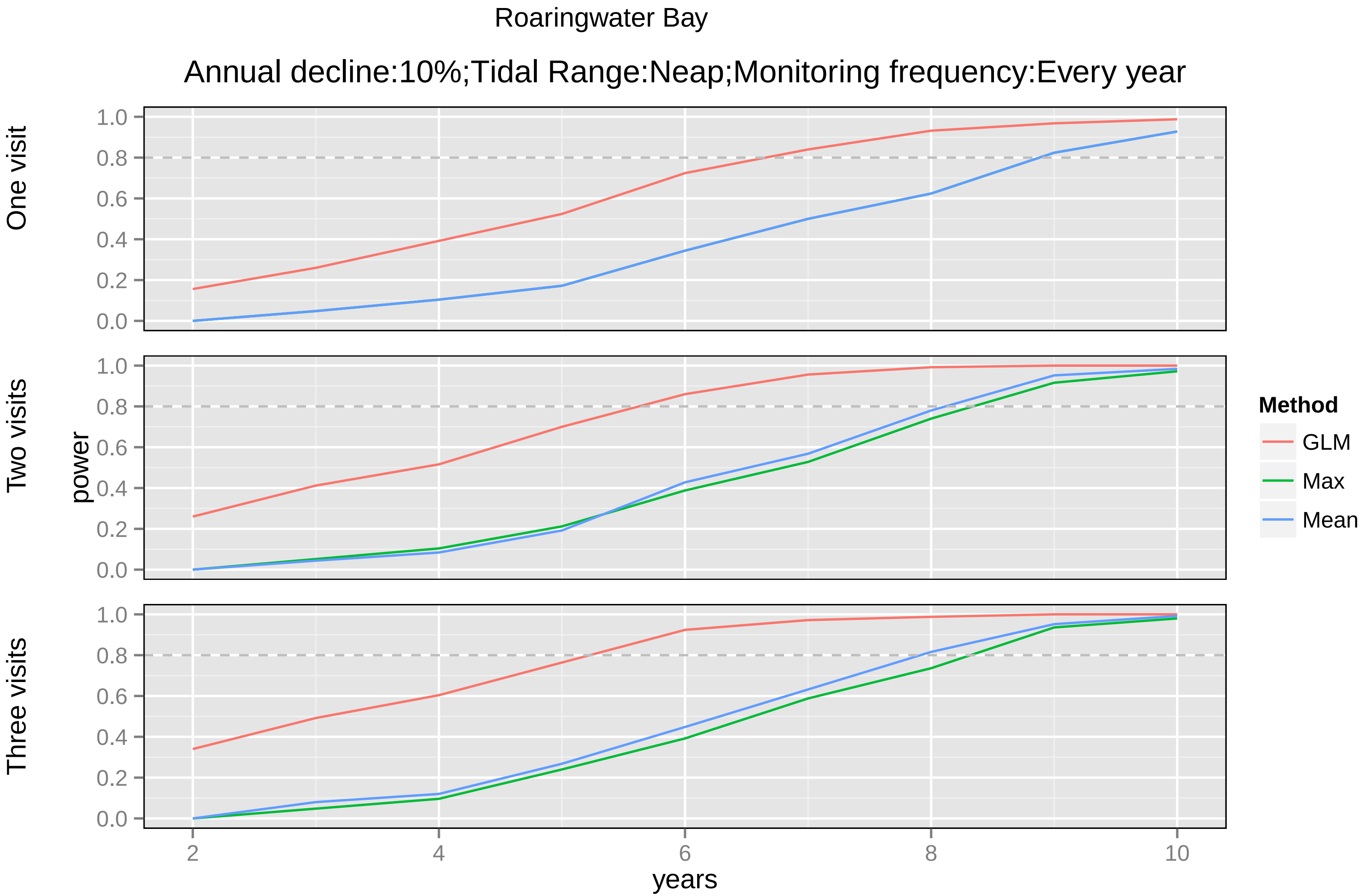

Roaringwater Bay
Annual decline:10%;Tidal Range:Neap;Monitoring frequency:Every year
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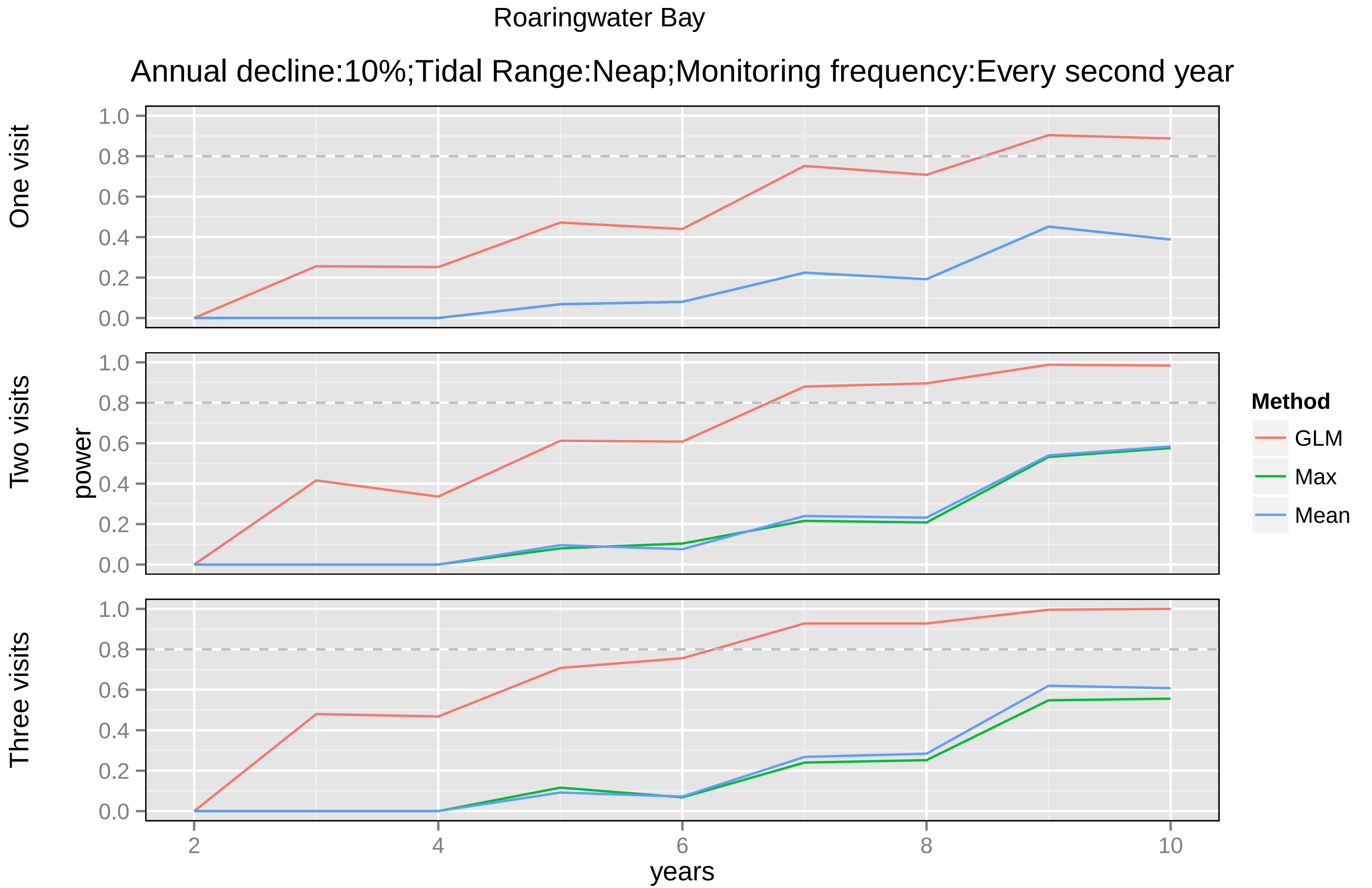
Roaringwater Bay
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Roaringwater Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every year
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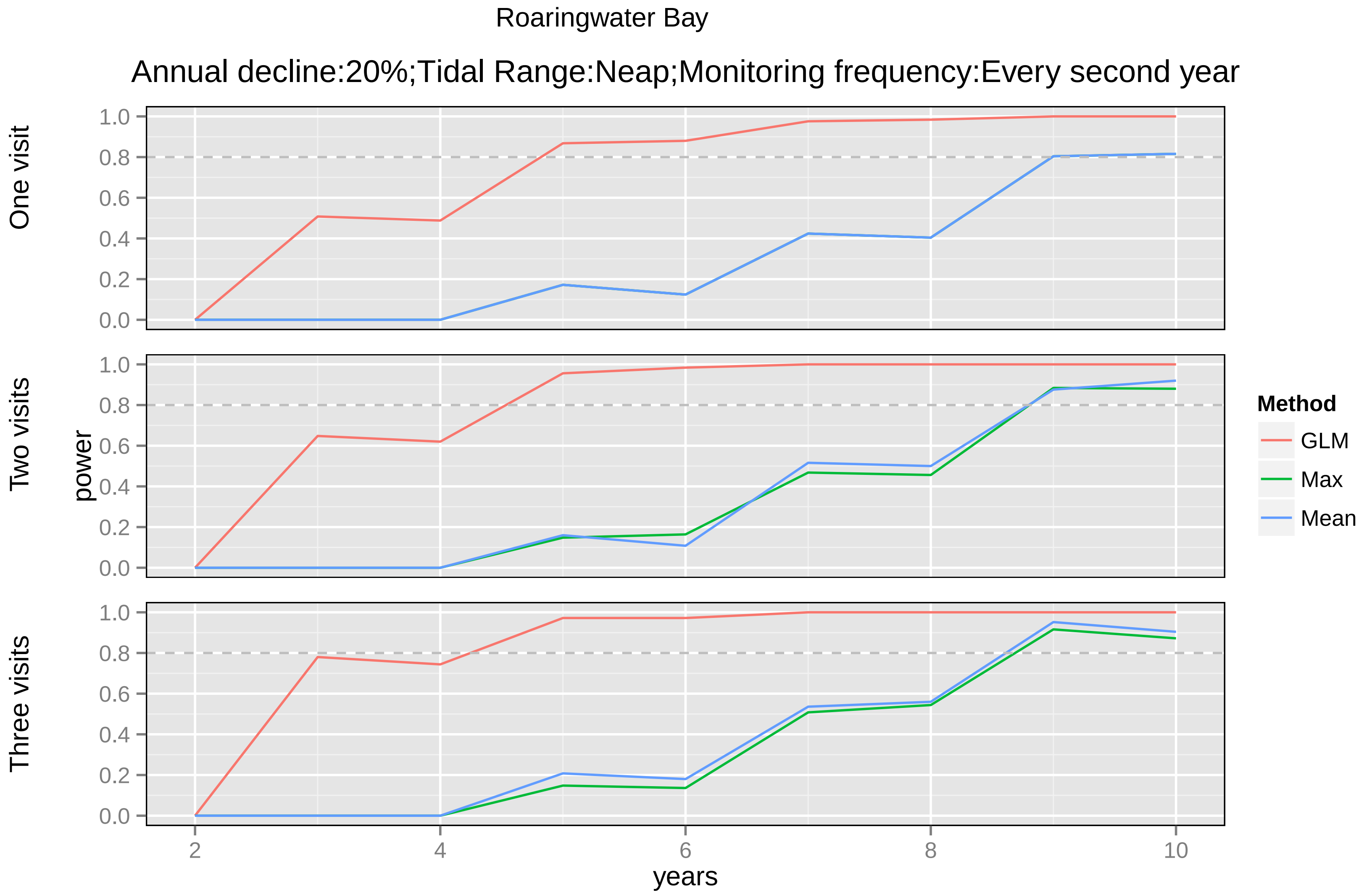
Roaringwater Bay
Annual decline:20%;Tidal Range:Neap;Monitoring frequency:Every second year
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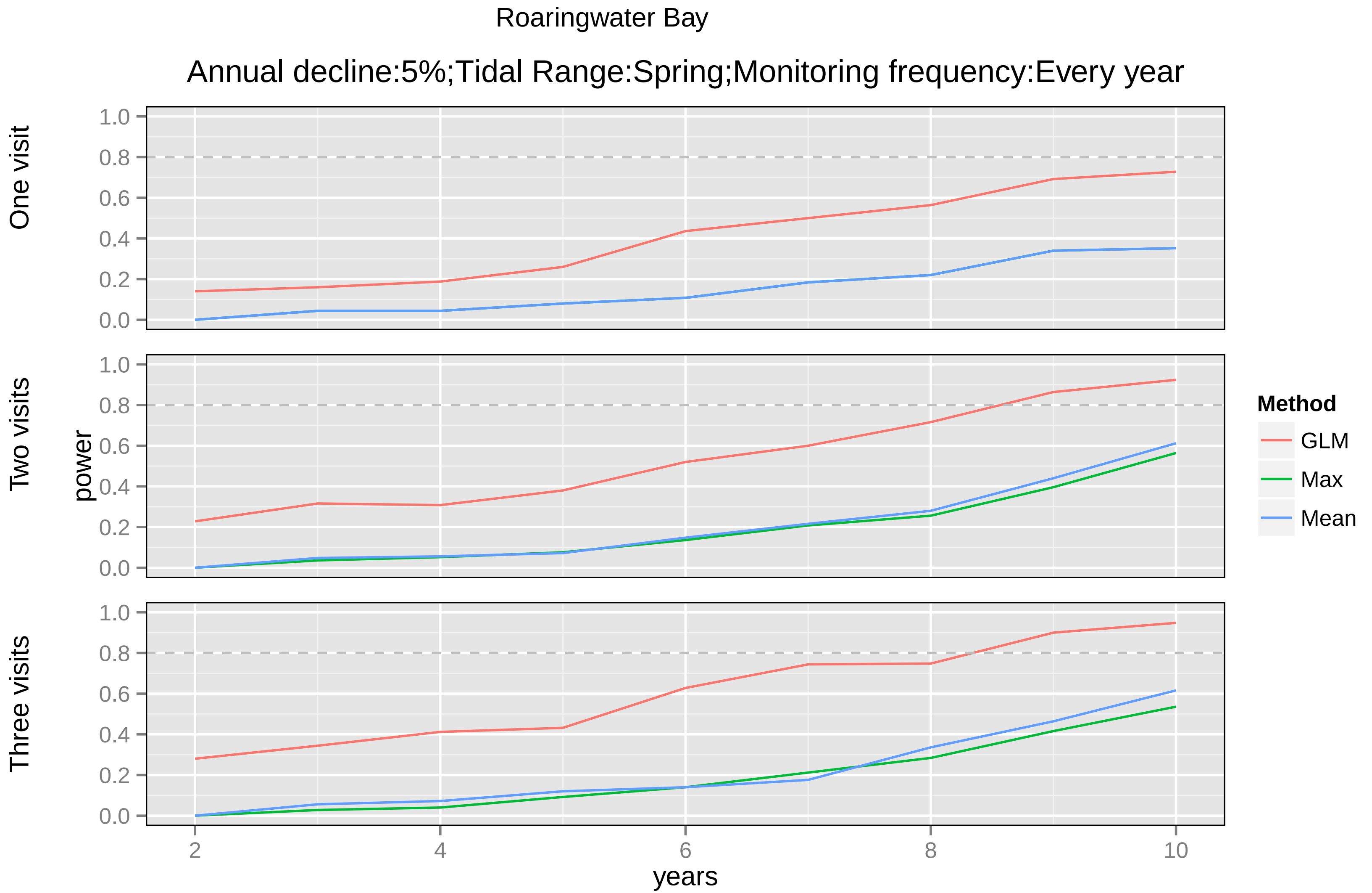
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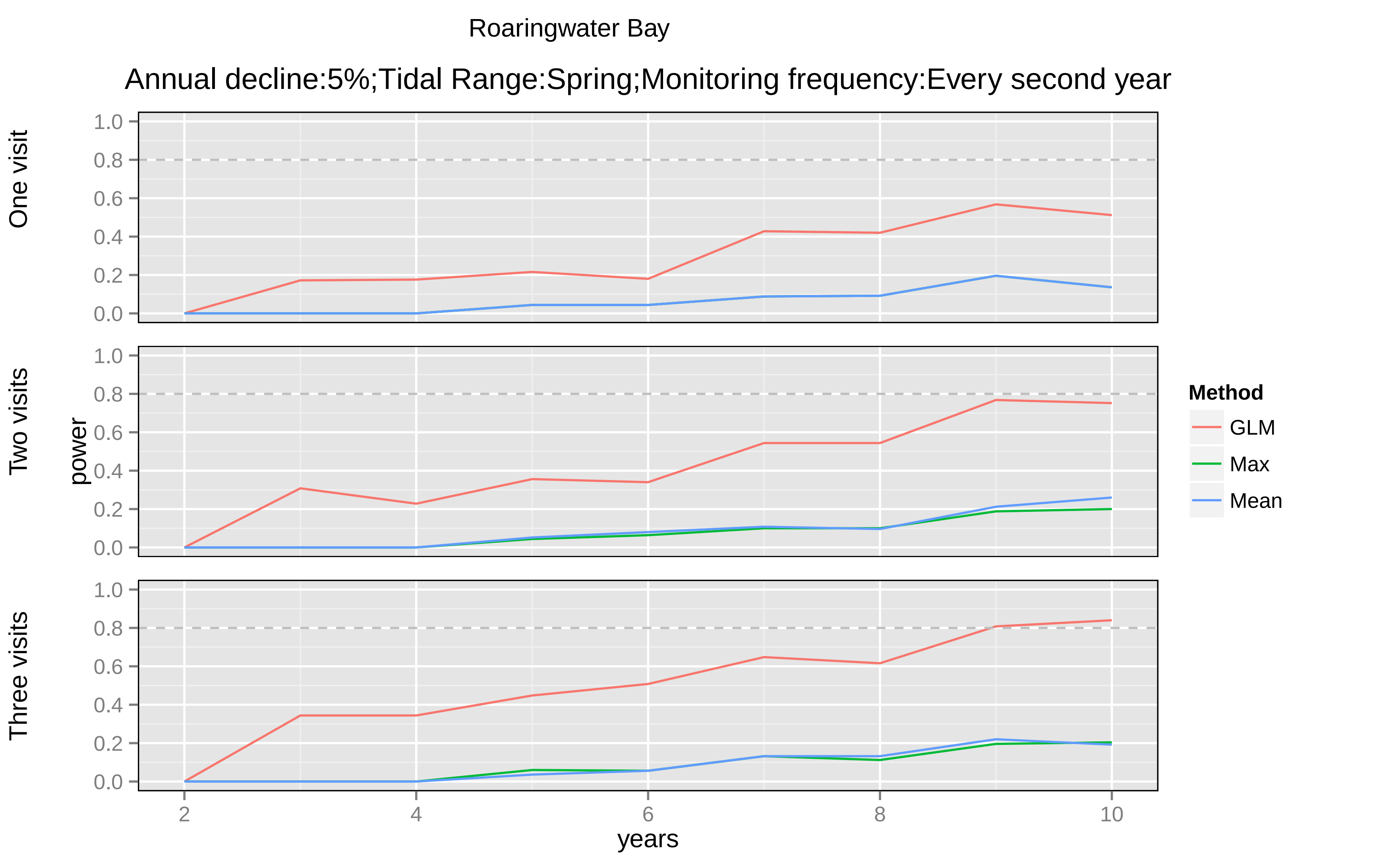
Roaringwater Bay
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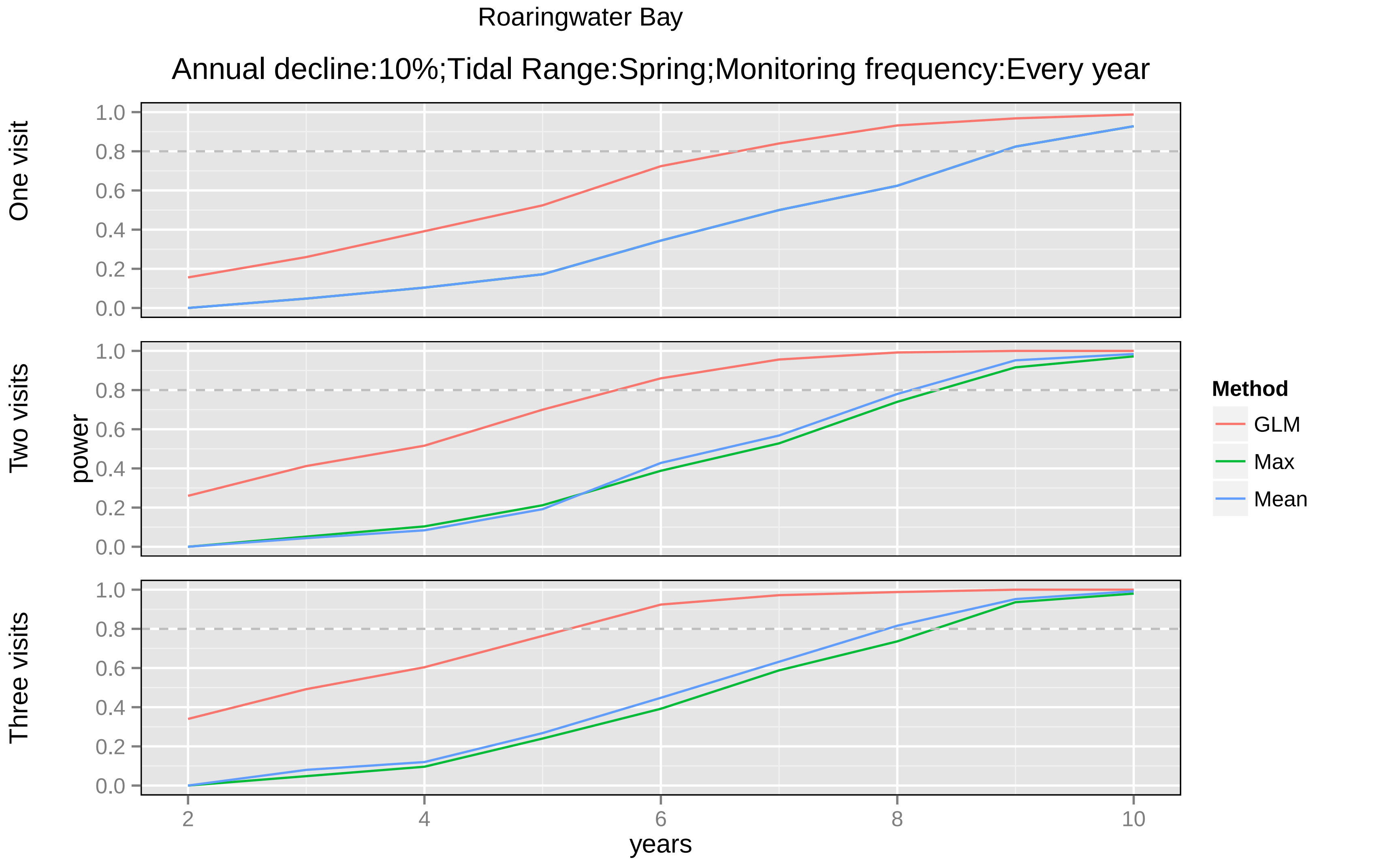
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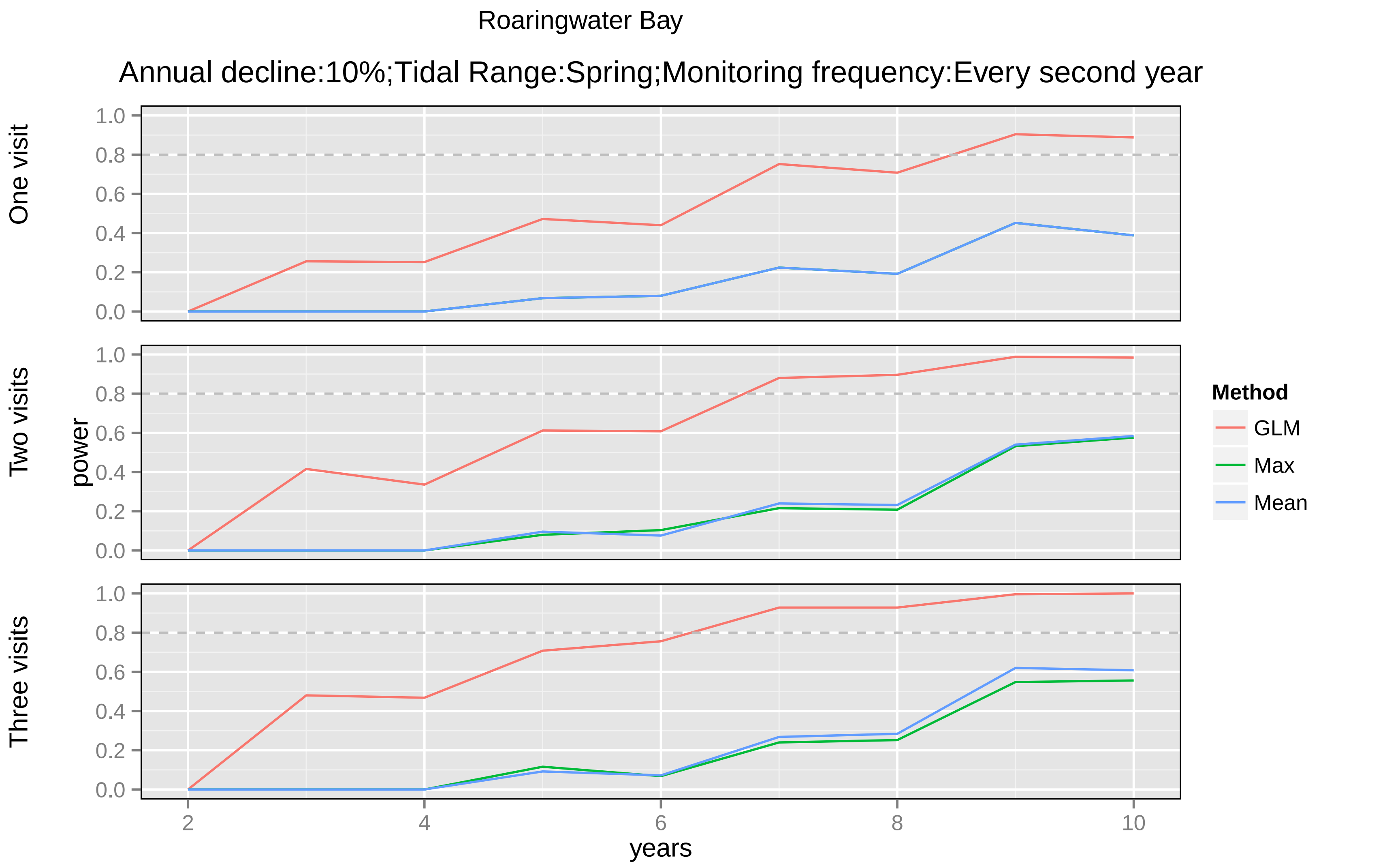

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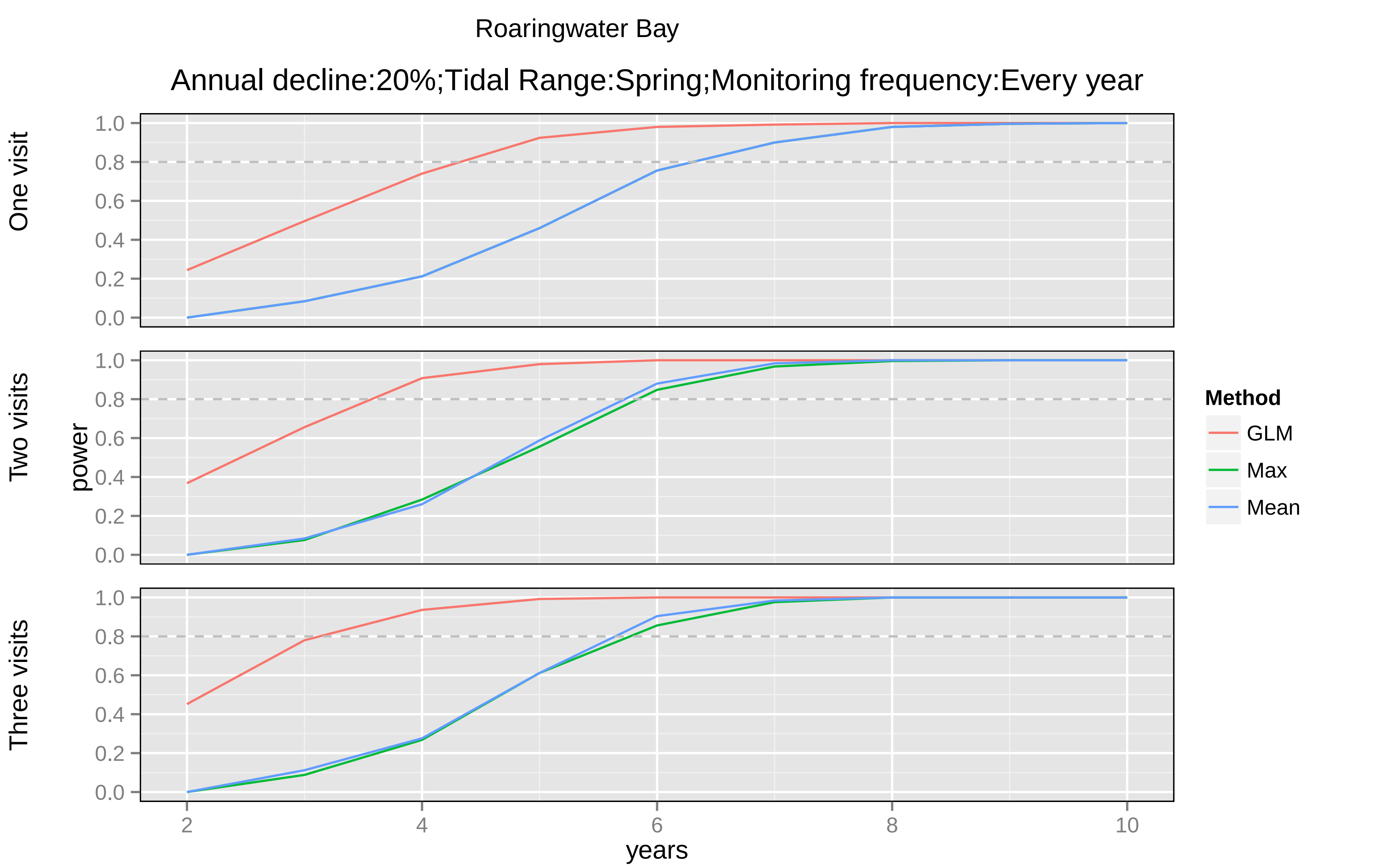

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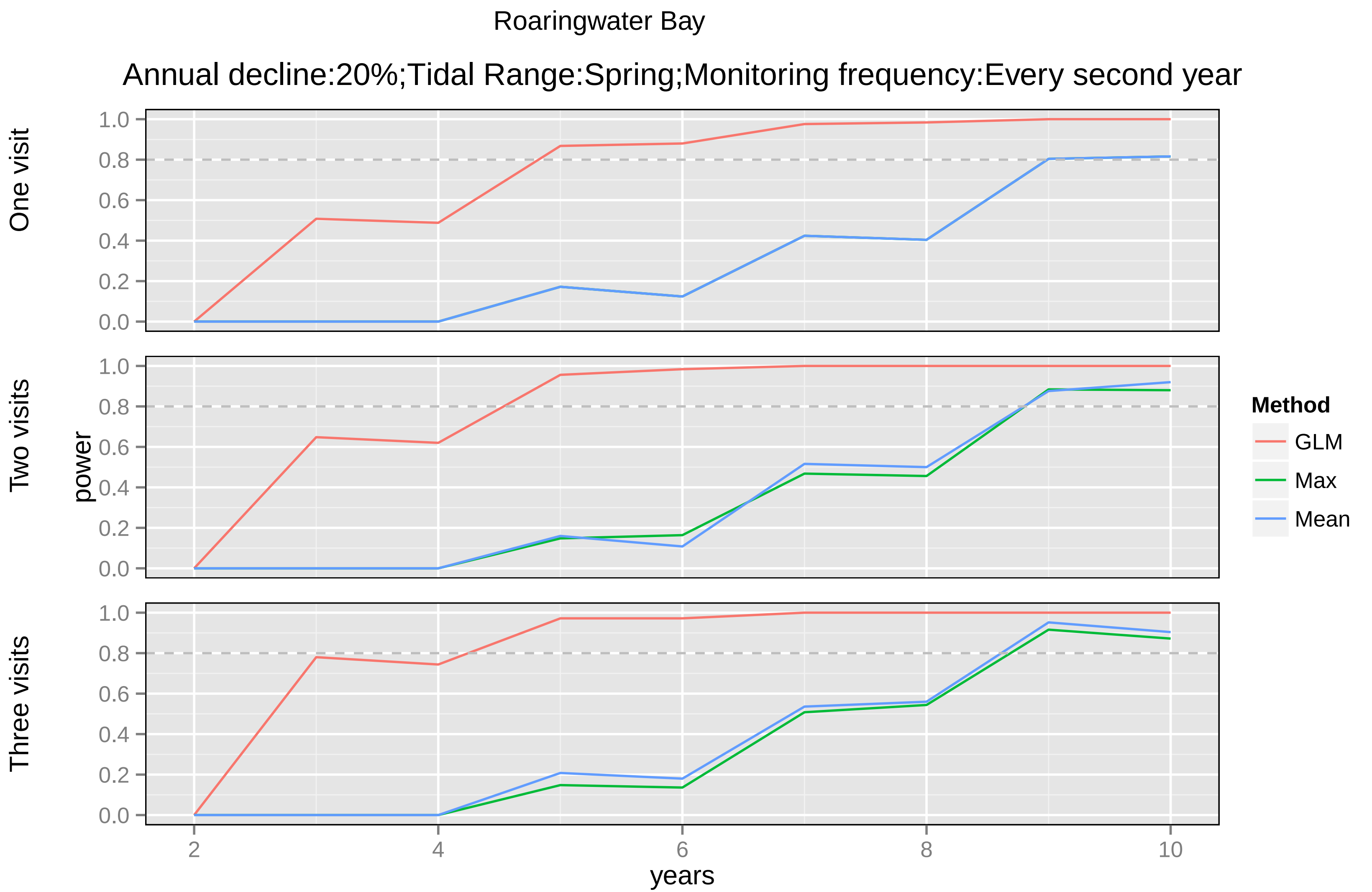

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Annual decline:20%;Tidal Range:Spring;Monitoring frequency:Every second year
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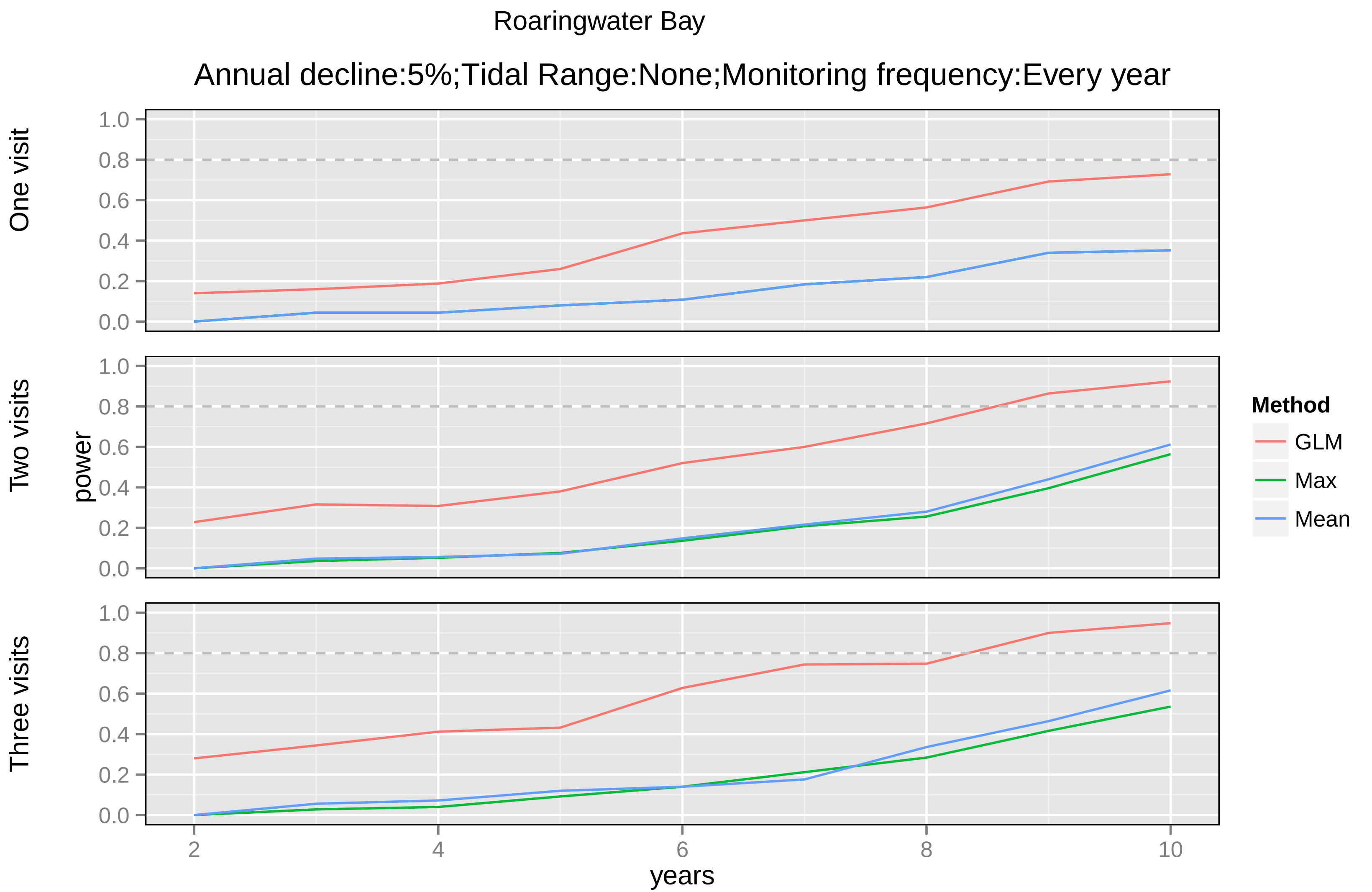

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Annual decline:5%;Tidal Range:None;Monitoring frequency:Every year
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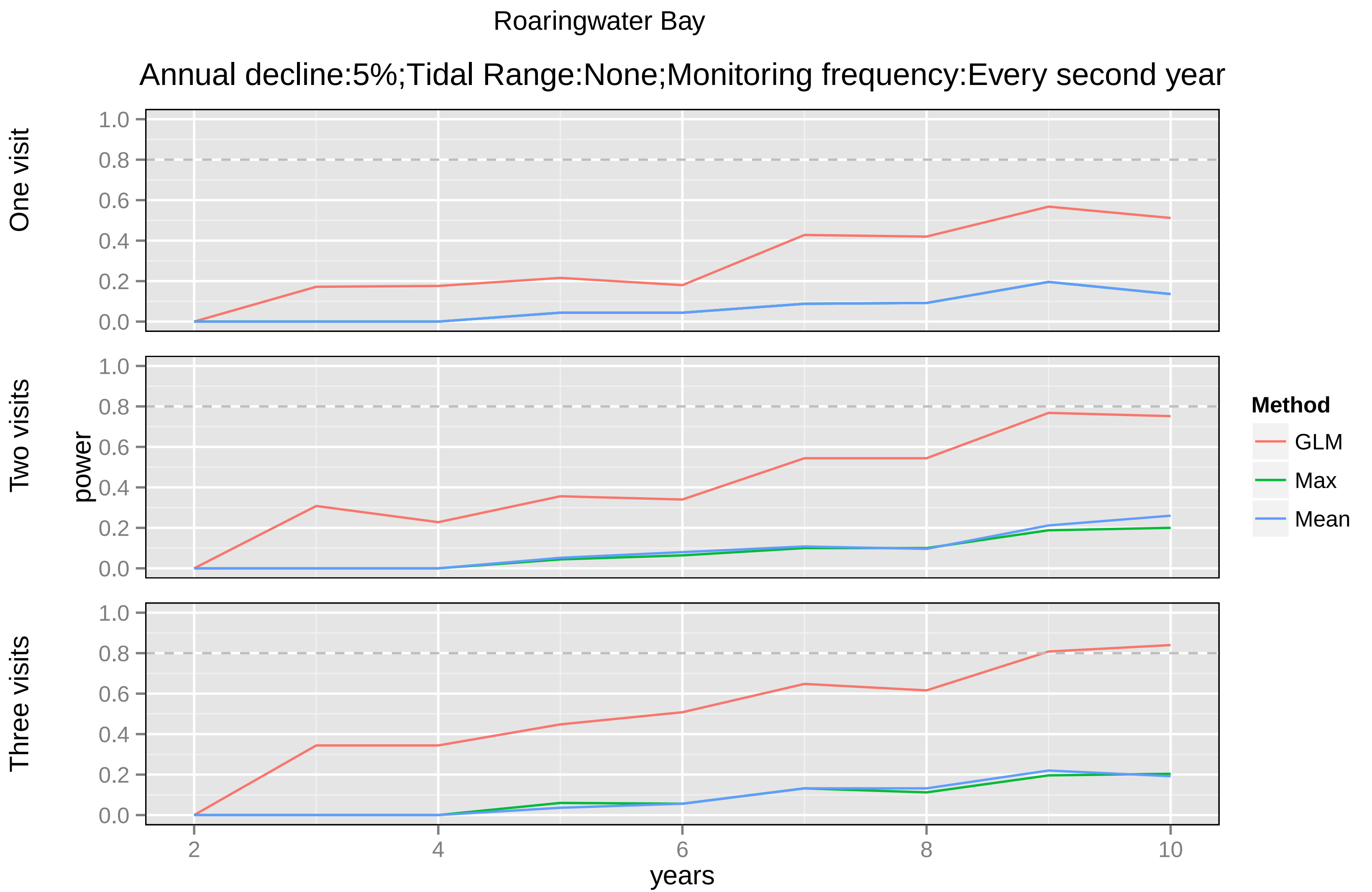
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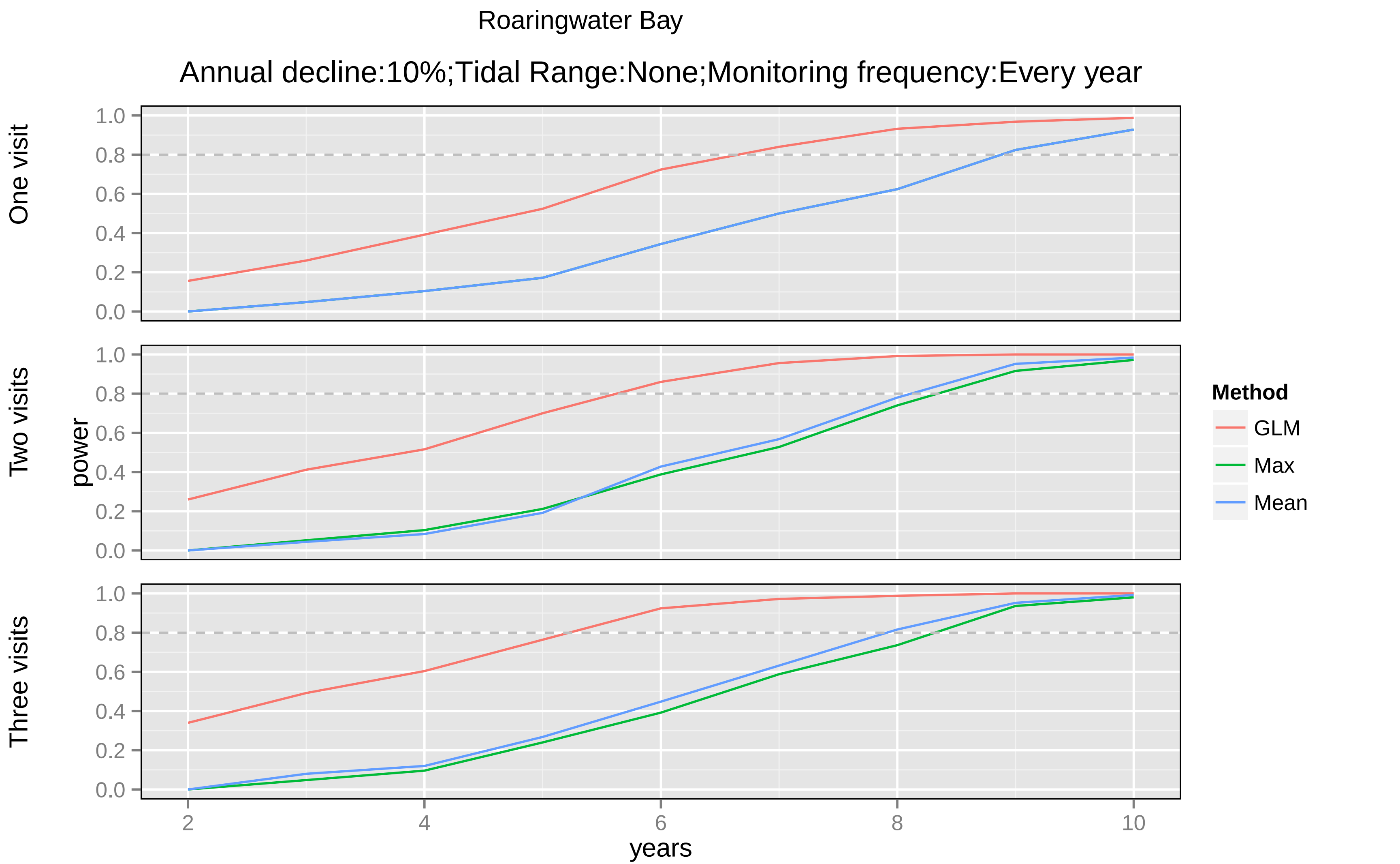

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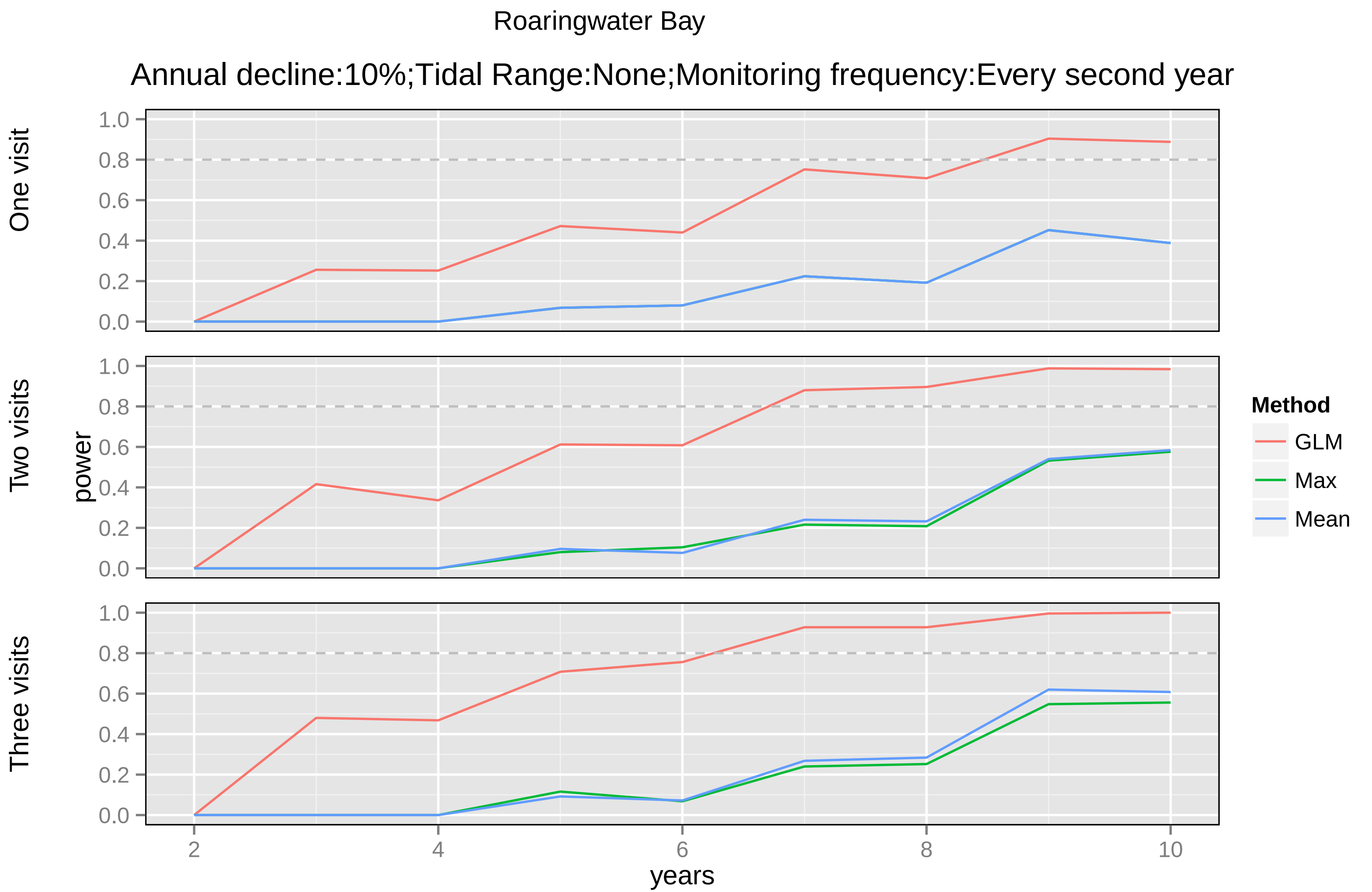

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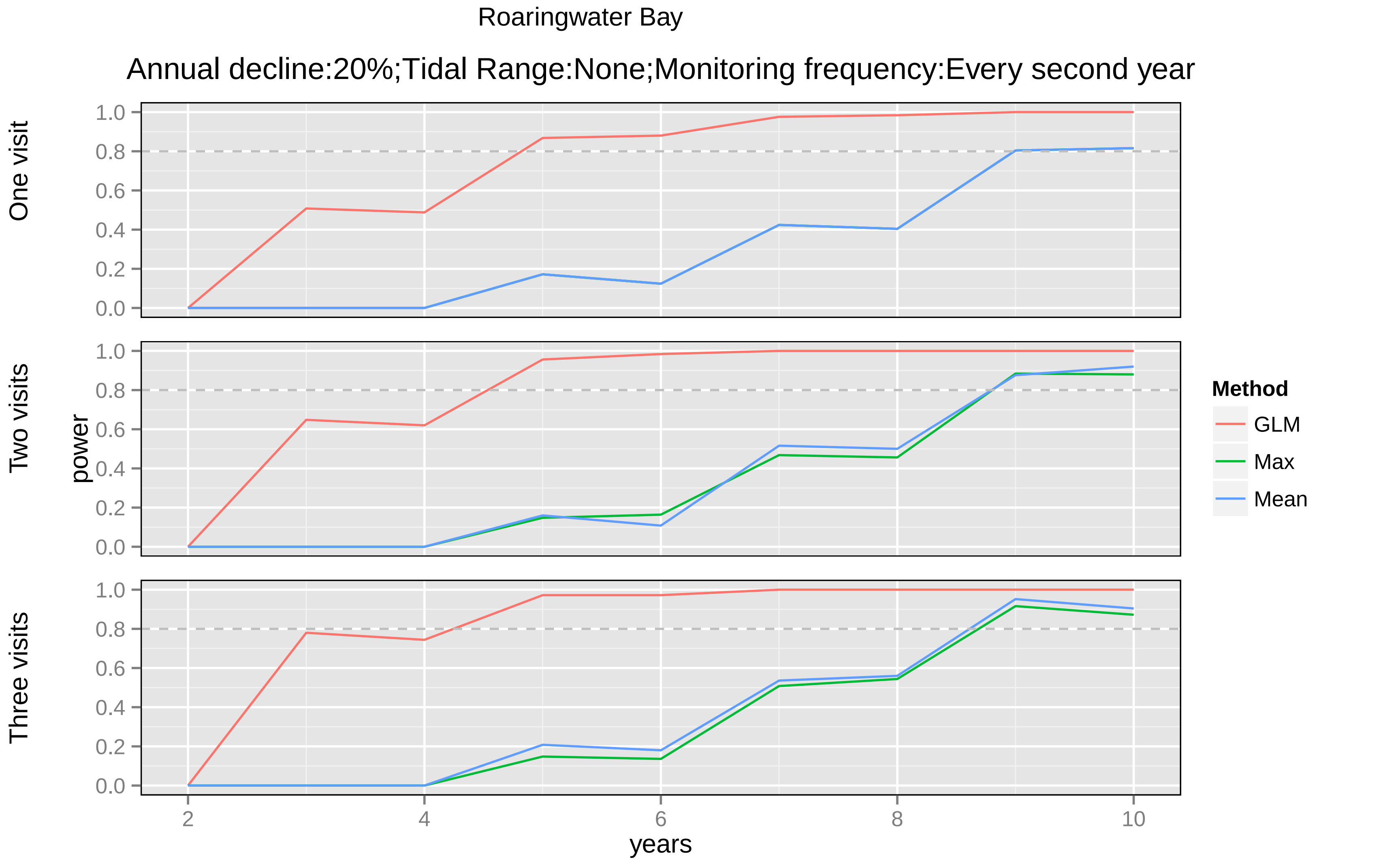
0.2
0.0
2
4
6
8
10
years
Method
GLM
Max
Mean

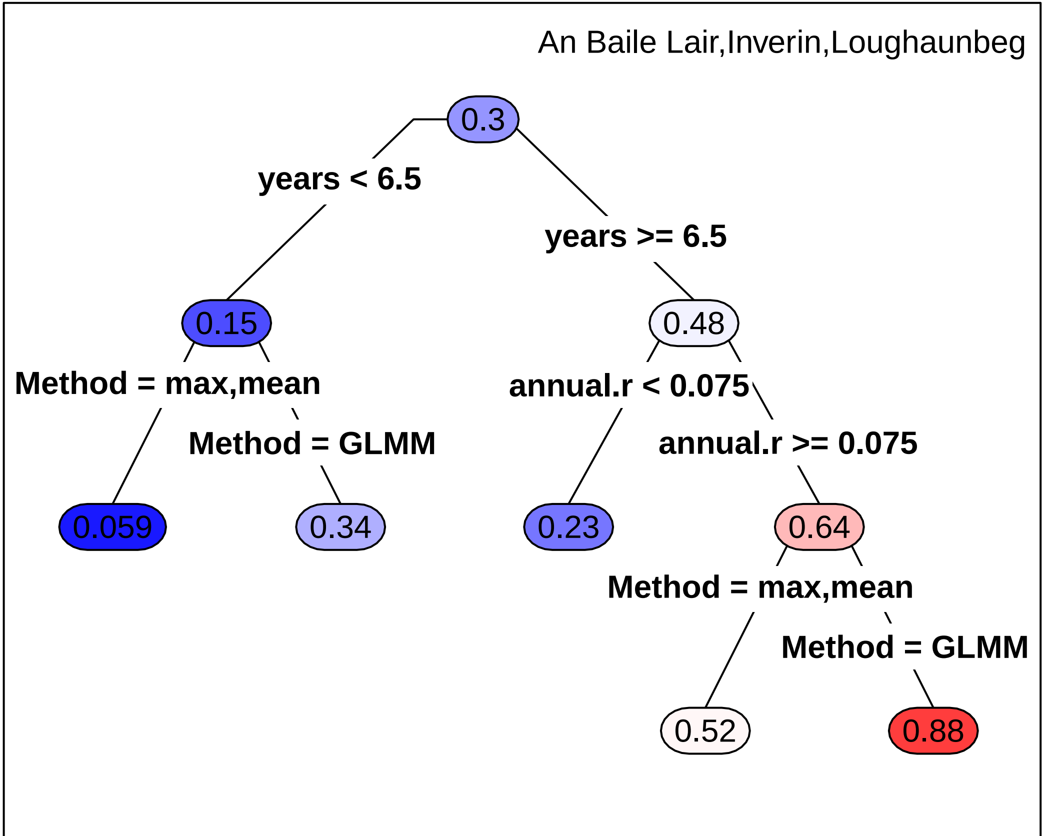

Roaringwater Bay
Annual decline:20%;Tidal Range:None;Monitoring frequency:Every second year
One visit
Two visits
Three visits
power
years
1.0
0.8
0.6
0.4
0.2
0.0
2
4
6
8
10
Method
GLM
Max
Mean

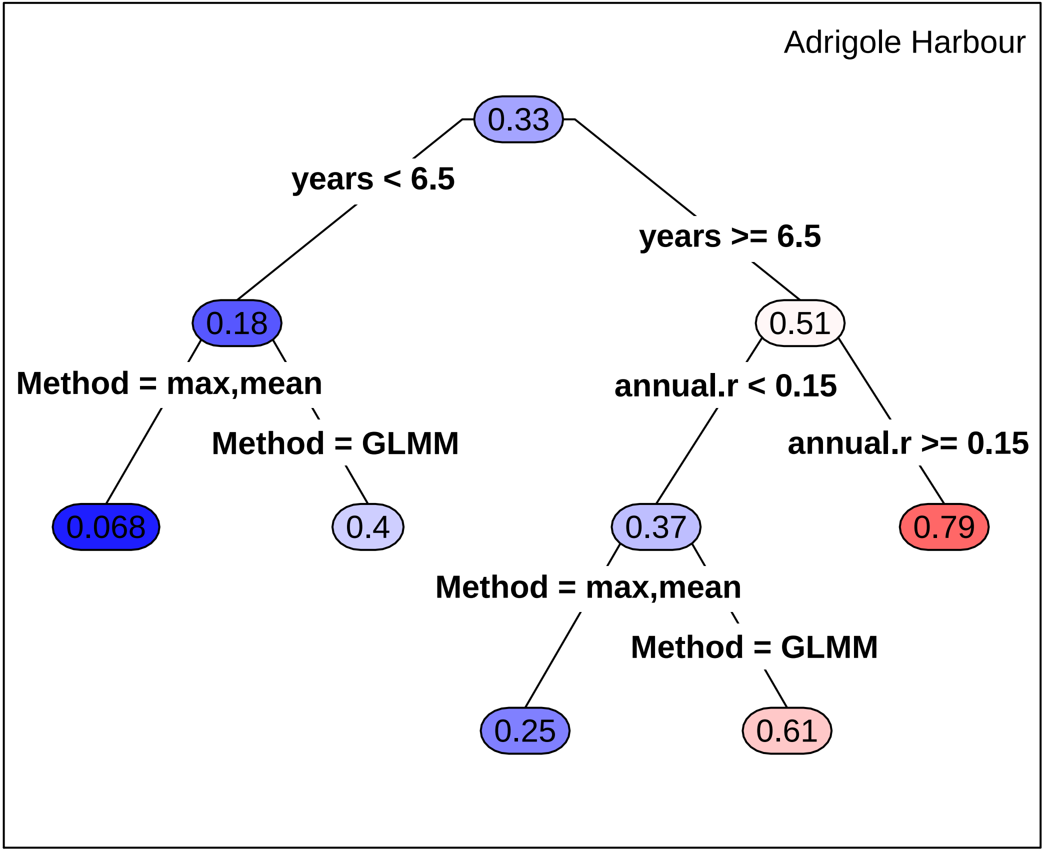
Appendix 2

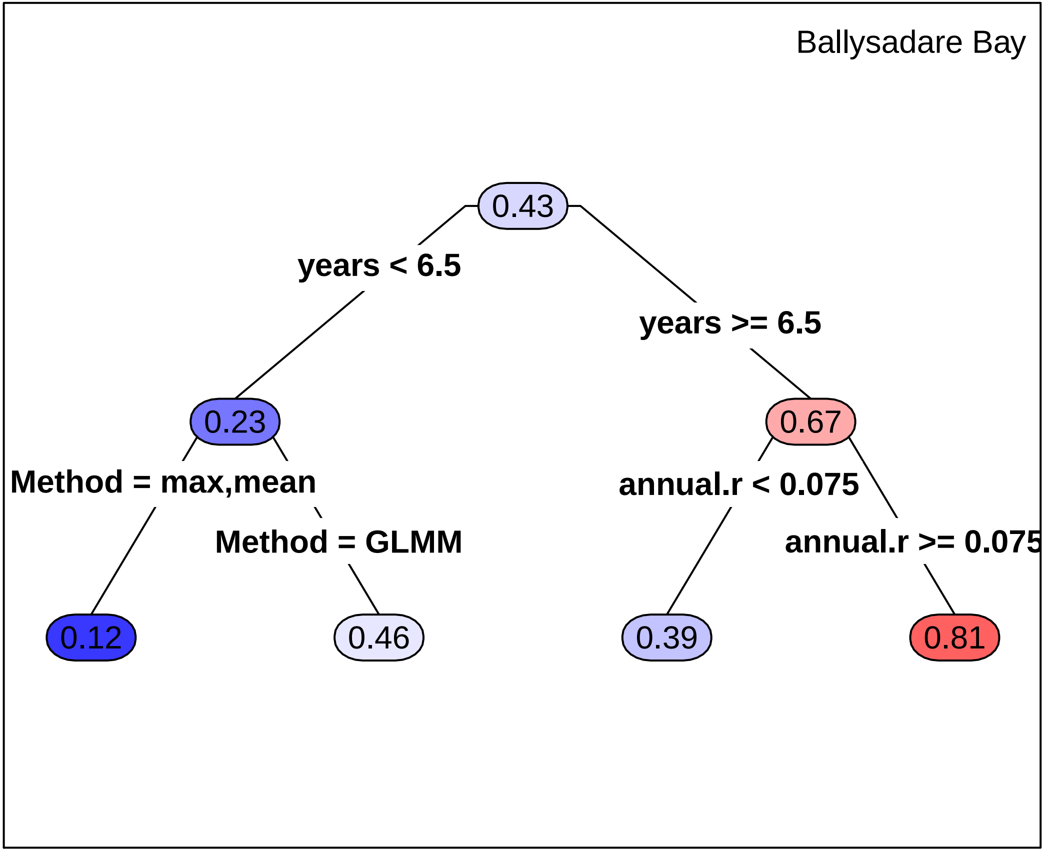
By-location regression trees displaying the hierarchy of influence of key programme design elements on the power to detect a given rate of change in the monitored population. Power is displayed in the nodes ranging from low (blue) to high (red).

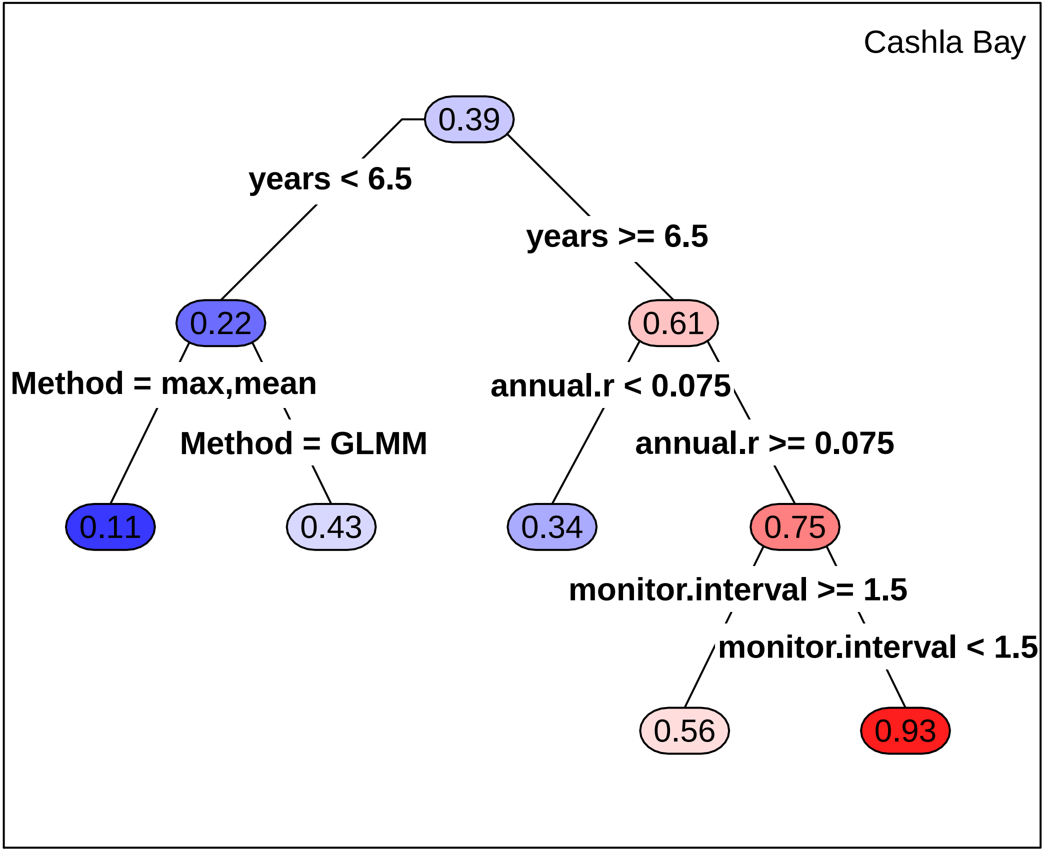
Variable abbreviations denote:

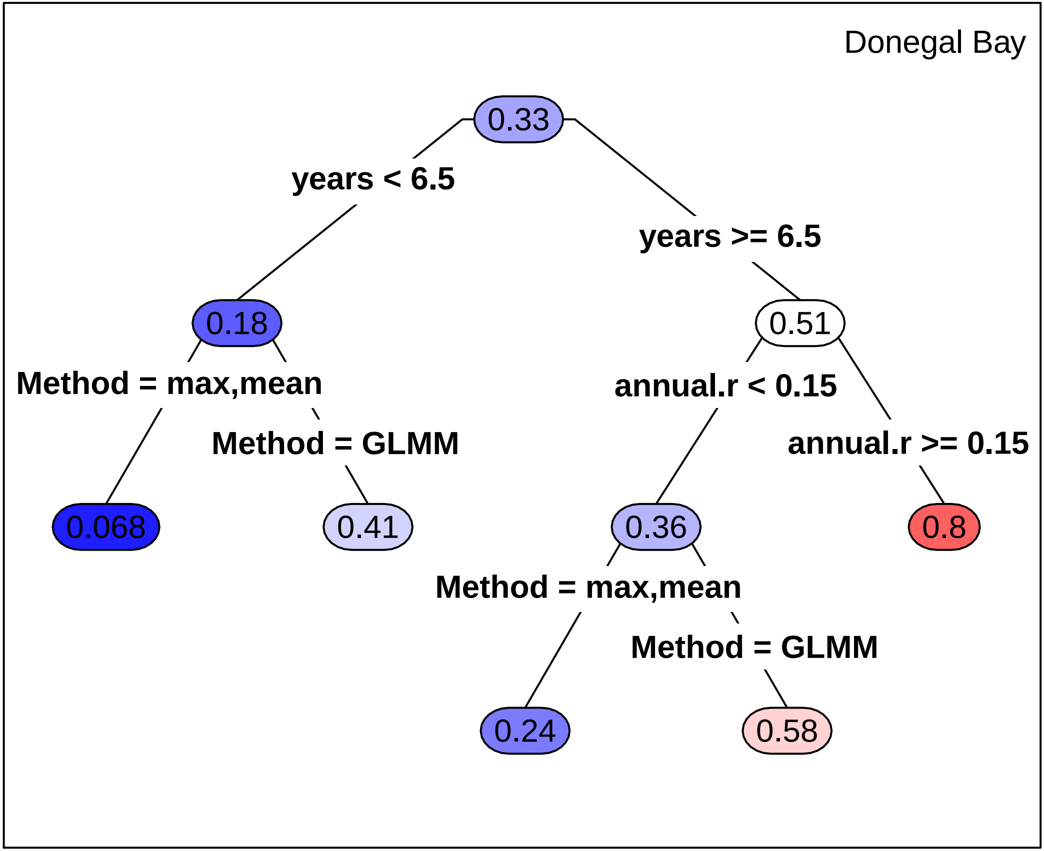
- ***Years*: number of monitoring years;**
- ***Method*: whether the population is monitored with yearly mean, yearly maximum or GLM/GLMM derived trend;**
- ***annual.r*: annual rate of change;**
- ***vis*: number of site visits per annum;**
- ***tide*: number of counts per day;**
- ***monitor.interval*: visits annual or every second year.**

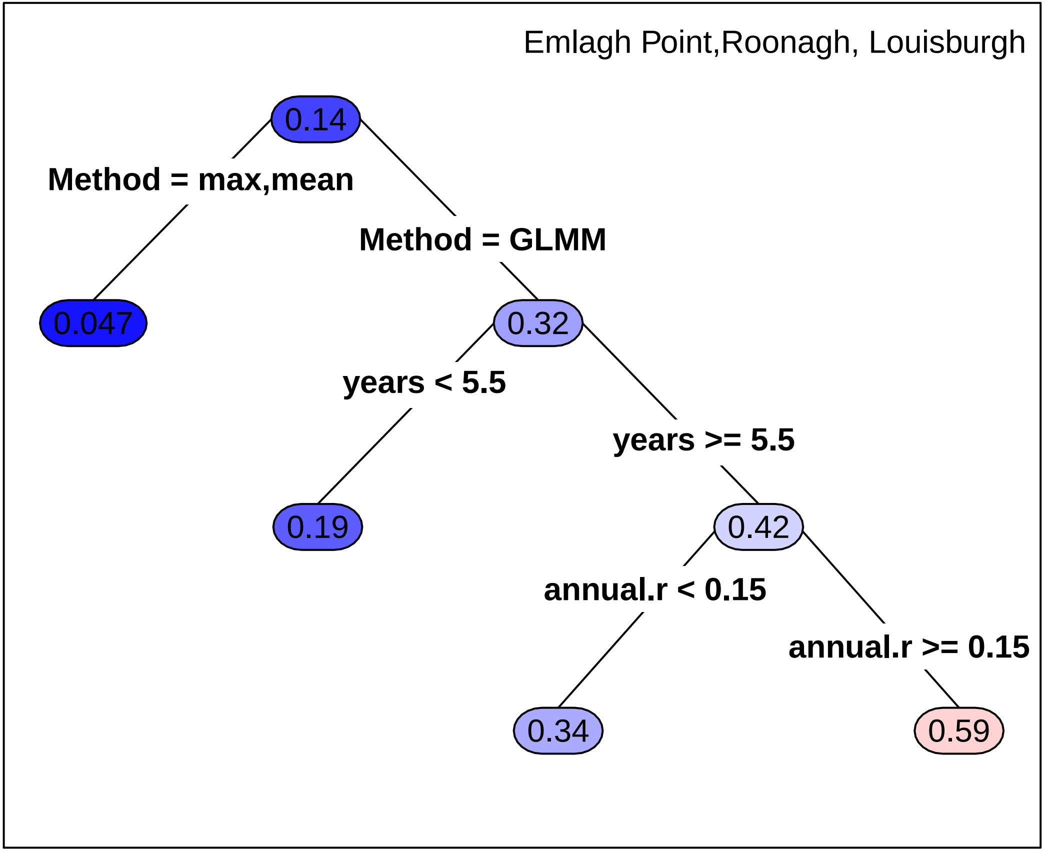

An Baile Lair,Inverin,Loughaunbeg
0.3
years < 6.5
years >= 6.5
0.15
0.48
Method = max,mean
Method = GLMM
annual.r < 0.075
annual.r >= 0.075
0.059
0.34
0.23
0.64
Method = max,mean
Method = GLMM
0.52
0.88

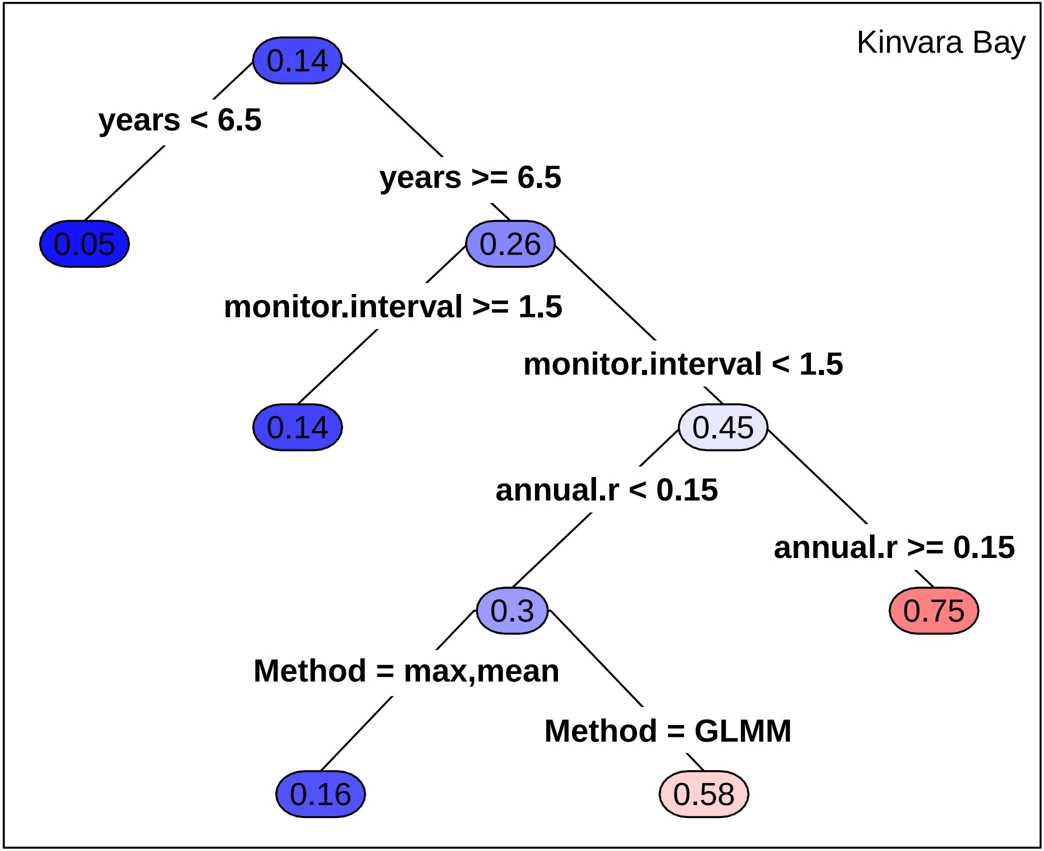

Adrigole Harbour
0.33
years < 6.5
years >= 6.5
0.18
0.51
Method = max,mean
Method = GLMM
annual.r < 0.15
annual.r >= 0.15
0.068
0.4
0.37
0.79
Method = max,mean
Method = GLMM
0.25
0.61

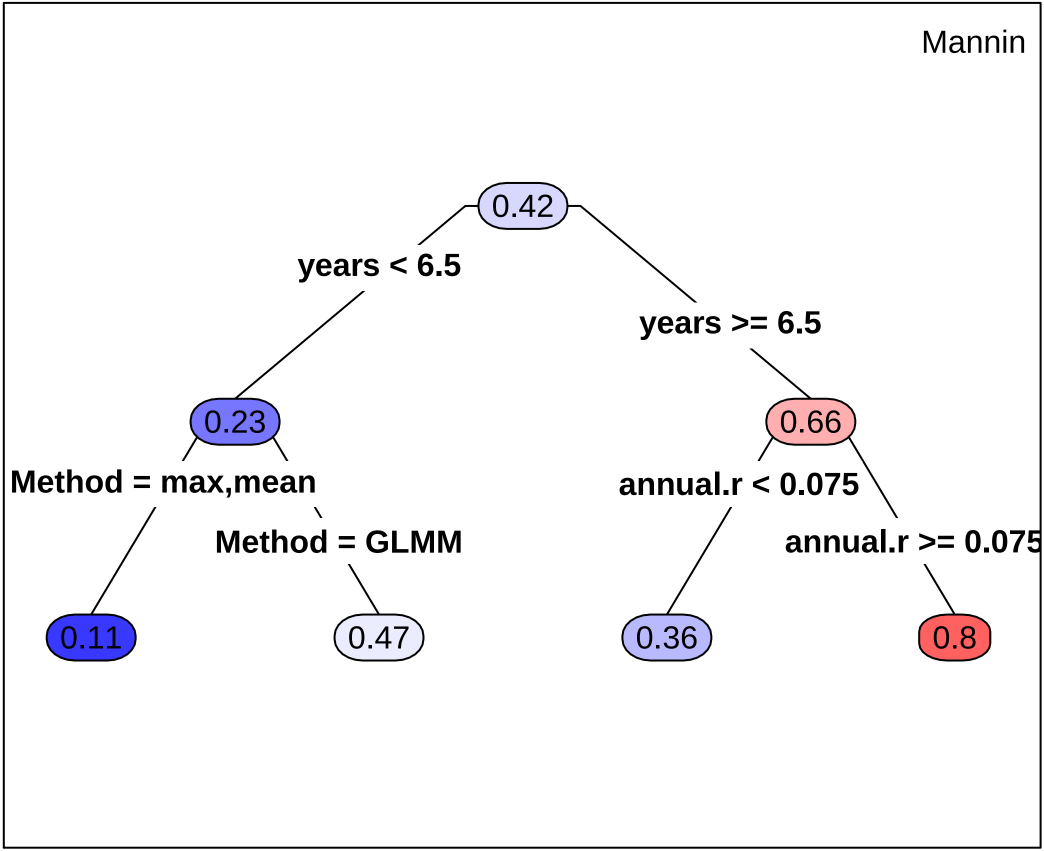

Ballysadare Bay
0.43
years < 6.5
years >= 6.5
0.23
0.67
Method = max,mean
Method = GLMM
annual.r < 0.075
annual.r >= 0.075
0.12
0.46
0.39
0.81

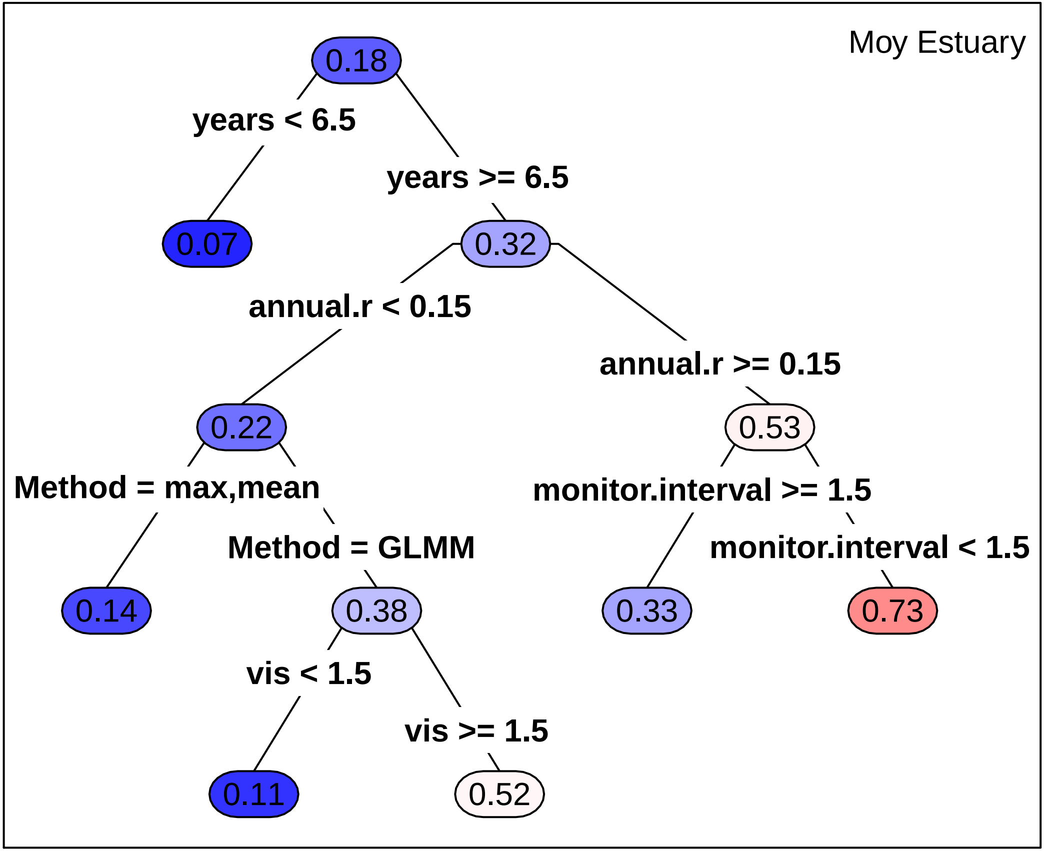

Cashla Bay
0.39
years < 6.5
years >= 6.5
0.22
0.61
Method = max,mean
Method = GLMM
annual.r < 0.075
annual.r >= 0.075
0.11
0.43
0.34
0.75
monitor.interval >= 1.5
monitor.interval < 1.5
0.56
0.93


Donegal Bay
0.33
years < 6.5
years >= 6.5
0.18
0.51
Method = max,mean
Method = GLMM
annual.r < 0.15
annual.r >= 0.15
0.068
0.41
0.36
0.8
Method = max,mean
Method = GLMM
0.24
0.58

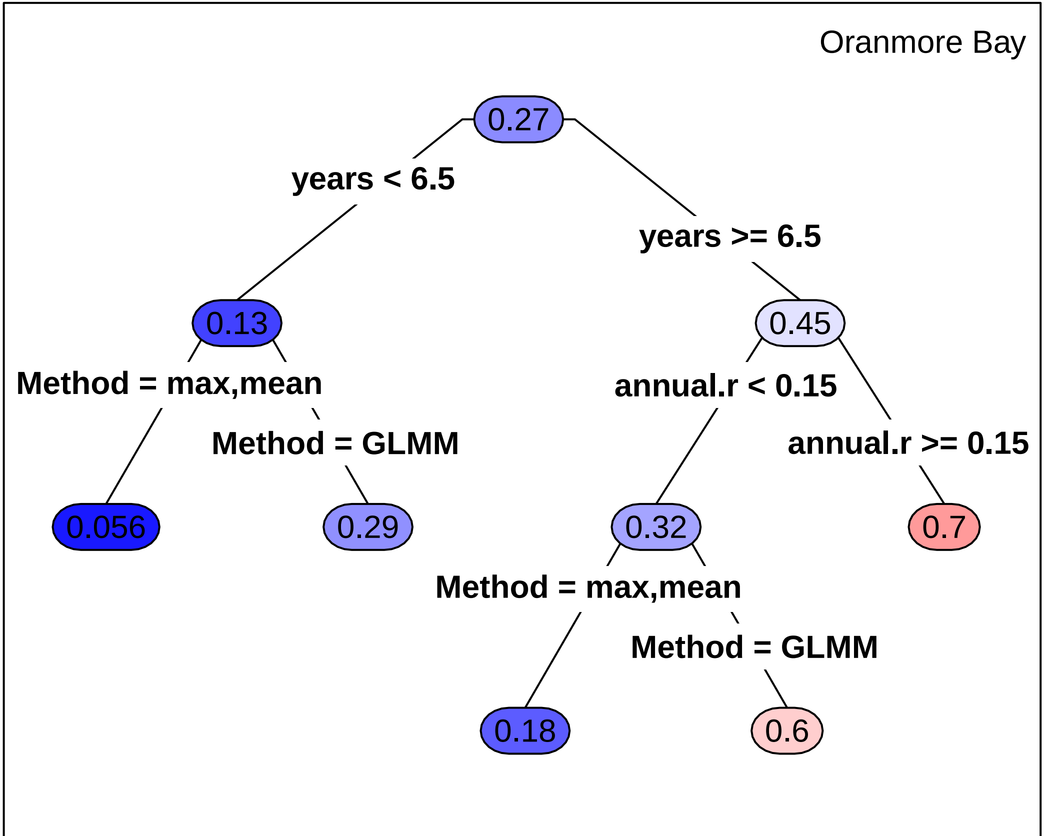

Emlagh Point,Roonagh, Louisburgh
0.14
Method = max,mean
Method = GLMM
0.047
0.32
years < 5.5
years >= 5.5
0.19
0.42
annual.r < 0.15
annual.r >= 0.15
0.34
0.59

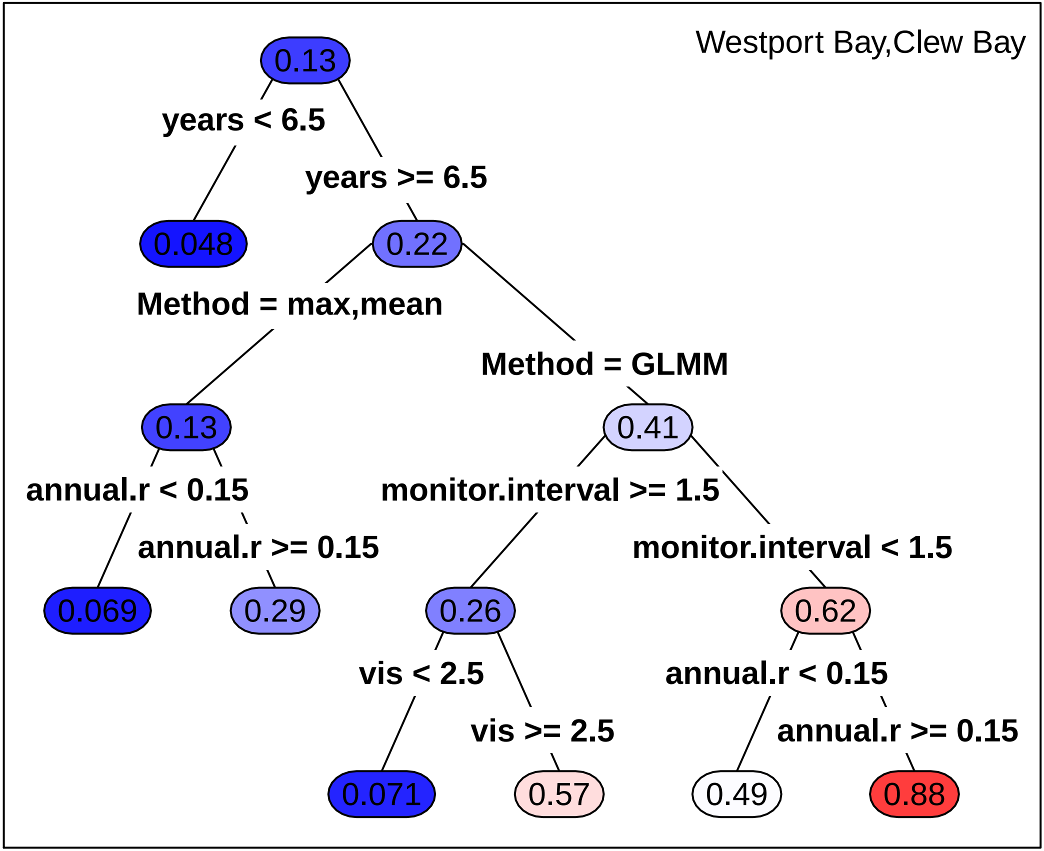

Kinvara Bay
0.14
years < 6.5
years >= 6.5
0.05
0.26
monitor.interval >= 1.5
monitor.interval < 1.5
0.14
0.45
annual.r < 0.15
annual.r >= 0.15
0.3
0.75
Method = max,mean
Method = GLMM
0.16
0.58

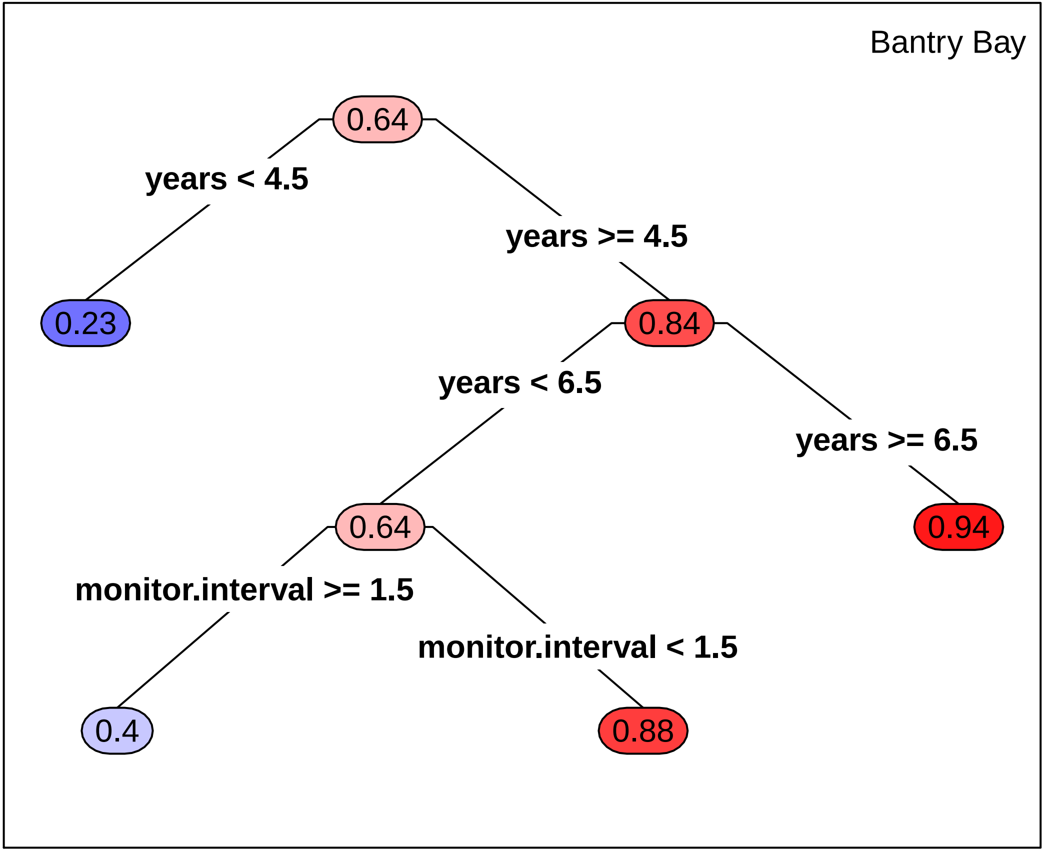

Mannin
0.42
years < 6.5
years >= 6.5
0.23
0.66
Method = max,mean
Method = GLMM
annual.r < 0.075
annual.r >= 0.075
0.11
0.47
0.36
0.8

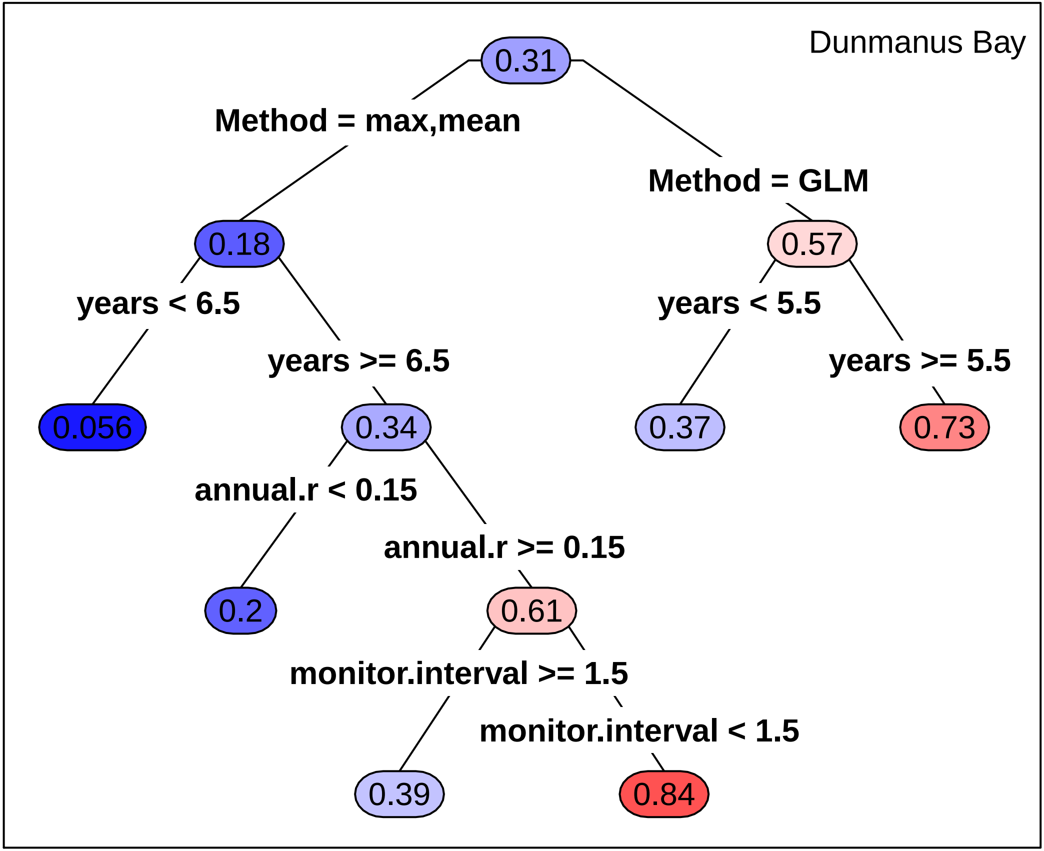


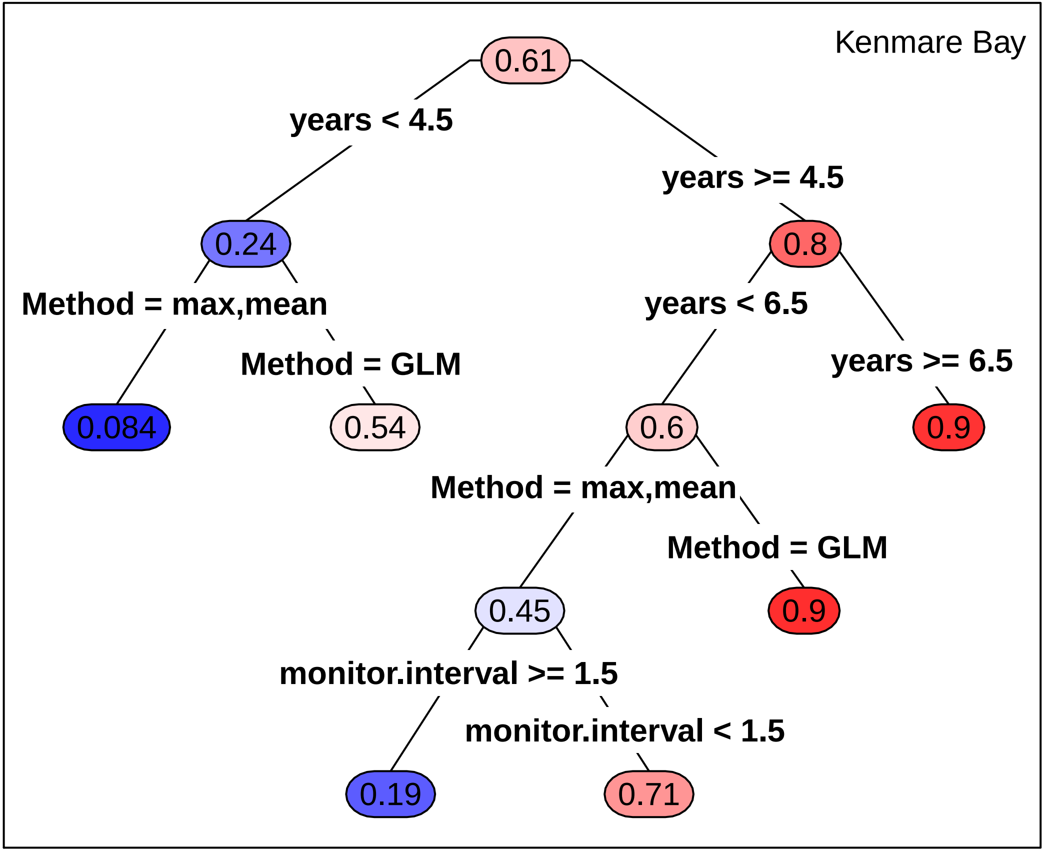
Moy Estuary
0.18
years < 6.5
years >= 6.5
0.07
0.32
annual.r < 0.15
annual.r >= 0.15
0.22
0.53
Method = max,mean
Method = GLMM
monitor.interval >= 1.5
monitor.interval < 1.5
0.14
0.38
0.33
0.73
vis < 1.5
vis >= 1.5
0.11
0.52

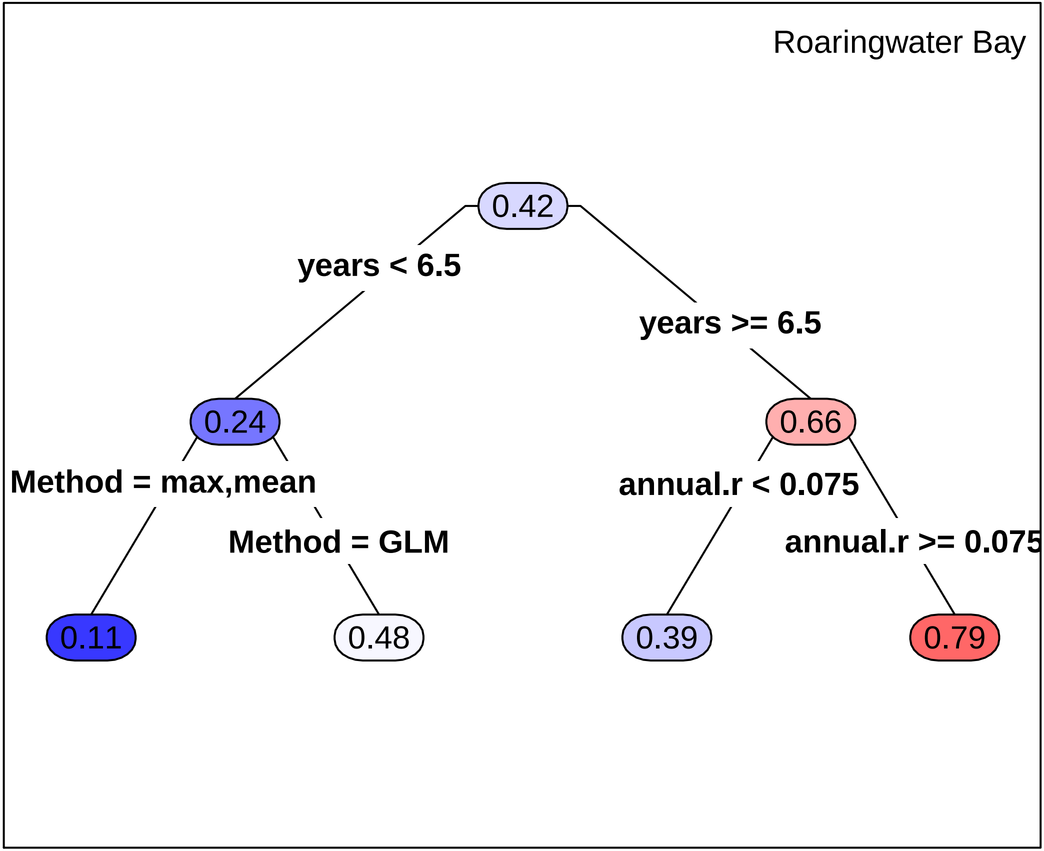

Oranmore Bay
0.27
years < 6.5
years >= 6.5
0.13
0.45
Method = max,mean
Method = GLMM
annual.r < 0.15
annual.r >= 0.15
0.056
0.29
0.32
0.7
Method = max,mean
Method = GLMM
0.18
0.6


Westport Bay,Clew Bay
0.13
years < 6.5
years >= 6.5
0.048
0.22
Method = max,mean
Method = GLMM
0.13
0.41
annual.r < 0.15
annual.r >= 0.15
monitor.interval >= 1.5
monitor.interval < 1.5
0.069
0.29
0.26
0.62
vis < 2.5
vis >= 2.5
annual.r < 0.15
annual.r >= 0.15
0.071
0.57
0.49
0.88


Bantry Bay
0.64
years < 4.5
years >= 4.5
0.23
0.84
years < 6.5
years >= 6.5
0.64
0.94
monitor.interval >= 1.5
monitor.interval < 1.5
0.4
0.88


Dunmanus Bay
0.31
Method = max,mean
Method = GLM
0.18
0.57
years < 6.5
years >= 6.5
years < 5.5
years >= 5.5
0.056
0.34
0.37
0.73
annual.r < 0.15
annual.r >= 0.15
0.2
0.61
monitor.interval >= 1.5
monitor.interval < 1.5
0.39
0.84


Kenmare Bay
0.61
years < 4.5
years >= 4.5
0.24
0.8
Method = max,mean
Method = GLM
years < 6.5
years >= 6.5
0.084
0.54
0.6
0.9
Method = max,mean
Method = GLM
0.45
0.9
monitor.interval >= 1.5
monitor.interval < 1.5
0.19
0.71


Roaringwater Bay
0.42
years < 6.5
years >= 6.5
0.24
0.66
Method = max,mean
Method = GLM
annual.r < 0.075
annual.r >= 0.075
0.11
0.48
0.39
0.79