APPENDIX D

ENDANGERED FISH POPULATION STATUS ASSESSMENT

Endangered Fish Population Status Assessment

Introduction

A practical approach is needed for determining the status of or trends in endangered fish populations and whether that status/trend is related to historic or new water development projects. This approach will use measurable population criteria to determine if the Service should (a) reinitiate consultation on water development projects that have been consulted on by the Service or (b) extend the water depletion limit above 60,000 acre-feet/year up to 120,000 acre-feet/year for the upper Colorado River above the 15-Mile Reach. This approach should utilize the best scientific information available and may be modified in the future based on review of available information and consultations with biostatisticians and other experts.

Assumptions/Limitations

There are a number of practical limitations to our ability to detect changes in the status of endangered fish populations in a timely and accurate manner:

o Colorado pikeminnow (formerly Colorado squawfish):
-Adult Colorado pikeminnow can be sampled relatively effectively and reliable population estimates can be developed. Estimates of the size of the adult Colorado pikeminnow population in the Colorado River subbasin will be made every 3-5 years.
-Colorado pikeminnow spawning success is monitored annually by sampling for young-of- the-year fish in the fall. The abundance of YOY fish varies greatly from year to year.
-It takes a long time to determine if a year-class of fish will successfully contribute to a population because Colorado pikeminnow do not reproduce in the wild until age 6-7.
-Estimates of the numbers of juvenile Colorado pikeminnow (ages 2-5) are unreliable because these life stages cannot be sampled effectively.
-The age-class structure of the population can be estimated based on length-frequency data. However, older year classes are harder to differentiate by this method as growth rates decrease with age.

o Humpback chub:
-Adult humpbacks can be sampled relatively effectively and the size of their populations can be estimated.
-Young and juvenile humpbacks cannot be sampled effectively.
-The age-class structure of the population can be estimated based on length-frequency data. However, older year classes are harder to differentiate by this method as growth rates decrease with age.

- <u>Razorback suckers and Bonytail</u>:
  -Only hatchery-stocked fish are currently found in the Colorado River subbasin. It will take 7-15 years to determine if stocked fish reproduce and contribute to the establishment of a wild population.

Proposed Approach

<u>Population Indicators</u>

Based on the above limitations/realities, the following indices were selected to assess the status of or trends in the endangered fish populations:

- <u>Colorado pikeminnow</u>
  -size of the wild adult Colorado pikeminnow population based on surveys of the adult population;
  -structure of the adult population as determined by the length-frequency distribution of wild adults;
  -annual production of Colorado pikeminnow based on the capture of wild young-of-year fish each fall;

- <u>Humpback Chub</u>
  -structure of the adult humpback chub population as determined by the length-frequency distribution of wild adult humpback chub;
  -size of the wild adult humpback chub population (when these estimates are finalized);

- <u>Razorbacks and Bonytails</u>
  -Colorado pikeminnow and humpback chub will serve as surrogates for razorback suckers and bonytails to assess the status of their populations for 10 years. After this period naturally produced fish should be large enough to monitor. Goals/expectations for razorbacks and bonytails will be established by the year 2005 based on adult population size, young-of-year production, and recruitment to the adult population. Population data also will be used to assess the status of bonytail and razorback populations when those data become available. Populations of bonytail and razorback need to show improvement by the 2015 checkpoint. Based on the biological criteria established by 2005.

<u>Other Factors</u>

Other factors also will be monitored/evaluated through existing/planned programs to assess the health of the population such as (a) expansion of the range of the endangered fish, (b) the success of efforts to control nonnative fishes and the success of fish passage structures, (c) increases in usable flooded bottom habitats, (d) survival/behavior of stocked fish. Ultimately, these recovery action measures should lead to an increase in the endangered fish populations. However, detecting a significant population response associated with these actions could take many years. These factors will be qualitatively considered in the assessment of the health of the fish population. However, consideration of these factors will be secondary to the assessment of the population indices above.

Role of Stocked Fish

The presence of stocked hatchery fish can provide an inaccurate picture of the size and health of the wild population. Therefore, fish stocked into the Colorado River will be marked to allow the size of the wild population to be differentiated from the size of the stocked population. While stocked fish contribute to the size of the adult population, the overall health of a specific population depends upon successful reproduction as indicated by increased numbers of young-of-the-year fish and corresponding increases in the wild adult population due to recruitment. Therefore, stocked fish will not be included in the population estimates for the population status assessment.

Population Response Criteria

Population baseline values will be established for each of the indices, including expected annual variations, to reflect the current status of fish populations. Future values of these indices will be compared to their population baseline values to determine if additional water depletions in the upper Colorado River are biologically justifiable. The Recovery Program currently is developing recovery goals for the four endangered fishes. If a population meets or exceeds the numeric goal for that species, it will be considered to exhibit a positive response. However, short of reaching a specific recovery goal, trends in certain population indices provide an interim assessment of a species' progress toward recovery. Increases in fish populations as determined using the population indices may support increasing the water depletion limit above 60,000 acre-feet/year up to 120,000 acre-feet/year as established in the biological opinion; decreases or no change in populations may indicate that additional depletions are not justifiable. The Recovery Program staff will develop these indices for review by the Biology Committee by April 2000.

Examples

Colorado pikeminnow from the Upper Colorado River were used in the examples described below because data are readily available to establish reliable population baseline values for each of the three indices: adult population size; adult length-frequency; and YOY. Similar assumptions could be made for the humpback chub, as well, when sufficient data are available.

Individual criteria or threshold values were selected for pikeminnow adult population size and YOY production. These indices provide an objective means by which to measure the pikeminnow population response. An unambiguous negative response in either one of these indices is presumptive of a negative population response. Age-class structure is more subjective and, therefore, must be viewed in context with the other indices. Age-class structure will never be used as a stand alone population indicator. If both the other indices are positive, we would expect age-class structure to show a positive response, as well. However, it provides a reasonable snapshot of the status of a population, when there are no discernible trends in the other indices.

Adult Population Size

Following the Interagency Standardized Monitoring Program protocol, catch per unit effort data were collected for adult pikeminnow every year from 1986 through 1997. Standard error, which is a measure of variability in CPE data, also was computed for each of these years (Table 1). Figure 1 presents these data graphically, where mean CPE values are represented as white diamonds with ±SE as solid vertical I-bars. In addition, for 1993-95, the adult pikeminnow population was estimated at 600 (dark gray squares) with a 95 percent confidence interval (CI) of ±250. This CI indicates that the actual adult pikeminnow population is likely to fall between 350 (600-250) and 850 (600+250) with 95 percent certainty.

To determine the response of the adult population, positive and negative threshold values were established (broken vertical lines in Figures 1-4). The threshold for a positive population response is the baseline population estimate plus two times the CI (600+(2*250) = 1,100), while the threshold for a negative population response is the population baseline minus the CI (600-250 = 350). Population estimates > 1,100 adults and maintained at this level, represent a positive response; population estimates < 350 represent a negative response; and population estimates $\geq$ 350 and $\leq$ 1,100 represent a neutral response. Numerical examples of positive, negative and neutral population responses are tabulated in Tables 2-4. In Figures 2-4, future CPE values are represented as gray diamonds, while positive, negative and neutral future population responses are indicated as white, black and light gray squares, respectively.

In the positive example (Table 2, Figure 2), the initial population estimate (850) in years 1998-2000, would be neutral because 850 is less than 1,100, the positive threshold value, and greater than 350, the negative threshold value. However, in years 2003-05 and 2008-10, population estimates are 1300 and 1400, respectively. Since these values exceed 1,100, both estimates express a positive response. When the population estimate increases above 1,100, a new population baseline is established at the higher population level.

In the negative example (Table 3, Figure 3), the initial population estimate (400) indicates a neutral response, because 400 is greater than 350 and less than 1,100. But population estimates for years 2003-05 (220) and 2008-10 (150), indicate a negative response, because both estimates are less than 350, the negative threshold value.

In the neutral example (Table 4, Figure 4), population estimates are greater than 350 and less than 1,100 for all years. Therefore, future population responses are neither positive nor negative.

Based on a preliminary estimate of the pikeminnow population in 1998 there are 735 adults in two reaches. Although these data suggest an increase over the baseline population estimate (600), this would be considered a neutral population response, since it does not exceed 1,100.

Adult Age-class Structure (based on length-frequency analyses)

The relationship between age and length can be used to determine the relative strength of different age-classes of fish based on the frequency with which fishes of different lengths appear in samples. Length-frequency data for Colorado pikeminnow were collected from 1986 through 1996 (Table 5, Figure 5).

Approximate age-classes and their corresponding average total lengths (mm) in parentheses are:
5 years (376); 6 years (424); 7 years (456); 8 years (496); 9 years (520); and 10 years (545). These are only averages, however, and some overlap in size can be expected between adjacent age-classes. Nevertheless, these data may allow the progress of individual year-classes to be followed from year to year. For example, the exceptionally strong 400-450mm total length range (nominally the 1986 year-class at age 6) in 1992 (n = 16) appears in 1993 as the 450-500mm length-class (7-year age-class, n = 12). This year-class is represented by bold n values in Table 5 and white bars in Figure 5 from 1992 (age 6) through 1997 (age 11). Individual variability in growth rates and declining growth rates as fish age make it more difficult to differentiate age-classes of older, larger fish. Therefore, after 1993 this year-class becomes increasingly harder to distinguish from adjacent year-classes.

In general, a population is considered more stable if it is represented by a variety of age-classes, which is indicative of both recruitment and survival. On the other hand, if the vast majority of a population is represented by only a few age-classes, the population is less stable because it is susceptible to mass mortality when these classes reach their maximum life expectancy. This scenario is exacerbated if age-class structure is skewed toward the maximum age of the species, which occurs when there has been insufficient recruitment into the adult population. In this case, age-class distribution shifts toward the right side of the length-frequency graph as the average age of the population increases.

Interpretation of length-frequency data can be highly subjective. Moreover, small sample sizes are likely to under- or over-represent certain age-classes in the population and present a misleading picture of age-class structure. However, if a population is expanding, we would expect sample sizes to increase also, reducing the uncertainty of these data.

A positive response (Table 6, Figure 6) requires existing age-classes to be expressed in future years and that strong, younger age-classes be recruited into the adult population. Under this scenario, the number of age-classes represented in the sample increases over time, while mean length remains relatively constant, with no discernable trends. We would expect the sample size to increase as the overall population increases, thereby reducing the uncertainty of the results.

If the existing population continues to age, but there is little recruitment, the population would experience a dramatic decline as it reaches its life expectancy (Table 7, Figure 7). Also, older fish may fail to reproduce, further reducing the potential for population growth in the future. A negative response is illustrated by the population shifting toward the right side of the length-frequency graph. Mean length increases between 1998 and 2007 and remains relatively constant thereafter, as the population becomes more skewed toward older age-classes. The number of age-classes decreases between 2003 and 2010, as the oldest age-classes begin dying off.

The neutral response is somewhat more difficult to define (Table 8, Figure 8). While the existing population ages, some recruitment into the adult population appears to be taking place; however, there are no strong age-classes coming up nor any apparent trends indicating overall population growth. However, there is no immediate concern of a significant decline in population either, because the age-class structure is diverse and is not shifting toward the right side of the graph. Colorado Pikeminnow YOY Production

Catch per unit effort data have been collected for YOY Colorado pikeminnow from 1982 through 1997 (Table 9, Figure 9). Geometric means of these data are represented as gray-shaded diamonds in Figures 9-12. In addition, from 1993 through 1997, standard error values also were computed for YOY (solid vertical I-bars in Figures 9-12). To establish a population baseline value for YOY production, we calculated an arithmetic mean (0=0.382733) and SE (±0.252791) from the annual geometric means of all existing CPE data. The population baseline value for pikeminnow YOY production (0+SE=0.635524) is represented by the broken horizontal line in Figures 9-12. This value serves as the threshold used to determine a positive, negative, or neutral response, based on the frequency with which future CPE-SE values for YOY exceed this value.

Future CPE±SE data were simulated for 1998 through 2010 (Tables 10-12, Figures 10-12). In Figures 10-12, simulated CPE geometric means are represented by diamonds with solid vertical I-bars representing ±SE values. In Figures 10-12, for years in which CPE-SE > 0.635524, CPE values are represented by white diamonds; for years in which CPE-SE ≤ 0.635524, CPE values are represented by black diamonds. We evaluated three different methods to compare simulated data in Tables 10-12 with baseline population data: a cumulative average exceedance frequency based on the number of years CPE-SE exceeds the threshold (population baseline) value divided by the total number of years after 1997; a rolling 5-year average which looks back 5 consecutive years from the present to determine the frequency with which CPE-SE exceeds the threshold value; and a rolling 10-year average which looks back 10 consecutive years from the present to determine the frequency with which CPE-SE exceeds the threshold value.

YOY are considered to exhibit a positive response (Table 10, Figure 10) whenever values of CPE-SE exceed the threshold in at least 20 percent of the years. In this example, the results are unambiguous. Beginning in 1999, all three methods show a positive response (i.e., values of CPE-SE exceed the threshold value in 20 percent or more of the years).

If CPE-SE values for YOY do not exceed 0.635524 at least once in 10 years (10 percent), a negative response would result (Table 11, Figure 11). In this case, the rolling 10-year average appears to provide the best index. A negative YOY response would not be indicated until 10 consecutive years had elapsed since values of CPE-SE last exceeded the threshold. Therefore, the first assessment of YOY response would not need to occur for 10 years (although field data on YOY CPE will be collected every year).

A neutral response would result if values of CPE-SE exceed the threshold at least once in 10 years, but less than once in 5 years (e.g., 2 in 15 years). While the negative and positive examples above are unambiguous, the neutral response scenario could be interpreted in several different ways, depending on which method is used (Table 12, Figure 12). In this example, only 1 year in 14 (7 percent) exceeds the threshold value. The cumulative average exceeds 10 percent only 5 out of 14 years, while the rolling 5-year average exceeds 20 percent (positive response) in 5 of 10 years, but is 0 percent (negative response) during the other 5 years. The rolling 10-year average equals 10 percent (neutral response) in 5 of 5 years. Because the rolling 10-year average discriminates between neutral and negative scenarios with greater reliability than the other two methods, it is recommended for assessing pikeminnow YOY production.

Next Steps

Following is a proposed process for implementing this approach:

1. The Recovery Program staff will develop population indices for Colorado pikeminnow and humpback chub for review by the Biology Committee by April 2000 or soon after the recovery goals have been developed. A technical workgroup will recommend the specific numeric values, as well as their application and interpretation. The numbers will be reviewed by the Biology and Management Committees prior to finalization. The Service will then make the final determination if reinitiation of consultation will be based on these numbers.

2. In 2005, baseline population values and population response criteria for razorback sucker and bonytail will be reviewed by the Recovery Program Biology and Management Committees before final approval by the Service. Once established these indices may be adjusted by the Recovery Program with concurrence by the Service.

3. Fish populations and other factors will be monitored according to approved monitoring plans. Populations will be assessed when depletions reach 50,000 acre-feet/year, but no later than 2015.

4. Beginning in FY 2003, the Recovery Program Director's office will prepare a report every 5 years describing fish population status and trends based on the population indices and other factors. The first report would be due December 31, 2003. If reinitiation is biologically justified, the Service would document its rationale in a report to the Biology, Management, and Implementation Committees. The Service would reinitiate consultation in accordance with the provisions of the biological opinion.

5. Prior to reaching the water depletion checkpoint of 60,000 acre-feet referenced in the biological opinion, but no later than 2015, the Recovery Program Director's office or the Fish and Wildlife Service will prepare a report describing fish population status and trends based on the population indices and other factors. The report will be reviewed by the Biology and Management Committees prior to finalization. Based on this report, the Service will determine whether continuing water depletions up to the 120,000 acre-feet/year limit established in the biological opinion is biologically justified. The Service's rationale and conclusions will be documented in a report to the Biology, Management, and Implementation Committees. If necessary, the Service would amend the biological opinion, as appropriate.

Note: This approach assumes that existing Recovery Program committees will continue to function through 2015.

Table 1. Adult Colorado pikeminnow 1986-1997 baseline CPE and SE values, 1993-95 population estimates and 95 percent Cl values.

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Catch/Effort (CPE)	0.30	0.35	0.17	0.17	0.17	0.55	1.08	0.65	0.92	1.07	1.10	1.60
Standard Error (SE)	0.11	0.10	0.08	0.09	0.08	0.23	0.23	0.13	0.22	0.20	0.20	0.30
Population Estimate								600	600	600		
95 Percent Confidence Interval (CI)								250	250	250		
Pop.+ 2CI (positive threshold)								1100	1100	1100		
Pop. - Cl (negative threshold)								350	350	350		

Table 2. Adult Colorado pikeminnow 1998-2010 simulated CPE and SE[1] values, 1998-2000, 2003-05 and 2008-10 simulated population estimates (positive response).

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Catch/Effort (CPE)	1.70	1.80	1.76	1.68	1.72	1.88	2.01	2.08	1.92	2.10	2.25	2.19	2.31
Standard Error (SE)[1]	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Population Estimate[2]	850	850	850			**1300**	**1300**	**1300**			**1400**	**1400**	**1400**

Table 3. Adult Colorado pikeminnow 1998-2010 simulated CPE and SE[1] values, 1998-2000, 2003-05 and 2008-10 simulated population estimates (negative response).

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Catch/Effort (CPE)	1.70	1.20	1.23	1.09	0.98	0.25	0.34	0.28	0.18	0.17	0.23	0.29	0.19
Standard Error (SE)[1]	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Population Estimate[2]	400	400	400			***220***	***220***	***220***			***150***	***150***	***150***

Table 4. Adult Colorado pikeminnow 1998-2010 simulated CPE and SE[1] values, 1998-000, 2003-05 and 2008-10 simulated population estimates (neutral response).

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Catch/Effort (CPE)	1.70	1.80	1.76	1.68	1.72	1.54	1.47	1.28	1.20	1.23	1.18	1.09	1.13
Standard Error (SE)[1]	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Population Estimate[2]	850	850	850			620	620	620			600	600	600

[1]Arithmetic average of baseline SE values.

[2]Population estimates in **bold typeface** > 1100 (positive threshold) = positive response.

Population estimates in ***underlined bold italics*** *<350* (negative threshold) = negative response.

Population estimates in normal typeface $ 350 and # 1100 = neutral response.

Table 5. Adult Colorado pikeminnow 1986-1997 length-frequency data (age-class structure baseline).

Age-class[1] (years)	Total Length (mm) Range	Median	Numbers of fish (n) in each length range by year[2] 1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	100-150	125			1									
	150-200	175		1									3	
	200-250	225											3	1
	250-300	275				1							2	3
	300-350	325						1	1	6				1
5	350-400	375	2				1	2	3	3		1	3	2
6	400-450	425		1			1	3	**16**	5	1	4	2	4
7-8	450-500	475	3	1	1	1		3	5	**12**	**12**	1	5	3
9-10	500-550	525	4	6		1	1	3	3	4	**13**	**18**	**11**	6
	550-600	575	1		1	1			2	2	5	**13**	**12**	**10**
	600-650	625	1	1					1	1		2	**10**	**10**
	650-700	675						1		3	2	1		**7**
	700-750	725		1		1	1					1		2
	750-800	775		1										
	800-850	825			1									
	850-900	875						1						
	900-950	925						1						
	950-1000	975						1						
Sample Size (N) = Sum of n			11	12	4	5	4	16	31	36	33	41	51	49
Length Ranges Represented			5	7	4	5	4	9	7	8	5	8	9	11
Mean Total Length (mm)[3]			498	529	500	515	513	550	451	467	520	540	491	542

[1]Age-classes are based on average length of fish of this age. Individual variability in growth rates may blur age-class boundaries (see text).

[2]Bold values of 'n' indicate the probable progression of the 1986 year-class from age 6 (1992) to age 11 (1997). Older year-classes are more difficult to distinguish from adjacent year-classes due to grow rate variability between individual fish and slower overall growth rates as fish age.

[3]Mean total length is the sum of the products of the median length times the number of fish (n) in each length range divided by the total number of fish (N) in each year.

Table 6. Adult Colorado pikeminnow 1998-2010 simulated length-frequency data (age-class structure positive response).

Age-class[1] (years)	Total Length (mm) Range	Median	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
			Numbers of fish (n) in each length range by year												
	100-150	125	1									3			
	150-200	175			1			2				2		1	
	200-250	225	1	5	2	1	1	1	5	3	2	1	10	10	4
	250-300	275	2	3	6	4	2	1	3	7	6	4	3	15	12
	300-350	325	5	1	5	7	4	3	1	2	6	5	1	5	14
5	350-400	375	2	2	4	3	8	5	2	2	3	2	2	2	3
6	400-450	425	3	3	1	3	4	11	8	8	7	3	6	1	3
7-8	450-500	475	3	3	2	2	3	8	12	13	15	3	3	6	2
9-10	500-550	525	4	4	5	2	2	3	6	11	18	18	4	4	3
	550-600	575	8	5	8	6	4	2	3	5	9	15	15	3	3
	600-650	625	9	8	10	8	7	4	2	3	3	9	8	10	8
	650-700	675	8	7	10	12	10	6	3	1	2	4	7	10	12
	700-750	725	4	7	11	9	12	8	8	3	2	2	7	5	9
	750-800	775	2	2	5	4	7	11	9	6	2	2	2	3	4
	800-850	825		1	2	1	2	10	12	10	6	3	1	1	1
	850-900	875		1	2	1	2	2	4	10	10	8	1	1	1
	900-950	925				1		2	1	2	6	8	10	12	1
	950-1000	975				2	1	3		2	3	2	2	3	1
Sample Size (N) = Sum of n			52	52	74	66	69	82	79	88	100	94	82	92	81
Length Ranges Represented			13	14	15	16	15	17	15	16	16	18	16	17	16
Mean Total Length (mm)[2]			541	553	571	587	597	616	600	595	583	589	587	551	515

[1]Age-classes are based on average length of fish of this age. Individual variability in growth rates may blur age-class boundaries (see text).

[2]Mean total length was calculated by taking the sum of the products of the median length times the number of fish (n) in each length range, then dividing that sum by the total number of fish (N).

Table 7. Adult Colorado pikeminnow 1998-2010 simulated length-frequency data (age-class structure negative response).

Age-class[1] (years)	Total Length (mm)		Numbers of fish (n) in each length range by year												
	Range	Median	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	100-150	125													
	150-200	175													
	200-250	225													
	250-300	275													
	300-350	325	1	2											
5	350-400	375	2	1	1										
6	400-450	425	3	3	2	2									
7-8	450-500	475	2	2	2	1	1								
9-10	500-550	525	4	3	2	2	3	2							
	550-600	575	5	4	3	1	2	3	3						
	600-650	625	6	5	3	2	2	3	3	3					
	650-700	675	3	4	4	3	2	2	2	2	2				
	700-750	725	2	3	5	4	3	1	2	3	3	1	2	1	
	750-800	775		1	2	3	4	3	2	3	8	2	2	2	2
	800-850	825	1	1		1	5	4	3	3	2	2	2	2	2
	850-900	875			1	1	2	3	2	3	2	3	2	2	2
	900-950	925			1	1		1		1	.4	3	3	2	1
	950-1000	975				1	1	1	2	1	2	2	4	3	2
Sample Size (N) = Sum of n			29	29	26	22	25	23	19	19	18	13	15	12	9
Length Ranges Represented			10	11	11	12	10	10	8	8	7	6	6	6	5
Mean Total Length (mm)[2]			563	577	635	684	717	734	743	775	828	867	872	871	869

[1]Age-classes are based on average length of fish of this age. Individual variability in growth rates may blur age-class boundaries (see text).

[2]Mean total length was calculated by taking the sum of the products of the median length times the number of fish (n) in each length range, then dividing that sum by the total number of fish (N).

Table 8. Adult Colorado pikeminnow 1998-2010 simulated length-frequency data (age-class structure neutral response).

Age-class[1] (years)	Total Length (mm) Range	Median	Numbers of fish (n) in each length range by year 1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	100-150	125			1										
	150-200	175													
	200-250	225				1				1					
	250-300	275		2	1	3		2	1	3		2	1		2
	300-350	325		2		1		2		1		2			2
5	350-400	375	2	3	3	2	2	3	3	2	2	3	3	2	3
6	400-450	425		1	3	4		1	3	4		1	3		1
7-8	450-500	475	3	1	3	3	3	1	3	3	3	1	3	3	1
9-10	500-550	525	4	4	3	6	4	4	3	6	4	4	3	4	4
	550-600	575	7	5	3	10	7	5	3	10	7	5	3	7	5
	600-650	625	9	2	3	10	9	2	3	10	9	2	3	9	2
	650-700	675	9	4	3	7	9	4	3	7	9	4	3	9	4
	700-750	725	2	5	2	2	2	5	2	2	2	5	2	2	5
	750-800	775	2	1	3		2	1	3		2	1	3	2	1
	800-850	825			1				1				1		1
	850-900	875		1	1			1	1			1	1	1	1
	900-950	925						1							
	950-1000	975						1					1		
Sample Size (N) = Sum of n			38	31	30	49	38	33	29	49	38	31	30	39	32
Length Ranges Represented			8	12	13	11	8	14	12	11	8	12	13	9	13
Mean Total Length (mm)[2]			605	562	563	542	605	586	578	542	605	562	592	612	570

[1]Age-classes are based on average length of fish of this age. Individual variability in growth rates may blur age-class boundaries (see text).

[2]Mean total length was calculated by taking the sum of the products of the median length times the number of fish (n) in each length range, then dividing that sum by the total number of fish (N).

Table 9. YOY Colorado pikeminnow 1982-1996 baseline catch/effort (CPE) geometric mean and standard error (SE) values; computation of threshold value.

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Mean[2]
CPE (actual)	0.24	0.24	0.05	0.75	0.85	0.32	0.37	0.21	0.44	0.37	0.23	0.41	0.18	0.15	0.93	0.382733
SE[1]	--	--	--	--	--	--	--	--	--	--	--	0.09	0.06	0.05	0.12	0.252791
CPE+SE[1]	--	–	–	–	–	–	–	–	–	–	–	0.50	0.24	0.20	1.05	0.635524
CPE-SE[1]	--	--	--	--	--	--	--	--	--	--	--	0.32	0.12	0.10	0.80	0.129942

Table 10. YOY Colorado pikeminnow 1997-2010 simulated catch/effort (CPE) and standard error (SE) values; evaluation of simulated data against the threshold (positive response).

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CPE (simulated)	0.50	0.68	1.08	0.65	0.55	0.77	0.60	1.15	0.70	0.45	0.88	0.63	1.10	0.71
SE (arithmetic mean of baseline)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
CPE-SE	0.42	0.60	1.00	0.57	0.47	0.69	0.52	1.07	0.62	0.37	0.80	0.55	1.02	0.63
CPE-SE > 0.635524 (threshold)?	No	No	**Yes**	No	No	**Yes**	No	**Yes**	No	No	**Yes**	No	**Yes**	No
Cumulative average[3]	***0%***	***0%***	**33%**	**25%**	**20%**	**33%**	**29%**	**38%**	**33%**	**30%**	**36%**	**33%**	**38%**	**36%**
Rolling 5-year average[3]	--	--	--	--	**20%**	**40%**	**40%**	**40%**	**40%**	**40%**	**40%**	**40%**	**40%**	**40%**
Rolling 1 0-year average[3]	--	--	--	--	--	--	--	--	--	**30%**	**40%**	**40%**	**40%**	**40%**

[1]Annual values of standard error (SE) were not computed for 1982-92 catch/effort (CPE) data.
[2]Arithmetic mean and overall SE of 1982-96 annual CPE geometric means.
CPE+SE (0.635524) is the threshold (exceedance) value used to determine YOY response.
[3]Values<10% (***underlined bold italic***) = negative response.
Values $ 10% but <20% (normal typeface) = neutral response.
Values $20% (**bold typeface**) = positive response.
[4]Based on rolling 10-year average.

Table 11. YOY Colorado pikeminnow 1997-2010 simulated catch/effort (CPE) and standard error (SE) values; evaluation of simulated data against the threshold (negative response).

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CPE (simulated)	0.24	0.18	0.22	0.25	0.20	0.35	0.38	0.45	0.32	0.11	0.12	0.16	0.22	0.19
SE (arithmetic mean of baseline)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
CPE-SE	0.16	0.10	0.14	0.17	0.12	0.27	0.30	0.37	0.24	0.03	0.04	0.08	0.14	0.11
CPE-SE > 0.635524 (threshold)?	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Cumulative average[3]	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***
Rolling 5-year average[3]	--	--	--	--	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***
Rolling 1 0-year average[3]	--	--	--	--	--	--	--	--	--	***0%***	***0%***	***0%***	***0%***	***0%***

Table 12. YOY Colorado pikeminnow 1997-2010 simulated catch/effort (CPE) and standard error (SE) values; evaluation of simulated data against the threshold (neutral response[4]).

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CPE (simulated)	0.64	0.18	0.22	0.35	0.20	0.87	0.38	0.65	0.32	0.45	0.35	0.65	0.22	0.19
SE (arithmetic mean of baseline)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
CPE-SE	0.56	0.10	0.14	0.27	0.12	0.79	0.30	0.57	0.24	0.37	0.27	0.57	0.14	0.11
CPE-SE > 0.635524 (threshold)?	No	No	No	No	No	**Yes**	No	No	No	No	No	No	No	No
Cumulative average[3]	***0%***	***0%***	***0%***	***0%***	***0%***	17%	14%	13%	11%	10%	***9%***	***8%***	***8%***	***7%***
Rolling 5-year average[3]	--	--	--	--	***0%***	**20%**	**20%**	**20%**	**20%**	**20%**	***0%***	***0%***	***0%***	***0%***
Rolling 10-year average[3]	--	--	--	--	--	--	--	--	--	10%	10%	10%	10%	10%

[1]Annual values of standard error (SE) were not computed for 1982-92 catch/effort (CPE) data.
[2]Arithmetic mean and overall SE of 1982-96 annual CPE geometric means.
CPE+SE (0.635524) is the threshold (exceedance) value used to determine YOY response.
[3]Values<10% (***underlined bold italic***) = negative response.
Values $ 10% but <20% (normal typeface) = neutral response.
Values $20% (**bold typeface**) = positive response.
[4]Based on rolling 10-year average.

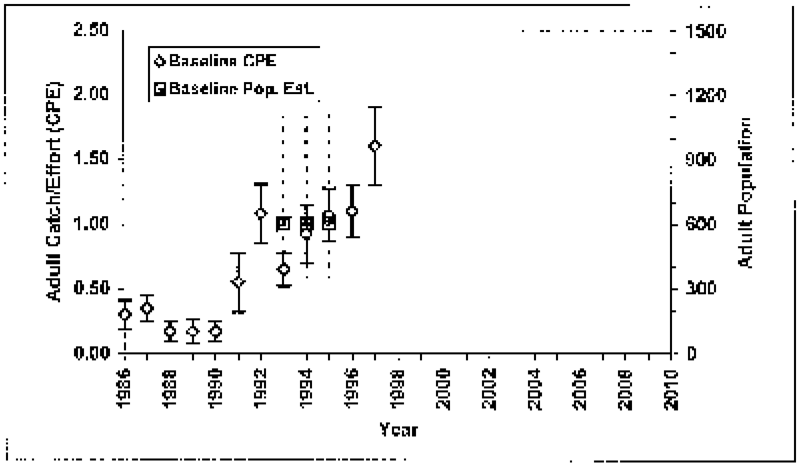

Figure 1. Adult Colorado pikeminnow baseline CPE±SE and population estimate (pop. = 600). Positive threshold = pop.+ 2*(95%CI) = 1100; negative threshold = pop. -1*(95%CI) = 350 (broken vertical line).

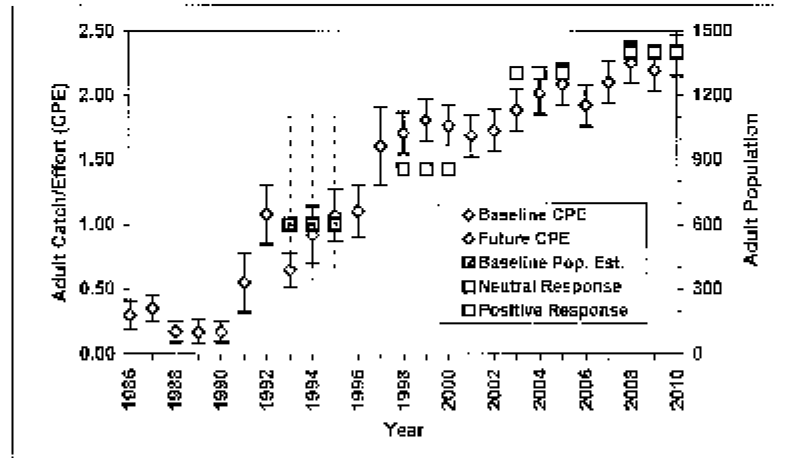

Figure 2. Adult Colorado pikeminnow 1998-2010 CPE; 1998-2000, 2003-05 and 2008-10 simulated population estimates and comparison to thresholds (positive response).

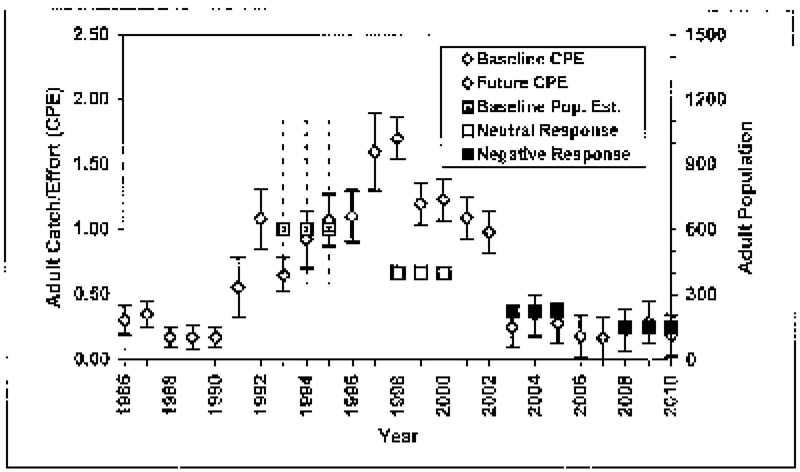

Figure 3. Adult Colorado pikeminnow 1998-2010 CPE; 1998-2000, 2003-05 and 2008-10 simulated population estimate and comparison to thresholds (negative response).

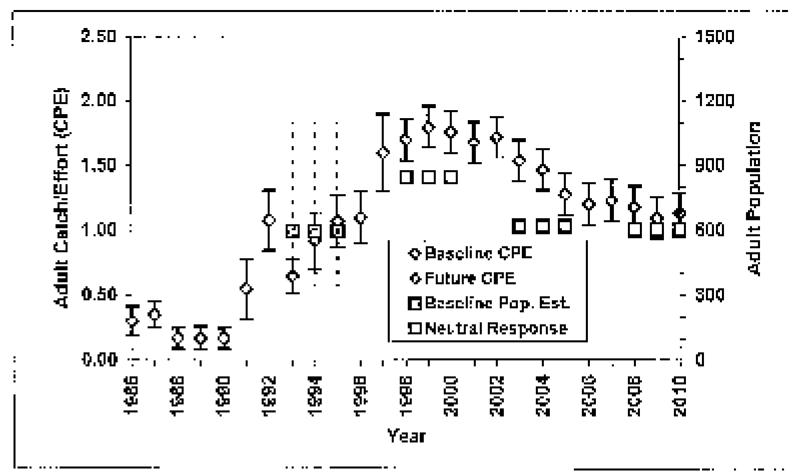

Figure 4. Adult Colorado pikeminnow 1998-2010 CPE; 1998-2000, 2003-05 and 2008-10 simulated population estimates and comparison to thresholds (neutral response).

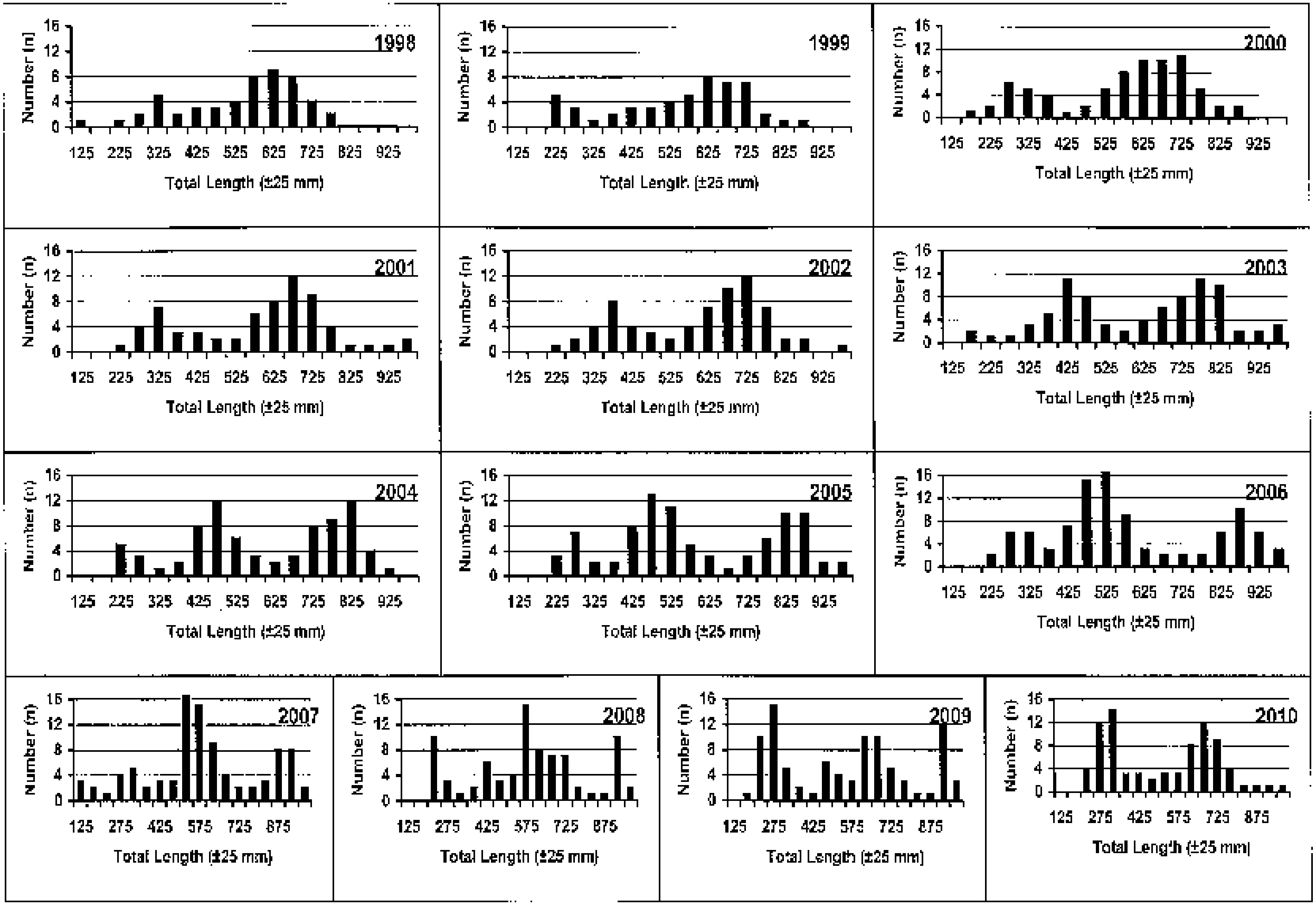

Figure 6. Adult Colorado pikeminnow 1998-2010 simulated length-frequency data (age-class structure positive response).

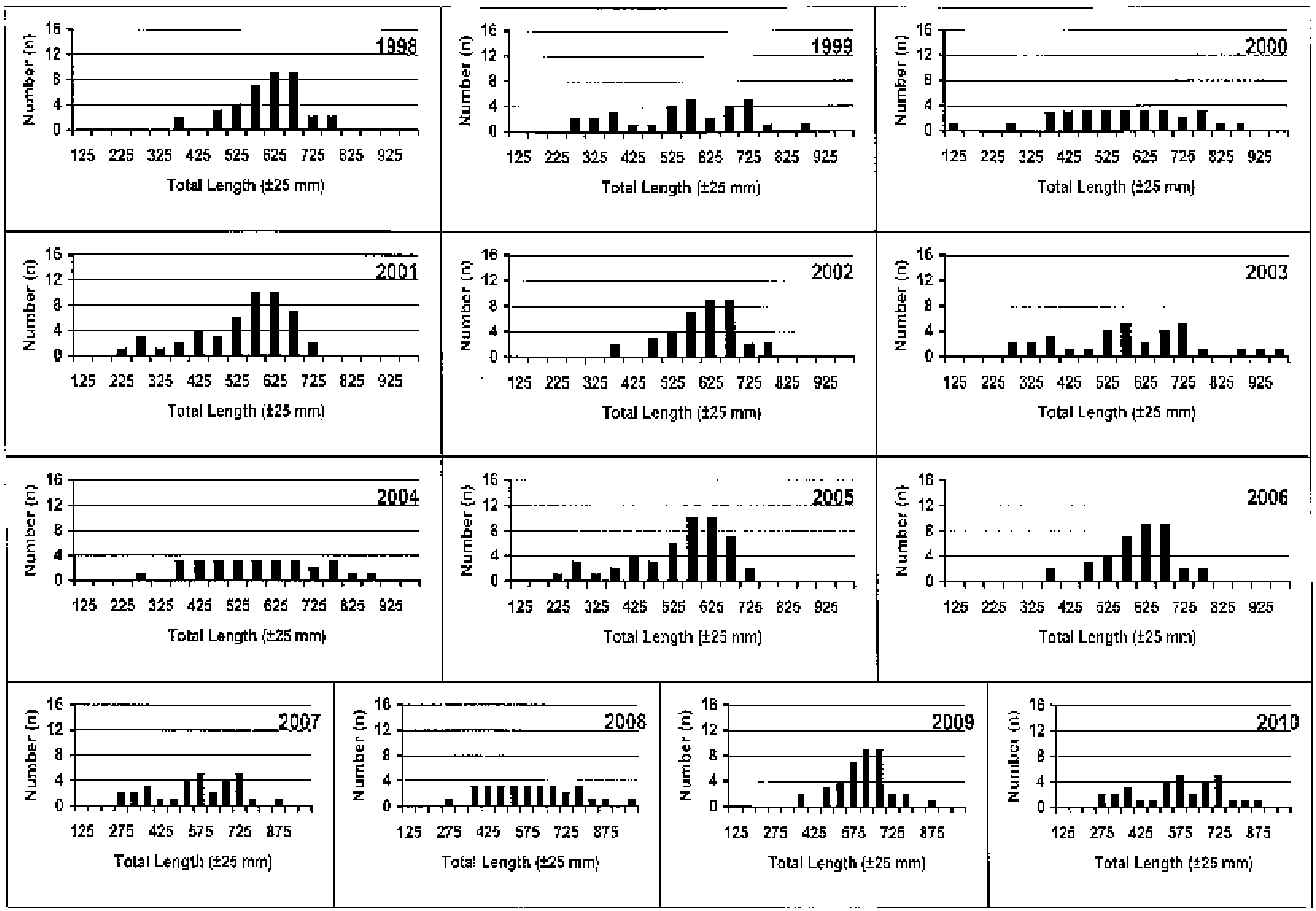

Figure 8. Adult Colorado pikeminnow 1998-2010 simulated length-frequency data (age-class structure neutral response).

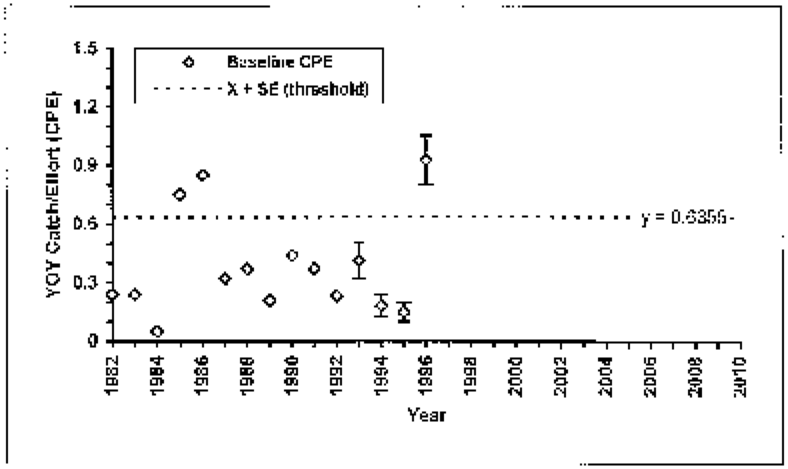

Figure 9. YOY Colorado pikeminnow baseline annual geometric mean CPE and arithmetic mean of annual CPE (X) + SE = 0.6355 (threshold).

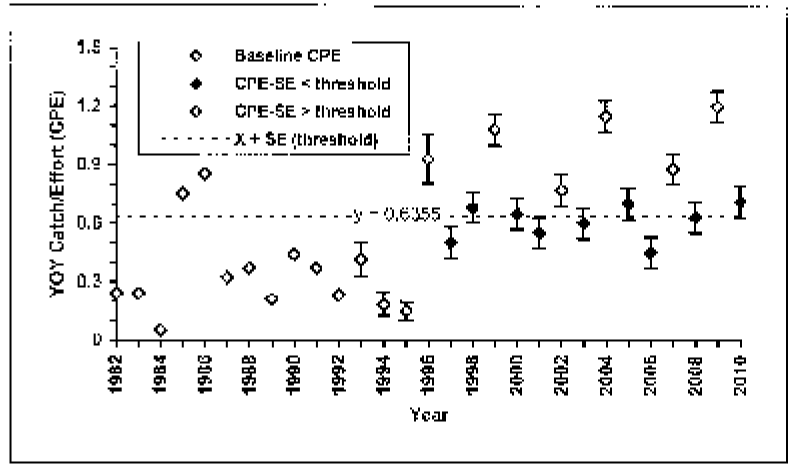

Figure 10. YOY Colorado pikeminnow 1998-2010 geometric mean CPE±SE simulation (positive response).

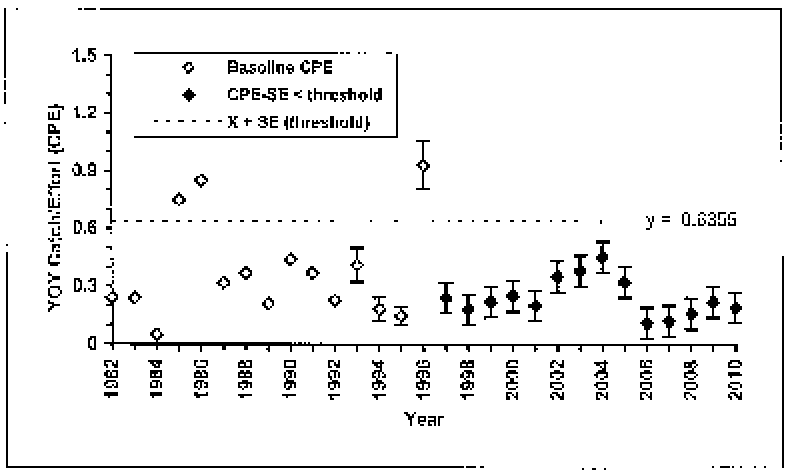

Figure 11. YOY Colorado pikeminnow 1998-2010 geometric mean CPE±SE simulation (negative response).

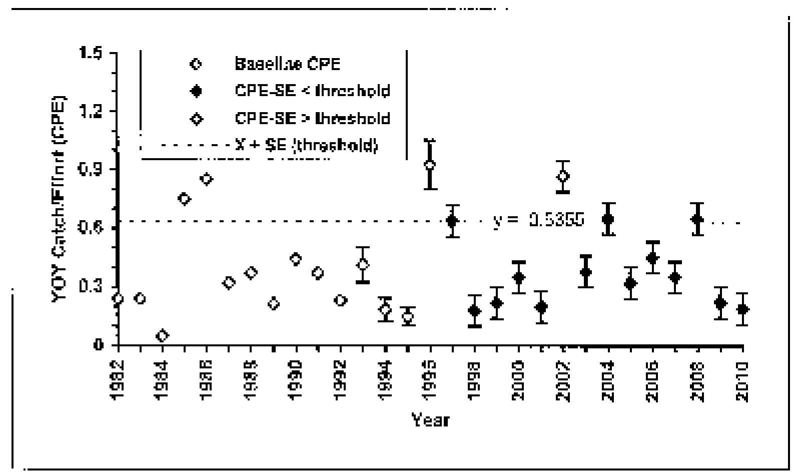

Figure 12. YOY Colorado pikeminnow 1998-2010 geometric mean CPE±SE simulation (neutral response).