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Lake Roosevelt Fisheries Evaluation Program

Assessment of the Lake Roosevelt Walleye Population: Compilation of 1997-1999 Data

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Lake Roosevelt Fisheries Evaluation Program

Assessment of the Lake Roosevelt Walleye Population: Compilation of 1997-1999 Data

Annual Report 1999-2000

Contributions to Fisheries Management in Eastern Washington State Number 3

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Table of Contents

List of Tables

List of Figures

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Abstract

A walleye mark-recapture study was conducted on Lake Roosevelt between 1997 and 1999. The primary objective of the study was to describe the status and biological characteristics of the walleye population in Lake Roosevelt by determining its abundance, movement patterns, age structure, growth, condition, and mortality. The abundance estimates were also to be used to estimate the consumptive impact of walleye on stocked kokanee and rainbow trout. Walleye were collected by electrofishing and angling. Each walleye was tagged with an individually numbered Floy tag. The Jolly-Seber model was used to estimate the size of the walleye population in 1999, using each year of the study as a mark-recapture occasion. Mark-recapture data collected in 1998 was re-analyzed in 1999 with the data pooled in various combinations, using closed and open population models, in an attempt to provide an estimate of walleye abundance that was unbiased, accurate, and more precise. Minimum distances traveled between mark and recapture location by tagged walleye were determined from tag returns.

Over the three study years, a total of 12,343 walleye ≥ 150 mm TL were collected by Eastern Washington University (EWU), Spokane Tribe of Indians, and Washington Department of Fish and Wildlife, and of those, 10,770 were tagged and released. Of the 10,770 walleye marked and released, 775 were recaptured and returned to EWU. The 1999 abundance estimate (± standard error) for walleye ≥ 150 mm TL was 129,183 (± 45,578) and the estimated abundance (± standard error) of walleye ≥ 200 mm TL was 101,508 (± 35,603). A total of 38 population estimates were calculated for 1998. The estimates of the abundance of walleye ≥ 150 mm TL in Lake Roosevelt ranged from 84,335 to 180,568 fish. Estimates of the size of the walleye population ≥ 200 mm TL

ranged from 14,971 to 173,702. The 1999 estimate, which used each study year as a mark-recapture occasion, was biased due to unequal capture probabilities. If biases were eliminated, the annual sampling strategy may be the most cost-effective. Of the re-analyzed 1998 estimates, the Schnabel corrected for tag loss and recruitment and the Jolly-Seber estimate, both calculated with the 200 mm minimum length, were recommended for modeling walleye consumption.

Minimum distances traveled between mark and recapture location by tagged walleye marked on the spawning run ranged from 0 to 245 km over a range of 11 to 486 days. Minimum distances traveled between mark and recapture location by tagged walleye marked during the summer/fall ranged from 0 to 217 km over a range of 8 to 788 days. Walleye exhibited seasonal movement trends that included a migration to the spawning area in the upper Spokane River Arm in the spring, with peak spawning occurring in April and May, and a migration following spawning to summer habitats. Once at the summer habitat, walleye appeared to establish summer home ranges (SHR).

Walleye collected in Lake Roosevelt in 1999 ranged in age from 0 to 8. Mean instantaneous and mean annual mortality were estimated at 0.62% and 46%. Mean condition factor (K_{TL}) of the 343 walleye measured and weighed in 1999 was 0.83 (SD = 0.13). Walleye mortality rates appeared to be relatively stable. Mortality and growth were average when compared to other walleye producing waters. Walleye condition was low when compared to condition factors in 1980-83, 1988, 1989, and 1990. The K_{TL}'s of walleye from Lake Roosevelt were slightly below average when compared to other walleye populations.

Introduction

A walleye (*Stizostedion vitreum vitreum*) mark-recapture study was conducted on Lake Roosevelt between 1997 and 1999. The primary objective of the study was to describe the status and biological characteristics of the walleye population in Lake Roosevelt by determining its abundance, movement patterns, age structure, growth, condition, and mortality. The abundance estimates were also to be used to estimate the consumptive impact of walleye on stocked kokanee and rainbow trout.

Walleye were the most abundant piscivore in Lake Roosevelt, based on catch-per-unit-effort (CPUE) and relative abundance (Cichosz et al. 1999). Relative importance indices have indicated that walleye were the primary predators of salmonids in the reservoir (Cichosz et al. 1999). The Washington Department of Fish and Wildlife (WDFW) is attempting to determine the limiting factors for the kokanee and rainbow trout populations in the reservoir (Baldwin et al. 1999). Predation was hypothesized as a possible limiting factor so WDFW is attempting to model consumption of salmonids by walleye, which requires an estimate of walleye abundance.

The 1997 abundance estimate was determined to be unreliable due to problems associated with sampling bias resulting from non-random movements of walleye and a nonrandom sampling strategy. The project was revised in 1998 to include a randomized sampling strategy to correct for the sampling bias. The resulting estimates were considered relatively unbiased, but lacked precision and required an extraordinary amount of effort. An extraordinary amount of effort was expended in 1998, which was why we believed it was necessary to re-analyze the data to try to improve the estimate. Mark-recapture data collected in 1998 was re-analyzed in 1999 with the data pooled in different combinations, using closed and open population models, in an attempt to provide an estimate of walleye abundance that was unbiased, accurate, and more precise.

Walleye collection and marking was continued in 1999, to explore an alternate sampling methodology that could provide accurate and precise abundance estimates with minimal effort and corresponding costs. A reduction in effort was accomplished by collecting walleye only at times when catch rates were high (spawning run and Governor's Cup Walleye Tournament) and in coordination with other projects, such as the Lake Roosevelt Monitoring Program (LRMP) sampling and kokanee coded wire tag collection.

We conducted a mark-recapture experiment on the Lake Roosevelt walleye population in 1999. The primary objective of this study was to estimate the abundance of walleye in Lake Roosevelt with limited sampling. The estimate will be used in a bioenergetics model that determines their consumptive impact on the kokanee and rainbow trout populations. Secondary objectives included: 1) improving the 1998 walleye abundance estimate by re-analyzing the data using various models and pooling combinations, 2) determining minimum movements of walleye in Lake Roosevelt, and 3) estimating the age composition, growth, and mortality rates of the walleye population.

Materials and Methods

Field Collection

Walleye were collected and marked during boat electrofishing surveys conducted on the walleye spawning run in the upper Spokane River Arm (April 1st through May 31st, 1999) and in coordination with kokanee research activities (June 1st through

December 1st, 1999) (Figure 1). Walleye were also collected and marked by angling on June 19th and 20th, 1999 in conjunction with the Governor's Cup Walleye Tournament in Kettle Falls, Washington.

All species of fish were collected during electrofishing surveys to standardize catch and effort data. All fish were measured to the nearest millimeter total length (TL) and weighed to the nearest gram (g). All walleye ≥ 150 mm TL were affixed with an individually numbered FD 94, ¾", monofilament long, "T"- anchor Floy® tag (Floy Tag, Inc., Seattle , WA) and immediately released. Tags were inserted at the posterior base of the first dorsal fin as described by Guy et al. (1996). Each tag was printed with the address "EWU CHENEY" so anglers would know where to return them. Posters informing anglers about Lake Roosevelt fisheries projects and where to report tag information were placed at major boat launches around the reservoir. Anglers who returned a walleye tag were sent a letter with information about their fish.

Only walleye data collected between 1997 and 1999 by EWU, Spokane Tribe of Indians (STI), and WDFW was used to calculate the 1999 estimate. Walleye tagged by another agency or tagged by EWU or STI prior to 1997 were treated as "marks" on their initial captures and were released with the original tag. Recaptures of fish tagged during the year were ignored during analysis.

For re-analysis of the 1998 data, only walleye marked and recaptured by STI and EWU during the study period were included in the analysis. Walleye tagged by another agency or tagged by EWU or STI prior to 1998 were treated as "marks" on their initial captures and were released with the original tag. Recaptures of fish tagged during the same pass were ignored.

Pass dates in 1998 were:

1. April 1st through June 11th,
2. June 12th through July 12th,
3. July 13th through August 2nd,
4. August 3rd through August 24th, and
5. August 25th through September 16th.

Abundance Estimates

The 1999 abundance estimates were calculated using three sampling occasions. Each of the study years, 1997, 1998, and 1999, were considered a sampling occasion. The 1999 estimates were calculated with the Jolly-Seber model (Seber 1982). The computer program POPAN5 was used to calculate the Jolly-Seber estimates and corresponding standard errors (Arnason and Schwarz 1999).

Abundance estimates using the 1998 data were calculated with the Chapman version of the Schnabel estimate (Seber 1982), the “most appropriate” model chosen by the computer program CAPTURE (Otis et al. 1978; White et al. 1982), and the Jolly-Seber model (Seber 1982). Standard errors of the Schnabel estimates were calculated by taking the square root of the variance (Seber 1982). CAPTURE provided standard errors with each estimate. The computer program POPAN5 was used to calculate the Jolly-Seber estimates and corresponding standard errors (Arnason and Schwarz 1999). Separate abundance estimates were calculated for 1998 with data from the third, fourth, and fifth passes pooled, the fourth and fifth passes pooled, and all five passes individually (no pooling), to improve precision.

Precision of all the estimates (1998 and 1999) was measured by calculating a coefficient of variance (CV), which was defined as the ratio of the standard error of the estimate to the estimate (Hightower and Gilbert 1984).

Capture probabilities of walleye were calculated for each pass using the M_t model in CAPTURE, because the probabilities changed over time and all the models used for the abundance estimates were robust to variations in capture probability over time. Capture probability was defined as the probability that a fish will be captured on a specific sampling occasion (Otis et al. 1978; White et al. 1982).

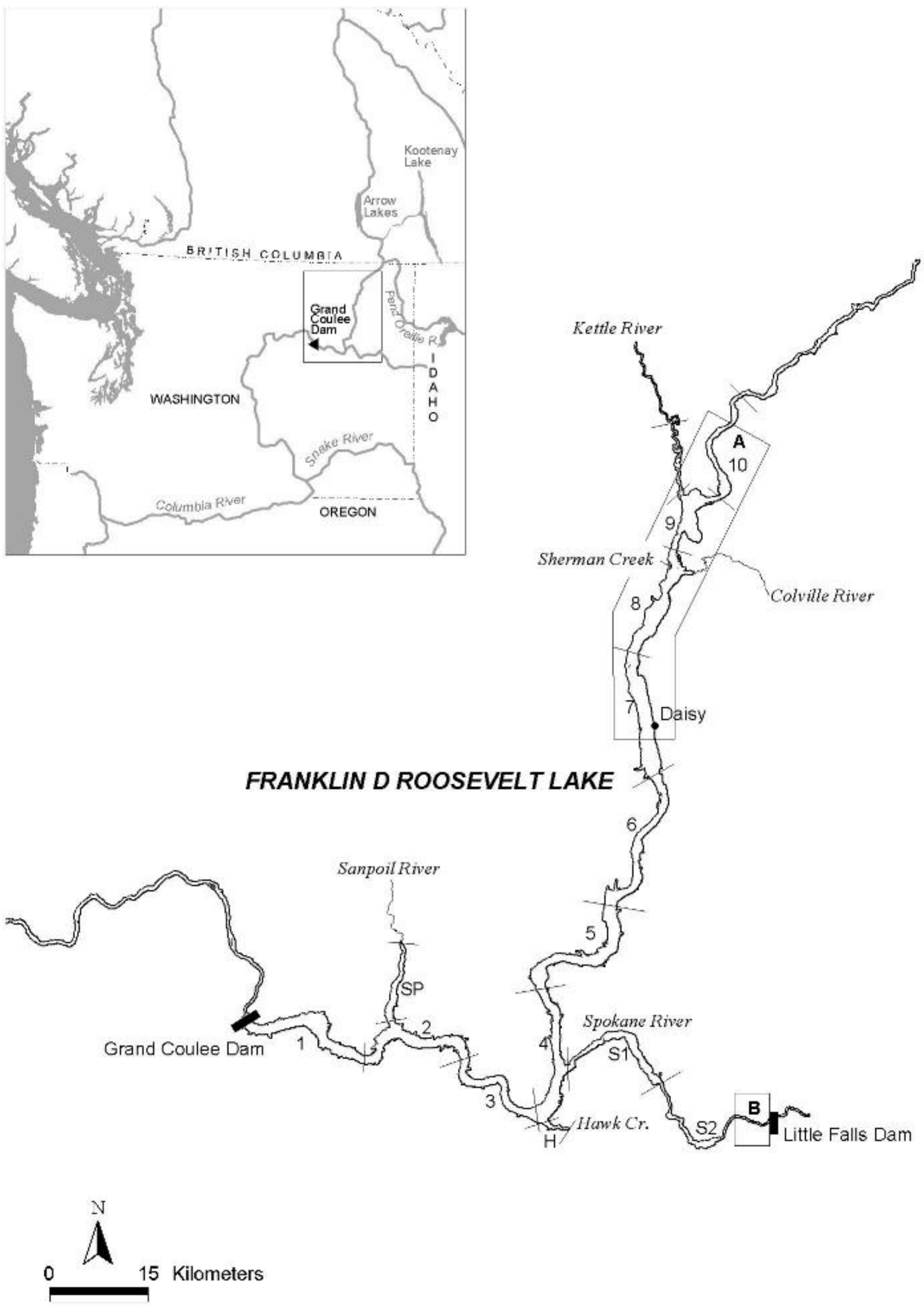

Figure 1. Map of Lake Roosevelt sampling sections. Box A indicates the location of the Governor's Cup Walleye Tournament. The area in box B indicates the upper 8 km of the Spokane Arm, where sampling of the spawning run was conducted.

Model Assumptions

All of the estimates were required to meet the mathematical and biological assumptions associated with each model, in order to be considered unbiased. Assumptions of the closed models were (Ricker 1975; Otis et al. 1978; White et al. 1982):

1. The population was closed.
2. Animals did not lose their tags during the study.
3. All animals in the population have an equal probability of being captured on each sampling occasion.

The assumptions of the Jolly-Seber model were (Seber 1982):

1. All animals alive and in the population had the same probability of capture at each sampling occasion.
2. All animals have the same probability of surviving or remaining in the population from sample *i* to sample *i*+1, if it was alive immediately after sample *i*.
3. Animals do not lose their tags.
4. All samples are instantaneous, so sampling time is negligible, and each release is made immediately after the sample.

We assumed that the walleye population in Lake Roosevelt was open during all study years (subject to losses and gains), due to angler harvest (tag returns) and emigrating fish (McLellan 1998; McLellan et al. 1998). The 1999 estimates were for the size of the population in the spring of 1998, but for clarity they were referred to as the 1999 estimate.

Despite the assumption that the population was open, closed population estimators were used in 1998 because the assumption of closure was relaxed which only affected the timing of the estimate. If mortality and emigration had equal effects on the marked and unmarked portions of the population and neither recruitment nor immigration occurred, the estimate was for the size of the population at the beginning of the study

(Otis et al. 1978; Pollock et al. 1990). However, if mortality (emigration) and recruitment (immigration) both occurred, the size of the population was overestimated (Otis et al. 1978). Estimates calculated with the Jolly-Seber model estimated the walleye abundance at the beginning of the second to last sampling pass (Seber 1982).

When the closed models were used, the assumption of closure was relaxed by assuming no immigration and adjusting for recruitment. Movement data suggested that walleye would have been migrating out of the study area during the study period rather than into it (Hildebrand, personal communication, 1998; McLellan et al. 1999).

Recruitment was adjusted for the 1998 estimates by increasing the minimum TL for tagging by 10 mm every two weeks, beginning June 1st, which was the approximate growth of Lake Roosevelt walleye in 1997 based on the recaptures that had adequate length data provided at each sighting (n=98; McLellan 1998; McLellan et al. 1998). By initiating the recruitment adjustment on June 1st, it was assumed that walleye ≤ 150 mm TL prior to the beginning of the study would not reach 150 mm TL by June 1st. The same assumption was made when the 200 mm TL minimum size was used. Effects of recruitment were determined and tested for statistical significance by comparing Schnabel estimates that were adjusted for recruitment with those that were not, using the test for differences between Schnabel estimates (Chapman and Overton 1966).

Alternative estimates of abundance were calculated in 1998 using the Schnabel method to determine whether tag loss was negligible. The alternative estimates were made by adding the number of recaptures per pass at the approximate observed rate of tag loss in 1998, similar to the method of Beamesderfer and Rieman (1991). The Schnabel estimates corrected for tag loss were compared statistically with the estimates assuming no tag loss, using the test for differences between Schnabel estimates (Chapman and Overton 1966).

Equal catchability was determined, in 1998, using the CAPTURE program's model selection procedure (Otis et al. 1978; White et al. 1982). CAPTURE had the ability to select the most "appropriate" of 11 different models, arranged to compensate for heterogeneity in capture probabilities (all animals not having equal probability of capture), based on the data set. The 11 models were as follows: M_o, the null model, which assumes no differences in capture probability among all animals; M_b, which accounts for differences in capture behavior of the organism; M_t, which deals with differences in capture methods or environmental conditions (day vs. night); M_h, which accounts for individual differences in capture probability (trap accessibility influenced by sex, territory, age, dominance, etc.); and all the possible combinations of models M_b, M_t, and M_h (Otis et al. 1978; White et al. 1982). All the models, excluding M_o, were designed to relax the assumption of equal catchability, because biological populations rarely follow mathematical rules (Otis et al. 1978; White et al. 1982).

Movements

Walleye movements, defined as the minimum distance between release and subsequent recapture locations, were estimated from biologist and angler reported recaptures. Only returns with specific dates and locations of recapture were included in the analysis. Walleye recaptured within 7 days of release were ignored for movement analysis. Movement (km) was estimated by measuring the shortest distance from the point of release to the location of recapture using the computer program Maptech®

(Greenland, NH). Movements were between release and subsequent recapture location were calculated for walleye tagged during the spawning run in the Spokane Arm each year and recaptured following the spawning run (after June 1st of their mark year), as well as walleye tagged in summer/fall of each year. Mean time (days) between mark and recapture was calculated for all of the walleye that were included in the movement analysis.

Movements of walleye recaptured on more than one occasion were analyzed separate from those recaptured on a single occasion. Movements of those walleye recaptured multiple times were divided into two groups for analysis; those marked on the spawning run and those marked during the summer/fall.

Age, Growth, Mortality, and Condition

In 1999, scales from five walleye per 1 cm length class were randomly selected for analysis, to ensure equal representation of all size classes. If fewer than five fish were collected in a length class, all the scale samples from fish in that specific length-class were analyzed. Ages were determined and total lengths (mm) were back-calculated according to the methods described by Devries and Frie (1996). Two individuals read all scales. If there was a disagreement about the age of a fish, the researchers discussed the scale until a consensus was reached.

The Fraser-Lee method was used to back-calculate the total length at each annulus formation. The equation for Fraser-Lee Method was (Devries and Frie 1996):

$$L_i = \left(\frac{L_c - a}{S_c}\right) S_i + a$$

where:

L_i	=	back-calculated TL of the fish at the formation of the i^{th} annulus,
L_c	=	TL of the fish at capture,
S_c	=	length from the focus to the outermost edge of the scale at capture,
S_i	=	length from focus of the scale to the outer edge of the i^{th} annulus, and
a	=	the Y-intercept of the body length vs. scale length regression line.

The standard intercept value of 55 was used in all back-calculations (Carlander 1983). Variations in intercept values calculated from the scale data in 1997 and 1998 made comparisons between years difficult (McLellan 1998; McLellan et al. 1998; McLellan 1999), therefore 1997 and 1998 scale data was re-analyzed using 55 as the intercept value.

An age-length key was created for the walleye aged in 1999, to assign ages to fish from which scales were not obtained or analyzed (Anderson and Neuman 1996). Age-frequency information derived from the age-length key was used to develop a catch-curve, according to the method in Ricker (1975). Instantaneous mortality (Z) was calculated via the Baranov method (Ricker 1975), where the absolute value of the slope of the regression line that described the descending limb of the catch-curve was multiplied by 2.3026. The age classes at the peak of the curve and represented by fewer than 10 individuals were not included in the calculation of the regression equation. Mean annual survival was calculated with the following formula (Ricker 1975):

$$S = e^{-Z}$$

where:

S	=	mean annual survival,
e	=	natural log constant (≈ 2.718), and
Z	=	instantaneous rate of mortality.

Mean annual mortality (A) was calculated with the formula A = 1-S (Ricker 1975). Mortality rates were estimated for the walleye collected in 1999.

Condition factors (K_{TL}) were calculated, for walleye collected in 1999, as an index of how Lake Roosevelt walleye added weight in relation to increasing length (Anderson and Neuman 1996). Condition factors were calculated using the following formula:

$$K_{TL} = \left(\frac{WT}{TL^3}\right) \times 10^5$$

where:

K_{TL}	=	condition factor based on total length,
WT	=	weight (g), and
TL	=	total length (mm).

Results

Abundance Estimates

Over the three study years, a total of 12,343 walleye ≥ 150 mm TL were collected by EWU, STI, and WDFW, and of those, 10,770 were tagged and released (Table 1). Of the 10,770 walleye marked and released, 775 were recaptured and returned to EWU (Table 2). Anglers recaptured the majority of the walleye returned to EWU (n=373; 49%; Table 2). There were 119 recaptures used in the calculation of the 1999 abundance estimates (Table 3). The 1999 abundance estimate (± standard error) for walleye ≥ 150 mm TL was 129,183 (± 45,578) and the estimated abundance (± standard error) of walleye ≥ 200 mm TL was 101,508 (± 35,603) (Table 3). Both estimates had CV values of 35%. Capture probabilities were 0.01 during all passes, except the second pass when the minimum TL was ≥ 200 mm the capture probability was 0.02.

The 1998 estimates were derived using a maximum of 5,503 walleye collected and 5,096 walleye tagged and released, during the 1998 study period (Table 4). There were a maximum of 56 recaptures used to generate the 1998 population estimates (Table 4). The number of walleye collected, tagged and released, and recaptured varied with each estimate as data from sampling occasions were pooled and adjustments were made to minimum sizes, for recruitment, and for tag loss (Tables 4 and 5).

A total of 38 population estimates were calculated for 1998. The estimates of the abundance of walleye ≥ 150 mm TL in Lake Roosevelt ranged from 84,335 to 180,568 fish (Table 6). Estimates of the size of the walleye population ≥ 200 mm TL ranged from 14,971 to 173,702 (Table 6). CV values ranged from 19 to 467%. Probabilities of capture ranged from 0.00 to 0.01 (Table 7).

Model Assumptions (1998)

The model assumptions of no recruitment (closed model), no tag loss, and equal capture probabilities were evaluated. There were no significant differences between the Schnabel estimates adjusted for recruitment and those without the adjustment (Table 8). The effect of recruitment on the estimates ranged from –720 to 27%, however all the differences, excluding the –720% value, were within 27%. However, we considered the adjusted estimates more accurate because we knew that walleye were growing into our size ranges during our study.

EWU and STI biologists examined 193 recaptures during the 1998 walleye study period, of which 7 had obvious tag scars, indicating a minimum tag loss rate of 3.6% (McLellan et al. 1999). Because only obvious tag scars were observed, total tag loss was estimated at 5%. There were no significant differences between the Schnabel estimates adjusted for 5% tag loss and those without the adjustment and the effect of tag loss on the Schnabel estimates ranged from 3 to 4% (Table 8).

Schnabel estimates adjusted for both recruitment and tag loss were not significantly different from Schnabel estimates that were not adjusted for either (Table 8). The combined effects of recruitment and tag loss on the Schnabel estimates ranged from 8 to 30%.

In all cases CAPTURE selected model M_{tb}, which indicated that there were time and behavioral effects on the capture probabilities. The capture probabilities of the fish that had never been captured were different than those of the fish that had been previously captured, and the capture probabilities of both groups varied over time. When the data was pooled to form three passes and the minimum size was 200 mm TL, CAPTURE indicated that the most appropriate model was probably M_{tb} or M_b, but CAPTURE suggested using model M_{tb}. Differences between Schnabel estimates and estimates corrected for time and behavioral effects on capture probabilities (CAPTURE model M_{tb}) ranged from –5 to 91%. The difference between the estimates calculated with CAPTURE model M_{tb}, when M_{tb} or M_b was appropriate, and its corresponding Schnabel was 91%.

Table 1. Data used to calculate the 1999 walleye abundance estimates for Lake Roosevelt.

	150 mm Total Length			200 mm Total Length		
Year	**No. Caught**	**No. Tagged**	**Recaptures**	**No. Caught**	**No. Tagged**	**Recaptures**
1997	3,720	3,404	0[a]	3,376	3,094	0[a]
1998	5,680	5,120	74	5,020	4,518	74
1999	2,943	2,246	45	2,888	2,224	45
Total	**12,343**	**10,770**	**119**	**11,284**	**9,836**	**119**

[a] There were walleye recaptured in 1997, but fish recaptured in the same pass that they were marked were excluded from the analysis.

Table 2. The number of recaptured walleye that were initially tagged and released in Lake Roosevelt by EWU and STI between 1997 and 1999.

	Number of Recaptures by Group or Agency							
	EWU	**SRAD[a]**	**GCWT[b]**	**STI**	**WDFW**	**Anglers[c]**	**Other[d]**	**Total**
Mark Year 1997								
1997	36	0	3	13	0	36	0	131
1998	44	3	20	14	0	93	0	174
1999	2	0	6	0	6	12	0	26
Total	82	3	29	27	6	141	0	331
Mark Year 1998								
1998	121	5	8	10	1	140	1	286
1999	13	0	14	0	5	36	1	69
Total	134	5	22	10	6	176	2	355
Mark Year 1999								
1999	13	0	3	5	12	43	0	76
Total	13	0	3	5	12	43	0	76
Grand Total	**229**	**8**	**54**	**42**	**24**	**360**	**2**	**762**

[a]Angling days conducted in the Spokane Arm during the 1997 and 1998 spawning runs, in conjunction with the Spokane Walleye Club (McLellan 1998; McLellan et al. 1998; McLellan et al. 1999).
[b]Walleye caught during the 1997, 1998, and 1999 Governor's Cup Walleye Tournaments.
[c]Voluntary tag returns from walleye recaptured by anglers. Does not include 13 returns that did not have adequate recapture data provided, such as date.
[d]Walleye tag returns from other agencies (1 from U.S. Geological Survey and 1 from Colville Tribal biologists).

Table 3. Estimates of walleye abundance in Lake Roosevelt, calculated in 1999, using each study year as a mark-recapture occasion.

Min. TL	N	S.E.	CV	Model
3 Passes				
150	129,183	45,578	0.35	Jolly-Seber
200	101,508	35,603	0.35	Jolly-Seber

Table 4. Data used to calculate the 1998 walleye abundance estimates for Lake Roosevelt, with no adjustments for recruitment or tag loss.

	150 mm Total Length			200 mm Total Length		
Pass	**No. Caught**	**No. Tagged**	**Recaptures**	**No. Caught**	**No. Tagged**	**Recaptures**
3 Passes						
1	2,166	2,036	0[a]	2,068	1,953	0[a]
2	1,990	1,807	20	1,565	1,404	19
3	1,342	1,253	30	1,211	1,141	21
Total	**5,498**	**5,096**	**50**	**4,844**	**4,498**	**40**
4 Passes						
1	2,166	2,036	0[a]	2,068	1,953	0[a]
2	1,990	1,807	20	1,565	1,404	19
3	1,029	946	26	917	852	18
4	318	307	9	299	289	8
Total	**5,503**	**5,096**	**55**	**4,849**	**4,498**	**45**
5 Passes						
1	2,166	2,036	0[a]	2,068	1,953	0[a]
2	1,990	1,807	20	1,565	1,404	19
3	1,029	946	26	917	852	18
4	238	229	8	232	224	7
5	80	78	1	67	65	1
Total	**5,503**	**5,096**	**55**	**4,849**	**4,498**	**45**

[a] There were walleye recaptured in Pass 1, but fish recaptured in the same pass that they were marked were excluded from the analysis.

Table 5. Data used to calculate the 1998 walleye abundance estimates for Lake Roosevelt, after the adjustment for recruitment.

	150 mm Total Length			200 mm Total Length		
Pass	**No. Caught**	**No. Tagged**	**Recaptures**	**No. Caught**	**No. Tagged**	**Recaptures**
3 Passes						
1	2,162	2,032	0[a]	2,068	1,953	0[a]
2	1,886	1,711	20	1,357	1,208	19
3	1,277	1,196	29	707	655	18
Total	**5,325**	**4,939**	**49**	**4,132**	**3,816**	**37**
4 Passes						
1	2,162	2,032	0[a]	2,068	1,953	0[a]
2	1,886	1,711	20	1,357	1,208	19
3	984	909	25	473	425	16
4	298	287	9	236	230	4
Total	**5,330**	**4,939**	**54**	**4,134**	**3,816**	**39**
5 Passes						
1	2,162	2,032	0[a]	2,068	1,953	0[a]
2	1,886	1,711	20	1,357	1,208	19
3	984	909	25	473	425	16
4	233	224	8	180	176	3
5	65	63	1	56	54	1
Total	**5,330**	**4,939**	**54**	**4,134**	**3,816**	**39**

[a] There were walleye recaptured in Pass 1, but fish recaptured in the same pass that they were marked were excluded from the analysis.

Table 6. Estimates of walleye abundance in Lake Roosevelt calculated using data collected during 1998.

Minimum TL	N	S.E.	CV	Model
3 Passes				
150	180,568	35,070	0.19	Schnabel
150	172,243[a]	33,978	0.20	Schnabel
150	170,511[b]	32,115	0.19	Schnabel
150	165,594[c]	31,984	0.19	Schnabel
150	174,212	785,806	4.51	CAPTURE M_{tb}
150	168,843[a]	788,855	4.67	CAPTURE M_{tb}
150	84,335	37,200	0.44	Jolly-Seber
4 Passes				
150	170,161	64,812	0.38	Schnabel
150	161,850[a]	63,424	0.39	Schnabel
150	164,264[b]	61,184	0.37	Schnabel
150	156,144[c]	59,797	0.38	Schnabel
150	133,459	153,867	1.15	CAPTURE M_{tb}
150	124,410[a]	141,902	1.14	CAPTURE M_{tb}
5 Passes				
150	170,488	190,230	1.12	Schnabel
150	162,115[a]	219,767	1.36	Schnabel
150	164,580[b]	177,297	1.08	Schnabel
150	156,399[c]	204,096	1.30	Schnabel
150	142,486	120,661	0.85	CAPTURE M_{tb}
150	168,844[a]	157,235	0.93	CAPTURE M_{tb}
3 Passes				
200	173,702	37,596	0.22	Schnabel
200	128,554[a]	32,846	0.26	Schnabel
200	165,594[b]	34,921	0.21	Schnabel
200	122,109[c]	30,309	0.25	Schnabel
200	14,971	26,887	1.80	CAPTURE M_{tb}
200	122,808[a]	363,054	2.96	CAPTURE M_{tb}
200	78,571	38,895	0.50	Jolly-Seber
4 Passes				
200	160,724	66,818	0.42	Schnabel
200	124,792[a]	57,211	0.46	Schnabel
200	153,996[b]	62,251	0.40	Schnabel
200	118,827[c]	52,687	0.44	Schnabel
200	158,257	237,957	1.50	CAPTURE M_{tb}
200	130,436[a]	178,244	1.37	CAPTURE M_{tb}
5 Passes				
200	161,050	232,652	1.44	Schnabel
200	125,038	199,768	1.60	Schnabel
200	154,308	212,847	1.38	Schnabel
200	119,061	180,161	1.51	Schnabel
200	130,383	132,406	1.02	CAPTURE M_{tb}
200	95,347	92,120	0.97	CAPTURE M_{tb}

[a]Adjusted for recruitment.
[b]Adjusted for 5% tag loss.
[c]Adjusted for both recruitment and 5% tag loss.

Table 7. Estimated capture probabilities of walleye for each pass. The capture probabilities were calculated using the M_t model in CAPTURE, because the probabilities changed over time and all the models used for the abundance estimates were robust to variations in capture probability over time.

	1998 Estimates		1998
Pass	**150 mm TL**	**200 mm TL**	**Spawners**
3 Passes			
1	0.01	0.01	0.02
2	0.01	0.01	0.04
3	0.01	0.01	0.03
4 Passes			
1	0.01	0.01	0.01
2	0.01	0.01	0.04
3	0.01	0.01	0.03
4	0.00	0.00	0.02
5 Passes			
1	0.01	0.01	0.01
2	0.01	0.01	0.03
3	0.01	0.01	0.03
4	0.00	0.00	0.02
5	0.00	0.00	0.01

Table 8. Comparisons of Schnabel estimates with and without adjustments for recruitment and 5% tag loss (α = 0.05).

Tests	Z Value	P Value
3 Passes		
150 mm TL		
Schnabel vs. Schnabel[a]	-0.33	0.74
Schnabel vs. Schnabel[b]	-0.39	0.70
Schnabel vs. Schnabel[c]	-0.54	0.59
Schnabel[a] vs. Schnabel[c]	-0.30	0.76
200 mm TL		
Schnabel vs. Schnabel[a]	-1.43	0.15
Schnabel vs. Schnabel[b]	-0.33	0.74
Schnabel vs. Schnabel[c]	-1.69	0.09
Schnabel[a] vs. Schnabel[c]	-0.34	0.73
4 Passes		
150 mm TL		
Schnabel vs. Schnabel[a]	-0.26	0.79
Schnabel vs. Schnabel[b]	-0.28	0.78
Schnabel vs. Schnabel[c]	-0.55	0.58
Schnabel[a] vs. Schnabel[c]	-0.38	0.70
200 mm TL		
Schnabel vs. Schnabel[a]	-1.26	0.21
Schnabel vs. Schnabel[b]	-0.31	0.76
Schnabel vs. Schnabel[c]	-1.50	0.13
Schnabel[a] vs. Schnabel[c]	-0.34	0.73
5 Passes		
150 mm TL		
Schnabel vs. Schnabel[a]	-0.36	0.72
Schnabel vs. Schnabel[b]	-0.28	0.78
Schnabel vs. Schnabel[c]	-0.55	0.58
Schnabel[a] vs. Schnabel[c]	-0.29	0.77
200 mm TL		
Schnabel vs. Schnabel[a]	-1.26	0.21
Schnabel vs. Schnabel[b]	-0.31	0.75
Schnabel vs. Schnabel[c]	-1.50	0.13
Schnabel[a] vs. Schnabel[c]	-0.34	0.73

[a]Adjusted for recruitment.
[b]Adjusted for 5% tag loss.
[c]Adjusted for both recruitment and 5% tag loss.

Movements

Of the walleye marked on the spawning run in the Spokane Arm during 1997, there were 13 recaptured in 1997 and 5 recaptured in 1998 (Table 9). Three of the fish recaptured in 1997 were collected outside of the Spokane Arm, 2 downstream and 1 upstream. The mean minimum distance traveled by walleye marked on the 1997 spawning run and subsequently recaptured in 1997 following spawning was 35 km (range: 0 to 147 km) over a mean time of 35 days (range: 11 to 114 days) (Table 9). All five of the walleye marked on the 1997 spawning run that were recaptured in 1998, were caught in the Spokane Arm within 15 km of their mark location and a mean 333 days later (range: 311 to 372 days) (Table 9).

A total of 80 walleye that were marked on the spawning run during 1998 were subsequently recaptured following the spawning run: 59 in 1998 and 21 in 1999. Forty-five (76%) of the walleye collected in 1998 remained in the Spokane Arm (Table 10). The other 14 walleye migrated out of the Spokane Arm, with 10 (17%) moving upstream and 4 (7%) moving downstream (Table 10). Of the 21 fish recaptured in 1999, thirteen (62%) were captured in the Spokane Arm and eight (38%) were upstream of the Spokane Arm (Table 10). The mean distance between the mark and recapture locations of the 1998 spawners was 39 km in 1998 and 57 km in 1999 (Table 10). The mean time between the mark and recapture of the 1998 spawners collected in 1998 and in 1999 was 60 days and 408 days, respectively (Table 10).

Six walleye marked on the spawning run in 1999 were recaptured following the spawning run. Two (33%) were collected in the Spokane Arm and four (67%) were collected outside (Table 11). Three of the four fish that migrated out of the Spokane Arm were recaptured a mean distance of 172 km upstream from their mark location (Table 11). The mean time between the mark and recapture of the 1999 spawners was 80 days (Table 11).

Walleye marked during the summer/fall of 1997 were recaptured in 1997 (n=92), 1998 (n=120), and 1999 (n=12). The majority of walleye marked and recaptured during the summer/fall of 1997 were recaptured in the same place that they were marked (n=66; 68%) and the same number of fish moved upstream as downstream (Table 12). The minimum distances traveled between mark and recapture in 1997 averaged 2 km and ranged from 0 to 36 km within a range of 8 to 147 days (n=92) (Table 12). Most of the walleye marked in 1997 and recaptured in 1998 moved from their marking location and approximately the same number of fish moved upstream (n=43; 36%) as downstream (n=47; 39%) (Table 12). The minimum distances traveled between the 1997 mark location and the 1998 recapture location averaged 26 km and ranged from 0 to 208 km (n=120) (Table 12). In 1999, few of the walleye that were marked in 1997 were recaptured in the same location. Most walleye marked in 1997 and recaptured in 1999 moved upstream (n=13; 59%) (Table 12). The minimum distances traveled between the 1997 mark location and the 1999 recapture location averaged 30 km and ranged from 0 to 115 km (n=22) (Table 12). The mean minimum distances traveled between the mark and recapture locations were 2, 26, and 30 km in 1997, 1998, and 1999 (Table 12). The mean time between the mark and recapture of the walleye marked in the summer/fall of 1997 was 28 days in 1997, 309 days in 1998, and 701 days in 1999 (Table 12).

The majority of the walleye marked during the summer/fall of 1998 and recaptured in 1998 had moved upstream (n=22; 34%) or downstream (n=26; 41%) from their mark location (Table 13). Walleye marked in 1998 and recaptured in 1999 were typically caught at locations upstream (n=19; 47%) or downstream (n=12; 30%) of their initial mark location (Table 13). The mean minimum distances traveled between the mark and recapture locations were 21 and 22 km in 1998 and 1999 (Table 13). The mean time between the mark and recapture of the walleye marked in the summer/fall of 1998, was 38 days in 1998 and 356 days in 1999 (Table 13).

Most walleye marked in the summer/fall of 1999 and subsequently recaptured in 1999 moved either upstream (n=13; 23%) or downstream (n=27; 59%) of their mark location (Table 14). The mean minimum distances traveled between the mark and recapture locations of walleye marked and recaptured in 1999 averaged 14 km and ranged from 0 to 103 km (Table 14). The mean time between the mark and recapture of the walleye marked in the summer/fall of 1999 was 29 days (Table 14).

One walleye that was tagged on the spawning run in 1997 was recaptured on two subsequent occasions over a period of 382 days, and it traveled a minimum of 2 km from its mark location (Table 15). There were six walleye tagged on the spawning run in 1998 that were recaptured on two subsequent occasions (Table 15). The mean minimum distance traveled between the initial mark location and the final mark location, via the intermediate recapture site, was 40 km over a mean of 220 days (Table 15).

Sixteen walleye that were marked during the summer/fall of 1997 were recaptured on more than one occasion between 1997 and 1999. The 16 walleye moved a mean minimum distance of 25 km between their mark and final recapture location over a mean time of 340 days (Table 15). One walleye marked in the summer of 1998 was recaptured on two separate occasions, with the final occasion occurring 138 km from the mark location, 370 days later (Table 15).

The majority of walleye marked on the spawning run and recaptured were recaptured within 24.9 km of their marking location (n=66; 63%), regardless of the amount of time between the mark and recapture events (Figure 2). Similarly, most walleye marked during the summer/fall were recaptured within 24.9 km of the mark location (n=308; 80%) (Figure 3). More walleye marked during summer/fall moved 25 km or more from their mark location in 1998 (n=16; 25%) when compared to 1997 (n=1; 1%) and 1999 (n=8; 17%) (Figure 3).

In general, walleye from all tagging years and groups were recaptured in the vicinity of where they were marked (Tables 16 through 26). Of the walleye marked on the spawning run in 1997 and 1998, the majority were recaptured in the Spokane Arm (Tables 16 through 19). Most of the recaptures of walleye marked on the 1999 spawning, occurred in the upper reservoir, north of section 8 (Table 20). The majority of recaptures of walleye marked during the summer/fall were recaptured near Spokane Arm (sections S1, S2, and S3), Kettle Falls (sections 8 and 9), and Hawk Creek (section H) (Tables 21 through 26).

Table 9. Mean distances between mark and recapture locations (± standard deviation) and direction of movements of walleye tagged in Lake Roosevelt during the spawn, 1997.

	n	Mean Distance (km)	Range (km)	Mean Time (days)	Range (days)
1997					
Upstream	1	147 (n/c)	147	35 (n/c)	35
Downstream	2	74 (± 65)	28 - 120	28 (± 8)	22 - 33
Spokane Arm	10	16 (± 10)	0 - 29	44 (± 31)	11 - 114
Total	13	35 (± 45)	0 - 147	35 (± 45)	11 - 114
1998					
Upstream					
Downstream					
Spokane Arm	5	11 (± 6)	2 - 15	333 (± 23)	311 - 372
Total	5	11 (± 6)	2 - 15	333 (± 23)	311 - 372
Grand Total	18	28 (± 39)	0 - 147	122 (± 137)	11 - 372

Table 10. Mean distances between mark and recapture locations (± standard deviation) and direction of movements of walleye tagged in Lake Roosevelt during the spawn, 1998.

	n	Mean Distance (km)	Range (km)	Mean Time (days)	Range (days)
1998					
Upstream	10	147 (± 64)	49 - 245	96 (± 51)	36 - 186
Downstream	4	71 (± 19)	48 - 94	67 (± 25)	39 - 91
Spokane Arm	45	13 (± 11)	0 - 38	51 (± 24)	14 - 115
Total	59	39 (± 58)	0 - 245	60 (± 34)	14 - 186
1999					
Upstream	8	140 (± 34)	80 - 200	448 (± 24)	417 - 486
Downstream					
Spokane Arm	13	5 (± 7)	0 - 18	383 (± 24)	344 - 425
Total	21	57 (± 70)	0 - 200	408 (± 40)	344 - 486
Grand Total	80	44 (± 62)	0 - 245	151 (± 158)	14 - 486

Table 11. Mean distances between mark and recapture locations (± standard deviation) and direction of movements of walleye tagged in Lake Roosevelt after the spawn, 1999.

	n	Mean Distance (km)	Range (km)	Mean Time (days)	Range (days)
1999					
Upstream	3	172 (± 45)	125 - 215	79 (± 58)	43 - 146
Downstream	1	78 (n/c)	78	34 (n/c)	34
Spokane Arm	2	10 (± 8)	5 - 15	105 (± 42)	75 - 135
Total	6	102 (± 85)	5 - 215	80 (± 49)	34 - 146

Table 12. Mean distances between mark and recapture locations (± standard deviation) and direction of movements of walleye tagged in Lake Roosevelt during the summer and fall, 1997.

	n	Mean Distance (km)	Range (km)	Mean Time (days)	Range (days)
1997					
Upstream	13	6 (± 4)	2 - 15	27 (± 17)	8 - 49
Downstream	13	8 (± 10)	4 - 36	42 (± 37)	10 - 147
No Movement	66	0	0	25 (± 15)	8 - 89
Total	92	2 (± 5)	2 - 36	28 (± 20)	8 - 147
1998					
Upstream	43	39 (± 53)	1 - 208	312 (± 51)	191 - 402
Downstream	47	32 (± 42)	0 - 137	297 (± 65)	155 - 419
No Movement	30	0	0	322 (± 51)	233 - 411
Total	120	26 (± 44)	0 - 208	309 (± 57)	155 - 419
1999					
Upstream	13	49 (± 45)	2 -115	688 (± 61)	565 - 788
Downstream	7	4 (± 3)	2 -11	718 (± 57)	639 - 788
No Movement	2	0	0	723 (± 6)	718 - 727
Total	22	30 (± 42)	0 -115	701 (± 58)	565 - 788
Grand Total	**234**	**17 (± 36)**	**0 - 208**	**235 (± 207)**	**8 - 788**

Table 13. Mean distances between mark and recapture locations (± standard deviation) and direction of movements of walleye tagged in Lake Roosevelt during the summer and fall, 1998.

	n	Mean Distance (km)	Range (km)	Mean Time (days)	Range (days)
1998					
Upstream	22	40 (± 50)	1 - 217	45 (± 26)	14 - 105
Downstream	26	17 (± 30)	1 -142	32 (± 15)	15 - 85
No Movement	16	0	0	41 (± 35)	18 - 159
Total	64	21 (± 38)	0 - 217	38 (± 25)	14 - 159
1999					
Upstream	19	21 (± 25)	1 - 88	350 (± 36)	250 - 406
Downstream	12	40 (± 58)	2 - 187	353 (± 50)	232 - 414
No Movement	9	0	0	371 (± 34)	319 - 422
Total	40	22 (± 38)	0 - 187	356 (± 40)	232 - 422
Grand Total	**104**	**21 (± 38)**	**0 - 217**	**161 (± 158)**	**14 - 422**

Table 14. Mean distances between mark and recapture locations (± standard deviation) and direction of movements of walleye tagged in Lake Roosevelt during the summer and fall, 1999.

	n	Mean Distance (km)	Range (km)	Mean Time (days)	Range (days)
1999					
Upstream	13	23 (± 31)	1 - 103	46 (± 38)	8 - 111
Downstream	27	13 (± 13)	2 - 45	19 (± 14)	8 - 57
No Movement	6	0	0	39 (± 34)	18 - 107
Total	46	14 (± 20)	0 - 103	29 (± 28)	8 - 111

Table 15. Mean total distances and times between the initial mark and the final recapture locations (± standard deviation) of walleye tagged in Lake Roosevelt and recaptured on more than one occasion between 1997 and 1999.

Year Marked	n	Mean Distance (km)	Range (km)	Mean Time (days)	Range (days)
Spawn					
1997	1	2 (n/c)	2	382 (n/c)	382
1998	6	46 (± 44)	13 - 132	193 (± 183)	45 - 428
Total	7	40 (± 43)	2 - 132	220 (± 182)	45 - 428
Summer/Fall					
1997	16	25 (± 48)	0 - 148	340 (± 166)	48 - 724
1998	1	138 (n/c)	138	370 (n/c)	370
Total	17	32 (± 54)	0 - 148	342 (± 161)	48 - 724

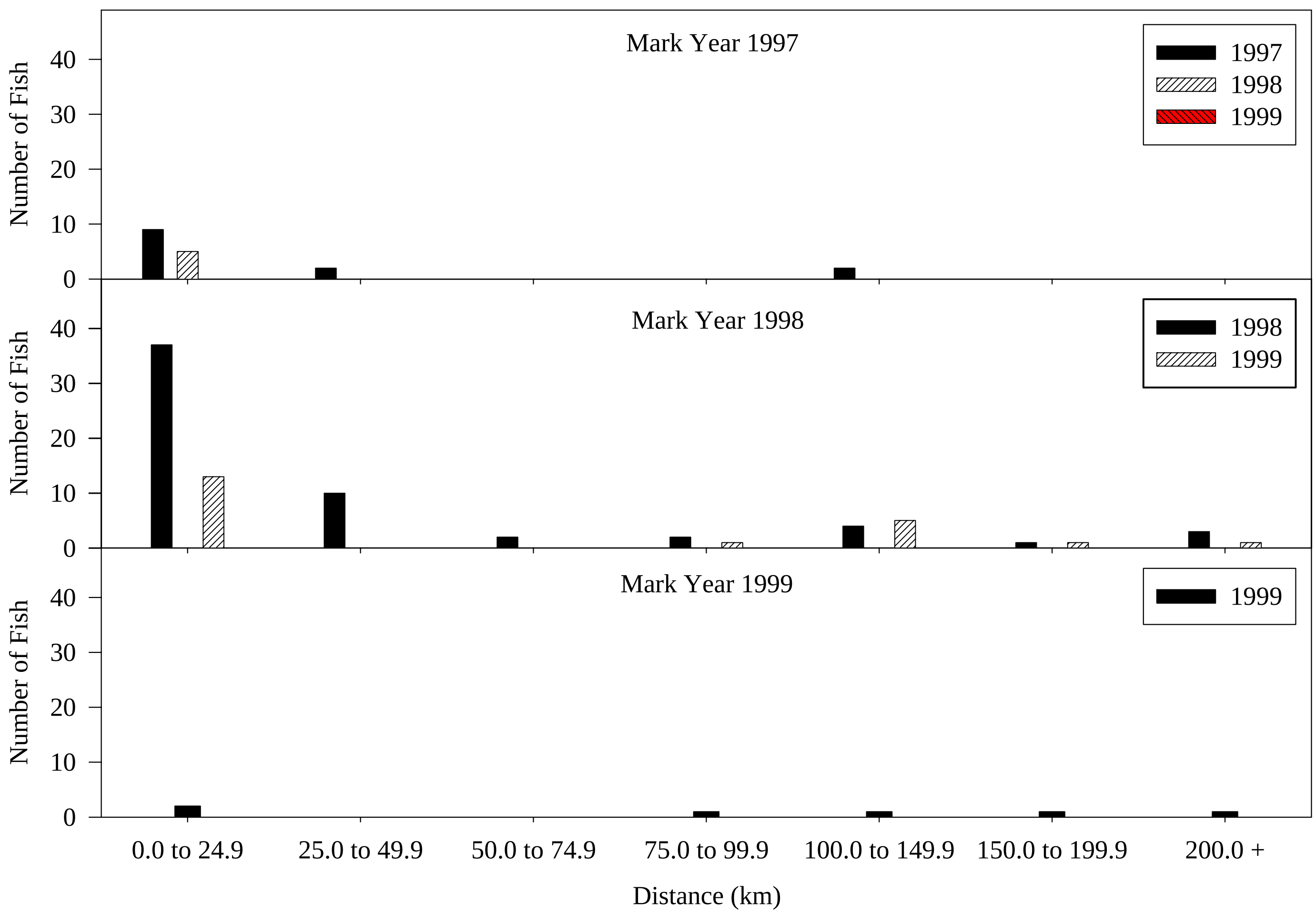

Figure 2. The number of walleye marked on the spawning run that were recaptured within specified distances from the mark location in Lake Roosevelt.

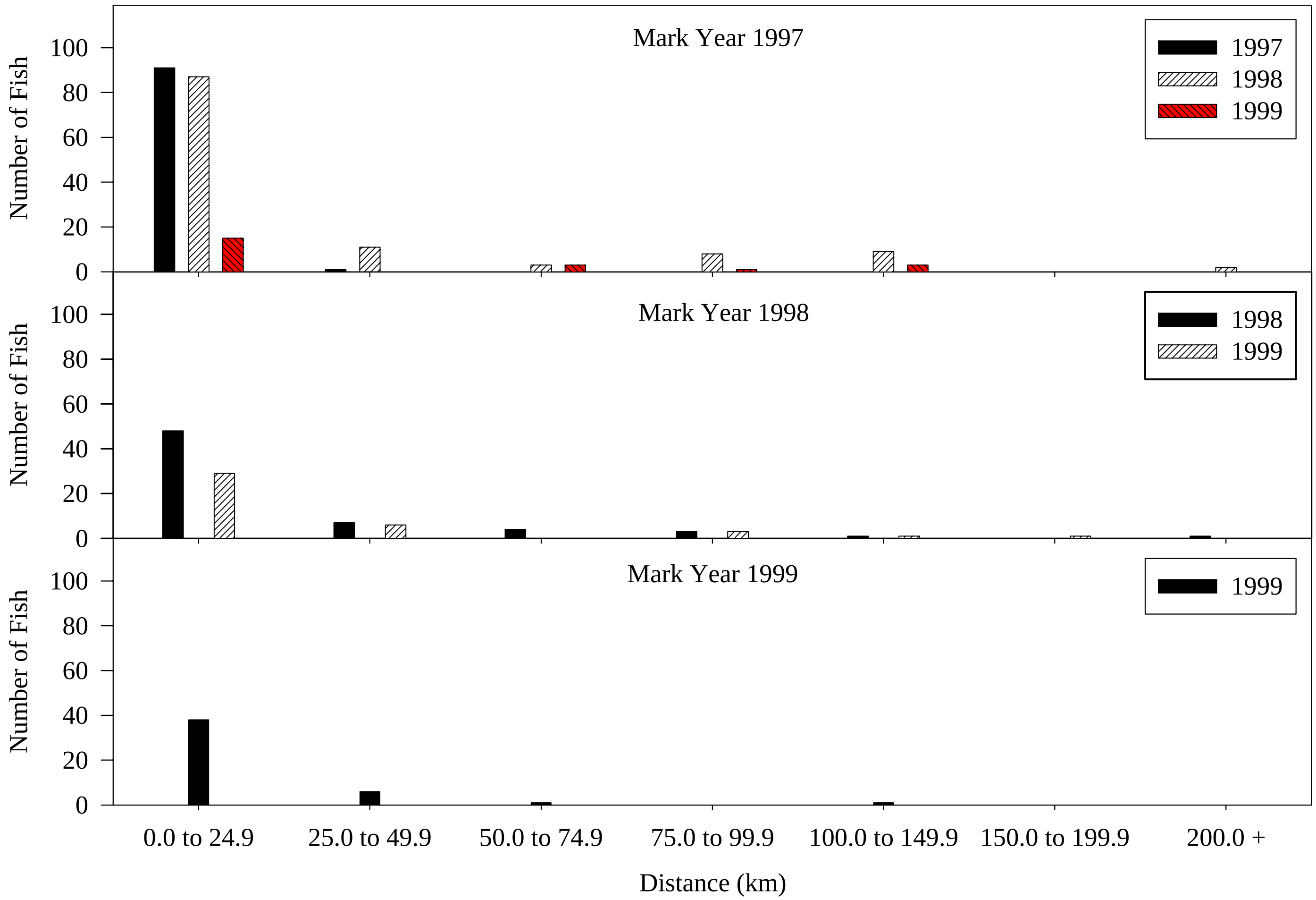

Figure 3. The number of walleye marked in the summer/fall that were recaptured within specified distances from the mark location in Lake Roosevelt.

Table 16. Recapture locations, in relation to mark location, of walleye marked during the spawn of 1997 and recaptured in 1997. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	Recapture Location																			
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
S1																				
S2	1						1	3	**2**	2							1			10
S3								1	1	**1**										3
Total							1	4	3	3							1			13

Table 17. Recapture locations, in relation to mark location, of walleye marked during the spawn of 1997 and recaptured in 1998. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	Recapture Location																			
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
S1																				
S2										3										3
S3									1	**1**										2
Total									1	4										5

Table 18. Recapture locations, in relation to mark location, of walleye marked during the spawn of 1998 and recaptured in 1998. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	Recapture Location																			
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
S1								**5**												5
S2								1	**4**											5
S3			1	1	1		2	12	12	**11**	1			3	1			1	3	49
Total			1	1	1		2	12	12	11	1			3	1			1	3	59

Table 19. Recapture locations, in relation to mark location, of walleye marked during the spawn of 1998 and recaptured in 1999. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	Recapture Location																		
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
S1							1													1
S2									**1**						1					2
S3									3	**9**		1		2	2		2		1	20
Total							1		4	9		1		2	3		2		1	23

Table 20. Recapture locations, in relation to mark location, of walleye marked during the spawn of 1999 and recaptured in 1999. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	Recapture Location																		
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
S1																				
S2																				
S3			1						1	**1**				1			1		1	6
Total			1						1	1				1			1		1	6

Table 21. Recapture locations, in relation to mark location, of walleye marked during the summer and fall of 1997 and recaptured in 1997. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	**Recapture Location**																			
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
1																				
2																				
SP																				
3																				
H						**16**		1												17
4																				
S1								**5**	2											7
S2								3	**5**	1										9
S3										**10**										10
5											**9**									9
6												**5**								6
7																				
8													2	**20**	3					25
9														3	**6**					9
K																				
10																				
NP																				
Total						16		9	7	11	9	5	2	23	9					92

Table 22. Recapture locations, in relation to mark location, of walleye marked during the summer and fall of 1997 and recaptured in 1998. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	**Recapture Location**																			
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
1																				
2						1				2										3
SP				**1**				1	1										1	4
3														1						1
H						**11**	1	1									1			14
4																				
S1								**2**	2											4
S2								4	**5**							1				11
S3								2	4	**10**									1	17
5							1					2		1						4
6							2				1	**8**					1			12
7													**4**							4
8								4	1	3				**22**	8	1	1			40
9							1			1			1	1			1		1	6
K																				
10																				
NP																				
Total				1		12	5	14	13	16	1	11	5	25	8	2	4		3	120

Table 23. Recapture locations, in relation to mark location, of walleye marked during the summer and fall of 1997 and recaptured in 1999. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	Recapture Location																			
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
1																				
2																				
SP																				
3																				
H						**1**														1
4																				
S1																				
S2																				
S3										**1**										1
5															1		2	1		4
6														1	1					2
7																				
8														**3**	5					8
9														1	**5**					6
K																				
10																				
NP																				
Total						1				1				5	12		2	1		22

Table 24. Recapture locations, in relation to mark location, of walleye marked during the summer and fall of 1998 and recaptured in 1998. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	**Recapture Location**																		
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
1							1													1
2																				
SP				**3**																3
3																				
H						**16**											1		1	18
4							**2**	1												3
S1								**1**												1
S2								2	**3**											5
S3								1	1	**1**										3
5											**1**				1					2
6											1	**3**								4
7													**2**				1			3
8											2			**4**	1		1		3	11
9				1									2	1	**1**	1		1	1	8
K																**1**				1
10																				
NP																				
Total				4			3	5	4	1	4	3	4	5	3	2	2	1	4	64

Table 25. Recapture locations, in relation to mark location, of walleye marked during the summer and fall of 1998 and recaptured in 1999. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	**Recapture Location**																		
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
1																				
2																				
SP				**1**																1
3																				
H						**3**		1												4
4								1												1
S1								**1**	1											2
S2	1								**2**				1							4
S3									1	**1**										2
5																				
6												**1**					1			2
7															1		2			3
8														**5**		1	1			7
9														1	**5**	3	1			10
K												1			1					2
10																				
NP										1										1
Total	1			1		3		3	4	2		2	1	6	7	4	5			40

Table 26. Recapture locations, in relation to mark location, of walleye marked during the summer and fall of 1999 and recaptured in 1999. NP represents the Columbia River between the upstream end Section 10 and the International Border. BC represents the Columbia River upstream of the International Border.

Mark Loc.	Recapture Location																			
	RW	**1**	**2**	**SP**	**3**	**H**	**4**	**S1**	**S2**	**S3**	**5**	**6**	**7**	**8**	**9**	**K**	**10**	**NP**	**BC**	**Total**
1																				
2																				
SP																				
3																				
H						**2**														2
4																				
S1																				
S2																				
S3																				
5																				
6																				
7														1						1
8														**5**	1					6
9													3	6	**10**	3		1		23
K																				
10														2	4	1	**5**		2	14
NP																				
Total						2							3	14	15	4	5	1	2	46

Age, Growth, Mortality, and Condition

Walleye collected in Lake Roosevelt in 1999 ranged in age from 0 to 8 (Figure 4). Back-calculated TL's (mm) at the formation of each annulus were determined for data collected in 1999 (Table 27). Mean back-calculated total lengths at each age were recalculated for walleye collected in 1998 and 1997 (Tables 28 and 29). Mean instantaneous and mean annual mortality were estimated at 0.62% and 46%, using the catch-curve (Figure 5). Mean K_{TL} of the 343 walleye measured and weighed in 1999 was 0.83 (SD = 0.13).

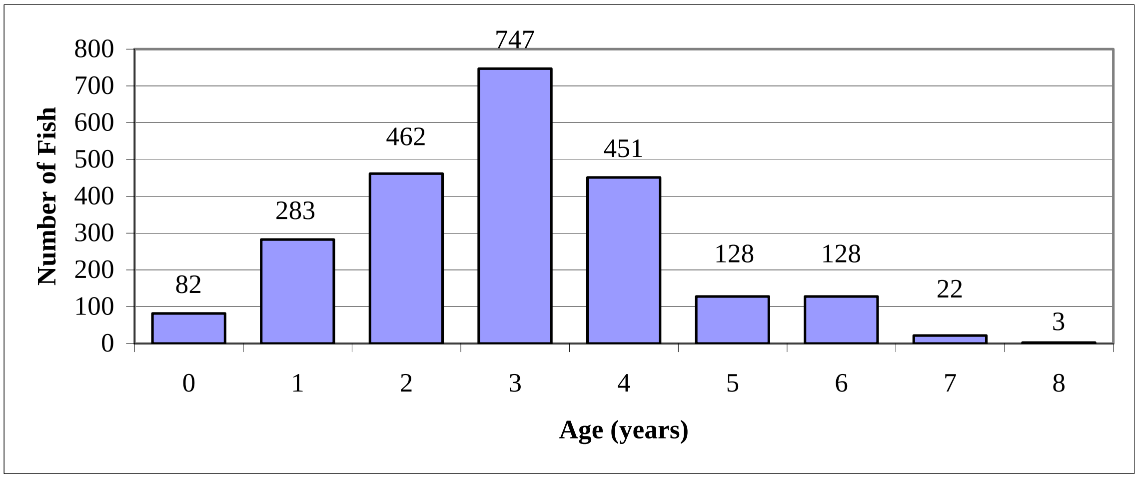

Figure 4. Age-frequency distribution of walleye collected in Lake Roosevelt in 1999.

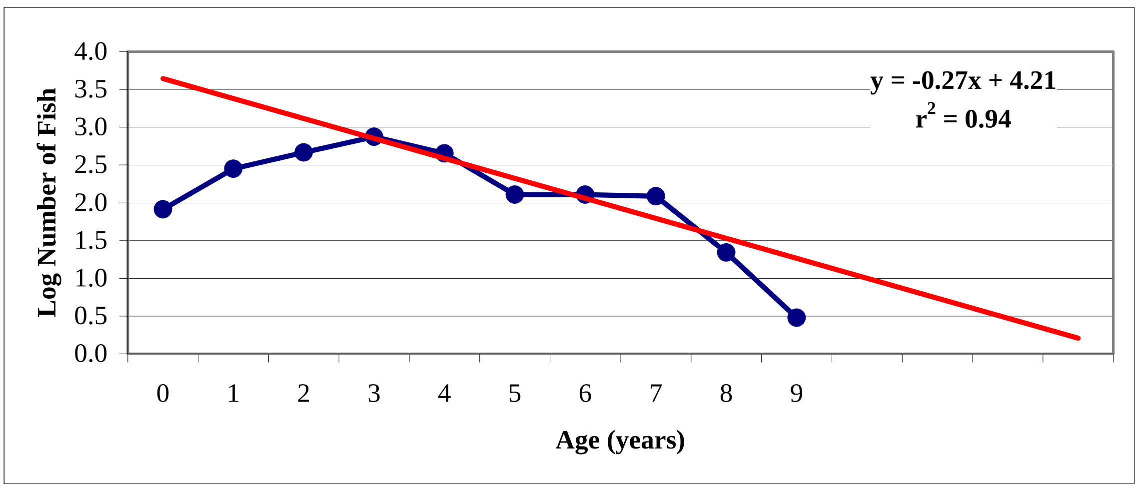

Figure 5. Catch-curve of walleye collected in Lake Roosevelt in 1999 and the regression line that described the descending arm.

Table 27. Mean back-calculated total lengths (± standard deviation) at the formation of each annulus for walleye collected in Lake Roosevelt during 1999.

		Mean Total Length (mm) at the Formation of Each Annulus							
Cohort	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1998	37	190 (± 22)							
1997	22	185 (± 22)	306 (± 26)						
1996	27	186 (± 19)	308 (± 27)	378 (± 37)					
1995	24	175 (± 24)	288 (± 28)	368 (± 31)	423 (± 33)				
1994	20	193 (± 29)	300 (± 41)	375 (± 45)	426 (± 47)	476 (± 46)			
1993	29	188 (± 24)	299 (± 31)	378 (± 38)	426 (± 36)	472 (± 41)	511 (± 46)		
1992	11	201 (± 25)	302 (± 44)	380 (± 48)	438 (± 46)	491 (± 45)	534 (± 46)	576 (± 42)	
1991	1	212 (nc)	317 (nc)	375 (nc)	428 (nc)	467 (nc)	532 (nc)	604 (nc)	643 (nc)
Grand Mean	171	188 (± 24)	301 (± 32)	375 (± 38)	427 (± 39)	476 (± 43)	518 (± 46)	578 (± 41)	643 (nc)
Mean Annual Growth		188 (± 24)	114 (± 24)	76 (± 24)	52 (± 13)	48 (± 16)	41 (± 16)	44 (± 14)	39 (nc)

nc=not calculable.

Table 28. Mean back-calculated total lengths (± standard deviation) at the formation of each annulus for walleye collected in Lake Roosevelt during 1998.

		Mean Total Length (mm) at the Formation of Each Annulus												
Cohort	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1997	71	162 (± 37)												
1996	31	172 (± 26)	277 (± 40)											
1995	35	166 (± 18)	270 (± 31)	339 (± 31)										
1994	25	165 (± 19)	280 (± 33)	350 (± 37)	402 (± 37)									
1993	24	192 (± 39)	292 (± 48)	361 (± 48)	415 (± 50)	455 (± 54)								
1992	33	188 (± 21)	302 (± 36)	378 (± 41)	434 (± 45)	479 (± 47)	518 (± 52)							
1991	26	197 (± 26)	299 (± 38)	375 (± 49)	435 (± 53)	490 (± 48)	532 (± 49)	571 (± 47)						
1990	26	196 (± 20)	303 (± 36)	373 (± 43)	431 (± 47)	480 (± 52)	525 (± 54)	563 (± 55)	599 (± 51)					
1989	10	196 (± 24)	308 (± 36)	374 (± 54)	435 (± 49)	489 (± 48)	531 (± 50)	571 (± 56)	603 (± 60)	633 (± 68)				
1988	13	204 (± 24)	292 (± 37)	369 (± 42)	446 (± 44)	499 (± 45)	555 (± 39)	602 (± 40)	644 (± 45)	684 (± 44)	716 (± 42)			
1987	5	203 (± 18)	310 (± 20)	385 (± 35)	444 (± 41)	500 (± 54)	543 (± 55)	582 (± 55)	626 (± 64)	667 (± 64)	704 (± 64)	731 (± 60)		
1986	1	225 (nc)	327 (nc)	394 (nc)	449 (nc)	510 (nc)	550 (nc)	598 (nc)	666 (nc)	713 (nc)	754 (nc)	781 (nc)	808 (nc)	
1985	2	200 (± 2)	308 (± 21)	374 (± 17)	442 (± 22)	482 (± 27)	554 (± 15)	624 (± 24)	674 (± 25)	709 (± 12)	744 (± 26)	772 (± 30)	798 (± 31)	829 (± 22)
Grand Mean	302	179 (± 31)	290 (± 39)	364 (± 43)	427 (± 47)	481 (± 50)	530 (± 50)	576 (± 51)	616 (± 55)	667 (± 59)	717 (± 48)	748 (± 36)	801 (± 23)	829 (± 22)
Mean Annual Growth		179 (± 31)	106 (± 29)	72 (± 21)	58 (± 19)	49 (± 15)	44 (± 13)	41 (± 12)	38 (± 13)	37 (± 10)	34 (± 9)	28 (± 5)	26 (± 1)	32 (± 9)

nc=not calculable.

Table 29. Mean back-calculated total length (mm), ± standard deviation, at the formation of each annulus for walleye collected in Lake Roosevelt, 1997.

Cohort	n	Mean Total Length (mm) at Annulus Formation							
		1	2	3	4	5	6	7	8
1996	1,051	175 (± 21)							
1995	688	167 (± 21)	273 (± 30)						
1994	290	167 (± 24)	282 (± 33)	359 (± 37)					
1993	183	177 (± 25)	286 (± 33)	361 (± 39)	418 (± 42)				
1992	108	179 (± 18)	294 (± 28)	372 (± 33)	428 (± 37)	472 (± 43)			
1991	31	190 (± 19)	295 (± 26)	377 (± 36)	438 (± 32)	487 (± 38)	527 (± 44)		
1990	4	186 (± 11)	307 (± 34)	416 (± 40)	473 (± 54)	527 (± 70)	571 (± 86)	607 (± 103)	
1989	2	197 (± 44)	301 (± 69)	381 (± 62)	470 (± 59)	540 (± 58)	589 (± 63)	637 (± 67)	662 (± 66)
Grand Mean	2,355	172 (± 22)	279 (± 32)	363 (± 37)	424 (± 40)	478 (± 44)	535 (± 52)	617 (± 87)	662 (± 66)
Mean Annual Growth		172 (± 22)	109 (± 25)	77 (± 21)	57 (± 17)	46 (± 16)	41 (± 15)	40 (± 17)	24 (± 1)

Discussion

The two estimates of walleye abundance calculated in 1999, were within the range of estimates calculated in 1998 using open and closed models. Despite the similarities, there were some concerns that using each year as a sampling occasion resulted in biased estimates. The first indicator of bias was related to the time that the estimate applied to. Since the timing of the 1999 abundance estimates calculated with the Jolly-Seber model were for the beginning of the second to last sampling occasion (April 1998), it was expected that the estimated abundance should have been closest to the 1998 estimates calculated with the closed estimator. The values calculated in 1999 were closer to those calculated with the Jolly-Seber model in 1998, which estimated the size of the population on June 12th, 1998.

The 1999 estimates also failed to meet the assumption that all of the fish alive in the population had the same probability of capture on each sampling occasion. The assumption required that fish that left the study area did not return during the study period (Pollock et al. 1990). Portions of the Lake Roosevelt walleye population migrate out of the study area following spawning and return the next year, violating the assumption (Hall 1985; Hildebrand et al. 1995). The method may be used if the sampling were confined to a single limited time period each year when the same aspect of the population would always be sampled. For example, the spawning run would be an opportune time to sample, because it is the only known spawning area in the reservoir and the entire spawning population would be available for capture. If sampling were to be conducted only during the spawning run, the corresponding abundance estimate would apply to the sexually mature aspect of the Lake Roosevelt walleye population, which was also likely the portion of the population responsible for kokanee and rainbow trout predation due to their size. Factors that need to be determined before establishing an annual mark-recapture population estimate strategy on the spawning run are spawning frequency, onset of senescence, and effects of electrofishing on walleye eggs and larvae. If sexually mature walleye in Lake Roosevelt do not spawn every year or reach senescence, then the assumption of equal capture probability would be violated. Electrofishing has been determined to have detrimental effects on walleye eggs (Newman and Stone 1992) and razorback sucker (*Xyrauchen texanus*) embryos (Muth and Ruppert 1997).

Of the 38 estimates of walleye abundance calculated from the 1998 data, there were four estimates that were probably the most accurate, precise, and unbiased. Two of the four estimates were the Schnabels of each minimum size, that were calculated with the data pooled into three passes and adjusted for recruitment and 5% tag loss. The other two estimates were the Jolly-Seber estimates of each minimum size, calculated with the data pooled into three passes.

Despite the fact that there were no significant differences between the Schnabel estimates with and without the adjustments for recruitment and tag loss, the adjusted estimates were considered the most accurate and unbiased due to the likely occurrence of recruitment and evidence of tag loss. The Jolly-Seber estimates were considered unbiased by recruitment and tag loss because the model accounts for recruitment, and tag loss was estimated to be low (5%). Arnason and Mills (1981) demonstrated that low levels of tag loss (≤ 20%) had no effect on estimates of fish abundance calculated with the Jolly-Seber model, except that precision may have been reduced.

The two estimates recommended for modeling walleye consumption were the estimates calculated with the 200 mm minimum length, because the predatory impact of walleye < 200 mm TL on hatchery kokanee or rainbow trout was likely minimal. Walleye in Lake Roosevelt generally preyed on salmonids that were less than 50% of their total length (C. Baldwin, WDFW, personal communication). Kokanee and rainbow trout released into Lake Roosevelt were typically larger than 100 mm TL (WDFW and STI, unpublished hatchery records).

Despite the indication of time and behavioral differences in capture probabilities by the model selection procedure of CAPTURE, the two recommended models were still considered the most unbiased. Both the Schnabel and Jolly-Seber models were robust to time variation in capture probabilities, however, unequal capture probabilities due to behavior would have biased their estimates (Otis et al. 1978; Begon 1979; White et al. 1982; Pollock et al. 1990). The effects of a behavioral response to capture were determined to be negligible on the selected models, because the percent differences between the three pass Schnabel and CAPTURE estimates for both minimum sizes, with and without the recruitment adjustment, were between 2 and 4%, except for the one 91% value when CAPTURE produced an unreasonable estimate of 14,971 fish. The differences between the Schnabel and CAPTURE estimates were also within the error bounds of each estimate.

In addition, the model selection aspect of the CAPTURE program was suspect considering the low capture probabilities observed in this study. Pollock et al. (1990) reported that the model selection procedure of CAPTURE was subject to error, especially when capture probabilities were less than 0.10. Menkens and Anderson (1988) reported that in simulations, CAPTURE never selected the appropriate model the highest percentage of the time, except with data generated under the null model (M_o) which had no variations in capture probability.

The differences between the Schnabel estimates and the Jolly-Seber estimates with the 200 mm minimum size were most likely related to timing. The Schnabel estimates were for the size of the population at the beginning of the project, April 1st, 1998, and the Jolly-Seber estimates were for the size of the population at the beginning of the second pass, June 12th, 1998. The number of walleye within the study area declined on the magnitude of the differences between the estimates (43,538) in late May and June. The declines were likely the result of angler harvest and emigration. Peak walleye harvest in Lake Roosevelt occurred in June (Cichosz et al. 1999) and Lake Roosevelt walleye make rapid, long distance migrations following spawning in April and May with the majority moving north, and many as far as Canada (Hildebrand et al. 1995; McLellan 1998; McLellan et al. 1998; McLellan et al. 1999). If walleye harvest was assumed to be constant throughout June, the number of walleye harvested between April 1st and June 12th, 1998 was 24,766 (STI, unpublished data). The sum of the estimated pre-June 12th harvest and the walleye abundance estimate for the Canadian portion of the walleye population (16,150) (Hildebrand et al. 1995), the majority of which was assumed to have immigrated from the Spokane Arm, was 40,916, which approximately explained the differences in the estimates (43,538). The harvest and emigration did not describe the differences between the estimates calculated with the 150 mm minimum size, because anglers rarely harvest walleye less than 200 mm TL and no walleye less than 200 mm TL have been collected in the upper Columbia River, Canada (Cichosz et al. 1999; Hildebrand et al. 1995).

Our estimates of the size of the walleye population in 1998 (122,109 and 78,571 fish ≥ 200 mm TL) were slightly greater and less than the estimated harvest (119,346; STI, unpublished data). We believe our population estimates were more accurate than the creel estimates, because the true annual walleye harvest was lower than reported. The LRMP used total fishing pressure to estimate harvest, which led to an overestimation of harvest for individual species (Cichosz et al. 1999). According to 1998 LRMP creel surveys, 26% percent of anglers targeted walleye annually and 8% targeted “other” species (STI, unpublished). The category “other species” were species other than walleye, kokanee, rainbow trout, or smallmouth bass, and included “any species”, therefore approximately 36% of anglers were targeting walleye on an annual basis (STI, unpublished data). We did not contend that the true walleye harvest was 36% of the estimated harvest, because anglers targeting other species, such as smallmouth bass or rainbow trout, probably harvested walleye. The total amount of fishing pressure from anglers targeting walleye and those incidentally harvesting walleye was not determined but it was greater than 36%. If the true walleye harvest in 1998 was 50% of the estimated harvest, it would have been 49% and 76% of the two recommended abundance estimates. The Schnabel estimate was for the size of the walleye population prior to peak walleye fishing, so it would was reasonable to assume that it could support a harvest rate of 49%, which was likely a conservative estimate.

The capture probabilities during 1998 may have been too low to provide accurate estimates. Robson and Reiger (1964) recommended three levels of accuracy (*p*), with a precision level of 1- α = 0.95, for mark-recapture population estimates. The first level, p = 0.50, was recommended for preliminary or general management studies. The second level, p = 0.25, for more accurate management work and the third level, p = 0.10, for scientific research. An estimate was considered adequate for a preliminary study if the investigator could assume with 95% confidence that the estimate was within 50% of the true population size (Hightower and Gilbert 1984). According to Hightower and Gilbert (1984), sampling intensities should be greater than 0.2 to provide an estimate of a large population (100,000 individuals), when survival was high (90%) and tag loss was absent, that is acceptable for a preliminary or general management study. If survival was lower and tag loss occurred, the sampling intensity would have to increase (Hightower and Gilbert 1984). Capture probabilities of walleye in Lake Roosevelt were lower than recommended ($\leq$ 0.01), survival was approximately 50%, and tag loss was occurring, so we could not say with 95% confidence that our abundance estimates were within 50% of the true mean. However, when compared to the creel harvest, our estimates appeared to be reasonably accurate.

Greater sampling effort, resulting in higher capture probabilities, was necessary to improve the accuracy of the estimates (Hightower and Gilbert 1984). Lake Roosevelt was an extremely large reservoir (approximately 80,000 ha) with variable and relatively unpredictable water level fluctuations related to hydro-operations at Grand Coulee Dam. The size of the reservoir and variable water conditions made sampling expensive and catch rates variable. We electrofished 1,090 sites during the project during 1998 and believe increasing effort would be unrealistic without a substantial financial investment.

Considering the logistic constraints, our 1998 estimates were the best estimates that could be calculated for the size of the Lake Roosevelt walleye population.

The CV values of the two recommended estimates were 19 and 25%, respectively. Results of this study indicate that acceptable precision can be attained for estimates of abundance for large populations (> 100,000), with survival rates of approximately 50% and capture probabilities ≤ 0.01.

The 1999 study was an attempt to estimate the size of the walleye population with limited effort. We determined that using walleye marking data collected throughout a year as a sampling occasion produced a biased estimate, due to seasonal walleye movements. A new study design should be developed in future years to alleviate the bias related to seasonal walleye movements.

Recaptures of walleye tagged on the spawning run in 1997 and recaptured in 1997, indicated that the majority of walleye that spawned in the Spokane Arm remained there following spawning. The number of recaptures of walleye marked during the spawning run was relatively small for interpretation. All of the walleye marked on the spawning run in 1997 and recaptured in 1998 were caught within 15 km of their mark location a mean of 333 days following marking, indicating that walleye spawning in the Spokane Arm either home to particular spawning area, never leave, or some combination.

Recapture information from walleye tagged during the 1998 spawning run supported the conclusion that the majority of walleye that leave the Spokane Arm following spawning move upstream. However, most of the walleye recaptured in 1998, that were tagged during spawning in 1998, were caught in the Spokane Arm indicating that most walleye did not leave the Spokane Arm following spawning, or their migration was not rapid and they were captured prior to leaving. The majority of the 1998 walleye spawners that were recaptured in 1999 were collected in the Spokane Arm, within a mean time of 383 days, again indicating that they either home to the spawning area, never leave, or some combination.

Walleye marked during the summer/fall of 1997 moved less (2 km) than those walleye marked during the summer/fall of 1998 (21 km) and 1999 (14 km). The differences were probably the result of sampling strategies. The 1997 sampling was conducted at index stations, which selected for walleye that remained in the same locations on each sampling occasion. Walleye sampling in 1998 was conducted according to a stratified random protocol, which would have provided equal chances for collection of walleye that were moving, had moved, and were stationary. Sampling in 1999 was relatively haphazard in comparison to 1997 and 1998. Incorporating other agencies walleye collection data, spawning run data, Tournament data, and walleye data collected during the kokanee study, without a standard sampling framework may have resulted in intermediate mean minimum distances traveled.

Mean minimum distances moved between mark and recapture locations of walleye marked during the summer/fall increased for those walleye recaptured in years following their initial marking year, indicating that walleye redistribute themselves between summers. Walleye were collected in the same locations that they were marked up to 727 days following tagging.

None of the movement data was telemetry data and there were few fish recaptured on multiple occasions, so we could not determine if fish recaptured in the same locations that they were marked were using these locations seasonally or if they never leave them.

However, the spawning locations were sampled throughout the year in 1997 and 1998, and the fall of 1999, and densities declined following spawning suggesting large numbers of fish leave (McLellan 1998; McLellan et al. 1998; McLellan et al. 1999). The recapture data also indicated that walleye do leave the Spokane Arm and redistribute throughout the reservoir, primarily to the north. Walleye marked in the summer/fall and recaptured in the same location were most likely on their summer home range (SHR). A SHR was an area less than 25 km long that was occupied for more than 2 consecutive weeks (Hall et al. 1985).

Most walleye were recaptured within 25 km of their mark location, regardless of their marking period (spawn or summer/fall) or their year of mark and recapture, supporting the hypothesis that walleye establish SHR's. Despite the fact that most walleye were recaptured within a short distance of the mark location, the distances between the mark and recapture locations of walleye collected in Lake Roosevelt were as great as 245 km indicating that some walleye were migratory.

Most recaptures, in all years, occurred in the Spokane Arm, Kettle Falls, and Hawk Creek. The high number of recaptures in these areas may have been the result of additional mark-recapture effort in these areas (spawning run, Governor's Cup Walleye Tournament) and/or high angler pressure in relation to other areas. The Spokane Arm, Kettle Falls, and Hawk Creek were considered to be popular walleye fishing areas, although pressure was not determine for these specific areas.

Similar to our results, previous walleye tagging studies on Lake Roosevelt collectively indicated that Lake Roosevelt walleye spawn in the upper reaches of the Spokane River Arm, the only known walleye spawning area in the reservoir (Nigro et al.

1982; Nigro et al. 1983; Beckman et al. 1985; Peone et al. 1990; Griffith and Scholz 1991; McLellan et al. 1998; McLellan 1998; McLellan 1999). Some spawning walleye migrated over long distances, from as far away as British Columbia, Canada. Hildebrand et al. (1995) tracked two walleye, using radio telemetry, that migrated from British Columbia into Lake Roosevelt in the late fall and early winter, were located in or near the mouth of the Spokane River Arm by the middle of May and had returned to British Columbia by July, where they remained until the fall. Three walleye tagged and released in the upper Columbia River, British Columbia by R.L. and L. Resource Consultants were recaptured by EWU in the Spokane Arm during the spawning run in 1998 (EWU, unpublished data).

After spawning, which peaked in late April and early May, the majority (51 to 75%) of walleye remained in the Spokane Arm (Nigro et al. 1982; Nigro et al. 1983; Beckman et al. 1985; Peone et al. 1990; Griffith and Scholz 1991; McLellan et al. 1998; McLellan 1998; McLellan 1999). The remaining walleye dispersed throughout the reservoir, and the majority that left the Spokane Arm moved upstream. In 1981, 1982, and 1989, twice as many walleye moved upstream from the mouth of the Spokane Arm, compared to downstream (Beckman et al. 1985; Peone et al. 1990). Some walleye moved as far upstream as Hugh Keenleyside Dam, British Columbia, Canada. Between 1997 and 1999, EWU had 15 walleye tags returned from the upper Columbia River, British Columbia. All of the other tagging studies conducted on Lake Roosevelt walleye had tag returns from Canada or tracked fish that moved into Canada (Nigro et al. 1982; Nigro et al. 1983; Beckman et al. 1985; Hall et al. 1985; Peone et al. 1990; Griffith and Scholz 1991; McLellan et al. 1998; McLellan 1998; McLellan 1999).

Following their migration, most walleye established a SHR. The USFWS tagged 10 walleye with radio transmitters in May 1983, while the fish were spawning in the Spokane Arm (Hall et al. 1985). Fish movements were monitored for 15 weeks and nine of the walleye established one or more SHR's (Hall et al. 1985). The relatively short distances moved between mark and recapture locations by walleye marked on during the summer/fall between 1997 and 1999 (80% moved less than 25 km), supported the idea that many walleye establish SHR's.

The age-frequency distributions of walleye collected in Lake Roosevelt in 1980-83, 1997, 1998, and 1999 were variable (Figure 6). The variation was the result of sampling strategies. Unlike 1980-83 and 1999, a large amount of sampling was conducted during the summers of 1997 and 1998 resulting in relatively large numbers of young walleye (age 1) collected. In 1980-83 and 1998, there were substantially more old walleye collected, which was attributed to efficient sampling years (based on number collected) on the spawning run. The sampling on the spawning runs in 1997 and 1999 were relatively poor. The differences in sampling were likely related to the water flows. In 1997 there were extremely high flows in the Spokane Arm that made sampling inefficient. During 1998, flows were average and the reservoir drawdown was average, which resulted in efficient sampling. Despite average flows in 1999, the reservoir drawdown was greater than average, resulting in below average water depths in the upper Spokane Arm and poor sampling efficiency. The poor sampling efficiency was the result of inaccessibility to sampling areas due to shallow water. We do not know how fluctuating water levels and flows affect the number of spawners each year. However, based on growth and mortality the population appeared to be stable, indicating similar recruitment and, presumably, number of spawners annually.

Back-calculated total lengths at age of Lake Roosevelt walleye collected in 1999 were relatively similar to those of walleye collected in 1988, 1989, 1990, 1997, and 1998, as well as the average values from walleye collected in 16 lakes and rivers in the U.S. and Canada (Peone et al. 1990; Griffith and Scholz 1990; McLellan 1998; McLellan et al. 1998; McLellan et al. 1999) (Table 30). The similarities were most apparent through age 5, and after age 5 the variation increased. Overall, walleye growth, as indicated by back-calculated total lengths, was average and relatively stable since 1988.

Walleye mortality rates appeared to be relatively stable and were average when compared to other walleye producing waters (Table 31). Walleye condition was slightly higher in 1999, when compared to 1997 and 1998, but lower when compared to condition factors in 1980-83, 1988, 1989, and 1990 (Table 31). The K_{TL}'s of walleye from Lake Roosevelt were slightly below average when compared to other walleye producing waters (Table 32).

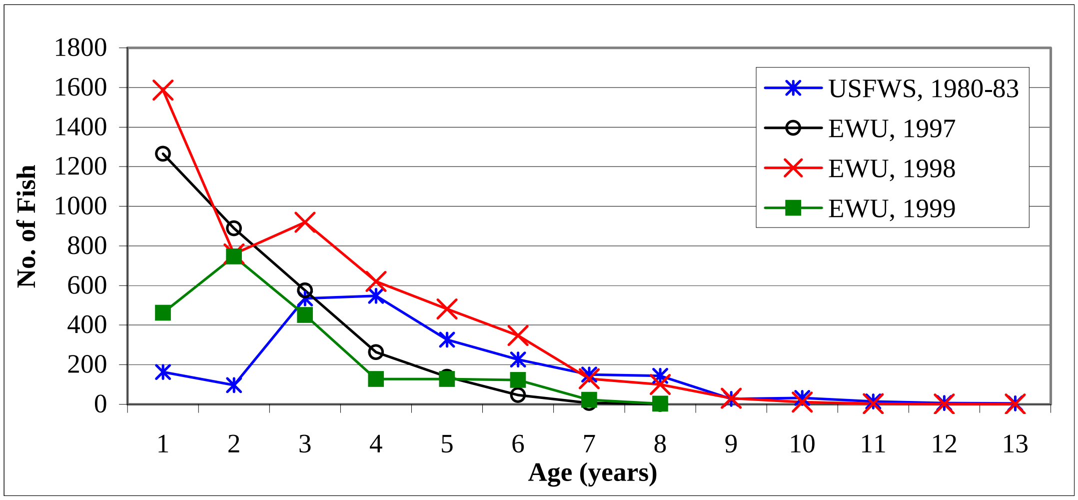

Figure 6. Comparison of age frequency distributions of walleye collected in Lake Roosevelt in 1980-83, 1997, 1998, and 1999.

Table 30. Comparison of mean back-calculated total lengths (mm) at annulus formation between an average from 16 lakes and rivers in the United States and British Columbia and Lake Roosevelt, Washington.

		Mean Total Length (mm) at Annulus Formation												
Location	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Average[a]		177	280	368	431	483	530	554	548	675	675	728		
Lake Roosevelt, 1980-83[b]	3,248	189	307	385	450	515	569	629	668	702	742	740	761	780
Lake Roosevelt, 1988[a]	369	204	273	348	410	470	532	590	635	688	689			
Lake Roosevelt, 1989[a]	467	210	282	351	418	493	571	603						
Lake Roosevelt, 1990[c]	311	184	295	380	439	511	597	651	698	734				
Lake Roosevelt, 1997[d]	2,355	172	279	363	424	478	535	617	662					
Lake Roosevelt, 1998[e]	320	179	290	364	427	481	530	576	616	667	717	748	801	829
Lake Roosevelt, 1999[f]	**171**	**188**	**301**	**375**	**427**	**476**	**518**	**578**	**643**					

[a]Cited from Peone et al. (1990)
[b]Cited from Beckman et al. (1985)
[c]Cited from Griffith and Scholz (1990)
[d]Cited from McLellan et al. (1998)
[e]Cited from McLellan et al. (1999)
[f]Current study

Table 31. Comparison of mean annual mortality rates (%) between Lake Roosevelt and other walleye producing waters.

Location	Mean Annual Mortality (%)	Source
20 NW Wisconsin Lakes	47	Klingbiel (1986)[a]
32 N. Cent. Wisconsin Lakes	48	Klingbiel (1986)[a]
Leech Lake, MN	37	Schupp (1972)[a]
Boyd Lake, CO	48	Weber (1976)[a]
Lake of Woods, MN, 1980-84	65	Payer et al. (1987)[a]
W. Blue Lake, Ontario	80	Kelso and Ward (1977)[a]
Manistee Lake, MI (ages 3 to 7)	56	Laarman (1981)[a]
Lake Oneida, NY, 1960-74	34	Forney (1977)[a]
Lake Roosevelt, 1980-83	52	Beckman et al. (1985)
Lake Roosevelt, 1997	48	McLellan et al. (1998)
Lake Roosevelt, 1998	46	McLellan et al. (1999)
Lake Roosevelt, 1999	**46**	**Current study**

[a] Cited in Carlander (1997).

Table 32. Comparison of mean condition factors (K_{TL}) between Lake Roosevelt and other walleye producing waters.

Location	n	Mean K_{TL} (±SD)	Source
Black Hawk Lake, IA	74	0.89	McWilliams (1983)[a]
Lake Sakakawea, ND	236	0.86	Wahtola et al. (1972)[a]
Red Rock Reservoir, IA	41	0.92	Paragamian (1975)[a]
Lake Erie, 1983	663	0.84	McWilliams (1984)[a]
Lake Roosevelt, 1980-83	2,477	0.87	Beckman et al. (1985)
Lake Roosevelt, 1988	360	0.92 (±0.20)	Peone et al. (1990)
Lake Roosevelt, 1989	521	0.84 (±0.21)	Peone et al. (1990)
Lake Roosevelt, 1990	333	0.88	Griffith and Scholz (1990)
Lake Roosevelt, 1997	1,553	0.81 (±0.16)	McLellan et al. (1998)
Lake Roosevelt, 1998	4,071	0.82 (±0.17)	McLellan et al. (1999)
Lake Roosevelt, 1999	**343**	**0.83 (±0.13)**	**Current study**

[a] Cited in Carlander (1997).

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