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Stock Assessment of Chinook, Sockeye, and Chum Salmon in the Nushagak River

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Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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The Fishery Manuscript series was established in 1987 by the Division of Sport Fish for the publication of technically-oriented results of several years' work undertaken on a project to address common objectives, provide an overview of work undertaken through multiple projects to address specific research or management goal(s), or new and/or highly technical methods, and became a joint divisional series in 2004 with the Division of Commercial Fisheries. Fishery Manuscripts are intended for fishery and other technical professionals. Fishery Manuscripts are available through the Alaska State Library and on the Internet http://www.adfg.alaska.gov/sf/publications/ This publication has undergone editorial and peer review.

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In 2005, the Alaska Department of Fish and Game began using dual frequency identification sonar (DIDSON) to measure escapement on the Nushagak River. The DIDSON replaced an earlier acoustic system (Bendix) that had been in use for many years. Over the course of several years, the two systems were operated side-by-side in the four spatial strata that are summed to produce the total salmon passage estimates. This comparison found the DIDSON detected a higher number of fish than the older system, particularly in the offshore strata. From the relationship between DIDSON and Bendix raw passage described in previous work, conversion factors for each species were calculated by first apportioning the daily sonar passage estimate to species by strata using DIDSON and Bendix daily estimates from 2002 to 2004 on the south bank and 2002 to 2005 on the north bank. Summing these strata estimates by species we determined strata conversion ratios for sockeye *Oncorhynchus nerka*, chum *O. keta*, and Chinook *O. tshawytscha*salmon. We expanded this analysis by applying these strata conversion factors to annual species passage estimates from 2002 to 2011 to come up with total conversion factors of 1.11, 1.27 and 2.08 for sockeye, chum and Chinook salmon, respectively. By applying these conversion factors to historical Bendix passage estimates, we produced revised total run and brood tables for Nushagak sockeye, chum, and Chinook salmon composed solely of DIDSON or equivalent estimates.

Key words: Pacific salmon, *Oncorhynchus* spp., sockeye salmon, *O. nerka*, Chinook salmon, *O. tshawytscha*, chum salmon, *O. keta*, Bristol Bay, Nushagak River, escapement, harvest, catch, commercial, sport, subsistence, age composition, total run, stock assessment.

INTRODUCTION

Many Alaska Department of Fish and Game (ADF&G) salmon escapement estimation projects conducted with hydroacoustics on migrating salmon in rivers have been in a period of transition in recent years, as older systems are being replaced with more modern technology. One such river is the Nushagak, where the sonar system (Bendix[1]) that has been in use since the late 1970s was replaced in 2005 with a dual frequency identification sonar (DIDSON; Belcher et al. 2002). As it was recognized that the transition to newer hydroacoustic equipment had the potential for altering the fish passage estimates, the Bendix and DIDSON methods were conducted simultaneously at various times during the 2003–2005, 2007 and 2009 runs. From these side-by-side comparisons, Maxwell et al. (2011) proposed a method to convert Bendix and DIDSON passage estimates. However, on rivers such as the Nushagak where estimated salmon passage is an amalgamation of multiple species, the species estimates used by managers are a function of the raw sonar estimate and the apportionment of that estimate into individual species. This report extends the Maxwell et al. (2011) analysis to the species level on the Nushagak River.

NUSHAGAK RIVER

The Nushagak River empties into the Nushagak Bay in southwestern Alaska near the town of Dillingham. The Nushagak watershed encompasses an area approximately 1.3 million km^2 of mostly broad and flat terrain with abundant standing water and slightly more than 5,000 km of flowing waters (Figure 1). Mean monthly temperatures range from -9^o C in January to 12^o C in July. Mean monthly precipitation ranges from 28 mm throughout February and April to 97 mm in August (NCDC 2012).

The United States Geological Survey measures discharge at four locations within the Nushagak watershed. Discharge on the fourth order Koktuli River (North fork) averages 5 m^3/s while discharge on the third order New Stuyahok River averages 13 m^3/s. The second order Nuyakuk

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

and Mulchatna rivers average 179 and 157 m^3/s respectively while discharge on the first order Nushagak River in the late summer of 2012 as measured at the Portage Creek sonar site was approximately 1,100 m^3/s (USGS 2012).

The Nushagak watershed provides spawning and rearing habitat for several anadromous species including Chinook *O. tshawytscha*, coho *O. kisutch*, sockeye *O. nerka*, chum *O. keta*, and pink *O. gorbuscha* salmon (Johnson and Blanche 2012). Other salmon-producing rivers emptying into Nushagak Bay include the Wood, Igushik and Snake rivers. In Nushagak Bay, only the Wood River produces more salmon than the Nushagak River.

The natural resources, particularly salmon, available in the Nushagak watershed have been important to residents of this area from the earliest settlements into the modern era (Fall 1990; Fall et al. 1986; Wolfe et al. 1986). A survey of Dillingham residents in 1984 found that households in this area harvested 324 kg (715 lbs) useable weight of subsistence resources per household per year and that Chinook salmon and sockeye salmon comprised 22% and 16% of that amount respectively (Wolfe et al. 1986).

Development of a commercial fishery in Bristol Bay began as early as 1884, primarily on sockeye salmon (Rich and Ball 1928) but expanded rapidly to include other species such as Chinook and chum salmon. Over the last 20 years an average of 6.4 million salmon have been harvested annually in the Nushagak fishing district, and this harvest has been 24% of the total Bristol Bay commercial salmon harvest (Jones et al. 2012). Of the total exvessel value of the Bristol Bay harvest, sockeye salmon account for 97.6%, chum salmon for 1.1%, Chinook salmon for 0.7%, coho salmon for 0.5% and pink salmon for 0.1% (Clark et al. 2006).

The Nushagak River also experiences significant amounts of sport fishing effort, particularly for Chinook salmon. Sport fishing effort averaged 14,000 angler days between 1996 and 2000, and a survey of sport fishing in 2001 counted 2,995 angler trips on the river (Cappiello and Dye 2006; Walker et al. 2003).

ESCAPEMENT ESTIMATION

Aerial Surveys

Beginning in 1956, ADF&G personnel began flying aerial surveys over the Nushagak River (Nelson 1987). Nelson (1966 and 1967) describes the “chain link” method used for aerial surveys of that period. Aerial surveys were used to generate escapement estimates through 1985. Starting in 1986, escapements were estimated solely based on sonar except for 1997 when sonar-derived escapement estimates of Chinook salmon were replaced with estimates based on aerial surveys due to concerns with the accuracy of sonar estimates that year. Currently, ADF&G does not fly aerial surveys on the Nushagak River.

Sonar

In 1979, a project designed to enumerate escapement was initiated using a near shore, single-beam sonar on the lower Nushagak River near Portage Creek, approximately 40 km upriver from Dillingham. The river at this location is highly turbid and confined to a single channel approximately 300 m wide with the exception of a minor slough running behind the north bank (right bank looking downriver) at the sonar site. The site is still used by ADF&G as a sonar enumeration site. While the equipment and the details of the operational protocol have evolved over the years, the general method has stayed fairly consistent (Brazil and Buck 2011). The sonar system has been composed of one or two side-looking transducers near shore on each bank aimed perpendicular to river flow. The south (left bank) transducer is located approximately 200 m upriver from the north bank transducer site (Figure 2). Both systems are operated from a camp located on the north bank.

Bendix

The initial sonar used to estimate returning adult salmon on the Nushagak River, known as the "Bendix" system for the company that initially produced it, was an automated echo counter that converted observed echoes into estimates of fish using a user-defined echo/fish criterion (Gaudet 1990). An oscilloscope assisted with aiming the beam and evaluation of target strength. Due to the uneven topography of the bottom, two transducers were used along each shore. The offshore transducer was situated 10 m offshore from the inshore transducer with the beams aligned in parallel. This arrangement created inshore and offshore strata on the north and south banks (four spatial strata total). In the initial years of using sonar, both sonar and aerial survey estimates Chinook and sockeye salmon.

DIDSON

In the early 2000s, because of difficulties inherent in maintaining and operating an antiquated system, ADF&G began searching for a Bendix replacement. After testing various hydroacoustic options, ADF&G selected the dual frequency identification sonar (DIDSON: Sound Metrics, Seattle, Washington). The DIDSON features a moveable acoustic lens that provides high resolution images, especially in the nearfield portion of the focus region. A long range DIDSON is currently used to detect fish out to 50 m on the north bank while a standard range unit is used to detect out to 30 m on the south bank. The standard range unit operates at either 1.1 MHz or 1.8 MHz while the low range unit operates at 0.7 MHz or 1.2 MHz. The low frequency is used to detect fish out to 10 m on each bank while the higher frequency is used to detect fish from 10 m out to 30 m on the south bank and from 10 m to 50 m on the north bank. The apportionment of detected fish targets to species is performed using the same protocol developed for the Bendix system.

Species Apportionment

While it is possible to estimate the number of passing fish that are the size of adult salmon, it is not possible with sonar to determine the species of individual fish. Therefore, the sonar estimate has to be apportioned into species to be useful for management. Initially, beach seines were used to sample the migrating salmon beyond a certain passage threshold. In time, this system was augmented with drift gillnets, drifted downstream of the sonar and within the range of each spatial stratum. Eventually, beach seining was discontinued. Brazil and Buck (2011) describe the current system that uses gillnet of three different mesh sizes to apportion the overall sonar passage estimate to species (sockeye, Chinook, and chum salmon). Earlier reports of this same series give species apportionment details for specific years (e.g., Brazil 2007 and 2008; McKinley 2002a, 2002b, 2003; Miller 1997, 1999, 2000). While Burwen et al. (2007) demonstrated that it is possible to measure fish lengths directly from DIDSON imagery with some degree of accuracy, the distances covered by the sonar on the Nushagak River as well as the length distributions present for salmon in the Nushagak River rule out species apportionment by this method.

OBJECTIVES

The objective of the analysis presented in this report is to standardize the passage estimates that have been produced with different techniques over the years on the Nushagak River by converting all passage estimates of sockeye, Chinook, and chum salmon not directly produced with DIDSON into "DIDSON-equivalent" estimates. Standardizing the passage estimates in this fashion should increase the precision of escapement goal estimates and forecasts.

METHODS

ESCAPEMENT ESTIMATION

ADF&G has generated escapement estimates of Nushagak River Chinook and sockeye salmon since the mid-1960s. Early estimates were made using various combinations of tower counts and/or aerial surveys. Between 1960 and 1986 towers were located in at least three areas within the Nushagak watershed: mainstem Nushagak River for 15 years; the Stuyahok River for one year; and the Nuyakuk River beginning in 1962 (Nelson 1987).

In 1979, ADF&G began operating a Bendix sonar (at the location still used today) along with test fishing methods to apportion sonar counts, allowing for an estimate of all salmon species present. From 1979 through 1985, final salmon passage estimates were a combination of tower, aerial surveys, and sonar. By 1986, apportioned sonar numbers became the final salmon passage estimates. Nevertheless, aerial surveys continued to be flown through the late 1990s for supplemental information such as spawn timing and distribution. In 1997, technical errors in sonar operations made it necessary to use aerial survey data as final estimates of escapement. The department no longer conducts aerial surveys of the Nushagak drainage. Sonar operated through at least mid-August allow for the estimation coho and pink salmon, in addition to earlier runs of Chinook, sockeye, and chum salmon. This was standard practice through the mid-2000s.

Sonar passage estimates by species are the product of the unapportioned sonar estimates (salmon-sized targets) and the proportions of the CPUE for each species by spatial strata and time period (Brazil and Buck 2011). This apportionment method was developed with the Bendix system and remains unchanged with the DIDSON.

Escapement is defined as the number of spawning fish. For Chinook salmon it is their estimated passage past the sonar site minus any upriver harvest (i.e., sport and subsistence). For sockeye and chum salmon, the sonar passage estimate is considered their escapement because sport and subsistence harvest upriver of the sonar are minimal relative to total run size.

In 2003, ADF&G began side-by-side comparisons of DIDSON estimates and Bendix sonar estimates. By 2005, DIDSON generated the final south bank estimate while Bendix generated the final north bank estimate. Beginning in 2006, the DIDSON produced all final passage estimates. The DIDSON and the Bendix sonar continued to operate in tandem in one or more spatial strata on various dates through 2009 in an effort to adequately compare their estimates (Table 1). From these comparisons, linear regressions related passage estimates (unapportioned by species) produced by each system in each stratum (Maxwell et al. 2011; Table 2). Maxwell et al. (2011) demonstrated that the DIDSON detected a higher number of salmon, particularly in the offshore strata. Initially it was believed that this increased detection efficiency made little difference to the sockeye and chum salmon passage estimates because these species tend to migrate within the 10 m "nearshore" strata where DIDSON and Bendix estimates are more similar. In 2010, the department developed correction factors for Chinook salmon and used them for inseason management through 2012[2] to make them comparable with the Bendix-based escapement goal. These correction factors were preliminary estimates of the strata ratios reported in this report (Tables 3–6) and are replaced with uncorrected DIDSON Chinook salmon passage estimates in this report.

HARVEST ESTIMATION

ADF&G collects harvest information from commercial, subsistence, and sport harvests in Nushagak District. Commercial harvest information is reported by processors using the state's Fish Ticket system (Savikko 1994). ADF&G samples the commercial harvest for sex, length, and weight at processor facilities. Scale samples are used to estimate the age composition of the harvest.

Sport harvest is estimated through the Statewide Harvest Survey and Guide Logbooks. Subsistence harvest data is collected via the permitting system. Neither sport nor subsistence harvest is sampled for weight, sex, or age.

AGE COMPOSITION

Age composition of the various species of Nushagak River salmon is assessed using scale collections from returning adults sampled at the sonar site as a part of the species apportionment process. The age composition of the commercial salmon harvest is determined through sampling conducted at the major processor in Nushagak Bay, Peter Pan Seafoods.

TOTAL RUN ESTIMATION

The total run for each species is defined as the sum of all commercial, sport, and subsistence harvest that occurs downriver of the sonar site plus the sonar passage estimate. Sport and subsistence harvest is included in the total run estimates for Chinook salmon but not for sockeye or chum salmon as these amounts are minimal relative to the run size.

DATA ANALYSIS

Data analysis consisted of two primary steps. First, daily unapportioned Bendix-based sonar estimates by stratum and year (2002–2004 for the south bank and 2002–2005 for the north bank) were adjusted to DIDSON equivalents using the regression models found in Maxwell et al. (2011). These daily adjusted (DIDSON equivalent) and unadjusted (Bendix) passage estimates were apportioned to species using CPUE proportions by stratum, and then summed to form annual estimates. From this, we generated the annual ratio of adjusted to unadjusted (DIDSON to Bendix) passage by stratum and species. The variation in this ratio between species comes from the variation in the relationship between direct comparisons of DIDSON and Bendix. For an intercept of zero when regressing DIDSON against Bendix, the ratio would be equal to the regression slope for all species. Because the intercept is not zero for any of the models, intercepts that are small compared to the daily estimates result in ratios similar to the slope values, while if the intercept is large compared to the daily estimates, the ratio will be much higher than the slope. The consequence is that years containing more low-estimate days will be more heavily influenced by the intercept parameter and years containing more high-estimate days will be more

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[2] Passage estimates from 2012 were considered preliminary at the time of this report and not included. They will be reported separately.

heavily influenced by the slope parameter. Because the variance of the prediction from the regression model is not available for our data analysis, we were not able to estimate the variance of the estimated annual ratios. Mean ratios by stratum and species were calculated from the annual ratios. Sonar data prior to 2002 were not included in this analysis because these data were not preserved in a by-day and by-strata format that would allow for the production of annual ratios.

In the second step, the ratios obtained by analysis of the daily counts in each strata for the years listed above were used to extend the analysis through 2011 using annual unapportioned strata totals. Ratios obtained in Step 1 were applied to total adjusted and unadjusted unapportioned annual sonar passage estimates. These adjusted and unadjusted estimates were summed for each species to produce river wide annual ratios, which were averaged to produce a mean (2002–2011) ratio for each species. We applied these ratios to annual species passage estimates prior to 2005 to make them equivalent to DIDSON estimates. Estimates made directly with DIDSON were not altered and inseason corrections (2010 and 2011) were dropped, returning those passage estimates to direct DIDSON estimates.[3]

RESULTS

Annual ratio of adjusted to unadjusted (DIDSON to Bendix) passage by species was produced for the south bank inshore (Table 3), south bank offshore (Table 4), north bank inshore (Table 5) and north bank offshore (Table 6). The mean adjusted-to-unadjusted ratios by species are 2.08 for Chinook, 1.11 for sockeye, and 1.27 for chum salmon (Table 7). Passage estimates derived from Bendix (pre-2005) were revised with these ratios.

Passage estimates for 2005 presented a special case: a Bendix unit was used to generate estimated passage on the north bank while a DIDSON was used on the south bank. The adjusted passage estimate for 2005 therefore consisted of adjusted estimates on the north bank while leaving the south bank DIDSON estimates unchanged (Table 8).

CHINOOK SALMON

Applying the correction of 2.08 to pre-DIDSON passage estimates resulted in a mean total run of 190,800 over the last ten years, up from an adjusted estimate of 148,264 and the mean exploitation rate decreased to 35% from 39%. (Tables 9 and 10).

The Nushagak River Chinook salmon population is largely composed of age-1.3 and 1.4 fish. These age classes make up more than 70% of the total returns over the last ten years (Appendix A1).

SOCKEYE SALMON

Our analysis of Nushagak River sockeye salmon was concurrent with a reconstruction of sockeye catch and escapement data for rivers in Bristol Bay that incorporates newly available genetics information (Cunningham et al. 2012). Our correction to the Nushagak sockeye salmon passage estimate proceeds from the results of that reconstruction.

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[3] Note that inseason estimates used during 2010 and 2011 differ slightly from Bendix equivalent estimates in this analysis. This is due to the fact that the 2010 and 2011 estimates used correction factors based on preliminary analysis that was finalized in Maxwell (2011).

Applying the correction of 1.11 to pre-DIDSON passage estimates resulted in a 10-year mean Nushagak district total run of 9,309,878 sockeye salmon, an increase from 9,299,859 and the district exploitation rate decreased to 70% from 71% (Table 11).

The Nushagak River sockeye salmon population is largely composed of age-1.3 fish which make up over 80% of the total returns over the last ten years (Appendix A2).

CHUM SALMON

Applying the correction of 1.27 to pre-DIDSON passage estimates resulted in a 10-year mean total run of 1,051,813 an increase from 1,018,537 and the mean exploitation rate decreased to 61% from 63%. (Table 12).

The Nushagak River chum salmon population is largely composed of age-0.3 fish. Fish of this age class make up more than 64% of the total run over the last ten years (Appendix A3).

DISCUSSION

Successful management of salmon stocks requires accurate forecasts and biologically meaningful escapement goals. Arriving at these requires a clear accounting of the returns per spawner that a run produces. Changes in escapement estimation methodologies will cloud this accounting to some degree. The question is always to what degree. In this case the answer varied widely between species because of the different cross-channel distribution displayed by the migrating salmon of each species. Fish traveling in the offshore strata were far less likely to be detected by Bendix than DIDSON, compared to the inshore, which was more similar in detection. Proportions of Chinook salmon in the inshore and offshore strata from both banks were highly variable, while sockeye salmon were less affected with around 95% of them passing through the inshore strata. When it became clear during the 2010–2012 seasons that we had Chinook salmon passage estimates (based on DIDSON) that were not well aligned with the historical data used to generate the escapement goal under which we were managing, we made inseason adjustments to the Chinook salmon passage estimates to make them more similar to historical Bendix estimates. No inseason adjustments were considered necessary for sockeye or chum salmon. We based the inseason Chinook salmon adjustments used in 2010–2011 were based on preliminary analyses of the comparison data, which were superseded by the more complete analysis provided in Maxwell et al. (2011), and this report. Findings from this report will form the basis of an evaluation of escapement goals for all species on the Nushagak River (Fair et al. 2012).

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REFERENCES CITED

Belcher, E. O., Hanot, W. and J. Burch. 2002. Dual-Frequency Identification Sonar. [*In*]: Underwater Technology 2002-Proceedings of the 2002 International Symposium on Underwater Technology, Institute of Electrical and Electronic Engineers, Inc., Piscataway, NJ. Pages 187-192.

Brazil, C. 2007. Sonar enumeration of Pacific salmon escapement into the Nushagak River, 2003. Alaska Department of Fish and Game, Fishery Data Series No. 07-37, Anchorage.

Brazil, C. 2008. Sonar enumeration of Pacific salmon escapement into the Nushagak River, 2004. Alaska Department of Fish and Game, Fishery Data Series No. 08-31, Anchorage.

Brazil, C., and G. B. Buck. 2011. Sonar enumeration of Pacific salmon escapement into the Nushagak River, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 11-14, Anchorage.

Burwen, D. L., S. J. Fleischman, and J. D. Miller. 2007. Evaluation of a dual-frequency imaging sonar for estimating fish size in the Kenai River. Alaska Department of Fish and Game, Fishery Data Series No. 07-44, Anchorage.

Cappiello, T., and J. E. Dye. 2006. Survey of the Chinook salmon sport fishery in the Lower Nushagak River, Alaska, 2001. Alaska Department of Fish and Game, Fishery Data Series No. 06-68, Anchorage.

Clark, J. H., McGregor, A., Mecum, R., Krasnowski, P. and A. Carroll. 2006. The commercial salmon fishery in Alaska. Alaska Fishery Research Bulletin 12(1):1–146.

Cunningham, C. J., R. Hilborn, J. Seeb, and T. Branch. 2012. Reconstruction of Bristol Bay sockeye salmon returns using age and genetic composition of catch. University of Washington, School of Aquatic and Fishery Sciences.

Fair, L. F., C. Brazil, X. Zhang, R. Clark and J. Erikson. 2012. Review of escapement goals in Bristol Bay, Alaska, 2012. Alaska Department of Fish and Game, Fishery Manuscript Series No. 12-04, Anchorage.

Fall, J. A. 1990. The Division of Subsistence of the Alaska Department of Fish and Game: An overview of its research program and findings: 1980–1990. Arctic Anthropology 27(2):68–92.

Fall, J. A., Schichnes, J. C., Chythlook, M. and R. J. Walker. 1986. Patterns of wild resource use in Dillingham: Hunting and fishing in an Alaskan regional center. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper No. 135, Juneau.

Gaudet, D. M. 1990. Enumeration of migrating salmon populations using fixed-location sonar counters. Rapports et Proces-Verbaux des Reunions, Conseil International pour l'Exploration de la Mer 187:197–209.

Johnson, J., and P. Blanche. 2012. Catalog of waters important for spawning, rearing, or migration of anadromous fishes–Southwestern Region, Effective June 1, 2012. Alaska Department of Fish and Game, Special Publication No. 12-08, Anchorage.

Jones, M., T. Sands, S. Morstad, T. Baker, G. Buck, F. West, P. Salomone, and T. Krieg. 2012. 2011 Bristol Bay area annual management report. Alaska Department of Fish and Game, Fishery Management Report No. 12-21, Anchorage.

Maxwell, S. L, A. V. Faulkner, L. Fair, and X. Zhang. 2011. A comparison of estimates from 2 hydroacoustic systems used to assess sockeye salmon escapement in 5 Alaska Rivers. Alaska Department of Fish and Game, Fishery Manuscript Series No. 11-02, Anchorage.

McKinley, L. 2002a. Sonar enumeration of Pacific salmon into Nushagak River, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02-22, Anchorage.

McKinley, L. 2002b. Sonar enumeration of Pacific salmon into Nushagak River, 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02-25, Anchorage.

McKinley, L. 2003. Sonar enumeration of Pacific salmon into Nushagak River, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A03-05, Anchorage.

REFERENCES CITED (Continued)

Miller, J. D. 1997. Sonar enumeration of Pacific salmon into Nushagak River, 1996. Alaska Department of Fish and Game, Division of Commercial Fisheries and Management, Regional Information Report 2A97-05, Anchorage.

Miller, J. D. 1999. Sonar enumeration of Pacific salmon into Nushagak River, 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries,Regional Information Report 2A99-05, Anchorage.

Miller, J. D. 2000. Sonar enumeration of Pacific salmon into Nushagak River, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A00-19, Anchorage.

NCDC (National Climatic Data Center). (cited: 10 September 2012). http://ncdc.noaa.gov

Nelson, M. L. 1966. Red salmon spawning ground surveys in the Nushagak and Togiak Districts, Bristol Bay, 1965. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 84, Dillingham.

Nelson, M. L. 1967. Red salmon spawning ground surveys in the Nushagak and Togiak Districts, Bristol Bay, 1966. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 96, Dillingham.

Nelson, M. L. 1987. History and management of the Nushagak Chinook salmon fishery. Alaska Department of Fish and Game, Bristol Bay Data Report No. 87-1, Dillingham.

Rich, W. H., and E. M. Ball. 1928. Statistical review of the Alaska salmon fisheries-Part I: Bristol Bay and the Alaska Penninsula. U.S. Department of Commerce, Bureau of Fisheries, Document No. 1041:41–95.

Savikko, K. E. 1994. TIX Quickstart. Alaska Department of Fish and Game, Division of Commercial Fisheries and Management, Special Publication No. 4, Juneau.

USGS (United States Geological Survey). Water Resources of the United States. (cited: 10 September 2012) http://water.usgs.gov.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05. Anchorage.

Wolfe, R. J., J. A. Fall, V. Fay, S. Georgette, J. Magdanz, S. Pedersen, M. Pete, and J. Schichnes. 1986. The role of fish and wildlife in the economies of Barrow, Bethel, Dillingham, Kotzebue, and Nome. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper No. 154, Juneau.

TABLES AND FIGURES

Table 1.–Dates and spatial location of simultaneously Bendix and DIDSON data collection.

	Year				
Spatial Strata	2003	2004	2005	2007	2009
South Bank Nearshore	6/26-7/19	6/12-8/3		6/9-7/8	
North Bank Nearshore		6/17-8/15	6/10-7/17	6/9-7/8	6/9-7/18
South Bank Offshore	6/26-7/19	6/12-8/3			6/9-7/18
North Bank Offshore		6/17-8/15	6/10-7/17		6/9-7/18

Source: Maxwell et al. 2011.

Table 2.–Coefficients of regression equations calculated for each spatial strata.

Spatial Strata	Slope	Intercept	R^2
South Bank Nearshore	0.85	1,284	0.78
North Bank Nearshore	0.89	2,738	0.82
South Bank Offshore	1.15	644	0.71
North Bank Offshore	3.01	1,742	0.18

Source: Maxwell et al. 2011.

Table 3.–Comparison of Bendix passage estimates by species in the south bank inshore spatial strata, 2002–2004.

	Adjusted Passage Estimate			Bendix Passage Estimates			Ratio		
Year	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum
2004	179,937	60,248	89,175	176,173	50,422	90,126	1.02	1.19	0.99
2003	115,467	24,930	79,994	107,088	14,255	71,474	1.08	1.75	1.12
2002	103,700	36,597	175,475	100,357	36,214	168,933	1.03	1.01	1.04
Mean							1.04	1.32	1.05
Standard deviation							0.03	0.38	0.07

Note: Estimates by species calculated after adjusting unapportioned passage estimate as recommended by Maxwell et al. (2011) with ratio of adjusted/unadjusted estimates.

Table 4.–Comparison of Bendix passage estimates by species in the south bank offshore spatial strata, 2002–2004.

	Adjusted Passage Estimates			Bendix Passage Estimates			Ratio		
Year	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum
2004	5,874	53,933	13,712	2,827	26,571	6,998	2.08	2.03	1.96
2003	7,122	49,233	17,031	4,152	26,451	8,571	1.72	1.86	1.99
2002	2,401	47,288	24,601	1,257	21,658	13,275	1.91	2.18	1.85
Mean							1.90	2.02	1.93
Standard deviation							0.18	0.16	0.07

Note: Estimates by species calculated after adjusting unapportioned passage estimate as recommended by Maxwell et al. (2011) with ratio of adjusted/unadjusted estimates.

Table 5.–Comparison of Bendix passage estimates by species in the north bank inshore spatial strata, 2002–2005.

	Adjusted Passage Estimates			Bendix Passage Estimates			Ratio		
Year	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum
2005	573,991	60,158	277,371	571,951	54,694	274,477	1.00	1.10	1.01
2004	344,353	44,496	194,666	305,509	30,504	174,109	1.13	1.46	1.12
2003	461,549	42,204	224,057	461,018	19,274	202,110	1.00	2.19	1.11
2002	238,293	26,954	270,468	212,545	21,013	224,594	1.12	1.28	1.20
Mean							1.06	1.51	1.11
Standard deviation							0.07	0.48	0.08

Note: Estimates by species calculated after adjusting unapportioned passage estimate as recommended by Maxwell et al. (2011) with ratio of adjusted/unadjusted estimates.

Table 6.–Comparison of Bendix passage estimates by species in the north bank offshore spatial strata, 2002–2005.

	Adjusted Count			Bendix Count			Ratio		
Year	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum	Sockeye	Chinook	Chum
2005	27,627	50,112	46,591	3,627	6,873	7,655	7.62	7.29	6.09
2004	27,482	35,049	51,961	7,222	8,903	12,579	3.81	3.94	4.13
2003	36,141	98,227	67,442	8,275	20,049	13,259	4.37	4.90	5.09
2002	10,652	61,536	80,266	1,522	8,256	13,162	7.00	7.45	6.10
Mean							5.70	5.90	5.35
Standard deviation							1.89	1.75	0.94

Note: Estimates by species calculated after adjusting unapportioned passage estimate as recommended by Maxwell et al. (2011) with ratio of adjusted/unadjusted estimates.

Table 7.–Bendix and DIDSON Passage estimates by strata and species based on Bendix and DIDSON, 2002–2011.

	Sockeye			Chinook			Chum		
	Bendix	DIDSON	ratio	Bendix	DIDSON	ratio	Bendix	DIDSON	ratio
Year				South Bank Inshore					
2002	**100,357**	103,700	1.03	**36,214**	36,597	1.01	**168,933**	175,475	1.04
2003	**107,088**	115,467	1.08	**14,255**	24,930	1.75	**71,474**	79,994	1.12
2004	**176,173**	179,937	1.02	**50,422**	60,248	1.19	**90,126**	89,175	0.99
2005	439,770	**459,255**	1.04	27,483	**36,226**	1.32	135,410	**142,062**	1.05
2006	231,728	**241,995**	1.04	14,723	**19,407**	1.32	149,819	**157,179**	1.05
2007	54,497	**56,912**	1.04	2,667	**3,516**	1.32	11,810	**12,390**	1.05
2008	175,898	**183,691**	1.04	14,220	**18,743**	1.32	122,978	**129,019**	1.05
2009	231,744	**242,012**	1.04	8,482	**11,180**	1.32	158,888	**166,693**	1.05
2010	164,539	**171,829**	1.04	9,067	**11,951**	1.32	126,374	**132,582**	1.05
2011	141,279	**147,538**	1.04	13,986	**18,435**	1.32	67,475	**70,790**	1.05
				South Bank Offshore					
2002	**1,257**	2,401	1.91	**21,658**	47,288	2.18	**13,275**	24,601	1.85
2003	**4,152**	7,122	1.72	**26,451**	49,233	1.86	**8,571**	17,031	1.99
2004	**2,827**	5,874	2.08	**26,571**	53,933	2.03	**6,998**	13,712	1.96
2005	7,778	**14,787**	1.90	36,998	**74,914**	2.02	16,464	**31,829**	1.93
2006	8,532	**16,221**	1.90	28,224	**57,149**	2.02	32,516	**62,861**	1.93
2007	2,929	**5,569**	1.90	7,528	**15,243**	2.02	6,765	**13,078**	1.93
2008	4,540	**8,632**	1.90	24,440	**49,486**	2.02	13,105	**25,334**	1.93
2009	9,156	**17,407**	1.90	28,037	**56,769**	2.02	49,304	**95,316**	1.93
2010	2,706	**5,145**	1.90	14,793	**29,953**	2.02	10,175	**19,670**	1.93
2011	4,047	**7,694**	1.90	23,089	**46,752**	2.02	6,877	**13,294**	1.93
				North Bank Inshore					
2002	**212,545**	238,293	1.12	**21,013**	26,954	1.28	**224,594**	270,468	1.20
2003	**461,018**	461,549	1.00	**19,274**	42,204	2.19	**202,110**	224,057	1.11
2004	**305,509**	344,353	1.13	**30,504**	44,496	1.46	**174,109**	194,666	1.12
2005	**571,951**	573,991	1.00	**54,694**	60,158	1.10	**274,477**	277,371	1.01
2006	262,944	**279,576**	1.06	16,401	**24,728**	1.51	334,712	**371,652**	1.11
2007	396,413	**421,487**	1.06	7,170	**10,810**	1.51	83,467	**92,679**	1.11
2008	258,359	**274,700**	1.06	4,870	**7,343**	1.51	117,870	**130,878**	1.11
2009	182,347	**193,881**	1.06	2,232	**3,365**	1.51	119,573	**132,769**	1.11
2010	264,636	**281,374**	1.06	6,264	**9,445**	1.51	91,086	**101,138**	1.11
2011	236,863	**251,845**	1.06	9,500	**14,324**	1.51	120,242	**133,512**	1.11
				North Bank Offshore					
2002	**1,522**	10,652	7.00	**8,256**	61,536	7.45	**13,162**	80,266	6.10
2003	**8,275**	36,141	4.37	**20,049**	98,227	4.90	**13,259**	67,442	5.09
2004	**7,222**	27,482	3.81	**8,903**	35,049	3.94	**12,579**	51,961	4.13
2005	**3,627**	27,627	7.62	**6,873**	50,112	7.29	**7,655**	46,591	6.09
2006	1,864	**10,618**	5.70	3,969	**23,399**	5.90	12,954	**69,310**	5.35
2007	5,981	**34,073**	5.70	5,240	**30,891**	5.90	8,099	**43,333**	5.35
2008	4,480	**25,523**	5.70	3,691	**21,758**	5.90	7,676	**41,069**	5.35
2009	5,415	**30,849**	5.70	1,724	**10,166**	5.90	8,168	**43,703**	5.35
2010	1,816	**10,348**	5.70	1,499	**8,836**	5.90	3,836	**20,524**	5.35
2011	3,706	**21,115**	5.70	4,880	**28,767**	5.90	5,734	**30,681**	5.35

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Table 7.–Page 2 of 2.

	Sockeye			Chinook			Chum		
	Bendix	DIDSON	ratio	Bendix	DIDSON	ratio	Bendix	DIDSON	ratio
Year				River Total					
2002	315,681	355,047	1.12	87,141	172,375	1.98	419,964	550,809	1.31
2003	580,534	620,279	1.07	80,028	214,595	2.68	295,413	388,523	1.32
2004	491,730	557,646	1.13	116,400	193,726	1.66	283,811	349,513	1.23
2005	1,023,127	1,075,659	1.05	126,049	221,410	1.76	434,007	497,853	1.15
2006	505,069	548,410	1.09	63,317	124,683	1.97	530,002	661,002	1.25
2007	459,821	518,041	1.13	22,605	60,460	2.67	110,141	161,480	1.47
2008	443,277	492,546	1.11	47,220	97,330	2.06	261,628	326,300	1.25
2009	428,663	484,149	1.13	40,475	81,480	2.01	335,933	438,481	1.31
2010	433,697	468,696	1.08	31,623	60,185	1.90	231,470	273,914	1.18
2011	385,895	428,192	1.11	51,455	108,278	2.10	200,328	248,277	1.24
Mean			1.11			2.08			1.27
Standard deviation			0.03			0.34			0.09

Note: Observed estimates are in bold.

[a] Rounded.

Table 8.–Original and revised passage estimates for Chinook, chum, and sockeye salmon, 2005.

Bank	Strata	Instrumentation	Correction	Passage Estimate Traditional	Passage Estimate Revised
		Chinook			
South	Inshore	DIDSON		36,226	36,226
	Offshore	DIDSON		74,914	74,914
North	Inshore	Bendix	1.51	54,694	82,465
	Offshore	Bendix	5.90	6,873	40,517
TOTAL				172,707	234,123
		Sockeye			
South	Inshore	DIDSON		459,255	459,255
	Offshore	DIDSON		14,787	14,787
North	Inshore	Bendix	1.06	571,951	608,127
	Offshore	Bendix	5.70	3,627	20,663
TOTAL				1,049,620	1,102,833
		Chum			
South	Inshore	DIDSON		142,062	142,062
	Offshore	DIDSON		31,829	31,829
North	Inshore	Bendix	1.11	274,477	304,769
	Offshore	Bendix	5.35	7,655	40,958
TOTAL				456,023	519,618

Table 9.–Historical harvest of Nushagak River Chinook salmon 1966–2011.

	Harvests by Fishery							
		Sport[a]			Subsistence[b]			Total
Year	Commercial[c]	Above	Below	Total[d]	Above[e]	Below[f]	Total	Harvest
1966	58,184	578	221	799	1,185	2,515	3,700	62,683
1967	96,240	578	221	799	1,185	2,515	3,700	100,739
1968	78,201	578	221	799	2,113	4,487	6,600	85,600
1969	80,803	578	221	799	2,274	4,826	7,100	88,702
1970	87,547	578	221	799	2,017	4,283	6,300	94,646
1971	82,769	578	221	799	1,409	2,991	4,400	87,968
1972	46,045	578	221	799	1,281	2,719	4,000	50,844
1973	30,470	578	221	799	2,113	4,487	6,600	37,869
1974	32,053	578	221	799	2,530	5,370	7,900	40,752
1975	21,454	578	221	799	2,274	4,826	7,100	29,353
1976	60,684	578	221	799	2,209	4,691	6,900	68,383
1977	85,074	667	256	923	1,665	3,535	5,200	91,197
1978	118,548	320	122	442	2,113	4,487	6,600	125,590
1979	157,321	473	181	654	2,850	6,050	8,900	166,875
1980	64,958	547	210	757	3,779	8,021	11,800	77,515
1981	193,461	882	338	1,220	3,682	7,818	11,500	206,181
1982	195,287	1,319	505	1,824	3,875	8,225	12,100	209,211
1983	137,123	1,448	555	2,003	3,779	8,021	11,800	150,926
1984	61,378	1,723	659	2,382	3,138	6,662	9,800	73,560
1985	67,783	1,339	513	1,852	2,530	5,370	7,900	77,535
1986	65,783	4,162	628	4,790	4,725	7,875	12,600	83,173
1987	45,983	3,173	1,286	4,458	2,680	8,770	11,450	61,891
1988	16,648	1,626	1,192	2,817	3,766	5,671	9,437	28,902
1989	17,637	2,210	1,404	3,613	2,155	5,688	7,843	29,093
1990	14,812	2,689	797	3,486	3,629	7,989	11,618	29,916
1991	19,718	3,758	1,793	5,551	3,010	8,093	11,103	36,372
1992	47,563	2,911	1,844	4,755	2,498	10,322	12,820	65,138
1993	62,971	3,492	2,408	5,899	2,919	14,498	17,417	86,287
1994	119,478	6,191	4,436	10,626	3,331	11,048	14,379	144,483
1995	79,942	2,713	2,238	4,951	2,419	10,800	13,219	98,112
1996	72,011	3,045	2,346	5,390	3,063	10,217	13,280	90,681
1997	64,160	2,567	931	3,497	2,981	11,397	14,378	82,035
1998	117,065	4,188	1,640	5,827	4,429	7,717	12,146	135,038
1999	10,893	3,304	934	4,237	2,477	7,450	9,927	25,057
2000	12,055	4,628	1,389	6,016	1,979	7,247	9,226	27,297
2001	11,568	4,299	1,600	5,899	3,372	7,972	11,344	28,811
2002	39,473	2,500	1,193	3,693	4,103	6,946	11,049	54,215
2003	42,615	3,752	2,203	5,955	4,448	13,399	17,847	66,417
2004	96,534	4,339	2,567	6,906	4,369	10,644	15,013	118,453
2005	62,308	5,702	2,863	8,565	4,471	7,951	12,422	83,295
2006	84,010	4,307	3,166	7,473	3,012	6,172	9,184	100,667
2007	51,473	6,088	3,581	9,669	3,411	9,564	12,975	74,117
2008	18,670	3,395	3,305	6,700	2,571	9,140	11,711	37,081
2009	24,287	3,903	2,451	6,354	2,796	9,312	12,108	42,749
2010	25,501	2,248	1,659	3,907	1,849	6,332	8,181	37,589
2011	26,443	3,302	1,542	4,844	2,718	8,532	11,250	42,537

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Table 9.–Page 2 of 2.

	Harvests by Fishery							
		Sport[a]			Subsistence[b]			Total
	Commercial[c]	Above	Below	Total[d]	Above[e]	Below[f]	Total	Harvest
Average								
Last 3 Years	21,121	3,112	1,903	5,015	2,428	7,799	10,227	36,364
Last 5 Years	21,264	3,327	2,293	5,620	2,530	8,370	10,900	37,784
Last 10 Years	44,326	4,082	2,584	6,667	3,236	8,958	12,194	63,187

[a] 1966–1986: above/below ratio obtained by averaging 1986–1990 total sport fish harvest from Nelson (1987) and applied to total sport fish harvest.

[b] Includes harvest listed as “Upper or lower Wood River” or “Wood River, site unknown” as these are believed to be Nushagak bound fish. Subsistence harvest estimates from 1980 to 1985 above and below the Sonar site were calculated by taking the five year average harvest from 1986 to 1990 above and below the sonar and dividing it by the average total harvest from 1986 to 1990 and multiplying it by the total harvest from the corresponding year.

[c] Personal use not included.

[d] 1966–1976: Average total sport fish harvest 1977–1981 used. Sport fish harvest estimates were not made prior to 1977.

[e] Includes following categories: Ekwok, Iowithla, Kokwok, Koliginek, New Stuyahok, Portage Creek, Klutuk.

[f] Includes Black Point, city dock/beach, Clarks Point, Coffee Point, Ekuk, Grassy Island, Igushik, Kanakanak, Lewis Point, Lower Wood River, Nushagak Point, Queen's Slough, Scandanavia, Scandanavian, Skinner, Snag Point, Squaw Creek, and Tulie Point.

Table 10.–Historical passage estimate, spawning estimate, total run and exploitation rate of Nushagak River Chinook salmon 1966–2011.

	Passage Estimate		Spawning Estimate[a]		Total Run[b]		Exploitation Rate	
Year	Traditional	Revised	Traditional	Revised	Traditional	Revised	Traditional	Revised
1966	40,000	83,224	38,237	81,462	100,920	144,145	0.62	0.43
1967	65,000	135,240	63,237	133,477	163,976	234,216	0.61	0.43
1968	70,000	145,643	67,309	142,951	152,909	228,551	0.56	0.37
1969	35,000	72,821	32,149	69,970	120,851	158,672	0.73	0.56
1970	50,000	104,030	47,405	101,435	142,051	196,081	0.67	0.48
1971	40,000	83,224	38,013	81,237	125,981	169,206	0.70	0.52
1972	25,000	52,015	23,141	50,156	73,985	101,001	0.69	0.50
1973	35,000	72,821	32,309	70,130	70,178	107,999	0.54	0.35
1974	70,000	145,643	66,892	142,535	107,645	183,287	0.38	0.22
1975	70,000	145,643	67,149	142,791	96,502	172,144	0.30	0.17
1976	100,000	208,061	97,213	205,273	165,596	273,657	0.41	0.25
1977	65,000	135,240	62,667	132,907	153,864	224,104	0.59	0.41
1978	130,000	270,479	127,567	268,046	253,157	393,636	0.50	0.32
1979	95,000	197,658	91,677	194,335	258,552	361,210	0.65	0.46
1980	141,000	293,366	136,674	289,040	214,189	366,555	0.36	0.21
1981	150,000	312,091	145,435	307,527	351,616	513,708	0.59	0.40
1982	147,000	305,849	141,806	300,656	351,017	509,867	0.60	0.41
1983	161,730	336,497	156,503	331,270	307,429	482,196	0.49	0.31
1984	80,940	168,404	76,079	163,544	149,639	237,104	0.49	0.31
1985	115,720	240,768	111,851	236,899	189,386	314,434	0.41	0.25
1986	44,056	91,663	35,169	82,777	118,342	165,950	0.70	0.50
1987	84,309	175,414	78,457	169,562	140,348	231,453	0.44	0.27
1988	56,905	118,397	51,514	113,006	80,416	141,908	0.36	0.20
1989	78,302	162,916	73,938	158,551	103,031	187,644	0.28	0.16
1990	63,955	133,065	57,637	126,747	87,553	156,663	0.34	0.19
1991	104,351	217,114	97,583	210,346	133,955	246,718	0.27	0.15
1992	82,848	172,374	77,439	166,965	142,577	232,103	0.46	0.28
1993	97,812	203,508	91,401	197,098	177,689	283,385	0.49	0.30
1994	95,954	199,643	86,433	190,121	230,916	334,604	0.63	0.43
1995	85,622	178,146	80,490	173,014	178,602	271,126	0.55	0.36
1996	52,127	108,456	46,020	102,348	136,701	193,029	0.66	0.47
1997	82,000	170,610	76,453	165,062	158,488	247,097	0.52	0.33
1998	117,495	244,461	108,879	235,845	243,917	370,883	0.55	0.36
1999	62,331	129,686	56,551	123,906	81,608	148,963	0.31	0.17
2000	56,372	117,288	49,766	110,682	77,063	137,979	0.35	0.20
2001	92,275	191,988	84,604	184,317	113,415	213,128	0.25	0.14
2002	87,141	181,307	80,538	174,704	134,753	228,919	0.40	0.24
2003	80,028	166,507	71,828	158,307	138,245	224,724	0.48	0.30
2004	116,400	242,183	107,692	233,475	226,145	351,928	0.52	0.34
2005	172,708	234,123	162,535	223,950	245,830	307,245	0.34	0.27
2006	124,683	124,683	117,364	117,364	218,031	218,031	0.46	0.46
2007	60,459	60,459	50,960	50,960	125,077	125,077	0.59	0.59
2008	97,330	97,330	91,364	91,364	128,445	128,445	0.29	0.29
2009	81,480	81,480	74,781	74,781	117,530	117,530	0.36	0.36
2010	31,623	60,185	27,526	56,088	65,115	93,677	0.58	0.40
2011	51,455	108,278	45,435	102,258	87,972	144,795	0.48	0.29

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Table 10.–Page 2 of 2.

Year	Passage Estimate		Spawning Estimate[a]		Total Run[b]		Exploitation Rate	
	Traditional	Revised	Traditional	Revised	Traditional	Revised	Traditional	Revised
Average								
Last 3 Years	63,621	114,183	58,081	108,642	94,444	145,006	0.43	0.28
Last 5 Years	73,935	104,272	68,077	98,414	105,862	136,198	0.39	0.30
Last 10 Years	92,395	134,931	85,077	127,613	148,264	190,800	0.39	0.35

[a] Inriver estimate minus harvest (sport and subsistence) above sonar site.

[b] Total harvest plus spawning escapement.

Table 11.–Historical harvest, escapement, total run, and exploitation rate for Nushagak district sockeye salmon 1963–2011.

Year	Harvest[a]	Nushagak River Escapement Traditional	Nushagak River Escapement Revised	Wood River Escapement[a]	Igushik Escapement[a]	Nushagak District Total Run Traditional	Nushagak District Total Run Revised	Exploitation Rate Traditional	Exploitation Rate Revised
1963	822,954	212,308	234,821	721,404	92,184	1,848,850	1,871,363	0.45	0.44
1964	1,391,790	121,924	134,853	1,076,112	128,532	2,718,358	2,731,287	0.51	0.51
1965	793,323	231,270	255,794	675,156	180,840	1,880,589	1,905,113	0.42	0.42
1966	1,170,270	211,184	233,578	1,208,682	206,360	2,796,496	2,818,890	0.42	0.42
1967	657,711	66,908	74,003	515,772	281,772	1,522,163	1,529,258	0.43	0.43
1968	749,281	128,712	142,360	649,344	194,508	1,721,845	1,735,493	0.44	0.43
1969	773,207	86,620	95,805	604,338	512,328	1,976,493	1,985,678	0.39	0.39
1970	1,188,530	409,472	452,892	1,161,964	370,920	3,130,886	3,174,306	0.38	0.37
1971	1,256,800	282,720	312,699	851,202	210,960	2,601,682	2,631,661	0.48	0.48
1972	355,760	36,030	39,851	430,602	60,018	882,410	886,231	0.4	0.4
1973	259,578	190,410	210,601	330,474	59,508	839,970	860,161	0.31	0.3
1974	489,163	184,614	204,190	1,708,836	358,752	2,741,365	2,760,941	0.18	0.18
1975	572,351	752,318	832,093	1,270,116	241,086	2,835,871	2,915,646	0.2	0.2
1976	1,224,380	470,420	520,303	817,008	186,120	2,697,928	2,747,811	0.45	0.45
1977	561,380	552,954	611,588	561,828	95,970	1,772,132	1,830,766	0.32	0.31
1978	3,025,540	663,666	734,040	2,267,238	536,154	6,492,598	6,562,972	0.47	0.46
1979	3,142,470	498,420	551,272	1,706,352	859,560	6,206,802	6,259,654	0.51	0.5
1980	4,351,560	3,317,368	3,669,136	2,969,040	1,987,530	12,625,498	12,977,266	0.34	0.34
1981	7,257,070	1,011,604	1,118,873	1,233,318	591,144	10,093,136	10,200,405	0.72	0.71
1982	5,753,050	600,865	664,580	976,470	423,768	7,754,153	7,817,868	0.74	0.74
1983	4,948,490	404,005	446,845	1,360,968	180,438	6,893,901	6,936,741	0.72	0.71
1984	1,957,470	592,872	655,739	1,002,792	184,872	3,738,006	3,800,873	0.52	0.52
1985	1,206,450	498,463	551,319	939,000	212,454	2,856,367	2,909,223	0.42	0.41
1986	2,565,300	990,238	1,095,241	818,652	307,728	4,681,918	4,786,921	0.55	0.54
1987	3,122,330	388,035	429,182	1,337,172	169,236	5,016,773	5,057,920	0.62	0.62
1988	1,654,100	483,220	534,460	866,778	170,454	3,174,552	3,225,792	0.52	0.51
1989	2,549,300	513,421	567,863	1,186,410	461,610	4,710,741	4,765,183	0.54	0.53
1990	3,223,210	680,368	752,513	1,069,440	365,802	5,338,820	5,410,965	0.6	0.6

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Table 11.–Page 2 of 2.

Year	Harvest[a]	Nushagak River Escapement		Wood River Escapement[a]	Igushik Escapement[a]	Nushagak District Total Run		Exploitation Rate	
		Traditional	Revised			Traditional	Revised	Traditional	Revised
1991	4,679,070	492,522	544,748	1,159,920	756,126	7,087,638	7,139,864	0.66	0.66
1992	2,789,740	695,108	768,816	1,286,250	304,920	5,076,018	5,149,726	0.55	0.54
1993	5,213,780	715,099	790,927	1,176,126	405,564	7,510,569	7,586,397	0.69	0.69
1994	3,150,870	509,326	563,334	1,471,890	445,920	5,578,006	5,632,014	0.56	0.56
1995	3,952,960	281,307	311,136	1,482,162	473,382	6,189,809	6,219,638	0.64	0.64
1996	5,365,940	503,651	557,057	1,649,598	400,746	7,919,937	7,973,343	0.68	0.67
1997	2,006,950	373,035	412,591	1,512,396	127,704	4,020,089	4,059,645	0.5	0.49
1998	2,696,120	458,874	507,532	1,755,768	215,904	5,126,668	5,175,326	0.53	0.52
1999	3,990,410	311,899	344,972	1,512,426	445,536	6,260,275	6,293,348	0.64	0.63
2000	4,873,410	403,500	446,286	1,300,026	413,316	6,990,256	7,033,042	0.7	0.69
2001	4,536,100	811,104	897,112	1,458,732	409,596	7,215,530	7,301,538	0.63	0.62
2002	2,259,500	315,681	349,155	1,283,682	123,156	3,982,017	4,015,491	0.57	0.56
2003	6,533,860	580,534	642,093	1,459,782	194,088	8,768,262	8,829,821	0.75	0.74
2004	6,219,630	491,730	543,872	1,543,392	109,650	8,364,400	8,416,542	0.74	0.74
2005	6,965,060	1,049,620	1,102,833	1,496,550	365,712	9,876,942	9,930,155	0.71	0.7
2006	10,698,100	548,410	548,410	4,008,102	305,268	15,559,880	15,559,880	0.69	0.69
2007	8,162,200	518,041	518,041	1,528,086	415,452	10,623,779	10,623,779	0.77	0.77
2008	6,567,270	492,546	492,546	1,724,676	1,054,704	9,839,196	9,839,196	0.67	0.67
2009	7,415,690	484,149	484,149	1,319,232	514,188	9,733,259	9,733,259	0.76	0.76
2010	6,893,190	468,696	468,696	1,804,344	518,040	9,684,270	9,684,270	0.71	0.71
2011	4,518,810	428,191	428,191	1,098,006	421,380	6,466,387	6,466,387	0.7	0.7
Average									
Last 3 Years	6,275,897	460,345	460,345	1,407,194	484,536	8,627,972	8,627,972	0.72	0.72
Last 5 Years	6,711,432	478,325	478,325	1,494,869	584,753	9,269,378	9,269,378	0.72	0.72
Last 10 Years	6,623,331	547,779	557,799	1,726,585	402,164	9,299,859	9,309,878	0.71	0.70

[a] As reported by Cunningham et al. 2012.

Table 12.–Historical harvest, escapement, total run, and exploitation rate for Nushagak River chum salmon 1985–2011.

		Escapement		Total Run		Exploitation Rate	
Year	Harvest	Traditional	Revised	Traditional	Revised	Traditional	Revised
1985	396,522	214,481	272,258	611,003	668,780	0.65	0.59
1986	488,375	168,276	213,607	656,651	701,982	0.74	0.70
1987	416,476	147,430	187,145	563,906	603,621	0.74	0.69
1988	371,199	186,418	236,636	557,617	607,835	0.67	0.61
1989	523,910	377,512	479,207	901,422	1,003,117	0.58	0.52
1990	375,631	329,793	418,633	705,424	794,264	0.53	0.47
1991	463,780	287,281	364,669	751,061	828,449	0.62	0.56
1992	398,619	302,858	384,442	701,477	783,061	0.57	0.51
1993	505,799	217,230	275,748	723,029	781,547	0.70	0.65
1994	328,164	378,928	481,004	707,092	809,168	0.46	0.41
1995	390,005	212,612	269,886	602,617	659,891	0.65	0.59
1996	331,295	225,029	285,648	556,324	616,943	0.60	0.54
1997	185,144	61,456	78,011	246,600	263,155	0.75	0.70
1998	207,782	299,215	379,818	506,997	587,600	0.41	0.35
1999	170,712	242,312	307,586	413,024	478,298	0.41	0.36
2000	114,342	141,324	179,394	255,666	293,736	0.45	0.39
2001	526,548	564,724	716,850	1,091,272	1,243,398	0.48	0.42
2002	276,733	419,964	533,095	696,697	809,828	0.40	0.34
2003	740,255	295,413	374,992	1,035,668	1,115,247	0.71	0.66
2004	457,896	283,811	360,265	741,707	818,161	0.62	0.56
2005	996,050	456,023	519,618	1,452,073	1,515,668	0.69	0.66
2006	1,239,791	661,002	661,002	1,900,793	1,900,793	0.65	0.65
2007	952,977	161,483	161,483	1,114,460	1,114,460	0.86	0.86
2008	491,379	326,300	326,300	817,679	817,679	0.60	0.60
2009	744,852	438,481	438,481	1,183,333	1,183,333	0.63	0.63
2010	423,992	273,914	273,914	697,906	697,906	0.61	0.61
2011	296,778	248,278	248,278	545,056	545,056	0.54	0.54
Average							
Last 3 Years	488,541	320,224	320,224	808,765	808,765	0.59	0.59
Last 5 Years	581,996	289,691	289,691	871,687	871,687	0.65	0.65
Last 10 Years	662,070	356,467	389,743	1,018,537	1,051,813	0.63	0.61

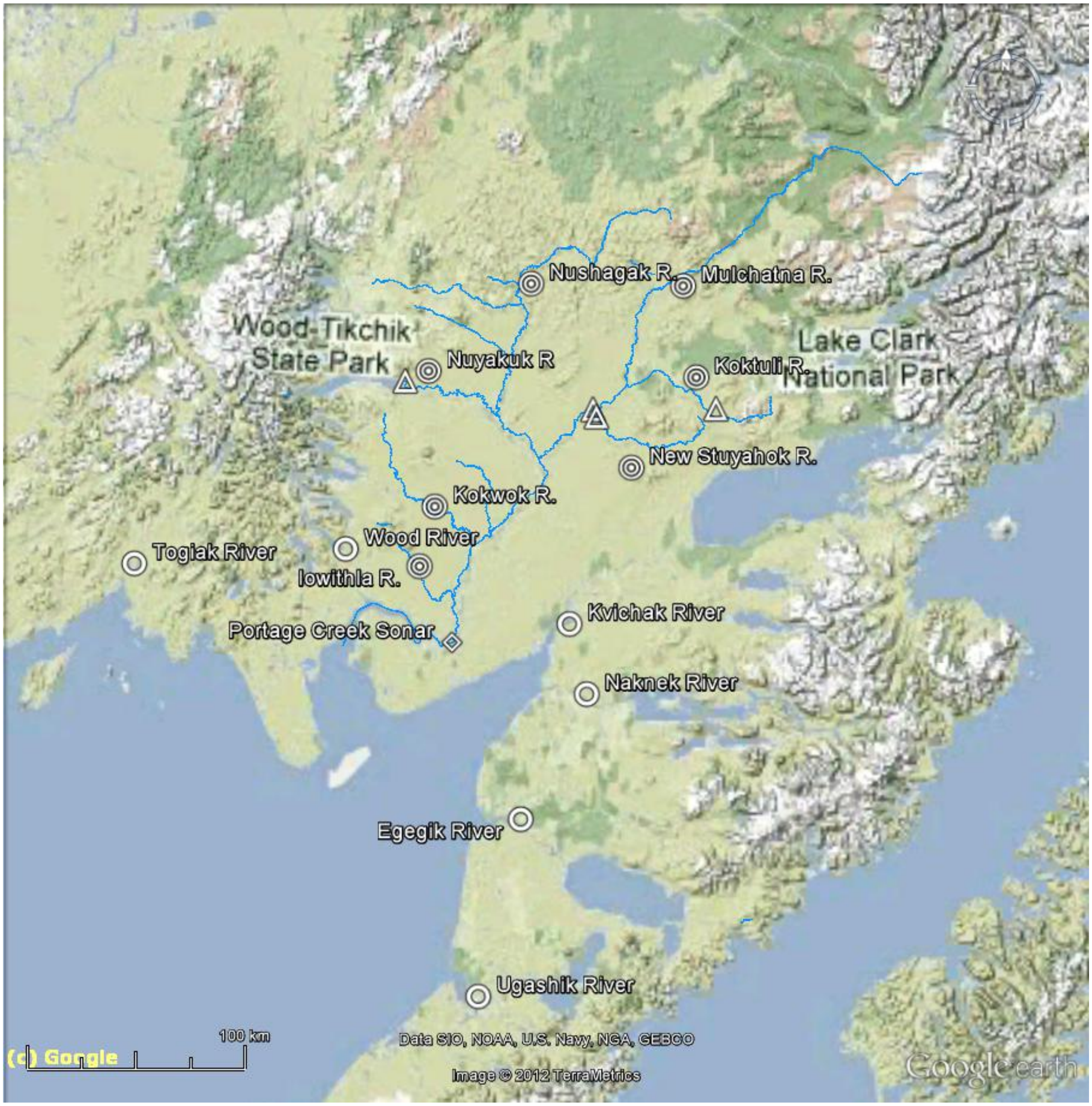

Figure 1.–Nushagak River showing sonar site and major tributaries (concentric circles) as well as other major Bristol Bay rivers (circles). Discharge measurement stations shown indicated with triangles.

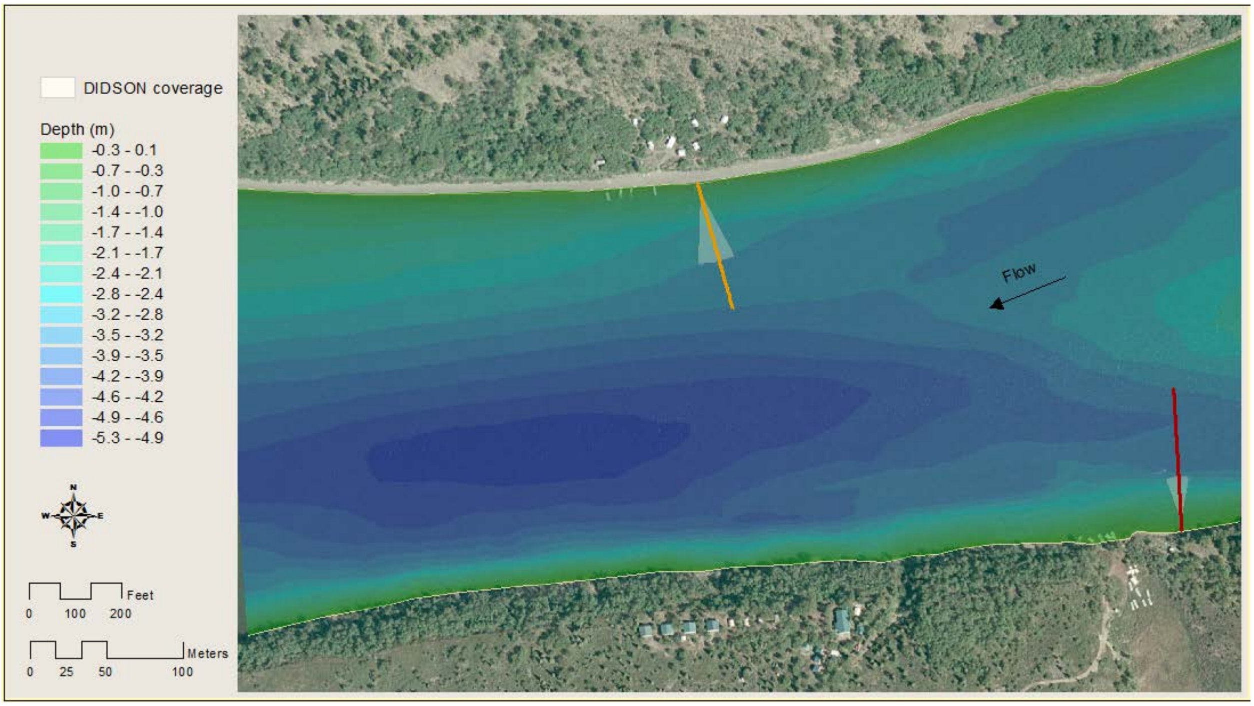

Figure 2.–Nushagak River sonar site showing north and south bank transducer placement and river bathymetry.

APPENDIX A: ADJUSTED NUSHAGAK RIVER BROOD TABLES

Appendix A1.–Adjusted Nushagak River Chinook salmon brood table.

Brood		Age Class							
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2
1959	NA	NA	NA	NA	NA	NA	NA	NA	NA
1960	NA	NA	NA	NA	NA	NA	NA	NA	NA
1961	NA	NA	NA	NA	NA	NA	NA	47,757	0
1962	NA	NA	NA	420	23,682	0	5,011	62,021	0
1963	NA	0	0	3,041	50,666	0	4,598	71,731	0
1964	NA	0	0	2,839	13,711	0	3,190	40,789	0
1965	NA	0	715	1,189	18,405	0	2,274	113,907	0
1966	81,462	88	35	10,096	19,056	0	6,211	36,530	0
1967	133,477	0	0	375	13,032	0	2,124	22,050	102
1968	142,951	0	0	1,124	18,145	0	563	27,410	0
1969	69,970	161	0	575	1,446	0	0	24,211	0
1970	101,435	0	0	0	2,308	0	0	99,035	0
1971	81,237	0	0	0	4,251	0	633	91,045	819
1972	50,156	0	0	223	54,319	0	985	75,030	0
1973	70,130	0	0	0	3,161	0	0	126,571	0
1974	142,535	0	0	666	36,709	0	0	58,166	3,008
1975	142,791	0	622	0	132,128	0	0	245,809	0
1976	205,273	0	1,187	0	12,794	0	0	162,171	824
1977	132,907	0	0	0	133,157	0	0	219,865	4,446
1978	268,046	0	3,591	0	38,275	0	0	73,414	426
1979	194,335	0	4,110	0	67,999	0	0	107,081	0
1980	289,040	0	0	0	16,843	0	0	82,043	0
1981	307,527	0	1,437	0	43,445	40	0	65,587	137
1982	300,656	0	2,171	0	2,336	0	0	66,162	336
1983	331,270	0	73	0	18,385	0	706	37,515	0
1984	163,544	0	336	0	28,503	0	0	49,848	0
1985	236,899	0	6,553	0	32,196	0	0	64,645	0
1986	82,777	0	0	0	48,212	0	0	91,683	0
1987	169,562	0	906	0	68,525	0	0	87,718	81
1988	113,006	0	1,085	29	61,258	0	0	100,816	0
1989	158,551	296	3,947	0	60,024	0	0	122,311	0
1990	126,747	0	1,235	0	52,337	0	0	49,636	0
1991	210,346	0	2,751	469	90,956	0	0	97,826	0
1992	166,965	0	1,912	343	45,116	0	0	76,219	0
1993	197,098	0	4,499	0	83,442	0	0	198,777	197
1994	190,121	0	1,867	0	37,359	0	0	47,034	0
1995	173,014	0	2,190	0	22,871	0	0	42,788	0
1996	102,348	0	974	0	31,377	0	0	60,853	0
1997	165,062	0	523	30	51,314	0	0	70,337	0
1998	235,845	0	1,037	0	70,092	0	0	101,055	0
1999	123,906	0	1,515	0	59,814	0	0	154,724	0
2000	110,682	0	648	0	86,335	0	0	139,796	112
2001	184,317	0	107	0	51,126	0	0	75,272	0
2002	174,704	0	236	0	56,007	0	0	36,759	0
2003	158,307	0	797	0	56,171	0	0	79,806	50
2004	233,475	0	1,269	0	20,537	0	0	38,378	0
2005	223,950	0	1,032	0	37,065	0	0	41,043	0
2006	117,364	0	492	0	31,417	0	0	55,957	0
2007	50,960	0	2,411	0	56,676	0	0	102,411	0
2008	91,364	0	1,125	0	53,036	0	NA	NA	NA
2009	74,781	0	1,423	NA	NA	NA	NA	NA	NA
2010	56,088	NA	NA	NA	NA	NA	NA	NA	NA
2011	102,258	NA	NA	NA	NA	NA	NA	NA	NA

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Appendix A1.–Page 2 of 4.

Brood	Age Class									
Year	0.5	1.4	2.3	0.6	1.5	2.4	1.6	2.5	Recruits	R/S
1959	NA	NA	NA	0	2,594	574	94	0	3,262	NA
1960	0	69,117	0	0	11,523	562	125	0	81,327	NA
1961	470	100,195	633	0	20,332	549	0	0	169,936	NA
1962	913	112,786	253	125	9,017	1,321	141	0	215,690	NA
1963	157	84,227	128	0	4,510	156	0	81	219,295	NA
1964	337	45,175	429	0	1,166	339	83	0	108,058	NA
1965	0	111,471	0	0	4,694	353	0	0	253,008	NA
1966	0	51,990	175	0	7,559	563	1,739	570	134,612	1.65
1967	282	69,031	570	0	40,928	570	481	0	149,545	1.12
1968	0	112,961	0	0	14,616	947	0	0	175,766	1.23
1969	0	51,403	1,412	0	3,968	438	0	0	83,614	1.19
1970	0	120,051	2,161	0	5,802	1,255	0	1,304	231,916	2.29
1971	0	136,055	1,816	0	19,377	10,753	0	0	264,749	3.26
1972	0	193,256	4,378	0	10,064	10,358	0	0	348,613	6.95
1973	0	146,299	0	0	21,957	0	0	0	297,988	4.25
1974	0	85,994	0	0	3,076	3,965	0	0	191,584	1.34
1975	0	201,490	5,433	0	12,712	10,569	0	0	608,763	4.26
1976	0	211,102	8,789	0	8,159	1,620	236	0	406,882	1.98
1977	0	330,217	360	0	23,654	0	80	0	711,779	5.36
1978	0	87,853	0	0	36,075	0	0	68	239,702	0.89
1979	0	150,580	0	0	9,315	427	0	0	339,512	1.75
1980	0	87,736	272	0	7,112	0	0	0	194,006	0.67
1981	0	139,122	0	0	12,808	0	0	0	262,576	0.85
1982	0	55,822	0	0	10,510	0	0	0	137,337	0.46
1983	0	95,090	0	0	2,135	0	0	0	153,904	0.46
1984	0	40,766	0	0	3,258	394	0	0	123,105	0.75
1985	0	81,772	0	0	2,795	296	0	0	188,257	0.79
1986	0	75,091	592	0	3,353	247	0	0	219,178	2.65
1987	0	117,710	0	0	8,420	87	0	0	283,447	1.67
1988	0	148,698	0	0	3,080	174	0	0	315,140	2.79
1989	0	124,899	0	0	3,963	343	0	0	315,783	1.99
1990	0	40,939	0	0	982	0	0	0	145,129	1.15
1991	0	84,588	0	0	5,435	0	0	0	282,025	1.34
1992	0	126,924	0	0	1,317	0	0	0	251,831	1.51
1993	0	76,676	91	0	3,891	0	0	0	367,573	1.86
1994	0	59,399	0	0	5,729	0	0	0	151,388	0.80
1995	0	93,836	329	0	4,710	0	236	0	166,960	0.97
1996	0	82,265	0	0	3,111	0	0	0	178,580	1.74
1997	0	59,759	103	0	2,472	0	0	0	184,538	1.12
1998	0	108,215	77	0	2,658	89	0	0	283,223	1.20
1999	0	113,227	0	0	1,651	0	0	0	330,931	2.67
2000	0	84,305	0	0	512	0	0	0	311,708	2.82
2001	0	30,367	0	0	343	0	0	0	157,215	0.85
2002	0	26,678	0	0	126	75	0	0	119,881	0.69
2003	0	41,319	75	0	661	0	0	0	178,879	1.13
2004	0	18,145	0	0	220	0	0	0	78,549	0.34
2005	0	30,818	0	0	338	0	NA	NA	NA	NA
2006	0	39,338	0	NA	NA	NA	NA	NA	NA	NA
2007	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2008	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix A2.–Adjusted Nushagak River sockeye salmon brood table.

Brood		Age Class						
Year	Escapement	0.2	0.3	0.4	0.5	1.1	1.2	1.3
1955	NA	NA	NA	NA	NA	NA	NA	NA
1956	NA	NA	NA	NA	NA	NA	NA	NA
1957	NA	NA	NA	NA	0	NA	NA	NA
1958	NA	NA	NA	0	0	NA	NA	311,993
1959	NA	NA	39,870	3	0	NA	0	0
1960	NA	0	51,366	3,589	0	34,663	0	213,741
1961	NA	6,980	51,759	0	0	0	210,436	22,240
1962	NA	11,314	19,634	10,665	0	1,451	31	0
1963	234,821	0	40,442	38,789	0	0	0	0
1964	134,853	13,964	9,661	1,351	0	0	0	51,330
1965	255,794	2,117	13,934	0	0	0	86,140	672,474
1966	233,578	4,968	83,443	1,061	0	670	91,353	520,071
1967	74,003	9,148	26,640	0	0	2,290	118,677	47,474
1968	142,360	0	0	7,854	0	0	35,190	293,845
1969	95,805	0	97,507	5,026	0	0	4,815	66,889
1970	452,892	2,654	3,370	0	0	0	127,285	12,169
1971	312,699	1,211	9,601	0	0	3,816	1	807,916
1972	39,851	3,598	75,229	887	128	0	71,034	863,255
1973	210,601	4,046	25,302	1,816	0	0	0	1,231,778
1974	204,190	1,112	0	0	0	0	0	70
1975	832,093	15,231	16,604	13,548	0	33,598	622,880	4,934,293
1976	520,303	6,033	62,381	0	2,596	0	190,047	3,422,923
1977	611,588	0	16,136	63,770	0	0	21,274	3,028,330
1978	734,040	0	345,825	133,718	0	0	89,106	933,192
1979	551,272	72,863	529,084	0	0	0	430,997	767,683
1980	3,669,136	22,436	523,065	34,504	0	0	19,768	312,947
1981	1,118,873	30,304	101,602	8,931	0	0	250,006	1,576,925
1982	664,580	82,470	420,279	34,031	0	1,195	125,109	594,091
1983	446,845	115,055	502,453	111,520	0	276	233,673	543,194
1984	655,739	10,147	218,564	26,533	0	0	46,771	432,523
1985	551,319	85,591	533,285	63,475	0	0	63,478	638,819
1986	1,095,241	94,281	803,990	54,040	0	0	98,020	791,155
1987	429,182	174,615	667,893	217,691	0	0	32,994	660,535
1988	534,460	53,520	450,950	110,430	0	0	206,199	1,651,453
1989	567,863	87,497	463,980	19,981	0	0	105,904	693,606
1990	752,513	108,080	588,590	113,335	0	0	37,828	292,042
1991	544,748	13,534	138,116	4,627	0	401	124,515	1,073,215
1992	768,816	102,933	340,638	1,047	0	0	130,535	567,660
1993	790,927	41,501	49,450	0	0	0	48,386	828,615
1994	563,334	1,504	28,616	0	0	207	70,182	277,738
1995	311,136	2,076	0	0	0	563	62,891	925,449
1996	557,057	0	0	0	0	0	363,788	1,857,241
1997	412,591	0	0	0	0	0	37,572	423,105
1998	507,532	0	0	0	0	0	154,934	2,237,869
1999	344,972	0	0	0	0	0	88,031	1,540,403
2000	446,286	0	0	0	0	0	240,485	3,299,220
2001	897,112	0	0	6,429	0	0	256,405	2,525,696
2002	349,155	0	38,496	0	0	0	192,085	1,783,792
2003	642,093	8,269	0	18,884	0	0	396,387	1,230,046
2004	543,872	0	55,992	0	0	0	160,719	1,156,550
2005	1,106,703	4,273	0	8,550	0	2,387	303,869	826,261
2006	548,410	0	6,070	1,429	0	0	95,890	976,883
2007	518,041	4,215	51,951	9,963	NA	1,034	30,183	835,027
2008	492,546	0	11,628	NA	NA	1,273	180,216	NA
2009	484,149	1,066	NA	NA	NA	633	NA	NA
2010	468,696	NA	NA	NA	NA	NA	NA	NA
2011	428,191	NA	NA	NA	NA	NA	NA	NA

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Brood	Age Class								
Year	1.4	1.5	2.1	2.2	2.3	2.4	3.2	Recruits	R/S
1955	NA	NA	NA	NA	NA	NA	NA	NA	NA
1956	NA	0	NA	NA	NA	0	NA	NA	NA
1957	0	0	NA	NA	0	0	0	NA	NA
1958	0	0	NA	65,872	38,995	0	0	NA	NA
1959	602	0	0	169,011	41,625	0	0	NA	NA
1960	2,225	0	0	47,670	188,107	0	12,801	NA	NA
1961	0	0	0	166,547	8,210	0	0	NA	NA
1962	22,925	0	0	66,348	20,282	0	0	NA	NA
1963	226	0	0	124,685	10,698	0	0	214,841	0.91
1964	0	0	0	15,074	1,963	0	0	93,342	0.69
1965	0	0	0	5,089	0	0	0	779,754	3.05
1966	0	0	0	0	0	0	0	701,566	3.00
1967	4,048	0	7,843	4,510	6,403	0	0	227,033	3.07
1968	2,760	0	0	0	4,530	0	0	344,179	2.42
1969	4,045	0	0	36,821	278,589	0	0	493,692	5.15
1970	3,442	0	486	745,793	93,565	0	0	988,764	2.18
1971	2,596	0	1	28,355	157,501	0	0	1,010,999	3.23
1972	0	0	0	46,130	87,718	0	0	1,147,980	28.81
1973	12,062	0	0	61,562	43,019	0	605	1,380,189	6.55
1974	0	0	0	347,528	34,914	0	0	383,623	1.88
1975	95,363	0	0	154,757	108,875	0	0	5,995,149	7.20
1976	57,970	0	0	203,260	406,715	0	0	4,351,924	8.36
1977	92,537	0	7,964	0	6,077	0	0	3,236,089	5.29
1978	0	0	0	11,883	0	0	0	1,513,725	2.06
1979	45,526	0	0	0	0	0	0	1,846,153	3.35
1980	8,820	0	0	167,393	121,331	0	0	1,210,266	0.33
1981	5,804	0	0	2,612	0	573	0	1,976,757	1.77
1982	71,345	0	0	0	6,628	0	0	1,335,148	2.01
1983	17,210	0	0	5,890	19,467	0	0	1,548,738	3.47
1984	20,858	0	0	3,962	1,890	0	0	761,247	1.16
1985	18,464	0	0	2,858	10,900	0	0	1,416,870	2.57
1986	200,174	0	0	0	50,092	820	0	2,092,574	1.91
1987	122,522	0	0	15,735	11,517	1,955	0	1,905,456	4.44
1988	72,229	0	0	5,343	7,214	0	0	2,557,339	4.78
1989	22,475	0	0	1,126	3,920	0	232	1,398,722	2.46
1990	8,433	0	0	13,239	21,791	5,910	0	1,189,247	1.58
1991	124,084	0	189	2,430	10,371	0	0	1,491,482	2.74
1992	56,242	0	0	9,027	4,493	0	0	1,212,574	1.58
1993	102,422	0	0	773	3,132	0	0	1,074,278	1.36
1994	7,774	0	0	5,625	34,269	0	0	425,915	0.76
1995	186,962	0	0	13,338	7,199	0	0	1,198,477	3.85
1996	99,273	0	0	4,811	10,398	0	0	2,335,512	4.19
1997	27,112	3,142	0	4,075	49,296	0	0	544,302	1.32
1998	207,961	0	0	7,352	57,380	0	0	2,665,496	5.25
1999	77,948	0	0	13,098	34,236	0	0	1,753,716	5.08
2000	389,773	1,084	0	5,167	16,590	4,222	0	3,956,541	8.87
2001	258,150	363	0	5,094	24,507	0	0	3,076,644	3.43
2002	68,193	0	0	30,928	7,787	0	0	2,121,281	6.08
2003	192,828	0	0	0	16,901	0	0	1,863,316	2.90
2004	72,574	0	0	4,828	13,032	0	0	1,463,695	2.69
2005	36,706	0	0	7,976	19,987	0	0	NA	NA
2006	96,150	NA	0	5,166	8,683	NA	0	NA	NA
2007	NA	NA	0	0	NA	NA	NA	NA	NA
2008	NA	NA	0	NA	NA	NA	NA	NA	NA
2009	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	NA	NA	NA	NA	NA	NA	NA	NA	NA
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix A3.–Adjusted Nushagak River chum brood table.

Brood Year	Escapement	Age Class 0.1	0.2	0.3	0.4	1.3	0.5	1.4	Recruits	R/S
1979	NA	NA	NA	NA	NA	NA	0	0	NA	NA
1980	NA	NA	NA	NA	132,310	0	22,901	0	NA	NA
1981	NA	NA	NA	530,810	347,765	854	4,756	0	NA	NA
1982	NA	NA	5,660	330,461	255,119	0	7,107	0	598,347	NA
1983	NA	0	0	313,332	198,657	0	14,789	0	526,778	NA
1984	NA	0	29,724	392,215	379,224	799	0	0	801,961	NA
1985	272,258	691	9,856	584,029	232,240	1,850	0	0	827,975	3.04
1986	213,607	0	23,860	557,584	296,757	1,998	0	0	880,199	4.12
1987	187,145	415	2,591	511,624	508,186	9,557	0	0	1,031,958	5.51
1988	236,636	0	18,070	263,825	440,070	29,339	0	0	751,305	3.17
1989	479,207	0	1,493	310,846	482,825	21,716	0	0	816,880	1.70
1990	418,633	0	1,291	303,349	259,291	36,955	0	0	600,887	1.44
1991	364,669	0	1,278	323,562	176,853	5,893	0	0	507,587	1.39
1992	384,442	0	40,082	433,502	91,966	931	0	0	566,481	1.47
1993	275,748	0	694	169,061	103,576	3,729	4,107	0	281,168	1.02
1994	481,004	0	1,197	476,982	170,970	377	71,325	0	720,851	1.50
1995	269,886	0	3,313	302,844	131,659	0	0	0	437,817	1.62
1996	285,648	0	0	78,405	219,208	0	6,272	0	303,885	1.06
1997	78,011	0	12,347	1,019,556	287,101	1,568	4,669	1,505	1,326,746	17.01
1998	379,818	0	4,635	471,523	165,389	13,553	684	0	655,783	1.73
1999	307,586	0	43,364	925,912	418,718	0	2,992	0	1,390,986	4.52
2000	179,394	0	4,219	320,023	189,672	0	10,309	0	524,223	2.92
2001	716,850	0	78,736	1,322,115	695,566	1,596	12,156	0	2,110,168	2.94
2002	533,095	0	888	1,172,579	573,236	0	15,323	0	1,762,026	3.31
2003	374,992	0	20,743	525,394	318,992	0	4,043	0	869,172	2.32
2004	360,265	0	3,674	470,827	443,526	0	4,380	0	922,408	2.56
2005	519,618	0	12,537	717,385	181,809	0	681	0	912,411	1.76
2006	661,002	0	18,379	494,696	182,395	1,213	0	54	697,237	1.05
2007	161,483	0	17,021	355,194	173,188	2,771	NA	NA	NA	NA
2008	326,300	0	4,893	383,517	NA	NA	NA	NA	NA	NA
2009	438,481	681	3,795	NA	NA	NA	NA	NA	NA	NA
2010	273,914	0	NA	NA	NA	NA	NA	NA	NA	NA
2011	248,278	NA	NA	NA	NA	NA	NA	NA	NA	NA