7.7 FISH RESOURCES

The analysis of the effects of the CWCP, the MCP, and the four GP options on fish resources was accomplished using the results of eight models. These models include young fish production in the lakes, coldwater fish habitat in the lakes, coldwater fish habitat in river reaches, warmwater fish habitat in river reaches, physical habitat for native river fish in river reaches, connectivity of the river to low-lying lands along much of the Lower River, spring spawning cue along the Lower River, and shallow water habitat along the Lower River. Several technical reports document the development of these models for assessing lake and riverine fishes, the model assumptions, and the data produced by the model runs (Corps, 1994j; Corps, 1994k; Corps, 1994l; Corps, 1994m; Corps, 1994n). In addition, supplemental information was recently published on riverine fishes (Corps, 1998f; Corps, 1998g). Results derived from the fish models are presented in this section.

7.7.1 Young Fish Production in Mainstem Lakes

The young of year fish production index uses annual hydrologic data to model fish productivity. It was developed through a process of correlating annual catch data for various species to hydrologic variables such as lake levels, inflows, and amount of shore area. For further detail, see Volume 7A: Environmental Studies, from the 1994 Missouri River Master Water Control Manual Review and Update Study. The values presented in the following discussion are useful as an indicator of the relative effects of the different alternatives. For example, if an alternative results in a young of year index value that is 2 percent higher than that of the CWCP, this indicates the potential for a slight increase in annual fish production under that alternative. Table 7.7-1 and Figures 7.7-1 through 7.7-4 present the data from the young fish production model, commonly referred to as the "young-of-year model."

Figure 7.7-1 graphically shows that the CWCP and the MCP are closely grouped together between 2.00 and 2.04 units, a difference of 4 hundredths. The four GP options are more closely related and are grouped between 2.13 and 2.14 units, a difference of only 1 hundredth. This figure also shows the values for the submitted alternatives discussed in Chapter 5 to provide perspective as to how the potential starting point for the GP options, the GP1528 option, and the other three GP options perform relative to the submitted alternatives. The GP1528 option provides a total average annual young fish production value that is closest to the MODC alternative. The GP1528 option provides only a 2 hundredths (0.9 percent) increase in young fish production values over the MODC alternative.

The average annual total relative index value for the CWCP is 2.00, the lowest among the MCP and the four GP options. The MCP's unbalanced intrasystem regulation and higher drought conservation measures increase the total index value over the CWCP by only 4 hundredths, or 2.0 percent. The Fort Peck spring rise included in the MCP does not appear to affect the total index value. The MRBA alternative is the same as the MCP except for the spring rise (unbalancing apparently already accounts for the increased effect of a spring rise). The GP1528 option's Gavins Point Dam 15-kcfs spring rise and flat 28.5-kcfs summer release increases the total index value for young fish production over the MCP 10 hundredths, or 4.9 percent. Compared to the value for the GP1528 option, the potential starting point for the GP options, the other GP options (GP2021, GP1521, and GP2028 options) all show a 1 hundredth, or 0.5 percent, decrease in total index values. This indicates that the various spring rise/summer flow combinations associated with the four GP options (i.e., a 15- or 20- kcfs spring rise combined with a 25/21-kcfs split summer flow or a 20-kcfs spring rise with a 28.5-kcfs flat summer release) would result in similar total relative index values for young fish production.

The MCP is the only alternative that increases young fish production index values over the CWCP within Fort Peck Lake. An unbalanced intrasystem regulation, greater conservation among the three upper lakes during drought periods, and greater conservation measures during the drought periods benefit young fish production within this lake and increase the index value by 2 hundredths, or 3.6 percent, over the CWCP.

Table 7.7-1. Average annual young fish production in the mainstem lakes (relative index).

		1898 to 1997					
Alternative	**Total**	**Fort Peck Lake**	**Lake Sakakawea**	**Lake Oahe**	**Lake Sharpe**	**Lake Francis Case**	**Lewis & Clark Lake**
CWCP	**2.00**	0.55	0.46	0.40	0.23	0.20	0.16
MCP	**2.04**	0.57	0.46	0.41	0.22	0.20	0.18
GP1528	**2.14**	0.54	0.53	0.41	0.23	0.25	0.19
GP2021	**2.13**	0.53	0.53	0.40	0.21	0.27	0.20
GP1521	**2.13**	0.53	0.52	0.39	0.22	0.26	0.20
GP2028	**2.13**	0.53	0.53	0.41	0.22	0.25	0.19

Within Lake Sakakawea and Lake Francis Case, the young fish production index value under the MCP does not change from the CWCP. The MCP increases the index value by only 1 hundredth, or 2.5 percent, in Lake Oahe and decreases the young fish production index values by 4.3 percent in Lake Sharpe, compared to the CWCP. Within Lewis and Clark Lake, the MCP increases the index value amount by 2 hundredths, or 12.5 percent, over the CWCP.

A potential starting point for the GP options, GP1528, has a 15-kcfs spring rise and a flat 28.5-kcfs summer release from Gavins Point Dam that represents a 6-kcfs decrease in minimum summer service level from the MCP. This results in a decrease in young fish production index values in Fort Peck Lake of 3 hundredths, or 5.3 percent, compared to the MCP. The GP1528 option has the same index value in Lake Oahe as the MCP. Compared to the MCP, the GP1528 option increases the index value in the remaining mainstem lakes. Lake Francis Case and Lake Sakakawea experience the greatest value increases under the GP1528 option (25.0 and 15.2 percent increases, respectively), while Lewis and Clarke Lake and Lake Sharpe experience lesser gains in index values (5.6 and 4.5 percent, respectively).

The GP2021, GP1521, and GP2028 options provide perspective for how young fish production index values could change in the future relative to a potential starting point for the GP options (GP1528 option). These include changes in the spring rise, total spring flow, and summer flow on the Lower River. The primary difference between the GP2021 and GP1521 options is the spring rise; the GP2021 has a 20-kcfs spring rise, whereas the GP1521 option has a 15-kcfs spring rise. Both options have a summer release that is split between 25 and 21 kcfs from Gavins Point Dam. These changes result in similar increases and decreases in young fish production index values within the mainstem lakes. For example, both options decrease index values in Fort Peck Lake, Lake Oahe, and Lake Sharpe and increase the index value in Lake Francis Case and Lewis and Clark Lake. In Lake Sakakawea the GP2021 option does not change the index value from the GP1528 option, while the GP1521 option results in a value decrease.

When compared to the values for the GP1528 option, both the GP2021 and GP1521 options decrease young fish production index values in Fort Peck Lake by 1 hundredth, or 1.9 percent. In Lake Sakakawea, the index value under the GP2021 option does not change; however, the GP1521 option decreases the value by 1.9 percent. The GP2021 option results in smaller value decreases than the GP1521 option in Lake Oahe (2.4 and 4.9 percent decreases, respectively), while the opposite is true in Lake Sharpe. Here, the GP2021 and GP1521 options reduce young fish production index values by 8.7 and 4.3 percent, respectively. Compared to the remaining options, the GP2021 option has the greatest percent reduction in index value from the GP1528 option within Lake Sharpe. The GP2021 and GP1521 options increase the young fish production index value by 8.0 and 4.0 percent, respectively in Lake Francis Case, and in Lewis and Clark Lake these two options would result in the same value increase of 1 hundredth, or 5.3 percent higher than the GP1528 option.

The GP2028 option has a 20-kcfs spring rise and a flat summer release of 28.5 kcfs that represents the minimum navigation service, summer low flow. Compared to the GP1528 option, this option decreases (1.9 percent and 4.3 percent, respectively) young fish production index values in two of the mainstem lakes, Fort Peck Lake and Lake Sharpe. The GP2028 option does not result in a change in index values in the remaining four lakes.

The annual values for young fish production in the mainstem lakes for the CWCP, the MCP, and the four GP options are shown on Figures 7.7-2 through 7.7-4. Generally, all of the alternatives discussed in this chapter show similar results during the full period of analysis; relative index values vary between about 1 and 3 units. The years that show the greatest decrease in young fish production index values are 1920, the mid- to late-1930s, 1961, the late 1980s, and the early 1990s. The greatest index value (about 4 units) occurs about 1943 for the GP1528 and GP2028 options. The alternatives discussed in this chapter with lower index values around this period are the CWCP, the MCP, and the GP2021 and GP1521 options.

7.7.2 Coldwater Fish Habitat in Mainstem Lakes

The minimum coldwater fish habitat volume available from July through October in the upper three Mainstem Reservoir System lakes was estimated for each year of the 100-year simulation period. The following is a comparison of results for the CWCP, the MCP, and the four GP options. Table 7.7-2 and Figure 7.7-5 present the average annual values for the 100-year period of analysis for the upper three lakes. Even though Lake Francis Case was modeled, data for this lake is not included because the average annual values are essentially zero.

The CWCP provides 9.88 million acre-feet (MAF) of coldwater fish habitat on an annual basis, the lowest amount of the alternatives discussed in this chapter. This total volume at the sites analyzed is distributed among Fort Peck Lake (36.3 percent), Lake Sakakawea (28.3 percent), and Lake Oahe (35.4 percent). As shown in Figure 7.7-5, the CWCP and the MCP group together

Table 7.7-2. Average annual coldwater fish habitat in the mainstem lakes (MAF).

		1898 to 1997		
Alternative	**Total**	**Fort Peck Lake**	**Lake Sakakawea**	**Lake Oahe**
CWCP	**9.88**	3.59	2.81	3.47
MCP	**10.18**	3.74	2.76	3.68
GP1528	**10.73**	3.89	3.09	3.75
GP2021	**10.76**	3.87	3.08	3.81
GP1521	**10.79**	3.89	3.07	3.83
GP2028	**10.68**	3.85	3.09	3.73

between 9.88 and 10.18 MAF, a difference of 0.30 MAF. The four GP options are more closely aligned with volumes that range between 10.68 and 10.79 MAF, a difference of only 0.11 MAF. Compared to the CWCP, the GP2021 and GP1521 options have the greatest total volume of average annual coldwater fish habitat in the mainstem lakes. To provide perspective as to how the GP options would perform relative to the submitted alternatives, this figure also illustrates the values for the submitted alternatives discussed in Chapter 5. The GP options provide a total average amount of coldwater fish habitat in the mainstem lakes that is closest to the ARNRC alternative. The ARNRC alternative provides 0.03 MAF (0.3 percent) more coldwater fish habitat than the GP1528 option. Both the GP1528 option and the ARNRC alternative have a 15.0-kcfs spring rise; however, the GP1528 option has a flat, 28.5-kcfs, summer low flow, whereas the ARNRC alternative has a lower summer flow of 18 kcfs. Because less water would be released from the mainstem lakes during the summer months, as with the ARNRC alternative, there would be more coldwater fish habitat available within the lakes.

Within the mainstem lakes, the MCP increases total coldwater fish habitat 3.1 percent, the smallest total percentage increase over the CWCP. Although the CWCP and the MCP have no additional spring rise and have a flat full navigation service level release during the summer at Gavins Point Dam, the MCP has greater conservation in the upper three lakes in the drought periods. These differences from the CWCP result in a habitat increase within Fort Peck Lake (4.2 percent) and Lake Oahe (6.1 percent). Under the MCP, coldwater fish habitat decreases in Lake Sakakawea by 1.8 percent.

A 15-kcfs spring rise and a flat summer release (28.5 kcfs) from Gavins Point Dam, as with the GP1528 option, results in a 6-kcfs decrease in summer navigation service level compared to the MCP. This increases total coldwater fish habitat in the upper three mainstem lakes by 5.4 percent. The GP1528 option creates additional habitat over the MCP in Fort Peck Lake (4.0 percent), Lake Sakakawea (12.0 percent), and Lake Oahe (1.9 percent).

The GP2021, GP1521, and GP2028 options provide some perspective for how coldwater fish habitat in the mainstem lakes could change in the future relative to a potential starting point for the GP options (the GP1528 option). The GP2021 and GP1521 options' respective 20- and 15- kcfs spring rise and split summer release from Gavins Point Dam result in similar changes in coldwater fish habitat compared to the GP1528 option. Also compared to the GP1528 option, the GP2021 and GP1521 options create 0.3 and 0.6 percent more total coldwater fish habitat, respectively. In Fort Peck Lake, the GP2021 option decreases habitat by 0.5 percent, while the GP1521 option results in a change in habitat from the GP1528 option. In Lake Sakakawea, the GP2021 and GP1521 options decrease habitat by 0.3 and 0.6 percent, respectively, while in Lake Oahe they provide 1.6 and 2.1 percent additional habitat, respectively, than the GP1528 option.

The GP2028 option's 20-kcfs spring rise and flat summer release result in a 0.5 percent decrease in total coldwater fish habitat compared to the GP1528 option. In Fort Peck Lake and Lake Oahe, the GP2028 option decreases coldwater fish habitat by 1.0 and 0.5 percent, respectively. In Lake Sakakawea, there is no variation in the amount of habitat from the GP1528 option.

The annual values of total mainstem lake coldwater fish habitat for the CWCP, the MCP, and the four GP options are shown on Figures 7.7-6 through 7.7-8. The 1930 to 1941 drought period show the least amount of total coldwater fish habitat for all of the alternatives discussed in this chapter. The alternatives that have slightly higher habitat values during this period are the MCP and the GP1528 and GP2028 options. The CWCP shows the least amount of habitat during this period. During the 1954 to 1961 and the 1987 to 1993 drought periods, other reductions of habitat occur, up to 5 MAF; however, they are less severe than that which occurred during the 1930 to 1941 drought period, which reduced habitat below 5 MAF. In addition, the duration for these latter two declines is about 2 to 5 years rather than 10 years. Other than these three periods, annual coldwater fish habitat is fairly stable, between 10 and 15 MAF, during the 100-year period of analysis.

7.7.3 Coldwater Fish Habitat in River Reaches

The number of miles of coldwater fish habitat downstream from Fort Peck and Garrison Dams was computed for the months of April through September. Two factors used to determine the amount of habitat for coldwater fish species were the amount of water released from the upstream dam and its water temperature. Generally, higher lake levels and higher releases result in more miles of coldwater habitat below the dams. Differences in the amount of this habitat for the CWCP, the MCP, and the four GP options are discussed in this section. Annual values were computed and then averaged to compute a single value for each of the two reaches. Table 7.7-3 and Figure 7.7-9 present the combined total value, for the two reaches, and the table presents the value for each reach over the 100-year period of analysis. Before reading the following paragraphs, one additional bit of information is important to understand. The Fort Peck numbers are high for all five alternatives to the CWCP because the coldwater habitat model does not account for the fact that warmer water will go over the spillway at Fort Peck in the years there is a spring rise or very high releases from the dam. The relative differences among the five alternatives should be about the same as presented.

The CWCP provides 183.6 miles of coldwater fish habitat in two of the river reaches of the Mainstem Reservoir System on an average annual basis. This total volume at the sites analyzed is distributed among the river reaches below Fort Peck Dam (76.4 percent) and Garrison Dam (23.6 percent). Figure 7.7-9 shows that the CWCP and the MCP are aligned between 183.6 and 186.7 miles, a difference of 3.1 miles. The four GP options are more closely grouped together between 196.3 and 197.4 miles, a difference of only 1.1 miles. The CWCP has the least amount of total coldwater fish habitat within the reaches below Fort Peck and Garrison Dams (183.6 miles), while the GP2028 option has the most total habitat (197.4 miles). This figure also depicts the values for the submitted alternatives discussed in Chapter 5, to show how the GP options perform relative to the submitted alternatives. The GP options provide total average annual coldwater fish habitat values that are closest to the FWS30 and BIOP alternatives. These two alternatives are very similar to the four GP options in that they have the same operating features except for different spring rises relative to all of the GP options and different summer low releases from Gavins Point Dam than the GP1528 and GP2028 options.

The CWCP and the MCP are very similar in that they have no spring rise and the same summer flat full navigation service level release at Gavins Point Dam. The MCP's unbalanced intrasystem regulation and higher level of drought conservation creates more total coldwater fish habitat (1.7 percent) in the two river reaches of the Mainstem Reservoir System than the CWCP. It also creates 1.4 and 2.5 percent more habitat below Fort Peck and Garrison Dams, respectively. Compared to the GP options, the increases in habitat under the MCP represent the smallest percent increase over the CWCP.

Compared to the MCP, a potential starting point for the GP options, the GP1528 option, increases total coldwater fish habitat within the river reaches by 5.2 percent. Compared to the MCP, the GP1528 option's added 15-kcfs spring rise combined with a reduced (6-kcfs lower) flat summer release increases coldwater fish habitat by 6.4 percent below Fort Peck Dam and by 2.5 percent below Garrison Dam.

The GP2021, GP1521, and GP2028 options provide perspective for how coldwater fish habitat in the river reaches could change in the future relative to the GP1528 option. The GP2021 and GP1521 options result in similar changes in coldwater fish habitat compared to the GP1528 option. Also, compared to the GP1528 option, the GP2021 and GP1521 options both create 0.4 to 0.5 more miles of total coldwater fish habitat below Fort Peck Dam and result in 0.9 percent less habitat below Garrison Dam. Compared to the two other GP options, the GP2028 option is the only one that results in an overall increase in coldwater fish habitat below both Fort Peck Dam (0.7 percent) and Garrison Dam (0.2 percent). Compared to the GP1528 option, the GP2028 option's 20-kcfs spring rise combined with a flat summer release of 28.5 kcfs creates more coldwater fish habitat in the river reaches than the two other GP options.

Table 7.7-3. Average annual coldwater fish habitat in the river reaches (miles).

Alternative	Total	1898 to 1997	
		Fort Peck	Garrison
CWCP	**183.6**	140.2	43.4
MCP	**186.7**	142.2	44.5
GP1528	**196.4**	151.3	45.0
GP2021	**196.4**	151.8	44.6
GP1521	**196.3**	151.7	44.6
GP2028	**197.4**	152.3	45.1

Figures 7.7-10 through 7.7-12 graphically depict the annual values for total coldwater river fish habitat for the CWCP, the MCP, and the four GP options. Generally, all of the alternatives discussed in this chapter maintain an average 200 miles of habitat during the full period of analysis. Habitat is reduced to between 100 and 150 miles, its lowest amount, during the late 1930s and early 1940s; however, the GP1528 option maintains higher habitat values during this period than the remaining alternatives.

7.7.4 Warmwater Fish Habitat in River Reaches

The number of miles of warmwater river fish habitat downstream from Fort Peck, Garrison, and Fort Randall Dams in each month from April through August was estimated using another fish habitat model. In general, the amount of warmwater habitat is expected to be lower for an alternative that has higher amounts of water in storage. This is the opposite of the effects described for coldwater river fish habitat. The following compares the amount of effects on warmwater river fish habitat of the CWCP, the MCP, and the four GP options. Table 7.7-4 and Figure 7.7-13 present the average annual warmwater river fish habitat for the 100-year period of analysis. The total value is the sum of all three reaches, with the reach downstream from Fort Peck Dam providing more than 60 percent of the habitat. The numbers for the Fort Peck reach for the alternatives should be generally higher than presented because there is a warmer water release over the spillway at Fort Peck when there is a spring rise or very high releases at Fort Peck Dam. The relative difference among these alternatives should stay about the same, however.

The CWCP provides 52.9 miles of warmwater fish habitat in three of the river reaches of the Mainstem Reservoir System on an annual basis. This total volume for the reaches analyzed is distributed among the river reaches below Fort Peck Dam (62.0 percent), Garrison Dam (11.5 percent), and Fort Randall Dam (26.3 percent). Figure 7.7-13 shows that the four GP options are closely grouped together between 44.6 and 45.3 miles, a difference of only 0.7 mile. The CWCP and the MCP are more aligned between 48.8 and 52.9 miles, a difference of 4.1 miles. While the CWCP provides the most total warmwater fish habitat in the three river reaches of the Mainstem Reservoir System (52.9 miles), both the GP1521 and GP2028 options provide the least amount of habitat (44.6 miles). Figure 7.7-13 also depicts the values for the submitted alternatives discussed in Chapter 5, to show how the GP options perform relative to the submitted alternatives. The GP options provide a total average warmwater fish habitat value that is similar to the FWS30, BIOP, and ARNRC alternatives.

Compared to the CWCP, the MCP is the only alternative that does not change the amount of warmwater fish habitat below Garrison Dam. The four GP options increase habitat in this reach. In addition, these options, including the MCP, provide less warmwater fish habitat than the CWCP below both Fort Peck and Fort Randall Dams. The MCP reduces total warmwater fish habitat by 7.8 percent and the reduction in habitat downstream of Fort Peck and Fort Randall Dams is nearly equal (8.5 and 8.6 percent less habitat, respectively). This reduction of habitat under the MCP represents the smallest percent change from the CWCP of all the alternatives discussed in this chapter.

Compared to the MCP, it appears that a lower, flat summer release from Gavins Point Dam, as with the potential starting point (GP1528) option, reduces total warmwater fish habitat by 7.2 percent. Below Fort Peck and Fort Randall Dams, the GP1528 option provides 9.7 to 7.9 percent less habitat than the MCP, respectively; however, this option increases habitat below Garrison Dam.

The following discussion on the GP2021, GP1521, and GP2028 options provide perspective for how warmwater fish habitat in the river reaches could change in the future if changes are made to the GP1528 option. A split summer release, as with the GP2021 and GP1521 options, tends to increase warmwater fish habitat downstream of Fort Peck Dam (0.7 and 0.4 percent, respectively) and decrease habitat below Fort Randall

Table 7.7-4. Average annual warmwater fish habitat in the river reaches (miles).

		1898 to 1997		
Alternative	**Total**	**Fort Peck**	**Garrison**	**Fort Randall**
CWCP	**52.9**	32.8	6.1	13.9
MCP	**48.8**	30.0	6.1	12.7
GP1528	**45.3**	27.1	6.5	11.7
GP2021	**44.7**	27.3	6.5	10.9
GP1521	**44.6**	27.2	6.4	10.9
GP2028	**44.6**	26.6	6.4	11.6

Dam (6.8 percent). Compared to the GP1528 option, the GP2021 and GP1521 options do not change the amount of habitat below Garrison Dam. The GP2028 option is the only option that reduces warmwater fish habitat below all three dams. A 20-kcfs spring rise and a flat summer release result in a 1.5 percent total decrease in warmwater fish habitat compared to the GP1528 option. Under the GP2028 option, habitat also is reduced below Fort Peck, Garrison, and Fort Randall Dams by 1.8, 1.5, and 0.9 percent, respectively.

As shown on Figures 7.7-14 through 7.7-16, the availability of warmwater fish habitat is highly variable during the full period of analysis. There is an overall increase in warmwater fish habitat during the 1930 to 1941 drought period, and in the following year or two. Of the fish models analyzed thus far, the warmwater fish habitat model is the only one that has shown an overall benefit in habitat during this period. The CWCP shows a greater benefit during this 13-year period.

7.7.5 Physical Habitat for Native River Fish

Native river fish habitat values were computed for the river reaches downstream from four of the dams and for five subreaches on the Lower River downstream from Sioux City. An index value (correlation coefficient) was computed for nine of the months based on how closely the velocity and/or depth distributions for a given river reach match the "natural" flow conditions based on pre-Mainstem Reservoir System channel conditions. In April, May, and June, the habitat value is dependent upon the potential for overbank flooding for each reach. The index value for each month can range from 0 to 1.0, with a value of 1.0 assigned to a perfect match. The values for each of the 12 months are summed to compute an annual index value that can be as high as 12.0 for each reach. A total annual value is computed by combining the values from the nine reaches. Average annual values are the means for the individual and total reaches. This section discusses the physical habitat values for native river fish that were computed for the CWCP, the MCP, and the four GP options. The total and individual reach average annual values are presented in Table 7.7-5 and only the total value is presented in Figure 7.7-17.

As shown in Figure 7.7-17, all of the alternatives discussed in this chapter are closely grouped together between 81.46 and 82.44 units, a difference of about 1.0 unit. The total relative index value for the CWCP is the lowest of the alternatives discussed in this chapter while the GP2028 option has the highest index value. Compared to the CWCP, the GP2028 option provides a 1.2 percent index value increase for total physical habitat for native fish. This figure also shows the values for the submitted alternatives discussed in Chapter 5, to illustrate how the GP options perform relative to the submitted alternatives. The GP options provide total average annual physical habitat index values in the same range as the FWS30 and BIOP alternatives.

Compared to the CWCP, the MCP increases the index value for physical fish habitat within two of the four river reaches (Fort Peck by 0.6 percent and Garrison by 1.0 percent), and within four of the five Lower River subreaches. The index value within the Boonville subreach does not change from the CWCP. Although the MCP increases the index values within these reaches, it provides the smallest percent changes from the CWCP within the Sioux City (0.1 percent), Nebraska City (1.0 percent), St. Joseph (0.9 percent), and Kansas City (0.1 percent) subreaches, and within the Fort Peck reach (0.6 percent). The MCP increases the index value over the CWCP within the Garrison reach, which represents the largest percentage increase over the CWCP of all the alternatives discussed in this chapter. While the MCP's added unbalanced intrasystem regulation and higher drought conservation measures result in an index value increase in the above reaches, these factors result in a decrease of 0.7 and 0.6 percent below Fort Randall and Gavins Point Dams, respectively. Compared to the four GP options, the decrease below Gavins Point Dam under the MCP represents the largest percentage decrease compared to the CWCP.

Table 7.7-5. Average annual physical habitat for native river fish in nine river reaches (relative index).

		1898 to 1997								
Alternative	**Total**	**Fort Peck**	**Garrison**	**Fort Randall**	**Gavins Point**	**Sioux City**	**Nebraska City**	**St. Joseph**	**Kansas City**	**Boonville**
CWCP	**81.46**	9.03	7.86	8.56	9.30	10.22	7.98	7.93	10.03	10.55
MCP	**81.64**	9.08	7.94	8.50	9.24	10.23	8.06	8.00	10.04	10.55
GP1528	**82.23**	9.20	7.80	8.57	9.31	10.24	8.23	8.15	10.11	10.62
GP2021	**82.12**	9.19	7.85	8.45	9.34	10.11	8.22	8.19	10.12	10.64
GP1521	**81.91**	9.19	7.84	8.44	9.33	10.07	8.18	8.15	10.09	10.62
GP2028	**82.44**	9.21	7.83	8.57	9.31	10.27	8.27	8.20	10.14	10.63

Compared to the MCP, the potential starting point option (GP1528) increases the index value for physical fish habitat within three of the four Mainstem Reservoir System river reaches (Fort Peck reach by 1.3 percent and the Fort Randall and Gavins Point reaches by 0.8 percent). The river reach below Garrison Dam is the only one that shows an index value decrease (1.8 percent) under this option. A 15-kcfs spring rise and flat summer release (28.5 kcfs) from Gavins Point Dam, as with the GP1528 option, increases index values within all five of the Lower River subreaches downstream from Sioux City. Under this option, the Sioux City subreach experiences the lowest percentage increase compared to the MCP (0.1 percent), while the Nebraska City subreach experiences the greatest percent increase (2.1 percent). The St. Joseph, Kansas City, and Boonville subreaches show a 1.9, 0.7, and 0.7 percent increase in index values over the MCP, respectively.

The following discussion on the GP2021, GP1521, and GP2028 options provides perspective for how physical habitat for native river fish could change in the future if changes are made to GP1528, a potential starting point for the GP options. A 5-kcfs difference in the spring rise, where the GP2021 option has a higher spring rise than the GP1521 option, and a split 25/21-kcfs summer release results in a similar change in index values within the four system river reaches. Compared to the GP1528 option, the GP2021 and GP1521 options decrease the index value for physical habitat for native river fish downstream of Fort Peck Dam by 0.1 percent and Fort Randall Dam by 1.4 and 1.5 percent, respectively. The GP2021 option provides slightly greater index value increases below both Garrison Dam (0.6 percent) and Gavins Point Dam (0.3 percent) than the GP1528 option. Compared to the GP1528 option, the GP2021 option increases physical habitat index values in three of the five subreaches downstream from Sioux City: St. Joseph (0.5 percent), Kansas City (0.1 percent), and Boonville (0.2 percent), and decreases the index value in the remaining two subreaches: Sioux City (1.3 percent) and Nebraska City (0.1 percent). The GP1521 option decreases the index value in three of the five subreaches: Sioux City (1.7 percent), Nebraska City (0.6 percent), and Kansas City (0.2 percent), and results in no change in the index value from the GP1528 option in the St. Joseph and Boonville subreaches. The GP2028 option has a 20-kcfs spring rise and a flat summer release of 28.5 kcfs that represents the minimum navigation service, summer low flow. It is apparent that an additional 5 kcfs during the spring rise increases the index values for physical fish habitat in two of the four system river reaches and in all of the five subreaches downstream from Sioux City over the GP1528 option. The GP2028 option increases the index value in the reaches below Fort Peck Dam (0.1 percent) and Garrison Dam (0.4 percent). This option does not result in a change in index values below Fort Randall Dam and Gavins Point Dams. Under this option, the Sioux City, Nebraska City, St. Joseph, Kansas City, and Boonville subreaches all increase index values over the GP1528 option. The improvements to the index values for the three GP options, when compared to the CWCP, are greatest in the Sioux City and St. Joseph reaches.

The annual values of total river fish physical habitat for the alternatives discussed in this chapter are shown on Figures 7.7-18 through 7.7-20. In general, the relative index values remain between 80.0 and 85.0 units during the full period of analysis. During the early-1920s and mid-1950s, the relative index values increase for all alternatives to about 88.0 units, whereas values decrease to about 78.0 units during the early 1900s and mid-to-late 1970s. These latter two periods include some high runoff years from the upper Missouri River basin.

7.7.6 Missouri River Connectivity to Low-Lying Lands during the Spring Rise

As stated in the November 2000 USFWS BiOp, "Floodplain connectivity refers to the seasonal flooding of areas adjacent to the river. The spring flood pulse often provides connectivity between the floodplain to the river. For native river fish like the pallid sturgeon, this floodplain connectivity, especially during May/June, provided spawning areas for forage species, increased phytoplankton production, and redistributed carbon to the river" (USFWS, 2000). This carbon, in the form of detritus scoured off of the floodplain, settled out in the shallow water areas along the river where the microscopic biota grew. As the pallid sturgeon hatched, the larval fish would float down the river until they were able to float into the shallow water areas. There they would reside during their fragile first months of life.

The physical habitat model discussed in the previous discussion on fish impacts acknowledged this important component for the growth of the young-of-year pallid sturgeon, and requires over-bank flooding to get high index values in April, May, and June. That is the period when organic matter needs to be flushed into the river to provide biota in the shallow water areas with a food source so that the larval pallid sturgeon have adequate food after spawning. Examination of the physical habitat output files for these 3 months shows very low index values, which means that river flows were generally lower than necessary for overbank flooding. To better understand how much floodplain connectivity may be occurring along the Lower River from Sioux City to the mouth, the Corps undertook an analysis. As a first step in the analysis, the Corps estimated the acreage and elevation of the low-lying lands (areas adjacent to oxbow lakes and chutes) that could be inundated by high river

flows. The elevations were then converted to river stages for the output nodes of the Daily Routing Model (DRM) hydrologic model to determine when the spring rises were inundating these areas. The months of May and June, the period when the spring rise was modeled in most of the DRM simulation runs, were checked to see how many acres were flooded for a varying number of days for the alternatives being analyzed. All of the alternatives selected for detailed analysis were analyzed with this model of connectivity.

The graphical results of the analyses of connectivity are duration plots of acres inundated versus percent of the time. Duration plots were developed for inundation for at least 2 days up to over 10 days. As the number of days is increased, the amount of acres inundated diminishes, and the curves slide to the lower left on the plots. The duration plot of the 2-day analysis is shown as Figure 7.7-21. This figure shows that the various alternatives provide similar duration plots of connectivity with the number of acres of connectivity for 2 days sometime during May or June increasing as the amount of spring rise increases (GP1521 and GP1528 acres are less than GP2021 and GP2028 acres). This figure also includes the duration plot for the ROR alternative to provide a perspective for how often these low-lying lands would have been inundated for 2 days with no flow control. This flow scenario has considerably higher values across the entire range of the plot from near zero percent to near 100 percent.

Table 7.7-6 presents the total values for the 25th percentile (lower quartile) from Figure 7.7-21 with a breakdown among the reaches making up the total reach from Sioux City to the mouth. The 25th percentile was selected for presentation in the RDEIS because the alternatives were designed to have spring rises about one-third of the time, and the 25th percentile falls within the range when spring rises may be affecting the amount of connectivity. The total connectivity values are also shown in Figure 7.7-22.

The CWCP provides a total of 3,282 acres of connectivity. The greatest share of this connectivity (39.8 and 23.4 percent) is provided in the Hermann and upstream Boonville reaches. The remaining acres are fairly evenly divided among the five other reaches. The Nebraska City reach has the lowest amount of acres at only 4.1 percent.

Figure 7.7-22 shows the 25th percentile acres of connectivity for the alternatives selected for detailed analysis, the ROR scenario, and the CWCP. The alternatives are clustered into four distinct groups. The lowest group includes the CWCP and the MCP, with a range of only 2 acres. The next group includes the GP options with 15-kcfs spring rises (GP1521 and GP1528), and they have about 100 acres more connectivity than the lowest group. The third group includes the GP options with 20-kcfs spring rises with about 70 acres more than those options with only 15-kcfs spring rises. Finally, the ROR scenario, which has no inflow control (uncontrolled releases from Gavins Point Dam), has the highest value, at 646 acres higher than the CWCP and almost 470 acres more than the higher spring rise GP options.

The MCP has basically the same spring release from Gavins Point Dam as the CWCP; therefore, it has essentially the same connectivity value for the 25th percentile. Two reaches, Sioux City and Nebraska City, increase by 3.0 and 0.7 percent, respectively, and two other reaches, Omaha and Kansas City decrease by of 1.1 and 1.5 percent, respectively.

The GP1528 option is a potential starting point for modified Gavins Point releases because it has the least amount of change from the MCP of the four GP options. This option has a 15-kcfs spring rise. Its 25th percentile value is 2.9 percent higher than the MCP. The greatest share of the increase occurs in the two reaches analyzed that are closest to Gavins Point Dam – Sioux City (23.1 percent increase over the MCP for this reach) and Omaha (10.2 percent increase) reaches. One of the other reaches, the Kansas City reach, has a change of 3.6 percent. The other four reaches have no change.

The GP2021 option has both a Gavins Point Dam spring rise change from 15 to 20 kcfs and a reduced summer release compared to the GP1528 option. A switch to this option with an extra 5 kcfs in the spring increases the 25th percentile connectivity value by 2.0 percent

Table 7.7-6. Connectivity to low-lying lands for 2 days in May and June (acres for the 25th percentile).

River Mile		CWCP	MCP	GP1528	GP2021	GP1521	GP2028
734-648	Sioux City	249	257	316	332	309	334
648-597	Omaha	270	267	295	344	298	351
597-497	Nebraska City	136	137	137	137	137	137
497-374	St Joseph	287	287	287	287	287	287
374-250	Kansas City	265	261	271	272	271	272
250-130	Boonville	768	768	768	768	768	768
130-0	Hermann	1,307	1,307	1,307	1,307	1,307	1,307
Total		**3,282**	**3,284**	**3,380**	**3,446**	**3,377**	**3,456**

compared to the value for the GP1528 option. The larger increases occur in the Sioux City (5.1 percent) and the Omaha (16.6 percent) reaches. There is some increase in the Kansas City reach, with an increase of 0.5 percent. The other four reaches have no change from the value for the GP1528 option.

The GP1521 option has the same spring rise as the GP1528 option; however, it has the reduced summer release. This option has essentially the same total value as the GP1528 option, which would be expected because the spring rise drives the changes in connectivity. The total connectivity value drops just 0.1 percent for the change from the GP1528 option to the GP1521 option. A decrease of 2.3 percent occurs in the Sioux City reach, and an increase of 1.0 percent occurs in the Omaha reach. The other four reaches have no change in connectivity value with the change to the GP1521 option.

The GP2028 option has a Gavins Point Dam spring rise change from 15 to 20 kcfs, but it has the same summer release as the GP1528 option. A switch to this option from the GP1528 option results in an increase of 2.2 percent in the total connectivity. The primary increases occur in the Sioux City (5.8 percent) and Omaha (19.0 percent) reaches. A minor increase (0.5 percent) occurs in the Kansas City reach. The other three reaches have no change.

The model was not set up to provide year-to-year values for acres of connectivity. If it had, the results would have shown considerable fluctuation throughout the 100-year period of analysis because the forced spring rises from Gavins Point Dam would have increased connectivity in the upstream reaches. The downstream reaches would have also shown considerable year-to-year variability as the flows on the lower reaches fluctuated with tributary inflows in the spring.

In conclusion, the gains in connectivity in the low-lying areas with flow increases via spring rises are relatively minor. In fact, there is effectively no increase in value downstream of the Omaha reach. By adding a spring rise of 15 kcfs, the gain in connectivity is about 100 acres, and the gain is about an additional 70 acres for adding an additional 5 kcfs (for a total spring rise of 20 kcfs). These data indicate that the spring rise should not be added based only on the gains in connectivity that could occur with the increased flows.

Another way of looking at the end result of connectivity, the flushing of detritus into the river, is to think about how this type of material gets into the river. Approximately 3,500 acres of low-lying lands would be inundated for 2 days during the May through June timeframe according to the data presented above. This is approximately 5.5 square miles. A small tributary to the Missouri River is likely to be several times larger than 5.5 square miles, and a rainfall event on the drainage area for each tributary flushes detritus into the tributary, which ultimately gets carried into the Missouri River. There are many thousands of acres that drain into the Missouri River, and many of the tributaries carry heavy sediment loads into the river during major rainfall events. These tributaries are, and will continue to be, the main source of detritus to the Missouri River.

7.7.7 Shallow Water Habitat Along the Lower River

In its November 2000 BiOp, the USFWS states that shallow water habitat has value to all life stages of native big river fish and other river organisms. As stated in the introductory remarks of the connectivity analysis discussion, shallow water habitat is especially important during the first few months of the life of the larval pallid sturgeon, an endangered species. The Corps and USFWS agreed during the formal consultation for, and the review of, the BiOp, that 20 to 30 acres of shallow water habitat per mile may provide the habitat necessary for initial recovery of pallid sturgeon. This part of the fish section of the RDEIS focuses on the amount of shallow water habitat occurring in the Lower River for the CWCP, the MCP, and the four GP options.

The analysis of existing shallow water habitat under the various alternatives was conducted using data obtained for the physical habitat model. As part of the development of that model, cross sections were taken at a representative subreach of seven reaches of the Lower River and hydraulically modeled. These data provided a basis for determining the amount of habitat fitting into a variety of depth and velocity classes for each of the seven reaches (habitat per mile times reach length). Shallow water habitat for the purpose of this analysis is habitat that is up to 5 feet deep with a velocity no greater than 2.5 feet per second. The amount of habitat in each depth and velocity class could be determined based on the amount of flow in each river reach. Using these relationships, the Corps developed a model that would provide duration plots of the acres of habitat per mile in each reach for any timeframe of interest. Generally, the Corps looked at individual months; however, the lowest flows for two of the alternatives occur from mid-July to mid-August. Data were computed for this period for the seven Lower River reaches. Figure 7.7-23 is one of the resulting plots for the CWCP, the MCP, and four GP options. Integration of the area under the duration curve leads to the average daily value per mile for shallow water habitat for each reach. Table 7.7-7 presents these data for all seven subreaches modeled for the CWCP, the MCP, the GP options, and the ROR scenario. Using these acres per mile, the total acreage available in each reach of the Lower River from Gavins Point Dam to the

Osage River (River Mile 130) can be computed. The data for five reaches are presented in Table 7.7-8 on a reach and total basis (data combined using data from two locations for the Sioux City to Omaha reach). Figure 7.7-24 shows the total acres for the five reaches from Sioux City to the Osage River for the CWCP, the MCP, the four GP options, and the ROR scenario (no control of system inflows by the Mainstem Reservoir System). Data are not presented for the reach downstream from Gavins Point Dam because there is already adequate habitat (63.8 acres per mile for the CWCP) in this reach.

The CWCP provides 3,717 acres of shallow water habitat for the five reaches. The greater share of this habitat is provided between the Grand and Osage Rivers in the central part of the State of Missouri: 2,193 acres, or 59.0 percent of the total. The Nebraska City to Kansas City reach provides 25.0 percent of the total, and the other three reaches provide only 16.0 percent of the total, with the Sioux City to Omaha reach providing about half of that.

Figure 7.7-25 shows that the total acreage varies among the CWCP, the MCP, the four GP options, and the ROR scenario. These can be divided up into three groupings. The lowest grouping has two alternatives, the CWCP and MCP. The range in values is from 3,717 to 3,767, a difference of 50 acres. The two GP options with a minimum navigation service summer flat release, and the ROR scenario are in the second lowest group at between 4,061 to 4,147 acres, a range of 86 acres and about 300 acres more than the top of the lowest group. Next come the two GP options with the 25/21-kcfs split summer release. These two options have values at about 4,900 acres, which is about 1,200 acres more than the lowest group.

The MCP provides a summer flat Gavins Point Dam release essentially the same as the CWCP; therefore, it generally has similar summer flows to the CWCP. As expected, it also has similar total shallow water habitat, at 3,767 acres, as presented in Table 7.7-8. This total represents a 1.3 percent increase in shallow water habitat in the mid-July to mid-August timeframe. There is some variation among the reaches. The three reaches between Sioux City and Kansas City have increased habitat ranging from an increase of 2.9 percent in the middle of the three reaches to an increase of 5.6 percent in the Sioux City to Omaha reach. In contrast, the lower two reaches have decreases of 4.6 and 0.5 percent.

GP1528 is the potential starting point for the GP options because it has the smallest changes in the spring and summer releases from Gavins Point Dam. This option has a summer flat release of 28.5 kcfs, which is assumed to provide minimum service to navigation. The 4,137 acres represent a 9.8 percent increase in habitat over the MCP. The greatest increase (43.5 percent) in a reach occurs in the Sioux City reach. The other reaches increase by from 3.5 to 20.3 percent over the MCP.

The GP2021 option has summer Gavins Point Dam releases split between 25 and 21 kcfs, with the 21-kcfs release occurring in the mid-July to mid-August timeframe. This alternative has the greatest amount of shallow water habitat at 4,906 acres, which is an increase of 18.6 percent over the GP1528 option. The greatest increases are for the Sioux City to Omaha and the Nebraska City to Kansas City reaches, with increases of

Table 7.7-7. Expected daily shallow water habitat for representative subreaches from mid-July to mid-August (acres/mile).

Reach	CWCP	MCP	GP1528	GP2021	GP1521	GP2028	ROR
Gavins Point	63.8	63.2	69.2	71.6	71.2	69.8	64.9
Sioux City	2.2	2.3	3.3	5.8	5.8	3.4	3.6
Omaha	1.9	2.0	2.9	5.1	5.1	3.0	3.3
Nebraska City	4.5	4.6	5.0	6.0	6.0	5.0	5.1
St. Joseph	4.8	5.1	5.7	7.9	7.9	5.7	6.2
Kansas City	1.4	1.4	1.6	1.7	1.7	1.6	1.2
Boonville	18.3	18.2	18.9	18.7	18.7	18.9	17.4

Table 7.7-8. Expected daily shallow water habitat available from mid-July to mid-August (acres).

Reach	CWCP	MCP	GP1528	GP2021	GP1521	GP2028	ROR
Sioux City to Omaha	288	304	436	757	754	442	479
Omaha to Nebraska City	144	148	161	191	191	161	165
Nebraska City to Kansas City	929	971	1,088	1,513	1,512	1,090	1,187
Kansas City to Grand River	164	157	189	200	198	188	144
Grand River to Osage River	2,193	2,187	2,263	2,245	2,243	2,266	2,086
Total	**3,717**	**3,767**	**4,137**	**4,906**	**4,899**	**4,147**	**4,061**

73.5 and 39.0 percent, respectively. The Omaha to Nebraska City and the Kansas City to Grand River reaches have increases of 18.4 and 6.1 percent, respectively.

The GP1521 option also has summer flows in the mid-July to mid-August timeframe that are split between 25 and 21 kcfs; therefore, it has shallow water habitat changes similar to the GP2021 option. The total habitat of 4,899 acres represents an increase of 18.4 percent over the GP1528 option. The four reaches between Sioux City and the Grand River increase, ranging from 5.2 to 72.9 percent. Only the lowest reach decreases (by 0.9 percent).

The GP2028 option has a minimum navigation service release from Gavins Point Dam. This release was modeled as a 28.5-kcfs flat release. This is the same as the GP1528 option; therefore, shallow water habitat is similar to the GP1528 option. Total habitat increases by only 0.2 percent. Four of the reaches have increased values and one, the Kansas City to Grand River reach, has a decreased value. The range in changes is from an increase of 1.3 percent to a decrease of 0.1 percent.

A special effort was made to have the shallow water habitat model create an output file of the average daily habitat values for each year. This data set allowed the creation of Figures 7.7-26 to 7.7-28. The first figure compares the annual values for the CWCP and the MCP. It shows relatively little difference except for noticeable increases during 3 years in the 1930 to 1941 drought and 1 low year in the mid-1960s. The drought years are likely nonnavigation years when Gavins Point Dam releases would be targeting an 18-kcfs water supply target in the mid-July to mid-August timeframe. The reason for the noticeable decrease in the mid-1960s resulted from the need to evacuate some extra water from the flood control storage zones. This resulted from the effect of coming out of the 1954 to 1961 drought at a higher storage level, which led to a greater amount of water in storage in a subsequent high inflow year. Going to a minimum service flat release under the GP1528 option (see Figure 7.7-27) increases habitat slightly in a relatively large number of years when compared to the MCP acreage. Finally, further reducing the summer Gavins Point Dam release to 21 kcfs during this mid-summer period results in even more shallow water habitat in most years, as shown in Figure 7.7-28. Results for the GP1521 and GP2028 options were similar to the GP2021 and GP1528 options results described above. The summer low-flow release value provides the changes among the alternatives.

Additional discussion is needed regarding the amount of habitat that exists per mile in the reaches from Sioux City to the Osage River. With the exception of the Grand River to Osage River reach, habitat acreage is well below the minimum of 20 acres per mile that the Corps and USFWS agreed upon for the pallid sturgeon. Even though there are some increases in shallow water habitat (as discussed above and shown in Figures 7.7-24 and 7.7-25), the gains provided by release changes alone are not enough to provide the minimum 20 acres per mile. Because of this, the USFWS included in its BiOp reasonable and prudent alternative (RPA) the recommendation for the Corps to construct additional shallow water habitat. If the GP1528 option or the GP2028 option were the selected plan, habitat construction would be reduced by about 400 acres compared to what would be needed for the CWCP or the MCP. If the GP1521 option or the GP2021 option were the selected plan, habitat construction would be further reduced by about 800 acres compared to the other two GP options, or about 1,200 acres less than what would be needed for the CWCP or the MCP. The relatively low acres per mile values indicate that the lower summer releases should not be made only to provide additional shallow water habitat.

7.7.8 Spawning Cue for the Lower River

The November 2000 USFWS BiOp RPA recommends a spring rise release from Gavins Point Dam to provide, among other biologically important functions, a spawning cue for native river fish, especially the endangered pallid sturgeon. The RPA specifies a modified annual release pattern that has a spring rise above the full navigation service releases of 15 to 20 kcfs. This release is to last for a duration of 2 weeks at its peak and a total of 4 weeks including the period over which the releases are gradually increased and decreased. Discussions between USFWS and Corps staff determined that the spawning cue requirements of the pallid sturgeon are basically unknown at this time.

In an e-mail sent to the Corps on January 22, 2001, the USFWS requested the Corps to conduct some hydrologic analyses. This set of analyses included a spring rise analysis. The USFWS requested, “For gage sites downstream of Gavins Point, document spring rise spawning cues. Rises should be defined as increases of discharge of at least 20% above the mean discharge prevailing for the preceding 15 days, during the period May – July. The rise should take place over three days or less” (USFWS, 2001). The USFWS provided no information on what duration of rise to analyze. This lack of information supported the general understanding between the Corps and USFWS staffs that the required spawning cue is basically unknown at this point in time. Corps staff understood that the aforementioned criteria were hypothetical, and they did not have supporting data,

analysis, and documentation of associated spawning success. A discussion of the analysis conducted for evaluating a spawning cue follows.

A model was developed that would access the daily flow data for each DRM node location from Gavins Point Dam to the mouth. A running average of the daily flows for the previous 15 days was conducted using the data starting on May 1 and ending on June 30 of each year. (The likelihood of spawning cues after June 30 is low, so it was not checked.) The flows for May 1, 2, and 3 would be checked to determine if the flows over this 3-day period exceeded the prior 15-day average by at least 20 percent. If the flows on one of the days met the 20 percent increase, the model would continue to check the daily average flow until it dropped to less than 20 percent of the flows for the 15 days prior to May 1. The model would continue day by day to check the prior 15 days, compute an average, and count the number of days the flows continued to be at least 20 percent above that prior 15-day average. This continued up to June 30.

In some years there were some short periods and some longer periods. The model recorded the longest period in terms of days. The longest period was recorded for each year, and when the 100 years of data were analyzed. The 100 annual values were sorted from highest to lowest with the highest value assigned a 1 (for equaled or exceeded 1 percent of the time) and the lowest value was assigned a 100 (for equaled or exceeded 100 percent of the time). A plot of these data is called a duration plot, and Figure 7.7-29 is an example of such a plot for the Sioux City gage. This figure shows the duration plots for the CWCP at all of the gage locations in the DRM simulation output files for the Lower River from Sioux City downstream. A similar plot was completed for the CWCP, the MCP, and the four GP options. Another set of curves was developed for the ROR scenario (no control of inflows to the mainstem of the Missouri River). Sets of curves can be compiled for each gage location using this first set of curves, as shown on Figure 7.7-30. This second set of curves, one for each gage location in the DRM, provides the spawning cues for a full range of days. For example, to determine how often a 20 percent increase in flow occurred for a total of 21 consecutive days, one would go to the point where the 21-day line crosses the duration curves. Next one would slide down and read off the percent of time from the bottom axis of the graph for each curve. In the case of the CWCP curve on the figure, this point is located at 7 percent of the time. Similarly, it is 15 percent of the time for the MCP.

Because the USFWS did not specify a length for the spawning cue, one was selected for analysis based on the spring rise recommended in the BiOp RPA. The total rise occurs over a 28-day period. If it takes 3 days to go up 20 percent, there will also be 3 days at the end of the spring rise where the releases will drop below the 20 percent value. This means that the spawning cue lasted 22 days (28 minus 6). Based on this basic consideration, a 3-week, or 21-day, length was evaluated for the spawning cue. Figure 7.7-31 shows a plot of the resulting data for all of the gage locations included in the DRM. The curves shown on this plot would shift upward for shorter lengths of spawning cues, and vice versa.

Figure 7.7-31 shows that the CWCP, the MCP, the four GP options, and the ROR have spawning cues that occur for differing amounts of time. The values are presented in Table 7.7-9. For example, the Sioux City line on the plot shows that the percent of time increases for the CWCP in a downstream direction, with a 21-day spawning cue occurring 7 percent of the time at Sioux City and a maximum of 38 percent of the time at Hermann. The values for Sioux City vary from alternative to alternative. For example, the MCP raises the value to 15 percent for Sioux City. The GP options further increase the percent value up to 29 percent of the time for the GP1528 and GP1521 options and to as high as 39 percent of the time for the GP2028 option. Generally, for the reaches from Kansas City upstream, the values are higher moving across the figure because the spring rise included in the alternative is higher. Downstream from Kansas City, however, the value for the percent of the time the spawning cue occurs remains relatively constant with the values ranging from 37 to 39 percent. The ROR scenario

Table 7.7-9. Percent of years with a 21-day spawning cue at Lower River gaging stations for CWCP, MCP, GP options, and ROR scenario.

	CWCP	MCP	GP1528	GP2021	GP1521	GP2028	ROR
Gavins Point Dam	18	22	37	39	31	46	78
Sioux City	7	15	29	36	29	39	79
Omaha	7	14	28	34	27	38	79
Nebraska City	10	15	27	33	27	35	68
St Joseph	17	19	23	26	24	28	63
Kansas City	33	35	33	40	36	37	62
Boonville	33	33	31	35	35	34	62
Hermann	38	39	37	38	38	39	54

has more spawning cues because the uncontrolled flows were historically much higher than the modeled spring rises, with the percent values ranging from high on the reaches closest to Sioux City (78 or 79 percent) to the lowest value occurring at Hermann (54 percent).

Figure 7.7-32 shows the same data as in the previous figure and the table, only a different format is used. This may help some readers better see the relationships that are occurring on the river among the array of alternatives. At Sioux City, there is a wide range of percents for the CWCP. Going across the figure in a downstream gage location, the differences among the alternatives diminish and approach the 33 percent line drawn on the plot. This line was drawn because the USFWS specified that the spring rises should happen about one-third of the time. This chart can be interpreted in a couple of ways relative to the 33 percent line. First, by the Kansas City gage location, the spawning cue can be found one-third of the time under the CWCP. In fact it happens one-third of the time for the MCP and the two GP options (with spring rises of 15 and 20 kcfs) shown on the figure. Second, beginning at Kansas City (or as far upstream from the mouth as Kansas City) the spawning cue lasts for 21 days for about one-third of the time, whether or not a spring rise release is made from Gavins Point Dam.

To demonstrate what happens when shorter length spawning cues are used in the analysis, a 14-day and a 7-day spawning cue length were analyzed. As stated earlier, the shorter the spawning cue, the more often it occurs (duration plots shift upward). Figure 7.7-33 shows that this is indeed the case. All of the bars in the graph have shifted upward. The one-third recommendation of the BiOp RPA is met by both the GP1528 and GP2021 options at all of the gaging locations with DRM output files. Those locations from Kansas City downstream all have percent values in excess of 35 percent, with some values approaching 50 percent. Figure 7.7-34 shows the results of only a 7-day spawning cue. The lowest value for the MCP and the four GP options is now 29 percent (at Sioux City). The one-third recommendation is met as far upstream as the Nebraska City gage for all four alternatives on the plot.

This brief analysis demonstrates how important it is to have a definitive length for a spawning cue. The MCP comes very close to meeting the one-third requirement for a relatively short spawning cue, and it has a 34.5-kcfs flat release from Gavins Point Dam. This release value is equivalent to a spring rise of about 5 to 6 kcfs in the May timeframe. The Corps' understanding of the primary purpose of the spring rise is to cue the pallid sturgeon to spawn; however, the absolute length and magnitude of the required flow to provide an adequate spawning cue are not known at this time.

The criticality of the spawning cue length is also demonstrated using another analysis that provides more insight into the relationship between spawning cues and shallow water habitat. For the pallid sturgeon to receive the greatest potential for future growth in numbers, the larval fish need to have adequate shallow water habitat following the spawn. Figures 7.7-35 to 7.7-37 show plots of both spawning cue length and shallow water habitat over the period of analysis from 1898 to 1997 for the Sioux City reach. The spawning cue lengths range from zero days up to 61 days, and the shallow water habitat areas range from zero up to 8.7 acres. The spawning cue length is affected by the spring flows, with the higher flows generally resulting in longer cue lengths. Conversely, the shallow water habitat size is affected by the summer flows, with the lower flows resulting in greater amounts of habitat. Because they are driven by different factors, they may not always coincide, as shown in the figures. The Sioux City data were selected for display because of the wider variation between the cue and habitat values, especially for the MCP, shown on Figure 7.7-35.

To assist with the identification of years in which these two values are coincident, an Excel spreadsheet model was developed to identify whether the two are coincident in each year, with the shallow water habitat held constant and the cue length allowed to be variable. Four different cue lengths were run to develop the output for the Sioux City reach. The output file was plotted, and the values for the MCP, the GP1528 option, and the GP2021 option are shown on Figure 7.7-38. This figure shows that the percent of the years increases as the spawning cue length decreases. It also shows that the two factors do not coincide very often for the MCP (5 to 11 percent of the years), but the two GP options increase the percent value considerably. A considerable percentage increase across the range of spawning cue lengths occurs for the GP1528 option, and the GP2021 option adds relatively little more percentage increase across the range of cue lengths. One can also determine the spawning cue length required to have both factors coincide in 33 percent of the years (note 33 percent line on the plot). To have at least 2 acres of shallow water habitat available for the MCP, there are not enough years in which there is even a 5-day spawning cue to meet the 33 percent desirable goal (occurs only in 11 years for the 5-day cue). For the GP1528 option, a spawning cue of no shorter than 9 days has a coincidence rate of 33 percent when at least 2 acres of shallow water habitat are available. Similarly, for the GP2021 option, a spawning cue length of at least 14 days has a coincident rate of 33 percent with at least 2 acres of shallow water habitat. In conclusion, shorter spawning cues of 9 days have to result in successful spawning to have a spawning cue with at least 2 acres of shallow water habitat in 33 percent of the years. This analysis was based on the spawning cue occurring in May or June and the shallow

water habitat being measured in the period from mid-July to mid-August.

Similar analyses were done for the Nebraska City and Boonville reaches. The results are shown on Figure 7.7-39 for at least 3 acres per mile of shallow water habitat in the Nebraska City reach and on Figure 7.7-40 for at least 15 acres per mile in the Boonville reach. For the Nebraska City reach, the MCP meets the 33 percent level as long as spawning cues can be as short as 7 days to count as a spawning cue. Similar numbers for cue length are 10 days for the GP1528 option and 16 days for the GP2021 option. For the Boonville reach, the spawning cue requirement needs to be no longer than 8 days for the MCP, 9 days for the GP1528 option, and 12 days for the GP2021 option if there are to be coincidental spawning cues and at least 15 acres of shallow water habitat in the same year for 33 percent of the years. If longer spawning cues are required, smaller habitat requirements are needed. Conversely, if more habitat requirements are needed, an "adequate" spawning cue needs to be shorter.

In conclusion, greater knowledge is required of what constitutes an adequate spawning cue. If the primary reason for having a spring rise is to provide an adequate spawning cue for the pallid sturgeon so this species can recover, better definition of an adequate spawning cue is essential. Without this definition, it is impossible to determine if the water control plan that is implemented at the end of the Study can adequately meet the spawning needs of the pallid sturgeon.

7.7.9 Fish Resources for Tribal Reservations

Young-of-Year Lake Fish Production

Table 7.7-10 presents the relative index of average annual young fish production for seven Tribal Reservations along the mainstem lakes during the full period from 1898 to 1997, for each of the alternatives discussed in this chapter. The Reservations analyzed include Fort Berthold Reservation on Lake Sakakawea; Standing Rock Reservation and Cheyenne River Reservation, which are on Lake Oahe; Lower Brule Reservation and Crow Creek Reservation on the lower portion of Lake Oahe; Yankton Reservation on Lake Francis Case; and Santee Reservation on Lewis and Clark Lake. As discussed in Section 7.7.1, the young fish index value is useful as an indicator of the relative effects of the different alternatives.

The total index value for average annual young fish production associated with these Reservations is 1.65 units for the CWCP. The MCP and the four GP options result in a total increase in young fish production values over the CWCP: the MCP by 1.2 percent, the GP1528 option by 12.5 percent, the GP2021 option by 13.7 percent, the GP1521 option by 11.9 percent, and the GP2028 option by 11.8 percent.

Within Fort Berthold Reservation, the MCP does not result in an index value change from the CWCP; however, the four GP options all increase the young fish production index value over the CWCP. The GP1521 option shows a 13.0 percent increase in young fish production index values, while the GP2021, GP1528 and GP2028 options all show a 15.2 percent index value increase.

The GP2021 option does not change the young fish production index value within Standing Rock Reservation and Cheyenne River Reservation. The MCP and the GP1528 and GP2028 options all provide the same increase amount over the CWCP (2.5 percent). The GP1521 option is the only option that actually decreases (by 2.5 percent) young fish production index values within Standing Rock Reservation and the Cheyenne River Reservation.

Within Lower Brule Reservation and Crow Creek Reservation, three of the four GP options (GP1521, GP2021, and GP1528) show an 11.6 percent increase in young fish production index values over the CWCP. The GP2028 option results in a 9.3 percent increase and the MCP shows a 2.3 percent decrease in index values.

Compared to the CWCP, the MCP does not result in an index value change within Yankton Reservation. The greatest index value increase over the CWCP occurs under the GP2021 option (35.0 percent), while the GP1521 option results in a 28.3 percent increase. Both the GP1528 and GP2028 options result in a 25.0 percent increase in young fish production index values within Yankton Reservation.

Within Santee Reservation, the two GP options that have a split summer low flow (GP1521 and GP2021) and the two options that have a flat summer release (GP1528 and GP2028) yield the same results. The GP1521 and GP2021 options both provide a 25.0 percent increase in young fish production index values, whereas the GP1528 and GP2028 options both provide an 18.8 percent increase. Under the MCP, the young fish production index value increases 12.5 percent over the CWCP.

Coldwater Fish Habitat in Lakes

Table 7.7-11 presents the average annual volume of coldwater fish habitat for three Tribal Reservations along the mainstem lakes during the full period from 1898 to 1997, for the alternatives discussed in this chapter. The Reservations analyzed include Fort Berthold Reservation on Lake Sakakawea; and Standing Rock Reservation

and Cheyenne River Reservation, which are on Lake Oahe.

Under the CWCP, the total volume associated with Fort Berthold Reservation and Standing Rock and Cheyenne River Reservations is 6.28 MAF. Compared to the CWCP, the MCP and the four GP options increase coldwater fish habitat: the MCP by 2.5 percent, the GP1528 option by 8.9 percent, the GP2021 option by 9.7 percent, the GP1521 option by 9.9 percent, and the GP2028 option by 8.6 percent.

Within Fort Berthold Reservation, the two GP options with a flat summer release (GP1528 and GP2028 options) increase coldwater fish habitat 10.0 percent over the CWCP. The GP2021 option provides 9.6 percent additional habitat than the CWCP, and the GP1521 option results in a 9.3 percent increase in habitat. The MCP reduces coldwater fish habitat in the mainstem lakes by 1.8 percent.

The MCP and the four GP options increase coldwater fish habitat over the CWCP in Standing Rock Reservation and Cheyenne River Reservation. The GP1521 option results in the greatest percentage increase over the CWCP (10.4 percent) and the GP2021 option provide the next highest increase (9.8 percent). The GP1528 and GP2028 options result in an 8.1 and 7.5 percent increase in habitat, respectively. The MCP increases coldwater fish habitat over the CWCP by 6.1 percent.

Coldwater Fish Habitat in the River

Table 7.7-12 presents the miles of average annual coldwater habitat for Fort Peck Reservation during the full period from 1898 to 1997, for the alternatives discussed in the chapter. Fort Peck Reservation is located downstream of Fort Peck Dam.

Compared to the CWCP, the MCP and the four GP options all increase total coldwater fish habitat within Fort Peck Reservation. The greatest percentage increase in habitat over the CWCP occurs under the GP2028 option (8.6 percent). The two options that have a split summer low flow, GP1521 and GP2021, increase habitat over the CWCP by 8.2 percent. The GP1528 option increases coldwater fish habitat in Fort Peck Reservation by 7.9 percent, and the least amount of habitat increase over the CWCP occurs under the MCP (1.4 percent).

Warmwater Fish Habitat in the River

Table 7.7-13 presents the miles of average annual warmwater habitat for Tribal Reservations along two river reaches during the full period from 1898 to 1997, for all of the alternatives discussed in this chapter. The Reservations analyzed include Fort Peck Reservation, located downstream of Fort Peck Dam, and Yankton Reservation and Ponca Tribal Lands, located downstream of Fort Randall Dam.

Under the CWCP, total warmwater fish habitat associated with these Reservations is 46.8 miles. Compared to the CWCP, the MCP and the four GP options decrease warmwater fish habitat. The MCP and the GP1528 option reduce total habitat by 8.5 and 17.0 percent, respectively; however, the greatest decreases in total habitat occur under the GP2021, GP2028, and GP1521 options where there would be an 18.2, 18.3, and 18.4 percent reduction in habitat, respectively.

Compared to the CWCP, the MCP reduces the least amount of habitat within Fort Peck Reservation (8.5 percent). The GP1528 and GP2021 options reduce habitat within this Reservation by 17.4 and 16.8 percent, while the GP1521 and GP2028 options reduce warmwater fish habitat by 17.0 and 19.0 percent, respectively.

Results are similar for Yankton Reservation and Ponca Tribal Lands, where the MCP reduces the amount of habitat the least (8.6 percent). The GP1528 and GP2028 options reduce habitat by 16.1 and 16.7 percent, respectively, while the GP2021 and GP1521 options both decrease warmwater fish habitat within this Reservation by 21.5 percent.

Physical Habitat for Native Fish

Table 7.7-14 presents the index of average annual physical habitat values for seven Tribal Reservations during the full period from 1898 to 1997, for the alternatives discussed in this chapter. The Reservations analyzed include Fort Peck Reservation, downstream of Fort Peck Dam; Yankton Reservation and Ponca Tribal Lands, which are downstream of Fort Randall Dam; and Winnebago Reservation, Omaha Reservation, Iowa Reservation, and Sac and Fox Reservation, all of which are downstream of Gavins Point Dam.

The index value (correlation coefficient) was computed for nine of the months based on how closely the velocity and/or depth distributions for given tribal lands match the "natural" flow conditions based on pre-Mainstem Reservoir System channel conditions. In April, May and June, the habitat value is dependent on the potential for overbank flooding. The index value for each month can range from 0 to 1.0, with a value of 1.0 assigned to a perfect match. The values for each of the 12 months are summed to compute an annual index value that can be as high as 12.0 for the tribal lands specified. A total annual value is computed by combining the values for the tribal lands and can range up to 48.0.

The total index value for average annual physical habitat associated with these Reservations is 35.74 under the CWCP. The MCP and the four GP options result in an increase in total physical habitat index values over the CWCP: the MCP by 0.2 percent, the GP1528 option by 1.2 percent, the GP2021 option by 0.6 percent, the GP1521 option by 0.3 percent, and the GP2028 option by 1.4 percent.

Within Fort Peck Reservation, the MCP and the four GP options all increase the physical habitat index values for native river fish. The greatest index value increases occur under the GP2028 option (2.0 percent) and the GP1528 option (1.9 percent). Both the GP1521 and GP2021 options result in a 1.8 percent increase, while the MCP only provides a 0.6 percent index value increase.

Within Yankton Reservation and Ponca Tribal Lands, both the GP1528 and GP2028 options result in a 0.1 percent increase in physical habitat index values for native river fish. Index value decreases occur under the MCP (0.7 percent) and the two remaining GP options, the GP2021 option (1.3 percent) and the GP2021 option (1.4 percent).

Within Winnebago Reservation and Omaha Reservation, the two GP options with a split summer low flow both reduce the index value for native river fish physical habitat while the remaining two GP options and the MCP provide an index value increase over the CWCP. The GP2028 and GP1528 options and the MCP all increase the physical habitat for native river fish by 0.5, 0.2, and 0.1 percent, respectively. The GP2021 and GP1521 options reduce this index value by 1.1 and 1.5 percent, respectively.

The MCP and four GP options would result in a physical habitat index value increase for native river fish within Iowa Reservation and Sac and Fox Reservation. The greatest percentage increases over the CWCP would occur under the GP2028 and GP2021 options, 3.4 and 3.3 percent, respectively. Both the GP1528 and GP1521 options result in a 2.8 percent increase and the MCP provides only a 0.9 percent increase in the index value for physical habitat for native river fish over the CWCP.

Table 7.7-10. Average annual young fish production in the mainstem lakes for seven Tribal Reservations (relative index).

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Berthold	0.46	0.46	0.53	0.53	0.52	0.53
Standing Rock and Cheyenne River	0.40	0.41	0.41	0.40	0.39	0.41
Lower Brule and Crow Creek	0.43	0.42	0.48	0.48	0.48	0.47
Yankton	0.20	0.20	0.25	0.27	0.26	0.25
Santee	0.16	0.18	0.19	0.20	0.20	0.19
Total	**1.65**	**1.67**	**1.86**	**1.88**	**1.85**	**1.85**

Table 7.7-11. Average annual coldwater fish habitat impact for three Tribal Reservations along the mainstem lakes (MAF).

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Berthold	2.81	2.76	3.09	3.08	3.07	3.09
Standing Rock and Cheyenne River	3.47	3.68	3.75	3.81	3.83	3.73
Total	**6.28**	**6.44**	**6.84**	**6.89**	**6.90**	**6.82**

Table 7.7-12. Average annual coldwater fish habitat for the Fort Peck Reservation (miles).

Reservation	1898 to 1997					
	CWCP	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	140.2	142.2	151.3	151.8	151.7	152.3

Table 7.7-13. Average annual warmwater fish habitat for Reservations in the reaches downstream from Fort Peck and Fort Randall Dams (miles).

Reservation	1898 to 1997					
	CWCP	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	32.8	30.0	27.1	27.3	27.2	26.6
Yankton and Ponca Tribal Lands	13.9	12.7	11.7	10.9	10.9	11.6
Total	**46.8**	**42.8**	**38.8**	**38.3**	**38.2**	**38.2**

Table 7.7-14. Average annual physical habitat values for native river fish impact on Reservations (index).

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	9.03	9.08	9.20	9.19	9.19	9.21
Yankton and Ponca Tribal Lands	8.56	8.50	8.57	8.45	8.44	8.57
Winnebago and Omaha	10.22	10.23	10.24	10.11	10.07	10.27
Iowa and Sac and Fox	7.93	8.00	8.15	8.19	8.15	8.20
Total	**35.74**	**35.81**	**36.16**	**35.94**	**35.85**	**36.25**

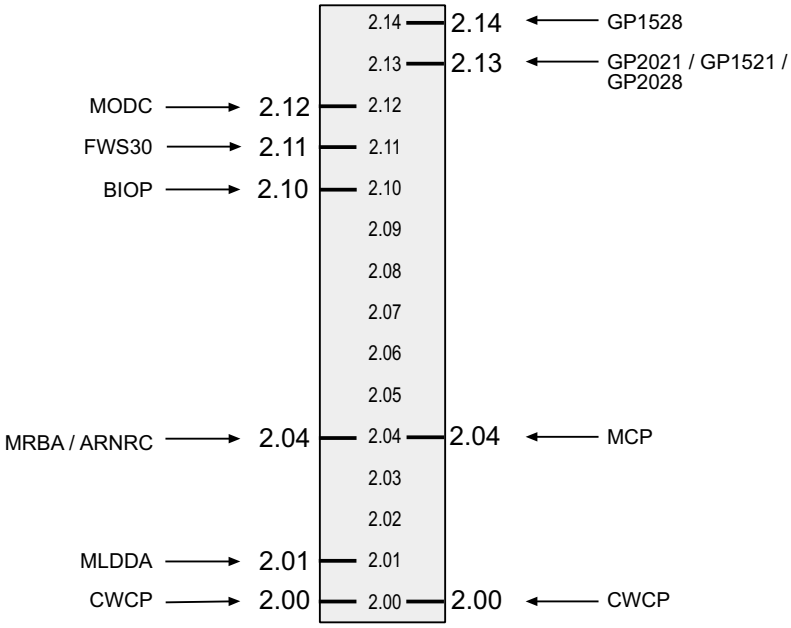

Figure 7.7-1. Average annual young fish production index values for submitted alternatives and the alternatives.

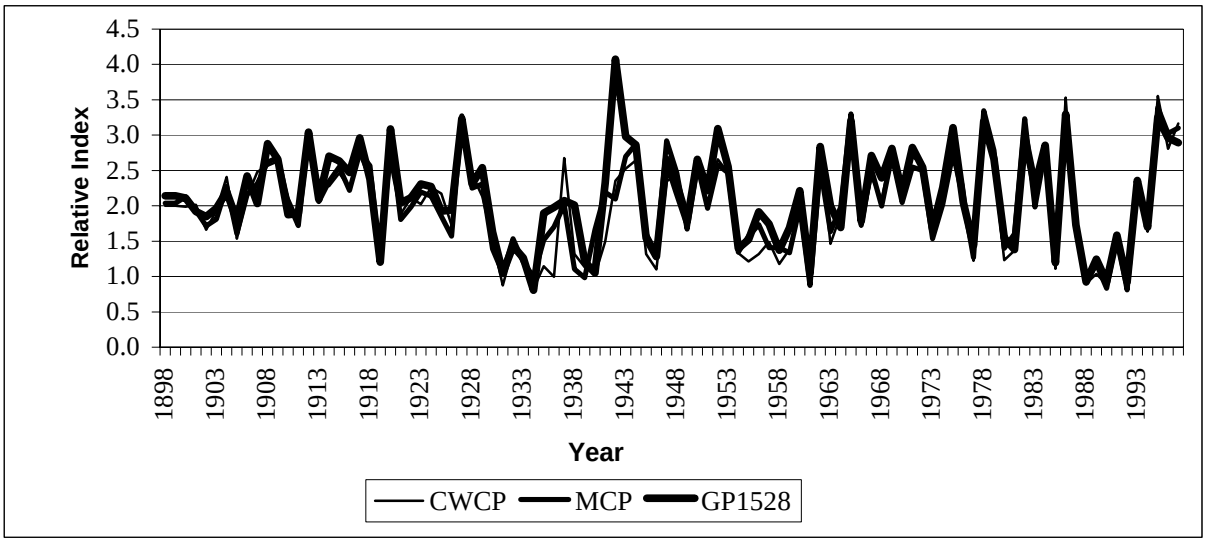

Figure 7.7-2. Average annual values for young fish production in the mainstem lakes for CWCP, MCP, and GP1528.

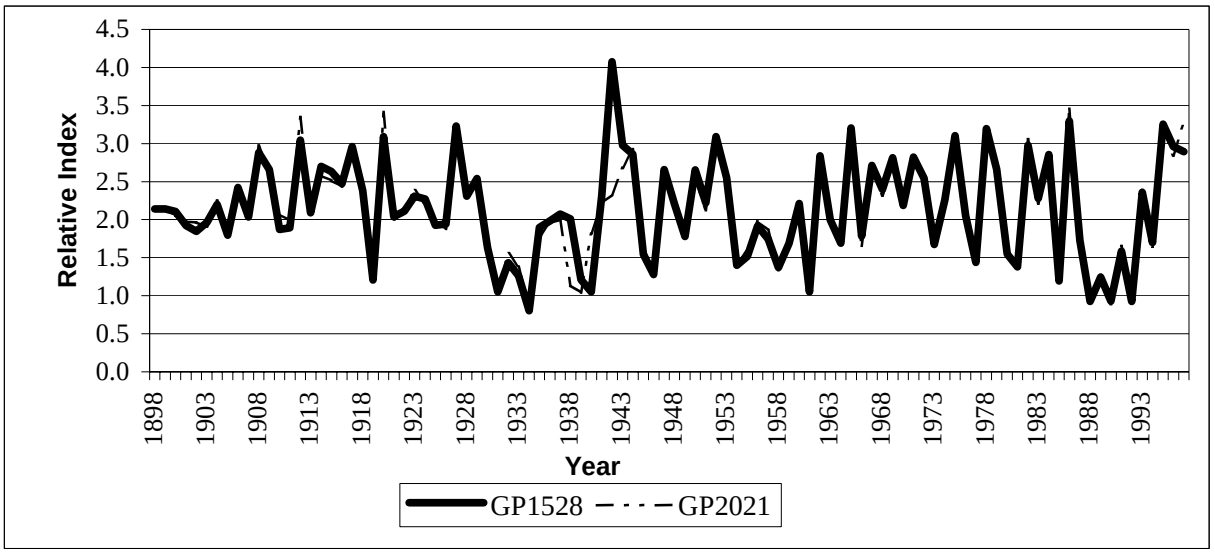

Figure 7.7-3. Average annual values for young fish production in the mainstem lakes for GP1528 and GP2021.

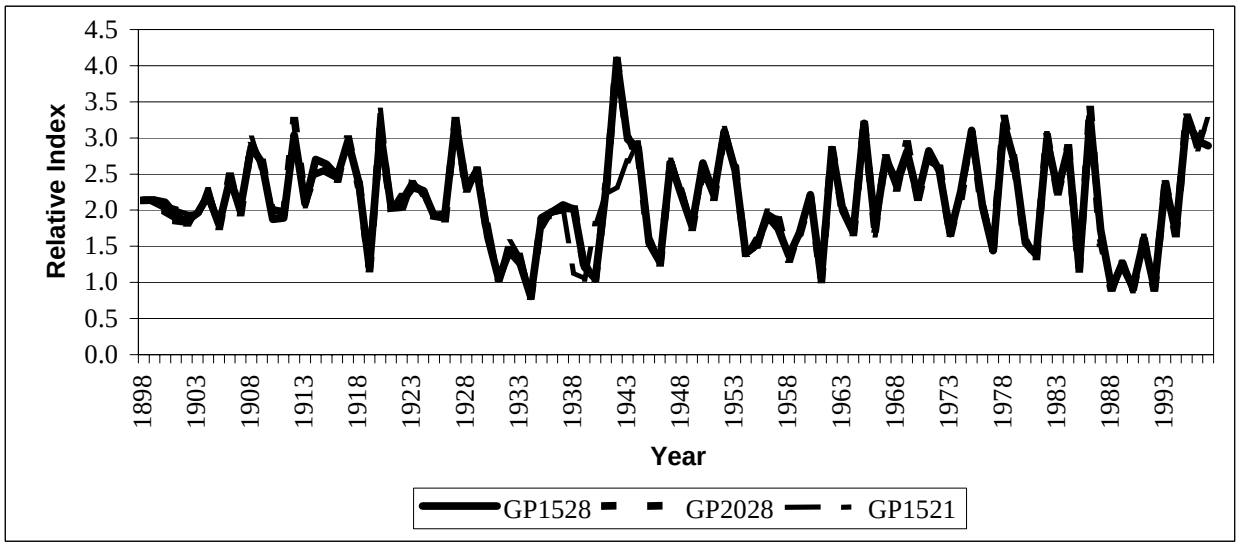

Figure 7.7-4. Average annual values for young fish production in the mainstem lakes for GP1528, GP2028, and GP1521.

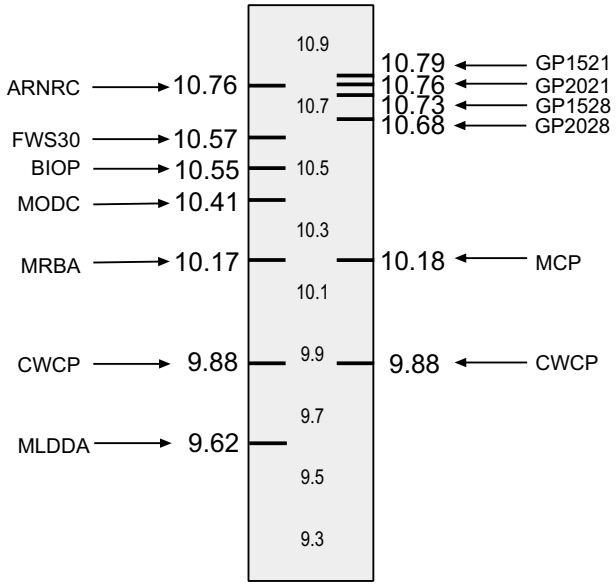

Figure 7.7-5. Average annual coldwater fish habitat in the mainstem lakes for submitted alternatives and the alternatives (MAF).

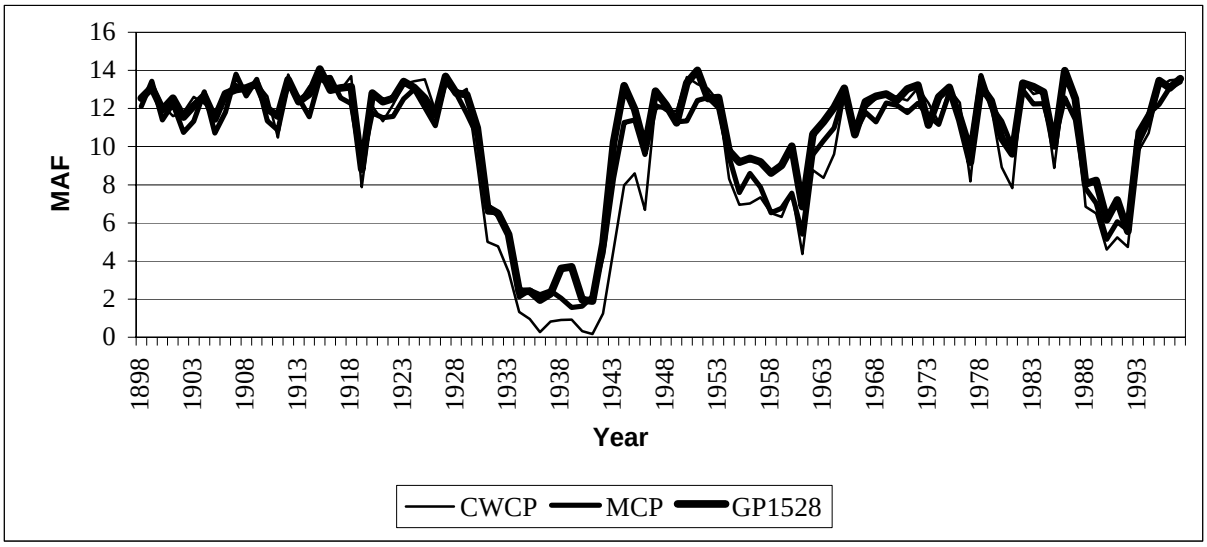

Figure 7.7-6. Average annual coldwater fish habitat in the mainstem lakes for CWCP, MCP, and GP1528.

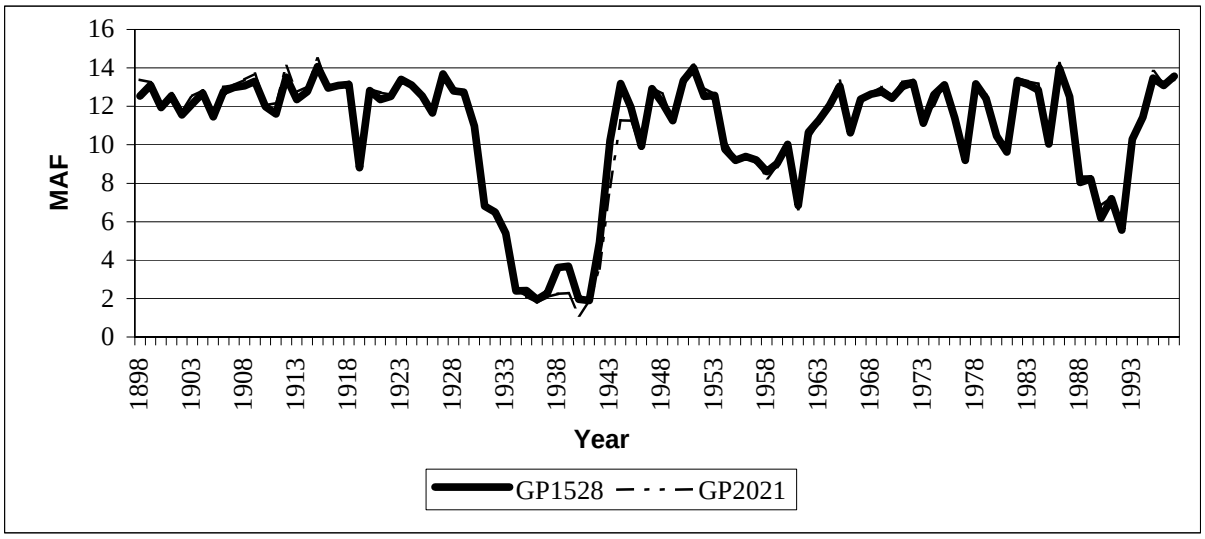

Figure 7.7-7. Average annual coldwater fish habitat in the mainstem lakes for GP1528 and GP2021.

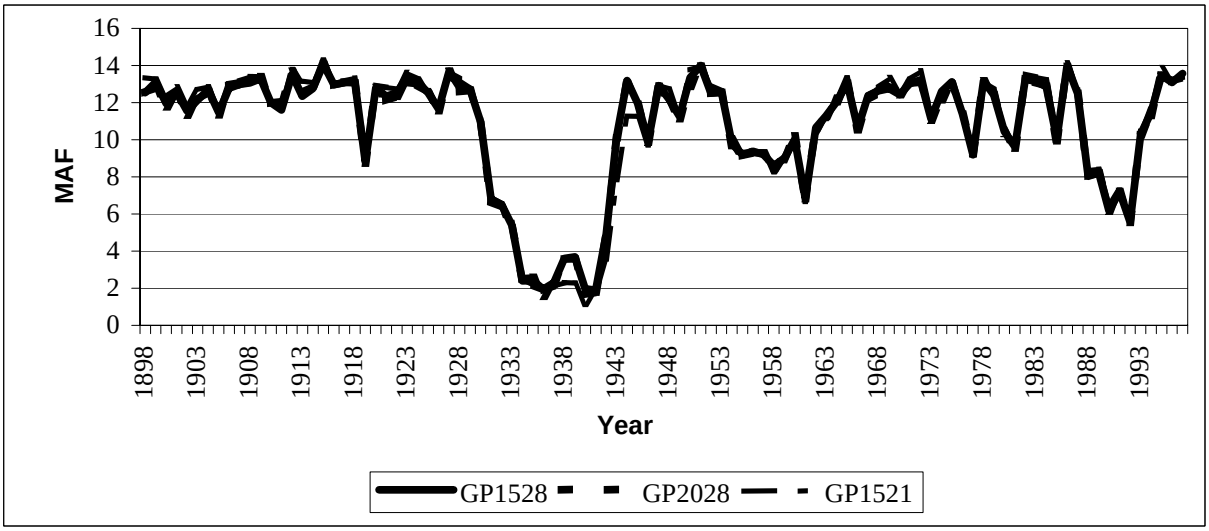

Figure 7.7-8. Average annual coldwater fish habitat in the mainstem lakes for GP1528, GP2028, and GP1521.

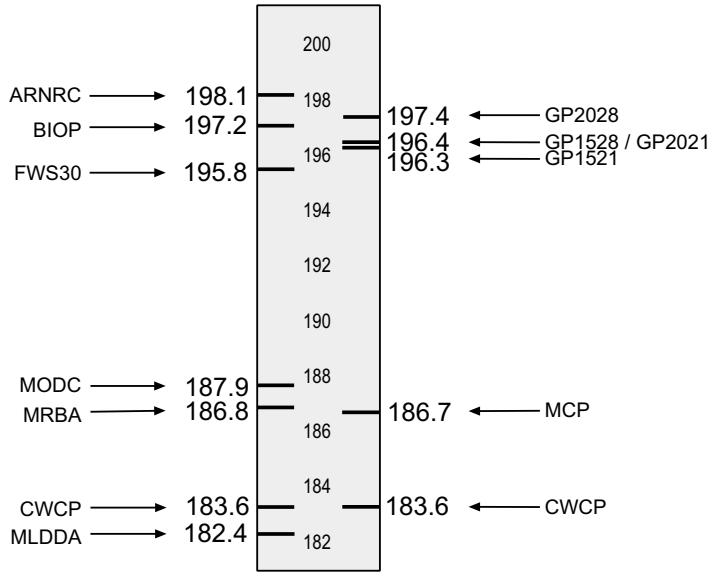

Figure 7.7-9. Average annual coldwater fish habitat in the river reaches for submitted alternatives and the alternatives (miles).

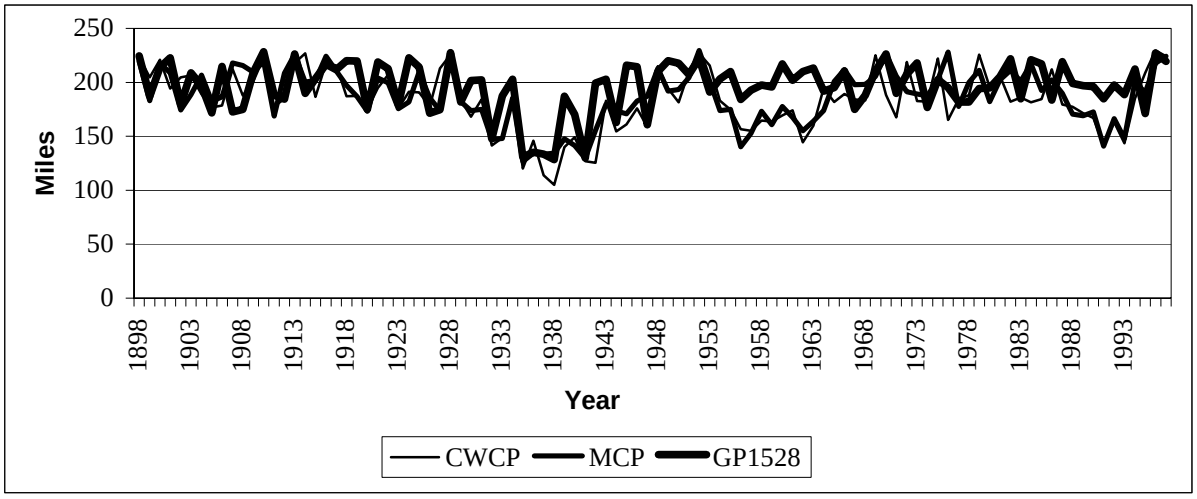

Figure 7.7-10. Average annual coldwater fish habitat in the river reaches for CWCP, MCP, and GP1528.

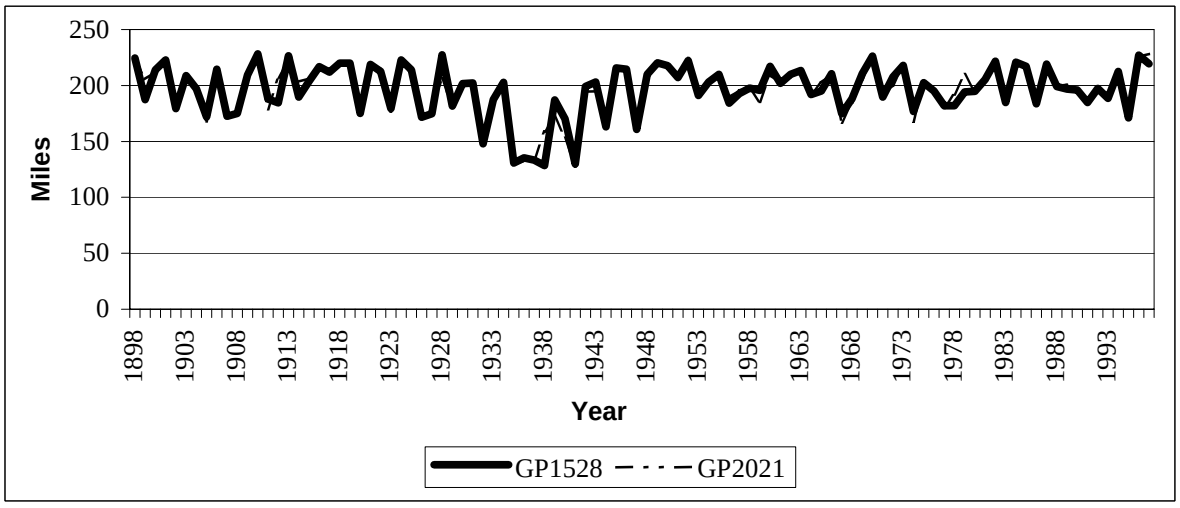

Figure 7.7-11. Average annual coldwater fish habitat in the river reaches for GP1528 and GP2021.

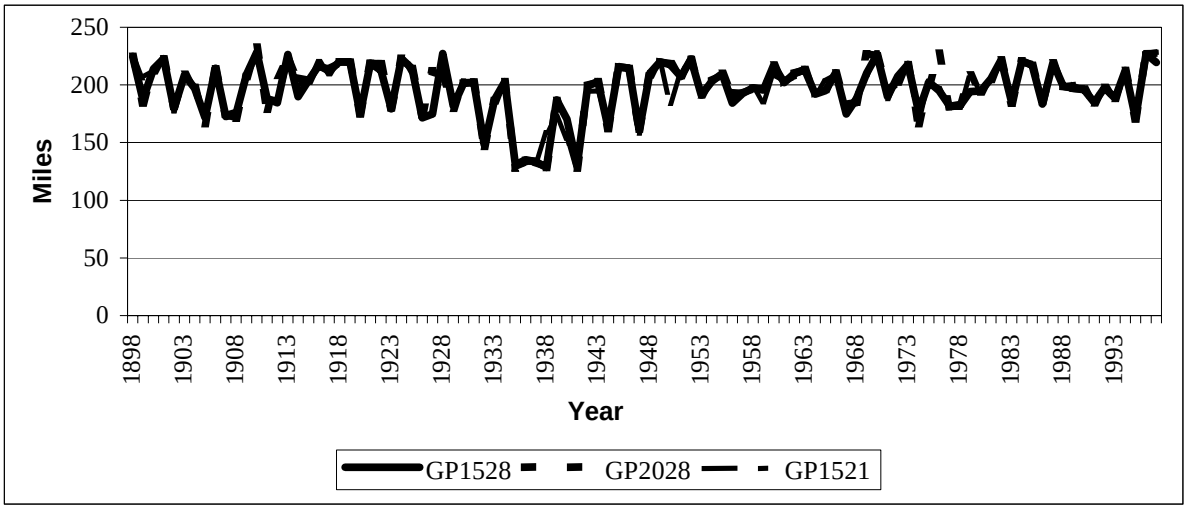

Figure 7.7-12. Average annual coldwater fish habitat in the river reaches for GP1528, GP2028, and GP1521.

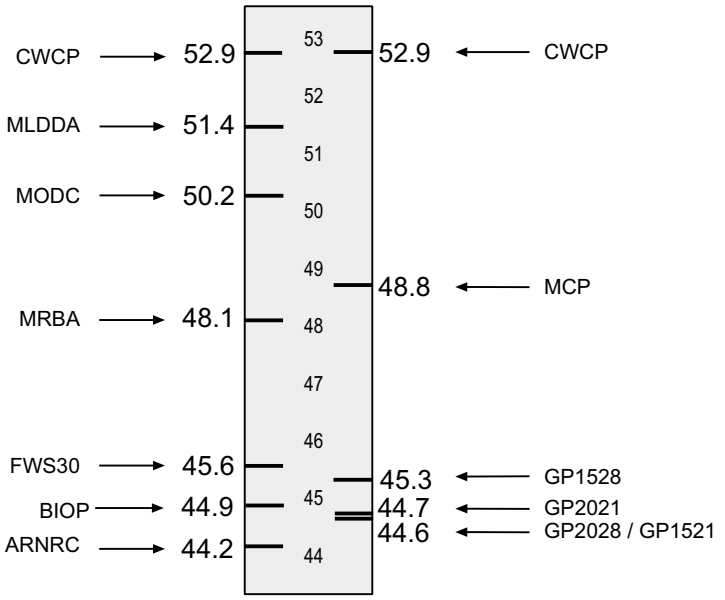

Figure 7.7-13. Average annual warmwater fish habitat in the river reaches for submitted alternatives and the alternatives (miles).

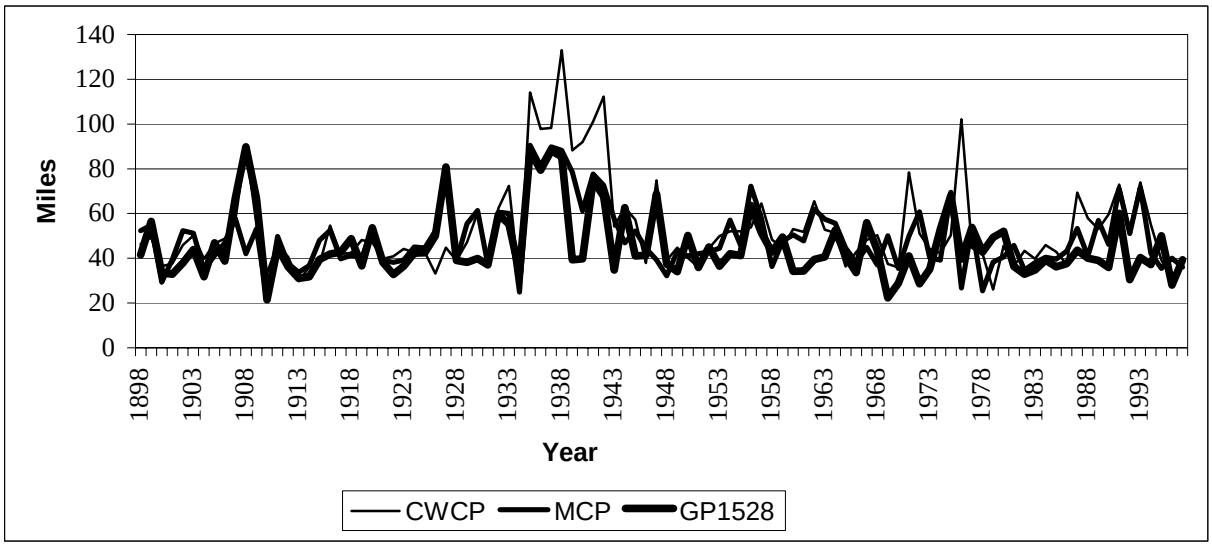

Figure 7.7-14. Average annual warmwater fish habitat in the river reaches for CWCP, MCP, and GP1528.

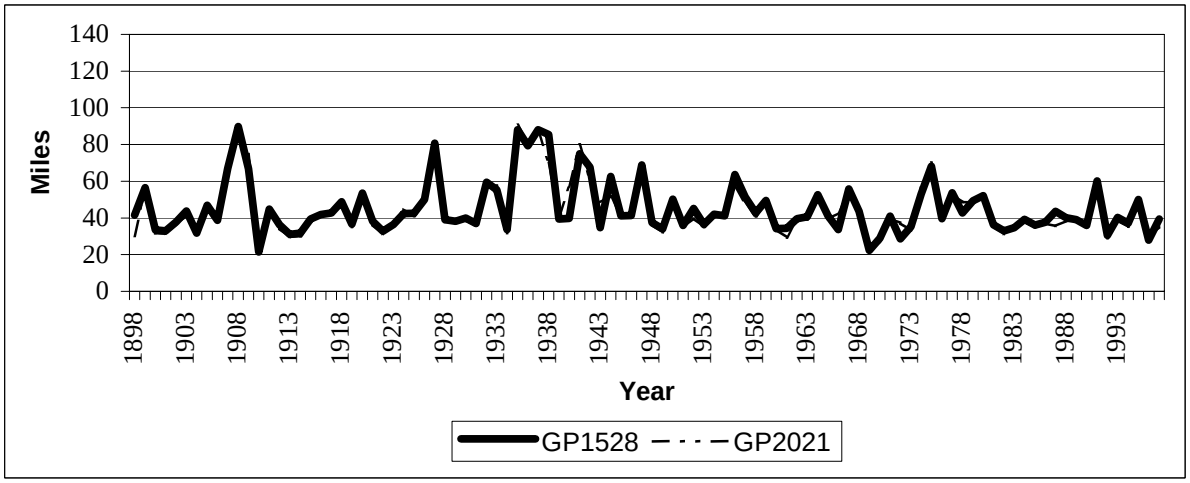

Figure 7.7-15. Average annual warmwater fish habitat in the river reaches for GP1528 and GP2021.

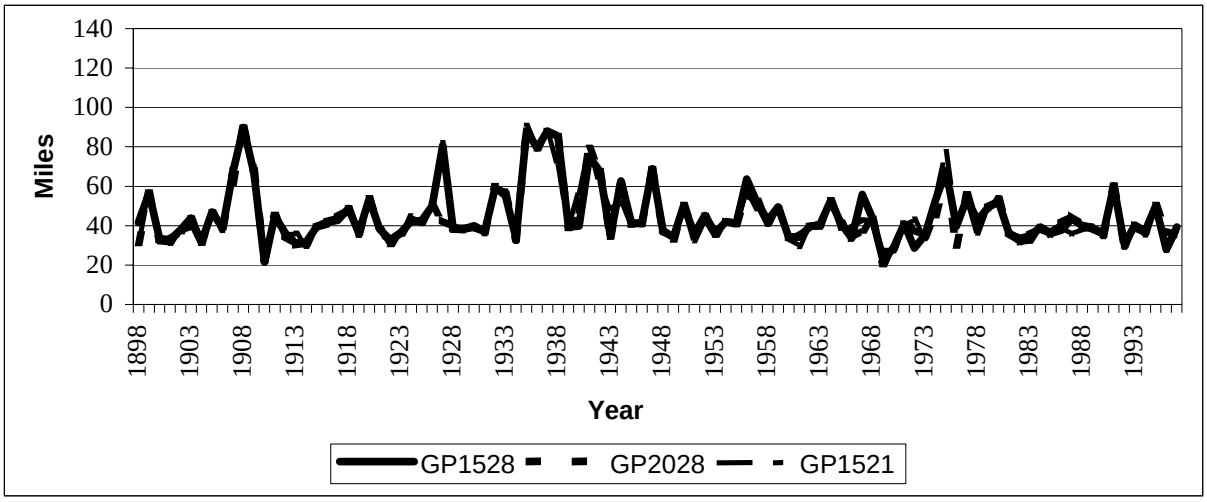

Figure 7.7-16. Average annual warmwater fish habitat in the river reaches for GP1528, GP2028, and GP1521.

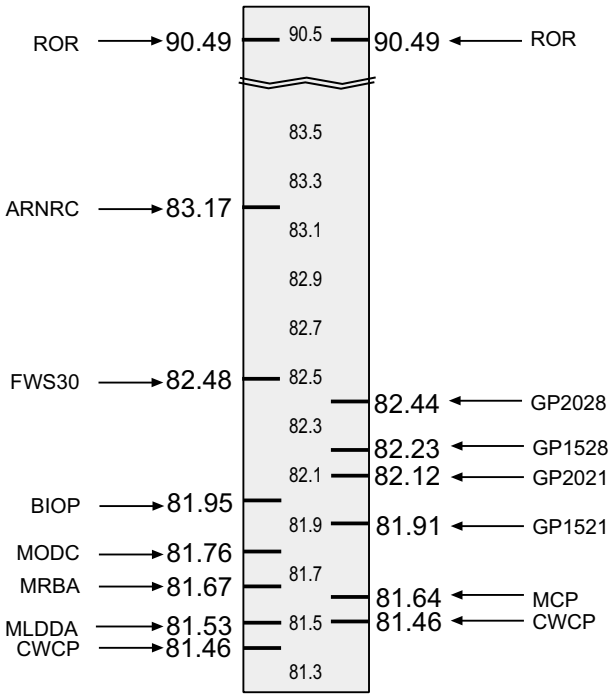

Figure 7.7-17. Average annual native river fish physical habitat index values for submitted alternatives and the alternatives.

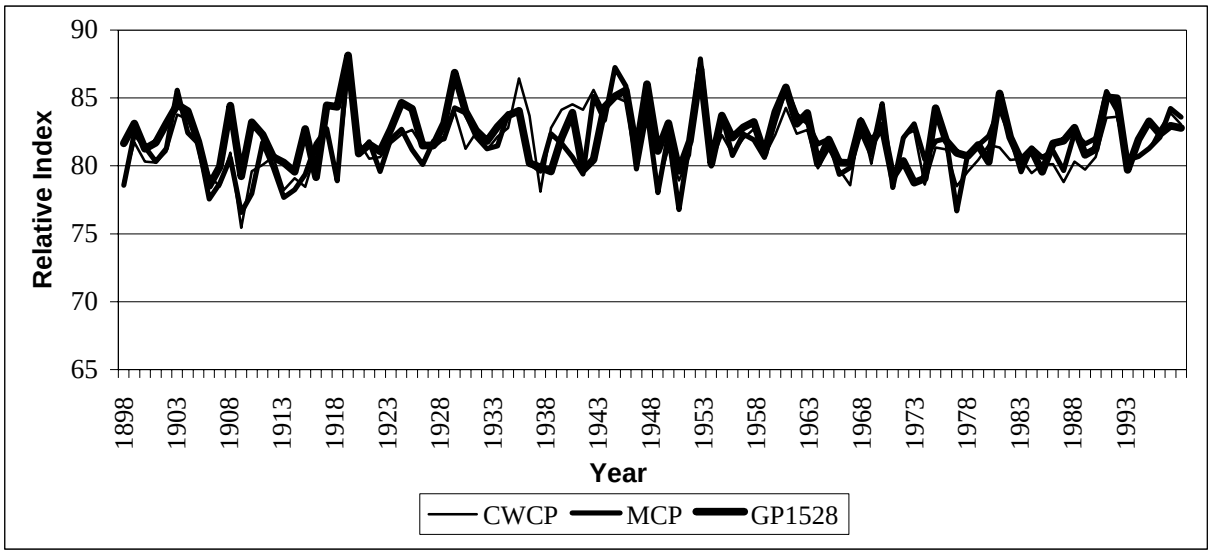

Figure 7.7-18. Average annual values for native river fish physical habitat for CWCP, MCP, and GP1528.

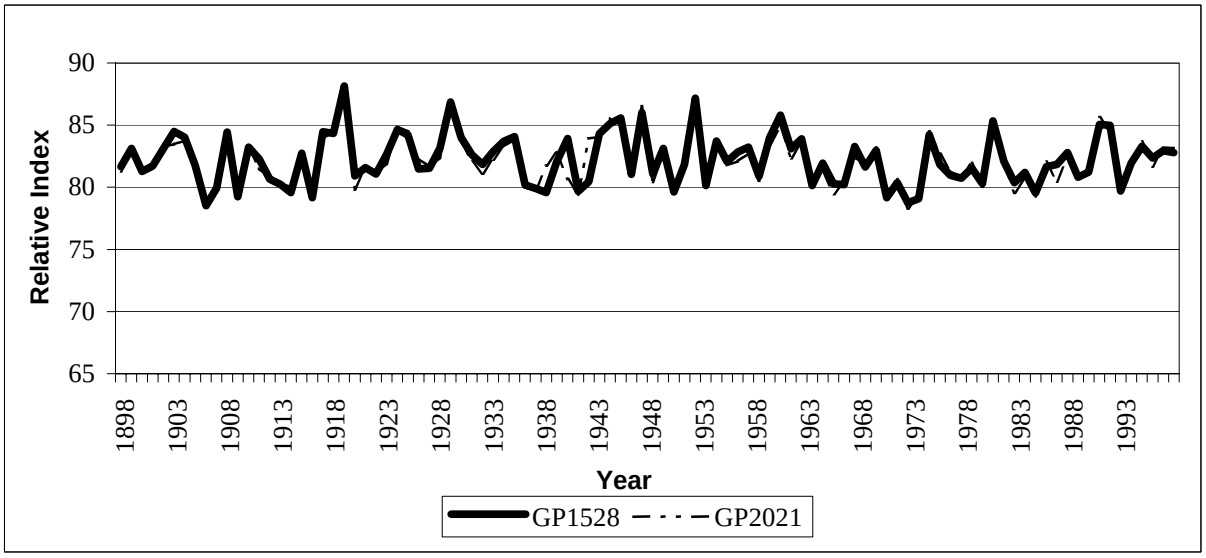

Figure 7.7-19. Average annual values for native river fish physical habitat for GP1528 and GP2021.

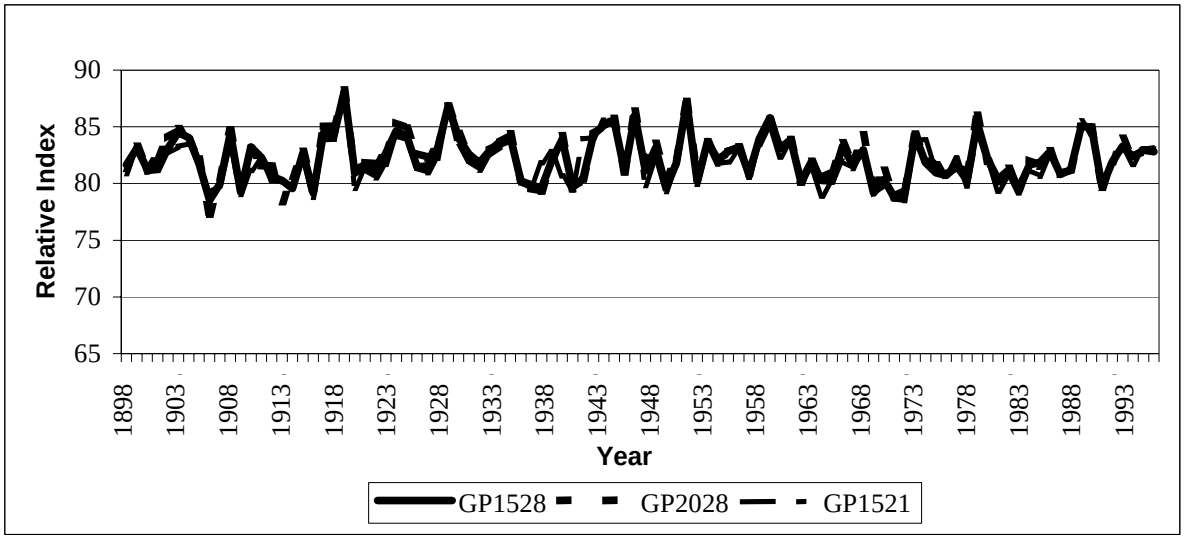

Figure 7.7-20. Annual values for native river fish physical habitat for GP1528, GP2028, and GP1521.

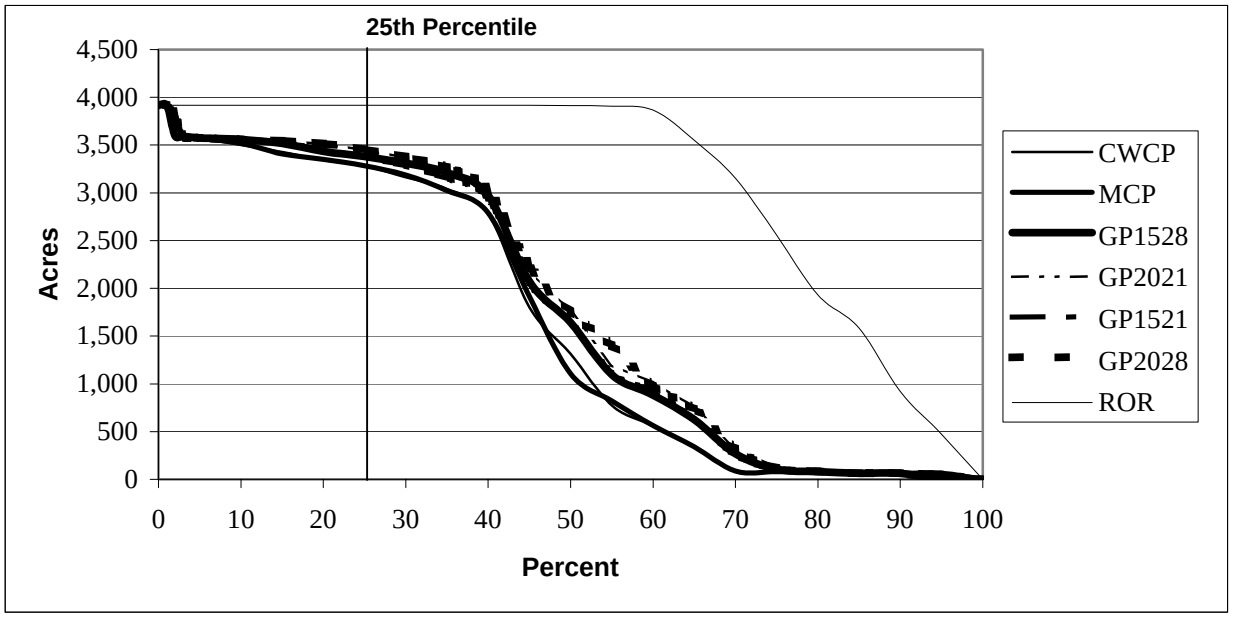

Figure 7.7-21. Acres of connectivity for 2 days during May and June.

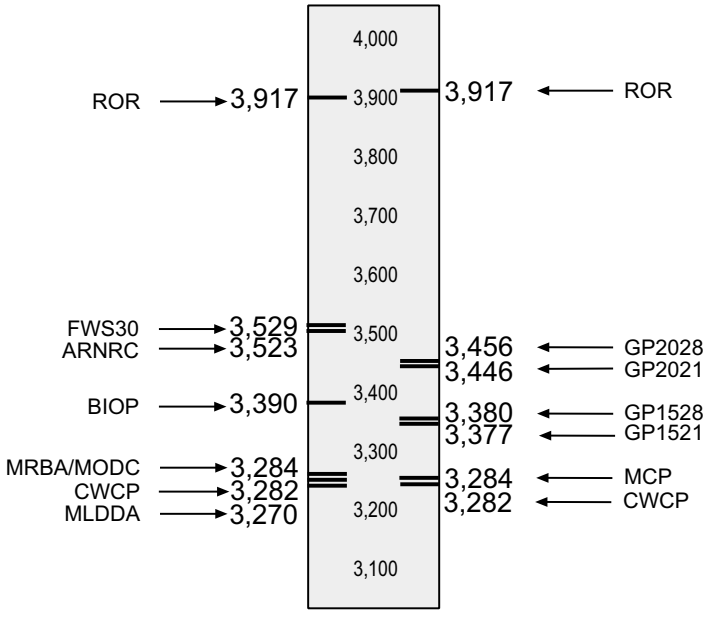

Figure 7.7-22. Acres of connectivity for 2 days in May and June (25th percentile) for the submitted alternatives and the alternatives.

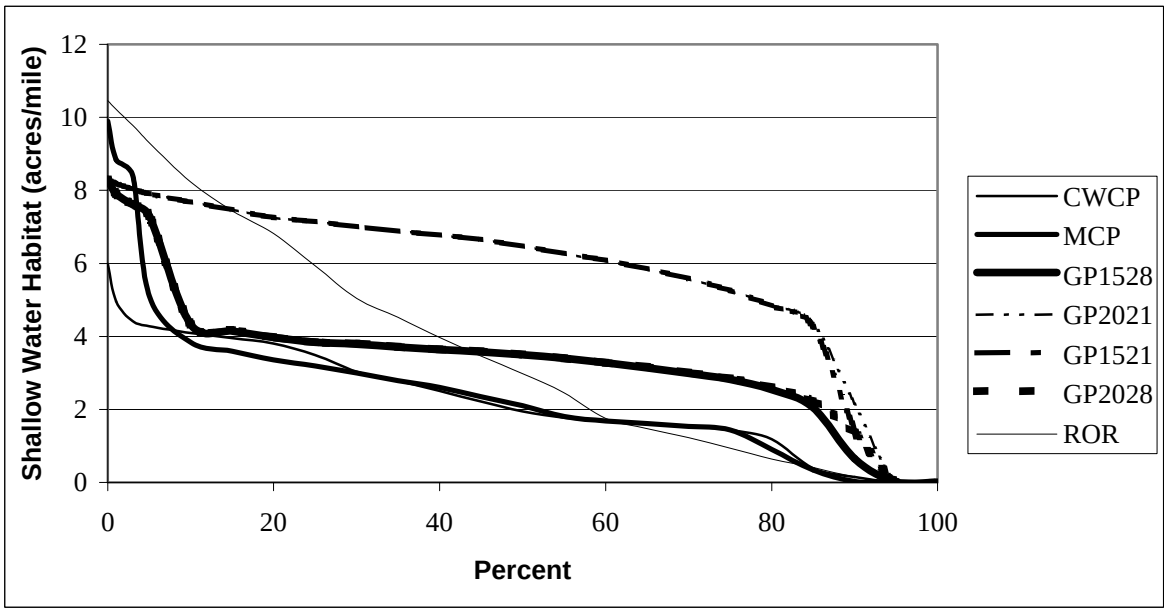

Figure 7.7-23. Duration plot of shallow water habitat (acres/mile) during the mid-July to mid-August period, Sioux City reach.

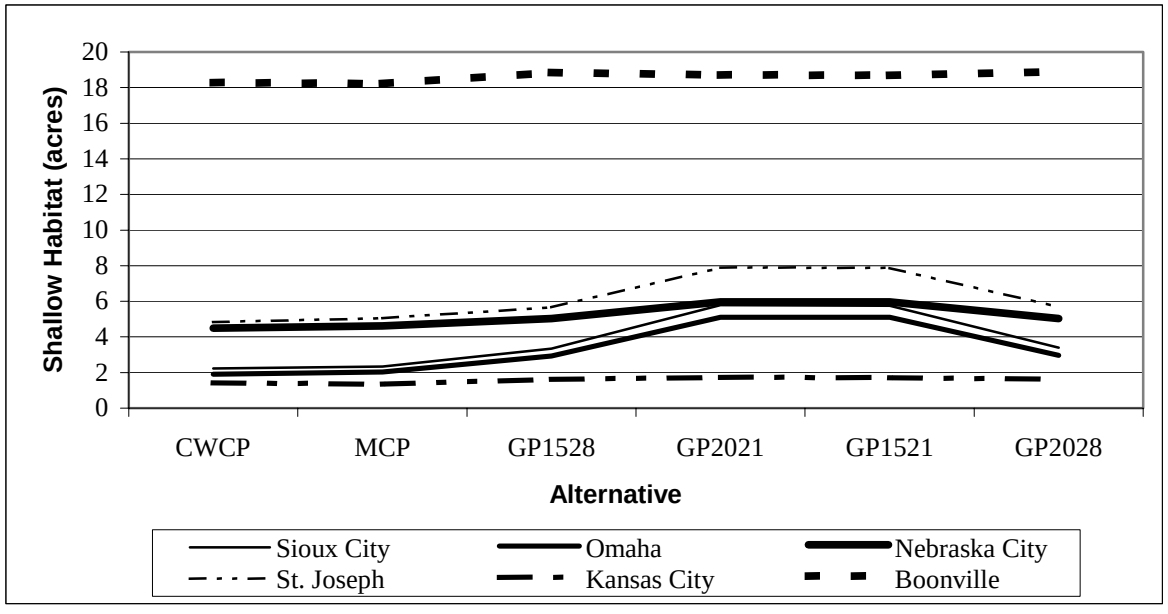

Figure 7.7-24. Expected daily shallow water habitat for river fish.

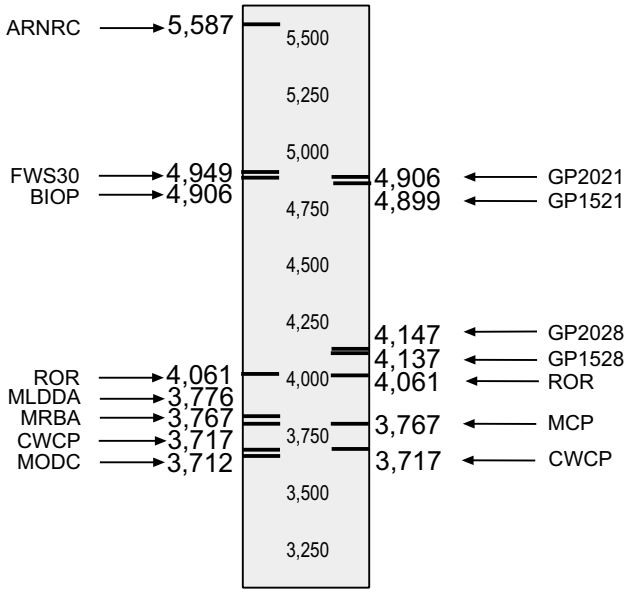

Figure 7.7-25. Shallow water habitat (acres), Sioux City to the Osage River for submitted alternatives and the alternatives.

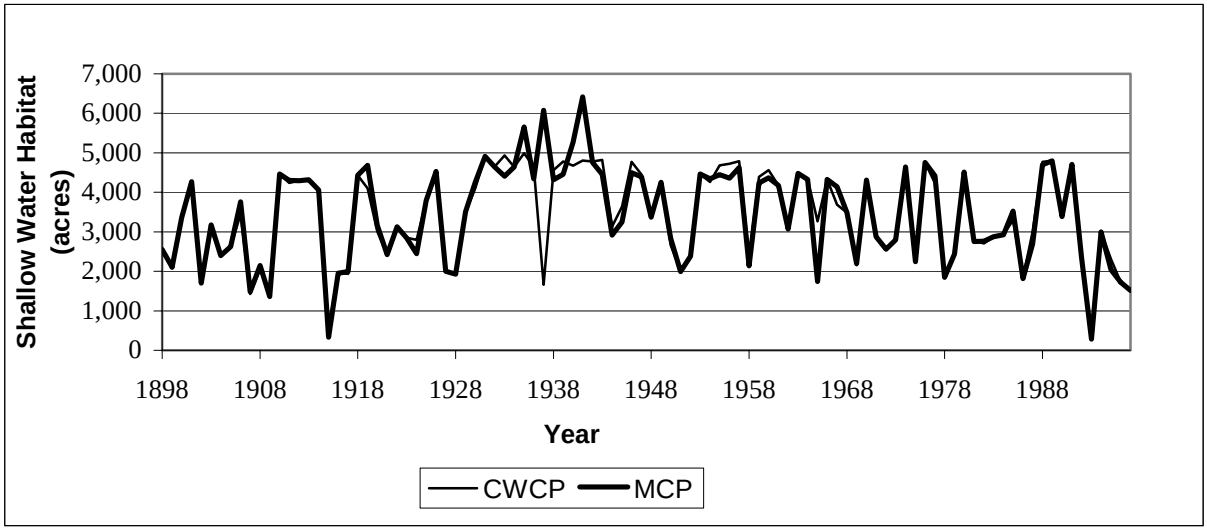

Figure 7.7-26. Annual average daily acres of shallow habitat from Sioux City to the Grand River from mid-July to mid-August for CWCP and MCP.

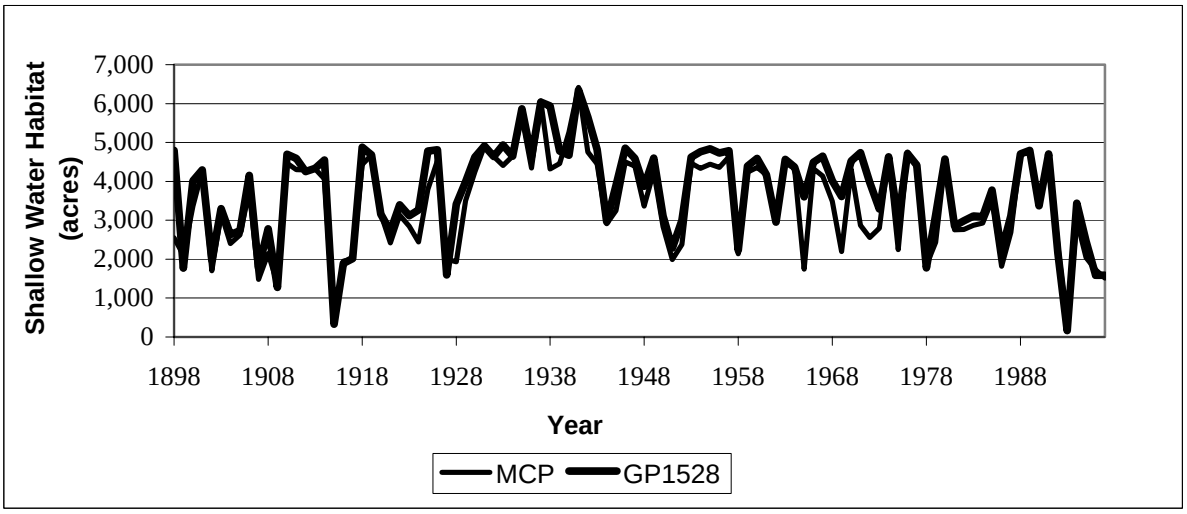

Figure 7.7-27. Annual average daily acres of shallow habitat from Sioux City to the Grand River from mid-July to mid-August for MCP and GP1528.

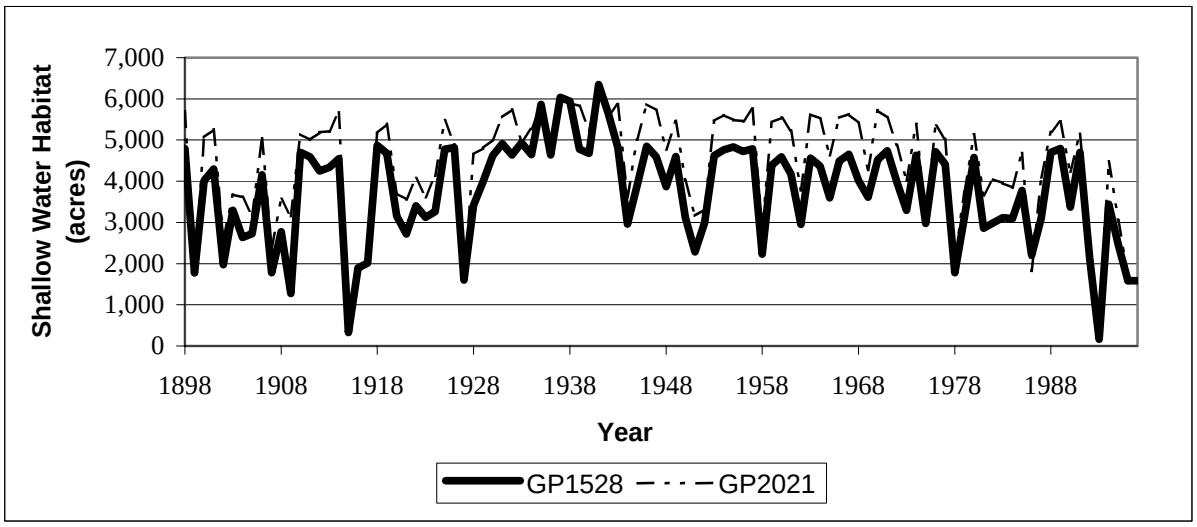

Figure 7.7-28. Annual average daily acres of shallow habitat from Sioux City to the Grand River from mid-July to mid-August for GP1528 and GP2021.

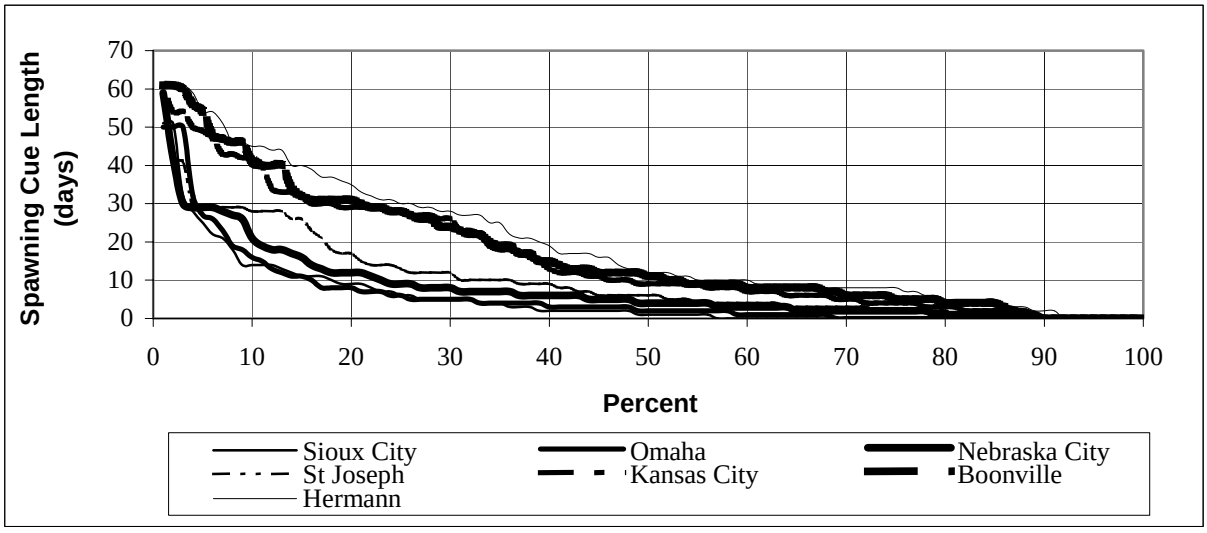

Figure 7.7-29. Duration plot of spawning cue length during May and June for CWCP.

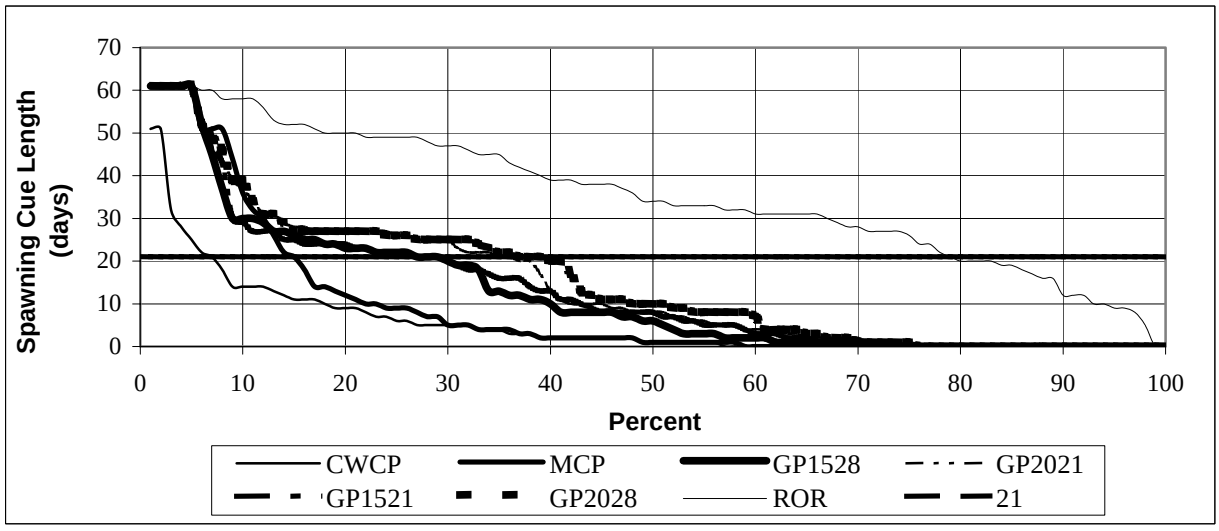

Figure 7.7-30. Duration plot of spawning cue length during May and June at Sioux City for CWCP, MCP, GP options, and ROR scenario.

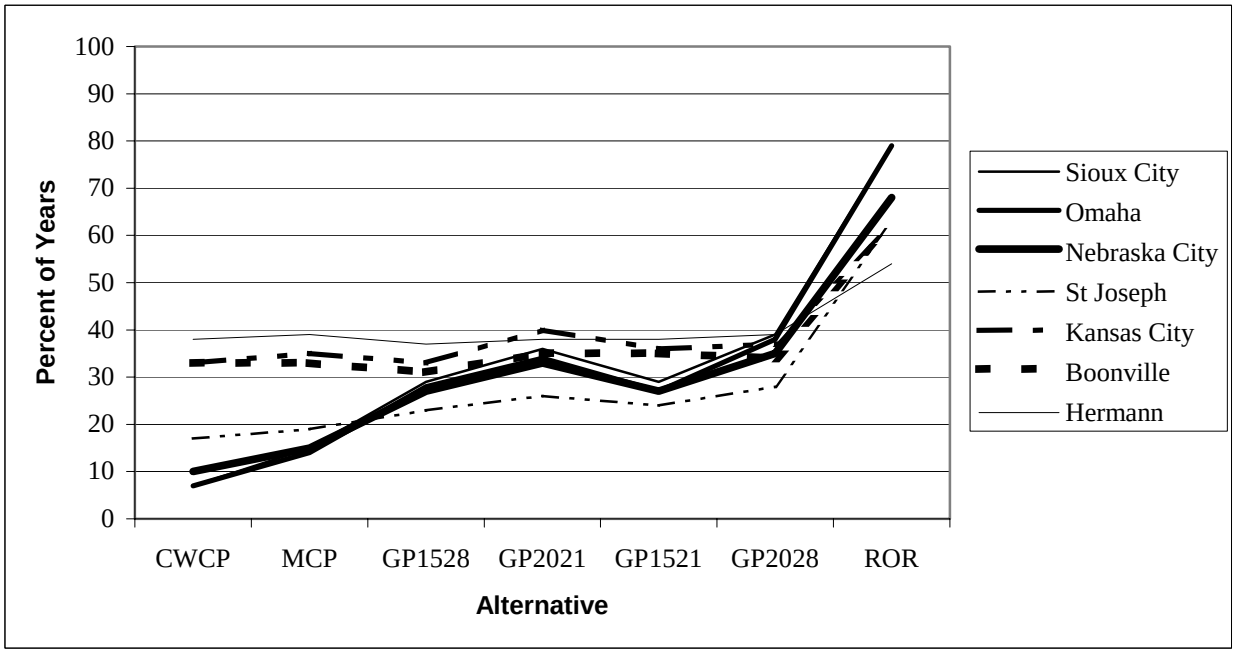

Figure 7.7-31. Percent of years with a 21-day spawning cue at Lower River gaging stations for CWCP, MCP, GP options, and ROR scenario.

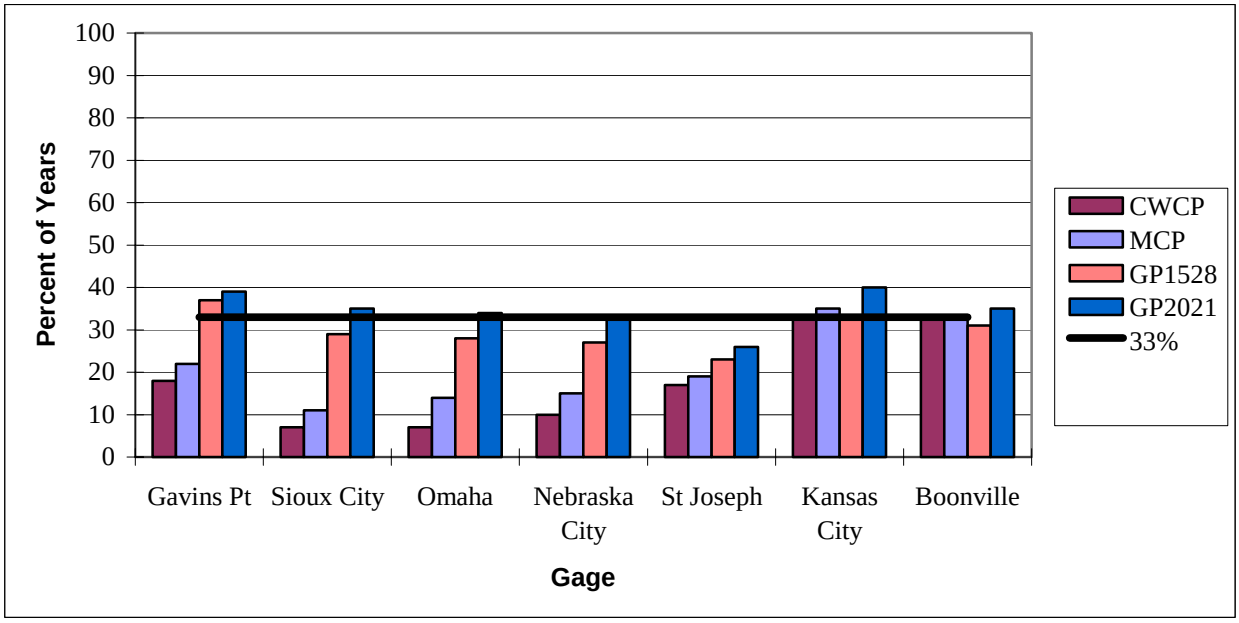

Figure 7.7-32. Percent of years that a 21-day spawning cue is provided.

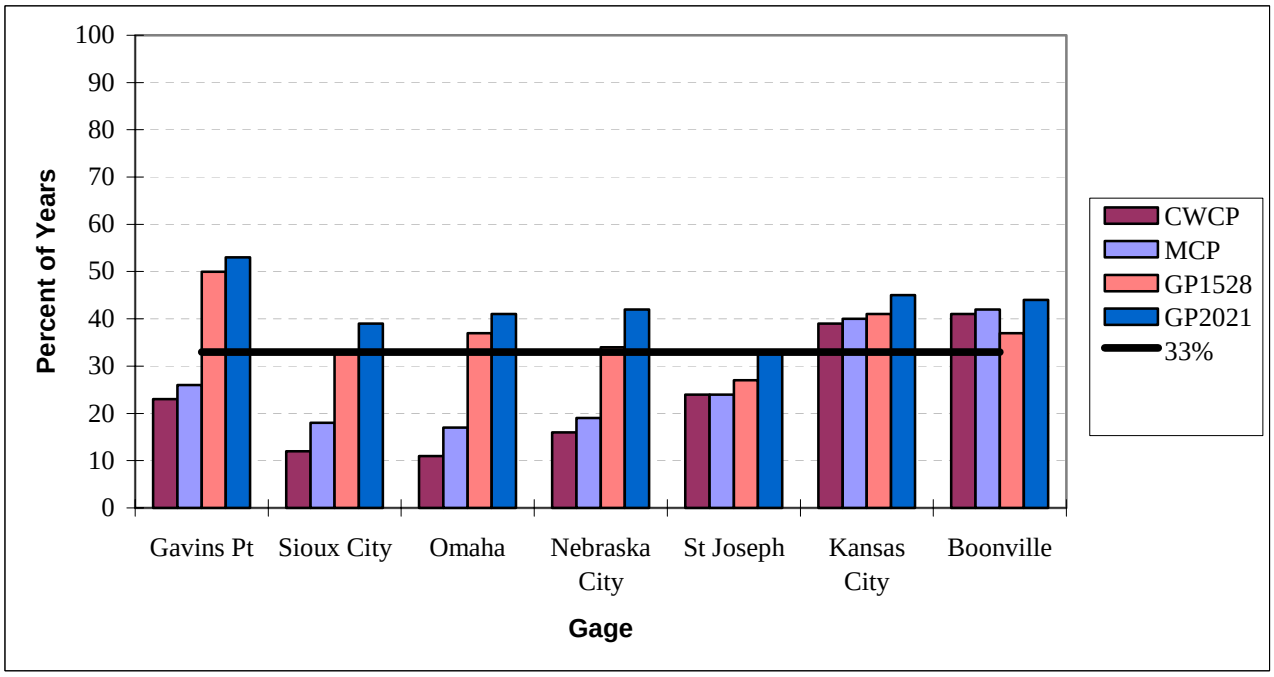

Figure 7.7-33. Percent of years that a 14-day spawning cue is provided.

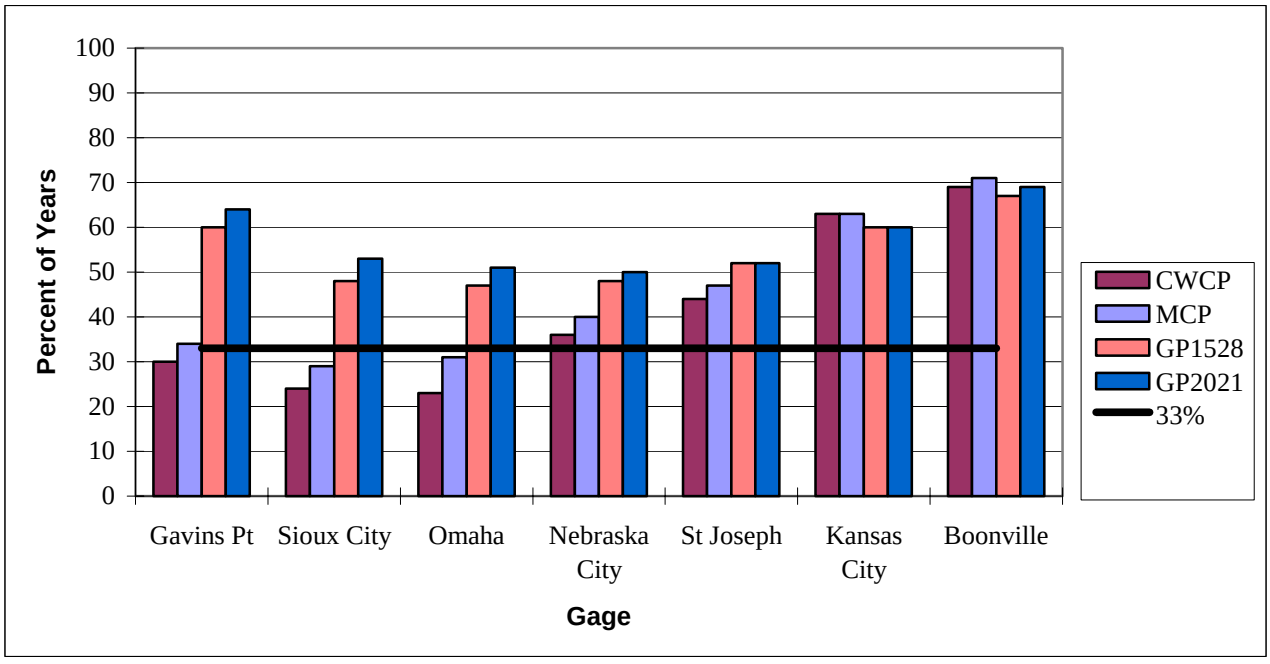

Figure 7.7-34. Percent of years that a 7-day spawning cue is provided.

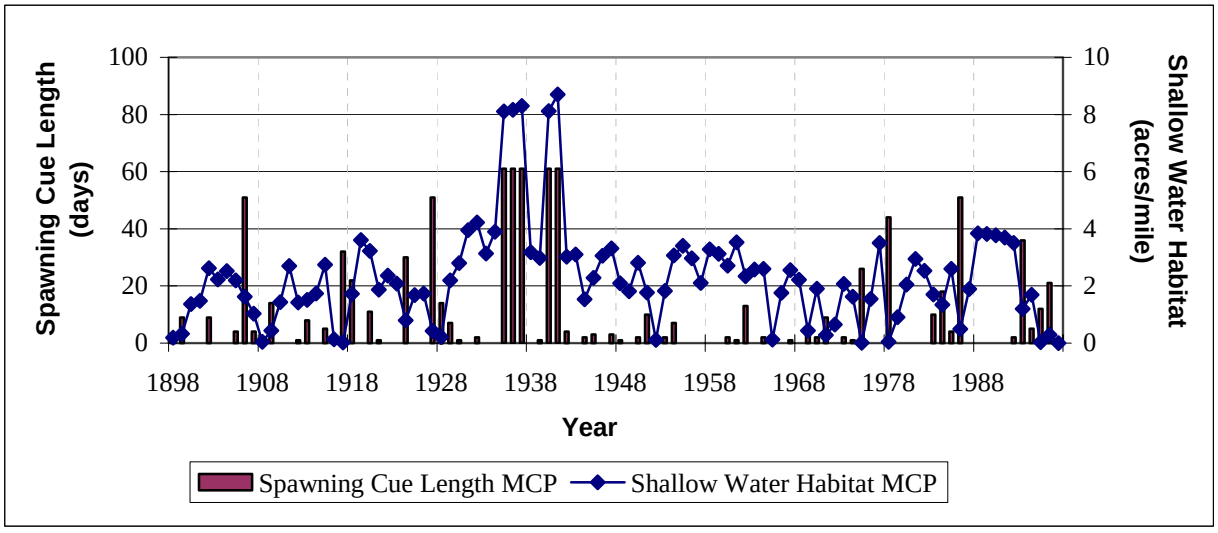

Figure 7.7-35. Annual values for spawning cue length and shallow water habitat at Sioux City for MCP.

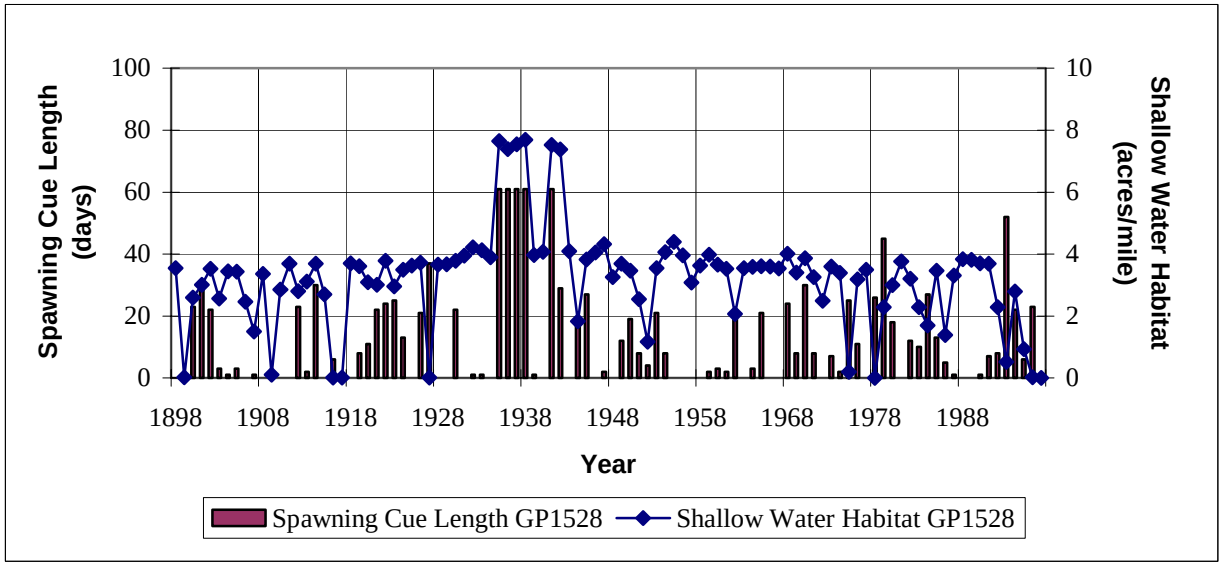

Figure 7.7-36. Annual values for spawning cue length and shallow water habitat at Sioux City for GP1528.

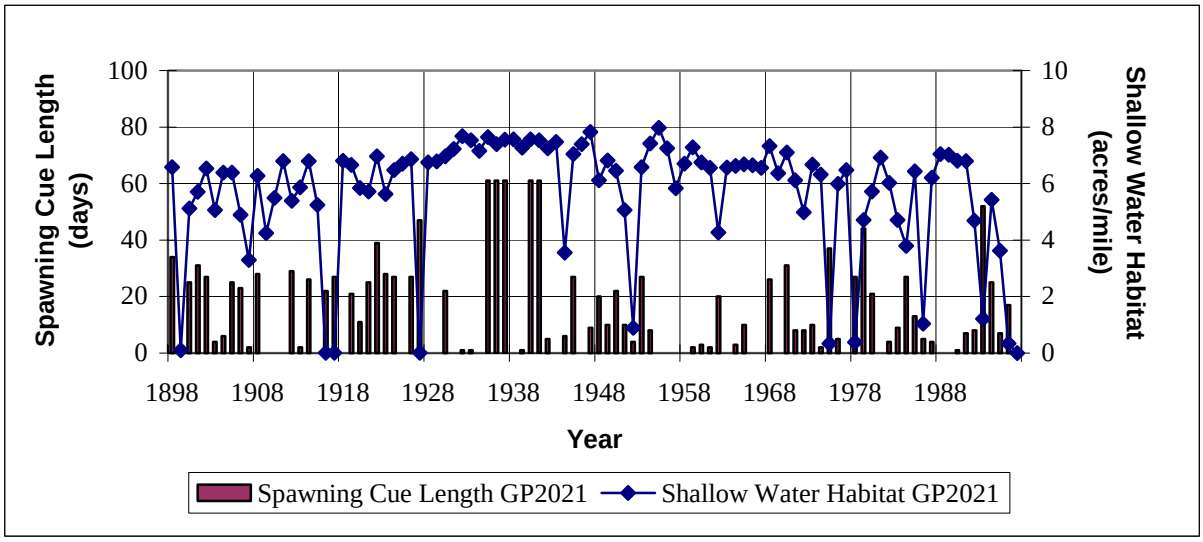

Figure 7.7-37. Annual values for spawning cue length and shallow water habitat at Sioux City for GP2021.

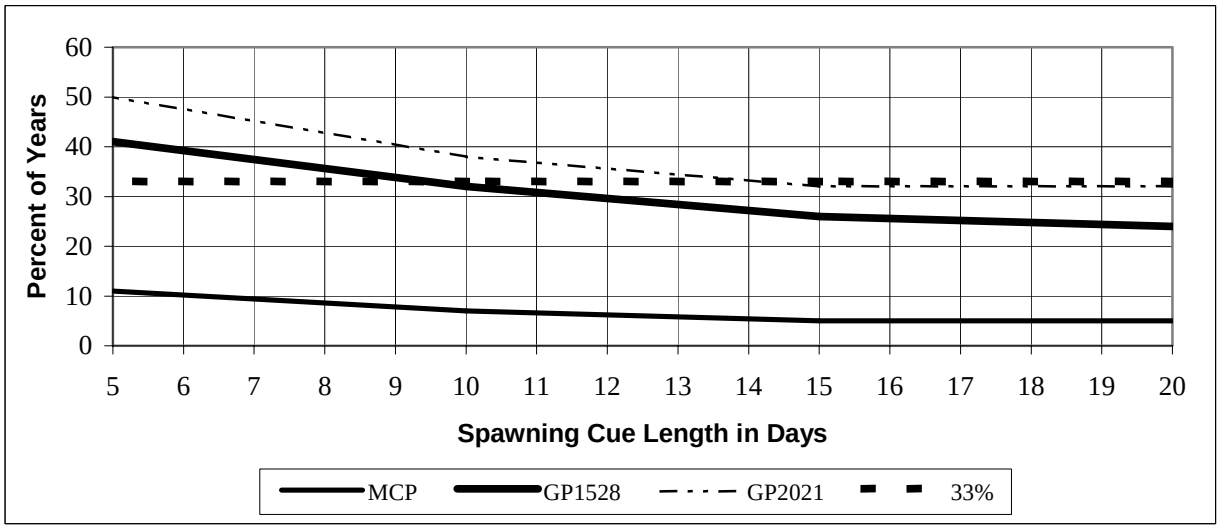

Figure 7.7-38. Percent of years when spawning cue length and shallow water habitat (2 acres/mile) coincide at Sioux City.

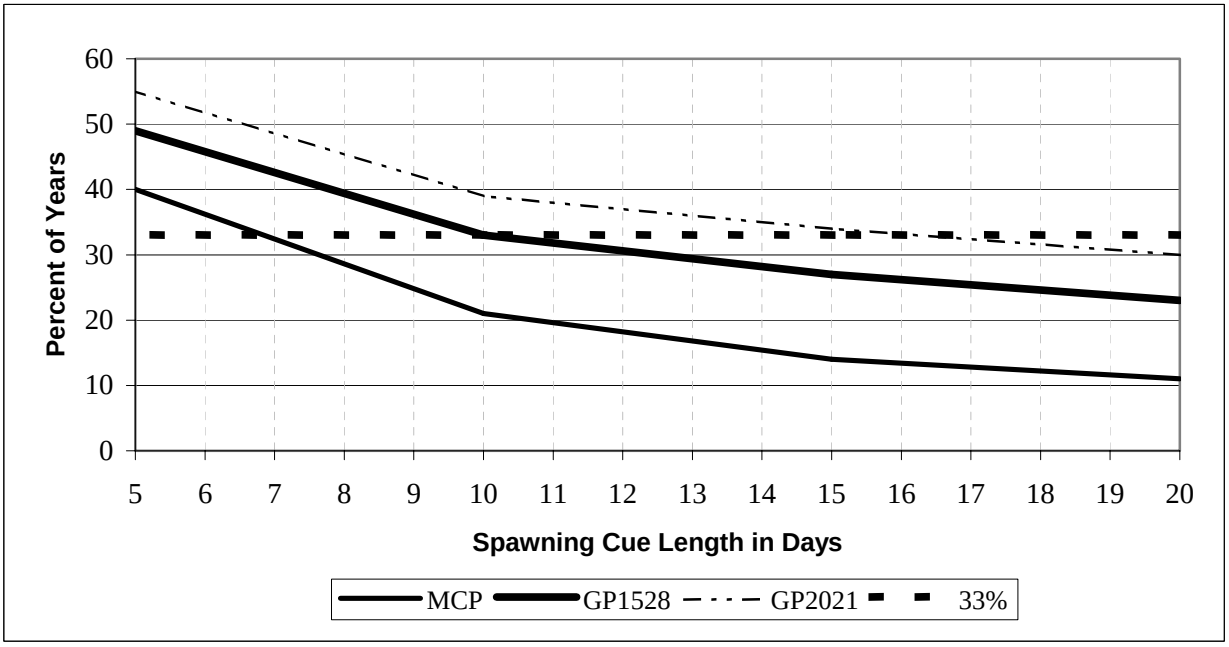

Figure 7.7-39. Percent of years when spawning cue length and shallow water habitat (3 acres/mile) coincide at Nebraska City.

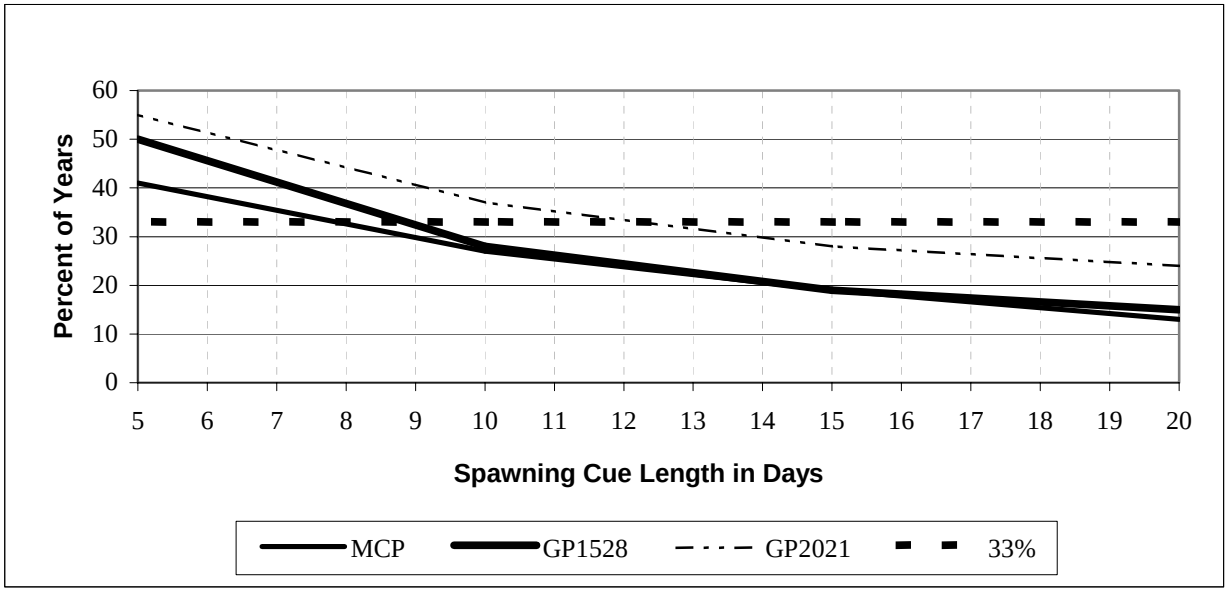

Figure 7.7-40. Percent of years when spawning cue length and shallow water habitat (15 acres/mile) coincide at Boonville.