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DATE: December 7, 2016

THRU: Kevin Schaberg, Regional Finfish Research Supervisor
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SUBJECT: Frazer Lake jack sockeye salmon review and plan, 2016.

FROM: M. Birch Foster, Regional Finfish Research Biologist
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In recent years, the Frazer Lake sockeye salmon run (located within the Alitak District of the Kodiak Management Area) has demonstrated a cyclical pattern of weak runs and high abundance of jacks. The purpose of the memorandum is to provide a background of Frazer Lake, an explanation of the jack life history, a description of the conditions that may have led to the cyclical pattern, and potential ramifications of an experimental program to reduce the proportions of jack sockeye salmon in the Frazer Lake escapement.

Background

Frazer Lake, located on the south end of Kodiak Island supports a commercially important sockeye salmon population in the Alitak District of the Kodiak Management Area. Frazer Lake was previously barren of anadromous fish due to a barrier falls on the upper portion of Dog Salmon Creek. Sockeye salmon were introduced into Frazer Lake from 1951 to 1971. Returning fish were initially backpacked over the falls to allow access to the lake. A fish ladder was constructed in 1962 to allow the fish to access Frazer Lake past the barrier falls (hereafter referred to as the fish pass).

Colonization and establishment of sockeye salmon in Frazer Lake occurred rapidly (Burger et al. 2000) and from 1974 to 1985 average run size increased to nearly 260 thousand fish (Table 1) and peaked in 1985 with a total run of over 637 thousand fish. However, the increasing runs and escapements were accompanied by decreases in macrozooplankton densities and juvenile sockeye smolt size (Kyle et al. 1988; Kyle 1994). From 1988 to 1992 fertilizer was applied to Frazer Lake, likely affecting fish from brood years 1985-1995. Through the 1990s, sockeye salmon production was high and the average run size increased to over 700 thousand fish, but by the 2000s had decreased to about 380 thousand fish (Figure 1).

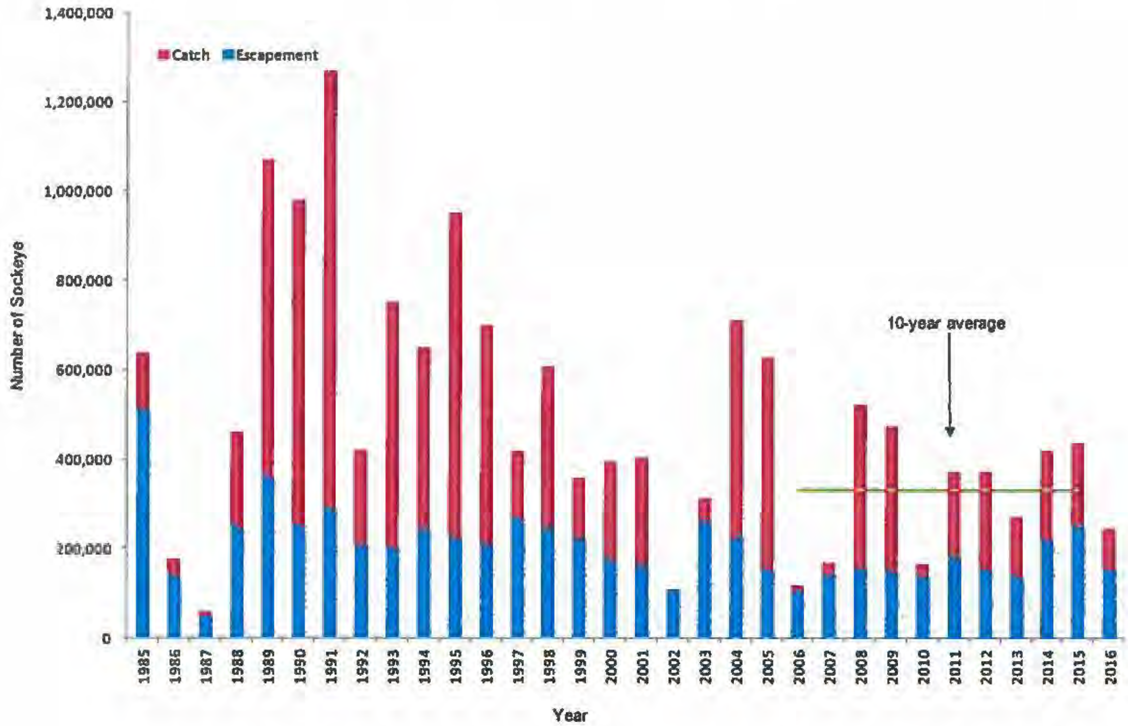

Figure 1. Frazer Lake sockeye salmon escapement (Dog Salmon weir counts), catch, and run estimates, 1985-2016, and the recent 10-year average estimated run (2006-2015).

The predominant brood stock source for Frazer Lake was Red Lake (Ayakulik), followed by Karluk and Becharof lakes (Blackett 1979). Genetic analysis of sockeye salmon spawning in Frazer Lake in 1995 indicated influence of more than one stock (Burger et al. 2000). The most recent genetic analysis by ADF&G demonstrated Frazer Lake populations remain weakly differentiated from their primary donor source of Ayakulik (Shedd et al. 2016).

Jack Life History and Frazer

Sockeye salmon typically spend two to three years in the salt water and return as full-sized adults. For all species and stocks of Pacific salmon, a portion of the fish, however, may return after one year in the ocean and are referred to as jacks (Burgner 1991). A large majority of jacks are male and while they are sexually mature, they are much smaller than other adults.

Frazer Lake sockeye salmon have been displaying uncharacteristically high proportions of the jack life-history type in recent escapements. Starting in 2003, and occurring about every four years following, the proportion of jacks in the escapement was above what is observed to be normal variability in comparison to parent stocks (Figure 2). Proportions of jacks in the Frazer Lake escapement have averaged 18.5% in the past 15 years. This average was affected heavily by 2003 (48%), 2007 (49%), and 2011 (39%) which were well above what has been historically observed in nearby systems. The jack life history trait also occurs in the Ayakulik sockeye salmon run and averages 5% but infrequently reaching 10 to 25% (Figure 2; Wattum 2016).

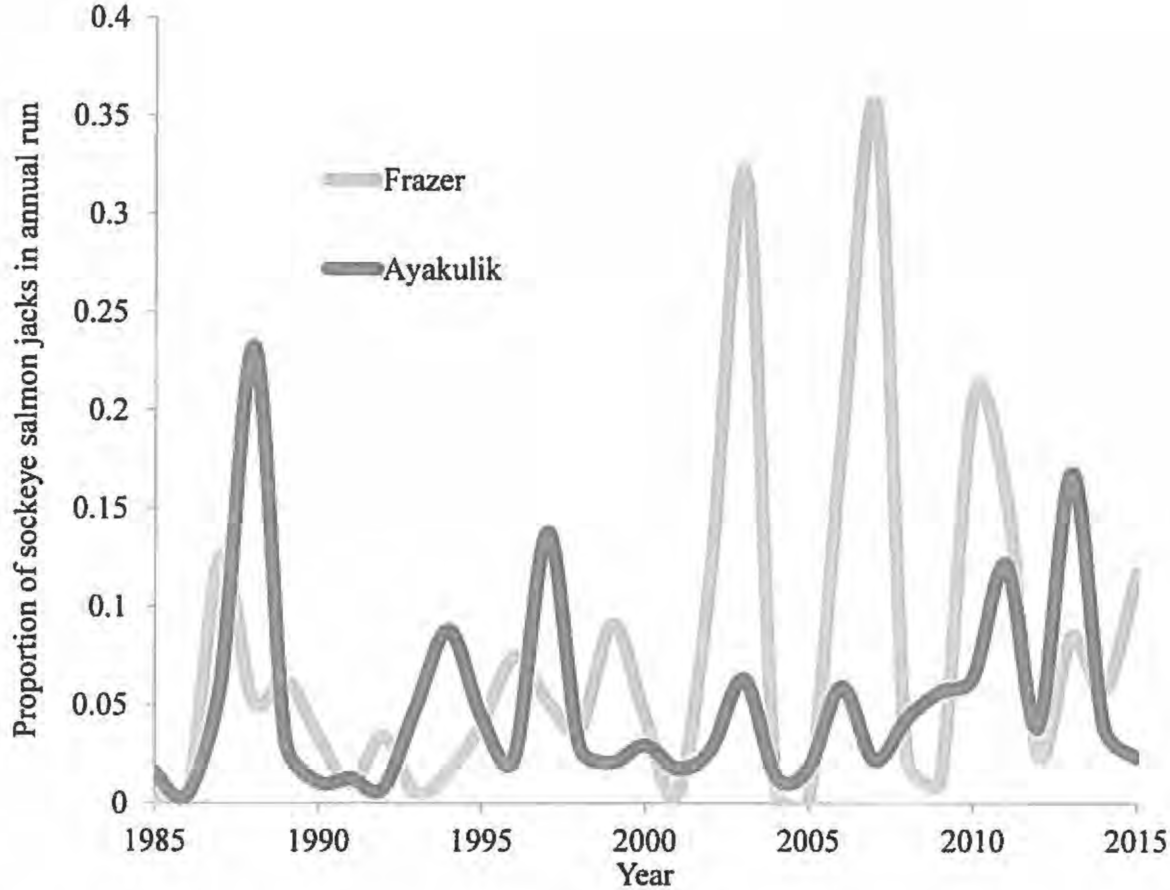

Figure 2. Proportion of jack sockeye salmon in the total run for Frazer Lake and Ayakulik River, 1985-2015.

Age at maturity is a heritable trait in salmon (Heath et al. 1994; 2002) but may be environmentally and energetically influenced (Shearer et al. 2006). Berejikian et al. (2011) found that the "decision" to mature as a jack depended on body size/condition at critical developmental periods. Achievement of this body condition is dependent upon environmental triggers where the fish resides during these critical periods. The jack life history, like any alternative mating strategy, is an evolutionary characteristic that is understood to play an important part in long term sustainability of salmon populations (Quinn et al. 2001).

Salmon spawning begins when the female constructs a nest or nests. Typically multiple males accompany the female and the males may be of different sizes, age-classes, and life-history types (Foote et. al. 1997). The largest male normally gains closest access to the female and other males occupy satellite positions downstream or lateral to the pair (Allen et al. 2007). From these satellite positions, the smaller males "sneak" in to fertilize the eggs once the female spawns (Gross 1985; Foote 1997; Quinn 2005).

While adult males outcompete jacks and often monopolize access to females during spawning (Berejikian et al. 2010), jacks are still successful. Jack sockeye salmon contribute to fertilizing a significant proportion of the eggs using the sneaker tactic (Chebenov et al. 1983). Foote et al. (1997) found that sockeye salmon jacks occupying a sneaker role on average fertilized 42% of the eggs when a female was paired with a lone adult male. Berejikian and Tezak (2005) found that jack Chinook salmon and adults were equally capable of egg fertilization when paired with a female. This suggests that jacks are an important part of overall salmon production via egg fertilization.

With the obvious success of the jack life history and the nature of age at maturity in salmon, the question is how do jack and adult life histories maintain stability over time and evolution? One such theoretical model is that of frequency dependent selection (FDS; Gross 1985, Hutchings and Myers 1994; Berejikian et al. 2010). The model of FDS predicts that during periods of high jack abundance the individual jack breeding success declines (and adult breeding success increases) while in years of low jack abundance the relative contribution by jacks will be quite high compared to adult male spawners. The level of increase or decrease in spawning success is not a concrete figure, but a generalization that is quite logical; i.e. the spawning success of an individual jack would decrease as it competes with other jacks.

It is noteworthy that while the Ayakulik system naturally produces increased levels of jacks in the total run, the relationship with jacks in the escapement between Frazer and Ayakulik should be clarified. The commercial fisheries associated with the Frazer and Ayakulik systems are quite different, compounding the difference in jack proportions. The terminal fishery for Ayakulik-bound fish is a seine fishery with no size selectivity in the harvest, while the terminal Frazer fishery is executed with gillnets that functionally does not capture jacks. Because of this, Frazer Lake can display a magnified proportion of jacks in the escapement (Figure 3). The only other sockeye salmon systems within the Westward Region that consistently produce high proportions of jacks in the escapement are Orzinski Lake on the South Alaska Peninsula and Bear Lake on the North Alaska Peninsula. Both also have size-selective terminal gillnet fisheries. Yet, it is important to note that many other systems in the region do not consistently produce high proportions of jacks in the presence of a size selective terminal fishery. A main concept of the size selectivity here is that generally jacks are not targeted for two reasons: (1) they are normally a much smaller part of the population and (2) they have little to no commercial value to the industry.

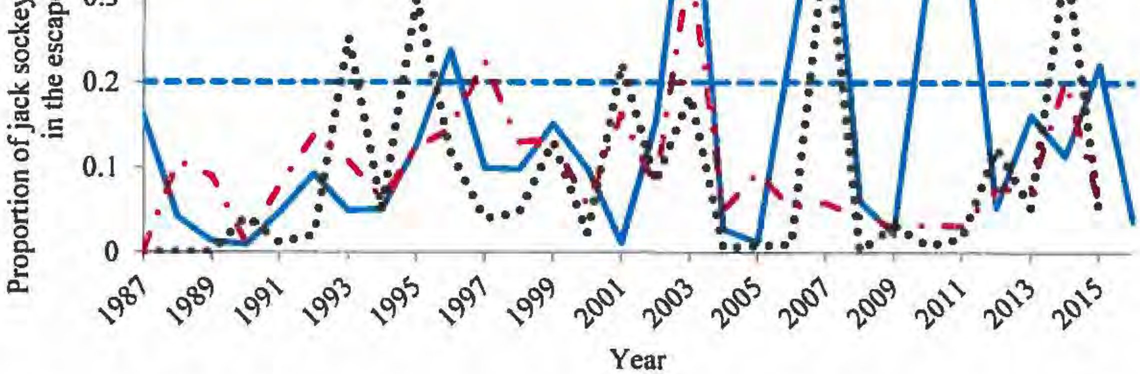

Figure 3. Proportion of jack sockeye salmon in the Frazer, Orzinski, and Bear lakes total escapement with 20% line highlighted, 1987-2016.

While the department does not believe jacks present a problem for the sustainability of the Frazer system, the observation that an initial (2003) event may have led to the cyclical repetition of high jack compositions, and the lack of similar patterns in other systems, does warrant investigation or action.

It is important to consider the prevalence and impact of jacks prior to the 2003 run. To do so, it is necessary to understand the relationship between the proportion of jacks in the escapement and the resultant jack proportions in the brood year return. Figure 4 shows that the production of jacks in the brood year return from the brood year escapement composition of jacks does not exceed 20%, even in years where nearly 50% of the escapement was composed of jacks. From 1977 to 1990, the relative numbers of jacks produced from the brood year escapement composition of jacks in the escapement were fairly low (Figure 5), and similar to what is observed in the ranges of other systems (Figure 3). However, from 1989 to 1994, the years including and immediately following fertilization, the brood year escapement produced more jacks than replacement (<0 in Figure 6). This seems to be a significant period as following those years, jack production by brood year is generally less than the proportion of jacks in the brood year escapement (Less than replacement; Figure 6), except in a few instances where jacks escapement proportions were low (<3%).

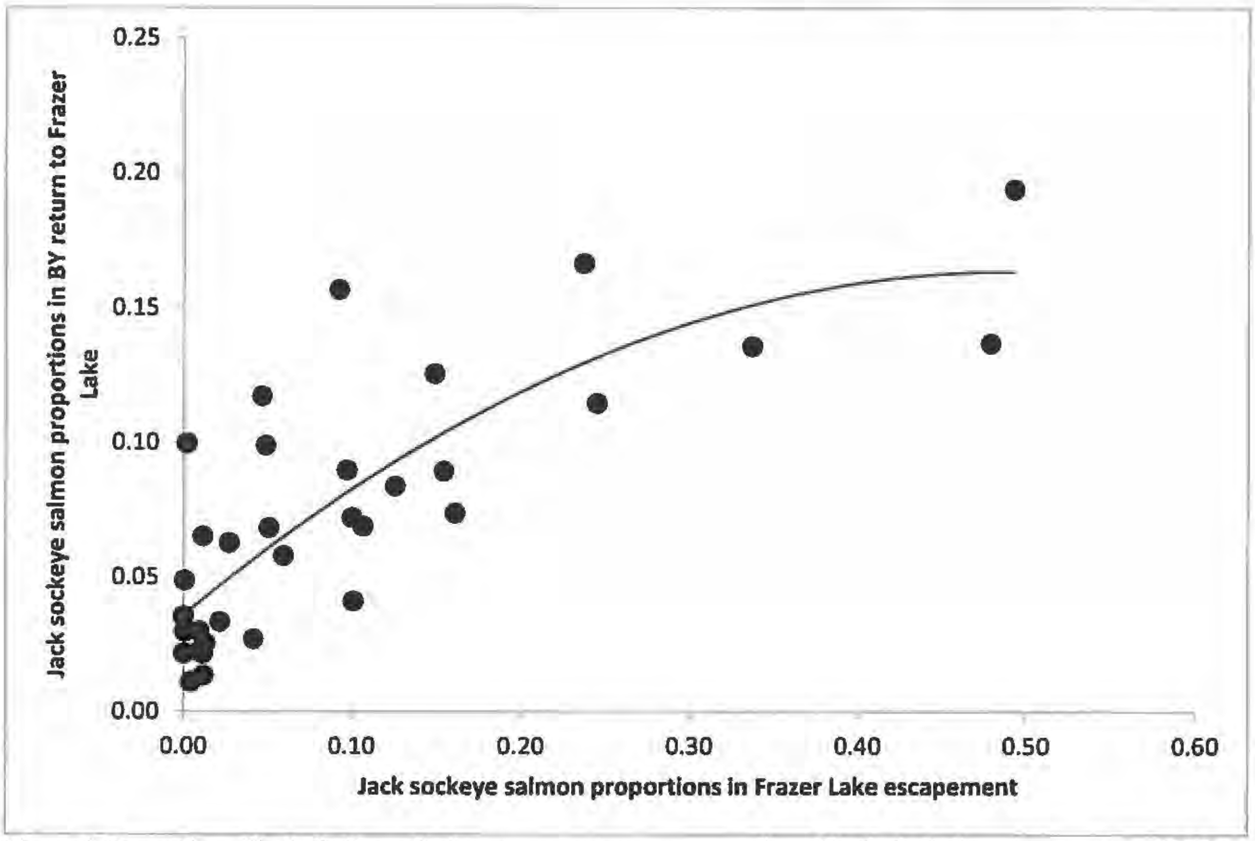

Figure 4. Proportion of jacks in Frazer Lake escapement versus proportion of jacks in the brood year return, 1977 to 2010.

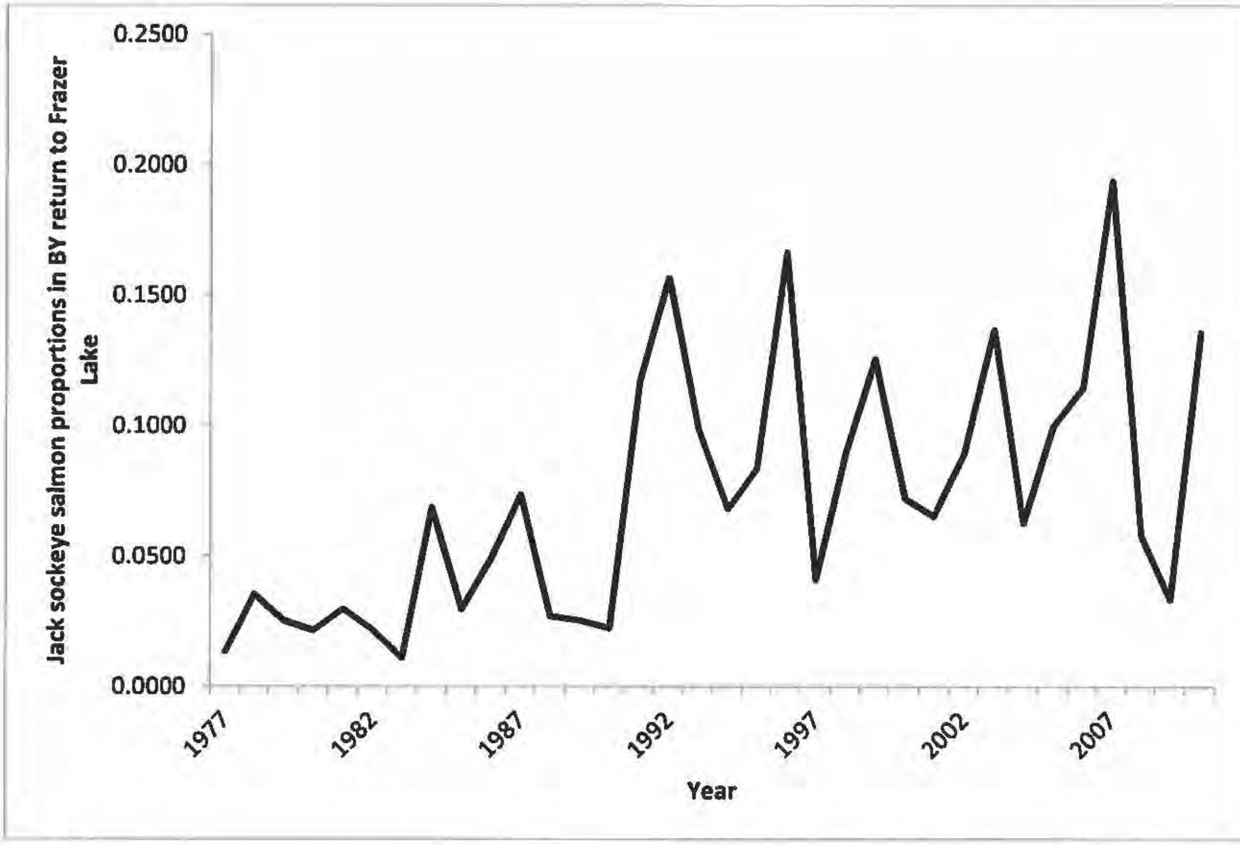

Figure 5. Jack sockeye salmon proportion in the brood year return to Frazer Lake, by year, 1977–2010.

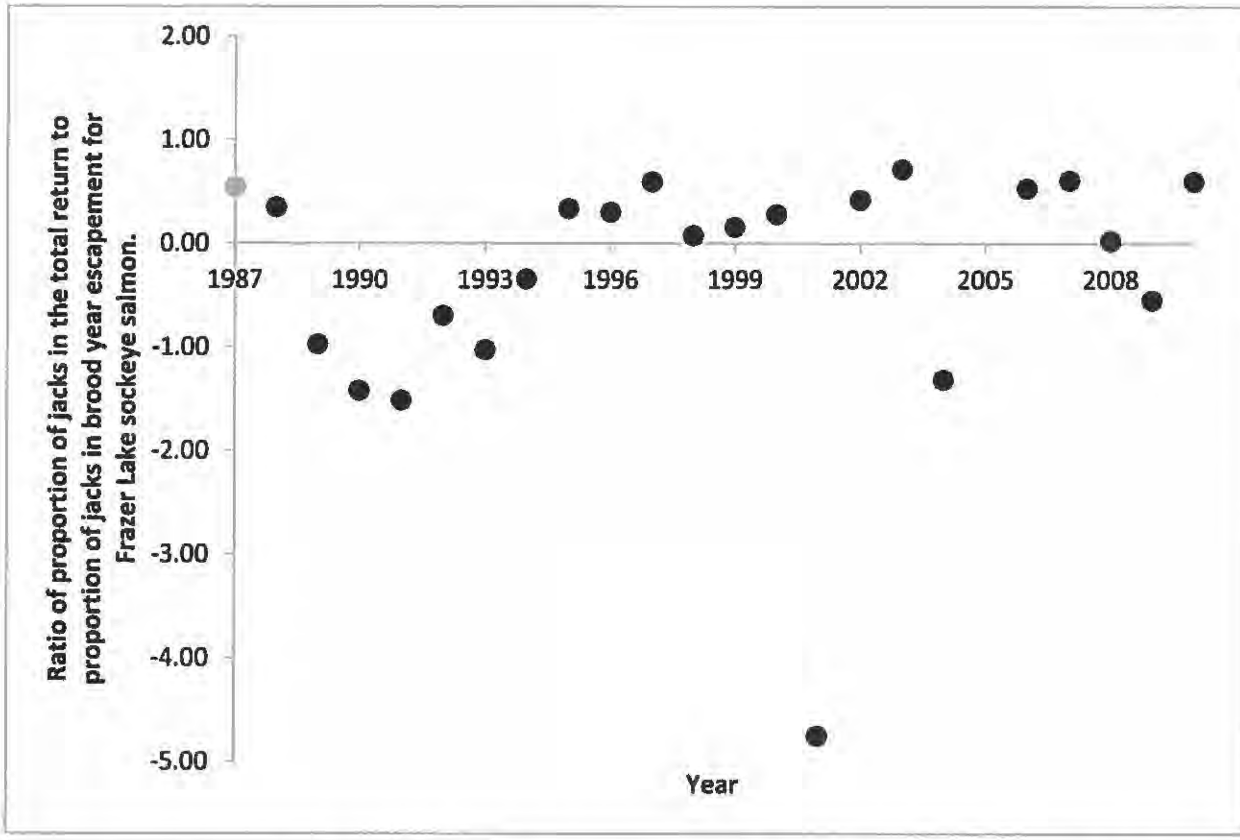

Figure 6. Ratio of proportion of jacks in the total return to proportion of jacks in brood year escapement for Frazer Lake sockeye salmon, 1987–2010. Negative numbers indicate more jacks were produced than were in the escapement. 2005 is not shown, as the result was -54.2, which is outside all other results, and is due to the near complete lack of jacks in the brood year escapement that year.

In 1997, Frazer Lake experienced a brood year failure despite an escapement that exceeded 200 thousand fish. Return-per-spawner (R/S) estimates were under 0.3 (Table 2). This was the lowest R/S estimate since the high escapements in 1980-1982. Due, for the most part, to the 1997 brood year failure, and lack of the dominant age-2.2 fish, the Frazer sockeye salmon run experienced an extremely poor run in 2002 of only 110 thousand fish (Figure 1). Despite only 13 thousand jacks in the Frazer Lake escapement, the jack percentage in the 2002 escapement was relatively high (>20%). The brood years of 1998 and more so 1999 fared much better than the 1997 brood year and the R/S estimates for those two years was 1.5 and 3.9 respectively.

The 2003 run appears to be a major contributor in the prevalence of jacks at Frazer currently: with the success of the 1999 brood year, a large number of jacks returned in 2003. While the production of jacks from the 1999 brood year was not by any means anomalously high (12.5%; Figure 5), in relation to the low abundance of older 2- and 3-ocean fish from the 1997 and 1998 brood years present in 2003, the relative number of jacks was extremely high (> 96,000 jacks; Table 2). The abundance of jacks caused concern in the department's management of the 2003 run. Inseason estimates of female sockeye escaping into Frazer were made in an attempt to reach half of the lower escapement goal in numbers of females (70 thousand). Despite escaping 263 thousand fish through Dog Salmon weir, high mortality in the river resulted in only 202 thousand sockeye salmon escaping in Frazer Lake; more than 96 thousand of which were jacks and only 59 thousand female fish. The high proportion of jacks in the 2003 escapement appears to be the initial event in a cycle of increased jacks that peaked again in 2007, 2011, and 2015 consistent with the 4-year life cycle of age-2.1 jacks but in decreasing intensity (Figure 2).

Due to concern about high jack abundance and proportions in Frazer Lake from members of the public and the Board at the 2013 Board of Fisheries meeting, in 2014 and 2015, management staff formalized an existing practice of putting more large fish in the escapement when jacks were prevalent. This is currently in the harvest strategy as the "10% rule" which allows only 10% of the inseason escapement of jacks to be counted toward inseason management objectives (all jacks are still enumerated after 10%). This means large fish are managed more conservatively in high jack years when targeting inseason management objectives. This does however result in more total fish, including jacks, in the actual spawning population. Since jacks are a viable component of the spawning population, this may result in over escapement and have negative production implications. Also in 2013, the Department was directed by the former Director of CFD to perform a pilot study to take a more active role in reducing the proportion of jacks from the spawning population. Staff at the Dog Salmon weir actively removed (culled) jacks by dipnetting them out of the sampling trap. This was intended to reduce the jack proportion in the spawning escapement. This was a tedious task and required increased staff time and expense. In 2014 and 2015, the total number of jacks removed was 6,429 (31% of jacks in the escapement and 2.9% of total escapement) and 11,647 (26% of jacks in the escapement and 4.9% of total escapement) respectively. With the low percentage of jacks observed in the escapement in 2016, no jacks were culled.

While culling was hypothesized to benefit long term sockeye salmon production, the potential benefits and detriments have yet to be assessed. Three important questions are present and relevant to this discussion:

- ***What is the cause of the jack cycle observed beginning in 2003?***
- ***What is the reasoning behind the 10% rule used in management?***
- ***Does the theory of removal (culling) of jacks from the escapement reduce the potential for jacks returning and what are the risks?***

Analysis

- ***What is the cause of the jack cycle observed beginning in 2003?***

A definitive shift in jack production occurred in the 1989-1994 brood years (Figure 6). This shift resulted in increased production of jacks relative to the proportion of jacks in the escapement. Those brood years (1989-1994) are very important to the timeline of Frazer Lake considering the age of outmigrating fish. The dominant outmigration years for those brood years is 1992-1997, and those outmigrating fish were the **first** progeny present throughout the fertilization effort, through the **first** progeny following the cessation of fertilization. Whether that initiated the jack cycle can only be speculated, but the production of jacks seems to normalize after this timeframe (Figure 6).

The perpetuation of the jack cycle that was initiated in 2003 is likely a combination of factors. Primarily there is a relationship between the proportion of jacks in the spawning escapement and the resultant brood year return (Figure 4; Figure 5). Secondarily, there is the strong cyclical pattern of relative abundance. The predominant age of a jack at Frazer Lake is age-2.1; that fish spends 2 years in the freshwater and 1 year in the ocean before returning. After accounting for the winter that the egg spends in the gravel, an age-2.1 sockeye salmon is a 4-year old fish from brood year 2003, and will return in 2007 (Table 2). In theory, there should have been an increase in jack proportions in 2007; there was, but at a greater level than the relationship predicted in Figure 4 would suggest. The reason we see this is in the difference between a brood-year return and a total run in any given year: this is imperative in the understanding of this concept. Production by brood year is wildly variable in concert with the variability in brood year escapement and rearing conditions, and in the case of Frazer Lake, has caused strong cycling of high production and low production (Figure 1; Table 2).

As an example, fish from consecutive, different brood years comprise the total run in a given year. For instance 2001 and 2002 brood year total production was fairly weak. Yet, the 2003 and 2004 brood year production was fairly strong with noticeable age-1.1 (from BY 2004) and -2.1(from BY 2003) jack components that would both return in 2007. Even though the 2003 brood year production of jacks was less than 13% of the total brood year production (Figure 5), the absolute number of jacks returning in 2007 was relatively high compared to the abundance of large fish present from earlier brood years(2001 and 2002). In 2011, Frazer Lake experienced another peak in jack proportions but less so than 2003 and 2007. The spawning escapement that produced the 2007 brood year was 50% jacks, but produced roughly 19% jacks in the brood year return (Figure 4). However, due to the strong 2006 brood year, the 2011 run was primarily composed of age-2.2 fish and the resultant proportion of jacks in the escapement was approximately 40%, less than the last two peak jack cycles.

In summary, the initial increase in production of jacks in Frazer Lake coincided with the administration and cessation of nutrient fertilization. The factors that have influenced the 4-year cycle of high proportion of jacks in the escapement are the cyclical pattern of relative abundance (with the normal stochastic variation of brood year production) and an overall increase in jack production that started in 1990 (Figure 5).

- ***What is the reasoning behind the 10% rule used in management?***

The management strategy of counting only 10% of the jack escapement towards the total inseason escapement places greater importance on large adult fish, and addresses the sex ratio and size range parameters outlined in the Policy for the Management of Sustainable Salmon Fisheries (5 AAC 39.222.(c)(2)(D)). The ultimate conveyor of production in a salmon run will always be linked to the number of eggs and thus the number of females that enter the spawning grounds. As a 1-ocean female has never been documented at Frazer Lake (but is biologically possible), the vast majority of females have to be large fish. It follows that in a year of high jack abundance, by constraining the counting of jacks to 10% of the spawning escapement, which is a 30-year historical average of jacks produced by a given brood year, the management strategy would put more large fish and females in the escapement. The escapement composition would then reflect a closer proximity to the data that was used to develop the escapement goal, which was calculated mostly from data and production estimates prior to high jack abundance. A biological escapement goal (BEG) is intended to constrain the escapement to an upper limit, which if exceeded could theoretically depress the run by taxing a finite rearing system. However, if the fish in excess of the goal are almost entirely made up of male jacks, it is unlikely that excess jack escapement would result in producing a significantly higher number of offspring because individual jacks would have less spawning success (assuming the FDS model).

- ***Does the theory of removal (culling) of jacks from the escapement reduce the potential for jacks returning and what are the risks?***

The basis for the theory that jacks beget jacks is that there is a genetic component to jacking. In genetic language, this is termed "heritability". A heritability of 1, means that 100% of the variation in the trait is genetically based (e.g., eye color), while a heritability of 0 means that 100% of the variation in the trait is environmentally mediated (e.g., being struck by lightning). Most traits are influenced by both genetics and environment (e.g., weight is mediated by nutrition and parents). Estimates of heritability for traits are therefore heavily influenced by the variation in environmental conditions present and need to be measured within populations of interest. Heritability is commonly quantified by measuring the additive variance associated with a trait of interest, often by analyzing half-siblings in breeding studies (Lynch and Walsh 1998).

The data in Figure 4 can be used to gain insights into the heritability of jacking for this population. This figure shows the brood-year escapement jack proportions versus the brood year return jack proportions. If heritability of jacking was 1 (and jacks and non-jacks had equal rates of fertilization, among other assumptions), we would expect all these data to line up on the 1:1 line (i.e: if jack proportions in the escapement = 20%, then jack proportions in the brood year return would = 20%). If heritability of jacking was 0, we would expect to see a flat line (no slope). The relationship observed has a positive slope, but deviates from the 1:1 line: very low proportions in the escapement (<2%) lead to higher jack proportions in the brood year returns (>2%) and very large proportions in the escapement (50%) lead to lower jack proportions in the brood year returns (15%). These data show that there is heritability for jacking, but this value is less than 1. To simplify further calculations, we will estimate heritability at 50%.

If a jack sires offspring, they have an equal chance of either being a male or a female, and if the offspring is a male, there is an equal chance of either being a jack or a large male (50% heritability) assuming there are no effects from environmental triggers. This creates a scenario that even if the entire male escapement is made of 100% jacks (and 75% of the total escapement), the highest proportion of jacks we would see in the brood year return would only be 25%. The other consideration is the obvious potential for a large male to produce jack offspring (Heath et al. 1994). Considering the Figure 4 relationship, this heritability probably lies somewhere less than 5% on average.

It becomes a straightforward calculation to simulate the effect of varying male escapement quantities while constraining the female escapement quantity. In theoretical jack culling application, the number of female spawners reaching the spawning grounds remains unchanged. It does shift the ratio of jacks to large males that pair up with the females. In a hypothetical scenario, simulating the conditions observed in 2003, there are 50,000 females, 50,000 large males, and 100,000 jacks in the spawning population. In an individual spawning situation, that leaves 1 female paired up with 1 large male and 2 jacks who are occupying sneaker roles. Best case for the jacks is that they are equally capable of fertilizing the female eggs so all 3 males have a 33% chance of siring offspring. If we decided to cull 50,000 jacks, that would reduce the individual spawning situation to 1 female, 1 large male, and 1 jack. Again assuming that jacks are equally capable of fertilizing an egg as a large male, that would mean the large male and jack both have a 50% chance of siring the offspring. So by the removal of 50,000 jacks (50% in this case), you have reduced the potential for eggs to be fertilized by a jack from 66% to 50%. While the overall probability of eggs being fertilized by jacks decreases, in line with FDS, the spawning success for the remaining jacks actually increases due to lack of competition. This theory can be modeled to simulate removal of jacks from a spawning population (Table 3). The simulated spawning population changes very closely match the observed Frazer Lake data depicted in Figure 4. The historical average (25-year) return per female spawner was assumed at 6.0.

Table 3. In 2003, a high number of jacks relative to large fish escaped. In this ***simulation***, the effects of different proportions of jacks and large males in the spawning population are calculated constraining the female escapement to 50,000 fish.

Spawning Escapement			% spawning Escapement			Total Return			% Total Return		
Females	Jacks	Lrg Males	Females	Jacks	Lrg Males	Females	Jacks	Lrg Males	Females	Jacks	Lrg Males
50,000	100,000	50,000	25%	50%	25%	150,000	52,500	97,500	50%	18%	33%
50,000	50,000	50,000	33%	33%	33%	150,000	41,250	108,750	50%	14%	36%
50,000	12,500	50,000	44%	11%	44%	150,000	21,000	129,000	50%	7%	43%
50,000	-	50,000	50%	0%	50%	150,000	7,500	142,500	50%	3%	48%
50,000	150,000	-	25%	75%	0%	150,000	75,000	75,000	50%	25%	25%

With no jacks removed from the spawning population, the total return of jacks is 52,500 equaling 18% of the return population; this is very close to our observed values (Figure 4). By removing 50,000 jacks from the spawning population a net loss of 11,250 jacks in the return is observed. By removing 87,500 jacks from the spawning population, a net loss of 31,500 jacks in the return is observed. Even if all 100,000 jacks were removed from the spawning population, since jacks can be sired by adult fish, 7,500 jacks would still return and compose 3% of the population. On the opposite end of the spectrum, if all large males were eliminated from the spawning escapement, the total return would still only be composed of 25% jacks, the theoretical upper limit of the model. While there is no possible way to get rid of jacks, there appears no possible way to select for a population that is over 25% jack.

The takeaway from this simulation is simple: an enormous amount of jack removals must be made to make a significant difference in the total return, yet even by removing all jacks from the spawning population they would still persist in the population.

Risks associated with culling large numbers of jacks include the obvious loss in contributions to lake nutrients, potential genetic risk, and lack of fertilization success; all factors individual or combined could be detrimental but are not easily quantified. The genetic risk of culling based on life history characteristics is that we lose genetic variation associated with those traits. Allowing the jack life history type to make up to 20% of the escapement provides low risk of losing genetic variation in the population.

Conclusions

The potential for inriver jack culling to mitigate future jack returns is poor. Measuring the effect, in years of high jack abundance, 4.4 jacks would need to be removed from the spawning population to stop the jack return of 1 fish; at the lower end of jack escapement, 2 jacks would need to be removed from the spawning population to stop the jack return of 1 fish. The potential detriments of decreased nutrients via carcasses and decreased egg fertilization rates are not figured into the simulation. When all aspects are considered qualitatively, including uncertainty in measurement and stochastic variation of biological systems, the department currently feels there is no scenario of Frazer Lake jack culling that would be a valuable use of state time and resources or would potentially benefit the health of Frazer Lake or the commercial fishery. The department also understands that the determination of any benefits from culling is highly subjective because the cost and value of the mitigation compared to the cost (positive and detrimental) and value of the return or lack of returns are difficult to quantify.

From a purely biological standpoint, the data defined in this memo are consistent with the idea that jack percentages in the escapement of less than 20% tend to produce a healthy age structure of returning fish (Figure 4). *With that in mind, the department will continue to research the potential methods that can be used at Frazer Lake fish pass to remove jacks from the spawning population and deposit their carcasses* *in the lake for nutrients as would occur if they were not culled. In the event a future run is composed of a large percentage of jacks, attempts will be made to reduce jacks down to 20% understanding that while not necessarily detrimental, the mitigation attempt may not be particularly valuable. While 20% is a target threshold, the inseason targeted percentage of jacks will be allowed to exceed 20% if it is necessary to increase the number of males in the population to maximize egg fertilization (~50% males). Though science may be debated, there is no debate that the public perception of removing a particular life history trait at a visible tourism location such as Frazer fish pass would be mostly negative.*

These proposed activities would take place at the Frazer Lake fish pass, which is within the boundaries of the Kodiak National Wildlife Refuge, and operates under a lease agreement with the Refuge. The purpose of the lease is to conduct fisheries evaluation, management, and protection operations. The department may use and occupy the fish pass site solely for fisheries research and management activities, but not for the operation of hatcheries. As this proposed action is not authorized under the lease it is considered to be a new activity, and it must be evaluated and approved by the refuge. A preliminary determination by the Refuge is that before the activity would be approved, there would need to be an administrative process including an Appropriate Use Determination, a Compatibility Determination, and a National Environmental Policy Act analysis and decision. See the attached letter from the Refuge for specifics.

If culling of jacks is continued in the future, it will be prosecuted under approval of the Refuge and the current department sampling permit (CF-2016-17). This permit is subject to the conditions, exceptions, and restrictions expressed in accordance with title 16 Alaska statutes of the administrative code. Specifically, the taking of fish in the project is required to be carried out by an authorized management program in which the procurement of biological samples is mandatory. Furthermore, the permit does not authorize the purchase, sale, or personal use of any fish acquired under the authority of this permit. Due to this, all culled salmon will be disposed of on site.

Since the 1960s the department has spent an enormous amount of time and resources into the conceptual background, stocking, construction, management, and research to understand this man-made and now naturally spawning salmon system. It is one of the most successful introduced runs in the world. The department is currently working with researchers at the University of Washington in an attempt to understand the ecological drivers of this unique system specific to the jack life history and also with respect to the current escapement goals.

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Table 1. Frazer Lake historical run size, escapement counts, and jack abundance.

Year	Total Run	Dog Salmon Ck. Esc.	Frazer Fish Pass Esc.	Total Jacks in Esc.	Proportion of Jacks in Escapement
1968			14,500		
1969			16,708		
1970			13,981		
1971			24,081		
1972			55,366		
1973			65,844		
1974	85,374		82,609		
1975	67,499		64,199		
1976	128,091		119,321		
1977	140,914		139,548	1,617	0.012
1978	172,317		141,981		0.000
1979	153,547		126,742	1,548	0.012
1980	460,708		405,535	4,578	0.011
1981	487,926		377,716	3,471	0.009
1982	506,655		430,423	46	0.000
1983	196,323	166,655	158,340	652	0.004
1984	67,377	48,844	53,524	5,704	0.107
1985	637,871	506,336	485,835	392	0.001
1986	178,205	136,553	126,529	58	0.000
1987	57,582	48,956	40,544	6,523	0.161
1988	458,461	248,055	246,704	10,208	0.041
1989	1,070,871	362,007	360,373	4,617	0.013
1990	979,833	254,540	226,707	2,097	0.009
1991	1,268,145	288,013	190,358	8,856	0.047

Year	Total Run	Dog Salmon Ck. Esc.	Frazer Fish Pass Esc.	Total Jacks in Esc.	Proportion of Jacks in Escapement
1992	418,773	206,406	185,825	17,147	0.092
1993	751,405	198,412	178,391	8,687	0.049
1994	650,045	240,913	206,071	10,441	0.051
1995	952,377	222,170	196,323	24,655	0.126
1996	700,913	206,677	198,695	47,142	0.237
1997	416,419	268,328	205,264	20,699	0.101
1998	606,343	245,393	233,755	22,675	0.097
1999	357,079	222,964	216,565	32,236	0.149
2000	394,705	173,340	158,044	15,806	0.100
2001	403,372	163,455	154,349	1,747	0.011
2002	110,226	105,989	85,317	13,160	0.154
2003	313,914	262,731	201,679	96,547	0.479
2004	712,251	226,266	120,664	3,261	0.027
2005	625,937	152,959	136,948	255	0.002
2006	117,900	108,343	89,516	21,922	0.245
2007	168,571	139,808	120,186	59,248	0.493
2008	520,603	153,276	105,363	6,251	0.059
2009	474,976	147,798	101,845	2,188	0.021
2010	165,112	135,100	94,680	31,909	0.337
2011	372,422	179,602	134,642	54,064	0.402
2012	372,047	154,416	148,884	7,949	0.053
2013	271,230	136,059	136,059	21,935	0.161
2014	426,345	223,890	200,296	22,763	0.114
2015	437,557	247,460	219,093	48,958	0.223

Note: Lower weir at Dog Salmon Flats not operated 1974 to 1982.

Table 2. Frazer Lake sockeye salmon brood table, 1976–2010.

Brood Year	Escapement	Age																	Total Return	Return/ Spawner
		0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	4.1	2.4	4.2	3.3	3.4 or 4.3		
1976	119,321	0	2,150	0	223,444	8,753	0	73,677	257,625	0	0	143,383	0	0	0	0	393	0	709,424	5.9
1977	139,548	0	2,764	0	73,189	2,928	0	92,211	107,917	0	0	146,064	393	0	0	0	0	0	425,466	3.0
1978	141,981	0	7,807	0	162,130	507	0	24,148	22,970	0	0	16,844	0	0	0	0	638	0	235,043	1.7
1979	126,742	0	507	0	1,374	982	0	2,965	24,323	0	0	26,791	0	0	0	0	2,165	0	59,106	0.5
1980	405,535	0	0	0	6,064	16,305	0	7,654	589,393	0	0	141,065	684	0	46	0	52	0	761,264	1.9
1981	377,716	0	876	0	12,120	0	0	2,455	7,748	0	172	5,239	0	0	0	0	862	0	29,471	0.1
1982	430,423	0	1,276	0	23,647	431	0	28,624	3,735	24	754	10,870	10,812	0	0	0	0	0	80,172	0.2
1983	158,340	0	10	26	8,935	9,729	0	13,438	380,531	1,604	0	586,833	0	0	0	0	36,986	0	1,038,092	6.6
1984	53,524	0	1,001	0	5,771	33,628	0	7,437	386,832	0	0	67,142	2,046	0	0	0	0	0	503,856	9.4
1985	485,835	0	192	0	16,502	4,399	0	49,290	53,978	151	0	22,578	9,032	0	1,595	0	2,694	0	160,412	0.3
1986	126,529	1,393	67,475	0	727,658	40,794	0	230,893	972,290	0	0	168,815	9,129	0	0	0	8,584	0	2,227,031	17.6
1987	40,544	0	1,787	1,851	3,019	26,596	0	3,902	187,581	0	0	159,822	104	0	156	0	882	0	385,701	9.5
1988	246,704	0	1,886	0	21,073	7,793	0	30,096	210,586	133	0	64,565	20,510	0	16	0	7,994	0	364,652	1.5
1989	360,373	0	16,191	208	327,929	12,847	0	153,078	373,277	5,752	0	300,182	145,325	0	0	0	40,754	0	1,375,543	3.8
1990	226,707	0	1,096	0	18,217	12,986	0	33,393	400,750	1,678	0	210,744	15,341	0	455	0	9,340	0	704,000	3.1
1991	190,358	0	621	0	2,031	57,463	0	1,728	330,834	302	0	105,361	630	0	0	0	0	0	498,970	2.6
1992	185,825	0	3,545	0	20,513	78,168	0	27,471	211,959	4,666	0	185,148	18,141	0	0	0	2,209	0	551,819	3.0
1993	178,391	0	2,529	45	12,677	41,759	0	56,178	291,218	4,831	0	64,155	17,867	0	256	0	5,830	0	497,344	2.8
1994	206,071	0	2,056	0	23,034	17,688	0	39,741	112,849	1,048	0	77,546	15,427	0	187	0	15,733	0	305,309	1.5
1995	196,323	0	10,106	0	59,574	39,574	0	77,223	152,287	1,251	0	251,356	11,284	0	878	0	5,794	0	609,328	3.1
1996	198,695	0	20,062	0	41,983	22,276	0	81,667	32,786	26	1,670	54,175	109	92	211	0	201	0	255,258	1.3
1997	205,264	0	626	0	8,327	1,639	0	10,462	15,598	176	833	19,673	2,251	0	0	0	0	77	59,662	0.3
1998	233,755	0	367	0	1,450	18,943	0	14,884	128,297	12,803	0	58,315	89,184	0	362	0	33,767	0	358,372	1.5
1999	216,565	0	879	0	3,754	104,150	0	79	484,554	0	0	239,961	1,297	0	649	0	2,576	97	837,997	3.9
2000	158,044	0	26,856	0	69,457	10,097	0	218,891	105,837	0	721	79,631	435	0	678	316	309	514	513,742	3.3
2001	154,349	0	565	0	21,563	2,508	0	7,110	5,096	8,508	145	14,177	38,040	223	774	706	80,473	1,502	181,390	1.2
2002	85,317	0	1,675	0	6,801	5,173	0	6,216	34,309	8,528	0	44,275	35,650	0	416	0	29,093	198	172,334	2.0
2003	201,679	0	1,201	0	9,899	44,359	0	16,348	169,365	3,430	0	81,123	31,296	0	184	0	1,236	0	358,440	1.8
2004	120,664	0	11,274	0	147,145	19,606	0	91,014	197,567	0	298	25,918	243	0	175	0	0	0	493,239	4.1
2005	136,948	0	2,318	0	34,034	8,824	0	43,136	36,815	5,935	435	36,735	3,222	89	339	0	500	0	172,382	1.3
2006	89,516	0	107	246	6,723	40,388	0	21,539	217,026	7,498	0	116,935	5,777	0	687	0	2,649	0	419,575	4.7
2007	120,186	0	3,793	661	13,301	67,117	0	21,050	171,111	0	0	87,987	576	0	454	0	0	0	366,050	3.0
2008	105,363	0	4,623	0	45,645	10,103	0	48,444	100,680	0	151	44,642	0	0	0	0	277		254,565	2.4
2009	101,845	495	93	0	10,784	17,550	0	16,452	322,752	860	0	174,311	12,255	0						
2010	94,680	0	1,873	0	13,154	26,967	0	23,316	160,354	2,047										

Note: Shaded brood years 1985-1995 are expected to have had some influence from fertilization, as fry present before fertilization would benefit, and residual nutrients are likely to remain for several years after fertilization stopped.

United States Department of the Interior

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IN REPLY REFER TO
Underwood

December 2, 2016

Kevin Schaberg, Regional Finfish Research Supervisor
Alaska Department of Fish and Game
Division of Commercial Fisheries, Region IV
351 Research Court
Kodiak, Alaska 99615-7400

Dear Kevin,

Thank you for the briefing you provided on Friday, November 18, regarding the Alaska Department of Fish and Game's (Department) consideration of Proposal #58, *Alitak District Salmon Management Plan*, currently before the Alaska Board of Fish. This proposal seeks a program to "Limit escapement of jack sockeye salmon into Frazer Lake to no more than 15 percent of total Frazer Lake sockeye salmon escapement." Further, the proposal suggests that "A system could be devised to trap and cull any excess jacks to be used as added nutrients into the lake should an overage occur." The program is proposed for a period of 4 years (until 2020) and requires reporting and a full evaluation at the conclusion of the program.

We understand from your briefing that, in response to this Proposal, the Department is considering the culling of jack sockeye salmon at the Frazer fish pass, transportation of the carcasses to Frazer Lake along the existing public access trail, and then depositing the carcasses in Frazer Lake. We followed through on our promised to initiate an internal review. Our intent is not criticism of the proposal; rather, we are fulfilling our requirement to consider all aspects of refuge, resource, and public-use management on the Refuge.

To begin, we reviewed the existing 50-year lease agreement (dated May 25th 1995) for weir operations at Frazer Lake (including the fish pass and other sites) signed by the Department and the U.S. Fish and Wildlife Service (Service). Section 5 of this lease, "Use Rights", is particularly pertinent to this proposal, and we concluded that the lease agreement does not authorize the proposed activities in and around Frazer Lake.

We then reviewed the Proposal in reference to national policies on appropriate use and compatible use, applied to all refuges in the National Wildlife Refuge System (NWRS). Based on the information in your briefing, the proposed amount, location, and disposal of culled salmon would be considered a new use. Refuge "uses" are defined in 603 FW2, which requires us to review new and existing uses within units of the NWRS. We understand that the activities in the proposal would be a "Specialized Use" described in 603 FW1 Section 1.10D of that policy. These are considered on a case by case basis. The Refuge must consider the potential effects of these proposed activities ("use") within the Refuge before they can be allowed. National policies for Appropriate Use and Compatibility were developed under statutory authority of the National Wildlife Refuge Administration Act of 1966 as amended by the Refuge Improvement Act of 1997 and others, specifically policies 603 FW 1 and 603 FW 2. Appropriate uses must meet specific criteria (603 FW 1, section 1.11). If the criteria are met, the use is appropriate, and then separately, compatibility is determined through analysis. All uses allowed must be determined to be compatible. A "compatible use" is defined as follows:

> **Compatible use:** A proposed or existing wildlife-dependent recreational use or any other use of a national wildlife refuge that, based on sound professional judgment, will not materially interfere with or detract from the fulfillment of the NWRS mission or the purposes of the national wildlife refuge.

Some concerns we have identified based on our preliminary assessment of the information provided in your briefing include these potential impacts:

- Bear behavior (attraction) at the Frazer Fish Pass as a result of the culling operation
- Bear behavior (attraction) to the access trail and lake access site due to carcass transportation
- Bear behavior changes in response to the deposition of carcasses in Frazer Lake
- Number and location of bear/human interactions
- Loss of production of sockeye salmon from under-seeding annual egg production,
- Ecology of Frazer Lake as impacted by carcass deposition
- Impact to the bear-viewing public and commercial operators supporting wildlife viewing, priority public uses for the Refuge
- Loss of the genetic diversity and structure of the run
- Impact to recreational fishers and cabin users at Frazer Lake and Dog Salmon Creek

Some concerns are location specific, i.e. to the Frazer fish pass. Others may or may not be "significant," but that determination would be made after appropriate analysis. A more detailed operations plan would be necessary to fully analyze some of these impacts.

We determined that it would take approximately 45 days for Refuge staff to complete an Appropriate Use analysis and Compatibility Determination, including a required public comment period for Compatibility. If the activities are found to be appropriate and compatible, and the Department wanted to conduct the activities, the Service would also need to conduct an analysis under the National Environmental Policy Act before the activities could begin.

If you have further questions on our concerns or additional details on the appropriate use and compatibility processes, or if we need to discuss the proposal further, please contact Tevis Underwood, Deputy Refuge Manager at 487-2600. Thank you again for your proactive communication.

Respectfully,

Tevis Underwood

for

Anne Marie La Rosa
Kodiak National Wildlife Refuge Manager

Cc: Nick Sagalkin, Regional Supervisor