Abundance of

Wild Pallid Sturgeon in Recovery-priority Management Area #2 of the Missouri and Yellowstone Rivers During 1991-2003

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Abstract

Pallid sturgeon *Scaphirhynchus albus* were once self-sustaining in the upper Missouri and lower Yellowstone rivers, but have declined drastically in abundance during the past century. One of the few remaining concentrations of pallid sturgeon occurs in the Missouri River downstream from the Fort Peck Dam to the headwaters of Lake Sakakawea and in the lower Yellowstone River. I used a modified Schnabel multiple-census mark-recapture procedure to estimate the abundance, with 95% confidence limits, of wild pallid sturgeon during 1991-2003 because abundance estimates were not calculated since 1995, and abundance estimates are needed for making management decisions. I also used linear regression to quantify the relation between abundances and time (years). My results show a decreasing trend in abundance of wild pallid sturgeon during 1991-2003. The abundance estimate for 2003 was 150, with upper and lower 95% confidence limits of 263 and 88. Furthermore, the rate of decline indicated from linear regression of abundance and time indicates that this population of wild pallid sturgeon will be extirpated during 2018. Decision-makers should err on the side of caution and adopt the lower 95% confidence limit (88 during 2003) as the working abundance estimate for wild pallid sturgeon in the study area. Furthermore, aggressive measures should be taken to maximize recovery efforts during the next 10 years. Habitats must be rehabilitated immediately if wild pallid sturgeon are expected to contribute to future generations.

Introduction

Although pallid sturgeon *Scaphirhynchus albus* were once self-sustaining in the Missouri and Mississippi River basins, a combination of habitat loss, commercial harvest, and pollution have caused drastic declines in reproduction, growth, and survival throughout their native range (Dryer and Sandvol 1993). Consequently, pallid sturgeon were listed as federally endangered throughout their range on 6 September 1990. One of the few remaining concentrations of pallid sturgeon is in recovery-priority management area #2 (RPMA #2; Braaten 2001) which encompasses the Missouri River downstream from Fort Peck Dam to the headwaters of Lake Sakakawea and the lower Yellowstone River as outlined in the Pallid Sturgeon Recovery Plan (Dryer and Sandovol 1993). Habitat fragmentation, degradation, and destruction due to the construction and operation of main stem dams have been described as the main cause for pallid sturgeon declines in RPMA #2 (Deacon et al. 1979; Dryer and Sandovol 1993); commercial harvest has been historically absent from the area.

Pallid sturgeon recovery efforts in RPMA #2 have included proposed warm-water releases form the Fort Peck Spillway, and augmentation of wild populations via stocking hatchery-reared pallid sturgeon. However, abundance estimates for wild pallid sturgeon in RPMA #2 were not calculated since 1995. Estimation of fish abundance is necessary for understanding basic changes in abundance and composition, and often provides the information needed for making fisheries management decisions (Everhart and Youngs 1981; Kohler and Hubert 1993). Krentz (1995) used the Schnabel method to estimate abundance of wild pallid sturgeon in RPMA #2 during 1991-1995, but did not account for mortality of marked pallid sturgeon between sampling periods (years) and did not consider small recapture sample sizes when calculating 95% confidence limits. Therefore, I modified the Schnabel multiple-census mark-recapture procedure to meet the greatest amount of assumptions possible, estimated abundances of wild pallid sturgeon in RPMA #2 during 1991-2003, and used linear regression to quantify the relation between estimated abundances and time (years).

Methods

Capture-recapture.—Sampling for pallid sturgeon in RPMA #2 has been conducted by Montana's Department of Fish, Wildlife & Parks, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. Marking pallid sturgeon began before 1990, but no recaptures occurred until 1991, so estimated abundance during 1991-2003 only. Most pallid sturgeon were sampled during April and May broodstock collection efforts, even though sampling generally occurred during April to October. Three hundred and fifty-one pallid sturgeon were captured in drifted trammel nets (1.8 m high by 22.86-45.7 m in length with a 22.7 kg lead core bottom line, 15.2 cm inner mesh and 25.4 cm outer mesh; or 1.8 m high by 22.86-45.7 m in length with a 13.6 kg lead core bottom line, 2.5 cm inner mesh and 15.2 cm outer mesh), 10 were captured by SCUBA divers, and one was captured in a stationary gill net (1.8 m high by 45.7 m in length, with 7.62, 10.16, 12.70 cm alternating mesh). Sampling efforts varied spatially and temporally because a standard sampling protocol was not followed.

Upon capture, pallid sturgeon were scanned for Biosonic 125 kHz passive integrated transponder (PIT) tags, and examined for Floy tags and internal combination acoustic-radio transmitters. Unmarked pallid sturgeon were uniquely tagged with PIT tags, Floy tags, or combination acoustic-radio transmitters and released for a series of samples (subsequent years). Recapture information (marked or unmarked, recapture site, site turbidity, etc.) was recorded, and fork length, weight, and character index values were measured when possible. Pallid sturgeon recaptured with the aid of telemetry devices were not considered in this study. No marked pallid sturgeon were found dead in the study area, and no marked pallid sturgeon were recaptured outside of the study area.

Data analysis.—I modified the Schnabel mark-recapture method, the simplest of the multiple-census procedures (Kohler and Hubert 1993), to estimate abundance of pallid sturgeon in RPMA #2 each year during 1991-2003:

$$\hat{N} = \frac{\sum_{t=1}^{n} C_t M_t}{\sum_{t=1}^{n} R_t}$$

Where $\hat{N}$ is the estimated abundance, M is the number of pallid sturgeon marked and released, C is the number of pallid sturgeon captured and examined for marks in the sampling period, R is the number of recaptured pallid sturgeon found in C, the subscript t refers to the sample period, and n is the number of sample periods. Each year of sampling was considered one sample period t.

In order to obtain valid abundance estimates from the Schnabel method, the following assumptions must not be violated: (1) marked fish do not shed their marks before the recapture period; (2) marked fish are not overlooked in the recapture sample; (3) marked and unmarked fish have equal mortality rates between the marking and recapture sampling periods; (4) marked fish become randomly mixed with the unmarked members of the population; (5) marked and unmarked fish are equally vulnerable to capture during the recapture period; (6) there are no additions (immigration or recruitment) to the population during the study; and (7) no mortality occurs during the study.

I considered assumptions 2-4 and 6 to be satisfied in this application because: only pallid sturgeon thoroughly examined for marks were included in this analysis; no marked pallid sturgeon were found dead during the study period; marked and unmarked pallid sturgeon were occasionally sampled in the same net drift and often sampled in the same area; and the study area is bordered by two main stem dams, no marked pallid sturgeon were found outside the study area, and there is no evidence of recruitment during the past 35 years (S. Krentz, U.S. Fish and Wildlife Service, unpublished data).

Assumption 1 was certainly violated during the study period, but it is not possible to estimate marker loss rates because not enough pallid sturgeon have been double PIT tagged, and the U.S. Fish and Wildlife Service disallowed the use of external markers on pallid sturgeon during 1998 (S. Krentz, U.S. Fish and Wildlife Service, personal communication). Violating assumption 1 could lead to an overestimation of abundance.

Assumption 5 may have been violated in this application, as sampling effort was not randomly distributed throughout RPMA #2 during 1991-2003, and therefore, marked and unmarked pallid sturgeon may not have been equally vulnerable to capture during the recapture period. Abundances may have been underestimated if marked pallid sturgeon were more likely to be recaptured than their unmarked counterparts.

Assumption 7 would have been violated, as mortality did occur during the study period 1991-2003. However, I addressed this issue by applying a 10% natural mortality rate to the population of marked pallid sturgeon every sampling period (each year), and subtracted marked pallid sturgeon that died from the population of marked pallid sturgeon. This modification provided abundance estimates for each sample period t, rather than one estimate for the first sampling period. A 10% annual natural mortality rate for adult pallid sturgeon was an estimate recommended by the Upper Basin Pallid Sturgeon Workgroup (1997). I believe this estimate is reasonable, as I have calculated an annual natural mortality estimate of $M = 0.1032$ from a simple catch curve for adult lake sturgeon *Acipenser fulvescens* aged 27-39 in Lake Winnebago, Wisconsin during 1955-1967 (unpublished data). Furthermore, a 10% annual natural mortality rate is within the range of total mortality rates reported by Rien and North (2002) for transplanted, sub-adult white sturgeon *Acipenser transmontanus* in the Columbia River. These three species should have similar natural mortality rates, since they are all long-lived, large sturgeon species native to North America (Citation).

I used a Poisson table to calculate 95% confidence limits of $\hat{N}$ when recaptures in a sample period (year) were less than 25 (12 of 13 years; Ricker 1975). These 95% confidence limits are more correct than those calculated when assuming $\hat{N}$ is normally distributed (Ricker 1975; Kohler and Hubert 1993). For the one sampling period where recaptures exceeded 25 (37 in 2003), I used E.S. Pearson's formulae (Ricker 1975) to calculate 95% confidence limits on R, and substituted them back into the original Schnabel equation to obtain the 95% confidence limits on $\hat{N}$.

I used linear regression to quantify the relation between estimated abundances and time (years). The abundance of wild pallid sturgeon in RPMA #2 should be a decreasing linear function of time due to natural mortality M, as I assumed annual fishing mortality, Z, to be zero (it is unlawful to take pallid sturgeon in the study area), and there has been no documented recruitment to the population for several years (Braaten 2001). The linear regression formula used was:

$$P = \beta_1 * Y + \beta_0$$

Where P is the estimated abundance, β_1 is the slope, Y is the year in which P was calculated, and β_0 is the intercept.

Results and Discussion

My abundance estimates for wild pallid sturgeon in RPMA #2 during 1991-1995 were less than those calculated by Krentz (1995) because I applied a natural mortality rate $M = 0.10$ to the population of marked pallid sturgeon annually, while Krentz assumed no mortality on the marked population during 1991-1995 (Figure 1). Peterson et al. (2002) and Rien and North (2002) did not apply mortality rates to populations of marked sturgeon during their 3- and 8-month study periods. If the number marked fish in a population is lower than expected, abundances will be overestimated. Therefore, abundance estimates calculated from marked populations at liberty across years should be more correct when considering mortality on marked populations.

Ninety-five percent confidence limits of the abundance estimates, $\hat{N}$, were large due to small recapture sample sizes in each year (Table 1). However, these confidence limits were similar in magnitude (33.7%-315.3% of $\hat{N}$) to those calculated by Peterson et al. (2002) for adult lake sturgeon in the Manistee River, MI during 1999-2000 (37.5%-364.6% of $\hat{N}$). The 95% confidence limits of the 2003 abundance estimate, $\hat{N} = 150$, yields that there may have been as many as 263 or as few as 88 wild pallid sturgeon in RPMA #2 during 2003 (Table 1). When dealing with a species as endangered as the pallid sturgeon, decision-makers should err on the side of caution and adopt the lower 95% confidence limit (88 in 2003) as the working abundance estimate for wild pallid sturgeon in RPMA #2.

While estimated abundances of wild pallid sturgeon in RPMA #2 during 1991-2003 do not appear to differ statistically across years (Table 1; Figure 2), there is a decreasing trend (Figure 3). Linear regression of abundances and time (years) resulted in the following:

$$P = -9.746282527 * \text{Y} + 19668.21955$$

Where P is the estimated abundance, -9.746282527 is the slope, Y is the year, and 19668.21955 is the intercept (Table 2). By substituting 0 for abundance P and solving the equation for year Y, we can see that if wild pallid sturgeon in RPMA #2 continue to decline in abundance at the rate described by the above function, they will be extirpated from RPMA #2 during 2018. The population of wild pallid sturgeon in RPMA #2 may be extirpated before 2018, however, if pallid sturgeon reach an old-age threshold before 2018, if fishing mortality, Z, is acting on the population, or if pallid sturgeon collected in future propagation efforts die. If the 15 dead pallid sturgeon form RPMA #2 form which ages have been estimated were alive today, the youngest would be age-37 while the oldest would be age-64 (S. Krentz, U.S. Fish and Wildlife Service, unpublished data). There is no legal recreational or commercial fishery for pallid sturgeon in RPMA #2, but pallid sturgeon are caught by anglers and people snagging for paddlefish *Ployodon spathula*. Pallid sturgeon may be extirpated from RPMA #2 before 2018 if they are suffering incidental fishing mortality. A total of 13 pallid sturgeon have died during propagation efforts during 1999-2003 (Ryan Wilson, U.S. Fish and Wildlife Service, personal communication), resulting in an average annual mortality of 1.4% of the estimated abundances during 1999-2003. If similar mortality rates from propagation efforts are observed in the future, pallid sturgeon will be extirpated from RPMA #2 during 2017; increased mortality rates will result in earlier extirpation.

The window of opportunity for recovering wild pallid sturgeon in RPMA #2 is closing rapidly. Aggressive measures should be taken to maximize recovery efforts during the next 10 years. Habitats must be rehabilitated immediately if wild pallid sturgeon in RPMA #2 are expected to contribute to future generations. Rapid population recovery is improbable, even in protected sturgeon populations, given that strong year-classes are widely separated periodic phenomena in natural populations (Sulak and Randall 2002).

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Table 1. Abundance estimates *N* of pallid sturgeon in RPMA #2 during 1991-2003 obtained from a modified Schnabel multiple-census mark-recapture procedure. Lower (LCL) and upper (UCL) 95% confidence limits are given.

Year	LCL	N	UCL
1991	27	255	2550
1992	67	304	1735
1993	84	249	782
1994	101	205	397
1995	108	217	436
1996	106	208	419
1997	100	186	357
1998	99	188	370
1999	96	180	354
2000	96	178	347
2001	97	179	352
2002	92	166	315
2003	88	150	263

Table 2. Output from linear regression of estimated abundance and time (years; 1991-2003).

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.895643639
R Square	0.802177528
Adjusted R Square	0.784193667
Standard Error	19.68706225
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	17288.1842	17288.1842	44.60541172	3.47405E-05
Residual	11	4263.384618	387.5804199		
Total	12	21551.56882			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	19668.21955	2914.231496	6.749024425	3.16152E-05	13254.03603	26082.40307
X Variable 1	-9.746282527	1.459302144	-6.678728301	3.47405E-05	-12.95818651	-6.53437854

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*
1	263.3710372	-8.371037204	-0.444112133
2	253.6247547	49.97774532	2.651490196
3	243.8784721	4.804164214	0.254877331
4	234.1321896	-29.56030212	-1.568275055
5	224.3859071	-7.305263596	-0.387569201
6	214.6396246	-6.568659863	-0.348489855
7	204.893342	-18.8312531	-0.999062336
8	195.1470595	-6.981068185	-0.370369526
9	185.400777	-5.187029226	-0.275189628
10	175.6544945	2.205112069	0.116988732
11	165.9082119	12.80283901	0.679234365
12	156.1619294	9.541014799	0.506183443
13	146.4156469	3.473737879	0.184293667

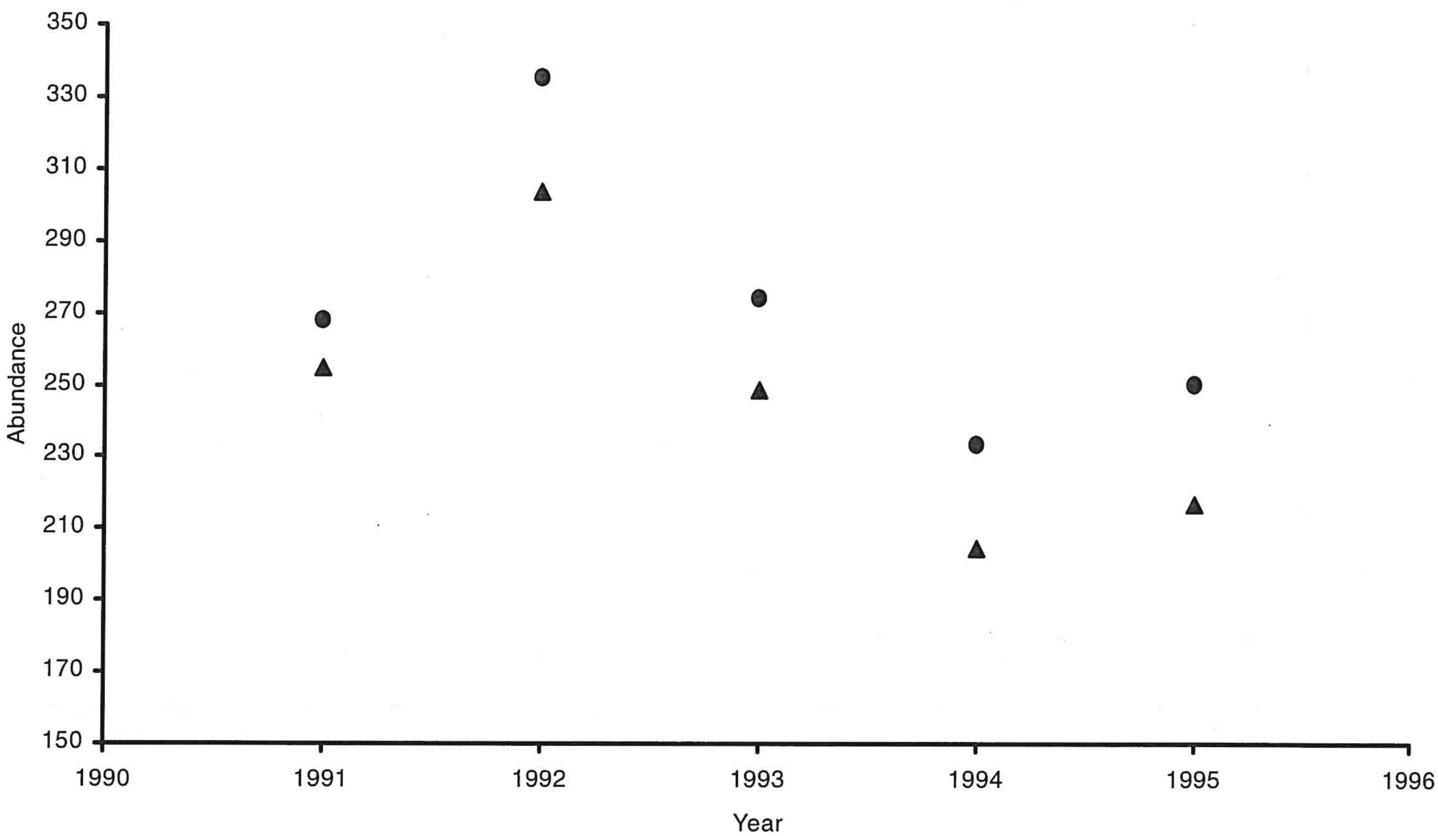

Figure 1. Abundance estimates for wild pallid sturgeon in RPMA #2 during 1991-1995. Krentz (1995) calculated the abundance estimates denoted by the circles, while my estimates are denoted by triangles.

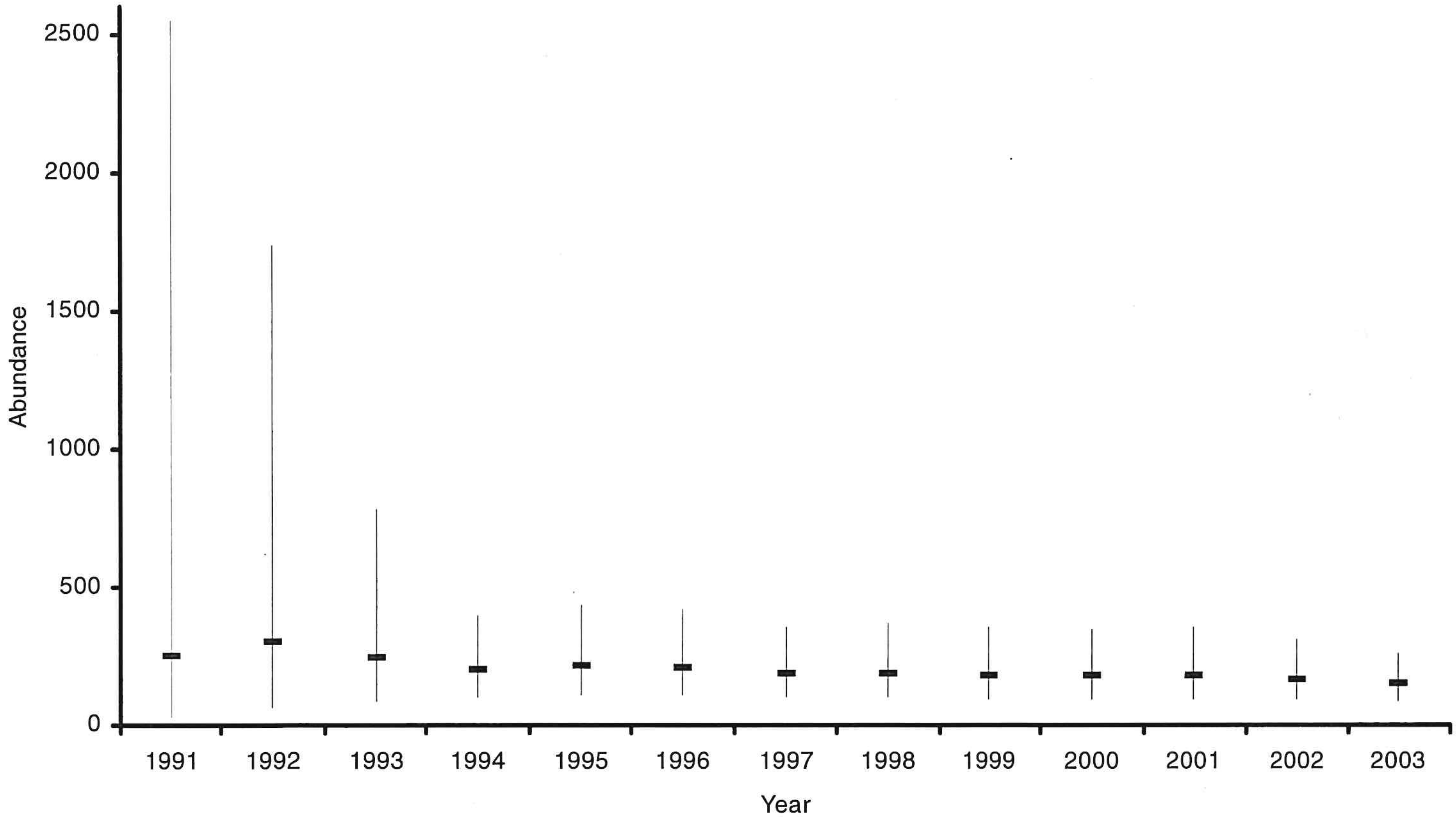

Figure 2. Abundance estimates and 95% confidence limts for pallid sturgeon in RPMA #2 during 1991-2003.

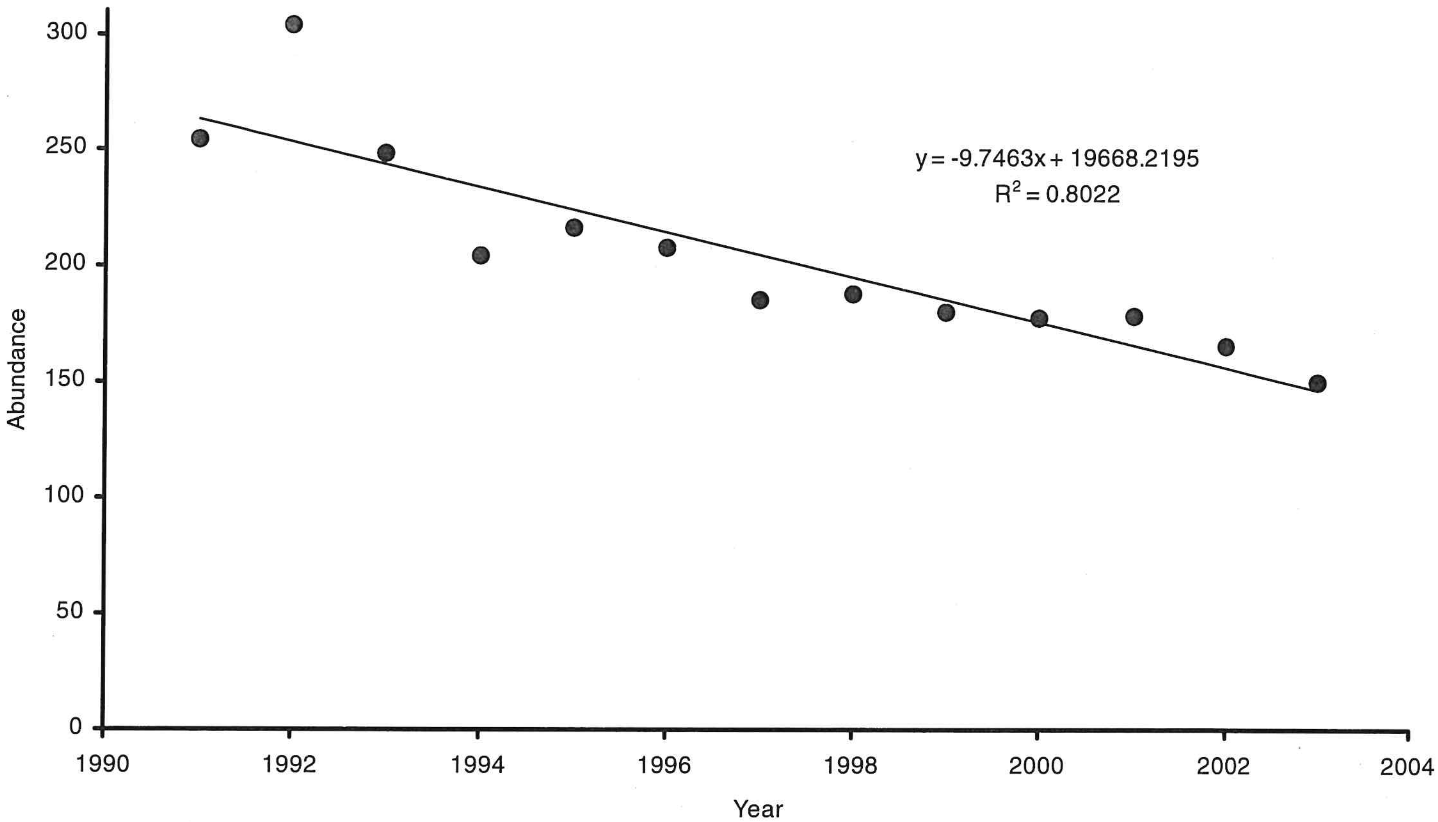

Figure 3. Abundance estimates for pallid sturgeon in RPMA #2 during 1991-2003. A regression line of the abundance estimates and time (years), equation, and r-squared value are given.