Power to Detect Trends in Pallid and Shovelnose Sturgeon Populations in the Missouri River

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December 2004

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EXECUTIVE SUMMARY

Monitoring population trends is necessary for designing and assessing the efficacy of conservation strategies for threatened and endangered species. However, monitoring natural populations is challenging because “noise” in counts often overrides the “signal” associated with trends. Statistical power is the probability of detecting a change in population size given that a change is occurring. Estimates of power can be used to determine how much sampling effort is needed to detect biologically meaningful population trends and identify sampling designs that are most likely to detect changes in population size when multiple approaches are available.

In this report, I estimated power to detect trends in Pallid Sturgeon, young Shovelnose Sturgeon (<500 mm in length), and adult Shovelnose Sturgeon (≥500 mm in length) in the Missouri River south of Fort Peck under a variety of levels of sampling effort. Second, I estimated power to detect changes in populations of these species at the scale of the individual river segment. Third, I estimated sensitivity of power to factors including the rate of population change, the duration of the monitoring program, and the level of sampling effort within years. Finally, I compared power to detect population change among the most frequently used gear types. The non-normal distribution of the catch data did not allow for treating the data as continuous and I therefore estimated power to detect trends in occurrence where fish of both species were treated as either present or absent.

Power to detect a 1% annual change in the occurrence of Pallid was low, but a 3% annual change could be detected 87% of the time when 24 river bends and 36 subsamples per bend were sampled in each of 10 years. Power to detect a 5% change in occurrence was always greater than 0.80 when 6 bends were sampled with 36 subsamples per bend. Power to detect trends in occurrence was much greater for both age classes of Shovelnose Sturgeon than it was for Pallid Sturgeon. Power to detect a 1% change in occurrence for either age class was at least 0.80 when 12 bends were sampled per segment. Power to detect 3% and 5% changes in occurrence was 1.0 for all levels of sampling effort.

When segments 5 and 6 were pooled, power to detect 1% and 3% changes in occurrence for Pallid Sturgeon was extremely low and power to detect a 5% change was only 0.61 even with 24 bends and 36 subsamples per bend. Power to detect trends in occurrence for adult Shovelnose Sturgeon in pooled segments 5 and 6 was much higher as a 3% change could be detected with 80% confidence when at least 12 bends were sampled with 24 subsamples per bend.

Gill nets provided more power to detect changes in occurrence for Pallid Sturgeon than trammel nets and otter trawls, but differences were small. Power to detect trends for both species and age classes was most sensitive to the duration of the monitoring program and the rate of change. Relatively modest, but potentially important, gains in power were achieved by doubling the number of bends and subsamples sampled in each year.

In summary, reasonable power to detect a 5% trend in the occurrence Pallid Sturgeon south of Fort Peck can be achieved in 10 years with a level of sampling effort similar to that implemented in 2003. However, detecting a 3% trend will require significantly greater sampling effort than was implemented in 2003. Detecting changes in the occurrence of Pallid Sturgeon at the scale of the individual segment was not feasible for any realistic level of sampling effort. Power to detect changes in the occurrence of adult and young Shovelnose Sturgeon was high given the level of sampling effort implemented in 2003.

INTRODUCTION

Monitoring population trends is necessary for designing and assessing the efficacy of conservation strategies for threatened and endangered species. However, monitoring natural populations is challenging because “noise” in counts often overrides the “signal” associated with trends (Gibbs et al. 1998). When this is the case, threatened populations may decline below acceptable levels or ineffective management strategies may be implemented before negative effects become apparent. Statistical power is the probability of rejecting a false null hypothesis of a stable population given that such a decline occurs. Rigorous estimates of power can be used to determine how much sampling effort is needed to detect biologically meaningful population trends (e.g., Peterman and Routledge 1983) and identify survey techniques and sampling designs that are most likely to detect changes in population size when multiple approaches are available (e.g., Holt et al. 1987, Campbell et al. 2001). Nevertheless, few monitoring studies conduct power analyses prior to project implementation and considerable resources can be spent on monitoring programs that have little chance of detecting trends. Conversely, it is possible to waste resources by “oversampling”.

Power to detect trends is a function of four parameters (Thompson et al 1998, Hatch 2003): (1) the number of samples taken in each year (i.e., within year-sampling effort) and the number of years samples are taken (i.e., the duration of the monitoring program); (2) the variability among samples not attributable to the trend in the population; (3) the effect size (i.e., the rate of population change); and (4) the significance criterion (i.e., the α-level) – the standard used for rejection of the null hypothesis of a stable population. The α-level determines the probability of falsely rejecting a true null hypothesis of a stable population (i.e., the probability of committing a Type 1 error). Power is positively related the number of samples, the effect size (the probability of detecting a large change in the population is greater than the probability of detecting a small change), and the α-level. Power is negatively related to the variability among samples.

The Pallid Sturgeon is one of the most endangered species in the United States and occurs in particularly low numbers in the Missouri River. A long-term interagency monitoring program has recently been developed which is based on a hierarchical, stratified random sampling design (Anonymous; Table 1). Fourteen different river segments have been delineated; segments 1-4 are located above Fort Peck and segments 5-14 are located below Fort Peck. A variable number of river bends are to be randomly sampled within each segment and all available habitat types are to be sampled within each bend. At least two subsamples are to be taken within each habitat type. Pilot data were collected in five river segments below Fort Peck in 2003, but power to detect trends in Pallid Sturgeon with the proposed sampling design has not yet been estimated and it is unclear whether it is possible to capture sufficient numbers of individuals to detect changes in the population. As a result, it has been suggested that Shovelnose Sturgeon in the Missouri River could be treated as a surrogate species for Pallid Sturgeon.

GOALS

In this report, I estimated power to detect trends in Pallid Sturgeon, young Shovelnose Sturgeon (<500 mm in length), and adult Shovelnose Sturgeon (≥500 mm in length) in the Missouri River south of Fort Peck under a variety of levels of sampling effort. Second, I estimated power to detect changes in the populations of these species at the scale of the individual segment. Third, I estimated sensitivity of power to the rate of population change, the duration of the monitoring program, the level of sampling effort within years, and the α-level. Finally, I compared power to detect trends among the most frequently used gear types.

METHODS

DATA USED TO ESTIMATE POWER TO DETECT TRENDS IN STURGEON POPULATIONS

To estimate power to detect trends for all species and age-classes I used a subset of the data available from segments 5, 6, 9, 13 and 14. In particular, I only used data from river bends that were selected randomly and subsamples that were selected randomly and taken using "standard" gear types (Anonymous). For Pallid Sturgeon, I only included data from gill nets, trammel nets, and otter trawls because no fish were captured with any other gear types. For young and adult Shovelnose Sturgeon, I only included data from gill nets, trammel nets, otter trawls, and hoop nets because only 20 fish were captured with other gear types.

STATISTICAL METHODS USED TO ESTIMATE POWER TO DETECT TRENDS IN STURGEON POPULATIONS

I estimated power to detect trends in Pallid Sturgeon, young Shovelnose Sturgeon, and adult Shovelnose Sturgeon using a Monte Carlo simulation approach. I modeled trends in the occurrence of fish rather than trends in counts of fish or catch-per-unit-effort because (1) the distribution of counts was highly non-normal; (2) most gear deployments captured zero fish, especially Pallid Sturgeon; (3) there was a large amount of heterogeneity in the number of fish captured among the gear types; and (4) some gears were active (effort measured in distance) while others were passive (effort measured over time). Pallid Sturgeon were only captured in 1.3% of subsamples (Table 2), while adult and young shovelnose sturgeon were captured in 35% of subsamples (Tables 3 and 4).

Preliminary analyses in which I treated catch-per-unit-effort as the dependent variable resulted in Type 1 error rates that were considerably greater than the α-level. To model trends in occurrence, fish from all three groups were treated as either present or absent within subsamples.

The Monte Carlo approach involved generating longitudinal datasets using gear- and segment-specific estimates of the probabilities of occurrence. I determined whether fish were present or absent for each simulated subsample using the following logistic regression models estimated from the 2003 catch data:

Pallid Sturgeon: $$P = 1 + \frac{1}{e^{-4.30+0.11*GN-0.04*OT+0.97*Seg5-0.08*seg6-0.64*seg9-0.20*seg13}}$$

Adult Shovelnose: $$P = 1 + \frac{1}{e^{-0.78+1.75*GN-1.84*HN+0.06*OT-0.60*Seg5-1.34*seg6+0.71*seg9+0.81*seg13}}$$

Young Shovelnose: $$P = 1 + \frac{1}{e^{-0.82+1.66*GN-1.94*HN+0.25*OT-0.07*seg9+0.01*seg13}}$$

where P was the probability of occurrence, GN was a dummy variable (i.e., 0 or 1) for gill nets, OT was a dummy variable for otter trawls, HN was a dummy variable for hoop nets, $Seg5$ was dummy variable for segment 5, $Seg6$ was a dummy variable for segment 6, $Seg9$ was a dummy variable for segment 9, and $Seg13$ was a dummy variable for segment 13. If a randomly generated number between 0 and 1 from a uniform distribution was less than P, fish were considered present for that subsample, otherwise they were treated as absent. I generated an underlying deterministic trend in the probability of occurrence over time using the following equation:

$$P_t = P_1 \bullet \lambda^{t-1}$$

where λ was the annual rate of population change (λ = 1.0 represents a stable population and λ = 0.95 represents population declining by 5% per year). The samples size for a given gear type in the simulated dataset was based on the proportion of subsamples taken with that gear type in 2003.

I tested for a trend in the probability of occurrence over time using logistic regression analysis implemented in PROC LOGISTIC of program SAS (SAS Institute 1990). I initially attempted to model river segment and bend (nested within segment) as random effects using PROC GLIMMIX (Littell et al. 1996). However, PROC GLIMMIX is much less efficient than other procedures in SAS and doing so was not feasible under existing time constraints. Gear type and river segment were treated as fixed effects and year was treated as a continuous covariate for all logistic models. Including gear type accounted for the large differences in occurrence among gears and including year provided a test of the null hypothesis that the simulated population was stable. The test-statistic for the year and gear effects followed a χ^2 distribution. Comparisons of tests of the year effect between PROC GLIMMIX and PROC LOGISTIC yielded nearly identical results.

The significance of the year effect was tested using a two-tailed test with an α-level of 0.10. Using a two-tailed test allowed for the detection of both increases and decreases in the probability of occurrence; a one tailed-test would have limited the detection of population trends to either increases or decreases. Note that the probability of detecting a 3% increase (for example) is identical to the probability of detecting a 3% decline. Power based on a two-tailed test refers to the probability of detecting change in either direction (positive or negative), although the actual population can only changes in one direction. Note also that required sample sizes to detect a given rate of change are often 20-50% greater for two-tailed tests than for one-tailed tests (Zielinski and Stauffer 1996).

I repeated the process of simulating a longitudinal dataset and testing for a significant year effect 200 times. The proportion of significant tests was considered as an estimate of power to detect trends in occurrence given the specified rate of change and sampling effort.

For each species and age class of interest, I estimated power to detect 1%, 3%, and 5% annual trends in abundance over 10 years assuming that 10 river segments were surveyed in each year (i.e., segments 5-14)(Table 1). I considered a variety of different levels of sampling effort within years ranging from 6 to 24 bends per segment and 12 to 36 subsamples per bend (Table 1). The mean number of bends per segment called for by the monitoring protocol is 6, but the mean number of bends actually sampled was 15 in 2003 when gill nets, trammel nets, and otter trawls were considered. The protocol specifies that at least two subsamples are to be taken per bend, but the actual; instead this number of subsamples is determined to a large extent by available habitat types. The mean number of subsamples per bend in 2003 was 15 when gill nets, trammel nets, and otter trawls were considered.

ESTIMATING THE EFFECT OF SCALE ON POWER TO DETECT TRENDS IN STURGEON POPULATIONS

I determined the feasibility of monitoring sturgeon populations at smaller scales than the entire lower portion of the Missouri River by developing a pooled logistic regression model for segments 5 and 6 based on the data collected in these segments in 2003. The significance of the year effect for each simulated dataset was determined as described above except that segment was not included as an effect in the model.

ESTIMATING THE SENSITIVITY OF POWER TO DETECT TRENDS IN STURGEON POPULATIONS

I estimated the sensitivity of power to detect changes in Pallid and Shovelnose Sturgeon populations in the Missouri River as a function of the number of subsamples per bend, the number of bends per segment, the rate of population change, the number of years surveyed, and the α-level. For Pallid Sturgeon, power was initially estimated assuming that 12 subsamples were taken from each of 6 river bends in each of the 10 river segments, the rate of population change was -3%, and the α-level was 0.10. I used the same initial parameter values for both age classes of Shovelnose Sturgeon, except that the rate of change was set to 1%. The sensitivity of power to each parameter was estimated by holding all parameters constant except the parameter of interest, which was doubled.

ESTIMATING THE EFFECT OF GEAR TYPE ON POWER TO DETECT TRENDS IN PALLID STURGEON

I compared power of gill nets, trammel nets, and otter trawls to detect trends in Pallid Sturgeon using the approach described above except that I developed separate logistic regression models for each gear based on the data collected in 2003. The significance of the year effect for each simulated dataset was determined as described above except that gear type was not included as an effect in the model.

RESULTS

ESTIMATES OF POWER TO DETECT TRENDS IN STURGEON POPULATIONS

As expected, power to detect trends in the occurrence of Pallid Sturgeon increased with sampling effort (Figure 1). However, power to detect a 1% change in occurrence was extremely low (≤ 0.25), even when 24 river bends and 36 subsamples per bend were sampled (Figure 1). Power to detect trends in occurrence was strongly influenced by the underlying rate of change as power to detect a 3% change was 0.87 with 24 river bends and 36 subsamples (Figure 1). Power to detect a 5% change in occurrence was always greater than 0.80 when at least 12 river bends were sampled or when 6 bends were sampled with 36 subsamples per bend.

Power to detect trends in occurrence was much greater for both age classes of Shovelnose Sturgeon than it was for Pallid Sturgeon (Figures 2 and 3). Power to detect a 1% change in occurrence for Shovelnose Sturgeon was essentially 0.80 when at least 12 bends were sampled per segment. Power for both age classes approached 1.0 when 18 bends were sampled. Power to detect 3% and 5% changes in occurrence was 1.0 for all levels of sampling effort considered.

EFFECT OF SCALE ON POWER TO DETECT TRENDS IN STURGEON POPULATIONS

When segments 5 and 6 were pooled, power to detect 1 and 3% changes in occurrence for Pallid Sturgeon was extremely low (data not shown). Power to detect a 5% change was only 0.61 even with the maximum level of survey effort considered - 24 bends and 36 subsamples per bend (Figure 4). Power to detect trends in occurrence for adult Shovelnose Sturgeon in pooled segments 5 and 6 was much more reasonable. Although power to detect a 1% change in pooled segments 5 and 6 was less than 0.40 (40%) for all levels of sampling effort (Figure 5), 80% power to detect 3% changes could be achieved when 12 bends were sampled with 24 subsamples per bend (Figure 6). Eighty percent power to detect a 5% change was achieved when only 6 bends were sampled with 12 subsamples per bend (Figure 7). No young Shovelnose Sturgeon were captured in segments 5 and 6 and it was not possible to estimate power to detect trends for this age-class.

SENSITIVITY OF POWER TO DETECT TRENDS IN STURGEON POPULATIONS

Power to detect trends for both species and age classes was most sensitive to a doubling of the duration of the monitoring program from 10 to 20 years (Table 5). In fact, power to detect a 3% change in the occurrence of Pallid Sturgeon could be increased to 0.74 (from 0.21) by sampling for 20 years. As mentioned above, relatively large gains in power were also achieved by increasing the rate of change. Only relatively modest gains in power were achieved by doubling the number of bends and subsamples (62% and 33%, respectively).

EFFECT OF GEAR TYPE ON POWER TO DETECT TRENDS IN PALLID STURGEON

Power to detect a 3% annual trend in occurrence across all 10 river segments in 10 years assuming 6 bends and 12 subsamples per bend was 0.22 for gill nets, 0.18 for otter trawls, and 0.16 for trammel nets. By comparison, power to detect a 3% change in occurrence when all three gear types were used was 0.21 (Figure 1).

DISCUSSION

Acceptable levels power to detect trends in a population will depend on a variety of factors including the level of the threat to the population and the cost/feasibility of sampling. The most commonly targeted levels of power in the conservation literature are 80% and 90% (e.g., Sauer 1993, Zielinksi and Stauffer 1996). In this report, I make no such judgment as such decisions are best left to the involved managers and researchers. To this end, the power curves presented in Figures 1-7 show power estimates for a variety of different sampling efforts. Nevertheless, I refer to the sampling effort required to achieve 80% and 90% power in some instances in the discussion below.

Power to detect trends in the occurrence of Pallid Sturgeon was low for the level of sampling effort called for by the monitoring program. However, a 3% annual change in occurrence could be detected in 10 years with reasonable confidence (≥80% power) with a larger sampling effort (24 bends and 36 subsamples per bend). Moreover, a 5% change could be detected with reasonable power with 18 bends and 12 subsamples - approximately the level of sampling effort implemented in 2003. It should be recognized that a 3% annual change results in a 24% total change over 10 years while a 5% annual change translates to 37% total change over 10 years. If the population is declining by 5% annually, it may be desirable to detect and ameliorate such a decline before 37% of the population is lost.

Power to detect changes in occurrence for both age classes of Shovelnose Sturgeon was strikingly good as 1% annual changes could be detected with a high probability in 10 years given the current level of sampling effort. Note that a 1% annual change translates to a 9% change over 10 years. Three and 5% declines will almost certainly be detected. It could be argued that the current monitoring program calls for greater sampling of Shovelnose Sturgeon than is necessary.

The above discussion applies to a monitoring program in which all river segments south of Fort Peck (segments 5-14) are sampled, not just those sampled in 2003. Results from this analysis suggest that monitoring Pallid Sturgeon at the individual segment scale, even when two segments are pooled, may not be feasible unless very intensive sampling is implemented. However, it will be possible to detect 3% and 5% annual changes (but not 1% changes) in adult Shovelnose Sturgeon in pooled segments 5 and 6 with a similar level of sampling effort to what was implemented in 2003.

STRATEGIES FOR INCREASING POWER TO DETECT CHANGES IN STURGEON POPULATIONS

Power to detect trends in Pallid Sturgeon was most sensitive to the rate of change in occurrence and the duration of the monitoring program. Clearly the rate of change cannot be manipulated by the investigators, but power to detect trends can be increased significantly by increasing the rate of change that is considered acceptable to detect. If for example, managers are willing to tolerate only being able to detect a 6% rather than a 3% annual change in the occurrence of Pallid Sturgeon, power can be increased by 162% from 0.21 to 0.55 with 6 bends per segment and 12 subsamples per bend (72 total subsamples per segment). This is an important consideration because achieving the same level of power by increasing sampling effort alone would require 12 bends and 36 subsamples (432 total subsamples per segment), a several fold increase. Of course, increasing the targeted rate of change will likely result in a greater proportion of the population being lost before declines are detected. I recommend carefully considering what rate of population change is acceptable to detect; a population viability analysis could be a useful means of guiding such an exercise.

Power can also be increased significantly by increasing the duration of the monitoring program to 20 years. If the monitoring program is conducted over 20 instead of 10 years, power to detect a 3% annual change in the occurrence of Pallid Sturgeon can be increased by 252% from 0.21 to 0.74 with 6 bends per segment and 12 subsamples per bend (72 total subsamples per segment). As described above, increasing power this much by increasing within-year sampling effort will require a several fold increase in sampling. However, if the population is declining, a 3% annual decline translates to a 44% total decline over 20 years compared to only a 24% total decline over 10 years and it may be desirable to detect declines before such a large percentage of the population is lost. Similarly, a 3% annual increase translates to a 24% and 44% total increase over 10 and 20 years, respectively.

Although increasing the duration of the monitoring program and the targeted rate of decline are the most efficient approaches for increasing power, increasing within-year sampling effort may be more desirable because doing so does not increase the percentage of the population that will be lost before a decline is detected. In fact, increasing sampling effort would result in significant improvements in the ability to detect changes in the occurrence of Pallid Sturgeon. Increasing effort to 24 bends per segment resulted in moderately high power (>80%) to detect a ± 3% change and high power (>90%) to detect a ±5% change if 36 subsamples are taken per bend. Moreover, power curves showed a fairly linear rate of increase with an increasing number of bends per segment, suggesting that increasing bends sampled above 24 would result in proportional increased power, at least for ±1% and ±3% rates of change.

Another possibility for increasing power is to increase the α-level because doubling the α-level to 0.20 resulted in a greater increase in power than a doubling of within-year sampling effort. However, doing so means that the null hypothesis of a stable population will be rejected 20% of the time when the population is in fact stable. Although a Type 1 error rate of 0.20 is less defensible then lower error rates, a precedent for this error rate was established by Zielinksi and Stauffer (1996), who developed a monitoring program for Fisher (*Martes pennanti*) and American Marten (*Martes Americana*) populations in California, as well as several other authors cited in Zielinski and Stauffer (1996). Smaller increases in the Type 1 error rate could also be considered.

LIMITATIONS AND ASSUMPTIONS OF THE POWER ANALYSIS

It is important to recognize that the dependent variable used to estimate power for all three groups of sturgeon was the probability of occurrence. This approach was adopted because a high proportion of gear deployments caught zero fish and the catch data was highly non-normal. The presence-absence approach was justified for Pallid Sturgeon because either zero or one fish was caught for all gear deployments. However, multiple fish were often captured by a single gear deployment for both age classes of Shovelnose Sturgeon. Thus a given rate of decline in Shovelnose Sturgeon populations does not necessarily translate into the same rate of decline in occurrence. For example, if there are 10 fish present at each of 5 sampling sites and zero fish present at 5 other sampling sites, a 10% decline in the number of fish in each site would not change the probability of occupancy (i.e., 50%) although the number of fish would have declined from 50 to 45. To adequately estimate power to detect changes in population size rather than occurrence of Shovelnose Sturgeon, it will be necessary to develop statistical approaches that can deal with the non-normality inherent in the catch data.

Another important consideration is the fact that only one year of pilot data were available and interannual variability in sturgeon populations was not considered. If there are large differences in the probability of occurrence among years, power to detect trends will be overestimated and more sampling effort will be needed to achieve desired levels of power. Further power analyses should be conducted when more years of data are available.

ACKNOWLEDGEMENTS

I am grateful the research biologists Wyatt Doyle, Robert Klumb, and Kurt Steffenson for providing the data necessary to parameterize the simulations and to the Pallid Sturgeon Assessment team for their additional information. I also thank Jim Baldwin for helping to develop the SAS code used to run the simulations.

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Table 1. Sampling hierarchy used in the monitoring program and power analysis.

	Number of Units Sampled	
Scale of Sampling	Monitoring Protocol	Power Analysis
Segment	14 Segments 1-4 and 5-14 represent two isolated populations	10 segments simulated (approximating segments 5-14). Simulations parameterized with 5 available segments
Bend	3-10 per segment (average 6 bends per segment)	6-24 per segment
Macrohabitat	All available	N/A
Mesohabitat	All available	N/A
Gear	2-3 per mesohabitat	3 total for Pallid Sturgeon 4 total for Shovelnose Sturgeon
Subsample	≥ 2 per habitat	12-36 per bend

Table 2. Probability of occurrence (*P*) and number (*N*) of Pallid Sturgeon captured in segments 5, 6, 9, 13 and 14 of the Missouri River with gill nets, trammel nets, and otter trawls (*n* = number of gear deployments). No Pallid Sturgeon were captured with hoop nets. The probability of occurrence was estimated as the number of number of subsamples for which a fish was captured divided by the total number of subsamples.

	Gill Nets			Trammel Nets			Otter Trawls			All Gears		
Segment	P	N	n	P	N	n	P	N	n	P	N	n
5	0.059	1	17	0.029	3	104	----	----	----	0.033	4	121
6	0.000	0	20	0.013	2	149	----	----	----	0.012	2	169
9	0.017	1	60	0.000	0	136	0.011	1	92	0.007	2	288
13	0.008	1	131	0.016	2	123	0.009	1	107	0.011	4	361
14	-----	----	----	0.014	2	148	0.010	1	101	0.012	3	249
All Segments	0.013	3	228	0.014	9	660	0.010	3	300	0.013	15	1118

Table 3. Probability of occurrence (*P*) and number (*N*) of adult Shovelnose Sturgeon (>500 mm) captured in segments 5, 6, 9, 13 and 14 of the Missouri River with gill nets, trammel nets, otter trawls, and hoop nets (*n* = number of gear deployments). The probability of occurrence was estimated as the number of number of subsamples for which a fish was captured divided by the total number of subsamples. The number of gear deployments for all gear types except hoop nets was presented in Table 1.

	Gill Nets		Trammel Nets		Otter Trawls		Hoop Nets			All Gears		
Segment	P	N	P	N	P	N	P	N	n	P	N	n
5	0.53	9	0.24	25	----	----	0.00	0	63	0.18	34	184
6	0.10	2	0.16	24	----	----	0.00	0	72	0.11	26	241
9	0.98	59	0.36	49	0.48	44	0.21	31	150	0.42	183	438
13	0.84	111	0.50	62	0.54	58	0.15	18	123	0.51	249	484
14	-----	----	0.47	70	0.43	43	0.04	6	146	0.30	119	385
All	0.79	181	0.35	230	0.46	145	0.10	55	554	0.35	611	1742

Table 4. Probability of occurrence (*P*) and number (*N*) of young Shovelnose Sturgeon (<500 mm) captured in segments 9, 13 and 14 of the Missouri River with gill nets, trammel nets, otter trawls, and hoop nets. No young Shovelnose were captured in segments 5 and 6. The probability of occurrence was estimated as the number of number of subsamples for which a fish was captured divided by the total number of subsamples. The number of gear deployments was presented in Tables 1 and 2.

	Gillnets		Trammel Nets		Otter Trawls		Hoop Nets		All Gears	
Segment	P	N	P	N	P	N	P	N	P	N
9	0.82	49	0.24	32	0.28	26	0.10	15	0.28	122
13	0.64	84	0.33	40	0.44	47	0.04	6	0.38	177
14	-----	----	0.37	55	0.36	36	0.03	4	0.24	95
All Segments	0.70	133	0.31	127	0.36	109	0.06	25	0.35	394

Table 5. Sensitivity of power to detect changes in Pallid and Shovelnose Sturgeon populations in the Missouri River as a function of the number of subsamples per bend, the number of bends per segment, the annual rate of population change, the number of years surveyed, and the α-level. For Pallid Sturgeon, power was initially estimated assuming that 12 subsamples were taken from each of 6 river bends in each of 10 river segments, the rate of population change was ±3%, and the α-level was 0.10 (with a 2-tailed test). I used the same initial parameter values for both age classes of Shovelnose Sturgeon, except that the rate of change was set to ±1%. The sensitivity of power to each parameter was estimated by holding all parameters constant except the parameter of interest, which was doubled.

		Pallid			Adult Shovelnose			Young Shovelnose		
Parameter	Change in Parameter	Initial Power	Final Power	%Change	Initial Power	Final Power	%Change	Initial Power	Final Power	%Change
Subsamples per Bend	12 to 24	0.21	0.28	33	0.55	0.79	44	0.59	0.81	37
Bends per Segments	6 to 12	0.21	0.34	` 62	0.55	0.80	45	0.59	0.79	34
Rate of Population Change	±1 to ±2%	----	----	----	0.55	0.97	76	0.59	0.96	75
	±3 to ±6%	0.21	0.55	162	----	----	----	----	----	----
Years Sampled	10 to 20	0.21	0.74	252	0.55	1.00	82	0.59	1.00	69
α-level	0.10 to 0.20	0.21	0.37	76	0.55	0.74	35	0.59	0.74	25

FIGURE LEGEND

Figure 1. Power to detect 1, 3, and 5% annual trends in the occurrence of Pallid Sturgeon in the Missouri River south of Fort Peck over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

Figure 2. Power to detect a 1% annual trend in the occurrence of adult Shovelnose Sturgeon in the Missouri River south of Fort Peck over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

Figure 3. Power to detect a 1% annual trend in the occurrence of young Shovelnose Sturgeon in the Missouri River south of Fort Peck over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

Figure 4. Power to detect a 5% annual trend in the occurrence of Pallid Sturgeon in river segments of the Missouri River over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

Figure 5. Power to detect a 1% annual trend in the occurrence of adult Shovelnose Sturgeon in river segments 5 and 6 of the Missouri River over 10 years as a function of the number of bends sampled and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

Figure 6. Power to detect a 3% annual trend in the occurrence of adult Shovelnose Sturgeon in river segments 5 and 6 of the Missouri River over 10 years as a function of the number of bends sampled and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

Figure 7. Power to detect a 5% annual trend in the occurrence of adult Shovelnose Sturgeon in river segments 5 and 6 of the Missouri River over 10 years as a function of the number of bends sampled and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

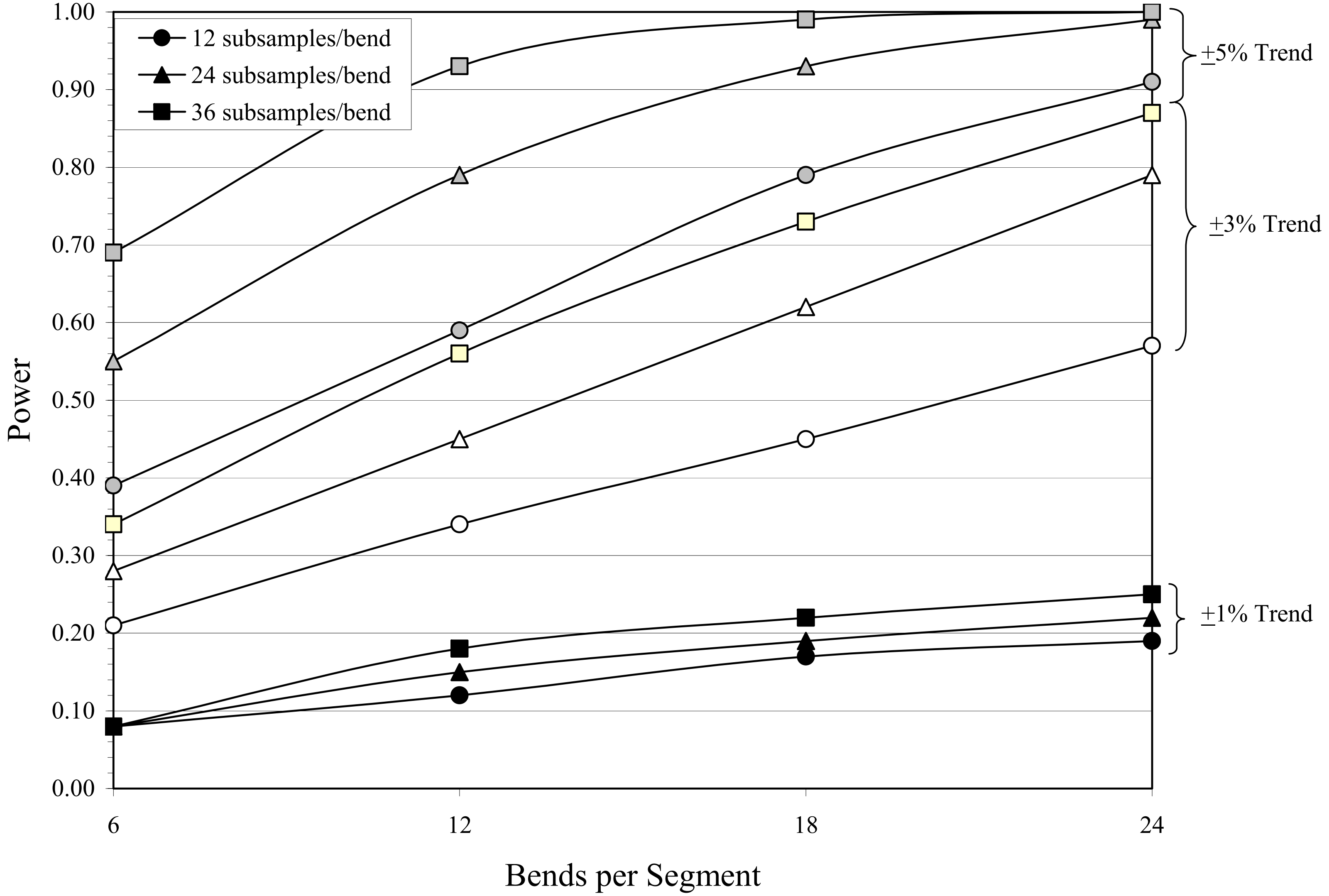

Figure 1. Power to detect 1, 3, and 5% annual trends in the occurrence of Pallid Sturgeon in the Missouri River south of Fort Peck over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

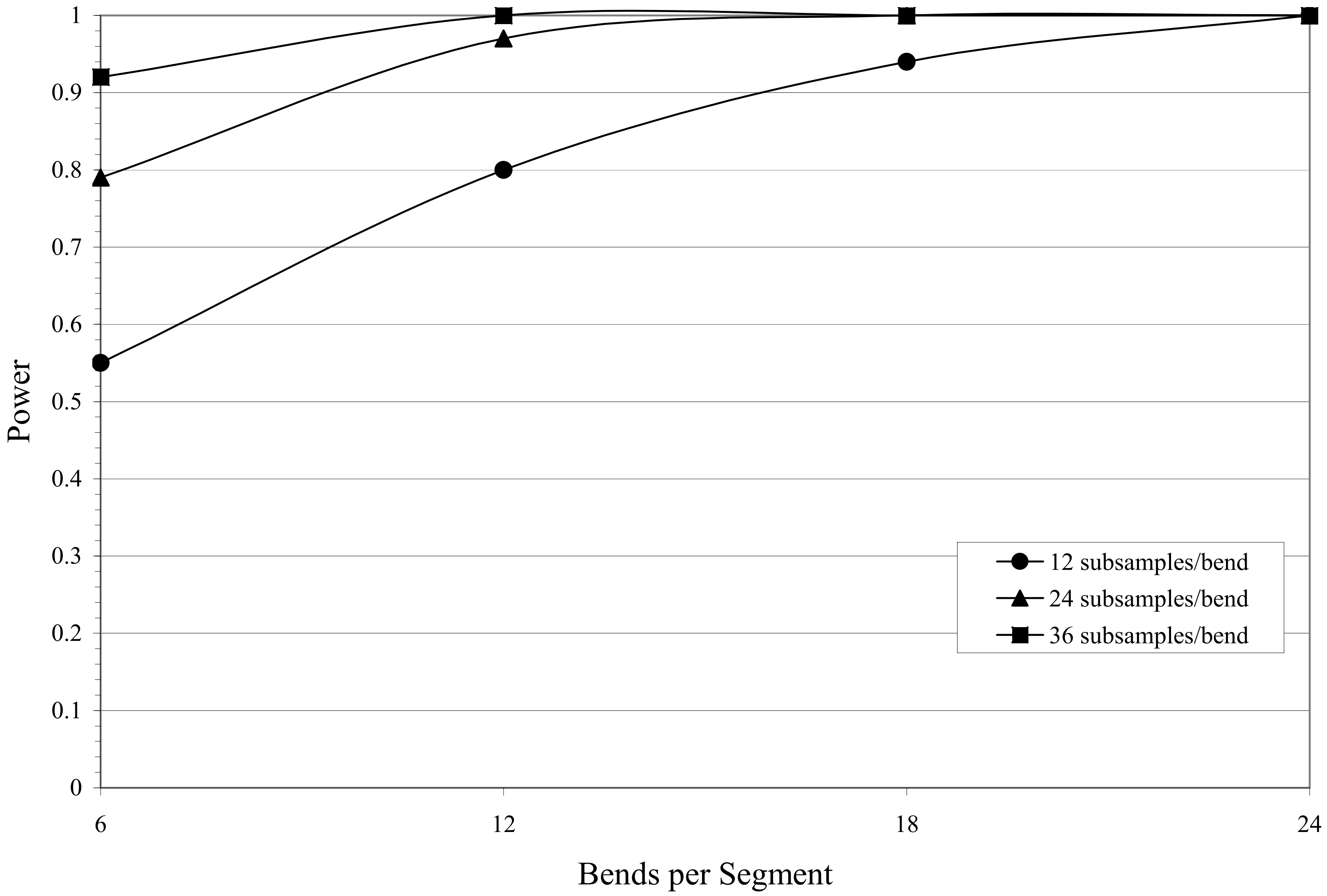

Figure 2. Power to detect a 1% annual trend in the occurrence of adult Shovelnose Sturgeon in the Missouri River south of Fort Peck over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

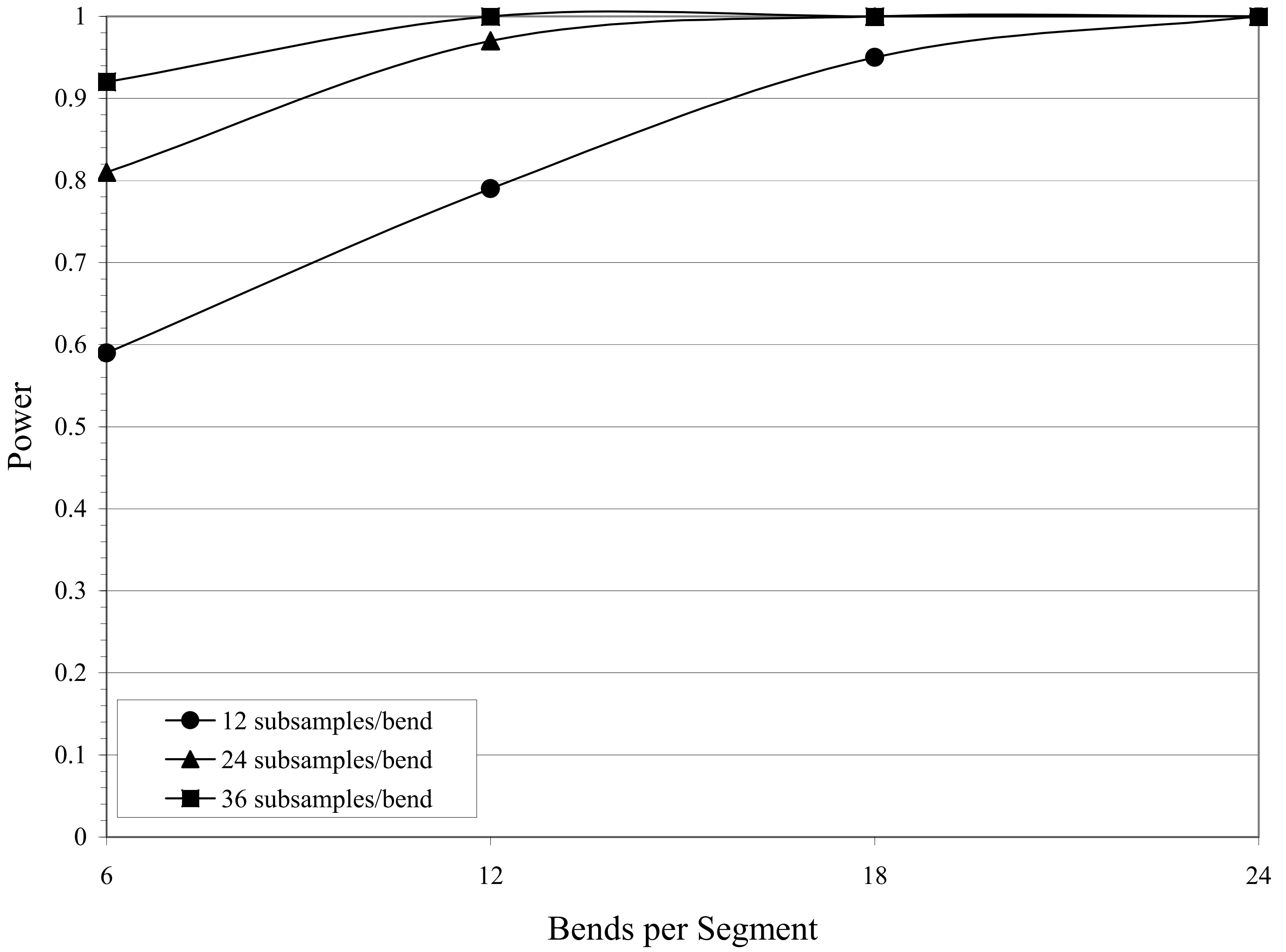

Figure 3. Power to detect a 1% annual trend in the occurrence of young Shovelnose Sturgeon in the Missouri River south of Fort Peck over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

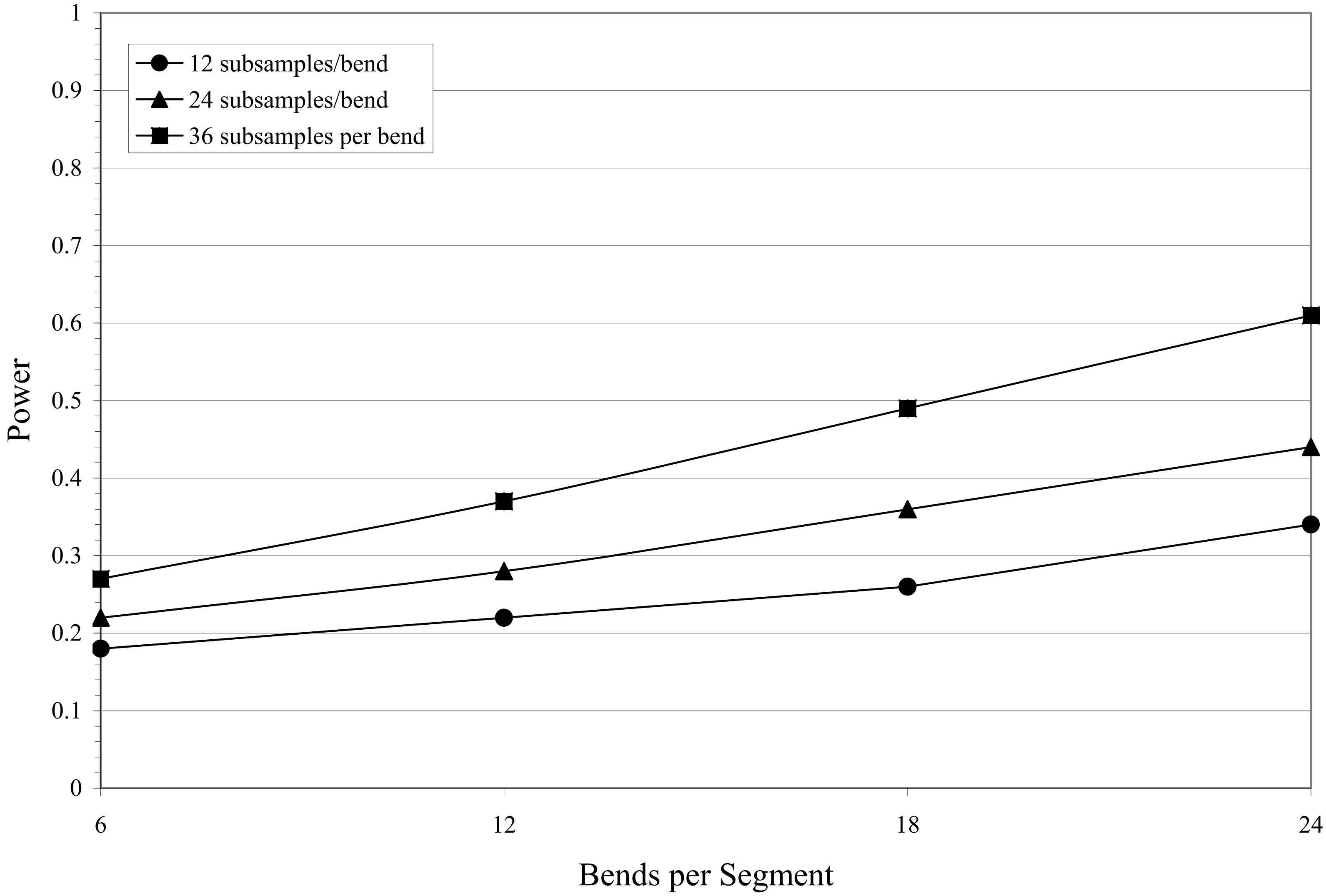

Figure 4. Power to detect a 5% annual trend in the occurrence of Pallid Sturgeon in river segments of the Missouri River over 10 years as a function of the number of bends sampled per segment and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

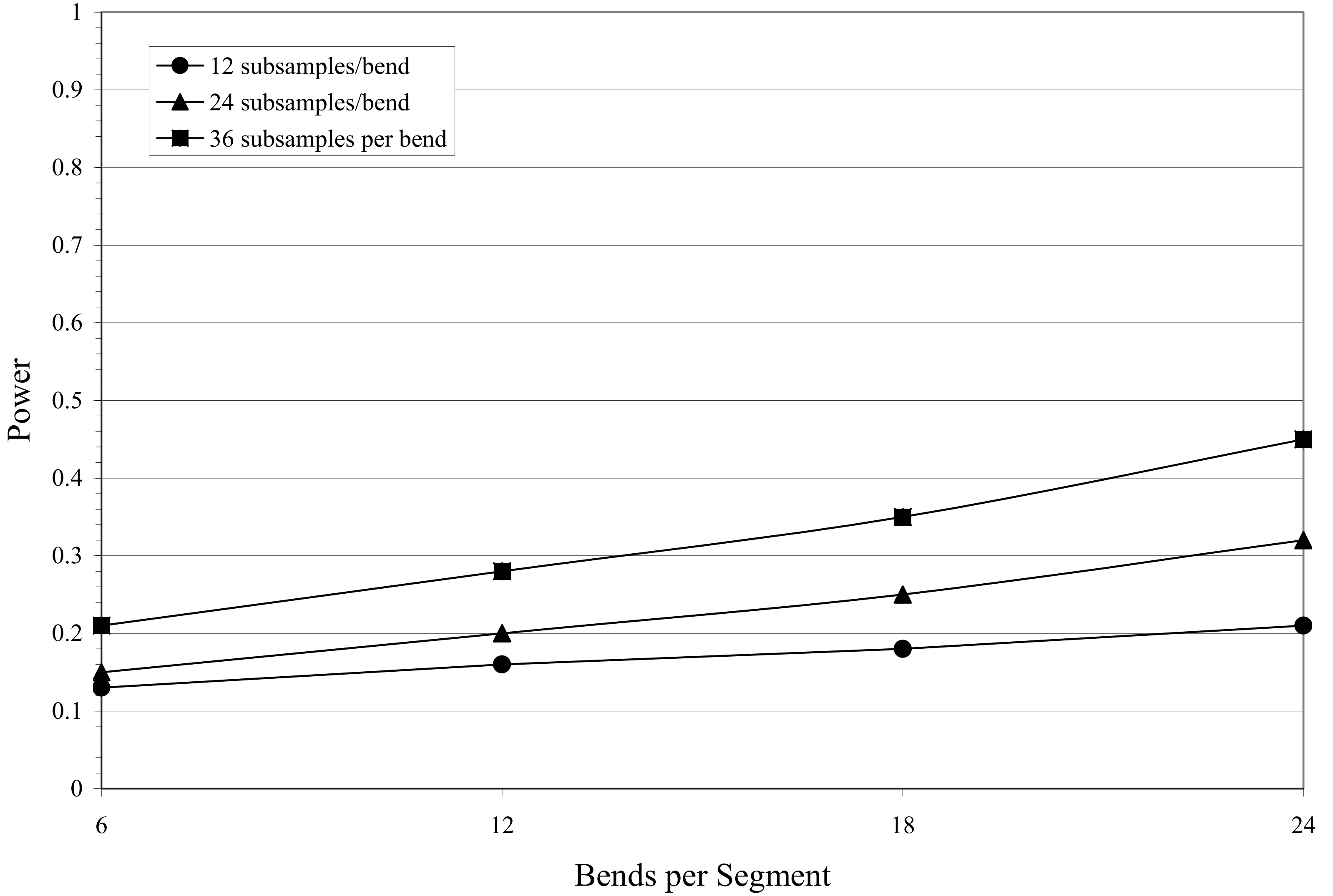

Figure 5. Power to detect a 1% annual trend in the occurrence of adult Shovelnose Sturgeon in river segments 5 and 6 of the Missouri River over 10 years as a function of the number of bends sampled and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

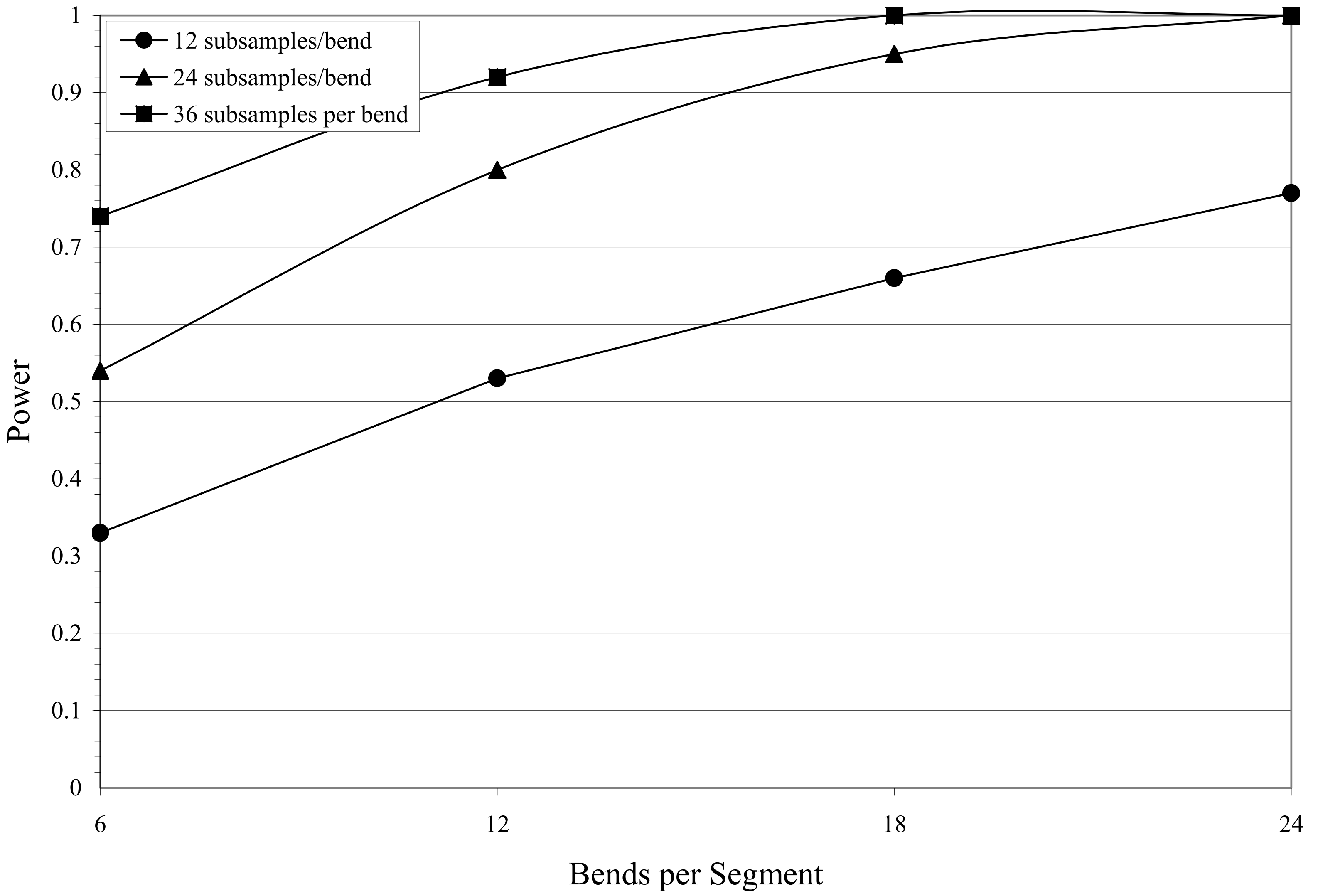

Figure 6. Power to detect a 3% annual trend in the occurrence of adult Shovelnose Sturgeon in river segments 5 and 6 of the Missouri River over 10 years as a function of the number of bends sampled and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.

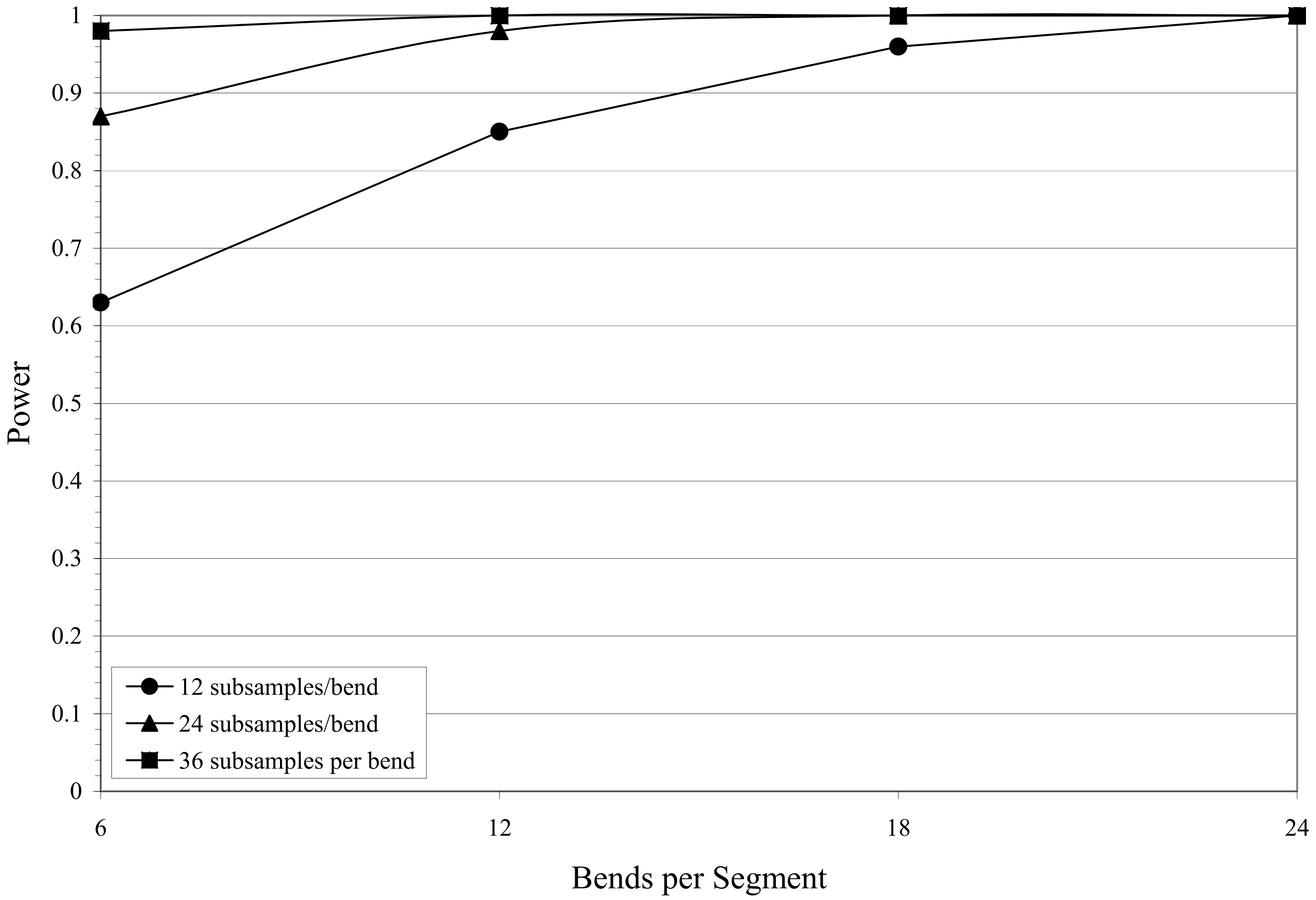

Figure 7. Power to detect a 5% annual trend in the occurrence of adult Shovelnose Sturgeon in river segments 5 and 6 of the Missouri River over 10 years as a function of the number of bends sampled and the number of subsamples per bend. Power was estimated using Monte Carlo simulations and trends in occurrence were tested for using a logistic regression model with a two-tailed test and a critical value of 0.10.