

Utah State University

DigitalCommons@USU

All Graduate Theses and Dissertations

Graduate Studies

5-2003

Foraging Behavior and Habitat Use Patterns of Brown Bears (*Ursus arctos*) in Relation to Human Activity and Salmon Abundance on a Coastal Alaskan Salmon Stream

Anthony P. Crupi
Utah State University

Follow this and additional works at: <https://digitalcommons.usu.edu/etd>



Part of the [Animal Sciences Commons](#)

Recommended Citation

Crupi, Anthony P., "Foraging Behavior and Habitat Use Patterns of Brown Bears (*Ursus arctos*) in Relation to Human Activity and Salmon Abundance on a Coastal Alaskan Salmon Stream" (2003). *All Graduate Theses and Dissertations*. 4777.

<https://digitalcommons.usu.edu/etd/4777>

This Thesis is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Theses and Dissertations by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.



FORAGING BEHAVIOR AND HABITAT USE PATTERNS OF BROWN BEARS
(*URSUS ARCTOS*) IN RELATION TO HUMAN ACTIVITY AND SALMON
ABUNDANCE ON A COASTAL ALASKAN SALMON STREAM

by

Anthony P. Crupi, Jr.

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Ecology

Approved:

Barrie K. Gilbert
Major Professor

Richard Toth
Committee Member

Jeffrey L. Kerschner
Committee Member

Thomas Kent
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2003

Copyright © Anthony P. Crupi, Jr. 2003

All Rights Reserved

ABSTRACT

Foraging Behavior and Habitat Use Patterns of Brown Bears (*Ursus arctos*)
in Relation to Human Activity and Salmon Abundance
on a Coastal Alaskan Salmon Stream

by

Anthony P. Crupi, Jr., Master of Science

Utah State University, 2003

Major Professor: Dr. Barrie K. Gilbert
Department: Fisheries and Wildlife

Over the past decade, demand for recreation has increased as part of Alaska's doubling growth in tourism. Along the Chilkoot River, near Haines, fishing and bear viewing have become increasingly popular. I investigated the ecological and behavioral interactions there between brown bears, salmon, and humans between 2000 and 2002. My objectives were to: (1) determine if specific human activities differentially influenced bear activity and foraging behavior, (2) identify temporal and spatial habitat use patterns, (3) evaluate brown bear response to natural and human disturbances and quantify related flight distances, (4) investigate changes in bear foraging behaviors in response to prey abundance and human activity to find if bears selectively forage to maximize energy intake, and (5) assess the role of individual tolerance for human proximity in relation to specific foraging behaviors.

Evidence clearly indicated that temporal and spatial brown bear activity patterns were influenced by human activity. Bears were most active and spent the longest periods of time fishing when the numbers of anglers and vehicles were below threshold levels. Adult female bears disproportionately preferred (73%) non-roaded riparian habitat, while subadults were less selective. I classified over 1000 disturbance responses and found human activity accounted for 46% of bear departures with a mean flight response distance of 97 meters. When humans were either absent or at distances ≥ 100 meters from bear activity, bears captured fish at higher rates, captured 2.65 times as many fish, and caught greater proportions of live fish (71%). The greatest predictors of capture rate were the time of day when bears fished, the proximity of human activity, and the individual's tolerance level. Bear tolerance for human proximity helped explain variation in capture rates, foraging bout lengths, and total salmon captured. This suggests nutritional rewards for bears adapting to human disturbance.

These analyses depict clear relationships with simple interpretation of the dynamic relationships between people, bears, and their environment. With improved understanding of the Chilkoot River's natural resources, managers can work to reduce bear-human conflicts and plan for continued growth in tourism and recreation.

(174 pages)

ACKNOWLEDGMENTS

Major funding for this project was provided by the National Fish and Wildlife Foundation, as part of restitution funds paid to benefit the marine waters of Alaska, and the Alaska Department of Fish and Game's Division of Wildlife Conservation. Generous contributions of support were also provided by Juneau's Skaggs Foundation and Lynn Canal Conservation in Haines. Corporate sponsors provided necessary gear and services including: Air Excursions, Alaska Nature Tours, Bear Paw Bakery, Brunton, Counter Assault, Patagonia, Pelican Products, Q Photo, Sockeye Cycles and Wings of Alaska.

Special thanks to my committee members, Dick Toth and Jeff Kershner, for their assistance throughout my academic pursuits. Their constructive criticisms greatly improved the scope of this work. I also owe many thanks to the advice and consultation of Utah State's statistical authorities, Adele Cutler and Susan Durham. Without their insight and knowledge of various techniques, the interpretability of these data would have been compromised.

I am extremely fortunate to have been given the opportunity to study with and receive guidance from Dr. Barrie K. Gilbert. As an advisor, he has been an inspiration to understanding the intricacies of behavioral research. As a mentor, I have learned so many valuable lessons and gained insights I never considered imaginable. And as a friend, I've appreciated his endless support and encouragement and all of our great times. It will be near forever before his integrity and humor will be forgotten.

I am indebted to an exceptional group of volunteer field technicians who persevered through the rigors of field research. Without their involvement, friendship, and dedication, our lives and the data in this thesis would feel inadequate. Special thanks to: Joselyn Fenstermacher, Scott Forbes, Lincoln Larsen, Kari Murabito, Raphael McGuire, Merc Pittinos, Ginna Purrington, Carrie Roeber, Caitlin Stern, Wade Ulrey, and Brian and Melinda Wright. I owe so much of the success of this project to my faithful volunteer and endearing wife, Lori. From your coordination of daily logistics to your bush travels necessary to see this project through, coupled with your never-ending love and support, I am enamored. You are the river to which I am gratefully joined.

If it were possible to thank Sally and Tom McGuire more than once, I would fill the rest of this page with sincere thank-you's. I will still be repaying your kindness in my afterlife. Since the beginning of this project, Polly Hessing, with all that she already juggles in life, has been there for me and for the bears of the Chilkoot. I am appreciative of each of her numerous contributions, especially financial support, datasheets, and most of all, fortitude in creating Chilkoot's bear monitor position. Lastly, Julie and Dick Folta, Ann Myren and Tim McDonough, and Burl Sheldon have contributed a wealth of knowledge, resources, and support. Without all of these generous offerings, this project could never have been completed.

Anthony P. Crupi, Jr.

CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGMENTS	v
LIST OF TABLES	x
LIST OF FIGURES	xi
 CHAPTER	
1 INTRODUCTION	1
BACKGROUND	1
PROBLEM ANALYSIS	5
CONTENT OF CHAPTERS	7
LITERATURE CITED	8
 2 THE INFLUENCE OF HUMAN ACTIVITIES AND SALMON ABUNDANCE ON FORAGING BROWN BEARS	 13
INTRODUCTION	14
STUDY SITE	17
METHODS	18
Sampling Procedures	18
Brown Bear Identification	19
Dependent Response Variables	20
Independent Variables	21
Data Analyses	22
RESULTS	24
Age-Gender Cohort Composition	24
Cohort Activity Comparison	24
Bear Activity Trends at Different Temporal Scales	25
Influence of Human Presence and Absence on Bear Activity	25
Bear Access in Relation to Salmon Run Timing	26
Human Use Patterns	26
Factors Influencing Bear Activity in 2000	27
Factors Influencing Bear Activity in 2001-2002	27

	Relationships with Bear Foraging Behavior in 2001-2002	28
	Canonical Correlation Analysis of Bear Activity and Foraging Behavior	28
	Thresholds Limiting Bear Activity	29
	DISCUSSION	30
	Influence of Human Presence on Bear Foraging Activity	30
	Disproportionate Effects of Human Activity	32
	Influence of Salmon Run Timing on Bear Activity	33
	Comparative Analyses of Multivariate Techniques	37
	MANAGEMENT IMPLICATIONS	39
	CONCLUSIONS	41
	LITERATURE CITED	43
3	BROWN BEAR HABITAT USE PATTERNS AND RESPONSES TO DISTURBANCE	66
	INTRODUCTION	67
	METHODS	70
	Sampling Procedures	70
	Brown Bear Identification	71
	Habitat Use	72
	Stimuli Eliciting Bear Departure	73
	Intolerance Index	74
	Statistical Analyses	75
	RESULTS	75
	Brown Bear Habitat Use	75
	Bear Activity in Relation to Distance from Humans	76
	Factors Influencing Bear Displacement	77
	Flight Distances in Response to Disturbance	77
	Relationship of Foraging Bout Length to Disturbance	78
	Individual Displacement	78
	Relationship Between Disturbance and Human Intolerance	78
	DISCUSSION	79
	MANAGEMENT IMPLICATIONS	83
	CONCLUSIONS	85
	LITERATURE CITED	87

4	THE INFLUENCE OF BROWN BEAR TOLERANCE FOR HUMAN ACTIVITY ON SALMON CAPTURE	103
	INTRODUCTION	104
	METHODS	107
	Sampling Procedures	107
	Brown Bear Identification	108
	Dependent Response Variables	109
	Intolerance Index	110
	Independent Variables	111
	Statistical Analyses.....	111
	RESULTS	112
	Sampling Effort	112
	Influence of Prey Availability on Foraging Behaviors.....	112
	Capture Rate in Relation to Time of Day	113
	Comparison of Foraging Behaviors Between Cohorts	114
	Comparison of Fishing Success in Relation to Human Activity and Habitat	115
	Gender and Consumption of Salmon Captured by Brown Bears	116
	Foraging Behavior Responses to Human Proximity	117
	DISCUSSION	118
	Evidence for Delayed Access	118
	Selective Capture and Consumption	122
	Influence of Tolerance on Foraging Behavior.....	125
	CONCLUSION	126
	LITERATURE CITED	128
5	SUMMARY	154
	APPENDIX	158
	SCAN DATA KEY	159
	FOCAL BEAR BEHAVIOR KEY	159
	FOCAL BEAR BEHAVIOR KEY	160
	CAPTURE DATA KEY	161
	OBSERVATION SESSION DATASHEET	162

LIST OF TABLES

Table		Page
2-1	Sampling intensity and hours of focal bear data recorded.	49
2-2	Age-gender classification of bears along the Chilkoot River.....	50
2-3	Salmon escapement counted passing through the Chilkoot River weir, 1999-2002, rates of bear and angler activity.....	51
2-4	Annual mean and maximum activity levels per day 2001-2002.	52
2-5	Pearson's rho correlations for factors relating to bear activity and foraging behaviors.....	53
3-1	Focal bear observation minutes according to habitat type and age class.	92

LIST OF FIGURES

Figure	Page
2-1	Map of the Chilkoot River study site in southeast Alaska, Haines. 54
2-2	Four observation zones along the Chilkoot River. 55
2-3	Cohort comparison between bear viewing sites. 56
2-4	Annual comparison of focal bear activity rates by primary cohorts. 57
2-5	Annual trends between anglers, bears, and pink salmon. 58
2-6	Diurnal pattern of bear and angler activity. 59
2-7	Annual bear activity rate when humans present versus absent. 60
2-8	Bear activity and pink salmon run timing. 61
2-9	Canonical correlation between bear activity, foraging bout length, human activity and salmon abundance. 62
2-10	Canonical correlation between bears foraging behavior, river depth, and vehicle activity. 63
2-11	Threshold of daily angler activity constraining bear activity. 64
2-12	Vehicle activity threshold constraining bear activity. 65
3-1	Annual adult brown bear habitat use. 93
3-2	Annual subadult brown bear habitat use. 94
3-3	Brown bear spatial distribution in relation to human proximity. 95
3-4	Bear activity in response to human presence. 96
3-5	Contribution of displacements with respect to time of day. 97
3-6	Annual mean flight distance according to disturbance stimulus. 98
3-7	Mean foraging bout length according to disturbance stimulus. 99
3-8	Individual bear response to human and vehicle disturbance. 100

3-9	Influence of bear tolerance for human proximity on foraging bout length. ...	101
3-10	Comparison of two disturbance measures, an intolerance index and vehicle displacement rate.	102
4-1	Relationship between pink salmon run timing and brown bear capture rate.	134
4-2	Relationship between brown bear activity and pink salmon run timing.	135
4-3	Annual patterns of bear activity in relation to pink salmon run timing and angler activity.	136
4-4	Weekly trend in brown bear capture efficiency throughout the study period.	137
4-5	Relationship between brown bear activity and pink salmon abundance.	138
4-6	Capture rate trends during evening hours.	139
4-7	Capture rate trends during morning hours.	140
4-8	Mean foraging bout length between cohorts for 2001-2002.	141
4-9	Effect of human presence on brown bear capture rate.	142
4-10	Proportion of live fish captured according to human proximity.	143
4-11	Comparison of brown bear capture rate by habitat.	144
4-12	Brown bear captures according to salmon spawning status and habitat.	145
4-13	Brown bear captures of live, senesced, and angler caught salmon.	146
4-14	Spawning status and salmon gender of brown bear captures.	147
4-15	Selective consumption of salmon captured by brown bears.	148
4-16	Mean percentage of salmon consumed by brown bears over time.	149
4-17	Bear tolerance for human proximity in relation to foraging bout length.	150
4-18	Bear tolerance for human proximity relative to total time observed.	151
4-19	Bear tolerance for human proximity in relation to capture rate.	152
4-20	Relationship between bear tolerance for human proximity and the number of salmon captured.	153

CHAPTER 1

INTRODUCTION

BACKGROUND

The popularity of outdoor recreation has grown in the United States since the establishment of the first national park in 1872. Throughout this time period our culture has realized social and economic disparity between highly industrial extraction of natural resources and expansion of conservation values including non-consumptive recreational uses such as boating, hiking, photography, and wildlife viewing (Flather and Cordell 1995). While activities such as these were once believed to be non-impacting to resources such as wildlife and habitat, it is no longer tenable to perceive recreational activities as benign (Wilkes 1977). Today, natural resource managers have a responsibility to actively manage for a balance between recreational use and conservation of the natural resources which the public seeks to enjoy.

The effects of human recreational activities on wildlife are diverse, and for numerous species, have been extensively examined (Knight and Cole 1995, Olson et al. 1997, Chi and Gilbert 1999, Cassini 2001, Williams et al. 2002, Bolduc and Guillemette 2003, Swarthout and Steidl 2003, Taylor and Knight 2003). In Boyle and Samson's (1985) review of 166 publications discussing the effects of recreation on wildlife, the majority (81%) were interpreted as imposing negative impacts, either direct, indirect or both. The impacts of recreation are examined as either immediate or long-term effects. Observational studies are most effective in evaluating the

immediate, direct effects of recreation on wildlife, such as changes in animal behavior, exclusion from specific habitats, implications for physiological responses to disturbance and alterations in energetic balances. For instance, behavioral responses to disturbance can result in changes in habitat selection, increased vigilance, modified energy intake, decreased parental investment and energy expended during displacement events (Lima and Dill 1990). The lesser-examined, indirect effects of human disturbance can also reduce individual fitness due to the bioenergetic cost of habitat destruction or risk avoidance (Longland and Price 1991). With both direct and indirect effects, wildlife forgoes fitness enhancing activities in attempts to minimize conflicts with people, resulting in increased time and energy expenditure and reduced energy gain (Geist 1978, Frid and Dill 2002). Through the understanding of immediate responses to human disturbance, as well as individual characteristics such as habitat use and foraging behaviors, managers can implement strategies to ameliorate the negative impacts of recreation on wildlife.

In order to develop appropriate study designs and management protocols, wildlife ecologists need to become familiar with species at the individual level; understanding their behavioral ecology, habitat preferences, resource requirements, and adaptive ability to tolerate human activity. Patterns of individual behavior can provide great insight into habitat use and resource needs. The temporal and spatial distribution of individuals is largely a function of their interactions with landscape, resource availability, and the competition with and avoidance of conspecifics and humans. When presented with alternatives, the variation and range of choices made

by individuals can be aggregated into a series of habitat preferences manifested at the population level. These mechanisms of habitat selection translate into the population's use of habitat, which in turn leads to the assemblage and structuring of communities. Therefore in an attempt to understand wildlife at the population level and sustainably manage resources, I must first investigate individual foraging behaviors and habitat preferences in relation to the availability of prey resources and human activity.

Foraging theory, applied in studies of feeding behavior and habitat selection, has been utilized to bridge the gap between individual behavior and population dynamics (Kamil and Sargent 1981, Werner and Mittelbach 1981, Lomnicki 1988, Green 1990, Frey-Roos et al. 1995). Stillman et al. (2000) defines foraging efficiency as an animal's intrinsic ability to forage in the absence of competitors. To optimize foraging efficiency and ultimately fitness, the theory predicts that animals pursue the best food types and habitats on the basis of maximizing net energy gain while minimizing time and/or energy required to pursue, catch and handle prey (Kamil and Sargent 1981). Two of the most critical factors limiting foraging behaviors are food availability and access to resources (Morse 1980). According to Collier and Rovee-Collier (1981) availability is largely influenced by competition, risk of predation, social dominance status and accessibility. The amount of food available is often believed to be a direct function of the amount of time and energy required to maximize efficiency. Therefore, when food is scarce or availability is compromised, the amount

of time required to obtain needed resources increases and efficiency in obtaining prey therefore decreases (Collier and Rovee-Collier 1981, Robbins 1993, Lima 1998).

Field studies of carnivore foraging behavior are often difficult because direct observation of consumption is challenging given large home ranges and dietary complexity. Each year brown bears aggregate to consume Pacific salmon as they migrate to natal freshwater streams. This provides a unique, observable predator-prey system in which to test predictions of foraging behavior and prey choice (Willson and Halupka 1995, Gende et al. 2001). Where human recreation activities temporally and spatially overlap with these congregations of bears and salmon, it is important to understand the relationships between the three species. In particular, since accessibility to food is a function of perceived risk, competition, and access to the resource, the role played by human activity has clear potential to influence these interactions. In understanding these foraging behaviors, individual variation of human tolerance should be considered as it may influence rates of prey capture and therefore energy intake.

At several regulated viewing sites in Alaska many brown bears habituate to human presence to maintain access to preferred food sources, while other individuals remain intolerant of human activity (Warner 1987, Gilbert 1989, Aumiller and Matt 1994, Olson et al. 1997, Chi and Gilbert 1999). McArthur Jope (1983) and Mattson (1990) proposed that habituated bears gain greater access to resources by foraging in areas near human activity because of reduced intra-specific competition. Individual variation in human tolerance may play an important role in foraging behavior (Olson

and Gilbert 1994) and when management eliminates tolerant bears, the remaining wary bears are more likely to decline (Keating 1986).

PROBLEM ANALYSIS

Alaska is known for its unique wilderness character, abundant resources and countless opportunities for recreationists to experience these treasures. Alaska's reputation for this unspoiled greatness has drawn visitors for well over a century. Over the past two decades, tourism has grown more than 10% per year (>200%) (Schroeder et al. 2001) and a large component of this increase is attributed to the expansion of outdoor recreation, including wildlife viewing. In 1996 alone, nearly 500 thousand people participated in wildlife watching activities and contributed more than 780 million dollars to Alaska's economy (USDOI-FWS 1998).

The demand for bear viewing had increased throughout Alaska (Titus et al. 1994) as bears are highly valued by visitors interested in observing them (Miller et al. 1998). Where bears gather to consume Pacific salmon (*Oncorhynchus spp.*) they provide predictable opportunities for people to view them. This interest in bear viewing has resulted in viewing opportunities varying from remote wilderness to roadside developments (Neary 1995, Matz 2000). Close interactions and consequent bear-human conflicts have raised management concerns. Investigations of the responses of bears to human activities have occurred at several regulated viewing sites (Warner 1987, Fagen and Fagen 1994, Olson et al. 1997, Wilker and Barnes 1998, Chi and Gilbert 1999). Monitoring bear and human behavior at these sites has proven to

be successful in guiding management of bears and people and has helped reduce bear-human conflict.

I studied a popular but unregulated wildlife viewing site, the Chilkoot River State Recreation Area in southeast Alaska, near Haines. It is notable for its road-accessible brown bear viewing, high concentration of bald eagle nest sites, and productive salmon runs. Numerous motor vehicles, boats, and floatplanes access the valley throughout the summer and autumn months. In 1996, an estimated 60,000 international and local visitors were attracted to the Chilkoot River: the majority were anglers, bear viewers, guided cruiseship passengers and wildlife photographers. In the absence of regulation and management, conflicts between bears and people led to several bears being destroyed in defense of life or property. In 2000, the Haines Chamber of Commerce began a project “to develop and implement a plan for the long range, sustainable management of the natural, cultural and economic resources of the Chilkoot River Corridor (CRC).” A collaborative working group has been developing a comprehensive management plan to preserve the resources of the Chilkoot River.

I designed a study to understand how brown bear activity patterns and foraging behaviors were influenced by human activity and salmon abundance. My objectives were to: 1) determine if specific human activities and environmental characteristics differentially influence bear activity and foraging behavior, 2) define temporal and spatial patterns of bear activity in relation to human recreation, 3) quantify human disturbance stimuli and related flight response distances, 4) investigate changes in bear foraging behaviors in response to prey abundance and human activity to find if bears

selectively forage to maximize energy intake, and 5) assess the role of individual tolerance for human proximity in relation to specific foraging behaviors.

Unregulated human activity along the Chilkoot River allowed us to observe changes in bear behavior, both in the presence of large numbers of people and vehicles, and in their absence. These factors varied daily within and between years, enabling us to evaluate their influence. This comparative approach allowed insights into bear activity and foraging behavior that would have been challenging to simulate under experimental conditions. Answers to these questions will have important implications for ecosystem management, should assist managers in implementing conservation strategies that minimize bear-human conflict and maximize recreational opportunities, and serve as a model for other tourism dependent communities challenged by similar issues.

CONTENT OF CHAPTERS

Understanding the dynamic behavioral and ecological interactions between bears, people, and salmon involved assessing multiple scales of effects influencing bear activity, foraging behavior, and habitat use patterns. The primary sources of data that I examined are bears' diurnal and seasonal activity patterns, spatial trends in habitat use, and immediate responses to disturbance, with implications from previous research.

In Chapter 2, I determined if bear activity and foraging behaviors were differentially influenced by particular human activities, salmon availability, and/or environmental attributes. I investigated the impacts of human recreation on diurnal

and seasonal patterns of bear activity, capture rates of salmon and the amount of time bears spent foraging. This chapter provided the background for subsequent analysis of impacts associated with specific human activities.

The focus of Chapter 3 was to evaluate brown bears' immediate responses to disturbance stimuli and the effect of human presence on bear activity rates. I quantified mean flight response distances to evaluate the utility of a traditional 100-meter setback at this site. I also documented spatial patterns of bear habitat use in relation to human recreation and addressed the differences found between cohorts. As well, I introduced the role of bear tolerance for human proximity and compared its utility to another measure of disturbance, vehicle displacement rate.

In my final chapter, I investigate seasonal changes in capture rates, bear foraging bout length, and bear activity in response to prey abundance and human activity. I provide evidence for the importance of increased energy intake to bears, by investigating selective foraging of salmon gender and spawning status. Also in Chapter 4, I further consider the role that bear tolerance for human proximity plays in regard to specific foraging behaviors and address potential nutritional advantages. This thesis is organized in multiple-paper format for journal publication.

LITERATURE CITED

- Aumiller, L. D., and C.A. Matt. 1994. Management of McNeil River State Game Sanctuary for viewing of brown bears. *International Conference on Bear Research and Management* 9(1):51-61.
- Bolduc, F., and M. Guillemette. 2003. Human disturbance and nesting success of common eiders: interactions between visitors and gulls. *Biological Conservation* 110:77-83.

- Boyle, S.A., and F.B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. *Wildlife Society Bulletin* 13:110-116.
- Cassini, M.H. 2001. Behavioural responses of South American fur seals to approach by tourists-a brief report. *Applied Animal Behaviour Science* 71:341-346.
- Chi, D.K., and B.K. Gilbert. 1999. Habitat security for Alaskan brown bears at key foraging sites: are there thresholds for human disturbance? *Ursus* 11:225-238.
- Collier, G. H., and C.K. Rovee-Collier. 1981. A comparative analysis of optimal foraging behavior: Laboratory simulations. Pages 39-76 in A.C. Kamil and T.D. Sargent, eds., *Foraging Behavior: Ecological, Ethological, and Psychological Approaches*. Garland STPM Press, New York.
- Fagen, J. M., and R. Fagen. 1994. Interactions between wildlife viewers and habituated brown bears, 1987-1992. *Natural Areas Journal* 14(3):159-164.
- Flather, C.H, and H.K. Cordell. 1995. Outdoor recreation: historical and anticipated trends. Pp. 3-16 in R.L. Knight and K.J. Gutzwiller, eds., *Wildlife and Recreationists: Coexistence Through Management and Research*. Island Press, Washington, D.C.
- Frey-Roos, F., P.A. Brodmann, and H. Reyer. 1995. Relationships between food resources, foraging patterns, and reproductive success in the water pipit, *Anthus sp. Spinoletta*. *Behavioral Ecology* 6(3):287-295.
- Frid, A., and L.M. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. *Conserv. Ecol.* 6(1):11. [online] URL: <http://www.consecol.org/vol6/iss1/art11>.
- Geist, V. 1978. Behavior. Pp. 283-296 in J.L. Schmidt and D.L. Gilbert, eds., *Big Game of North America: Ecology and Management*. Stackpole Books, Harrisburg, Pa.
- Gende, S.M., T.P. Quinn, and M.F. Willson. 2001. Consumption choice by bears feeding on salmon. *Oecologia* 127:372-382.
- Gilbert, B.K. 1989. Behavioral plasticity and bear-human conflicts. Pp. 1-8 in M. Bromley, ed., *Bear-People Conflicts - Proceedings of a Symposium on Management Strategies Northwest Territories Department of Renewable Resources*, Yellowknife.
- Green, R.F. 1990. Putting ecology back into optimal foraging theory. *Comments on Theoretical Biology* 1(6):387-410.

- Kamil, A.L., and T.D. Sargent. 1981. Foraging Behavior: Ecological, Ethological, and Psychological Approaches. Garland Publishing, Amherst, Mass. 534 pp.
- Keating, K.A. 1986. Historical grizzly bear trends in Glacier National Park, Montana. *Wildlife Society Bulletin* 14:83-87.
- Knight, R.L., and D.N. Cole. 1995. Wildlife responses to recreationists. Pp. 51-69 *in* R.L. Knight and K.J. Gutzwiller, eds., *Wildlife and Recreationists: Coexistence Through Management and Research*. Island Press, Washington, D.C.
- Lima, S.L. 1998. Stress and decision making under the risk of predation: Recent developments from behavioral, reproductive, and ecological perspectives. *Advances in the Study of Behavior* 27:215- 290.
- Lima, S.L., and L.M. Dill. 1990. Behavioural decisions made under the risk of predation. *Canadian Journal of Zoology* 68:619-640.
- Lomnicki, A. 1988. *Population Ecology of Individuals*. Princeton University Press, Princeton, N.J. 223 pp.
- Longland, W.S., and M.V. Price. 1991. Direct observations of owls and heteromyid rodents: can predation risk explain micro-habitat use. *Ecology* 72(6):2261-2273.
- Mattson, D.J. 1990. Human impacts on bear habitat use. *International Conference on Bear Research and Management* 8:33-56.
- Matz, G. 2000. The value of Cook Inlet bears. Report to the Chenik Institute. Anchorage, Alaska. Unpublished manuscript.
- McArthur Jope, K.L. 1983. Habituation of grizzly bears to people: a hypothesis. *International Conference on Bear Research and Management* 5:322-327.
- Miller, S.M., S.D. Miller, and S. D. Miller. 1998. Attitudes toward and relative value of Alaskan brown and black bears to resident voters, resident hunters, and nonresident hunters. *Ursus* 10:357-376.
- Morse, D.H. 1980. *Behavioral Mechanisms in Ecology*. Harvard University Press, Cambridge, Mass. 383 pp.
- Neary, J. 1995. Workshop for viewing area managers: summary and notes. U.S. Forest Service, Juneau, Alaska. Unpublished typescript.

- Olson, T.L., and B.K. Gilbert. 1994. Variable impacts of people on brown bear use of an Alaskan river. *International Conference on Bear Research and Management* 9(1):97-106.
- Olson, T. L., B.K. Gilbert, and R.C. Squibb. 1997. The effects of increasing human activity on brown bear use of an Alaskan River. *Biological Conservation* 82:95-99.
- Robbins, C. T. 1993. *Wildlife feeding and nutrition*. Academic Press, Inc., San Diego, Calif. 352 pp.
- Schroeder, R., L. Cerveny, G. Robertson. 2001. Tourism growth in Southeast Alaska: trends, projections, and issues. *Tongass National Forest Tourism Symposium*, 23-25 October 2001. Ketchikan, Alaska.
- Stillman, R.A., R.W. Caldrow, J.D. Goss-Custard, and M.J. Alexander. 2000. Individual variation in intake rate: the relative importance of foraging efficiency and dominance. *Journal of Animal Ecology* 69:484-493.
- Swarthout, E.H., and R.J. Steidl. 2003. Experimental effects of hiking on breeding Mexican spotted owls. *Conservation Biology* 17(1):307-315.
- Taylor, A.R., and R.L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. *Ecological Applications* 13(4):951-963.
- Titus, K., J.N. Trent, L.D. Aumiller, J.H. Westland, and M. Sigman. 1994. Managing brown bears as both game and nongame: past experience and future prospects. *Transactions of the North American and Natural Resources Conference* 59:353-362.
- U.S. Department of the Interior, Fish and Wildlife Service, U.S. Department of Commerce, US Census Bureau. 1998. *National survey of fishing, hunting, and wildlife-associated recreation*.
- Warner, S. H. 1987. Human impacts on brown bears at Pack Creek, Admiralty Island, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 95 pp.
- Werner, E.E., and G.G. Mittlebach. 1981. Optimal foraging: field tests of diet choice and habitat switching. *American Zoologist* 21(4):813-829.
- Wilkes, B. 1977. The myth of the non-consumptive user. *Canadian Field Naturalist* 91(4):343-349.
- Wilker, G. A., and V.G. Barnes. 1998. Responses of brown bears to human activities at O'Malley River, Kodiak Island, Alaska. *Ursus* 10:557-561.

- Williams, R., A.W. Trites, and D.E. Bain. 2002. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *Journal of Zoology* 256:255-270.
- Willson, M. F., and K.C. Halupka. 1995. Anadromous fish as keystone species in vertebrate communities. *Conservation Biology* 9(3):489-497.

CHAPTER 2

**THE INFLUENCE OF HUMAN ACTIVITIES AND SALMON ABUNDANCE
ON FORAGING BROWN BEARS¹**

ABSTRACT: Tourism has doubled in Alaska over the past decade. The Chilkoot River, near Haines, experienced rapid expansion of fishing and bear viewing over this period. We investigated the ecological and behavioral interactions between humans, brown bears, and salmon from mid-July to mid-October between 2000 and 2002. We identified temporal and spatial habitat use patterns, evaluated brown bear responses to an array of human activities, and examined the influence of people and salmon on bear foraging behavior. Human activity, salmon abundance, and environmental conditions varied within and between years allowing comparison of their influence on bear activity, especially foraging behavior. Bear activity, rates of salmon capture, and foraging bout length were assessed, as these measures are important indicators of nutritional intake.

We explored these relationships through several multivariate statistical techniques with the intent of identifying parameter predictors and threshold determinants. In the 2001 and 2002 field seasons maximum bear activity occurred well after the peak of the pink salmon run, thus limiting the number of live fish available to bears. Canonical correlation analysis indicated that bears were most active and spent the longest periods of time fishing when the numbers of anglers and

¹ Coauthored by Anthony P. Crupi and Barrie K. Gilbert.

vehicles were lowest, which did not occur until the combined total of live and dead salmon were high. Bears' salmon capture rates were greatest when foraging bouts were longer which correlated with decreased river levels, cooler temperatures and lower numbers of vehicles. Short foraging bouts were most strongly correlated with high numbers of anglers and human activity. These analyses depict clear relationships with simple interpretation of the dynamic relationships between people, bears and their environment. This investigation and analysis provide the scientific data needed to greatly improve human safety and resource protection, and management now resides in the hands of state and local agencies.

INTRODUCTION

The effects of human recreational activities on wildlife are complex but have been increasingly well documented for numerous terrestrial and marine species (Knight and Cole 1995, Olson et al. 1997, Chi and Gilbert 1999, Cassini 2001, Williams et al. 2002, Mann et al. 2002, Bolduc and Guillemette 2003, Swarthout and Steidl 2003). Non-consumptive human recreation, such as wildlife viewing, is projected to increase between 63% and 142% over the next 50 years (Flather and Cordell 1995), while habitat availability is expected to decrease. As demand for viewing opportunities increases, the potential for negative effects will also increase, creating risks for the conservation many species. Understanding how specific human activities influence foraging behaviors and wildlife habitat utilization is important for recreation management and wildlife protection.

Throughout Alaska tourism revenues and numbers of visitors have increased more than 200 percent in the past two decades (McDowell Group 2000, Schroeder et al. 2001) leading to rapid growth in bear viewing (Aumiller and Matt 1994, Olson and Gilbert 1994, Titus et al. 1994, Chi and Gilbert 1999, Smith 2001). Bears rank highest among Alaska species for viewing resulting in the development of rural and remote wilderness for bear viewing (Neary 1995, Matz 2000). When recreational visitation impinges on primary feeding habitats, the potential for negative impacts to bears increases (Mattson et al. 1987).

Coastal brown bears (*Ursus arctos*) and black bears (*Ursus americanus*) typically aggregate at salmon streams in late summer and autumn, providing predictable opportunities for viewing. The amount of salmon that bears consume during this time is crucial to brown bear population density and reproductive success (Miller et al. 1997, Hilderbrand et al. 1999). Therefore, it is important to assess the potential impacts of decreased salmon consumption that may be influenced by increased human recreational activity. Bear responses to human activity have been examined at several regulated viewing sites (Warner 1987a, Gunther 1990, Fagen and Fagen 1994, Olson et al. 1997, Wilker and Barnes 1998, Chi and Gilbert 1999, Hood and Parker 2001, Naves et al. 2001). However, no comprehensive studies have evaluated the influence of high volume activity and vehicle traffic at an unmanaged, de facto wildlife-viewing site.

The growing popularity of wildlife viewing at southeast Alaska's, Chilkoot River State Recreation Area, is matched by its need for regulation. A combination of

road accessible brown bear viewing and productive salmon runs draws numerous motor vehicles, boats, and floatplanes throughout the summer and autumn months. In 1996, an estimated 60,000 international and local visitors were attracted to the Chilkoot River: the majority were anglers, wildlife photographers, bear viewers, independent travelers and guided cruiseship passengers. In the absence of regulation and management, fishing and wildlife viewing activities have produced pronounced conflicts with bears resulting in bear mortalities.

Well designed animal behavior studies are able to measure deteriorating or stressful conditions, including those imposed by human activity (Sutherland 1998). Unregulated and variable human activity along the Chilkoot River provided an opportunity to compare bear behavior in the absence and presence of small and large numbers of people and vehicles. These factors varied daily within and between years, enabling comparisons of human impacts on bear behavior that approaches simulation of experimental conditions.

Our goal was to understand how brown bear activity patterns and foraging behavior were influenced by specific human activities, salmon abundance and environmental conditions. We address three questions. First, do high daily levels of human activity influence temporal and spatial patterns of bear activity relate to human recreation? We hypothesize that human activity serves to temporally limit bear activity. Secondly, do particular human recreational activities differentially influence bear activity and foraging behavior? Lastly, how do bear foraging behaviors respond to changes in fish abundance and human activity? We expected that capture rates and

foraging bout lengths would increase with salmon run timing and negatively correlate with human activity. A better understanding of the effects of recreational activity on brown bear behavior may have important implications for conservation and ecosystem management.

STUDY SITE

Research was conducted along the Chilkoot River located 12 km northwest of the city of Haines, Alaska (Figure 2-1). As many as 130,000 people visit the Chilkoot River each year, primarily for fishing and wildlife viewing opportunities. We focused our sampling efforts on the lower 3 km of river and tidal estuary, where the majority of bear and human activity occurs. The majority of human activity is concentrated along the roaded habitat which parallels the western side of the river, while the non-roaded habitat is undeveloped and fairly pristine. The surrounding forest is old growth habitat consisting primarily of a western hemlock (*Tsuga heterophylla*) and sitka spruce (*Picea sitchensis*) canopy with rusty menziesia, (*Menziesia ferruginea*), blueberry (*Vaccinium spp.*) and devil's club (*Oplopanax horridum*) in the understory.

The Alaska Department of Fish and Game (ADF&G) maintains a salmon counting weir from June to September (Kelley and Bachman 1999). The daily weir counts provided us with the timing of the salmon return, hence brown bear prey abundance estimates. Sockeye salmon (*Oncorhynchus nerka*) return in early summer, followed by pink salmon (*Oncorhynchus gorbuscha*) in late summer and coho salmon (*Oncorhynchus kisutch*) in early autumn. Brown bears feed on spawning pink salmon in and along the river, as well as in front of the weir on spawned salmon that wash

downstream into the barrier. Residential development borders the lower river and estuary and in year 2000 three bears were destroyed in defense of life and property (DLP). Alaska Game Management Unit 1D, permits big game hunting beyond a 400 meter buffer strip along Chilkoot Lake Road.

METHODS

Our 3-y study was conducted from mid-July to late October, 2000-2002.

Similar bear-human interaction data collection procedures were utilized throughout the study, though methods were improved to record specific foraging behaviors, such as capture rate and salmon gender, in the 2001 and 2002 field seasons.

Sampling Procedures

Systematic observations occurred daily throughout daylight hours, during scheduled sessions, on the Chilkoot River using methods similar to previous studies (Olson et al. 1990, Chi 1999). Three hour observation sessions were randomly distributed throughout seven day sample blocks and stratified within six time sessions between 0530 hours and 2300 hours, as light permitted (Crupi and Gilbert 2003). The river was divided into four sampling zones of approximate equal area. Sampling locations were established in each zone to minimize observer impacts and maximize sightability and included an elevated tree blind (Figure 2-2).

Sampling procedures included focal animal and scan sampling techniques (Altmann 1974, Olson et al. 1990, Lehner 1998). We used focal animal sampling to record arrival and departure times, classify behavior, determine age-gender

classification, calculate activity budgets, identify access corridors, and assess behavioral responses to human and vehicle activity (Appendix). Observers censused human activity and bear presence at fifteen-minute interval scans throughout the observation session. People and vehicles were counted and classified according to activity and behavior. This information provided us with important demographic human activity patterns needed to evaluate relationships with bear activity.

Locations of bears and people were assessed with a Geographic Information System to determine distances between humans and bears. We integrated the data from the GIS with our Access database, which proved to be essential to data maintenance and analyses.

Brown Bear Identification

We identified individual bears according to natural markings, morphological characteristics, pelage patterns, scars, and behavioral traits, similar to previous studies (Olson et al. 1997, Chi and Gilbert 1999, Gende et al. 2001). Each observer was equipped with binoculars and/or a spotting scope. As in previous studies, family groups were counted as one bear, as cub activity is not independent of its parent.

To maintain accurate identifications, researchers utilized digital video recorders (Sony Inc.: TRV-120, 400x digital zoom with O Lux, infrared Super NightShot®) to document and record information on bear identity, access routes, foraging behavior, and responses to human activities. Video records facilitated reliable discrimination between bears and their behavior, and improved inter-observer reliability within and between observers and years. Experienced researchers trained

new observers during the first several weeks of the study period in the field and with video sequences collected on site depicting specific individuals, behaviors and interactions. Identifying characteristics of individual bears were reviewed with all observers on a routine basis. After each observation session, videotapes were reviewed and when necessary images were transferred to computer for additional magnification and scrutiny of gender and identification. The Super Night Shot feature allowed us to identify individuals and collect data in low light conditions, as long as 90 minutes after sunset.

Identifying characteristics of individuals changed significantly between the beginning and end of the study period. Bears arriving in late July and early August often exhibited hues of blond and rouge in their summer coats. By season's end, coat color morphed to deep brown and significant increases in body mass were noted. Video recordings and assiduous daily observation maintained accurate identification throughout these transformations.

Dependent Response Variables

To assess bear behavioral responses to human activities and environmental conditions we measured daily rate of bear activity ($\text{total bears} \cdot \text{total scans}^{-1}$), salmon capture rate ($\text{captures} \cdot \text{minutes searching}^{-1}$), and foraging bout length (mean length of foraging bouts viewed entirely). Captures included live fish and dead fish that were consumed.

Independent Variables

We classified human activity into six categories and analyzed the average daily number counted in each scan, as potential explanatory variables influencing bear activity. These classes were anglers, commercially guided tourists, non-guided tourists, officials, and a combination of all humans, as well as, vehicles. Datapoints represent the mean number of people, vehicles or bears, within a day for each of the specific independent variables and bear responses.

Sockeye, pink, and coho salmon counts were obtained from the ADF&G weir to assess salmon returns. We analyzed two indices of pink salmon activity: the number of daily salmon counted passing through the weir was used for run timing. The second index, pink salmon abundance, was determined as follows: As pink salmon are semelparous (reach sexual maturity, spawn once, and then die) abundance declines after a certain period of time in fresh water (Schindler et al. 2003). The mean lifespan of pink salmon in fresh water is approximately 8 days (± 4) in southeast Alaska (Dickerson et al. 2002). Many dead fish are consumed by brown bears over time, with 73% scavenged by bears after ten days (Quinn and Buck 2000). Therefore, to estimate fish abundance, including both live and senescent fish, we decreased the cumulative number of fish counted at the weir by the total arrival of pink salmon counted twenty days prior. This best reflects the natural decline in abundance and accounts for the array of prey available to brown bears.

At the end of the salmon run, after weir removal, we imputed the number of Pinks, from the 9-year daily average. This period accounts for fewer than fifty fish per

day. We also recorded environmental data including, mean ambient temperature, weather conditions and river depth at a fixed location above tidal influence.

Data Analyses

We employed several statistical techniques in the analysis of these data, including correlation matrices, multiple regression, principal components analysis, and canonical correlation analysis following established procedures (Johnson 1998). We computed Pearson product-moment correlation coefficients, to evaluate relationships between strongly correlated variables, ρ (rho) >0.25 . These provided the greatest explanatory effect in the analysis of the relationship between independent and dependent variables. Statistical package, SAS Institute 8.0, was used for all data analyses with statistical significance selected at $\alpha < 0.05$.

We tested the data for deviations from normality by assessing the dataset through box plots, histograms, normal probability and residual plots, as well as with Kolmogorov-Smirnov tests of normality. There were a few deviations from normality though minor and the majority of data were homoscedastic. It is unwarranted to assume that human and animal behavior conforms to an ideal normal distribution. Assessment of the first two principal component's pairwise scatterplots indicated multivariate normality, hence, we maximized interpretability by not transforming data. Also, the data used to assess daily influences on bears were not independent, as all bears were observed at the site on more than one day. However, given the size of the population we found this approach to be more appropriate than using the individual animals as the unit of replication. As well, it was assumed that the probability of

detecting an individual bear was random and that each bear had equal chance of detection. We used 2-sample T- tests to compare foraging bout lengths between years. We used non-parametric tests, Kruskal-Wallis to evaluate differences between cohorts and Wilcoxon rank-sums to test differences between samples (Zar 1999).

To determine the sources of variability within bear activity and foraging behavior we performed a series of multiple regressions, including R square, backward, forward, and stepwise selections, to derive predictive models of bear presence (2000-2002) and foraging attributes (2001-2002). We present the analyses of 2000 data separately from the 2001-2002 dataset, as data collection the first year did not incorporate capture rates and foraging bout lengths. We measured three dependent response variables in 2001 and 2002 and combined years into one dataset.

We recognized limitations of regression techniques given the multidimensionality of the data. Therefore, we employed multivariate methods designed for such complexity. Principal components analysis was performed first to assess and determine which variables captured the majority of the variability. A principal components analysis is also useful for data exploration, detection of possible outliers, and depiction of the data's "true dimensionality" (Johnson 1998). Canonical correlation analysis was used next to identify linear combinations between the set of independent and dependent variables. Canonical correlation generally finds linear transformations that maximize the correlation coefficient between predictor and response variates (Johnson 1998). We employed canonical correlation analysis on the 2001-2002 dataset to identify how the combination of relationships between human

activity, salmon, and environmental attributes related to responses in bear activity and foraging behavior. The correlations (ρ_c) are interpreted through the assessment of the coefficients' weights and loadings. We interpreted coefficients greater than $|0.4|$. The canonical R_c^2 , signified the proportion of variance in bear activity and behavior that was contributed by the explanatory variables.

Once we identified variables potentially limiting brown bear activity, we examined threshold levels of effects. Following established techniques, we utilized non-linear piecewise regression to identify thresholds (Toms and Lesperance 2003).

RESULTS

Systematic sampling of brown bear activity and foraging behavior in response to human activity resulted in over 3600 hours of observation. During 260 days, we recorded over 512 hours of focal observation on individual brown bears (Table 2-1).

Age-Gender Cohort Composition

Bear age and gender ratios on the Chilkoot varied significantly from other brown bear viewing sites in Alaska and British Columbia ($H = 9.45$, $df = 4$, $P = 0.009$) (Figure 2-3). While proportions of adult females and subadult females were similar to other populations, male classes were significantly different. In three years, we observed zero adult males, while subadult males were frequently observed (Table 2-2).

Cohort Activity Comparison

Bear activity on the river was dominated by subadults in 2000 (87%) and 2002 (55%), while family groups were observed most in 2001 (52%) (Figure 2-4). Overall,

adult animals contributed 41% of the observed focal minutes with family groups constituting 68% of the adult minutes. Subadults were responsible for 58% of bear activity, with the remainder due to unclassified individuals. Foraging bout lengths differed between years, with each class having longer bouts in 2001 than 2002 ($T = 2.52$, $df = 5$, $P = 0.05$), though there was little difference in mean bout length between cohorts.

Bear Activity Trends at Different Temporal Scales

Bear activity was significantly greater in 2000 when compared to weekly bear activity in subsequent years (2000 vs 2001: $T = 3.075$, $df = 13$, $P = 0.009$; 2000 vs. 2002: $T = 2.342$, $df = 11$, $P = 0.039$). In all years the majority of bear activity occurred between mid-August and mid-October with peaks in activity occurring between weeks 35 and 38. The apex of bear activity consistently coincided with minimum levels of human activity (Figure 2-5).

Bear use of the Chilkoot River showed a distinct bimodal distribution pattern during daylight hours varying inversely with human activity throughout the day (Figure 2-6). The majority of bears were active during crepuscular hours when human activity was least. Overall, evening use of the river was slightly higher than morning activity, 0.30 vs. 0.23 bears per scan, though not significantly different when all weeks were compared ($W = 1480$, $P > 0.17$).

Influence of Human Presence and Absence on Bear Activity

Overall, bear activity was 40% greater at times when people were absent. This trend was consistent between years with increased activity during human absence totaling 9%, 87%, and 44% in 2000, 2001, and 2002, respectively (Figure 2-7). Humans were present on the river in 11, 534 of 14, 590 scan samples (79%).

Bear Access in Relation to Salmon Run Timing

Salmon increased over the 3-y study with sockeye and pink escapements exceeding 10-y averages in each year (Table 2-3). While there was temporal and spatial overlap in salmon runs, the peak of each species run was discrete. Bear activity in 2000 lagged about one week behind the salmon peak with 8 of 11 bears arriving by this time. In contrast, bear activity in 2001-2002 was delayed until well after the peak salmon return (Figure 2-8). Only 3 of 9 (2001) and 6 of 12 (2002) bears arrived by the pink salmon peak in subsequent years, when fewer live fish were available for capture.

Human Use Patterns

After year 2000, mean angler effort, salmon escapement and human activity increased substantially (Table 2-4). Vehicle activity increased each year with 39% growth between 2000 and 2002. In the evening, bears were often active when large numbers of people and vehicles were present. Maximum numbers of people reached 237 in 2000, 266 in 2001, and 485 in 2002 when two zones were sampled. The four observation zones received similar proportions of human use between years.

Factors Influencing Bear Activity in 2000

Bear activity positively correlated with pink salmon abundance (both live and dead fish) ($\rho = 0.70$, $P < 0.0001$) and non-guided tourists ($\rho = 0.34$, $P < 0.0015$). Angler activity ($\rho = -0.27$, $P = 0.01$) and river depth ($\rho = -0.25$, $P = 0.02$) correlated negatively with bear activity.

We derived predictive models of bear activity, using multiple regression, including all potential explanatory environmental and human activity variables ($F = 15.56$, $df = 10$, $P < 0.0001$, $r^2 = 0.68$). Independent variables that contributed significantly to the model included salmon abundance, daily pink salmon arrivals, guided activity, anglers, overall human activity, and non-guided tourists. Using forward and stepwise regression we found the most parsimonious model included daily pink arrivals and salmon abundance to accounting for the majority of the variability ($F = 61.41$, $df = 2$, $P < 0.0001$, $r^2 = 0.60$). These relationships, while significant, were less pronounced in subsequent years.

Factors Influencing Bear Activity in 2001-2002

Angler activity ($\rho = -0.47$, $P = 0.0001$) and vehicle traffic ($\rho = -0.32$, $P < 0.0001$) negatively correlated with bear activity while salmon abundance and inclement weather correlated positively (Table 2-5).

The regression model derived to predict bear activity was highly significant ($F = 25.22$, $df = 10$, $P < 0.0001$, $r^2 = 0.62$). With forward and stepwise regression we

found the most parsimonious predictive model of bear activity ($P < 0.0001$, $r^2 = 0.41$) included all variables except salmon run timing.

Relationships with Bear Foraging Behavior in 2001-2002

Brown bear capture rates of pink salmon correlated negatively with vehicle activity ($\rho = -0.20$, $P = 0.009$), temperature ($\rho = -0.26$, $P = 0.0005$), and river depth ($\rho = -0.30$, $P < 0.0001$) (Table 2-5). In stepwise regression models, the subset of explanatory variables that best predicted capture rates were river depth, vehicles and non-guided tourists ($F = 9.09$, $df = 3$, $P < 0.0001$, $r^2 = 0.14$).

Foraging bout length negatively correlated with vehicle traffic ($\rho = -0.33$, $P < 0.0001$), anglers ($\rho = -0.32$, $P < 0.0001$), and temperature ($\rho = -0.21$, $P = 0.006$). Pink salmon abundance was the only factor positively correlating with foraging bout length ($\rho = 0.20$, $P = 0.008$) (Table 2-5). Using forward and stepwise selection, foraging bout length was best described by vehicle activity, non-guided tourists and temperature ($F = 15.69$, $df = 3$, $P < 0.0001$, $r^2 = 0.22$).

Canonical Correlation Analysis of Bear Activity and Foraging Behavior

Canonical correlation analysis yielded three new canonical variables identifying significant correlations between linear combinations of explanatory variables influencing the activity level and foraging behaviors of bears. The first canonical combination ($\rho_c = 0.79$) ($P < 0.0001$) described the association between high bear activity and longer bout lengths during days with few anglers, low vehicle traffic,

and high abundance of salmon (Figure 2-9), in order of loading contribution. A canonical redundancy analysis served to explain 44% of the variance within the first canonical variable ($r_c^2 = 0.62$). Analysis of the second canonical variable explained the relationship between high capture rates and longer bout lengths when river levels, temperatures, and vehicle numbers were low ($\rho_c = 0.46$) ($P = 0.0009$) (Figure 2-10). The first and second dependent canonical correlations combined accounted for 79% of the variability in the data. The third canonical correlation explained the relationship between short foraging bout lengths when the number of anglers and human totals were high, contributing 21% of the variability. Our test of linearity between the collection of independent and dependent variables signified a highly significant relationship (Wilkes' $\lambda = 0.29$, $P < 0.0001$).

Thresholds Limiting Bear Activity

We used nonlinear piecewise regression to determine thresholds on bear activity resulting from angler activity and vehicle traffic. In 2001, the threshold for mean daily anglers was $1.9 (\pm 0.5)$ ($F = 38.01$, $df = 95$, $P < 0.0001$). The angler threshold for bear activity was $2.9 (\pm 1.96)$ in 2002 ($F = 13.35$, $df = 81$, $P < 0.0001$). Both years combined yielded a threshold break point of $2.6 (\pm 0.6)$ ($F = 38.27$, $df = 176$, $P < 0.0001$) (Figure 2-11). Bear activity was constrained by a threshold of vehicle activity at $2.4 (\pm 4.4)$ ($F = 6.51$, $df = 176$, $P < 0.0003$) (Figure 2-12).

We present one random day in 2002 that was under the angler threshold to provide a sense of the activity that coincides with this level of use ($\bar{x} = 2.46$ anglers*scans⁻¹). The first two zones were sampled in both the morning and evening

session on day 244. Five bears were present and all departed by 0645 hours when anglers commenced fishing. By 0700 hours, 4 vehicles had entered the corridor and there were two anglers fishing. At 0800 hours there were 5 anglers fishing, and 14 vehicles counted: two subadult bears gained access to human food from an unattended cooler. Human activity continued through the day. Between 1900 and 2000 hours, 72 vehicles passed through the site and there were 10 anglers fishing while two subadult bears captured fish near the weir. Adult bear activity did not begin until nearly 2000 hours when 5 anglers were fishing and one adult female entered 200 meters away. Five bears were observed fishing after angler activity ceased at 2015 hours.

DISCUSSION

Influence of Human Presence on Bear Foraging Activity

We found the Chilkoot age-gender composition to be significantly different from the compositions observed in other bear viewing areas in Alaska and British Columbia. We expected to find cohort compositions similar to other viewing sites where adult males occupy the best available habitats. In three years, we never observed a large male during the study, neither during human absence, near darkness, nor on remote trail cameras. Mattson's (1990) comprehensive assessment of the impacts of human activities on bear habitat use, found that adult females and subadult male bears were typically found in less productive habitats often in close proximity to people. They were also the most likely cohorts to seek humans as a source of food. The composition of Chilkoot bears, therefore, suggests that the habitat is somehow

compromised, likely an effect of extensive human use. This is a hunted population with a small 400 meter no-hunting buffer along the road. Most other sites compared offer protected closures at least the size of an average female home range. It is possible to suggest that the exclusion of adult males may actually benefit females with cubs, as human activity serves to provide a refuge from adult males (Nevin 2003). While this possibility exists, it places a large assumption on the premise that these females are obtaining adequate nutrition, a fairly tenuous conclusion given their restricted access and the high costs associated with repeated displacement.

Bear activity along the Chilkoot River was strongly influenced by human activity on two temporal scales, diurnal and seasonal. Most bears were displaced from foraging activities during the middle of the day and seasonal activity was delayed until angler and vehicle activity dropped below threshold levels. These findings are further substantiated by several published studies which have demonstrated that daily and seasonal activity patterns of brown bears are adjusted in response to human recreational activity (Roth 1983, Warner 1987a, Gunther 1990, Reinhart and Mattson 1990, Fagen and Fagen 1994, Olson et al. 1997, Olson et al. 1998). Furthermore, in regions where human activity is limited, bear activity has been shown to be most prevalent during daylight hours (Stemlock and Dean 1986, Warner 1987b, Olson et al. 1998, MacHutcheon et al. 1998, Crupi 2003) debunking the myth that bears are naturally crepuscular.

Disproportionate Effects of Human Activity

We found that high levels of bear activity and longer foraging bouts were facilitated by low numbers of anglers and vehicles correlated with an abundance of live and dead salmon. In reviewing these disproportionate effects of specific activities, it is helpful to consider anglers as a potential competitor for limited fishing sites. As anglers concentrated on the riverbanks, their impact was likely more significant because they displaced bears from essential foraging sites and increased the potential for closer bear-human interactions. The impacts associated with anglers are not surprising given the overlapping spatial and temporal use of the river. Other studies have documented the influence of anglers on wildlife and have found similar responses by wildlife. Knight et al. (1991) found that when anglers were fishing, the number of eagles and ravens observed decreased. They also found that these bird species foraged less when anglers were present. Similarly, Olson et al. (1990) observed temporal and spatial shifts in brown bear habitat use in Katmai National Park depending upon angler activity levels.

It is possible that this increased competition with anglers caused bears to delay seasonal use of the river. Studies of brown bear social behavior indicated that at times fishing bears aggressively defend foraging sites, but more often waited their turn for access or deferred to another site (Egbert and Stokes 1976). Bears typically avoid one another by spacing out over the available fishing locations, as well as temporally throughout the day (Stonorov and Stokes 1972). Therefore, it is reasonable to assume

that bears are treating anglers similarly by temporally and spatially avoiding recreational activities that directly displace them from foraging habitat.

We did not find commercial activity to negatively correlate with daily bear activity levels. While commercial activity by itself was not found to constrain activity, it was not independent of increased human totals and vehicle activity, both of which were correlated with decreased bear activity. We had assumed that the large influx of guided tourists, often besieging bears with flashbulbs and headlights, would have reduced bear activity levels, though commercial displacements were not specifically analyzed in this analysis.

Influence of Salmon Run Timing on Bear Activity

Maximum bear activity in 2000 lagged one week behind the peak pink salmon return, however run magnitude in 2000 was substantially lower than subsequent years. The majority of bears in 2001-2002 utilized the river well after peak run timing consistently correlating with low angler numbers and minimal vehicle traffic. This delayed access to the river combined with displacement from diurnal feeding activities limited the number of live fish available to bears (see Chapter 4). As coastal brown bears rely on salmon to accumulate fat necessary for maintenance, metabolism and hibernation, we assumed a positive relationship between salmon run timing and the daily response of bear activity. Contrary to our hypothesis, the only year that bear activity correlated with live pink salmon was when angler activity dropped below thresholds before salmon run timing reached the peak. Similar relationships have been

shown at other sites, though this study's precise run timing estimates provide much clearer evidence than estimates of density reported in Reinhart and Mattson (1990) and Olson et al. (1997). As an alternative hypothesis to human avoidance, we could employ a bottom up approach, assuming that evolutionary selection or a predator confusion strategy enables salmon to evade bear predation. Thereby, the number of newly arrived fish would be negatively associated with bear activity. While this possibility exists, it appears highly unlikely.

In the absence of human disturbance bears have been shown to prefer newly arriving salmon, captured within the first few days in fresh water (Quinn and Kinnison 1999). This is logical as bears are targeting lipids to store fat and salmon are 76-86% more lipid rich prior to spawning (Gilbert and Lanner 1997, Gende 2002). Gard (1971) found that peak brown bear activity and predation on sockeye salmon on Kodiak Island coincided closely with salmon run timing and was maintained for nearly a week afterwards. Egbert (1978) provided further evidence of brown bear activity mirroring salmon run timing and availability. At Anan Creek in southeast Alaska, Chi (1999) found that black bears also tracked fish availability, maximizing use of the river within a week of peak salmon numbers. Differences in stream flow, water temperature and weather conditions do not influence the amount of time for pink salmon to reach senescence (~8 days) in southeast Alaska (Gende 2002). This further supports our hypothesis that bears attempting to maximize live fish captures should be most active within a week of the peak salmon return, and certainly not as many as four weeks delayed, as observed in this study.

escapements during this study were prolific. Over the past hundred years that data were available, cyclic fluctuations in water temperatures have significantly correlated with changes in harvest and escapement levels of southeast Alaska's pink salmon (Mantua et al. 1997). The relationship between these massive variations in salmon abundance and oceanic conditions may partially be explained by an *El Nino* concept known as Pacific Decadal Oscillation (PDO) (Hare et al. 1999). Given these long-term fluctuations in climate and fishery production, we can anticipate decreases in salmon abundance in the future. What will be the impact of recreation when abundance is low? Will population demographics change in response to decreased prey abundance or will bears alter habitat use to avoid foraging near human proximity if the benefits are not paramount to the costs? Evaluating these relationships through the long-term should be a priority, and prediction of likely bear responses is therefore important for managers to consider.

In this study, the greatest number of aggressive interactions between bears occurred during record salmon escapement in 2002 (Crupi, unpublished data). On the contrary, Egbert and Stokes (1976) demonstrated that aggression between bears increased when salmon became limited and bears sought alternative food resources. The increased competition for limited fishing sites and food resources at other sites may explain the increased aggression between bears but it is possible that the profound increase in human activity at this site may be creating stressful conditions as bear activity becomes increasingly constrained. Will bears respond more aggressively to each other and eventually people when salmon returns become low? If bears are

forced to search for alternative foods they will likely find improperly stored human food and refuse at the nearby State campground and neighboring residential residences. Improved management efforts to prevent these negative outcomes are increasingly necessary.

Comparative Analyses of Multivariate Techniques

Our multivariate approach to assessing the influence of various dependent variables has advantage because of the numerous interactions between people, bears, and their environment. A good example of the complexity involved when numerous interactions occur between multiple variables was realized by Bell and Austin's (1985) evaluation of the effects of anglers and sailboats on waterfowl. At first they believed that boats and anglers had no direct effect on waterfowl for the habitats used were separated; boats occupied the open water while birds congregated in habitats near shore. However, during fishing season, waterfowl were displaced from shore by anglers into habitat used by sailboats. Only then were the cumulative effects of multiple interactions clearly understood. This reinforces the need to understand seasonal variations and the multi-dimensional relationships between recreationists and bears.

Our objective in using various multivariate techniques was to determine the contribution of each factor and capture the information with the least number of predictive variables so as to reduce the dimensionality of the data. In general, multiple regression did not effectively reduce the number of variables nor adequately provide

meaningful biological interpretations of the data with subset selections with inconsistent results. The multiple regression selection models did not contribute to bear activity in the 2001-2002 dataset. We presented data from stepwise and forward selection models, as the backwards and R square selection procedures repeatedly failed to reduce the number of variables in the model and appeared unstable. Ecologists often employ multiple linear regression to find the best model that predicts the dependent data. Mac Nally (2000) thoroughly discussed the weaknesses of this approach as evidenced in our experience. The largest problems inherent with multiple regression in the analysis of complex datasets, involve the shortcomings within variable subset selection and multicollinearity between predictor variables. Model subset selection excludes variables for one of two reasons, either the variable captures significant variability or another variable captures that similar variability (Mac Nally 2002). This arbitrary and capricious selection technique seems inferior to the multivariate analysis approach that we employed.

We found canonical correlation analysis provided strong linear relationships within the first two newly created canonical variables which best explained the complexity of the dynamic situation along the Chilkoot River. Interpretation of the first canonical correlation supported our prediction that elevated levels of human activity impact seasonal levels of bear activity as well as the amount of time spent foraging. The second pair canonical correlation depicted the trend between bears spending less time foraging and reduced capture rates when vehicle activity, river levels and temperatures were high. Surprisingly, there were no clear density

dependent relationships between capture rates and the numbers of salmon, either live, dead or both. While these canonical analyses provide simple interpretability of the dynamic relationships between people, bears and their environment.

MANAGEMENT IMPLICATIONS

For management purposes, it is important to observe current trends in bear activity and evaluate the potential factors limiting brown bear access to limited food resources. At this site, the duration of the pink salmon spawning run extends approximately two months and the evidence suggests that intense human activity constrains bear activity during this critical feeding time. Hilderbrand et al. (1999) found a strong positive linear relationship between proportion of meat in brown bear diet, particularly salmon, and several important reproductive parameters, including increased litter size, mean adult female body mass, and decreased first age to reproduction. Unless bears can consume 2-3 times as many senescent carcasses (Gende 2002, see Chapter 4), necessary to defray the cost of not utilizing peak lipid and energy contents of live salmon, long-term reproductive costs may exist. This could have profound impact on brown bear population productivity.

Wilker and Barnes (1998) experimentally examined the effect of brown bear viewing on Kodiak Island with both regulated and unregulated management treatments. They found bears to be less impacted and more predictable during the managed treatment. They used this study to address the development of new and expanding bear viewing programs throughout Alaska. In considering the cost of regulating numerous sites and the benefits to human safety and bear populations they

of these results in relation to our findings would enhance managers' ability to support both human recreation and bears. An alternative treatment would be to temporally limit activities during identified critical foraging periods to observe changes in foraging behaviors, capture success and overall levels of activity. Through adaptive management procedures, we could effectively manage for coexistence between bears and human recreational uses, therefore providing maximum benefits.

CONCLUSIONS

A consistent inverse relationship between bear activity and human recreation suggested that bear response to human activity is more limiting than prey abundance. Bear response to human activity is significantly and directly correlated to levels of sports fishing and associated vehicle traffic. When human recreational use was substantially lower in 2000, with nearly 40 % fewer anglers, non-guided tourists and vehicles, bear activity was 37% greater than the 2001-2002 seasons, irrespective of prey abundance. The evidence strongly supported the interpretation that increases in specific human activities limited bear activity. As well, the composition of cohorts foraging at this site, mostly subadults and females with offspring, correlates with what would be expected in sub-optimal habitats, indicating that access to this abundant resource is somehow compromised.

Nearly every measure of bear activity and foraging behavior was impacted by human activity, particularly as human use of the site continued to increase. Seasonal timing of bear access to salmon was clearly dependent upon angler activity dropping below critical threshold levels. Bear activity during the daytime displayed a pattern

that was inversely correlated with human activity. As vehicle traffic began in the morning, adult females departed the river first, followed by subadult bears. They did not return until later in the evening. Furthermore, it was surprising that salmon abundance (both live and senesced fish) and salmon run timing were not strongly correlated with brown bear capture rates of salmon or foraging bout lengths, yet it was apparent that the degree of human activity served to regulate these foraging behaviors. Bears' ability to balance these costs and benefits in a complex human dominated matrix is a testament to their adaptability and plasticity.

While traditional multiple regression techniques were useful, examination of the data using canonical correlation analysis proved to be even more robust and interpretable. We found that three explanatory factors simultaneously influenced bear activity and foraging bout length which are predictors of energy intake. Bears were most active and spent the longest periods of time fishing when the numbers of anglers and vehicles were minimal, in combination with high abundance of live and senescent salmon. Bear capture rates of salmon were greatest when they spent longer foraging bouts. These conditions correlated with decreased river levels, cooler temperatures and lower numbers of vehicles. When the numbers of anglers and overall human activity was greatest bears were subject to short foraging bouts. It is interesting to note that while human activity increased by 25% between 2001 and 2002 foraging bout lengths were shorter for all cohorts.

Can bears and recreationists coexist? The data suggest that bears are strongly influenced by increased levels of various human dimensions. If human activity

continues to expand and infringe upon the windows of opportunity currently available to bears, then decreased bear activity and population productivity should be expected. Bears may even eventually abandon the river completely. The need for temporally restricting human use is apparent: coexistence will rely upon strategic implementation of user guidelines. Years of decreased salmon abundance can be expected to exacerbate the need for such restrictions. Sound scientific management of bear-viewing areas must be based upon actual impacts of human activity rather than perceived effects. Our assessment provides guidance for management and future studies to assess effectiveness of management. This investigation and analysis provide the scientific data needed to greatly improve human safety and resource protection, and management now resides in the hands of state and local agencies.

LITERATURE CITED

- Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour* 49:227-267.
- Aumiller, L. D., and C.A. Matt. 1994. Management of McNeil River State Game Sanctuary for viewing of brown bears. *International Conference on Bear Research and Management* 9(1):51-61.
- Bell, D.V., and L.W. Austin. 1985. The game-fishing season and its effects on overwintering wildfowl. *Biological Conservation* 33:65-80.
- Bolduc, F., and M. Guillemette. 2003. Human disturbance and nesting success of common eiders: interactions between visitors and gulls. *Biological Conservation* 110:77-83.
- Cassini, M.H. 2001. Behavioural responses of South American fur seals to approach by tourists-a brief report. *Applied Animal Behaviour Science* 71:341-346.
- Chi, D.K. 1999. The effects of salmon availability, social dynamics, and people on black bear (*Ursus americanus*) fishing behavior on an Alaskan salmon stream. Ph.D. Dissertation. Utah State University, Logan. 157 pp.

- Chi, D.K., and B.K. Gilbert. 1999. Habitat security for Alaskan brown bears at key foraging sites: are there thresholds for human disturbance? *Ursus* 11: 225-238.
- Crupi, A.P. 2003. Chinitna Bay brown bear foraging activity and behavioral response to aircraft overflights. Lake Clark National Park and Preserve, Alaska. Unpublished manuscript.
- Crupi, A.P., and B.K. Gilbert. 2003. Bear and human use patterns of the Chilkoot River in Haines, Alaska, 2000-2001. ADF&G, Division of Wildlife Conservation, Technical Progress Report, Contract No. COOP 02-114, Juneau, Alaska.
- Dickerson, B.R., T.P. Quinn, and M.F. Willson. 2002. Body size, arrival date and reproductive success of pink salmon, *Oncorhynchus gorbuscha*. *Ethology, Ecology, and Evolution* 14:29-44.
- Egbert, A.L. 1978. The social behavior of brown bears at McNeil River, Alaska. Ph.D. Dissertation, Utah State University, Logan. 117 pp.
- Egbert, A.L., and A.W. Stokes. 1976. The social behaviour of brown bears on an Alaskan salmon stream. *International on Bear Research and Management* 3:41-56.
- Fagen, J. M., and R. Fagen. 1994. Interactions between wildlife viewers and habituated brown bears, 1987-1992. *Natural Areas Journal* 14(3):159-164.
- Flather, C.H, and H.K. Cordell. 1995. Outdoor recreation: historical and anticipated trends. Pp. 3-16 in R.L. Knight and K.J. Gutzwiller, eds., *Wildlife and Recreationists: Coexistence Through Management and Research*. Island Press, Washington, D.C.
- Gard, R. 1971. Brown bear predation on sockeye salmon at Karluk Lake, Alaska. *Journal of Wildlife Management* 35(2):193-204.
- Gende, S.M. 2002. Foraging behaviors of bears at salmon streams: intake, choice, and the role of salmon life history. Ph.D. Dissertation. University of Washington, Seattle. 259 pp.
- Gende, S.M., T.P. Quinn, and M.F. Willson. 2001. Consumption choice by bears feeding on salmon. *Oecologia* 127:372-382.
- Gilbert, B.K., and R.M. Lanner. 1997. Energy, diet selection and restoration of brown bear populations. *International Conference on Bear Research and Management* 9(2):231-240.

- Gunther, K. A. 1990. Visitor impact on grizzly bear activity in Pelican Valley, Yellowstone National Park. *International Conference on Bear Research and Management* 8:73-78.
- Hare, S.R., N.J. Mantua, and R.C. Francis. 1999. Inverse production regimes: Alaska and west coast pacific salmon. *Fisheries* 24(1):6-13.
- Hessing, P., and L. Aumiller. 1994. Observations of conspecifics predation by brown bears, *Ursus arctos*, in Alaska. *Canadian Field Naturalist* 108:332-336.
- Hilderbrand, G.V., C.C. Schwartz, C.T. Robbins, M.E. Jacoby, T.A. Hanley, S.M. Arthur, and C. Servheen. 1999. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. *Canadian Journal of Zoology* 77:132-138.
- Hood, G.A., and K.L. Parker. 2001. Impact of human activities on grizzly bear habitat in Jasper National Park. *Wildlife Society Bulletin* 29(2):624-638.
- Johnson, D.E. 1998. *Applied Multivariate Methods for Data Analysis*. Brooks and Cole Publishing Co., Pacific Grove, Calif. 816 pp.
- Kelley, M.S., and Bachman, R. L. 1999. Chilkoot River weir results, 1998. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report No. 1J99-25. Juneau, Alaska.
- Knight, R.L., D.P. Anderson, and N.V. Marr. 1991. Responses of an avian scavenging guild to anglers. *Biological Conservation* 56:195-205.
- Knight, R.L., and D.N. Cole. 1995. Wildlife responses to recreationists. Pp. 51-69 *in* R.L. Knight and K.J. Gutzwiller, eds., *Wildlife and Recreationists: Coexistence Through Management and Research*. Island Press, Washington, D.C.
- Lee, K.N. 1999. Appraising adaptive management. *Conservation Ecology* 3(2):3. [online] URL: <http://www.consecol.org/vol3/iss2/art3>.
- Lehner, P.N. 1998. *Handbook of Ethological Methods, Second Edition*. Cambridge University Press, Cambridge, U.K. 672 pp.
- MacHutcheon, A.G., S. Himmer, H. Davis, and M. Gallagher. 1998. Temporal and spatial activity patterns among coastal bear populations. *Ursus* 10:539-549.
- Mac Nally, R. 2000. Regression and model-building in conservation biology, biogeography and ecology: the distinction between - and reconciliation of - 'predictive' and 'explanatory' models. *Biodiversity and Conservation* 9:655-671.

- Mac Nally, R. 2002. Multiple regression and inference in ecology and conservation biology: further comments on identifying important predictor variables. *Biodiversity and Conservation* 11:1397-1401.
- Mann, S.L., R.J. Steidl, and V.M. Dalton. 2002. Effects of cave tours on breeding *Myotis velifer*. *Journal of Wildlife Management* 66(3):618-624.
- Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78:1069-1079.
- Mattson, D.J. 1990. Human impacts on bear habitat use. *International Conference on Bear Research and Management* 8:33-56.
- Mattson, D. J., R.R. Knight, and B.M. Blanchard. 1987. The effects of development and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. *International Conference on Bear Research and Management* 7:259-273.
- Matz, G. 2000. The value of Cook Inlet bears. Report to the Chenik Institute. Anchorage, Alaska. Unpublished manuscript.
- McDowell Group. 2000. The economic impacts of the cruise industry in southeast Alaska. [online]URL:<http://www.alaskacruises.org/econ/library/cruiseimpacts.pdf>.
- Miller, S., S.D. Miller, D. McCollum. 1998. Attitudes toward and relative value of Alaskan brown and black bears to resident voters, resident hunters, and nonresident hunters. *Ursus* 10:357-376.
- Miller, S.D., G.C. White, R.A. Sellers, H.V. Reynolds, J.W. Schoen, K. Titus, V.G. Barnes, R.R. Nelson, W.B. Ballard, and C.C. Schwartz. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques. *Wildlife Monographs* 133:1-55.
- Naves, J., A. Fernandez-Gil, and M. Delibes. 2001. Effects of recreation activities on a brown bear family group in Spain. *Ursus* 12:135-140.
- Neary, J. 1995. Workshop for viewing area managers: summary and notes. U.S. Forest Service, Juneau, Alaska. Unpublished typescript.
- Nevin, O.T. 2003. The influence of prey abundance and risk-sensitive behavioral change on individual access to high-energy food (salmon): impacts on the density and viability of bear populations. Ph.D. Dissertation, Utah State University, Logan. 170 pp.

- Olson, T.L. 1994. Infanticide in brown bears, *Ursus arctos*, at Brooks River, Alaska. *Canadian Field Naturalist* 107(1):92-94.
- Olson, T.L., and B.K. Gilbert. 1994. Variable impacts of people on brown bear use of an Alaskan river. *International Conference on Bear Research and Management* 9(1):97-106.
- Olson, T. L., B.K. Gilbert, and S. Fitkin. 1990. Brown bear behavior and human activity at salmon streams in Katmai National Park, Alaska. Final Report. Natl. Park Serv. Contract No. IA 9700-7-8028. Utah State University, Logan. 123 pp.
- Olson, T. L., B.K. Gilbert, and R.C. Squibb. 1997. The effects of increasing human activity on brown bear use of an Alaskan River. *Biological Conservation* 82:95-99.
- Olson, T.L., R.C. Squibb, and B.K. Gilbert. 1998. Brown bear diurnal activity and human use: a comparison of two salmon streams. *Ursus* 10:547-555.
- Quinn, T.P., and G.B. Buck. 2000. Scavenging by brown bears, *Ursus arctos*, and glaucous-winged gulls, *Larus glaucescens*, on adult sockeye salmon, *Oncorhynchus nerka*. *Canadian Field Naturalist* 114:217-223.
- Quinn, T.P., and M.T. Kinnison. 1999. Size-selective and sex-selective predation by brown bears on sockeye salmon. *Oecologia* 121:273-282.
- Reinhart, D.P., and D.J. Mattson. 1990. Bear use of cutthroat trout spawning streams in Yellowstone National Park. *International Conference on Bear Research and Management* 8:343-350.
- Roth, H.U. 1983. Diel activity of a remnant population of European brown bears. *International Conference on Bear Research and Management* 5:223-229.
- Salafsky, N., R. Margoulis, K.H. Redford, and J.G. Robinson. 2002. Improving the practice of conservation: a conceptual framework and research agenda for conservation science. *Conservation Biology* 16(6):1469-1479.
- Schindler, D.E., M.D. Scheuerell, J.W. Moore, S.M. Gende, T.B. Francis, and W.J. Palen. 2003. Pacific salmon and the ecology of coastal ecosystems. *Frontiers in Ecology and Environment* 1(1):31-37.
- Schroeder, R., L. Cervený, and G. Robertson. 2001. Tourism growth in Southeast Alaska: trends, projections, and issues. *Tongass National Forest Tourism Symposium*, 23-25 October 2001. Ketchikan, Alaska.

- Smith, J.S. 2001. Bear viewing ecotourism in British Columbia: ecological, economic and social perspectives using a case study analysis of Knight Inlet Lodge, B.C. M.S. Thesis, Plan B. Utah State University, Logan. 102 pp.
- Stemlock, J.J., and F.C. Dean. 1986. Brown bear activity and habitat use, Denali National Park-1980. International Conference on Bear Research and Management 6:155-167.
- Stonorov, D., and A.W. Stokes. 1972. Social behavior of the Alaska brown bear. International Conference on Bear Research and Management 2:232-242.
- Sutherland, W.J. 1998. The importance of behavioural studies in conservation biology. Animal Behaviour 56(4):801-809.
- Swarthout, E.H., and R.J. Steidl. 2003. Experimental effects of hiking on breeding Mexican spotted owls. Conservation Biology 17(1):307-315.
- Toms, J.D., and M.L. Lesperance. 2003. Piecewise regression: a tool for identifying ecological thresholds. Ecology 84(8):2034-2041.
- Titus, K., J.N. Trent, L.D. Aumiller, J.H. Westland, and M. Sigman. 1994. Managing brown bears as both game and nongame: past experience and future prospects. Transactions of the North American and Natural Resources Conference 59:353-362.
- Warner, S. H. 1987a. Human impacts on brown bears at Pack Creek, Admiralty Island, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 95 pp.
- Warner, S. H. 1987b. Visitor impacts on brown bears, Admiralty Island, Alaska. International Conference on Bear Research and Management 7(3):377-382.
- Wilker, G. A., and V.G. Barnes. 1998. Responses of brown bears to human activities at O'Malley River, Kodiak Island, Alaska. Ursus 10:557-561.
- Williams, R., A.W. Trites, and D.E. Bain. 2002. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. Journal of Zoology 256:255-270.
- Zar, J. H. 1999. Biostatistical Analysis, Fourth Edition. Prentice-Hall, Saddle River, N.J. 931 pp.

Table 2-1. Sampling intensity and hours of focal bear data recorded.

	2000	2001	2002
Observation Hours	992	1362	1267
Focal Bear Hours	152	143	217

Table 2-2. Age-gender classification of bears along the Chilkoot River, July 15-October 28, 2000-2002.

AGE/GENDER	2000		2001		2002	
	#	Class %	#	Class %	#	Class %
Adult Female	4	33%	1	11%	2	18%
Adult Female with young	1	8%	3	33%	4	36%
Adult Male	0	0%	0	0%	0	0%
Sub-adult Female	2	17%	2	22%	3	27%
Sub-adult Male	5	42%	2	22%	2	18%
Sub-adult undetermined	0	0%	1	11%	0	0%
Dependent offspring*	(1)		(6)		(11)	
Black bear	(2)		(2)		(0)	
Total	12	100%	9	100%	11	100%

Table 2-3. Salmon escapement counted passing through the Chilkoot River enumeration weir 1999-2002 and rates of bear and angler activity.

	Sockeye	Pink	Coho ^a	Total Bears * Total Scans ⁻¹	Total Angler * Total Scans ⁻¹
1999	19,284	62,370	11	n/a	n/a
2000	43,555	23,636	47	0.23	2.42
2001	76,283	32,294	200	0.12	3.45
2002	58,361	79,639	304	0.21	3.12
Maximum (weeks)	30-33	33-36	40-42	35-38	32-35 40-42

^aMajority of coho escapement occurs after the operation of the weir.

Table 2-4. Annual mean and maximum activity levels per day 2000-2002.

	2000 μ	2001 μ	2002 μ	2000 max μ	2001 max μ	2002 max μ
Bear Activity	0.23	0.10	0.19	1.25	0.57	0.68
Foraging Bout Length	na	10.10	14.21	na	58.75	50.67
Capture Rate	na	0.24	0.24	na	2.00	1.00
Vehicle Traffic	3.79	4.73	4.65	11.07	14.04	11.90
Anglers	1.97	3.59	3.32	8.91	18.73	22.08
Guided Tourists	2.19	0.80	2.23	16.20	11.94	18.57
Non-guided Tourists	2.26	3.36	4.67	8.04	7.23	12.40
Officials	0.07	0.06	0.12	0.57	0.33	0.50
Human Activity Total	6.49	7.81	10.34	20.61	23.02	28.21
Pink salmon daily	203	340	964	1250	2846	9635
Pink salmon abundance	4789	7259	20787	15842	21985	58462
Temperature	49.63	50.57	50.19	63.00	61.40	60.80
Weather	2.95	2.94	2.92	5.00	5.00	4.83
River Depth (cm)	142.45	139.22	130.95	176.00	195.00	163.40
Days sampled	84	95	81	84	95	81

Table 2-5. Pearson's rho correlations for factors relating to bear activity and foraging behaviors.

	Bear Activity	Capture Rate (CPUE)	Foraging Bout Length
Angler Activity			
rho	-0.47	-0.03	-0.32
p	<0.0001	0.74	<0.0001
Vehicle Activity			
rho	-0.32	-0.20	-0.33
p	<0.0001	0.009	<0.0001
Human Activity			
rho	-0.10	-0.02	-0.17
p	0.19	0.77	0.03
Commercial Guided			
rho	0.21	0.02	0.05
p	0.004	0.83	0.52
Non-Guided			
rho	0.19	-0.04	0.03
p	0.01	0.63	0.72
Officials			
rho	0.22	-0.03	0.04
p	0.002	0.66	0.62
Daily Pink Salmon			
rho	0.08	-0.01	-0.03
p	0.27	0.87	0.68
Pink Abundance			
rho	0.26	0.06	0.20
p	0.02	0.41	0.008
Temperature			
rho	-0.05	-0.26	-0.21
p	0.51	0.0005	<0.006
Weather			
rho	0.29	0.11	0.17
p	<0.0001	0.13	0.02
River Depth			
rho	0.10	-0.30	-0.13
p	0.20	<0.0001	0.08

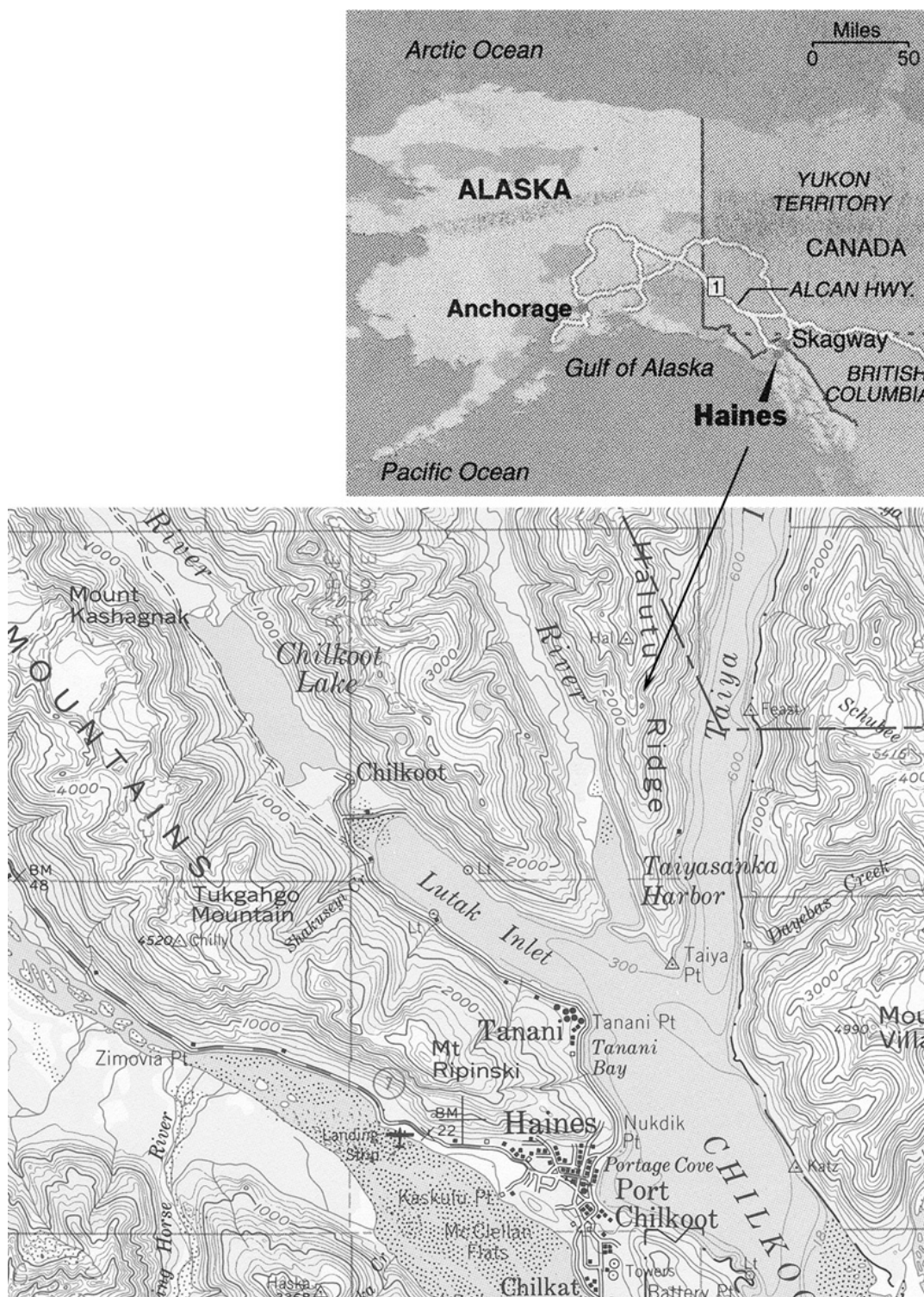


Figure 2-1. Map of the Chilkoot River study site in southeast Alaska, Haines.

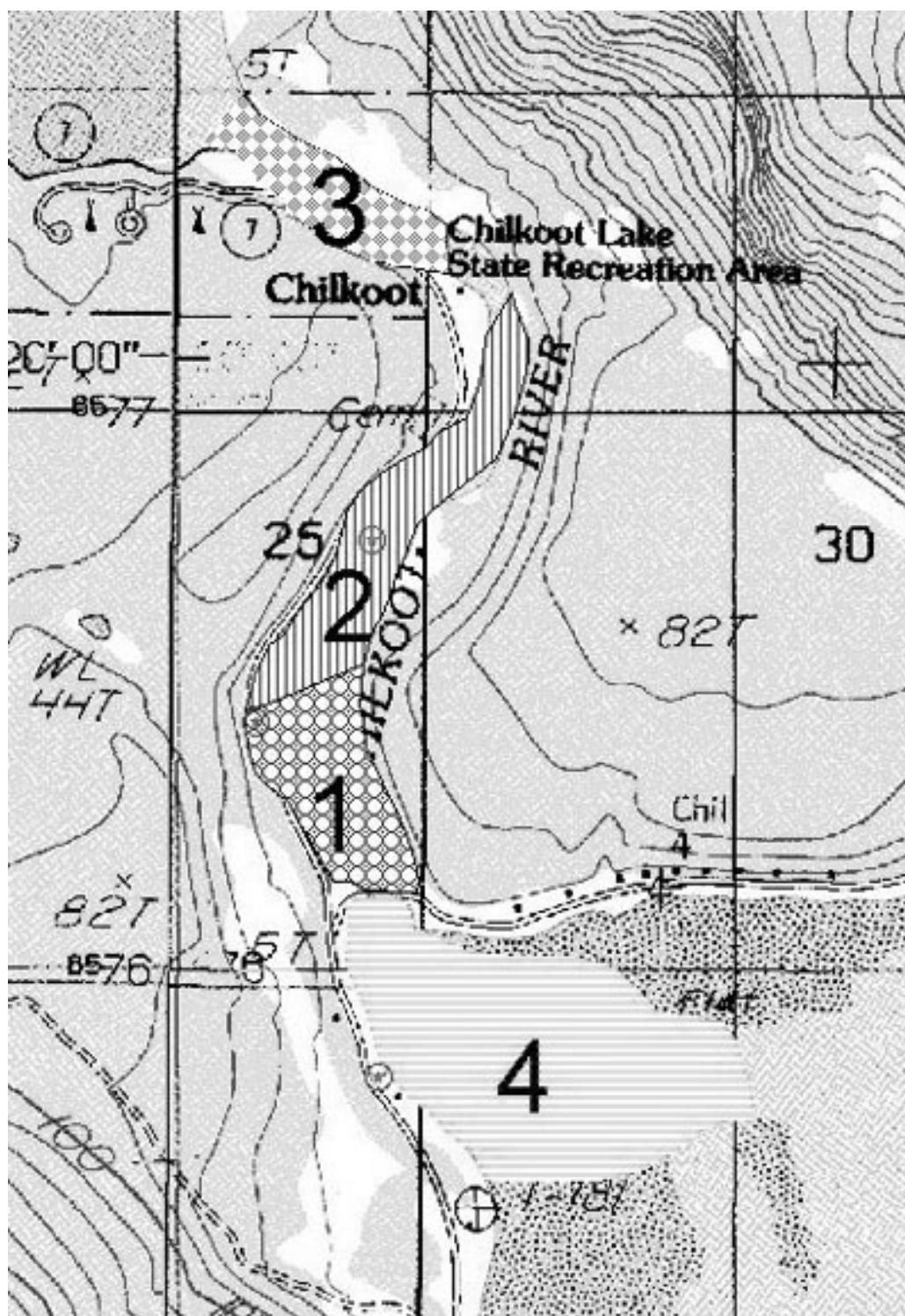


Figure 2-2. Four observation zones along the Chilkoot River.

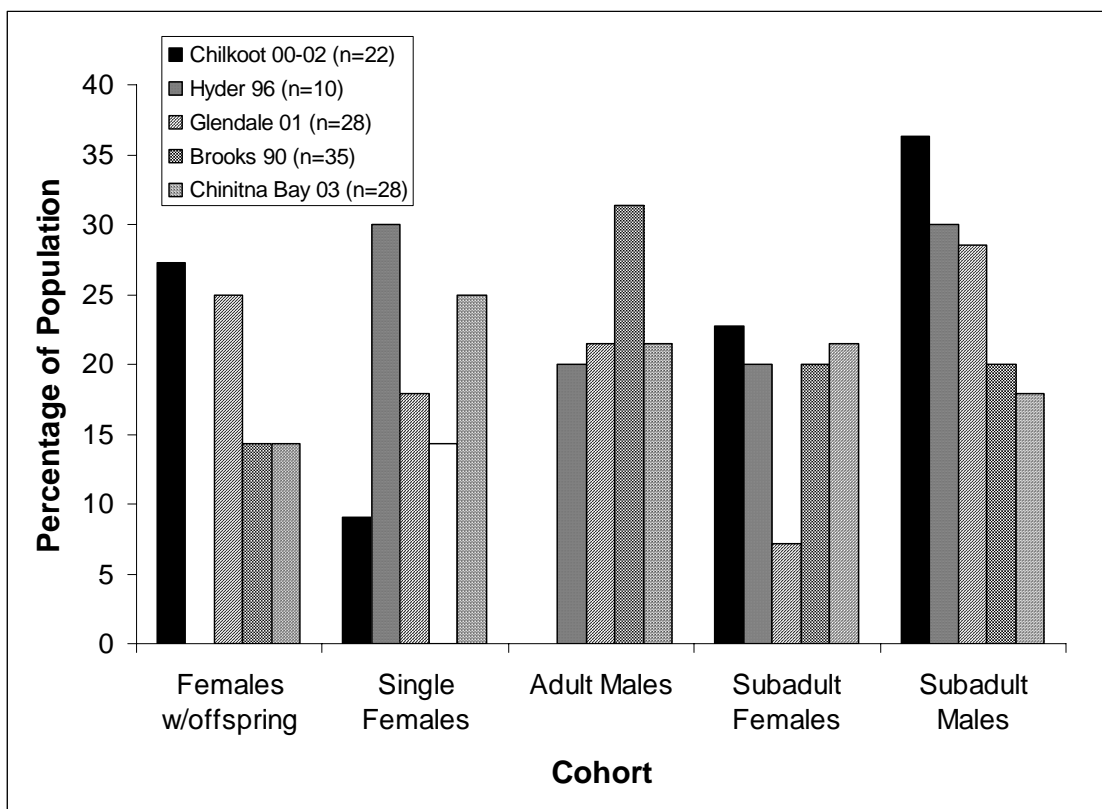


Figure 2-3. Cohort comparison between bear viewing sites.

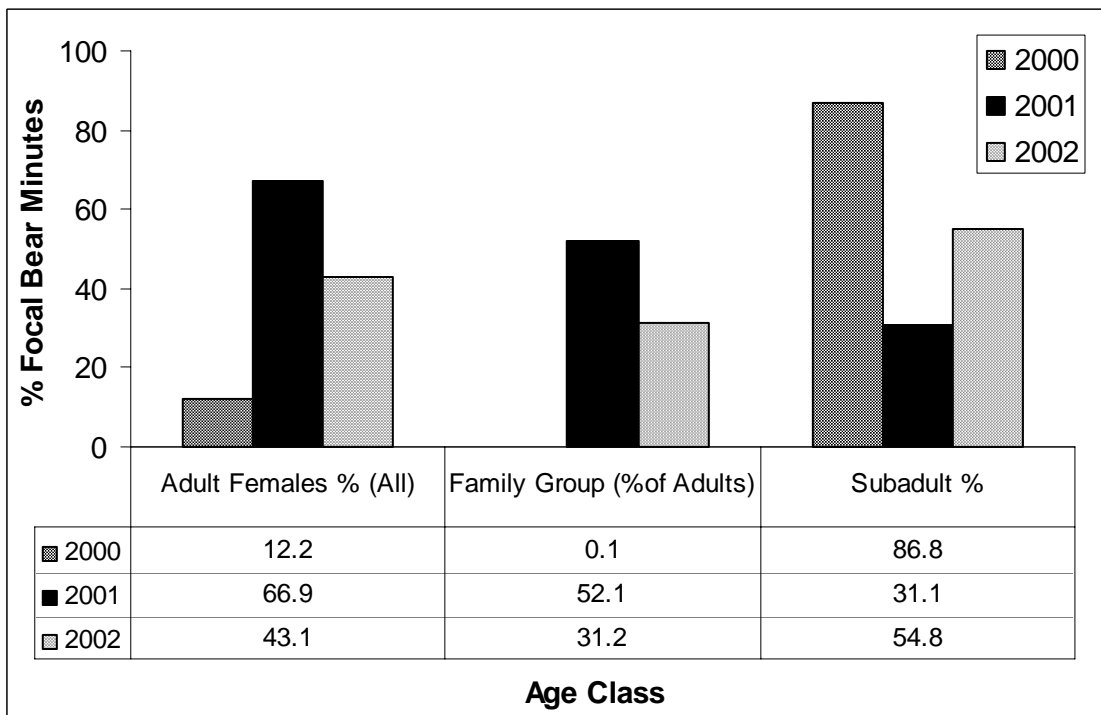
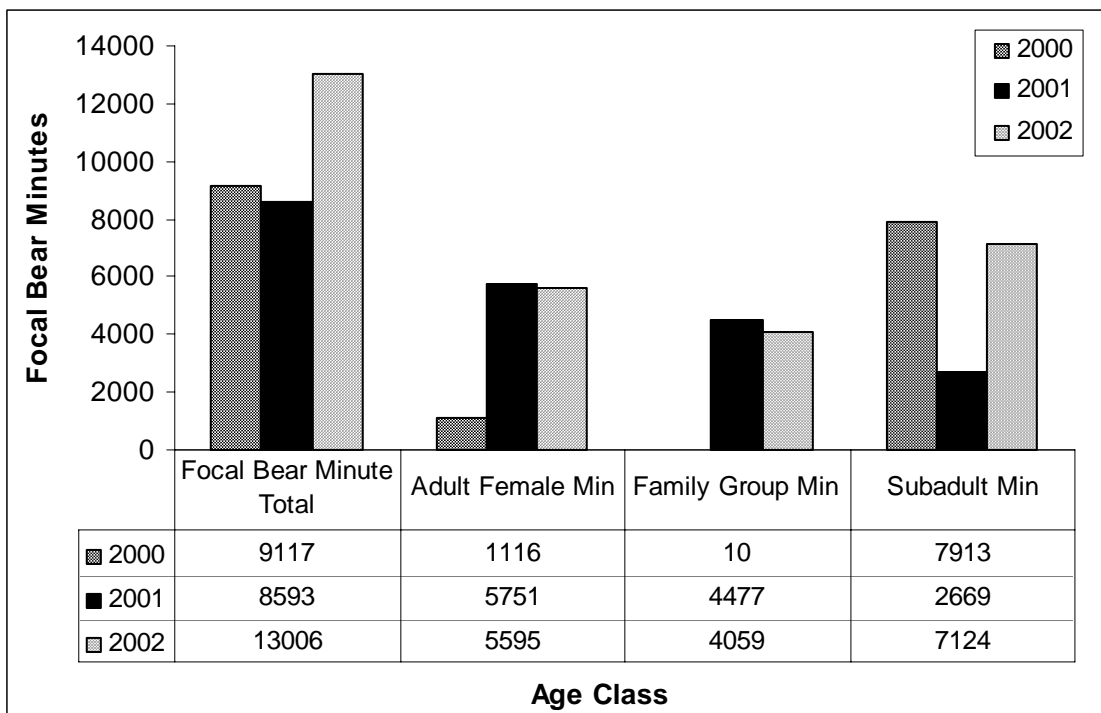


Figure 2-4. Annual comparison of focal bear activity rates by primary cohorts.

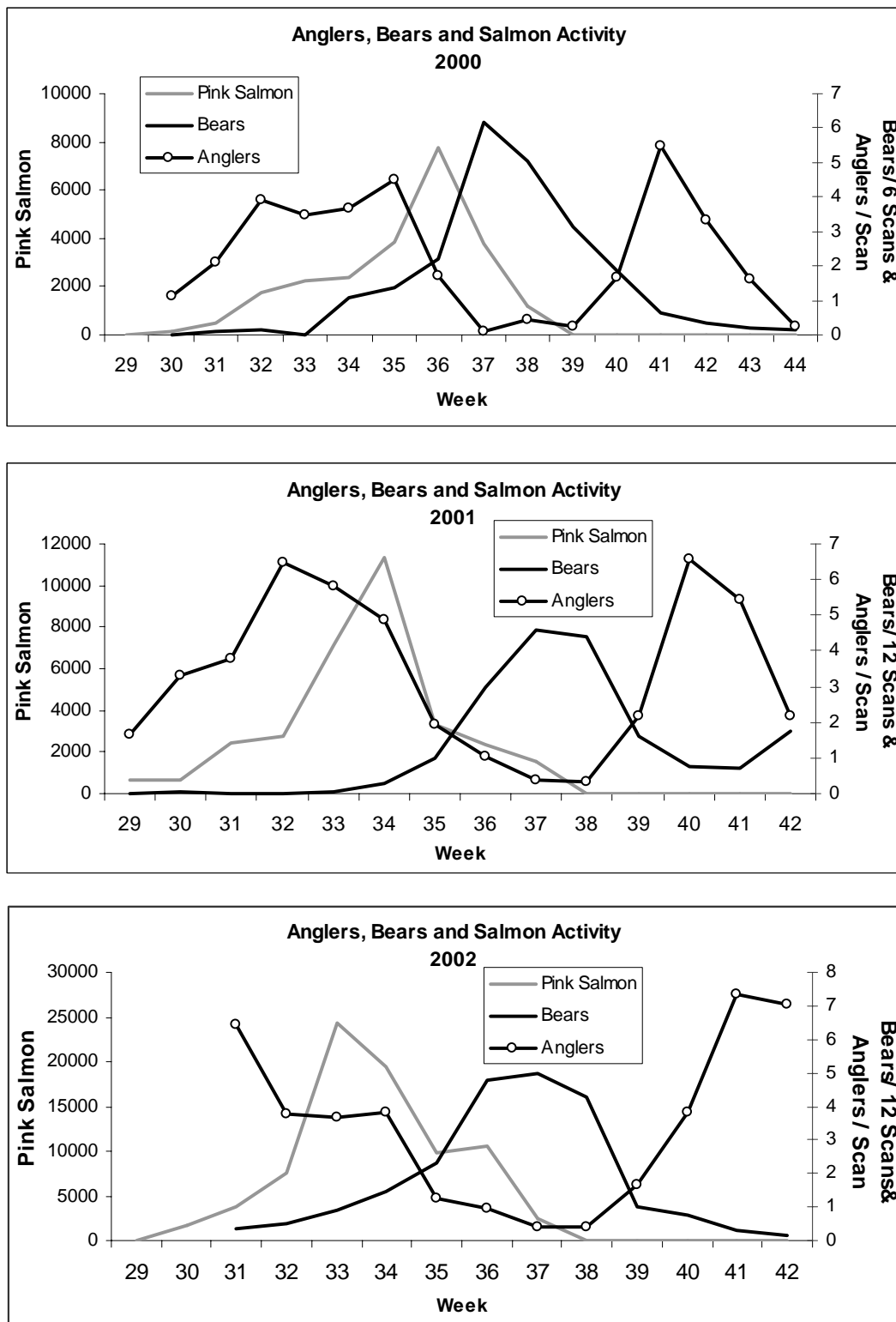


Figure 2-5. Annual trends between anglers, bears, and pink salmon.

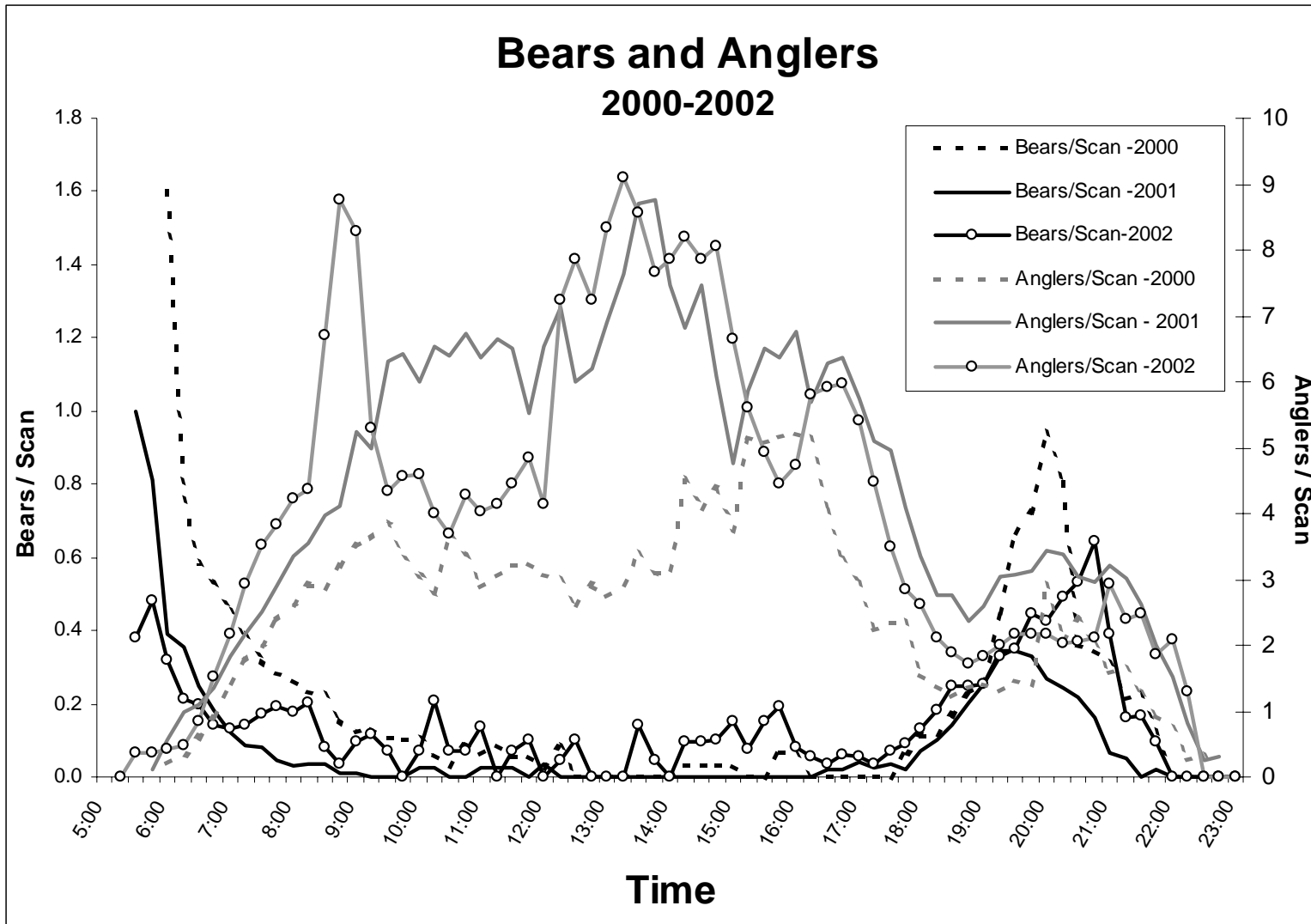


Figure 2-6. Diurnal pattern of bear and angler activity.

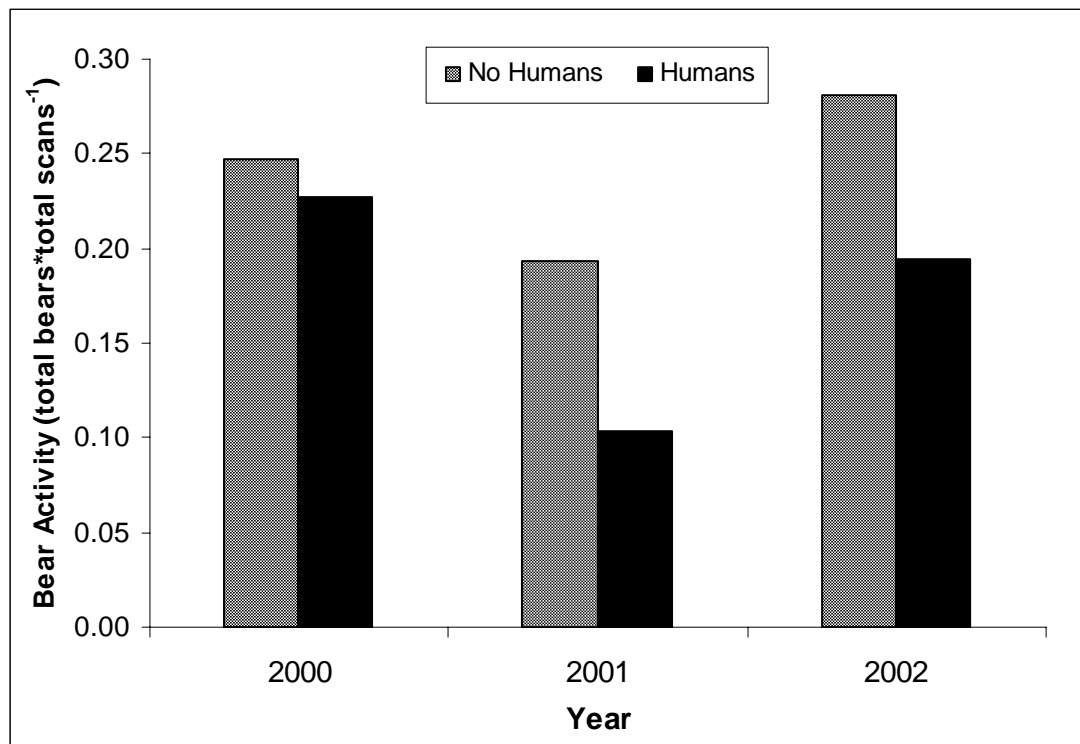


Figure 2-7. Annual bear activity rate when humans present versus absent.

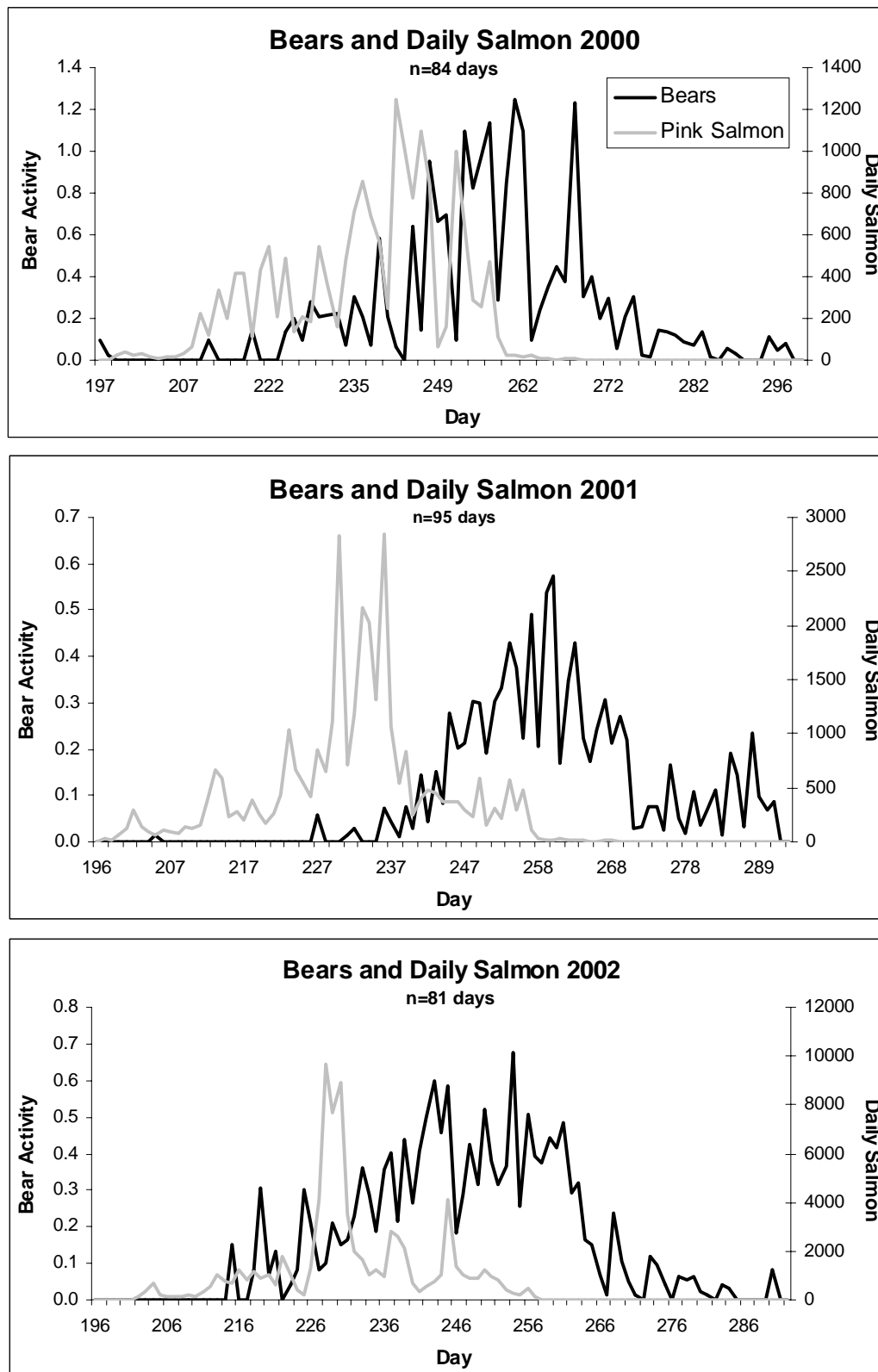


Figure 2-8. Bear activity (total bears*total scans⁻¹) and pink salmon run timing.

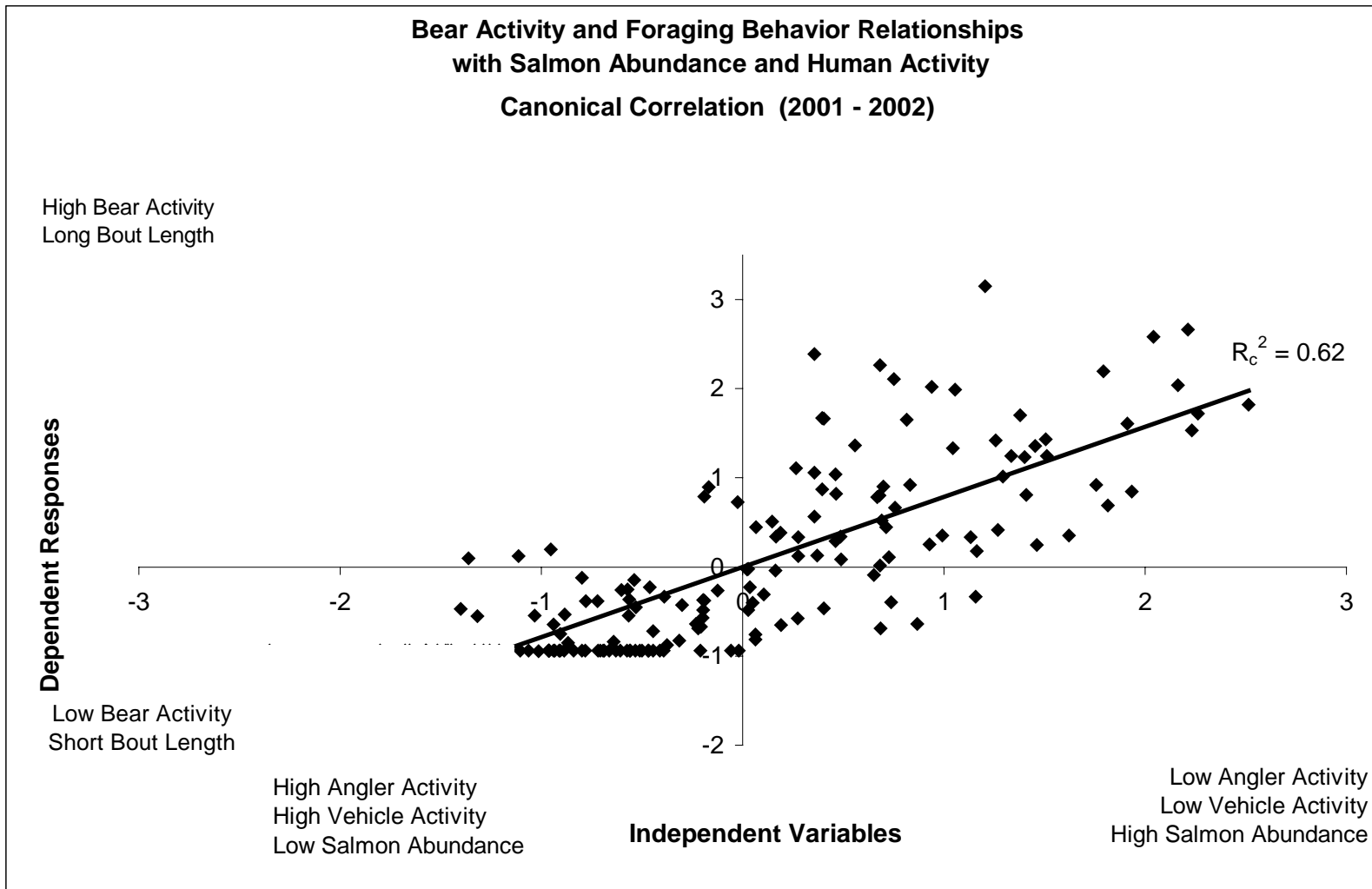


Figure 2-9. Canonical correlation between bear activity, foraging bout length, human activity, and salmon abundance.

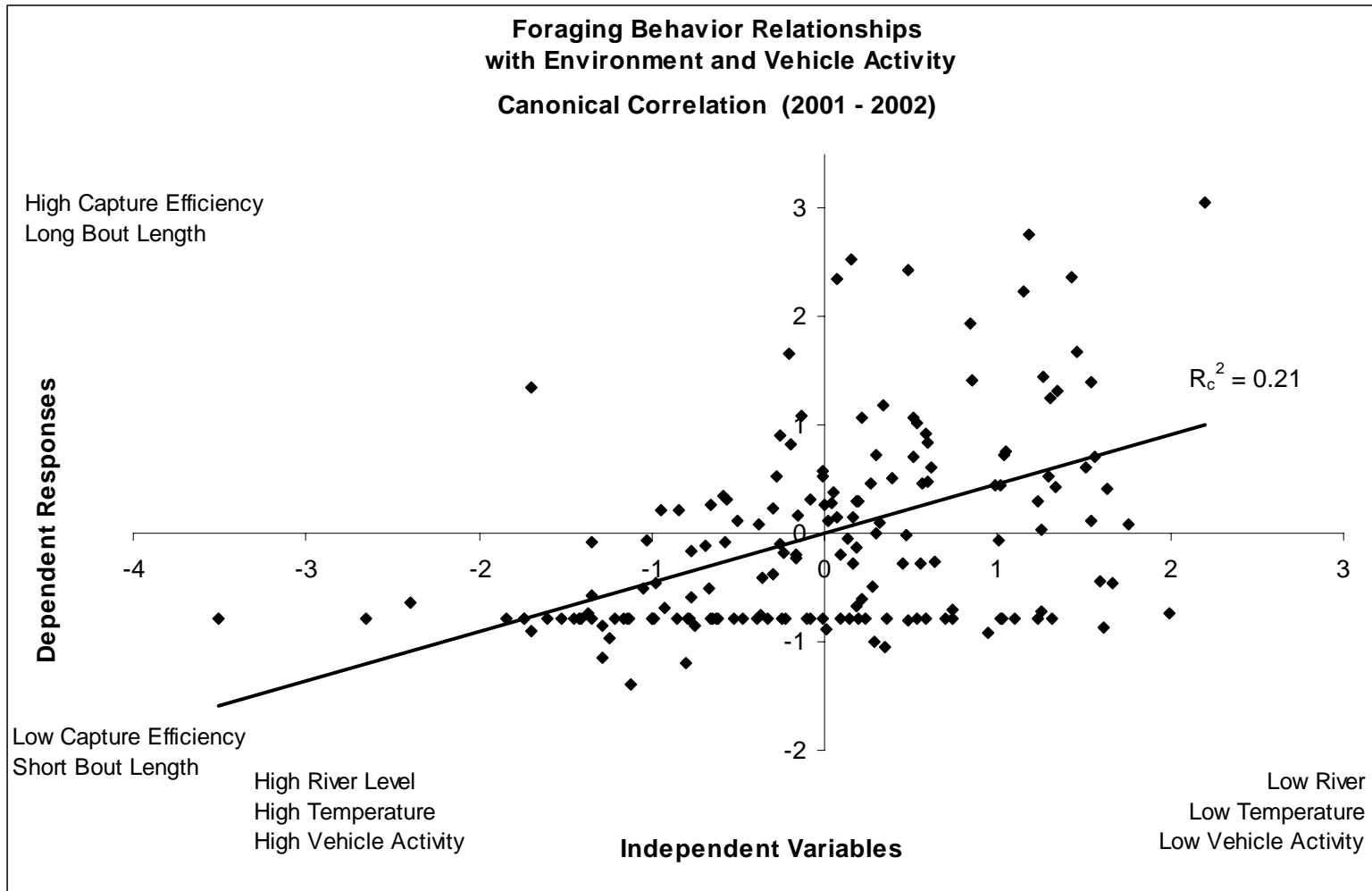


Figure 2-10. Canonical correlation between bears foraging behavior, river depth, and vehicle activity.

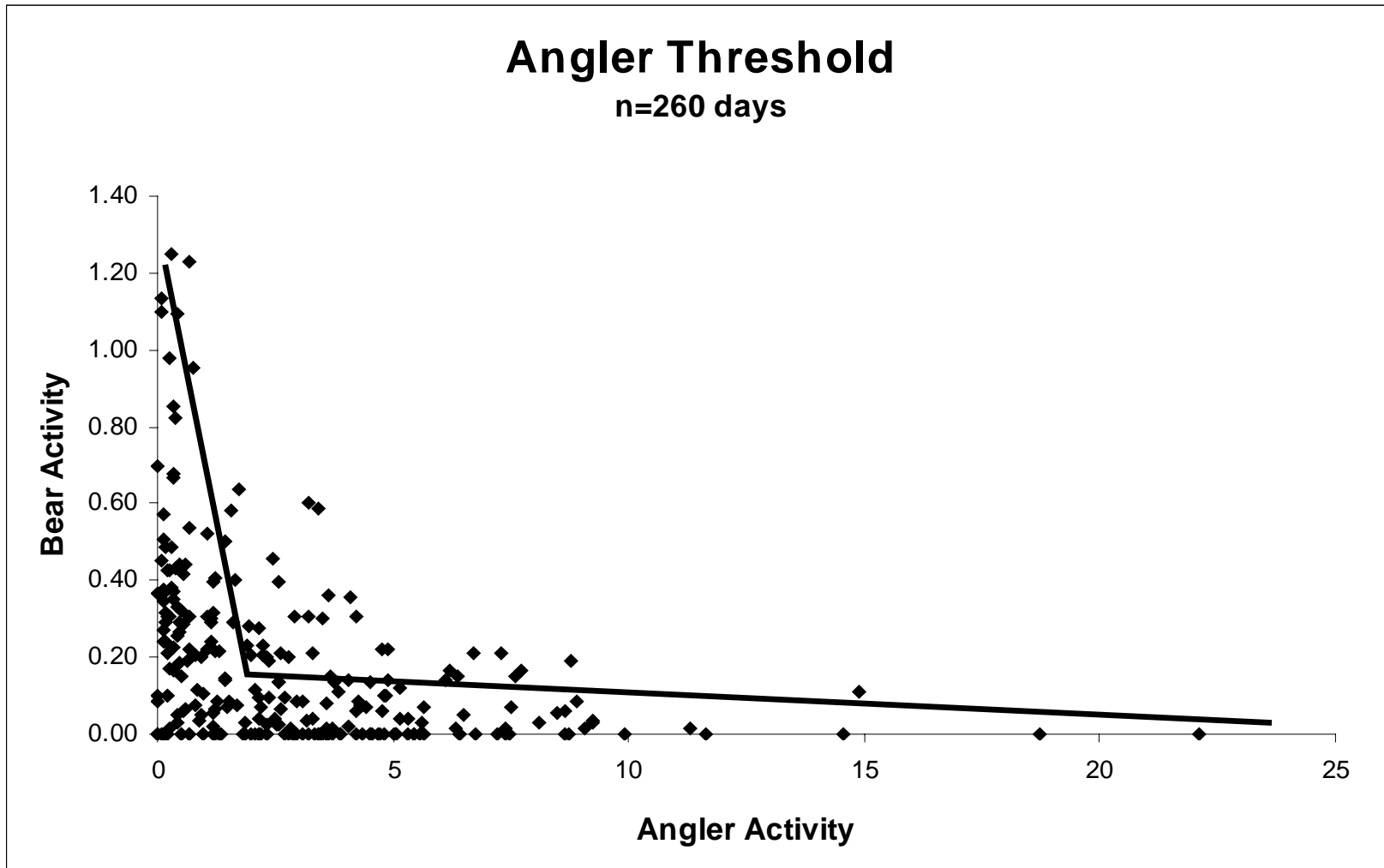


Figure 2-11. Threshold of daily angler activity constraining bear activity.

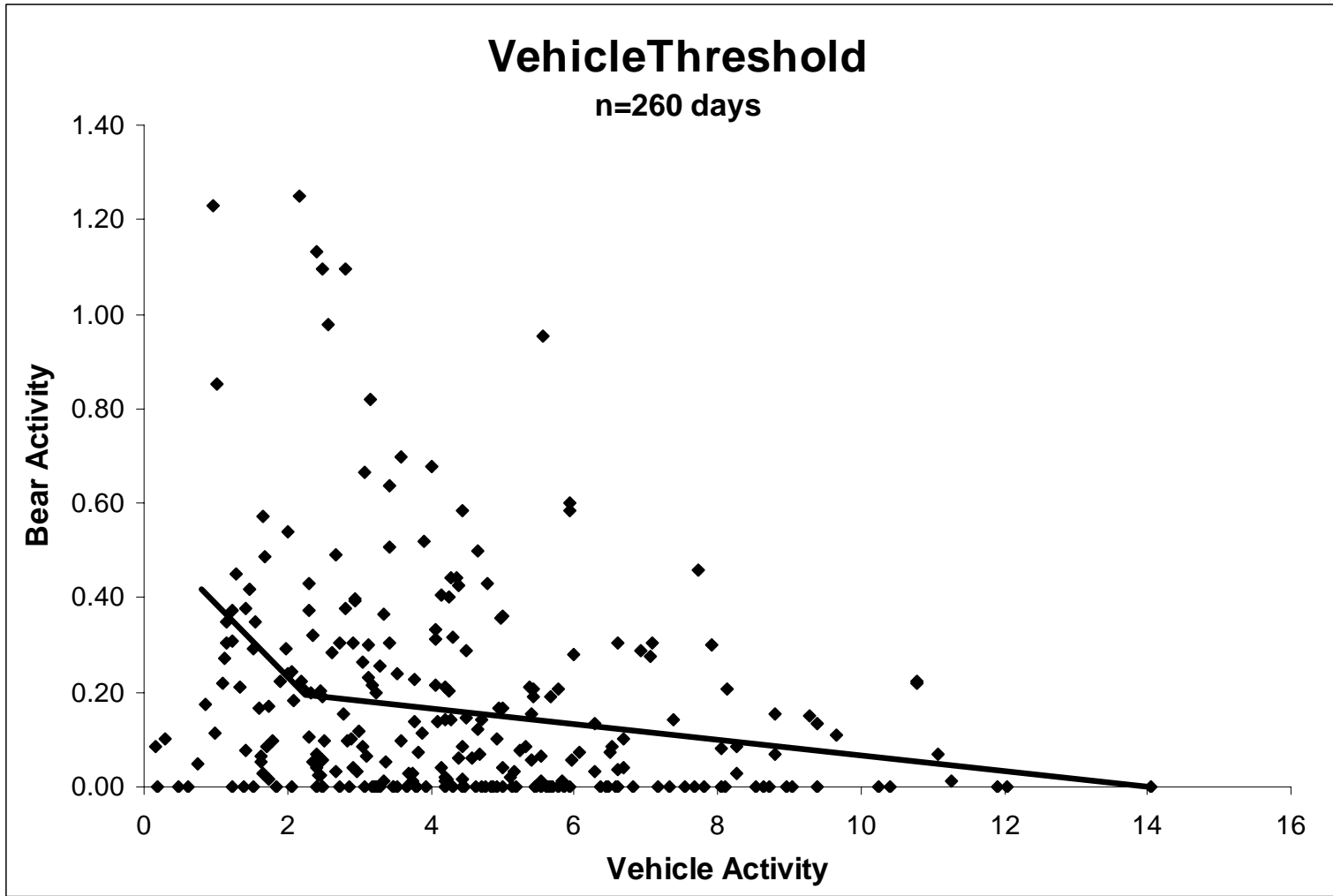


Figure 2-12. Vehicle activity threshold constraining bear activity.

CHAPTER 3
BROWN BEAR HABITAT USE PATTERNS AND
RESPONSES TO DISTURBANCE²

ABSTRACT: Tourism has doubled in Alaska over the past decade. The Chilkoot River, near Haines, experienced rapid expansion of fishing and bear viewing over this period. We investigated the ecological and behavioral interactions between humans, brown bears, and salmon from 2000 to 2002. From mid-July to mid-October we identified brown bear temporal and spatial habitat use patterns, evaluated their responses to natural and human disturbances, and examined flight response distances. Adult female brown bears used non-roaded riparian habitat disproportionately with 73% of their activity there. We classified disturbance stimuli causing over 1000 bear departures from open riparian and estuarine habitat. Human disturbances accounted for 46% of bear departures with a mean flight response distance of 97 meters. We identified a significant positive relationship between two independent measures of bear responsiveness to human disturbance, the intolerance index and vehicle displacement response rate. Habitat use, human activity and distances between bears and people varied within and between years permitting more refined analysis of their influence on bear response and foraging behavior. Identifying the dominant influence of human activities on habitat use patterns, displacement response distances and individual bear tolerance for human recreation has strong implications for

² Coauthored by Anthony P. Crupi and Barrie K. Gilbert.

conservation and management. We examine these relationships with the intent of identifying appropriate guidelines for managing newly established and opportunistic viewing programs.

INTRODUCTION

Along with increasing participation in outdoor recreational activities has come a greater concern for its effects on wildlife (Flather and Cordell 1995, Knight and Cole 1995). While non-consumptive recreation, such as wildlife viewing, was once assumed to have negligible impacts to wildlife, a growing body of literature suggests otherwise (Wilkes 1977, Steidl and Anthony 1996, Geist 1978, Olson et al. 1997, Cassini 2001, Mann et al. 2002, Williams et al. 2002, Bolduc and Guillemette 2003, Swarthout and Steidl 2003, Taylor and Knight 2003). As these activities are projected to increase 63-142% in the next 50 years (Flather and Cordell 1995), the impetus for wildlife managers to understand the associated impacts and appropriately manage them, hinges upon implementation of mitigating strategies.

Human disturbance of wildlife has been defined as a deviation in an animal's behavior from patterns occurring without human influence (Frid and Dill 2002). Observational studies are most effective in evaluating the immediate, direct effects of recreation on wildlife, such as changes in animal behavior, exclusion from specific habitats, implications for physiological responses to disturbance and alterations in energetic balances. For instance, behavioral responses to disturbance can result in changes in habitat selection, increased vigilance, modified energy intake, decreased parental investment and energy expended during displacement events (Lima and Dill

1990, Frid and Dill 2002). When human activity impinges on primary feeding habitats, the potential for negative impacts to resources also increases (Mattson et al. 1987, Knight and Cole 1995).

Brown bear (*Ursus arctos*) habitat use and habitat selection are influenced by a suite of dynamic factors, such as seasonal food availability, competition for limited resources, habitat security, risk of predation and human disturbance (Darling 1987, Mattson 1990, Olson et al. 1997, Hall et al. 1999, McLellan and Hovey 2001, McLoughlin et al. 2002). To adequately manage bear populations at popular recreation areas, it is important to patterns of habitat use in relation to human activity.

Wildlife responses to human disturbance have been suggested to be context and/or individual specific (Bratten and Gilbert 1987, Knight and Temple 1995, Whittaker and Knight 1998). It has been suggested that habituation, or the waning of a response to a neutral stimulus (Thorpe 1956), may limit individual reaction to disturbance stimuli (Ward and Low 1997). Frid and Dill's (2002) risk-disturbance hypothesis predicts that when perceived risks are low, an animal's response to disturbance stimuli is decreased, yet the animal is still expected to maximize fitness by overestimating rather than underestimating risk. At several regulated viewing sites in Alaska many brown bears habituate to human presence while others remain intolerant of human activity (Warner 1987, Aumiller and Matt 1994, Olson et al. 1997, Chi and Gilbert 1999). McArthur Jope (1983) and Mattson (1990) proposed that habituated bears gain greater access to resources by foraging in areas near human activity because of reduced intra-specific competition. Therefore, individual variation in bear tolerance

for human activity needs to be systematically studied to best understand bear responses to human disturbance. We investigated immediate responses and flight distance, the minimum distance at which escape behavior is initiated (Hediger 1955, Altmann 1958, Papouchis et al. 2001), to study bear tolerance for human disturbance.

Habitat utilization and human disturbance responses have typically been studied using aerial telemetry data (Archibald et al. 1987, McLellan and Shackleton 1989, Kasworm and Manley 1990, Mace et al. 1996, Wielgus et al. 2002). However, this coarse approach does not incorporate physical observation of the disturbance event and involves substantial distance errors (Mattson et al. 1987, Wielgus et al. 2002). This study employed direct observation of immediate responses and assessment of minimum distances with GPS technology.

We evaluated bear displacement responses to several natural and human induced stimuli. The objectives were to: (1) identify habitat use patterns (2) examine the disturbance stimuli influencing bear responses (3) evaluate flight response distances in relation to disturbance, and (4) assess the relationship between individual tolerance for human proximity and frequency of human displacement. In particular, we asked if there is a threshold distance that minimizes human impact on bears and, does human tolerance play a role in disturbance responses? Results should assist managers in planning for facilities development, setting limits for visitation and establishing viewing protocols that ameliorate bear-human conflicts.

METHODS

Our study was conducted each year mid mid-July to late October between 2000 and 2002 along the Chilkoot River. The study site is located 12 km northwest of Haines, Alaska (see Chapter 2). Methods were improved to detail more accurate response distances in the 2001 and 2002 field seasons, hence flight distances and individual intolerance levels are only analyzed for these years.

Sampling Procedures

Systematic observations were scheduled daily throughout daylight hours on the Chilkoot River using methods similar to previous studies (Olson 1993, Chi and Gilbert 1999). Three hour observation sessions were randomly distributed throughout seven day sample blocks and stratified within six time sessions between 0530 hours and 2300 hours, as light permitted (Crupi and Gilbert 2003). The river was divided into four sampling zones of approximately equal area (see Figure 2-2). We established optimally vantage sampling locations in each zone, including an elevated tree blind, to minimize observer impacts and maximize sightability.

Sampling procedures included focal animal and scan sampling techniques (Altmann 1974, Olson 1993, Lehner 1998). We used focal animal samples to document the behavior of independent bears: record arrival and departure times, determine age-gender classification, calculate activity budgets, identify distances between people and bears, and assess behavioral responses to disturbance stimuli (Appendix). Distance between bears and humans were determined and responses that resulted in bear departure or displacement were classified according to the apparent

stimuli: 1) own accord, 2) other bear, 3) unknown, 4) vehicle passing, 5) human presence. Observers censused human activity and bear presence at fifteen-minute interval scans throughout the observation session. Each vehicle and human was counted and classified according to activity and behavior. This information provided us with important demographic characteristics of human activity patterns to be evaluated in relation to bear activity.

Distances between bears and people were determined using a Geographic Information System (GIS), with the Arcview 3.2 distance measurement tool. We geo-referenced 1:24,000 digital raster graphics (DRG) from Alaska-Skagway quadrants with differentially corrected shape files projected with WGS 1984. We integrated data from the GIS with our Access database, which proved to be fundamental to data analyses.

Brown Bear Identification

We identified individual bears according to natural markings, morphological characteristics, pelage patterns, scars, and behavioral traits, similar to previous studies (Olson 1993, Chi and Gilbert 1999). As in previous studies, family groups were counted as one bear, as cub activity is not independent of its parent. To maintain accurate identifications, researchers utilized binoculars, spotting scopes and/or digital video recorders (Sony Inc.: TRV-120, 400x digital zoom with O Lux, infrared Super NightShot®) to document and record information on bear identity, access routes, foraging behavior, and responses to human activities. Video records facilitated reliable discrimination between bears and their behavior, and improved inter-observer

reliability within and between observers and years. Experienced researchers trained new observers during the first several weeks of the study period in the field and with video sequences collected on site depicting specific individuals, behaviors and interactions. Identifying characteristics of individual bears were reviewed with all observers on a routine basis. After each observation session, videotapes were reviewed and when necessary images were transferred to computer for additional magnification and scrutiny of gender and identification. The Super Night Shot feature allowed us to identify individuals and collect data in low light conditions, as long as 90 minutes after sunset. Video recordings and assiduous daily observation maintained accurate identification throughout pelage and body mass transformations.

Habitat Use

We evaluated brown bear use of habitat for all three years of the study using the total focal bear minutes collected in each habitat type. Throughout each zone bear habitat use was classified according to four defined habitat types; riparian and estuarine habitats which were either roaded or non-roaded. Roaded and non-roaded riparian habitat each accounted for approximately 37% of the available exposed habitat. Non-roaded and roaded estuarine habitat comprised 15% and 10% of available habitat respectively (Table 3-1). There are numerous bear trails, access routes, and foraging sites within each habitat type with nearly equal opportunities for bears to capture salmon. In the expansive estuary and tidal flats, 500 meters was the furthest distance that bears were considered focal individuals for accurate data collection. Most focal bear activity was observed within 300 meters of observation

stations. Our measure of foraging behavior was foraging bout length, the mean length of foraging bouts viewed entirely.

Stimuli Eliciting Bear Departure

To assess immediate responses to human activities, each bear departure and displacement from the river corridor was assessed and classified according to stimulus. Bear exits not preceded by an apparent behavioral reaction (ie. looking, standing, intent sniffing), in the direction of the stimulus were considered departures by own accord. We may have overestimated departures as “own accord,” for if the bear responded with no overt behavioral reaction, it was impossible for the researcher to ascertain the stimulus and the bear was coded as departing on own initiative.

Displacements classified in response to human stimuli, such as vehicles passing or human presence, were preceded by an overt olfactory or visual sensory response to the appropriate stimulus. Human presence stimuli which elicited displacement responses included people directly approaching bears, people amplifying bears with high-powered lights (“spotlighting”), and strident noises such as vehicle doors, loud voices, unmuffled vehicles, and barking dogs. Responses of this type emanated from various human activities ranging from anglers fishing on the riverbank to busses full of guided cruiseship passengers observing wildlife.

Bears occasionally interacted with other bears and at times these interactions resulted in the displacement of one or both bears and were classified as such. Occasionally we observed departures that signified a response to an apparent stimulus that was undetermined by the observer. These were classified as unknown.

Bears were frequently displaced laterally; for instance when they continued from one sampling zone into the adjacent zone or increased their distance from people. These were not analyzed as displacements, despite the fact that they may have been responding to a stimulus such as a close human approach. This analysis only considered departures that involved a retreat to forest cover, thereby ending a foraging bout (arguably the most costly displacement). Also, when bears remained in the zone after the end of the observation session they were classified as “present at end of session.”

Intolerance Index

To more accurately assess the tolerance of individual bears for people, we investigated an alternative to binary habituation classification. This index is intended to represent the continuum of behavioral plasticity (Gilbert 1989) of bear tolerance for human proximity at this site. The Intolerance Index of each bear is the product of the distance (meters) between the subject and people, multiplied by the amount of time (minutes) the individual spends in that proximity. This product divided by the subjects' total focal bear minutes provides an index of the individual's intolerance level. To prevent multiplying time (minutes) when humans were absent by a distance of zero we substituted a distance one meter further than human proximity (meters) was recorded, or 501 meters. Bears exhibiting intolerance scores with greater magnitude were considered more intolerant (wary) while individuals spending more time in close proximity to people earned lower scores.

Statistical Analyses

We tested the data for deviations from normality by assessing the dataset through box plots, histograms, normal probability and residual plots as well as with Kolmogorov-Smirnov tests of normality. We used chi square tests of homogeneity to evaluate differences between habitat uses. We used linear regression models to evaluate the relationships and variances explained by the intolerance index (Zar 1999). Given the small size of the population and our assessment of the behavioral changes of identified individuals, we considered each foraging bout an independent event. We found this approach to be more appropriate than using the individual animal as the unit of replication. As well, it was assumed that the probability of detecting an individual bear was random and that each bear had equal chance of responding. Statistical package, SAS Institute 8.0, was used for all data analyses with statistical significance selected at $\alpha < 0.05$.

RESULTS

Brown Bear Habitat Use

Non-roaded riparian habitat had significantly higher use than other habitat types garnering over 50% of total bear use ($\chi^2 = 4701$, $P < 0.0001$) (Table 3-1). Adult bear use of this habitat type (73%) was significantly higher than expected in all years ($\chi^2 = 1295$, $P < 0.0001$) (Figure 3-1). In 2000 and 2002 subadults were less selective than adults in their use of habitat ($\chi^2 = 7201$, $P = 0.66$). However, subadult bear habitat use in 2001 did not follow this, as they spent 76% of their time in non-roaded

riparian habitat (Figure 3-2). In both riparian and estuary habitat types, bears preferentially selected for non-roaded habitat (66%) ($\chi^2 = 18.77$, $P < 0.0001$).

Use of estuarine habitat was similar to that expected with the majority of activity occurring before late September. In 2000, subadult bears selected estuary habitat, as nearly 3,200 focal bear minutes, or 45%, of all estuary habitat use occurred at this time. Adult bears used the estuary substantially less than subadult bears in all years. The majority of foraging activity in estuarine habitat involved scavenging for salmon carcasses, roots and graminoids (i.e. *Carex spp.*).

Bear Activity in Relation to Distance from Humans

We analyzed bear activity occurring when humans were absent, at distances greater than 100 meters, and at less than 100 meters from human activity. Bears used habitat according to human presence and their distance from people (Figure 3-3). The majority of bear activity (71%) occurred when humans were absent or when distances from people were greater than 100 meters ($\chi^2 = 3646$, $P < 0.0001$), contributing a majority of focal bear minutes in 2001 (79%) and 2002 (65%). Humans were present within 100 meters of bears in 21% of focal bear activity in 2001 and 35% in 2002. Subadult bears typically occupied this space although a dominant adult female with three offspring did in 2001. Given the wide temporal and spatial human use of the site, bears were rarely (<3%) able to obtain distances greater than 300 meters from human activity. Overall, bear activity was 40% greater when people were absent than

when humans were present. This trend existed in all years: 2000 (9%), 2001 (87%), and 2002 (44%) (Figure 3-4).

Factors Influencing Bear Displacement

We classified 1028 brown bear departures and displacements from the river corridor according to response stimulus. This included 352 displacement responses in 2000, 276 in 2001, and 400 in 2002. Displacement because of human activities, including both vehicles (137) and human presence (335), represented 46% (472) of all displacements and departures. Bears left the river corridor on their own accord on 337 (33%) occasions and due to other bears on 93 (9%) instances. The stimulus for 126 (12%) exits was undetermined.

Overall, human disturbance (118) was pronounced between 0600-0700 hours with vehicle disturbance and human presence responsible for the majority of displacements. Prior to 0800 hours, we observed 192 (46%) bear displacements caused by vehicle traffic. During 1900-2000 hours, human presence (n=66) was responsible for most displacements. Between 2000-2100 hours bears displaced other bear 24 times. The greatest number (n=89) of unprovoked departures (own accord) occurred between 0600-0700 hours (Figure 3-5).

Flight Distances in Response to Disturbance

We assessed the distance between bears and people when bears departed from the river corridor for 508 known stimulus-response events in 2001 and 2002. The mean flight distance between bears and people according to disturbance stimulus were

as follows: 1) own accord ($n = 183$) $\bar{x} = 117 \pm 83$ m, 2) other bear ($n=51$) $\bar{x} = 147 \pm 91$ m, 3) unknown ($n = 33$) $\bar{x} = 138 \pm 49$ m, 4) vehicle passing ($n = 75$) $\bar{x} = 127 \pm 67$ m, 5) human presence ($n = 166$) $\bar{x} = 85 \pm 64$ m (Figure 3-6). The combination of human-elicited response stimuli ($n=241$) yields a flight distance of $\bar{x} = 97 \pm 67$ m.

Relationship of Foraging Bout Length to Disturbance

The longest foraging bouts were associated with bears departing the river on their own accord, $\bar{x} = 21.4$ min. The shortest mean foraging bout lengths were associated with human presence, $\bar{x} = 12.3$ (Figure 3-7).

Individual Displacement

Among individual bears, the proportion of human caused displacements ranged between 20 and 50%. Five bears were present in both years and their behavioral response to human disturbance was similar between years ($\rho = 0.47$) (Figure 3-8).

Relationship Between Disturbance and Human Intolerance

We calculated an index of bear tolerance for human proximity for nine consistently observed individual bears in 2001 and 2002. Of the 5 individuals present in both years our index depicted a consistent behavioral pattern ($\rho=0.84$). Average subadult bear intolerance ($\bar{x} = 226 \pm 92$) for human proximity was lower than adult intolerance ($\bar{x} = 281 \pm 102$).

Mean foraging bout length was negatively correlated with individual wariness ($F = 33.84$, $P = 0.000$, $r^2 = 0.68$) (Figure 3-9). All bears with intolerance levels

exceeding 400, signifying pronounced wariness, engaged in shorter foraging bouts ranging from 7 to 15 minutes. It is reasonable to expect that these intolerant individuals would spend shorter amounts of time foraging but compensate by increasing the number of bouts. However, a negative relationship between the number of total foraging bouts and brown bear intolerance for human proximity was also apparent in both years ($F = 3.45$, $P = 0.082$, $r^2 = 0.18$). Similarly, the total amount of time that each bear was observed along the river, foraging or otherwise, was clearly a function of its behavioral relationship with people ($F = 8.80$, $P = 0.009$, $r^2 = 0.36$).

There was a clear relationship between individual bear intolerance for human proximity and the rate of displacements due to vehicles ($F = 64.20$, $P = 0.000$, $r^2 = 0.80$) (Figure 3-10). We also compared the relationship between tolerance and the rate of displacement due to human activity. While a positive relationship also exists between human intolerance and human displacement, its predictive value is not as clearly defined ($F = 3.34$, $P = 0.086$, $r^2 = 0.17$).

DISCUSSION

Our study clearly demonstrated that brown bears utilized habitat further from human activity. Certain bears did occupy areas nearest to human activity to access salmon and avoid other bears, though many of these individuals were subadults who were more likely to be tolerant of human proximity. Subadult avoidance of adult females was obvious in 2001, when habitat use switched in response the dominant adult female's increased use of the roaded riparian habitat. While a few of these more tolerant subadult bears gained access to unstored human food, the behavioral

development of tolerance for human proximity was not dependent upon their obtaining human food. Several bears with high tolerance for human activity were not observed gaining any human food rewards.

Human presence as a disturbance stimulus was associated with the shortest flight distance, suggesting that bears responded to people once they exceed a threshold distance. Greater distances were recorded when vehicles caused the disturbance. This could be explained by less tolerant individuals responding at greater distances to the first sign of human activity in the morning. Previous studies found flight response distances to be influenced by age, gender, body temperature, size (Johnson 1970), seasonal changes in reproductive and nutritional status, habitat type and previous knowledge or experience (Altmann 1958, Steidl and Anthony 1998). Blumstein et al. (2003) suggested that flight distances were species-specific and that once the response distance is determined for that species, it may be applied as a management guideline in other regions. While this possibility may exist for brown bears, we encourage caution. Response distances in this study apply specifically to this site and several factors need to be considered. First, individual tolerance of human activity varies within and between sites. How an individual at this site learns to tolerate people may not be applicable at another location. Secondly, the presence of and distance to secure cover may be extremely important when considering response distance (Taylor and Knight 2003). We found that response distances in estuary habitat, which was further from cover and more exposed, were greater than those in riparian habitat.

Both Thomas et al. (2003) and Swarthout and Steidl (2003) recently evaluated flight response distances in birds by experimentally approaching birds and nest sites, often at close distances, to elicit displacement responses. While an experimental approach would improve this study, it would be nearly impossible to manipulate and reproduce the current level of disturbance, not to mention the imprudence of approaching wild carnivores. Furthermore, encouraging more disruption to brown bears limited feeding regime would likely negatively impact foraging behavior. Therefore, we utilized the trends and patterns collected over two years and evaluated the responses of individual bears to human activity and vehicle traffic and found this approach provided similar results for determining minimum flight distance.

Previous bear research has documented significant reductions in bears' use of habitat within 100 meters of roads containing traffic as light as 1.3 vehicles per hour, and bears tend to use habitat near roads more frequently at night (McLellan and Shackleton 1989, Kasworm and Manley 1990). In Denali National Park, Singer and Beattie (1986) assessed the effects of increasing levels of vehicle traffic along the park road. Between 1973-1983, vehicle traffic increased 50%, which corresponded with a 72% decrease in moose sightings and a 32% decrease in bear sightings. Given the 40% rise in Chilkoot vehicle traffic over 3 years and the pronounced level of bear response to human disturbance observations of bears are likely to decline.

Given that disturbance resulted in bear displacement and that conspecifics or humans were likely occupying other suitable habitats, one might hypothesize that displaced bears are resuming foraging elsewhere. It is reasonable to conclude that

disturbance will lead to decreased foraging efficiency by missing opportunities to consume maximum energy from salmon, or be relegated to less profitable foods such as berries. Further, what is the relationship between immediate responses to disturbance and the long-term impacts of perpetual avoidance? Answers to these questions would likely provide a more complete picture of potential reproductive and fitness costs.

Habituation has been defined as a binary categorization based upon a specific definition, such as consistent tolerance of people ≤ 50 m with no noticeable change in behavior (Olson 1993). In particular, researchers have identified a difficulty in assessing habituation of subadult bears, which constituted over 50% of the observed population throughout our study (Bratten and Gilbert 1987, Bratten 1988, Olson 1993). We observed contextual variability in individuals based on location, reproductive status, perceived reward, and intra-specific competition for habitat. Our measure of bear tolerance appears to adequately reflect the spectrum of individual tolerance levels observed during this study. In this study, the risk avoidance hypothesis appears to be supported as human disturbance serves to function as predation risk. This is evident in the frequent human induced displacements of all bears whether tolerant or wary of human recreation. It is interesting to note that the two individuals with human disturbance proportions exceeding 50% in 2001 were not observed again in 2002, a trend similar to 2000 data (Crupi, unpublished data).

We determined the distance between humans and bears only when disturbance resulted in bear departure. However, this conservative approach has limitations and

small number of individuals could bias results. Responses not resulting in escape for cover could include temporary avoidance, directional changes, or lateral displacements related to increasing distance from people without departing. Other studies have documented relationships between the probability of escape and flight distance in relation to the distance from cover, the angle, direction and speed of approach, and the level of the disturbance (Stiedl and Anthony 1996, Burger 1998, Frid 2001, Papouchis et al. 2001). While these may significantly influence flight decision and the distance at which that decision is made, we do not provide detailed relations to these less apparent and difficult to assess responses. Future research should weigh the costs associated with collecting this data to the benefits gained from these relationships.

MANAGEMENT IMPLICATIONS

To ensure the sustainability of current viewing operations and the safety of people and bears, we suggest implementing temporal and spatial restrictions during brief critical foraging periods through an adaptive management approach (Lee 1999, Salafsky et al. 2002). Based on the past trends at the Chilkoot River an improved management scenario would restrict human recreation to times of day and during weeks which minimize the conflict between people and bears. Strategic restrictions in conjunction with a monitoring protocol to evaluate the behavioral response of bears will benefit both conservation of bears and human recreation users. This study provides a scientific foundation for improved understanding of the Chilkoot River's natural resources conflicts. Future generations may continue to use and rely on this

region for subsistence, tourism, recreation, fishing, and wilderness values, if managers implement the necessary steps based on current understanding.

It has been demonstrated that creating situations where bears are allowed secure access to resources, in conjunction with human activity that is consistent and predictable, can minimize bear-human conflict (Wilker and Barnes 1998). An appropriate management goal might be to ensure that the costs at either the individual or population level do not outweigh the economic benefits or the conservation value of bear-viewing. If wildlife managers and recreation planners desire to minimize bear-human conflict while maximizing bear activity, tools for determining appropriate use levels are necessary.

Our study can enhance management in two ways. First, it identifies the mean distance at which bears were displaced by humans. This data may be used to establish a baseline set-back distance in management protocols (Rodgers and Smith 1997). Many bear viewing areas suggest a standard 100-meter set-back, to reduce impact to bears and increase human safety. Our results provide the ecological and behavioral basis and rationale for mitigating negative impacts of human activities on Chilkoot bear activity and foraging behavior. We suggest establishing a minimum approach distance of at least 85 meters, though a 100-meter restriction at this site would prove even more effective, as 55% of human displacements occurred at or within this distance. This would minimize close interactions and allow brown bears to spend less time avoiding human activities, thereby ensuring a safe, sustainable bear viewing program. The effectiveness of this action should be evaluated and assessed through an

experimental adaptive management approach which considers adjustments to this setback distance and alternative management options.

Second, the biological cost of displacing individuals during productive foraging times, especially during weeks when live fish are most abundant and times of day when capture rates are maximized, has important management implications. Providing brown bears with consistent and predictable foraging opportunities during these critical periods would increase their ability to capture and consume live fish. With targeted temporal restrictions during these times, managers could effectively maintain high levels of human use during the daytime and minimize the overall impact of displacement on bears. In particular, minimizing morning vehicular traffic before 0800 hours would likely improve bear access to the river and minimize the costs associated with bear displacement. If protecting bears is a priority, we believe it is imperative to provide greater security in non-roaded riparian habitat, by enforcing a three-month spatial restriction limiting human use and permanently prohibiting structural development in this habitat.

CONCLUSIONS

The majority of brown bear habitat use was concentrated in habitat lacking developed roads (66%). Habitat use by adult females was strongly associated with non-roaded riparian habitat, providing 73% of all activity. Our evidence suggests that adult females partitioned their use of habitat to avoid temporal and spatial overlaps with human activity. In contrast, subadult bears appear to be less selective of habitat and respond more strongly to adult female habitat use than human use. While

subadults are commonly observed occupying similar habitats as adult females, we observed temporal avoidance of adult females. In 2001 we also observed spatial avoidance of adult females, as subadult preference for non-roaded riparian habitat was substantially higher than other years. Their departure from roaded riparian habitat use was correlated with a significant increase in use of this habitat by a dominant adult female.

This study of brown bear response to human disturbance revealed a consistent relationship between bear behavior and human proximity. We found that bears spent the majority of their time on the river when humans were not present or at distances greater than 100 meters from human activity. Bear activity was 40% higher when people were absent than when they were present.

We also documented frequent brown bear displacement in response to human activity, vehicles passing and human presence. Overall, human disturbance accounted for 46% of bear departures with a mean flight response distance of 97 meters. Foraging bout lengths were nearly two times as long when bears departed on their own accord compared to displacements resulting from human presence. This type of human disturbance commonly resulted from people directly approaching bears, producing loud noises, entering the river to fish in close proximity to bears, and “spotlighting” after dark.

We identified a strong relationship between two independent measures of bear responsiveness to human disturbance, the intolerance index and vehicle displacement response rate. Bears spending more time when people were absent and at greater

distances from human activity exhibited more frequent displacement responses due to vehicle activity. We also found a significant positive relationship between tolerant individuals and foraging bout length. This suggests a nutritional advantage for individuals adapting to human activity. Implementation of strategic temporal and spatial restrictions on human activity can be expected to improve brown bear access to salmon and mitigate the effects of bear response to human disturbance.

LITERATURE CITED

- Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour* 49:227-267.
- Altmann, M. 1958. The flight distance in free-ranging big game. *Journal of Wildlife Management* 22(2):207-209.
- Archibald, W.R., R. Ellis, and A.N. Hamilton. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River valley, British Columbia. *International Conference on Bear Research and Management* 7:251-257.
- Aumiller, L. D., and C.A. Matt. 1994. Management of McNeil River State Game Sanctuary for viewing of brown bears. *International Conference on Bear Research and Management* 9(1):51-61.
- Blumstein, D.T., L.A. Anthony, R. Harcourt, and G. Ross. 2003. Testing a key assumption of wildlife buffer zones: is flight initiation distance a species-specific trait? *Biological Conservation* 110(1):97-100.
- Bolduc, F., and M. Guillemette. 2003. Human disturbance and nesting success of common eiders: interactions between visitors and gulls. *Biological Conservation* 110:77-83.
- Bratten, A.M. 1988. Adaptation of brown bears to people on an Alaskan salmon stream: A quantitative study. M.S. Thesis, Utah State University, Logan. 93 pp.
- Bratten, A.M., and B.K. Gilbert. 1987. Profile analysis of human-bear relationships in Katmai National Park and Preserve. Final Rep. Nat. Park Serv. Contract No. CX-9700-4-0019. Utah State University, Logan. 104 pp.

- Burger, J. 1998. Effects of motorboats and personal watercraft on flight behavior over a colony of common terns. *Condor* 100:528-534.
- Cassini, M.H. 2001. Behavioural responses of South American fur seals to approach by tourists-a brief report. *Applied Animal Behaviour Science* 71:341-346.
- Chi, D.K., and B.K. Gilbert. 1999. Habitat security for Alaskan brown bears at key foraging sites: are there thresholds for human disturbance? *Ursus* 11:225-238.
- Crupi, A.P., and B.K. Gilbert. 2003. Bear and human use patterns of the Chilkoot River in Haines, Alaska, 2000-2001. ADF&G, Division of Wildlife Conservation, Technical Progress Report, Contract No. COOP 02-114, Juneau, Alaska.
- Darling, L. M. 1987. Habitat use by grizzly bear family groups in interior Alaska. *International Conference on Bear Research and Management* 7:169-178.
- Flather, C.H, and H.K. Cordell. 1995. Outdoor recreation: historical and anticipated trends. Pp. 3-16 *in* R.L. Knight and K.J. Gutzwiller, eds., *Wildlife and Recreationists: Coexistence Through Management and Research*. Island Press, Washington, D.C.
- Frid, A. 2001. Fleeing decisions by Dall's sheep exposed to helicopter overflights. *Biennial Symposium of the Northern Wild Sheep and Goat Council* 12:153-169.
- Frid, A., and L.M. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology* 6(1):11. [online] URL: <http://www.consecol.org/vol6/iss1/art11>.
- Geist, V. 1978. Behavior. Pp. 283-296 *in* J.L. Schmidt and D.L. Gilbert, eds., *Big Game of North America: Ecology and Management*. Stackpole Books, Harrisburg, Pa.
- Gende, S.M. 2002. Foraging behaviors of bears at salmon streams: intake, choice, and the role of salmon life history. Ph.D. Dissertation. University of Washington, Seattle. 259 pp.
- Gilbert, B.K. 1989. Behavioral plasticity and bear-human conflicts. Pp. 1-8 *in* M. Bromley, ed., *Bear-People Conflicts - Proceedings of a Symposium on Management Strategies Northwest Territories Department of Renewable Resources*, Yellowknife.

- Hall, L.S., P.R. Krausman, and M.L. Morrison. 1999. The habitat concept and a plea for standard terminology. *Wildlife Society Bulletin* 25(1):173-182.
- Hediger, H. 1955. *Studies of Psychology and Behavior of Captive Animals in Zoos and Circuses*. Butterworth Scientific Publications, London. 166 pp.
- Kasworm, W.F., and T.L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. *International Conference on Bear Research and Management* 8:79-84.
- Knight, R.L., and D.N. Cole. 1995. Wildlife responses to recreationists. Pp. 51-69 in R.L. Knight and K.J. Gutzwiller, eds., *Wildlife and Recreationists: Coexistence Through Management and Research*. Island Press, Washington, D.C.
- Knight, R.L., and S.A. Temple. 1995. Origins of wildlife responses to recreationists. Pp. 81-91 in R.L. Knight and K.J. Gutzwiller, eds., *Wildlife and Recreationists: Coexistence Through Management and Research*. Island Press, Washington, D.C.
- Lee, K.N. 1999. Appraising adaptive management. *Conservation Ecology* 3(2):3. [online] URL: <http://www.consecol.org/vol3/iss2/art3>.
- Lehner, P.N. 1998. *Handbook of Ethological Methods, Second Edition*. Cambridge University Press, Cambridge, U.K. 672 pp.
- Lima, S.L., and L.M. Dill. 1990. Behavioural decisions made under the risk of predation. *Canadian Journal of Zoology* 68:619-640.
- Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, H. Zuuring. 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. *Journal of Applied Ecology* 33:1395-1404.
- Mann, S.L., R.J. Steidl, and V.M. Dalton. 2002. Effects of cave tours on breeding *Myotis velifer*. *Journal of Wildlife Management* 66(3):618-624.
- Mattson, D.J. 1990. Human impacts on bear habitat use. *International Conference on Bear Research and Management* 8:33-56.
- Mattson, D.J., R.R. Knight, and B.M. Blanchard. 1987. The effects of development and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. *International Conference on Bear Research and Management* 7:259-273.
- McArthur Jope, K.L. 1983. Habituation of grizzly bears to people: a hypothesis. *International Conference on Bear Research and Management* 5:322-327.

- McLellan B.N., and F.W. Hovey. 2001. Habitats selected by grizzly bears in a multiple use landscape. *Journal of Wildlife Management* 65(1):92-99.
- McLellan, B.N., and D.M. Shackleton. 1989. Immediate reactions of grizzly bears to human activities. *Wildlife Society Bulletin* 17:269-274.
- McLoughlin, P.D., R.L. Case, R.J. Gau, H.D. Cluff, R. Mulders, and F. Messier. 2002. Hierarchical habitat selection by barren-ground grizzly bears in the central Canadian Arctic. *Oecologia* 132:102-108.
- Olson, T.L. 1993. Resource partitioning among brown bears at Brooks River in Katmai National Park and Preserve, Alaska. M.S. Thesis, Utah State University, Logan. 159 pp.
- Olson, T. L., B.K.Gilbert, and R.C. Squibb. 1997. The effects of increasing human activity on brown bear use of an Alaskan River. *Biological Conservation* 82:95-99.
- Papouchis, C., F.J. Singer, and W.B. Sloan. 2001. Responses of desert bighorn sheep to increased human recreation. *Journal of Wildlife Management* 65:573-582.
- Rodgers Jr., J.A., and H.T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. *Conservation Biology* 9:89-99.
- Salafsky, N., R. Margoulis, K.H. Redford, and J.G. Robinson. 2002. Improving the practice of conservation: a conceptual framework and research agenda for conservation science. *Conservation Biology* 16(6):1469-1479.
- Singer, F.J., and J.B. Beattie. 1986. The controlled traffic system and associated wildlife responses in Denali National Park. *Arctic* 39:195-203.
- Steidl, R.J., and R.G. Anthony. 1996. Responses of bald eagles to human activities during the summer in interior Alaska. *Ecological Applications* 6:482-491.
- Swarthout, E.H., and R.J. Steidl. 2003. Experimental effects of hiking on breeding Mexican spotted owls. *Conservation Biology* 17(1):307-315.
- Taylor, A.R., and R.L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. *Ecological Applications* 13(4):951-963.
- Thomas, K., R.G. Kvitek, and C. Bretz. 2003. Effects of human activity on the foraging behavior of sanderlings *Calidris alba*. *Biological Conservation* 109:67-71.
- Thorpe, W.H. 1956. *Learning and Instinct in Animals*. Harvard University Press, Cambridge, Mass. 284 pp.

- Ward, C., and B.S. Low. 1997. Predictors of vigilance for American crows foraging in an urban environment. *Wilson Bulletin* 109:481-489.
- Warner, S. H. 1987. Human impacts on brown bears at Pack Creek, Admiralty Island, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 95 pp.
- Whittaker, D., and R.L. Knight. 1998. Understanding wildlife responses to humans. *Wildlife Society Bulletin* 26(2):312-317.
- Wilker, G. A., and V.G. Barnes. 1998. Responses of brown bears to human activities at O'Malley River, Kodiak Island, Alaska. *Ursus* 10:557-561.
- Wilkes, B. 1977. The myth of the non-consumptive user. *Canadian Field Naturalist* 91(4):343-349.
- Williams, R., A.W. Trites, and D.E. Bain. 2002. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *Journal of Zoology* 256:255-270.
- Wielgus, R.B., P.R. Vernier, and T. Schivatcheva. 2002. Grizzly bear use of open, closed, and restricted forestry roads. *Canadian Journal of Forest Resources* 32:1597-1606.
- Zar, J. H. 1999. *Biostatistical Analysis*, Fourth Edition. Prentice-Hall, Saddle River, N.J. 931 pp.

Table 3-1. Focal bear observation minutes according to habitat type and age class.

Habitat Type	All Bears			
	Observed	(% Use)	Expected	(% Use)
roaded riparian	7711	(26)	11173	(37)
nonroaded riparian	15263	(51)	11475	(38)
roaded estuary	2625	(9)	3020	(10)
nonroaded estuary	4599	(15)	4530	(15)

Habitat Type	Adults			
	Observed	(% Use)	Expected	(% Use)
roaded riparian	1771	(14)	4612	(37)
nonroaded riparian	9156	(73)	4736	(38)
roaded estuary	248	(2)	1246	(10)
nonroaded estuary	1289	(10)	1870	(15)

Habitat Type	Subadults			
	Observed	(% Use)	Expected	(% Use)
roaded riparian	5940	(33)	6562	(37)
nonroaded riparian	6107	(34)	6739	(38)
roaded estuary	2377	(13)	1773	(10)
nonroaded estuary	3310	(19)	2660	(15)

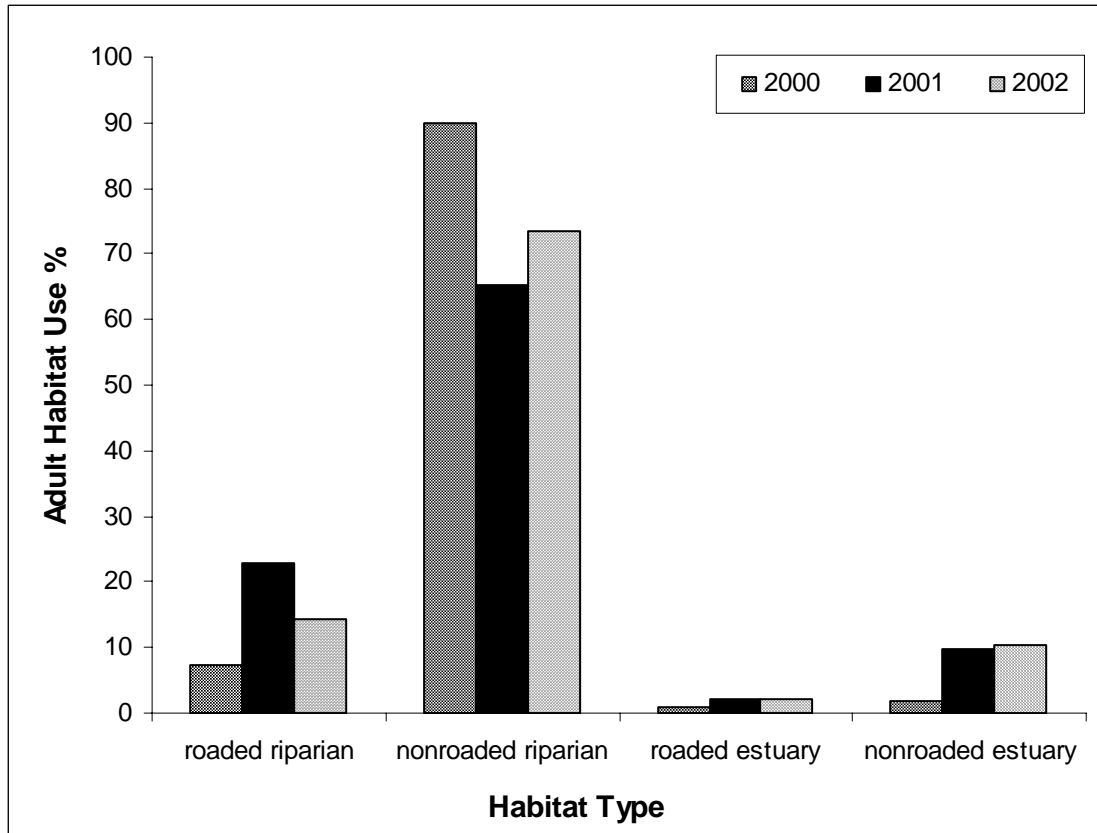


Figure 3-1. Annual adult brown bear habitat use. Includes seven individual identified adult females between 2000-2002.

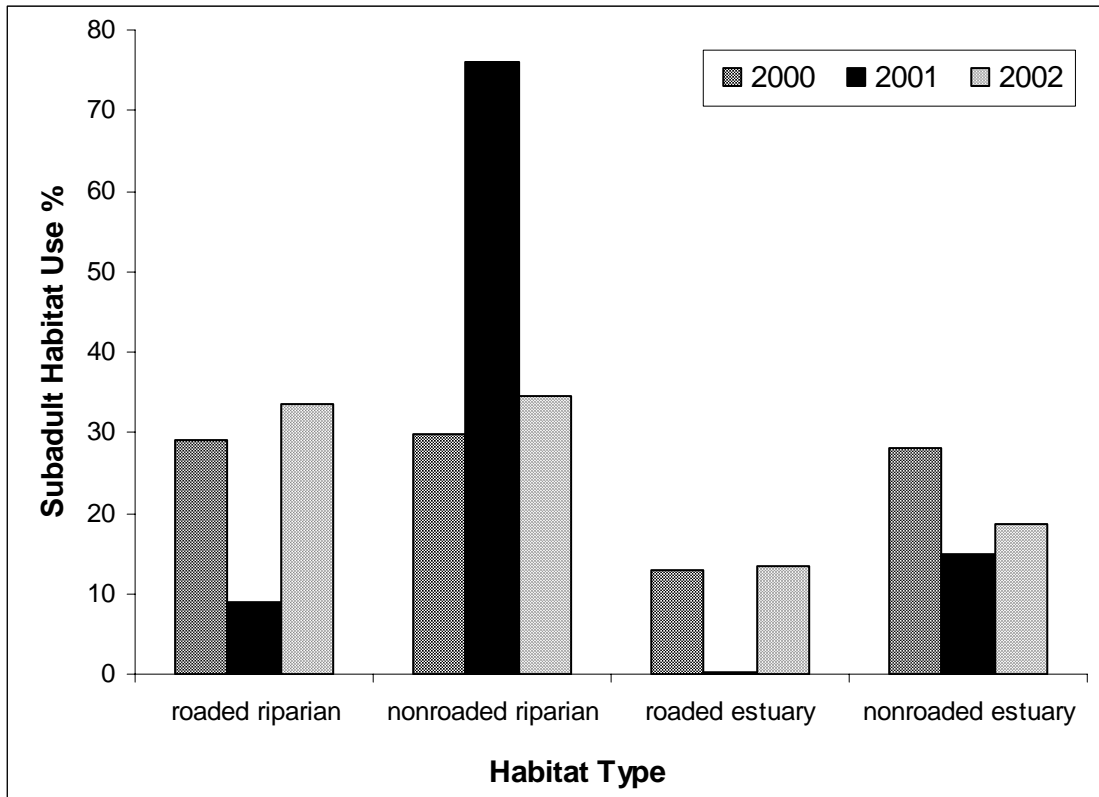


Figure 3-2. Annual subadult brown bear habitat use. Includes twelve individual identified subadults between 2000-2002.

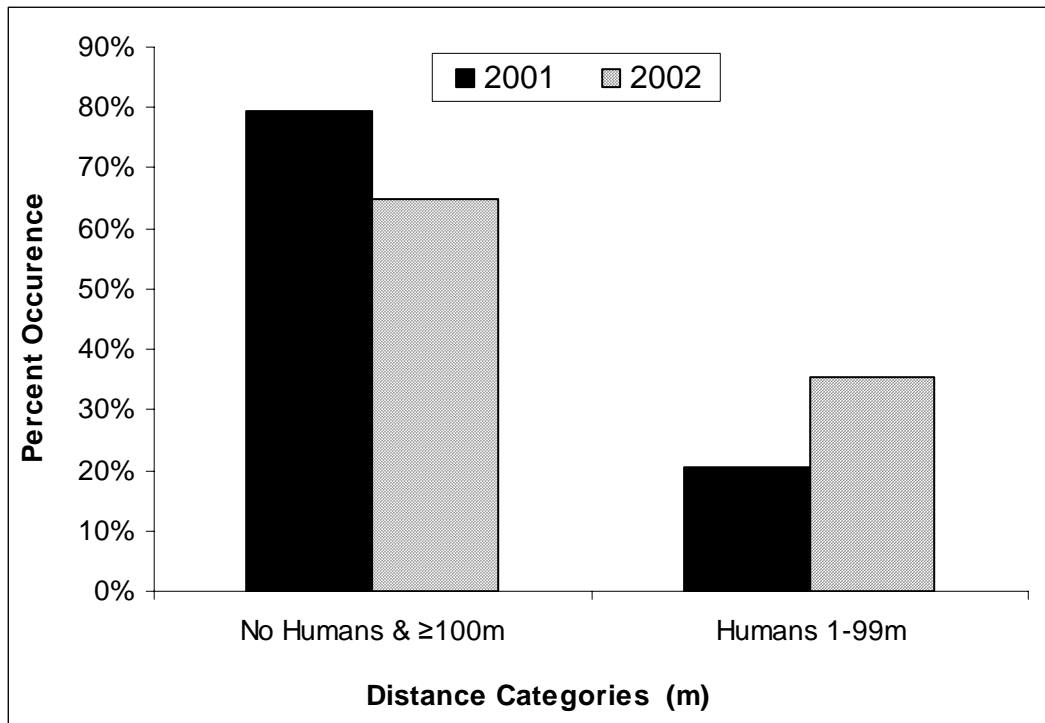


Figure 3-3. Brown bear spatial distribution in relation to human proximity, including human absence.

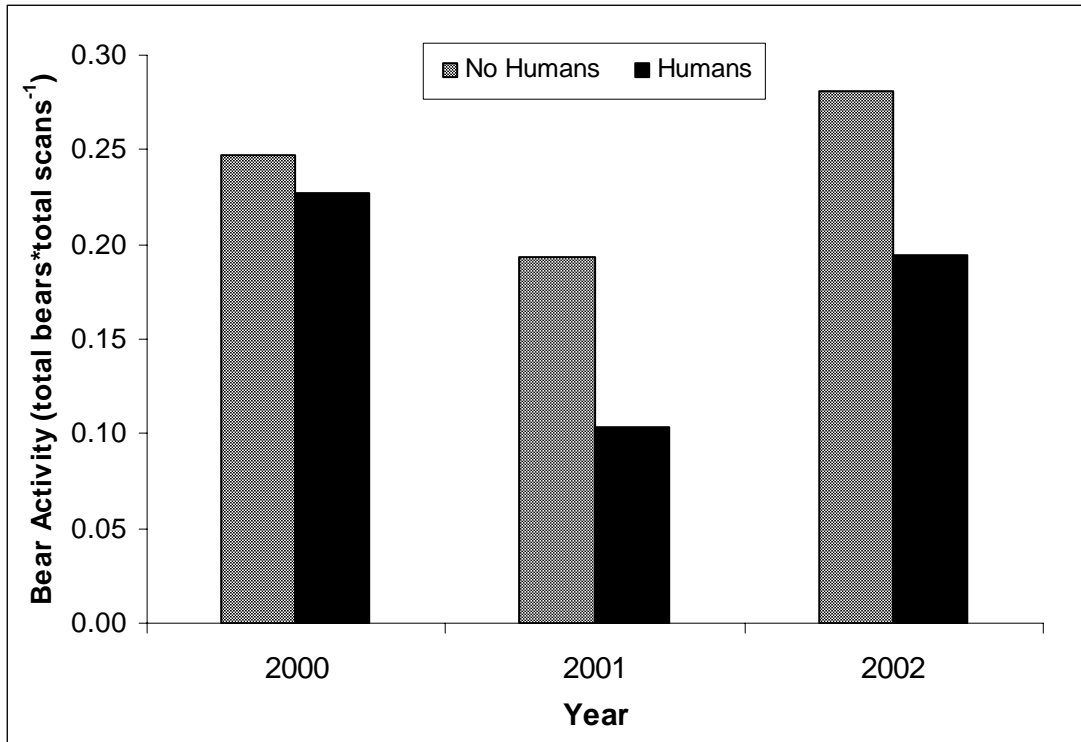


Figure 3-4. Bear activity in response to human presence.

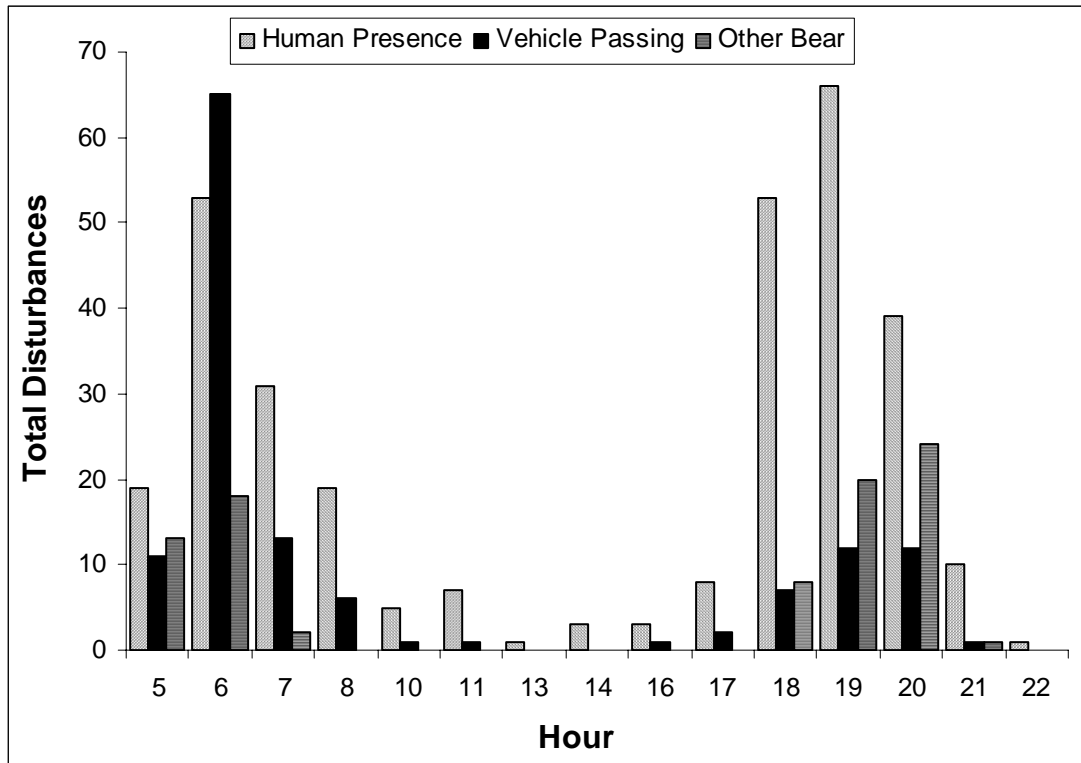


Figure 3-5. Contribution of displacements with respect to time of day. The number of displacement events in each hour correlates to hours when bears are most active.

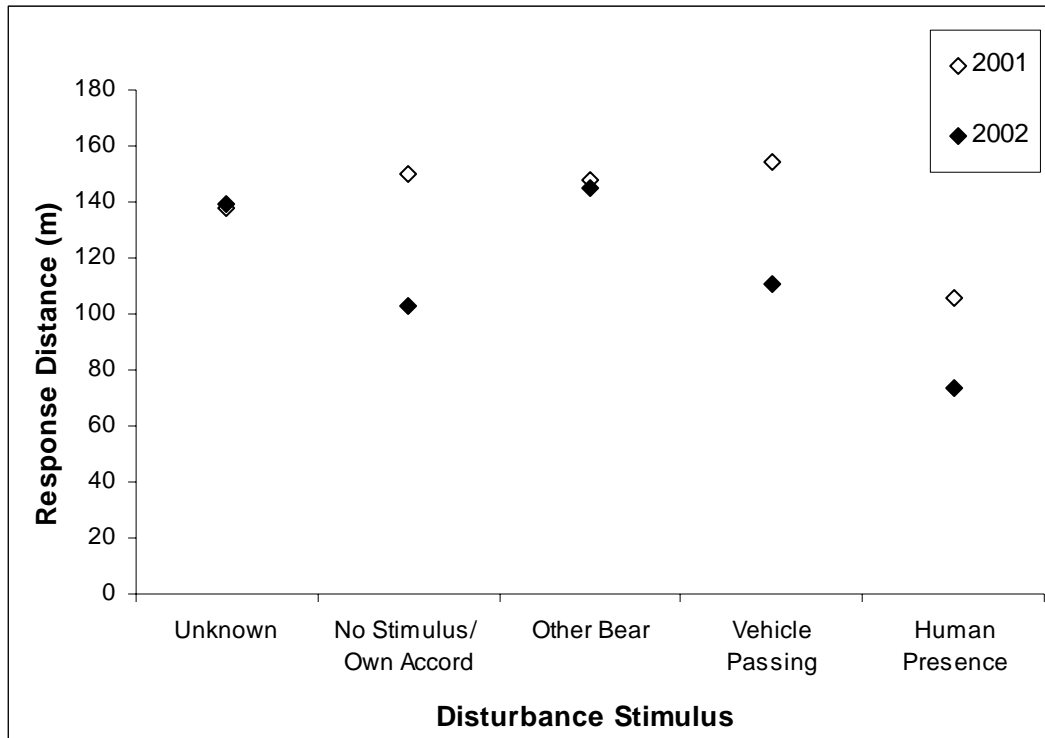


Figure 3-6. Annual mean flight distance according to disturbance stimulus.

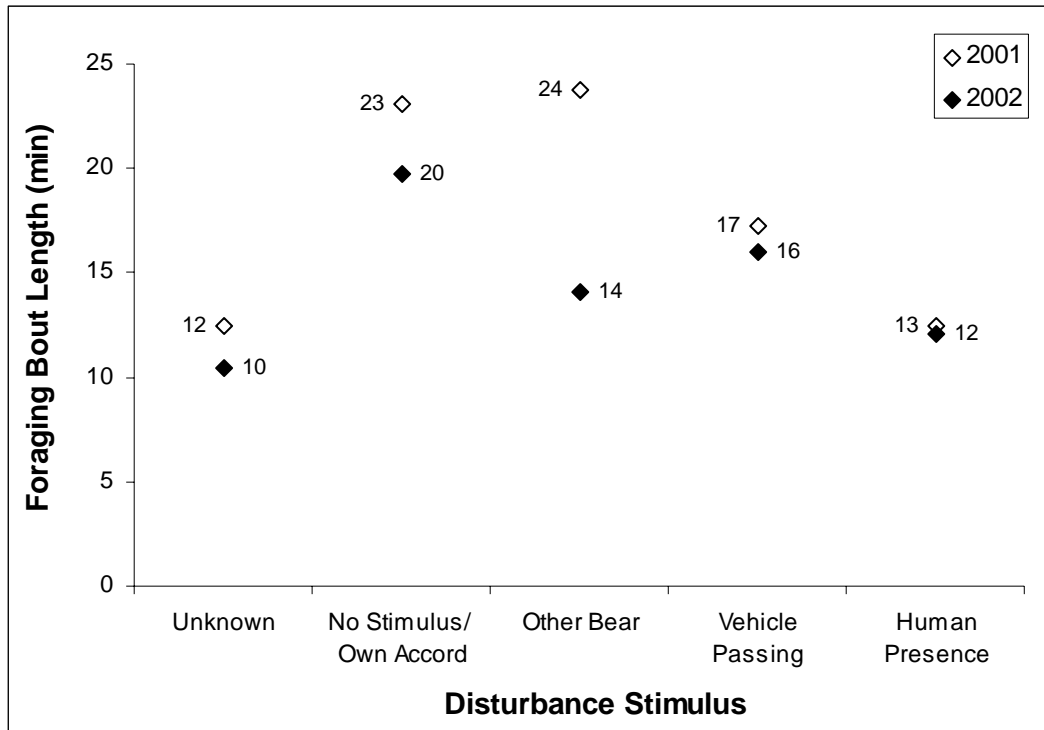


Figure 3-7. Mean foraging bout length according to disturbance stimulus.

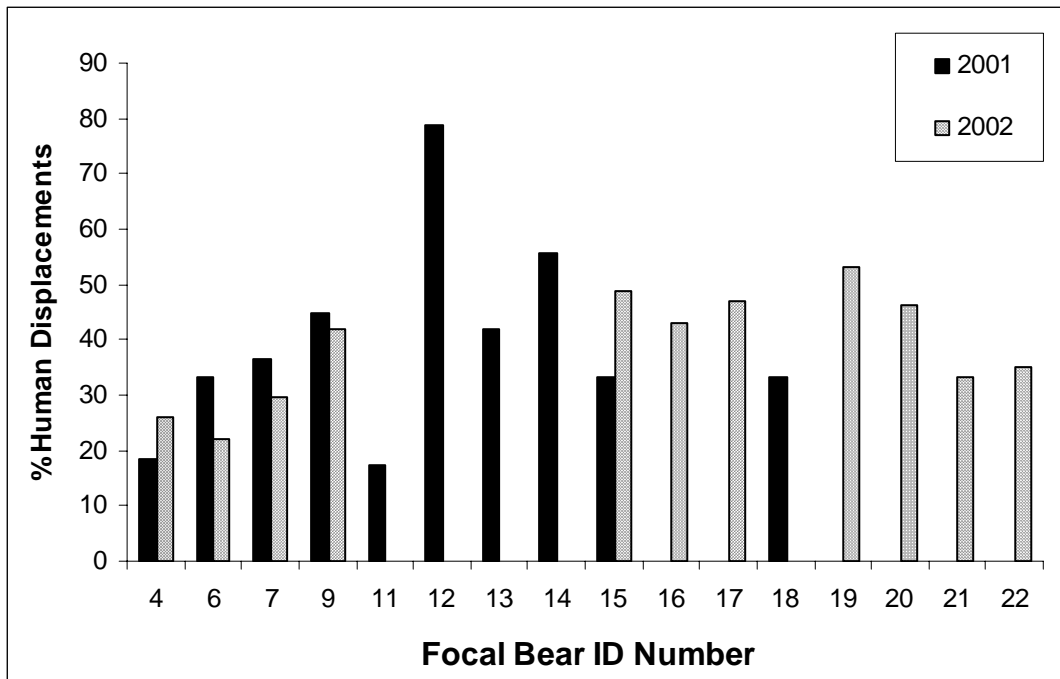


Figure 3-8. Individual bear response to human and vehicle disturbance.

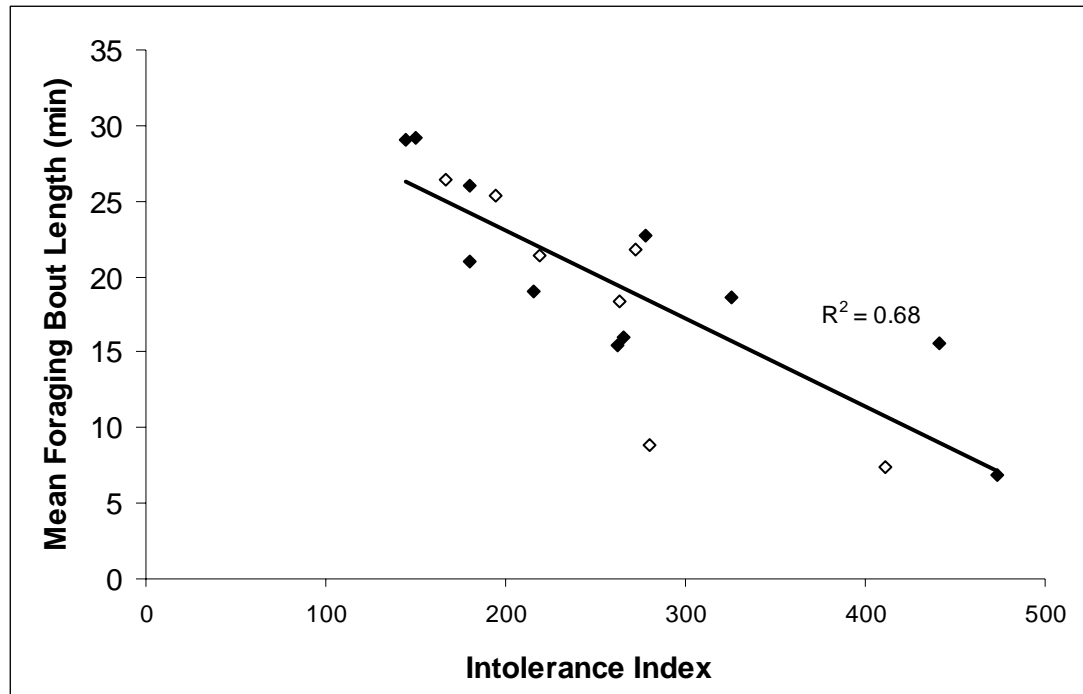


Figure 3-9. Influence of bear tolerance for human proximity on foraging bout length. Higher values indicate less tolerant individuals. Hollow diamonds represent individual bears in 2001, solid diamonds 2002.

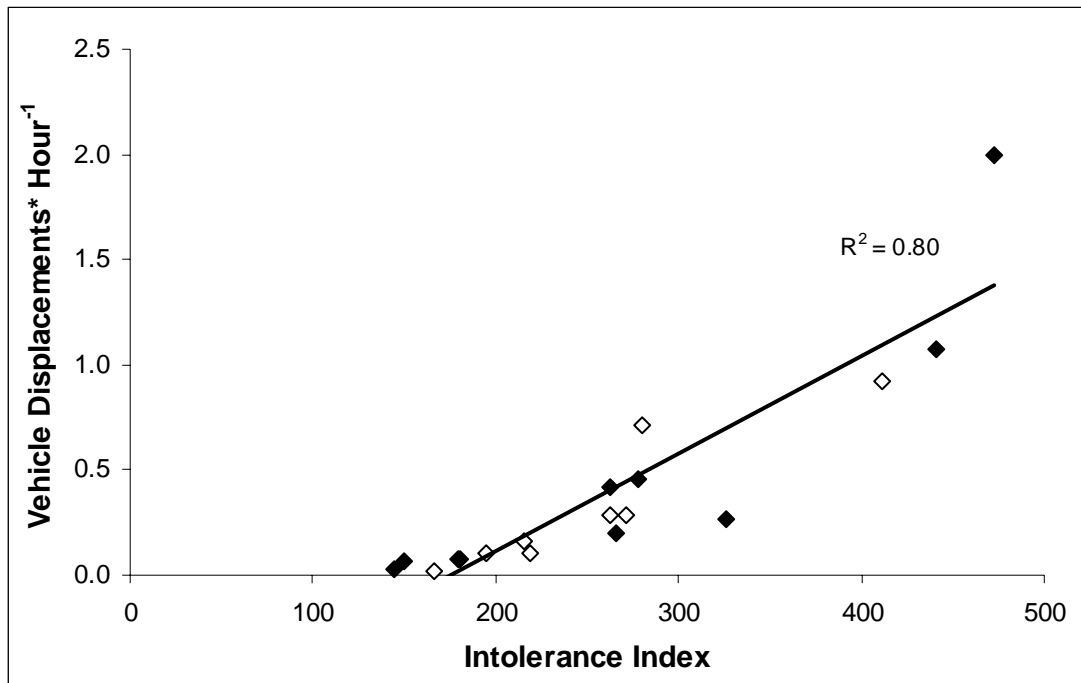


Figure 3-10. Comparison of two disturbance measures, an intolerance index and vehicle displacement rate. Hollow diamonds represent individual bears in 2001, solid diamonds 2002.

CHAPTER 4

**THE INFLUENCE OF BROWN BEAR TOLERANCE FOR
HUMAN ACTIVITY ON SALMON CAPTURE³**

ABSTRACT: We investigated brown bear foraging behavior in relation to salmon abundance and human activity from mid-July to mid-October, 2000 to 2002, along the Chilkoot River in Haines, Alaska. As nature-tourism and sport-fishing activities predominate recreational use of the area, we were interested in assessing responses in bears' activity level, captures rates and length of foraging bouts throughout changes in prey abundance and proximity to human activity.

We provide clear evidence that brown bears responded to human influences, such as presence and distance, more so than to salmon abundance and run timing. Given the substantial increases in energy and lipid content between live and senescent salmon, we assumed that bear activity, capture rates, and foraging bout length would be relative to salmon run timing. However, the greatest predictors of bear activity and capture rates were human proximity, individual tolerance for human proximity, and the time of day when bears fished. First, when humans were either absent or at distances beyond 100 meters from bear activity, bears 1) captured fish at higher rates, 2) captured 2.65 times as many fish, and 3) caught greater proportions of live fish (71%). Secondly, bear tolerance for human proximity determined brown bear capture rates, foraging bout length, total time on the river and therefore, number of salmon

³ Coauthored by Anthony P. Crupi and Barrie K. Gilbert.

captures. Thirdly, bears captured fish more effectively when light levels were greater (ie. later in the morning and earlier at night), though pronounced human use during the daytime typically precluded bear activity. This suggests energetic rewards for bears capable of adapting to human disturbance.

The majority of salmon captured were senescent carcasses (61%) with most of those captured in nonroaded habitat, similar to levels of habitat use. However, a larger proportion of live captures (81%) was associated with non-roaded habitat. Bears also attempted to maximize energy intake by capturing more female than male salmon and consuming greater proportions of live fish than senescent carcasses. With improved understanding of the mechanisms influencing foraging behavior, future generations may continue to manage and rely on this region for tourism, fishing, and wildlife viewing opportunities.

INTRODUCTION

Considering the roles of prey abundance and human dynamics on brown bear foraging behavior is important to understanding the mechanisms regulating predator access to available resources. In many instances, predators exponentially increase their attacks on prey as the density of that prey increases, until the prey are so abundant the predator can no longer benefit due to the constraints of handling time and/or satiation (Holling 1959). The optimal foraging theory is often used to predict feeding behavior, evaluate prey profitability and quantify feeding preference. Foraging theory has been utilized to bridge the gap between individual behavior and population dynamics (Kamil and Sargent 1981, Werner and Mittelbach 1981, Green

1990, Frey-Roos et al. 1995). It assumes that a foraging animal selects its diet based upon a maximum gain in energy (Kaiser et al. 1992). As costs of foraging are most easily measured in units of time and energy, this is the total energy gained per unit time minus the energetic cost of foraging (Robbins 1993). It is clearly dependent upon the energy content of the prey type, as well as the time it takes to search for, capture, and handle the given prey. The maximization of such energy is assumed to increase an individual's fitness (Stephens and Krebs 1986). We predicted that brown bear (*Ursus arctos*) foraging behaviors would functionally respond to salmon abundance and run timing, as they are believed to have evolved an energy maximizing strategy (Schoener 1969, Wilmers and Stahler 2002).

Field studies of foraging behavior in carnivores are often difficult because direct observation of consumption is challenging, given large home ranges and dietary complexity. Each year brown bears aggregate to consume Pacific salmon as they migrate to natal freshwater streams. This provides a unique, observable predator-prey system in which to test predictions of foraging behavior and prey choice (Willson and Halupka 1995, Gende et al. 2001). As coastal bears prepare for winter dormancy, salmon dominate their diet, providing the lipids and fats necessary to fuel metabolic and reproductive functions (Gilbert and Lanner 1997, Hilderbrand et al. 1999). Bears commonly select the energy-rich portions of salmon apparently to maximize energy intake (Frame 1974, Olson 1993, Gende et al. 2001, Quinn and Buck 2000). With little human disturbance, Gende et al. (2001) found an inversely density-dependent

relationship between brown bear selective consumption and the availability of spawning salmon. When salmon density declined bears consumed more of each fish.

Individual variation in bear tolerance for humans may affect access to food and thus its foraging efficiency, defined as their intrinsic ability to forage in the absence of competitors (Stillman et al. 2000). At several regulated viewing sites in Alaska numerous brown bears habituate to human presence while other individuals remain intolerant of human activity (Warner 1987, Aumiller and Matt 1994, Olson et al. 1997, Chi and Gilbert 1999). McArthur Jope (1983) and Mattson (1990) proposed that habituated bears reduce intra-specific competition for resources by foraging in areas near human activity. Individual variation in human tolerance may play an important role in foraging behavior (Olson and Gilbert 1994) and where management eliminates tolerant bears, the remaining wary bears are more likely to decline (Keating 1986).

We investigated the effects of changes in human activity and salmon abundance, between and within years, on brown bear foraging behavior, prey preference, and individual tolerance for human proximity. Three questions were addressed. First, do bears have adequate access to maximum numbers of live spawning salmon with regards to salmon run timing and times of day when foraging opportunities are optimal? We expected that bear activity, capture rates, and foraging bout length would increase with newly arriving pink salmon. Second, are bears selectively capturing salmon to maximize intake? If so, how does human activity affect their success? We expected that brown bears would capture salmon based on spawning status and gender, preferring females and live salmon to spawned-out

senescent salmon when choices were presented, irrespective of human activity.

Lastly, we quantified individual tolerance for human presence to examine if foraging behaviors such as capture rate, foraging bout length and number of captures are influenced by the individual's tolerance level. Answers to these questions will have important implications for conservation and ecosystem management in regions where human activity dominates the landscape.

METHODS

Our 3-y study was conducted along the Chilkoot River from mid-July to late October, 2000-2002. The study site is located 12 km northwest of Haines, Alaska (see Chapter 2). Similar bear-human interaction data collection procedures were utilized throughout the study, though methods were improved to record specific foraging behaviors, such as capture rate and salmon gender, in the 2001 and 2002 field seasons.

Sampling Procedures

Systematic observations were scheduled daily throughout daylight hours on the Chilkoot River using methods similar to previous studies (Olson et al. 1990, Chi 1999). Three hour observation sessions were randomly distributed throughout seven day sample blocks and stratified within six time sessions between 0530 hours and 2300 hours, as light permitted (Crupi and Gilbert 2003). The river was divided into four sampling zones (see Figure 2-2). Sampling locations were established in each zone, to minimize observer impacts and maximize sightability, and included an elevated tree blind.

Sampling procedures utilized focal animal and scan sampling techniques (Altmann 1974, Olson et al. 1990, Lehner 1998). We used focal animal sampling to record arrival and departure times, classify behavior (Appendix), determine age-gender classification, document spawning status and gender of salmon captured and determine proximity to human activity. A Geographic Information System (GIS), based on geo-referenced digital raster graphic (DRG) maps, was used to determine distances between bears and people. Observers censused human activity and bear presence at fifteen-minute interval scans throughout the observation session. People were classified according to user group (angler, guided, non-guided, official) and the number of vehicles both stopped and moving were tallied.

Brown Bear Identification

We identified individual bears according to natural markings, morphological characteristics, pelage patterns, scars, and behavioral traits, similar to previous studies (Olson et al. 1997, Chi and Gilbert 1999, Gende et al. 2001). Bears were classified and coded into one of the following cohorts: Undetermined age and gender; Adult, undetermined sex; Adult, single female; Adult, male; Female with offspring; Sub-adult, undetermined sex; Sub-adult, female; Sub-adult, male. Family groups were considered one individual bear, as cub activity is not independent of its parent (Bratten and Gilbert 1987, Olson 1993, Chi 1999).

Color and coat condition of individuals changed significantly throughout the study requiring assiduous daily observation to maintain accurate identification. Each observer was equipped with binoculars/spotting scope and a digital video recorder

(Sony Inc.: TRV-120, 400x digital zoom with O Lux, infrared Super NightShot®) to document information on bear identity, access routes, foraging behavior, and responses to human activities. Video records were crucial to reliable identification of bears and their behaviors, and improved inter-observer reliability within and between observers and years. Experienced researchers trained new observers in the field and with video sequences depicting specific individuals, behaviors and interactions. Identifying characteristics of individual bears were reviewed with all observers on a routine basis. After each observation session, videotapes were reviewed and, when necessary, images were transferred to computer for additional magnification and scrutiny of gender and identification. The Super Night Shot feature allowed us to identify individuals and collect data in low light conditions, as long as 90 minutes after sunset.

Dependent Response Variables

We measured four indices of foraging behavior to assess brown bear response to salmon availability and human activity: 1) bear activity (total bears*total scans⁻¹), 2) foraging bout length, 3) total number of foraging bouts, and 4) capture rate. Bear activity was measured using scan counts to provide a weekly rate of the total individual bears sighted in all scans. Foraging bout length, was the mean length of time spent per individual during all visits to the river. Only entire bouts observed in one zone were included in the calculation. When bears were present after the end of the scheduled observation session or traveled into an adjacent zone they were excluded from the analyses of foraging bout length. The total number of foraging

bouts for each individual were totaled for each sample block. Lastly, we defined brown bear capture rate as the number of live or dead fish caught per minute searching (catch per unit effort) during all bouts.

Spawning status, gender and proportion of salmon consumed by brown bears were documented for each fish captured during focal data collection and verified with video recordings. We determined spawning status as live or senesced after observing the vitality of the fish during capture. We considered fish that bears captured and released as pursuit for food and therefore not subject to capture analysis.

Intolerance Index

To more accurately assess the tolerance of individual bears for people, we investigated an alternative to binary habituation classification. Our index was developed to represent the continuum of behavioral plasticity (Gilbert 1989) of bear tolerance for human proximity at this site. The Intolerance Index of each bear is the product of the distance (meters) between the subject and people, multiplied by the amount of time (minutes) the individual spent in that proximity. This product divided by the subjects' total focal bear minutes provided an index of the individual's intolerance level. To prevent multiplying time (minutes) when humans were absent by a distance of zero we substituted a distance 1 meter further than human proximity (meters) was recorded or 501 meters. Bears exhibiting intolerance scores with greater magnitude were considered more intolerant (wary) while individuals spending more time in close proximity to people earned lower scores.

Independent Variables

During scan periods we classified human groups into four categories including anglers, commercially guided tourists, independent tourists, and officials (Appendix). We tallied both stopped and moving vehicles during scans and totaled moving vehicles over the course of the observation session.

Sockeye, pink, and coho salmon counts were obtained from the ADF&G weir to assess salmon returns. We analyzed two indices of pink salmon activity: the number of daily salmon counted passing through the weir was used for run timing. The second index, pink salmon abundance, was determined as follows: As pink salmon are semelparous (reach sexual maturity, spawn once, and then die) abundance declines after a certain period of time in fresh water (Schindler et al. 2003). The mean lifespan of pink salmon in fresh water is approximately 8 days (± 4) in southeast Alaska (Dickerson et al. 2002). Many dead fish are consumed by brown bears over time, with 73% scavenged by bears after ten days (Quinn and Buck 2000). Therefore, to estimate fish abundance, including both live and senescent fish, we decreased the cumulative number of fish counted at the weir by the total arrival of pink salmon counted twenty days prior. This best reflects the natural decline in abundance and accounts for the array of prey available to brown bears.

Statistical Analyses

We tested the data for deviations from normality by assessing the dataset through box plots, histograms, normal probability and residual plots as well as with Kolmogorov-Smirnov tests of normality. We computed Pearson product-moment

correlation coefficients to evaluate relationships between independent and dependent variables. To determine sources of variability between foraging behavior indices, salmon availability and scores of individual intolerance, we performed linear regression to derive predictive models (Zar 1999). The data used to assess individual tolerance were not independent, as all bears were observed at the site on multiple occasions and their index is a combination of their experiences with people. However, it was assumed that the probability of detecting an individual bear was random and that each bear had equal chance of detection. Because sampling sizes were small, we set significance levels at $\alpha < 0.10$ (Johnson 1999). Statistical package, SAS 8.0 was used for data analyses.

RESULTS

Sampling Effort

Sampling of brown bear foraging behavior included 3600 hours of systematic observation between 2000 and 2002. During 260 days spanning the majority of the three pink salmon spawning returns, we recorded 512 hours of focal bear observation. Sows with offspring and sub-adult bears contributed most of these observations; no adult males were observed. We documented the capture and partial consumption of 2038 live, senesced and angler caught salmon: 766 in 2001 and 1,272 in 2002.

Influence of Prey Availability on Foraging Behaviors

We assessed salmon run timing to determine if brown bears gained access to maximum levels of live lipid-rich salmon. We found little evidence that bear capture rates ($F = 0.325$, $P = 0.574$, $r^2 = 0.01$) (Figure 4-1) and foraging bout lengths ($F = 0.12$, $P = 0.730$, $r^2 = 0.01$) responded to numbers of live pink salmon returning. In 2001-2002, bear activity also did not correlate with salmon run timing ($F = 0.01$, $P = 0.923$, $r^2 = 0.00$) (Figure 4-2). Only in 2000 did bear activity did positively correlate with daily counts of pink salmon ($\rho = 0.70$, $P < 0.0001$). It is apparent that bear activity was consistently delayed until after angler numbers decreased below threshold levels and only in 2000 did this allow bears access to peak numbers of live spawning salmon (Figure 4-3).

We found overall bear activity positively correlated with salmon abundance, combination of live and senesced carcasses ($F = 7.19$, $P = 0.013$, $r^2 = 0.24$) (Figure 4-4). However, this measure of pink salmon abundance did not correlate with capture rates ($F = 0.00$, $P = 0.963$, $r^2 = 0.00$) or foraging bout length ($F = 0.01$, $P = 0.945$, $r^2 = 0.00$). Irrespective of prey abundance, capture rates did steadily increase over the course of the season ($F = 60.60$, $P = 0.000$, $r^2 = 0.72$) (Figure 4-5).

Capture Rate in Relation to Time of Day

The majority of brown bear activity and maximum numbers of salmon captured were observed within three hours of sunrise and sunset. About equal numbers of salmon (926 morning vs. 984 evening) were captured in these periods comprising 93% of all captures. During all hours with adult activity, bears consistently caught salmon at higher rates relative to the amount of available daylight.

Decreased capture rates in the evening correlated with diminishing daylight ($F = 15.657$, $P = 0.011$, $r^2 = 0.76$) with an average of 15 fish captured for every hour spent fishing ($\bar{x} = 0.25 \text{ captures} \cdot \text{min searching}^{-1}$) (Figure 4-6). In the morning, capture rates were positively correlated with increased daylight ($F = 6.182$, $P = 0.047$, $r^2 = 0.51$) (Figure 4-7) with an average of 17 fish captured per hour spent fishing ($\bar{x} = 0.29 \text{ captures} \cdot \text{min searching}^{-1}$).

Comparison of Foraging Behaviors Between Cohorts

In 2001, we observed 371 foraging bouts of known individuals with 207 (56%) events being full length bouts. In 2002, we recorded 632 foraging bouts of which 493 (78%) were full bouts. Foraging bout lengths were longer in 2001 than in 2002 for all four cohorts. Mean foraging bout length ranged from 13 to 28 minutes between cohorts, though no clear relationship was evident between cohorts or years (Figure 4-8). For all cohorts, foraging bout length increased over the course of the 2002 season ($F = 4.48$, $P = 0.072$, $r^2 = 0.39$) though a similar relationship did not exist in the 2001 season ($F = 0.129$, $P = 0.732$, $r^2 = 0.02$).

Between cohorts capture rates were highest among adult females with offspring who made over 19.2 captures per hour spent fishing ($\bar{x} = 0.32 \text{ captures} \cdot \text{min searching}^{-1}$). Adult females were the next most productive with 15.6 ($\bar{x} = 0.26$) followed by sub-adult females 13.2 ($\bar{x} = 0.22$) and males 12.6 ($\bar{x} = 0.21$). Adult females also spent the least amount of time between captures searching for fish ($\bar{x} = 2.5 \text{ min}$) while sub-adult males took nearly on minute more ($\bar{x} = 3.4 \text{ min}$). When

consuming live fish, females with offspring elapsed the least time ($\bar{x} = 1.8$ min) while sub-adult females took the longest time ($\bar{x} = 2.9$ min). Consumption time of each senescent fish was slightly less, with females with offspring again being the fastest ($\bar{x} = 1.4$ min) and sub-adult females slowest ($\bar{x} = 1.9$ min).

Comparison of Fishing Success in Relation to Human Activity And Habitat

Overall, when humans were present versus absent, capture rates declined by 7% in 2001 and 24% in 2002 (Figure 4-9). When humans were absent or beyond 100 meters from bears, the numbers of salmon captured (live and senescent fish) more than doubled (2.65=1480 live/ 558dead). Likewise the proportion of live fish increased 71%, as 23% (129 of 558) all fish captured within 100 meters were live while 40% (586 of 1480) were live when humans were absent or beyond 100 meters (Figure 4-10). This accounted for 86% (238 of 276) of the live captures in 2001 and 79% (348 of 439) in 2002.

Brown bear capture rates were slightly higher in non-roaded habitat with 10% and 13% reductions in roaded habitat during 2001 and 2002 respectively (Figure 4-11). This small difference in capture rate, however, does not adequately explain the preferential use (66%) of non-roaded habitat in both riparian and estuarine habitat types (see Chapter 3).

The majority of the 2038 fish captured and consumed by brown bears were senesced (61%), while 715 of all fish captured were live (35%). Of the senescent captures, 67% (840) were caught in non-roaded habitat, and 33% (409) in roaded

habitat, similar to bears' use of habitat. However, live salmon were disproportionately captured in non-roaded habitat where 81% (578) salmon were observed being captured, compared to only 19% (137) in roaded habitat (Figure 4-12).

In both years, zone 1 produced the largest number of live and senescent captures (see Figure 2-2). Zones 3 and 4 were substantially less productive, however the estuary habitat of zone 4 provided numerous senescent carcasses (Figure 4-13). Consumption of angler caught entrails constituted 4% of the total catch with more tolerant bears consuming entrails of pink salmon in zone 1 and coho salmon in zone 3.

Gender and Consumption of Salmon Captured by Brown Bears

Positive identification of salmon gender was ascertained for 282 captures. Brown bears captured both live (76%) and senesced (66%) female salmon more often than male salmon (Figure 4-14). The proportion of female salmon captured was similar between non-roaded (71%) and roaded habitats (72%) and we found that all cohorts captured female salmon with similar preference (71-73% females).

Although bears selectively captured female salmon, amount of salmon consumed was not dependent upon salmon gender. Bears consumed similar proportions of individual male (70%) and female (67%) salmon. However, consumption of salmon was correlated with salmon spawning status, as more of each salmon was consumed when captured live (67%) versus scavenged after senescence (55%) (Figure 4-15). The mean percentage of salmon consumed also steadily declined

in both years as weeks progressed (2001: $F = 27.92$, $P = 0.001$, $r^2 = 0.80$; 2002: $F = 53.12$, $P = 0.000$, $r^2 = 0.87$) (Figure 4-16).

Foraging Behavior Responses to Human Proximity

We established a relative index of bear tolerance for human proximity for nine consistently observed individual bears in 2001 and 2002. Five individuals were present in both years and our index of each bear's tolerance was consistent between years ($\rho = 0.84$, $P = 0.076$). Brown bear tolerance for human activity explained several foraging behavior indices: foraging bout length, number of foraging bouts, total time on river, capture rate and total captures. Mean foraging bout length negatively correlated with intolerance as individuals with greater tolerance for human proximity were more likely to spend longer periods of time foraging ($F = 33.84$, $P = 0.000$, $r^2 = 0.68$) (Figure 4-17). All bears with intolerance levels exceeding 400 (signifying pronounced wariness) had the shortest foraging bouts ($\bar{x} = 7 - 15$ min). Furthermore, they did not compensate by increasing their number of bouts: bear intolerance negatively correlated with total foraging bouts in both years ($F = 3.45$, $P = 0.082$, $r^2 = 0.18$). Similarly, the total amount of time that each bear was observed along the river related directly to its intolerance for people ($F = 8.80$, $P = 0.009$, $r^2 = 0.36$) (Figure 4-18). Capture rate positively correlated with intolerance, as less intolerant individuals captured more fish per unit of effort ($F = 20.25$, $P = 0.000$, $r^2 = 0.56$) (Figure 4-19). However, while these bears had higher capture rates, they spent less time fishing and captured fewer fish ($F = 3.23$, $P = 0.091$, $r^2 = 0.17$) (Figure 4-20).

DISCUSSION

Evidence for Delayed Access

In 2000, when overall human activity was nearly 40% lower than 2002, bear activity was highly correlated with the pink salmon run timing ($\rho=0.70$, $P < 0.0001$). When the salmon run peaked, bear activity lagged closely behind suggesting that bears gained reasonable access to maximum numbers of live fish. In the two subsequent years, as human activity, particularly angler activity, increased and extended into the peak salmon run, bear activity was delayed. This finding is consistent with other studies correlating bear postponement from peak spawning migration with pronounced human activity, particularly by non-habituated individuals (Reinhart and Mattson 1990, Olson et al. 1997). Hence, it appears that access to salmon was not limited by competition or social dominance, but rather was impeded by perceived risks from human activity (Frid and Dill 2002, Gende 2002).

Previously, bear activity has been found to follow salmon run timing closely (Barnes 1990). Gard (1971) found that peak brown bear activity coincided with the salmon run at a stream where human influence was negligible. Gard also found an increased rate of predation as prey abundance increased. As well, brown bear activity and capture rates at McNeil River were directly related to prey abundance and salmon run timing (Luque and Stokes 1976, Egbert 1978). Olson and Gilbert (1994) found that habituated family groups concentrated activity in relation to availability of salmon while nonhabituated family groups were displaced by human activity from habitats with the highest capture rates. As well, at Anan Creek in southeast Alaska, Chi (1999)

found that black bears showed maximum use of the river within a week of the peak salmon return. Thus, Chilkoot bears could be expected to maximize activity, capture rates, foraging bout lengths and spatial habitat use in relation to prey availability but the data fail to support this hypothesis. Bears at this study site appeared to be precluded from maximum numbers of live salmon due to human activity, resulting in greater levels of bear activity when carcasses were abundant but fewer live fish were entering the stream.

Bear activity levels correlated loosely with abundance (live and senescent salmon), but their failure to access maximum numbers of live fish would require consuming more carcasses to compensate for the loss in energy. We estimated this required increase in consumption to be 2-3 times as many carcasses. On average pink salmon arrive with energy equivalent to 4.8 Kj/g for males and 5.9 Kj/g for females which declines by 31% and 46% respectively following senescence (Gende 2002). As well, mean body mass of pink salmon declines from 1.6 to 1.4 kg for males and 1.4 to 1.0 kg for females with energy declining from 7,680 to 4,480 Kj for males and 8,260 to 3,200 Kj for females. Given that bears consume nearly similar amounts of males and females, metabolize approximately 90% of energy consumed (Pritchard and Robbins 1990), and consumed 67% of live fish and only 55% of senescent fish, it would require 2 times as many senescent male captures and 3 times as many female captures to compensate for the loss in energy (Males-4631:2218 Kj/male, Females-4981:1584 Kj). Thus, limited access during peak abundance implies the potential for severe energetic repercussions.

This study also demonstrated frequent mid-day displacement of bears from productive foraging periods and total abandonment by adult males (see Chapter 3). At other sites, with limited human activity, bears tend to be more active during daylight hours (MacHutcheon et al. 1998, Olson et al. 1998, Crupi 2003). Egbert and Stokes (1976) found that bears fishing in the mid-afternoon and early evening captured salmon at faster rates. Our data suggest that bears fishing during hours of increased daylight captured more fish relative to the amount of time spent fishing. This appeared to be due to better visual detection of salmon. Higher capture rates during daylight hours has been discussed in terms of visual acuity resulting from enhanced color and detail discrimination (Bacon and Burghardt 1976, Lariviere et al. 1994) and given the opacity of the Chilkoot River this could help explain improved capture rates. It is possible that brown bears forage extensively under the cover of darkness, but the data indicate that foraging at these times will not be the most cost efficient and likely difficult given the active fishing techniques employed in capturing prey.

Frame (1974) described nighttime predation by black bears on chum and pink salmon. He found bears employed similar capture techniques as during the daytime but were generally less persistent, as they often departed the stream without capturing a fish. However, Klinka and Reimchen (2002) suggested that bears were more effective nocturnal foragers and referenced Reimchen's (1998) belief that bears were not able to detect competitors because of darkness. Their study involved only ten days of observation; I suggest their findings could be anomalous, site specific, or an artifact of one bear. An estimated 550,000 salmon returned to the weir gate of a shallow,

artificial spawning channel making capture techniques and rates contrary to any natural system. Females with cubs and sub-adults were seen feeding during the daylight, and adult males observed in the night, yet Klinka and Reimchen (2002) made no mention of differences between cohort specific foraging behaviors or individuals. Variation between capture rates of adult males and other cohorts could certainly confound these dubious results.

We found that brown bear capture rates increased over time irrespective of run timing or salmon abundance. The cause of this increased capture rate is potentially two-fold. First, bears may improve capture techniques with experience (Luque and Stokes 1976), as we observed a decrease in number of capture methods employed as the season progresses suggesting a preference for successful techniques. Several studies have documented bear capture success rates (Frame 1974, Luque and Stokes 1976, Egbert 1978, Olson 1993, Gende 2002), with numerous attempts associated with each capture, suggesting that salmon capture can be challenging and possibly improved with repetition. Second, salmon's decreased ability to escape predation is also a potential factor. As salmon age, their energy reserves which fuel escape decline, possibly improving a predator's ability to capture (Gende 2002).

Roaded habitat appeared to provide equal foraging opportunities, as evidenced through large numbers of spawning salmon, numerous obstructions in the river, angler success, and similar capture rates. Thus the possibility that the non-roaded habitat was selected for its easier foraging can be eliminated. Capture rates along the roaded habitat likely appear lower because of proximity to people and vehicles. When fewer

humans were present or beyond critical distances, bears improved capture rates possibly because they were less vigilant and thus better able to focus on capturing fish. A few individuals have learned to exploit this available habitat and trade-off risks of people for salmon rewards and possibly reduced intra-specific competition (Olson et al. 1997).

Selective Capture and Consumption

In order to store adequate fat for hibernation (Gilbert and Lanner 1997), brown bears maximize energy intake by selecting lipid-rich portions of salmon. Gende (2002) measured a rapid, substantial decline (76 % - 86%) in available lipid content between pre-spawned and post-spawned pink salmon. This suggests a significant cost to bears not consuming live fish. Consequently, the proportion of live fish captured may be an important indicator of brown bear foraging success.

Hilderbrand et al. (1999) determined that brown bear consumption of meat, particularly salmon, is significantly correlated with reproductive success and population density. If bears do not exceed threshold levels of body fat and mass prior to hibernation, reduced reproduction and recruitment could occur (Archibald et al. 1987, Rogers 1987, Stringham 1989, Gilbert and Lanner 1997). However, this study does not address fitness costs because to properly investigate fitness responses, long-term research relating to one or more reliable fitness surrogates (mortality, survival, fecundity and reproductive rate) would be necessary, though costly and difficult to conduct. The potential biological costs of decreased foraging opportunity should be considered when associated with increased human activity and pronounced human-

induced displacement (Hamilton and Bunnell 1987, White et al. 1999). Given the increased growth in human activity and associated decline in foraging opportunities, conservative and responsible management of the population would minimize human disturbance during peak abundance of live salmon and at times of day when capture rates are most productive.

While Chilkoot bears may be missing the most productive opportunities for salmon capture, some observations suggest that bears are maximizing energy intake. Bears consumed the most profitable portions of salmon (skin, belly, brain, and eggs of females), similar to the findings reported by Frame (1974), Luque and Stokes (1976), Egbert (1978), Olson (1993), Gilbert and Lanner (1997), and Gende et al. (2001). Amount of salmon consumed was not sex biased but was correlated with spawning status. Olson (1993) found similar consumption percentages and little variation between cohorts. Likewise, Gende et al. (2001) found that live salmon were consumed to a greater degree than spawned-out fish, and they found little difference between the percentage of males and females consumed. They did find, though, a bias in body parts consumed: in males, the body, hump and brain were most frequently consumed while in females the belly was most often consumed, especially in live ripe fish. The partial consumption of salmon appears to be a consequence of satiation or constraint on gut capacity (Rode et al. 2001, Wilmers and Stahler 2002).

Our data indicated a steady decline over time in the amount of each salmon consumed irrespective of salmon run timing or salmon abundance. Conversely, Gende et al. (2001) found that the proportion of salmon consumed was inversely related to

availability. Our observed decline could be explained by the declining lipid and energy content in these fish and bear selectivity for specific body parts. We observed bears consuming salmon skin in nearly all captures irrespective of spawning status. Gende's (2002) analysis of pink salmon chemical composition found that energy content of skin was among the highest of all body parts and the difference between live and dead fish was minimal. Partial selection strategies such as these, which maximize consumption of body parts maintaining value even after death, are testament to predator ability in optimizing diet selection.

Our results are consistent with selective predation and capture rates reported elsewhere (Frame 1974, Quinn and Buck 2000). Although the male:female ratio of pink salmon in the Chilkoot River is unavailable, it is believed to be approximately 1:1 as in other stocks throughout Alaska (Dickerson et al. 2002). Female pink salmon spawn quickly, approximately 2 days after arrival into fresh water (McPhee and Quinn 1998), and their longevity had been believed to be shorter than male salmon. However, Dickerson et al. (2002) found little difference in lifespan between male and female pink salmon subsequent to arrival in fresh water, thereby maintaining near equal sex ratios throughout the return. Contrary findings of sex biased predation, however, have been reported. Gard (1971) found slight preference for male salmon as they represented 52% of the returning salmon and 57% of the salmon killed by bears. Ruggerone et al. (2000) found that male salmon were selectively harvested by bears, however the number of salmon returning to the stream were few and the percentage of sockeye salmon killed by brown bears declined relative to the number of spawners.

Male salmon were believed to be selected because of their greater size, longer period of time on the spawning grounds or perhaps greater palatability (Ruggerone et al. 2000). From our observations, size was not believed to be a determinant of bear predation as the opaque water of the Chilkoot River would likely inhibit accurate bear detection of salmon size. Furthermore, we noted brown bears rejecting captured male and female fish, following olfactory examination of the salmon's ventral side, potentially indicating choice for pre-spawned females. We also saw bears reject male and/or female fish in apparently prime condition in exchange for meager portions of severely decayed carcasses, thereby disputing any regimented rule for consumption choice by brown bears.

Influence of Tolerance on Foraging Behavior

Habituation has been defined as a binary categorization based upon a specific definition, such as consistent tolerance of people ≤ 50 m with no noticeable change in behavior (Olson 1993). Yet, we observed individual differences in behavior based on context, location, cohort (age and reproductive status), and perceived payoff. Previous researchers have also reported difficulty in assessing habituation of sub-adult bears (Bratten and Gilbert 1987, Olson 1993), who represented over 50% of the bears observed in our study. The intolerance index that we developed appeared to better reflect the spectrum of individual tolerance levels observed during this study and served to explained several attributes of foraging behavior. In this study, tolerant individuals had longer and more foraging bouts, spent additional time on the river, and

accumulated more captures with a greater proportion being live fish. This provides clear nutritional advantage for individuals capable of adapting to human activity.

CONCLUSION

The foundations of foraging theory provide a context for understanding attributes of brown bear foraging behavior. We addressed three questions relating to bear foraging behavior, prey abundance and bear tolerance of human proximity. While brown bears were undoubtedly drawn to the Chilkoot River each year for an abundance of pink salmon, their ability to respond to changes in prey abundance appeared to be severely constrained by human activity and proximity. There was no evidence that bears increased activity and capture rates of salmon in relation to salmon run timing as we had anticipated, suggesting a sub-optimal foraging strategy. We found that bear access to maximum numbers of live pink salmon was impacted by human activity during the most productive foraging weeks and times of day when capture rates were highest. Bears captured more salmon with less effort in both the morning and the evening hours when available light was greater. For instance, bears captured 18 fish per hour fishing during 1800 hours and only 12 fish per hour fishing at 2100 hours. If bears were consistently allowed unfettered access during these more productive time periods, managers could effectively maintain high levels of human use between these hours and minimize bear-human conflicts resulting from pronounced temporal and spatial overlaps of limited available habitat.

Bears were selective in capture and consumption of prey. All cohorts preferentially captured female salmon, live and senesced, over male salmon, perhaps

because they offer greater energetic rewards. However, the amount of each fish consumed was not sex biased. Bears were typically relegated to capturing senescent fish (61%) with lower energy content. When live fish were captured, bears consumed greater proportions (67%) of them than senescent fish (55%). Percent consumption decreased through time with less than 50% of each fish consumed at the end of the season.

Our data suggested that intolerance for human proximity was a stronger predictor of brown bear foraging activity than salmon run timing or abundance. Less tolerant individuals captured fish at higher rates but had fewer fishing trips, shorter and fewer foraging bouts, hence less time on the river and ultimately fewer fish captures. Bears exhibiting more tolerance for humans at closer distances spent longer periods of time searching for fish and capture more fish. This suggests energetic rewards for bears capable of adapting to human disturbance.

When humans were absent or at distances greater than 100 meters, bears captured fish at higher rates, captured 2.65 times as many fish, and caught greater proportions of live fish (71%). The majority of salmon captured were senescent carcasses (61%) with most of those captured in nonroaded habitat, similar to habitat use. However, a larger proportion of live captures (81%) was associated with non-roaded habitat.

In view of the decrease in live fish captured when humans were near bears, and the associated energetic cost, we suggest two management alternatives. To obtain full use of habitat brown bears need predictable foraging opportunities during the most

productive foraging hours at the peak of the pink salmon return. To achieve this, several temporal and spatial restrictions of human activity are needed. During the peak of the pink salmon run, limiting human access in the hours near dawn and dusk while enforcing no-trespassing regulations on the non-roaded side of the river would positively impact levels of bear activity and foraging success. Another alternative supported by the data, would be to limit numbers of people to year 2000 levels and better manage the distance between people and bears. These management options facilitate continued recreation opportunities with moderate modifications to human access. These would allow brown bears to spend less time avoiding human activities and to benefit from their traditional access to rich salmon, thereby ensuring a safe and sustainable bear population for the enjoyment of future generations.

LITERATURE CITED

- Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour* 49:227-267.
- Archibald, W.R., R. Ellis, and A.N. Hamilton. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River valley, British Columbia. *International Conference on Bear Research and Management* 7:251-257.
- Aumiller, L. D., and C.A. Matt. 1994. Management of McNeil River State Game Sanctuary for viewing of brown bears. *International Conference on Bear Research and Management* 9(1):51-61.
- Bacon, E.S., and G.M. Burghardt. 1976. Learning and color discrimination in the American black bear. *International Conference on Bear Research and Management* 3:27-36.
- Barnes, V.G. 1990. The influence of salmon availability on movements and range of brown bears on southwest Kodiak Island. *International Conference on Bear Research and Management* 8:305-313.

- Bratten, A.M., and B.K. Gilbert. 1987. Profile analysis of human-bear relationships in Katmai National Park and Preserve. Final Rep. Nat. Park Serv. Contract No. CX-9700-4-0019. Utah State University, Logan. 104 pp.
- Chi, D.K. 1999. The effects of salmon availability, social dynamics, and people on black bear (*Ursus americanus*) fishing behavior on an Alaskan salmon stream. Ph.D. Dissertation, Utah State University, Logan. 157 pp.
- Chi, D.K., and B.K. Gilbert. 1999. Habitat security for Alaskan brown bears at key foraging sites: are there thresholds for human disturbance? *Ursus* 11:225-238.
- Crupi, A.P. 2003. Chinitna Bay brown bear foraging activity and behavioral response to aircraft overflights. Lake Clark National Park and Preserve, Alaska. Unpublished manuscript.
- Crupi, A.P., and B.K. Gilbert. 2003. Bear and human use patterns of the Chilkoot River in Haines, Alaska, 2000-2001. ADF&G, Division of Wildlife Conservation, Technical Progress Report, Contract No. COOP 02-114, Juneau, Alaska.
- Dickerson, B.R., T.P. Quinn, and M.F. Willson. 2002. Body size, arrival date and reproductive success of pink salmon, *Oncorhynchus gorbuscha*. *Ethology, Ecology, and Evolution* 14:29-44.
- Egbert, A.L. 1978. The social behavior of brown bears at McNeil River, Alaska. Ph.D. Dissertation, Utah State University, Logan. 117 pp.
- Egbert, A.L., and A.W. Stokes. 1976. The social behaviour of brown bears on an Alaskan salmon stream. *International Conference on Bear Research and Management* 3:41-56.
- Frame, G. W. 1974. Black bear predation on salmon at Olsen Creek, Alaska. *Z. Tierpsychol* 35:23-38.
- Frey-Roos, F., P.A. Brodmann, and H. Reyer. 1995. Relationships between food resources, foraging patterns, and reproductive success in the water pipit, *Anthus sp. Spinoletta*. *Behavioral Ecology* 6(3):287-295.
- Frid, A., and L.M. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology* 6(1):11. [online] URL: <http://www.consecol.org/vol6/iss1/art11>.
- Gard, R. 1971. Brown bear predation on sockeye salmon at Karluk Lake, Alaska. *Journal of Wildlife Management* 35(2):193-204.

- Gende, S.M. 2002. Foraging behaviors of bears at salmon streams: intake, choice, and the role of salmon life history. Ph.D. Dissertation, University of Washington, Seattle. 259 pp.
- Gende, S.M., T.P. Quinn, and M.F. Willson. 2001. Consumption choice by bears feeding on salmon. *Oecologia* 127:372-382.
- Gilbert, B.K. 1989. Behavioral plasticity and bear-human conflicts. Pp. 1-8 in M. Bromley, ed., *Bear-People Conflicts - Proceedings of a Symposium on Management Strategies Northwest Territories Department of Renewable Resources*, Yellowknife.
- Gilbert, B.K., and R.M. Lanner. 1997. Energy, diet selection and restoration of brown bear populations. *International Conference on Bear Research and Management* 9(2):231-240.
- Green, R.F. 1990. Putting ecology back into optimal foraging theory. *Comments on Theoretical Biology* 1(6):387-410.
- Hamilton, A.N., and F.L. Bunnell. 1987. Foraging strategies of coastal brown bears in the Kimsquit River Valley, British Columbia. *International Conference on Bear Research and Management* 7:187-197.
- Hilderbrand, G.V., C.C. Schwartz, C.T. Robbins, M.E. Jacoby, T.A. Hanley, S.M. Arthur, and C. Servheen. 1999. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. *Canadian Journal of Zoology* 77:132-138.
- Holling, C. S. 1959. The components of predation as revealed by a study of small-mammal predation on the European pine sawfly. *Canadian Entomologist* 91:293-320.
- Johnson, D.H. 1999. The insignificance of statistical significance testing. *Journal of Wildlife Management* 63(3):763-772.
- Kaiser, M.J., A.P. Westhead, R.N. Hughes, and R.N. Gibson. 1992. Are digestive characteristics important contributors to the profitability of prey: A study of diet selection in the fifteen-spined stickleback, *Spinachia spinachia*. *Oecologia* 90:61-69.
- Kamil, A.L., and T.D. Sargent. 1981. *Foraging Behavior: Ecological, Ethological, and Psychological Approaches*. Garland Publishing, Amherst, Mass. 534 pp.
- Keating, K.A. 1986. Historical grizzly bear trends in Glacier National Park, Montana. *Wildlife Society Bulletin* 14:83-87.

- Klinka, D.R., and T.E. Reimchen. 2002. Nocturnal and diurnal foraging behavior of brown bears (*Ursus arctos*) on a salmon stream in British Columbia. *Canadian Journal of Zoology* 80:1317-1322.
- Lariviere, S., J. Huot, and C. Samson. 1994. Daily activity patterns of female black bears in a northern mixed-forest environment. *Journal of Mammalogy* 75:613-620.
- Lehner, P.N. 1998. *Handbook of Ethological Methods, Second Edition*. Cambridge University Press, Cambridge, U.K.
- Luque, M. H., and A.W. Stokes. 1976. Fishing behavior of Alaska brown bear. *International Conference on Bear Research and Management* 3:71-78.
- Mattson, D.J. 1990. Human impacts on bear habitat use. *International Conference on Bear Research and Management* 8:33-56.
- McArthur Jope, K.L. 1983. Habituation of grizzly bears to people: a hypothesis. *International Conference on Bear Research and Management* 5:322-327.
- MacHutcheon, A.G., S. Himmer., H. Davis, and M. Gallagher. 1998. Temporal and spatial activity patterns among coastal bear populations. *Ursus* 10:539-549.
- McPhee, M.V., and T.P. Quinn. 1998. Factors affecting the duration of nest defense and reproductive lifespan of female sockeye salmon, *Oncorhynchus nerka*. *Environmental Biology of Fishes* 51:369-375.
- Olson, T.L. 1993. Resource partitioning among brown bears at Brooks River in Katmai National Park and Preserve, Alaska. M.S. Thesis, Utah State University, Logan. 159 pp.
- Olson, T.L., and B.K. Gilbert. 1994. Variable impacts of people on brown bear use of an Alaskan river. *International Conference on Bear Research and Management* 9(1):97-106.
- Olson, T. L., B.K. Gilbert, and S. Fitkin. 1990. Brown bear behavior and human activity at salmon streams in Katmai National Park, Alaska. Final Report. Natl. Park Serv. Contract No. IA 9700-7-8028. Utah State University, Logan: 123 pp.
- Olson, T. L., B.K. Gilbert, and R.C. Squibb. 1997. The effects of increasing human activity on brown bear use of an Alaskan River. *Biological Conservation* 82:95-99.
- Olson, T.L., R.C. Squibb, and B.K. Gilbert. 1998. Brown bear diurnal activity and human use: a comparison of two salmon streams. *Ursus* 10:547-555.

- Pritchard, G.T., and C.T. Robbins. 1990. Digestive and metabolic efficiencies of grizzly and black bears. *Canadian Journal of Zoology* 68: 1645-1651.
- Quinn, T.P., and G.B. Buck. 2000. Scavenging by brown bears, *Ursus arctos*, and glaucous-winged gulls, *Larus glaucescens*, on adult sockeye salmon, *Oncorhynchus nerka*. *Canadian Field Naturalist* 114:217-223.
- Reimchen, T.E. 1998. Diurnal and nocturnal behaviour of Black bear, *Ursus americanus*, on Moresby Island, British Columbia. *Canadian Field Naturalist* 112:446-450.
- Reinhart, D.P., and D.J. Mattson. 1990. Bear use of cutthroat trout spawning streams in Yellowstone National Park. *International Conference on Bear Research and Management* 8:343-350.
- Robbins, C. T. 1993. *Wildlife Feeding and Nutrition*. Academic Press, Inc., San Diego, Calif. 352 pp.
- Rode, K. D., C.T. Robbins, and L.A. Shipley. 2001. Constraints on herbivory by grizzly bears. *Oecologia* 128:62-71.
- Rogers, L. L. 1987. Effect of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. *Wildlife Monographs* 97:1-72.
- Ruggerone, G.T., R. Hanson, and D.E. Rogers. 2000. Selective predation by brown bears (*Ursus arctos*) foraging on spawning sockeye salmon (*Oncorhynchus nerka*). *Canadian Journal of Zoology* 78:974-981.
- Schoener, T.W. 1969. Models of optimal size for solitary predators. *American Naturalist* 103:277-313.
- Schindler, D.E., M.D. Scheuerell, J.W. Moore, S.M. Gende, T.B. Francis, and W.J. Palen. 2003. Pacific salmon and the ecology of coastal ecosystems. *Frontiers in Ecology and Environment* 1(1):31-37.
- Stephens, D.W., and J.R. Krebs. 1986. *Foraging Theory*. Princeton University Press, Princeton, N.J. 247 pp.
- Stillman, R.A., R.W. Caldrow, J.D. Goss-Custard, and M.J. Alexander. 2000. Individual variation in intake rate: the relative importance of foraging efficiency and dominance. *Journal of Animal Ecology* 69:484-493.
- Stringham, S. F. 1989. Black bear reproductive rate relative to body weight in hunted populations. *International Conference on Bear Research and Management* 8:425-432.

- Warner, S. H. 1987. Visitor impacts on brown bears, Admiralty Island, Alaska. *International Conference on Bear Research and Management* 7(3):377-382.
- Werner, E.E., and G.G. Mittlebach. 1981. Optimal foraging: field tests of diet choice and habitat switching. *American Zoologist* 1(4):813-829.
- White Jr., D., K.C. Kendall, and H.D. Picton. 1999. Potential energetic effects of mountain climbers on foraging grizzly bears. *Wildlife Society Bulletin* 27:146-151.
- Willson, M. F., and K.C. Halupka, K.C. 1995. Anadromous fish as keystone species in vertebrate communities. *Conservation Biology* 9(3):489-497.
- Wilmers, C.C and D.R. Stahler. 2002. Constraints on active-consumption rates in gray wolves, coyotes, and grizzly bears. *Canadian Journal of Zoology* 80:1256-1261.
- Zar, J. H. 1999. *Biostatistical Analysis*, Fourth Edition. Prentice-Hall, Saddle River, N.J. 931 pp.

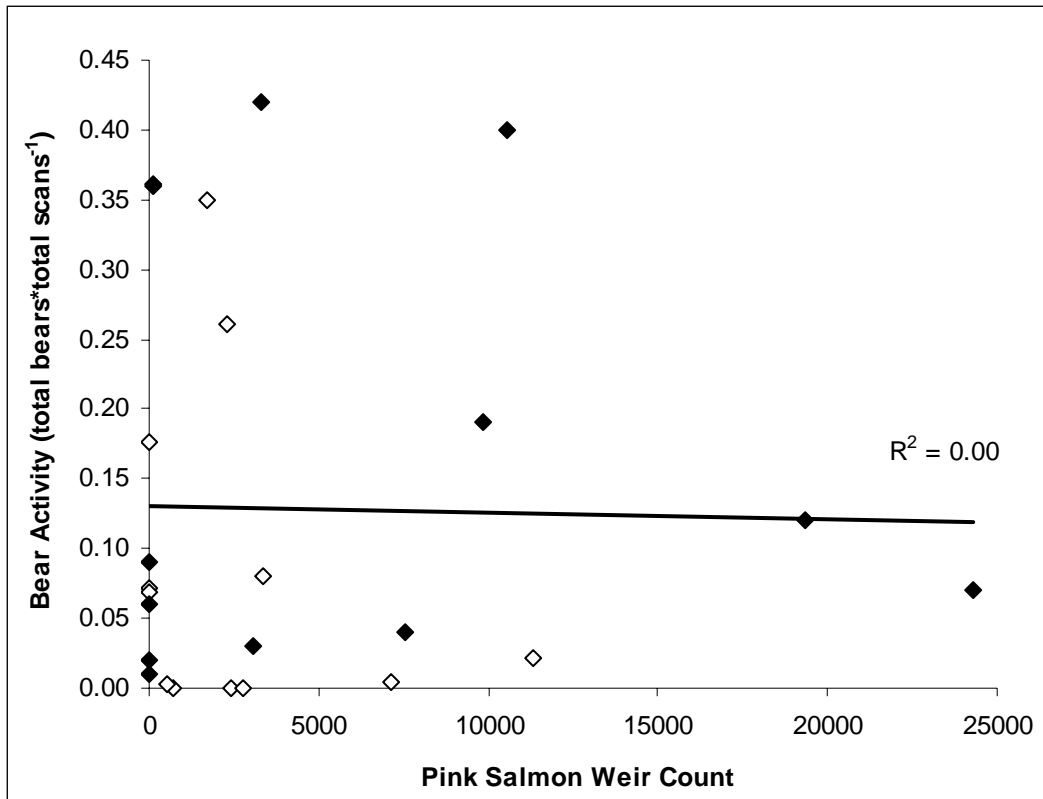


Figure 4-2. Relationship between brown bear activity and pink salmon run timing. Hollow diamonds represent individual weeks 2001, solid diamonds 2002.

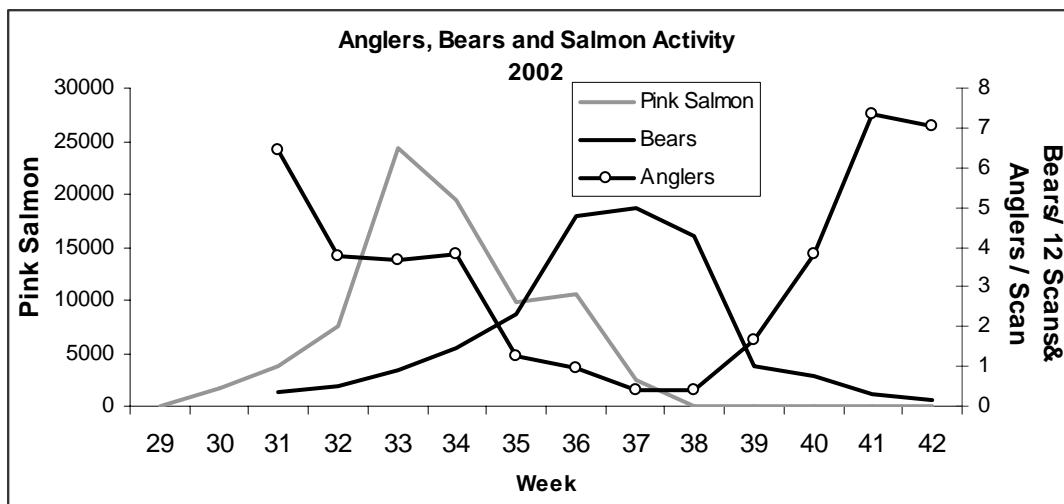
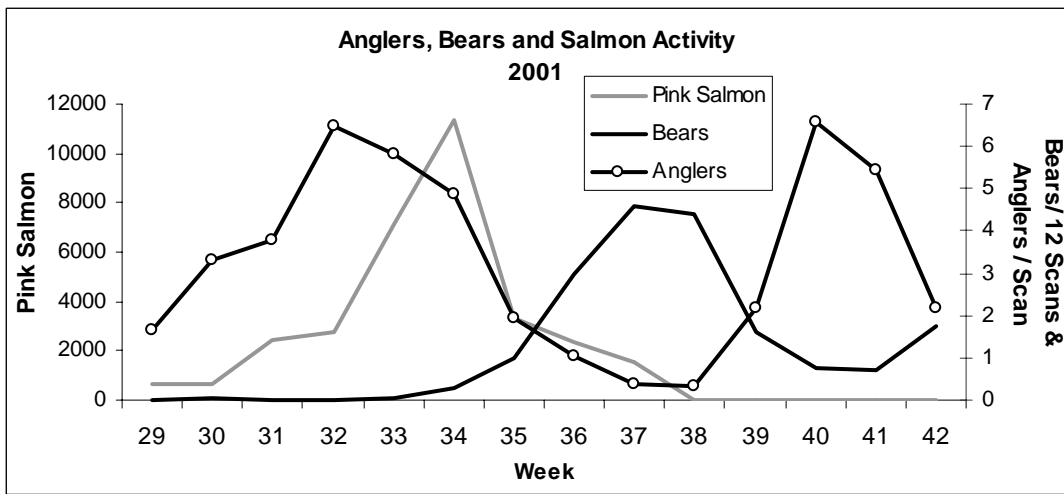
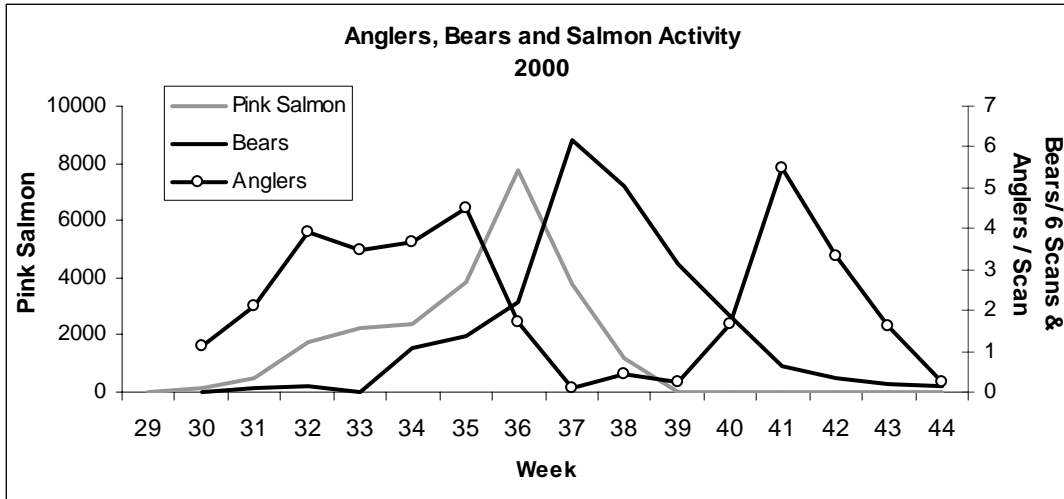


Figure 4-3. Annual patterns of bear activity in relation to pink salmon run timing and angler activity. Note changes in scale.

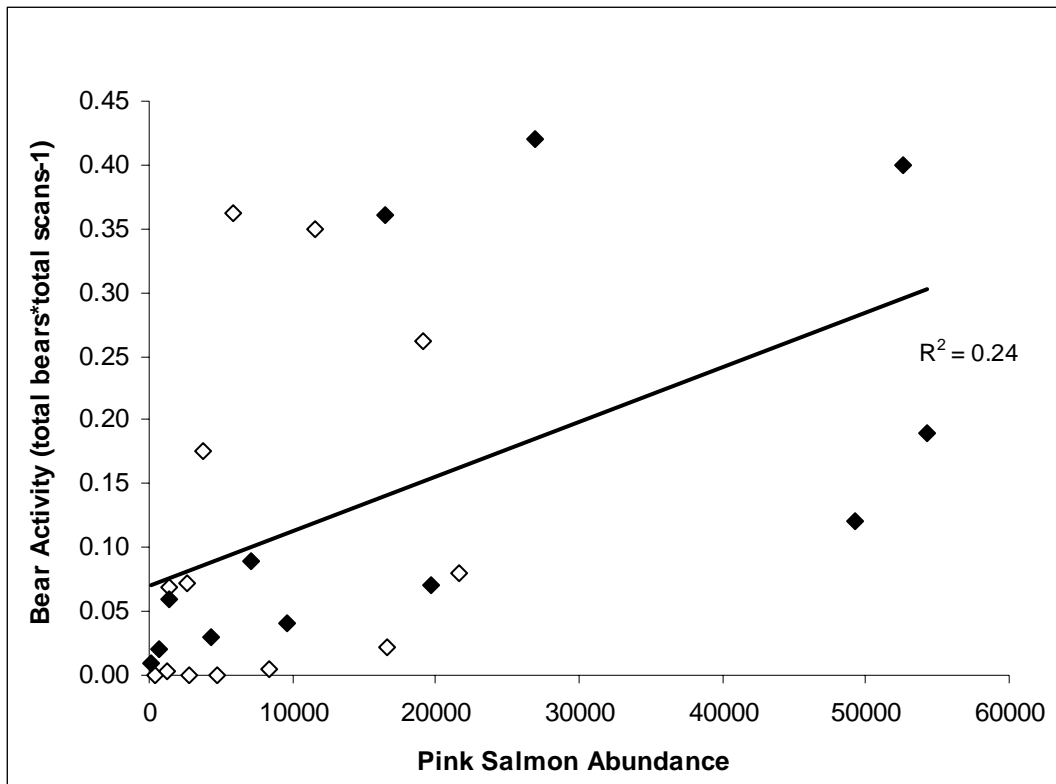


Figure 4-4. Relationship between brown bear activity and pink salmon abundance. Abundance includes average weekly salmon, both live and senesced, available for 20 days after passing through the weir. Hollow diamonds represent individual weeks 2001, solid diamonds 2002.

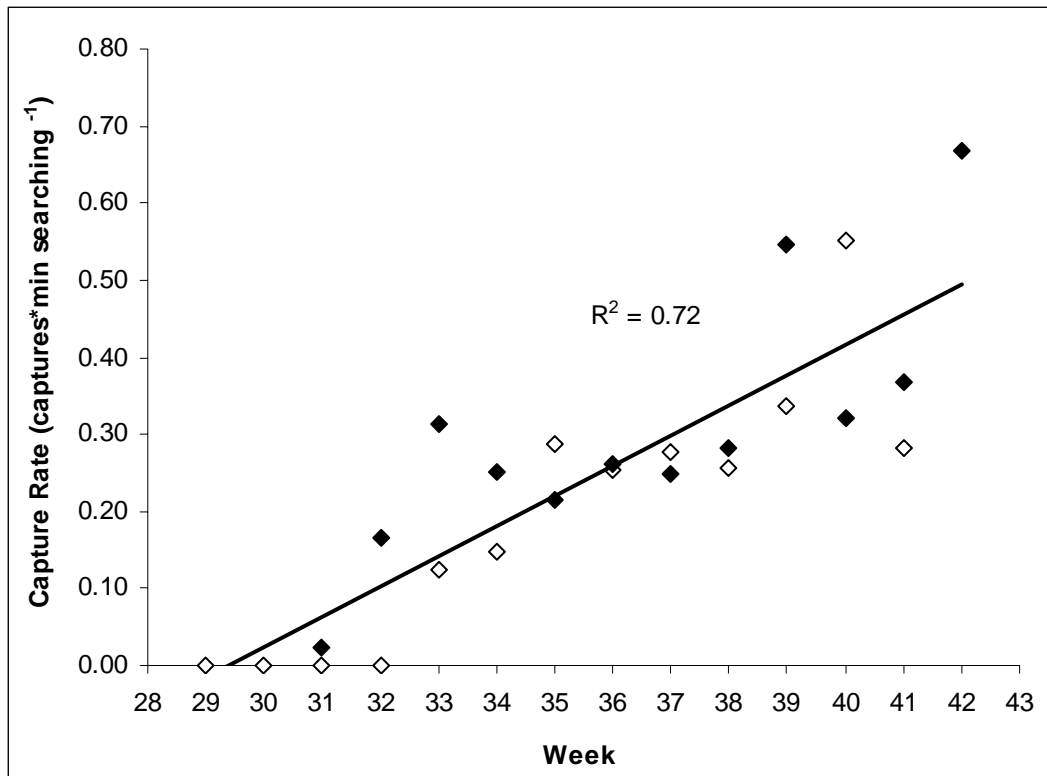


Figure 4-5. Weekly trend in brown bear capture rate throughout the study period. Hollow diamonds 2001, solid diamonds 2002.

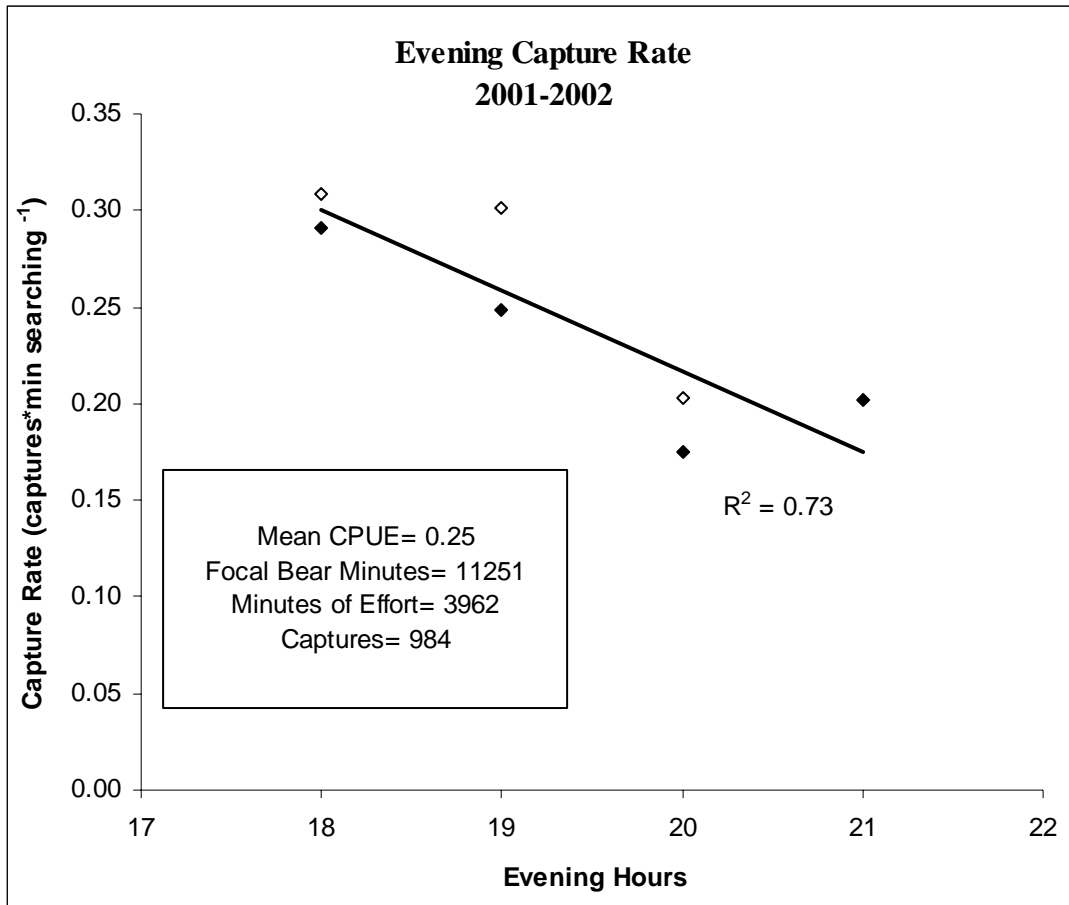


Figure 4-6. Capture rate trends during evening hours. Bears consistently catch salmon at higher rates relative to the amount of available daylight. Hollow diamonds 2001, solid diamonds 2002.

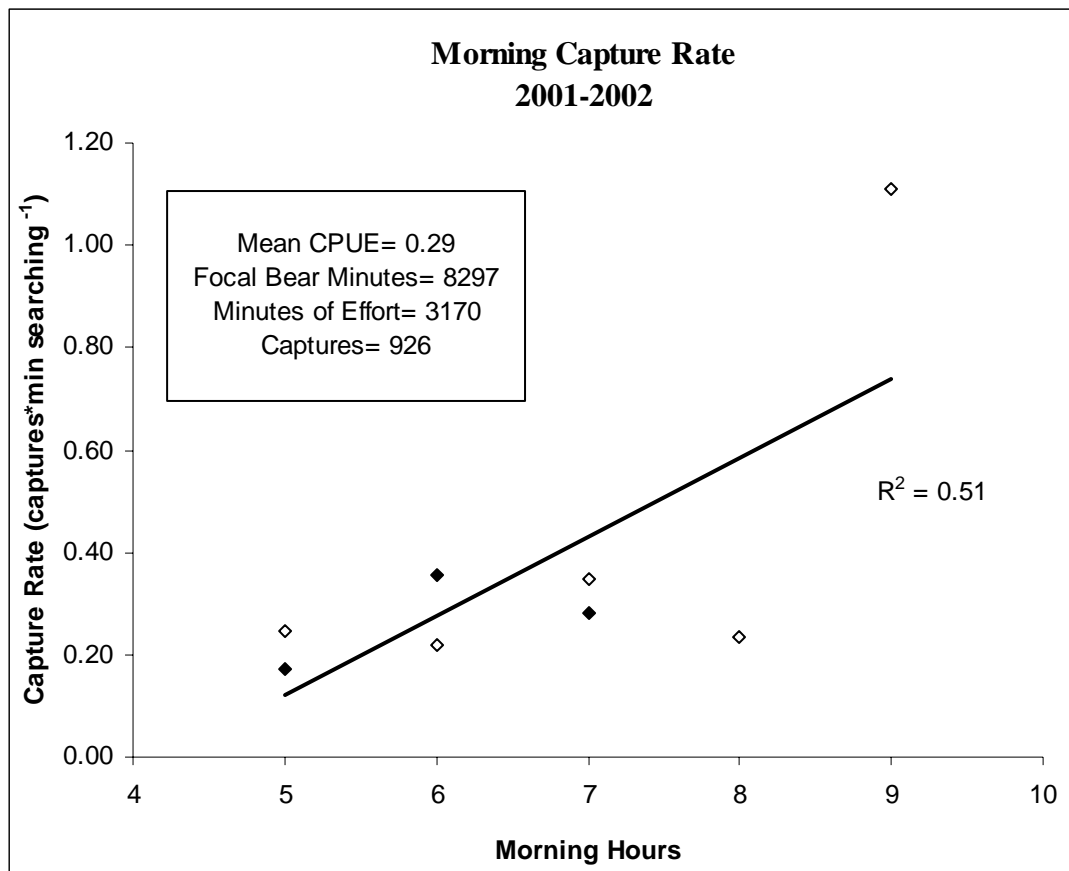


Figure 4-7. Capture rate trends during morning hours. Bears consistently catch salmon at higher rates relative to the amount of available daylight. Hollow diamonds 2001, solid diamonds 2002.

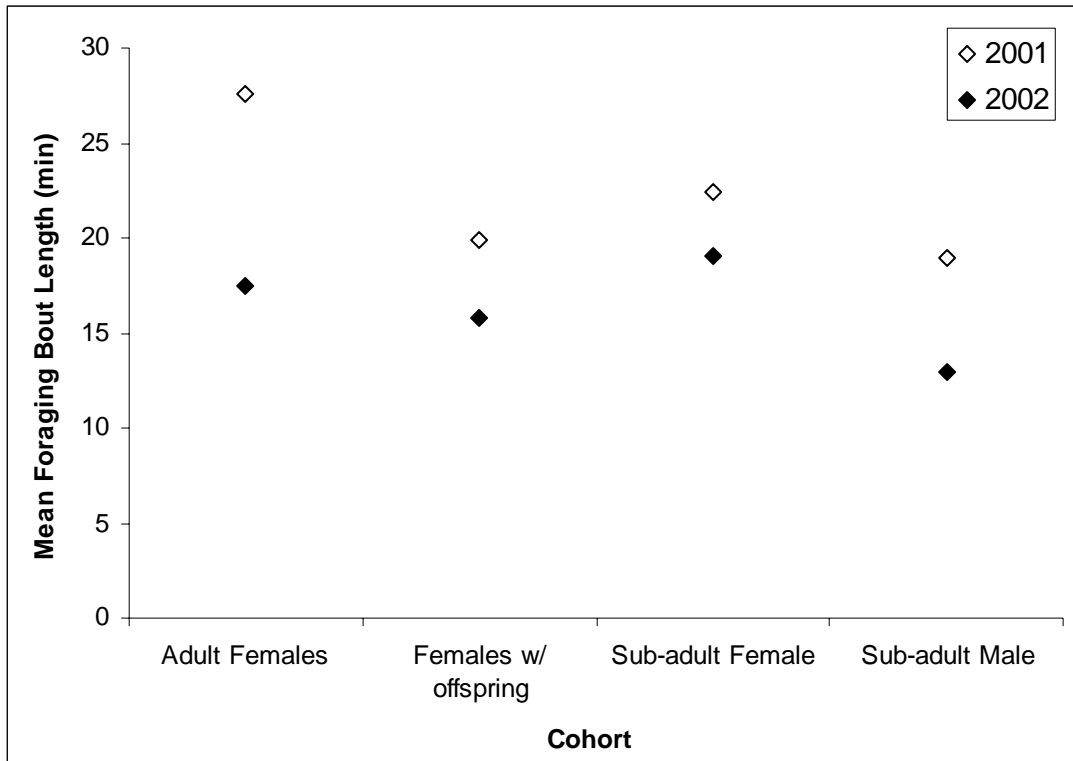


Figure 4-8. Mean foraging bout length between cohorts for 2001-2002.

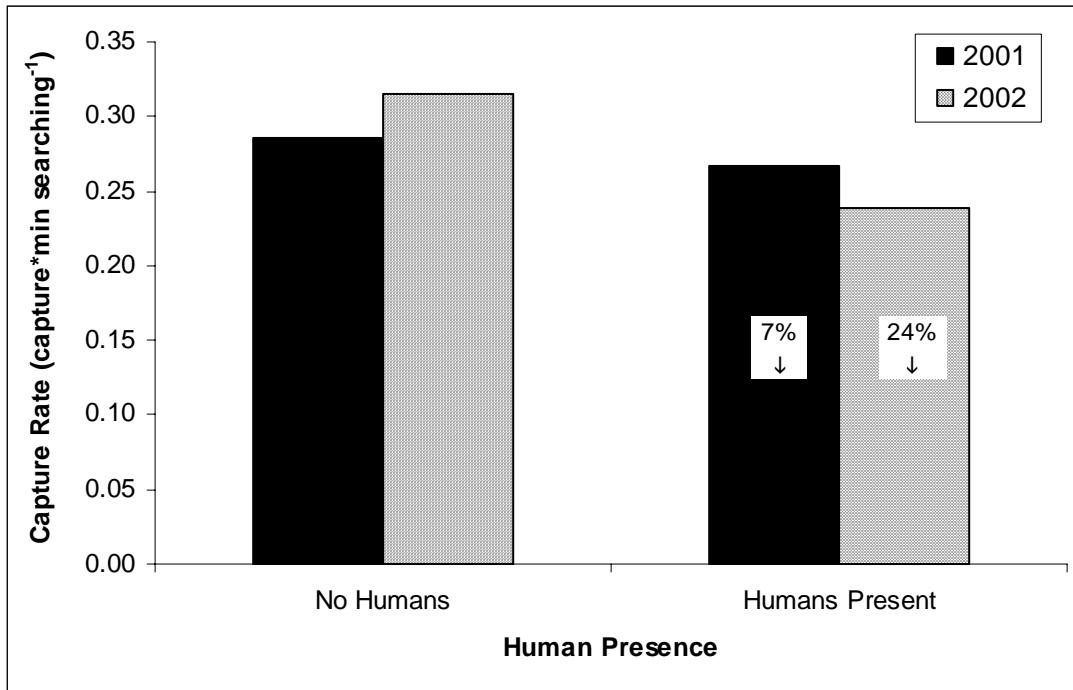


Figure 4-9. Effect of human presence on brown bear capture rate.

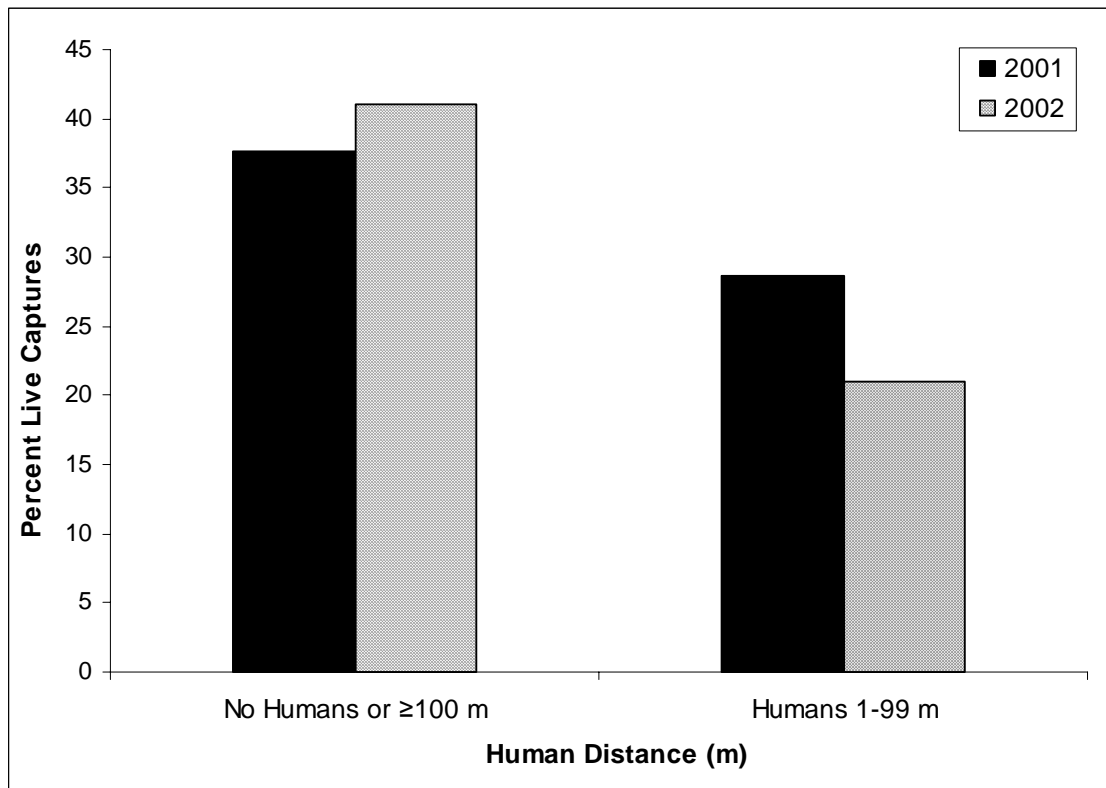


Figure 4-10. Proportion of live fish captured increased 74% when humans absent or greater than 100 meters from bear activity.

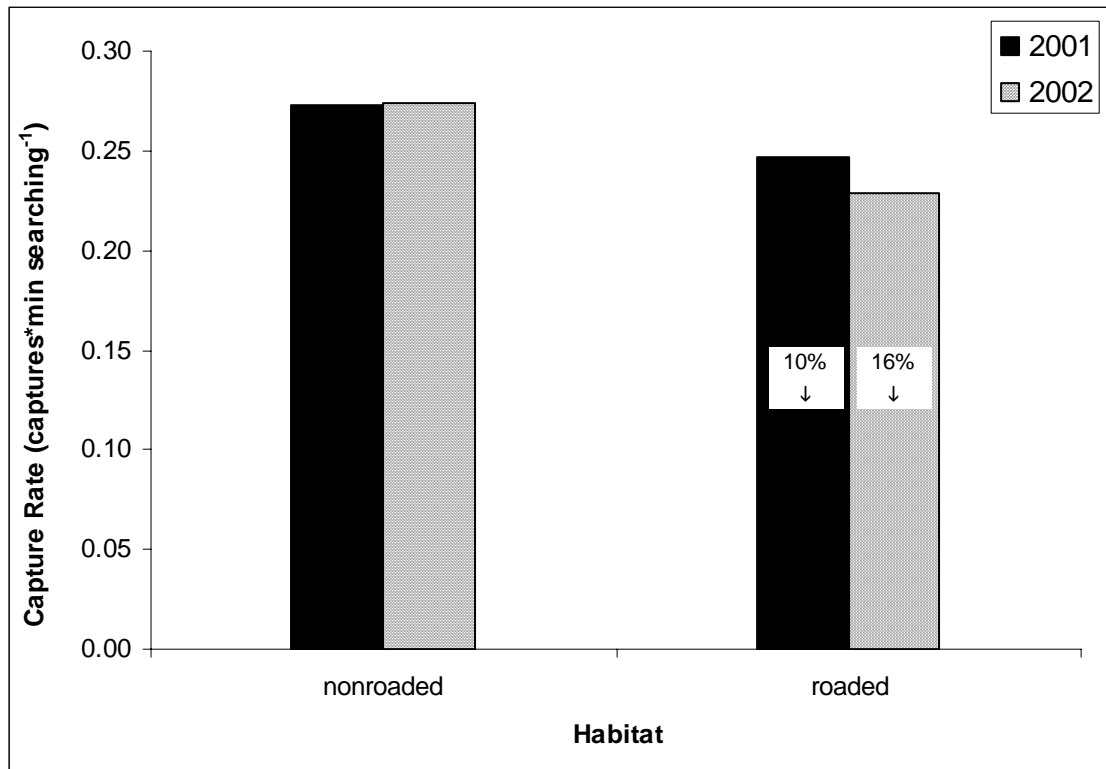


Figure 4-11. Comparison of brown bear capture rate when fishing on roaded habitat side of the river versus nonroaded riparian and estuarine habitat.

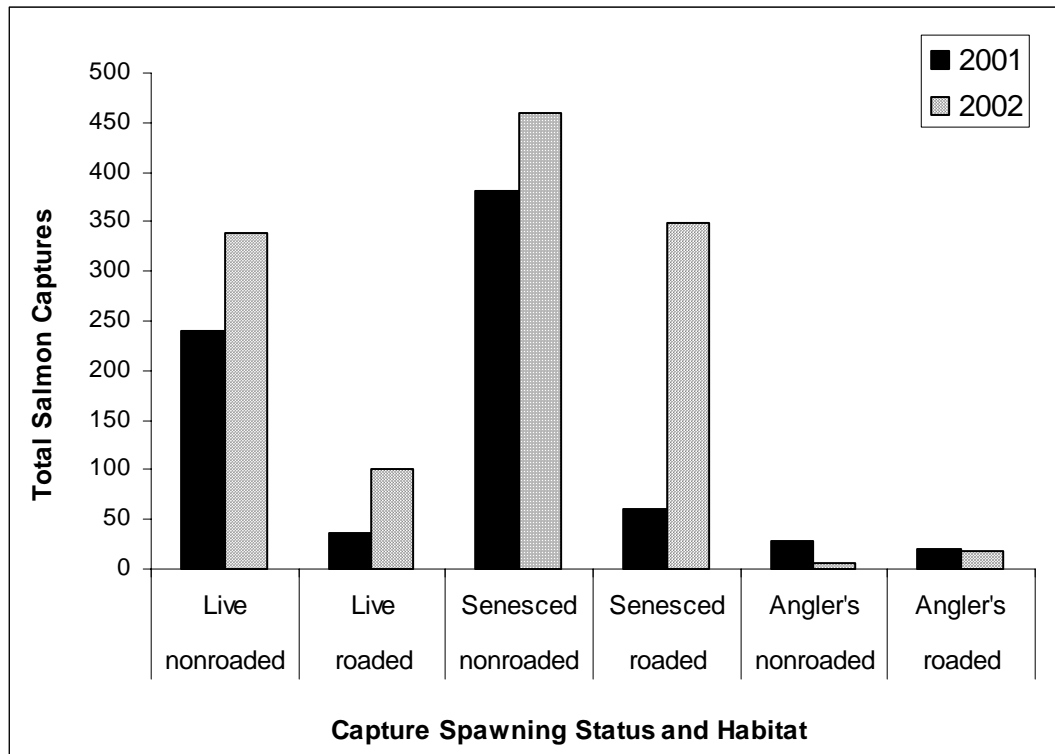


Figure 4-12. Brown bear captures according to salmon spawning status and habitat in which captured.

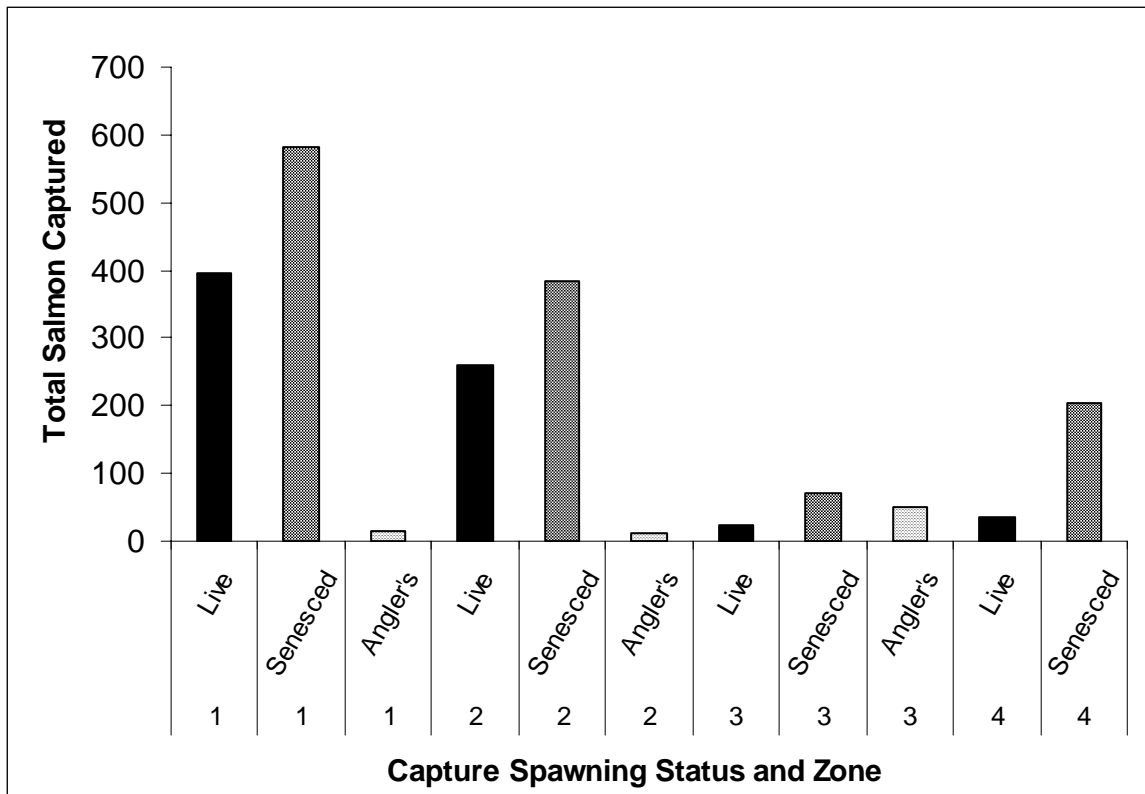


Figure 4-13. Brown bear captures of live, senesced, and angler caught salmon according to observation zone 2001-2002.

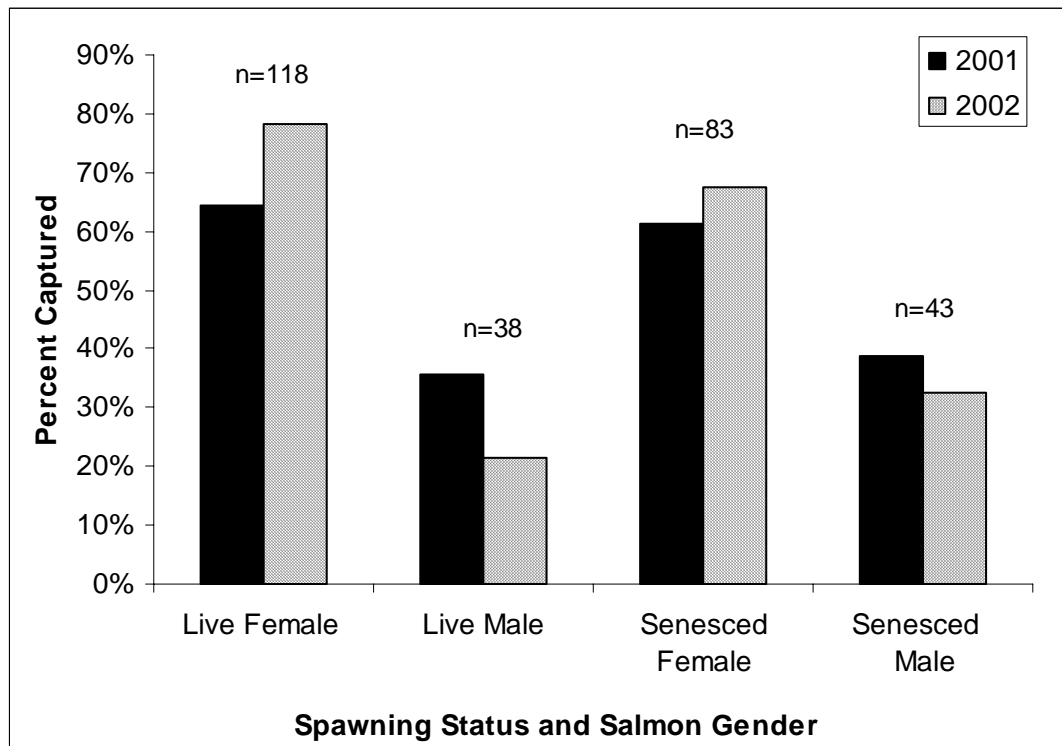


Figure 4-14. Spawning status and salmon gender of brown bear captures.

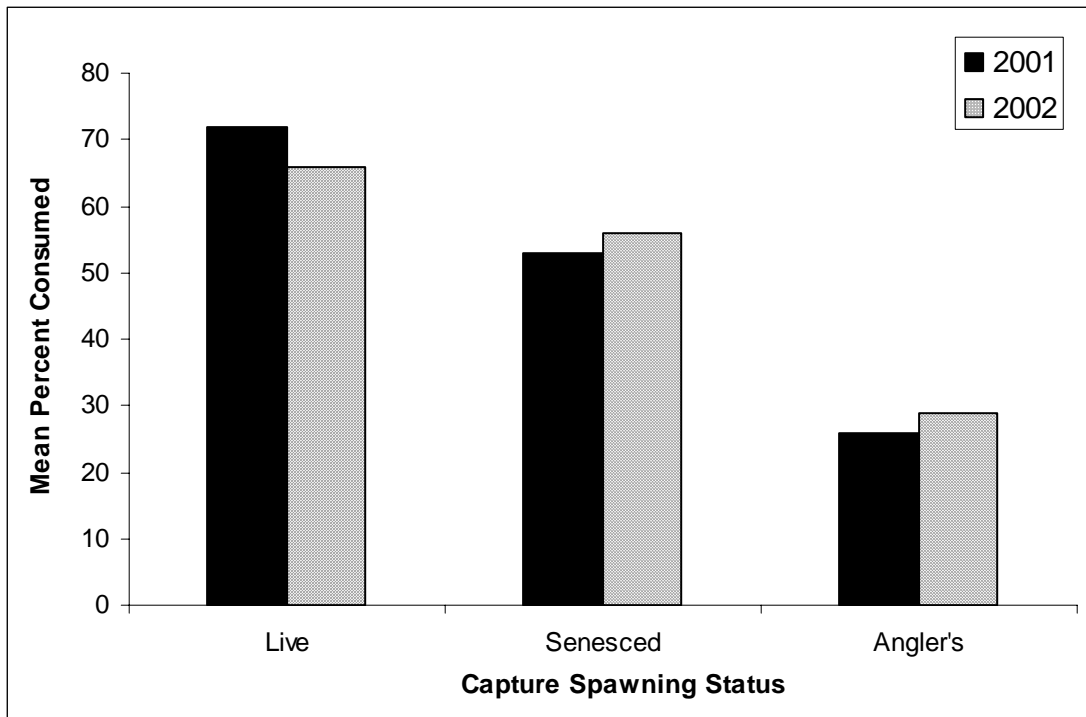


Figure 4-15. Selective consumption of salmon captured by brown bears according to salmon spawning status.

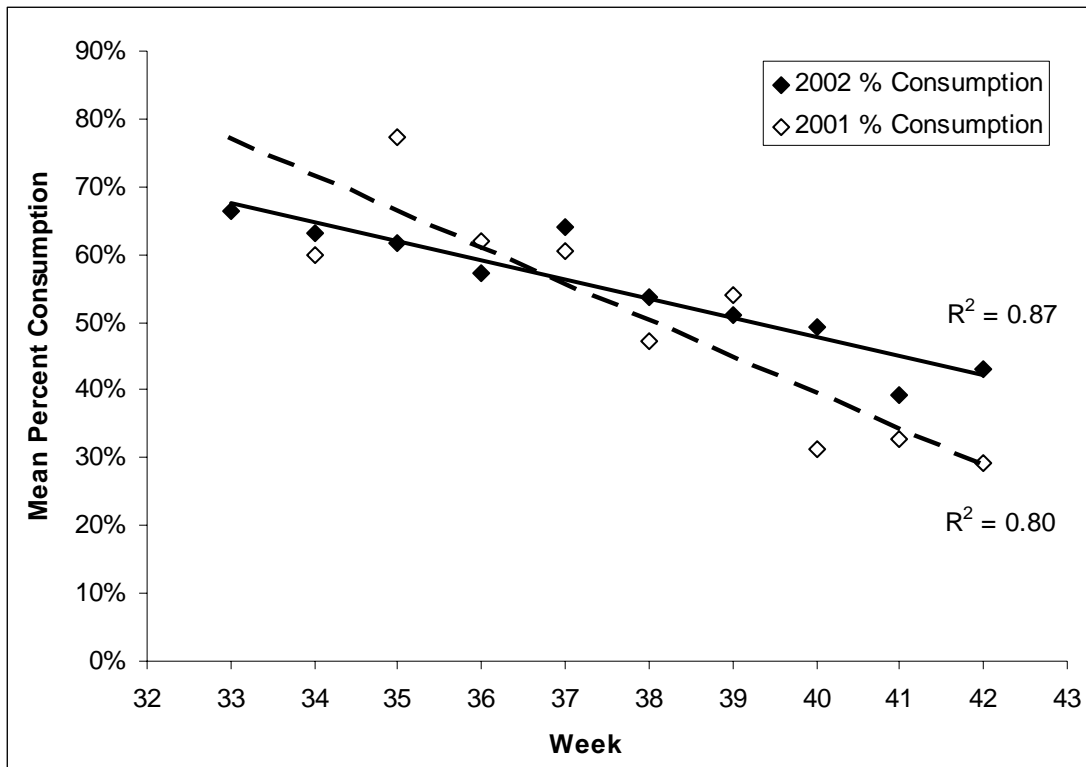


Figure 4-16. Mean percentage of salmon consumed by brown bears over time.

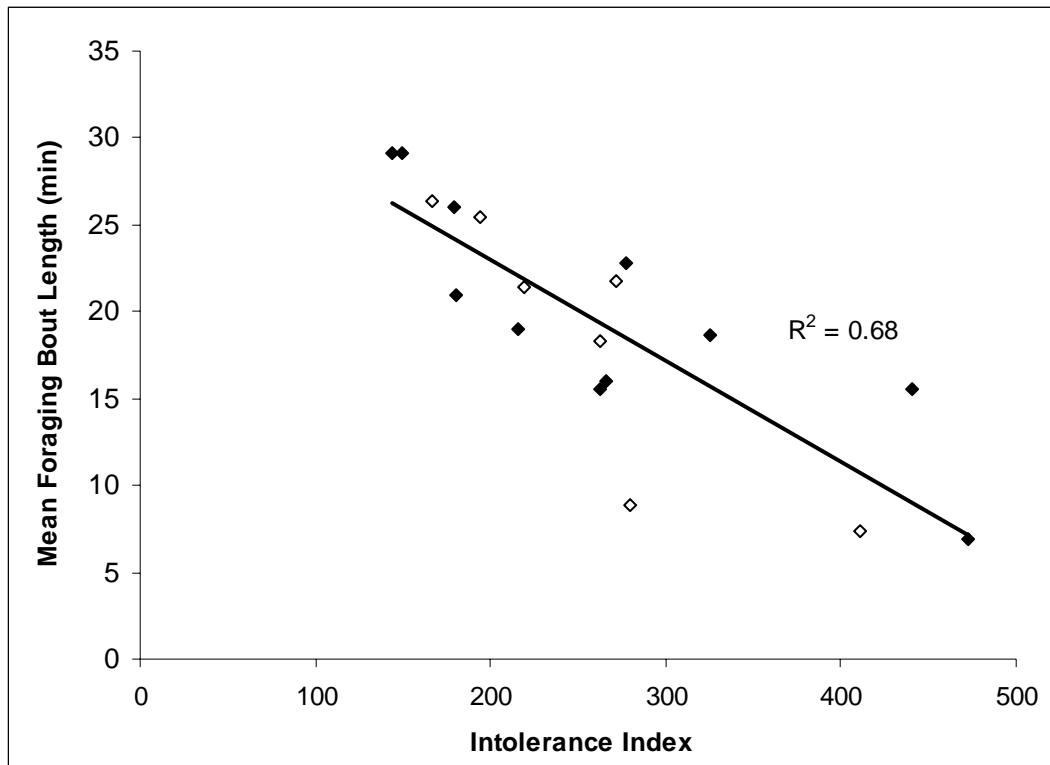


Figure 4-17. Bear tolerance for human proximity in relation to foraging bout length. Hollow diamonds represent individual bears in 2001, solid diamonds 2002.

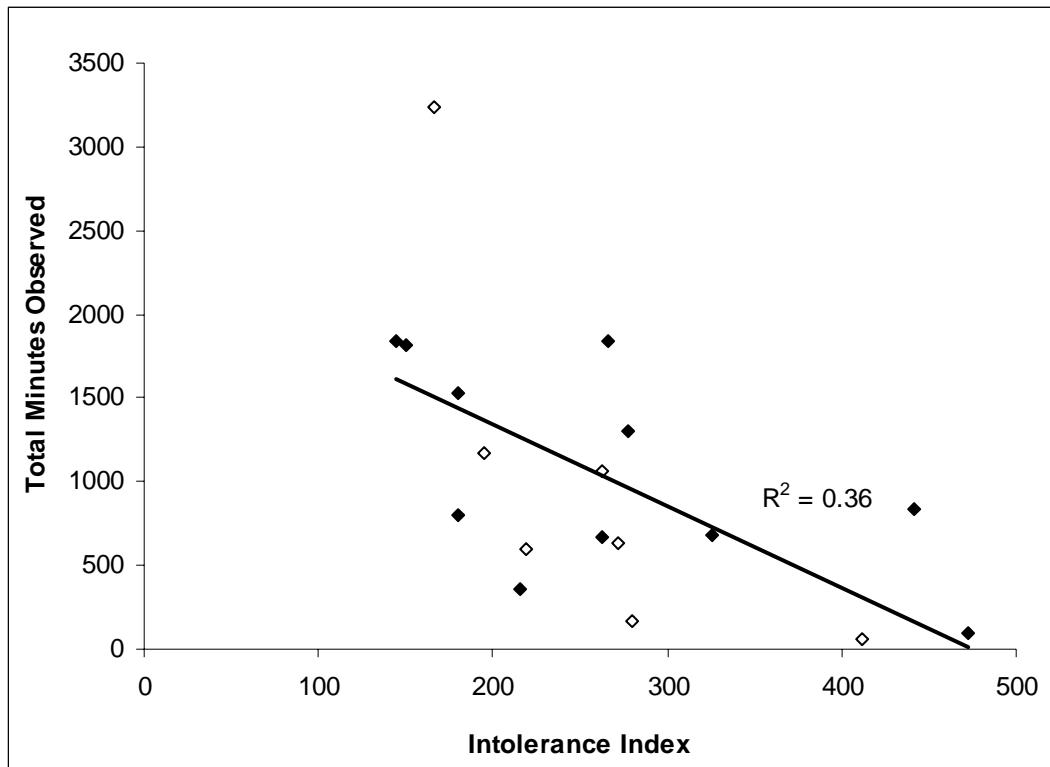


Figure 4-18. Bear tolerance for human proximity relative to total time observed. Hollow diamonds represent individual bears in 2001, solid diamonds 2002.

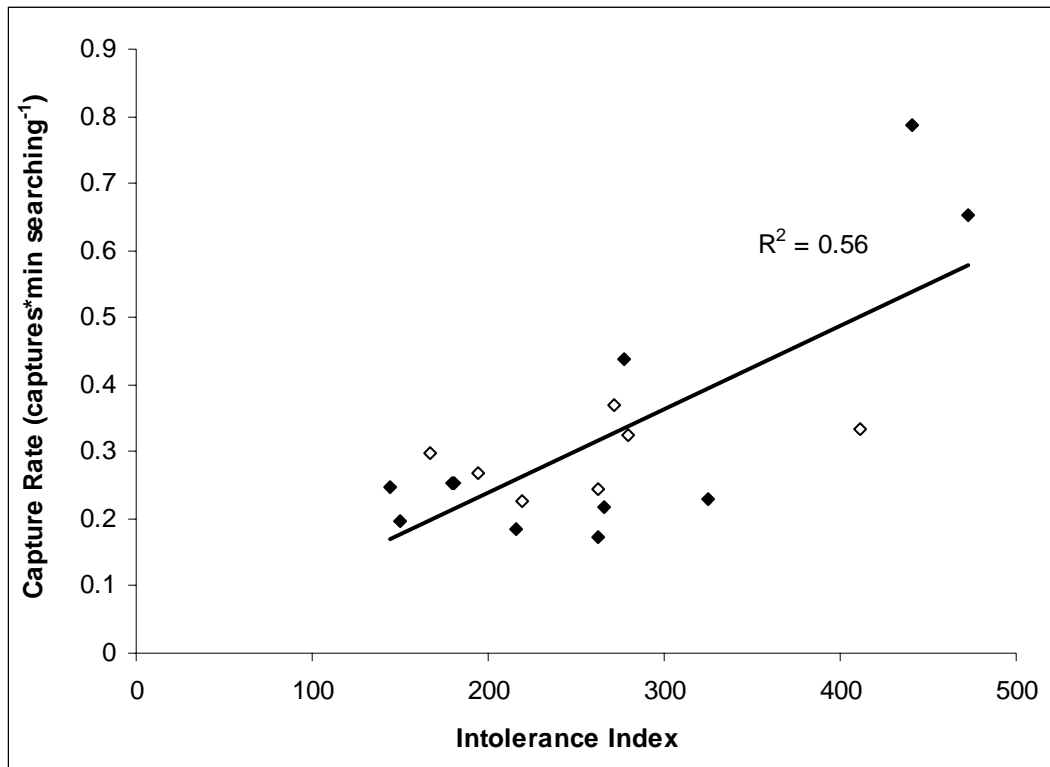


Figure 4-19. Bear tolerance for human proximity in relation to capture rate, the number of salmon captured per minute spent fishing. Hollow diamonds represent individual bears in 2001, solid diamonds 2002.

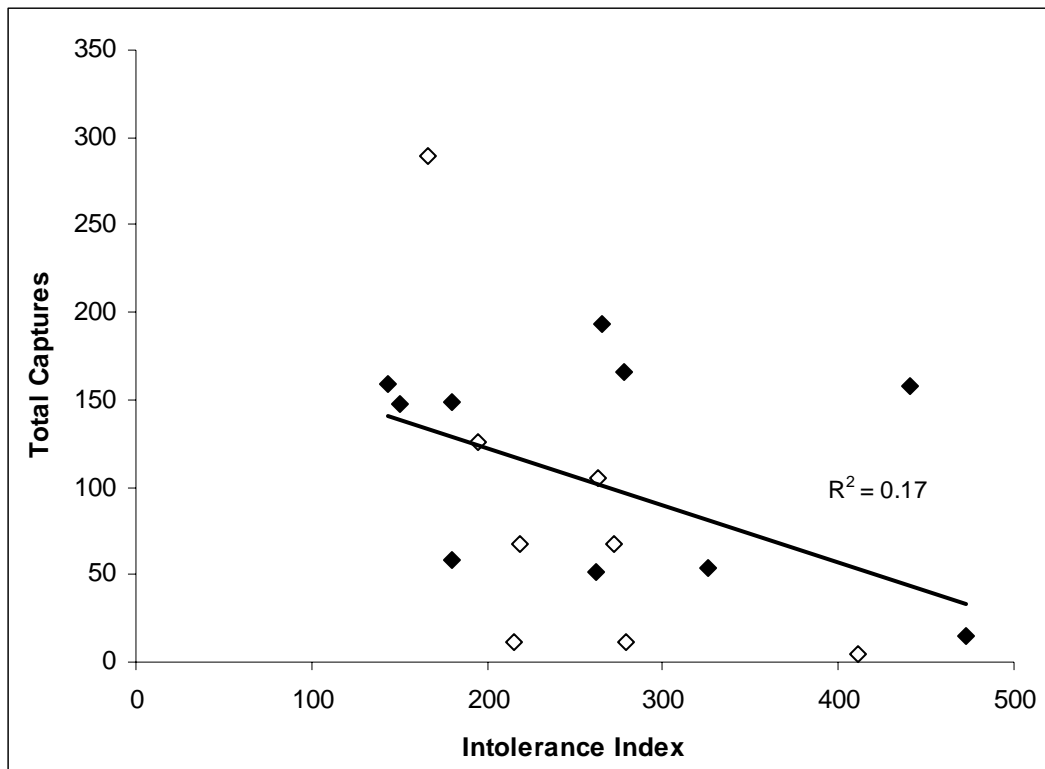


Figure 4-20. Relationship between bear tolerance for human proximity and the number of salmon captured. Hollow diamonds represent individual bears in 2001, solid diamonds 2002.

CHAPTER 5

SUMMARY

This thesis examined the diurnal, seasonal, spatial, and immediate influences of human recreational activity and salmon abundance on brown bears at the Chilkoot River in southeast Alaska. Bears responded to human recreation, particularly angler activity, at both diurnal and seasonal scales, more than to salmon abundance. Nearly every attribute of bear activity and foraging behavior was influenced by human activity. Increases in anglers, non-guided tourists and vehicles consistently impacted bear activity despite substantial increases in salmon. Bear activity on a daily basis showed an inverse pattern to human activity. As vehicle traffic increased in the morning, adult females departed the river first, followed by subadult bears, and neither returned until later in the evening. Seasonally, bears were most active and spent the longest periods of time fishing when the numbers of anglers and vehicles were below threshold levels. The expectation that bear activity, capture rates and foraging bout lengths would be closely tied to salmon run timing was not supported. Bears' access to live salmon was delayed, well after the peak of the return, and consequently bears realized significant losses of energy and nutrition.

This study of immediate brown bear responses to human disturbance revealed a consistent relationship between bear behavior and human proximity. Bear activity was 40% greater when humans were absent and bears were frequently displaced by people and vehicles. Overall, human disturbance (people and vehicles) accounted for 46% of bear departures with a mean flight distance of 97 meters. We then considered

this in combination with traditional set-back distances and assessed bear foraging behaviors. When humans were absent or at distances beyond 100 meters from bears, they (1) spent more time on the river, (2) captured fish at higher rates, (3) captured 2.65 times as many fish, and (4) caught greater proportions of live fish (71%).

This study also related bear foraging success to individual tolerance of human proximity. Differences in bears tolerance for human proximity explained variation in capture rates, foraging bout length, and number of salmon captures. Less tolerant individuals captured more fish per minute spent fishing but their wariness amounted to less time on the river, resulted in fewer fishing trips, and ultimately fewer fish captures. Bears exhibiting more tolerance for humans at closer distances were more likely to spend longer foraging bouts and captured more fish. This suggests energetic rewards for bears capable of adapting to human disturbance.

Consistent with energy maximization, bears were selective in capture and consumption of prey. All bear cohorts preferentially captured female salmon, both live and senesced, over male salmon, as female salmon offer greater energetic rewards. Amount of each fish consumed was not sex biased, however consumption did relate to spawning status, as greater proportions of live fish (67%) were consumed than senescent fish (55%). However, bears were typically relegated to capturing senescent fish (61%) with lower energy content, likely because access to peak run timing was delayed by human activity. While I expected bears to consume more of each fish as they approached denning, consumption actually decreased with less than 50% of each fish consumed at the end of the season.

Can bears and recreationists coexist? The data suggest that bears are strongly influenced by increased levels of human recreation. If human activity continues to expand and infringe upon the windows of opportunity currently available to bears, then decreased bear activity and population productivity can be expected. The need for implementing well-designed user guidelines in conjunction with strategic spatial and temporal restrictions of human activity is apparent. If bears were allowed to exploit more productive morning and evening periods, managers could permit high levels of human use during other periods and minimize the impact of decreased accessibility to bears. Future years of decreased salmon abundance will potentially exacerbate the need for such restrictions.

In view of the decrease in live fish captured when humans were near bears, and the associated energetic cost, I suggest two management alternatives. To obtain full use of habitat, brown bears need predictable foraging opportunities during the most productive foraging hours, particularly at the peak of the pink salmon return. Limiting human access during the hours near dawn and dusk, while enforcing no-trespassing regulations on the non-roaded side of the river would positively impact levels of bear activity and foraging success. An alternative approach supported by the data, would be to limit numbers of people to year 2000 levels and better manage the distance between people and bears. These management options would facilitate continued recreation opportunities and allow brown bears to spend less time avoiding human activities, thereby ensuring a safe, sustainable and high quality bear viewing program which serves to benefit the local economy.

These analyses depict clear relationships with simple interpretation of the dynamic interactions between people, bears and their environment. This investigation and analysis provide the scientific data needed to greatly improve human safety and resource protection, and management now resides in the hands of state and local agencies.

APPENDIX

SCAN DATA KEY

<p>Scan Sampling</p> <p>Every 15 min on the ¼ hour, scan the entire zone for two minutes keeping note of the following information. If following a focal animal take a quick scan but not as to lose focal animal.</p>
<p># Bears Present in Zone</p> <p>Enter the total number of independent bears counted in the zone during the scan.</p>
<p>Classification of Humans and Quantity</p> <p>1- Official/Agency Personnel/Monitor 2- Angler/ Angler East 3- Guided visitors 4- Non-guided visitors 5- Other</p>
<p>Human Behavior Sampling</p> <p>1- Quietly observing with minimum movement 2- Loud disturbance with minimum movement 3- Quietly observing but excessive movement 4- Loud disturbance and excessive movement 5- Approaching bears within 25 meters 6- Fishing 7- Passing by in moving vehicle 8- Passengers in parked vehicle</p>
<p>Vehicles</p> <p>Count the number of vehicles that are both stopped in the zone and moving through the zone. The number of people in each vehicle category is recorded according to human classification. At the bottom of datasheet, keep track of vehicles and tours per hour and total them at the end. Also track overnights and coolers.</p>
<p>Human Behavior</p> <p>0- No humans 1- Low impacting, quiet respectful groups 2- Mixed interaction, could be disturbing to bears 3- High Impact</p>
<p>Human Distribution</p> <p>0- No humans 1- Tightly organized groups remaining in the vicinity of their vehicle 2- Mixed 3- Spread out configuration of humans within each group and overall</p>

FOCAL BEAR BEHAVIOR KEY

Category	Behavior	Description / Context	
1- Feeding/Foraging	11- Pursuit for Food	Indicates one or more of the following behaviors. Useful when specific feeding behavior not easily distinguished. Actively seeking following food types. Includes locomotion.	
	12- Grasses/Sedges	Ingestion of herbaceous material, ie. sedges, veg, roots, tubers. Not to be confused with scavenging carcasses on the bank.	
	13- Berries	High-bush cranberries, salmonberries, thimbleberries, blueberries, rosehips, gooseberries, raspberries, wild strawberries, devil's club.	
	14- Live Fish	Capture and consumption of living fish. Refer to Capture Key.	
	15- Dead Fish	Capture and consumption of expired fish. Refer to Capture Key.	
	16- Human Food	Consumption of abandoned human food items.	
	17- Angler's Fish	Consumption of fish or entrails procured by angler.	
	2- Non-Interactive		Walking without interest in pursuing food. Running to or from no apparent stimulus. River crossing while not actively pursuing fish.
3- Bear Interaction	31- Alert/Vigilance	Interaction between individuals is evident but behavior uncertain. Looking and/or sniffing intently towards another bear.	
	32- Playing	Non-agonistic amicable behavior, includes wrestling, chasing, etc.	
	33- Sharing Food	Fish caught by one indiv. consumed by more than 1 in close prox.	
	34- Fighting	Agonistic interaction with or without vocalization.	
	35- Defense	Active or passive deferral to aggressor, retreat or standing ground.	
4- Human Interaction	41- Alert/Vigilance	Interaction with humans is evident but behavior uncertain. Looking and/or sniffing intently toward humans or vehicle.	
	42- Retreat from Human Presence	Active increase of distance away from stimulus in response to humans or vehicles.	
	43- Approach by Hx	Human actively approaches bear within 25 meters.	
	44- Bx approaches Hx	Bear approaches human in either passive or aggressive manner.	
5- Other		For activities that do not conform to the above list. May include interactions with other animals or inanimate objects.	
6- Summary		Focal observation entries begin with a summary. Brief overview of bear's activity described in comments. Approximate mean distance to people, 0 if no Hx or Vx present. Indicate access routes. Used to calculate foraging bout length. If bear captures fish and escapes to forest cover to consume then reappears, entered as two separate summaries.	
EXIT STIMULUS		AGE/GENDER CLASSIFICATION	
0- Uncertain	5- Human Presence	0- Uncertain	5- Sub-adult, undetermined sex
1- No Stimulus/Own Accord	6- Present at Trial End	1- Adult, undetermined sex	6- Sub-adult, female
2- Other Bear	7- Other	2- Adult, single female	7- Sub-adult, male
3- Vx Passing	8- Present at Activity End	3- Adult, male	8- Cub with mother
4- Vx Density		4- Sow with offspring	
EXIT CERTAINTY			
0- Uncertain	1- Potential	2- Certain	

CAPTURE DATA KEY

Capture Data	Description
1- Feeding/Foraging 14- Live Fish 15- Dead Fish	Useful when specific feeding behavior not easily distinguished. Capture and consumption of living fish. Time used to compute consumption rates. Capture and consumption of expired fish. Capture total used to calculate CPUE.
Fish Consumption	
0 0.25 0.5 0.75 1 -1 -2 C+R TO GO	Minimal ingestion. Typically includes one of the following parts: brain, skin, belly, tail, angler entrails. Greater than one of the parts: brain, skin, belly, tail, body meat. Majority of the fish consumed: brain, skin, belly, tail, body meat. Entire fish consumed, not including viscerals or gill plates. See TO GO. Unknown amount of fish consumed but not yet verified with video record. Unknown amount of fish consumed after verified with video record. Catch and release. Entered in comments of pursuit for food entry. Fast-food take-out sushi bar. Entered in comments with # Fish = 1.
Salmon Gender	
U- Unknown (0) M- Male (1) F- Female (2)	Gender of fish uncertain. Fish identified as male through observation of pronounced hump or gametes. Fish identified as female through observation of gametes.
Location	
Refer to list of GPS locations. Enter with identical characters.	
Capture Method	
Orientation 1 Standing 2 Sitting 3 Walking	Minimal movement prior to approach and capture, not bipedal. On haunches, most commonly at weir. Locomotion while fishing.
Approach A Loping B Plunge C Snorkel D Pick E Pin	Increased speed over normal gait, typically in shallow water. Sudden rapid movement. Similar to pin but speed associated with this approach. Moving through water with eyes submerged. Captures dead or slow moving fish by picking it up with mouth and/or forepaws. Traps fish from escape by holding against rock, bank, or weir.
Capture a Forepaws b Forepaws+ Mouth c Mouth d Forepaw (1) e Forepaw + Mouth	Both forepaws used to catch fish and then fish brought to mouth to eat. Both forepaws used in conjunction with mouth to catch fish, not including eating. Mouth used as a capture implement not just for consumption. One forepaw used to catch fish. One forepaw used in conjunction with mouth to catch fish, not including eating.
Example 3Be 3Dd 3Ab	While walking, bear rapidly pounces onto live fish with one forepaw and mouth. While slowly traversing the weir, bear picks a carcass out with one forepaw. Running search through shallow water before capturing fish with forepaws+mouth.

