

Alaska Sustainable Salmon Fund Project Completion Report

AKSSF Project Number: 45646
Project Title: Restore Salmon Runs in Resurrection Bay at Alaska SeaLife Center (Year 3)

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Co-Principal Investigator/ Project Manager:
Not applicable
Total Funding: \$694,132
Congressionally Designated: yes
Project Period: Start: 9/19/06 End: 6/30/10

Project Objectives:

Goal 1: Continue the Chinook salmon restoration program under development at the Alaska SeaLife Center (ASLC) including expanding production.

Objective A: Provide support for rearing, SeaReady™ treatments and release of 25,000 age-1 Chinook salmon smolt in May 2007.

Objective B: Provide support for rearing, SeaReady™ treatments and release of approximately 100,000 brood year 2006 Chinook salmon smolt. Of these smolt, 75,000 are planned for release as age-0 smolt in June/July 2007, and 25,000 are planned for release as age-1 smolt in May 2008.

Objective C: Collect, process and analyze otoliths from 400 adult Chinook salmon harvested in the sport fishery in 2009 to determine the smolt cohort contribution from Chinook salmon released from the ASLC into Resurrection Bay in 2006 and 2007.

Objective D: Expand incubation and rearing capacity at ASLC to the meet Alaska Department of Fish and Game (ADF&G) – ASLC Cooperative Agreement production goal of 250,000 smolt.

Goal 2: Continue the coho salmon SeaReady™ treatment and release program in collaboration with Cook Inlet Aquaculture Association (CIAA).

Objective A: Coordinate with CIAA to assure the rearing and release of 100,000 SeaReady™ treated and 100,000 control coho smolt in 2007.

Objective B: Collect, process and analyze otoliths from adult coho salmon harvested in the 2008 sport fishery and from 400 adult coho salmon captured at the Bear Lake weir or used for hatchery spawning in 2008 to determine the smolt cohort

contribution from SeaReady™ treated coho salmon stocked in Resurrection Bay in 2007.

Goal 3: Produce a salmon sport fish economic impact study and cost benefit analysis on how salmon enhancement and wild stock restoration in Resurrection Bay impacts the City of Seward.

Objective A: Contract McDowell Group to conduct the analysis and report on findings.

Goal 4: Continue and expand the current research and salmon enhancement effort to aid in the restoration of sockeye salmon at Bear Lake.

Objective A: Process and analyze ~100 gill samples for Na+K+ATPase activity, chloride cell distribution and calcium receptor protein expression from SeaReady™ treated and control untreated hatchery sockeye smolt released into Bear Lake in June 2006.

Objective B: Collect, process and analyze otoliths from 400 adult sockeye salmon harvested annually in the commercial fishery and from 400 adult sockeye salmon captured at the Bear Lake weir or used for hatchery spawning in 2009 to determine the smolt cohort origin (wild, fry and pre-smolt and smolt stocking) from BY04 Bear Lake sockeye salmon that entered Resurrection Bay in 2006.

Objective C: Collect, process and analyze sensory, muscle and reproductive tissue and blood from 100 adult sockeye salmon harvested in the commercial fishery in Resurrection Bay, from 100 adult sockeye captured at the Bear Lake weir and from 100 adult sockeye used for hatchery spawning.

Objective D: Conduct a paleolimnology investigation at Bear Lake: core sampling of the lake sediment, carbon date strata in relation to geologic markers, determine $\delta^{15}\text{N}$ content, and identify diatom assemblages to reconstruct past population dynamics.

Preliminary Synopsis:

Chinook, coho and sockeye salmon production and research were conducted through the ASLC in collaboration with MariCal, Inc., and Cook Inlet Aquaculture Association (CIAA). We also proposed an enhancement and wild stock restoration cost benefit analysis under contract to the McDowell Group. We further proposed a paleolimnology investigation under subaward to the University of Alaska Fairbanks to assess historical salmon returns to Bear Lake. Specific goals included restoring Chinook and coho salmon to Resurrection Bay, and aiding in the restoration of sockeye salmon to Bear Lake. Rearing and release strategies for each species included treating fry with MariCal's SeaReady™ technology to reduce osmotic stress in young salmon with the expectation this process would increase adult returns compared to untreated fish. All hatchery fish were otolith thermally marked for later identification. At the adult stage, Chinook, coho and sockeye salmon were collected in local and otoliths collected and assessed.

Final Synopsis:

Laboratory analysis of tissue samples collected from SeaReady™ treated Chinook, coho and sockeye salmon indicate positive initial increases in blood sodium and gill ATPase activity in treated fish as well as increase physical factors such as weight gain. However, these results were not long term and balanced with untreated typically by Day 42 of the trials. Studies suggest that the SeaReady™ treatment did not provide any advantage in hypo-osmoregulation at least in comparison to fish which received extra NaCl in their diet. Importantly, based on otolith assessment, unmarked sockeye salmon adults originating from Bear Lake suggests natural spawning to result in significantly higher adult returns than hatchery fry and smolts planted into the lake.

Project Activities and Results:

Goal 1:

Objective A: 21,607 age-1 Chinook were released in May, 2007.

Objective B: 96,235 age-0 Chinook were released in June, 2007 with designated thermal mark groups combined and fin clipped for optional marking due to area flooding and infrastructure damage that forced protocol change.

(Appendix 1)

Objective C: Due to weak Chinook salmon returns otoliths from only 59 salmon were collected. **(Appendix 2)**

Objective D: Infrastructure was expanded at the Alaska SeaLife Center to accommodate the 250,000 smolt production goal.

Goal 2:

Objective A: 100,500 coho served as controls and 136,500 fish were SeaReady™ treated.

Objective B: 666 adult coho salmon were otolith sampled and analyzed. While 27% were determined to be from various hatcheries compared to unmarked fish, there were no otolith marks found for salmon that had been SeaReady™ treated. **(Appendix 3)**

Goal 3:

Objective A: McDowell Group delivered the economic impact study report suggesting important benefits to the City of Seward from salmon enhancement and restoration actions. **(Appendix 4)**

Goal 4:

Objective A: Sockeye salmon fry were SeaReady™ treated and released in collaboration with CIAA. No significant differences between control and treated fish were found after 42 days. **(Appendix 5)**

Objective B: 800 adult fish were sampled and otoliths assessed. Based on results SeaReady™ treatment of smolt produced at Trail Lakes Hatchery appears to have had little if any benefit to the rebuilding of Bear Lake sockeye production. Importantly, data suggests that natural spawning at the lake may result in higher adult survival rates than hatchery sockeye fry and presmolts stocked in the lake. **(Appendix 6)**

Objective C: Tissues were collected and assessed.

Objective D: Bear Lake paleolimnology assessment was completed offering insights to a 500 year sedimentary record suggesting Bear Lake salmon production variability particularly during the “Little Ice Age” when temperatures were cooler regionally. **(Appendix 7)**

Reports and Other Products:

Reports have been forward to the Alaska Department of Fish and Game as part of semi-annual reporting and are included herein as attachments to this final report. There are no published scientific reports or papers.

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ASLC Chinook Age-0 SeaReady Trial and Seawater Rearing

The SeaReady trial began on April 4, 2007. Approximately 12,000 fish were divided into three groups. Control A received no SeaReady diet (EWOS diet #3 Cr) or salts during the six-week trial. Control B also received no SeaReady diet or salts but the feed was top dressed with 7% NaCl (Corey diet 1.0gr). The last group received both the SeaReady diet (Corey diet 1.0gr) and Ca/Mg salts two times per day and is noted as the SeaReady group.

All fish were reared in 12 - 0.225 m³ tanks supplied with 8 C flowing freshwater. In adding the Ca/Mg salts for the SeaReady group, the water level in the tanks were dropped half way, salts added and tanks allowed to refill. For those tanks not receiving the Ca/Mg, they also had the water level drop to the same level but no salts added. All groups were exposed to 20,000 K lighting for 16 hours per day for the first four weeks of the trial. For the last two weeks the photoperiod was increased to provide 20 hours of light per day.

On a weekly basis, 60 fish from each group were removed from their freshwater tanks and placed into a tank which had flowing seawater (32ppt) heated to 7-8 C to challenge the fish. Fish remained in the seawater for 96 hours in which percent survival was determined. In addition, after a 24 hr exposure to seawater, 10 fish were sampled for blood (Day 0, 7, 14, 21, 28, 35, 42). On a bi-weekly basis, these fish were also sampled for histology, gill Na⁺K⁺ ATPase and Western Blot (Day 0, 14, 28, 42).

At the same time that sampling occurred from the seawater challenge tanks, 10 fish were also sampled from the freshwater tanks. Samples were the same as for seawater with blood being sampled every week and histology, gill Na⁺K⁺ ATPase and Western Blot sampling occurring bi-weekly.

After completion of the SeaReady treatment (Day 42; May 16, 2007), one half of the fish for each group were transferred to seawater (32 ppt, 7-8 C, 1.5 m³) tanks while the remaining fish stayed in freshwater, but were transferred to the larger 1.5 m³ tanks for an additional three weeks. For Control B and SeaReady treated fish, the special diets (additional NaCl and SeaReady respectively) were stopped and changed to regular diet (EWOS #3 Cr). For the SeaReady group the addition of twice daily Ca/Mg was also stopped. Sampling remained on the same schedule with blood sampling and 96 hr seawater challenge occurring weekly (Day 49, 56, 63) and histology, gill ATPase and Western blot sampling occurring on Day 56 only. After Day 63, these fish were then transferred to the seawater (32 ppt, 7-8 C) for three weeks before being released.

For the fish transferred to seawater on Day 42, they were sampled for blood, histology, gill ATPase and Western blot on Days 56 and 70 (from start of trial). For the fish transferred to seawater after Day 63 of the trial (Control A (lag), Control B (lag) and SeaReady (lag)), they were only sampled on Day 70. All groups were released Day 84.

This trial had three objectives: (1) to demonstrate the advantage of using the SeaReady technology to enhance hypo-osmoregulation; (2) to determine if and when the advantage gained by the SeaReady technology would be lost once the treatment (diet and salts) were removed; and

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(3) to demonstrate the benefits of transferring fish to seawater as soon as possible after treatment was completed. For the purposes of reporting, the results are broken down into these three objectives. At this time results for histology and western blot are not yet available.

SeaReady Technology to Enhance Hypo-osmoregulation

As noted above the SeaReady trial started on April 4, 2007 (Day 0) and was completed on May 16 (Day 42). Figure 1 shows the change in weight for the 3 groups during this time. Control A was larger than the other two groups but was this difference was only significant between the SeaReady group ($P=0.0224$). It was noted that for the first two weeks of the SeaReady treatment, the fish were not eating well once the salts were added to the tank. This delay in feeding may have been the reason why these fish were smaller than the other two groups. In addition, both the SeaReady and Control B groups were originally on a EWOS diet, but were switched at the start of the trial to Corey.

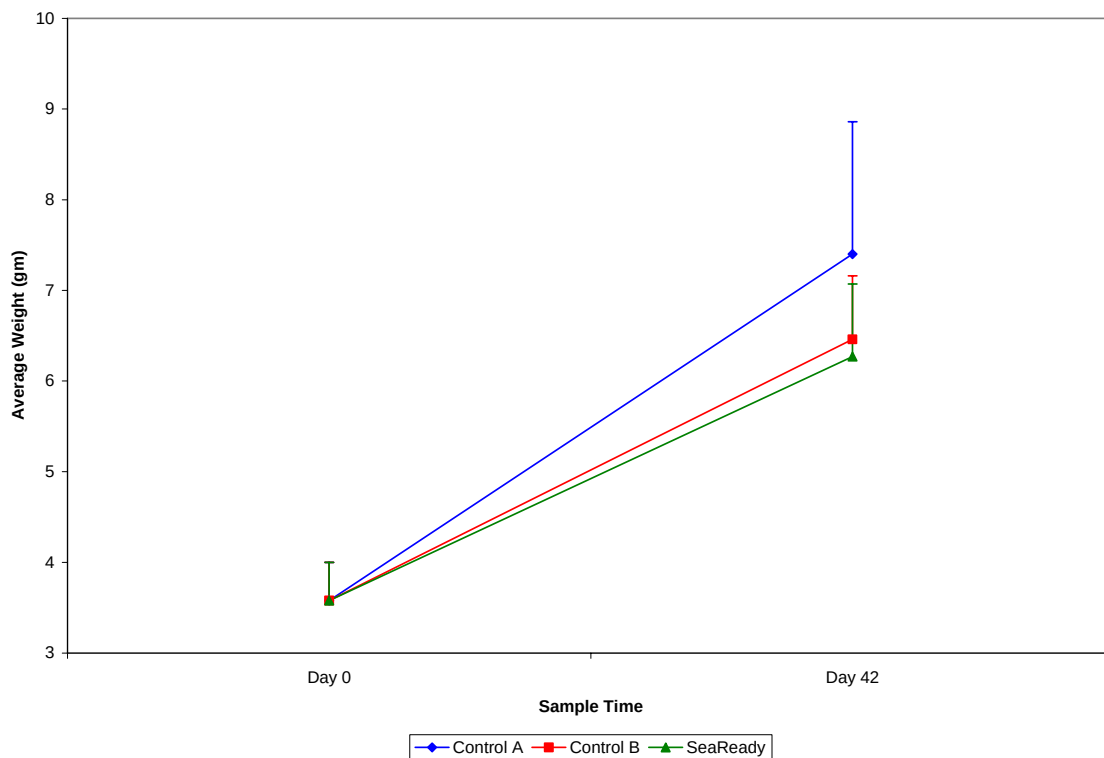


Figure 1. Average weight for Control A, Control B and SeaReady fish during the six week trial.

Blood sodium, calcium and chloride were monitored weekly during the entire trial. Figures 2, 3 and 4 show the results respectively. The fish were not large enough to provide enough blood to do the analysis on each individual fish, hence blood was pooled.

While blood sodium levels were significantly different between the start and end of the trial for fish in freshwater ($P<0.002$) there was no difference between the treatment groups at the end of the trial ($P>0.481$). Blood sodium levels for fish that were challenged for 24hrs in seawater

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showed the same trend with values decreasing significantly from Day 0 to Day 42 ($P < 0.023$), but no differences were reported among the treatment groups on Day 42 ($P > 0.172$).

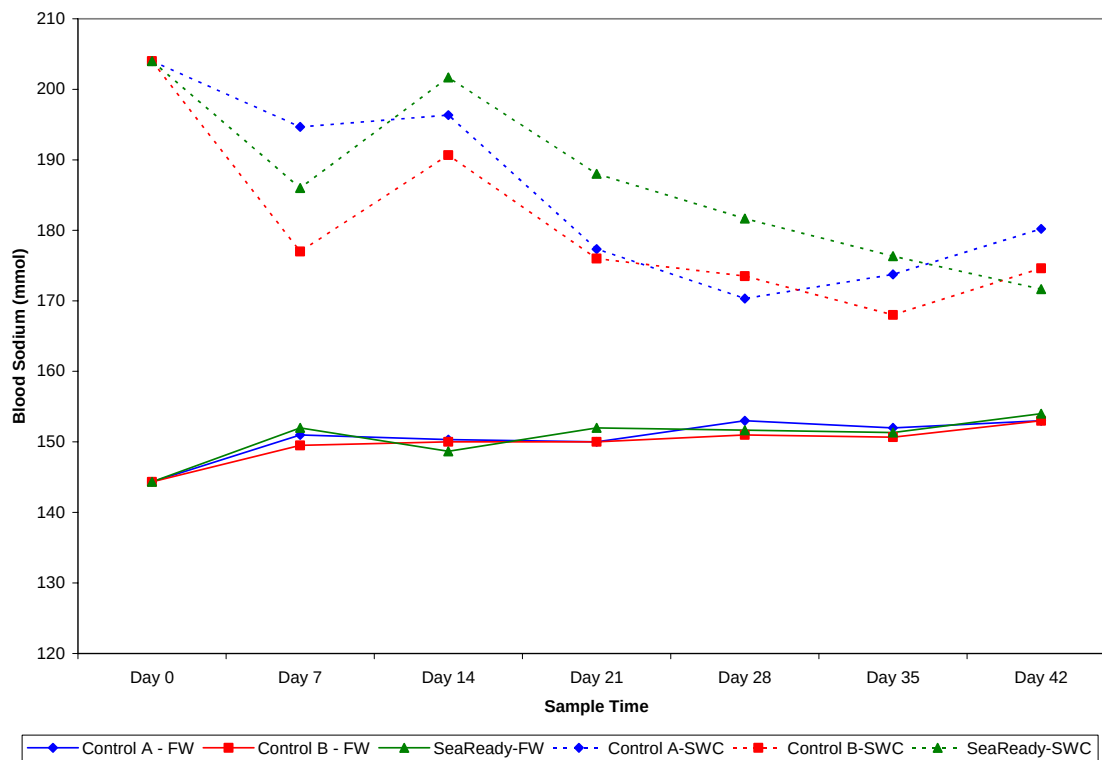


Figure 2. Average blood sodium levels for the three treatment groups during the six week trial. Solid lines are freshwater values. Dotted lines are after a 24 hour challenge to seawater (32 ppt, 7-8C).

Blood calcium levels varied widely throughout the trial, with no particular trend noted for either the freshwater or 24 hr seawater challenged fish. Blood chloride levels increased significantly ($P < 0.0017$) over the course of the trial from 118 mmol to approximately 132 mmol for the freshwater fish. However, as with the blood sodium there was no significance between the treatment groups at the end of the trial ($P > 0.474$). For fish challenged for 24 hours in seawater the trend again was the same as with the blood sodium, with values decreasing significantly over the course of the trial for all three groups ($P < 0.028$), yet no differences were noted between the three groups ($P > 0.785$).

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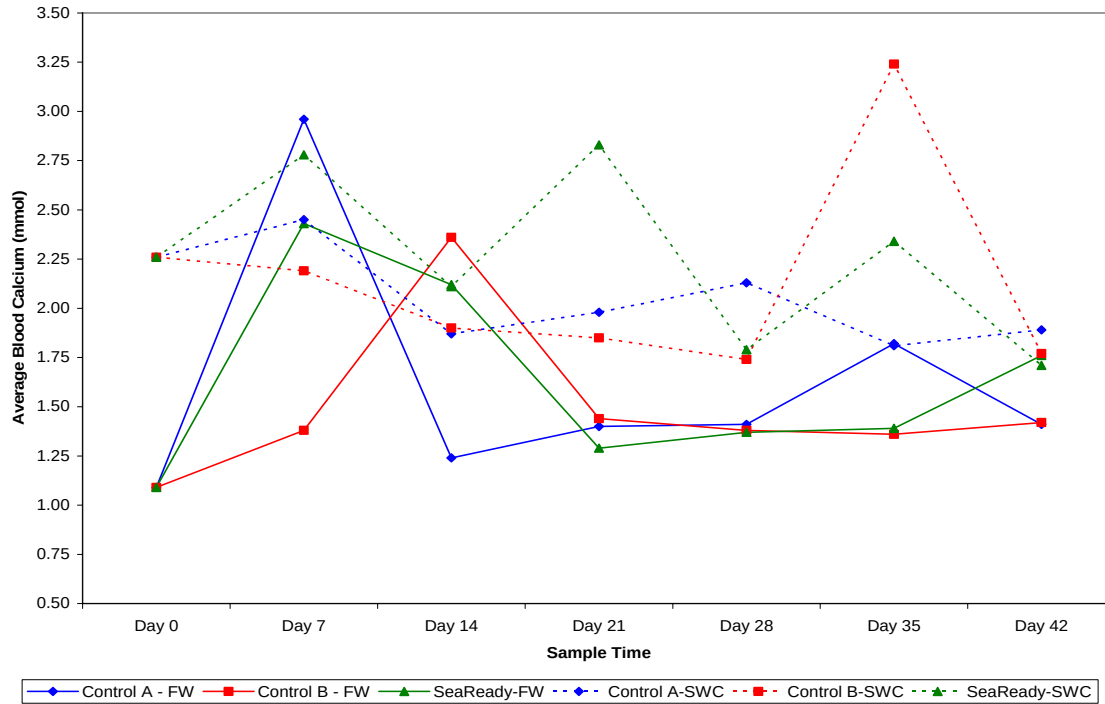


Figure 3. Average blood calcium levels for the three treatment groups during the six week trial. Solid line are freshwater values. Dotted lines are after a 24 hr challenge to seawater (32 ppt, 7-8C)

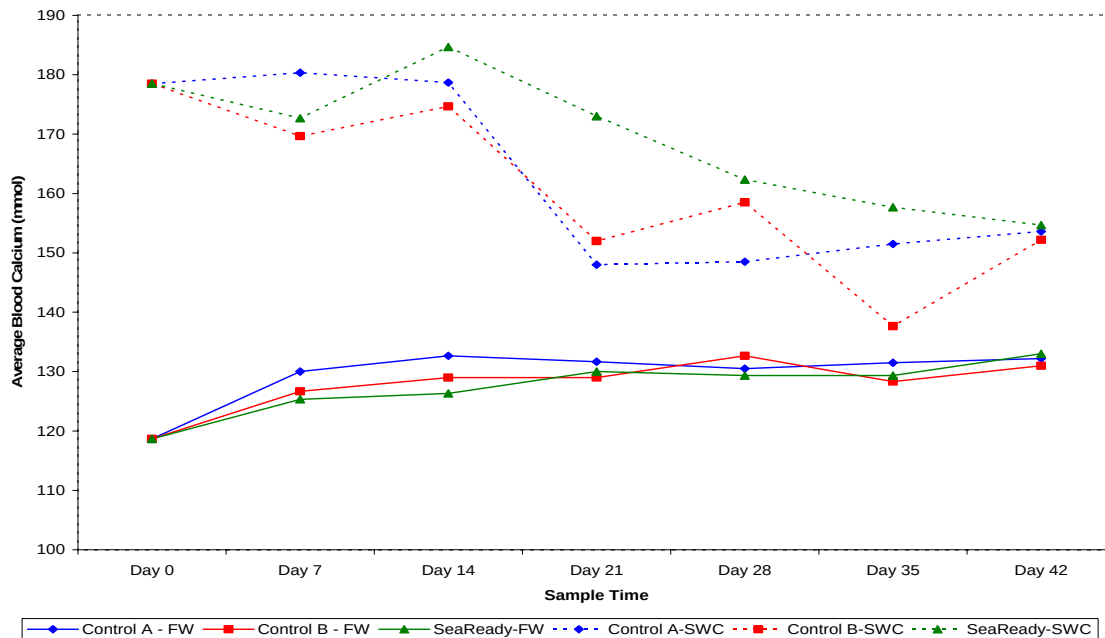


Figure 4. Average blood chloride levels for the three treatment groups during the six week trial. Solid line are freshwater values. Dotted lines are after a 24 hr challenge to seawater (32 ppt, 7-8 C).

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Figure 5 demonstrates the values reported for gill Na⁺K⁺ ATPase during the course of the SeaReady trial for fish sampled from freshwater while Figure 6 shows the same for the fish sampled after 24 hr seawater challenge. All three groups had the gill ATPase increase at each sampling period until Day 42 (freshwater values) with the SeaReady and Control B having the higher levels. At Day 42 the freshwater values for both the SeaReady and Control B declined with Control B showing the largest decline. On Day 42 there was a significant difference between SeaReady and Control B ($P=0.009$) and between Control A and Control B ($P=0.020$).

However, despite having the lowest ATPase at Day 42 for freshwater fish, Control B had the highest ATPase levels at Day 42 for those fish which were challenge in seawater for 24 hours. Again ATPase levels increased for all three groups until Day 42 where Control A and SeaReady groups declined slightly. Significant differences were reported between Control A and Control B ($P= 0.001$) and Control A and SeaReady ($P=0.011$) at Day 42 for seawater challenged fish.

Figure 7 shows the survival after exposure to seawater for 96 hrs in relation to gill ATPase values reported after 24 hr seawater challenge. For the SeaReady and Control B treatment groups, as ATPase levels increased so did survival. However, Control A did not follow a similar pattern. Despite lower ATPase levels, survival still increased with the Control A treatment group.

This study would seem to indicate that the SeaReady technology did not provide any advantage in hypo-osmoregulation at least in comparison to fish which just received extra NaCl in their diet.

These results are not similar to those reported for the BY05 Chinook Age 0 reported in the previous year, despite fish size and timing being similar (BY05 started two weeks earlier than BY06). For the BY05 trial, there were significant differences in both gill ATPase and survival between the Control and SeaReady groups. Differences between the trial in 2007 and the 2006 trial are: (1) different lighting: 2006 trial was done in S. Holding where fluorescent lighting was also used whereas 2007 had 20000 K blue lighting (no fluorescent lighting); and (2) seawater for challenges was heated to 7-8 C for the 2007 study whereas ambient (4 C) was used in 2006.

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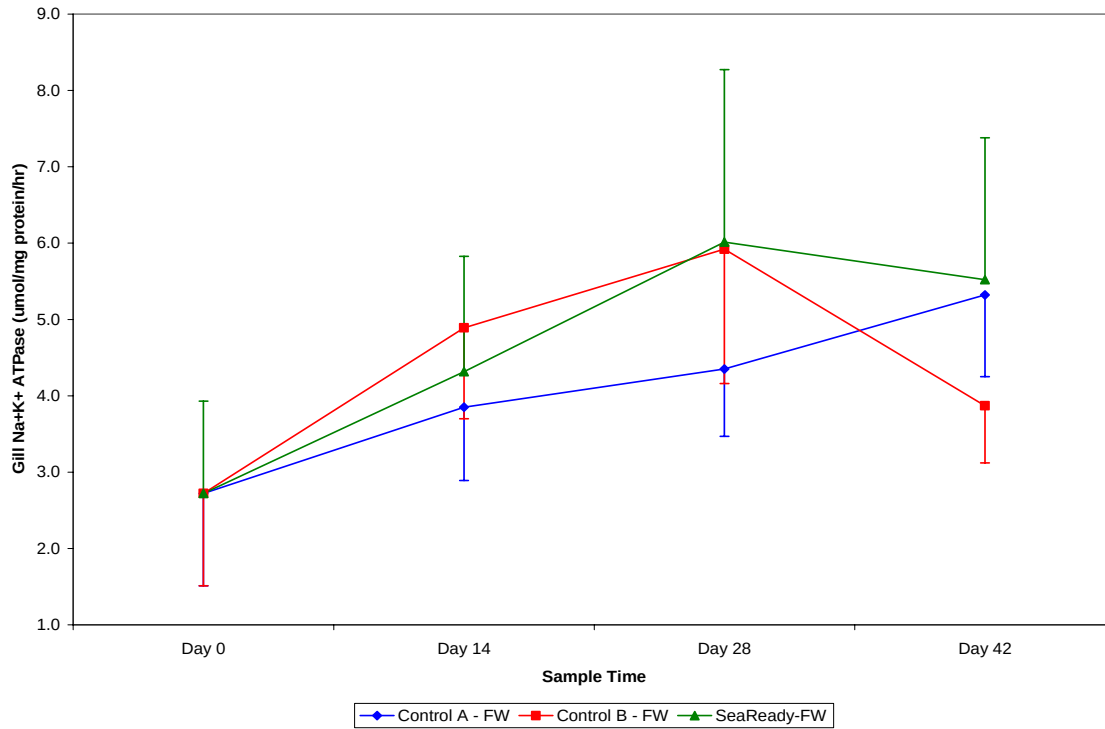


Figure 5. Freshwater gill Na⁺ K⁺ ATPase levels for the three treatment groups over the course of the SeaReady trial.

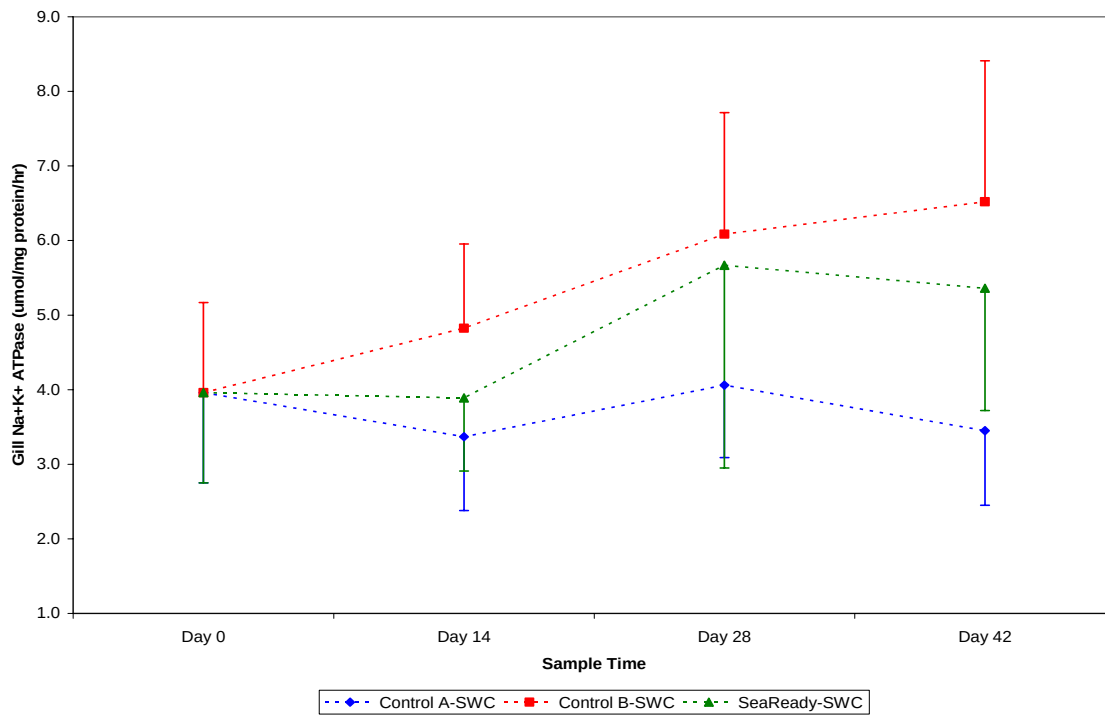


Figure 6. Seawater challenge (24 hr) gill Na⁺ K⁺ ATPase levels for the three treatment groups over the course of the SeaReady trial.

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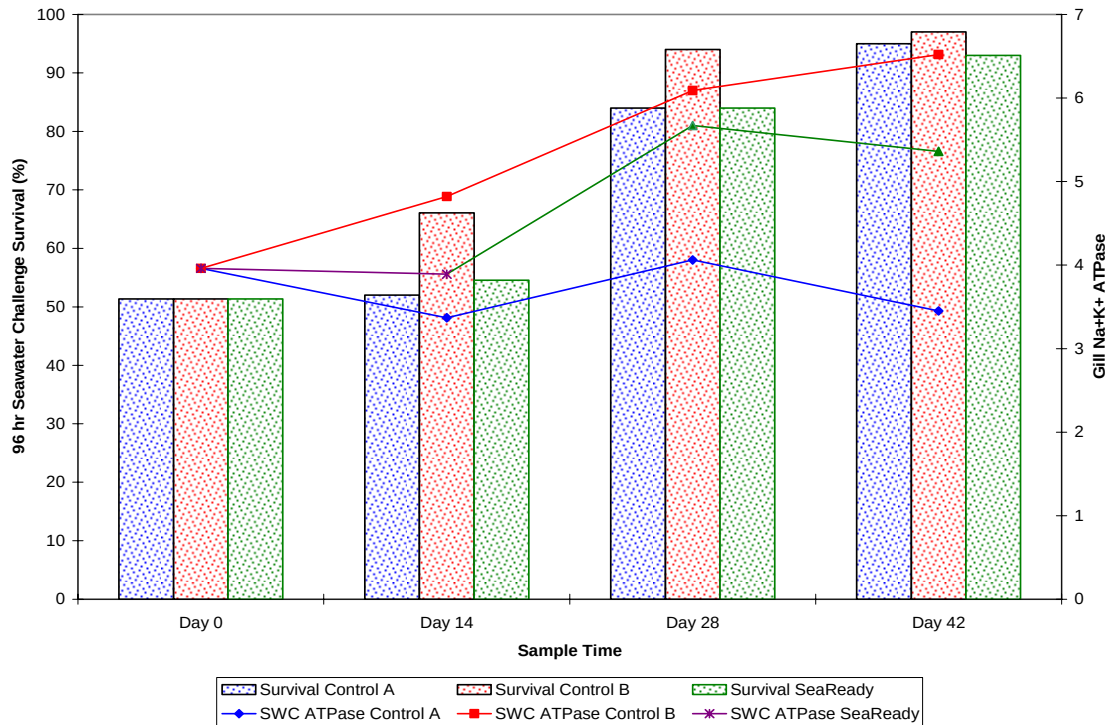


Figure 7. Survival and gill ATPase values for all three treatment groups after exposure to seawater (96 hr for survival; 24hr for ATPase).

Changes in Hypo-Osmoregulation Once SeaReady Treatment is Stopped

As noted in the introduction, one half of the fish were transferred to seawater at Day 42 while the remaining fish stayed in freshwater, but diets changed to regular feed (ie same as Control A) and additions of Ca/Mg were stopped (SeaReady group).

Figure 8 shows the growth over the three additional weeks the fish remained in freshwater. All groups continued to grow after the SeaReady trial was over, but the largest gains occurred for both the Control B and SeaReady treated fish. This would seem to support the observation made during the SeaReady trial that the Corey diet plus the additions of Ca/Mg (SeaReady only) had a negative effect on growth.

Figures 9, 10 and 11 demonstrate the changes in blood sodium, calcium and chloride during this three week time period. All three groups continued to show a decline in levels after a 24 hr exposure to seawater despite no longer being on the SeaReady treatment. In contrast to the six weeks during the SeaReady application, blood calcium levels became less erratic during these three weeks. Figure 12 shows the gill ATPase results for the same time period. With the exception of Control A, all groups showed increasing enzyme levels.

These results would seem to indicate there was continuing improvement in the fish's ability to hypo-osmoregulate despite no longer being on the SeaReady process. It is possible the time of

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year might have an effect here. This time corresponds to late May to early June in which natural migration of Chinook smolts would occur. Therefore, it could be assumed that in order for the full benefit of the SeaReady technology to be noted, the application should occur well in advance of the natural smolting window.

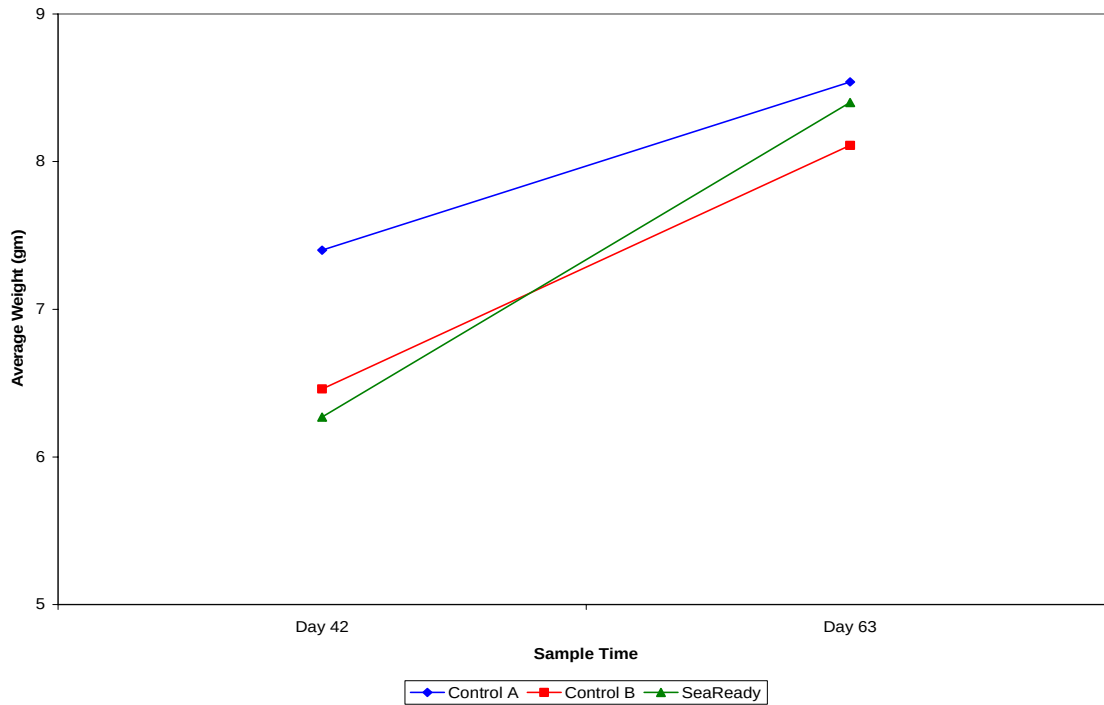
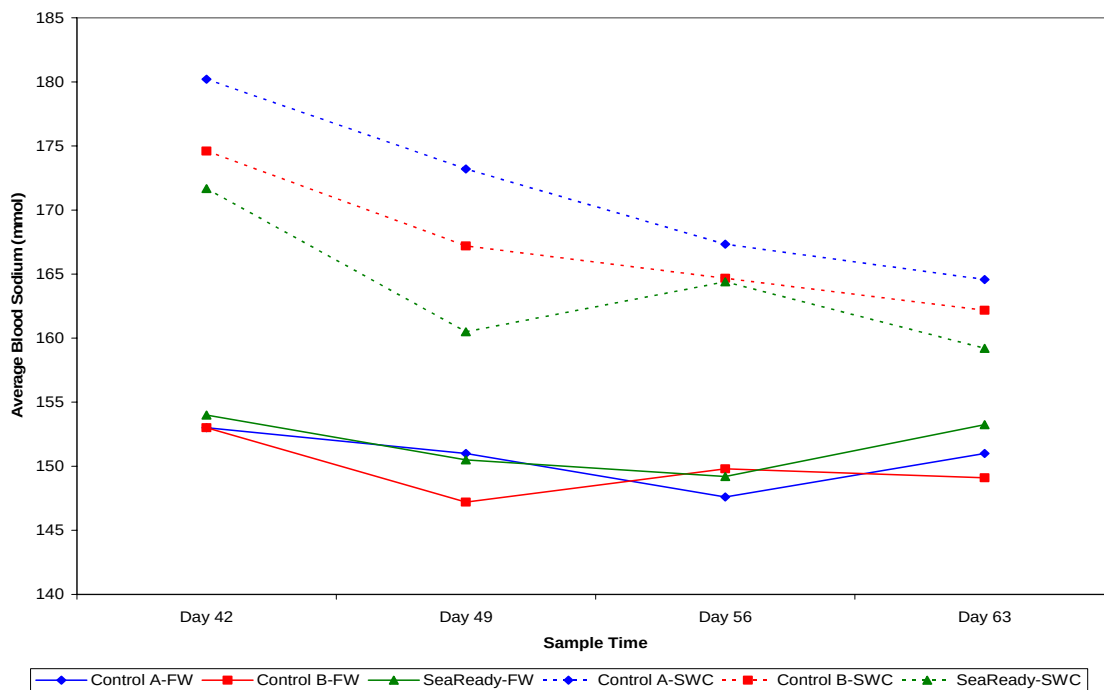


Figure 8. Change in growth for the three treatment groups which remained in freshwater after completion of the SeaReady trial.



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Figure 9. Change in blood sodium levels for the three treatment groups which remained in freshwater after completion of the SeaReady trial.

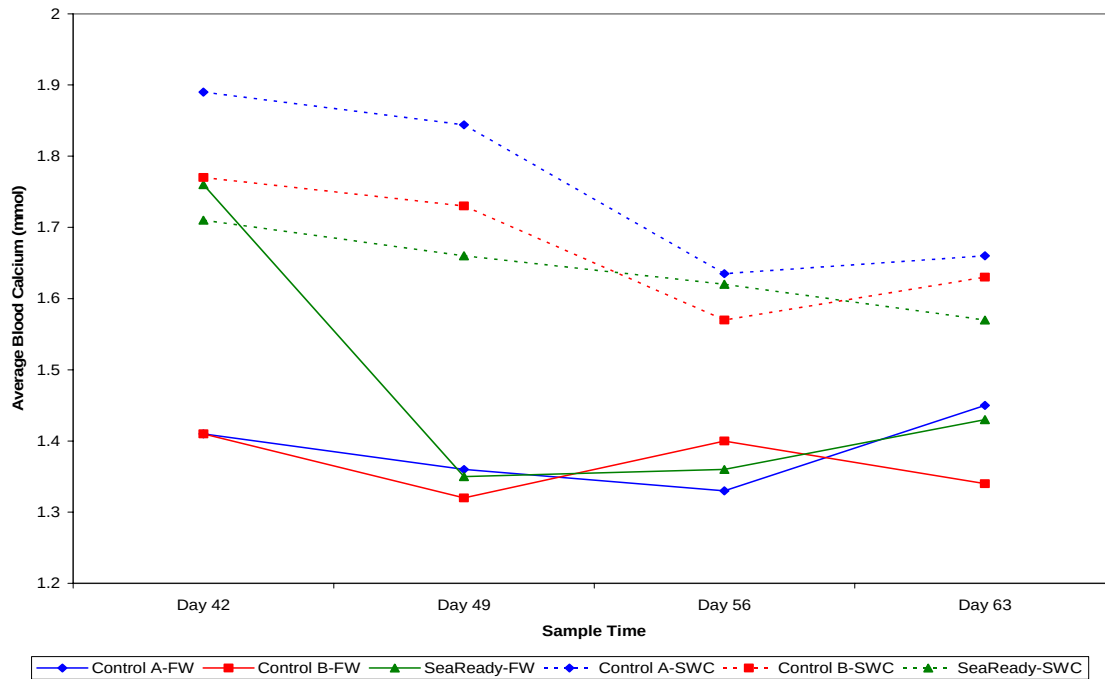


Figure 10. Change in blood calcium levels for the three treatment groups which remained in freshwater after completion of the SeaReady trial.

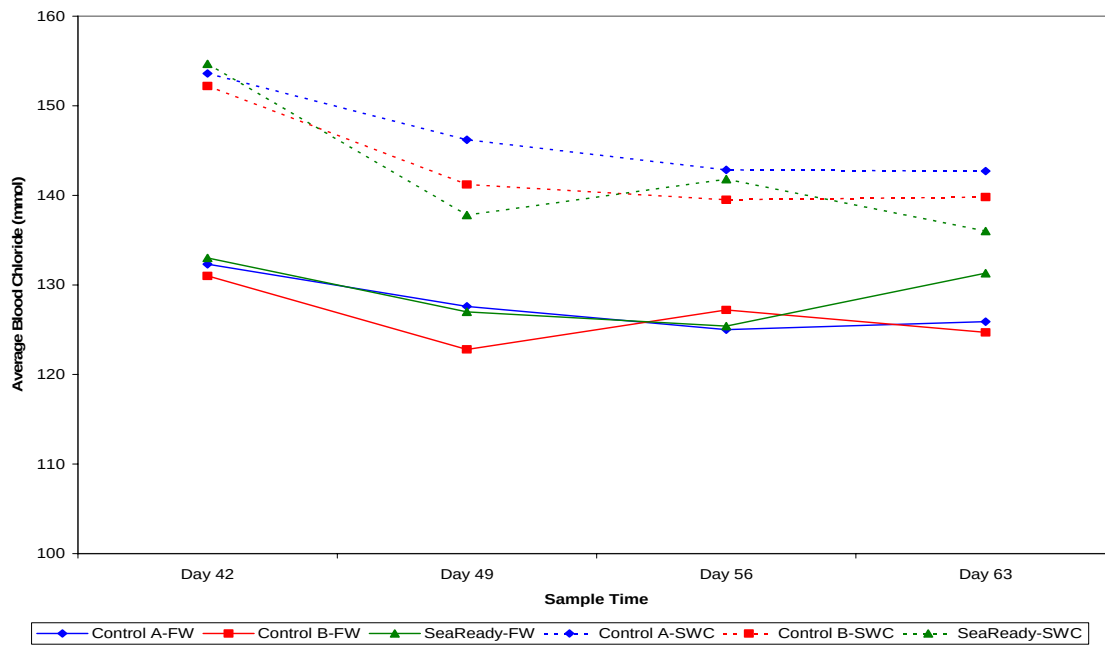


Figure 11. Change in blood chloride levels for the three treatment groups which remained in freshwater after completion of the SeaReady trial.

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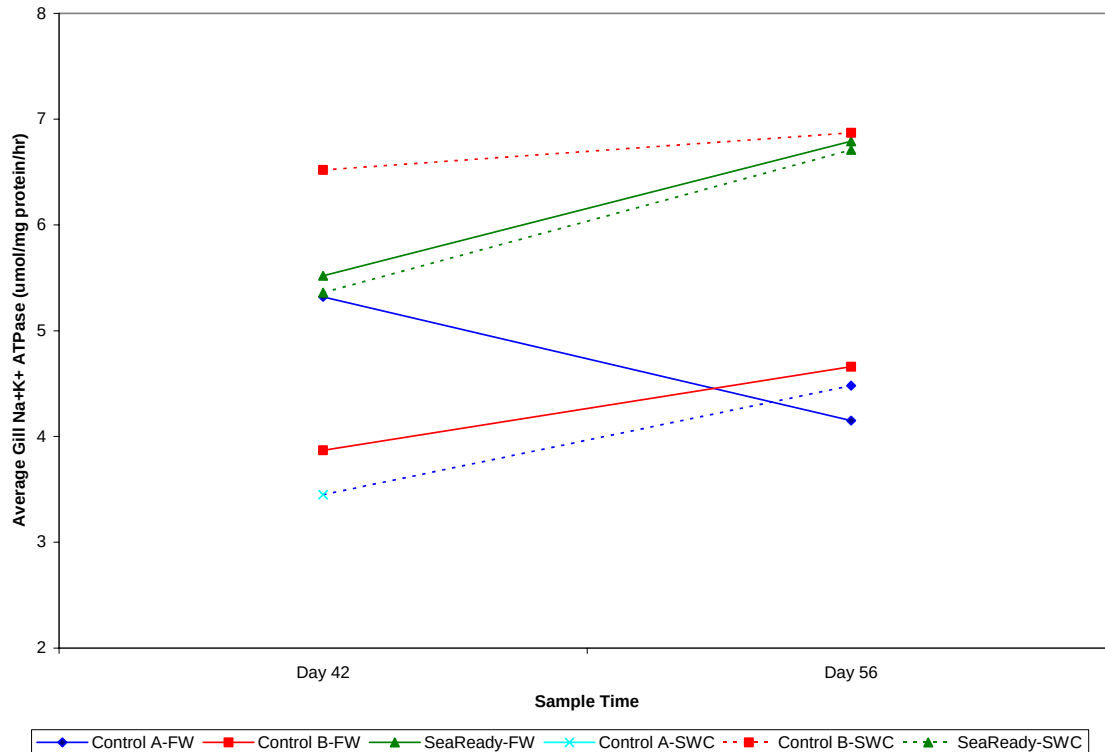


Figure 12. Change in gill Na+K+ ATPase for the three treatment groups which remained in freshwater after completion of the SeaReady trial.

Growth in Seawater

As previously mentioned, one half of the fish were transferred to seawater after completion of the SeaReady trial (Day 42). The remaining fish remained in freshwater until Day 63 when they transferred to seawater (referred to as lag group). All fish were then reared in seawater until Day 84 at which time they were released into Resurrection Bay. Samples were collected for weight, blood analysis, gill ATPase, histology and western blot on Day 56 and Day 70. Only weight data was collected on Day 84 prior to release.

Figure 13 shows the weight gain between fish which transferred to seawater immediately after completion of the SeaReady process (six weeks total in seawater) versus fish which didn't transfer to seawater until three weeks later. There was no significant differences reported between fish size in any of the groups at the time of release ($P=0.681$).

Figure 14, 15 and 16 demonstrate the change in blood sodium, calcium and chloride respectively. Blood sodium levels reached their lowest point on Day 70 regardless of the time reared in seawater. However, no significant difference were noted between any of the treatment groups at Day 70 ($P=0.216$). Blood calcium levels showed a dramatic decline on Day 70 for all treatment groups. Again, there were no reported significant differences between any of the treatment groups ($P=0.866$). In contrast to blood sodium and calcium, blood chloride levels increased over the time period in seawater. At Day 70, there were no reported differences between any of the treatment groups regardless of the amount of time they were reared in seawater ($P=0.549$).

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Figure 17 shows the gill Na⁺K⁺ ATPase levels for the seawater rearing phase. Gill Na⁺K⁺ ATPase levels increased as the amount of time in seawater increased. Unfortunately for the lag phase group, no starting value for gill ATPase is known since no samples for ATPase (only blood was sampled) were collected at the time of transferring to seawater. The normal transfer group had significantly higher gill ATPase levels than the same treatment groups which were transferred three weeks later ($P < 0.017$). Within the same transfer groups, there were no significant differences reported among the three treatment groups ($P > 0.054$).

Results would seem to indicate that the extra three weeks of seawater rearing did not provide any additional benefit in terms of short-term growth and blood ionic levels. However, since there were significant differences in short-term ATPase levels, it is possible that over a longer time period, an advantage might be gained.

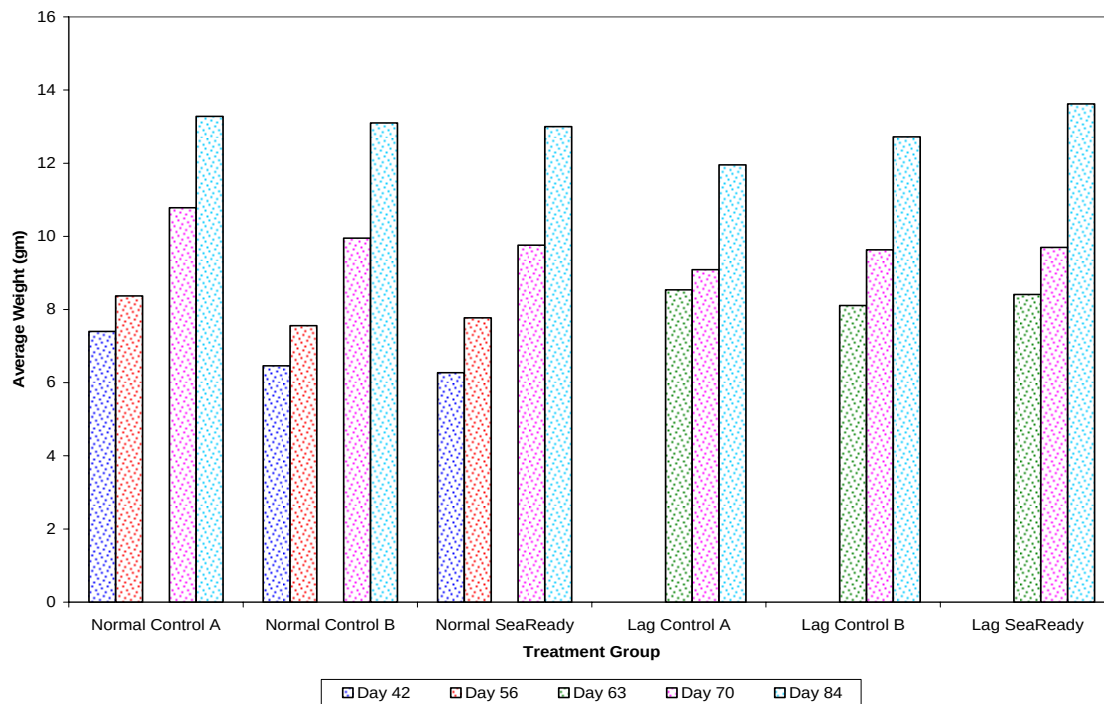


Figure 13. Change in weight during seawater rearing. Normal treatment groups were reared in seawater for 6 weeks. Lag treatment groups were only reared in seawater for 3 weeks.

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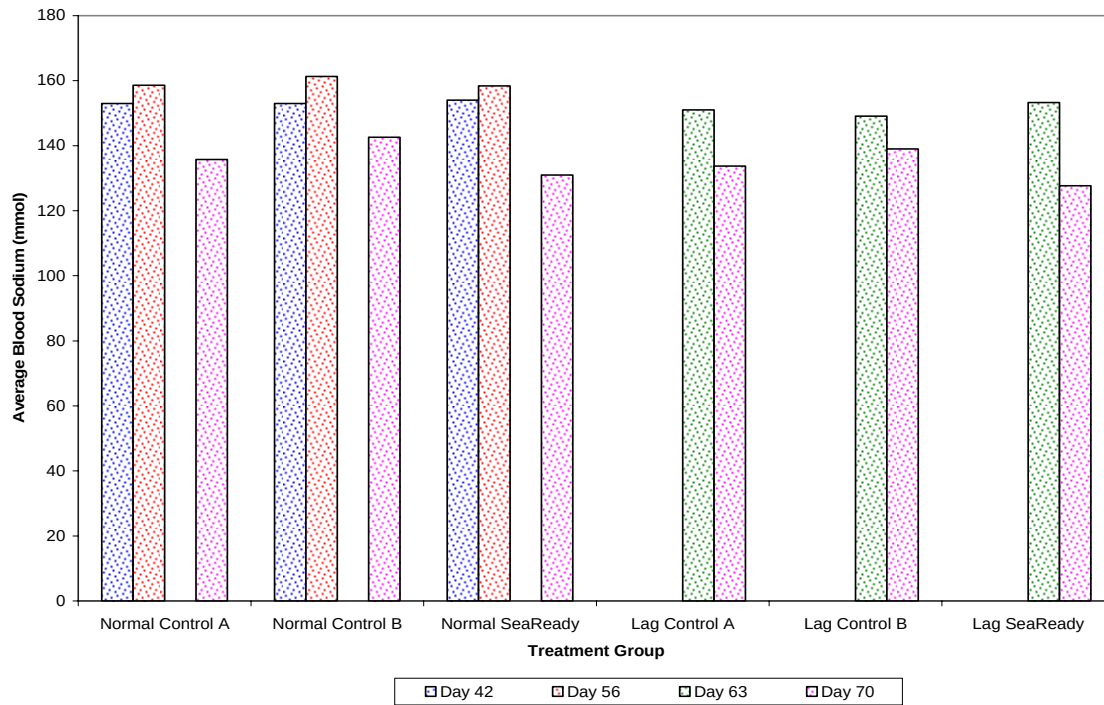


Figure 14. Change in blood sodium levels during seawater rearing. Normal treatment groups were reared in seawater for 6 weeks. Lag treatment groups were only reared in seawater for 3 weeks.

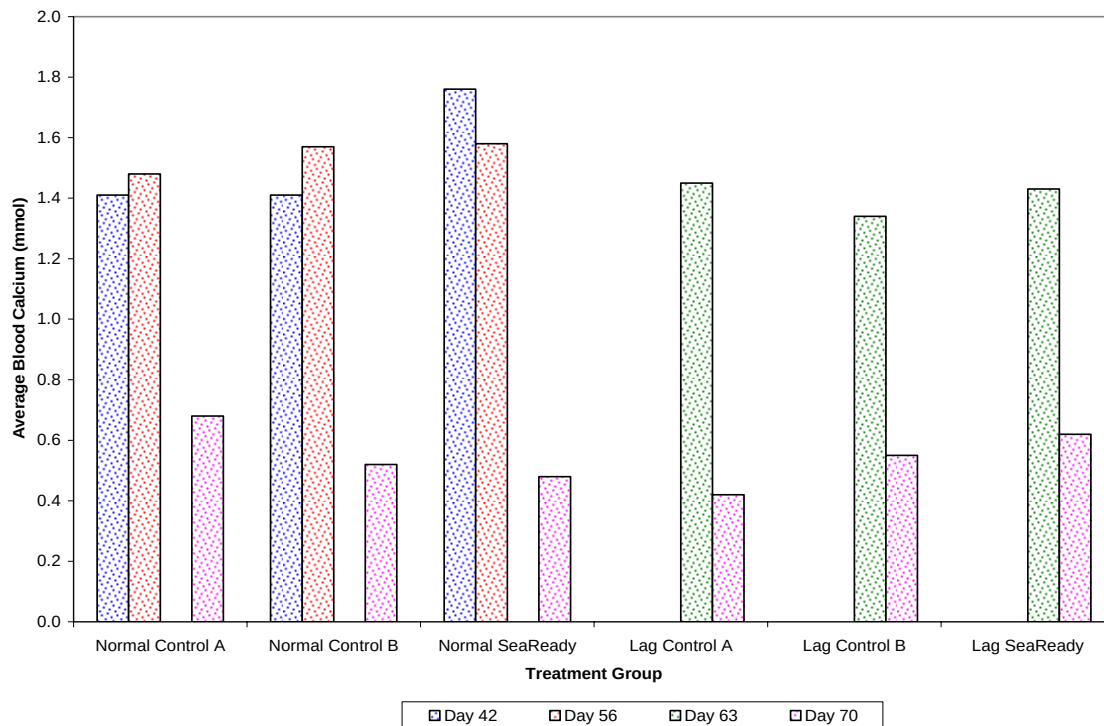


Figure 15. Change in blood calcium levels during seawater rearing. Normal treatment groups were reared in seawater for 6 weeks. Lag treatment groups were only reared in seawater for 3 weeks.

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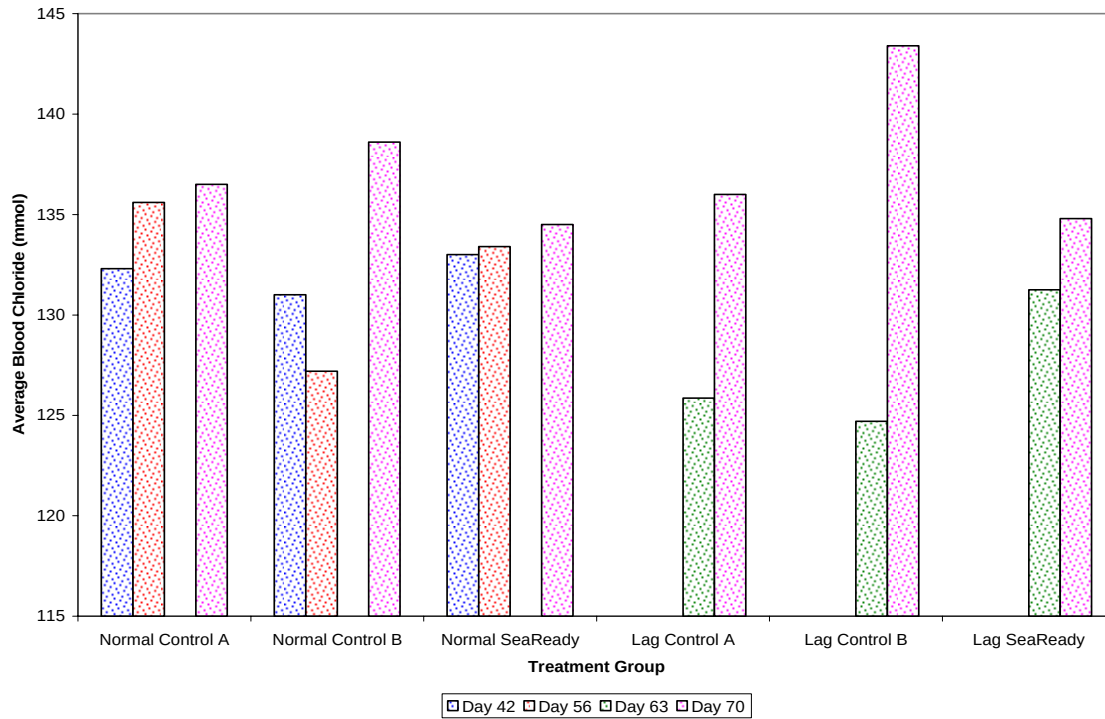


Figure 16. Change in blood chloride levels during seawater rearing. Normal treatment groups were reared in seawater for 6 weeks. Lag treatment groups were only reared in seawater for 3 weeks.

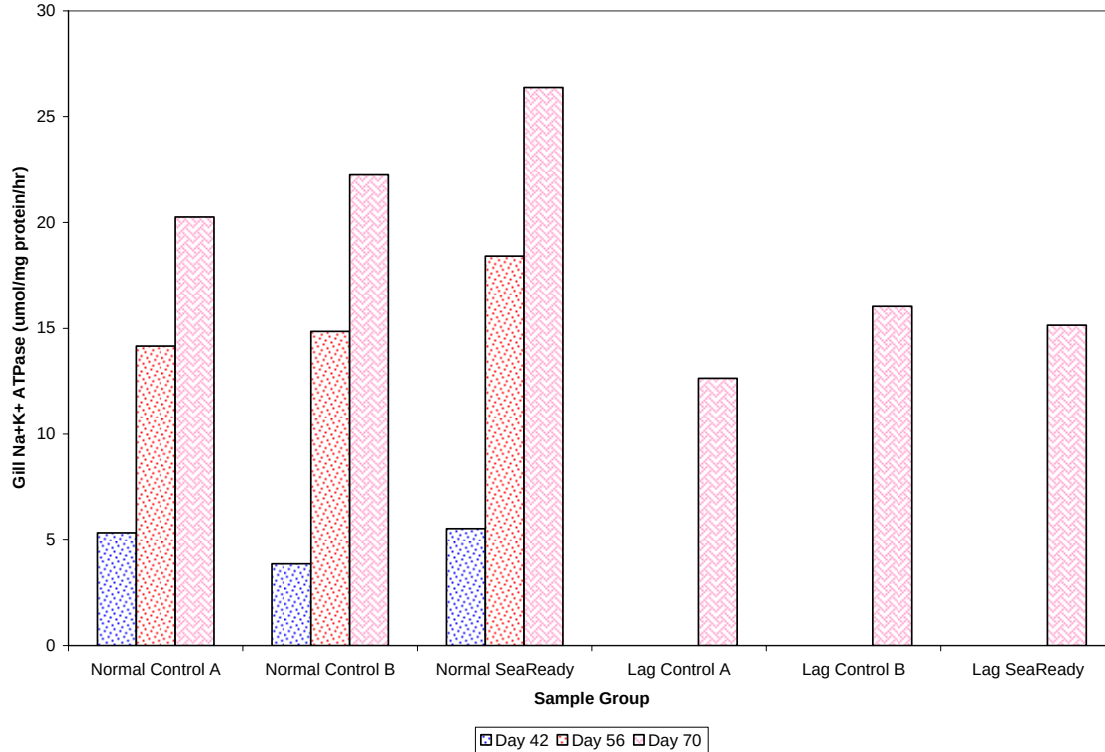


Figure 17. Change in gill Na+K+ ATPase during seawater rearing. Normal treatment groups were reared in seawater for 6 weeks. Lag treatment groups were only reared in seawater for 3 weeks.

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2009 Resurrection Bay Chinook Sport Fish Otolith Report

Background

This report summarizes information on the release and return of Chinook salmon in Resurrection Bay from 2005 through 2009. Releases of Chinook salmon by the Alaska SeaLife Center (ASLC) were funded through the Pacific Coastal Salmon Recovery Fund (PCSRF). The goal of the Alaska SeaLife Center program was to expand opportunities for sport fish harvest of Chinook salmon by supplementing the smolt releases in Resurrection Bay by the Alaska Department of Fish and Game (ADF&G). Smolt releases by the ADF&G involved transporting fish from either the Fort Richardson Army Base or Elmendorf Air Force Base Hatcheries near Anchorage and releasing these fish directly into Resurrection Bay or the Seward Lagoon. By contrast, the ASLC reared and released fish directly from its facility on Resurrection Bay using a combination of freshwater and seawater supplies to produce both age-0 and age-1 smolt. Additional rearing strategies (Sea Ready Process, MariCal Inc.) were also tested to determine if these could improve smolt to adult returns of released fish. Due to changes in funding and project management, detailed results of experimental releases were not available from 2009 return data. As a result, this report provides information for adult returns by facility and smolt age and size at release.

Methods

Creel surveys were conducted each year from 2006 to 2009 to sample adult salmon caught in the sport fishery in Resurrection Bay. Adult fish were collected from private and charter vessels, as well from the beach fishery in the City of Seward. Adult Chinook salmon sampled in these fisheries were measured for length, sex was recorded and otoliths were removed for later identification for hatchery and wild fish contributions. Otoliths were sent to the ADF&G Mark Lab in Juneau, AK for mark identification. Estimates of marine survival and the actual contribution of ASLC and ADF&G releases to the sport fishery are not available because not all Chinook salmon caught in the fishery were reported, so expansion by date and area strata of fish identified by their otolith mark can not be made. Thus, the reported data reflect only the actual recoveries.

Results and Discussion

The total number of Chinook smolt released by the ASLC and the ADF&G since 2005, their age, size and otolith mark code is shown below in Table 1, which also includes the number of fish recovered from each of these releases in the sport fishery. Releases by ADF&G numbered approximately 200,000 in both 2005 and 2006, but there were no further releases through 2008. Releases by the ASLC ranged from ~ n=71,000 in 2007 to > n=140,000 in 2008, which was the last year of Pacific Coastal Recovery Funding and the last year Chinook salmon were released by the ASLC. Size at release ranged from 9.2 gm (ASLC age-0 smolt 2005) to 139 gm (ASLC age-1 smolt 2006). Except for the initial release in 2005 of brood year 2003 fish, all fish released from the ASLC were produced using a combination of freshwater and seawater rearing. Age-1 smolt releases were reared in seawater over winter, whereas age-0 smolt were reared in seawater for approximately two months prior to release. A combination of age-0 and age-1 smolt were

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released from the ASLC in both 2006 and 2007, but only age-0 fish were released in 2008. From 2005 to 2008, a total of n=875,165 Chinook salmon smolt were released by the ASLC (n=443,609) and the ADF&G (n=441,556).

Table 1. Chinook salmon smolt releases and recoveries by facility, location, year and size.

Facility	Release Site	Brood Year	Release Year	Number	Size (gm)	Otolith Mark	Return Year				Total
							2006	2007	2008	2009	
ASLC	ASLC	2003	2005	12,196	85.3	2,5H					
ADFG	Lowell Cr	2003	2005	100,088	18.2	2,5H	2		31		33
ADFG	Lowell Cr	2003	2004	114,847	12.1	2,5H	4				4
ASLC	ASLC	2004	2005	63,950	9.3	2,6H	2		7		9
ASLC	ASLC	2004	2005	7,903	12.3	2,6H					0
ASLC	ASLC	2004	2005	12,653	17.5	2,6H					0
ASLC	ASLC	2004	2006	5,719	119.0	2,6H					0
ASLC	ASLC	2004	2006	5,452	139.0	2,6H					0
ADFG	Lagoon	2004	2006	116,826	13.3	2,3H	4		5	6	15
ADFG	Lagoon	2004	2006	109,795	12.5	2,3H			7		7
ASLC	ASLC	2005	2006	45,895	12.3	1,6H			4	12	16
ASLC	ASLC	2005	2006	19,530	19.2	4,3H			2	2	4
ASLC	ASLC	2005	2007	21,607	105.0	3,3,1H			1	1	2
ASLC	ASLC	2006	2007	69,963	11.3	1,5,1H				5	5
ASLC	ASLC	2006	2007	4,331	11.3	4,2,1H				1	1
ASLC	ASLC	2006	2007	21,941	11.3	3,2,2H					0
ASLC	ASLC	2006	2008	7,478	81.1	1,5,1H					0
ASLC	ASLC	2006	2008	463	81.1	4,2,1H					0
ASLC	ASLC	2006	2008	2,345	81.1	3,2,2H					0
ASLC	ASLC	2007	2008	6,788	12.0	5,2H					0
ASLC	ASLC	2007	2008	7,070	12.0	3,1,3H				1	1
ASLC	ASLC	2007	2008	59,257	11.8	1,3,3H				3	3
ASLC	ASLC	2007	2008	59,068	13.0	4,3H				1	1
ASLC				433,609			2	0	14	26	42
ADFG				441,556			10	0	43	6	59
Other							20	1	8	1	30
Unmarked							22	49	78	22	171

Adult salmon recovered in the sport fishery have been dominated by unmarked fish in each year of sampling (Figure 1). Over all years, unmarked fish represented 57% of the recoveries, and in 2008 comprised 98% of the fish recovered. ADF&G releases represented 20% of the total number of fish sampled for all years, followed by the ASLC (14%) and releases from other hatcheries or locations (10%), which included ADF&G releases into Cook Inlet.

Comparisons of the relative (to release) number of adult salmon recovered each year are difficult to make because the age and size of fish at release varied widely among years and the number of fish recovered from any specific group within years was generally low. Moreover, complete returns for adult salmon with an ocean age of at least three years are only available for the 2005 and 2006 releases. The highest relative recoveries are for ADF&G fish released as age-1 smolt in 2005 (0.033%) and ASLC fish released as age-0 smolt in 2006 (0.035%). Relative recoveries

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with at least $n=5$ fish from other releases were at most $\sim 1/3$ of these rates. For all release years, ADF&G recoveries have been greater ($n=59$) than recoveries of ASLC fish ($n=42$) even though approximately equal numbers of fish were released by these two facilities between 2005 and 2008 ($\sim n=441,000$ and $n=433,000$, respectively). However, since most hatchery Chinook salmon in Alaska typically spend two to three years in the ocean, the majority of ADF&G fish have likely returned (no releases after 2006), whereas returns from ASLC fish released in 2007 and 2008 are mostly incomplete. If these fish are recovered from the fishery at rates comparable to those observed from 2006 to 2008, the relative returns of ASLC salmon released in Resurrection Bay will likely exceed those of fish released by the ADF&G. These fish are expected to return to Resurrection Bay in 2010 and 2011.

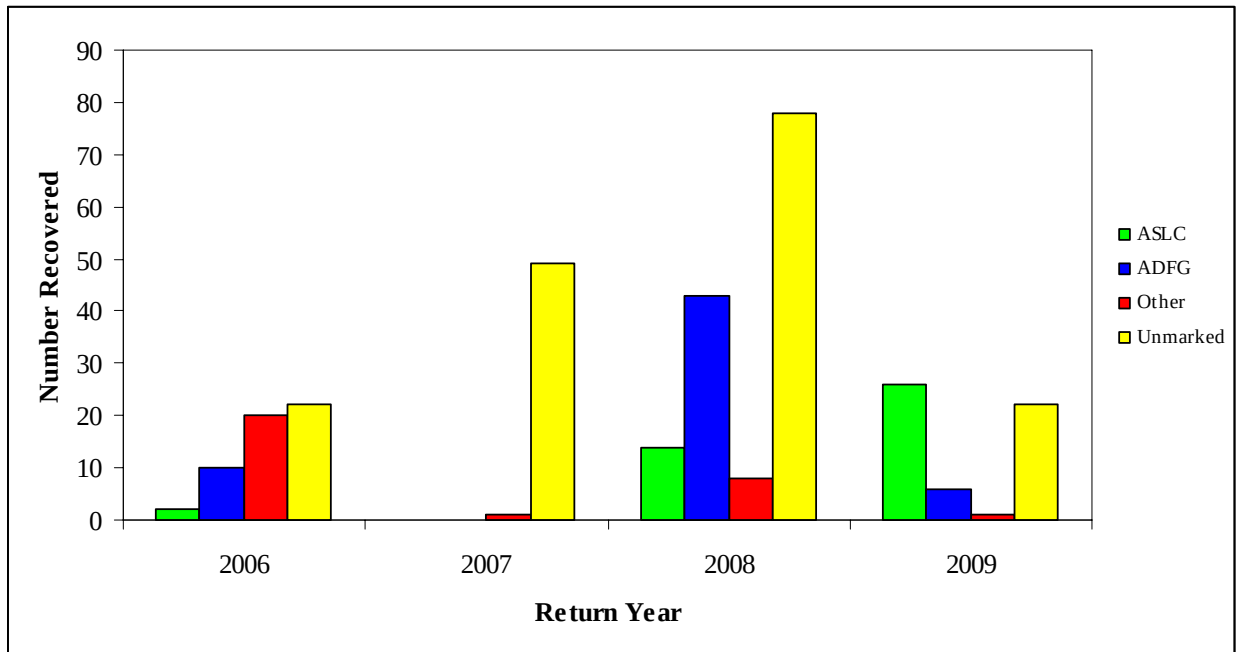


Figure 1. The number of adult Chinook salmon recovered by return year from the sport fishery in Resurrection Bay. Other are hatchery fish released from other facilities (e.g. Prince William Sound) and locations (ADF&G releases in Cook Inlet).

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2008 Adult Coho Sportfish Creel Survey

Background

To determine the contribution of Cook Inlet Aquaculture Association (CIAA) SeaReady™ treated coho to the Resurrection Bay sport fish harvest in 2008, we collected otoliths from fish landed in Seward from during late June, July, August and September 2008. Adult coho harvested in the sport fishery are represented by hatchery releases in Resurrection Bay (CIAA, Alaska Department of Fish and Game), hatchery releases outside Resurrection Bay (Prince William Sound Aquaculture Corporation, Valdez Fisheries Development Association), and natural production from within and outside Resurrection Bay. We assumed that coho smolt released from hatcheries within and outside Resurrection Bay possessed a unique otolith mark to identify their hatchery of origin and to distinguish hatchery fish from naturally produced smolt. In June 2007 ~100,500 SeaReady™ treated smolt (thermal mark H3,1), and 136,500 Control smolt (thermal mark H2,2) were released by CIAA to Bear Lake Creek. In addition, CIAA stocked an additional 447,000 fry (thermal mark H3,3) to Bear Lake that migrated to the ocean during the spring of 2007. An additional 263,703 smolt (thermal mark 2,4H) produced by Department of Fish and Game (ADF&G) were released in the Seward lagoon and at the outlet of the Lowell Creek diversion. Prince William Sound Aquaculture Corporation (PWSAC) and Valdez Fisheries Development Association (VFDA) released approximately 1,850,000 and 1,973,604 coho smolt respectively into Prince William Sound (PWS) in 2007.

Methods

Otolith collection began on June 29, 2008 and was completed on September 7, 2008. The following information was collected for each fish sampled:

1. Sample location (e.g. Captain Jacks, J Dock, Waterfall etc)
2. Date
3. Area fish was caught (i.e. Area 1 – inside the line from X to Y, Area 2 outside the line from X to Y and inside the line from Z to A).
4. Sample number
5. Fork length in millimeters
6. Sex
7. Number of otoliths in sample (1 or 2)

Samples were collected from as many fish as possible on any given day from the charter, private, and beach fisheries. However, due to limitations in funding and the closure of the Salmon Project at the Alaska SeaLife Center (ASLC) no interns were hired and sampling was conducted by two ASLC employees who also had other fish culture and otolith collection duties (Chinook and sockeye). The collection protocol and schedule followed that described in the Scope of Work Project Code 45646. Since our primary purpose was to determine the contribution of SeaReady™ treated fish to the fishery, we assumed the sampling distribution was binomial: SeaReady™ treated and not treated, and 100% of the hatchery fish presumably marked, the sample size needed for a given level of precision would not be affected by the total population

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size. Under this scenario, the maximum sample size needed for a mixed stock fishery where the 95% confidence intervals fall within $\pm 5\%$ of the estimated marked proportion is 400 fish (Beckman et al. 1999). We proposed to sample adult coho according to the schedule below to approximate run strength over the historical five-week peak for the sport fishery. Additionally, because sampling in prior years had shown that the contribution of hatchery and naturally produced fish to the sport fishery differed between Areas 1 and 2, we attempted to collect at least 400 otoliths from each area (800 total). The actual numbers of fish sampled each week varied depending on the timing and strength of the return.

<u>Week</u>	<u>Number sampled or examined</u>
1	50
2	75
3	150
4	75
5	50

Our proposed sampling effort was based on guidelines established from prior otolith collections in Resurrection Bay (Hagen et al. 1995) and from our previous sampling in 2005 and 2006. More specifically, the time allocated to sampling the catches from boat and shore anglers was designed to obtain otolith samples in proportion to the most recent estimates of the annual harvest of 57% from private vessels, 33% from charter vessels and 10% from the shore-based harvest.

Otolith sampling and preparation followed ADF&G protocols. Briefly, otoliths (left and right sagittae) were washed and rinsed in ethanol, dried and stored in 1 ml polyethylene vials for shipment to the ADF&G Mark Lab and post-season identification. Each fish sampled was also measured for fork length. Data were entered into a database on a weekly basis. At the end of the season, the data were summarized by statistical week, area caught and fishery type (charter, private, beach). A sub-sample ($n = 400$ from Area 1 and $n = 400$ from Area 2) from the total number of otoliths collected was sent to the Mark Lab for identification. Otoliths in the sub-sample were selected to approximate the harvest effort by gear type and statistical week within each area (i.e. private, charter and beach fisheries).

Results

A total of 1476 fish were sampled from June 9 to September 7, 2008 (Table 1). The majority of the fish sampled (88.28%) were caught in Area 2, of which 79.7% were from the charter fleet and 20.3% were from private vessels. In Area 1 (11.72% of the total fish sampled), 0% of the samples were obtained from the charter fishery, 93.1% from private vessels and 6.9% from the beach catch. For combined areas (Area 1 & 2), the charter fishery contributed 70.33% of the samples, private boats 28.86% and the beach fishery 0.81%.

A sub-sample of $n=666$ otoliths was sent to the Mark Lab for identification ($n = 173$ from Area 1 and $n = 493$ from Area 2). Overall, the charter fishery represented 51.5% of all the samples submitted, the private fishery accounted for 46.7% and the beach fishery 1.80%. Among the $n=666$ samples submitted to the Mark Lab, $n= 651$ otoliths were readable. Approximately 70.27% were from unmarked fish and 27.48% were from marked fish. A greater proportion of

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unmarked fish were collected in Area 2 (58.96%) than in Area 1 (74.24%). The largest hatchery contribution (45.90%) measured as the percent of marked fish was provided by VFDA (5.80% in Area 1 and 70.18% in Area 2). This was followed by ADF&G contribution of 27.87% overall. PWSAC origin coho represented 19.13% of the marked fish captured of the marked samples collected in both areas. The total CIAA contribution to the fishery in 2007 was 7.10%.

Of the n=51 fish identified as ADF&G, n=47 were from BY 2005 and n=3 from BY 2004 Resurrection Bay releases. One fish from BY 2005 was identified as a Cook Inlet release. For 13 fish identified as CIAA, six were from BY 2004 Bear Lake fry stocking, three were from BY 2005 Bear Lake fry stocking and remainder (n=4) were from BY 2005 smolt release (Control group). No SeaReady™ fish were identified.

In comparison to past years (2005 and 2006) in which the sampling/fishing effort ratio was approximately 1:3 (Area 1: Area 2), the ratio in 2007 increased to 1:7.5 (Area 1: Area 2). The technicians that conducted the sampling indicated that fewer people were beach fishing in 2007 compared to 2005 and 2006. Whether this was due to fewer fish in the beach areas or weather related is not known. However, CIAA was able to fulfill the coho broodstock and escapement requirements at Bear Lake indicating that there were fish present in the near shore area although possibly at a later time (mid- September) than in 2006 (late August). Figure 1 shows the daily and cumulative coho counts at Bear Lake weir. Note that returns peaked between September 13 and 24, 2008, 1 -2 weeks after ASLC otolith creel collection had been completed. Hence it is possible that the CIAA contributions were under represented in the fishery. Unfortunately, both CIAA and ASLC did not collect any otoliths from returning adults at the weir.

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Area	Stat Week	Total Samples Collected				Total Samples Selected			
		Charter	Private	Beach	Total	Charter	Private	Beach	Total
Area 1	27	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0
	31	0	0	0	0	0	0	0	0
	32	0	20	0	20	0	20	0	20
	33	0	38	0	38	0	38	0	38
	34	0	63	0	63	0	63	0	63
	35	0	27	0	27	0	27	0	27
	36	0	9	6	15	0	9	6	15
	37	0	4	6	10	0	4	6	10
Total Area 1		0	161	12	173	0	161	12	173
% Selected Area 1		0.00%	93.06%	6.94%		0.00%	93.06%	6.94%	
Area 2	27	31	1	0	32	10	0	0	10
	28	241	40	0	281	80	22	0	102
	29	317	35	0	352	105	20	0	125
	30	169	62	0	231	56	35	0	91
	31	219	2	0	221	72	1	0	73
	32	61	54	0	115	20	31	0	51
	33	0	52	0	52	0	30	0	30
	34	0	19	0	19	0	11	0	11
	35	0	0	0	0	0	0	0	0
	36	0	0	0	0	0	0	0	0
	37	0	0	0	0	0	0	0	0
Total Area 2		1038	265	0	1303	343	150	0	493
% Selected Area 2		79.66%	20.34%	0.00%		69.57%	30.43%	0.00%	
Total All Areas		1038	426	12	1476	343	311	12	666
% Selected All Areas		70.33%	28.86%	0.81%		51.50%	46.70%	1.80%	

Table 1. The total number of samples collected and the number of samples submitted to the Mark Lab from sampling Areas 1 and 2 and by fishery types (charter, private, beach).

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Area	Stat Week	# Selected	# UnMarked	# Marked	ADF&G	CIAA	VFDA	PWSAC
Area 1	27	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0
	31	0	0	0	0	0	0	0
	32	20	12	8	1	1	2	4
	33	38	28	10	6	1	1	2
	34	63	39	24	14	6	1	3
	35	27	13	20	19	1	0	0
	36	15	6	7	4	3	0	0
	37	10	4	0	0	0	0	0
Area 1 Total		173	102	69	44	12	4.00	9
% Total			58.96%	39.88%	25.43%	6.94%	2.31%	5.20%
% Marked					63.77%	17.39%	5.80%	13.04%
Area 2	27	10	9	1	0	0	1	0
	28	102	82	16	1	0	14	1
	29	125	110	17	1	0	11	5
	30	91	56	30	0	0	23	7
	31	73	50	24	1	0	17	6
	32	51	34	15	1	0	10	4
	33	30	18	9	1	1	4	3
	34	11	7	2	2	0	0	0
	35	0	0	0	0	0	0	0
	36	0	0	0	0	0	0	0
	37	0	0	0	0	0	0	0
Area 2 Total		493	366	114	7	1	80	26
% Total			74.24%	23.12%	1.42%	0.20%	16.23%	5.27%
% Marked					6.14%	0.88%	70.18%	22.81%
Total All Area		666	468	183	51	13	84	35
% Total			70.27%	27.48%	10.34%	1.95%	17.04%	5.26%
% Marked					27.87%	7.10%	45.90%	19.13%

Table 2. The number of unmarked and marked samples identified by the Mark Lab and hatchery contribution for Areas 1 and 2.

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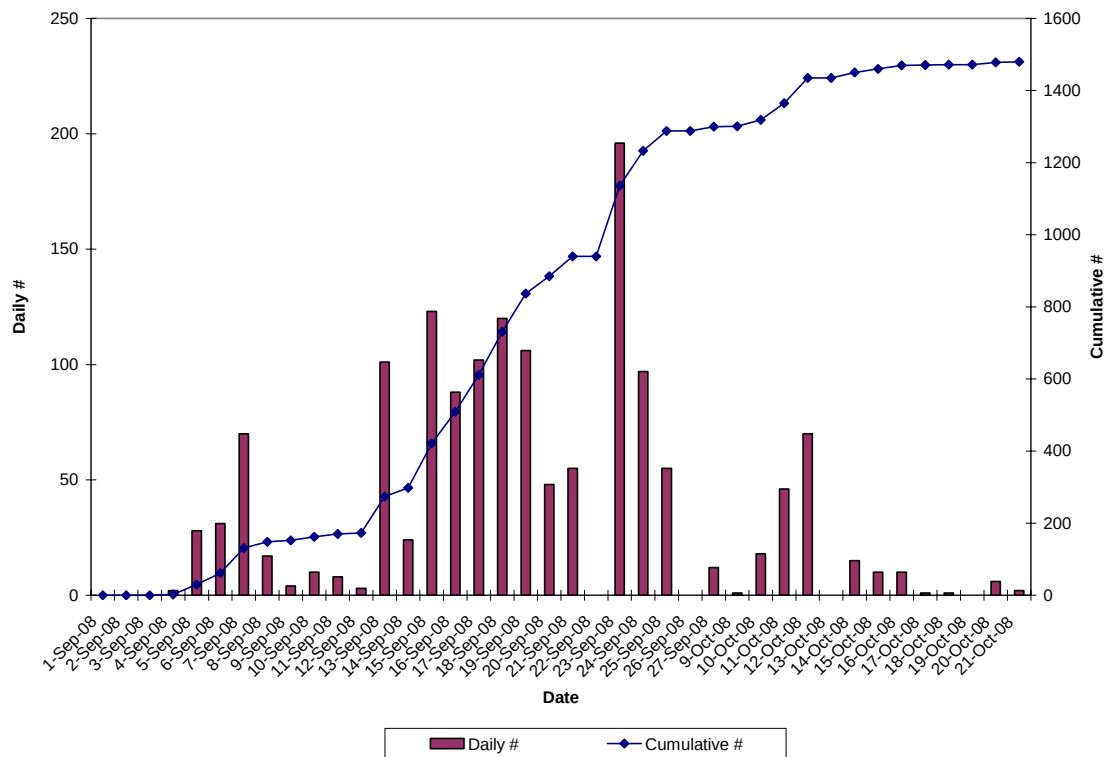


Figure 1. Daily and cumulative counts of returning adult coho salmon to Bear Lake Weir in 2008.

Economic Impact of Enhanced Salmon in Resurrection Bay

*Prepared for:
Alaska SeaLife Center*



Research-Based Consulting

Juneau
Anchorage
Kodiak

October 2007

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*Prepared for:
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PREPARED BY:



Juneau • Anchorage • Kodiak

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Executive Summary

This study examines the contribution that hatchery releases make to the sport fishery in the Seward/Resurrection Bay area. It estimates the economic impact of these enhancements, and considers the potential for other kinds of run enhancements in the area, as well.

Saltwater sport fishing activity is an important part of the economies of numerous coastal Alaska communities including Seward. Alaska's salmon resource draws thousands of Alaska resident and non-resident anglers, alike. Halibut, rockfish, trout, and other species also contribute to the sport fishing opportunity. The economic impact of sport fishing includes all the spending on goods and services in support of the fishing activity. This may include charter services, lodging, food and other goods and services purchases by non-residents, and fuel, bait, gear and boat-related expenses.

In certain marine and freshwater systems in Alaska, including several river systems in the Seward/Resurrection Bay area, wild salmon resources are complemented by hatchery enhancement programs. In the Seward area, hatcheries augment wild runs through coho, sockeye, and chinook production and releases. Some of the salmon released in these programs return to the area and are harvested in the regional sport fisheries.

Assessing the economic impact of a particular species targeted in a sport fishery presents significant challenges. Participation in sport fisheries is driven by many factors that are not directly related to the type, volume or count of harvested fish. Participants may derive value by simply being on the water, experiencing a new location, viewing fish and wildlife, or recreating with friends. In an activity where adding one more fish to the day's catch may only marginally increase the angler's perceived value of the experience, how are values assigned to individual fish or the number of fish harvested? In fact, per-fish values in sport fisheries are only minimally meaningful.

Nevertheless, the availability of the sport fishing resource, including wild run fish and enhanced (hatchery) fish, contribute to the sport fishery and its economic activity.

Sport Fishing Activity in the Seward Area

Measures of sport fishing activity in the Seward area include:

- In 2006, there was a total of 102,239 sport fishing angler days in the North Gulf Coast. Of these, 30,200 were on charter boats, 59,800 were on private vessels, and 12,200 were shore-based.
- Approximately 36 percent of the vessel-based sport fishing activity in the North Gulf Coast is estimated to be in pursuit of salmon species. Effectively all of the shore-based fishing is in the pursuit of salmon.
- Coho salmon were the most significant in terms of catch and harvest (retained catch), accounting for 36 percent and 44 percent, respectively.

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- Halibut was the second most important species (after coho), accounting for 29 percent of catch and 27 percent of harvest. Other salmon were 23 percent of catch and 21 percent of harvest.

Role of Hatchery-Produced Salmon

The economic impact of sport fishing depends on much more than the number of fish available for catch and harvest. Still, resource availability plays a role in fishing effort and therefore economic impact. Would investment in additional hatchery production (or in habitat enhancement for wild fish) lead to greater sport fishing-related economic activity? And, further, would this additional economic activity outweigh the costs of additional hatchery production? This analysis suggests the answer to both questions is, in general, yes.

- Approximately one-third of the coho and one-half of the chinook salmon harvested are thought to be from hatchery sources.
- Therefore, the total sport fishing effort attributable to hatchery-origin salmon in the Seward-area fisheries is estimated at 14,700 days for coho salmon and 1,275 days for chinook in 2006.
- Of this effort, approximately 60 percent is by resident Alaskans and the remainder by non-Alaska residents. The total direct economic impact of these fishing activities is estimated at \$2.6 million annually.
- Including the indirect and induced economic impacts, the total estimated impact rises to \$3.9 million.

Estimated Direct Expenditures by Sport Fishermen harvesting Hatchery-Raised Coho, 2006

	Resident	Non-Resident	Total
Angler days attributable to hatchery coho	9,300	5,500	14,700
Angler days attributable to hatchery chinook	675	400	1,275
Angler expenditures per day	\$51	\$355	
Total estimated expenditures	\$500,000	\$2,100,000	\$2,600,000

Source: McDowell Group estimates; expenditure data from USFWS, adjusted to 2006 dollars.

Note: Rows may not sum to totals due to rounding.

Estimates include food and lodging, transportation, boating costs (boat launching, mooring, storage, maintenance, insurance, pump-out fees and fuel), other trip costs (equipment rental, guide and access fees, ice and bait for fishing, and heating and cooking oil). Additional expenditures for fishing equipment also occur. However, we assume that these equipment expenditures would also occur in the absence of the hatchery resource; they are not included in the economic analysis

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- Depending on a number of factors, the economic impact of hatchery releases is estimated at approximately \$20,000 to \$30,000 per 10,000 coho smolt or fry released. This compares to a cost of production that averages \$4,700 per 10,000 smolt and less—approximately \$1,200—per 10,000 fry.¹
- Based on these estimates hatchery production has a positive return on investment, in terms of benefit to the Seward economy. For every dollar spent on hatchery production the community realizes at least \$4 in local economic activity.
- It is important to note that the addition of more salmon to the fishery resource does not guarantee increased economic impact. Sport fishing activity also relies on adequate support infrastructure, effective marketing, and other elements.

OTHER MECHANISMS FOR AFFECTING SPORT FISH IMPACT

While this report specifically considers the economic impact of hatchery salmon in the Seward-area sport fisheries, other mechanisms for enhancing salmon runs also can be expected to affect the overall impact of the fishery. Among these would be river system enhancements that support wild run salmon. Though it is beyond the scope of work for this project to conduct a cost/benefit analysis for any specific enhancement proposal, it is clear that an increase of salmon available to fisheries, supported by other necessary infrastructure and business investment, would be expected to increase the economic impact of salmon sport fishing in the region.

¹ The cost of producing coho fry and smolt depends on numerous factors including, importantly, economies of scale. The figures presented here are specific to production in the Seward area, but can be expected to fluctuate moderately. In recent years, costs for producing fry have been significantly lower than \$1,200 per 10,000, but this figure is considered a reasonable long-term cost estimate.

Introduction

The Alaska SeaLife Center (ASLC) is a research and public education facility located in Seward, Alaska, on the shores of Resurrection Bay. The SeaLife Center includes a state-of-the-art marine aquarium, extensive research and animal rehabilitation laboratories, and serves as a workplace for staff scientists and visiting or affiliated researchers. ASLC is also an important component of the economy of Seward.

Research Purpose

Scientists at the Alaska SeaLife Center conduct research on the husbandry of Alaska salmon. The organization raises chinook salmon on-site, and partners with the Cook Inlet Aquaculture Association (the private non-profit hatchery for the Kenai Peninsula region) to raise coho salmon for research purposes. Coho salmon enhancement has occurred in Resurrection Bay for decades, but ASLC involvement dates only to 2004. The various salmon enhancement research projects conducted by ASLC include research into methods for speeding the development time of salmon smolt into ocean-ready fish. Potential future projects include studying returning chinook salmon for information on sea conditions, contaminants, and other oceanographic and environmental indicators.

Salmon released by the Alaska SeaLife Center, as well as other salmon enhancement organizations such as the Cook Inlet Aquaculture Association (CIAA) and the Alaska Department of Fish and Game (ADF&G), contribute to the sport and commercial fisheries in the Seward region and beyond.

The purpose of this research is to measure the contribution of the sport-harvested hatchery salmon on the regional economy. The research considers the contribution of the enhancement activities to the overall salmon run, and considers the resultant economic impacts of sport salmon fishing by visiting and resident fishermen on the Seward economy. This information will contribute to a better understanding of the way sport-caught fish support economic activities in Seward.

Methodology & Data Sources

The McDowell Group used primary and secondary research to support the economic impact estimates presented in this report. Our research combined data on hatchery returns, sport catches and harvests, and sport fishing effort with information on resident and non-resident angler expenditures, visitor data, and other information collected in interviews and through a variety of economic data sources.

Methodology

This research relied on numerous data sources and information sources to support the economic impact estimates.

Site Visits

The research team met with Alaska SeaLife Center staff and conducted a site visit of the ASLC research laboratories. The team developed an understanding of ASLC's salmon research programs, as well as the greater enhancement programs in Resurrection Bay. These include programs run by the Alaska Department of Fish and Game (ADF&G) and the Cook Inlet Aquaculture Association (CIAA).

Fishery Data

The team collected data from various ADF&G sources. Data on hatchery/enhancement releases and returns were taken from the draft 2007 Annual Management Report (AMR) for the North Gulf Coast salmon management area. This included information on the release of smolt and fry for three salmon species, by location.

The 2007 AMR also provided data on sport fishing effort, catch, and harvest, by species or species group. This data was supplemented with charter vessel logbook data, provided by ADF&G through special data requests. This data provided information on the importance of coho and chinook species as a part of total sport fishing activity in Seward. It also provided information on catch versus retained harvest. The logbook data revealed important information about charter boat anglers' targeted species, in contrast to those species that were actually caught or retained. This is an important consideration, as time spent targeting does not translate directly into catch or harvest. The study team assumed that the relative effort on different species, as demonstrated by the charter log books, was a reasonable proxy for the relative effort of the private boat fleet. The study team also considered comparative data on angler effort (days or parts of days spent fishing) from shore, private boats, and charter boats.

To estimate the economic contribution of the hatchery/enhanced salmon fisheries, it was necessary to estimate the percentage of the total sport salmon harvest that is of hatchery fish. In the summers of 2003-2005, ADF&G biologists conducted otolith (ear bone) studies on coho salmon landed at the port of Seward. The work is currently unpublished, but preliminary data were available. The data showed that approximately one-quarter to one-third of the coho salmon landed in Seward annually were of hatchery origin. ADF&G's work showed that the proportion of hatchery fish increases significantly as the season progresses. This is likely

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because silver salmon from wild-run streams have already entered those streams further out from the head of Resurrection Bay, while hatchery fish are congregating at the terminal areas at the head of the bay (in Seward), where they are easily harvested.

Economic and Demographic Data

To estimate the economic impact of the hatchery-raised component of Seward's sport fishery, the research team collected data on angler expenditures, visitor trends, local participation, and other economic indicators. Individuals participating in sport fisheries can expend money on a variety of goods and services, from fishing tackle to lodging, to charters, to food. While no single data source compiles all this information, a number of indicators provide input that helps form the basis for sound estimates.

Angler expenditure data for Alaska residents was provided by the "2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Alaska," which was jointly conducted by numerous agencies in the US Departments of Commerce and the Interior. The expenditure data was adjusted for inflation using the consumer price index ratios for Anchorage, Alaska, as provided by the US Bureau of Labor Statistics. Data on visitor trends and activities for non-resident visitors came from the 2006 Alaska Visitor Statistics Program (AVSP), a comprehensive survey project conducted by the McDowell Group for the Alaska Department of Commerce, Community and Economic Development. Additional data on the Alaska visitor industry come from the McDowell Group's statewide tourism research program, the Alaska Travelers Survey, from 2001, 2003, and 2005.

Executive Interviews

The research team spoke with business and government personnel to develop a refined understanding of the dynamics of the Seward sport fisheries. Interviewees ranged from Chamber of Commerce staff to municipal finance staff to individual charter business and hotel operators.

Literature Search

The research team also reviewed existing economic research on sport fishing in Seward and other relevant research looking at sport fisheries in Alaska. Included in the review were:

- Criddle et al. *Participation Decisions, Angler Welfare, and the Regional Economic Impact of Sportfishing*. Marine Resource Economics, Volume 18 (2003), pp. 291-312.

This paper explores the relationship between the regulatory availability of fishery resources (in this case, halibut) and the potential economic impact of shifts in resource availability on the Kenai Peninsula. The scenarios presented by the researchers in their survey instrument included varying catches of salmon species (chinook and coho) but their analysis and paper address only those outcomes related to halibut. Nevertheless, the authors provide an excellent overview of the challenges of researching sport fish impact, and present the pros and cons of several approaches.

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- *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Alaska*. U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. Revised March 2003.

The survey provided information on fishing, hunting, and wildlife viewing activities in Alaska by U.S. residents; and that by Alaska residents in Alaska or elsewhere in the United States. The survey was first conducted in 1955, and is the tenth in a series.

The survey provides data on expenditures by sport fishermen, hunters, and people engaged in wildlife viewing, among other data. Trip expenditures for Alaska residents, participating in Alaska sport fisheries, were \$81 per day in 2001. Expenditures for non-Alaska residents were \$320 per day.

- Haley et al. *Economics of Sport Fishing in Alaska*. Institute for Social and Economic Research, University of Alaska Anchorage. December 1999.

The research by the Institute of Social and Economic Research (ISER) examined the economic significance of sport fishing activity in Alaska in 1993. Estimates of resident and non-resident impact were prepared. The research included an angler survey and data from secondary sources. ISER's analysis included breakdowns to the Southeast, Southcentral, North, and Southwest regions of Alaska.

- Herrman et al. *An Economic Assessment of the Sport Fisheries for Halibut, and Chinook and Coho Salmon in Lower and Central Cook Inlet*. University of Alaska, Coastal Marine Institute. April 2001.

This study modeled participation rates by sport fishermen in Cook Inlet, depending on variables related to trip cost and catch. Predicted changes in participation were also linked to predicted increases or decreases in economic output from the sport fish activities on the Kenai Peninsula. For example, the researchers' model predicted that a 10 percent decrease in the availability of salmon and halibut from the base year of 1997 would result in a 23 percent decrease in value (from the same year).

- King, Jonathan to Bud Alto, memorandum regarding *Hatchery Valuation Analysis*, May 21, 2004, Northern Economics.

This research provided a valuation of the hatchery-produced fish in Alaska's sport fisheries. The researchers looked at enhanced anadromous and non-anadromous systems throughout the state and estimated the economic output generated by the state's investment in enhancement. This work estimated the value of hatchery chinook and coho salmon in the Resurrection Bay area at between \$3.0 and \$4.5 million.² This research also estimated an indirect effect multiplier of 1.486.

² The Northern Economics research attributed 50 percent of the harvest of fish in the Resurrection Bay system to hatchery-produced fish.

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- Romberg, William. *Market Segmentation, Preferences, and Management Attitudes of Alaska Nonresident Anglers*. Graduate thesis, Virginia Polytechnic Institute and State University. December 16, 1999.

Romberg's work examined preferences and characteristics of Alaska's non-resident sport fishing participants. Among findings relevant to our research was that non-resident fishermen place higher importance on the aesthetic characteristics of the sport fisheries (scenery, wildlife viewing, etc.) than on the opportunity than "catch-related attributes," such as bag limit or species mix.

The Seward Economy

Seward is a small community of approximately 4,500 people. The economy is based largely on the community's natural resources (including marine resources and its status as the home-base for Kenai Fjords National Park) and on the State of Alaska correctional facility located there. Natural resources support sport and commercial fishing, a busy wildlife-viewing and park tour industry, and the research at the ASLC.

Data sources for considering income and employment in Alaska are very detailed for the wage and salary portion of the economy. This data is based on unemployment insurance quarterly filings, which every employer is obligated to provide to the state. For other sectors of the economy, though, where self-employment and contract work are the general rule (such as charter boat operations or commercial fishing) data are sparse.

Seward's economy does support a number of the self-employed/contract worker positions, particularly in seasonal jobs. However, employment and earnings data provide excellent information on a large portion of the community economy.

The list of the top 10 wage and salary employers in Seward in 2006 is topped by the Alaska Department of Corrections. The Spring Creek Correctional Center, a maximum security prison, is located in the community, and employed an annual average of 178 people in 2006. The Alaska SeaLife Center is the second-largest employer, with an annual average of 143 employees. Providence Hospital and Icicle Seafoods are third and fourth, and are the only other employers with an annual average of more than 100 employees (112 and 103, respectively).

Table 1
Seward Top Ten Employers, 2006

Employer	Number of Employees (Annual Average)
Alaska Department of Corrections	178
Alaska SeaLife Center	143
Providence Hospital	112
Icicle Seafoods	103
City of Seward	99
Kenai Peninsula Borough School District	96
Ocean Beauty Seafoods	89
Safeway	85
Alaska Vocational and Technical Center (AVTEC)	79
CIRI Alaska Tourism Corporation	56

Source: Alaska Department of Labor and Workforce Development

Annual wages in Seward totaled \$75.5 million in 2006, and average annual employment was 2,288 people. Average wages were approximately \$33,000 annually. These figures exclude income by individuals who are self-employed.

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Table 2
Employment and Earnings, Seward, 2006

Description	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg Empl	Wages (million \$)	Avg Annual Wages
TOTAL, ALL INDUSTRIES	1,807	2,475	3,026	1,842	2,288	\$75.5	\$33,024
TOTAL FEDERAL GOVERNMENT	41	68	80	44	58	\$2.8	\$47,736
TOTAL STATE GOVERNMENT	357	356	350	378	360	\$17.3	\$48,030
TOTAL LOCAL GOVERNMENT	213	224	184	214	209	\$8.6	\$41,031
TOTAL PRIVATE	1,196	1,827	2,413	1,206	1,661	\$46.9	\$28,254
Goods-Producing	224	319	554	186	321	\$9.4	\$29,245
Natural Resources and Mining	9	11	22	22	16	-	
Mining	9	11	22	22	16	-	
Construction	55	54	59	62	58	\$1.8	\$30,457
Construction of buildings	25	26	28	29	27	-	
Heavy and civil engineering construction	1	-	-	1	1	-	
Specialty trade contractors	29	28	31	32	30	\$1.0	\$33,090
Manufacturing	160	254	473	102	247	\$6.7	\$27,180
Durable Goods Manufacturing	50	57	41	39	47	-	
Transportation equipment manufacturing	49	57	41	39	46	-	
Ship and boat building	49	57	41	39	46	-	
Furniture and related manufacturing	1	1	-	-	-	-	
Nondurable Goods Manufacturing	110	196	432	64	201	-	
Seafood product prep and pkg	110	196	432	64	201	-	
Service-Providing	972	1,508	1,859	1,020	1,340	-	\$28,017
Trade, Transportation, and Utilities	297	491	618	297	426	\$37.5	\$29,565
Wholesale Trade	45	56	69	50	55	\$12.6	
Retail Trade	170	210	233	163	194	-	\$22,181
Transportation and Warehousing	82	224	316	84	177	\$4.3	\$35,743
Scenic and sightseeing transportation	49	175	239	48	128	\$6.3	\$33,148
Support activities for transportation	13	24	47	13	24	\$4.2	
Information	8	8	8	8	8	-	
Financial Activities	23	26	26	21	24	-	\$27,059
Finance and insurance	9	10	10	10	10	\$0.7	
Real estate and rental and leasing	14	16	16	11	14	-	\$25,006
Professional and Business Services	27	33	41	26	32	\$0.4	\$44,893
Professional, Scientific and Tech Services	5	7	8	5	6	\$1.4	\$25,162
Management of Companies and Enterprises	19	19	20	18	19	\$0.2	
Admin & Support & Waste Management & Remediation Services	3	7	13	3	7	-	\$15,494
Educational Services	-	2	3	1	1	\$0.1	
Health Care and Social Assistance	217	224	234	224	225	-	\$35,328
Hospitals	110	110	113	113	112	\$7.9	
Social assistance	90	99	104	94	97	-	\$22,415
Leisure and Hospitality	308	625	828	342	526	\$2.2	\$23,603
Arts, Entertainment, and Recreation	141	176	201	134	163	\$12.4	
Accommodation and Food Services	167	449	627	208	363	-	\$18,583
Accommodation	92	224	307	96	180	\$6.7	\$21,355
Food services and drinking places	75	225	320	112	183	\$3.8	\$15,862
Other Services	91	100	98	99	97	\$2.9	\$21,299
Unclassified	-	-	4	2	1	\$2.1	

Source: Alaska Department of Labor and Workforce Development

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In 2006, the Kenai Peninsula Borough reported gross sales of \$198.3 million in Seward. Approximately 40 percent of total sales occurred in the third quarter, or July through September. Retail (\$44.3 million, 22 percent), construction (\$38.3 million, 19 percent) and wholesale (\$27.7 million, 14 percent) accounted for the largest portions of gross sales. Other important contributors included transportation/warehousing, and accommodations and food service.

Table 3
Seward Gross Sales, 2006

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	TOTAL
Agriculture, Forestry, Fishing, Hunting	\$37,988	\$37,198	\$199,754	\$357,787	\$632,727
Mining	28	96	-	48,714	48,838
Utilities	751,746	964,113	1,230,113	1,055,935	4,001,907
Construction	1,781,517	7,478,292	9,574,088	19,492,445	38,326,342
Manufacturing	1,131,882	3,279,075	4,079,526	1,920,026	10,410,509
Wholesale	3,994,826	6,886,194	8,673,074	8,103,529	27,657,623
Retail	6,534,240	12,422,602	17,799,109	7,568,653	44,324,604
Transportation, Warehousing	533,155	6,327,756	13,557,638	1,214,331	21,632,880
Information	845,840	887,963	1,359,647	1,066,349	4,159,799
Finance and Insurance	2,866	2,834	3,291	93,168	102,159
Real Estate, Rentals, Leasing	1,744,363	2,174,552	2,235,361	3,120,585	9,274,861
Professional, Scientific, Technical	563,701	477,596	686,373	1,088,513	2,816,183
Management of Companies, Enterprises	-	-	-	-	-
Administration, Support, Waste Management	203,082	354,768	480,483	207,637	1,245,970
Educational Services	48,750	28,246	18,417	11,110	106,523
Health and Social Services	360,405	439,935	468,006	649,355	1,917,701
Arts, Entertainment, Recreation	1,004	942,261	1,886,398	19,765	2,849,428
Accommodations, Food Services	1,343,141	5,897,749	10,950,645	1,375,759	19,567,294
Other Services	519,193	1,092,491	887,848	586,871	3,086,403
Public Administration	1,297,827	1,447,992	1,647,369	1,766,151	6,159,339
TOTAL	\$21,695,554	\$51,141,713	\$75,737,140	\$49,746,683	\$198,321,090

Source: Kenai Peninsula Borough, Economic Analysis. Retrieved from <http://www.borough.kenai.ak.us/Econ/default.htm> on July 16, 2007. Data last updated March 28, 2007.

Some important sectors of the economy are not captured in employment and earnings data and/or gross sales data. Commercial fishing is excluded from employment and earnings and gross sales. (Commercial fishermen are self-employed and therefore excluded from employment and earnings data. Sales of

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commercially harvested seafood are not subject to sales or other taxes and are therefore not captured in gross sales data.) The majority of charter fishing is excluded from employment and earnings data, because charter operators and crew are typically self-employed. Gross sales data are available for the charter fleet.

In 2006, 64 Seward residents held commercial fishing permits. In 2005, the last year for which the data was available, 102 Seward residents held commercial crew licenses. Not all of these permits are for fisheries that occur in the Seward region. Some residents participate in fisheries in Prince William Sound, Kodiak, or Bristol Bay, for example. However, a portion of their earnings from these fisheries can be assumed to enter the economy of the community in which they reside.

Table 4
Commercial Fishery Participation and Earnings
by Seward Resident Permit Holders, 2001-2006

	Number of permit holders	Number of fishermen who fished	Number of permits fished	Total pounds landed	Estimated gross earnings
2001	77	48	79	8,749,000	\$5,421,000
2002	74	45	68	6,831,000	\$5,513,000
2003	65	41	61	5,072,000	\$6,382,000
2004	65	46	65	4,232,000	\$6,275,000
2005	62	47	69	4,374,000	\$5,619,000
2006	64	38	57	5,233,000	<i>not available</i>

Source: Alaska Commercial Fisheries Entry Commission, Permit and Fishing Activity. Retrieved from http://www.cfec.state.ak.us/gpbycen/2006/00_ALL.htm; June 10, 2007.

Fish landed in the port of Seward also contribute to the local economy, regardless of the residence of fishermen landing them.

The charter fleet also is characterized by high levels of self-employment. While this means employment data is not available for the fleet, the Kenai Peninsula Borough collects data on the gross sales by sport fish charter businesses. Though the data may not capture every sport fish charter operation in Kenai, it does account for the great majority of them.

Data from the Kenai Peninsula Borough shows that gross sales for sport fish charters in Seward in 2006 were approximately \$6.8 million, with two-thirds of those sales occurring in the third quarter (July through September).

Table 5
Gross Sales by Sport Fish Charter Fleet, Seward, 2006

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Total
Gross sales	\$61,900	\$1,673,400	\$4,472,000	\$612,000	\$6,819,300

Source: Kenai Peninsula Borough Gross Sales Data, special data request.

The Sport Fishery in Seward

In order to assess the economic impact of sport-harvested hatchery salmon on Seward's economy, the study team examined the structure of the sport fishery in the area. Data from ADF&G and the City of Seward provided insight into the composition of the sport boat fleet, as well as information on the shore-based fishery. Additionally, data on species mix for catch, harvest, and effort were considered.

Characteristics of the Seward Sport Fleet

Sport fishing is executed by one of three primary means: from shore, from personal/private vessels, and from charter vessels. Understanding the relative role of each of these sectors helps us understand the sport fishery overall, including resident and non-resident participation.

Charter Boats Home-Ported in Seward

The number of licensed charter boats home-ported in Seward is the best measure of the size of the charter fleet. Charter vessel logbook data from ADF&G provides a count of the number of licensed charter boats that register with Seward as their home port. (Some vessels register with more than one homeport.) Since 2000, the number of licensed charter boats with their home port in Seward has increased 49 percent, from 92 boats to 137 boats.

Table 6
Licensed Charter Boats
Home Port Seward

Year	Licensed Boats
2000	92
2001	96
2002	91
2003	92
2004	107
2005	129
2006	137

Source: ADF&G. Vessel counts include some vessels reporting more than one home port.

Harbor Usage

Data from the City of Seward Harbor Department provides additional insight into the composition of the Seward fleet. While the Harbor Department's figures do not differentiate between sport fishing boats and other types of vessels (such as sailboats or commercial fishing vessels), harbor statistics nevertheless reveal relevant information about Seward's role as a port for residents of other communities. As of July 20, 2007, there were a total of 679 slipholders in Seward's harbor facilities. Of this total, only 121 were Seward residents. The other 558 slipholders (or 82 percent of the total) were non-Seward residents. These numbers

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likely include vessel owners from Anchorage, Mat-Su, and other areas. Additionally, there were 2,149 registered transient users as of July 20, 2007. Of this number, 214 were sport fishing charter boats.

The Harbor Department also maintains a wait-list for individuals interested in procuring a permanent slip. The wait list included 48 Seward residents, and 210 residents of Anchorage and other communities.

Table 7
Harbor Usage Statistics
Seward Municipal Harbor Facilities
Year-to-Date, July 20, 2007

Slipholder Type	Vessel Count
Seward Resident	121
Non-Seward Resident	558
Total	679

Source: City of Seward, Harbor Department, special data request.

No precise conclusions can be drawn about the sport fish component of the total harbor activity. However, viewed as a whole, the Seward Harbor Department data demonstrates that Seward's facilities are heavily used by non-Seward residents, as well as residents. The majority of non-resident use is assumed to be by residents of other Alaska communities (rather than non-Alaskans).

Sport Fishing Activity in Seward

Two salmon species are mainly targeted by Resurrection Bay fishermen: chinook and coho. Fishermen target chinook in the early part of the summer and coho later in the summer and into early fall. Halibut is also targeted during the summer months. Other species in the total sport fish harvest include rockfish, lingcod, and additional salmon species.

Alaska resident and non-resident fishermen participate in the sport fisheries in Resurrection Bay. Seward has a small population, but is connected to the Alaska road system and is a popular destination for Alaska resident and non-resident visitors. Fishermen visiting Seward may bring their own boats, fish with friends or relatives, take charter trips, or fish along the shoreline.

Effort

Fishing effort is measured in angler days (any portion of a day spent sport fishing). Data on effort are collected by fishing method, including charter boat, private boat, and shore-based effort. In 2006, sport fishing effort totaled 102,239 angler days. Data on fishing effort, by sector (shore-based, private vessel, or charter vessel) is presented below.

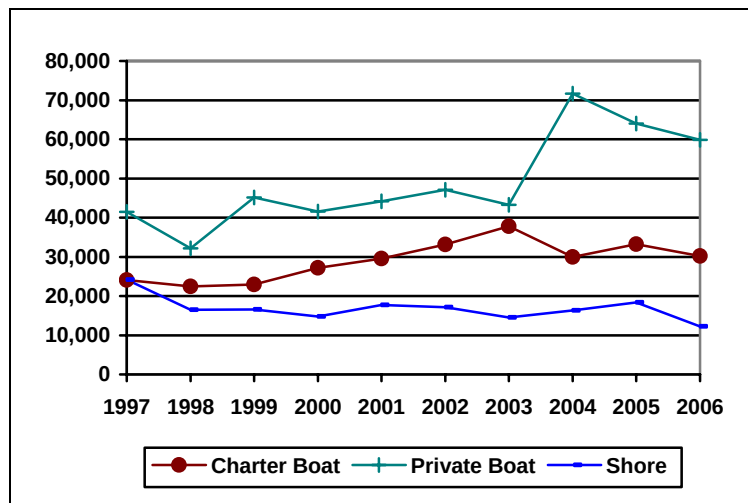
FISHING METHOD

In Resurrection Bay, fishing from a private vessel is the most common form of sport fishing, followed by charter fishing and shore fishing. Total saltwater fishing effort has been increasing over the years, with vessel-

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based effort increasing in both number of angler days and proportion of overall effort. Shore fishing has become a less important component of overall effort.

Figure 1
Saltwater Sport Fishing Effort in North Gulf Coast Waters, 1997 to 2006
Number of Angler Days



Source: ADF&G, Annual Management Report. Data are preliminary.

Saltwater sport fish effort as a percentage of total effort in North Gulf Coast waters was 30 percent charter boat, 59 percent private boat, and 12 percent shore based in 2006. Since 1996, boat effort has increased while shore-based effort has decreased.

CATCH, HARVEST, AND TARGET SPECIES

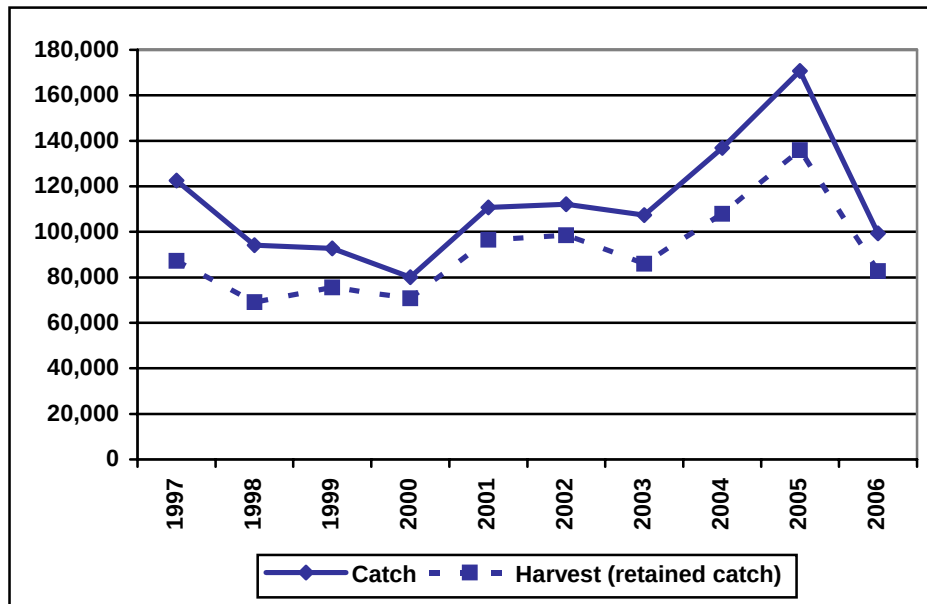
In order to understand the contribution of hatchery salmon to the total Resurrection Bay sport fishery, it is important to gauge sport fishermen's interest in harvesting salmon versus other species. Catch and harvest (retained catch) information provide one tool for answering this question, but they only provide information on fishermen's success at *catching* different species. For example, a fisherman may spend six hours unsuccessfully trying to catch a halibut, then catch four coho salmon in the last half-hour of the day. That person's intent, then, was primarily to catch halibut, even if the catch data for the day only reflect salmon.

Data on time spent targeting different species is also available, though only for the charter boat fleet. The data come from charter log books and provide another layer of valuable information on fishermen's *intent* while fishing in Resurrection Bay. This is measured in terms of hours spent targeting a given species group (such as salmon or bottomfish/groundfish).

CATCH AND HARVEST

Catch of coho salmon has ranged from 80,000 to more than 170,000 in the past decade. Harvest (retained catch) has ranged from about 70,000 to nearly 140,000. Retention of coho salmon is generally about 10 to 20 percent lower than catch. In comparison to other species, such as pinks (where 40 percent of the catch or less is retained), coho are clearly valued by anglers.

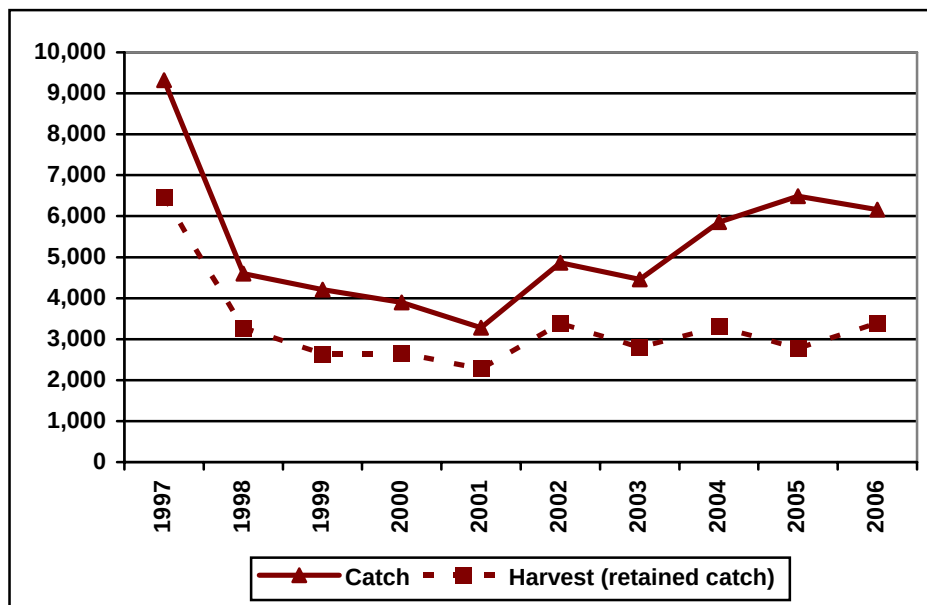
Figure 2
Catch and Harvest (Retained Catch) of Coho Salmon
in North Gulf Coast Sport Fisheries, 1997 to 2006



Source: ADF&G Annual Management Report, North Gulf Coast, 2007. Draft report.

Catch of chinook salmon has also increased in the last five years, but harvest (retained catch) has remained fairly constant. The differing trends between catch and harvest may reflect the bag limit (1 per day/1 in possession) for chinook salmon, rather than a lack of interest by harvesters in retaining their catch.

Figure 3
Catch and Harvest (Retained Catch) of Chinook Salmon
in North Gulf Coast Sport Fisheries, 1997 to 2006



Source: ADF&G Annual Management Report, North Gulf Coast, 2007. Draft report.

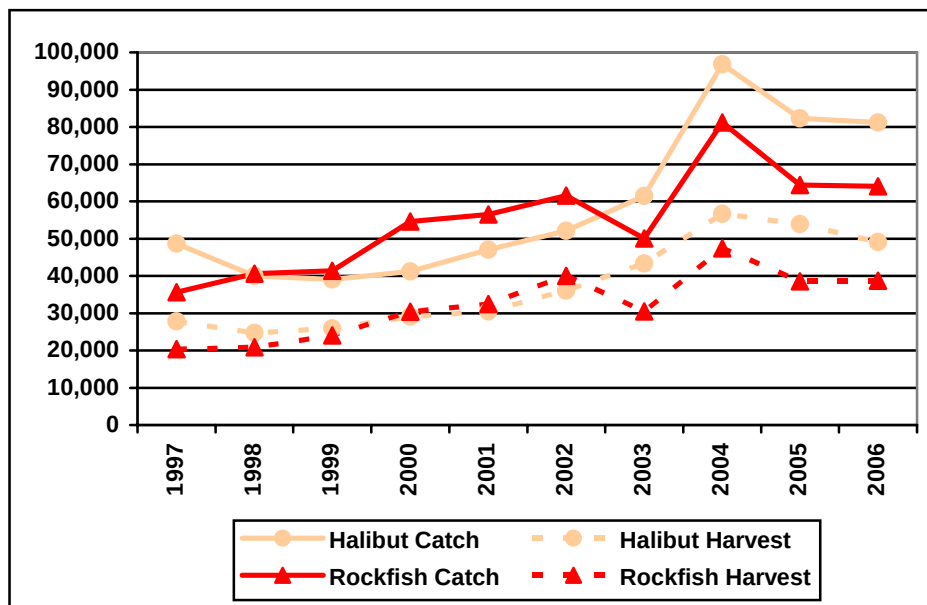
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Other salmon species are also harvested in sport fisheries in Seward. Sockeye catch has trended upward over two decades, with a catch in 2005 of 6,300 fish. (In 1995 it was only 1,400; in 1990 it was fewer than 900.) Chum catches are very cyclical, but fewer than 1,500 fish are retained in most years. Pink catches are typically fewer than 20,000 fish (though there was a significant spike to more than 30,000 in 2005). Retention is relatively low, however, at about 5,000 fish.

Overall, coho are the dominant species in the Seward-area salmon fisheries. Though pink salmon are also abundant, they are less desirable (as shown by retention/harvest rates). Other species are relatively small components of the total salmon sport fishery.

Catch and harvest of halibut and rockfish are also significant. Both have trended upward, overall, in the last decade, though both have seen some variability in the last several years.

Figure 4
Catch and Harvest (Retained Catch) of Halibut and Rockfish
in North Gulf Coast Sport Fisheries, 1997 to 2006



Source: ADF&G Annual Management Report, North Gulf Coast, 2007. Draft report.

Considering comparative catches and harvest for salmon species and groundfish/bottomfish species, it is clear that coho are an important part of both the catch (at 36 percent of the total number of fish caught) and the harvest (at 44 percent of the retained catch, by number of fish).

Figure 5
Sport Catch, by Species, 2006
North Gulf Coast

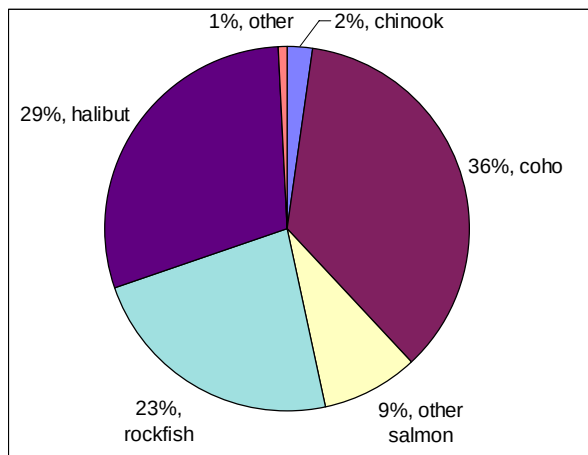
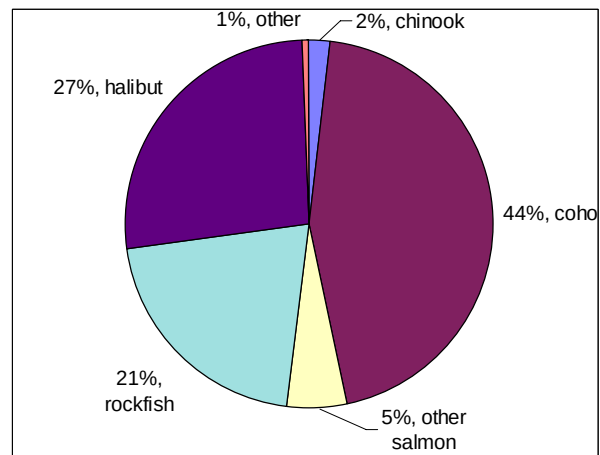


Figure 6
Sport Harvest, by Species, 2006
North Gulf Coast



Source: ADF&G

Notes: Ling cod are excluded. They are estimated at 3 percent of catch and 2 percent of harvest. The category of other salmon includes Dolly Varden (a trout). They are less than two-tenths of 1 percent of catch and harvest.

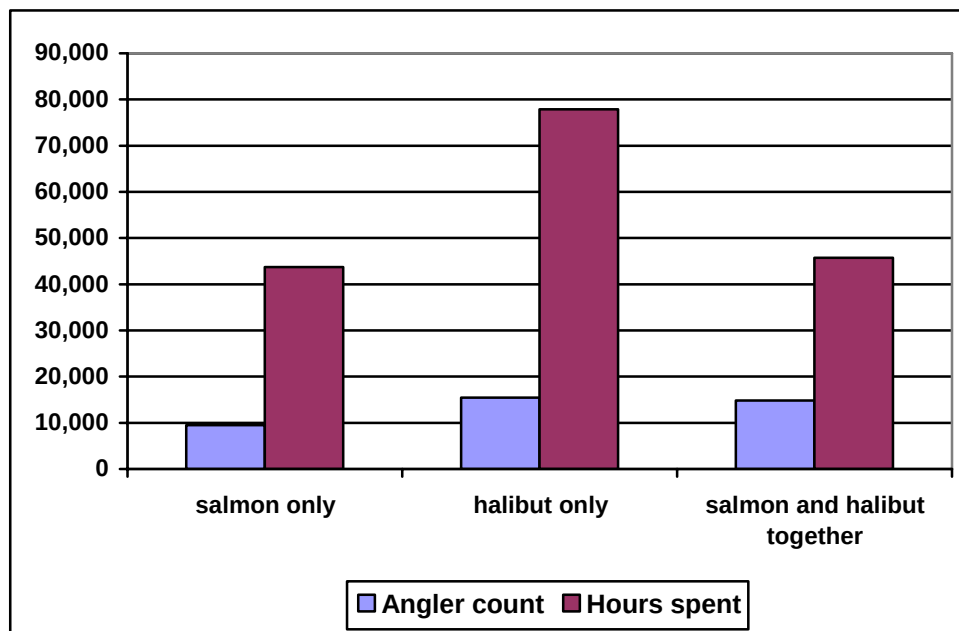
TARGET SPECIES

Charter operators are required to keep log books of their activities, including the number of clients, hours spent fishing, and hours spent targeting salmon or groundfish. Data from the charter fishing fleet logbook program provides an additional layer of information on the fishing behaviors of some Seward-area sport fishermen.

Log book data reveal that, although sport fishermen overall catch and harvest a greater number of salmon than bottomfish (see Tables 13 and 14, above), among the charter fleet more time is spent targeting bottomfish than salmon. In 2006, a total of 5,631 charter trips landed in the ports of Seward, Lowell Point, and Miller's Landing. Of these trips, 36 percent were bottomfish-only charters, for a total of about 77,900 hours of fishing time. Another 36 percent were salmon/bottomfish combination trips. However, only 36 percent of the time on these charters is estimated to have been spent targeting salmon, or 16,500 hours. Salmon-only charters contributed another 43,800 hours of salmon angler effort. This is a total of approximately 60,000 hours spent in the pursuit of salmon, significantly fewer than the 107,000 estimated bottomfish hours.

In total, within the charter fleet, an estimated 9,500 anglers spent 43,800 hours targeting only salmon while 15,400 anglers spent 77,900 hours targeting only bottomfish. A total of 14,800 anglers spent 45,700 hours targeting both salmon and bottomfish.

Figure 7
Angler Count and Hours Spent Targeting Salmon and Bottomfish
Seward Charter Boat Fleet, 2006



Source: ADF&G charter logbook, special data request.

It is important to note that bottomfish are only effectively targeted from boats, while salmon fishing can occur from shore. All of the shore-based fishing reported for the North Gulf Coast is assumed to be for salmon species, with negligible amounts focused on trout.

According to ADF&G and ASLC staff, most salmon sport fishing effort takes place at the head of Resurrection Bay and on the west side of the bay. A commercial fishery occurs seasonally on the East side of Resurrection Bay. Shore fishing occurs almost exclusively on the road system in Seward (at the head of Resurrection Bay). Charter and private fishing vessels move throughout the area, extending as far away as Prince William Sound, to the east, and south and west along the Kenai Peninsula coast into Cook Inlet. Halibut and other bottomfish fishing are focused more on the waters outside the mouth of Resurrection Bay, and onward to the east, toward Prince William Sound.

HATCHERY SALMON IN THE RESURRECTION BAY FISHERIES

ADF&G and the Cook Inlet Aquaculture Association have been enhancing salmon runs in the Resurrection Bay area for decades. In 2004, CIAA released coho salmon that they had raised on contract with the Alaska SeaLife Center. ASLC was conducting scientific experiments, with the help of CIAA, on means to improve lifecycle advances in hatchery salmon, as well as other research.

In total, including ASLC, ADF&G, and CIAA releases, approximately 413,000 coho fry, 577,000 coho smolt, and 252,000 chinook smolt were released into Resurrection Bay or its river systems annually between 2002 and 2006. Sockeye fry total another 2.4 million in each year but 2003, and sockeye smolt and pre-smolt averaged 745,000 fish.

Table 8
Hatchery Releases in Resurrection Bay, 2002 to 2006

	2002	2003	2004	2005	2006	5-yr avg
Coho fry	404,700	404,800	406,000	400,500	447,300	412,660
Bear Lake	404,700	404,800	406,000	400,500	447,300	412,660
Coho smolt	365,055	501,343	740,787	752,705	523,987	576,775
Bear Creek	123,800	253,400	285,000	488,200	115,300	253,140
Lowell Creek	119,512	124,225	131,989	132,276	131,261	127,853
Seward Lagoon	121,743	123,718	131,798	132,229	131,326	128,163
Seward SeaLife	-	-	192,000	-	146,100	169,050
Chinook Smolt	193,610	220,307	229,054	311,637	303,217	251,565
Lowell Creek	93,296	110,331	89,388	100,088	-	98,276
Seward Lagoon	100,314	109,976	109,600	114,847	226,621	132,272
Seward SeaLife	-	-	30,066	96,702	76,596	67,788
Sockeye fry	2,407,700	1,467,000	2,406,000	2,416,000	2,413,900	2,222,120
Bear Lake	2,407,700	1,467,000	2,406,000	2,416,000	2,413,900	2,222,120
Sockeye smolt & pre-smolt	802,600	334,000	603,000	1,005,700	979,200	744,900
Bear Lake (Bear Creek*)	802,600	334,000	603,000	1,005,700	979,200	744,900

Source: Alaska Department of Fish and Game Annual Management Report, draft 2007 report.

* Sockeye smolt and pre-smolt releases were in Bear Lake through 2005 and Bear Creek in 2006.

ADF&G staff estimate that 5 percent of hatchery released coho return as adults and 2 percent of chinook salmon return as adults. Coho salmon return to their natal streams after one winter at sea, while chinook return after one to four years at sea and sometimes even five years.

ADF&G, ASLC, and CIAA all release salmon into Resurrection Bay or river systems that drain into it. Sockeye releases primarily benefit commercial salmon fisheries, while chinook and coho releases are intended primarily for the sport fisheries. While ADF&G and CIAA have both released fish into these systems for decades, Alaska SeaLife Center's involvement began in 2004, through a contract with CIAA. ASLC raises chinook for release at its Resurrection Bay location. The Center also works cooperatively with CIAA and Marical (a private research firm) on releases of coho salmon into the Bear Lake system. Marical is a firm working on salmon enhancement technology. The Center purchases smolt from CIAA and treats them with a Marical process before they are released.

ESTIMATING THE IMPORTANCE OF HATCHERY-REARED SALMON TO THE TOTAL SPORT FISHERY

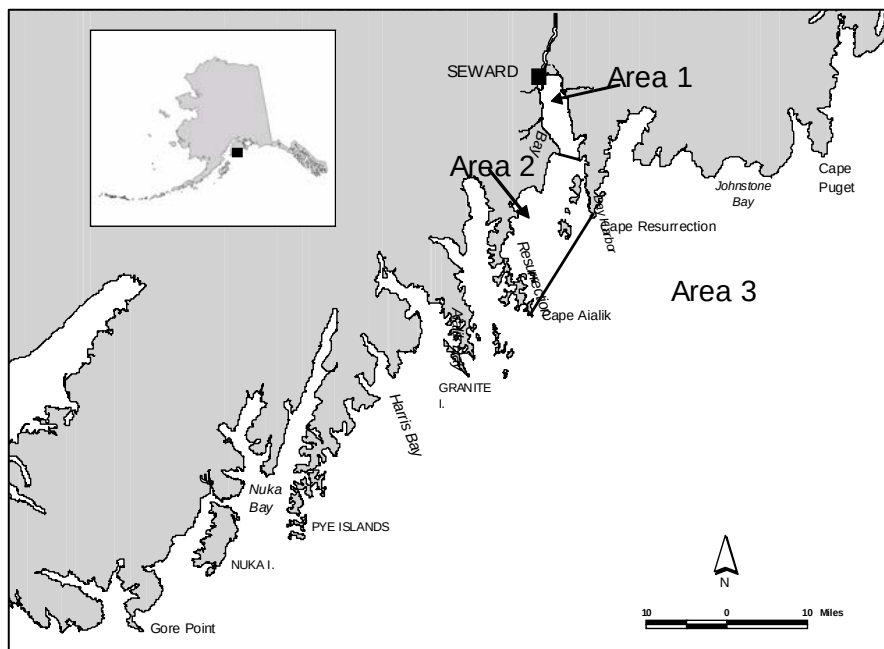
Effort, catch, harvest, and targeted species data help provide insight into the fishing activities of sport fishermen in the Seward area. In order to assess the role of hatchery salmon as a component of the total fishery, additional data on hatchery fish harvests were used.

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ADF&G conducted dockside sampling in 2003, 2004, and 2005, examining salmon ear bones, or otoliths, to determine what percentage of the sport salmon harvest was from enhanced stocks. The study found that enhanced fish accounted for about one-quarter to one-third of the total sport fish harvest in Resurrection Bay, depending on the year. ADF&G staff said that, in their opinion, one-third (33 percent) was a good average estimate. The research also showed that the percentage of hatchery-origin fish increases closer to the city of Seward, at the head of Resurrection Bay. Hatchery-raised fish are bound for systems at the head of the bay where they were released as fry or smolt, while wild fish move from saltwater to freshwater in their natal rivers along the way.

Figure 8
Otolith Study Regions

The harvest of hatchery fish peaks at the end of the summer, from late August to early September. Data collected by ADF&G indicate that over two-thirds of the hatchery harvest in Area 1 (see Figure 8) is by private boat and shore based fishermen. According to the same data, in Area 3 over 90 percent of the harvest of hatchery fish is from charter boats. The study period lasted from the first week of July to the second week of September, so later returns are not considered in these figures.



Source: ADF&G

Participants in the Seward Sport Fisheries

To assess the economic impact of the sport fishery in Seward, it is important to understand the composition of the sport fish user group. Participation in the sport fisheries in Seward is by three major groups: residents of Seward and the surrounding area; residents of other Alaska communities who travel to Seward to fish; and non-Alaska residents who travel to Seward and fish while visiting the community. The different kinds of participants have differing levels of impact on the community economy, as they require varying levels of services while in Seward. For example, a resident of Southcentral Alaska may not overnight in the community, or may have friends in the area, reducing their need for dining and lodging services. An out-of-state visitor, lacking local knowledge, may be more likely to participate in a guided fishing activity, and may use lodging and dining services.

Data on non-Alaska resident visitation to Seward and other Alaska communities is readily available through the Alaska Visitor Statistics Program (AVSP). AVSP is an in-depth non-resident visitor intercept survey program. In 2006, the McDowell Group conducted the AVSP program through a contract with the State of Alaska. Data from AVSP provide insight into the activities, preferences, and expenditures of visitors to Alaska.

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Additional data on the Alaska visitor industry come from the Alaska Travelers Survey, a McDowell Group proprietary research program.

VISITOR INDUSTRY

As a road-system community located proximate to Anchorage, Seward receives a significant number of visitors—Alaska resident and non-resident alike. The community is also a major port for the origination and termination of cruise ships voyages, and sees more than 100,000 visitors annually for that reason alone. Seward also is the southern terminus for the Alaska Railroad, which provides access to the community for visitors traveling without their own vehicles.

Sport fishing is among the major draws for visitors to the community. Other important attractions include the Kenai Fjords National Park, for which Seward serves as the hub community, and the Alaska SeaLife Center's visitor facilities. Additionally, the U.S. Army and the U.S. Air Force operate recreational camps in Seward for active and retired personnel and their families. The Army facility receives 70,000 to 80,000 visitors annually, while the Air Force facility receives another 8,000. Half of the Army visitors and 70 percent of the Air Force visitors are stationed in Alaska. Staff at the Air Force recreation camp estimate that about 6,000 of their visitors go fishing annually. The Army recreational camp staff estimate that approximately 175 people go fishing daily during the peak fishing season.

NON-RESIDENT VISITORS

The 2006 AVSP research program provides counts of the number of non-resident visitors to many Alaska communities. According to AVSP data, total Seward visitor volume in summer 2006 was 341,000 visitors. Of these, nearly 135,000 either embarked or disembarked from a cruise ship in Seward.

Seward attracted nearly 40 percent of Alaska's total non-cruise/non-business travelers in 2006. This included day visitors who traveled from Anchorage or other communities, and overnight visitors.

Table 9
Seward Visitor Profile, Summer 2006
Non-Alaska Resident Visitors

Visitor volume (summer 2006)	341,000
Cruise visitors embarking/disembarking in Seward	135,000
Non-cruise visitors	206,000
Estimated overnight visitors	135,000
Estimated day visitors	71,000
Average length of stay (overnight visitors)	2.3 nights
Percent sport fishing while in Seward	9%
Guided fishing	6%
Unguided fishing	3%

Sources: Alaska Visitor Statistics Program, Summer 2006; Cruise Line Agencies of Alaska.

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Data on overnight visitors to Seward from 2001, 2003, and 2005, show that approximately one in five visitors overnights in the community.

Table 10
Seward Overnight Visitor Trends, Non-Cruise Market

Year	Percentage of Market
2001	16%
2003	23
2005	19

Source: Alaska Travelers Survey, McDowell Group

Seward serves as one of the two major northern origin/terminus ports for cruise ships in Alaska. As a result, it hosted nearly 135,000 cruise passengers in 2006. While many passengers transit directly from the ship to the rail or motorcoach transportation, others spend time in Seward as itineraries allow. Others may visit Seward as part of a shore excursion from Anchorage, and still others may travel to Seward independently, before or after their cruise.

However, Seward has seen a significant reduction in the total number of cruise passengers visiting the community in recent years. This is due in large part to the development of Whittier as a competing northern terminus for Alaska cruises. From 2003 to 2004 alone, the number of cruise visitors in Seward fell by half.

Table 11
Seward Cruise Visitor Trends

Year	Number of Cruise Visitors
1996	230,042
1997	208,900
1998	280,543
1999	280,229
2000	274,733
2001	337,241
2002	316,888
2003	293,230
2004	142,277
2005	152,557
2006	134,579

Source: Cruise Line Agencies of Alaska

NON-RESIDENT SPORT FISH VISITORS

Of the total visitors to Seward, 9 percent sport fished while in the community: 6 percent of visitors participated in guided trips and 3 percent in unguided. (It should be noted that there is likely some nominal amount of overlap between the two groups, with people participating in both types of activity, though in this case not enough to offset the data by a full percentage point.)

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Of the Seward visitors who participated in sport fisheries while in the community, approximately 70 percent stayed the night in the community. Of these overnight visitors, 39 percent stayed in hotels/motels, 23 percent in commercial or public campgrounds (including RV parks), 14 percent in a lodge, 12 percent in bed and breakfasts, and 7 percent in private homes. Other possible overnight accommodations included wilderness camping.

ALASKA RESIDENT VISITORS

There are no data sources currently available on Alaska resident travel within their own state. As a result, quantifying the number of Alaska resident visitors to Seward is not possible. However, it is known that Seward is an important recreational destination for residents of Anchorage, the Kenai Peninsula Borough, and the Matanuska Borough. The population base for these three areas is significant, and growing (from 369,296 in 2000 to 411,484 in 2006, an increase of 11 percent). The Matanuska-Susitna Borough is experiencing the most marked increase (up 35.7 percent during the same period, more than 20,000 people). The impact of Alaska resident visitation on Seward is considered an important piece of the total picture of Seward sport fish activity.

Table 12
Area Population Figures

Area	Estimated 2006 Population	2000 Population	Percent Change 2000- 2006
Anchorage Municipality	278,700	260,283	7.1%
Matanuska-Susitna Borough	80,480	59,322	35.7
Kenai Peninsula Borough	52,304	49,691	5.3

Source: US Census Bureau; Alaska Department of Labor and Workforce Development

Economic Impacts

Measuring the economic value of sport fishing activity presents significant challenges. Sport fishing is, at its base, a leisure activity. In Alaska, as in other parts of the United States and the world, significant amounts of time and money are expended by people participating in sport fisheries. But estimating the value of individual fish, or a group of fish (such as the hatchery-raised salmon in the Seward area), poses significant methodological challenges. The activity of sport fishing in itself can be perceived as valuable by a participant, regardless of his or her success in actually catching or harvesting a fish. And what is the marginal contribution of one additional fish to the overall value of the fishery? For example, an individual participating in a day-long sport fishing charter may catch coho salmon, halibut, pink salmon, and lingcod. How does an additional coho or pink salmon impact the total value or the perceived value of the charter? How does the researcher account for the non-fishing value of charter: simply being on the water, being in Alaska, observing marine mammals, birds, scenery? Clearly, the addition of one salmon to the day's catch does not correlate directly with the total value of the sport fishing activity. In another scenario, if a family visits Seward from out-of-state and goes sport fishing, but also takes a wildlife tour, spends a day shopping in local establishments, and visits the SeaLife Center, how much of the value of that family's stay in Seward, including hotels and restaurants, car rental, or other services, should be attributed to their participation in a sport fishery? Would that family have come to Seward regardless of opportunities to sport fish? Or did the sport fishing drive their visit to the community? These scenarios demonstrate the challenges in assigning an economic value to sport-harvested fish.

Nevertheless, it is evident that sport fisheries do have economic value and can contribute importantly to local and regional economies. Numerous studies have been conducted around the United States and the world attempting to assess the impact of these fisheries. In the case of Seward and the sport fishery for hatchery salmon that occurs there, data exist to support estimates of economic impact.

In the preceding section of the report, information was presented on the catch, harvest, effort (in number of angler days), and relative importance of salmon and groundfish species to the sport fisheries in the Seward area. Data were also presented on the proportion of the coho salmon catch that is of hatchery-origin salmon. These and other data, including visitor industry activity and sport fish-related expenditures in Alaska, were used to develop the key assumptions underlying the economic model.

Assumptions

To estimate the economic contribution of hatchery salmon to the Seward economy, the study team used data on angler expenditures collected every five years as part of the U.S. Fish and Wildlife Service *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*. The most recent state-level data for Alaska comes from the 2001 survey. (Nation-level preliminary data from the 2006 survey has recently been released, but state-level data is not yet available.) The study estimated trip expenditures in Alaska on items such as food and lodging, transportation, boating costs (such as launching, mooring, storage, maintenance, insurance, pump-out fees, and fuel), and other trip costs (such as equipment rental, guide and access fees, ice and bait for fishing, and heating and cooking oil). The study also looked at equipment costs related to fishing.

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After adjustment of the values for inflation (using the Consumer Price Index for Anchorage from the Bureau of Labor Statistics), trip expenditures per day in Alaska for sport fishermen are as follows.

Table 13
Expenditures in Alaska on Sport Fishing per Angling Day
Alaska and Non-Alaska Residents

	Alaska Residents	Non-Alaska Residents
Trip and equipment expenditures per day	\$92	\$364
Trip expenditures only (no equipment) per day	\$51	\$355

Source: 2001 National Survey of Fishing, Hunting and Wildlife-Associated Recreation, US Department of Fish and Wildlife and US Census Bureau. Figures from 2001 adjusted for inflation to 2006 using the Consumer Price Index for Anchorage, Alaska, from the US Bureau of Labor Statistics.

It is important to note that these figures are statewide averages for Alaska. This is a broad average, capturing people fishing in their own communities or traveling elsewhere in the state to participate in sport fisheries. For lack of better data, we assume they are representative of Seward activity. No Seward-specific data were available.

It was also necessary to estimate the sport fishing effort related to salmon produced in hatcheries. Of course, hatchery-origin salmon are not explicitly targeted when people are sport fishing. Rather, hatchery production augments the size of the total salmon run, increasing the resource and therefore the availability of fish for catch and harvest.

Several additional assumptions underlie the economic estimates. Data from ADF&G show that approximately 36 percent of the total fishing time logged by Seward-based charter boats in 2006 was in the pursuit of salmon. The study team assumed that this percentage was representative of the relative effort by the private boat fleet as well.³ In addition, it was assumed that 100 percent of the shore-based effort was in pursuit of salmon.

Table 14
Assumptions for Effort, by Species
and Harvester Group

	Effort by species	
	Salmon	Groundfish
Charter boat	36%	64%
Private boat	36%	64%
Shore fishing	100%	0%

Source: McDowell Group estimates.

As the previous table demonstrates, the economic impact of resident and non-resident sport fishermen is significantly different. It was therefore important to estimate the resident and non-resident component of the

³ Anecdotal evidence suggests that vessels in the private vessel fleet may consist of vessels that are somewhat smaller than those in the charter fleet. These boats may fish closer to town, in the protection of Resurrection Bay. It is possible that these vessels expend somewhat more effort in the pursuit of salmon. Nevertheless, we believe the assumptions outlined here are a reasonable estimate of average effort.

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total fishing activity. Charter logbook data provide information on the residency of anglers aboard charter vessels. Based on the logbook data, the study team assumed that 75 percent of the charter-based fishing was by non-Alaska residents, and the remaining 25 percent by resident fishermen. For the private boat fleet, however, it was assumed that 95 percent of the fishing activity was by Alaska residents. (Again, no differentiation is made in this research between Seward residents and residents of other Alaska communities. Though economic impacts can be expected to be different between the two groups, no community-level data were available to support a more refined estimate.) Finally, the study team considered visitor data from the Alaska Visitor Statistics Program Summer 2006 research to develop estimates of the shore-based fishing activity by non-residents. Based on this data, the study team assumed 60 percent of the shore-based fishing activity was by non-resident anglers, with the balance by Alaska residents.

Table 15
Assumptions for Residency of Anglers
by Harvester Group

	Alaska Residents	Non-Alaska Residents
Charter boat	25%	75%
Private boat	95%	5%
Shore	40%	60%

Source: McDowell Group estimates, based on data from ADF&G and the Alaska Visitors Statistics Program V.

As discussed above, otolith studies conducted by ADF&G indicate that approximately one-third of the coho harvested in sport fisheries in North Gulf Coast waters come from hatcheries. This includes an even more significant proportion in waters closer to Seward, in the head of Resurrection Bay. However, effort (angler day) and target species logbook data presented above do not differentiate between coho and other salmon species. For chinook salmon, 50 percent of the fishing activity is assumed to be on hatchery salmon. This is based on attribution rates developed in previous studies.⁴

Estimated Impact

In total, in 2006, angler effort for all species in North Gulf Coast waters totaled 102,239 days. Of that total, 29.5 percent was by the charter boat fleet (30,201 angler days), 58.5 percent by the private boat fleet (59,815 angler days) and 12.0 percent by shore-based fishermen (12,223 angler days).

Using the assumptions outlined in Table 14 we estimate that approximately 44,600 (or 44 percent) of these angler days are spent targeting salmon species. The balance is spent targeting groundfish/bottomfish species, such as halibut, rockfish and lingcod. In interviews with local sport fish charter operators we learned that, generally, salmon seems to be a secondary draw for sport fishermen coming to Seward, after halibut. However, this dynamic shifts later in the summer, when people are targeting coho and participating in the annual derby competition.

⁴ See Northern Economics, 2004

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Considering the relative contribution of hatchery-raised coho and chinook to the overall salmon fishery, we estimate that 9,300 resident angler days and 5,500 non-resident angler days are attributable to hatchery coho. Hatchery chinook contribute another 1,275 days. Resident and non-resident expenditures for this sport fishery total \$2.6 million.

Table 16
Estimated Direct Expenditures by Sport Fishermen
Harvesting Hatchery-Raised Coho, 2006
Excludes Equipment

	Resident	Non-Resident	Total
Angler days attributable to hatchery coho	9,300	5,500	14,700
Angler days attributable to hatchery chinook	675	400	1,275
Angler expenditures per day	\$51	\$355	
Total estimated direct expenditures	\$500,000	\$2,100,000	\$2,600,000

Source: McDowell Group Estimates

Note: Rows may not sum to totals due to rounding.

The expenditures included in these estimates include such items as:

- food and lodging,
- transportation,
- boating costs (boat launching, mooring, storage, maintenance, insurance, pump-out fees, and fuel),
- other trip costs (equipment rental, guide and access fees, ice and bait for fishing, and heating and cooking oil).

The per-day expenditures estimated in the USFWS study are Alaska averages, but are assumed to be representative of spending in Seward.

In addition to direct impacts of money spent on services or goods directly related to the fishing activity, this activity also generates indirect and induced impacts. Indirect impacts are those by providers of direct services. For example, a hotel is directly impacted by expenditures from a sport fisherman. That hotel's expenditures on goods such as cleaning supplies, or on services such as accounting and insurance, are enabled by the direct spending. Induced impacts are caused by local spending of payroll dollars linked to sport fishing. For example, money spent on groceries, entertainment, or financial services by the household of a charter boat operator would be induced by the primary activity. In other words, dollars spent by sport fishermen cycle through the economy, creating additional economic activity. This is often referred to as a "multiplier" effect.

In their 2004 work, Northern Economics estimated a multiplier for sport fishing-related expenditures of 1.486. By applying this multiplier to the direct impacts estimated above, it is possible to estimate the total direct and indirect impact of sport fishing for hatchery salmon. This analysis reveals that the total estimated economic impact in 2006 was \$3.9 million, including \$3.1 million in impacts resulting from non-resident fishing activity and \$800,000 from resident activity.

Table 17
Total Estimated Direct and Indirect Expenditures
by Sport Fishermen Harvesting Hatchery-Raised Coho, 2006

	Resident	Non-Resident	Total
Total estimated direct expenditures	\$500,000	\$2,100,000	\$2,600,000
Total direct, indirect and induced expenditures	\$800,000	\$3,100,000	\$3,900,000

Source: McDowell Group Estimates

Note: Rows may not sum to totals due to rounding.

As the figures indicate, the magnitude of non-resident spending is significantly greater than that of spending by residents, by a 4-to-1 ratio. This reflects increased needs for lodging, dining, transportation, and other services by non-residents. Alaska residents who do not live in Seward can also be expected to incur more costs for sport fishing than Seward residents. However, even theirs are expected to be significantly lower than those for out-of-state visitors. Alaska residents may make day trips, stay with friends and family, require fewer guide or support services, or bring supplies such as food from home.

The Relationship between Hatchery Production and Community Economics

This analysis provides an estimate of the economic impact of enhanced salmon sport fisheries in the Seward area in 2006. But how do changes in production, run size, or other factors impact the economics of the community? Does higher or lower production directly impact the economy?

Based on our analysis, the direct economic return on fry and smolt that were produced in salmon enhancement facilities and eventually returned to Resurrection Bay systems in 2006 was positive: for every 10,000 coho released, the community saw approximately \$20,000 to \$30,000 in direct economic benefit from the returning fish. This compares to an investment in a typical year of approximately \$1,200 per 10,000 fry or \$4,700 per 10,000 smolt. (Production costs can vary significantly with volumes and resultant economies of scale. These are representative figures specific to production for Resurrection Bay.)

It is important to recognize the variability associated with any year's releases or returns and associated economic impact. If fewer fry or smolt are released in a given year, will effort in the year those fish are returning to their natal systems be significantly impacted as a result of a smaller run size? While there may be some association, other factors such as the number of visitors, the weather, or macroeconomic trends likely have greater impacts. The impact of shifts in hatchery production is likely to be evident over time. For example, with several years of consistently smaller releases and resultant returns the sport fishery is likely to be impacted, either with fishermen redirecting their effort toward other regions with stronger salmon run characteristics, or through a shift in recreation effort from sport fishing to other activities. Or fishermen may simply redirect their effort to other species in the same area, with modest resultant economic impact.

ROLE OF CHINOOK PRODUCTION

Overall, in the North Gulf Coast fisheries, chinook salmon are a relatively minor percentage of the total sport catch and harvest (about 2 percent of all sport catch in harvest in 2006; approximately 5 and 4 percent of salmon catch and harvest, respectively). Nevertheless, chinook salmon have special appeal for sport anglers.

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As the “king” of salmon, the chinook acts as a draw for many anglers. While fishermen may participate in Alaska fisheries for a number of ascetic and practical reasons, the potential for catching chinook is a tempting one. When fishermen buy sport licenses from ADF&G, they must purchase special endorsements (king stamps) in order to retain chinook salmon while fishing. Data from 2006 show that 50 percent of Alaska resident fishermen and 43 percent of non-residents purchased king stamps for their sport licenses that year. By comparison, only 16 percent of the salmon harvested in sport fisheries in Alaska in 2006 were chinook. This demonstrates the relative appeal of catching a chinook salmon, as compared to the actual likelihood.

While chinook enhancement has occurred in the Seward area for years, the Alaska SeaLife Center has recently initiated a chinook program that augments this historical production, with releases of 16,700, 96,700, and 76,600 smolt in 2004, 2005 and 2006. First returns from the releases were anticipated in 2007. Data is not yet available on the returns for this program. The average total chinook release in 2004-2006 was 277,000, compared to 228,000 for the preceding five-year period.

Generally, an increase in the availability of chinook salmon can be expected to have a positive impact on the sport fishery in the Seward area. The estimates of economic value presented in this report do not model potential results of species shifts. They do, however, present general information on the impact of additional days of fishing on the community economy. However, as sport fishermen perceive a greater availability of chinook salmon, it is likely that an incremental increase in sport fishing effort would occur. For example, assuming relatively similar return rates between coho and chinook salmon, the release of an additional 100,000 chinook fry or smolt would result in approximately \$200,000 in direct economic impact.

OTHER POTENTIAL ENHANCEMENTS TO SALMON RUNS

The economic impacts of the sport fishery detailed here, though based on salmon enhancements through hatcheries, can be expected to generally occur with any augmentation of the available salmon resource. Among these enhancements could be restoration of natural river and lake systems that support wild salmon. It is beyond the scope of this work to quantify the potential impacts of any specific habitat restoration project. Generally speaking, an increase in the availability of salmon from any source would be expected to have comparable potential to increase economic activity.

A cost-benefit analysis of proposed enhancements would be necessary to determine whether the investment would likely result in similar, greater, or lesser economic returns than an investment of the same funds in hatchery production. At the same time, it is important to note that there may be non-economic benefits to habitat restoration, or economic benefits not directly tied to the harvest of salmon in fisheries. The data provided within this report can provide a point of comparison for an initial analysis of the potential benefit of a restoration project, as compared to hatchery enhancements.

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BEAR LAKE SOCKEYE SEAREADY™ TRIAL 2006

Bear Lake Sockeye were reared and treated at the Cook Inlet Aquaculture Association (CIAA) Eklutna Hatchery. SeaReady™ treatment began April 11, 2006 (Day 0) and was completed on May 23 (Day 42). Fish were sampled on both Days 0 and 42 as well as Day 21 (May 2, 2006).

The SeaReady™ treated fish were reared outdoors in four raceways while the Control fish were reared indoors in five raceways. There were approximately 700,000 fish treated with the SeaReady™ process and 661,000 Control fish.

For Day 0 sampling, the fish to receive the SeaReady™ treatment were used as the Control group. For Day 21 and 42, the Control group came from fish which were thermally marked as Fry or PreSmolt, but not stocked as such. Hence, no comparison can be made between Day 0 and 21 or between Day 0 and 42 for the Control fish. However, comparison can be made between Control fish at Day 0 and the SeaReady™ fish at the other sampling points.

For the Control fish at Day 21 and 42, ten fish were sampled from both the freshwater fish and fish challenged in saltwater for 24 hours. Five fish came from the group marked as Fry and the remainder from the PreSmolt. For the SeaReady™ fish, ten fish sampled at each sampling interval from both freshwater and saltwater challenge.

Fish were sampled for length/weight and gills were removed for histology (gill arch 1) and Na+K+ ATPase (gill arch 2). All ATPase samples were analyzed as 37 C. Histology results are not available at this time.

No significant differences ($P>0.05$) existed between the Control fish which were thermally marked as Fry and PreSmolt (both weight and ATPase). Therefore, these values were combined to give one Control group.

Table 1 summarizes the results from the six-week trial. Results for weight and gill Na+K+ ATPase are shown graphically in Figures 1 and 2 respectively. The fish treated with the SeaReady™ process increased significantly ($P<0.05$) in weight over the six week period. The Control fish were also significantly larger ($P<0.05$) in size than the SeaReady™ treated fish at Day 21 (both FW and SWC). However at Day 42, there was no significant difference between the Control and SeaReady™ fish ($P=0.317$) for the saltwater challenged group only.

Gill ATPase values increased significantly ($P<0.05$) over the trial period for the SeaReady™ treated fish. At Day 21, the Control fish had significantly higher ($P<0.05$) ATPase levels, but by Day 42 these levels were no longer significant ($P>0.239$).

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Sample Time	Group	Avg Wgt (gm)	Avg Gill ATPase (umol/mg protein/hr)	Gill ATPase per Fish Wgt
Day 0	Control FW	6.25 ± 0.99	3.44 ± 0.93	0.56 ± 0.14
	Control SWC	5.29 ± 0.87	3.54 ± 1.01	0.68 ± 0.22
Day 21	Control FW	11.37 ± 2.77	17.94 ± 3.07	1.64 ± 0.38
	Control SWC	12.05 ± 3.36	15.34 ± 4.94	1.31 ± 0.35
	SeaReady™ FW	6.45 ± 1.50	10.92 ± 4.08	1.70 ± 0.59
	SeaReady™ SWC	5.59 ± 1.36	9.70 ± 2.80	1.78 ± 0.52
Day 42	Control FW	11.63 ± 3.69	15.72 ± 4.06	1.45 ± 0.48
	Control SWC	10.99 ± 3.38	17.84 ± 5.64	1.84 ± 0.88
	SeaReady™ FW	7.66 ± 1.53	14.61 ± 3.01	1.95 ± 0.38
	SeaReady™ SWC	9.78 ± 1.54	16.07 ± 2.48	1.67 ± 0.25

Table 1. Results from 2006 SeaReady™ trial on Bear Lake Sockeye (04G). Control group on Day 0 is different than the Control group on Day 21 and 42.

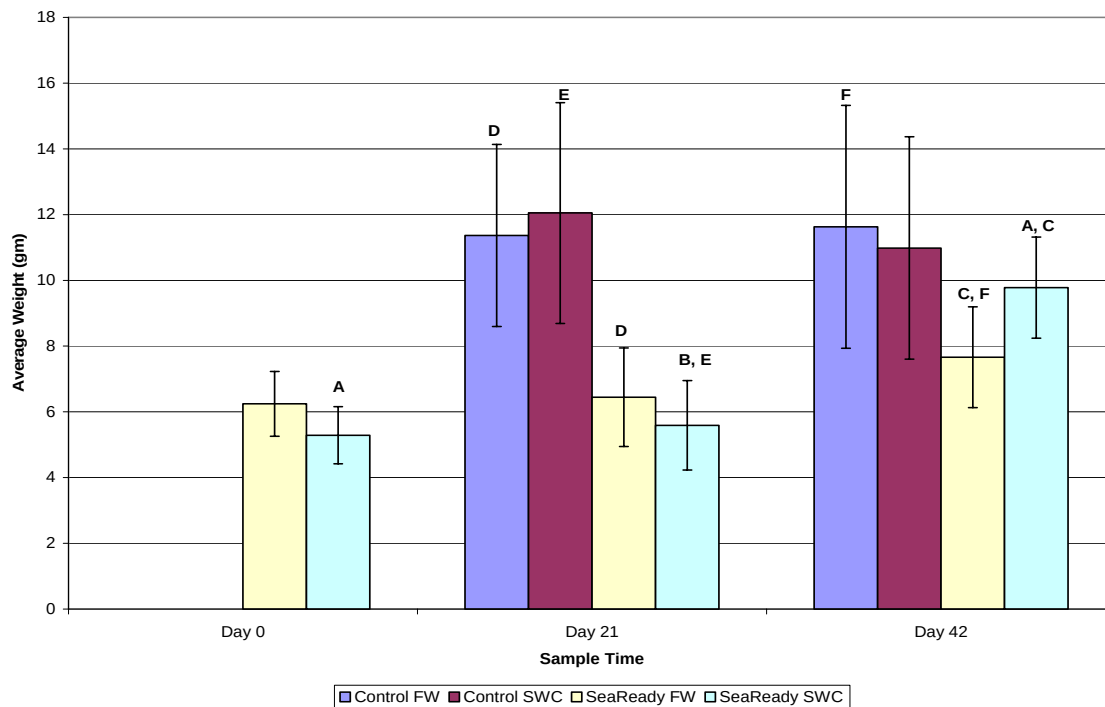


Figure 1. Average weight for Control and SeaReady™ groups during the 6 week SeaReady™ trial. Columns with the same letter are significantly different (P<0.05).

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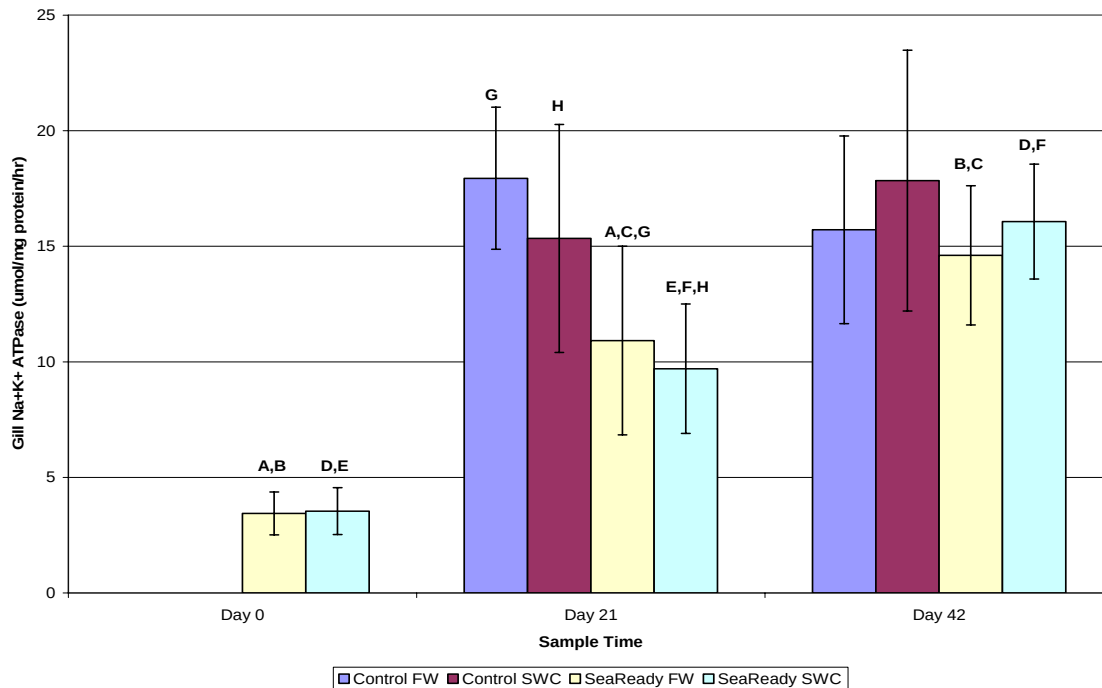


Figure 2. Average gill Na⁺K⁺ ATPase for the Control and SeaReady™ groups during the 6 week SeaReady™ trial. Columns with the same letter are significantly different (P<0.05).

Figure 3 demonstrates the gill ATPase values on a per fish weight basis. For the SeaReady™ fish the values increased significantly over the course of the trial (P<0.05). However, there were no differences (P=0.564) at Day 42 between the Control and SeaReady™ fish with the exception of freshwater group (P=0.0188).

Figure 4 shows a scatter plot of the reported gill ATPase values versus fish size for each treatment group. From this we can see that the SeaReady™ process was successful at taking smaller fish (in comparison to Control) and achieve similar gill ATPase levels. This provides us with insight on what to expect from a S0 sockeye program.

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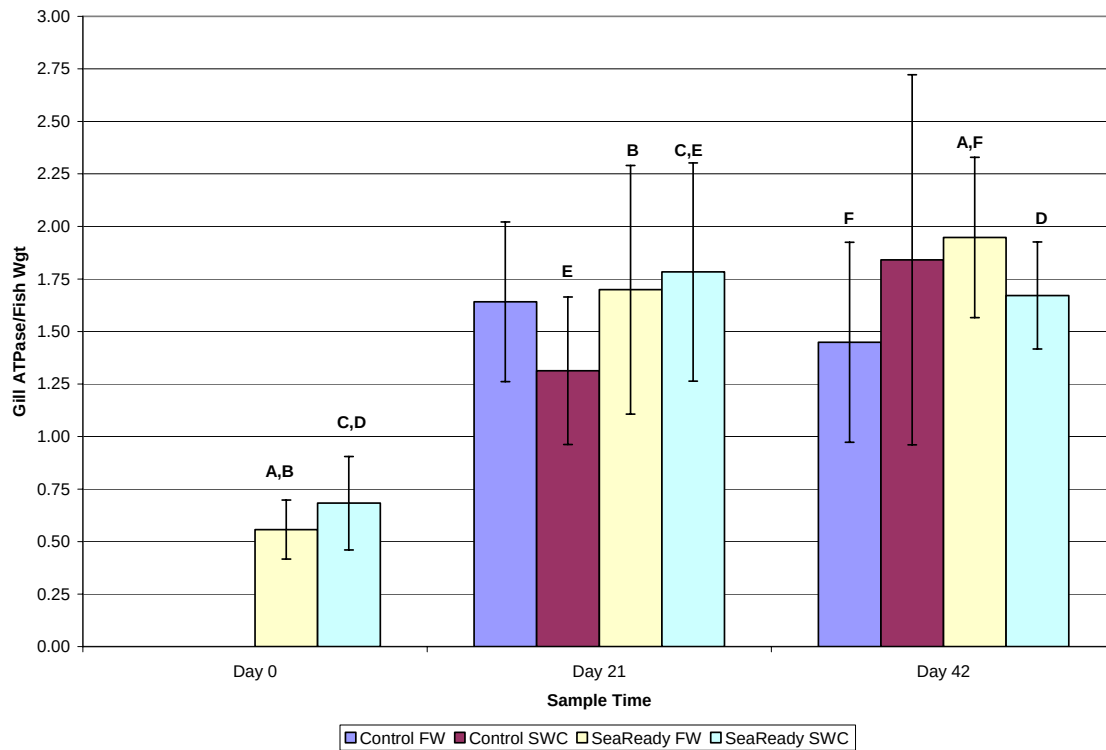


Figure 3. Gill ATPase values on a per fish weight basis for Bear Lake Sockeye SeaReady™ trial. Columns with the same letter are significantly different ($P < 0.05$).

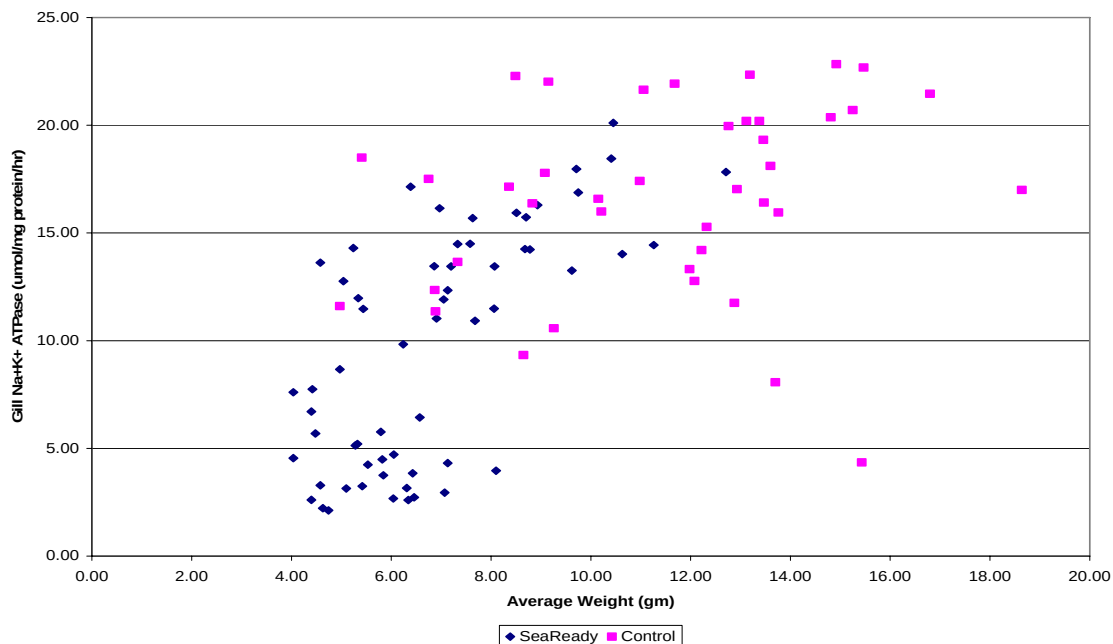


Figure 4. Gill ATPase versus Fish Weight. The SeaReady™ program was successful at achieving similar ATPase values as the Control fish despite the fish being smaller in size.

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Comparison with the 2005 Bear Lake Sockeye SeaReady™ Trial

There was approximately five days difference between the start of the SeaReady™ trial in 2006 in comparison to the trial completed in 2005 (April 11, 2006; April 16, 2005). For purposes of comparison only the fish treated with SeaReady™ process will be analyzed.

While the start and end dates are comparable, the fish size was significantly different ($P < 0.05$) between the two trials (see Figure 5). In absolute terms, the 2005 SeaReady™ treated fish (SWC) had significantly higher ($P < 0.05$) gill Na+K+ ATPase levels at all sample points (Figure 6). Relative ATPase levels (gill ATPase per fish weight) was significantly higher ($P < 0.05$) at Day 0 and 42 but not for Day 21 ($P = 0.066$) (see Figure 7). Figure 8 is a scatter plot of the ATPase values in comparison to average weight. In the 2006 SeaReady™ trial we were successful in treating smaller fish with the SeaReady™ process. While the gill ATPase levels are lower in comparison to the 2005 SeaReady™ trial, it is not known at this point whether there is a direct link to survival (adult returns). The fish from the 2005 SeaReady™ trial are scheduled to return in 2007/2008, while the 2006 SeaReady™ group will return in 2008/2009.

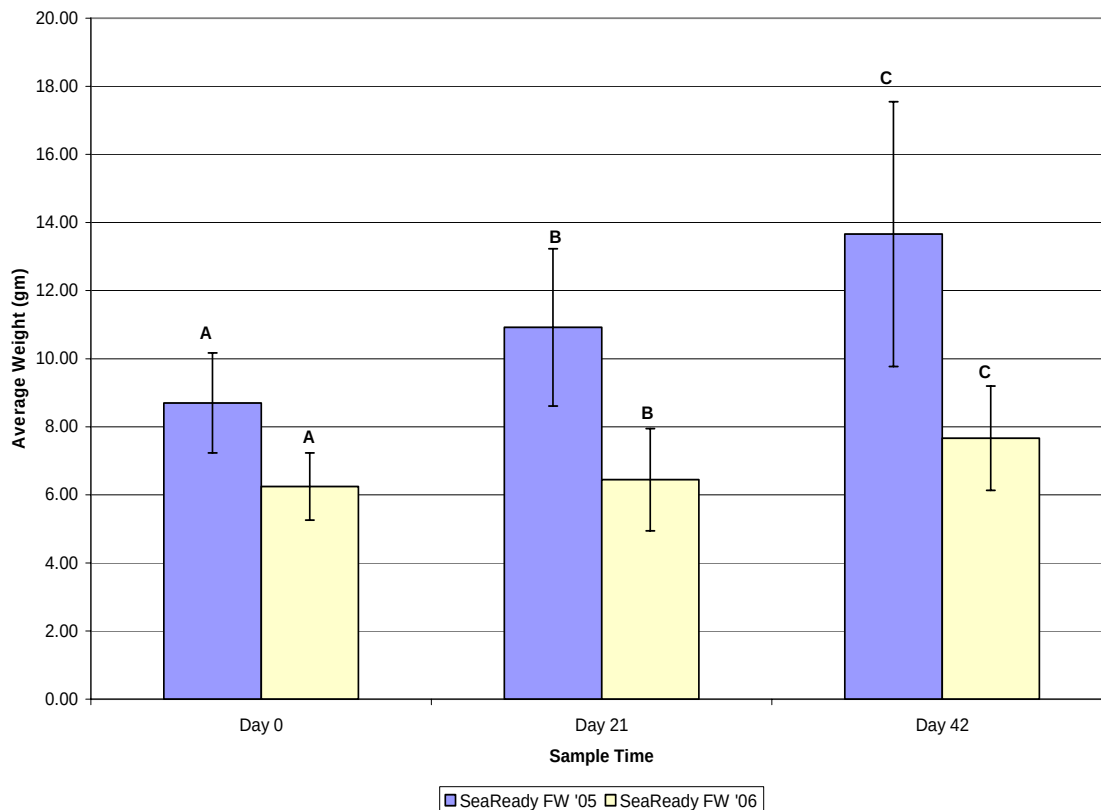


Figure 5. Average weight of Bear Lake sockeye treated with the SeaReady™ process in 2005 and 2006.

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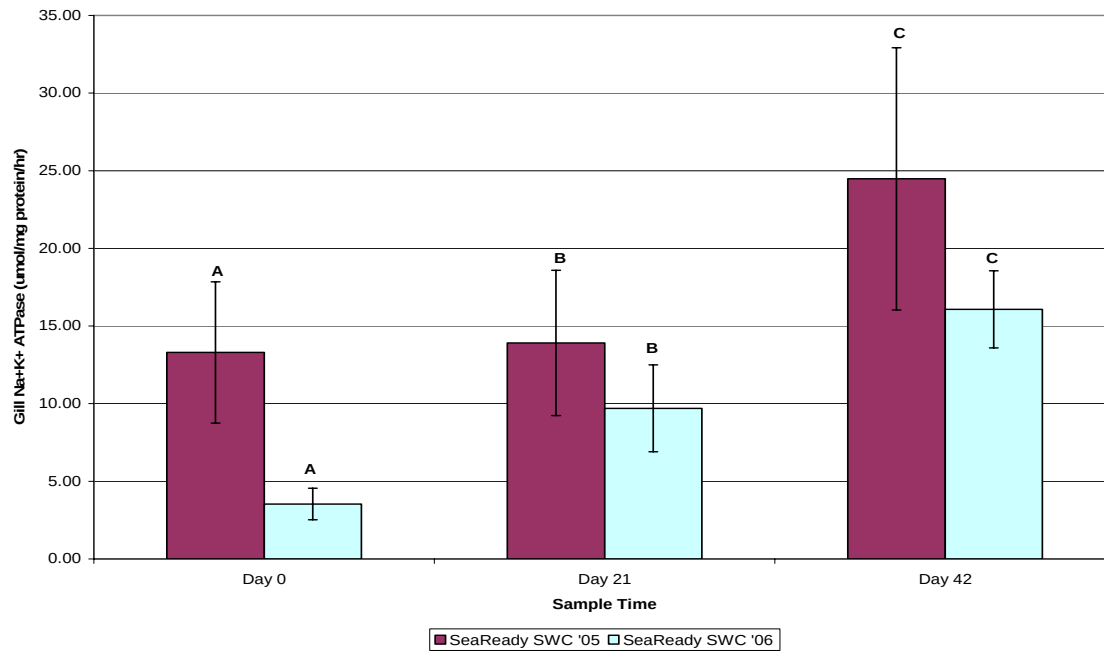


Figure 6. Gill ATPase values for Bear Lake sockeye treated with the SeaReady™ process in 2005 and 2006.

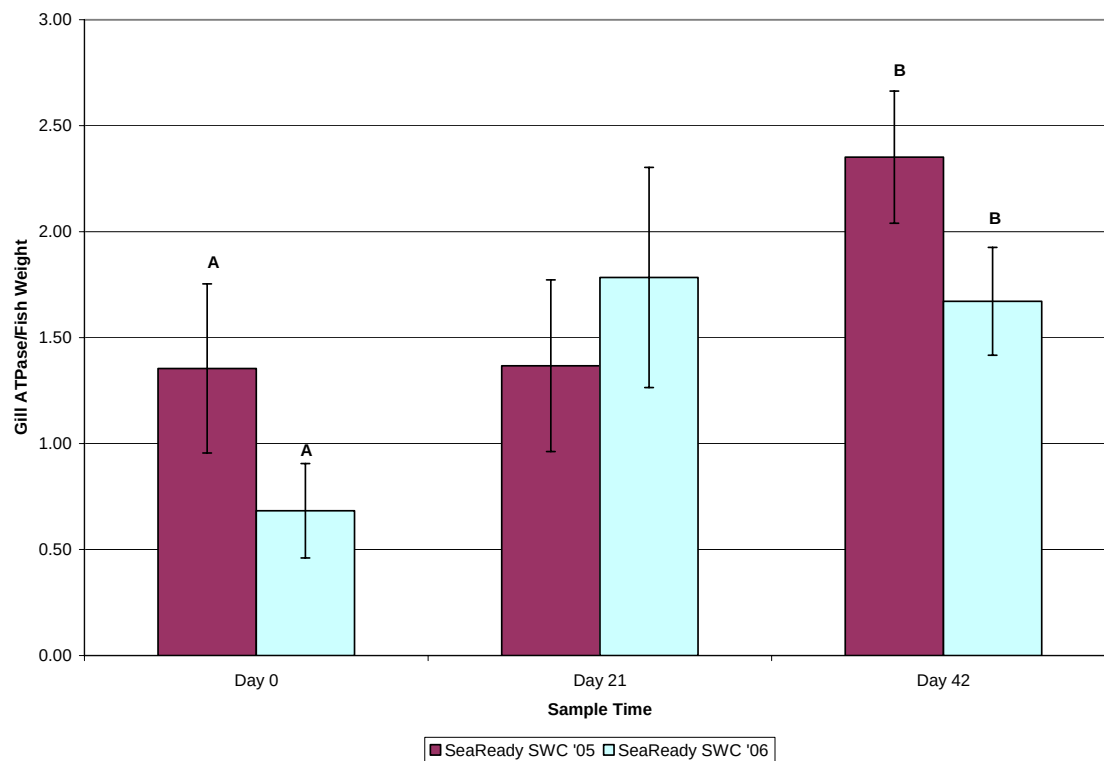


Figure 7. Gill ATPase per Fish Weight for Bear Lake sockeye treated with the SeaReady™ process in 2005 and 2006.

APPENDIX 5

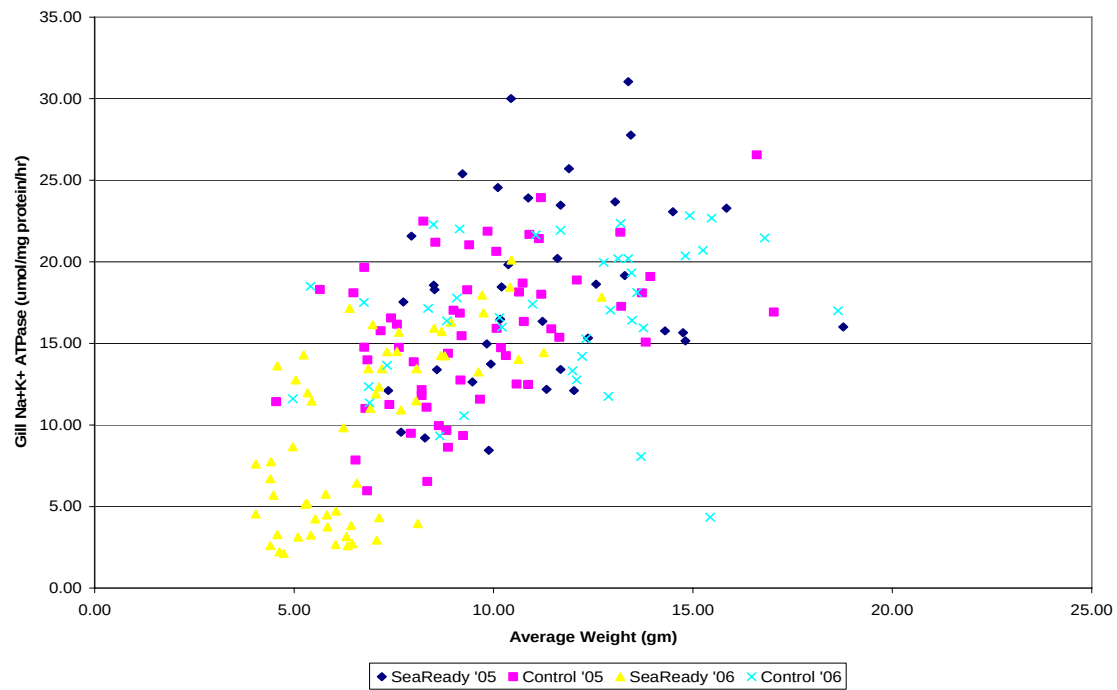


Figure 8. Gill ATPase vs Fish Weight.

Bear Lake Sockeye Adult Returns 2009

Background

This report extends previous work documenting efforts to rebuild sockeye salmon production from Bear Lake for Resurrection Bay fisheries. The native population of sockeye salmon in Bear Lake was largely extirpated in the 1960's to initiate coho stocking in the lake for sport fisheries and remained depressed for until the early 1990's when Cook Inlet Aquaculture Association (CIAA) initiated a stocking program to restore sockeye salmon production in Bear Lake to historic harvest levels.

As part of this effort, the Alaska SeaLife Center (ASLC), in collaboration with MariCal, Inc., contributed funds and technical assistance to CIAA to stock yearling sockeye smolt in Bear Lake in 2005 (n=400,000), 2006 (n=680,000) and 2007 (n=619,000). Prior to release, these fish were treated with MariCal's SeaReady™ process to determine if this technology could increase the rate and size of returning adults produced by hatchery-origin smolt. This process acclimates juvenile salmon to seawater while remaining in fresh water. Presumably, such adaptation would allow for more rapid movement through estuaries and near shore waters where predation is often high.

Methods

Otoliths were collected from adult sockeye caught in the commercial purse seine fishery in June (n=400) and at the Bear Lake weir during July 2009 (n=400). Paired or individual otoliths were washed with distilled water, placed in collection trays and shipped to the Alaska Department of Fish and Game (ADF&G) Mark Lab in Juneau, AK for reading. Contributions to these strata were calculated simply from the proportions of otoliths recovered and were not weighted the number of fish caught during time period the fish were sampled.

Smolt contributing to the 2009 adult return are shown by brood year and stocking group in Table 1. The data were collected by CIAA staff during the 2006 and 2007 smolt migrations at Bear Lake. Analysis of otolith samples collected from these smolt indicated that n=1,962,415 sockeye smolt passed through the Bear Lake weir in 2006 and n=1,339,089 in 2007. In both years the majority of the migrants were from fry stocking with approximately equal numbers of derived from smolt and pre-smolt stocking. Low numbers (n=20,000-40,000) of age-2 smolt from fry and pre-smolt stocking also migrated in 2007 as did an additional ~20,000 unmarked smolt that presumably originated from natural spawning in the lake.

Results and Discussion

A total of n=800 otoliths from adult sockeye were collected and shipped to the ADF&G Mark Lab in 2009. Of this total, n=687 (85.9%) were marked fish. On a simple proportional basis, the total adult returns to Resurrection Bay and Bear Lake in 2009 were composed mainly of fish from brood year 2004, primarily pre-smolt stocked in Bear Lake in the fall of 2005 that migrated as smolt in 2006, and from unmarked fish that migrated as smolt in 2005 and 2006. Overall, n=587 (73.4%) of the samples collected came from BY04 pre-smolt, whereas n=113 (14.1%)

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were obtained from unmarked fish. Contributions from BY04 smolt (n=14), BY04 fry (n=41) and BY05 fry (n=22) were negligible and taken together represented less than 10% of the fish sampled. When viewed by sample location (Figure 1), BY04 pre-smolt (n=344) accounted for 86% of the samples taken in the fishery and ~ 60% (n=243) of the samples collected at the weir. Interestingly, unmarked fish (n=104) comprised 28% of the fish sampled at the weir, but only 2% of the fishery samples.

This marks the second year in a row that the Resurrection Bay sockeye returns were composed primarily of fish that spent three years in the ocean (3 SW). Historically, these returns have been divided roughly evenly between 2 SW and 3 SW adults (Gary Fandrei, CIAA personal communication). The reason for the weak return of 2 SW adults is not clear, but historically cold ocean temperatures near Seward in the spring of 2007 may have reduced the number of returning adults in this age class (source Univ. Alaska Fairbanks, GAK1 Time Series). Cold water temperatures at the time of ocean entry can directly reduce both the growth and survival of smolt and potentially delay adult age at return. These effects will not be known until the return of the 2007 smolt in 2010.

The low number of smolt releases that contributed to the adult return is also consistent with 2008 return of fish from this stocking group. Based on these results, the treatment of smolt produced at Trail Lakes with the SeaReady process appears to have had little if any benefit to the rebuilding effort. Whether this can be attributed to stocking smolt in the lake rather directly into Resurrection Bay or in to net pens in Resurrection Bay is not known. It is clear, however, that the strategy of stocking smolt that are fully adapted to seawater into Bear Lake has not worked and should be reviewed in future stocking plans.

The large numbers of pre-smolt and unmarked fish that contributed to the 2009 return are also notable, as is the weak return of adults from fry stocking. Our previous otolith analyses (2006-2008) showed that adult returns were dominated by fish originating from fry stocking (range 52-71%), with limited contribution from pre-smolt (range 7-29%) and unmarked (naturally produced) smolt (range 1-8%). By contrast, pre-smolt and unmarked fish represented 73% and 14%, respectively, of the total return in 2009. Moreover, when sample location is taken into account, unmarked fish accounted for 25% of the return to Bear Lake weir. Even if the all of the 2006 and 2007 unmarked smolt are included in the total seaward migrants for these years (Table 1, n=41,500), this would represent a marine survival of ~ 25% for these fish also based on a total return of ~ 40,000 to the Bear Lake weir in 2009 (ADF&G 2009 Lower Cook Inlet Management Report). If correct, this would support the suggestion that re-establishing natural spawning in Bear Lake may well increase adult production beyond that obtained from stocking alone.

Finally, the 2009 return of 151,000 sockeye represented the highest number of adults since inception of the stocking program in 1989. What is most interesting is that this return was largely the result of smolt originating from (presumably) natural spawning and pre-smolt stocking that have previously contributed only limitedly to adult returns. Whether this trend continues in 2010 is unknown, but at the time of this writing the preliminary returns of sockeye to Resurrection Bay were well below forecast. Future efforts to rebuild the Bear Lake population may need to consider the shifting benefits of stocking strategies and natural production.

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Table 1. Stocking group(s) and numbers that contributed to the 2009 adult sockeye return to Bear Lake.

Brood Year	Migration Year	Stocking	Thermal Mark	# Stocked	# Thru Weir
2004	2006	Fry	6H	2,416,000	1,314,818
2004	2006	PreSmolt	H4	604,000	
2004	2006	Control Smolt	6H, H4	380,000	
2004	2006	SeaReady™ Smolt	3,3H3	680,000	633,860
2004	2006	Wild	No Mark		13,737
2004	2007	Fry	6H	2,416,000	24,907
2004	2007	Pre-Smolt	H4	604,000	44,591
2005	2007	Fry	6H	2,413,900	767,158
2005	2007	SeaReady™ Smolt	2,1H	619,000	481,677
2005	2007	Wild	No Mark		20,756

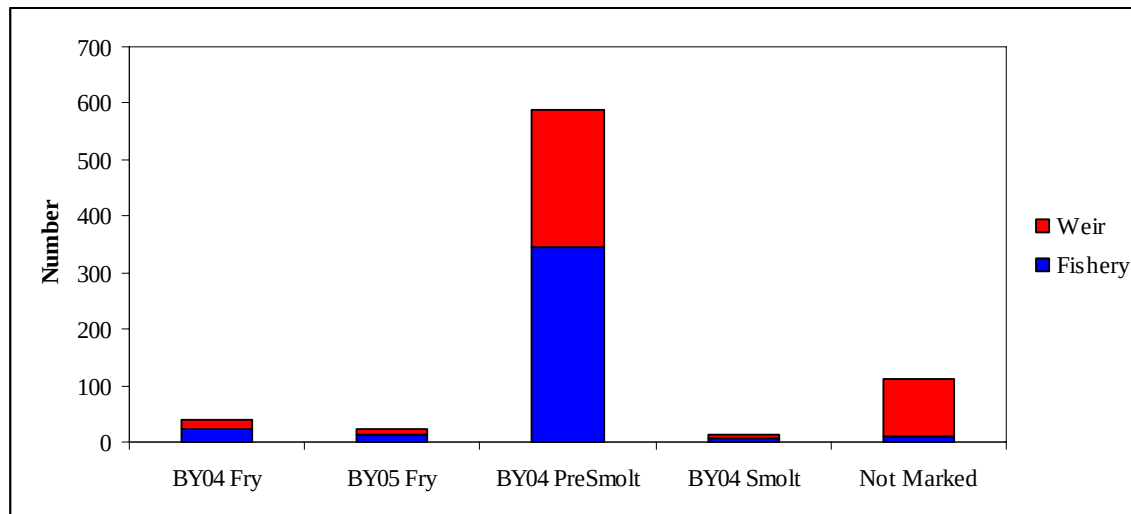


Figure 1. Number of fish sampled by location, brood year and stocking group that contributed to the 2009 adult sockeye return. Data are for fish sampled for otoliths only.

FINAL REPORT

**Paleolimnology and Reconstruction of past Trends of Adult Salmon
Abundance in Bear Lake near Seward, Alaska**

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To: Alaska Sea Life Center

Abstract

Paleolimnological techniques were applied to sediment cores from Bear Lake, near Seward, Alaska, to better understand processes and long-term trends in its biota and environments, with a focus on sockeye salmon (*Oncorhynchus nerka*). CIAA, in a cooperative agreement with the ADF&G, initiated a program to restore sockeye salmon production from Bear Lake to historic harvest levels through fry stocking beginning in 1990. Sediment core analysis of this sockeye salmon nursery lake system uses nitrogen stable isotopes ($\delta^{15}\text{N}$) as an analog for past changes in sockeye salmon abundance, and other proxies to examine lake paleoproductivity and past environmental conditions. The core data allowed such reconstructions over the past ~500 years. This data helps define the natural variability of sockeye salmon in these systems, and its relationship to past changes in climate, landscape processes, ocean condition and commercial fishing. Three cores from Bear Lake were recovered and analyzed as part of this project. The $\delta^{15}\text{N}$ variability in Bear Lake is likely related to past fluctuations in salmon abundance, as the signatures in the core are higher than values typical of non-salmon lakes in Alaska, and other watershed and limnologic factors known to enrich sediments in $\delta^{15}\text{N}$ are not probable in this setting. Sedimentary $\delta^{15}\text{N}$ is relatively high in the upper and lower parts of the core; the middle unit of low $\delta^{15}\text{N}$ appears to coincide with local Little Ice Age (LIA) glacial advances. This evidence suggests that in the Bear Lake watershed, glacial advances and resultant sediment loads may have caused local reduction in sockeye salmon escapement. Lower lake production and its influence on carrying capacity for juveniles, or other detrimental factors to the system such as a decrease in the euphotic zone extent from increased turbidity, may have all contributed to the depleted $\delta^{15}\text{N}$ values over this time period. Significant increases in $\delta^{15}\text{N}$ ~ 1700 AD suggest a peak in lake production and salmon escapement during this period relative to the 500-year record. The $\delta^{15}\text{N}$ values are generally high over the last ~300 years, but indicate a significant declining trend towards present. The low values in the upper few cm of the sediments, which corresponding to the latter part of the 20th century, may reflect the near extirpation of the sockeye salmon stocks beginning in the 1960s. The very low recent sedimentation rates, and resultant smoothing of the sedimentary record, do not readily allow for detailed comparisons to historical data. Overall, the sediments recovered from Bear Lake provide a long-term perspective on its limnological and environmental history, and contain key information for interpretation of past sockeye salmon abundance.

Introduction

To continue to aid in rebuilding the sockeye salmon population in Bear Lake, sediment cores were collected and analyzed to investigate pre-historical variability in sockeye salmon abundance and lake environments. For nearly a decade, studies at the Institute of Marine Science, University of Alaska Fairbanks, have led to the development of a method to reconstruct long-term changes in salmon abundance from sediment core analysis. This method is based on the observation that salmon strongly impact freshwater environments via input of significant quantities of marine-derived nutrients released from carcasses after spawning, death, and subsequent decomposition. This input, which can be quantified through analysis of stable isotopes ($\delta^{15}\text{N}$), will vary depending on escapement. Therefore, downcore changes in the abundance of $\delta^{15}\text{N}$ will reflect changes in the number of returning adult salmon. Rationale, evaluation and further details regarding the sedimentary nitrogen isotope technique are summarized in Finney et al. (2000).

Methods

Field Methods. Field work including, site surveys and sediment core collection, was carried out on Oct 26, 2006. Selection of potential coring sites was made prior to going to the field by examining the available 3-m contour interval bathymetric map of the lake bottom. Bear Lake, which runs north-south from its headwaters to the outlet of Bear Creek, generally has steep contours near shore, which fall quickly to a fairly deep basin. On the south end of the lake, a deep basin is found (~15-20 m), which grades upward to more shallow depths toward the inlet to the north (~12 m). The deepest basin is located adjacent to the southeast shoreline (18-20 m). In the field, the pre-selected sites based on the bathymetric map assessment were further assessed. The coring site was chosen based on field surveys of bathymetric gradients and watershed conditions such as locations of inlets and hill slope features, to avoid complications from processes such as turbidities and gravity flows. Field collections were made at a depth of 17 m in the south-central extent of the lake (N 60° 11.874' W 149° 21.390').

Three cores were obtained from the lake to ensure that representative records were produced. Hammer core (BL_HC1) had a total length of 113 cm. A high-quality surface core (BL_SC1) was obtained from the lake with a light-weight corer designed for sampling unconsolidated sediments and obtaining an undisturbed sediment-water interface. Field observations indicated this core preserved the delicate sediment-water interface. It was collected at a site a few meters to the north (total length of 61 cm). A second hammer core (BL_HC2) was collected at this location in order to recover deeper sediments and to check reproducibility (total length 145 cm). Once on shore BL_SC1 was continuously sampled in at 0.5 cm increments using a precision extruder to a depth where the sediments were consolidated enough (5 cm) for safe transport to the laboratory. The extruded sediment was then frozen until further analyses. The cores are stored in cold

rooms at the University of Alaska at ~4°C. Both the surface core (BL_SC1) and the second hammer core (BL_HC2) have been "opened" (split lengthwise), described and analyzed.

Laboratory Methods. The Bear Lake cores were analyzed using standard sedimentological techniques (PALE, 1994). The cores were first opened and described in terms of sediment characteristics and diagnostic features. The long core selected for detailed study was sampled continuously at 1 cm increments in the laboratory. Physical properties measured on each sample include water content, and wet and dry bulk density. Magnetic susceptibility is measured on each sample to determine the distribution of volcanic ash layers and to provide other stratigraphic information. Magnetic susceptibility is a measure of the degree to which sediments may be magnetized and is expressed as SI units (SI = standard international, a unitless measure). Magnetic susceptibility was a useful tool in this study, as it allowed for correlation between cores based on matching of diagnostic features of magnetic susceptibility profiles. Dating of the cores was determined by radiocarbon (^{14}C) analysis and tephrochronologic (tephra stratigraphy) methods. One radiocarbon date was obtained near the bottom of the longest core. A tephra layer in the cores was also identified and used in developing the age model (Appendix 1). Organic matter and carbonate content was determined by high temperature ignition, using the standard loss on ignition (LOI) methodology. Downcore analyses of carbon %, nitrogen %, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ was conducted on a Finnigan Delta Plus mass spectrometer coupled with a Costech 4010 elemental analyzer. Analysis was conducted on finely ground samples. Nitrogen and carbon isotopic ratios are expressed in standard δ notation, indicating the difference between a sample and the universally accepted standards (Peterson and Fry, 1987):

$$\delta^{15}\text{N} \text{ or } \delta^{13}\text{C} (\text{‰}) = [\text{R}_{\text{sample}} - \text{R}_{\text{standard}}] \times 1000$$

Where R is the ratio of $^{15}\text{N}:^{14}\text{N}$ or $^{13}\text{C}:^{12}\text{C}$. All isotope results were expressed relative to the international standards Vienna Pee Dee Belemnite (VPDB) for $\delta^{13}\text{C}$ and atmospheric N_2 (AIR) for $\delta^{15}\text{N}$.

Summary of core analyses conducted:

1. Initial core examination and sediment description
2. 1-cm incremental sediment sub-sample collection
3. Freeze drying, physical property analysis (water content, bulk density, magnetic susceptibility) and sample preparation for subsequent analyses
4. Loss on Ignition (organic matter and calcium carbonate contents)
5. Stable Isotope analyses

6. Chronologic control via basal radiocarbon dating, and analysis of a prominent tephra (volcanic ash) layer

Results

General sediment characteristics. The bulk of the sediments appear to be glacially-derived lithogenic material, but diatoms and other micro and macro fossils are present throughout much of the core. The magnetic susceptibility profiles reveal one prominent peak (Fig. 1). Examination of sediments corresponding to this zone demonstrated it to be a brown tephra layer, which is present in all cores. The near surface green-brown pelagic sediment in Bear Lake grades rapidly downcore to firm grey inorganic sediment with a silty-clay texture. The sediments are subtly banded, with the lighter bands differing only slightly in color and texture from darker bands. The LOI profile (Fig. 2) illustrates three distinct units of organic matter content. The three units are defined as: Unit 1 - relatively higher %LOI (to 6%) from the surface to 30 cm, Unit 2 - 30 to 120 cm which is relatively low in organic matter (2 - 3% LOI), and Unit 3 - 129 to 145 cm with relatively higher organic matter concentrations 6 to 4%. On average sediment LOI (organic matter content) is 3.4%, which is relatively low for lakes with regard to organic content. This data suggest distinct changes in either the production or dilution of organic matter over time. The LOI technique indicated that carbonates are not present in significant quantities in the Bear Lake sediments.

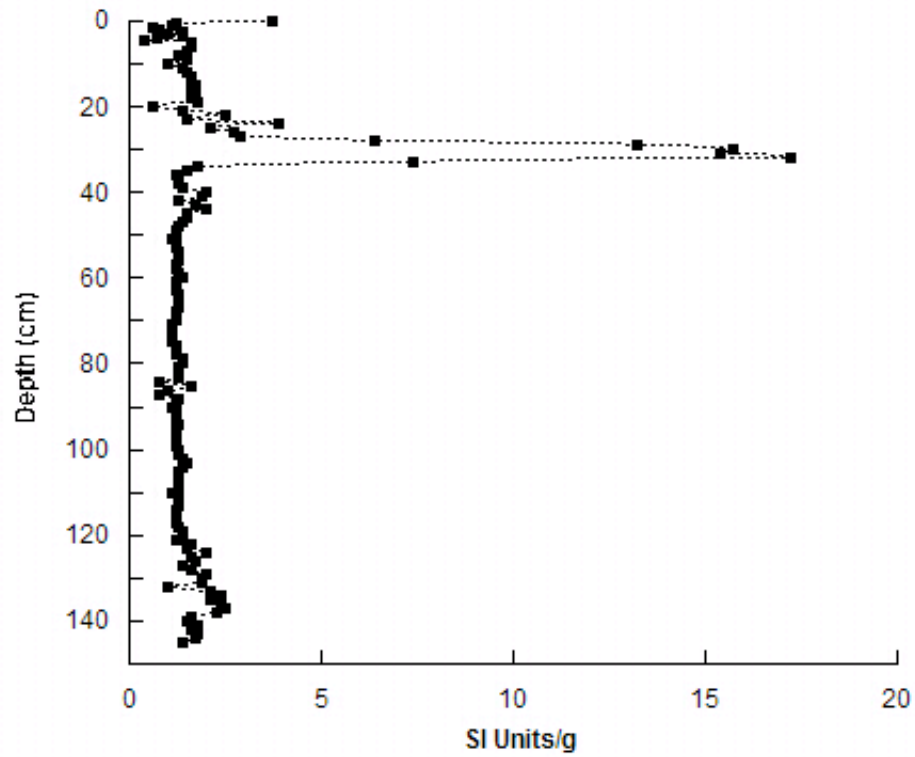


Figure 1. Magnetic Susceptibility profile of the Bear Lake sediment cores. The high values reflect the prominent tephra layer at 26-32 cm.

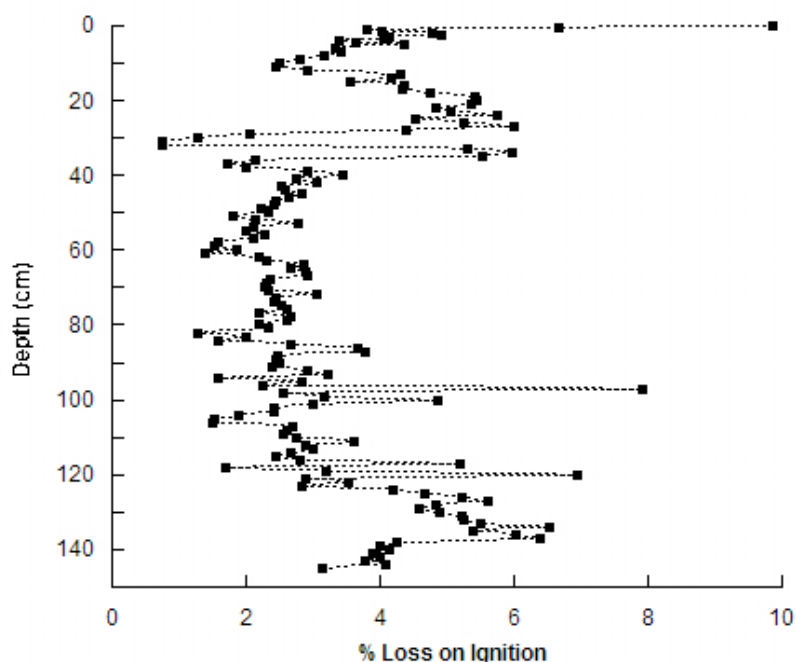


Figure 2. Organic matter (% Loss on Ignition) profile for composite core of Bear Lake (BL_SC1 and BL_HC2).

Sediment chronology. Using the prominent tephra marker, the surface core and longer hammer cores have been correlated to develop a composite record for the lake which spans approximately 500 years over 145 cm. A terrestrial macrofossil (conifer needle) obtained from near the bottom of the core (126 cm) was radiocarbon dated using the AMS technique at Lawrence Livermore National Laboratory. The calibrated radiocarbon age estimate of this sample is 1520 $\pm$ 50 years AD. As discussed, the magnetic susceptibility profile and visual and microscopic descriptions show that the susceptibility peak at 26-32 cm is a tephra. A tentative correlation (Appendix 1) for this event has been made by comparison with detailed tephrochronological data from nearby Skilak Lake (48 km to the northwest; Beget et al. 1994). The best geochemical match of the Bear Lake tephra is to the 1700 $\pm$ 50 years AD eruption of Mt. Spurr, Crater Peak found in the Skilak Lake tephra record. The age for this event in Skilak Lake was determined from extrapolation of the ^{210}Pb -based sedimentation rates of its recent sediment (last ~100 years) and thus has some uncertainty. The Bear Lake age model is constructed from the AMS ^{14}C date at 126 cm, the tephra marker, and the core top age (= date of coring). The age depth plot based on these 3 points (Fig. 3) can be used to infer ages of downcore changes in the sedimentary record. The changes in LOI and $\delta^{15}\text{N}$ (see below) at ~30 and 120 cm correspond to approximately 1690 and 1550 AD, respectively.

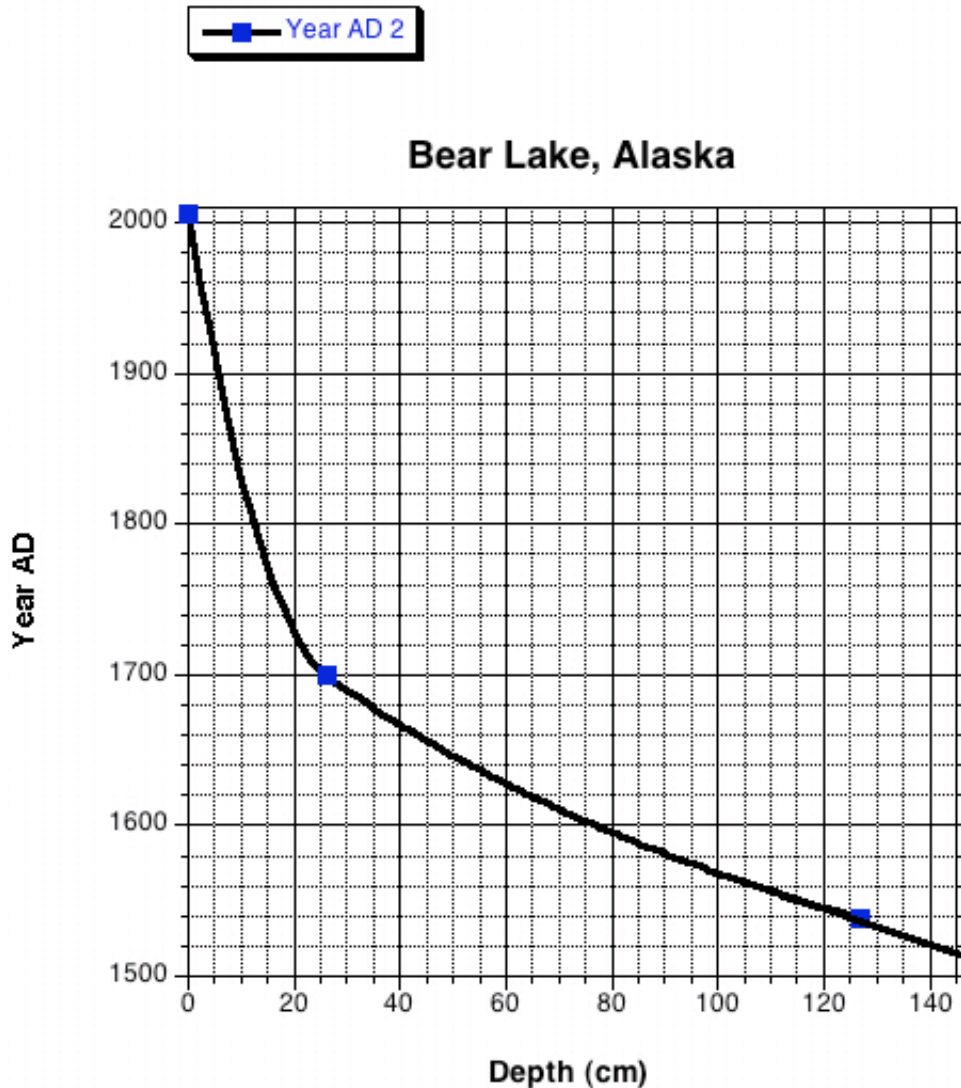


Figure 3. Age depth plot for Bear Lake based on 3 points: core top age (date of coring), tephra at 26-32 cm, and ^{14}C date at 126 cm.

Carbon, nitrogen and isotopic data. The C to N ratio is used to infer organic matter source (lake [aquatic] vs. watershed [terrestrial]). Low C/N ratios (<10) are characteristic of aquatic sources, whereas higher values ($\sim >20$) are typical of terrestrial organic matter. Over the core length the lake appears to be dominated by aquatic organic matter, as it has C/N values averaging ~ 10.5 (Fig. 4). Thus the low organic content appears to result from high input of inorganic sediment from the watershed. In general, isotope-based reconstructions of salmon abundance are stronger in cases where sediments are

dominated by aquatic sources, as in such cases variability in $\delta^{15}\text{N}$ is a better reflection of nutrient fluctuations in salmon nutrient loading.

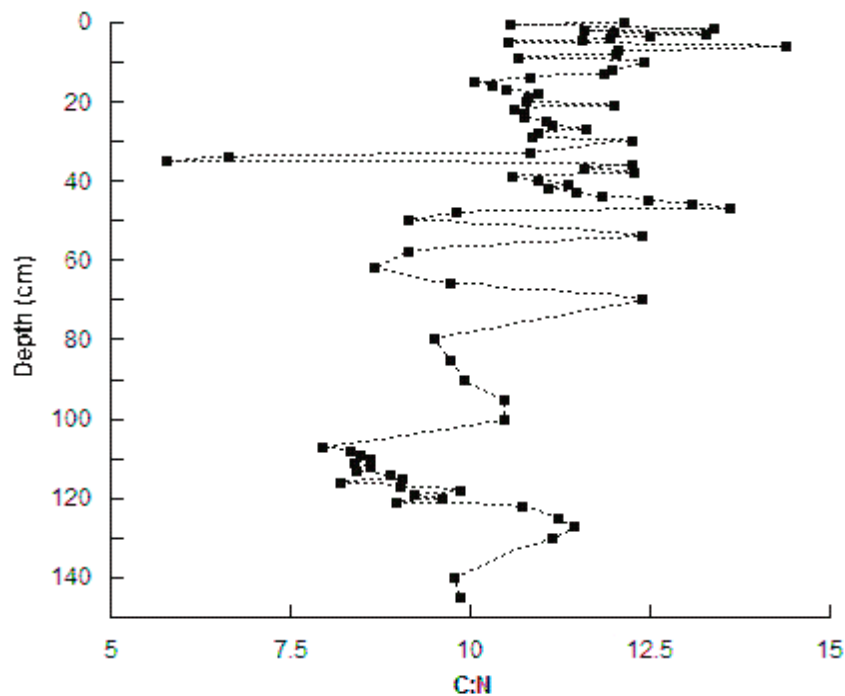


Figure 4. Profile of carbon-to-nitrogen ratio (weight percent) in Bear Lake sediments. The relatively low ratios suggest the dominance of aquatic-derived organic matter.

The $\delta^{15}\text{N}$ data of the Bear Lake sediment show relatively moderate values ranging from $\sim 1\text{‰}$ to 4.5‰ (Figure. 5). A few low values (-0.5‰) correspond to the zone of the tephra, and are suspect due to the low %N in these samples. Relatively high values are found in Units 1 and 3. The highest values are in Unit 1, which shows a trend of declining values from $\sim 30\text{ cm}$ to the core top. Relatively lower values are found in the zone of sediment (Unit 2) with low organic content between $40 - 120\text{ cm}$.

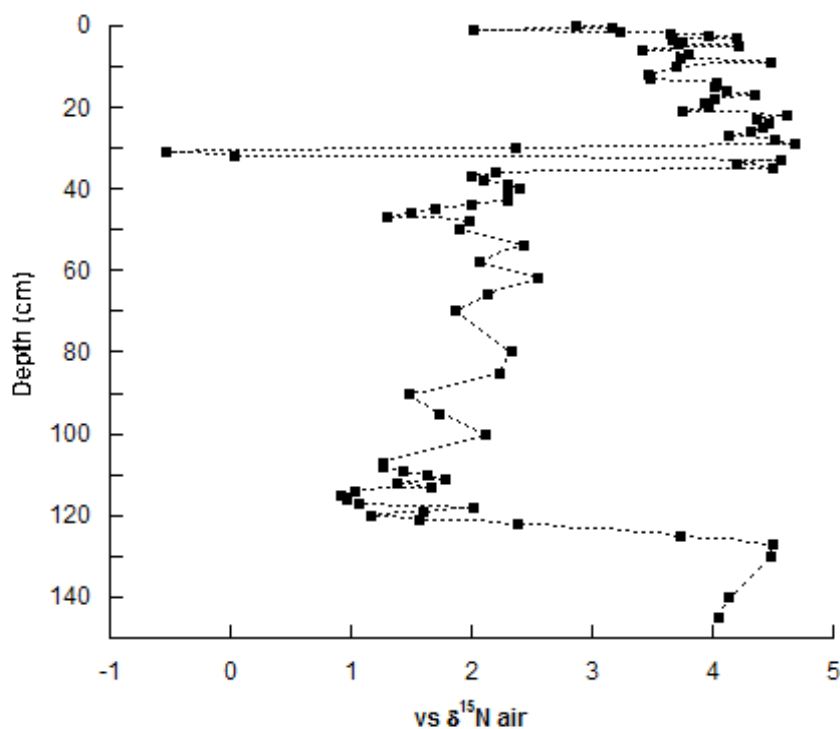


Figure 5. Stable nitrogen isotope data ($\delta^{15}\text{N}$) vs. depth for Bear Lake composite core.

Trends in the Bear Lake $\delta^{13}\text{C}$ data generally correspond with the variability in organic content and $\delta^{15}\text{N}$ (Fig. 6). The $\delta^{13}\text{C}$ ratios are highest in Unit 2, and lowest in Units 1 and 3. Lower $\delta^{13}\text{C}$ values typically reflect one or more of the following factors: higher pCO_2 of water, lower $\delta^{13}\text{C}$ of lake water dissolved carbon, or lower aquatic productivity. It is likely that changes in hydrology and lake chemistry associated with changes in glacial input effected the lake carbon system, which thus complicates the use of $\delta^{13}\text{C}$ as a proxy for estimating aquatic productivity. Regardless, the changes in $\delta^{13}\text{C}$ imply relatively minor productivity variations over the course of the core. Part of the very recent $\delta^{13}\text{C}$ decline may be attributed to the fact that in the past 100 years $\delta^{13}\text{C}$ in atmospheric CO_2 ($\delta^{13}\text{CO}_{2\text{atm}}$) has been declining at an increasing rate as an effect of the accelerating release to the atmosphere of CO_2 from fossil fuel burning. The change in $\delta^{13}\text{C}$ content of the atmosphere can result in lower $\delta^{13}\text{C}$ signatures in lake sediments.

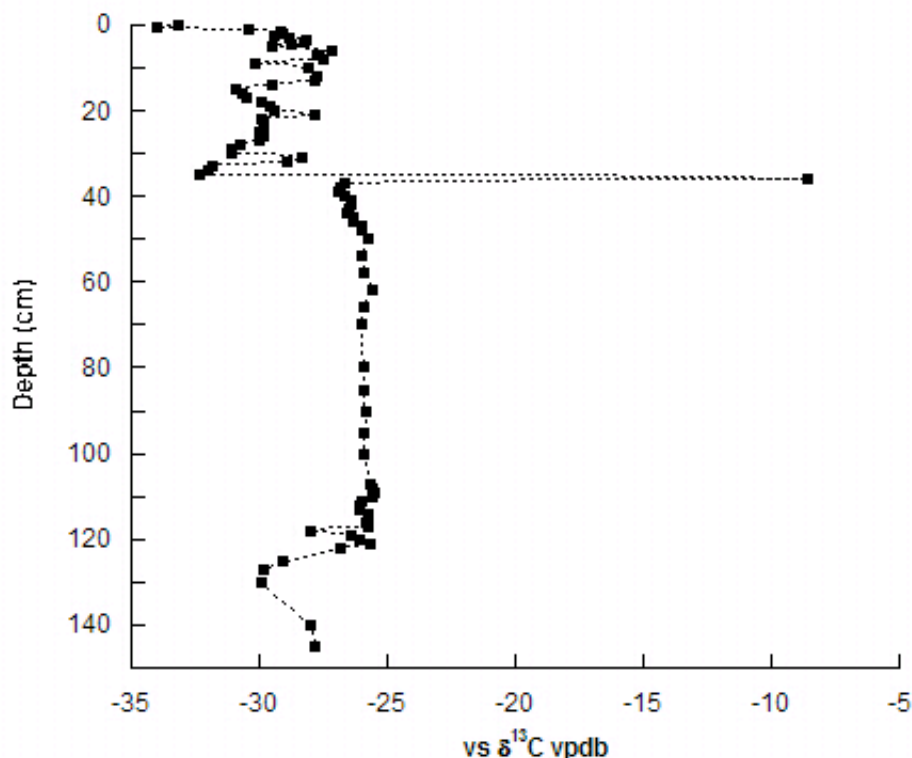


Figure 6. Stable carbon isotope data ($\delta^{13}\text{C}$) vs. depth for Bear Lake composite core.

Discussion

The Bear Lake sediments comprise three major units. The upper unit with relatively high organic content and $\delta^{15}\text{N}$ corresponds to roughly 1690 AD to present. The sediment $\delta^{15}\text{N}$ values in this unit are relatively high, much higher than $\delta^{15}\text{N}$ typical of non-salmon lakes in Alaska (average $\sim 1\text{‰}$; Finney et al. 2000). Thus the relatively enriched $\delta^{15}\text{N}$ in Bear Lake suggests that it may represent contributions of salmon-derived nitrogen, and therefore record past fluctuations in salmon abundance. Other watershed and limnologic factors known to enrich sediments in $\delta^{15}\text{N}$, such as denitrification, are not probable in this setting (Finney et al. 2000). Significant increases in $\delta^{15}\text{N}$ ~ 1700 AD suggest a peak in salmon escapement during this period relative to the 500-year record. Though the $\delta^{15}\text{N}$ values are generally high over the last ~ 300 years, a significant declining trend is observed towards present. The low values in the upper few cm of the sediments, which corresponding to the latter part of the 20th century, may reflect the significant decline in

sockeye salmon stocks beginning in the 1960s. However, the very low recent sedimentation rates, and resultant smoothing of the sedimentary record, do not readily allow for detailed comparisons to historical data.

Today, glacial activity within the Bear Lake watershed is largely absent. However, the nature and timing of changes in sediment properties down core suggest active periods in the past where advances in glaciers during the Little Ice Age (LIA) influenced sedimentation. Low organic content is observed between ca. 1690 – 1550 AD. This likely resulted from increased glacial sediment input possibly coupled with a resultant reduction in lake productivity, and may reflect local LIA glacial advances in the Bear Lake watershed. The timing of this sequence coincides with a known period of glacial advance during the LIA (Fig. 7; note period of glacial advance beginning ~ 1600 AD). Interestingly, the Bear Lake record does not show strong evidence for the subsequent period of glacial advance in the Gulf of Alaska during the 1800s. It has been demonstrated that there is spatial variability in the importance and magnitude of LIA pulses of glacial activity in this region, which probably reflects different paleoclimatic patterns of atmospheric circulation, and differential local and regional effects on glaciation depending on factors such as orientation of snow accumulation zones (Calkin et al. 2001).

The low $\delta^{15}\text{N}$ observed in the LIA period between ca. 1690 – 1550 AD probably reflects lower salmon abundance. If the reduction in $\delta^{15}\text{N}$ was caused by higher watershed inputs of N with low $\delta^{15}\text{N}$, then lake productivity would have been expected to be higher. Lower salmon production during this period could have resulted from either poor marine conditions or lower lake carrying capacity, or both. However, it is probable that increased glacial sediment input would have greatly reduced lake productivity (i.e. greater turbidity and decrease in euphotic zone extent), which could have had subsequent effects on salmon production. Lower salmon abundance during this period may reflect this reduced carrying capacity, as other clearwater lakes in Alaska do not systematically show lower salmon abundance during the LIA (Finney et al. 2000). The lowermost sediments recovered, ca. 1550 – 1500 AD show a return to higher organic content and higher $\delta^{15}\text{N}$. This may suggest a period of lower glacial activity in the watershed and a return to relatively higher salmon abundance.

Overall, the Bear Lake record suggests natural variability in limnologic and lake trophic status as a result of climate change and glacial fluctuations. The sedimentary data suggests that higher salmon abundance occurred during periods of lower glacial activity; glacial advances in the watershed, and resultant sediment loads, may have caused local reductions in sockeye salmon escapement. However, following the apparent rebound in salmon abundance ~ 1700 AD, abundance remained relatively high until recent times.

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Thus the record may demonstrate that the recent reductions in $\delta^{15}\text{N}$ are anomalous in general relative to periods of ice-free conditions in the watershed. This appears to reflect the known escapement history of the lake, and supports the idea that the lake is naturally able to support higher sockeye salmon runs than at present.

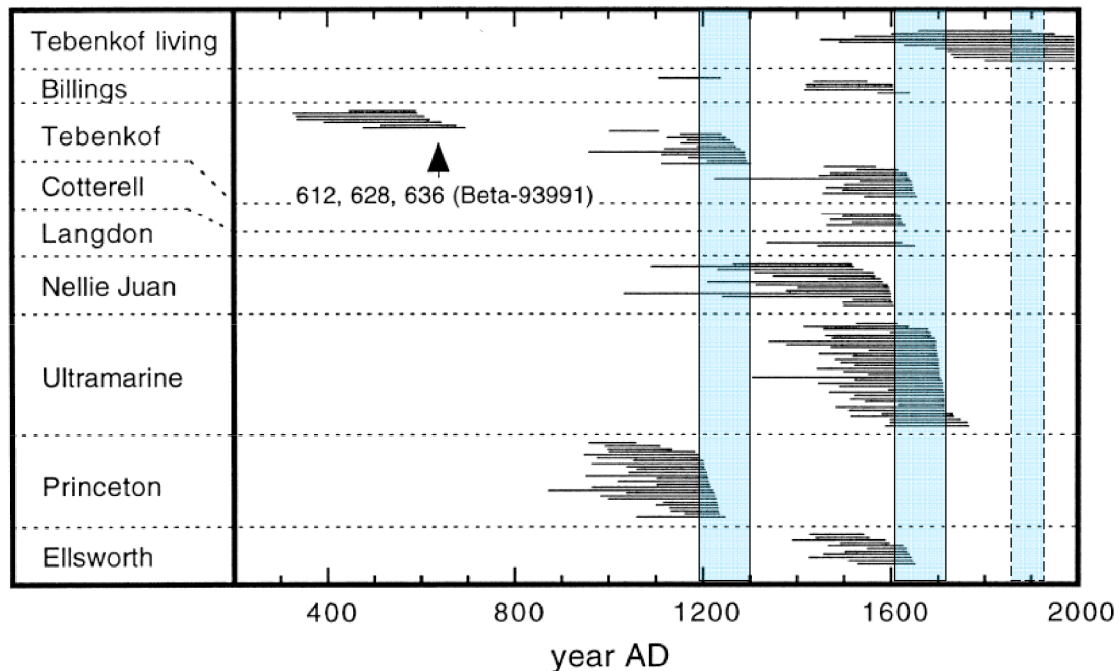


Figure 7. Record of tree ring dated glacial advances in the Gulf of Alaska Region (from Calkin et al. 2001).

References

- Beget, J.E., Stihler, S.D., Stone, D.B., 1994. A 500-year-long record of tephra falls from Redoubt Volcano and other volcanoes in upper Cook Inlet, Alaska, *J Volcanology and Geothermal Research* 62:55-67.
- Calkin, P.E., Wiles, G.C., and Barclay, D.J. 2001. Holocene coastal glaciation of Alaska. *Quaternary Science Reviews* 20, 449-461.
- Finney, B. P., Gregory-Eaves, I., Sweetman, J., Douglas, M.S.V. and Smol, J.P. (2000) Impacts of Climate Change and Fishing on Pacific Salmon Abundance Over the Past 300 Years. *Science* 290:795-799.

APPENDIX 7

Hecky R.E. and Hesslein R.H. (1995) Contributions of benthic algae to lake food webs as revealed by stable isotope analysis. *J N Am Benthol Soc* 14:631–653

PALE (1994). Research Protocols for PALE (Paleoclimatic of Arctic Lakes and Estuaries initiate, US National Science Foundation). PAGES Workshop Report, 94-1, Bern, Switzerland, 53 p.

Peterson, B.J., Fry, B. (1987) Stable isotopes in ecosystem studies. *Annual Review of Ecology Systematics* 18: 293-320

Appendix 1. Bear Lake tephrochronology analysis

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Methods

A six-centimeter-thick brownish-black fine sandy unit with sharp basal & upper contacts was identified in the surface Bear Lake core HC-2. Magnetic susceptibility measurements and smear slide analysis (Fig. 1) confirmed this unit as a volcanic tephra. Approximately 20 cm³ of material was collected and then dried at 50°C for several days to drive off moisture. A thin section was then prepared for this unit by setting grains in a matrix of Petro-Poxy© and the surface was polished to a smoothness of <1 μm. Following the application of a 300-Å-thick carbon coating, the sample was analyzed for major elemental compositions using grain-specific electron microprobe analysis (EPMA) on a Cameca SX-50 microprobe with four wavelength-dispersive spectrometers. Beam conditions were set to an accelerating voltage of 15 keV at 10 nA current with a beam diameter of 10 microns. A minimum of forty glass grains per sample were analyzed to minimize intra-sample variations. Replicate samples of the Old Crow tephra (Beget & Keskinen, 2003) were also analyzed to maximize inter-run accuracy and minimize machine drift during analysis. Inaccurate grain analyses were removed from the sample dataset based on the following qualifiers: (i) obvious non-tephra geochemistry (e.g. feldspar, quartz, olivine, etc.); (ii) calculated H₂O content >10 wt% (Pollard et al., 2006); (iii) any elemental concentration below EPMA detection limits; and (iv) outliers in discernible grain populations.

The tephra sample was then classified according to the IUGS total alkali-silica classifications of Le Bas et al. (1986). Correlations to published Late Holocene tephras from the Cook Inlet region were made using the datasets of Riehle (1985), Beget et al. (1994), Harbin et al. (1995), and Wallace (20003). Correlation coefficients between samples were calculated using the multivariate SIMAN analysis of Borchardt (1974). This statistical approach derives a similarity coefficient d between tephra sets A and B such that

$$d_{(A,B)} = \frac{\sum_{i=1}^n R_i g_i}{\sum_{i=1}^n g_i} \quad [\text{Eqn 1.1}]$$

where R is the ratio between a mean elemental concentration ($\bar{X}$) from A and B such that

$$R_i = \frac{\bar{X}_{iA}}{\bar{X}_{iB}} \text{ if } \bar{X}_{iB} > \bar{X}_{iA} \text{ or } R_i = \frac{\bar{X}_{iB}}{\bar{X}_{iA}} \text{ if } \bar{X}_{iA} > \bar{X}_{iB} \quad [\text{Eqn 1.2}]$$

Eqn 1.1 also includes a weighting term g that is derived from the relationship between the standard deviation (σ) and mean of an elemental analysis by means of the relative analytical deviation function RD

$$g_i = 1 - \frac{RD_i}{ERLEV} \quad [\text{Eqn 1.3}]$$

$$RD_i = \sqrt{\left(\frac{\sigma_{iA}}{\bar{X}_{iA}}\right)^2 + \left(\frac{\sigma_{iB}}{\bar{X}_{iB}}\right)^2} \quad [\text{Eqn 1.4}]$$

The ERLEV function is the relative analytical deviation corresponding to the instrumental detection limits, and is assigned a value by the investigator. It has the practical effect of minimizing the weighting of a particular element that may have a large uncertainty associated with its measurement as determined by the standard deviation from the mean. In this paper, ERLEV was intentionally minimized to the degree that the elements with the largest standard deviations were excluded from the similarity calculations; this treatment specifically removed TiO₂, and occasionally Cl, from the similarity determinations. The accuracy of the SIMAN analysis was verified using elemental bivariate plots.

Results

Twenty-four volcanic glass shards were analyzed via EPMA (Table A1). Based on the Le Bas et al. (1986) IUGS classification, the Bear Lake tephra is andesitic in composition, a rarity in the Cook Inlet region (Riehle 1985). SIMAN similarity coefficient analyses with other well-characterized andesitic tephra (Table A2) suggests a strong similarity with the AD 1700 ± 50 Crater Peak tephra described by Beget et al. (1994) from Skilak Lake in the northeast corner of Cook Inlet. Oxide variation diagrams support this result (Figure A2).

Discussion

Based on the geochemical similarities between the Bear Lake tephra and the Skilak Lake tephra of Beget et al. (1994), the Bear Lake tephra is tentatively identified as the AD 1700 ± 50 Crater Peak tephra, which is derived from Mt. Spurr (Nye & Turner, 1990). The relatively large age constraint errors associated with this deposit are due to a date based on a linear sedimentation model. Nevertheless, the more recent Crater Peak eruptions of AD 1953 and AD 1992 are distinct from this earlier eruption, suggesting either increased magma fractionation over time, or increased crustal contamination.

A further line of evidence connecting the Bear Lake tephra to the Skilak Lake deposit are the deposits' relative thicknesses: 6 and 10 cm, respectively. The maximum thickness of the more widely dispersed AD 1953 Crater Peak eruption deposited only 6 mm of ash in Anchorage (Waythomas & Nye, 2002; Fig. A3). Thus, the thicknesses of the Skilak and Bear Lake deposits both suggest that the AD ~1700 eruption of Crater Peak was a much more explosive event, and may serve as an important stratigraphic marker in the northern sections of the Kenai Peninsula.

References

- Beget, J.E. and Keskinen, M.J., 2003. Trace-element geochemistry of individual glass shards of the Old Crow tephra and the age of the Delta glaciation, central Alaska. *Quaternary Research*, 60(1): 63-69.
- Beget, J.E. and Nye, C.J., 1994. Postglacial Eruption History of Redoubt Volcano, Alaska. *Journal of Volcanology and Geothermal Research*, 62(1-4): 31-54.
- Borchardt, G., 1974. The SIMAN coefficient for similarity analysis: Classification Society Bulletin 3(2): 2-8.
- Harbin, M.L., Swanson, S.E., Nye, C.J., Miller, T.P., 1995. Preliminary petrology and chemistry of proximal eruptive products. *In* Keith, T.E.C. (edi), The 1992 eruptions of Crater Peak vent, Mount Spurr Volcano, Alaska: USGS Bulletin, Report B2139: 139-148.
- Le Bas, M.J., Lemaître, R.W., Streckeisen, A. and Zanettin, B., 1986. A Chemical Classification of Volcanic-Rocks Based on the Total Alkali Silica Diagram. *Journal of Petrology*, 27(3): 745-750.
- Pollard, A.M., Blockley, S.P.E. and Lane, C.S., 2006. Some numerical considerations in the geochemical analysis of distal microtephra. *Applied Geochemistry*, 21(10): 1692-1714.
- Riehle, J.R., 1985. A reconnaissance of the major Holocene tephra deposits in the upper Cook Inlet region, Alaska. *Journal of Volcanology and Geothermal Research*, 26: 37-74.
- Wallace, K.L., 2003, Characterization and discrimination of Holocene tephra-fall deposits, Mount Spurr Volcano, Alaska [Master thesis]: Flagstaff, Northern Arizona University, 175 p.
- Waythomas, K.L., & Nye, C.J., 2002. Preliminary volcano hazard assessment for Mount Spurr Volcano, Alaska. USGS Open-File Report 01-0482, 40 pp.

APPENDIX 7

Table A1. EPMA analyses of individual glass shards from the Bear Lake tephra

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	Cl	K ₂ O	CaO	TiO ₂	Fe ₂ O ₃	H ₂ O
	4.25	3.20	16.26	57.66	0.14	1.56	6.37	1.40	9.15	0.53
	4.17	3.15	16.36	57.67	0.09	1.49	6.58	1.64	8.86	0.89
	4.44	3.15	16.47	57.71	0.08	1.32	6.85	1.61	8.35	0.67
	4.25	2.88	16.62	57.85	0.12	1.61	6.51	1.30	8.87	-0.49
	4.27	3.01	16.48	57.89	0.09	1.61	6.53	1.37	8.75	0.49
	4.30	2.75	16.78	57.97	0.13	1.50	6.67	1.44	8.46	0.06
	4.12	2.95	16.67	57.98	0.04	1.64	6.50	1.25	8.83	-0.19
	4.06	3.09	16.06	58.09	0.09	1.61	6.48	1.46	9.07	0.19
	3.92	3.04	16.90	58.19	0.07	1.62	6.33	1.27	8.66	0.29
	4.20	3.03	16.39	58.25	0.15	1.63	6.53	1.31	8.51	1.35
	3.92	2.99	16.24	58.30	0.10	1.65	6.44	1.37	8.99	0.52
	4.13	3.08	16.54	58.35	0.08	1.58	6.59	1.39	8.27	0.48
	4.15	3.04	16.53	58.45	0.07	1.56	6.50	1.18	8.50	2.23
	4.09	2.81	16.69	58.72	0.06	1.78	6.01	1.37	8.46	-0.47
	3.94	3.08	15.95	58.72	0.14	1.76	6.29	1.24	8.89	2.29
	4.04	2.83	16.77	58.75	0.08	1.63	6.33	1.20	8.38	0.43
	4.06	2.84	16.41	59.43	0.11	1.71	5.73	1.29	8.41	0.79
	4.54	2.79	15.95	59.51	0.08	1.76	5.95	1.39	8.02	-0.05
	4.59	2.70	16.42	59.61	0.09	1.73	5.65	1.39	7.83	0.41
	4.24	2.73	16.19	59.76	0.08	1.88	5.51	1.27	8.33	0.24
	4.51	2.65	16.31	59.96	0.12	1.79	5.84	0.93	7.91	0.87
	4.44	2.59	16.20	60.04	0.09	1.96	5.73	1.18	7.78	-0.64
	4.39	2.63	15.84	60.17	0.08	1.80	5.62	1.20	8.27	2.64
	4.19	2.68	16.31	60.43	0.15	1.82	5.39	1.18	7.84	1.08
mean	4.22	2.90	16.39	58.73	0.10	1.67	6.21	1.32	8.47	0.61
1 σ	0.19	0.19	0.28	0.89	0.03	0.14	0.42	0.15	0.40	0.84
n	24									

Table A2. SIMAN similarity coefficients for Late Holocene andesitic tephra deposits from the Cook Inlet region.

	Bear Lake tephra (this study)
1992 AD Crater Peak eruption	
<i>Harbin et al., 1995</i>	0.813
1953 AD Crater Peak eruption	
<i>Wallace, 2003</i>	0.857
<i>Riehle, 1985</i>	0.887
~1700 AD Crater Peak eruption	
<i>Beget et al., 1994</i>	0.971

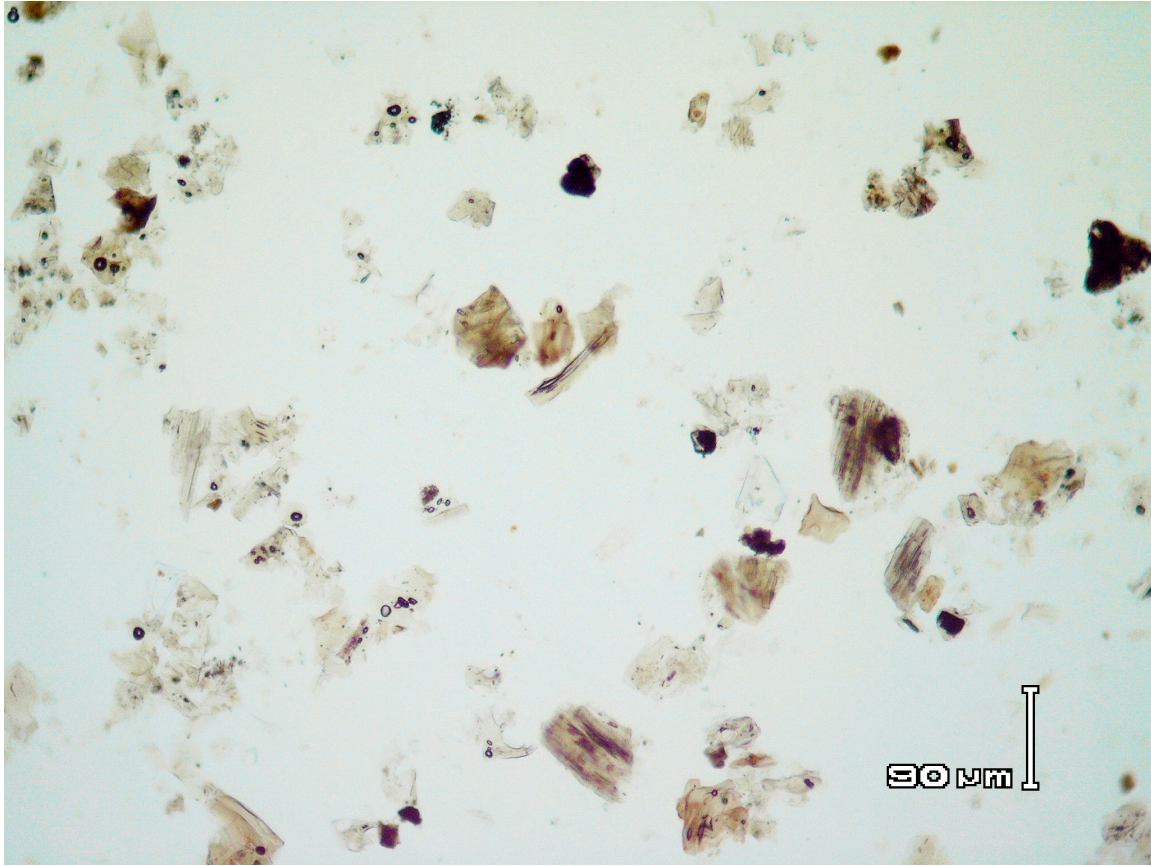


Figure A1. Light micrograph of smear slide preparation of the Bear Lake tephra. Note the angularity & vesicular nature of individual glass shards. Shard morphologies include vesicular pipes, fractured bubble shard walls, & scoria fragments.

APPENDIX 7

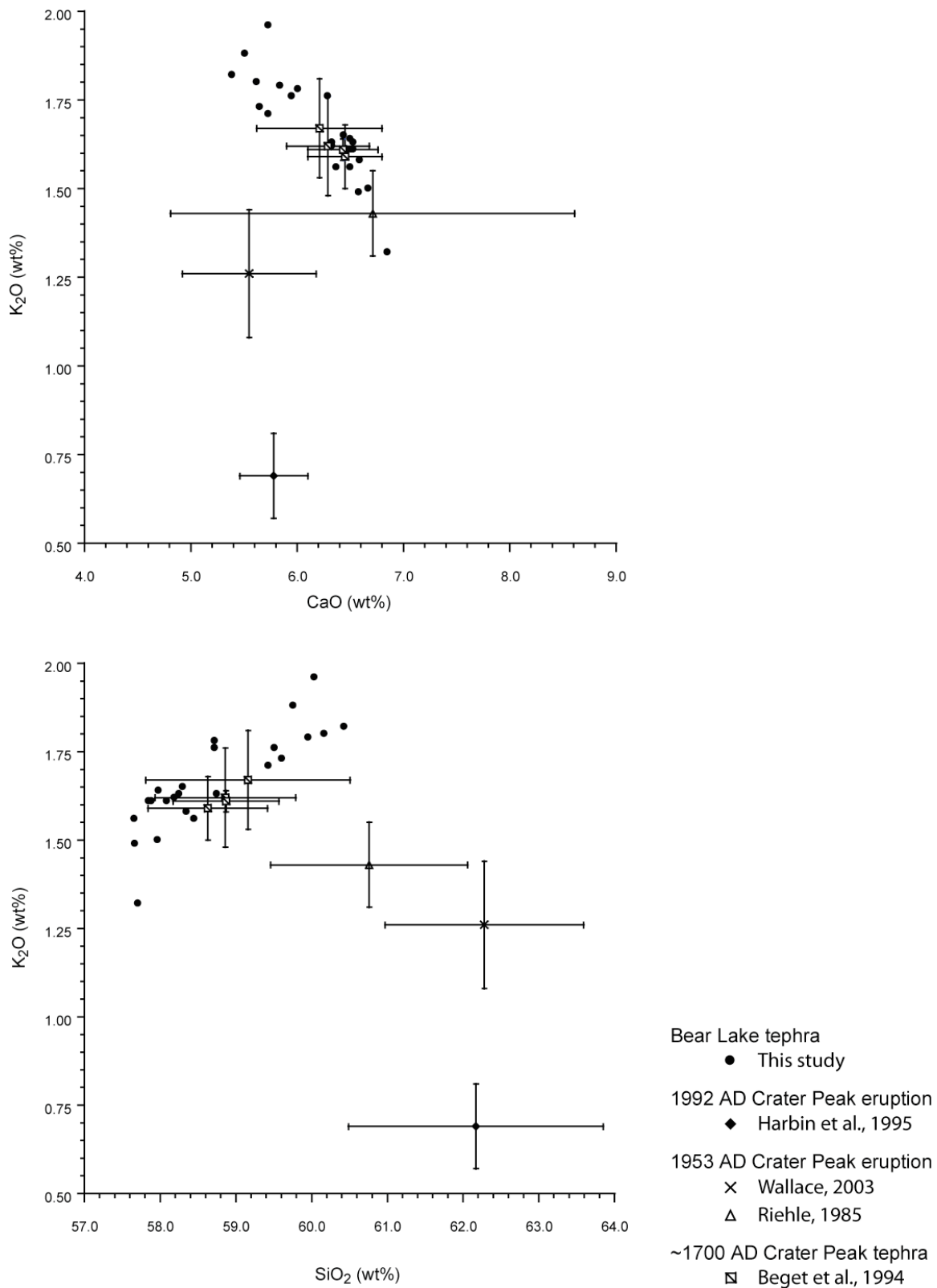


Figure A2. Oxide variation diagrams for Late Holocene andesitic tephra in Cook Inlet. Error bars represent one standard deviation from mean populations.

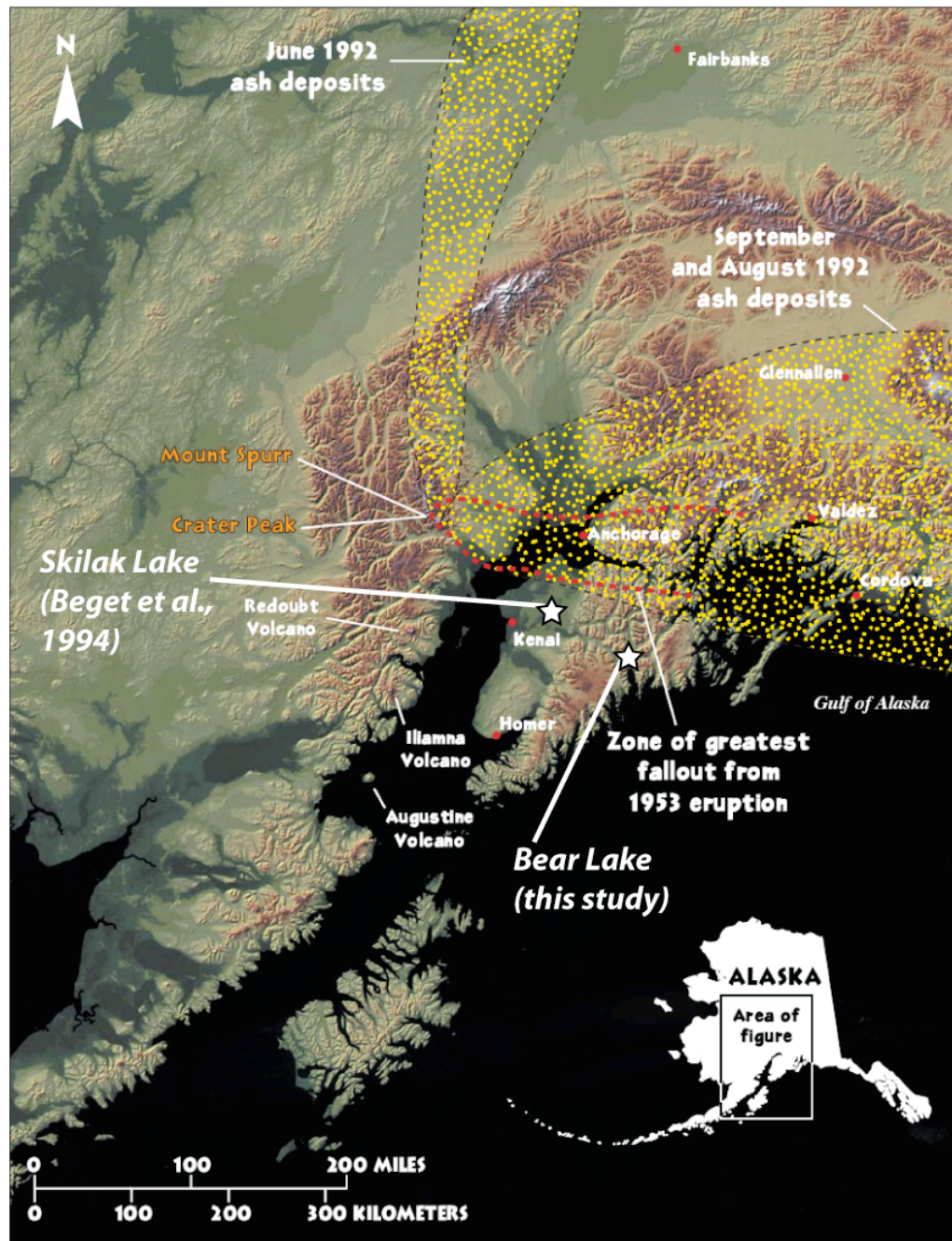


Figure A3. Distribution of 1953 and 1992 AD Crater Peak ash. Note location of ash dispersal clouds relative to Skilak Lake of Beget et al. (1994) and Bear Lake (this study). Modified from Waythomas and Nye (2002).