Ozark Hellbender Long-term Monitoring SWG Project

Final Report

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Photograph of a juvenile Ozark Hellbender from the Eleven Point River, Randolph County, Arkansas, courtesy of Stan Trauth.

Executive Summary

Over the past 25 years populations of the Ozark Hellbender *Cryptobranchus alleganiensis bishopi* have been shown to be declining throughout its range in the Ozark Plateau of Arkansas and Missouri. This decline has been attributed to: over collection for commercial and scientific purposes, habitat alteration/ loss, contaminants, and emerging infectious diseases, leaving the long-term survival of this unique salamander in question. This large aquatic salamander formerly inhabited several streams in the upper White River basin of northeastern Arkansas. The only remaining viable population is now restricted to the Eleven Point River (EPR) of Randolph County. The establishment of a long-term population monitoring program was needed to standardize quantifiable assessment of this remaining population.

Surveys at 20 localities in a 31.6 km reach of the upper EPR from 2005 to 2007 yielded 81 individuals. The metric used for quantified measures of population change over time is: catch per unit effort (CPUE or the number of Hellbenders per man hour of search time = H/hr). The CPUE was not significantly different between years and the mean annual CPUE yielded a value of 1.0 H/hr. However, this value is considerably less than historic values (8.6 H/hr) from the EPR in Missouri. Data from 2000-2007, reveal that the population structure, based on size class distribution, was normally distributed and both sexes exhibited trends in increasing total length, snout-vent length, and mass over time, but only females exhibited statistically significant changes in these metrics. The female to male sex ratio (1F:1.8M) is more similar to ratios in populations of the Eastern Hellbender, showing an increase in the number of males over historic samples (1F:0.6M) from the EPR in Missouri. The presence of the infectious fungal disease *Batrachochytrium dendrobatidis* (*Bd*) was detected in the EPR Hellbender population in 2007, with a 10% infection rate. The implications of the presence of this lethal pathogen in this population remain unknown at this time.

Appreciable changes in population numbers and demographics will only be detected through the continuation of this long-term monitoring program through biannual surveys. It is hoped that any appreciable positive demographic changes detected in the EPR Hellbender population in the future will be an indicator of the success of our efforts to improve riverine habitat and water quality, via on the ground stream bank remediation and cattle exclusion implementation projects.

The Hellbender (*Cryptobranchus alleganiensis*) is one of the largest fully aquatic salamanders in North America, surpassed in length only by the swamp dwelling Amphiumas (*Amphiuma* spp.) of the southeastern United States. Hellbenders formerly inhabited clear, cool water rivers and streams throughout much of the Ohio and Tennessee River basins in the eastern United States, with allopatric populations in the Ozark Plateau of Arkansas and Missouri (Conant and Collins 1991; Petranka 1998). The nominate race *C. a. alleganiensis*, the Eastern Hellbender, occurs east of the Mississippi River and in east-central Missouri. The Ozark Hellbender *C. a. bishopi* is restricted to the streams of south-central Missouri and northern Arkansas in the Whiter River basin. Historic evidence suggests that the Ozark Hellbender had a much greater distribution in the upper White River basin of Arkansas, in the main stem of the White, North Fork of the White, Black, and Current rivers. However, by the 1980s and 1990s the only known Ozark Hellbender populations in Arkansas occurred in the Spring and Eleven Point rivers (Fig. 1). In 2007 the Arkansas Game and Fish Commission herpetologist deemed the Spring River population functionally extinct, after surveys over a 3-year period (2003-2005) (Trauth et al., 2007) produced only 12 individuals in an area where 300+ individuals had been captured in the early 1980s (Peterson, 1985). At present, the only viable population in Arkansas occurs in the EPR in Randolph County.

The reduction in geographic distribution and population declines in the Ozark Hellbender has been attributed to several factors: commercial and scientific collection, contaminants, and habitat loss/ alteration (Wheeler et al. 2003; Nickerson and Briggler, 2007). This situation has been further exacerbated by the recent (2006-2007) detection of the presence of emerging infectious diseases – chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*) and flesh-eating bacteria *Citrobacter freundii* (pers. comm., J. Briggler, December 2007) in Ozark Hellbenders in Missouri and Arkansas. *Bd* is a lethal fungal disease that affects larval development and is fatal in recently metamorphosed amphibians. *Bd* has been well documented as the culprit in significant amphibian population declines and extinctions worldwide (Young et al., 2004). Research to determine the long-term effects of *Bd* on Hellbender populations is ongoing through the efforts of the St. Louis Zoo and Missouri Department of Conservation. The effects of the flesh-eating bacterium *Citrobacter* in Hellbender populations are incompletely known at this time, but may be the primary causal agent for the loss of digits and feet in individuals observed in the EPR population over the past seven years.

Even though the Ozark Hellbender has been a Candidate Species for listing under the Endangered Species Act since 2001, it has become increasingly imperiled; based on documented populationa declines, loss of historic populations, continued anthropogenically induced threats to remaining populations, and presence of emerging infectious diseases. Therefore, it is essential that an established long-term monitoring program be in place to provide quantifiable data for detecting appreciable changes in remaining populations. Such a program will not only provide the necessary population demographic trend data, but will complement the need to provide additional samples for analysis in combating the threat of insidious emerging infectious diseases, and as a measure of the future success of riverine habitat remediation programs.

Life History Overview. — Prime Hellbender habitat consists of swiftly flowing water, such as deep-water runs or riffles, with large cover rocks on a gravel or cobble substrate. Such sites provide the necessary structure for nest sites, foraging areas, diurnal cover, and swift current that provides well oxygenated water for Hellbender respiration, via O^2 absorption through the fleshy folds of skin along the sides of the body. Hellbenders are very philopatric, preferring specific cover objects within their home range, with some seasonal up- and downstream movements. The primary food is crayfish, but small fish and a variety of aquatic invertebrates are also consumed. Ozark Hellbenders are generally considered to be nocturnal, when they come out to forage, though they are diurnally active during the breeding season (September – October). Females can lay from 200-700 eggs, under rocks or in crevices, which the male guards until hatching four to six weeks later. Ozark Hellbenders may become sexually mature in five to eight years and individuals can live over 35+ years in the wild (pers. comm. J. Briggler, 2008). In spite of their high fecundity, recruitment is low in Hellbender populations. Hence, removal of large numbers of breeding adults from a population can have a significant negative impact on maintaining a stable population.

Threats to the Eleven Point River Population — The anecdotal *a priori* threats (these have not been quantified) to the EPR Hellbender population are contaminants in the form of cattle waste and sediment inputs. Active cattle operations along the river allow direct access of cattle to the water, which not only creates stream bank erosion but allows for the input of large amounts of cattle waste directly into the river. Cattle waste runoff from adjacent pastures can also add nutrients and hormones to the river during heavy rainfall events, as does the fertilizing of adjacent pasturage with chicken litter, from local chicken farming operations. Clearing of riparian forests along the river have created large, sheer faced eroding stream banks which add tons of fine sediment to the system during high water events. Add to this, the sediment loads from unpaved county road runoff during rain events and the system is obviously receiving significantly greater sediment inputs than the pristine system ever did. Hence, efforts to implement stream bank stabilization and cattle exclusion and watering systems projects are critical to improving water quality and habitat maintenance for the EPR Hellbender population.

Materials and Methods

From 2000-2004 surveys in a 31.6 km reach, from the Arkansas-Missouri state line downstream to Arkansas State Highway 90, of the upper EPR in Randolph County, Arkansas, identified 20 localities that harbored Hellbenders. These 20 sites have now been established as long-term monitoring localities and precise locality information, as well as detailed site descriptions, is withheld due to the sensitive nature of this declining species. Each survey locality was assigned a locality number as it was surveyed; hence, locality numbers are not sequential in the tabularized data. The majority of sites are deep water runs (2-4 m) composed of subaqueous limestone talus slopes, which afford suitable cover and structure. Due to the depth of these sites SCUBA gear was used in the initial surveys to locate prospective sites, but a hookah dive system (surface gasoline powered air compressor) was employed during this study (2005-2007). This enabled workers to dive for extended periods of time with an unlimited air supply and eliminated the necessity of having to transport large numbers of air cylinders, which require daily refilling and is not feasible given the remote location of the study site. Snorkeling was also utilized to search the shallow margins of deep water sites and at the single rocky riffle locality. The number of collectors generally consisted of two divers, with a maximum of five collectors on two surveys. Hellbenders were collected by hand and individually placed in pillow cases (=collecting bags). Total dive time was recorded in minutes for each collector at every survey site then converted to total man hours (hrs) search time for each survey event. This metric was then used to calculate the catch per unit effort (CPUE) in terms of total number of Hellbenders captured per man hour of search time (H/hr). Surveys were conducted during the months of July through September, when males are in breeding condition which is determined by the presence of a swollen ring of flesh around the cloaca, thus enabling accurate gender identification. Standard morphometric measurements snout-vent length (SVL) and total length

(TL) were recorded to the nearest whole millimeter, using a measuring board constructed of 11 cm OD PVC. Mass was recorded to the nearest whole gram on an Ohaus© 2000 g Scout Pro electronic pan balance. Individuals were marked using Avid© brand PIT (passive integrated transponder) tags and scanned with an Avid Power TracKer IV© multi tag reader. Samples for *Bd* testing were taken by rubbing the venter and palms with the swab tip and wooden tip of the handle of a cotton swab applicator. The cotton swab and wooden tip ends were then stored in 95% EtOH for later analysis. Data were recorded on field survey forms and entered into a Microsoft Office Excel© spreadsheet program for later analysis. To help reduce the potential spread of *Bd* pillow cases (collecting bags) were treated in one of two ways in-between collecting days: bags were disinfected by soaking in 10% bleach then rinsed in fresh water or dried in direct sunlight on a hot >45° C surface for 2+ hrs, the *Bd* pathogen is killed with prolonged exposure to temperatures ≥30° C. PIT tagging syringe needles were disinfected by soaking in 10% bleach, rinsed in fresh water, then sterilized by soaking in 100% EtOH.

Comments on PIT Tagging and Sampling Bias — It should be noted that concerns have been expressed among Hellbender researchers over the possibility of double or triple PIT tagging of a previously marked animal when a scanner does not record an existing tag. This has been proven in one instance in Missouri when a radiograph revealed the presence of two tags in what was thought to have been a previously unmarked individual (pers. comm. J. Briggler, 2008). However, it is logistically and financially impracticable to obtain radiographic images of all the individuals in the EPR populations. Hence, each animal is scanned with great care prior to PIT tagging to make sure it does not have any previously existing PIT tag.

While the metric, catch per unit effort (CPUE = H/hr) allows for comparability between years and localities, and is the easiest method for quantifying changes in Hellbender populations over time, it is not without its inherent problems. Variables that can influence CPUE measures are: the total number of collectors, which can influence total man hours of search time per locality and reduce the CPUE values; collector experience, which can influence the number of individuals located for search time expended, thereby reducing CPUE; amount of searchable habitat, sites with small areal extent may yield one or two individuals in a short time producing a high CPUE; and visibility/ water clarity, which can greatly influence search time as the collector can not locate potential cover rocks and search a given locality as quickly when visibility/ water clarity is low, thereby extend search time which would reduce the CPUE value.

Results

Surveys were conducted at all localities in 2005 and 2007. However, only three localities were surveyed in 2006 due to diving equipment break down, the report of the presence of *Bd* in Missouri Hellbender populations (Briggler, 2007), and a re-evaluation of the frequency of sampling on an annual basis.

Sampling Effort, CPUE, and Recaptures — All localities (n = 20) were sampled in 2005 yielding (n = 37) individuals and 19 localities yielded (n = 41) individuals in 2007 (Tables 1-4). The increase in captures in 2007 was likely the result of having four experienced collectors conduct the surveys at six localities. The mean number of captures ($\bar{x}$ = 1.8) and search time ($\bar{x}$ = 1.7) per locality was less in 2005, than in 2007 ($\bar{x}$ = 2.2) and ($\bar{x}$ = 2.3), respectively. Yet the mean annual CPUE was not significantly different between 2005 ($\bar{x}$ = 1.0) and 2007 ($\bar{x}$ = 1.2). The annual recapture rate in 2005 was 27% and in 2007 it was 34%, the gross recapture rate for the period 2000-2007 was 17.3% (Table 5). Duration between recaptures is summarized in Table 8, 81% of which had recapture durations of 3 years or less, while 9% of the sample had a maximum duration of six years.

A total of 190 individuals have been tagged since 2000 (Table 5), but several juveniles were not tagged due to their small size, out of concern for the potential injury to the animal and tag retention. Tables 6 and 7 illustrate the number of captures and recapture counts for those localities that were surveyed multiple times in the same year from 2001-2004. This work was conducted by Ben Wheeler, Ph.D. student, Arkansas State University, as part of his graduate research. Multiple surveys at the same locality within the same year have not occurred since 2004 and all surveys in 2005-2007 were conducted only once a year, and future surveys will be conducted only every other year. Locality 5 was surveyed six times in 2003 and seven times in 2004, hence, this locality has the greatest number of captures (n = 67) (Table 6).

Population Structure and Morphometrics — The population structure exhibits a normal distribution (Fig. 2) based on size class data (Tables 9-14). Only three Hellbenders <200 mm TL (juveniles) have been collected during the course of this study (2000-2007), and were not included in the size class distribution analysis. A substantial overlap in TL size class distribution exists between males and females (Fig. 3), but females are larger and heavier than males e.g., the pooled annual mean mass for males was 363.2 g (n = 8) and 508.4 g (n = 6) for females (Tables 11 and 14). Annual mean TL, SVL, and mass data (Figs. 4-9) exhibit increasing trends over time in both sexes, but only the female data were statistically significant. The overall female to male sex ratio was 1:1.8 (Table 15), which compared favorably to the annual sex ratios in 2001 and 2003-2007.

Infectious Disease Sampling — Skin swab samples (n = 39) were taken during the 2007 survey for testing of the presence of *Bd* in the EPR population. This testing was coordinated by Jeff Briggler, Herpetologist, Missouri Department of Conservation, and the results of the Arkansas samples yielded four positives, ~10% of the sample. This is a lower rate than in the Missouri EPR sample which exhibited a 25% infection rate. Since *Bd* thrives in colder water temperatures the increased water temperatures in the lower EPR may be of benefit to the Arkansas population by inhibiting or reducing the infection rate. Furthermore, we do not know what the implications of the presence of *Bd* are to our resident population. Is *Bd* killing adults, juveniles, or transforming larvae? Or is it simply present within the population without any adverse effects? Only further monitoring can answer such questions.

Discussion and Conclusions

A total of 81 Ozark Hellbenders were found at 20 widely dispersed localities along a 31.6 km reach of the EPR in Randolph County, Arkansas from 2005-2007. Hellbender localities are of limited areal extent, and are separated by long stretches of river that do not contain the two limiting factors for the presence of Hellbenders: (1) structure, in the form of rocky riffles or subaqueous talus slopes; and (2) swift current, which supplies well oxygenated water for respiration and prevents sediment deposition on cover structure. These variables were not quantified during the course of this project, but future work will focus on habitat quantification and its potential influence on population correlates.

The primary goal of this long-term monitoring project is focused on detecting changes in population numbers and structure over time, with the intent of using such data in the future as a measure of the effectiveness of efforts to ameliorate the negative impacts to Hellbender habitat and water quality in the EPR. Based on the quantified CPUE metric, the annual mean of approximately 1.0 H/hr showed no significant difference from 2005 to 2007. However, this is significantly less than the mean of 8.6 H/hr of Peterson (1985), from two sites in the upper EPR in Oregon County, Missouri. Whether this considerable difference in CPUE is a function of differences in habitat quality or quantity between localities or demonstrates a significant decline in the Arkansas population is unknown, due to the lack of historical Arkansas data for comparison.

Wheeler et al. (2003) analyzed historic (late 1970s and early 1980s) and recent (1998-1999) morphometric data as part of a Hellbender population decline study, looking at both Hellbender subspecies from five rivers in Missouri, including the EPR. Their size class distribution data (TL's of both sexes combined) indicated a shift towards a preponderance of larger individuals and fewer small individuals in all rivers. They suggested that this indicated a lack of recruitment as a result of either reproductive failure or reduced survivorship of eggs or young. However, their sample size for the EPR was not as large, historic (n = 68) and recent (n = 25) (Wheeler et al., 2003:154, Fig. 1) as this study (n = 222). The greatest proportion of their historic sample was in the 300-349 mm size class and the recent sample 400-449 mm size class. Our data were centered in the 350-399 mm size class (Fig. 2) which compares favorably to the historic sample (n = 641) of *C. a. bishopi* from the North Fork of the White River (Wheeler et al., 2003:154, Fig. 1). Our morphometric data exhibits increasing size and mass trends over time (Figs. 4-9), which may be similar to the shift in larger size class structure of Wheeler et al. (2003). Peterson (1985) determined an average mass (both sexes combined) of 214 g (n = 121) and 340.6 g (n = 90) (at two EPR study sites in Missouri. The average mass for all samples in this study was 417.6 g (n = 256), which is considerably greater than the mean ($\overline{x}$ = 277.3) of Peterson's sample.

Female to male sex ratios appear to fluctuate widely between geographic regions and subspecies. Petranka (1998) reported a 1:1 sex ratio for most Ozark populations, and Peterson (1985) reported a 1F:0.6M ratio in his Missouri EPR population. Wheeler et al. (2003) reported an overall sex ratio of 1.3F:1M for both subspecies in Missouri, which was consistent between their historic and recent samples. Studies of the Eastern Hellbender produced sex ratios of 1F:3M in Ohio and varied from 1F:1.6M to 1F:3M in Pennsylvania (Petranka, 1998). The overall sex ratio of 1F:1.8M in this study more closely resembles that of the Pennsylvania population.

This study is essentially of very short duration (2005 and 2007), in terms of quantifiable metrics i.e., CPUE, and only through continued monitoring will we obtain a better understanding of changes in the EPR population. A relative measure of the health of the population is suggested by the positive growth trend seen in the morphometric data and the normally distributed size class data indicates a stable population over the study period. In spite of the fact that only three juveniles (<200 mm TL) were captured from 2000-2007, most recently in 2005, this is an indicator that successful reproduction is still occurring within the past 5+-years. It should be noted that due to their seemingly cryptic nature juveniles are inherently difficult to find and have not been found with any frequency in any previous studies on Ozark Hellbenders. Longer-term data sets and field observations for signs of continued reproduction will aid us in determining whether this population is showing signs of senescence or if other factors are affecting reproductive success. Appreciable changes in population numbers and demographics will only be detected through the continuation of this long-term monitoring program through biannual surveys. It is hoped that any appreciable positive demographic changes detected in the EPR Hellbender population in the future will be an indicator of the success of our efforts to improve riverine habitat and water quality, via on the ground stream bank remediation and cattle exclusion implementation projects.

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Table 1. Summary of survey data for 2005–2007: number of localities surveyed, number of individuals, total man hours search time (Time), gross catch per unit effort = the number of Hellbenders captured per man hour of search time (CPUE) and annual mean CPUE (from Tables 2-4).

Year	Localities	N	Time	Gross CPUE	Annual ($\bar{x}$) CPUE
2005	20	37	34.0	1.1	1.0
2006	3	3	3.8	0.8	0.8
2007	19	41	43.4	0.9	1.2
				$\bar{x}$ = 0.9	$\bar{x}$ = 1.0

Table 2. Summary statistics for 2005 survey. An asterisk (*) denotes one individual observed but not captured in that survey.

Locality #	N	Time	CPUE	Recaps
2	1	1.2	0.8	–
3	3	1.5	2.0	1
4	1	1.0	1.0	–
5	4	2.5	1.6	3
7	–	0.2	–	–
8	1	1.2	0.8	–
9	5*	2.8	1.8	1
10	1	1.2	0.8	–
11	6*	2.7	2.2	–
12	3	3.0	1.0	3
13	1	1.0	1.0	–
15	3	3.2	0.9	–
16	1	1.0	1.0	–
17	2	2.2	0.9	1
18	–	1.2	–	–
20	–	1.3	–	–
21	–	1.6	–	–
22	1	1.5	0.7	1
23	3	3.2	0.9	–
24	1	0.5	2.0	–
Total	37	34	$\bar{x}$ = 1.0	10

Table 3. Summary statistics for 2006 survey.

Locality #	N	Time	CPUE	Recaps
2	1	1.0	1.0	–
3	–	1.3	–	–
20	2	1.5	1.3	1
Total	3	3.8	$\bar{x}$ =0.8	1

Table 4. Summary statistics for 2007 survey.

Locality #	N	Time	CPUE	Recaps
2	–	1.8	–	–
3	1	2.0	0.5	–
4	–	1.3	–	–
5	7	2.0	1.8	6
7	1	1.0	1.0	–
8	–	1.0	–	–
9	3	1.5	2.0	–
10	6	4.0	1.5	3
11	2	5.0	0.4	1
12	2	4.0	0.5	–
13	2	2.0	1.0	1
15	6	10.0	0.6	1
16	–	1.0	–	–
17	4	0.8	5.3	–
18	2	0.5	4.0	–
20	1	1.5	0.7	1
21	2	2.0	1.0	1
22	–	1.0	–	–
24	2	1.0	2.0	–
Total	41	43.4	$\bar{x}$ =1.2	14

Table 5. Summary statistics for all survey localities from 2000–2007. Note: multiple recaptures of the same individual in the same calendar year were counted only once in the recaptures column.

Locality #	N	Tagged	Recaps	% Recaps
2	8	8	1	12.5
3	17	16	1	6.2
4	13	12	1	8.3
5	45	44	12	27.3
7	2	2	–	–
8	4	4	1	25.0
9	11	11	1	9.1
10	12	12	3	25.0
11	10	9	1	11.1
12	13	13	5	38.5
13	13	13	1	7.7
15	11	11	1	9.1
16	3	3	–	–
17	6	6	1	16.7
18	3	3	–	–
20	8	8	3	37.5
21	4	4	1	25.0
22	3	3	–	–
23	4	4	–	–
24	4	4	–	–
Total	194	190	33	$\bar{x}$ = 17.3

TABLE 6. Number of captures (including recaptures) for all localities by year. Note: multiple recaptures of the same individual in the same calendar year were counted only once in these yearly totals. Values with an asterisk (*) are localities with multiple surveys within the same calendar year (see Table 7 for data).

	Year								
Locality #	2000	2001	2002	2003	2004	2005	2006	2007	Total
2	1	–	–	2	4	1	1	–	9
3	1	6*	5*	–	2	3	–	1	18
4	–	1	8*	1	2	1	–	–	13
5	10	14	–	17*	15*	4	–	7	67
7	–	1	–	–	–	–	–	1	2
8	–	3	–	–	1	1	–	–	5
9	–	4	–	1	–	5	–	3	13
10	–	2	–	–	6*	1	–	6	15
11	–	–	2	–	3	6	–	2	13
12	–	–	1	2	11*	3	–	2	19
13	–	–	7*	1	3	1	–	2	14
15	–	–	–	3*	–	3	–	6	12
16	–	–	–	2	–	1	–	–	3
17	–	–	–	1	–	2	–	4	7
18	–	–	–	1	–	–	–	2	3
20	–	–	–	4*	4*	–	2	1	11
21	–	–	–	–	3	–	–	2	5
22	–	–	–	–	2*	1	–	–	3
23	–	–	–	–	1	3	–	–	4
24	–	–	–	–	1	1	–	2	4
Total	12	31	23	35	58	37	3	41	240

Table 7. Localities with multiple surveys within the same calendar year and number of multiple recaptures (Recaps). Multiple recaptures are considered as those records of the same individual being captured more than once within the same calendar year.

Locality #	Year	# Surveys	Recaps
3	2001	2	–
3	2002	2	–
4	2002	3	1
5	2003	6	5
5	2004	7	9
10	2004	3	2
12	2004	3	1
13	2002	2	–
15	2003	2	–
20	2003	2	2
20	2004	3	1
22	2004	2	1
Total			22

Table 8. Number of recaptured individuals and maximum number of years between recaptures. Note: some individuals may have been captured multiple times in the intervening years but these data are not included.

# Individuals	Recap Duration (yrs)
8	1
7	2
12	3
2	4
1	5
3	6

Table 9. Comparison of annual variation in male total length (mm).

Year	N	Range	Mean ($\bar{x}$)	SD
2000	9	329–448	362.3	42.5
2001	15	242–476	386.4	65.8
2002	15	274–401	353.9	44.0
2003	20	301–442	378.0	43.0
2004	35	229–499	376.5	55.9
2005	22	267–454	385.2	49.3
2006	3	332–386	364.7	28.7
2007	25	317–450	399.1	34.6

Table 10. Comparison of annual variation in male snout-vent length (mm).

Year	N	Range	Mean ($\bar{x}$)	SD
2000	–	–	–	–
2001	15	160–338	257.3	47.4
2002	15	182–274	238.5	29.8
2003	20	200–298	253.7	28.5
2004	35	140–325	255.4	38.3
2005	22	181–315	262.3	34.3
2006	3	230–260	247.7	15.7
2007	25	223–300	268.9	20.5

Table 11. Comparison of annual variation in male mass (g).

Year	N	Range	Mean (x̅)	SD
2000	9	196–450	272.2	98.0
2001	15	106–702	397.9	179.1
2002	15	138–460	311.1	101.2
2003	19	192–625	358.7	131.6
2004	35	60–835	384.8	170.2
2005	22	160–719	399.3	135.0
2006	3	257–369	328.0	61.7
2007	25	219–780	453.8	121.4

Table 12. Comparison of annual variation in female total length (mm).

Year	N	Range	Mean (x̅)	SD
2000	–	–	–	–
2001	12	318–500	403.3	56.5
2002	4	387–472	413.3	39.4
2003	13	300–515	411.2	74.2
2004	20	327–536	418.6	59.4
2005	12	353–560	445.4	64.3
2006	–	–	–	–
2007	14	358–497	429.2	43.0

Table 13. Comparison of annual variation in female snout-vent length (mm).

Year	N	Range	Mean (x̅)	SD
2000	–	–	–	–
2001	12	216–342	270.4	39.5
2002	4	254–317	275.2	28.6
2003	13	202–346	280.8	52.2
2004	20	214–362	285.2	41.5
2005	12	251–380	306.3	43.6
2006	–	–	–	–
2007	14	251–345	292.0	29.3

Table 14. Comparison of annual variation in female mass (g).

Year	N	Range	Mean ($\overline{x}$)	SD
2000	–	–	–	–
2001	13	222–904	416.4	196.3
2002	3	322–620	448.7	153.9
2003	13	178–1288	539.5	346.5
2004	20	234–1102	518.1	269.0
2005	12	299–904	578.8	210.3
2006	–	–	–	–
2007	14	332–980	548.8	184.4

Table 15. Comparison of annual variation in female-male ratios. These data count multiple recaptures of marked individuals only once per year if more than one capture event occurred in the same calendar year.

Year	Females (N)	Males (N)	Total (N)	Ratio (F:M)
2000	1	9	10	1:9
2001	13	15	28	1:1.2
2002	4	15	19	1:3.8
2003	13	20	33	1:1.5
2004	20	35	55	1:1.8
2005	12	22	34	1:1.8
2006	–	–		–
2007	14	25	39	1:1.8
Pooled	77	141	218	1:1.8

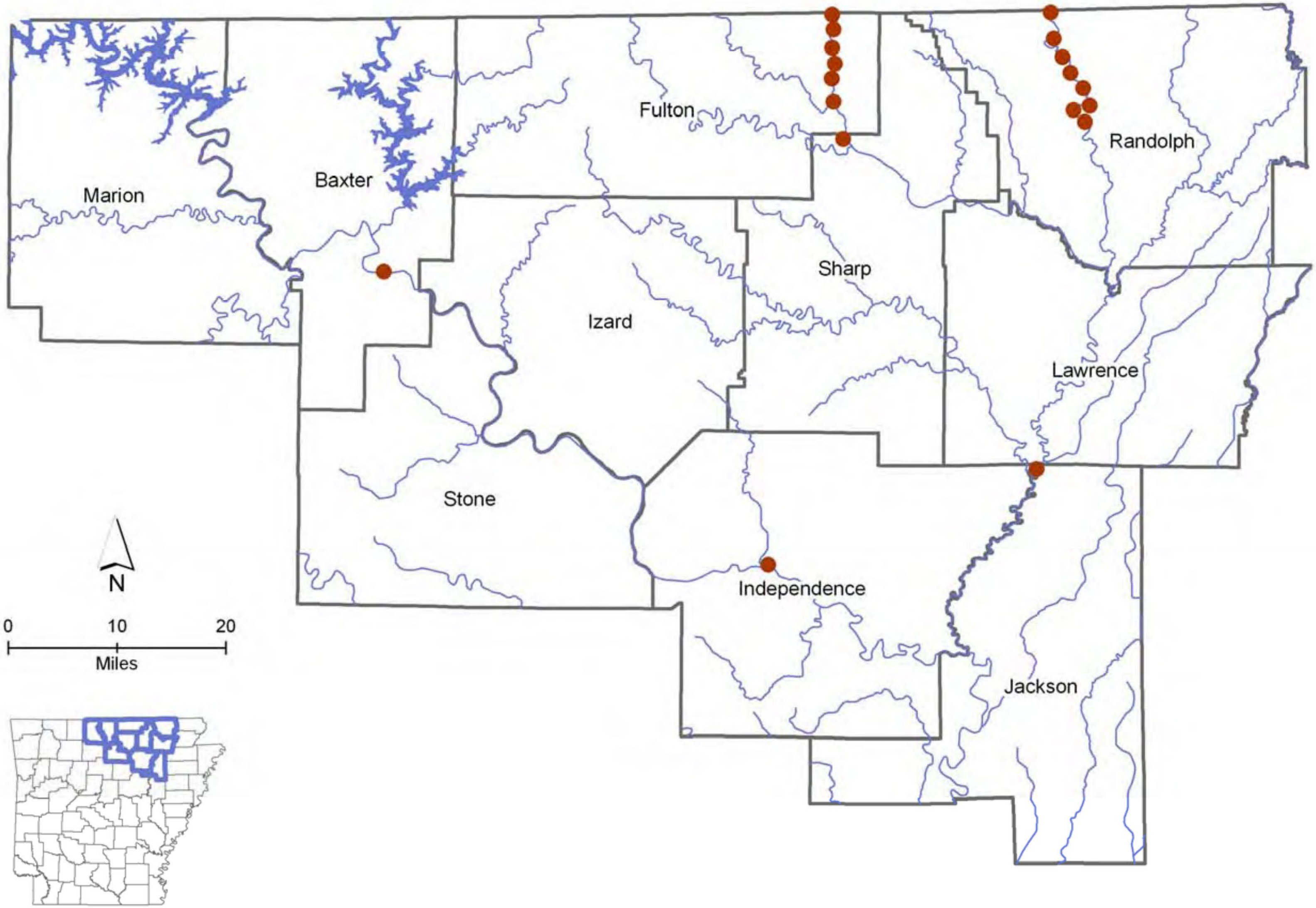

Fig. 1. Distribution records of the Ozark Hellbender in Arkansas

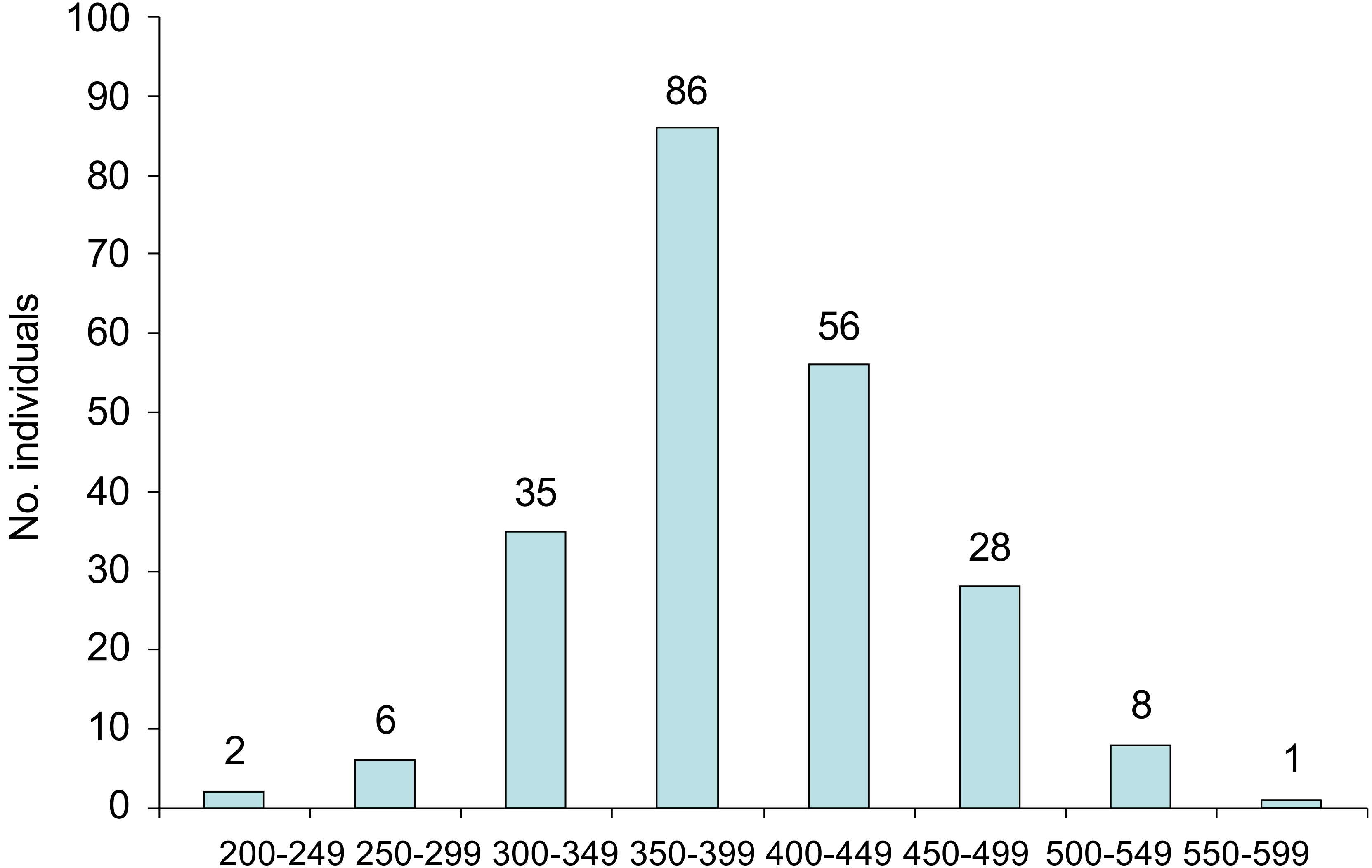

Fig. 2. Size class (TL) distribution both sexes combined (mm) (n = 222).

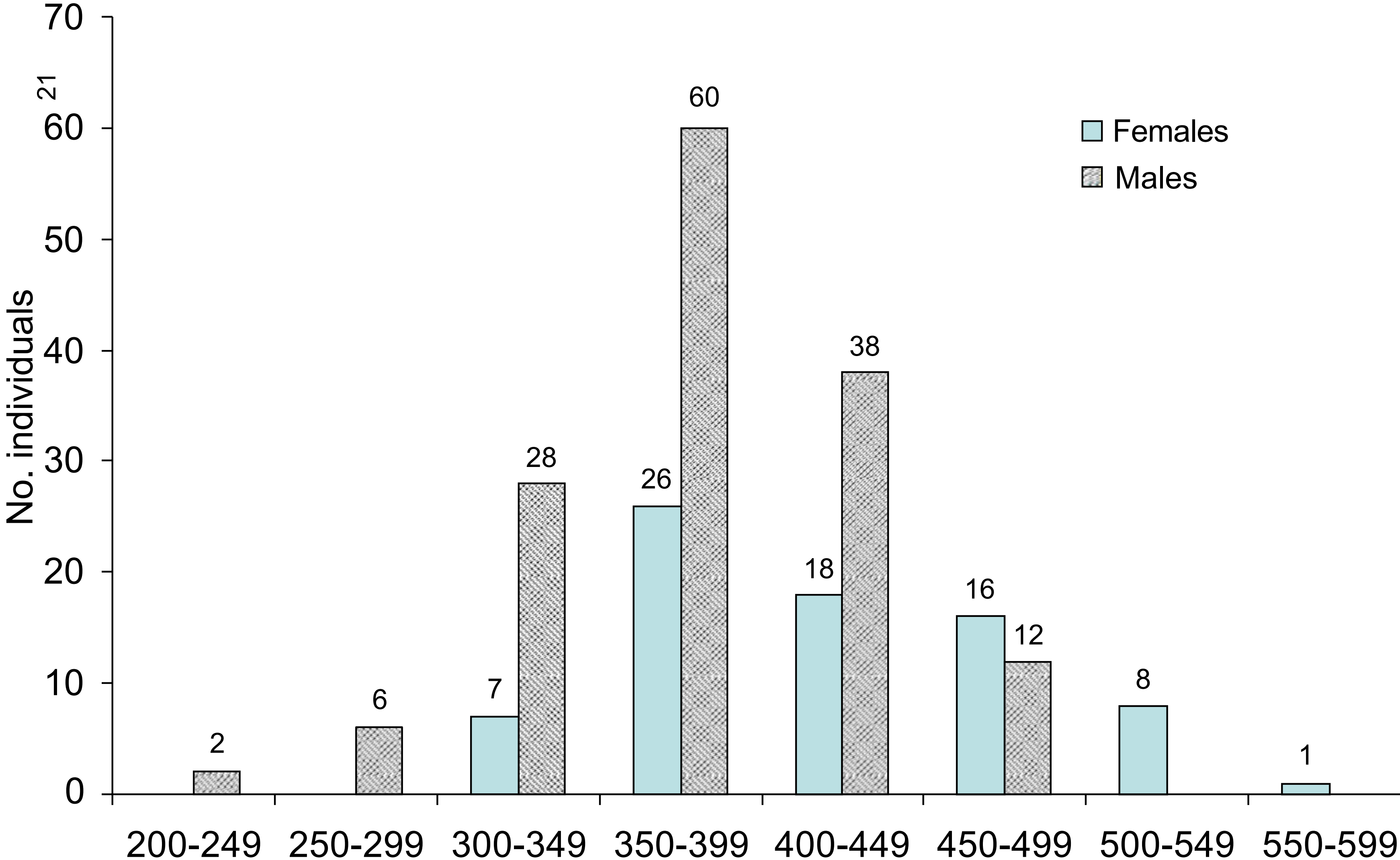

Fig. 3. Size class (TL) distribution of males and females (mm) (n = 222).

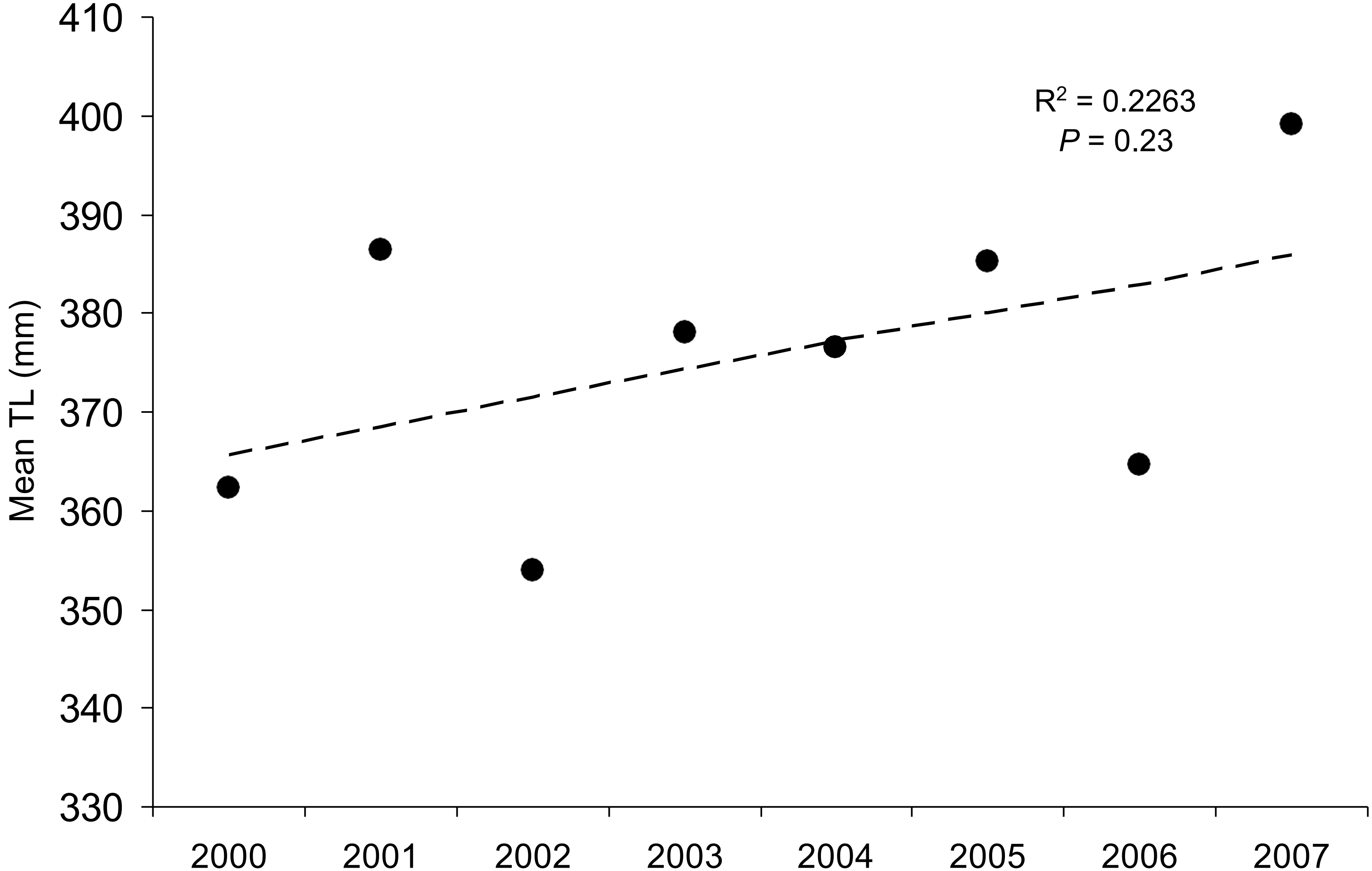

Fig. 4. Annual male mean TL with linear regression.

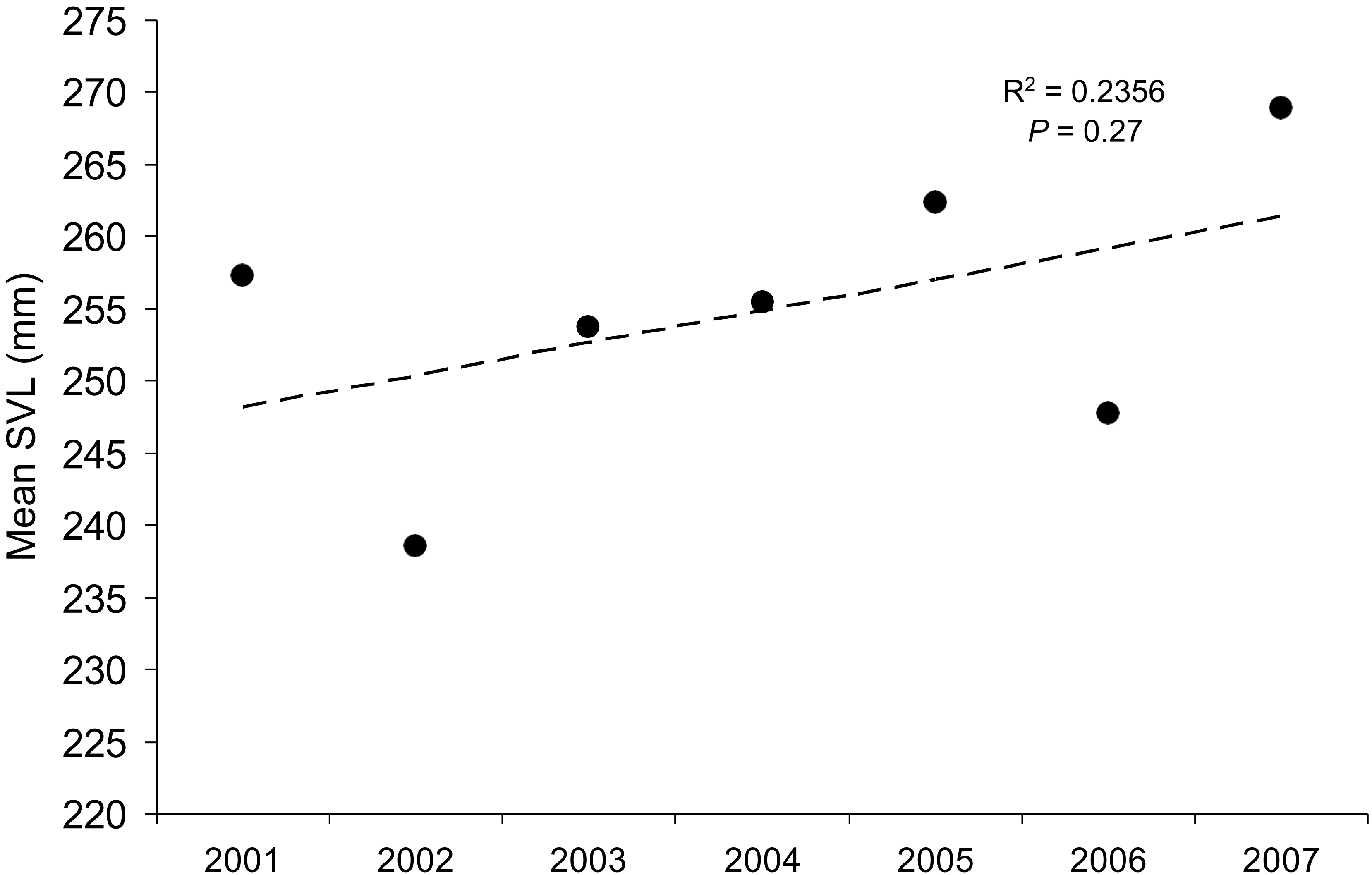

Fig. 5. Annual male mean SVL with linear regression.

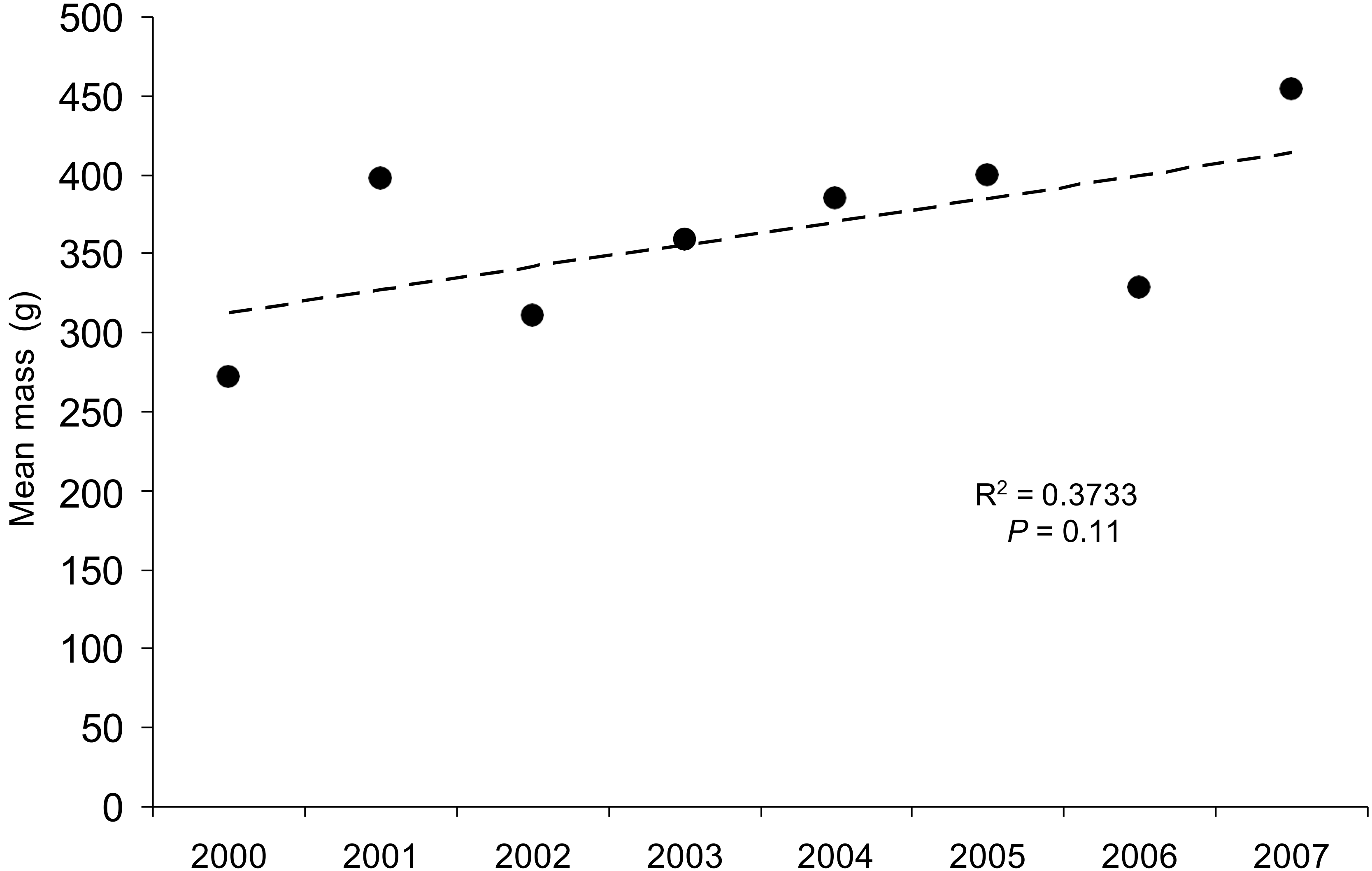

Fig. 6. Annual male mean mass with linear regression.

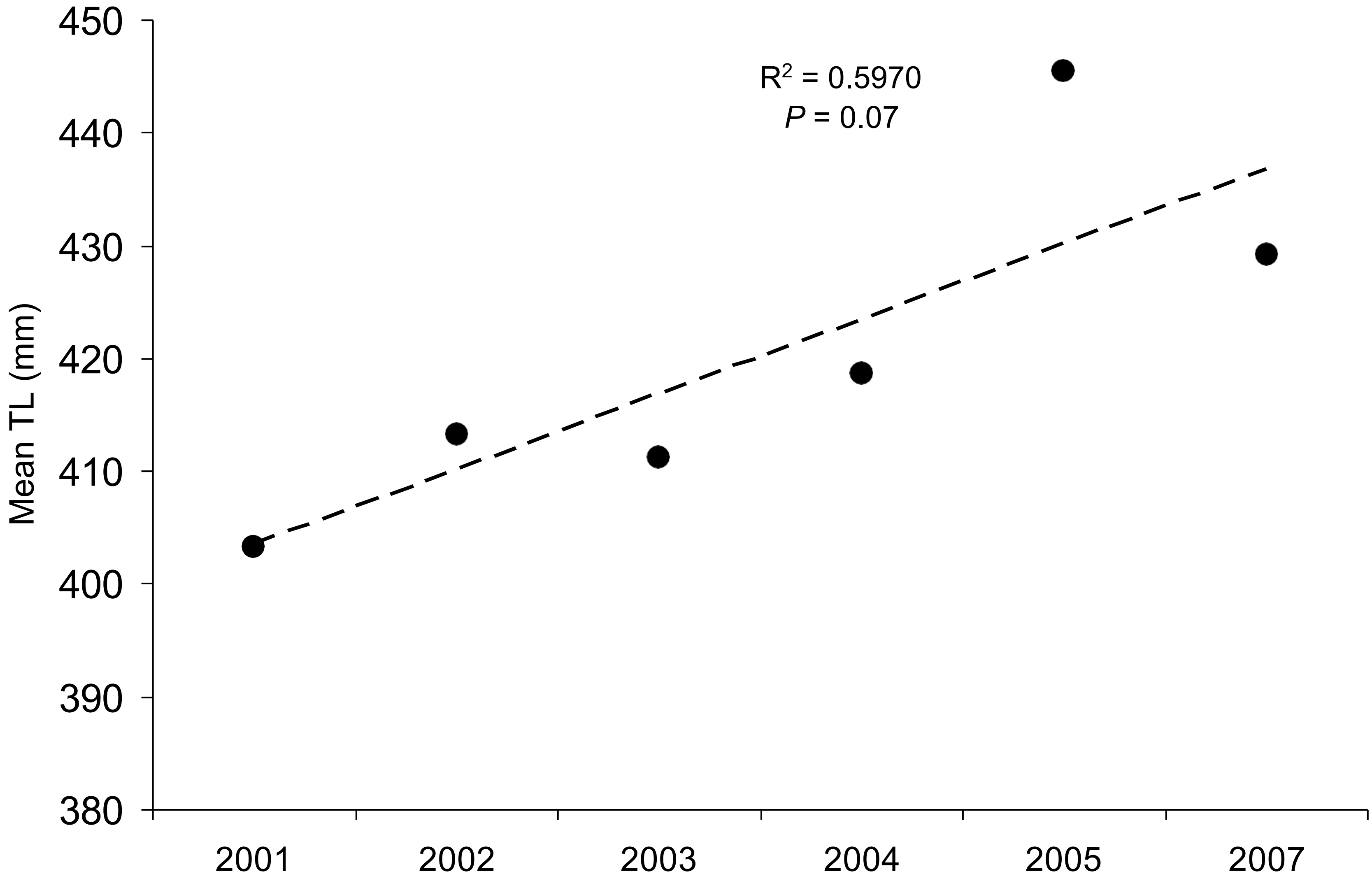

Fig. 7. Annual female mean TL with linear regression.

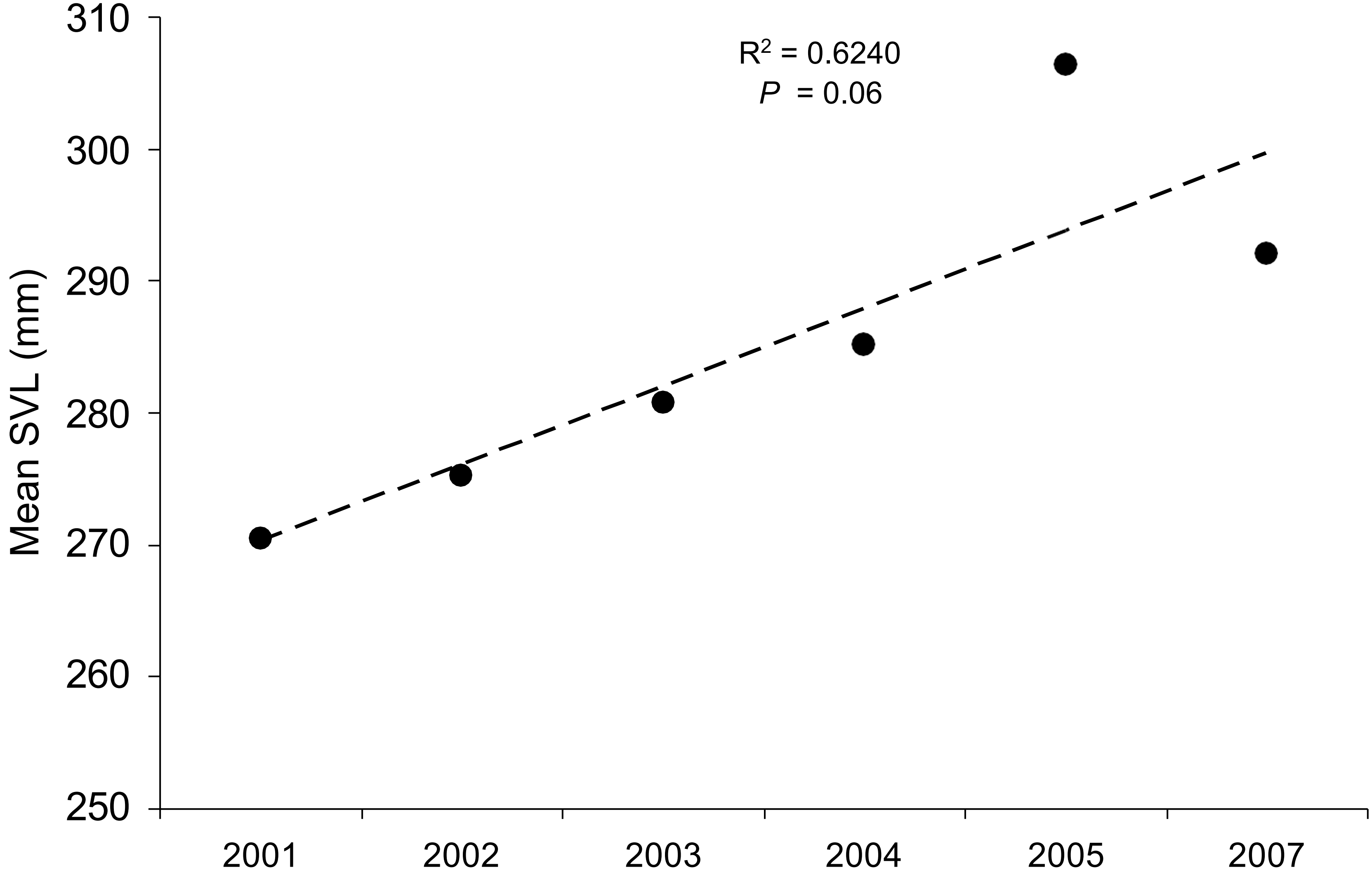

Fig. 8. Annual female mean SVL with linear regression.

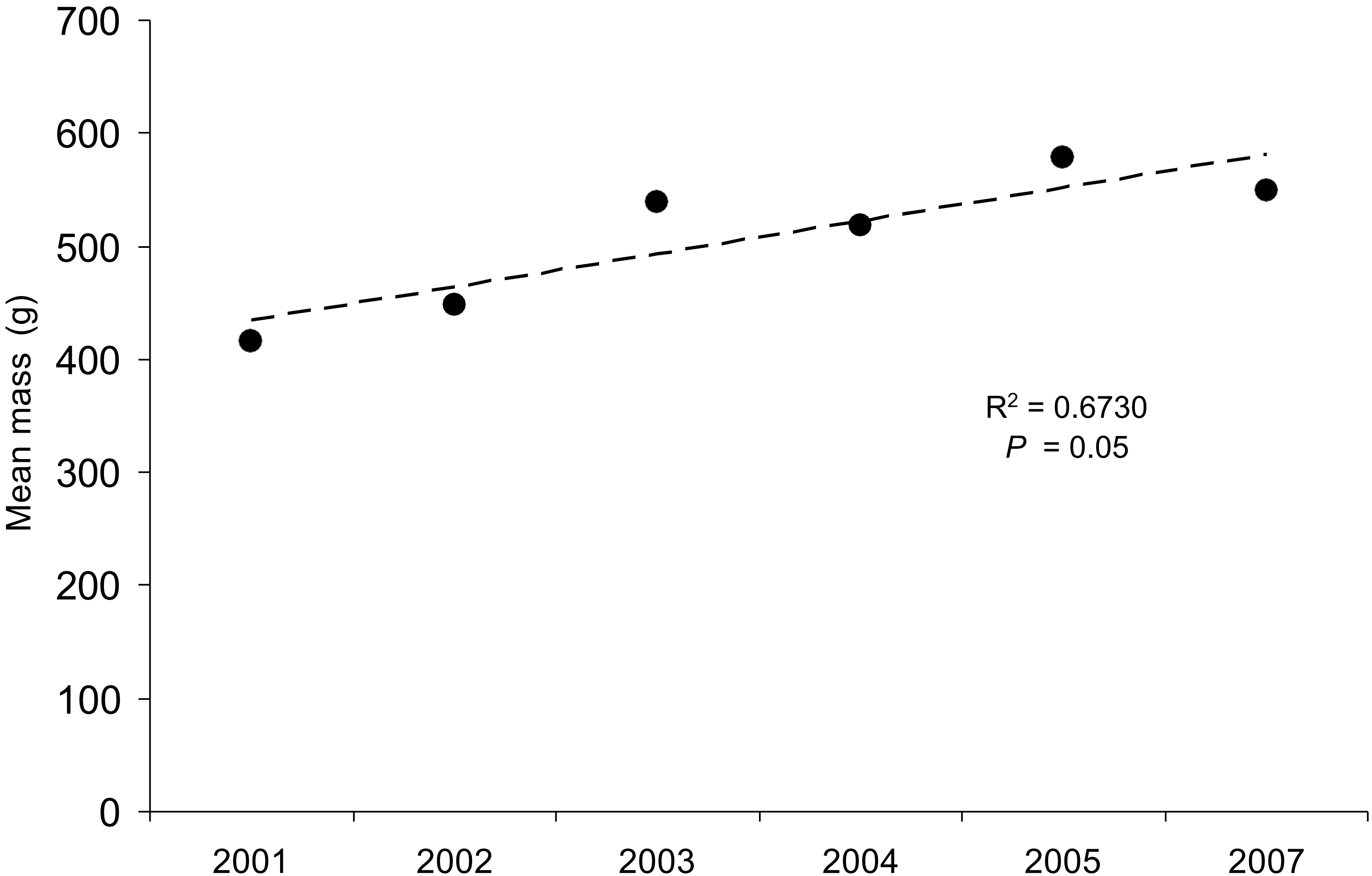

Fig. 9. Annual female mean mass with linear regression.