Volume 086
Article 05

FISHERY RESEARCH

STATUS AND ANALYSIS OF SALMONID FISHERIES

Kokanee Salmon Population Dynamics-
Kokanee Salmon Monitoring Guidelines

Project F-73-R-14
Subproject 11, Study II

Bruce E. Rieman
Principal Fishery Research Biologist

September 1992

TABLE OF CONTENTS

Page

ABSTRACT 1

INTRODUCTION 2

ABUNDANCE 3

Application of Information 3
Trawling to Estimate Abundance 10
Sample Size and Allocation 12
Sampling Time 12
Limitations of Trawling 14
Costs - Tim Manpower 17
Alternative Methods for Abundance 17
Hydroacoustics 18
Spawner Counts 18

AGE AND GROWTH 19

Application of Information 19
Methods for Age and Growth 19
Length at Age and Age Composition 19
Condition 22

OTHER DATA 24
Fecundity, Potential Egg Deposition 24
Age-at-Maturity 24
Lake or Reservoir Productivity 24
Physical Characteristics of Lakes and Reservoirs 26
Fisheries 26
Predation 27

LITERATURE CITED 28

LIST OF TABLES

Table 1. Estimated densities (fish/hectare), standing crop[a] (kg/hectare), and late September length-at-age[b] for kokanee in ten lakes and reservoirs in Idaho 4

Table 2. Error bounds[a] for survival estimates with two coefficients of variation (CV)[b] typical of trawl density estimates[c] 16

LIST OF FIGURES

Figure 1. Relationships of September length-at-age and densities for kokanee in Idaho Lakes and reservoirs of varied productivity. Productivity is indexed by Secchi transparency and observations have been classified in these groups. Data are summarized in Table 1. Methods for estimates are summarized in Rieman and Myers (1992) 7

Costs associated with this publication are available from Dept. of Ash and Game In accordance with Section 00202, Idaho Code. 0642/54477111W266.t4$661i1.29 - $206.05

LIST OF FIGURES (cont.)

Page

Figure 2. Predictions of relative yield to anglers for age 3+ kokanee at varied densities and three levels of lake or reservoir Secchi transparency. From Rieman and Myers (1990b) 8

Figure 3. Empirical relationships of angler effort, catch rate, and yield to the angler, against kokanee density. Lines were fit by inspection. From Rieman and Myers (1990a) 9

Figure 4. Empirical relationship of kokanee biomass estimated by midwater trawl and summer mean chlorophyll a. The equation represents regression of the geometric mean biomass for each lake against estimated chlorophyll. The open points represent observations from populations known to be depressed and dropped from the regression. Data are from Rieman and Myers 1991, but biomass estimates have been adjusted to a September equivalent in cases where sampling occurred earlier 11

Figure 5. Relationship of sample variability (coefficient of variation for the sample fish per haul [SD/X]) against mean trawl catch for kokanee sampling done throughout Idaho lakes and reservoirs in 1990 and 1 9 9 1 . Lines were fit by inspection 13

Figure 6. Predicted variability for the mean catch (coefficient of variation for the mean fish per haul [SE/X] with varied numbers of trawls [N]). The SD for calculation of the SE was predicted by regression from the relationship in Figure 5 13

Figure 7. Correction factor to estimate September equivalent biomass of kokanee estimated by trawling between June 1 and September 30. Correction factors were estimated from simulation of kokanee production as outlined in Rieman and Myers 1991a. The lines were fit by inspection 15

Figure 8. Predicted length at age for kokanee at varied densities and three levels of lake or reservoir Secchi transparency. From Rieman and Myers 1992 20

Figure 9. Length weight relationships for kokanee in 7 lakes or reservoirs in Idaho sampled in 1991. The regression equation was fit to the pooled data only for fish larger than 100 mm. Note the log-log axes on B demonstrating a change in slope in the relationships at about 100 mm 21

Figure 10. Correction factors to estimate September equivalent length for kokanee sampled by trawling between June 1 and September 30. Correction factors were estimated as outlined in Rieman and Myers 1992. The lines were fit by inspection 23

Figure 11. Relationship of fecundity to length for female kokanee collected from lakes throughout Idaho 25

LIST OF APPENDICES

Page

Appendix A. Trawl Field Guidelines and Procedures 30

Figure 1. Example of hours of darkness 34
Figure 2. Example calibrations 35
Figure 3. Sample data sheet 36

Appendix B. Example of a minimum standard data report of kokanee trawl estimates 37

Appendix C. Documentation for Lotus 123 Spreadsheet, Trawl.wkl, for estimating kokanee density, number, and biomass 38

Table 1. Sample output from TRAWL.WK1 41

Appendix D. "Cookbook" for Kokanee Trawling 45

JOB PERFORMANCE REPORT

State of: Idaho

Name: Status and Analysis of Salmonid Fisheries

Project No.: F-73-R-14

Title: Kokanee Salmon Population Dynamics-Kokanee Salmon Monitoring Guidelines

Subproject No.: II

Study No.: II

Period Covered: March 1, 1991 to March 31, 1992

ABSTRACT

This report outlines a long-term monitoring approach for kokanee *Oncorhynchus nerka* populations in lakes and reservoirs throughout Idaho. This monitoring is designed to provide an opportunity to learn and to fine-tune management. Monitoring coordinated among populations and fisheries can also provide perspective and a description of the current status of any single population. The monitoring program outlined here focuses on the kokanee population and emphasizes information on abundance and growth. Recommended methods are based on long-term sampling by trawl, of kokanee populations throughout Idaho. Included is a summary of existing data and models, and the application of that information to kokanee management.

Author:

Bruce E. Rieman
Principal Fishery Research Biologist

INTRODUCTION

The purpose of this report is to outline approaches for long-term monitoring of Idaho kokanee populations and fisheries. Monitoring is a critical part of management for most commercially important fish stocks, but is less frequently employed in management of resident sport fish. In many cases if the fishery is important, active management carries some cost (e.g. hatchery stocking, predator introductions, enforcement) and some risk (over-exploitation, collapse, overpopulation and stunting). A successful management program will maximize the value or yield of the fishery relative to cost and risk. It will be impossible to do that without information on 1) where the fishery or population is relative to the optimum, 2) which actions are effective, and 3) which actions are risky.

Unless the outcome is certain (de-watering a reservoir), management activities intended to manipulate a stock or fishery are like large scale experiments (Peterman 1980). Without some form of evaluation, the experiment will provide no new information. In most fisheries, management is an ongoing process, and thus an ongoing series of experiments. With an appropriate monitoring program, the manager can develop an adaptive approach, learning both from successes and from failures, thus, fine tuning a program through time. Monitoring, in this sense, becomes an integral part of management to be carried on indefinitely.

A thoughtful program of monitoring and adaptive management may also be the most effective form of research. Short-term evaluations (one or more years, before and after) evaluations of management actions typical of many past research projects are often confounded by environmental variation or poor precision in sampling that make interpretation difficult. Many fish populations (especially kokanee) are unstable. Long-term trends in abundance, size, age-at-maturity, and dramatic short-term fluctuations in abundance (and even collapse) are common. Short-term evaluations run the risk of either looking at a changing system in an uncommon year; or confusing normal variation or long-term trends driven by the environment with short-term management changes. A long-term monitoring program will allow important trends to emerge from inherent variation and sampling error.

By coordinating monitoring programs among similar fisheries, managers may extend the information gain dramatically. Intensive research programs are often expensive, which require the commitment of manpower, equipment, and large blocks of time to a single system. A monitoring program focusing only on key data collected at single representative time would allow coverage of many systems with the same effort. By looking at many systems with the same species, a number of natural experiments are available. Observations that might take decades (ten-fold variation in fish density) or be impossible for any single population (e.g. varied lake productivity) can be accomplished in one or more years among several populations. For example, by simultaneously observing several kokanee populations at varying densities and in lakes of varying productivity, we gained information about the effects of density and productivity on kokanee growth and fishing success (Rieman and Myers 1990a, 1991b). Those data allow a manager to predict relative changes in growth, size of fish in the catch, and success rates that will accompany management changes in any kokanee fishery.

By estimating kokanee density with the methods used on other populations a manager can also gain an instant perspective. Existing data on fish density, standing stock, growth, and yield describe the range for Idaho populations (Rieman and Myers 1990b; Myers and Rieman 1991) and simple empirical models allow prediction of fishery or population potential. If the data for a particular population or fishery is not consistent with expectations, then a manager might consider some change and the existing models would allow prediction of the effects of that change. If the data indicate a fishery or population near its

potential, then a manager might conclude there will be little benefit to be gained for the cost or risk of any change in management.

An effective monitoring program should provide the best possible information for the lowest possible cost in time and money. The selected parameters and sampling detail may vary with individual circumstances, but some information should be common to all programs. In Idaho, our experience with kokanee research and management has produced a substantial body of information on populations, fisheries, and sampling methods. That information should be useful in providing a comparison for newly sampled fisheries and in developing an effective monitoring program for any fishery. The purpose of this report is to review the collection, interpretation, and application of information that has been used in kokanee management and research and to recommend approaches for long-term monitoring of populations and fisheries.

The information used to monitor and manage kokanee fisheries can be broken into three major areas: 1) the population including information on abundance, growth of individuals, annual mortality rates, and age at maturity; 2) the fishery including information on catch rates, yield, and angler effort; and 3) the lake or reservoir environment including information productivity, morphometry and other physical characteristics. This report deals primarily with information about the population and only cursorily with fishery and environmental observations. More detailed reviews of the latter two topics are available elsewhere.

ABUNDANCE

Application of Information

Estimates of kokanee number (total or age specific) density (f/hectare) and standing crop (kg/hectare) are useful for comparisons among populations and to describe trends or evaluate the effect of management changes within populations.

Initially, estimates of kokanee density can give a manager perspective on the status of an individual population. Estimated densities in Idaho populations range from near 0 to more than 1200 kokanee/hectare. Most of the important fisheries support trawl estimated densities of catchable size fish in the range of 20 to 100 fish per hectare (Table 1). Densities outside that range or strong variation in the abundance of individual year classes can help define the causes of poor or erratic fishing.

More detailed information about the lake or reservoir environment can substantially improve the interpretation or application of a kokanee density estimate. Rieman and Myers (1992) related the growth of individuals among ten populations to estimates of density and lake productivity. Density and productivity, together, explained a large part of the variation in size of fish at age (Figure 1). Because catchability of kokanee is strongly related to size of fish, fishing success is expected to be a tradeoff between growth and fish density (Rieman and Myers 1990b). Both mechanistic and empirical models predict that the best kokanee fishing will occur at intermediate densities (Figures 2 and 3). With estimates of density (and productivity), then, a manager can determine whether a fishery is near the optimum level or whether substantial improvement might be gained by increasing or decreasing the density through management. The optimum kokanee density for an unproductive system like Payette Lake, for example, is predicted to be about 20 to 50 age 3 or older f/hectare. The number of mature fish in the spawning

Table 1. Estimated densities (fish/hectare), standing crop[a] (kg/hectare), and late September length-at-age[b] for kokanee in ten lakes and reservoirs in Idaho.

Site	Year of observation	Length-at-age 1	Length-at-age 2	Length-at-age 3	Density-at-age 1	Density-at-age 2	Density-at-age 3	kg/hectare
Alturas Lake	1990	60	95	120	57	261	71	5.2
	1991	---	95	135	---	310	239	6.3
Anderson Ranch Reservoir	1986	210	267	---	10	11	4	---
	1987	211	234		5	111	8	12.3
	1989	---	---	320	---	---	5	2.8
	1990	130	---	---	15	---	---	---
Coeur d'Alene Lake	1978	163	205	250	307	129	121	---
	1979	158	**195**	245	237	186	47	26.3
	1980	158	185	255	174	202	110	24.1
	1983	144	182	220	198	233	84	23.3
	1984	150	182	---	121	**196**	83	17.9
	1985	161	192	225	89	193	262	39.6
	1986	162	198	---	268	190	75	27.9
	1987	161	---	---	**247**	303	92	---
	1988	---	---	---	---	---	---	---
	1989	137	190	220	---	410	97	---
	1990	154	205	226	---	**256**	137	---
	1991	144	205	231	---	158	110	---
Dworshak Reservoir	1988	210	261	310	45	4	10	7.7
	1990	220	285	---	161	11	---	5.7
	1991	207	325	347	39	4	1	4.8
Payette Lake	1980	90	**156**	240	4	36	9	2.5
	1988	105	175	---	2	6	---	---
	1989	100	---	---	14	---	---	3.0
	1990	100	135	---	14	3	---	---
	1991	100	---	240	7	---	1	---

Table 1. Continued.

Site	Year of observation	Length-at-age 1	Length-at-age 2	Length-at-age 3	Density-at-age 1	Density-at-age 2	Density-at-age 3	kg/ hectare
Pend Oreille Lake	1977	148	205	235	52	131	29	17.2
	1978	148	195	235	31	89	57	13.2
	1979	153	215	245	58	75	30	11.1
	1980	148	205	255	44	42	46	9.6
	1984	158	215	240	67	54	12	8.0
	1985	157	221	262	46	55	16	8.9
	1536	149	214	233	51	30	24	8.2
	1987	142	214	252	35	37	19	8.9
	1988	140	205	242	73	23	17	8.0
	1989	163	207	233	52	53	20	9.7
	1990	143	198	234	70	64	15	7.7
	1991	150	195	220	37	78	34	8.9
Priest Lake	1978	144	213	245	15	14	7	3.0
	1979	172	208		13	2	1	
	1980	150			7			
	1983	133			4			
	1984	162			27	2		1.0
	1985	188	245	290	3	4		0.7
	1986		263		3	1		
Redfish Lake	1990	100	150	190	21	4	6	1.8
Spirit Lake	1981	194	224	260	128	143	161	62.7
	1982	204	240	260	364	101	84	55.5
	1983	192	224	260	475	256	94	85.7
	1984	198	229	250	30	280	180	74.9
	1985	192	224	256	360	197	129	74.3
	1986	192	229	245	501	188	98	72.6
	1987	204	229	270	311	605	170	142.5

Table 1. Continued.

Site	Year of observation	Length-at-age 1	2	3	Density-at-age 1	2	3	kg/ hectare
	1988	204	240	270	393	160	272	119.1
	1989	186	220	270	228	389	151	
	1990	196	225	265	69	197	157	
	1991	176	210	260	571	236	72	
Upper Priest	1978	150	229		3	6		7.8
	1979	139			28			
	1980	138	200		25	19		
	1984	133		---	6			2.09
	1985	150			15			1.8
	1986	161	254		7	7		
	1987	15			21	6		

[a]Standing crop was corrected to expected late September based on Figure 7.
[b]Sample length was corrected to expected late September length based on Figure 10.

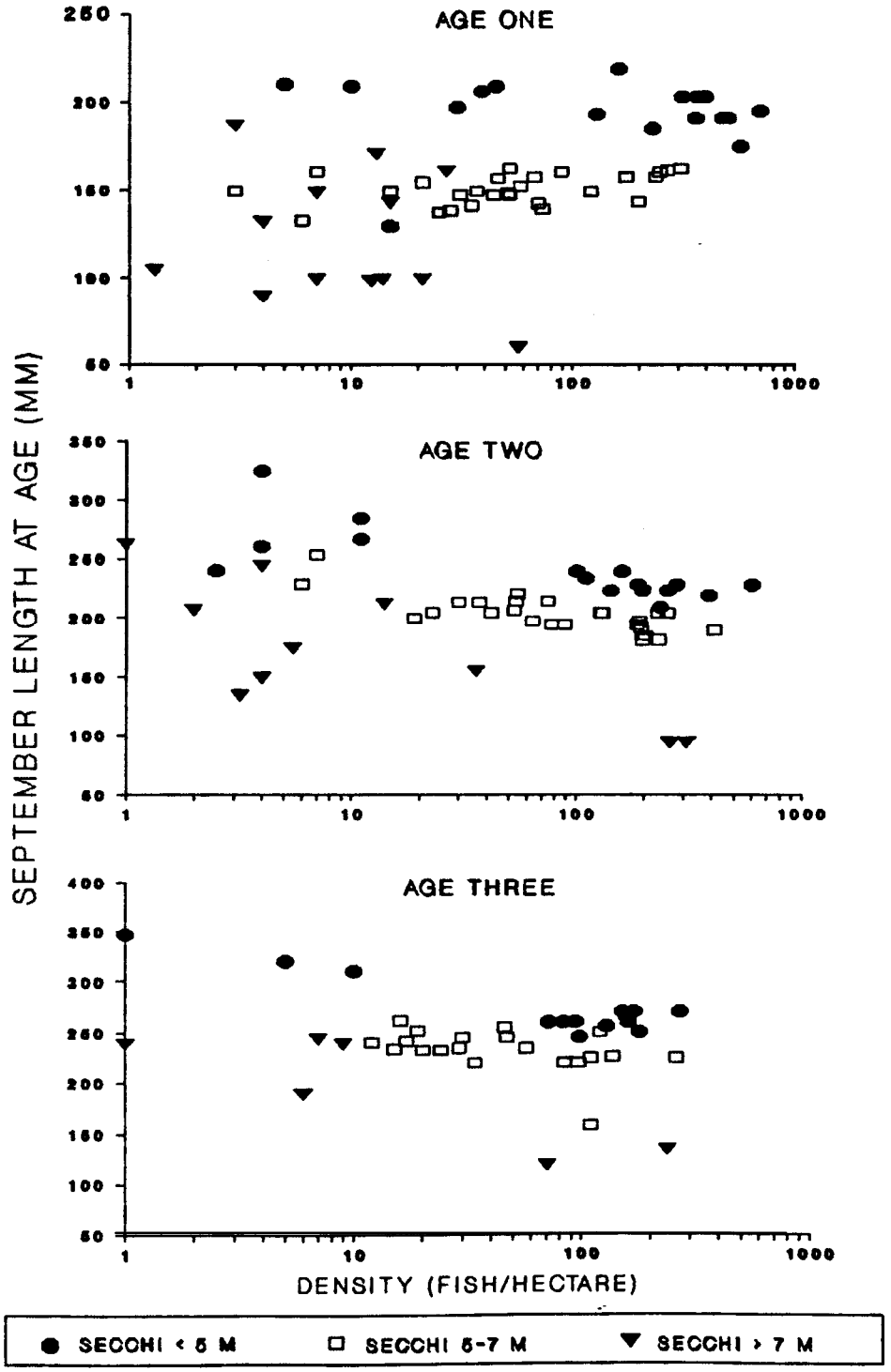


Figure 1. Relationships of September length at age and densities for kokanee in Idaho Lakes and reservoirs of varied productivity. Productivity is indexed by Secchi transparency and observations have been classified in these groups. Data are summarized in Table 1. Methods for estimates are summarized in Rieman and Myers (1992).

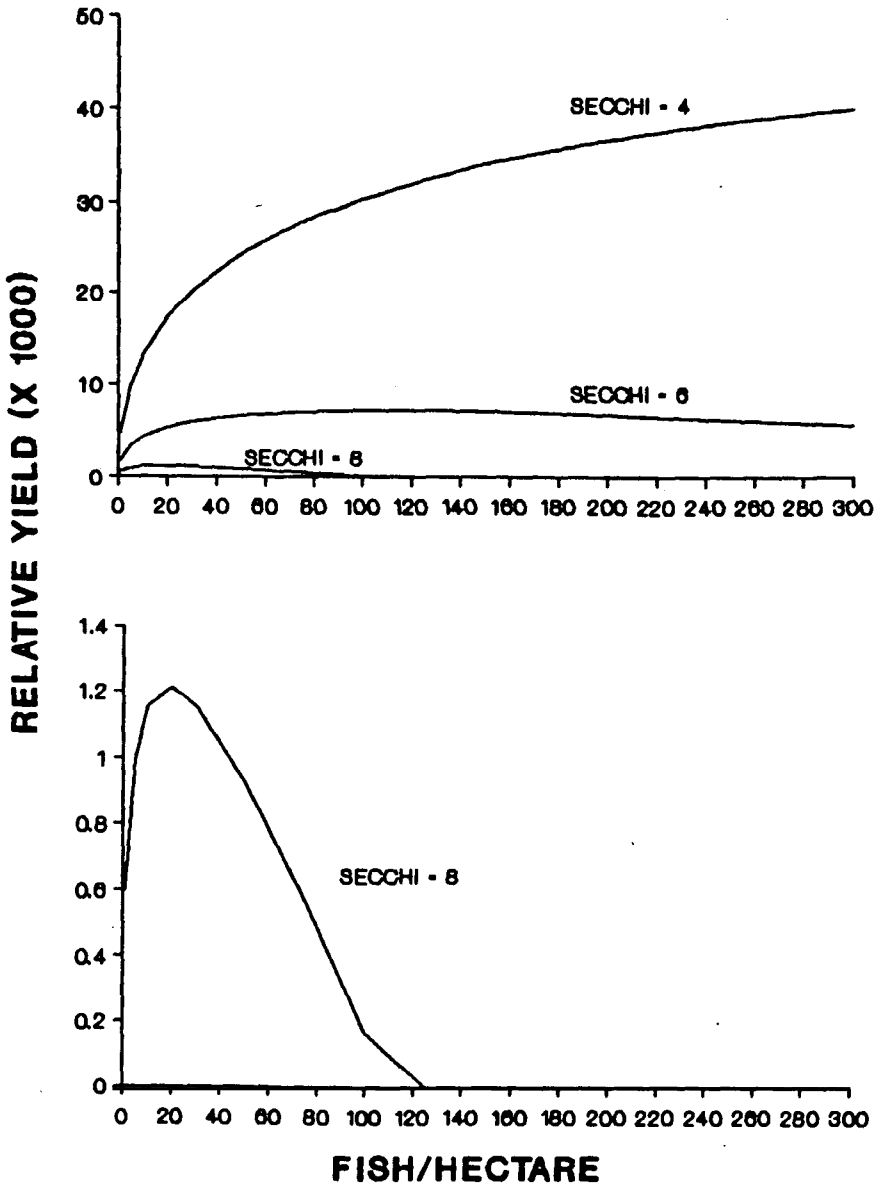


Figure 2. Predictions of relative yield to anglers for age 3+ kokanee at varied densities and three levels of lake or reservoir Secchi transparency. From Rieman and Myers (1990b).

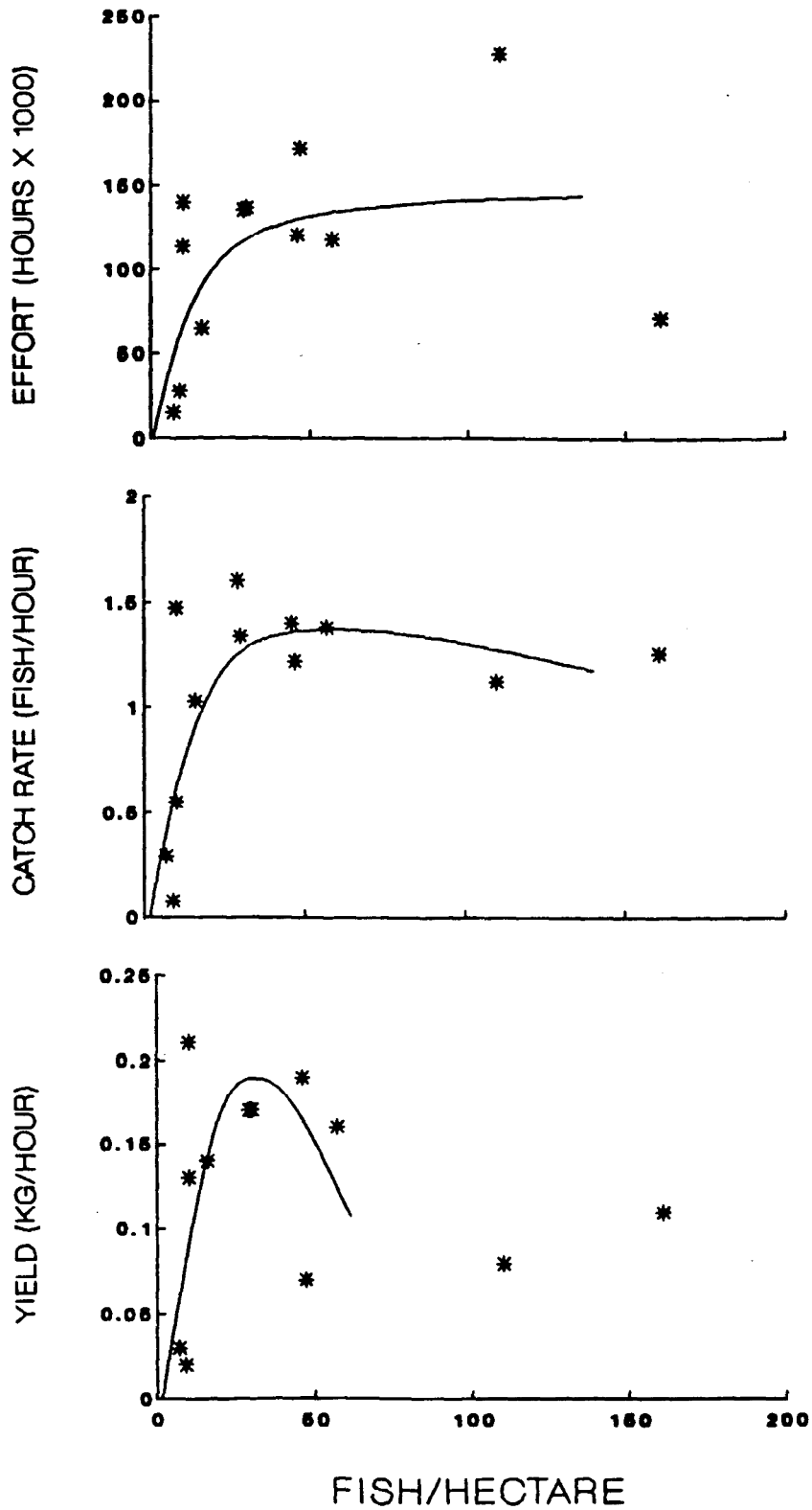


Figure 3. Empirical relationships of angler effort, catch rate, and yield to the angler, against kokanee density. Lines were fit by inspection. From Rieman and Myers (1990a)

escapement appears to be relatively stable at about 10 f/hectare. A reasonable goal for enhancement might then be a doubling of the existing population. In other cases, managers often seek to maximize the size of kokanee available to anglers by stocking predators, limiting spawning escapements, encouraging exploitation, or otherwise reducing numbers to lower than normal levels. The existing models predict no benefit in any fishery by reducing densities below about 20 f/hectare. Although size of fish may increase substantially at lower densities, fishing success should not, and the risks of collapse may increase dramatically (Rieman and Myers 1990b, 1992). Populations with densities near or below the level expected to provide the optimum fishery should be managed very cautiously.

We have also related standing crop or fall biomass of kokanee to lake or reservoir productivity (Figure 4) (Rieman and Myers 1991). Similar relations have been demonstrated for other fish populations and communities (Maiolie and Elam) and can be used to predict the relative capacity or potential of particular system. The predicted kokanee biomass for Anderson Ranch Reservoir is about 35 kg/hectare; for example, recently estimated biomass has been from two to four kg/hectare. We should anticipate that Anderson Ranch Reservoir can support a substantially larger kokanee population. In contrast, the predicted biomass for Lake Pend Oreille is about 10 kg/hectare while recent estimates have been very close to that (mean = 9.7 kg/hectare). We should not expect that major increases in kokanee biomass for Lake Pend Oreille are possible.

Long-term monitoring of kokanee density can be used to evaluate individual management programs. For Lake Pend Oreille, annual estimates of kokanee number are used to describe the relative influence and success of hatchery introductions and indicate that hatchery fish represent an important, if not dominant, part of the population. In Coeur d'Alene Lake, trends in abundance of individual year classes have been related to numbers of chinook salmon oncorhynchus tshawytscha which prey directly on kokanee. Monitoring in Coeur d'Alene Lake is being used in an attempt to "fine tune" predator introductions. Monitoring in Priest Lake showed that hatchery introductions did not survive well enough to rebuild the population. Monitoring in Payette Lake also indicates that hatchery introductions have done little to enhance that population.

Trawling To Estimate Abundance

Methods used to estimate abundance of kokanee in Idaho waters include mid-water trawl, hydroacoustics, and enumeration of spawners. Gillnetting has also been used to index abundance on a limited basis. Trawling and spawner number have been used most in Idaho and provide the best data for comparison among lakes or for use in predictive models. We recently completed a trawl comparison survey with all three Idaho trawl boats and a British Columbia (B.C.) boat. The trawl comparison data will allow development of corrections for differences in efficiency between the Idaho and B.C. trawl systems and thus the exchange of data. Because of the established data base and the potential to expand with more observations from B.C., we believe mid-water trawling should represent the primary method for sampling and monitoring Idaho kokanee populations.

Idaho has three boats available for trawl sampling. Two large (9 m with inboard diesel power) boats located in northern Idaho are best suited to the large lakes of that area. A smaller boat (7 m with I/O gas power) is more portable and is best suited for the smaller and less accessible waters throughout the southern part of the state. The trawl comparison survey showed that all three boats produce comparable estimates of kokanee density for fish from 50 to 200 mm in length. Data generated by all three boats for fish in

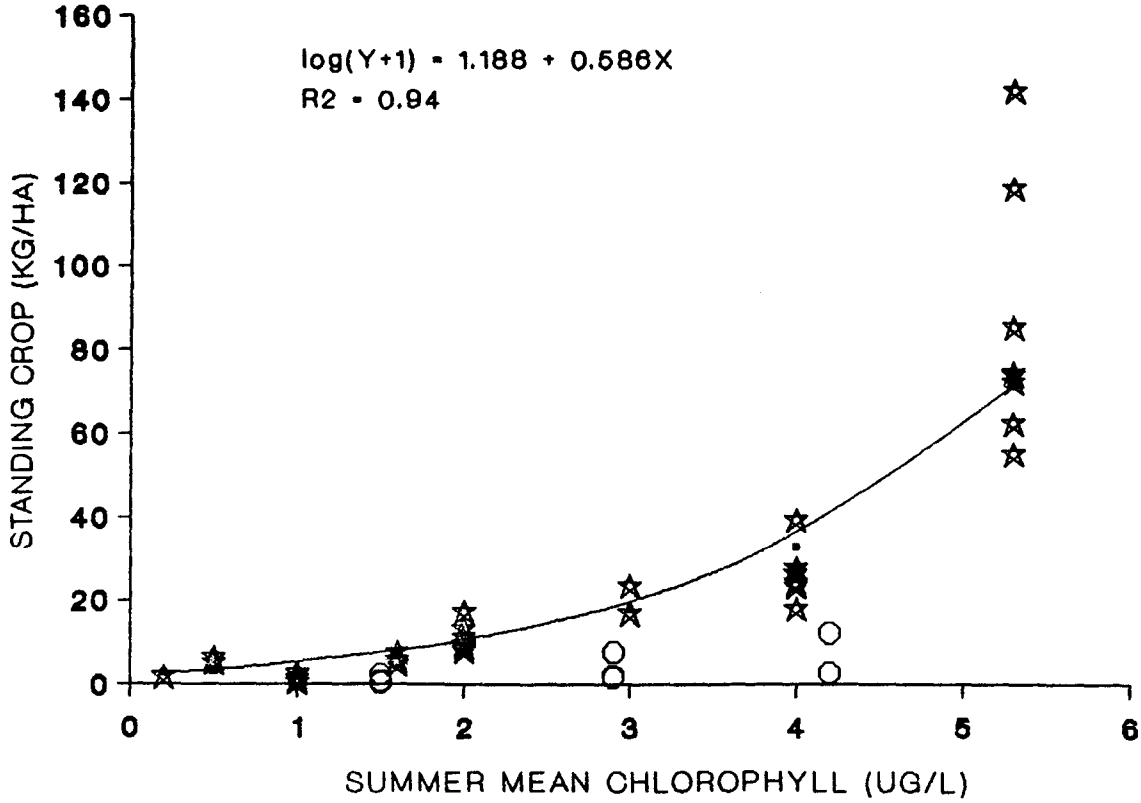


Figure 4. Empirical relationship of kokanee biomass estimated by midwater trawl and summer mean chlorophyll a. The equation represents regression of the geometric mean biomass for each lake against estimated chlorophyll. The open points represent observations from populations known to be depressed and dropped from the regression. Data are from Rieman and Myers 1991, but biomass estimates have been adjusted to a September equivalent in cases where sampling occurred earlier.

that size range can be directly compared. A description of trawl procedures and equipment operation applicable to all waters is in Appendix A. Sample size, allocation, and timing must be considered by population.

Sample Size and Allocation

The number of trawls necessary to provide an adequate population estimate depends on variability among samples and the size or complexity of the lake or reservoir basin. Stratification of sampling is useful in large waters (>5000 hectares) because kokanee are rarely distributed evenly over large areas. Individual age classes often are aggregated in specific regions of the lake. Stratification may also be useful if there are distinct basins or arms that might restrict random movement or distribution of fish throughout the year. If there is no prior information on fish distribution, sampling can be stratified by natural features within the lake or simply into areas of roughly equal size. The number of trawls within each strata should be based on variability, but that data is rarely available in advance. Without previous knowledge of variability, samples should be allocated by the relative size of each strata.

The variability in trawl estimates is often high and tends to increase as the density of fish (and catch per sample) decreases (Figure 5). At low fish densities, the variability among trawls can be reduced by *increasing* the hauling time (and thus the catch) per sample. Increased hauling time reduces the number of catches with 0 fish. Longer hauling time also increases the total sample of fish, because more time is spent with the net in the water and less time is spent retrieving, setting, and processing. Increased trawling time, however, will reduce the number of trawls possible. As long as catches are not very low (e.g. mean catch <1 fish per trawl), precision of an estimate will be improved more by increasing the number of samples rather than the length of hauling time (Figure 6). If densities are low and a sample of fish (e.g. for mark recovery or growth information) is more important than the precision of the estimate, longer hauling times may be more appropriate. We recommend a minimum of five trawls for any strata (entire water or substrata) when a density estimate will be made. If densities are very low (less than 10 to 15 f/hectare or about one fish per haul) many more replications will be necessary to get reasonable precision. Figure 6 can be used as an initial guide for sample allocation.

Sampling Time

Generally the best sampling time is as late in the growing season as possible. Vertical distribution of kokanee is strongly influenced by temperature. During peak stratification (late summer or early fall) kokanee are distributed in a relatively narrow layer below the thermocline. Earlier in the year the layer can be much wider. Late season sampling thus requires the least vertical range to trawl and produces the highest possible catches. Vulnerability of kokanee to the trawl gear is probably related to fish size. Age 0 fish are not fully recruited early in the year. Late season samples should also provide the least biased estimate of age 0 numbers.

Late season sampling is not possible in all waters. Reservoir drawdown can limit boat access and can also restrict or eliminate areas that can be safely trawled (as the water is drawn down fish move too close to the bottom for comfort). The sampling time in each month is also limited to six or seven nights around the new moon. Usually only two or three different waters can be sampled in any month, obviously all cannot be late in the year. In most waters stratification is adequate to begin trawling by early to mid July.

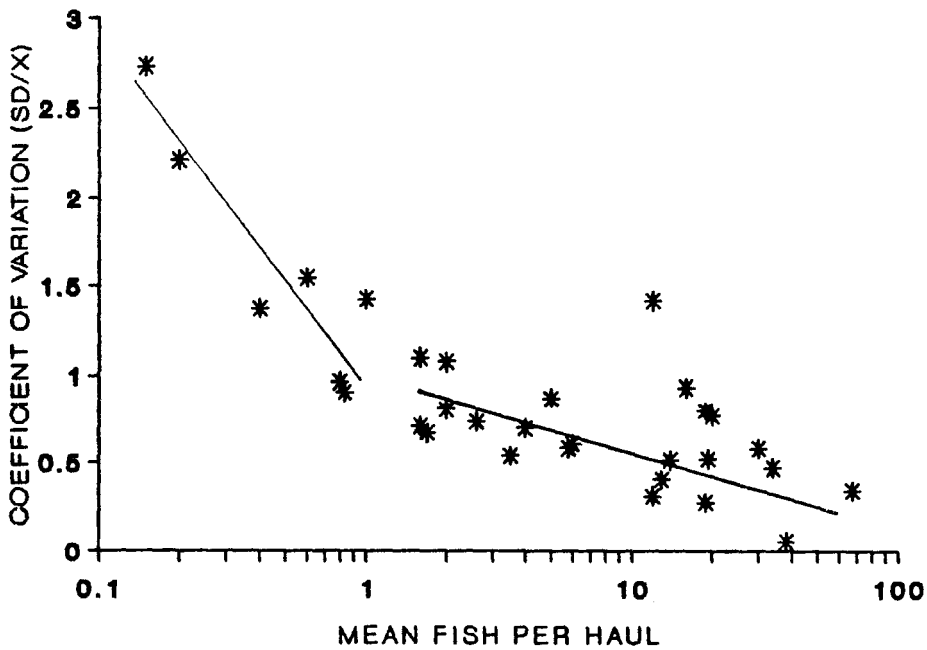


Figure 5. Relationship of sample variability (coefficient of variation for the sample fish per haul [SD/X]) against mean trawl catch for kokanee sampling done throughout Idaho lakes and reservoirs in 1990 and 1991. Lines were fit by inspection.

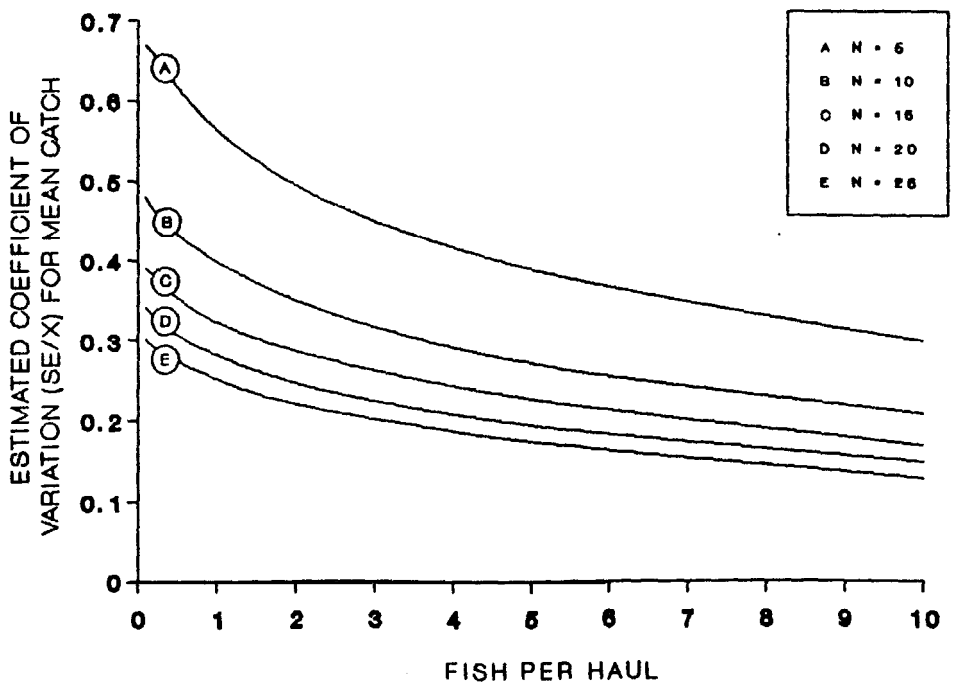


Figure 6. Predicted variability for the mean catch (coefficient of variation for the mean fish per haul [SE/X] with varied numbers of trawls [N]). The SD for calculation of the SE was predicted by regression from the relationship in Figure 5.

Generally drawdown systems should be sampled first and lakes and stable reservoirs last.

Because much or even most kokanee growth occurs late in the season, biomass estimates made early can be substantially lower than those made later. To compare among lakes, biomass estimates must be standardized for time of sampling. To do that we modeled the seasonal variation in kokanee biomass based on the seasonal distribution of kokanee growth observed in Lake Pend Oreille and Coeur d'Alene Lake. Resulting correction factors (Figure 7) should be used to standardize an estimate to a late September equivalent biomass.

Depending on time of spawning, maturing kokanee also may not be available to the trawl. Early spawning stocks often begin schooling near spawning streams and even leaving the lake in August. Adults may also be large enough to avoid the trawl. Estimates of biomass must consider the potential bias in not adequately representing mature fish. If adults are not taken in the trawl or appear to be under represented, the September biomass estimate can be corrected if an estimate of spawning escapement is available. In stable populations, the adults normally represent about 30% of the total September biomass. If spawning escapement cannot be estimated, the true September biomass should be approximated by multiplying the September biomass of immature fish by 1.4.

Limitations of Trawling

There are several important limitations that must be considered with the use of the trawl for kokanee monitoring.

The trawl probably provides a biased estimate of abundance and age or size composition of the population. We know that small (<50 mm) kokanee can pass through the net and are underestimated. Larger fish may also avoid or escape from the net once they sense it. Comparison of catches among trawl boats suggests that efficiency may decline with fishing speed for fish larger than about 220 mm. As yet, we have been unable to estimate efficiency by size so the magnitude of bias relative to size, is unknown, but trawl estimates of total number average about 60 to 70% of those made with hydroacoustics. We believe that the best (least-biased) estimates of abundance are for fish between about 50 mm and 220 mm. Until trawl efficiency is actually estimated by kokanee size, caution should be used with density estimates for fish outside that range.

As discussed above, trawl density estimates are often imprecise. Sequential annual estimates have been used to estimate survival between ages or from hatchery release or potential egg deposition to resulting fry in the lake. The precision of the survival estimate will be directly related to the precision of the two population estimates and is rarely computed. Given the expected precision in trawl estimates outlined in Table 2 we simulated the precision that could be expected in survival estimates. In most cases it will be very difficult to detect anything but very large changes in survival among years and estimates of survival between ages that span the sizes where trawl efficiency changes may also be biased. If estimates of survival are important, every effort should be made to maximize the precision of the abundance estimates (i.e. large sample sizes); caution is also advised in estimates that incorporate fish below 50 mm or above 220 mm. Because variability in catches tends to increase dramatically as density declines, survival estimates based on density estimates of less than 10 to 15 f/hectare will also be suspect.

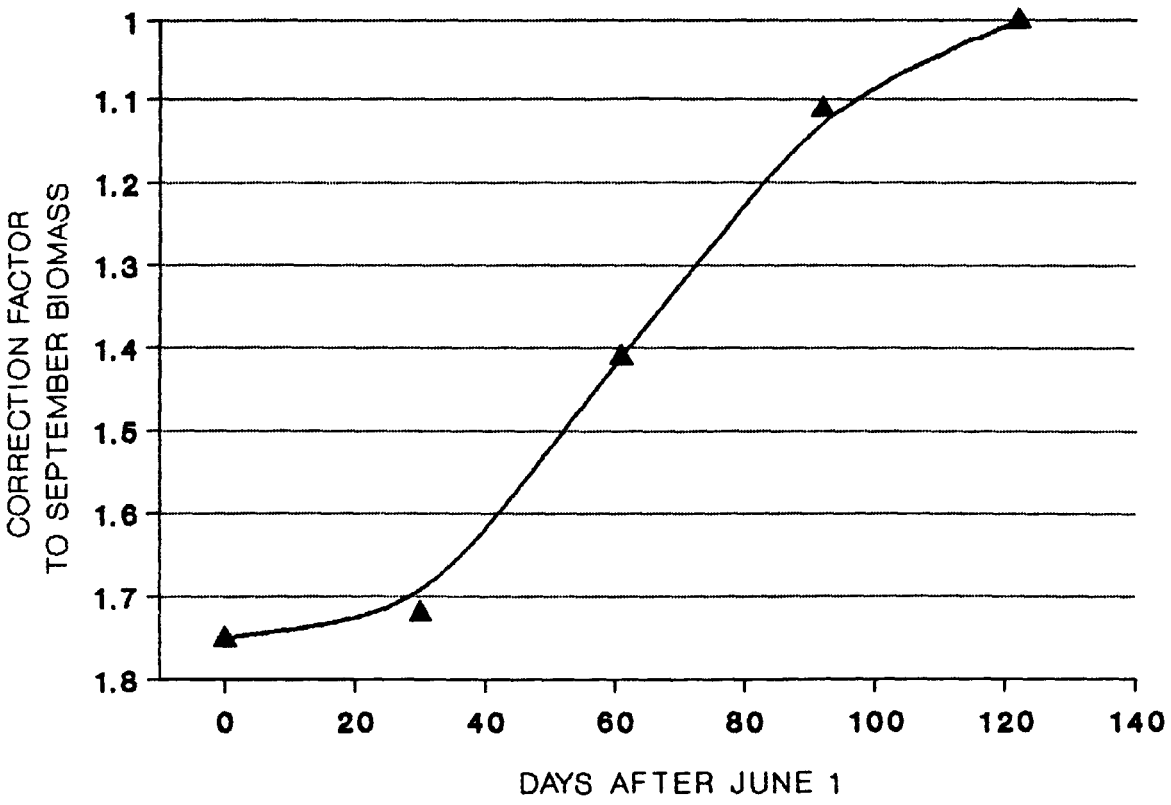


Figure 7. Correction factor to estimate September equivalent biomass of kokanee estimated by trawling between June 1 and September 30. Correction factors were estimated from simulation of kokanee production as outlined in Rieman and Myers 1991a. The lines were fit by inspection.

Table 2. Error bounds[a] for survival estimates with two coefficients of variation (CV)[b] typical of trawl density estimates[c].

	Error bounds for survival estimates with CV of:			
	0.20		0.40	
True Survival	lower	upper	lower	upper
0.05	0.03	0.08	0.015	0.15
0.10	0.06	0.17	0.03	0.38
0.50	0.35	0.80	0.18	1.60
0.75	0.50	1.20	0.20	2.25

[a] Approximate 90o error bounds were generated by Monte Carlo simulation of simulation of survival (N_1/N_0) estimates where No equals an estimate of abundance for year class in the first year and N_I an estimate for the same year class in the following year. The estimates were assumed to have normally distributed errors with mean of N_I or No and CV of 0.20 or 0.40.

[b] $CV = SD_N/N$ where N is the population or density estimate.

[c] See Figure 6 for anticipated CV for typical trawl sample sizes and catches.

In addition to the expected variation and bias, trawl catches are also influenced by other factors. Light can have a strong influence on efficiency, with obvious net avoidance occurring under even partial moonlight (Robinson and Barraclough 1978). Uncertainty in depth can also lead to under or over-sampling segments of the kokanee layer and thus a negative or positive bias in the abundance estimate respectively. Net depth is influenced by boat speed, the configuration of the trawl gear (doors, foils, and floats), and by the crews calibration of wire-out-to-depth fished. In any survey, care should be taken to make the sampling approach, timing, and gear as consistent as possible. Trawling should be only at times of full darkness (no moon) (see Appendix A). The trawl depth x wire out calibration (Appendix A) should be made every year or any time configuration of the gear is changed. Trawl speed (not RPM) should be monitored carefully throughout the survey and modified as conditions (wind, chop) require to maintain a constant speed through the water. The kokanee layer should be monitored throughout the survey and fishing depth should be adjusted as the layer changes. Fishing depths should be selected conservatively to insure the layer is fished completely (i.e. trawl depths completely bound the layer).

Despite the imprecision and bias in trawl estimates, careful sampling should keep the uncertainty within a factor of two. Trawl data will be best used to monitor long-term trends in populations or for comparisons among populations where relatively large differences are expected and are important. Special care should be used for any interpretation of year-to-year variation or cases where estimates of absolute number are important.

Costs - Time Manpower

Assuming 5 to 10 trawls per night of work, most kokanee waters in Idaho can be adequately sampled in two nights. A work night, including daily travel to and from the lake, setting up the equipment, shakedown and actual sampling, will be 6 to 10 hours. Sample work during the day (lengths, weights, scales, otoliths) is two to four hours for each night of sampling depending on the size of the catch. The crew for trawling is a minimum of three people and a maximum of four. Field work, excluding the travel time to and from the lake or reservoir, should be 30 to 40 person hours per night of sampling. Additional hours required for maintenance of the boat, transport to and from the regions, and other routine support activities will depend on the crew hired, amount of work scheduled, etc.

The trawl boat is operated on a Department reimbursable account for about $50 per hour which covers all maintenance, equipment, and fuel. Trawl operation costs are about $400 per night.

Time and costs for sample and data analysis depend on the detail necessary in aging and the information requirements of the region. Once age and growth work is done, data entry and computation of the estimate require only one or two hours depending on computer competence and familiarity with the spread sheet.

Alternative Methods for Abundance

Hydroacoustics, gillnetting, and spawning surveys have all been used to monitor kokanee abundance. Only hydroacoustics and spawning surveys have the potential to provide estimates of absolute number that may be used for comparison among lakes and with the existing data base. Gillnetting can provide information on relative abundance for a single population through time if netting is intensive and consistent in approach. Gill net samples, however, are notoriously variable and the number of net nights necessary to provide reasonable precision for annual comparisons is often unrealistic (Dillon 1989).

Hydroacoustics

Hydroacoustic estimates can provide very precise (± 10 to 20%) estimates of abundance with a minimal amount of effort (less than one night on most waters). It is possible to make hydroacoustic estimates of kokanee abundance with much less effort than by trawling. Presently, hydroacoustic estimates can provide only crude estimates of fish size frequency and total biomass and no estimate of species composition. In most cases it is necessary to have some other sampling (gill nets or trawl) in addition to the hydroacoustic work to make an estimate of kokanee abundance by age or size.

Presently hydroacoustic work must be contracted through consultants at costs of $1000 to $2000 per night of sampling including data analysis. If several lakes were done at one time, the total costs of hydroacoustic estimates would be similar to that for trawl estimates.

Hydroacoustic estimates should be most useful in circumstances where precise estimates are necessary, where kokanee are the dominant or only limnetic species and where trends in total abundance or biomass are adequate for monitoring, or in cases where trawling is not reasonable (e.g. reservoir drawdown or without room to trawl). A combination of hydroacoustic estimates and trawling should be useful in systems where absolute estimates of year class abundance are important to estimate survival (e.g. monitoring the influence of predator introductions or artificial fry or spawning enhancement).

Spawner Counts

The utility and quality of estimates of spawning escapement depend on the individual system. In some lakes, spawners use only one stream while in others spawning may be in multiple creeks and along the shoreline. In the first case, an absolute estimate of escapement can be made by trapping the run. An approximation can be made by periodically counting all fish in the stream(s), and then making an expansion of the mean or peak count for the average time an adult is in the stream. The expansion factor should be estimated by trapping the full run on several occasions and comparing spawner trend counts to the known escapement. In reality, this has been done rarely, but approximations of escapement as two times the peak count are often used. Without confirmation there **is** no way to know the relative bias of such estimates, but they are probably within an order of two.

Absolute estimates of escapement are useful, because they allow a direct comparison with the other estimates of abundance. When comparing directly with the trawl data, care must be taken to account for the lower efficiency of the trawl estimates (i.e. trawl estimate is probably 60 to 70% of true number and perhaps less with fish larger than 220 mm). Comparison of spawner estimates should also consider mortality that may occur between the timing of lake estimates and spawning escapement (i.e. spawner abundance may be reduced 50% or more from the year preceding maturity because of natural mortality and exploitation).

AGE AND GROWTH

Application of Information

The quality of a kokanee fishery is a tradeoff between the size and number of fish available to anglers (Rieman and Myers, 1990b). The size of available fish is influenced by growth and age at maturity. Growth and size at maturity can be useful indices of the status of a kokanee fishery. Information on growth is relatively easy to get. Lacking any information on a kokanee population or fishery, it is probably the most important data to gather.

Information on growth can provide a crude index of fish abundance. Growth is strongly influenced by fish density and lake productivity (Rieman and Myers, 1992). With the existing empirical relations (Figure 8) biologists can infer density with knowledge of length-at-age and lake productivity. Long-term trends in length at age can also provide information on the stability of a population. Size of spawners documents the establishment and long-term growth of the kokanee population in Coeur d'Alene Lake, for example, and has been used to infer fluctuations in abundance related to discharge in Dworshak Reservoir (Maiolie and Elam 1991).

Growth can serve as a "redflag" for management. Vulnerability of kokanee is strongly influenced by size. Few, if any, fish will be taken by anglers when length drops below 200 mm regardless of abundance. When the maximum size available to anglers ranges below about 220 mm, biologists may assume that either densities are too high or productivity is too low to support a good fishery. On the other hand, high length-at-age for a given productivity indicates that numbers may be approaching a dangerously low level. Vulnerability and exploitation may increase dramatically as densities and size decline creating an unstable system (Rieman and Myers, 1990b). The collapse of some fisheries including Flathead Lake may well have been triggered by attempts to manage for relatively low numbers and large fish (Rieman and Myers, 1990b). The optimum density for most populations appears to be in the range of 20 to 50 age 3+ f/hectare (trawl estimated density). Using Figure 8 for a lake of intermediate productivity (summer mean Secchi = 6 m), densities of 20 to 50 age 3+ f/hectare should result in September lengths of about 240 to 250 mm. Lacking any other information about density, fish substantially larger would be evidence of dangerously low numbers.

We have used length-at- ge in lake samples as the standard measure of growth for kokanee populations monitored over the last 15 years. The length weight relationship has been used commonly as an index of well-being in many fishes but not commonly in kokanee populations. Condition may be positively related to rate-of-growth but not always. Condition of kokanee varies substantially among Idaho populations and is not clearly related to growth (Figure 9). Estimates of weight are required for any estimates of total biomass. A length weight relationship can be used to estimate weights for missing observations and may be useful for monitoring trends in the status of any single population.

Methods for Age and Growth

Length at Age and Age Composition

We use total length and summarize data in 10 mm length groups. Length-at-age is represented by the modal length for each age class. Length-at-age

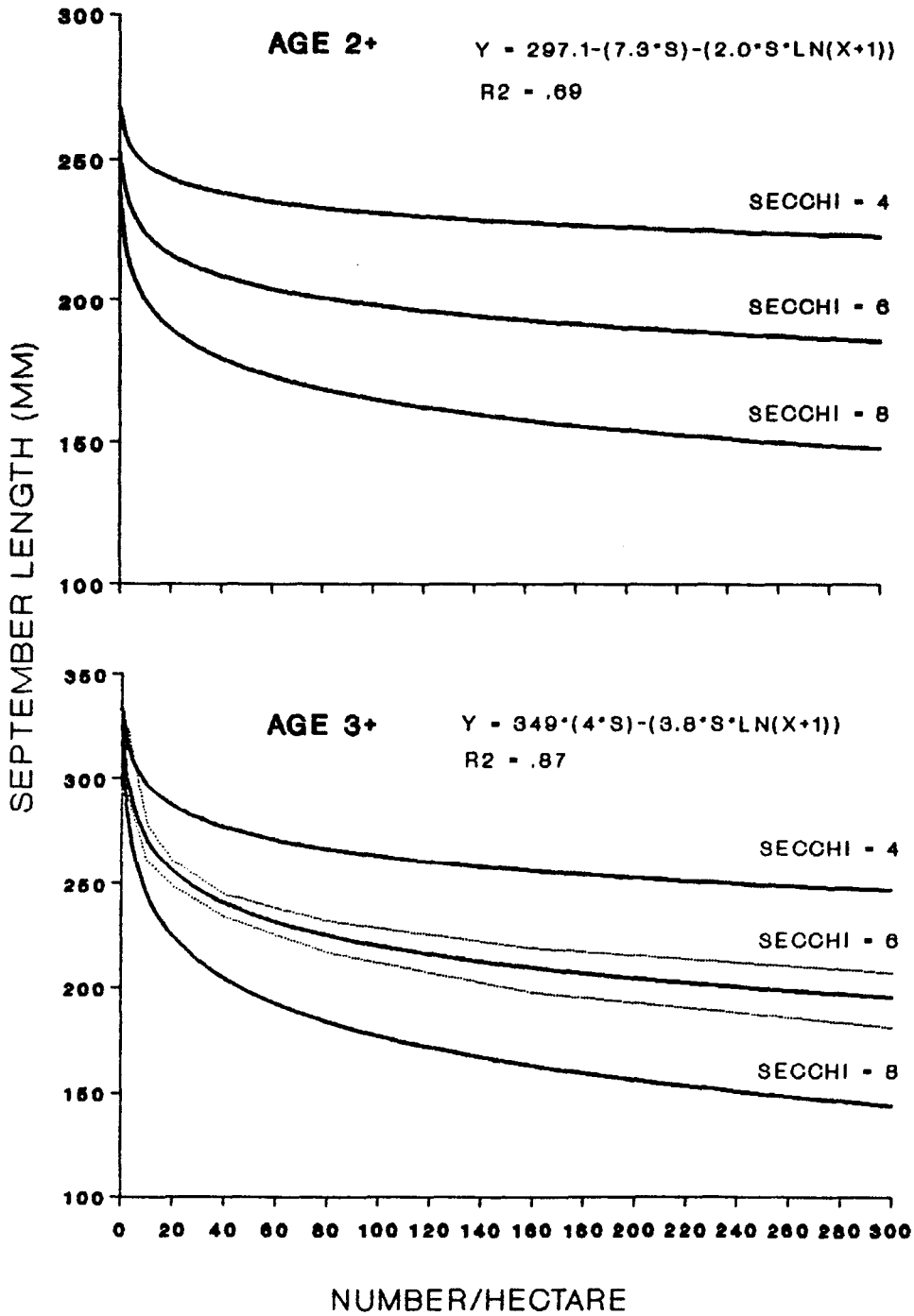


Figure 8. Predicted length at age for kokanee at varied densities and three levels of lake or reservoir Secchi transparency. From Rieman and Myers 1992.

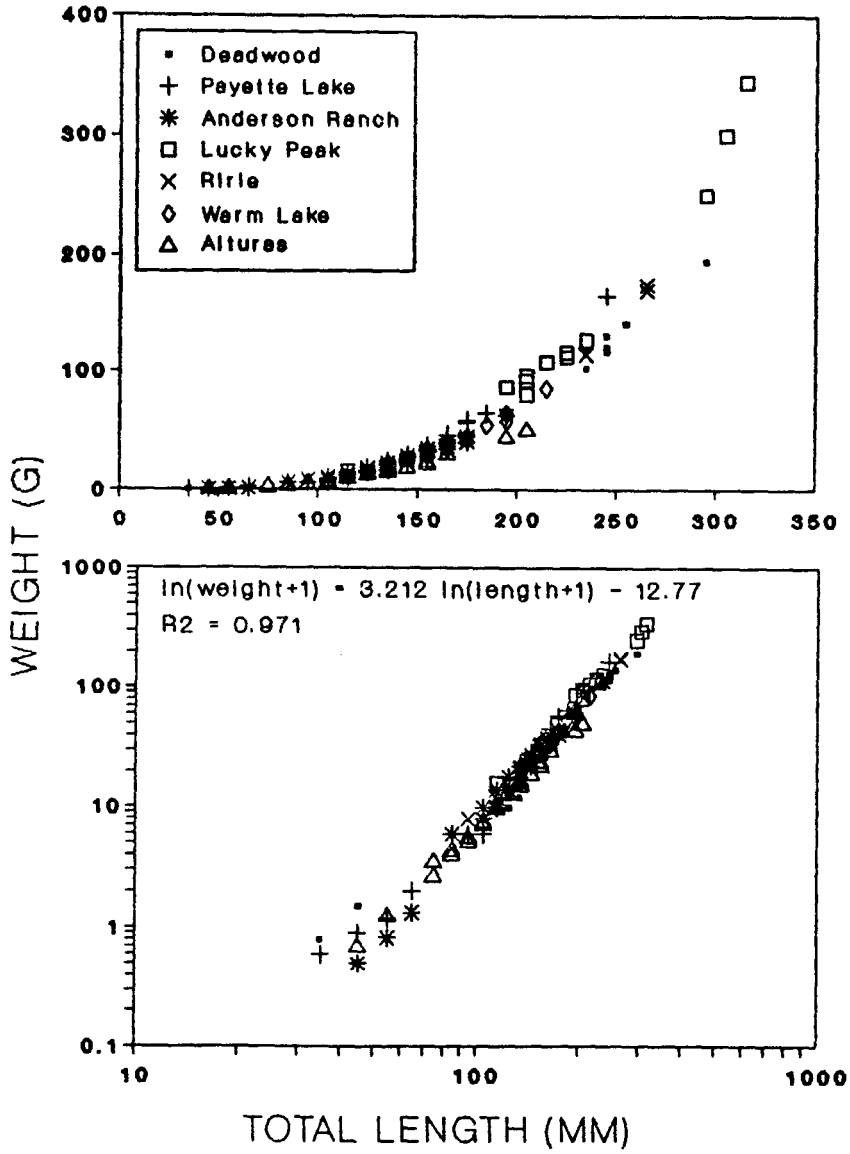


Figure 9. Length weight relationships for kokanee in 7 lakes or reservoirs in Idaho sampled in 1991. The regression equation was fit to the pooled data only for fish larger than 100mm. Note the log-log axes on B demonstrating a change in slope in the relationships at about 100mm.

of spawners can also be used to estimate growth and often can be obtained more easily than samples of fish in the lake.

Kokanee are growing rapidly during the season, and because sampling cannot be conducted on all waters at the same time (especially with trawl), it is necessary to correct the estimated length-at-age to a standard sampling time for comparison among lakes. Relatively little growth occurs after September in immature kokanee and virtually no growth occurs in mature fish (especially if they spawn in August). We have also tried to emphasize sampling in the fall for the populations monitored over the longest time (e.g. Lake Pend Oreille, Coeur d'Alene Lake). For those reasons, we have used length-at-age in late September as the standard measure of growth. September length can be estimated for fish sampled on earlier dates from Figure 10.

Aging of kokanee is required both for estimating growth and for making estimates of abundance by cohort. Aging estimates can be made from scales, otoliths, length frequency analysis, or a combination of any or all. Length frequency analysis can be misleading especially when year class strength varies dramatically or when growth is slow and lengths tend to overlap among cohorts. For that reason we, recommend always verifying length frequency analysis with at least some direct aging.

Kokanee scales are usually easy to read and are the preferred aging structure for most populations. Scales often are lost on small fish captured in the trawl and *cannot* be used for aging mature fish because of resorption. Otoliths are best in these circumstances. We advise caution in the use of otoliths, however, because interpretation is often difficult especially in slow growing populations. Any aging studies should be checked by blind replication among several biologists. If agreement in assigned age is not common, alternative methods should be used to develop consistent aging criteria and interpretations.

Data should be reported for each age class as the modal length at time of sample and as the length corrected to late September (Appendix B). Modal lengths-at-age for spawners should be reported separately for males and females. Secondary sexual characteristics for males will bias the estimate of length in comparison with prespawning fish. For comparison among populations, the length-at-age for spawning fish should be made only for females.

Condition

Weights should be collected on fish throughout the full length distribution in any sample. It is important to provide replication in each size range but not necessarily in every 10 mm size group. Sample size recommendations are in Appendix A. If regression analysis is used to describe the length weight relationship, replication should be balanced throughout the length groups (e.g. if 10 samples for 50 to 100 mm fish then 10 samples for 150 to 200 mm) to avoid bias in the model.

Our observations of growth in weight of kokanee suggests a shift in slope at about 100 mm in length (Figure 9). If length weight models are used to describe and compare *condition* among populations, it is important to fit separate models to upper and lower segments of the distribution.

For standardization, data on the weight of kokanee should be reported as the mean weight observed by length group (Appendix B). The number of samples should also be reported for each group. The spreadsheet for calculating population estimates (Appendix C) provides this printout directly.

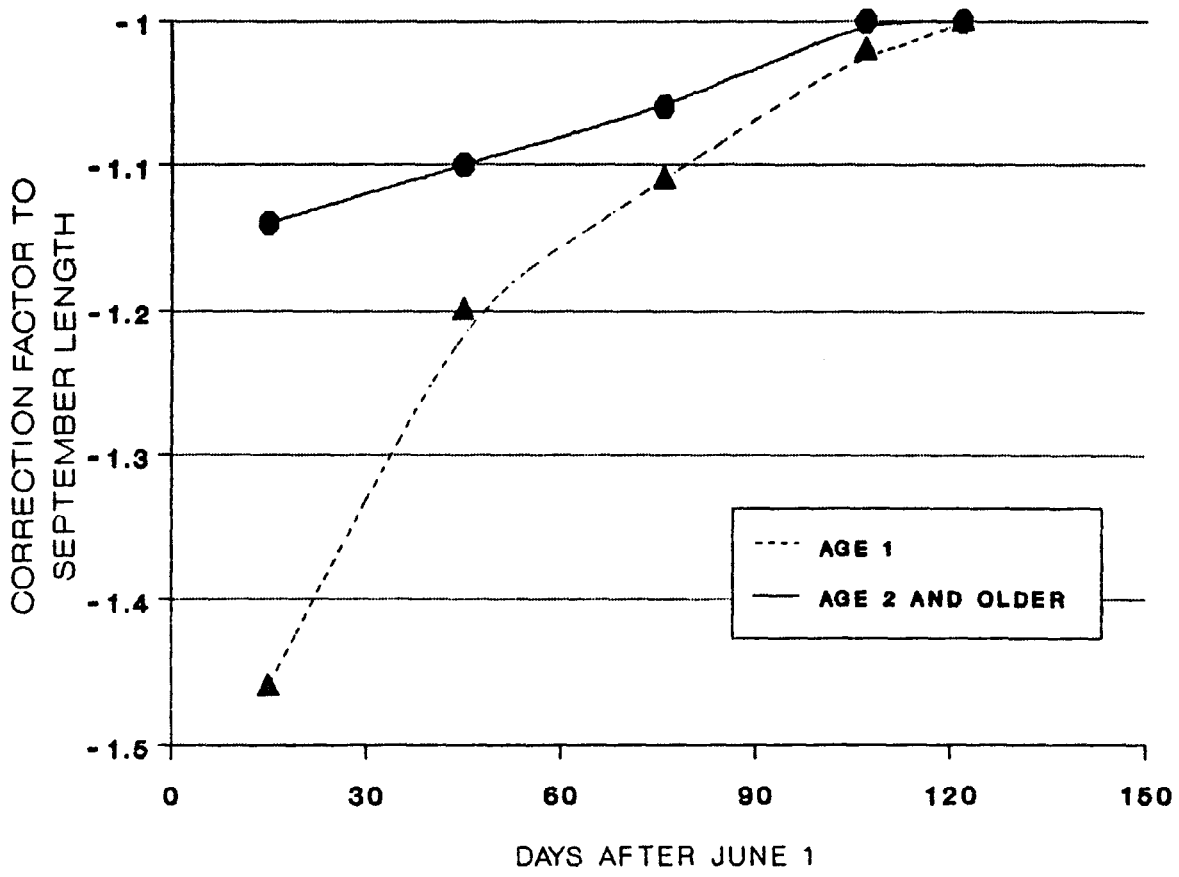


Figure 10. Correction factors to estimate September equivalent length for kokanee sampled by trawling between June 1 and September 30. Correction factors were estimated as outlined in Rieman and Myers 1992. The lines were fit by inspection.

OTHER DATA

Fecundity, Potential Egg Deposition

The fecundity of female adults obviously has a direct influence on potential recruitment. Estimates of survival from potential egg deposition to resulting fry the following fall have been used as a measure of relative productivity in individual stocks. Typical survival estimates for Coeur d'Alene, Spirit, and Pend Oreille lakes may range from less than 1% to about 4%. Estimates in the lower part of that range may be associated with declining or unproductive populations while the higher estimates suggest a more productive or growing population. Estimates in Anderson Ranch Reservoir have been as high as 10% which suggests potentially, a very productive kokanee population.

Potential egg deposition is the product of mean fecundity and female escapement. Female escapement may come either from the trawl estimates or direct estimates of escapement. If the former is used, its important to consider the potential bias in the estimate related to trawl efficiency and mortality of adults prior to escapement.

Fecundity is estimated directly by counting the eggs in individual females. Trawl samples of maturing females are often too few to develop a good relationship of fecundity to female size which is necessary to estimate fecundity in unsampled size classes. One alternative is to sample green females in the spawning run. In the absence of data from the population of interest, existing data from other lakes (Figure 11) can be used. The relation of fecundity to size may vary among populations, however, other sources of error in estimates of egg deposition are probably substantially larger.

Age-at-Maturity

Age-at maturity can have an important effect on the ultimate size of kokanee in a population and the quality of the fishery (Rieman and Myers, 1990b). Much of the annual variation in a fishery, and egg production at spawning, may be due to variation in age at maturity. Later maturation also means fish may be vulnerable to anglers for more years. In general, for our purposes, the later kokanee mature, the better. Age-at-maturity is probably genetically controlled but also seems to be influenced by growth (Rieman and Myers, 1990b). Maturity rates then may vary as a result of changing fish density and could be influenced by either hatchery selection or hatchery rearing.

Lake or Reservoir Productivity

Growth and standing crop of kokanee is strongly associated with relative productivity or lake or reservoir rearing environments. Temperature may also influence growth (Rieman and Myers, 1992). Traditionally, studies of kokanee or sockeye salmon growth have included full blown limnological investigations and especially estimates of zooplankton abundance and size structure (zooplankton represent the primary food source).

Complete limnological work probably is not necessary for monitoring of most populations. Complete zooplankton work (full season description of biomass or abundance) necessary to describe food production among lakes is

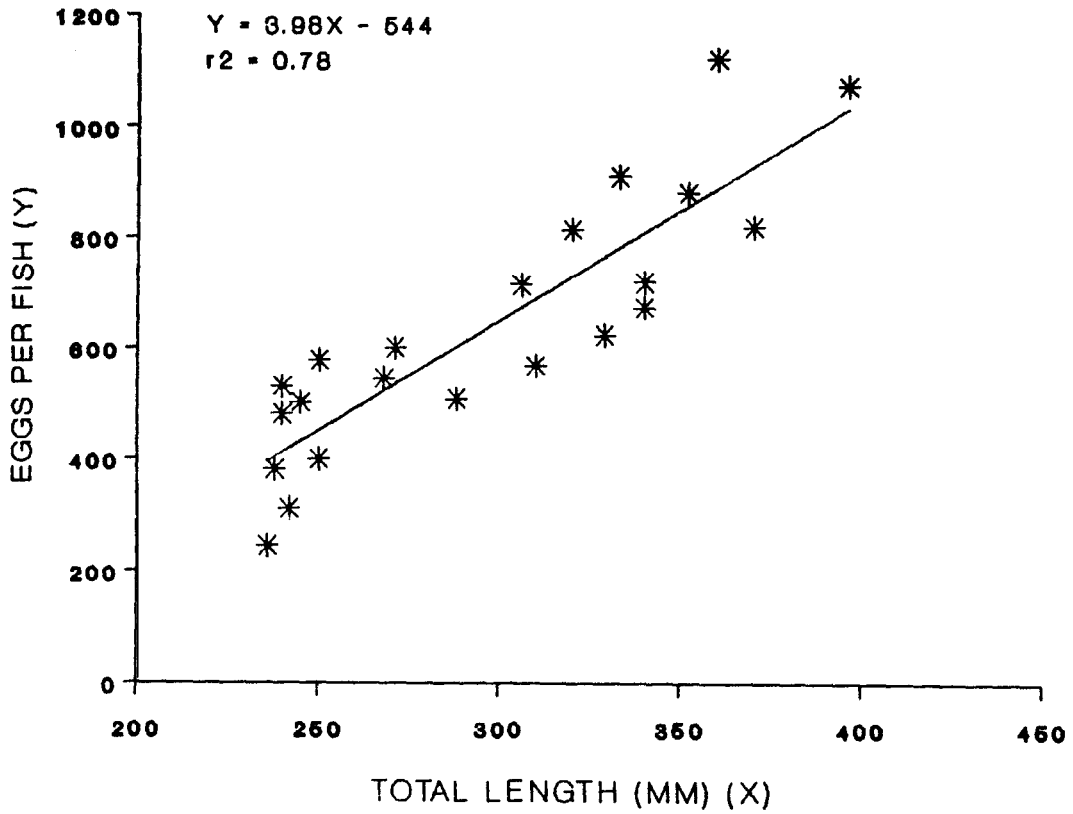


Figure 11. Relationship of fecundity to length for female kokanee collected from lakes throughout Idaho.

time consuming and difficult. Consistent zooplankton data that would allow comparison among kokanee lakes is also limited and thus of little utility for explaining growth patterns in any multisystem empirical model. Monitoring of simple trends such as size and species composition within a lake, however, may be accomplished with a lot less work (e.g. two samples per season) (see Maiolie and Bowles IDFG "Limno-Cookbook"). Such data could be useful for interpreting long-term fluctuations in abundance within a single lake (e.g. a shift to smaller zooplankton forms should accompany increasing density and slowing growth) and could be incorporated in a long-term monitoring program.

Other indices of lake or reservoir productivity are easier to get and more useful for predicting growth. Simple measures of trophic status like Secchi transparency and chlorophyll "a" explain a large part of the variation in growth and standing crop among Idaho kokanee populations. Total phosphorous and conductivity may also be useful as they are often correlated with the other measures and have commonly been used to predict fisheries yields (Myers and Rieman, 1991). We recommend that any kokanee monitoring program incorporate summer mean Secchi transparency as a minimum measure of trophic status. Sampling should be at least monthly from early May through September to calculate a summer mean. Sampling should be conducted as frequently as possible but does not need to be done every year. The more detailed limnological information should be incorporated whenever possible, particularly if inorganic turbidity may influence measures of transparency.

Physical Characteristics of Lakes and Reservoirs

Lake morphometry, temperature, oxygen, elevation, and surface area undoubtedly influence the productivity of kokanee populations and fisheries. Other than the obvious influence of lake size, those effects have not been well described. Such data are easily obtained, however, and should be incorporated in any data base for kokanee monitoring to allow more detailed analyses in the future. Lake morphometry should be characterized as surface area, total volume, mean depth, and shoreline length at full pool and obviously need to be done only once. Temperature and oxygen profiles should be taken during peak stratification, usually in late August or early September. Temperature and oxygen may vary substantially from year to year, but occasional samples (once every five years) are probably adequate to characterize differences among kokanee systems.

Drawdown and discharge may have important effects on the survival of kokanee. Maiolie and Elam (1992) showed a strong relationship between discharge and spawner abundance in Dworshak Reservoir. Their data suggest that entrainment losses may produce very weak year classes during high flow years. Large drawdowns have also be associated with the collapse of kokanee in Anderson Ranch Reservoir, though predation by introduced chinook may have been important as well (Rieman and Myers, 1991). Discharge and drawdown records are also easy to obtain and should be incorporated into annual records with any long-term kokanee monitoring on reservoirs.

Fisheries

The quality of the fishery is the ultimate measure of any kokanee management program. Absolute yield (kg/hectare/year) catch rates and angler effort can be compared among systems to determine whether a fishery is approaching its potential or has room for improvement (Rieman and Myers, 1990b; Myers and Rieman, 1991; see Figure 3). To allow comparison among fisheries, data must be collected throughout the year to account for seasonal variability in success and size of

fish. A full census should be incorporated into any monitoring program as frequently as possible.

Predation

Fish predators can strongly influence kokanee populations and fisheries (Rieman and Myers 1991) and probably explain the collapse of some Idaho fisheries. Stocking records of potential kokanee predators should be a minimum requirement for any kokanee monitoring program. Other data on growth, population dynamics, and food habits of predators by size or age, are also important if an evaluation of potential predatory effects is to be done. Such information should be incorporated into a kokanee monitoring program whenever possible.

LITERATURE CITED

Dillon, J.C. 1989. Alternate fish species and strains for fishery development and enhancement. Idaho Department of Fish and Game, Job Performance Report F-73-R-11. Boise, Idaho.

Maiolie and Elam 1992 ....

Myers, D.L. and B.E. Rieman. 1990. Kokanee population dynamics. Regional database. Idaho Department of Fish and Game, Job Performance Report F-73-R-12, Job 3. Boise, Idaho.

Myers, D.L. and B.E. Rieman. 1991. Kokanee population dynamics. Statewide Kokanee inventory: prediction of yield. Idaho Department of Fish and Game, Job Completion Report F-73-R-13, Job 2. Boise, Idaho.

Peterson, R.M. 1980. Testing for density-dependent marine survival in Pacific salmonids. In McNeil and Himoworth (editors). Salmonid ecosystems of the North Pacific. Oregon State University Press, Corvallis.

Rieman, B.E. and D.L. Myers. 1990(a). Kokanee population dynamics. Density dependent growth and productivity of the rearing lake or reservoir. Idaho Department of Fish and Game, Job Performance Report F-73-R-12, Job 1. Boise, Idaho.

Rieman, B.R. and K.L Myers. 1990(b). Kokanee population dynamics. Influence of density on potential yield: prediction of stocking rates. Idaho Department of Fish and Game, Job Performance Report F-73-R-12, Job 2. Boise, Idaho.

Rieman, B.E. and D.L. Myers. 1991. Kokanee population dynamics. Costs benefits and risks of salmonid predators in Kokanee waters. Idaho Department of Fish and Game, Job Completion Report F-73-R-13, Job 1. Boise, Idaho.

Rieman, B.E. and D.L. Myers. 1992 (In press). Influence of fish density and relative productivity on growth of kokanee in ten oligotrophic lakes and reservoirs in Idaho. Transactions of the American Fisheries Society. 12:XXX-XXX.

Robinson, D.G. and W.E. Barraclough. 1978. Population estimates of sockeye salmon (Onchorhynchus nerka) in a fertilized oligotrophic lake. Journal of Fisheries Research Board of Canada. 35:851-860.

A P P E N D I C E S

APPENDIX A

Trawl Field Guidelines And Procedures

Map the lake and identify basins and subbasins with constant minimum depths of at least 90 feet (or 15 fathoms). These represent the safe trawling areas. Each basin must have at least one nautical mile of open water to be a potential trawling site. If a morphometric map is not available or is questionable, then some echo sounding is necessary before trawling to "secure" the trawling sites and to identify hazards.

Spend some time on the lake during daylight even if a good map is available. Do enough sounding to be familiar with the bottom and the tight spots. Set out the flashing navigation lights to help locate others at night; note obvious landmarks on the lake chart.

Take a Secchi reading in open water between 10 am and 4 pm. Also, take a temperature profile. If timing is too tight, these things can be dropped.

Sampling goals should be determined by size and expected variability for each lake or reservoir. If space and/or time is limited, the minimum should be seven trawls for any water where we need an actual estimate of density. Without complications, 14 trawls should be possible in one long and one short night. Without sacrificing travel and rest time or safety, add as many additional trawls as possible. Identify all possible trawling locations within the water body and number them sequentially. If there are 14 locations, then trawl each one. If there are less than 14 possible sites, select sites randomly. If there is more than one distinct basin (e.g. fish would not move easily back and forth after the water stratifies, or habitat such as depth, bottom contour, or exposure differs dramatically between two or more areas), then stratify the sampling among basins. The number of trawls allocated to each basin should be proportional to size of the basin, but never less than two (better with three).

Kokanee can avoid the net with very low available light. To avoid biased samples do not begin trawling until one hour after sunset and stop at the first sigh of light. An early trawl is okay for practice or to identify the kokanee layer but should not be used as part of the normal sample. The working time available by month for 1992 is shown in Figure 1. In other years working time will be approximately the same in each month, but data will change with the date of the new moon.

Echo sound at about 1200 to 1500 rpm (as fast as you can go without noise on the echo gram) just prior to the first trawl. Identify the fish layer and set up the trawl steps to completely bracket the layer (Figure 2, identify depths and recalibrate every season). Select the step times to maximize the length of trawl but still provide a safe working room. Step times should not be less than three minutes and should not need to be longer than eight minutes.

APPENDIX A (cont.)

Number of Steps	Time per step	Distance traveled while trawling Meters	Nautical
3	3 min	1140	0.62
4	3 min	1380	0.75
5	3 min	1620	0.87
3	5 min	1500	0.81
4	5 min	1860	1.0
5	5 min	2220	1.2
4	8 min	2580	1.4
5	8 min	3100	1.7

Most trawls should be run by dropping to the bottom step and then working up (minimizes risk for unknown hazards or miscalculation down the way). If one needs to work out of shallow water into deep water, the steps can be reversed or started short of the bottom working down and then back up (take extra care to keep track of your depths).

For the small trawl boat, set the trawl at 1,000 to 1,200 rpm. Trawl at about 1,500 rpm but verify the boat speed to select the final trawl rpm. Target boat speed should be 0.98 mps to keep the trawl depths accurate. When checking the boat speed, make sure the flow meter is not influenced by the bow wave.

Minimize lights as much as possible while trawling. If there is other boat traffic, use the running lights and flash the deck lights or spotlight to warn them.

DATA COLLECTION

Trawl catches should be worked up as soon as possible, but can be held on ice if catches are large or timing is tight for getting in all the trawls.

If catches are small and trawls are long, the catch can be worked up while traveling between sites or while trawling. If catches are large or time is short, bag the fish from each trawl, number the bag to match the data sheet, and hold on ice until the next day. Use one data sheet for each trawl (Figure 3).

Lengths

Measure total length on all fish (pinch the tail closed). Truncate the lengths to the lowest whole 10 mm length group (i.e. a 245 mm fish is recorded as 240, 259 mm as 250, and 260 mm as 260). If there are large numbers of age 0 fish, measure at least 10 per trawl, then count the remaining fish and allocate them to length groups in the same proportions as the measured fish. Measure at least 50 age 0 fish from all the trawls combined. Record the lengths on the data sheet corresponding to the trawl of capture. **Be** sure that trout are not mistaken for kokanee, but do note all species caught.

APPENDIX A (cont.)

Weights

Weights should be taken from a pooled sample of all the trawls (i.e. they do not need to be trawl specific). Weights should be taken from 10 mm length groups. No more than five weights per length group are necessary. Fish under 100 mm may be grouped (by 10 mm group) and weighed together to get an average for the length groups. Weights should be recorded on a single master data sheet.

Otoliths and Scales

Otoliths should be taken from a pooled sample of all trawls. Otoliths should be taken to represent the major length groups or age classes that may be present. Samples should be concentrated in 10 mm length groups where there appears to be overlap in age classes. Do not take more than 10 otoliths per 10 mm length group with a goal of 60 otoliths for the entire sample. A coin envelope should be labeled with length, date, and location for each otolith. Clean each otolith by moistening and rubbing between your fingers to remove as much tissue and debris as possible (they are tough to clean later). Place otoliths in the plastic vial and then in the envelope. Take scales (10 per length or age group) and pair with an otolith sample (i.e. same fish) and smear on a small piece of paper placed in the envelope with the otolith container. Seal the envelope. If you do not have time to get all the necessary otoliths, bag the fish by length group and keep on ice until back in the office.

Maturity and Fecundity

Open **all** fish longer than 200 mm. If obviously maturing note sex on the data sheet. Remove mature egg skeins and preserve with formalin or 80% alcohol in a whirl pack. Label with fish length, date, and location.

The goal should be 25 females from each population but probably will not be possible in most samples.

Miscellaneous

In some populations hatchery fish have been stocked and will show up in the same length classes as age 0 and age 1 kokanee. In these populations it will be important to take a large sample of otoliths from the smaller length groups so that we can identify hatchery fish. If one is unsure about how many to sample or do not have time to get the otoliths, bag the fish by length group and keep on ice until back in the office.

Equipment and Check List

Remind the Region or Sheriff of presence.

Coolers (1 large and 1 small)
Electronic balance
Block ice
Scale packets and otolith vials

APPENDIX A (cont.)

Equipment and Check List (cont.)

Marking pens
Filet knife and scalpel
Food, water
Secchi disk
Rain gear and rubber boots
Radar functions
Computer, diskettes
Thermistor
Timers, extra batteries
Measuring board
Small garbage bags
Equipment manuals
Scale packets

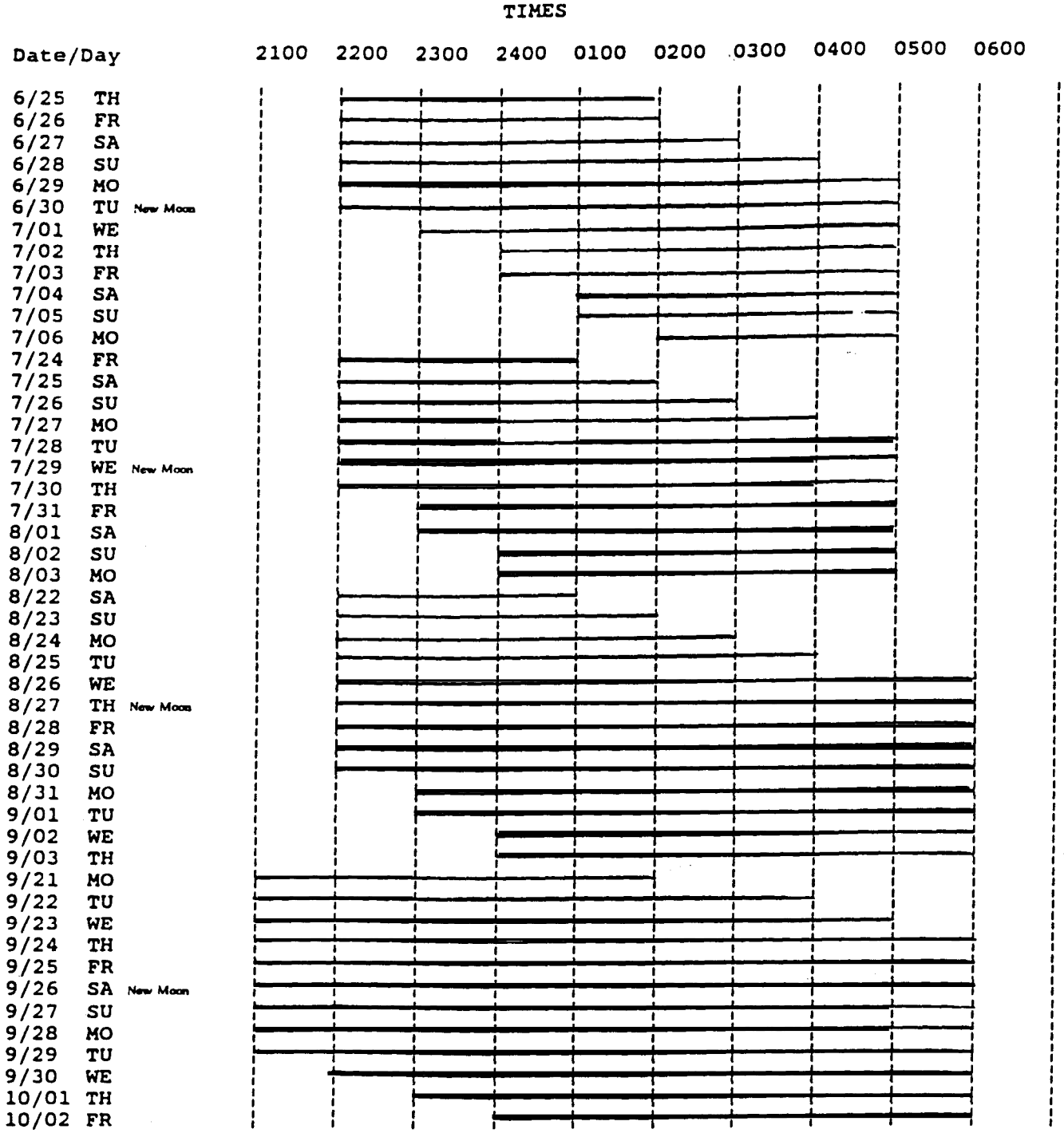
Alcohol or formalin
Back-up sounder and chart paper
Navigation lights
Flashlight batteries
Whirl packs
Lotus spread sheet
Gonad Tissue vials
Data sheets
Ziplock bags
Forceps
Flashlight bulbs
Otolith vials

Appendix A. Figure 1. Example of hours of darkness.

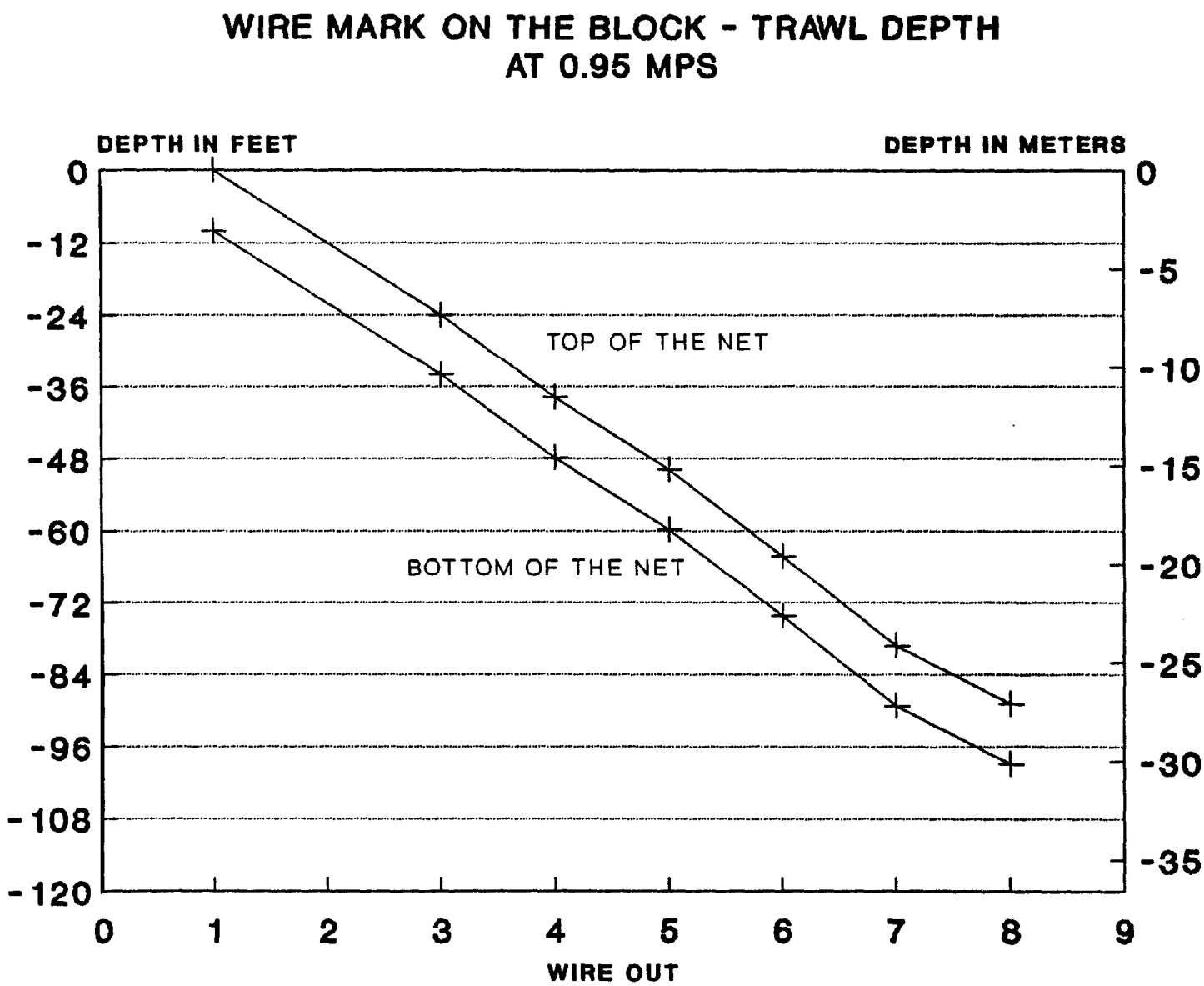
PERIODS OF DARKNESS

June-July-August-September 1992

(Times are Daylight Savings Time)



Appendix A. figure 2. Example calibrations.



Appendix A. Figure 3. Sample data sheet.

DATE _____

LOCATION _____

Page ___ of ___

Number	Weight (n) (g)	Age Str	♂	♀	Number	Weight (n) (g)	Age Str	♂	♀
30					300				
40					310				
50					320				
60					330				
70					340				
80					350				
90					360				
100					370				
110					380				
120					390				
130					400				
140					410				
150					420				
160					430				
170									
180									
190									
200									
210									
220									
230									
240									
250									
260									
270									
280									
290									

Trawl Number _____

Minimum Depth _____ Maximum Depth _____

Number of Steps _____

Time/Step (S) _____ Time Between Steps _____(S)

Boat Speed _____(M/S) RPM _____ Angle _____

Crew _____

Conditions _____

Comments _____

APPENDIX B

Example of a Minimum Standard Data Report of Kokanee Trawl Estimates

LAKE: ALTURAS

TOTAL SURFACE AREA: 337
Kokanee USEABLE SURFACE AREA: 212

YEAR 1991
DATE Sept. 8

NUMBER OF STRATA SAMPLED 1 TOTAL # TRAWLS 7

	AGE 0	AGE 1	AGE 2	AGE 3	>AGE 3	TOTAL
Number	5,600	67,200	48,600	3,700		125,900
Variance	0.7×10^6	1.0×10^8	1.0×10^8	2.2×10^6		
Density Fish/hectare	26	311	239	19		590
Modal Length (mm)	45	65	95	190	205	
September Corrected length	45	65	95	190	205	

Estimated Biomass of Sample 6.3 September Corrected Biomass 6.3

Adult Bias Corrected Biomass Method: (30%) X Corrected Est. 8.2 (Estimated Escapement) _____

COMMENTS: Aging incomplete. Age 1 (1+) fish may have been included in Age 2 estimates.

>Age 3 length from sample of spawners in mid-Sept. Spawning escapement very weak and correction for spawner bias (30%) probably too high.

All Age 3 sample was immature.

Useable surface area best guess of area of lake at 60' contour, morphometric map not available.

Sampling conditions good; calm; dark!

APPENDIX C

Documentation for Lotus 123 Spreadsheet, Trawl.wkl, for Estimating Kokanee Density, Number, and Biomass

The estimating method for kokanee number, density, and biomass is set up as a LOTUS 123 spreadsheet named TRAWL.WK1. To use the spreadsheet, one should be prepared with the following:

1. Numbers caught per trawl by length group.

2. For each trawl, the vertical depth encompassed (from the bottom of the net on the lowest step to the top of the net on the highest step); the average time at step and the average time between steps; average boat speed during the trawl (should be very close to 1.0 m/second). The assumed mouth area of the trawl is 9.29 square meters.

3. The surface area used by kokanee for each strata sampled (note that there cannot have more than three strata for one spread sheet). The surface area used by kokanee is estimated as the surface area of the lake at the mid-depth of the nighttime kokanee layer. If one does not have an estimate of surface area, the program will give estimates of fish density (f/hectare) but will not give a total population estimate.

4. An estimate, approximation, or assumption of the length groups representing each age class. If aging is uncertain, the estimate may be portioned into any length groups that make sense based on the length or other data (they just will not be estimates of individual cohorts).

5. The measured or estimated mean weight for fish in every sampled 10 mm length group. The program will calculate the mean for your observations from total weight and total observations in each length group. If one does not measure weight directly for each length group, then missing observations should be estimated from a length x weight relationship from the available observations.

Use the spreadsheet trawl.wkl as a template for each lake or estimate that is done and save under a new name.

The program provides both an arithmetic and a total ratio estimate of mean fish density as a check for potential bias. Normally the two estimates should be very similar, but when variance is very high or when one sample is a real flyer, the two estimates will diverge. In that case, one may want to look carefully at the outlying estimates for possible bias. The ratio estimate is the best (least biased) estimate to report in all circumstances.

The program is run entirely by macros. One can enter up to three strata with up to 10 trawls from each. Instructions for running the program are at location Al.

The following is a summary of the Macros:

Alt-E Puts the cursor at the top of the data entry form. Alt-E can be used at anytime during the program.

When entering data one <u>must</u> complete the lake information part for all three strata - even <u>if</u> it does not apply. Enter 0 for number

of hectares for missing strata. Be sure to enter the number of trawls in each strata, Lotus uses this number to calculate variances.

Enter all weights from all fish with strata one if possible. If **filling in later, enter with Strata 3 in data storage area.**

One only need to enter data from the weight sample once. Do not worry about missing length groups here, the final estimate will prompt one for missing data.

Alt-A Moves data from the entry form to a storage area at DA1 then clears the original entry form for one to enter data for the next section.

Alt-B Moves data for 2nd strata from the entry form to a storage area at DA62 then clears the original form for one to enter data for 3rd strata.

Alt-C Moves data for the 3rd strata from the entry form to a storage area at DAl23 then clears the original form. Puts the cursor at an instructional screen.

Alt-V Generates length frequency histogram in Lotus. To return to the spreadsheet hit ENTER then 'Q'. Histogram includes all fish from all strata.

Alt-D Use after entering size ranges for each age group (inclusive). Calculates density estimates and stores results at DT1. It takes a VERY LONG time to run this macro - drink a cup of coffee now.

Returns the cursor to a screen that prompts one to enter missing weights for length groups that are marked by an asterisk.

Alt-F Calculates biomass estimates.

Alt-P Prints input data and a summary of estimates. **Set printer to condensed print before using Alt-P**.

Once everything is stored, one can revise the data at DA1..DA184, or length ranges for age groups at F91, and rerun the program (Alt-D) at any time.

APPENDIX C (cont.)

LOTUS ADDRESSES:

Spreadsheet Location		Macro	Locations
Al	Instructions	AA1	E
A25	Data entry form	AA6	A
F91	Enter length ranges	AD6	B
A168	Enter weight estimates	AG6	C
DA1	Strata 1 data storage	AAl2	V
DA62	Strata 2 data storage	AA15	D
DAl23	Strata 3 data storage	AA90	SUB
DT1	Summary of estimates	AL1	BIO
		A150	P
		AL80	F

To import data from length frequency histogram into Harvard Graphics:

X Range EE9..EE46
Y Range EF9..EF46

Appendix C. Table 1. Sample output from TRAWL.WK1.

DATE: AUGUST 19-20, 1990
LAKE: ALTURAS
SECTION: 1 of 1
USEABLE SURFACE AREA (HA) FOR SECTION 212
NUMBER OF TRANSECTS IN SECTION 7

	TRANSECT 1	2	3	4	5	6	7	8	9	10	SECTION TOTAL	NUMBER IN WT. SAMPLE	TOTAL WT. OF SAMPLE	NUMBER OF MALES	NUMBER OF FEMALES
MAX DEPTH (M)	28.65	23.16	23.16	23.16	23.16	23.16	23.16								
MIN DEPTH (M)	9.14	9.14	9.14	9.14	9.14	9.14	9.14								
NUMBER OF STEPS	5	4	4	4	4	4	4								
TIME/STEP (S)	240	240	240	240	240	240	240								
TIME BETWEEN STE	21	21	21	21	21	21	21								
BOAT SPEED (M/S)	0.98	0.98	0.98	0.98	0.98	0.98	0.98								
NET MOUTH AREA (	9.25	9.25	9.25	9.25	9.25	9.25	9.25								
SIZE CLASS															
30							2				2				
40	1	1	2	4	9	10	2				29				
50	5	8	15	5	11	15	5				64				
60		2	2	7	2		7				20				
70		2									2				
80	1		4	1		1					7				
90	5	7	8	3	5	7	5				40				
100	4	10	11	5	7	3					40				
110	5	8	20	3	9	7	3				55				
120	5	1	6		7	5	4				28				
130				1	1		2				4				
140						2					2				
150											0				
160											0				
170						1					1				
180											0				
190	3		1	1	1						6				
200		1			2		1				4				
210				1							1				
220		1									1				
230											0				
240											0				
250											0				
260											0				
270											0				
280											0				
290											0				
300											0				
310											0				
320											0				
330											0				
340											0				
350											0				
360											0				
370											0				
380											0				
390											0				
400											0				

Appendix C. Table 1. (cont.)

LAKE: ALTURAS
STRATA: 1 DATE: AUGUST 19-20. 1990

TRANSECT	DEPTH SAMPLED MIN	DEPTH SAMPLED MAX	DENSITY ESTIMATE (NO/HA) 0	1	2	3	4	TOTAL
1	9.14	28.65	94.3962	15.7327	220.257	78.6635	47.1981	
2	9.14	23.16	128.171	56.9652	356.033	14.2413	28.4826	
3	9.14	23.16	242.102	85.4479	555.411	85.4479	14.2413	
4	9.14	23.16	128.171	113.930	156.654	14.2413	28.4826	
5	9.14	23.16	284.826	28.4826	299.067	113.930	42.7239	
6	9.14	23.16	356.033	14.2413	242.102	113.930	0	
7	9.14	23.16	128.171	99.6892	113.930	85.4479	14.2413	
8	0	0	0	0	0	0	0	
9	0	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	
RATIO ESTIMATE (SUM N/SUM HA)			195.928	59.8097	278.424	72.1841	24.7488	631.095
MEAN (NO/HECTARE)			194.553	59.2128	277.636	72.2718	25.0528	628.727
VARIANCE OF RATIO			141[illegible],39	240.631	3159.97	259.028	24.7488	5100.78
VARIANCE OF MEAN			1422.30	242.452	3089.41	252.239	40.1817	5046.59
POPULATION EST (RATIO)			41536.8	12679.6	59026.0	15303.0	5246.75	133792.
POPULATION EST (MEAN)			41245.3	12553.1	58859.0	15321.6	5311.20	133290.

LAKE: ALTURAS
STRATA: 2 DATE: AUGUST 19-20. 1990

TRANSECT	DEPTH SAMPLED MIN	DEPTH SAMPLED MAX	DENSITY ESTIMATE (NO/HA) 0	1	2	3	4	TOTAL
1	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	
4	0	0	0	0	0	0	0	
5	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	
7	0	0	0	0	0	0	0	
8	0	0	0	0	0	0	0	
9	0	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	
RATIO ESTIMATE (SUM N/SUM HA)			0	0	0	0	0	0
MEAN (NO/HECTARE)			0	0	0	0	0	0
VARIANCE OF RATIO			0	0	0	0	0	0
VARIANCE OF MEAN			0	0	0	0	0	0
POPULATION EST (RATIO)			0	0	0	0	0	0
POPULATION EST (MEAN)			0	0	0	0	0	0

LAKE: ALTURAS
STRATA: 3 DATE: AUGUST 19-20. 1990

TRANSECT DEPTH SAMPLED DENSITY ESTIMATE (NO/HA)

LENGTH FREQUENCY: LENGTH GROUP	TOTAL NUMBER	NUMBER IN WT. SAMPLE	TOTAL WT. OF SAMPLE	NUMBER OF MALES	NUMBER OF FEMALES
30	2				
40	29				
50	64				
60	20				
70	2				
80	7				
90	40				
100	40				
110	55				
120	28				
130	4				
140	2				
150	0				
160	0				
170	1				
180	0				
190	6				
200	4				
210	1				
220	1				
230	0				
240	0				
250	0				
260	0				
270	0				
280	0				
290	0				
300	0				
310	0				
320	0				
330	0				
340	0				
350	0				
360	0				
370	0				
380	0				
390	0				
400	0				

Appendix C. Table 1. (cont.)

	MIN	MAX	0	1	2	3	4	TOTAL
1	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	
4	0	0	0	0	0	0	0	
5	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	
7	0	0	0	0	0	0	0	
8	0	0	0	0	0	0	0	
9	0	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	
RATIO ESTIMATE (SUM N/SUM HA)			0	0	0	0	0	0
MEAN (NO/HECTARE)			0	0	0	0	0	0
VARIANCE OF RATIO			0	0	0	0	0	0
VARIANCE OF MEAN			0	0	0	0	0	0
POPULATION EST (RATIO)			0	0	0	0	0	0
POPULATION EST (MEAN)			0	0	0	0	0	0

TOTAL POP'N ESTIMATE (MEAN)		41245	12553	58859	15322	5311
TOTAL POP'N ESTIMATE (RATIO)		41537	12680	59026	15303	5247
VARIANCE OF POPULATION (MEAN)		6E+07	1E+07	1E+08	1E+07	1805926
VARIANCE OF POPULATION (RATIO)		6E+07	1E+07	1E+08	1E+07	1112312
ERROR BOUND (MEAN)	HIGH	57235.8	19155.1	82426.0	22055.6	7998.90
	LOW	25254.8	5951.06	35292.0	8587.65	2623.51

MEAN WEIGHT (G)	0	0	0	0	0
BIOMASS BY SIZE CLASS (KG)	0	0	0	0	0

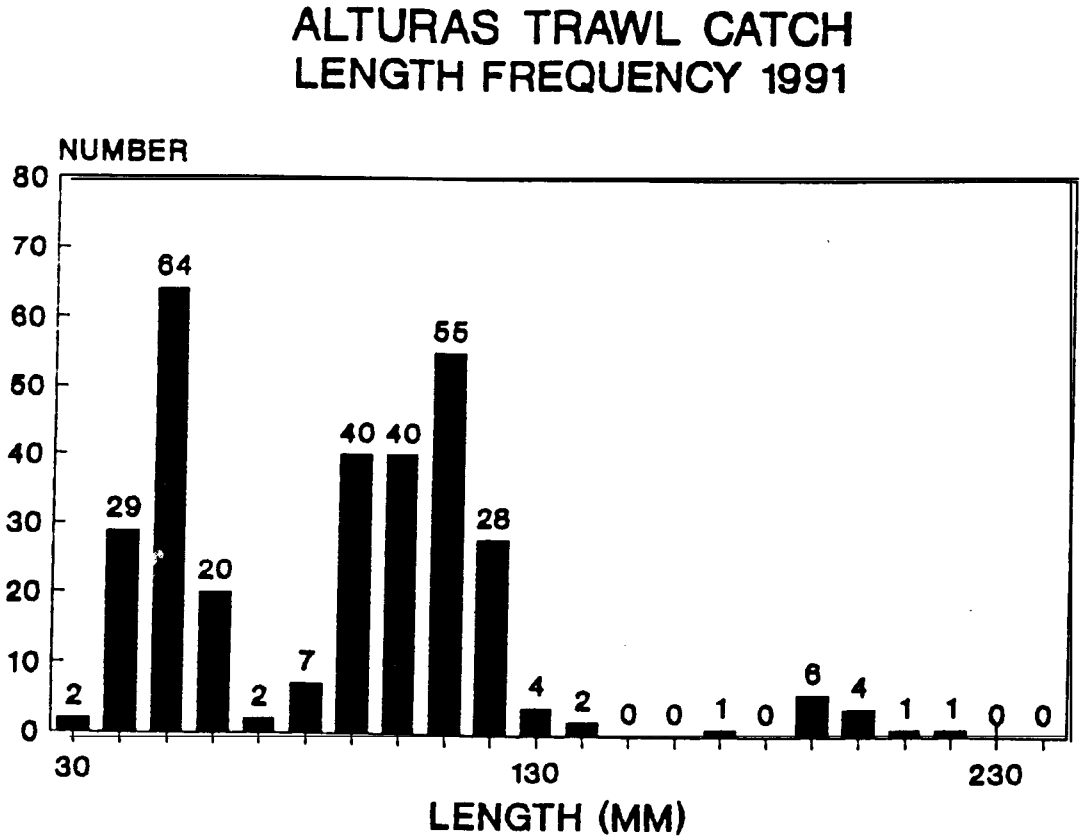
TOTAL BIOMASS FOR LAKE (KG/HA): 0

SIZE CLASS	LOW	HIGH
0	30	50
1	60	80
2	90	110
3	120	180
4	190	230

EXPANSION ASSUMING USEABLE HABITAT AS FOLLOWS:

SECTION	NO. HECTARES
1	212
2	0
3	0
TOTAL	212

Appendix C. Table 1. (cont.)



APPENDIX D. "Cookbook" for Kokanee Trawling.

STANDARD COOKBOOK
for Kokanee Trawling

	Reference
1. Justification Goals-Determine Necessary Precision	Page 9, 13-15
2. Sampling Design	
Map Lake	Appendix A
Identify strata and safe sampling area	Page 9
Estimate surface area	Appendix A
Determine sampling effort and allocation	Page 9, Appendix A
3. Trawl scheduling with trawl crew	
Note hours of working darkness and determine number of work nights for appropriate sample size Make arrangements for housing, etc	Appendix A
4. Sampling	
Trawling	
Identify the layer on echo sounder	Appendix A, Page 13
Select sampling depths and haul time	Appendix A, Page 13
Sample collection	Appendix A
Data Recording/Summary/Collection	
Lengths, Weights, Scales, Otoliths, Fecundity	Appendix A Figure 3
5. Data Analysis	
Identify age groups and length	Page 18
Estimate density and standing crop	Appendix C
Length/weight relationship	Page 21, Figure 9
Potential egg deposition	Page 21
Describe modal length-at-age	Page 18
Correct to September equivalent	
Length	Figure 10
Total biomass	Figure 7
Spawner Biomass Adjustment	Page 13
6. Summarize in Standard Format	Appendix B
7 Interpretation	
Compare densities, biomass, growth, with predictions based on lake productivity . .	Figure 1, Figure 4 Pages 2-7
Survival estimates	Page 13, Table 2

Submitted by:

Bruce E. Rieman
Principal Fishery Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Steven M. Huffaker, Chief
Bureau of Fisheries

Virgil K. Moore
Fisheries Research Manager

SIGNPAGE