COOK INLET BELUGA WHALE POPULATION DECLINE AND RECOVERY: AN EXPLORATION THROUGH LOCAL ECOLOGICAL KNOWLEDGE

by

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Abstract

This study documents local ecological knowledge from Alaska Natives and non-indigenous participants to explore contributing factors for the endangered Cook Inlet beluga whale (*Delphinapterus leucas*) population decline and lack of recovery. Data were collected through 16 semi-structured interviews with key informants from the region using participatory techniques and analyzed for convergent information. Local knowledge was compared with existing scientific research to explore similarities and differences. Findings identified noticeable beluga whale declines beginning in the mid-1980s, shark and northern pike population increases, higher frequency of killer whale sightings, decreased salmon numbers and increased siltation and mudflat expansion all in association with beluga whale habitat. Additional findings of terrestrial plant, animal and insect change and wetland drying suggest broader environmental and climate related changes. These findings contribute to conservation objectives outlined NMFS's conservation plan and provide direction to future research and conservation management.

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CHAPTER ONE

Introduction

The Cook Inlet beluga whale (*Delphinapterus leucas*) is one of five Alaskan stocks, genetically distinct and geographically isolated from the other four populations. This population was hunted commercially, for sport and for subsistence uses (Huntington 2000; Mahoney and Shelden 2000; NMFS 2008) until the passage of the Marine Mammal Protection Act (MMPA) in 1972 which ended commercial and sport hunting. Subsistence hunting by Alaska Natives within the Cook Inlet watershed continued until 1999.

In 2000 the National Marine Fisheries Services (NMFS) determined the population had declined by 47% between 1994 and 1998, resulting in a listing of “depleted” under the MMPA. In 2008 the Cook Inlet beluga whales were listed as endangered after their recovery rate was did meet expectations. Uncertainty about the factors impacting the whales and their population abundance from the 1980’s to the early 1990’s indicated a need for further research to better understand this population and their associated ecosystem.

This study documents local ecological knowledge from Alaska Natives and non-indigenous knowledge holders to explore possible contributing factors for the Cook Inlet beluga whales’ (*Delphinapterus leucas*) population decline and recovery. For the purposes of this study the knowledge utilized is defined as a cumulative body of current knowledge and understanding of a given environment acquired through extensive experience and observation of an area and its associated processes and species spanning an individual's lifetime. This knowledge was compared and contrasted with published scientific research to examine areas that may open new directions for research. Data were collected through semi-structured group and individual interviews with key informants from communities around Cook Inlet using participatory mapping and timeline exercises to facilitate discussions. These data were then analyzed for overlapping information through triangulation across groups to capture a range of knowledge from community to community and assess trustworthiness.

Findings indicated noticeable beluga whale population declines and distributional shifts northwards beginning in the mid-1980's, increases in shark and northern pike (*Esox lucius*) populations in both the central and upper inlet beginning in the early to mid-1990's, higher frequency of killer whale (*Orcinus orca*) sightings in the upper inlet since the early 1990's, decreases in razor clam (*Siliqua patula*) populations and size in the central inlet, decreased northern district salmon numbers and increased siltation and mudflat expansion in the upper inlet all in association with beluga whale use areas. Additional findings suggest broader environmental change through observations of terrestrial plant and animal change and wetland drying on the Kenai Peninsula and the Susitna River drainage which may be indicators of climate change related regime shifts.

The subsequent chapters will outline the current research and knowledge of the Cook Inlet beluga whales, this study's purpose, methods and analysis, the study's findings and conclusions. Chapter two includes the historic human use of the whales, previous and current population abundance, and understanding of the whales' ecology, an explanation of traditional and local ecological knowledge, its uses and benefits and this study's purpose and objectives. Chapter three details the methods and data analysis employed in this study. Chapters four and five, written and formatted as standalone journal articles, present the results of this study. The first paper focuses on the core observational data from the group and individual interviews identifying beluga whale, species and habitat changes overtime illustrating potential factors affecting the Cook Inlet beluga whale. The second paper details the participatory mapping process, its use and incorporation into geographic information systems (GIS) and serves as the companion paper to the primary findings. Chapter six presents this study's conclusions, identification of priorities for further research and continued conservation and management efforts.

CHAPTER TWO

Literature Review

Beluga whales (*Delphinapterus leucas*) are odentocetes cetaceans or toothed whales, in the family of Monodontidae which they share with only one other member, the narwhal (*Monodon monoceros*). They have specialized, evolutionary adaptations for the use of echolocation. Belugas are relatively small whales, growing to lengths of approximately 12 to 14 feet (NMFS 2008). Adult whales tend to be white or yellowish-white while their young are grey or brownish-grey in color and lighten with age (Huntington 2000; Rugh, Shelden, and Mahoney 2000; NMFS 2008). Beluga calves stay with their mothers for approximately 3 years. Sexual maturity ranges from 4 to 10 years for females and 8 to 15 years for males and are believed to live up to 60 years (NMFS 2008). Beluga whales are opportunistic feeders preying upon fish, crustaceans and cephalopods (Moore et al. 2000). In Cook Inlet they have been observed feeding on fish including herring, smelt species, cod and salmon (Rugh, Shelden, and Mahoney 2000). Stomach content analysis found flounder, sole, sculpin, snail, sandworms and lingcod. Many of the invertebrate and some fish species may represent secondary ingestion through the belugas' consumption of cod which feed on a number of the epibenthic species (NMFS 2008). While the Cook Inlet belugas feed on a wide variety of prey they focus on specific, seasonally available prey species including eulachon or hooligan and salmon (NMFS 2008). The beluga have been regularly observed following these fish runs into river deltas and up into rivers themselves (Moore et al. 2000), following the ebb and flow of the tides (Huntington 2000; Rugh, Shelden, and Mahoney 2000). It is believed the belugas' winter prey on deep dwelling species such as sculpin, cod, polluck and flatfish (NMFS 2008). Beluga whales' predators included killer whales (*Orcinus orcas*) (Shelden et al. 2003; Fish and Vania 1971; Huntington 2000; Moore et al. 2000; NMFS 2008) and humans (Mahoney and Shelden 2000).

Humans harvested belugas historically in Cook Inlet for subsistence and commercial and sport fishing uses (Stanek 1994; Huntington 2000; Speckman and Piatt 2000; Mahoney and Shelden 2000). Commercial hunting occurred sporadically in the early and mid 20th Century. The Beluga Whaling Company operated in Cook Inlet along the Beluga River for about 5 years during which time 151 belugas were processed. In the 1930's another venture began and was reported to have harvested approximately 100 whales. During the 1940's and on into the early 1950's native hunters from the villages of Knik and Eklutna sold beluga meat in Anchorage (Stanek 1994; Mahoney and Shelden 2000). Sport fishing was also practiced as part of the activities sponsored by the Beluga Whale Hunt Club and Kenai Days Fair from 1963 to 1965 (Mahoney and Shelden 2000). This appears to be the extent of commercial and sport fishing of beluga whales and was subsequently outlawed under the Marine Mammal Protection Act of 1972. Subsistence use of Cook Inlet beluga whales has been practiced by Alaska Native hunters residing in the Village of Tyonek, the Dena'ina people, the Kenai River area and Yup'ik and Inupiat hunters who reside in the greater Anchorage area, including the Matanuska-Susitna Valley (Stanek 1994). Prehistorically, beluga whales were hunted through the use of harpoons and a "spearing tree" with a hunting platform at the mouth of a river and fences and moveable dams (Mahoney and Shelden 2000). In recent decades they were hunted from outboard motorboats and high powered rifles (Stanek 1994).

During the 20th Century, it is believed that small numbers of beluga whales, 6 to 7 whales, were taken annually between the 1930's and 1940's (Mahoney and Shelden 2000). In the 1970's a resurgence of beluga hunting took place after hunting focus switched to terrestrial animals in the mid-1940's (Mahoney and Shelden 2000; Stanek 1994). From the mid-1970's through the early 1990's the number of belugas harvested increased from 2-5 whales per year in the 1970's to 6-11 whales per year in the 1980's to 9-13 whales per year up until 1993. From 1994 to 1998 there was a sharp increase in belugas taken and those reported to be "struck and lost" (SL). These numbers were reported to have increased from 19 taken, 2 SL in 1994 to 49 taken, 49-98 SL in 1996 and then decreased to 21-35 taken, 21-35 SL during the last two years of unrestricted hunting which was voluntarily halted by the Alaska Native hunters in 1999 in the Cook Inlet region. These harvest numbers were acquired from the 1994 subsistence use study by Ronald Stanek of the Alaska Fish and Game, National Marine Fisheries Services' (NMFS) Barbara Mahoney's 2000 beluga harvest history paper and reports from NMFS and the Cook Inlet Marine Mammal Council (CIMMC). There is, however, a relatively high level of uncertainty pertaining to past harvest numbers and beluga whale abundance estimates. Harvest reports performed by ADF&G and the CIMMC from 1987 through the late 1990's are considered minimal since not all hunters participated in the reporting efforts. Prior to the 1990's there were no reliable annual abundance surveys which required scientist to estimate historical abundances (NMFS 2008). Additionally, the

Conservation Plan indicates that, “Cook Inlet beluga whale abundance surveys prior to 1993 were often incomplete, highly variable…”

Despite the uncertainties of early estimates aerial surveys through the 1990’s illustrated a declining population trend. Based on these surveys, the National Marine Fisheries Service determined that between 1994 and 1998 the Cook Inlet beluga population had declined by 47% (NMFS 2008). In a letter to NMFS, the Alaska Scientific Review Group of the Marine Mammal Commission concluded that, “the Cook Inlet beluga situation is one of the most pressing conservation issues facing Alaskan marine mammals at this time.” (Moore and Demaster 2000). In 2000, NMFS designated the population as “depleted” under the Marine Mammal Protection Act of 1972. However, annual aerial surveys from 1994-2000 “…have not yet detected a significant increase in abundance, which remains under 400 whales.” (Moore and Demaster 2000) Based on the results of six years of aerial surveys and count estimates by NMFS, it became evident that the population of belugas was not recovering at the rate expected. Subsequently, and in response to pressure from environmental groups and Native Alaskan organizations, in April 2007 NMFS recommended that the Cook Inlet beluga whales be placed on the endangered species list. In October 2008 this population of beluga whales was listed as endangered under the Endangered Species Act of 1973. Aerial surveys during the 2009 season determined the beluga whale population is currently reported at 321 individuals.

A variety of alternative hypotheses have been proposed to explain the failure of the Cook Inlet beluga whale recovery with little conclusive scientific evidence of direct causal factors. The NMFS lists a number of potential natural and anthropogenic threats based on scientific and TEK studies. These include: strandings, predation from killer whales (*Orcinus orcas*), parasites and disease, environmental change, illegal harvest, commercial and personal use fishing of beluga prey, pollution, oil and gas activities, coastal development, vessel traffic, anthropogenic noise, tourism and whale watching and effects of climate change (NMFS 2008). The level of uncertainty and limited information about the threats and "our incomplete knowledge of the Cook Inlet beluga whales themselves" suggests there is a significant need "…to fill in the big picture gaps" and for further research into those potential factors contributing to the unresponsive recovery (NMFS 2008).

Given this need for additional information the Conservation Plan for the Cook Inlet Beluga Whale identifies conservation actions and strategies to facilitate this beluga whale population's recovery. These include; improving understanding Cook Inlet beluga biology and the factors limiting their population growth and recovery; stop direct losses of individuals; protect valuable habitat; and to continually evaluate conservation actions as new information becomes available. Narrower objectives include documenting beluga distribution and movements; assessing killer whale impacts; determining baseline environmental conditions; assessing prey base and availability; and assessing impact from anthropogenic activities (NMFS 2008).

Traditional and Local Ecological Knowledge

Traditional ecological knowledge (TEK) or local ecological knowledge (LEK) has been used interchangeably depending on the study. Huntington (2000) defined traditional ecological knowledge as "…the knowledge and insights acquired through extensive observation of an area or a species." Taking this further it can be explained as "a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission. [It concerns] the relationship of living beings (including humans) with one another and with the environment (Gilchrist, Mallory, and Merkel 2005). However, these two definitions differ temporally from the typical information gathered through interviews which entails more recent knowledge acquired through an individual's lifetime. This is referred to as "current local knowledge" (Gilchrist, Mallory, and Merkel 2005). For the purposes of this study the knowledge utilized is defined as a cumulative body of current knowledge and understanding of a given environment acquired through extensive experience and observation of an area and its associated processes and species spanning an individual's lifetime. In order to better encompass the knowledge and observations from this study's varied participants, this knowledge will from this point referred to as local ecological knowledge (LEK).

While scientific studies may help to reduce the level of uncertainty, traditional and local ecological knowledge has been promoted as useful, cost-effective tools for exploratory and baseline wildlife studies and resource management (Anadón et al. 2009; Aswani and Lauer 2006; Gilchrist, Mallory, and Merkel 2005; Huntington 2000). Its strength lies in the ability to collect large amounts of data covering broad geographical areas in a reduced amount of time utilizing fewer personnel. These abilities vary depending on the type of study performed, however in appropriate situations TEK/LEK utilization can significantly contribute to data collection in instances when cost and time constraints limit traditional scientific data collection methodologies. The combination of these two data collection methodologies can add strength to the overall datasets and compensate for each method's areas of weakness. In addition local knowledge may identify broader areas of study not previously considered by researchers. Throughout the TEK/LEK literature a common theme was prevalent, expressing the need to document traditional or local ecological knowledge for the purpose of its inclusion, along with traditional scientific processes, in conservation planning and management strategies and programs (Huntington 2000; Gilchrist, Mallory, and Merkel 2005; Anadón et al. 2009; Aswani and Lauer 2006).

The consensus of the authors and proponents of the use of LEK is that it would be a compliment to current scientific methodologies by filling the gaps that exist in research and management practices (Gilchrist, Mallory, and Merkel 2005; Hall and Close 2007). In turn, science can serve to compensate for the shortcomings that are prevalent in LEK data (Gilchrist, Mallory, and Merkel 2005; Moller et al. 2004). Local ecological knowledge is appropriate for gathering localized data on specific species where science can study areas and regions on a much larger scale (Gilchrist, Mallory, and Merkel 2005). On a temporal scale, scientific study can concentrate resources for sporadic periods of time during certain seasons while LEK draws on observations made throughout the entire year and over many years (Parlee, Manseau, and Nation 2005). Because of this LEK has the capability to observe unique or dramatic events that can easily be missed by scientific methods and the relatively short time researchers are present (Huntington 2000;

Huntington et al. 2004; Moller et al. 2004). In the case study of the common eider duck, LEK holders alerted scientist to a significant reduction in population numbers which the Inuit communities of Northeastern Canada attributed to an increase of sea ice that reduced the amount of open water feeding areas (Gilchrist, Mallory, and Merkel 2005). This population observation was later demonstrated as accurate while the ultimate cause for this was the eruption of Mt. Pinatubo, which lowered temperatures globally (Gilchrist, Mallory, and Merkel 2005). In this instance science was able to validate the drop in population numbers and the local causes of the decline but LEK was not capable of making attributable connections on a broader scale. Science was able to make the link to the eruption and its effect on global temperatures resulting in the increased accumulation of sea ice.

LEK research methodologies have additionally been illustrated as cost-effective and time-saving approaches for large scale studies encompassing broad geographical areas. Three studies in particular noted the time and cost-effectiveness of LEK methods. Aswani and Lauer’s 2006 study incorporated local fishermen’s knowledge into the design process for marine protected areas in Oceana indicating that the utilization of local knowledge into the creation of management plans was “a cost-effective strategy for obtaining missing data essential for selecting biodiversity conservation priority areas, data which would otherwise take years to collect.” (Aswani and Lauer 2006). The second study, an evaluation of LEK methods for spur-thighed tortoise (*Testudo graeca*) abundance data collection showed that LEK interviews produced a large dataset which encompassed 40% of the study area or approximately 1500 km^2 over a 51 day period utilizing only one researcher. The 51 days of interviews covered 595 cells of the study area as compared to 17 cells covered in 3 days through distance sampling. The overall cost analysis for this study showed exploration using LEK methods were hundred times less expensive than traditional field surveys (Anadón et al. 2009). The third study found that distribution surveys of harlequin ducks (*Histrionicus histrionicus*) in remote areas of the Canadian Arctic were not cost-effective. As a result LEK was deemed more appropriate for monitoring occurrence and distribution of harlequin duck on south Baffin Island (Gilchrist, Mallory, and Merkel 2005).

Because of this apparent mutually beneficial partnership between LEK and science there are a growing number of researchers advocating its use. However, addressing controversy surrounding the ability, or inability, to validate the observations and results from LEK studies is an issue (Gilchrist, Mallory, and Merkel 2005; Huntington 2000). Even though quantifying LEK data is beneficial, in some situations this may be a hindrance for data collection. The data collection and information gathering processes depend on flexibility by allowing participants to explore their knowledge and experiences through interviews with the researcher or conversations with others in group sessions. These conversations do not necessarily follow a preset path but often follow seemingly unrelated directions that in the end produce the desired information. An example of this occurred in one instance presented in Huntington's 1998 paper where the focus turned to a discussion of the increases in beaver populations. This did not appear to be associated with beluga ecology but when it was explained that increased beaver populations meant increased dam building which reduced the spawning area for salmon affecting their behavior and distribution and in turn affected beluga distribution (Huntington 1998). Instances such as this illustrate alternative areas of association that may well be overlooked in other types of studies. As this pertains to quantifying the process, it is anticipated that it would place limitations on both the participants and the researcher, preventing useful deviation mentioned in the example above. Perhaps the goal should be for consistency, consistency between individuals, groups and communities in order to increase reliability.

Qualitative research methods commonly used in TEK and LEK studies are rooted in the social sciences. These include semi-structured interviews (both individual and in group sessions) (Frey and Fontana 1991; Chambers 1994), participant observation, questionnaires, surveys, analytical workshops, participatory mapping and collaborative fieldwork (Huntington 2000; Huntington et al. 2004; Gilchrist, Mallory, and Merkel 2005; Moller et al. 2004; Nakashima and Murray 1988; Parlee, Manseau, and Nation 2005). The focus for maintaining the reliability of interviewees and informants should lie in researchers determining and ensuring participants have an appropriate level of knowledge and experience to contribute substantially to the study's objectives.

It is clear that there is a need for further study into the potential contributing factors for the decline and apparent lack of recovery of Cook Inlet beluga whales. In order to address this it may prove beneficial to delve into the knowledge of those who have hunted these whales, who have lived in and around the Inlet and who have had the opportunity to observe changes that have occurred in the Cook Inlet region for the better part of their lives. Analysis of local knowledge holders' observations and exploration of changes overtime may provide hypotheses to be tested using scientific methodology. Through the combination of the results of this local ecological knowledge study and the findings of scientific research up to this point, ecological relationships and processes may suggest new paths for future research, conservation efforts and management planning to better address associated recovery issues for the Cook Inlet beluga whale.

Purpose and Objective

The purpose of this study is to document local ecological knowledge of Cook Inlet beluga whales to explore possible contributing factors for their population decline and lack of recovery. This knowledge will be compared to existing scientific research and the 2008 Conservation Plan for the Cook Inlet Beluga Whale (NMFS 2008). Areas of divergence and convergence will be analyzed in order to supplement the current findings, suggest new areas of investigation and contribute to the overall understanding of beluga whale conservation and the Cook Inlet population's recovery.

The objectives of this study were:

1) To gather sufficient data from knowledgeable sources to gain an understanding of local ecological knowledge holders' perceptions as they pertain to changes within the Cook Inlet region and beluga whale habitat over time;

2) To compare and contrast local ecological knowledge with existing scientific findings for the Cook Inlet beluga whale population and distribution in order to

identify potential contributing factors for population decline and lack of recovery and,

3) To compare the two areas of knowledge and discuss divergences that may identify alternatives for further research.

CHAPTER THREE

Methods and Data Collection

The primary method for data collection in this study was conducted through group and individual interviews with key informants (Frey and Fontana 1991; Krueger and Casey 2000; Becker et al. 2003). Half to full-day, semi-structured group interview sessions were performed with Alaska Native fishers, beluga hunters and non-native commercial set-net fishers. Individual interviews were used in the place of group sessions when circumstances were such that group meetings were not appropriate or possible. Village councils were consulted to both gain permission and support for the study and to gain access to participants who have an appropriate level of knowledge and experience to provide useful data for the study. Criteria sampling (Miles and Huberman 1994) was utilized for participant selection and based on the extent of the participant’s knowledge and experience of the marine habitat of Cook Inlet, beluga whales and/or associated species, and observations of beluga whale populations, distributions and behaviors. Snowball and criteria sampling (Miles and Huberman 1994; Becker et al. 2003; Mackinson 2001; Stanek 1994) was utilized throughout the consultation period with tribal councils and fishing industry leaders. This type of sampling was utilized as the participant selection process moved forward and particular individuals were repeatedly referred to as useful participants, these people were selected and approached for their involvement in the study.

Group interview sessions have proven to be one of the most useful methods for traditional ecological knowledge data collection (Frey and Fontana 1991). As opposed to individual interviews, group sessions allow participants to encourage each other to recall memories of past events and spur discussion of particular details based on their knowledge of the region and each other and identify topics of interest and importance (Frey and Fontana 1991; Huntington 1998; Nakashima and Murray 1988; Chambers 1994). This method is also beneficial when compared to individual interviews, in that contradictory information may arise between separate interview sessions, requiring further validation of the reliability of the contradictions. In group sessions, these differences can be addressed and solved through discussions between numerous individuals thus providing reliability then and there. The method of semi-structured group discussions can bring out interrelated occurrences that, to the researcher, may be unrelated to the focus topic (Huntington 1998).

Fig. 1 Study Area. Observations obtained during this study occurred within the enclosed circle.

Participants lived and worked within the study area which encompassed the central and upper inlet (Fig. 1). Five group interviews were performed. Two group interviews each were held in the Village of Tyonek and Kenai, and one in Palmer, Alaska with setnet fishers from the Susitna River area. Eleven other individual interviews were performed in Anchorage with participants who fished in the Susitna River area, the northwestern portion of the upper inlet and the western portion of the central inlet. Other individual interviews took place in Soldotna, Alaska with Alaska Native and commercial setnet fishers. A total of thirty-two participants took part in the study which included twenty Alaska Native fishers and beluga hunters, eleven commercial fishers from the upper and central inlet and one bush pilot with an average age of 55 years and an average of forty years of experience fishing and hunting on Cook Inlet (Table 1). Five group interviews and eleven individual interviews were performed between September 2007 and March 2008. The composition of the interviews and varied locations served to increase validity through cross-group triangulation, gaining a full range of knowledge from community to community (Miles and Huberman 1994; Frey and Fontana 1991) across a broad geographic area.

The interview sessions were composed of semi-structured interviews (Miles and Huberman 1994), utilizing digital United States Geological Survey (USGS) 1:250,000 topographical maps of the Cook Inlet region, a timeline ranging from 1950 to 2008 and a relationship mapping which served as tools to facilitate the discussions. The interviews began with both the maps and timeline placed on a large table in front of the participants. Participants used the maps as a tool to illustrate and discuss their observations of changes in beluga whale populations, beluga habitat and associated species. The researcher marked directly on the maps (Appendix 1) asking questions that delved further into particular observations. Semi-structured interviews included questions such as; when and where did a particular change take place, was it a one-time occurrence or was it ongoing, did the change affect the beluga whales, and if so how did it affect the whales, were there other areas particular changes occurred and asking other participants within a group interview if they observed similar occurrences. The timeline (Appendix 2) was used to document additional temporal data associated with the mapping and to collect broader temporal data that were not appropriate for map placement, such as when participants began noticing declines of beluga numbers, timeframe in which increased sandbar formation was observed, or when shark observations became noticeable. Relationship mapping, which illustrated relationships between participant identified factors, was used in four interviews as a tool to illustrate in more detail the ecological relationships mentioned in the map and timeline discussion portion. In the course of the majority of the interviews participants discussed in detail these ecological relationships and employing this additional exercise in these cases was deemed redundant.

Data from each group and individual interview was recorded through audio and/or visual recordings and researcher note taking. Permissions for the utilization of these data collection formats were gained beforehand through village or tribal councils. All participants were informed of the recording and data capture techniques to be used. Confidentiality for each participant was offered, provided and respected if it is so wished.

The raw data for this study will be the property of the village or tribe and any further use will require permissions for use. There were also agreements made between the village or tribal council and the researcher to identify where other materials such as maps, audio/visual recordings and other records will be stored and shared.

Study sites and communities were selected through consultation with tribal, state and federal agencies and included the Village of Tyonek, whose members have participated previous studies, and the Kenaiitze tribe in Kenai, Alaska. Other participants include non-native commercial setnet fishers from the upper inlet and Kenai Peninsula and one bush pilot who regularly flew across the study area and made observations of the upper inlet over a ten year period.

Data Analysis

Each interview was recorded and transcribed into a word processing document. The transcriptions were exported into QSR NVivo 7 qualitative research software within which a study project was created. The transcripts were coded under thematic “tree” nodes or categories which started with the creation of broad categories such as Beluga Whales, Environmental Change, Management and Human Activity. Text or keyword queries were run on the transcripts to identify observations, discussions and comments related to the broad categories. Examples of text queries included searches for such keywords as beluga, sharks, salmon, clams and siltation. As more specific references were identified sub-themes were created under the broad tree node categories to illustrate narrower topics. Examples of these included species change, beluga health, wetland drying, orca sightings, beluga prey and noise related to human activity.

At this point sets were created by examining relationships between tree nodes. These were groupings of nodes and their associated participant comments and observations. The nodes in each set were identified as related by participants during the interviews or their potential relationship was identified by myself, as the researcher, based on my knowledge acquired through literature reviews and academic study. Examples of relationships or potential relationships include; glacial melt may be related to siltation and/or erosion, reduction in snowfall- rain instead of snow- may be related to erosion, increased siltation and glacial melt, northern pike increases may relate to reduction in northern district salmon, beluga prey and possibly beluga health. Additional queries were run using these sets. The AND or NEAR functions were used to identify particular keywords in association with other potentially related keywords. This type of query was used to find portions of text where, for example, “salmon” and “decline” were located either next to one another or within a certain distance from one another with a particular comment. These queries identified further areas of the participant interviews where potential relationships were discussed and possibly missed by previous queries. NVivo’s Modeler was used to visually map associations, connections and relationships identified through the analysis queries and sets. This created a visual framework formed thus far in the analysis. In addition to modeling the concepts forming in the text, the timelines and relationships diagrams used during the interviews were brought into this portion of the process to analyze further what is being said and how the perspectives and observations compare to one another. These then were combined into more encompassing models to gain a broader picture of what is taking place.

Matrix Queries were then used to facilitate the identification of patterns or frequency of particular keywords or even themes. These were set up in rows and columns, named for these keywords or themes to see where they intersect and showed the frequency that each of these appear together, displayed in a table format (Margoluis and Salafsky 1998; Miles and Huberman 1994). The matrices were analyzed and served as a starting point to identify the weighting for each relationship or factor of change

Through advanced queries and matrix queries, relationships, connections and patterns were assessed and identified through the use of the AND and NEAR functions but the absence of a connection or presence of one criteria but not the other may point to an exception (Miles and Huberman 1994). For example, a query is run to identify associations between the presence of killer whales and beluga strandings. The results may show numerous accounts in association with one another. However, there may be an instance of a beluga whale stranding without the presence of killer whales. This exception could then be investigated further that may illustrate other possibilities or associations of strandings that do not involve killer whales. It was essential, however, not to assume causal relationships when looking at patterns and relationships. Connections identified may suggest causation but there may well be other factors involved. Care was taken before identifying a connection, an association or a relationship as causal.

Based on the results of the queries, models and matrices, a logical chain of evidence was constructed to illustrate the changes observed overtime by the participants that was compared and contrasted with existing scientific literature and current management plans. Relationships and patterns were analyzed and interpreted based on supportive evidence and outliers or exceptions were explored to determine where they would fit into the broader context of the results. Direct quotes from participants were used to add depth to the findings, illustrate their observations and further detail the demographic and location of the sources.

GIS Data Analysis

For the GIS component of this study the maps and timeline were used to create GIS layers which were digitized using ESRI's ArcMap software. Data was separated into categories that included Beluga Whale Observations, Species Changes and Habitat Changes with each based on date ranges in ten year increments from 1950 to 1979 and in five year increments from 1980 to 2004 and one for the remaining four years, 2005 to 2008. The ten and five year increments were chosen for data management purposes. There were few participant observations of ecological change prior to 1980 compared to the years after 1980 when observed changes became more numerous. For this reason decadal increments were deemed appropriate for pre-1980 years. After 1980 increased observations of change dictated a smaller interval in order to capture the increased quantity of data. These GIS data layers were then analyzed through spatial overlay analysis based on timeframe associations and cross referenced with the timelines generated during interviews and transcribed participant interviews.

In order to identify observed trends from 1950 to 1984, after which participants reported decreases in beluga numbers, all observations from that date range were merged together. The merging decision was based on trends illustrated in the timelines generated during interviews and participant observation. This operation was repeated for those observations from 1985 to 2008, resulting in two layers, one prior to observed beluga decline and one illustrating the timeframe of the observed decline. These two layers were separated into two additional layers representing the central and upper inlet in order to analyze changes between the two geographic areas.

The analysis sought to identify areas of species and habitat change in association with observed beluga whale sightings. The observed species and habitat changes, according to participants, occurred predominantly during the same period of time the beluga whales were noticed to be in decline and have continued through to 2008. The spatial analysis focused on those changes identified across interviews. These included beluga observation areas, sighting frequencies and abundance; shark distribution change; killer whale observations; northern pike (*Esox lucius*) expansion; and siltation increases and mudflat expansion. The layers were overlayed with observed beluga whale habitat to identify areas of association. The results and findings were reported in the GIS portion of this study where their contributions to the overall qualitative LEK study are discussed.

CHAPTER FOUR

Cook Inlet Beluga Whale Population Decline and Recovery: An Exploration of Contributing Factors through Local Ecological Knowledge

Abstract

The Cook Inlet beluga whale, one of five Alaskan stocks, is genetically distinct and geographically isolated from other populations. Historically, Cook Inlet whales were hunted commercially, for sport, and for subsistence uses. The Marine Mammal Protection Act (MMPA) of 1972 ended commercial and sport hunting; in 1999, subsistence hunting voluntarily ended. In 2000 the National Marine Fisheries Services (NMFS) determined the population had declined by 47% between 1994 and 1998, resulting in a listing of “depleted” under the MMPA. In 2008, Cook Inlet beluga whales were listed as endangered under the Endangered Species Act after annual aerial surveys indicated the population was not recovering as expected. A combination of natural and anthropogenic factors may be affecting this population’s recovery. This study utilized local ecological knowledge of Alaska Native subsistence hunters and fishers and non-native commercial fishers to explore ecological changes in Cook Inlet overtime and to identify potential factors impacting this beluga whale population. Study results identified potential environmental and climate change factors including prey competition from predatory fish species, health of beluga and their prey, and the presence of killer whales, the majority of which may indicate an ecosystem regime shift in the Cook Inlet region. Human-related

factors included fisheries management and related prey reduction, water contamination, and anthropogenic-related noise.

Keywords: Beluga whales, Alaska, LEK, participatory research

1.0 Introduction

The Cook Inlet beluga whale (*Delphinapterus leucas*) is one of five Alaskan stocks, genetically distinct and geographically isolated from the other four populations. Historically, they were hunted commercially, for sport and subsistence uses (Huntington 2000; Mahoney and Shelden 2000). Commercial and sport hunting ended with the Marine Mammal Protection Act (MMPA) in 1972. Subsistence hunting by a number of Alaska Native villages within the Cook Inlet watershed was voluntarily ended in 1999.

Historic figures for beluga whale harvests in Cook Inlet and early reports from aerial surveys indicate a relatively high level of uncertainty for the beluga whale population status. This is reflected in the recent efforts to obtain population status data with the first reporting of beluga hunting takes in 1993 (Stanek 1994) and aerial surveys which began in 1994 (NMFS 2008). It is believed that annually, 6 to 7 whales were taken by native hunters through the 1980s; by mid-1990s, the estimated annual take of whales increased steadily, culminating in 1994 with 49 reported taken and up to 96 “struck and lost” (Stanek 1994; Mahoney and Shelden 2000). Concern expressed by native hunters and National Marine Fisheries Service (NMFS) over these harvest numbers led to voluntary suspension of hunting in 1999. In 2000 it was estimated that, between 1994 and 1998, the population declined by 47% (NMFS 2008). In a letter to NMFS, the Marine

Mammal Commission and the Alaska Scientific Review Group concluded: "the Cook Inlet beluga situation is one of the most pressing conservation issues facing Alaskan marine mammals at this time" (Moore and Demaster 2000). This led to listing the Cook Inlet beluga as a "depleted" stock under the MMPA. Annual aerial surveys over the subsequent 8 years indicated the whales were not recovering at the expected rate, and only 375 individuals were reported in 2008, down from an estimate of 1,293 in 1979 (NMFS 2008). As a result of this decline and lack of recovery, in 2008, the Cook Inlet beluga whale was listed as endangered under the Endangered Species Act (ESA).

A variety of alternative hypotheses were proposed to explain the failure of the Cook Inlet beluga whale's recovery with little conclusive scientific evidence of direct causal factors. The NMFS lists potential natural and anthropogenic threats based on scientific and TEK studies, including: strandings, predation from killer whales (*Orcinus orca*), parasites and disease, environmental change, illegal harvest, commercial and personal use fishing of beluga prey, pollution, oil and gas activities, coastal development, vessel traffic, anthropogenic noise, tourism and whale watching, and effects of climate change (NMFS 2008). The level of uncertainty about the threats to this particular beluga whale population suggests there is a significant need for further research into those potential factors contributing to the unresponsive recovery (NMFS 2008; Huntington 2000).

Studying traditional ecological knowledge (TEK), or in this study's case, local ecological knowledge (LEK), is one approach to gain a better understanding of individual species and ecological changes. LEK's benefits include the ability to close gaps in existing research and management practices through localized data collection over extended periods (Gilchrist, Mallory, and Merkel 2005; Hall and Close 2007). It has been utilized to create large-scale data sets for conservation and management planning at significantly lower costs (Aswani and Lauer 2006; Anadón et al. 2009).

LEK data can complement mainstream scientific research as well as identify patterns and relationships not previously documented or considered (Anadón et al. 2009; Huntington 2000; Huntington et al. 2004; Moller et al. 2004; Gilchrist, Mallory, and Merkel 2005).

Previous research includes subsistence use of beluga whales in Cook Inlet (Stanek 1994) and one traditional ecological knowledge study of beluga whale ecology (Huntington 2000). Huntington's study focused on beluga hunters' knowledge of beluga whales and associated changes in the Upper Cook Inlet from the Kenai River north through a small sample of TEK holders. The study identified observed beluga whale feeding and calving areas, beluga prey species, reported changes in beluga abundance and distributions, observed prey species declines and run-time changes and potential links between these changes and increased human population and activity in the Inlet. This present study builds on Huntington's research by including the Central and Upper Inlet, expanding the number and scope of sources by interviewing additional Alaska Native subsistence users and commercial fishers, and broadening the research focus to include broader environmental and anthropogenic changes over time in Cook Inlet.

This study documents LEK of Cook Inlet beluga whales and explores possible contributing factors for their population decline and impacts affecting their recovery. This knowledge is then compared and contrasted with existing scientific research and the 2008

Conservation Plan for the Cook Inlet Beluga Whale (NMFS 2008). Through the documentation of LEK and literature comparison, the following research questions will be answered: “What changes took place in Cook Inlet prior to, during and after the beluga whale decline?”; “What were the potential direct and indirect impacts of these changes, or factors, on the beluga whale decline and recovery?”, and; “Where are the gaps in current knowledge and what areas may require further research?”.

2.0 Methods and Analysis

Data were generated through semi-structured individual and group interviews with Alaska Native fishers, beluga hunters from the Village of Tyonek and the Kenaitze Tribe, and non-native commercial set net fishers from the upper and central inlet. Thirty-two study participants, selected through criteria and snowball-sampling methods (Miles and Huberman 1994; Becker et al. 2003), included 20 Alaska Native fishers and beluga hunters, 11 commercial fishers from the upper and central inlet, and one bush pilot; participants’ average age was 55 and years of experience fishing and hunting on Cook Inlet was an average of 40 (Table 1). Five group interviews and 11 individual interviews occurred between September 2007 and March 2008. The semi-structured interviews (Miles and Huberman 1994) were complemented with participatory mapping and timeline exercises (Chambers 1994) and relationship mapping (Chambers 1994).

Each interview was recorded and transcribed into a word-processing document, then exported into QSR NVivo 7 qualitative research software within which, a study project was created (QSR 2007). Within this project, text from interviews was coded into thematic categories and subcategories. Matrix queries were then run on the coded references to identify relationships within and across the categories. When analyzed, these matrices served as a starting point to identify the weighting for each relationship or factor of change. Each relationship was verified through a manual review of associated thematic categories to ensure accuracy.

Weighting for each factor or relationship was based on the number of discretely identified coded themes from the transcripts. Each participant, who commented on a particular factor or relationship, or identified a related observation, was counted. In order to avoid overweighting, additional discussion of a particular factor, relationship, or observation was not included. This overall weighting is illustrated in the Factor Model (Fig. 2). Cross-group triangulation was used to analyze the factors between groups, or across interviews. The purpose of this method was to add depth to the analysis by analyzing factor occurrence across sources and between user groups (Alaska Native or commercial users) and geographic regions (upper and central inlet). This additional dimensionality added strength and trustworthiness as particular factors were observed. Further participant discussion about these relationships is addressed in the results and discussion sections of this article.

3.0 Results

Themes that emerged from the analysis were organized into the broad categories of natural and environmental and human-related factors with sub-categories and factors detailed within. This analytic structure, which the threat matrix detailed in the 2008

Conservation Plan for the Cook Inlet Beluga Whale (NMFS 2008) – referred to hereafter as the conservation plan – provides the basis for comparison of previously identified factors and those identified in this study. Factors are listed within each broad category: the cross-group weighting, the geographic area in which each was observed, and the user group that identified each (Table 2).

3.1 Beluga Abundance and Distribution Change

Beginning in the mid-1980s, beluga whale abundance decline was reported by participants throughout the upper and central inlet. The central inlet, according to participant observations, experienced pronounced distributional change beginning during the same time period. From 1950 to approximately 1984, beluga whales were commonly observed along the eastern Kenai Peninsula, west of Kalgin Island, and portions of the western inlet coast of the inlet. These abundance decline and distributional changes continued throughout the 1990s until, by 2000 to 2001, participants no longer observed beluga whales along the eastern Kenai Peninsula. Central inlet beluga whale observations were sparsely reported only along the west coast. In the upper inlet, the sighting areas remained consistent with their abundance levels in continual decline beginning in the mid-1980s.

3.2 Natural/Environmental Changes

The Natural and Environmental Change category encompasses those factors and changes influenced by environmental or natural causes and distinguished them from those factors directly related to human activity. This broad category is broken down into sub-categories which include beluga whale prey competition, killer whale impacts, prey health, potential climate change related factors and beluga whale health.

3.2.1 Prey Competition

Participants identified observed increases of predatory fish species, specifically of sharks and northern pike (*Esox lucius*) that may contribute to beluga prey competition or prey reduction. Sharks were reported across 11 interviews, in both the upper and central inlet while northern pike was identified across seven interviews from the upper inlet. Beginning about 1994, increases in shark species were reported by one group, with others noting higher numbers over the past 5-10 years, primarily along the Kenai Peninsula from south of Ninilchik, and later, north to Moose Point and along northwestern portion of the Inlet near the Village of Tyonek. Northern pike were reported to have expanded throughout many of the rivers in the Susitna River drainage since the early 1990s.

Reports of sharks caught in commercial and Alaska Native fishers’ set nets in increasing numbers, sometimes up to 60 at a time, included sharks that were dark on the dorsal side and white-ish on the underside; Tyonek residents indicated some were up to 10 ft. long and referred to as salmon sharks (*Lamna ditropis*) while others were called mud sharks, dogfish, or sand sharks by other Kenai Peninsula participants. According to the Alaska Department of Fish and Game, there are three species of sharks found in Cook Inlet: salmon and sleeper (*Somniosus pacificus*) sharks and spiny dogfish (*Squalus acanthias*) (Meyer et al. 2009). It is likely that participants are describing increases in two of the three Cook Inlet species. The identification of the salmon shark is straightforward, given their 10 ft. length and their documented presence in the Inlet. Spiny dogfish are a smaller shark species up to 5 ft. long and are known to travel in large packs that number from hundreds to thousands (Meyer et al. 2009). It is possible that participants referred to dogfish by other names but their size, description, and numbers caught in single nets suggest that these are spiny dogfish. A group interview from the Kenaitze Tribe described the apparent rapid increase of the sharks:

> Yeah we never seen any, any and then all of sudden they start showin' up and now… And now, now you see 'em, now you see 'em all summer. We catch 'em all summer in the net. That one morning round here where [name omitted] was fishin', got up and he had uh, we had that north net and that south net out between those two minutes we got almost 60 shark. It was just, just made me sick.

In another group interview, participants from the Village of Tyonek from the northwestern portion of the Inlet described this phenomenon as, “And we got sand sharks right on the beach down here” and “Yeah, yeah those start showin’ up in our nets now.”

Northern pike, an invasive species to southcentral Alaska, was reported to have spread through many of the lakes and rivers in the Susitna River drainage including Red Shirt, Alexander and Flat Horn lakes, Alexander and Three Mile creeks, the Susitna, Chuit, and Beluga rivers; the participants believe the pike have negatively affected salmon populations. According to participants, this expansion was the result of a large flood that allowed lake transplanted northern pike to escape into the Susitna Drainage. During a Northern District commercial fishers’ group interview, one fisher commented:

> So all this pike got out into the rivers then they migrated up the streams into Flat Horn Lake, they are up in Alexander Lake, Red Shirt Lake are all full of pike now. Flat Horn was probably first one, completely annihilated the salmon.

Additionally, multiple northern district fishers independently observed pike moving out of rivers into Cook Inlet, which indicated the capability of traveling to unconnected rivers. One participant described this:

> I caught a northern pike out in the Inlet, right at the mouth of the Little Susitna. Well I pulled up to Whitney’s Dock and there was a Fish and Game officer there and I told him I did and he told me, “No, you’re mistaken”. I says, “I’ve been a

> salmon fisherman almost all my life." I says, "I know the pike from salmon." Well, he argued with me about it enough that I took it out and threw it up on the dock. I says, "Is that the pike or not?" He kept the fish.
>
> It was a northern pike. But he argued with me that there was no pike out there in salt water. They will live in salt water. That's the only one I've ever caught but he was swimming and doing well which tells me that they can come out of the Big Su…They can get into the Beluga River, they can come around here get up into Cottonwood Creek or whatever. They can live in salt water.

3.2.2 Killer Whale Impacts

Impacts associated with killer whales (*Orcinus orca*) included beluga whale behavioral changes, predation on belugas, and beluga whale stranding. Participants reported killer whales in both the central and upper inlet with associated beluga behavioral change across three interviews and predation and stranding observations reported across five and six interviews, respectively. Observations near Tyonek indicated an increased presence of killer whales. The observations ranged from sightings in association with strandings near the Susitna River and Turnagain Arm, chasing beluga near Fire Island, sightings in common beluga feeding areas, and in Turnagain Arm apparently feeding on hooligan runs. Most were infrequent sightings. In an individual interview, one participant, a Northern District commercial fisher, described beluga whale avoidance behavior in the presence of killer whales:

> When the killers came in, the [beluga] whales just acted erratic, I've never seen them act so weird. They would go sit and feed you see them run and hide. Now I didn't see killer whales eating them they were broken up and you'd see them one day then not see them for three days. It was like they were just passing through they weren't hanging around probably because they'd been attacked somewhere through here.

Observations of killer whales near the native Village of Tyonek were more frequent beginning in the late 1980s to early 1990s, with participants saying they are, "Right out in front of the village" and "All of those are fairly new phenomena…whales, sharks, everything." Another participant in the same group interview from the Village of Tyonek indicated that his father, who was from the southern portion of the Inlet, had a word for killer whales in his language but his mother, who was from the northern portion and spoke a different dialect, did not. This seems to illustrate historical killer whale sightings were infrequent in the northwestern inlet and that regular sightings were a new phenomena.

3.2.3 Beluga Prey Health

A variety of fish maladies, reported across five interviews from both the upper and central inlets, included tumors, parasites, deformities, and observations regarding the general health of the salmon catch. Tumors were observed in fish by participants along the Kenai Peninsula and in the northwestern portion of the Inlet. Kenaitze Tribal members who fished near the Kenai River observed, "…some of them fish like ah, open had white, white spots… like little tumors all over." During one follow-up discussion with one participant after the 2009 fishing season, tumors were observed in several fish, resulting in a number of them being discarded.

Another Kenaitze Tribal participant in a group interview observed a salmon with a purple-ish ball in its head while another observed a halibut with a similar ailment:

> There was people down there one time cleaning halibut that had the same thing happen. There was, it was so odd looking and so much of it that they just threw the whole thing away. It was like jelly inside.

Another reported that, "…last year we cut open a belly of the fish, you know too and it was literally full, full like bloated full of worms. I've never seen that before." There was no indication if the number of fish with parasites either increased or decreased.

Observations of a certain type of deformity in salmon catches were reported in three separate interviews where participants all fished in different areas — south of the Kasiloff River, in the Kenai River, and near Tyonek. Each of the interviews observed catching "crooked" fish. In an individual interview, one Central District commercial fisher participant described this:

> …there is a deformity in fish where instead of being a nice salmon shaped fish, it will have the hump in it, it'll have an arch [on] its back. Looks like it's the Hunchback of Notre Dame where it'll start the shape then it'll come down and then hump up. …I was watching with him and we probably saw ten of those this year and that seemed like an awful lot to me. I'm not talking about a natural hump growing in the middle, I'm talking about the fish bending down back before its dorsal fin having a down bend and then bending back up like the whole thing was crooked. Like how it came out of the fish cookie cutter all crooked.

Participants reported catching these crooked fish from the early to mid-1990s through the present.

Observations pertaining to the general health of fish indicate issues related to water temperature changes, a reduction in the oil content of the fish, and the manner in which their meat is preserved. Participants commented on catching "stressed" fish, connecting their condition to a rise in water temperature. One participant from Tyonek spoke about the condition of salmon meat: "I don't think they have the oil content in there that they used to because even our King salmon is not as oily as it used to be because some of it is, it's brittle". This required a change in how they preserved the meat.

Participants from the upper inlet observed changes in chinook salmon populations, indicating reduced numbers, smaller sizes, and increases of "jacks" — a smaller early return chinook salmon. In the past five years, Kenai fishers also observed low catches of chinook. Participants reported population reductions as well as smaller sizes in three main salmon species in the northern district since 1990, with closures occurring in the Theodore, Chuit, and Lewis Rivers for chinook. In an individual interview, a Northern District commercial fisher said, “I’ve caught a lot of pinks out there on some years. Some years I don’t catch any. They’re tiny, too, little things about two pounds, little bitty fish. A four pound pink is a big pink.”

The increase in the early return “jacks” were of concern due to the numbers caught in recent years. All participants from one group of northern district fishermen reported increases in jack catches with one noting that twenty years ago, only a few were caught though recently, they account for 50% of the catch. This participant explained that chinook salmon typically return on five-year cycles with jacks returning early with other fish runs in three to four years.

Not all participants thought these fish health changes represented overall trends. Some indicated that observed oddities were infrequent; they felt the overall health of the Cook Inlet fish populations were sound.

3.2.4 Potential Climate Change Related Factors

Participant discussions of changes over time revealed a number of observations potentially related to climate change, including water temperature change, erosion and siltation, reduction in snowfall, wetland drying, insect, bird and plant changes, and declines in frog populations.

3.2.4.1 Water Temperature

Across eight interviews, participants from both upper and central inlet observed changes that are potentially related to water temperature change including species distribution changes, changes in fish in run timing and fish health related to temperature change, and less severe winters.

Participants related the increases of sharks farther north to water temperature change. There were also changes observed in jellyfish populations, which may be another indicator of apparent temperature change.

Participants from the Northern District commercial fishers' group interview, upper inlet, commented, "Seems like the Kings are running about two weeks to three weeks earlier than they did say fifteen years ago. I think the water warming."

In an individual interview, another upper inlet participant, a Northern District commercial fisher, related an observation of changing Inlet water temperature:

> I do check water temperatures now on a regular basis for the last 17 years and the average has been going up. I've seen really stressed fish though from heat. They just can't handle the heat and we've had some really hot summers up here. We had a 90 degree day on August 13th and the fish were so stressed they were almost grateful to be caught, they were lazy and sluggish acting and producing a lot of slime. Which is what they do when they're stressed.

3.2.4.2 Erosion and Siltation

Across ten interviews, observations of increased erosion and siltation were reported by participants from both the Kenai Peninsula and in the upper inlet. Erosion was identified along the Kenai River and north along the coastal bluff. Erosion along the Kenai River was reported to have both natural and human activity related causes. According to Kenai Peninsula area participants, the erosion of the bluff near the mouth of the Kenai River and north along the coast has been significant, endangering numerous structures and at times, the altogether removal of some. Bluff erosion has been occurring for the past 40 years but participants noticed an increase in recent years.

Bank erosion, upstream from the mouth of the Kenai River and in its tributary creeks, was also observed with participants expressing concern over potential impact to salmon spawning habitats through filling in of gravel beds or in some cases, making the creeks shallower.

Participants observed that siltation, expansion of mudflats, and formation of sandbars in the upper inlet from the McArthur River north along the western coast up through the Susitna River drainage and across to Fire Island and may be impacting fish runs and the beluga whales' access to traditional feeding habitat. According to some participants, glacial melt may be contributing heavily to increased siltation. In an individual interview, an Alaska Native participant from the Kenai Peninsula related:

> And with the way the Su is it runs so much silt outta there that it’s piled so high that you can't get in there in the summer. In the, you can’t, you can’t and when the tide is low you can’t get in there. Before you could kind of work your way in through these little channels and go in there but now you can’t. So with that blockin’ off I mean it’s, it’s not letting the fish and everything in there the way they should.

In another individual interview, a Northern District commercial fisher participant also discussed increased siltation:

> The belugas come up the west channel here and they feed on fish. In the fall, especially. On this side there’s a place where the channels used to be deep and it’s not really deep in here anymore there’s kind of a shoal that crosses here now. That’s all silted in. With normal tides they can’t really get over there unless it’s a 32 or 33 foot tide. No, you used to be able to go in here at any tide in this main channel and the belugas would get in here and the fish are focused in those places so it optimal feeding conditions and now it mostly on this west side.

3.2.5 Beluga Whale Health

Beluga hunter participants discussed long-term observations of beluga health including the presence of kidney worms and other parasites, skin sores, and reduction in blubber. In an individual interview, one longtime hunter from the Alaska Native Kenai

Peninsula made many of the reported health-related observations — he reported a heavy parasite load in the blood vessels of the whales' neck and kidneys: "…if you look at the kidneys they're so full of it that it looks just like a fish egg sac."

These observations were said to have increased between the 1980s and 1995, when this participant's last whale was caught. According to this same participant, there were few observations of parasites during the 1970s, "…they were starting up…you notice that, but then every ten years you'd notice a change of how it was really getting worse."

In contrast, there was one other beluga hunter from the Anchorage area who stated that during the late 1970s, the beluga were "sickly" with parasites in their internal organs. The infected organs were discarded and the remaining portions of the whales were used. By the early 1980s, the belugas' health was reported to have improved.

Reduction in blubber was observed by a longtime hunter from Tyonek who stated that blubber was thicker from the 1960s-1970s, compared to the 1990s. This participant added that his final piece of beluga blubber, cooked in 2008, was thinner than in previous years.

3.3 Human-Related Factors

The broad category of human-related factors encompasses observed changes related to human activity within Cook Inlet. The sub-categories include fisheries management, industrial and boating pollution sources and noise associated with oil and gas development, and shipping and boating increases.

3.3.1 Fisheries Management

Reduction in salmon populations was a prevalent theme in five upper inlet interviews. The primary human-related factor for these reductions was identified by participants as a focus, by fisheries management, on the central district fisheries, specifically on the drift fleet management. The observations centered on drift fleet interception of northern district bound fish which resulted in a reduced number of sockeye and chinook salmon returning to upper inlet rivers and reduced northern district commercial and subsistence fishing opportunities. One observation, made by a native fisherman in a Village of Tyonek group interview during a season when the drift fleet was closed, illustrates a comparison of fish quantities from typical fishing seasons and this unusual period: “After the [Exxon Valdez] oil spill they shut the drifters down and we swamped a couple of tenders and filled up a couple of boats, we even had to fly fish out there, that’s how much was getting past out there.”

In addition, a northern district, commercial fisher spoke of the switch from a “mixed stock” fishery, one with multiple species runs, in multiple rivers and streams throughout the inlet, to a fishery with a narrower species focus, managing for only a few rivers. The result of focusing on one or two strong runs, specifically the Kenai River stocks, is that smaller runs of differing species tend to decline or cease all together.

In contrast, a number of participants, two from the northern district and three from the central district, commented on the increase of fish in the inlet since the 1970s, with credit given to fishery management plans. These comments referred to fish increases in Cook Inlet as a whole and did not indicate specific geographic areas with increases.

Another aspect of fishery management that central district commercial fisher participants noted was an increase in sport fishing, with increases in guided fishing tour companies and associated fishing activities. Kenai River area Alaska Native participants reported 400 fishing guides and 600 sport fishing boats currently operating in the river. A commercial fisher who fishes from Kalgin Island – the western portion of the central inlet – commented that since the mid-1990s the number of sport fishers has increased “dramatically” as has the use of larger boats.

3.3.2 Noise

Observations of anthropogenic noise were noted in association with oil and gas activities and personal observations across three interviews of related beluga whale behavior in both the upper and central inlet. Participants from Tyonek indicated that, from shore, they were able to hear constant engine and pumping related noise from off-shore platforms, illustrating the distance sound traveled. Additionally, ongoing exploration activities specifically observed by a commercial fisher from the Kenai Peninsula, north of Ninilchik included on- and offshore air-burst seismic testing.

Upper inlet participants related personal experiences of beluga reacting to noise which included belugas moving away from shore when four-wheel all-terrain vehicles approached on the beach; the whales appeared to hear or detect vibration and moved away. Another commercial fisher spoke about his experience in a group interview:

> If you drive up the Little Su and shut your motor off you can drift right down through a pod of whales, you can almost reach right over and touch ‘em. You can’t walk on the bottom of an aluminum boats ‘cause it scares them, if you hold still and be quiet, you can drift…. Really, you’ll be four or 5 ft. away from them. They’ll, pick and roll right beside ya. They’re not scared of the boat, they’re afraid of the sound.

These results indicated numerous changes in Cook Inlet including environmental changes and those related to human activities. Factors that potentially affect beluga whales and their habitat can be placed into four categories: environmental and climate change; beluga prey decline; beluga recovery and distribution; and human factors. Through the combination of participants’ observations and speculation, as well as researcher interpretation, relationships between these factor groupings were analyzed and illustrated in the Factor Model (Fig. 2).

Increases of sharks and northern pike impact fish populations through increased feeding pressure which may reduce available prey for beluga. Prey health indicated by participant observations may indicate peripheral environmental changes impacting fisheries and may include the effects of water contamination. Wetland drying may be related to climate change through temperature increases and reduced precipitation, resulting in habitat change for other species including waterfowl. The same processes associated with drying may impact other aspects of the ecosystem that reflect participant land-based observations. Similar climate related changes that impact wetlands may affect marine environments and relate to changes in fish run timing and reported shark distributional changes. Climate change may also be related to increased siltation due to reduced snowfall during less severe winters, which relates to glacial melt that releases additional sediment into river drainages. This increased siltation and deposition may affect beluga whale access to river mouths, impeding their access to feeding habitat.

Increased frequency of killer whales may be a result of these changes in the marine environment, as food sources change and they prey upon alternate sources. Their presence may influence beluga whale distribution. Distributional shift in the beluga whale population may also be influenced by anthropogenic noise sources related to reported increases in boating and oil exploration activities in the central inlet.

Participants related salmon abundance decline to fisheries management’s focus on central inlet fisheries. With apparent beluga whale distribution shift to the upper inlet and away from the central inlet, reductions in northern district fish populations may well impact beluga food sources and energy needs.

4.0 Discussion

Comparing the findings of this study and those from the conservation plan as was done in the combined threat-factor matrix (Table 2) seven common factors emerged: killer whale predation and stranding; water temperature change; siltation and filling in river channels; beluga whale health; commercial fishing as related to prey competition; pollution; and habitat change or loss (NMFS 2008). Of those identified in the 2000 TEK study, five common factors included: reduction in upper inlet fish abundance; fish run timing change; observations of fish with “crooked spines”; silting of river channels; and human activity influence on beluga distribution(Huntington 2000).

Beluga whale decline reported by participants from both the upper and central inlet by both Native Alaskan users and commercial fishers extends the date range of noticeable declines back 8 to 10 years from the mid 1990s to the mid to late 1980s. Since NMFS’s aerial surveys did not begin until 1993 (NMFS 2008)the differences between participant observations and survey data do not necessarily represent a contradiction but an expansion on current information which indicate the potential presence of additional factors impacting the beluga whale population. These findings expand on observations of diminished beluga abundance in Trading Bay during the same time period (Huntington 2000).

This study identified additional environmental and human activity related factors not previously identified as threats. These included: natural competitors for prey; killer whale influence on beluga whale distribution; wetland drying, terrestrial animal and plant changes; siltation impacting beluga access to rivers; reduction in snowfall; reduction of belugas' blubber; fisheries management influence on prey declines; and beluga whale avoidance behavior associated with anthropogenic noise.

Natural prey competition involved increases or redistribution of shark species and expansion of northern pike in the upper inlet. Increases in sharks' numbers were primarily observed and interpreted as spiny dogfish and salmon sharks. Spiny dogfish populations are, according to studies performed by the Alaska Department of Fish and Game (ADFG), increasing in lower and southern reaches of the central inlet. Increases are represented by higher numbers caught as bycatch in drift boat fisheries (Trowbridge et al. 2008). Participant observations, however, indicated sharks appearing in the mid-1990s and farther north than identified in previous studies. Spiny dogfish have been called a "nuisance species", as they have disrupted salmon fishing in other areas of Southcentral Alaska (Meyer et al. 2009), traveling in large packs, that at times, number into the thousands (ADF&G 2009). Both species of sharks observed by participants feed on salmon, hooligan, and other potential beluga prey species (ADF&G 2009). Given the observed increases of these sharks and past fisheries disruptions in the Copper River, it may be hypothesized that they have the potential to disrupt Cook Inlet fisheries and compete with beluga whales for prey.

Participant observations of expanded northern pike populations were complemented by two ADF&G studies, which found significant impacts of northern pike on salmonid species in numerous river systems throughout the Susitna drainage and the northwestern inlet (Whitmore and Sweet 1998; Rutz 1999). According to Rutz (1999) many of the lakes and interconnected rivers and streams in the upper Cook Inlet watershed that “once maintained native populations of coho, chinook and sockeye salmon, rainbow trout, and Arctic grayling now contain only northern pike” (Rutz 1996). This suggests the need to address these questions: What is the impact of northern pike consumption of juvenile salmonid species on beluga whale prey availability and the potential contribution to beluga population declines? To what extent are northern pike contributing to issues of beluga prey population declines?

Water temperature change was identified by participants across user groups and geographical areas as a factor related to fish health, changes in fish run timing, and migration patterns. Changes in water temperature beyond the thermal limits or tolerances of salmonid species has been documented as causing physiological stress, susceptibility to disease, influencing out-migrations, spawning, embryo survival, and direct mortality in association with extreme temperatures (Richter and Kolmes 2005). The conservation plan identified variable water temperature events or cycles which increased or decreased primary productivity in the southcentral Alaska region in turn affecting food availability for beluga prey (NMFS 2008). However, specific issues related to fish health and migration timing in association with changing water temperatures were not explored in the plan. The previous TEK study noted fish run timing changes but participants did not identify a potential reason (Huntington 2000). These findings suggest the need to investigate water temperature changes effects on prey health, distribution, and timing of prey availability.

Increases in siltation and expansion of mudflats primarily along upper Cook Inlet river deltas and the potential impediment on beluga access to feeding areas were observed by numerous participants from those areas. While Huntington's 2000 TEK study (Huntington 2000) acknowledged consistently shifting river channels in the Susitna River, participants did not indicate passage obstacles. The primary cause of siltation increases was identified as an increase in glacial melt, potentially due to reduction in snowfall. An increase in river siltation material, due to glacial melt and its subsequent river delta accumulation, is corroborated by other studies (Holmlund, Burman, and Rost 1996; NMFS 2008). In the case of upper Cook Inlet, this situation may be exacerbated by its long, sloping coastal, land shelf, or expanded mudflats. Further study is warranted to determine the extent to which these alterations affect the whales' access to prey, limit access to habitat, and affect seasonal movements, given this study's results.

A number of participants' land-based observations agree with documented wetland drying in southcentral Alaska. According to a recent study, over the past 50 years, Kenai Peninsula wetlands experienced significant drying due to temperature increases and precipitation decreases (Klein, Berg, and Dial 2005). The same study's findings, at two sites, suggested water drawdown began in the mid-1970s, and in the late 1980s to early 1990s respectively. Participants reported reductions in migrating waterfowl populations beginning in the 1970s which noticeably accelerated by the mid-1990s. Reduction in wetlands, resultant of temperature changes and decreased precipitation, can affect bird migrations or nesting (Kusler 1999). Utilizing these two studies and this study's participant observations, it is suggestive that the observed decrease of waterfowl may be related to the wetland drying in southcentral Alaska, specifically in the Kenai Peninsula.

Additionally, what are the implications of inland and coastal wetland drying on ecosystem nutrient input and primary productivity of the Cook Inlet watershed and associated marine habitats? While there is ongoing research that focuses on terrestrial indicators of climate change (Klein, Berg, and Dial 2005; Gracz et al. 2008) and terrestrial systems, similar systematic research on marine environments, Cook Inlet in particular, may be warranted given the apparent ecosystem wide changes.

Potentially related to these ecosystem wide changes are participant observations of beluga prey health and decline. While many fish health observations were sporadic, ongoing instances of tumors and "crooked fish" may be indicators of broader changes in the inlet. Declines in salmon species and herring may have multiple causes. Herring crashes were reported by participants in the same time frame as the Exxon Valdez oil spill in 1989. Although there was uncertainty as to whether the spill was the cause, herring may represent a decline of a high value energy food source (Perez 1994) needed by beluga whales to replenish fat layers depleted during winter. While some herring fisheries are beginning to recover, the crashes' timing coincided with the same period as belugas' decline. The reduction of a high energy food source in the midst of the belugas' own population decline may indicate that change occurred at a critical time.

Many changes related to beluga prey decline may also be associated with energetics and what one participant called "energy nodes" or localized areas of high value energy sources. This biologist and commercial fisher suggested the reduction of certain fisheries represented losses of energy nodes and questioned the impacts of their loss on the beluga population and associated energy requirements during particular seasons. The beluga whale conservation plan identified and discussed the issue of prey reduction, centering on commercial fishing, management, and the importance of high value prey, primarily hooligan and other smelt, and salmon (NMFS 2008). These findings of various prey associated change present questions about cumulative impacts and suggest the need to assess occurrence and relation to broader environmental changes.

The majority of factors identified as environmental changes are related to climate change processes. Wetland drying studies identified climate related causes, changes in species populations and distributions suggest environmental and climate change influences. The broad range of changes reported in this study's finding compared to existing literature suggest potential ecosystem regime shifts, not only on land but in marine systems. While generally Cook Inlet and southcentral Alaska experiences multiple fluctuations on annual and decadal scales, these fluctuations may still reflect multiple steady-states. However, identified factors may reflect gradual changes which have lowered the system's resilience now culminating in the beginning of a regime shift in the Cook Inlet ecosystem.

Instances of transient killer whale interaction with beluga whales have been reported sporadically in the inlet, predominantly in the upper inlet and were associated with killer whale hunting of the belugas and related stranding events, suggesting that killer whales are not regularly present in the upper reaches of Cook Inlet. However, residents of Tyonek reported regular killer whale sightings beginning in the late 1980s to early 1990s. With evidence suggesting the Cook Inlet beluga whale contracted distribution into the upper inlet (Lerczak, Shelden, and Hobbs 2000; NMFS 2008) and increases in killer whale sightings by Tyonek participants and NMFS in the upper inlet, there is a possibility that the presence of killer whales influences beluga distribution and migration away from the central inlet. This lends support to experimental work of killer whale vocalization playbacks that drove beluga movements (Fish and Vania 1971). Participants' descriptions of beluga behavior, in association with killer whales, as erratic and bizarre as well as the belugas' subsequent avoidance of the particular area for three days, adds further support for this assertion.

Both transient and resident, fish eating, killer whales are present in Cook Inlet (NMFS 2008). While transient killer whales tend not to vocalize during hunts, both resident and transient killer whales have distinctive vocalizations (Saulitis, Matkin, and Fay 2005), though Cook Inlet belugas may not distinguish between the two ecotypes. Studies on harbor seals in British Columbia, Canada, found significant avoidance behavior exhibited by seals during playback recordings of transient and unfamiliar resident killer whale vocalizations, compared to habituated behavior during familiar resident vocalization playback (Deeke, Slater, and Ford 2002). The conservation plan acknowledges the possibility of killer whale influence on beluga distribution and identifies the need to assess the impacts of killer whale presence on the beluga whale population. Additionally, are there environmental or habitat changes in other portions of the Inlet that may influence killer whale distribution?

Fisheries management was discussed in detail by northern district fishermen indicating a focus on the central district stocks as a factor in reduced fish abundance and low escapements in the northern district. Participants indicated the declines began in the mid-1980s; ADF&G documented low chinook salmon harvest rates and escapements in the upper inlet since the early 1990s (Whitmore and Sweet 1998). Since 2004, poor fish runs were reported by northern district fishers. According to a 2006 ADF&G Upper Cook Inlet salmon escapement report, the rivers monitored for salmon included three in the central district: Kenai, Kasilof, and Crescent Rivers; and the Yentna River in the upper inlet, a tributary of the Susitna River (Westerman and Willette 2006). In a 1999 Board of Fisheries Upper Cook Inlet Findings Report, the board stated there was detailed information on the Kenai River salmon stocks but the Department and the Board “are totally lacking good, reliable, long term information upon which to base management decisions except in the grossest of terms (e.g., Northern District sockeye, all chum, all pink and most coho salmon)” (BOF 1999).

The conservation plan discussed fisheries management responsibilities, practices and variety of fish runs in specific geographical areas of the Inlet. This study was able to focus on additional detail for particular run areas in the central and northern districts including the Susitna drainage; the importance of maintaining these runs lies in the relatively high site fidelity exhibited by beluga whales, based on participant observations, previous TEK data, satellite tagging, and aerial surveys (Huntington 2000; NMFS 2008).

Participants identified sources of anthropogenic noise from oil and gas operations and exploration, commercial shipping, dredging, and boating. Studies of cetacean avoidance behavior in the presence of seismic airgun use show a broad range of behavioral responses including decreased sightings, localized avoidance and strandings, depending on the species (Gordon et al. 2004; Stone and Tasker 2006). Overall, these avoidance behaviors were temporary, as the animals returned after the disturbance ceased. While there were no direct observations of beluga whale avoidance behavior in association with shipping or boating activity, beyond the two personal experiences reported previously, the changes in beluga whale distribution in those areas participants reported activity increases present questions about potential correlations.

Two studies of Cook Inlet beluga whale behavior in the presence of ships and smaller boats potentially contradict this speculation of beluga avoidance behavior. One, observed a beluga whale swimming near docked, running cargo vessel (Blackwell and Greene Jr 2002); the other observed belugas avoided a research vessel during repeated approaches until they appeared to habituate to the vessel's presence (Lerczak, Shelden, and Hobbs 2000). These studies involved belugas in association with one or two vessels at a time and may not necessarily reflect actual levels of disturbance in particular areas of the Inlet. In the Beaufort Sea, belugas' avoidance behavior was observed associated with icebreaker vessel activity; swimming behavior changes were reported at distances of 40-60 kilometers (Erbea and Farmer 2000). More naturalistic studies suggest behavioral changes in dolphins and killer whales from anthropogenic noise. These included: significant abundance decline in bottlenose dolphins (*Tursiops truncatus*) with increased tour boating in Australia (Bejder et al. 2006) and observations of the Bristol Bay stock of beluga whale found that "it is generally believed in western and northern Alaska, however, that modernization of coastal communities, with its associated noise, is causing beluga whales to pass farther from shore and to abandon traditional sites" (NMFS 2003). Additionally, in industrialized areas, cumulative effects of continuous anthropogenic noise may cause serious problems for beluga whales (Erbea and Farmer 2000). It is difficult to ascertain levels of habituation or degrees of disturbance anthropogenic noise has on Cook Inlet beluga whales. However, further research focused on potential avoidance behavior with multiple vessels in a given study area or with seismic testing would provide a better understanding of the potential impacts on this beluga whale population.

5.0 Conclusions

The Conservation Plan stated that the Cook Inlet beluga whale will continue to decline into extinction "unless factors that determine beluga whale growth and survival were altered to improve the stock's chances to recover" (NMFS 2008). The conservation plan's actions and objectives express the need to "fill in the big picture gaps" given the limited information on the impacts of the identified threats to the beluga whales (NMFS 2008). This reflects a need for more research and monitoring of this population of beluga whale and related ecosystem.

This study documented local knowledge of ecological change in Cook Inlet over time and identified contributing factors for beluga whale decline and recovery, corroborating a number of findings of NMFS's beluga whale conservation plan and those in Huntington's 2000 traditional knowledge study and extended the date range for the beluga whale decline. Participants also identified numerous factors of ecological change over time including marine habitat, predatory and prey population and distributional changes, climate related terrestrial and plant shifts, and a range of human-activity related impacts.

As a result, these findings present alternate areas for research and suggest priorities for further conservation planning, including limits on the expansion of northern pike into salmon spawning areas, including shark populations in Cook Inlet fisheries, status reviews to collect data on their distribution and numbers to better understand emerging trends, and increasing the focus on the northern district fisheries to ensure that escapement goals are met through additional monitoring. Similar to ongoing database development and breadth of research on terrestrial ecosystems, an expansion of research into the continual changes occurring in marine environment and terrestrial/marine transition zones would improve understanding of the interrelations between these areas in southcentral Alaska.

Furthermore, this study's findings contribute to objectives identified in the conservation plan. These objectives include documenting beluga distribution and movement, determining baseline environmental conditions, assessing prey base and prey availability, determining temporal and spatial shifts of prey species, assessing prey reduction effects of commercial fishing, assessing impacts of killer whales, and identifying valuable habitat. Many of this study's results factor into these objectives and provide application information to begin filling knowledge gaps.

Given the broad range of participant observation and knowledge of Cook Inlet ecological processes, it is essential that inclusion of local knowledge be included in conservation planning and research, not only on this population of beluga whales, but for other wildlife and natural resource management planning. Its value and efficacy has been illustrated in this study and others. Utilizing this area of research in conjunction with traditional methods will provide a more complete understanding of the environment in which management and planning efforts are based.

Table 1

Participant Group Demographics: Participant user group demographic breakdown illustrates geographic location, number of participants per user group, average age, and average years of experience on the waters of Cook Inlet.

	User Group	Number of Participants	Average Age	Average Years of Experience
Upper Inlet	Alaska Native Village of Tyonek	9	49	43
	Alaska Native Anchorage	1	48	32
	Commercial Fishers	8	57	35
	Bush Pilot	1	64	10
Central Inlet	Kenaitze Tribe Village of Kenai	8	56	45
	Alaska Native Kenai Peninsula	2	52	48
	Commercial Fishers	3	50	33

Table 2

Factor/Threat Assessment Matrix: The matrix is separated into both Natural/Environmental and Human-Related factors/threats with associated sub-factors and compares those threats identified in NMFS Beluga Conservation Plan and those identified by this study's participants. Each factor is identified as appearing in either this study, in the conservation plan or both, the level of impact to recovery assessed by NMFS, the weighting across interviews, the geographic area where the factor was observed and the user group that reported the particular factor.

	Factor/Threat	Reported Observation in Current Study	Reported in NMFS Conservation Plan	NMFS Suggested Impact to Beluga Whale Recovery	Observed Occurrence Across Interviews	Geographic Area Observed (Upper or Central Inlet)	Observed by: (Alaska Native or Commercial)
Natural/ Environmental Factors/Threats	Prey Competition • Shark Increase	X	-	???	11	Both	Both
	• Northern Pike Expansion	X	-	???	7	Upper Inlet	Both
	Killer Whale Impacts • Beluga Behavior/ Avoidance	X	-	???	3	Both	Both
	• Predation	X		Moderate	5	Upper	Both
	Stranding	X	X	High	6	Upper	Both
	Prey Health Deterioration	X X	-	???	5	Both	Both
	Potential Climate Change Related: • Water Temperature Change	X	X	???	8	Both	Both

	• Animal/Plant Species Change	X	-	???	12	Both	AK Native
	• Erosion/Siltation	X	X*	Low	10	Both	Both
	• Reduced Snowfall	X	-	???	3	Both	Both
	• Wetland Drying	X	-	???	2	Both	Both
	Beluga Health • Blubber Reduction • Disease • Parasites	X	X**	High-Low	3	Upper Inlet	AK Native
Human Activity Related Factors/Threats	Fisheries Management • Commercial Fishing	X	X	High	5	Upper Inlet	Both
	Personal Use, Subsistence and Recreational Fishing	-	X	Low	-		-
	Beluga Subsistence Harvest (Legal)	-	X	Low	-		-
	Commercial Fishing Incidental Take (Beluga)	-	X	Moderate	-		-
	Poaching/Illegal Harassment (Beluga)	-	X	High	-		-
	Pollution • Industrial Sources	X	X	???	7	Both	Both
	• Urban Sources	X	X	???	7	Both	Both

	• Sport Boating Related	X	-	???	3	Central Inlet	Both
	Development • Habitat Change/Loss	-	X	Moderate	-	-	-
	Vessel Traffic • Ship strikes-Large ships	-	X	Low	-	-	-
	• Ship strikes-Small ships	-	X	Moderate	-	-	-
	Noise • Shipping & Sport Boating increases	X	-	High	3	Central Inlet	Both
	• Oil & Gas Production	X	-		3	Both	Both
	• Seismic Testing	X	-		2	Central Inlet	Commercial
	Research	-	X	Moderate	-	-	-

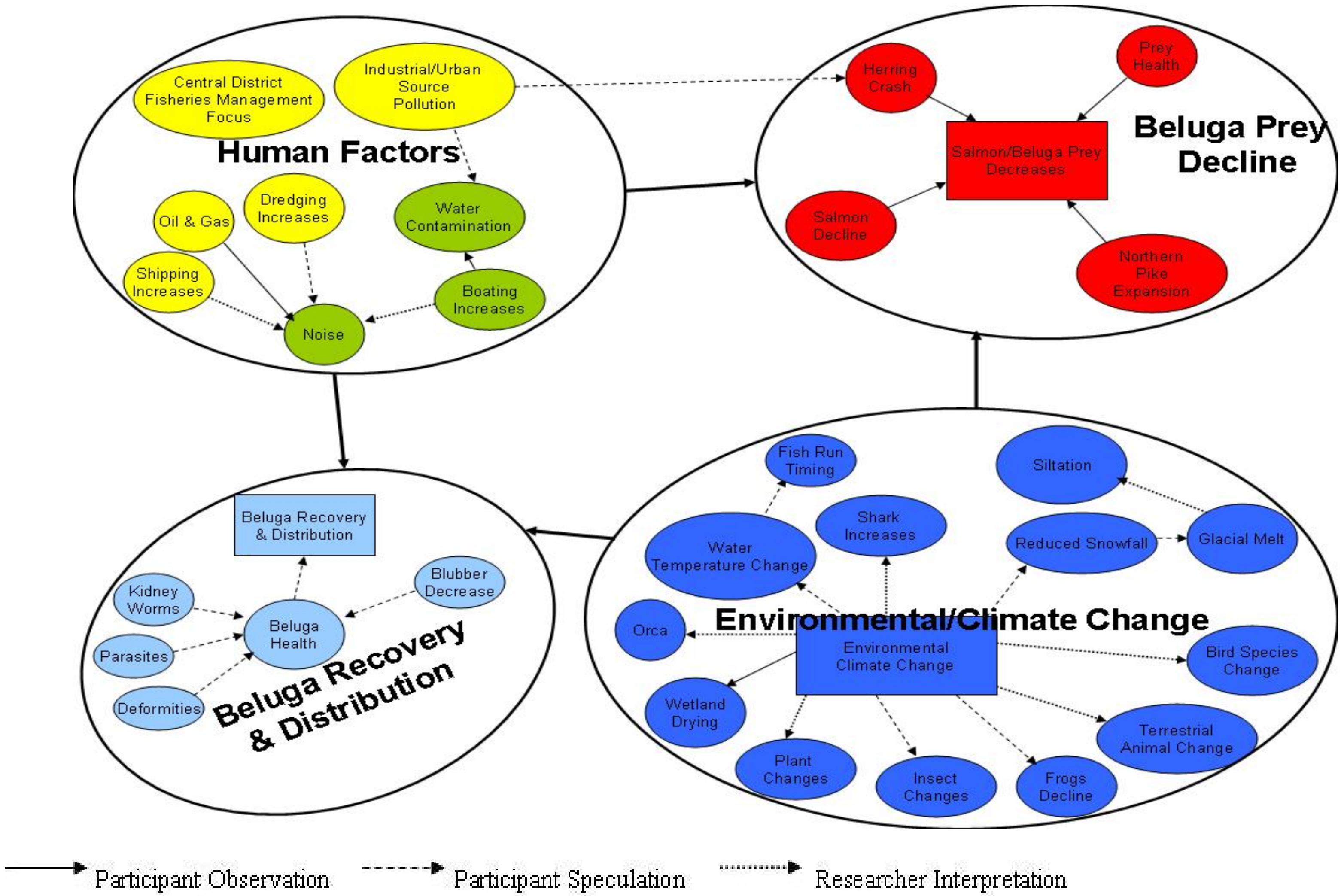

Fig. 1. Factor Model is based on results of participant observations, participant speculation, and researcher interpretation. The four categories (represented as large circles) encompass related factors with larger arrows indicating the direction of interrelatedness. Details of each are discussed in the results and discussion section

CHAPTER FIVE

Participatory Mapping of the Cook Inlet Beluga Whale (*Delphinapterus leucas*) Population and Ecological Change through Local Ecological Knowledge

Abstract

The Cook Inlet beluga whale, one of five Alaskan stocks, is genetically distinct and geographically isolated from other populations. Historically, Cook Inlet whales were hunted commercially, for sport, and for subsistence uses. The Marine Mammal Protection Act (MMPA) of 1972 ended commercial and sport hunting; subsistence hunting voluntarily ended in 1999. In 2000 the National Marine Fisheries Services (NMFS) determined the population had declined by 47% between 1994 and 1998, resulting in a listing of "depleted" under the MMPA. In 2008, Cook Inlet beluga whales were listed as endangered under the Endangered Species Act after annual aerial surveys indicated the population was not recovering as expected. A combination of natural and anthropogenic factors may be affecting this population's recovery. Through individual and group interviews and participatory mapping exercises, this paper documented local ecological knowledge of Cook Inlet beluga whales to analyze changes overtime in a spatiotemporal context as they relate to contributing factors for decline and recovery. Results of participatory mapping and GIS analysis indicate increases in shark and northern pike (*Esox lucius*) populations and increased instances of killer whale (*Orcinus orcas*)

sightings in spatial association with beluga habitat. These changes illustrate broader environmental or climate related changes potentially affecting the whales' recovery.

Keywords: Beluga whale, GIS, participatory mapping, LEK

1.0 Introduction

The Cook Inlet beluga whale (*Delphinapterus leucas*) is one of five Alaskan stocks, genetically distinct and geographically isolated from the other four populations. Historically, they were hunted commercially, for sport and subsistence uses (Huntington 2000; Mahoney and Shelden 2000). Commercial and sport hunting ended with the Marine Mammal Protection Act (MMPA) of 1972. Subsistence hunting by a number of Alaska Native villages within the Cook Inlet watershed was voluntarily ended in 1999 after the population was reported to have declined by 47% between 1994 and1998 resulting in listing this population as a "depleted" stock in 2000. In 2008, after eight years of annual surveys, the Cook Inlet beluga whales were listed as endangered under the Endangered Species Act (ESA) of 1973 after it was determined the population was not recovering as expected.

A variety of alternative hypotheses have been proposed to explain the failure of the Cook Inlet beluga whale's recovery with little conclusive scientific evidence of direct causal factors. The NMFS lists potential natural and anthropogenic threats based on scientific and TEK studies, including: strandings, predation from killer whales (*Orcinus orca*), parasites and disease, environmental change, illegal harvest, commercial and personal use fishing of beluga prey, pollution, oil and gas activities, coastal development, vessel traffic, anthropogenic noise, tourism and whale watching, and effects of climate change (NMFS 2008). The level of uncertainty about the threats to this particular beluga whale population suggests there is a significant need for further research into those potential factors contributing to the unresponsive recovery (NMFS 2008; Huntington 2000).

Documenting traditional ecological knowledge (TEK), or in this study's case, local ecological knowledge (LEK) is one approach to gain a better understanding of individual species and ecological changes. LEK's benefits include the ability to fill gaps in existing research and management practices through data collection of localized data over extended time periods (Gilchrist, Mallory, and Merkel 2005; Hall and Close 2007). It has been utilized to create large scale data sets for conservation and management planning at significantly lower costs (Aswani and Lauer 2006; Anadón et al. 2009).

LEK data can serve to complement mainstream scientific research as well as identify patterns and relationships not previously documented or considered (Anadón et al. 2009; Huntington 2000; Huntington et al. 2004; Moller et al. 2004; Gilchrist, Mallory, and Merkel 2005). Participatory mapping has been utilized to document stakeholders' knowledge before it is lost and provide baseline data for long-term planning and management (Tobias 2000) and can serve to illustrate ecological changes over time.

Previous research documented subsistence use of beluga whales in Cook Inlet (Stanek 1994) and traditional ecological knowledge of the ecology of the whales (Huntington 2000). Huntington's study focused on beluga hunters' knowledge of beluga whales and associated changes in the upper Cook Inlet from the Kenai River north. The study identified observed beluga whale feeding and calving areas, beluga prey species, reported changes in beluga abundance and distributions, observed prey species declines and run time changes and indicated potential links between these changes and increased human population and activity in the Inlet (Huntington 2000). This present study expands on Huntington's research to include the central and upper inlet, interviewed additional Alaska Native subsistence users and commercial fishers focusing on broader environmental and anthropogenic changes overtime in Cook Inlet to identify additional direct and indirect factors that may be impacting this population of beluga whales. This article focuses on those changes identified through participatory mapping and timeline discussion as part of the broader LEK study exploring contributing factors for the Cook Inlet beluga whale decline and recovery.

The purpose of this article is to document Cook Inlet beluga whale habitat change through LEK participatory mapping and through geographic information systems (GIS), analyze for spatiotemporal ecological changes in association with beluga whale habitat.

2.0 Methods

Data were generated through semi-structured individual and group interviews with Alaska Native fishers, beluga hunters from the Village of Tyonek and the Kenaitze Tribe, and non-native commercial set net fishers from the upper and central inlet. Thirty-two study participants, selected through criteria and snowball-sampling methods (Miles and Huberman 1994; Becker et al. 2003), included 20 Alaska Native fishers and beluga hunters, 11 commercial fishers from the upper and central inlet, and one bush pilot; with average age of 55 years and an average of 40 years of experience fishing and hunting on Cook Inlet. Five group interviews and 11 individual interviews occurred between September 2007 and March 2008.

The semi-structured interviews (Miles and Huberman 1994) were complemented with participatory mapping and timeline exercises (Chambers 1994). United States Geographical Survey (USGS) 1:250,000 topographical maps of the Cook Inlet region were used to guide the interviews. These maps encompassed the entire study area which included Knik Arm in the north, to south of the town of Happy Valley on the eastern Kenai Peninsula and across to Chinitna Bay on the western Inlet (Fig 3). The interviews began with both the maps and timeline placed on a large table in front of the participants. Participants used the maps to illustrate and discuss observed beluga whale population and ecological change. The researcher marked directly on the maps asking questions that delved further into particular observations. Interview questions included: when and where did a particular change take place; was it a one-time occurrence or was it ongoing; was the change observed to affect the beluga whales; and if so, how did it affect the whales; were there other areas particular changes occurred and asking other participants within a group interview if they observed similar occurrences. The timeline was used to document additional temporal data associated with the mapping and to collect broader temporal data that were not appropriate for map placement, such as when participants began noticing declines of beluga numbers, time-range in which increased sandbar formation was observed, or when shark observations became noticeable.

The maps were digitized using ESRI's ArcMap software and the timeline data was used to create GIS layers. Data were organized into three groups within the study's primary geodatabase; Beluga Whale Observations, Species Changes, and Habitat Changes with each based on date ranges in ten year increments from 1950 to 1979 and in five year increments from 1980 to 2004 and one for the remaining four years, 2005 to 2008, each of which chosen for data management purposes. There were few participant observations of ecological change prior to 1980 compared to the years after 1980 when observed changes became more numerous. This did not appear to reflect deficiencies of memory but indicated noticeable changes which began during that time period. For this reason decadal increments were deemed appropriate for pre-1980 years. After 1980 increased observations of change dictated a smaller interval in order to capture the increased quantity of data. Within each of the primary groups, each of the associated changes examined in this study were digitized with attributes including; geographic location, Central or Upper Inlet; years observed; and the user group associated with the observation. For example, spatial areas where shark observations occurred were digitized into the Sharks layer along with associated attributes, located within the Species Changes group. The same process was followed for the other observed changes.

Those changes selected for analysis were based on those which occurred across interviews and were dominant within discussions. These included beluga whale sighting locations overtime, observed shark increases, areas of northern pike (*Esox lucius*) expansion, killer whale (*Orcinus orcas*) sightings including those associated beluga whale stranding and locations of increased siltation and mudflat expansion. While these changes and observations were based on cross-interview weighting, some observations of beluga whale sightings by only one person were included in the analysis. These observations included those individuals who utilized relatively remote areas and were the only sources of information in those areas for this study. Specifically, these instances included a commercial fisher from Kalgin Island, two Native Alaskan users, one from the Chickaloon Bay area and one who witnessed a beluga whale stranding event near the Susitna River in association with killer whales.

These GIS data were then analyzed through spatial overlay analysis based on timeframe associations and cross referenced with the timelines generated during interviews and transcribed participant interviews. In order to identify observed trends from 1950 to 1984, after which participants reported decreases in beluga numbers, all beluga whale observations from that date range were merged together. The merging decision was based on trends illustrated in the timelines generated during interviews and participant observation. This operation was repeated for those beluga whale observations from 1985 to 2008 which represented primary period of observed decline, resulting in two layers; one prior to observed beluga reductions and one representing the timeframe of the observed decline. These two layers were separated into two additional layers representing the central and upper inlet in order to analyze changes between the two geographic areas then used to examine areas of association between beluga observations and species and habitat changes.

Beluga observation and distributional change was analyzed by utilizing the two previously created beluga whale observations layers. The 1985-2008 layer was spit into one layer representing beluga observations from 1985-2000, one representing observations from 2001-2004 and one for the 2005-2008 time-ranges to refine observational changes, primarily in the central inlet.

Observations of species changes were examined for those in association with beluga whale observation areas. To analyze observed shark distribution, the layers representing upper and central inlet beluga observations from 1985 to 2008 was intersected with shark observations.

Northern pike expansion was analyzed using 1985-2008 Upper Inlet beluga observations layer, layers for rivers and streams where northern pike are present and an anadromous rivers layer. In order to identify rivers and streams containing northern pike in association with those waterways utilized by the beluga, a new layer was created by selecting anadromous rivers within 1.75 miles of commonly observed beluga feeding areas. This layer was then intersected with those rivers where northern pike expansion had occurred. This resulted in a layer showing those beluga utilized rivers where northern pike are present.

Killer whale sightings in association with common beluga feeding areas were analyzed by intersecting the upper inlet beluga habitat extent with killer whales observations which was overlaid with the beluga whale observations layer. In order to show those killer whale observations associated with beluga stranding events, two new layers were created based on common timeframes in the two aforementioned base layers. The new layers illustrated killer whale sightings and stranding events observed by participants from 1985-2008.

Beluga whale habitat changes were examined using the layers created for increase siltation and mudflat expansion. This analysis was performed by simply overlaying the siltation and mudflat expansion layer with the beluga habitat extent and 1985-2008 Upper Inlet beluga whale observations layers. This resulted in illustrating those areas in common. The 1985 to 2008 timeframe was used for each analysis because this was the common time-range for each observed change.

3.0 Results

Three themes emerged from the participatory mapping. These include beluga whale observation decline and distribution change; species change including shark population change, an increased presence of killer whales and northern pike expansion, and siltation and mudflat expansion in the upper inlet.

3.1 Beluga whale observation decline and distribution change

While beluga whales have historically been observed throughout the Inlet, the analysis focused on their extent within the central and upper portions (Fig. 3). Spatial and temporal analysis illustrated that changes in beluga whale distribution occurred predominantly in the central inlet where large pods (>20) were observed regularly through the mid-1980s along the Kenai Peninsula north of Ninilchik and south of the Forelands and west of Kalgin Island. Consensus among participants indicated that noticeable declines in the beluga population began in the mid-1980s throughout the upper and central inlet and continued to decline thereafter while observation areas remained fairly consistent. Beluga whale distributions in the upper inlet remained consistent with sightings near Tyonek; the Beluga, Susitna and Little Susitna Rivers; in Knik Arm and Turnagain Arms and Chickaloon Bay (Fig. 3). On the western portion of the central inlet there also appeared to be a shift away from Kalgin Island towards the western coast through the 1990s with decreasing frequency. By 2000-2001 participants no longer were observing beluga whales along the eastern Kenai Peninsula with people stating that, “they don’t remember the last time the saw a beluga” or “if I saw one now it would be quite a surprise” (Fig 4).

One beluga hunter from the Anchorage area did report, during an individual interview, an increase in upper inlet beluga abundance from the early-1990s to 2005 with a small decline in the mid-1990s which did not last long. She stated that others she hunted were in agreement with this timeframe. This participant took part in beluga hunts near the mouth of the Susitna River from the mid-1970s until the voluntary hunting suspension in 1999. This participant related her mother’s observations, who hunted in the area since the late 1960’s, stated that:

> From what my mother said just from two years ago. In ‘65 when they first started hunting here it was the most she’s ever saw. To me it increased also from back in the 70’s. 75’, 74’ to now it’s bigger.

3.2 Species Change

Species change in associated with beluga whale sighting areas, in the post-1985 time period, include increased shark observations, expansion of northern pike and increased killer whale observations. Shark population change occurred primarily in the central inlet with recent observations near Tyonek, northern pike expansion (Fig 5) and higher frequency killer whale observations occurred in the upper inlet (Fig 6).

Sharks are caught in commercial and Alaska Native fishers' setnets in increasing numbers as illustrated by an Alaska Native fisher during a group interview on the Kenai Peninsula; "You know what else there's a lot of is those mud sharks, fill up the net rather than fish."

The descriptions of the observed sharks included sharks that were dark on the dorsal side and white-ish on the underside and were identified as dogfish (*Squalus acanthias*) and mud or sand sharks while others, up to 10ft long, were identified as salmon sharks (*Lamna ditropis*). Participants from the Village of Tyonek observed salmon sharks and dogfish beginning in 2002. Other participants from the central inlet observed increases in dogfish catches and sightings along the Kenai Peninsula and mouth of the Kenai River since the mid to late-1990's (Fig. 5). Shark increase locations are in association with commonly observed beluga whale areas.

Northern pike expansion was observed by participants in a number of the northwestern inlet's rivers. These included Alexander and Fish Creeks, tributaries of the Susitna River along with tributaries of the Chuitna River near Tyonek. Many of these rivers affected by northern pike are utilized by beluga whales or are tributaries of those used by the whales for hunting (Fig. 5).

Killer whales have been observed sporadically by participants in the upper inlet during the 1985-2008 timeframe. However, since the early 1990s Tyonek residents indicated an increase in killer whale sightings (Fig. 6). Participants from separate interviews directly observed beluga whale stranding events in association with killer whales sightings. One participant observed one event along the northern Kenai Peninsula and while the other observed a similar instance near the mouth of the Susitna River (Fig 6). Additional sightings of killer whales were observed multiple times at the eastern end of Turnagain Arm speculated to be feeding on hooligan (Fig. 6). The killer whales observed within Turnagain Arm were observed multiple times and those near Tyonek were observed with increased frequency since the early 1990s

3.3 Increased siltation and mudflat expansion

Areas of increased siltation and expanded mudflats were identified by participants along many of the upper inlet river mouths and peripheral areas. These beluga utilized rivers included the McArthur River north to just south of Tyonek; at the mouth of the Beluga River north along the Ivan, Susitna and Little Susitna Rivers. Increased siltation was also reported east and west of Fire Island; and at the entrance of Turnagain Arm near Potter Marsh and along Chickaloon Bay (Fig. 7). A time range for these changes was difficult to narrow down from participant comments. There were a number of people who said the increased accumulation along river mouths began approximately ten years ago and increased fairly rapidly. Others indicated these changes occurred at a slower rate over a twenty year period. Participants indicated these changes have affected or hindered their transportation and fishing activities in those areas, particularly in the McArthur, Susitna and Little Susitna River.

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4.0 Discussion

The results of the participatory mapping and analysis identified increases in shark populations, northern pike expansion, increased killer whale observations and increased siltation and mudflat expansion. These suggest environmental or climate change related changes are the predominant factors affecting beluga whale population and potentially threatening recovery.

Participants from both the upper and central inlet consistently observed decreases in beluga whale sightings beginning in the mid-1980s. With the exception of one Anchorage participant who indicated a population increase in the upper inlet. Given the reduced sightings along the Kenai Peninsula and an apparent shift to the western coast of the central inlet, this may reflect a distributional shift or contraction into the upper inlet. Huntington (2000) similarly reported reduced beluga numbers over the previous decades along the Kenai River indicating this may be in response to increased human activity. Upper inlet sighting areas remained consistent throughout the period of observed decline potentially reflecting high site fidelity (NMFS 2003) along major anadromous fish spawning rivers – McArthur, Chuitna, Beluga, Theodore, Ivan, Susitna and Little Susitna

Rivers. These finding led support to the previous TEK study in which participants reported, “In Trading Bay, up until 10-15 years ago, there were great numbers of belugas in June and July…” (Huntington 2000), which places diminishing beluga number in the upper inlet between 1984 and 1989.

The observed start of the beluga whale decline in the mid-1980s somewhat contradicts the aerial survey data which indicated a significant decline between 1994 and 1998 (NMFS 2008). Since aerial surveys were not performed prior to 1993 the differences between participant observations and survey data does not necessarily represent a contradiction but should be viewed as an expansion on current information. While the 47 percent decline during the mid to late1990s represents a significant decline, the observations by this study’s participants pushes the date range of noticeable declines back 8 to 10 years which indicates the potential presence of additional factors impacting the beluga whale population.

In contradiction to the observed beluga abundance declines by other participants, one prior beluga hunter indicated an increase in the upper inlet beginning approximately in 1979 with a small decline during the mid-1990s with a general increase thereafter. This observed increase in the upper inlet may reflect a distributional shift or habitat contraction away from the central inlet.

Species and habitat changes, as observed by study participants, in association with beluga habitat include increased siltation and mudflat expansion along river mouths, expansion and proliferation of northern pike, an invasive, predatory fish, into salmon spawning rivers and streams of the upper inlet and regular killer whale sightings since early 1990s (Fig. 5-7).

Observed increases of sharks in the central upper inlet may suggest shark population range shifts, reproduction changes, shifting prey base, water temperature change and could present increased feeding pressure on fish populations and compete with beluga whales for prey based on observation in associated beluga whale use areas. Spiny dogfish are the most prevalent of the two shark species and have increased over the past decade based on Cook Inlet bycatch reports from the lower inlet and southern portion of the central inlet (Trowbridge et al. 2008). These reported increases over the past decade correspond to participant observations. The diet of both shark species include a number of commercially viable fish such as herring, smelt and juvenile salmon, which are known beluga whale prey (Meyer et al. 2009). These findings suggest a progression of shark populations northwards since the mid-1990s along the eastern central inlet and their relatively recent appearance in rivers near Tyonek. While this apparent, observed progression is not identified in fisheries reports or as a threat to beluga in the NMFS beluga whale conservation plan (NMFS 2008) these data can be utilized to expand on current assessments.

The expansion of northern pike, an invasive species in Southcentral Alaska, into anadromous rivers and salmon spawning habitat present a significant impact on associated salmon fisheries in that they prey on young salmonid species (Rutz 1996, 1999). Given these findings and participant observations of northern pike expansion into rivers observed as beluga whale feeding areas (Fig 6) the impact on beluga prey species may be of concern. Potential connections between northern pike impacts on associated fish abundance and the effects on beluga whale prey in the northwestern inlet watersheds have yet to be assessed.

Increases in siltation and mudflat expansion hindered participants' access to fishing sites and may affect beluga whale movement in the same feeding area. This was mentioned in the 2008 Conservation Plan for Cook Inlet Beluga Whale, which speculated, since beluga whales are continually observed in the river mouths, they may be able to adapt to such changes (NMFS 2008). Huntington (2000) commented on shifting channels in the Susitna River which influence routes the beluga whales take upriver but there was no mention that these changes hinder their access. However, there was a consensus among the participants that there has been noticeable increased accumulation in the form of observed mudflats expansion and sandbar formation which has impacted their activities in those areas.

Killer whales are natural predators of beluga whales and, as noted in two separate interviews, have been regularly sighted in the upper inlet since the early 1990's, with a higher frequency near the Village of Tyonek. Killer whales have been associated with mass stranding of beluga in the past and have been observed hunting them in Turnagain Arm (NMFS 2008). Killer whales are listed in the NMFS's Conservation Plan as a "high probability" threat affecting the beluga whale in the next 5 years (NMFS 2008). With the observed increased presence of killer whales north of the Forelands they may also influence beluga whale movement into the central inlet. A 1971 publication documented how beluga whales were driven from the Kvichak River, on the western side of the

Alaskan Peninsula by recorded killer whale vocalizations (Fish and Vania 1971). With the apparent increase of killer whale presence along the northwest coast of Cook Inlet and experimental research there may be a distributional influence on the beluga due to killer whale presence.

5.0 Conclusions

This study documented local ecological knowledge of Cook Inlet beluga whales through participatory mapping and GIS analysis in order to explore spatiotemporal change associated with beluga whale habitat. The analysis identified changes in beluga whale observation frequency and distribution, predominantly in the central inlet. Environmental change was prevalent throughout the interviews which included increases in shark and killer whale presence, expansion of northern pike and increased siltation and mudflat expansion. The use of participatory mapping proved useful for facilitating discussion and recollection of previous events and was deemed essential for the broader LEK study. While the participatory mapping findings in this study identified trends of change, specifically central inlet beluga observational change, more detailed spatial and abundance data may have been attained by focusing on smaller time-ranges.

With ten years separating the previous Cook Inlet beluga whale TEK study and this study, additional information presented here supports and expands on previous findings. Beluga whale distributional and abundance changes were similar in both this study and Huntington's providing additional support for initial declines beginning in the middle to late 1980s. Participant observations of frequent beluga sighting areas in the upper inlet, primarily along the northwestern coast and Susitna River drainage are similar to the 2000 study.

The findings supply additional factors which have not been previously discussed in the context of this beluga whale population and in what manner they may impact the beluga whale recovery. This additional information should prove useful in future conservation efforts, for additional scientific research and contribute to the expanding knowledge of this beluga whale population. This method of research is useful and appropriate for wildlife management in areas where little data is available, where baseline data in absent, when significant financial limitations exist and when geographic conditions hinder researcher access.

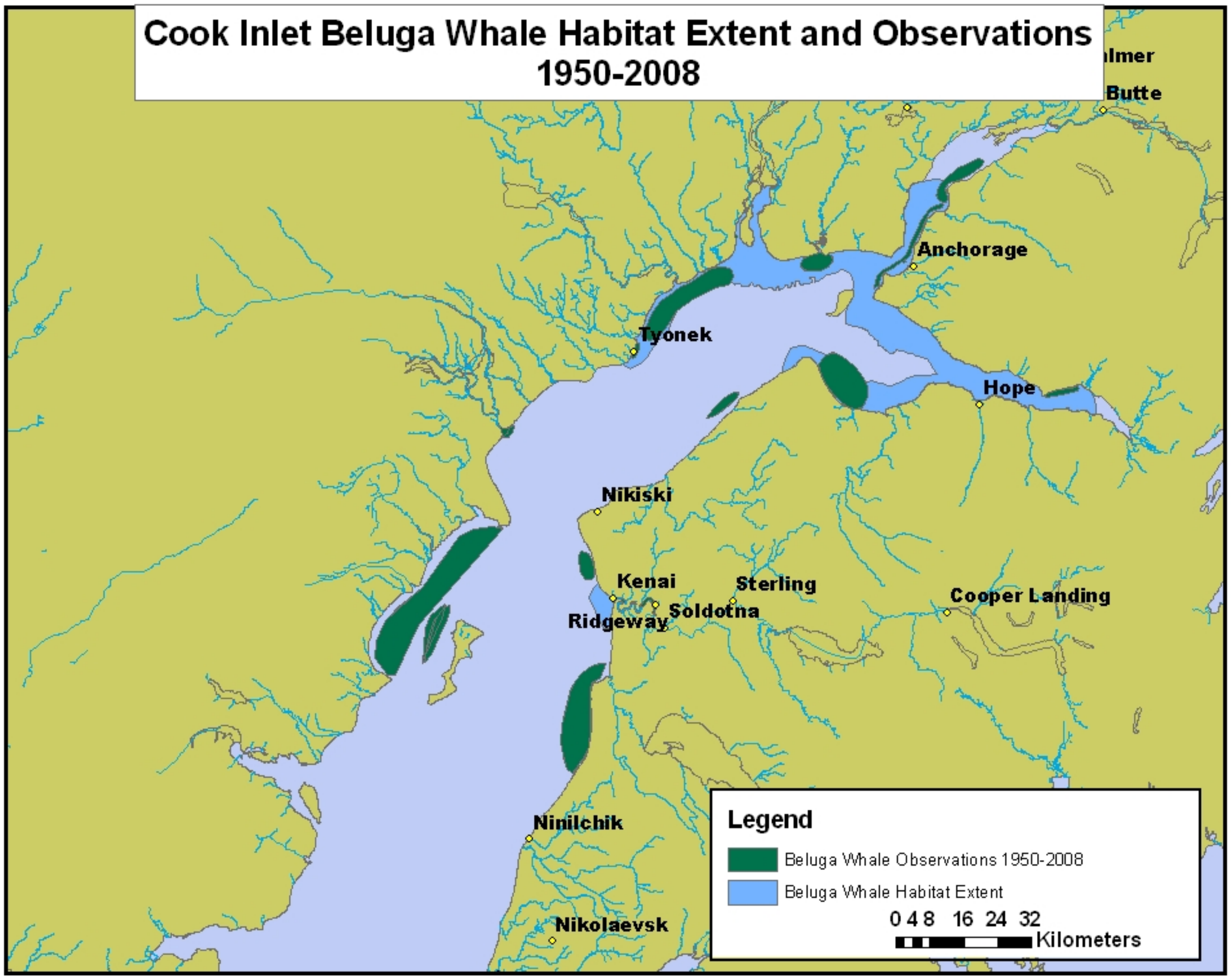

Fig. 3 Beluga habitat extent and areas of observation 1950-2008. The blue layer represents traditional summer habitat extent of beluga whales (CookInletKeeper 1997) and the dark green represents participant beluga whale observations from 1950-2008.

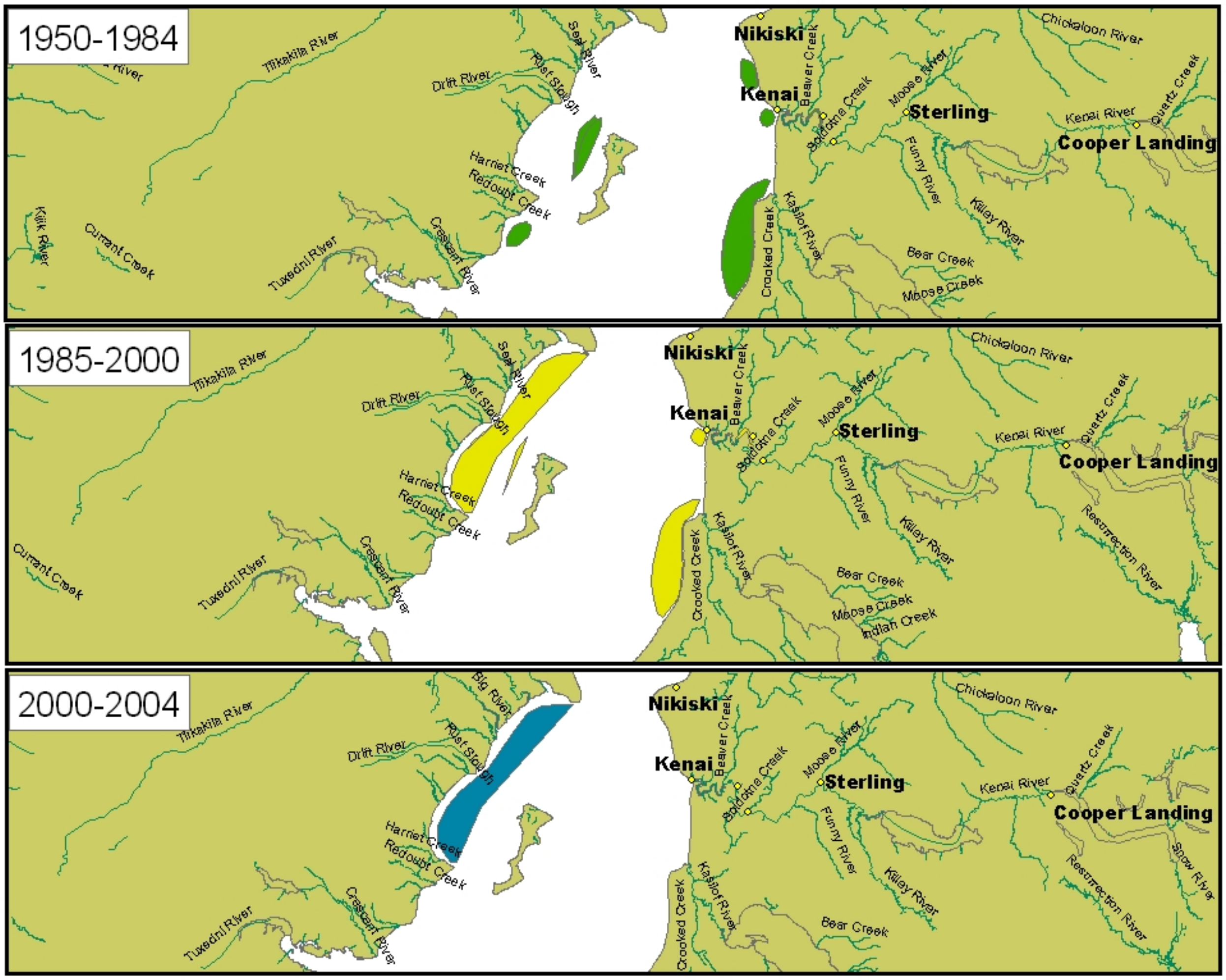

Fig. 4 Central inlet beluga whale observation change from 1950-2004. The top map shows areas where participants commonly observed beluga whales from 1950 through to 1984. While sighting areas remained fairly consistent, participants indicated noticeable declines in the beluga observation beginning in the mid-1980s and continued to decline thereafter, with an apparent shift away from Kalgin Island towards the western coast. By 2000-2001 participants no longer were observing beluga whales along the eastern Kenai Peninsula.

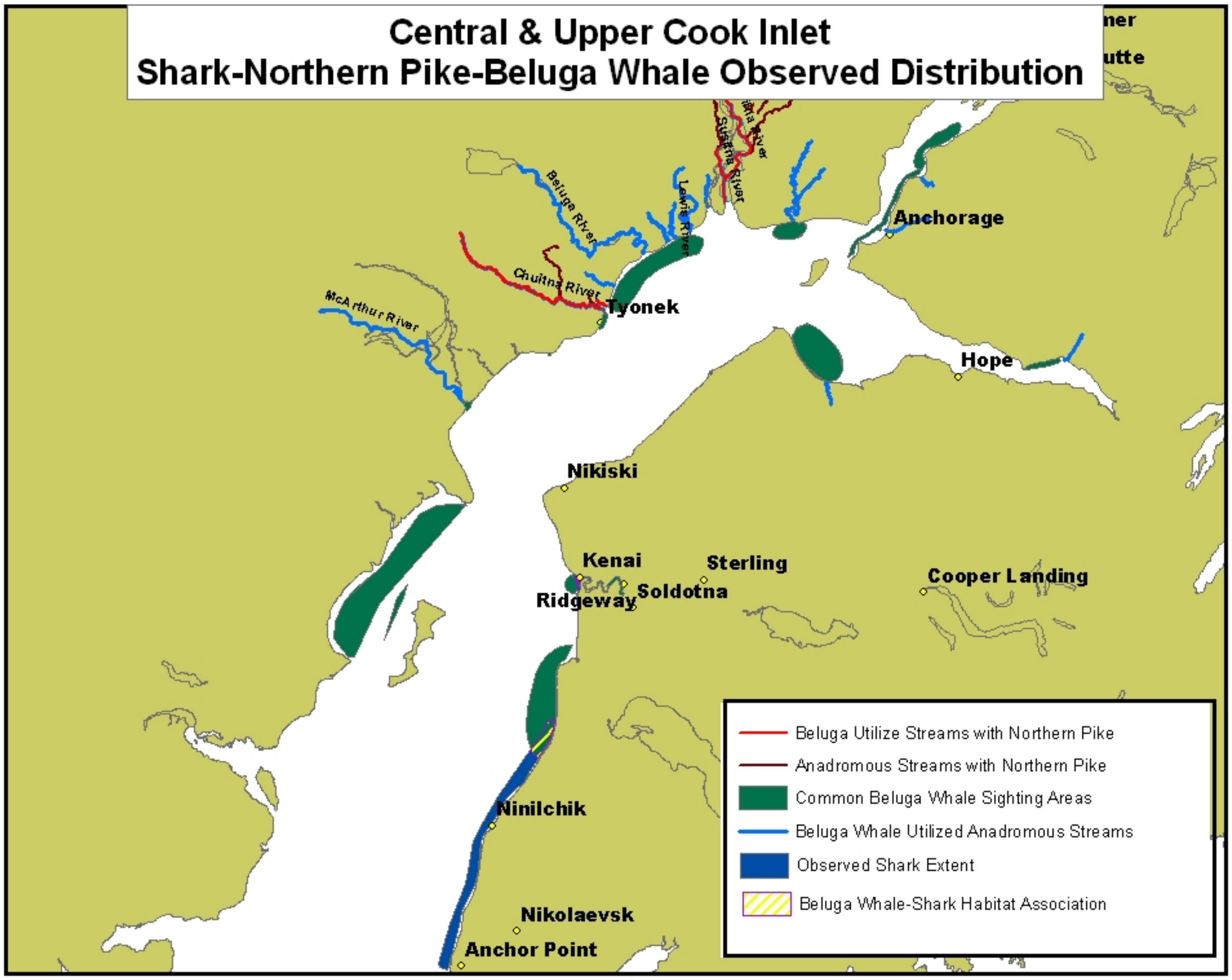

Fig. 5 Areas of observed shark and northern pike increases or distributional change during the period of beluga whale decline. Sharks were observed in association with beluga use areas in both the central and upper inlet. Northern pike was observed in numerous beluga whale utilized rivers in the upper inlet.

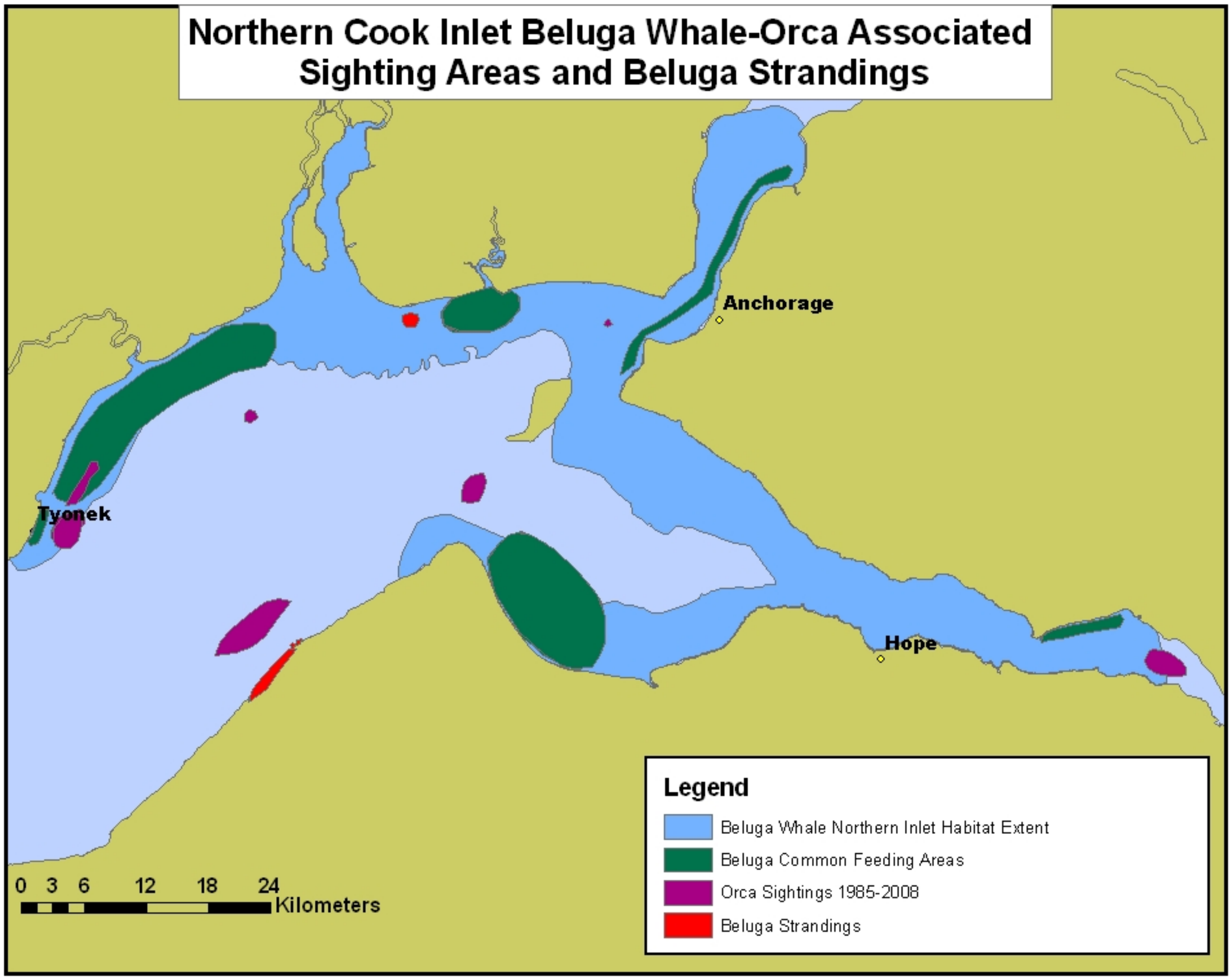

Fig. 6 Areas of association between commonly observed beluga whale feeding areas, killer whale sightings and associated beluga whale stranding events. This map shows where killer whale sightings have occurred in association with common beluga whale feeding areas in and near Turnagain Arm and near the Village of Tyonek. Increased observations of killer whales by Tyonek participants was a notable change in the 1985-2008 timeframe The two beluga whale stranding event shown in red and associated killer whale sighting were directly observed by participants.

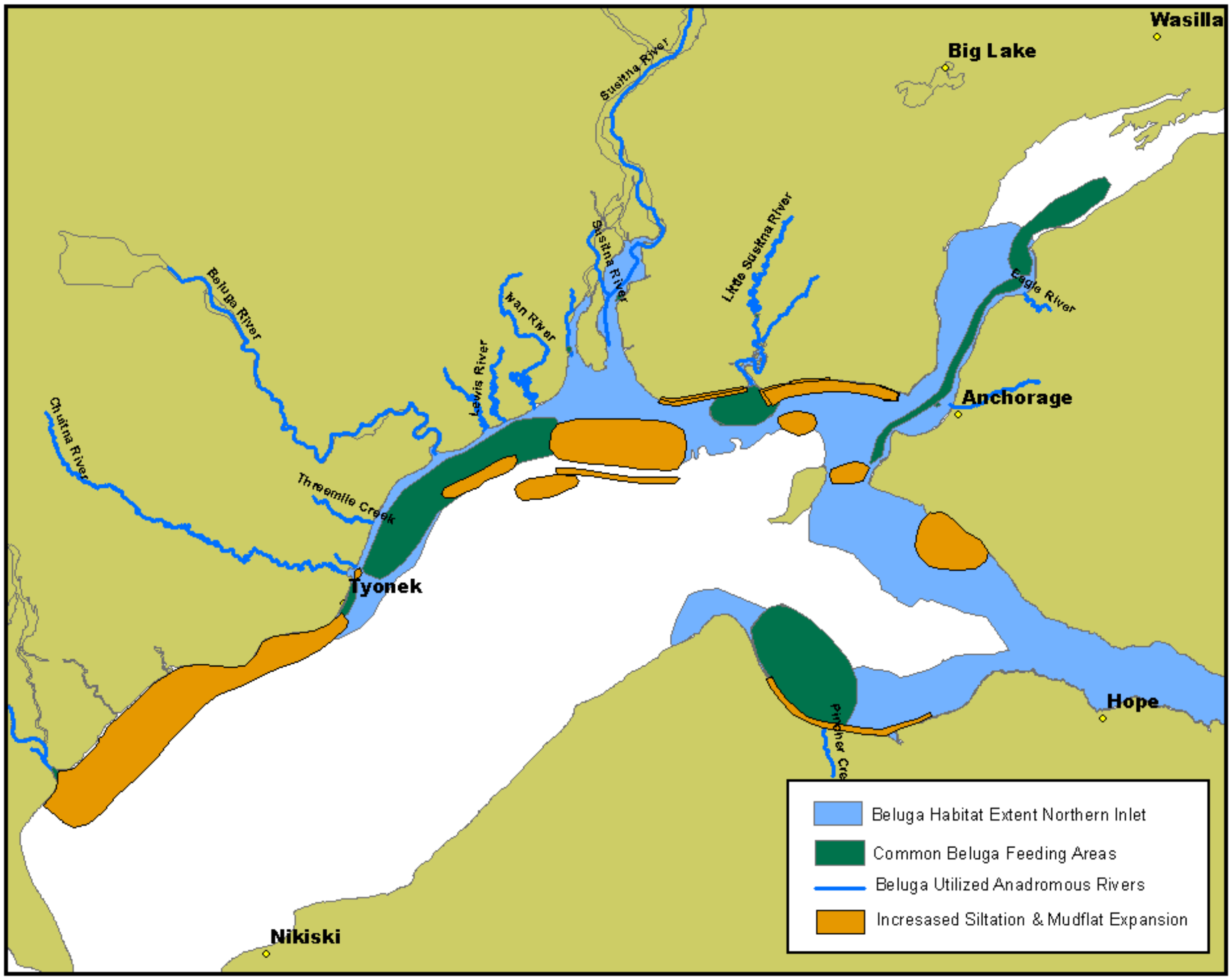

Fig. 7 Increased siltation, mudflat expansion and sandbar formation was observed in the upper inlet from the McArthur River are northwards, along the Susitna River drainage, around Fire Island and the entrance to Turnagain Arm. Expansion has hindered participants' access to rivers and was speculated to also hinder the belugas' access.

CHAPTER SIX

Thesis Conclusions

The purpose of this study was to examine ecological changes in the Cook Inlet over time and identify potential factors which contributed to the beluga whales' decline and those affecting their recovery, possibly hindering conservation efforts. Based on local ecological knowledge a variety of natural and human activity related factors were identified, which included environmental and climate change, declines of beluga prey, prey health, beluga health, beluga access to prey due to natural and human activity and broader environmental changes.

With ten years separating this study and Huntington's (2000) Cook Inlet beluga whale TEK study similarities were found along with additional information which expanded on the initial findings from the 2000 study. Beluga whale distributional and abundance changes were similar in both this study and Huntington's. Based on participant observations, this study reported initial beluga whale declines during the middle to late 1980s in the upper and central inlet. Supported by observations reported in the previous TEK study, this finding pushes the date range of noticeable declines back 8 to 10 years which suggests the presence of additional factors that impacted the beluga whale population in the past and may be affecting the whales now. Additional similarities between these two studies included observations of fish run changes and reduction of fish populations in the upper inlet, reports of fish with crooked spines and speculation that increased human activity may influence beluga whale distribution. Huntington's 2000 study focused primarily on the upper inlet but included observations from the Kenai River area. This current study expanded on this geographic focus to include the central inlet which in turn added support for the previous findings through identification of similar occurrences beyond the upper inlet.

Prior to undertaking this research numerous other studies speculated about and identified alternative factors which contributed to the beluga whale decline and have hindered their recovery beyond the sole beluga hunting associated cause. Alternative hypothesis identified factors which included strandings, predation from killer whales, illegal harvest, commercial and personal use fishing of beluga prey (NMFS 2008), oil and gas development discharge and related exploration (Goetz, Rugh, and Hobbs 2007; Moore et al. 2000), growing urban centers (Huntington 2000; Moore et al. 2000; Rugh, Shelden, and Mahoney 2000), beluga whale health issues (Houde, Measures, and Huot 2003; Huntington 2000; Van Bressem, Van Waerebeek, and Raga 1999; Dehn et al. 2006), anthropogenic noise (Speckman and Piatt 2000), dwindling prey abundance (Speckman and Piatt 2000; Huntington 2000) and the effects of climate change (NMFS 2008; Moore et al. 2000). Many of these were supported in this study, specifically beluga whale health issues, presence of killer whales, commercial fishing competition, oil and gas exploration, increased population, anthropogenic noise and effects of environment and climate change.

There were also additional factors introduced and new aspects revealed about previously considered factors. These involved the inclusion of environmental or natural factors specifically changes in shark distributions, northern pike expansion, and an increased presence of killer whales in the upper inlet and their potential influence on beluga whale distribution. Increased siltation and accumulation was noted in other studies but it was thought belugas would adapt. Participants in this study identified this river delta accumulation as a potential hindrance for beluga prey access based on their own access difficulties. Indirect and peripheral changes such as water temperature change, fish health, wetland drying, and land-based animal and plant change were identified as indicators of broader ecological change. Anthropogenic factors included a central district fisheries management focus impacting northern district fisheries; boating related pollution, specifically in the Kenai River, anthropogenic noise associated with shipping and boating activity, and oil and gas exploration and seismic testing. Factor modeling indicated broad interrelation among these factors illustrating the breadth of the potential impact on the beluga whales, the marine environment and reflecting overall ecosystem change. The broad range of changes reported in this study's finding compared to existing literature suggest potential ecosystem regime shifts, not only on land but in marine systems. While generally Cook Inlet and southcentral Alaska experiences multiple fluctuations on annual and decadal scales, these fluctuations may still reflect multiple steady-states. However, identified factors may reflect gradual changes which have lowered the system's resilience now culminating in the beginning of a regime shift in the Cook Inlet ecosystem.

These findings present additional areas for research and suggest priorities for further conservation planning, including; 1) controlling the expansion of northern pike into salmon spawning areas, 2) incorporating shark populations in Cook Inlet fisheries management and conducting status reviews to collect data on their distribution and numbers to better understand emerging trends, and 3) increasing the focus on the northern district fisheries to ensure that escapement goals are met through additional monitoring. Similar to ongoing database development and breadth of research on terrestrial ecosystems, an expansion of research into the continual changes occurring in marine environment and terrestrial/marine transition zones would improve understanding of the interrelations between these areas in southcentral Alaska in the context of climate change.

Additional areas of research suggested include; 1) beluga whale energetics, 2) cumulative effects of anthropogenic noise and 3) influence of killer whales on beluga whale distribution. Study of Cook Inlet beluga energetics, as related to beluga prey decline and loss of “energy nodes”, would contribute to a better understanding of their energy and dietary needs in turn identifying what high value food sources require additional preservation. Research focused on observing potential beluga avoidance behavior in association with multiple vessels or in the presence of seismic testing would give managers a better understanding of the potential effects these activities have on beluga whale distribution.

Furthermore, this study’s findings contribute to objectives identified in the conservation plan. These objectives include documenting beluga distribution and movement, determining baseline environmental conditions, assessing prey base and prey availability, determining temporal and spatial shifts of prey species, assessing prey reduction effects of commercial fishing, assessing impacts of killer whales, and identifying valuable habitat (NMFS 2008). Findings from this study provide additional information to meet these research objectives.

Given the broad range of participant observation and knowledge of Cook Inlet ecological processes, it is essential local knowledge be included in conservation planning and research, not only on this population of beluga whales, but for other wildlife and natural resource management planning where historical and baseline data is absent. As was illustrated in Anadón 2009, this study was able to provide a wide breadth of information, on various areas of change, in a relatively short period of time, in a fairly cost-effective manner with the purpose of identifying priorities for further research and conservation efforts. Utilizing this area of research in conjunction with traditional methods will provide a more complete understanding of the environment in which management and planning efforts are based.

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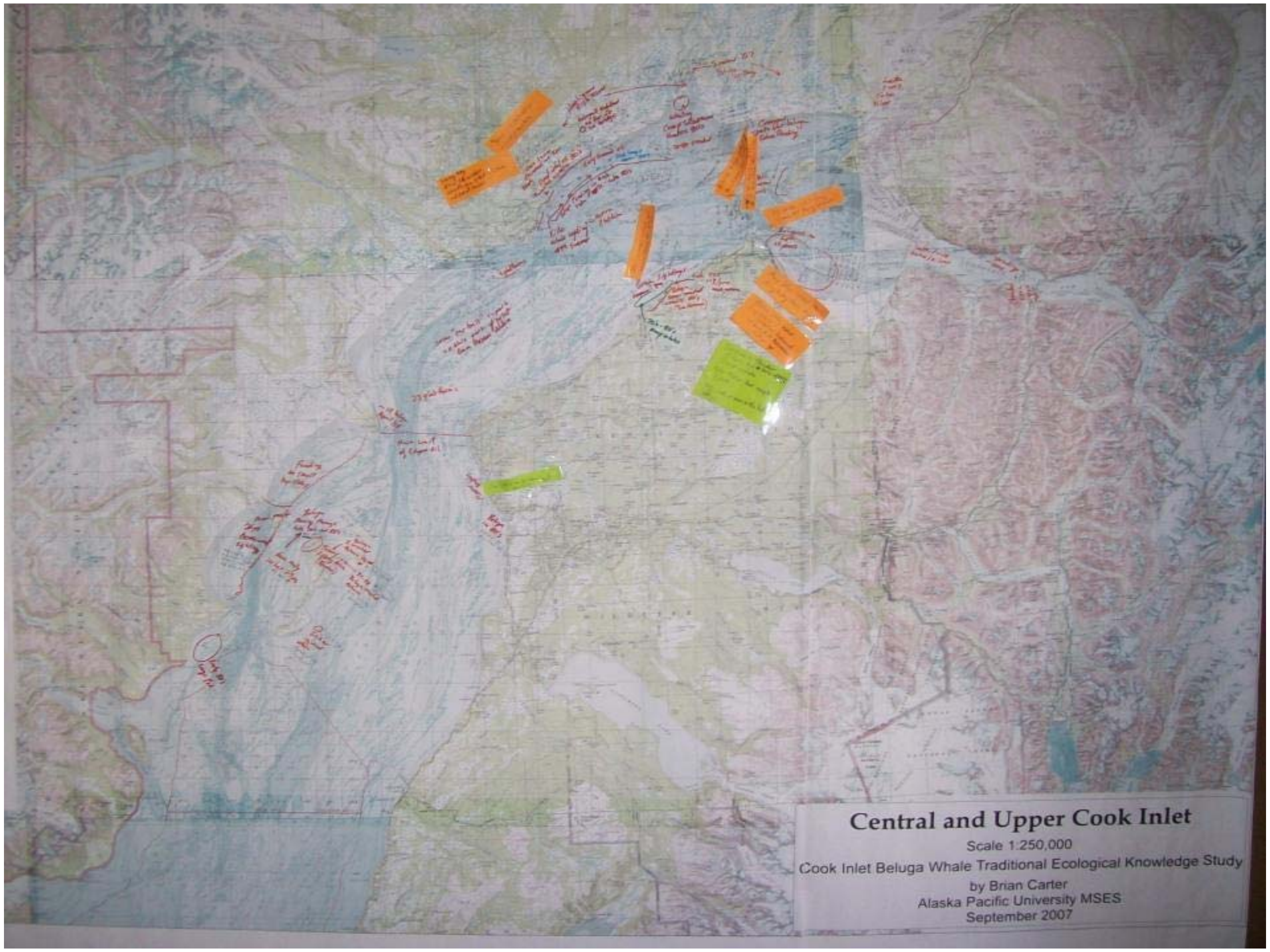
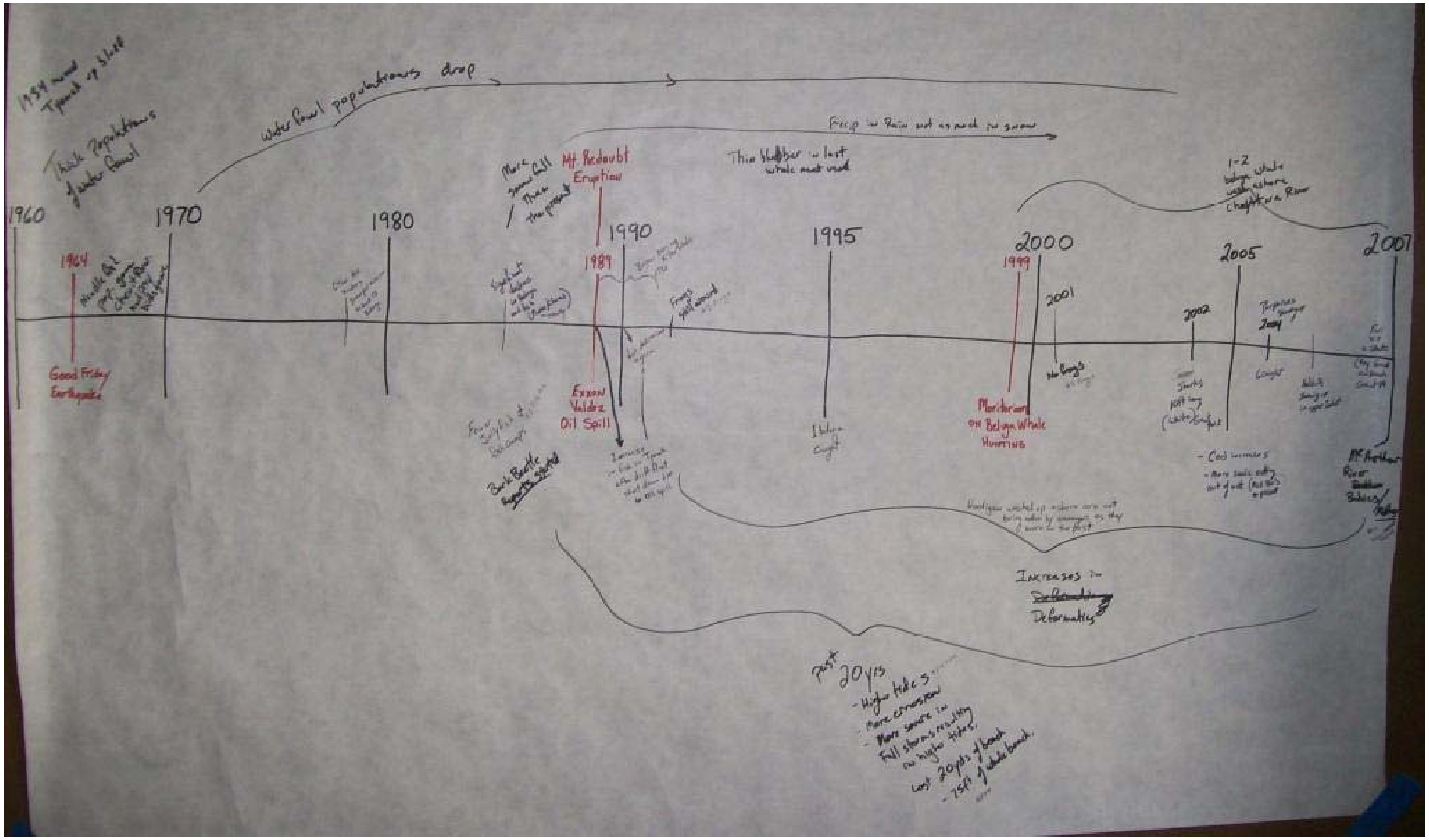
APPENDIX ONE



Base map used to create GIS layers for the spatial analysis. This map was used during interviews at the 2008 Board of Fisheries meetings held on February 2-5, 2008. It documents participant observations from several setnet fishers from the Upper and Central Cook Inlet.

APPENDIX TWO



Timeline created during the second group interview at the Village of Tyonek on March 13, 2008. The timeline shows when participants observed such changes as beluga declines in the mid-1980’s, salmon population declines, change in precipitation from snow to rain, waterfowl declines, observations of sharks and increases in fish deformities.

APPENDIX THREE

This appendix includes additional results which were removed from chapter four due to length constraints.

From Results;

Beluga Health

He reported finding parasites in the blood vessels of the whales' neck, observing that these vessels had exploded.

Additionally, this participant reported numerous sores on the whales' skin, described as yellow, puss pockets. He stated that many of the whales that were caught were in such poor condition that they were not viewed as suitable for consumption.

From Results;

Additional Climate Change

Additional Climate Change Related Factors

The remaining potential climate change related factors were not as heavily weighted individually as water temperature change and erosion and siltation. However these factors may indicate broader environmental change involving the weather, the land and wetlands.

Reduction in snowfall and less severe winters were reported across three interviews by participants from both the central and upper Inlet:

"Well we got no more snow compared to the eighties when we were kids and we saw a 10 foot. snow birms now forget our birms, like 2 feet it's been so long too since we used to drive snow machines around, through our own trails around the village."

--Village of Tyonek group interview

Others who spoke about reduction or disappearance of berry patches on the Kenai Peninsula speculated that with the lack of an adequate, insulating snow cover during the winter, the plants froze and died. This reduction of berry patches was discussed in depth during both Kenaitze Tribe group interviews representing the major plant changes they observed.

Wetland drying was observed by participants in the Susitna drainage and in Potter Marsh at the western portion of Turnagain Arm which became noticeable in the mid-1990's. Observations included encroaching vegetation and the ability to walk across or drive all-terrain vehicles across these areas in recent years. Potentially related to wetland drying and associated processes are observations of waterfowl abundance declines. These observations were based on comparisons between the present and when participants were young indicating the changes began in the 1970's and noticeably accelerated by the mid-1990's.

Participants believed the wetland drying reduced primary food sources for smaller fish species, wetland associated insect species and bird breading habitat.

Observations of bird species changes included reports of different species in the area and fewer waterfowl species, specifically ducks and geese compared to when participants were young. Participants stated these change began in the 1970’s and noticeably accelerated by the mid-1990’s. One Kenai Peninsula participant spoke about the changes he noticed in the following comment:

“But this year [2007] it’s just dead, dead. I mean everybody is complainin’ 'cause they haven't been able to go… I mean, I haven't even seen no ducks and I got goose and duck callers here [laughs]. You know, I mean ‘cause before I’d had a duck and geese and cranes land right here. And it’s like nothin’. An’ everybody’s sittin’ there goin’ even those, other birds, no birds nothin’. This year’s been the worst.”

Insect changes included observations of the spread of the spruce bark beetle, an apparent reduction of mosquitoes and the appearance of a new species of beetle. “There was yellow and white striped beetle, those big ones. I’ve never seen those around here before either.”

From Results;

Pollution section

Pollution

Industrial Sources

Industrial pollution sources primarily were associated with oil and gas development however there were participant observations and concerns about fertilizer production north of the Kenai River. Participants observed numerous instances of Cook

Inlet oil and gas development associated pollution. Participants reported observations related to the 1989 Exxon Valdez oil spill. Observations of “tar balls”, or balls of crude oil, were reported as far north as the Forelands – a coastal geographic formation marking the general boundary between the Upper and Central Inlet. Participants reported that the drift fishing fleet was shut down during that year and the crash in herring fisheries crashed in the early 1990’s. Another oil spill occurred two years before, in 1987, resulting from the T/V Glacier Bay oil tanker running aground near the Kenai River. The oil from this spill was reported to have circulated around Kalgin Island, western Cook Inlet across from the Kenai Peninsula, for a month. A participant from the northwestern portion of the Inlet reported that, in 1990, 40,000 gallons of diesel fuel, from an oil platform rig tender washed ashore on their fishing site.

A Kenaitze Tribe participant commented on wind-blown contaminants from a fertilizer plant near Kenai. They spoke of trees in the surrounding are dying due to overexposure of the fertilizer nutrients and expressed concern over what the impact of those contaminants are on the environment including fish and beluga whale populations. Another participant from the same area also commented,

“…that fertilizer plant is so contaminated there that uh, it’s one of the biggest clean up sites here in Alaska that they have… and nitrates is really bad for the ground, for the water. I mean it’s good for the ground but bad for the water eventually. They don’t think about that either. And that just keeps leaking out into the water. All the time.”

--Alaska Native Kenai Peninsula, individual interview

Urban Sources

Pollution from urban areas surrounding Cook Inlet was discussed by participants and focused primarily on the presence of refuse debris in Cook Inlet. Northern district commercial fishers near Anchorage mentioned catching prophylactics during fishing seasons which they believed came from the discharge of secondary treatment sewage. Another participant stated the smell of sewage is noticeable in the upper Cook Inlet. Participants from the Village of Tyonek reported increases of garbage washing up on their beaches. These include plastic bottles, hardhats, safety glasses and an instance while fishing:

"I caught the red salmon and he had one of these uh, these bands around from some packing box just about that big and it stopped right by his dorsal fin there because it couldn't get over it and then from the looks of it he got it when he was younger 'cause it's kind of ate into his meat and stuff chokin' it off you know."

--Village of Tyonek group interview

Boating Sources

Participant observations concerning hydrocarbon pollution from boating sources were centered primarily in the Kenai River however, observed across three interviews, there were some direct observations associated with commercial shipping. One participant, who was involved in water testing performed by the Kenaitze Tribe along the river mouth, reported that hydrocarbon levels "were about 26, 24 parts per billion, so more than twice what they know can cause cancer and other things. That's not every day but that’s during dip-netting in July.” Additional monitoring of Kenai River tributaries indicated smaller increases of hydrocarbons. Participant observations of increases in commercial shipping hydrocarbon pollution included instances of fuel sheen on the water after ships passed.