Estimating run timing of Lake Clark sockeye salmon relative to other Kvichak River drainage populations.

Annual Report for Study 04-411

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Abstract:

Lake Clark of sockeye salmon provide a large component of the subsistence harvest in Iliamna, Lime Village, Newhalen, Nondalton, Pedro Bay and Port Alsworth. Recent reductions in escapement of Lake Clark stocks are partly responsible for lower subsistence harvest levels. Lake Clark and Iliamna Lake sockeye are also targeted in commercial fishery prosecuted in the Kvichak district. Understanding the run timing of the Lake Clark stock relative to other Kvichak River stocks may provide tool for managers to target stocks with harvestable surplus. The run timing of Lake Clark stocks is not well understood. In the first year of this three-year project, we analyzed 13 microsatellites and four SNPs on 1,668 fish captured on 12 days which represented a period when 77% of the run. We found proportions significantly larger than zero on all but two days and significant variation in the proportion of Lake Clark stocks through time, but no clear pattern indicating early or late arrival. In an add-on to this project we also tested and found no significant difference in the proportions of Lake Clark stocks from 400 out migrating smolt in the Kvichak River taken during two time periods three weeks apart in 2000.

Key Words**:** Bristol Bay, genetics, Kvichak River drainage, Lake Clark National Park, Lake Clark National Preserve, microsatellite, *Oncorhynchus nerka*, run-timing, single nucleotide polymorphisms (SNP), sockeye salmon, Stock Status and Trends.

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Introduction:

Salmonids, primarily sockeye salmon, support a large subsistence fishery in Bristol Bay. However, recent declines in subsistence harvest have been observed especially, in the Kvichak River. The 20-year average subsistence harvest of salmonids in Bristol Bay is 148,000 fish. Sockeye salmon make up 75% of this subsistence harvest. Just over half of the Bristol Bay harvest of sockeye salmon is taken in the Naknek/Kvichak district.

Subsistence harvest levels in the Naknek/Kvichak district have taken the steepest drop of all the regions in 2002 with harvest at the lowest levels since 1973 and 34% below the most recent ten-year average. Most of this decline has been in the Kvichak drainage where harvest was 41% below the most recent 10-year average and 50% below the 20-year average. The 2001 and 2002 harvests in the Kvichak drainage are the lowest since records have been kept in 1963.

The communities most affected by these declines in harvest levels include those in the Lake Clark drainage (ADF&G 2003) which includes the Lake Clark National Park, Lake Clark National Preserve and the Tlikakila River National Wild and Scenic River. Sockeye salmon is recognized as a federal subsistence resource with customary and traditional use. Subsistence fishery for sockeye salmon in the Lake Clark drainage is open to residents of the Iliamna, Lime Village, Newhalen, Nondalton, Pedro Bay and Port Alsworth with a Bristol Bay subsistence permit issued by the State or who anyone with a Section 13.44 subsistence use permit issued by the park superintendent. Fish may be caught by set or drift gillnet between May 1 and May 31 and October 1 and October 31 from 9:00 am Monday to 9:00am Friday and from June 1 to September 30 during State commercial salmon fishing periods in commercial salmon fishing districts except in the Tazimina River where subsistence fishing with nets is closed from September 1 to June 14. Emergency orders may also be issued to open subsistence fisheries when extended closures to commercial fishing occur.

Subsistence harvest of sockeye salmon destined for Lake Clark are taken primarily in the communities of Nondalton and Port Alsworth where annual harvest averaged 19,000 from 1981 to 2000. In addition, some of the fish harvested in the Iliamna-Newhelen communities were also destined for Lake Clark. These subsistence catches averaged 20,000 between 1981 and 2000. In total these three communities accounted for 31% of the subsistence sockeye salmon harvested in the whole Bristol Bay area. By contranst, in 2002, there were 2,365 fish harvested from “Lake Clark: General”, 150 from “Kijik”, 422 from “Port Alsworth”, and 3,395 from “Six Mile Lake” which includes fish spawning in the Tazimina River. For these areas a total of 52 permits were issued in 2002.

Two factors have led to this decrease in the number of fish harvested in the Lake Clark drainage: the superintendent of Lake Clark National Park and Preserve closed subsistence fishing to all but federally qualified local rural residents starting in 2001 and the numbers of fish returning to the drainage are near historical low levels (ADF&G 2003). Changes in subsistence regulations alone do not explain the reduction in numbers of fish harvested for subsistence use because number of fish harvested per permit has decreased (ADF&G 2003) along with catch per unit effort and delays in the completion of harvests (Jim Fall, Subsistence Division, ADF&G, Anchorage, personal communication).

The decrease in subsistence harvest may signal a risk to the conservation of populations that support subsistence fisheries. This decrease also indicates that there is a risk of failure to provide a priority to subsistence uses because commercial fisheries are executed along the Alaska Peninsula and within Bristol Bay which are along the likely migration pathway of Lake Clark-bound sockeye salmon. Because fish destined to spawn in drainages along this pathway depart the migration corridor to enter their natal streams, concentrations of Lake Clark-bound fish increase as they approach the Naknek/Kvichak commercial fishing district and the Kvichak River.

This decline led the Bristol Bay-Alaska Peninsula Regional Advisory Council, after six village meetings conducted by the BBNA in 2000 to identify the need to "document run timing and spawning areas for Lake Clark sockeye salmon stocks" as one of the six information needs under the “Stock Status and Trends” category (Anonymous 2002).

Characterizing the run timing of Lake Clark-bound sockeye salmon adults as they migrate in the Kvichak River may allow for adjustments in the commercial fishery in the Naknek/Kvichak commercial fishing district that would be designed to allow Lake Clark-bound fish to escape the fishery. ADF&G managers have requested information that could confirm run timing and interception rates of Lake Clark stocks and, with this information, they would have the option to adjust harvest and take precautionary measures when necessary to protect Lake Clark stocks (James Browning, ADF&G, CF personal communication).

Characterizing the run timing of Lake Clark-originating sockeye salmon smolt as they emigrate on their seaward migration will provide better stock-specific estimates of smolt production. ADFG currently manages the Lake Clark and other Kvichak stocks separately. Currently, the assumption is that stock composition (proportion of Lake Clark to other stocks) of out-migrating smolt mirrors the stock composition of their parental cohorts. Knowing the stock composition of the smolt would provide better inputs into both the stock-recruit model and into the return forecast model. Due to the potential for these two stocks to vary in their out-migration timing, characterizing smolt out migration during the entire out-migration period will likely be needed to estimate stock-specific smolt production.

The temporal distribution of Lake Clark-bound sockeye salmon entering the Kvichak River is not clear and no information exists on the out-migration run timing of Lake Clark smolt relative to other Kvichak River drainage stocks. According to the Issues and Information Needs, “Local residents think the early run of sockeye salmon to the Kvichak River system spawns in Lake Clark” (Anonymous 2002). This timing is supported by early tagging work by Poe and Mathisen (1980) who found that fish bound for Lake Clark system tended to be predominatly in the early part of the Kvichak run. Another study indicated that over a three-year period, Kijik Lake fish generally passed Igiugig (at the outlet of Iliamna Lake) earlier than fish destined for other locations (Smith 1964). However, this same study found that this pattern was not observed for fish taken at other sites in Lake Clark (Smith 1964). In addition, during a more recent one-year study, tagging data indicated that Lake Clark-bound sockeye salmon entered Iliamna Lake later in the season than other stocks (Jensen and Mathisen 1987). In that study, by the time 75% of the sockeye bound for Kvichak River drainages had passed Igiugig only 50% of Lake Clark-bound sockeye salmon had passed. The same study found that fish destined to spawn in the Newhalen River (which drains Lake Clark) made up the largest segment of the first group of fish to pass Igiugig. These observations indicate that there may be differentiation in the timing of entry to the Kvichak River of various stocks, that stock timing may not be consistent among years, or the speed of migration up the Kvichak River may vary among stocks.

Genetic methods may be a cost-effective means to determine the run timing of Lake Clark-bound sockeye salmon as they pass Igiugik which is close to where the Naknek/Kvichak district commercial fisheries are prosecuted and to determine the run timing of Lake Clark-originating smolt as they emigrate to sea. Genetic data are widely used in salmonids to estimate stock compositions (Pella and Milner 1987, Wood et al. 1987, 1989, Shaklee and Phelps 1990, Shaklee et al. 1999, Beacham and Wood 1999, Guthrie et al. 2000, Seeb et al. 2000, Wilmot et al. 2000, Habicht et al. 2001, Seeb et al. 2003). USGS, Biological Science Office, Alaska Science Center documented spawning areas through OSM grant # FIS00-042, and identified and mapped spawning areas on Lake Clark beaches and tributaries by using both tagging and TEK. Through this grant, USGS also produced an extensive analysis of genetic stock structure of Lake Clark sockeye and shared sockeye salmon tissue collections from Lake Clark with GCL for use in mixed-fishery analyses (Table 1). GCL has amassed an extensive baseline of stocks from throughout the Bering Sea with a strong focus on stocks in Bristol Bay and in particular the Kvichak River system (Table 1). Similarity among the Lake Clark stocks that represent the majority of spawning sockeye salmon from Lake Clark and differences between these stocks and all other Bristol Bay stocks (Figure 1) indicate that these stocks are highly identifiable in samples containing stock mixtures.

Lake Clark spawning aggregates are highly genetically differentiated from other Kvichak River drainage fish (Figure 1). This differentiation provides estimates of the Lake Clark contribution to a sample within 5 percentage points of the actual proportion 95% of the time (Antonovich 2003). In simulations where the baseline and simulated mixtures of 400 fish from the Lake Clark drainage were resampled 1000 times in the Statistical Program to Analyze Mixtures (SPAM; Debevec 2000), the 90% confidence intervals for the estimate of Lake Clark drainage fish were 94% to 99%. More importantly, when simulations of 100% non-Lake Clark drainage fish were run, the 90% confidence intervals were 0% to 2.4% Lake Clark drainage fish. These results indicate that we will be 95% confident that Lake Clark drainage fish are present in a mixture if the mixture estimates are above 2.4% for Lake Clark drainage fish. Similar results were obtained using BAYES (Masuda 2002) algorithm where there was a power of 0.70 to detect as little as 4% Lake Clark-bound fish in a mixture sample sizes of 200 fish (Antonovich 2003). This database provides a cost-effective basis for identifying the timing of these populations as they migrate through the mouth of the Kvichak River near where the Naknek/Kvichak district commercial fishery is executed.

Objectives:

1) To estimate the proportion of sockeye salmon originating from the Lake Clark drainage and captured at the Kvichak River tower site (near Igiugig) during each day during the time period when the majority of the fish migrate into Iliamna Lake within each of three years such that the estimate is within 5 percentage points of the actual proportion 95% of the time. The original proposal called for investigating five periods, but we expanded the analysis to investigate stock proportions for every day (12 sampling periods) because the additional single-nucleotide polymorphisms (SNPs) markers we screened in both the baseline and the tower samples provided tighter confidence internals for the Lake Clark stock than the microsatellite data alone. This enabled us to get a better handle on day-to-day fluctuations in stock composition in addition to the trend analysis.
2) To test the hypothesis that the proportion of sockeye salmon originating from the Lake Clark drainage and captured at the Kvichak River tower site remains constant during each day within each year such to detect at least a difference of 5 percentage points between proportions with alpha = 0.05 and beta = 0.30.
3) To test the hypothesis that the relative proportions among days of sockeye salmon originating from the Lake Clark drainage and captured at the Kvichak River tower site remains constant among the three years such to detect at least a difference of 5 percentage points between proportions with alpha = 0.05 and beta = 0.30.
4) To estimate the proportion of sockeye salmon smolt originating from the Lake Clark drainage captured at the Kvichak River smolt site during two time periods within one year such that the estimate is within 5 percentage points of the actual proportion 90% of the time.
5) To test the hypothesis that the proportion of sockeye salmon smolt originating from the Lake Clark drainage and captured at the Kvichak River smolt site remains constant over the two sampling periods such as to detect at least a difference of 5 percentage points between proportions with alpha = 0.10 and beta = 0.30.
6) To test the first three hypotheses on other stock components of the Kvichak River drainage. This component was added because the addition of the SNP markers to the project allowed for the resolution of additional stocks within the Kvichak River.

Methods:

Adults –Fin tissues were sampled from a target of 400 sockeye salmon captured at the Kvichak River tower site operated by ADF&G below the outlet of Lake Iliamna every four days starting on approximately June 28 and ending on approximately July 14 in 2004 for a total of 2,000 fish. Dates may have shifted by a day or two depending on whether managers felt the run was early or late in that year. Historic data collected at Igiugig indicate the 80% of the sockeye salmon ascending the Kivchak River pass Igiugig between July 1 and July 15 (L. Fair, Commercial Fisheries Division, ADF&G Anchorage).

Before choosing the tower site as the sampling location for this project, we also considered two other sampling locations: the Naknek/Kvichak commercial fishery and Kvichak River test fishery operated by ADF&G near Levelock. In fact, we began sampling the test fishery during 2004 since we felt this would allow us to collect fish regardless of fishery openings and in a specified and repeatable location, which would provide for a more controlled experimental design with fewer confounding variables and would produce more easily interpreted results. However, we moved our sampling location up river to the tower site when it became obvious it would be difficult to obtain adequate sample sizes at the test fishing site. Moving the sampling location up river was also expected to greatly reduce the number of Alagnak River fish in samples, which would increase the proportion of Lake Clark fish in samples. The higher proportions of Lake Clark fish in the mixtures should increase the sensitivity to detect them and provide more power to detect variation in their abundance over time. This was particularly important given the record escapement into the Alagnak River in 2004 (Clark 2005).

Moving the sampling location from the test fishing to tower site introduced more uncertainty into estimates of run timing and abundance of Lake Clark sockeye salmon within the Commercial Fishery District. This was because the tower site is further from the Commercial Fishery District (about 100km upstream of the northern boundary and 140km from the southern boundary) than the test fishing site (approximately 20km upstream of the northern boundary and 60km from the southern boundary). While it takes sockeye salmon, on average, about one day to travel from the Commercial Fishery District to the test fishing site and an additional two days to travel to the tower site (L. Fair, Commercial Fisheries Division, ADF&G Anchorage), the travel times vary throughout the season. We also do not know when sockeye salmon arrived in the Commercial Fishery District, or how long they remained there, before beginning their migration up the Kvichak River.

The change in sampling location and the concern of proposal reviewers with increasing the involvement of local residents were instrumental in redirecting our approach to capacity development. Neither the test fishing or tower sites have facilities to accommodate more personnel than the field crew. So, instead of flying local residents out and back each sampling day, we opted for more direct involvement of a local resident each year in all aspects of the project by creating an internship/scholarship program. The internship portion of the program would involve a local resident in the field collecting samples, in the laboratory analyzing samples, and in the community disseminating information. The scholarship portion of the program would provide an incentive for local residents to apply for this program and to attend post secondary education.

A target sample size of 400 fish was selected in order to meet the criteria outlined in the objectives. Lake Clark spawning aggregates are highly genetically differentiated from other Kvichak River drainage fish (Figure 1). This differentiation provides estimates of the Lake Clark contribution to a sample within 5 percentage points of the actual proportion 95% of the time (Antonovich 2003). In simulations where the baseline and simulated mixtures of 400 fish from the Lake Clark drainage were resampled 1000 times in the Statistical Program to Analyze Mixtures (SPAM; Debevec 2000), the 90% confidence intervals for the estimate of Lake Clark drainage fish were 94% to 99%. More importantly, when simulations of 100% non-Lake Clark drainage fish were run the 90% confidence intervals were 0% to 2.4% for Lake Clark drainage fish. These results indicate that we will be 95% confident that Lake Clark drainage fish are present in a mixture if the mixture estimates are above 2.4% for Lake Clark drainage fish. Similar results were obtained using BAYES (Masuda 2002) algorithm where there was a power of 0.70 to detect as little as 4% Lake Clark-bound fish in a mixture sample sizes of 200 fish (Antonovich 2003).

Since the proposal was submitted, we assayed the baseline for an additional five microsatellites and four SNPs (Table 2). The microsatellite loci include: Omy77* (Morris et al. 1996); One102*, One103*, One108*, One109*, One 110*, One111*, One112*, One 114* (Olsen et al. 2001); Ots3* (Banks et al. 1999); Ots103* (Small et al. 1998); Ots107* (Nelsen and Beacham 1999); and uSat60* (Estoup et al. 1993) . This updated baseline provided higher correct allocations with tighter confidence intervals. As a result, we are able to provide estimates for samples as low as 100 fish while meeting the accuracy and precision requirements outlined in the objectives (Table 3). Due to this increased power, we are able to provide estimates of stock composition on a daily basis.

We estimated the stock composition from these samples for each day and calculated the proportion of fish bound for Lake Clark. We determined that if the 90% confidence interval on the stock composition included the value zero then we interpreted this result to indicate that the Lake Clark reporting group may not have been present. We used the stock composition estimates and multiplied them by the escapement numbers for each day to visualize run timing of each of the reporting group components. We used linear interpolation to estimate the proportions of each stock present for the three days when samples were not available and multiplied these estimates by the escapement numbers to derive the cumulative run timing for each reporting group. Based on this timing curve, we identified the day when 50% of each reporting group passed the Igiugig site.

Smolt - Fin tissue from 190 sockeye salmon smolt captured using fyke nets in the Kvichak River during 2000 for the smolt enumeration project operated by ADF&G near Igiugig for two time periods, early (May 21-23) and late (June 9-11) run, for a total of 380 fish were assayed for the 13 microsatellite and 4 SNP markers. This assay is an increase of 5 microsatellites and 4 SNPs beyond those originally proposed. Due to the higher power of this complement of, the confidence interval for estimated Lake Clark proportions will be increased to 95% from the 90% in the proposal and the alpha level for differences between time interval proportions will be reduced to 0.05 from the 0.10 in the proposal.

Data Collection and Reduction:

Mixed-stock analysis using SPAM was performed for each group. These analyses incorporated existing baseline from Bristol Bay (Table 1). Results provided the proportions and 95% confidence intervals around the proportions of Lake Clark fish present for each time strata (Objective 1).

To test the hypothesis that the proportion of sockeye salmon originating from the Lake Clark drainage and captured in the Kvichak River test fishery remained constant over the sampling periods within 2004, we performed Pearson Chi-squared (X^2) and log-likelihood (G^2) tests. If we found significance in the overall G^2 statistic, we partitioned the G^2 test statistic into individual components to examine which proportions cause the significance of the overall.

Results:

Adults – We sampled fin tissue from sockeye salmon captured at the Kvichak River tower site at Igiugik starting on June 30 and ending on July 14 in 2004. Between 100 and 200 fish were sampled each day (except on July 6, 11 and 12 when no fish were sampled) for a total of 1,669 fish (Table 1). The dates when samples were taken accounted for 77% of the fish passing the Igiugik site (Figure 3).

Using ADF&G's entire Bristol Bay genetic baseline (75 collections from Meshik river to Kuskokwim River), an average of 96% of the samples allocated to Kvichak drainage populations upstream of the Iguigig site. This proportion is in line with the 100% simulation estimates for these populations from these regions which ranged from 94% to 99%. We therefore restricted the remaining analyses to the baseline consisting of collections upstream of the Iguigig site (Table 1).

The proportion of sockeye salmon originating from Lake Clark is not constant over time (G^2 = 33.89, 11 df, $P < 0.001$). This significant finding is largely due to significant deviations in the proportions of the Lake Clark component on July 7th and July 9th (Figure 2).

The proportion of fish bound for Lake Clark was significantly present in all but two of the dates sampled (July 4 and July 5) and was present in samples taken early and late in the run (Figure 4a). The highest proportions of Lake Clark sockeye were observed during the latter part of the run (Figure 4a). No early or late trend was evident for the Lake Clark component. After multiplying the stock proportion estimates by the escapement numbers for each day, we observed that most of the reporting groups were present throughout the run but that there was a high level of variation from day-to-day and that some reporting groups appeared to have patterns including later arrival (Iliamna Lake, late) and early arrival (Sixmile Lake; Figures 2 and 4). These patterns were also evident after linearly interpolating to estimate the proportions of each stock present for the three days when samples were not available and multiplying these estimates by the escapement numbers to derive the cumulative run timing for each reporting group (Figure 3). The day when 50% of each reporting group passed the Igiugig site varied among reporting groups, again with the Iliamna Lake, Late collection reaching this point four days after the Sixmile Lake reporting group (Figure 5).

Smolt - Fin tissue from 190 sockeye salmon smolt captured using fyke nets in the Kvichak River during 2000 for the smolt enumeration project operated by ADF&G near Igiugig for two time periods, early (May 21-23) and late (June 9-11) run, for a total of 380 fish were used in the analysis.

The proportion of Lake Clark-originating smolt was not significantly different between the two sampling dates (P = 0.11; Figure 7). The only region that showed variation in the proportion of allocated smolt was Sixmile Lake, which showed higher proportions during the second sampling period relative to the first sampling period. Iliamna Islands was marginally significant (P = 0.014) with a trend in the opposite direction (Figure 6).

Discussion:

We exceeded the study objectives in the first of this three-year project by providing stock composition estimates for adults on a daily rather than a multi-day basis, by providing estimates of stock composition for not only the Lake Clark component but also for four stocks within Iliamna Lake, and for providing more precise estimates of stock composition for the Lake Clark component. These improvements to the project were made possible the addition of loci screened in the baseline and mixture samples. We proposed to screen eight microsatellite loci but instead screened 13 microsatellites and 4 SNP loci. The addition of these loci improved precision and allowed for the separation of additional spawning aggregates (stocks). We were able to identify four stocks in Iliamna Lake and it’s tributaries along with Sixmile Lake and Lake Clark. In addition, the 100% simulations for Lake Clark produced an outstanding 99% correct allocation. These results allowed for the differentiation of all six stocks in the mixtures and exceptionally high confidence in the proportion of Lake Clark stocks present.

The proportion of Lake Clark fish migrating up the Kvichak River did not show a simple pattern over time. Higher proportions of the fish were headed for Lake Clark both in the earliest days and during the second half of the run (Figure 3). After adjusting for the numbers of fish passing the Igigig Tower throughout the run, the majority of Lake Clark fish entered later than the rest of the stocks, but there were some Lake Clark stock present early in the run. If this timing pattern is representative of the relative run timing of Lake Clark fish over time and is representative of the run timing through the commercial fisheries which occur 50 miles downstream, this pattern does not appear to provide a clear tool for fishery managers to target more abundant stocks from the Kvichak River drainage while avoiding Lake Clark stocks.

The observation of significant day-to-day variation in stock compositions without clear trends throughout the sampling period indicates that the adults passing by the Igiugig tower may not be well mixed. Because each daily sample was taken from just a few gillnet sets, the day-to-day variability may be due to schooling of fish by stock. If this is the case, then the extrapolation of single day stock estimates to the rest of the 24-hour periods may be showing higher variability than is present during these daily periods. To reduce this variability, stock compositions from multiple days may be a better indication of the stock composition of fish passing by the tower site over time because these estimates represent more gill-net sampling events.

Although Lake Clark stocks showed little clear pattern in proportion of the catch over time, some of the other stocks did. The most pronounced of these the Iliamna, Late stock, which appeared later in the run and the Iliamna Islands stock, which made up higher proportions early in the run.

The smolt analyses were on a much reduced set of samples compared with the adult analyses. It is difficult to determine if the marginal patterns observed or if the lack of patterns for most of the stocks observed were due to sampling issues. Smolt may be even more likely to migrate in schools made up of fish predominantly from single stocks than adults because they are just leaving their nursery lakes. Further analyses on additional samples both within and between years might provide some insights into these potential phenomena or might show some consistent patterns in stock-specific out-migration timing.

The patterns observed in 2004 in stock-specific run timing for adults will be tested in this project over the next two years to determine if these patterns are consistent over time.

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Figures:

PowerPoint document (inserted at page 19 of this document.)

Tables:

Table 1. Collection sites, collection sizes, and sampling year, sampling site lake drainage and collectors for sockeye salmon used to develop genetic baseline in the Kvichak River system.

Sample site	N	Year	Reporting group	Collector[a]
Iliamna River, late	100	1999	Iliamna late	ADFG/FRI
Flat Island	99	2000	Iliamna island	FRI
Woody Island	100	2001	Iliamna island	FRI
Triangle Island	100	2000	Iliamna island	FRI
Finger Beach	85	2000	Iliamna N. E.	FRI
Knutson Bay Beach	100	2000	Iliamna N. E.	FRI
Chinkelyes Creek	98	2000	Iliamna N. E.	ADFG/FRI
Lower Talaric Creek[b]	100	2000	Iliamna tributary	ADFG/FRI
Lower Talaric Creek[b]	70	2001	Iliamna tributary	ADFG/FRI
Dennis Creek	100	2000	Iliamna tributary	ADFG
Gibraltar River	100	2000	Iliamna tributary	ADFG/FRI
Southeast Creek[b]	100	2000	Iliamna tributary	ADFG
Dream Creek[b]	100	2001	Iliamna tributary	ADFG
Nick N. Creek	100	2000	Iliamna tributary	ADFG
Copper River	100	2000	Iliamna tributary	ADFG
Upper Newhalen River	100	2003	Sixmile[c]	ADFG
Tazimina River	100	2001	Sixmile[c]	USGS
Chulitna Bay Beaches	100	1999	Clark[c]	USGS
Kijik Lake Beach	100	2000	Clark[c]	USGS
Kijik River	100	2001	Clark[c]	USGS
Lower Kijik River	100	2001	Clark[c]	USGS
Upper Tlikakila River	100	2001	Clark[c]	USGS

[a] ADFG: Alaska Department of Fish and Game; FRI: T. Quinn, Fisheries Research Institute; USGS: C. A. Woody, U.S. Geological Survey.
[b]Both Upper Talaric Creek collections were pooled and Southeast and Dream Creeks were pooled following insignificant pair-wise G-tests.
[c]Reporting groups with 99% correct allocations in 100% simulated mixtures, remaining reporting groups were between 84% and 93% correct allocation.

Table 2. Single nucleotide polymorphism (SNP) loci added to the baseline and screened in the mixture samples to determining the relative run-timing of Lake Clark sockeye salmon adults and smolt in the Kvichak River drainage.

Locus	Genome	Source information used to sequence DNA	Assay names
Cytochrome *b* (26)	mtDNA	(Bickham et al. 1995)	ADFG|One_Cytb_26
Prolactin II	nuclear	(Xiong et al. 1992)	ADFG|One_Prl2
Major Histocompatibility Complex 190 and 251	nuclear	ADFG unpublished	ADFG|MHC190/251 treated as haplotype

Table 3. Results from mixed-stock analyses using simulated mixtures composed of 100% mixtures of 400 fish from the fine-scale geographic groups visualized in the UPGMA tree. Results from each simulation are presented in each column. Green cells contain the percent correctly allocated back to the grouping while shaded cells denote misallocations greater than 3% (yellow), greater than 5% (pink). Collections making up each fine-scale group are designated in Table 1.

	Source					
	Iliamna late	Iliamna islands	Iliamna northeast	Iliamna tributaries	Sixmile Lake	Lake Clark
Allocated to:						
Iliamna late	0.86	0.00	0.03	0.00	0.00	0.00
Iliamna islands	0.00	0.84	0.04	0.05	0.00	0.00
Iliamna northeast	0.12	0.03	0.87	0.01	0.00	0.00
Iliamna tributaries	0.01	0.12	0.05	0.93	0.01	0.00
Six-Mile Lake	0.00	0.00	0.00	0.00	0.99	0.00
Lake Clark	0.00	0.00	0.00	0.00	0.00	0.99

Non-Discrimination Statement:

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973,Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972. If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, Alaska 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfield Drive, Suite 300, Arlington, Virginia 22203; or O.E.O., U.S. Department of the Interior, Washington, D.C. 20240. For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-4120, (TDD)907-465-3646, or (FAX) 907-465-2440.

Figure 1. UPGMA dendrogram based on Cavalli-Sforza Edwards genetic distances shows the five major reporting groups for sockeye salmon spawning in the Kvichak River Drainage.

Figure 2. Stock proportions of sockeye salmon migrating up the Kvichak River past the Igiugig counting tower for each day from June 30 to July 14, 2004 as inferred from 13 microsatellites and 4 SNP loci. Days when no stock composition estimates were made are blank.

Figure 3. Number of fish from each stock of sockeye salmon migrating up the Kvichak River past the Igiugig counting tower for each day from June 30 to July 14, 2004 as inferred from 13 microsatellites and 4 SNP loci. Days when no stock composition estimates were made are blank.

Figure 4. Trend line over time in the proportions of sockeye salmon migrating up the Kvichak River past the Igiugig counting tower for each day from June 30 to July 14, 2004 as inferred from 13 microsatellites and 4 SNP loci. Days when no stock composition estimates were made are blank. A: Lake Clark; B: Iliamna Lake Northeast; C: Iliamna Late; D: Iliamna Lake tributaries; E: Iliamna lake Islands; F: Six-mile Lake.

Figure 5. Run curves for each stock of sockeye salmon migrating up the Kvichak River past the Igiugik counting tower from June 30 to July 14, 2004 as inferred from 13 microsatellites and 4 SNP loci. We used linear interpolation to estimate the proportions of each stock present for the three days when samples were not available and multiplied these estimates by the escapement numbers to derive the cumulative run timing for each reporting group. Based on this timing curve, we identified the day when 50% of each reporting group passed the Igiugig site.

Figure 6. Stock proportions of sockeye salmon smolts migrating down the Kvichak River past the Igiugig counting tower early (5/21-23/2002) and late (6/9-11/2000) during the out-migration period as inferred from 13 microsatellites and 4 SNP loci.

Fig. 1

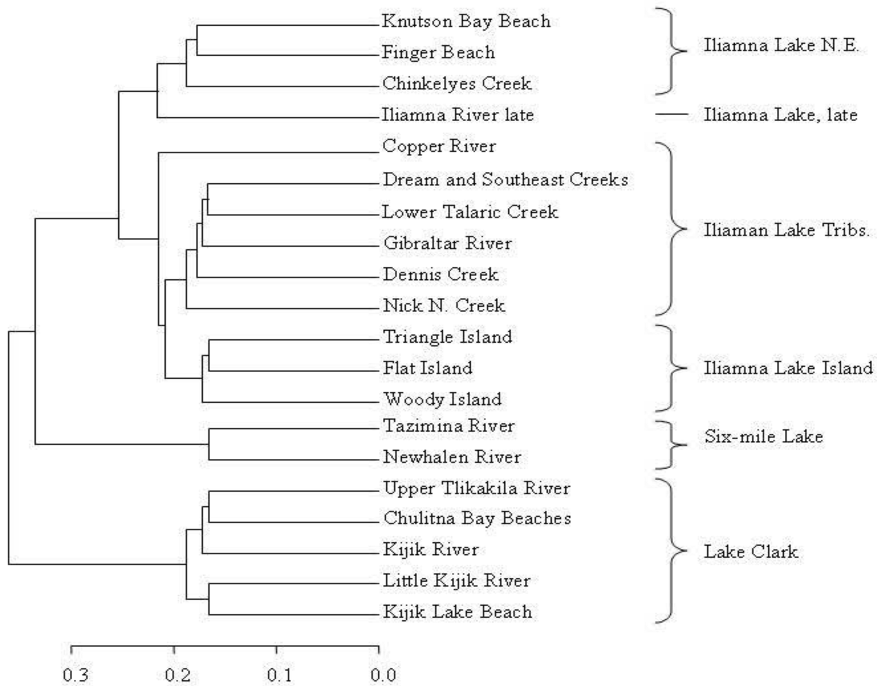

Knutson Bay Beach
Finger Beach
Chinkelyes Creek
Iliamna River late
Copper River
Dream and Southeast Creeks
Lower Talaric Creek
Gibraltar River
Dennis Creek
Nick N. Creek
Triangle Island
Flat Island
Woody Island
Tazimina River
Newhalen River
Upper Tlikakila River
Chulitna Bay Beaches
Kijik River
Little Kijik River
Kijik Lake Beach
Iliamna Lake N.E.
Iliamna Lake, late
Iliaman Lake Tribs.
Iliamna Lake Island
Six-mile Lake
Lake Clark
0.3
0.2
0.1
0.0

Fig. 2

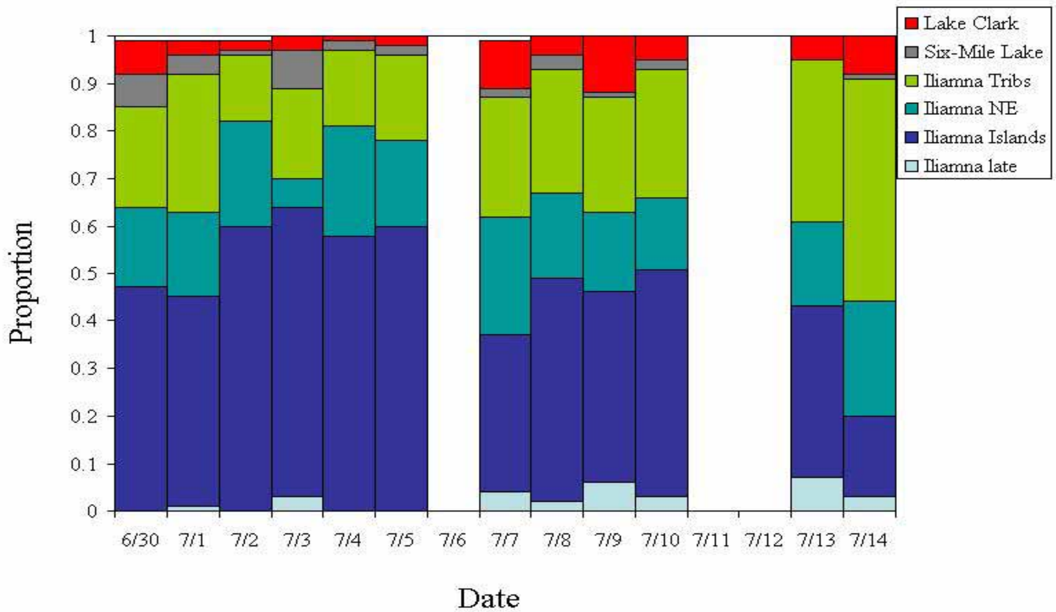
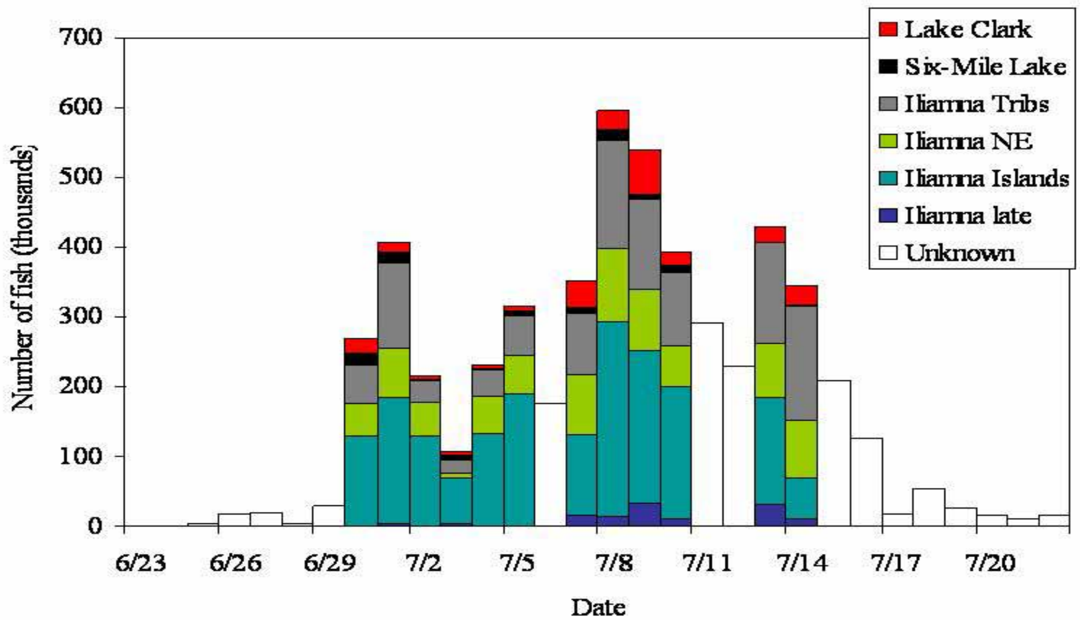
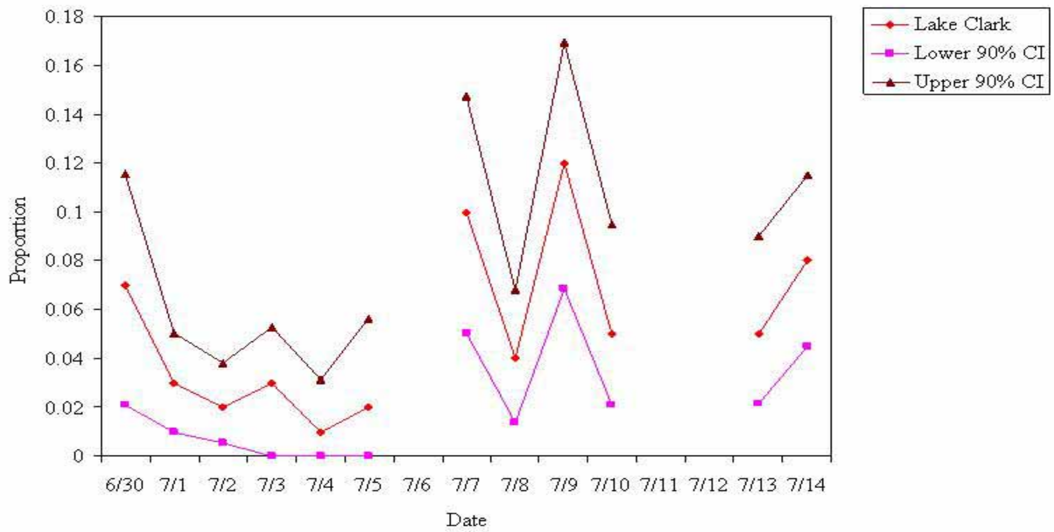

Lake Clark
Six-Mile Lake
Iliamna Tribs
Iliamna NE
Iliamna Islands
Iliamna late
Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6/30
7/1
7/2
7/3
7/4
7/5
7/6
7/7
7/8
7/9
7/10
7/11
7/12
7/13
7/14
Date

Fig. 3

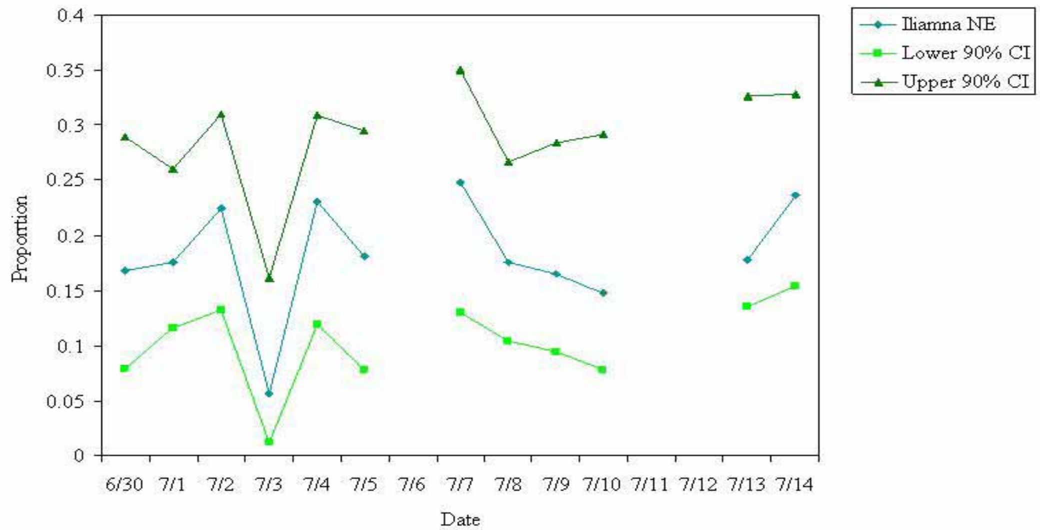

Lake Clark
Six-Mile Lake
Iliamna Tribs
Iliamna NE
Iliamna Islands
Iliamna late
Unknown
Number of fish (thousands)
700
600
500
400
300
200
100
0
6/23
6/26
6/29
7/2
7/5
7/8
7/11
7/14
7/17
7/20
Date

4 A.



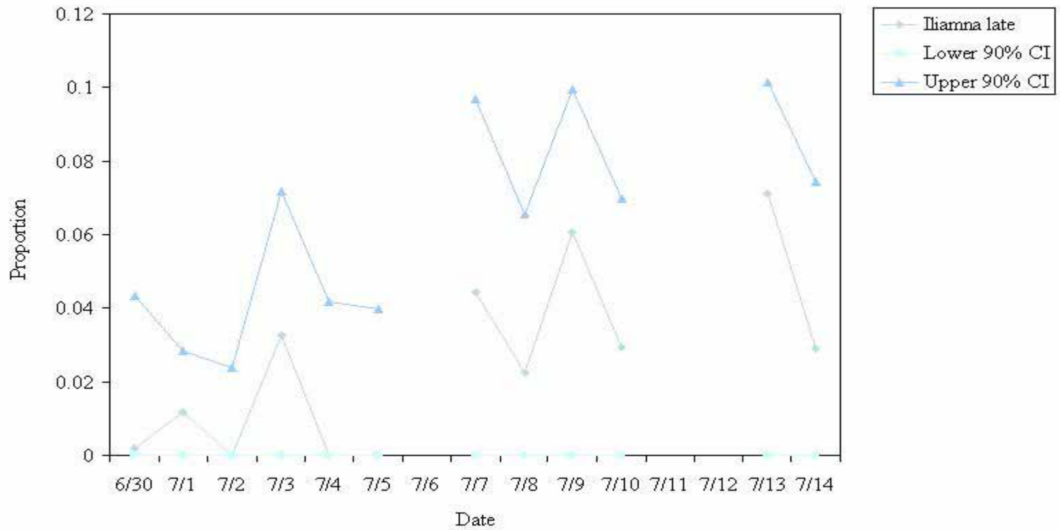
Lake Clark
Lower 90% CI
Upper 90% CI
Proportion
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
6/30
7/1
7/2
7/3
7/4
7/5
7/6
7/7
7/8
7/9
7/10
7/11
7/12
7/13
7/14
Date

4 B.

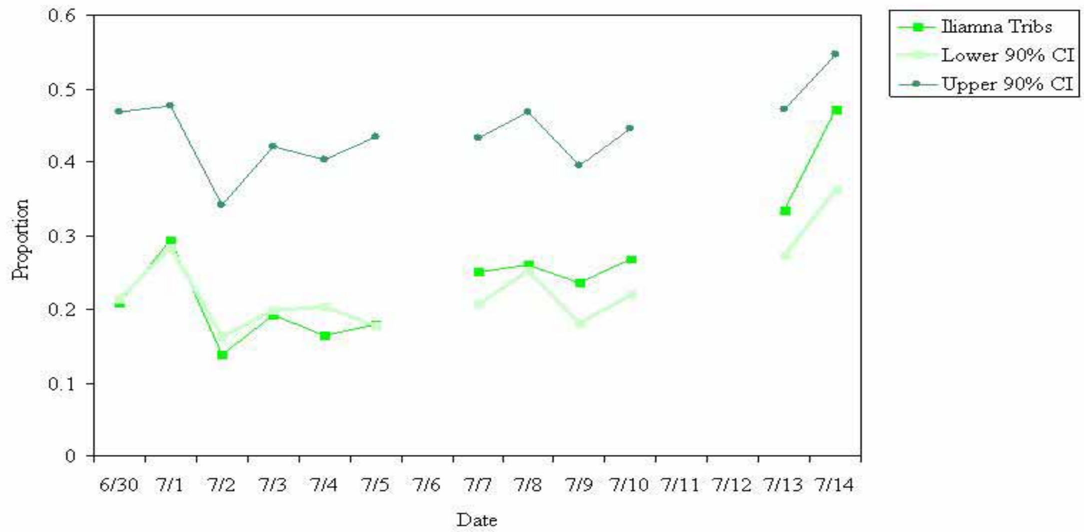


0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Proportion
6/30
7/1
7/2
7/3
7/4
7/5
7/6
7/7
7/8
7/9
7/10
7/11
7/12
7/13
7/14
Date
Iliamna NE
Lower 90% CI
Upper 90% CI

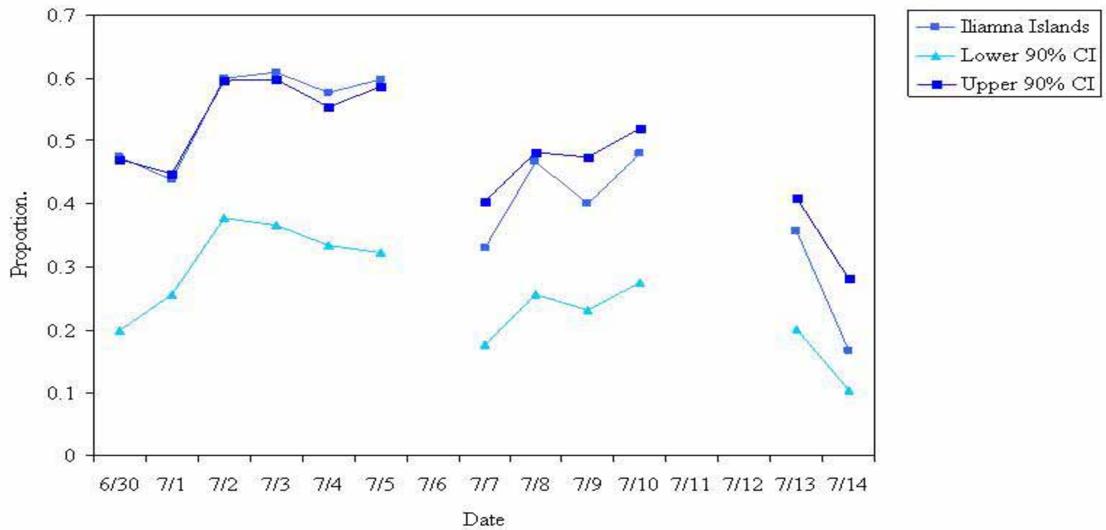
4 C.


0.12
0.1
0.08
0.06
0.04
0.02
0
Proportion
6/30 7/1 7/2 7/3 7/4 7/5 7/6 7/7 7/8 7/9 7/10 7/11 7/12 7/13 7/14
Date
Iliamna late
Lower 90% CI
Upper 90% CI

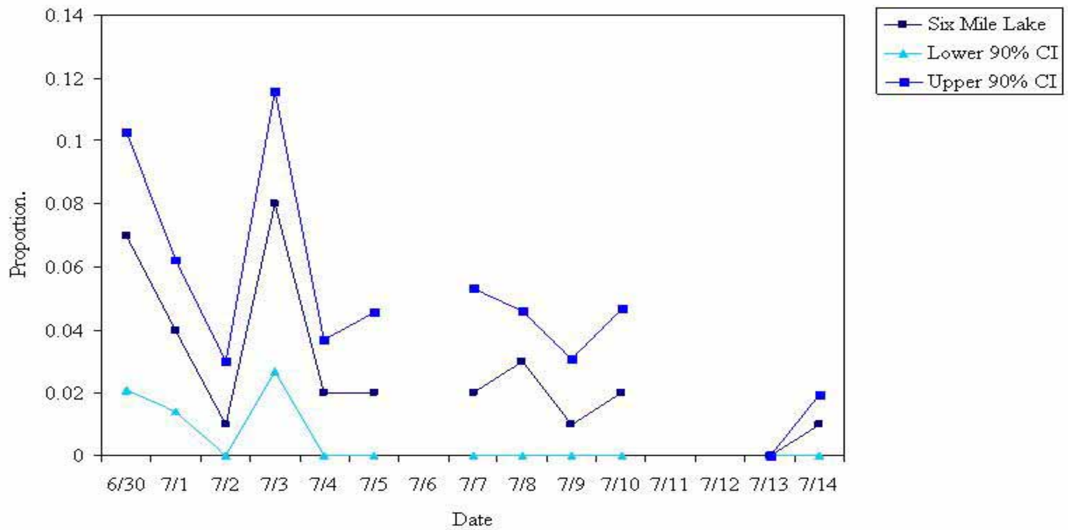
4 D.


Iliamna Tribs
Lower 90% CI
Upper 90% CI
Proportion
0.6
0.5
0.4
0.3
0.2
0.1
0
6/30 7/1 7/2 7/3 7/4 7/5 7/6 7/7 7/8 7/9 7/10 7/11 7/12 7/13 7/14
Date

4 E.


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Proportion.
6/30 7/1 7/2 7/3 7/4 7/5 7/6 7/7 7/8 7/9 7/10 7/11 7/12 7/13 7/14
Date
Iliamna Islands
Lower 90% CI
Upper 90% CI

4 F.



0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Proportion.
6/30 7/1 7/2 7/3 7/4 7/5 7/6 7/7 7/8 7/9 7/10 7/11 7/12 7/13 7/14
Date
Six Mile Lake
Lower 90% CI
Upper 90% CI

Fig. 5

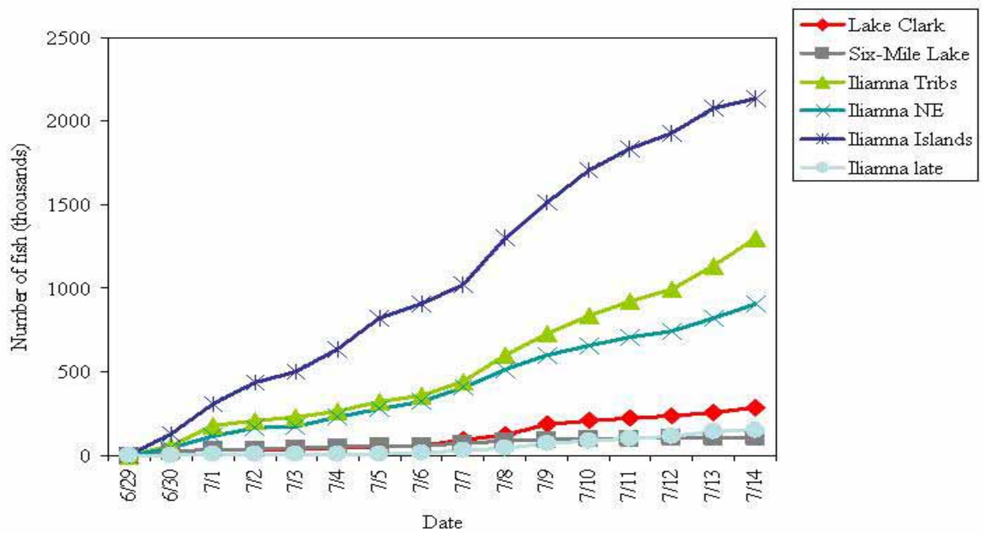
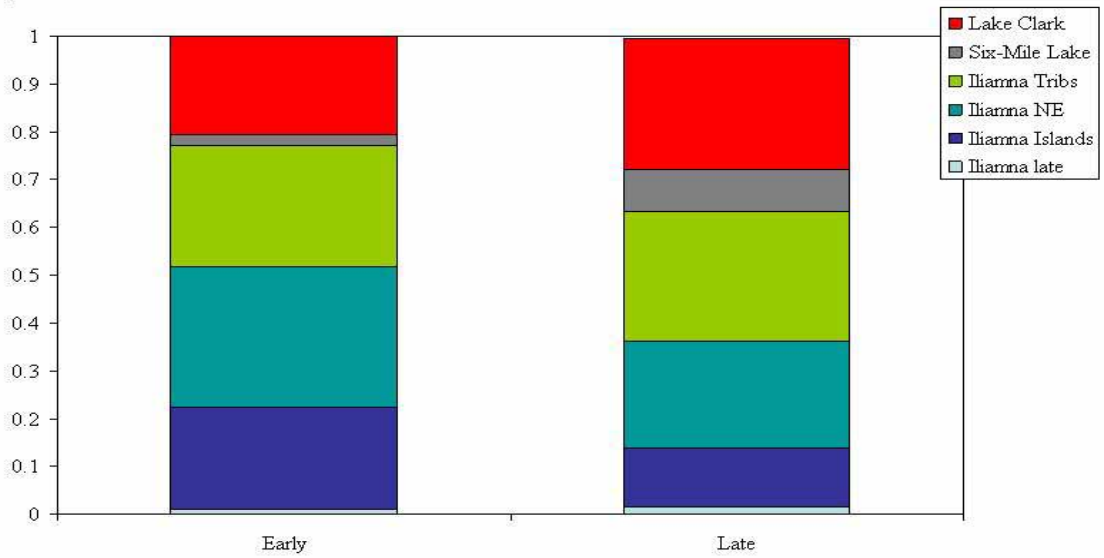

Lake Clark
Six-Mile Lake
Iliamna Tribs
Iliamna NE
Iliamna Islands
Iliamna late
Number of fish (thousands)
2500
2000
1500
1000
500
0
6/29
6/30
7/1
7/2
7/3
7/4
7/5
7/6
7/7
7/8
7/9
7/10
7/11
7/12
7/13
7/14
Date

Fig. 6



1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Early
Late
Lake Clark
Six-Mile Lake
Iliamna Tribs
Iliamna NE
Iliamna Islands
Iliamna late