An ecological comparison of juvenile chum salmon from two watersheds in Norton Sound, Alaska: migration, diet, estuarine habitat, and fish community assemblage

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An ecological comparison of juvenile chum salmon from two watersheds in Norton Sound, Alaska: migration, diet, estuarine habitat, and fish community assemblage

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EXECUTIVE SUMMARY

Two adjacent watersheds were studied in Norton Sound, Alaska, to describe and compare the use of estuaries by juvenile chum salmon. The two watersheds were presumed to have different amounts of estuarine habitat. One watershed, the Eldorado River, flows through the Safety Sound estuary before emptying into the marine waters of Norton Sound. This system was presumed to have the greater amount of estuarine habitat, and was surveyed in 2003 and 2004. The other watershed, the Nome River, has a relatively confined river mouth that empties directly into Norton Sound. This system was thought to have relatively little estuarine habitat, and was surveyed in 2004. Both types of watersheds are prevalent in Norton Sound, but the importance of estuaries for chum production in the region has never been evaluated. Surveys were designed to compare conditions in each watershed to see if the lower portions offered substantially different conditions for juvenile chum, and to provide baseline data for future studies of chum salmon, invertebrate fauna, and the fish communities in local watersheds.

The Eldorado River watershed provided a temperature and salinity transition for juvenile chum salmon moving from fresh to salt water (i.e., the Safety Sound estuary), whereas the Nome River watershed provided none. In Safety Sound, there was a transition zone from warmer, lower salinity water at the freshwater end to colder, higher salinity water at the marine end. Within the estuary, however, environmental conditions were highly variable and juvenile chum with extended residence times may have had the opportunity to find isolated areas with specific temperature and salinity conditions. The Nome River, by contrast, had almost no transition zone from the cooler, lower salinity water at the river mouth to the slightly warmer, higher saline water of Norton Sound.

The two watersheds had differences in prey availability that likely had ramifications for chum salmon. In Safety Sound, invertebrates were distributed throughout the water column, and chum consumed prey from the bottom to the surface. Chum closest to marine water mainly consumed zooplankton found in the water column. In the Nome River, nearly all invertebrates were chironomids found only on the river bottom (benthos). Nome River chum salmon fed almost exclusively on these benthic prey right up until emigration into marine waters. These differences in prey consumption and prey location likely result in different energy costs and benefits for chum feeding in the two systems.

Densities of all fish in Safety Sound were higher than in the Nome River in 2004, but species diversity and evenness were lower. Chum in the two systems likely experienced differences in competition (for either food or space) or predation. It was beyond the scope of work in 2004 to quantify these differences.

Within the Safety Sound estuary, there were a number of interannual changes in fish density and community composition that may have affected juvenile chum salmon. Chum salmon catch in Safety Sound dropped from 2003 to 2004 amid a variety of other changes. In 2003, chum salmon were caught early in the summer near the freshwater end of Safety Sound, then frequently caught later in the summer in the interior and the marine end. In 2004, chum catches began the same way, with regular catches at the freshwater end early in the season. Later in the season, however, chum were rarely caught in the interior or marine end of Safety Sound. Chum

were similar size in June of each year; in 2004, however, chum appeared to grow more slowly after June than they had in 2003. Because juvenile salmon size affects marine survival, this difference in growth rate could have important consequences for interannual variation in marine survival. Catches of each species in the salmonid family also declined from 2003 to 2004, most by over 80%. At the same time, there was a substantial increase in the catch of threespine stickleback (+2,100%) and saffron cod (+250%) from 2003 to 2004. This abundance was responsible for most of the change in species diversity and evenness noted above. Altogether, 2004 was marked by reduced chum catches in the late summer that came in concert with reduced chum distribution, reduced chum growth, and a substantial increase in the dominance of two non-salmon species throughout Safety Sound. Chum also fed on a wider range of prey in 2004 than 2003, and the relative importance of each prey differed between years.

The study also yielded baseline descriptions that should be useful for comparisons with future populations or environmental conditions. Juvenile chum salmon were present in freshwater as late as June in both the Nome and Eldorado rivers in 2004. These chum were actively feeding, which is not always true of chum in freshwater. Marine zooplankton, primarily copepods, were the most abundant mid-water invertebrate in Safety Sound in 2003 and 2004, but did not comprise a large portion of the chum diet. Water salinity and turbidity were relatively similar in Safety Sound in 2003 and 2004, but water temperature was slightly higher throughout Safety Sound in 2004. Such baseline observations may be especially valuable in the future given predicted climate changes at high latitudes such as Norton Sound. They may also be useful when attempting to compare environmental conditions and chum behavior in years of high and low salmon abundance.

Future studies should evaluate whether chum run timing and growth in 2004 was anomalous, the potential for competition and predation from the increased abundance of threespine stickleback and saffron cod, and whether chum diet between the two river systems remains as different as that observed in 2004.

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INTRODUCTION

Early marine residence is a critical phase in the life cycle of Pacific salmonids and can influence ocean growth, survival, and the subsequent return of spawning adults. Coastal estuaries are an important aspect of this early marine phase, providing environmental transition zones (Salo 1991), early opportunities for feeding and growth (Salo 1991), and predator refuge (Pearcy 1992). Brackish estuaries can allow out-migrant salmon to acclimate from lower-salinity freshwater to higher-salinity marine water (Iwata and Komatsu 1984) and between waters of differing temperature. Such transitions may be especially important for chum salmon (*Oncorhynchus keta*), which appear particularly sensitive to temperature conditions (Beitinger and Bennett 2000). Estuaries often provide the first substantial opportunity for feeding and growth for chum salmon (Salo 1991), and typically have higher food productivities than adjacent ocean or freshwater (Odum 1959). Estuaries may thus offer the opportunity for enhanced growth or size at ocean entry, which is known to correlate with salmon marine survival (Healey 1991; Mortensen et al. 2000) and can thereby potentially increase the abundance of returning adult salmon. Finally, estuaries frequently have fewer predators on juvenile salmon, either because there are fewer predatory species, or because many predators are also in a juvenile stage and thus less piscivorous (Pearcy 1992).

Little is known about the role of estuaries in producing chum salmon in western Alaska, both for the entire region and for specific populations. Estuarine studies of juvenile chum in the region are limited to a few in the Kuskokwim River watershed (Hillgruber and Zimmerman 2004), Yukon River watershed (Martin e al. 1986), and Kotzebue Sound (Merritt and Raymond 1983). These studies have only provided preliminary information on juvenile chum movement, size, and diet in estuaries and nearshore marine waters. The subject populations are also spread over great geographic distances, and the degree to which their behavior and ecological requirements can be applied to other populations or times is unknown. Chum populations exposed to different environments (e.g., climate, daylight, ice breakup time), for example, may have different hatch times, prey resources, or marine entries that make them respond differently to environmental change. Overall, juvenile chum ecology and habitat use remains largely unknown in this remote part of Alaska and we thus do not know the role of different habitats in the production of juvenile and, subsequently, adult chum. Estuaries in other regions are important for both the abundance and diversity of chum populations (Fresh et al. 2005), but the role of estuaries for western Alaska chum population has not been described.

In the Norton Sound region of northwestern Alaska, chum salmon populations are found in watersheds with varying amounts of estuarine rearing habitat. This variances raises questions about the importance of different habitats for chum production. Are estuaries critical to chum production in Norton Sound and, if so, why do chum populations appear to do well in some rivers without estuaries? Do estuaries enhance juvenile chum growth and subsequent marine survival and, if so, are they the critical habitat that maintains populations during periods of adverse marine conditions? And what role, if any, do estuaries play in metapopulations of chum in which some populations may be sources and others may be sinks? Until the ecology and habitat requirements of chum are better understood, resource managers in Norton Sound will not

have the answers to these questions while attempting to manage fish populations and essential habitats.

Improved knowledge of the factors that affect chum salmon abundance in Norton Sound is especially important because of recent declines in chum abundance and fishing opportunity in the region. Historically, Norton Sound residents have relied heavily on chum salmon for both subsistence food and for cash income (NSSTC 2002). This reliance has been jeopardized by an apparent decrease in chum abundance from 1980 to 1999 (Sandone 2001), followed by some of the lowest returns on record from 1999 through 2003. The 1999 harvest was the lowest to that date, resulting in a fishery disaster declaration by the U.S. Secretary of Commerce (Sandone 2001). The diminished returns have continued since 1999, altering chum salmon management (Brennan et al. 2003), restricting harvests (Sandone 2001), and displacing local subsistence users to other chum populations (Magdanz et al. 2001). The declines have also generated strong interest in understanding their causes, whether they be anthropogenic or environmental (Sandone 2001), and of marine or freshwater origin. Increased understanding of chum salmon life history and habitat use is a necessary precursor to identifying these causes of change (NSSTC 2002).

Chum salmon habitat in Norton Sound is also important to document now because of the potential for changing environmental conditions, especially temperature, at high latitudes. Water temperature affects chum in numerous ways, ranging from ecological factors such as food availability to physiological factors such as the ability to osmoregulate. Chum salmon are known to have the lowest temperature tolerance window of the Pacific salmon (Brett 1952), in part because of a relatively low ability to extend their upper and lower temperature thresholds via acclimation (Beitinger and Bennett 2000). Juvenile chum exposed to suboptimal temperatures may suffer impaired growth, osmoregulation, or behavior that then have latent effects on survival. Chum tested in laboratories showed a marked avoidance of temperatures above 15° C, suggesting that this may be the upper limit of their preferred temperature (Brett 1952). Juvenile chum also have a poor ability to survive in low temperature water once they have acclimated to warm temperatures (Brett 1952). Chum that move among waters – such as from rivers to the ocean – are susceptible to mortality if water temperatures differ by as little as 10° C (e.g., moving from 15° degree to 5° degree water; Brett 1952). Scientists do not currently monitor most of the waters inhabited by Norton Sound chum in their first year, but long summer days (peaking at 22 hours of daylight) are known to raise water temperatures in some chum habitats well above 15° C (Nemeth et al. 2003). Documenting these temperatures will help indicate where and when chum encounter conditions that could have detrimental effects on growth and survival. Documenting current temperature conditions will also provide a basis for comparisons in future decades, when temperatures are predicted to change (ACIA 2004; Clark and Harris 2003).

This project is intended to further the understanding of Norton Sound chum salmon by studying the estuarine ecology of juvenile chum salmon from two Norton Sound watersheds. The watersheds have differing amounts of estuarine habitat (based on total surface area), providing contrast useful for studying the potential benefit of estuaries to Norton Sound chum. The intent of the project is to address ecological questions that include:

1. Biological aspects such as feeding, growth, and distribution of chum
   - *When do chum migrate and what habitats do they use?*

- *Are they feeding successfully in the rivers and estuaries?*
- *What food is available before, during, and after their migration?*

2. Habitat characterizations such as water conditions
   - *Under what range of conditions do chum migrate?*
   - *Is the transition from fresh to salt water gradual or abrupt?*
   - *Are conditions of temperature and salinity within the optimal ranges identified for chum salmon (e.g., Brett 1952)?*

3. Fish community assemblage
   - *What potential competitors and predators of chum are present?*
   - *What are the species diversities and evenness indices?*

One long-term benefit of the project is that it provides a baseline, or reference point, for determining future changes in chum ecology, physical habitat, or the fish community at these sites. Such references points may also be essential modeling how such change may affect salmon production (e.g., Bottom et al. 2005), and may be especially important given the likelihood of climate change (ACIA 2004). The baseline can also help address how ecological characteristics differ in years when chum survival is high versus when it is low. The ability to conduct the current project over multiple years in two watersheds increases the value of all of this information.

This report describes results from June and July in the Eldorado/Flambeau River watershed (including the Safety Sound estuary) in 2003 and 2004 and lower Nome River in 2004. The specific objectives of this study were to:

1) Assess juvenile chum salmon presence and timing in June and July in the lower river and estuary;
2) Describe juvenile chum length, weight, body condition, and stomach contents for all study populations;
3) Evaluate estuarine habitat conditions and prey availability during juvenile chum residence.
4) Describe water temperature and salinity during juvenile chum residence to determine whether conditions are within known optimal ranges for chum (Brett 1952; Beitinger and Bennett 2000);
5) Describe environmental transition zones encountered by juvenile chum migrating from fresh water (rivers) into salt water (Norton Sound);
6) Estimate invertebrate composition and energy value of juvenile chum prey;
7) Examine chum otoliths to determine ability to identify estuarine residence time and estimate growth;
8) Wherever possible, compare Objectives 2-7 between an estuarine (Eldorado River) and non-estuarine (Nome River) system.

Results from a pilot study in 2002 (reported by Nemeth et al. 2003) are included in this report in places where the 2002 data help to assess trends among years.

METHODS

Study Area

In 2003 and 2004, the study was conducted in Safety Sound, a large estuary approximately 30 km east of the town of Nome, Alaska (Figure 1). The Sound is oval-shaped, with the long axis (~12 km) running SW to NE and the short axis (~3 km) running NW to SE. Fresh water enters the Sound from the Eldorado/Flambeau River complex in the NW corner (hereafter referred to as the Eldorado River watershed) and exits to Norton Sound about 6 km to the ESE via a narrow (~300 m wide) strait. Fresh water also enters Safety Sound from the SE corner of the sound via Bonanza channel, which contains approximately half the water from the Bonanza River. Water inflow from the Bonanza channel is much less than from the Eldorado River watershed, and fish biota from the Bonanza River are thought to contribute relatively little to Safety Sound. Safety Sound has uniformly shallow water depths (mean = 2 m) with a muddy and sandy bottom. Extensive beds of eelgrass (*Zostera marina*) are found throughout Safety Sound. From early June to late July, the salinity profile at the inlet of the Sound appears to change from oligohaline (0.5 to 5 ppt) to mesohaline (5 to 18 ppt) water (definitions from Odum 1959). Over the same time, the salinity profile at the outlet of the sound ranges from polyhaline (18 to 30 ppt) to marine (30 to 35 ppt) water (Nemeth et al. 2003). Local Norton Sound tide cycles occur twice daily. Differences between high and low daily tides rarely exceed 1 m (NOAA 2005), and wind-driven water often alters the time and height of the observed high tide.

In 2004 the study was expanded to include the Nome River, the watershed immediately to the north of the Eldorado River watershed. The Nome River watershed is ~ 51 km long, drains 420 km^2, and has an estimated mean discharge of 6.5 m^3/s (Selkregg 1976, as reported by Webb and McLean 1991). The Nome River empties into Norton Sound ~ 5 km east of Nome (Figure 1) via an outlet that is narrow (~100 m). Based on data in this report, the Nome River is essentially a non-estuarine system entering directly into Norton Sound with minimal mixing of fresh and marine waters in the summer.

Fish Capture and Sampling

Sampling gear and locations

Fyke nets were the primary gear used to capture fish in 2003 and 2004. Each fyke net consisted of paired cod end traps of 1.27-cm stretched-mesh netting, supported by stainless steel frames (1.7 m x 1.8 m; Figure 2). The cod end frames were joined side-by-side. A lead net bisected the pair of frames to direct fish from either side of the lead into one of the two cod ends. The lead was made of 2.5-cm knotless nylon mesh, was 2 m deep, and ran 60 m to the shoreline when fully extended. A single 15-m wing extended from the outside edge of each cod end frame, at an angle approximately 45° to the lead net. The entire assemblage was installed so that the lead ran perpendicular from shore to cod end entrances set parallel to shore (Figure 2). This arrangement allowed the detection of the original movement direction of fish entering each cod end (i.e., fish caught in the west-side cod end were traveling east).

Fyke nets were fished in areas with water depths ranging from 1.0 m to 2.0 m, gradually sloping bottoms, smooth substrate, and some shoreline protection from wind and current-driven debris.

Optimally, sites were 1.5 m deep at a distance 80 m from shore, with a smooth bottom that sloped uniformly up to the shoreline. All sites in the main areas of interest were monitored throughout the study to observe how changes in water level, water currents, and debris load altered the sites' suitability for fyke net use. Fyke nets were fished at several sites in Safety Sound in 2003 and 2004, and at the outlet of the Nome River in 2004 (Figures 3 and 4).

An incline plane trap (IPT) was also fished in the Nome River in 2004, ~1.2k m upstream from the river mouth (Figure 4). The IPT consisted of a 1.5 m x 2.4 m perforated aluminum plate that rises from the stream substrate to ~1m in height. The trap empties into a 1.2 m x .9 m x .6 m live box (Todd 1994). Nine-meter Vexar© wings with 1.2 cm mesh were attached to the IPT to increase the sampling area. The target fishing area for the IPT was near the head of a pool, just below a section of fast flowing water. Minor adjustments were made to the trap position as stream flows changed.

Beach seines (30.5 m x 1.8 m with 0.3 cm mesh) were used to catch juvenile chum at multiple locations (Figures 3 and 4) in the Eldorado River (2004 only), Safety Sound (2003 and 2004), and the Nome River (2004).

Fish capture and processing

Fyke nets and the IPT were checked twice daily, at approximately 12 hour intervals. At each check, fish were removed from the cod-end traps and held in floating net pens for processing. All fish were identified to species and counted. Juvenile chum, pink (*O. gorbuscha*), coho (*O. kisutch*), chinook (*O. tshawystcha*), and sockeye (*O. nerka*) salmon were measured to the nearest mm (fork length). Fish not retained for diet or otolith analysis were released.

Fishing effort

Catch per unit effort (CPUE) was calculated for fish caught with fyke nets. CPUE was expressed as the number of fish for an individual species collected per fyke net per 24 h of fishing effort (fish/net/24 h). The total catch from each cod end was divided by the proportion of the day that the cod end fished, yielding the number of fish caught per day by side of net. The total (and reported) CPUE for each two-sided fyke net was calculated by summing the CPUE of the two cod ends. Catch and effort from the beach seines and from the IPT were not included in the CPUE computations because these gear types were considered to have higher gear selectivity towards some species and sizes, and because of the interest in limiting the interannual CPUE comparisons to identical gear types and sites (e.g., the fyke nets).

Chum Size and Growth

Size by date and location

Chum salmon lengths were evaluated using length frequency histograms, length vs. weight regressions, and a table recording the number of fish caught in each length class by date (Craig et al. 1984). Growth rates can be difficult to estimate in situations where larger fish exiting the system are replaced by smaller fish entering the system (e.g., Moulton 1997). This problem can be alleviated by partitioning fish into likely groups or pulses based on length and date, then calculating growth rates for individual groups (e.g., Craig et al. 1984.).

Change in size over time
Growth was calculated as the change in length over the course of the season, both for the entire run and for potential sub-groups identified using the tables described above. Change in growth was calculated according to the formula:

$$\Delta L = (L_t - L_{t-1})/t$$

where L_t = mean length at time t, L_{t-1} = mean length at prior event, and t = elapsed time in days (Yerokhin and Shershneva 2000). Sub-groups of chum were only included if the number of chum caught exceeded 3 fish on a given date.

Otolith analysis
Otoliths were taken from subsamples of the juvenile chum collected for diet analysis in 2003 and 2004. Otoliths were sent to a contractor to be analyzed for strontium levels to determine whether entry time into saline water can be detected. If so, otolith banding patterns will be used to detect the number of days spent in the estuary. Otoliths from chum captured early (before June 15) and late (after July 1) at the exit from Safety Sound will also be examined to determine banding pattern differences (which can reveal differences in growth and habitat use) between chum groups that leave Safety Sound early and late.

Diet and Food Availability

Diet sampling and assessment
Subsamples of chum were retained for diet analysis, with a target of 10 fish per week at the inlet (upstream end) and outlet (downstream end) in Safety Sound and at both sites in the lower Nome River. Fish in these subsamples were selected without known bias. Juvenile chum retained for diet analysis were euthanized with clove oil diluted in ethanol and then preserved in a solution of 80% STF (Streck Laboratories, Inc., Omaha, Nebraska). These samples were patted dry, measured, weighed to the nearest 0.01 g, and returned to the preservative solution. The samples were shipped to Applied Technical Services (Victoria, British Columbia) for diet analysis. Subsamples of these fish were examined under a microscope to verify species identifications using the descriptions in Pollard et al. (1997) and the keys in Mecklenburg et al. (2002) and Phillips (1977).

Stomach content weight was calculated as the difference in weight between full and empty stomachs. A stomach fullness index was calculated by visually estimating the fullness of the stomachs and placing them into quartiles. Stomach contents were identified to major taxonomic groups. For each prey grouping, four analyses were performed to estimate the importance to chum diets. First, percent frequency of occurrence (%FO) was calculated as the proportion of stomachs in which the grouping was found. Second, the total number (%N) was calculated as the proportion of prey by number that the grouping comprised. Third the % biomass (%W) was calculated as the proportion of biomass that each grouping comprised (Cailliet 1976; Moulton 1997). Finally, an index of relative importance (IRI) was calculated for each grouping by adding %N and %W, then multiplying the result by %FO (Cailliet 1976).

Prey sampling and assessment
Prey availability was estimated at six stations in Safety Sound in 2003 and 2004 (Figure 5) and at

two stations in the Nome River in 2004 (Figure 5). These eight sites were known as the invertebrate sampling stations. In 2003 and 2004, prey were sampled in the water column using a WaterMark plankton net (50-cm diameter mouth, 1.5-m length, and 250-µ mesh). Two to five tows were conducted for every sample at each site to achieve a target sample volume of 200 l of water. In 2004 benthic and epi-benthic prey were also sampled at each site using a single pass with a drop-net (50 cm-diameter mouth, 1.5-m length, and 250-µ mesh). Sampled water volume for zooplankton and drop-net samples was calculated as the area of the net's mouth multiplied by the distance towed (i.e., water depth). Net contents were rinsed from the plankton net and cod ends into collection bottles and preserved in 2 parts water and 1 part 80% STF.

Invertebrate samples were shipped to Applied Technical Services for identification of invertebrates to major taxonomic groups, as described earlier for chum diet analysis. Invertebrate densities (count/m^3) were calculated by dividing the abundance estimate by the volume of water sampled. The number of organisms in each group was divided by the total number of organisms samples (all groups combined), and reported for each group as %N. This fraction was used as an estimate of the relative availability for feeding fish. Change in density over time was estimated for taxa comprising the largest proportions of the zooplankton samples and chum diets.

Diet selectivity

The food selection index developed by Strauss (1979) was used to estimate food selection by chum salmon for individual prey taxa. Strauss's index, L_i, was calculated as

$$L_i = r_i - p_i$$

where r_i is the relative proportion of prey taxon i in the predator stomach and p_i is the relative proportion of the same taxon in the environment. Index values range from –1 to 1, with 1 indicating strong selectivity for the prey item, -1 indicating avoidance or inaccessibility of the item, and 0 indicating neutral selection or random feeding. Strauss's index was used because it is normally distributed and is therefore relatively robust (Williams et al. 2003) and useful for comparison among populations (Ready et al. 1985). L_i is easily interpretable (Strauss 1979) and has been widely used in other feeding studies (e.g., Hansen and Wahl 1981; Ready et al. 1985; Dahl-Hansen et al. 1994; Williams et al. 2003).

Energetic value of invertebrate prey

The energetic value of invertebrates eaten by juvenile chum was estimated by combining prey size estimates from empirical Safety Sound data with prey energy values reported in the literature. First, the weight of prey (mg wet weight) sampled in Safety Sound in 2003 was measured for each life stage of each major prey taxa; weights were averaged across all life stages to yield a mean weight per taxa. This mean taxa weight was multiplied by the frequency of occurrence in the chum diet to arrive at a total weight per taxa in each chum stomach. Second, energy value was calculated for each taxa from literature sources (e.g., Boldt and Haldorson 2002). Where needed, these values were converted to cal/g of wet weight of the invertebrate. Third, the average calories per organism were calculated as the calories per gram (from the literature) multiplied by the average weight (from the 2003 zooplankton collections in Safety Sound).

The total calorie content within each chum stomach sampled was then calculated for Safety Sound in 2003 and 2004 and the Nome River in 2004. Caloric content of chum was compared between years in Safety Sound and between the two river systems in 2004.

Fish Assemblage, Community Composition, and Species Diversity

Total catch and CPUE was computed for all species of fish captured at the fyke net stations in 2003 and 2004. Species diversity was described using species richness (r), Shannon-Wiener's index of diversity (H'), and Pielou's (1968) evenness index (J').

Species diversity was calculated as:

$$H' = [-P_i * (\ln P_i)],$$

where P_i is the proportion of species ($_i$) in the community, and $\ln(P_i)$ is the natural log of that proportion (Elliott and Hewitt 1997).

Species evenness was calculated as:

$$J' = H'/H'_{max},$$

where H' is the Shannon-Wiener index, H'_{max} (the maximum diversity) = ln (r), and r = the total number of species (Elliott and Hewitt 1997).

Environmental Sampling

Water quality was sampled at two sets of sites in both Safety Sound and the Nome River. The first set of sites consisted of the eight invertebrate sampling stations where water temperature, salinity, turbidity and invertebrates were sampled. These sites were established along the presumed corridor used by chum migrating from the river into Norton Sound (Figure 5). The second set of sites, known as the transect stations, were designed to provide better physical description of the entire water body; these consisted of six sites arranged from east to west across Safety Sound (2003 and 2004), and five sites arranged from north to south (upstream to downstream) down the Nome River (2004; Figure 6). Invertebrates were not sampled at this second set of sites. At all stations, salinity and temperature were measured with a Yellow Springs Instruments hand-held water quality meter (YSI Inc.; Yellow Springs, Ohio) at 0.5 m intervals from the surface to the water bottom. Water turbidity was estimated with a 20 cm Secchi disk. Air temperature, current direction and speed, wind direction and speed, and cloud cover were measured during each sampling event at these stations.

Continuous temperature recorders (Tidbit model, Onset Computer Corp., Pocasset, MA) were also used to record water temperature at 1-hr intervals at select locations in June and July. Recorders were anchored approximately 0.5 m below the water surface, and deployed at the inlet fyke net in Safety Sound, the outlet fyke net in Safety Sound, and the IPT in the Nome River (Figures 3 and 4). Water temperature data from upstream on the Nome and Eldorado rivers were also supplied by Kawerak, Inc., from recorders set near Banner Creek on the Nome River (approximately river km 21; river mile 13) and near the weir on the Eldorado River (approximately river km 10; river mile 6; Kroeker and Dunmall 2005).

Wind and precipitation records for 2003 and 2004 were acquired from hourly weather observations recorded at the Nome airport by NOAA (http://www.ncdc.noaa.gov/oa/ncdc.html).

Trawling

Nearshore Norton Sound (just offshore of Safety Sound) was trawled for juvenile chum salmon using a paired Kodiak style trawl (2003) and a modified Kvichak trawl (2004). A grid transect was established in 2003 and expanded upon in 2004 (Figure 7). Zooplankton samples as well as water salinity and temperature profiles were collected at stations along the transect.

RESULTS

Fish Capture and Sampling

Sampling gear and locations
In 2003, one fyke net was operated continuously at the outlet of Safety Sound for 40 days, another was operated continuously near the inlet for 41 days, and a third was operated for different durations at three other sites in the interior of Safety Sound (24 days total; Figure 3).

In 2004, fyke nets were fished at three of the same sites from 2003 in Safety Sound; at the outlet site (54 days), the inlet site (48 days), and one of the interior sites (23 days). Beach seines were also used to capture fish 61 times across 8 different sites in Safety Sound and the Eldorado River in 2004 (Figure 3).

In the Nome River in 2004, the lower fyke net (down river) was fished near the river mouth for 66 days in 2004. The IPT was fished for 43 days at the upstream site (up river), and was replaced by a fyke net for another 27 days (Table 1; Figure 4).

Fish capture and CPUE
From 2003 to 2004, total fish catch in Safety Sound (all species combined) increased from 78,519 to 314,809 fish (Table 2). The CPUE increased from 455 fish/d to 1,426 fish/d (Table 3). The increased catch from 2003 to 2004 was due primarily to large increases in CPUE of threespine stickleback (*Gasterosteus aculeatus*; from 44 to 967 fish/d, a 2,069% increase) and saffron cod (*Eleginus navaga*; from 66 to 232 fish/d, a 251% increase). Species in the Salmonidae family, conversely, decreased substantially from 2003 to 2004. Juvenile chum, pink, and coho salmon comprised at least 1% of the total fish CPUE in 2003, but CPUE of each declined by at least 84% in 2004 (Table 3). Four other salmonines also comprised at least 1% of the CPUE in 2003; of these, round whitefish (*Prosopium cylindraceum*), humpback whitefish (*Coregonus pidschian*), and Bering cisco (*C. laurettae*) declined by at least 70% in 2004, and least cisco (*C. sardinella*) declined by 20% (Table 3). Overall, the number of species comprising over 1% of the daily CPUE decreased from 11 species in 2003 to 4 species in 2004 (Table 3). Thirty-two identified fish species were captured in the fyke nets in 2003 and 2004 combined (Table 2). There were nineteen unidentified fish captured in 2003 and three in 2004.

In the Nome River in 2004, 25,266 fish were captured from the two fyke nets (upstream and downstream sites), for an average CPUE of 188 fish/d (Table 3). As in Safety Sound, threespine

stickleback had the highest CPUE (33% of the total CPUE). Unlike Safety Sound, however, coho salmon (32%), starry flounder (*Platichthys stellatus*; 12%), Arctic grayling (*Thymallus arcticus;* 5%) and round whitefish (4%) also comprised substantial portions of the daily CPUE.

Juvenile chum were captured in freshwater in both the Nome and Eldorado rivers throughout June in 2004 (Figure 8). Most of the chum captured in the Nome River were at the site 1 km upstream from the mouth, with few being captured at the fyke net closer to the mouth of the river (Figure 4). In the Eldorado River, chum were captured at numerous sites in the lower 2.5 km of the river.

In Safety Sound in 2003, juvenile chum catches peaked at the inlet site (upstream end of the estuary) in June; catches at the outlet (downstream end of the estuary; entering Norton Sound) had a bimodal peak, one in mid-June and another in mid-July (Figure 8). The peak in mid-July was consistent with that seen in July of 2002 (Nemeth et al. 2003). In 2004, juvenile chum again peaked in mid-June at the inlet, but almost no chum were captured at the outlet (Figure 8). Chum distribution, CPUE, and total catch all declined from 2003 to 2004 (Tables 2 and 3).

Chum Size and Growth

Size by date and location

Chum salmon length frequencies were normally distributed in Safety Sound in 2003 and 2004 (Figure 9). Lengths ranged from 35 – 80 mm (mean = 53.6, SD = 10.9) in 2003 and from 39 – 65 mm (mean = 52.6, SD = 4.5) in 2004 (Figure 9). In Safety Sound, four distinct groupings of chum catch by date and size were observed in 2003 and again in 2004 (Table 4). In 2004, juvenile chum were also captured less frequently and in smaller groups than in 2003, and were rarely caught in Safety Sound in July (Table 4; Figure 10).

In 2004, length frequencies of chum salmon from both the Eldorado and Nome rivers were skewed to the right (Figure 11). Chum lengths ranged from 30 – 55 mm (mean = 41.8, SD = 6.1) in the Nome River and from 31-57 mm (mean = 39.6, SD = 5.3) from the Eldorado River (Figure 11). There were five distinct groupings of chum by date and size from the Nome River and two from the Eldorado River (Table 5).

Change in size over time

Chum salmon lengths in Safety Sound increased consistently in 2003 (Figure 10). This increase was not detected in 2004 (Figure 10). In the Nome River, chum salmon lengths increased slightly over time in 2004 (Figure 12).

In 2003 in Safety Sound, chum growth rates were relatively high early in the season, then consistent across all time periods and sampling sites (Table 6). From the first time period (June 10-18) to the second (June 21-28), mean size of chum increased an average of 1.07 mm/d. Mean daily growth slowed in July, with lengths increasing an average of 0.50mm/d from the second to third (July 5 – July 12) time period, and an average of 0.46 mm/d from the third to the fourth (July 15-20) time period. There was little variation in growth rates between fish captured at the inlet and outlet of Safety Sound during each time period (Table 6). Based on both individual and combined site data, overall growth rates were highest in late June and remained lower, but consistent, throughout July (Table 6). Average daily growth rate across all sites and dates was

0.70 mm/d in Safety Sound, which is consistent with those reported by other field studies evaluating change in size of unmarked juvenile chum (e.g., Moulton 1997).

In 2004, chum from Safety Sound were captured almost exclusively in June. In early June, these chum were larger than chum captured in June of the prior year (Figure 10). Throughout the rest of June, however, chum in 2004 grew more slowly (0.23 mm/d) than in 2003 (1.07 mm/d; Table 6).

In 2004, mean daily growth in the Nome and Eldorado rivers was usually between 0.32 and 0.59 mm/d, and declined from June to July. In mid-June, chum growth was similar among all water bodies (Nome River, Eldorado River, Safety Sound). Chum were captured over a greater length of time in the Nome River and showed relatively consistent growth rates, except for negative growth in late June that appeared to be due to a group of relatively small chum passing downstream from June 22 to June 25 (Table 5; Table 6). Excluding this group, overall growth rate in the Nome River from late May to mid-July was 0.41 mm/d (Table 6).

Length / weight regressions
Regressions of juvenile chum length vs. weight violated regression assumptions of linearity and data were thus log transformed. Regressions were similar across years and rivers (Figure 13).

Otoliths
Otolith analysis has been delayed by a series of events stemming from the replacement of the equipment used to analyze the otoliths at the University of Alaska – Fairbanks. The otolith contractor is working through these delays and expects to complete the otolith analysis in the spring of 2006. This analysis will be reported in the results from the 2005 sampling season.

Diet and Food Availability

Diet sampling and assessment
In 2003, 114 juvenile chum from Safety Sound were kept for diet analysis. In 2004, 64 juvenile chum from the Safety Sound / Eldorado River system and 51 from the Nome River were kept for diet analysis (Table 7). Most juvenile chum sampled in 2003 and 2004 were actively feeding, both in the Safety Sound estuary and in freshwater. In 2003, prey was found in 99 of 114 (87%) chum stomachs sampled from Safety Sound. In 2004, prey was found in 51 of 53 (97%) chum stomachs from Safety Sound, all 11 (100%) chum stomachs collected from the Eldorado River, and 49 of 51 (96%) chum stomachs collected from the Nome River (Table 7).

Most measures of diet composition indicate an annual shift in diet in Safety Sound from 2003 to 2004, with the importance of marine crustaceans decreasing and the importance of chironomids increasing. Marine crustaceans and terrestrial insects comprised the greatest percent of the diet by number, weight, frequency of occurrence (%FO), and index of relative importance (IRI) in 2003 (Tables 8 and 9). In 2004, crustaceans were the dominant prey by number, but chironomids became the dominant prey by weight, %FO, and IRI. Insects appeared to be relatively unimportant. Chum salmon also preyed on a greater number of taxa in 2004 than in 2003 (Table 9). The diet composition in 2003 was similar in nearly respect (IRI, prey diversity, etc.) to the diet of juvenile chum in Safety Sound in 2002 (Nemeth et al. 2003).

In the Nome and Eldorado rivers, chum diets were dominated by chironomids in 2004 (Tables 8 & 9).

In 2003, chum salmon appeared to feed throughout the water column, from the substrate to the surface (Table 8 and 9). Insects (67% FO) were nearly all adult dipterans that likely had become stranded on the surface of the water. Marine crustaceans (57% FO, 78% N) were probably consumed on the substrate and in the water column. The most common crustacean class was copepods, primarily Harpacticoids and *Eurytemora spp*. (a calanoid copepod). Harpacticoids are typically found on or in the substrate, whereas *Eurytemora* typically inhabit the water column. Finally, chum also fed on small amount of chironomids (5% FO, 7% N), indicating that chum foraged for at least some time in the benthos.

In 2004, chum salmon appeared to forage more in the benthos and less in any other part of the water column than in 2003. In 2004, 81% of chum fed on benthic-dwelling chironomid larvae (as opposed to 5% in 2003), whereas only 32% fed on marine crustaceans (predominantly *Eurytemora*) from the water column (Table 8). Marine crustaceans were the most abundant prey by number, but had only half the IRI value of chironomids (Table 9)

Chum diets varied spatially in Safety Sound in 2003. At the inlet of Safety Sound, nearly all chum (16 of 17) were feeding on adult dipterans (Figure 14); five chum were also feeding on crustaceans. Nearly half (9 of 20) of the chum stomachs sampled from the interior of Safety Sound were empty. Of the remaining 11 chum, 9 were feeding entirely on adult dipterans and 2 were feeding entirely on crustaceans. At the outlet site, 59 chum (of 76 sampled) were feeding on adult dipterans and 57 were feeding on crustaceans. Only 5 of the 76 chum sampled from the outlet contained neither insects nor crustaceans.

At the inlet site in 2003, diet shifted from primarily insects and crustaceans (mostly copepods) in June to chironomids and insects in July (Appendix B). At the outlet site, chum diets were composed primarily of copepods and insects in June and only of copepods in July. Mean food weight in the chum stomachs was 15 mg, with a range from 0 to 179 mg.

Prey sampling and assessment

Marine crustaceans were the dominant invertebrate fauna in Safety Sound in 2003 and 2004. Most of these crustaceans were copepods. In 2004, chironomids comprised an increased proportion of the invertebrates at the two most upstream stations (Table 10). Invertebrate counts (n) were higher in the water column (tow net samples) than in the benthos (drop net samples) at all sites in Safety Sound in 2004 (Tables 10 and 11). Densities of invertebrates in the water column were two to three orders of magnitude higher in Safety Sound than in the Nome River in 2004 (Figures 15a and 15b).

In the Nome River, chironomids dominated the invertebrate fauna in both the water column and the benthos; marine crustaceans comprised a relatively low proportion of the fauna (Tables 10 and 11). Unlike Safety Sound, total invertebrate counts in the Nome River were much higher in the benthos (drop net samples) than in the water column (tow net samples; Table 11). Density of epi-benthic organisms was higher in the Nome River at the downstream station than the upstream station (Figure 16).

Diet selectivity

In 2004, chum in Safety Sound consumed crustaceans in about the same proportion as crustacean presence in the water column (Figure 17). Chum also consumed chironomids, but selectivity was more difficult to assess. If these chironomids were taken from the water column (where they were scarce, Figure 17), chum would have been selectively targeting them. If the chironomids were taken from the benthos (where they were abundant, Figure 18), chum would have been taking them in about the same proportion as their availability.

In the Nome River, chum prey were eaten in almost exact proportion to their presence in the benthos (Figure 18), but out of proportion to all prey in the water column (Figure 17).

Energetic value of invertebrate prey

The main sources of total calorie intake by chum salmon changed within Safety Sound from 2003 to 2004 (Table 12). In 2003, the majority of the total calories came from amphipods, which contributed 73% of the total calories (all chum combined). Dipterans (16%), chironomids (5%), and copepods (3%) contributed relatively low proportions of the total caloric content. In 2004, the contributions of amphipods (7%) and chironomids (55%) nearly reversed, and the contribution of copepods (18%) increased substantially. Dipterans were not a source of energy in 2004, and were approximately replaced by harpacticoids (13%). Copepods were the primary prey consumed by juvenile chum in both 2003 and 2004, but amphipods (in 2003) and chironomids (in 2004) provided greater total energy because of higher mean weight per prey item (Table 12).

Chironomids provided the most energy (91%) in the diets of juvenile chum from the Nome River. Unlike Safety Sound, chum from the Nome River had relatively little energy contribution from any other source (Table 12).

Fish Assemblage, Community Composition, and Species Diversity

Overall, the fish catch (total or CPUE) in Safety Sound increased substantially from 2003 to 2004 (Table 3; Figure 19). The increase was almost entirely due to increases in threespine stickleback (Figure 20) and saffron cod, whose dominance in the system in 2004 was further accentuated by drastic declines in other fish, especially species in the family Salmonidae (Table 3). The abundance of threespine stickleback in 2004 was obvious during the field sampling, with the species dominating both fyke net (Figure 21) and beach seine catches throughout the Sound over the entire season (Figure 22). Saffron cod catches were low in June and increased sharply in July (Figures 23 and 24). Species composition in the Nome River was markedly different from Safety Sound, with threespine stickleback, juvenile pink salmon, and juvenile coho salmon dominating the total catch (Table 2).

The total number of species, as indicated by the species richness indices (S), was relatively similar from 2003 to 2004 (Table 13). There was a marked change in the proportion of these species, however, as indicated by substantial drops (50%) in indices of diversity (H') and evenness (J') from 2003 to 2004 (Table 13). This drop in species diversity and evenness was driven by the aforementioned increase in threespine sticklback and saffron cod, coupled with marked decreases in the catches of several other species.

The dominance of threespine stickleback and saffron cod, relative to other species, changed throughout the summer of 2004. Threespine stickleback were dominant from ice-out through mid-July in 2004; saffron cod were then the dominant species during the second half of July (Figure 21). In 2003, CPUE of both species peaked earlier in the year, and neither species was as dominant at any point as in 2004 (Figure 24).

Compared to Safety Sound in 2004, the lower Nome River had a similar species assemblage (Table 2) and richness (actual number of species), but higher species diversity and evenness (Table 13). Fauna in the lower Nome was indicative of a freshwater complex (Table 14), as follows:

- The CPUE of species with known freshwater dependences (coho salmon, Arctic grayling, and Dolly Varden [*Salvelinus malma]*) all had CPUEs an order of magnitude higher in the Nome River than in Safety Sound.
- The CPUE of species with known marine dependences (saffron cod, Artic flounder [*Pleuronectes glacialis]*, rainbow smelt [*Osmerus mordax]*, fourhorn sculpin [*Myoxocephalus quadricornis]*) were an order of magnitude lower in the Nome River than in Safety Sound (Table 14).

Threespine stickleback was the only species that comprised more than 1% of the total CPUE in both the Nome River and Safety Sound in 2004 (Table 3). Although threespine stickleback CPUE was substantially lower in the Nome River than in Safety Sound, it was still the dominant species in the Nome River, based on CPUE (Table 3).

Environmental Sampling

Inseason patterns - 2003

Water temperatures at the environmental stations in Safety Sound peaked in late June, then dropped two to six degrees in July (Figure 25). Temperatures fluctuated during a general warming trend from early July to the end of the study on July 21st. Mean daily water temperature peaked at 18.2° C in the middle of Safety Sound on June 27th. The coldest water temperature, 7.0°C, was measured on 10 June in Norton Sound (Figure 6), the deepest station where the depth was typically ~2m. Water temperature patterns during the summer were closely linked to air temperature patterns recorded at the airport in the City of Nome (Figure 26).

Salinity was uniformly low at the inlet of Safety Sound (near the Eldorado River) and high near the outlet (near Norton Sound). The highest salinity was recorded in Norton Sound and at the outlet of Safety Sound, where both measured 31.2 ppt on July 7th. Salinity in the middle of the Sound was intermediate between the inlet and outlet, with the most variable locations being the western (Figure 27) and central parts (Figure 28).

Inseason patterns - 2004

In Safety Sound, water temperatures in early June were already between 12° C and 14° C at the outlet site and 14° C to 17° C at the inlet site (Figure 25). These temperatures then fluctuated between 15° and 20° through the end of July. Mean daily water temperatures exceeded 15 degrees from July 12 to 31 in the Eldorado River and for nearly the entire period from June 5 to July 31 at the inlet of Safety Sound.

Water temperatures were higher at the inlet to Safety Sound than at the outlet throughout both June and July (Figure 25). Both sites were warmer than the Eldorado River water monitored approximately 10 km upstream by Kroeker and Dunmall (Figure 25). Temperature trends throughout the Safety Sound / Eldorado River watershed tracked each other closely (Figure 25). Point samples taken weekly within Safety Sound showed a water temperature decrease from the inlet of Safety Sound to the water in Norton Sound. This pattern was more evident in 2004 than 2003 (Figure 27).

Water salinity on the surface of Safety Sound was similar to 2003 (Figure 27). As in 2003, salinity increased along a gradient from the Eldorado River through Safety Sound and into Norton Sound (Figure 27). In 2004, salinity at the inlet ranged from 1.2 ppt (1.2) in June to 4.2 ppt (4.1) in July; at the outlet, salinity ranged from 26.0 ppt (6.2) in June to 27.0 ppt (3.6) in July.

At the transect sites running East-West across Safety Sound (Figure 6), the lowest temperatures and highest salinities were recorded at the middle site (T3) in both 2003 and 2004. Moving eastward from T3, salinity decreased slightly while temperature increased slightly (Figure 28). Moving westward from T3, salinity dropped substantially while temperature increased slightly (Figure 28). Mean temperature was slightly higher (1 to 2° C) at all sites in 2004 than in 2003. Salinity was similar among all sites from 2003 to 2004.

In the lower Nome River, water temperatures were 8° C when sampling began in early June and increased steadily until late July (Figure 25). Mean daily water temperatures exceeded 15° C from July 10 to July 31 (Figure 25). Upstream at river km 20, water temperatures were consistently 4° C lower (Kroeker and Dunmall 2005) than in the lower Nome River (Figure 25). Temperature patterns at the two sites mimicked each other closely.

The lower Nome River water temperatures were up to 6° C higher than water nearby in Norton Sound in mid-June (Figure 29). The differences diminished over the rest of the summer, and Norton Sound was warmer than the lower Nome River by early August (Figure 29). Overall, mean water temperatures at the different sites were similar when averaged over the course of the summer (Figure 30).

Surface water salinity in the lower Nome River did not change throughout the sampling period in 2004 (Figure 30). Salinity changed abruptly from the stations within the lower Nome River, however, to Norton Sound; the lower river was entirely freshwater in all sampling events (n=7), but ranged from 12 to 22 ppt just offshore in Norton Sound (Figure 30). Unlike Safety Sound, fish emigrating from the Nome River to Norton Sound had little salinity transition.

Winds in both 2003 and 2004 came primarily from the southeast and the southwest during June and July (Figure 31). The southwest winds were the most prevalent, and increased in frequency from 2003 to 2004. There were no obvious associations between water height in Safety Sound and wind direction in either 2003 or 2004 (Figure 32).

Trawling

In 2003, nine separate trawl tows were made along five transects on August 21st (Figure 7). Tows were conducted in Norton Sound, just offshore from the outlet of Safety Sound. Tows

were conducted for approximately 10 minutes each, at an average speed of ~3 knots. The net appeared to fish well and caught over two thousand fish; threespine stickleback were the most abundant fish species captured (Table 15). Four juvenile chum salmon were caught in one tow and none in any of the others.

In 2004, Norton Sound trawling was conducted on June 25th and July 24th. Tows on both dates were made along an established grid in the same area as in 2003 (Figure 7). Tows were made for approximately 10 minutes at an average fishing speed of ~3 knots. In June, the primary catch (n = 3,532) was an unidentified species of larval fish, which were probably larval saffron cod. Eighty-seven identifiable juvenile saffron cod were also caught. In July only threespine stickleback (n = 747) were captured in the trawl (Table 15). No chum salmon were caught in either June of July.

DISCUSSION

Fish Catch

The catch results suggest juvenile chum salmon migration from freshwater may not be a simple model in which most fish enter the estuary at once, reside together for a time, and then migrate together into Norton Sound. In 2004, when few chum were caught anywhere in Safety Sound, chum were caught in the Eldorado River until late June and the Nome River until mid-July. In the Nome River, chum emigrated in three distinct groups (based on number by size class and date) in June and a smaller, but detectable, group in mid- to late-July. Chum had been feeding in freshwater, indicating an ability to remain in freshwater after hatching. Based on these observations, it appears that some chum emigrate from the river when the ice breaks up, while others migrate as many as six weeks later. These chum appear to be different groups and not just the two tails of a normal distribution curve.

Chum salmon migration from Safety Sound into Norton Sound also appeared to vary between years. In 2003, chum catches at the outlet had distinct peaks in mid-June and again in mid-July (Figure 8). The mid-July peak was consistent with a peak seen in 2002 (when July was the only month sampled; Nemeth et. al 2003). In 2004, however, a peak was only seen in mid-June. Chum that spent differing amounts of time in Safety Sound (e.g., mid-June emigration vs. mid-July) experienced substantially different conditions of temperature (Figure 25), salinity, prey availability (Figures 15 and 16), and fish community structure (Figure 21 and 24). These different conditions could reasonably be expected to affect growth and survival.

The emigration patterns of chum in the Nome and Eldorado watersheds have implications for human activities or policies that could affect habitat in the summer. The observations that juvenile chum remain in rivers for protracted lengths of time refute a prevailing belief that all chum migrate from rivers at or immediately after ice breakup. If these late-remaining chum contribute meaningfully to future adult returns, land managers may need to evaluate any actions that affect wild chum habitat, food resources, or competition in the summer months.

The low catch of juvenile chum in 2004 was notable. Chum were frequently captured upstream in the rivers, but not downstream in either the lower Nome River or Safety Sound. The

decreased catch came despite increased sampling effort, the presence of chum upstream in the rivers as late as the end of June, and consistency (in Safety Sound) in gear type, sampling times, and location from 2002 through 2004.

There are at least four possible explanations for the reduced catch of chum in Safety Sound in 2004. First, chum recruitment to the juvenile stage may simply have been reduced (e.g., from poor egg survival) in 2004. Second, chum migration routes or residence time in 2004 may have changed from the two prior years. The additional seining in Safety Sound (which was effective in the rivers upstream), does not support this hypothesis because no new migration routes were detected. Third, substantial changes in fish species composition (e.g., increased abundance of threespine stickleback, decreased abundance of salmonines) resulted in competition (or predation) that either reduced chum catchability, chum survival, or both. Fourth, the migration of chum was substantially earlier in 2004 than in 2003 and 2002, and the chum detected in mid-June in the estuary corresponded to those groups caught in mid-July in the two prior years.

The third hypothesis (increased competition or predation) is consistent with four general observations from the rest of the study. First, there was a substantial change in fish species composition in Safety Sound, including more than a 25-fold increase in threespine stickleback. Second, chum had a markedly different diet in 2004, which included a much broader diet (eight different taxa in 2004 vs. five in 2003 and four in 2002) and an increased dependence on chironomids. Third, an effect resulting from competition or predation in the Sound would explain why many chum were seen in freshwater in both rivers, but not downstream in the estuary. Fourth, chum catches in Safety Sound in 2004 were similar to 2003 until mid-way through June, when chum suddenly stopped being caught.

Some of these observations also support the fourth hypothesis, that migration was a month earlier in 2004. This hypothesis is consistent with the warmer conditions observed in 2004. It is not consistent, however, with the observations that chum captured in Safety Sound in mid-June were of similar size in both 2003 and 2004, and many chum were still in freshwater as late as June in 2004.

Diet

The diet of juvenile chum salmon shifted from a dependence on insects and crustaceans in 2002 and 2003 towards chironomids and crustaceans in 2004. Chum from Safety Sound fed on a greater variety of prey (in smaller quantities) in 2004 than in 2002 or 2003. The diet shift in 2004 occurred amid a slight increase in water temperature, earlier ice breakup, and a substantial change in fish species composition. Overall, chum diets from Safety Sound in 2004 were more similar to chum diets in the Nome River in 2004 than to chum diets from Safety Sound in 2003 or 2002.

The change in diet composition from 2003 to 2004 was accompanied by an apparent change in feeding strategy by juvenile chum salmon. Conceptually, %N in the diet represents the dominance of that prey item; as %N increases from 0% to 100%, the prey importance goes from rare to dominant (Figure 33). Increased %FO, meanwhile, indicates the degree of generalized feeding on that item; as %FO increases, the prey item goes from one specialized on by a few individual predators to one in which all predators consume in a generalized strategy (Figure 33).

(Costello 1990). Plotting both of these in two dimensions identifies whether the item is rare or dominant, either to a few specialists or to the general population (Figure 33).

At the inlet of Safety Sound, the feeding strategy in 2003 was one in which many chum ate small quantities of insects, indicating a generalized feeding strategy for a relatively rare diet item (Figure 34B). At the same time, a few chum specialized in eating crustaceans (also in low quantities, and thus a rare diet item) and a few chum specialized in eating chironomids (in relatively high quantities, and thus a dominant item for these few chum). In 2004, this strategy changed to one in which all chum at the inlet ate high quantities of chironomids, and few chum targeted other prey items – a generalized feeding strategy in which chironomids were dominant (Figure 34B).

At the outlet of Safety Sound, the feeding strategy also changed from 2002 to 2004, with chironomids essentially replacing insects in the chum diet (Figure 34C). In 2002, chum exhibited a generalized feeding strategy on both insects and crustaceans, both of which were relatively dominant. A few chum also specialized on chironomids, but consumed them in low quantities. In 2003, insects and crustaceans were again eaten by high proportions of chum (generalized feeding), but crustaceans were eaten in higher numbers (dominant prey) and insects were eaten in lower number (scarce prey). Chironomids remained the same in 2003 (specialized feeding by a few chum, and in scarce quantities). In 2004, crustaceans remained the same as in 2003. Insects, however, were eaten in still lower quantities, and only by a few chum (strategy changing from generalized to specialized). This was concurrent with an almost exact replacement by chironomids, which were eaten by many chum (strategy changing from specialized to generalized), but in low numbers. These chironomids were estimated to have lower caloric content than the insects (0.39 calories/individual vs. 0.59 calories/individual). Over the three years, a relatively high-energy prey item (insects) was gradually replaced by a relatively low-energy prey item (chironomids; Figure 34C).

In 2004, chum in the Eldorado and Nome rivers also exhibited a generalized feeding strategy on chironomids, and consumed them in high abundance (Figure 34A). In the Eldorado River, a large proportion of chum also fed on small quantities of mayflies. In the Nome River, a much smaller proportion of chum consumed about the same numbers of mayflies (per fish) as in the Eldorado River. The feeding strategy in freshwater in 2004 thus appeared to be one in which nearly all chum consumed large quantities of chironomids, and supplemented this diet with much smaller quantities of insects. A greater proportion of chum from the Eldorado than the Nome River fed on these insects.

The Nome River differed from Safety Sound in 2004 in that the Nome River had almost no invertebrate prey besides chironomids, and the densities of these chironomids were lower. Given the high species richness in the Nome River, it thus appears that there could be greater competition for invertebrate prey. More work is needed to evaluate the levels of resource competition within the two different water bodies. It is worth noting, however, that the majority of chum stomachs sampled from the Nome River in 2004 were less than 50% full; in Safety Sound, conversely, the majority of stomachs were greater than 50% full (Table 7).

The energetic trade-off between prey availability and energy content is interesting in light of chum prey energy estimates for Safety Sound. Chum exhibited a generalized, dominant feeding

strategy on copepods, perhaps because of the relatively high availability of copepods in the estuary. Copepods have low energy per individual, however, and majority of energy in the chum stomachs came from other sources (amphipods in 2003 and chironomids in 2004; Table 12). It thus appears that copepods may be a supplementary source of energy, with chum relying on other invertebrates for their primary energy source. If these higher-energy prey are scarcer or more difficult to access in some years (e.g., not synchronized with chum emigration times), chum may have to work harder to obtain their primary energy source. The energetic costs for obtaining amphipods (primary source in 2003) versus chironomids (primary source in 2004) will be evaluated in the future.

It is important to note that the energetic assessment is preliminary and may have at least one source of error. We pooled all chum stomachs when assessing the energy contributions of different prey, thereby masking the effects of collecting chum from different habitat types. A greater proportion of the chum stomachs came from the outlet of Safety Sound in 2003 than in 2004. The inlet and outlet of Safety Sound have different prey fauna, which certainly accounted for some of the differences seen in energy contribution by prey type from 2003 to 2004. This difference in prey availability, however, is unlikely to explain all of the observed change in energy source because other assessments show distinct prey changes from 2003 to 2004 for chum within both the inlet and outlet sites (above text; Figure 34B and 34C). We will evaluate this potential error in future reports.

Two additional aspects of the chum diets from Safety Sound in 2003 are important. First, juvenile chum fed primarily on marine crustaceans in both 2002 and 2003. These crustaceans were primarily mysids in 2002. In 2003, however, the crustaceans were nearly all copepods and mysids were nearly absent from the diet. Mysids were seen throughout the sampling period in 2003, and thus appeared to be available as prey for chum. Second, many of the chum stomachs from the outlet site in 2003 contained insects typically found in freshwater. These insects were primarily adults, and most likely entered the water from the air or surrounding littoral zone. Insects were not abundant in zooplankton net samples, indicating that chum were selectively targeting insects or that the sampling missed these insects. It is also possible that the insects found in chum stomachs had been eaten in freshwater; if so, juvenile chum migrated quickly down from the Eldorado River and were captured before the stomach contents were digested.

The diets of juvenile chum in the Nome and Eldorado rivers is consistent with observations that juvenile chum often feed on chironomids in river systems (Salo 1991). The dominance of copepods by number (Table 8) in Safety Sound is also consistent with observations that juvenile chum often feed on copepods in estuaries (Kaczynski et al. 1973; Mason 1974; Mayama and Ishida 2003; Quinn 2005).

Fish Assemblage, Community Composition, and Species Diversity

One of the most striking changes from 2003 to 2004 in Safety Sound was the increased abundance of stickleback and saffron cod, combined with the decreased abundance of all species in the family Salmonidae. Sticklebacks were ubiquitous in 2004; they were caught in nearly every sampling event in Safety Sound and comprised the vast majority of every catch through most of the season. Saffron cod catches were unevenly distributed, with the vast majority being caught after July 12 (Figure 23). Recent research with food webs suggest that the observed

increase of saffron cod and threespine stickleback from 2003 to 2004 should affect other species in Safety Sound. Williams et al. (2002) found that 95% of species in large communities were within three linkages of one another on the food chain. If species in Safety Sound are similarly linked, it is likely that the increased abundance of threespine stickleback and saffron cod would have affected other fish species such as salmonids, either from competition (for food or space) or from predation. Diet studies will be needed to determine the presence and source of any competition. Such studies will be conducted in 2005.

Total catch and CPUE data from 2003 and 2004 provide some insights into which species or groups may have been affected by the influx of saffron cod and threespine stickleback. There were 14 species that comprised at least 1% of to the total annual catch in 2003 (Table 2). These species, by group, were flatfish (two species of flounder), stickleback (two species), coregonids (four species of whitefish and cisco), salmon (three species), cottids (various sculpin species), cod (one species), and smelt (one species). CPUE of all stickleback (+1,531%) and cod (+254%) increased dramatically from 2003 to 2004. At the same time, CPUE of flounder (+15% increase) and sculpin (-5%) remained relatively unchanged. The other groups declined substantially (coregonids decreased 41%, smelt 82%, and salmon 89%). These ecological differences among these fish groups will be evaluated in the 2005 season and included in a future report. Many species had marked differences in CPUE between the Nome River and Safety Sound. For most species, this difference can be explained by the different salinities between the two areas: most species with a higher CPUE in Safety Sound are known to be associated with marine environments, whereas those with higher CPUEs in the Nome River have an important freshwater component to their life history. Some CPUE differences, however, could not be explained solely by differences in salinity between the lower Nome River and Safety Sound. For these species, something such as competition, habitat suitability, or life stage may explain their differences between the two systems in 2004 (Table 14).

Three coregonid species (least cisco, Bering cisco, and humpback whitefish) are known to inhabit both brackish and fresh water (Mecklenburg et al. 2002), but were rarely found in the Nome River. It is not known whether these species migrate into freshwater rivers in the Nome subdistrict. If they do, they appear to be using the Eldorado River complex more heavily than the Nome River. Also, threespine stickleback are known to inhabit both brackish and fresh water (Mecklenburg et al. 2002), but were far more abundant in Safety Sound than in the Nome River and were far more dominant compared to the other fish species.

It is not known whether the changes in fish assemblage seen in Safety Sound from 2003 to 2004 are common in this system because fish communities have not previously been described in Norton Sound estuaries and rivers. Thus, we do not know how the community assemblage in Safety Sound or the Nome River differs from times when salmon populations were historically abundant. If the changes seen from 2003 to 2004 are simply a periodic fluctuation, they may be of no long-term concern to salmon. If the changes are a relatively new phenomenon, however, they may have substantial implications for salmon populations in the Norton Sound area. The data presented from this study will provide a basis for tracking and comparing future changes in the fish community.

The information gathered on species diversity may also provide insight into the potential

robustness and resilience of the ecosystem and its fish assemblage. Ecosystem diversity, for example, is thought to be linked with long-term site stability and productivity (Tilman 1996). Diverse systems are also thought to be less susceptible to invasion by foreign species and to changes brought about by pathogens. Documenting such diversity in advance of climate change, colonization by invasive species, or other perturbations help identify how the ecosystem changes in future years, and what the effects of this change will be on individual species such as chum salmon.

Environmental Conditions

Water temperatures throughout Safety Sound were higher in 2004 than 2003, and ice breakup occurred approximately one week earlier. Although the temperature difference was not statistically significant, it was consistent across all sites and may have been biologically significant. Such warming, for example, may have sped development of eelgrass and algae or caused earlier hatching and emigration juvenile chum salmon. Elevated water temperatures later in the season could also have affected physiological processes such as metabolism, or altered the temperature transition zones among habitats.

Safety Sound clearly serves as a transition zone between the mouth of the Eldorado and the exit to Norton Sound. At the eastern and northwestern ends of Safety Sound, environmental conditions (temperature and salinity) are intermediate between freshwater and marine, whereas in the central part of the Sound the conditions are mostly marine. Chum salmon that migrate from the Eldorado River can thus find areas in Safety Sound in which to acclimate to marine temperatures and salinities. The lower Nome River, conversely, was almost entirely freshwater in 2004 and appeared to provide no transition zone for juvenile chum moving from the Nome River to Norton Sound. It is not known whether this lack of a transition zone is normal for the river because there is no prior baseline.

The abrupt temperature transition from the Nome River to Norton Sound was probably not extreme enough to pose an acute, lethal threat to migrating chum. Based on our observations in 2004, Nome River temperatures exceed Norton Sound temperatures after the first week of June, and chum must thus transition from warmer to cooler water. Chum need acclimation before exposure to temperatures below approximately 7° C (Beitinger and Bennett 2000). In 2004, chum moving into Norton Sound would have experienced temperatures below 7° only in the first week of June, when the Nome River was still cold enough to provide the necessary acclimation (Figure 25). A problematic transition would have to be more extreme, such as moving from 15° C to 5° C degree water (Brett 1952); this would only appear to be likely in a year in which the rivers heated unusually fast in the spring while the ocean remained unusually cool.

The water temperatures in both the Nome and the Eldorado River systems may still have had negative, sublethal effects on chum because the temperatures frequently exceeded the optimal and preferred levels reported for chum. Preferred temperatures (i.e., the temperature chosen by fish when exposed to a range of temperatures) for chum usually range from 11° C to 15°C (Brett 1952; Beschta et al. 1987). The optimal temperature for normal feeding activity, physiological processes, and behavior appears to be somewhere around 13.5° C for rearing chum salmon (Beschta et al. 1987). Above 15° C, metabolic efficiency drops and salmonids begin to suffer detrimental effects (Bestcha et al. 1987). Juvenile coho salmon, for example, appear to require

twice as much food to grow at 17° C as at 5° C (Averett 1968, reported in Beschta et al. 1987). In 2002 and 2003, water temperatures throughout Safety Sound were generally within this optimum range. In 2004, water temperatures increased slightly throughout Safety Sound; this increase, while not significant, raised the average temperature above 15° C in most of the northwestern parts of Safety Sound. Water temperatures exceeded 15° C for nearly the entire summer of 2004 at the Safety Sound inlet, for most of July at the Safety Sound outlet, and for most of July in the lower Nome River. Chum were rarely captured at any site after the temperature had risen above 15° C.

The actual exposure of chum to elevated temperatures in the Nome and Eldorado rivers is unknown. It is possible that chum may find cool water refuges within the rivers and thus not be exposed to the elevated temperatures (e.g., on the river bottom, which also may explain the high numbers of benthic chironomids in the diet). It is also possible that the temperatures observed in 2004 are normal for these streams and that the chum have adapted to these temperatures. A third possibility is that the elevated temperatures are a recent trend that can have the same negative consequences on Norton Sound chum as they do on other populations (e.g., Beschta et al. 1987; Coutant 1977). If so, increasing temperature trends could have important implications for chum that normally remain in freshwater until late June, either by forcing them into marine waters before they are ready, or by subjecting them to suboptimal conditions if they remain in the river. Norton Sound rivers should be monitored annually to determine when and where the water temperatures exceed 15° C, and whether those temperatures coincide with chum movement and habitat use. The establishment of baseline conditions now is also important to evaluate future temperature changes predicted in higher latitude waters (ACIA 2004).

The abrupt salinity transition in the Nome River appears to be less of a concern than temperature. Chum can acclimate to high salinity relatively quickly, apparently within hours (Iwata and Komatsu 1984), and can move between salinity zones to accomplish this acclimation. Chum in the lower Nome River were motile enough to feed, increasing the likelihood that they can move between fresh and marine waters as needed to acclimate to new salinity zones.

CONCLUSION AND RECOMMENDATIONS

This project provides baseline information on chum salmon habitat, diet, and basic aquatic conditions in the Norton Sound region. Such reference information may be essential for determining if and how habitats change in the future, and for evaluating how these changes affect chum. For maximum benefit, this information should be made available in manuscripts or data reports that can be indexed and searched electronically. Such availability could be through any searchable information-sharing platform established by the Norton Sound Disaster Relief Funds. Alternatively, data presented here should be developed for publication in peer-reviewed scientific journals.

The project also identifies several issues that may have affected juvenile chum populations in 2004, and may warrant further inquiry. These include:

- Annual variability in chum salmon diet and the possible effects on survival;

- The effect of threespine stickleback abundance on juvenile chum;
- The presence of chum populations with substantially different life history requirements within the Nome and Eldorado rivers; and,
- Whether the absence of a transition zone for temperature and salinity exerts affects the behavior and survival of chum migrating from the Nome River to Norton Sound.

Addressing these issues in advance of any dramatic changes in populations, habitat, or environmental conditions will help identify how to manage and conserve these populations as the environmental and political landscape changes.

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Table 1. Sampling location, gear type, and dates sampled.

Location and year	Site	Gear	Dates sampled	# of sampling events
Safety Sound, 2003	Inlet	Fyke	June 7 - July 19	41 days
	Various	Fyke	June 15-July 13	24 days
	Outlet	Fyke	June 10 - July 21	40 days
Safety Sound, 2004	Inlet	Fyke	June 3 - July 28	48 days
	Interior	Fyke	June 30 - July 26	23 days
	Outlet	Fyke	June 1 - July 31	54 days
	Various	Seining	June 7 - July 21	61*
Nome River, 2004	Up River	IPT	May 28 - July 18	43 days
	Up River	Fyke	July 6 - Aug 7	27 days
	Down River	Fyke	May 30 - Aug 28	66 days

* this is a count of seining locations; multiple seine hauls were made at each location

Table 2. Total catch and % catch by year for species in Safety Sound and the Nome River, Alaska.

		Safety Sound						Nome River	
		2002[1]		2003		2004		2004	
Common Name	Scientific Name	n	%	n	%	n	%	n	%
Alaska blackfish	*Dallia pectoralis*			1	0%			2	0%
Arctic flounder	*Pleuronectes glacialis*	3,014	36%	11,963	15%	16,294	5%	136	0%
Arctic grayling	*Thymallus arcticus*			18	0%	3	0%	1,271	3%
Bering cisco	*Coregonus laurettae*	990	12%	1,894	2%	131	0%	14	0%
Bering poacher	*Occella dodecaedron*			1	0%	5	0%		
Bering wolffish	*Anarhichas orientalis*			1	0%				
Broad whitefish	*Coregonus nasus*					11	0%		
Burbot	*Lota lota*			2	0%	16	0%	3	0%
Capelin	*Mallotus villosus*	2	0%						
Chum salmon (juvenile)	*Onchorhynchus keta*	213	3%	694	1%	120	0%	610	1%
Chum salmon (adult)	*Onchorhynchus keta*	10	0%					3	0%
Coho salmon (juvenile)	*Onchorhynchus kisutch*	9	0%	272	0%	59	0%	8,753	20%
Coho salmon (adult)	*Onchorhynchus kisutch*							1	0%
Crested sculpin	*Blepsias bilobus*	1	0%						
Dolly varden	*Salvelinus malma*	228	3%	129	0%	62	0%	372	1%
Four horn sculpin	*Myoxocephalus quadricornis*	285	3%	2,976	4%	3,126	1%	17	0%
Humpback whitefish	*Coregomus pidschian*			3,459	4%	489	0%		
Inconnu (sheefish)	*Stenodus leucichthys*			6	0%				
King salmon (juvenile)	*Onchorhychus tshawytscha*	2	0%	17	0%	14	0%	58	0%
King salmon (adult)	*Onchorhychus tshawytscha*					2	0%		
Least cisco	*Coregonus sardinella*	608	7%	18,141	23%	18,819	6%	122	0%
Ninespine stickleback	*Pungitius pungitius*			3,268	4%	3,761	1%	1,601	4%
Pacific herring	*Clupea pallasi*	19	0%	49	0%	18	0%	7	0%
Pacific lamprey	*Lampetra tridentata*					2	0%	1	0%
Pink salmon (juvenile)	*Onchorhynchus gorbuscha*			2,020	3%	14	0%	16,447	37%
Pink salmon (adult)	*Onchorhynchus gorbuscha*	292	3%	8	0%	120	0%	734	2%
Pond smelt	*Hypomesus olidus*							1	0%
Rainbow smelt	*Osmerus mordax*	515	6%	9,649	12%	2,373	1%	6	0%
Rainbow trout / steelhead	*Oncorhynchus mykiss*			1	0%				
Round whitefish	*Prosopium cylindraceum*			3,253	4%	1,281	0%	1,069	2%
Saffron cod	*Eleginus navaga*	1,545	18%	10,398	13%	51,292	16%	10	0%
Sockeye salmon (juvenile)	*Onchorhynchus nerka*	8	0%			217	0%	188	0%
Starry flounder	*Platichthys stellatus*	85	1%	2,413	3%	2,201	1%	3,152	7%
Threespine stickleback	*Gasterosteus aculeatus*	415	5%	7,766	10%	213,586	68%	9,646	22%
Tubenose poacher	*Pallasina barbata*	19	0%	35	0%	40	0%		
Unidentified greenling	*Hexagrammidae*					9	0%		
Unidentified juvenile	*Salmonidae*	46	1%						
Unidentified sculpin	*Cottidae*	53	1%	66	0%	744	0%	529	1%
Unidentified fish		14	0%	19	0%			3	0%
Total		8,373		78,519		314,809		44,756	

[1]Nemeth et al. 2003

Table 3. Fyke net CPUE (fish/d) for select groups and species in Safety Sound (2003 and 2004) and the Nome River (2004). Percent difference of CPUE is calculated as the difference between the 2004 and 2003 CPUE, divided by the 2003 CPUE.

	Safety Sound					Nome River	
	2003		2004		% Difference in Safety Sound CPUE, 2003 - 2004	2004	
	CPUE (fish/d)	% of total CPUE	CPUE (fish/d)	% of total CPUE		CPUE (fish/d)	% of total CPUE
All fish	455	100%	1,426	100%	213	188	100%
Coregonids	159	35%	94	7%	-41	9	5%
Flounders	73	16%	84	6%	15	24	13%
Salmonids	20	4%	2	0%	-89	83	44%
Sculpins	19	4%	18	1%	-6	2	1%
Sticklebacks	60	13%	985	69%	1,531	74	39%
Arctic flounder	59	13%	74	5%	25	1	0%
Arctic grayling	0	0%	0	0%	-88	9	5%
Bering cisco	12	3%	1	0%	-95	0	0%
Chum salmon	4	1%	1	0%	-88	0	0%
Coho salmon	2	0%	0	0%	-84	61	32%
Dolly Varden	1	0%	0	0%	-64	3	1%
Humpback whitefish	20	4%	2	0%	-89	NA	NA
Least cisco	107	24%	85	6%	-20	1	0%
Ninespine stickleback	16	3%	17	1%	8	11	6%
Pink salmon	13	3%	0	0%	-99	0	0%
Rainbow smelt	58	13%	11	1%	-82	0	0%
Round whitefish	20	4%	6	0%	-71	8	4%
Saffron cod	66	14%	232	16%	254	2	1%
Starry flounder	14	3%	10	1%	-27	23	12%
Threespine stickleback	45	10%	968	68%	2,069	62	33%

Table 4. Number of chum salmon caught by length class on each sampling date in Safety Sound, 2002 - 2004. Table is designed to show major groupings by size over the course of a season (e.g. 4 groupings for Safety Sound in 2003).

		June																						July																													
		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2004 length (mm)	30																																																		
	35																																																		
	40								1																																										
	45						1	1									2																																	
	50			2	1		1	14	3	1	4	1					2				1																							1					
	55			5				11	3	1	9						2	1				2		3	1																		1						1
	60	1		2			1	2	3	5	3	1			1			2				1		2	1																								
	65							1			1			1																																				
	70																																																	
	75																																																	
	80																																																	
	85																																																	
	90																																																	
2003 length (mm)	30																																																	
	35		1		5	4	4	5																																										
	40		1	1	1	7	17	7	1						1																																			
	45		1			5	6	5	7						5			4			2																		1										
	50					1	2	4	17					1	4	1	1	18			3										2									2									
	55					1			2		1				3	1	1	29		2	6									2	5				1				1	2		1						
	60						1									1		12	2	1	4									6	5	2	2	4	2				26	4			1					
	65														1			2	1									2	2	4	5	1	1	3	2				16	4		1	1					
	70																		1											1		1	3						6			1	12					
	75																														1			1	1			1	3			3	7					
	80																																					1	1				3					
	85																																						2				1					
	90																																																	
2002[1] length (mm)	30																																																	
	35																																																	
	40																																																	
	45																															3																		
	50																															4																		
	55																																					2	6			11							
	60																												1							1	1	21	17	2		11	1					
	65																											1		1						3	7	14	5	4		11	2					
	70																										2	2	6	1					1	2	1	4	9	2		9						
	75																											3	4									6	1	4		3						
	80																											3				2						1		2								
	85																															1							1									
	90																																																	

[1]Nemeth et al. 2003

Table 5. Number of chum salmon caught by length class on each sampling date in Safety Sound, the Eldorado River and the Nome River, 2004. Table is designed to show major groupings by size over the course of a season.

		May				June																																July																												
		28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	#	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2004 Safety Sound Length (mm)	30																																																															
	35																																																															
	40																				1																																											
	45																		1	1									2																																			
	50															2	1		1	14	3	1	4	1					2				1																							1								
	55															5				11	3	1	9						2	1				2		3	1																	1							1			
	60													1		2			1	2	3	5	3	1			1			2				1		2	1																											
	65																			1			1			1																																						
	70																																																															
	75																																																															
	80																																																															
	85																																																															
	90																																																															
2004 Eldorado River Length (mm)	30																																																														
	35													7						1																																										
	40											15		17						6																												1																
	45											2		2						3																																												
	50																											1																				1																
	55																									2		1																																				
	60																									2																																						
	65																																																															
	70																																																															
	75																																																															
	80																																																															
	85																																																															
	90																																																															
2004 Nome River Length (mm)	30											1																																																			
	35	16	9	1	2	9	3	5				3				2																																																
	40	9	17	18	16	7	8	3	6			9		4	5	10						1					1		9	2																																		1
	45			1	2	4	2	1	2			7		11	8	8			9	3		7	1						4	5										1	1	1	3				1			3	1													
	50								1					4	8				5	1	1	11	1			1			1	1							1			1	2	2	17						1	6														
	55													1								1															1						11				1	1		11				1		1		1						
	60																																				1				1	1	2					1								1						1		
	65																																																															
	70																																																															
	75																																																															
	80																																																															
	85																																																															
	90																																																															

Table 6. Mean daily chum salmon growth by time period in the Nome River, Eldorado River, and Safety Sound, 2003 and 2004. Time periods determined from Tables 4 and 5.

Location and year	Site		Time period						
				June 10-18		June 19-28	June 29 -July 12	July 13 -20	All Dates
Safety Sound 2003	All stations	Days elapsed from prior period		NA		10	14	9	33
		Change in mean chum size (mm)		NA		10.71	8.28	4.14	23.14
		Growth rate (mm/d)				1.07	0.59	0.46	0.70
		Sample size (# of chum)		107		107	59	101	374
	Inlet	Change in mean chum size (mm)		NA		10.82	6.87	5.18	22.86
		Growth rate (mm/d)				1.08	0.49	0.58	0.69
		Sample size (# of chum)		29		3	15	8	55
	Outlet	Change in mean chum size (mm)		NA		10.62	8.01	5.73	24.36
		Growth rate (mm/d)				1.06	0.57	0.64	0.74
		Sample size (# of chum)		78		33	35	93	239
	Interior	Change in mean chum size (mm)		NA		NA	10.38	NA	10.38
		Growth rate (mm/d)					0.74		0.74
		Sample size (# of chum)		NA		71	9		80
				June 9-12	June 13-19	June 20-25	June 26-July 2		All Dates
Safety Sound 2004	All stations	Days elapsed from prior period		NA	6	7	7		20
		Change in mean chum size (mm)		NA	2.88	0.22	1.4		4.50
		Growth rate (mm/d)			0.48	0.03	0.2		0.23
		Sample size (# of chum)		15	71	10	10		106
				June 4-9	June 15-23				All Dates
Eldorado River 2004	All stations	Days elapsed from prior period		NA	12				12
		Change in mean chum size (mm)		NA	6.80				6.80
		Growth rate (mm/d)			0.57				0.57
		Sample size (# of chum)		63	16				79
			May 28-June 4	June 5-11	June 12-18	June 19-25	June 26-July 8	July 9-16	All Dates
Nome River 2004	Upper	Days elapsed from prior period		8	7	7	13	8	43
		Change in mean chum size (mm)	NA	4.69	4.16	-5.31	6.30	2.60	17.74*
		Growth rate (mm/d)		0.59	0.59	-0.76	0.48	0.32	0.41*
		Sample size (# of chum)	142	80	41	22	14	24	323

* 2004 total growth statistics in the Nome River 2004 excludes fish sampled from June 22-25 (see text).

Table 7. Juvenile chum salmon stomach fullness index by system and year. Data represent the number of fish for each fullness category.

	Safety Sound			Eldorado R.	Nome R.
Stomach Fullness	2002[1]	2003	2004	2004	2004
Empty	3	15	2	0	2
Trace	9	13	6	0	2
Trace- 25%	6	29	12	1	24
25-50%	16	22	7	3	14
50-75%	9	13	16	2	3
75-100%	12	22	10	5	6
# of stomachs sampled	55	114	53	11	51

[1]Nemeth et al. 2003

Table 8. Chum salmon diet composition by number, weight, and frequency of occurrence of prey for Safety Sound, the Eldorado River, and the Nome River. %N = the proportion of prey by number; %W = the proportion of prey by weight; %FO = the proportion of stomachs with the prey type present.

	Safety Sound			Eldorado R.	Nome R.
% N	2002[1]	2003	2004	2004	2004
Worms	1	-	0	-	-
Crustacea (marine)	51	78	84	0	0
Crustacea (fresh)	-	0	0	-	0
Insects (terrestrial)	42	15	0	-	0
Mayflies	-	-	0	5	2
Diptera	-	-	0	4	4
Chironomid larvae	6	7	15	91	93
Fish	-	0	0	-	0
Number of prey	149	1,527	8,918	626	2,214
% W					
Worms	1	-	0	-	-
Crustacea (marine)	73	92	24	1	1
Crustacea (fresh)	-	0	0	-	0
Insects (terrestrial)	21	5	1	-	0
Mayflies	-	-	0	18	11
Diptera	-	-	2	12	5
Chironomid larvae	5	1	70	69	77
Fish	-	1	3	-	6
Total weight of prey (g)	1,601	2,691	1,205	158	814
% FO					
Worms	4	-	2	-	-
Crustacea (marine)	67	57	32	9	4
Crustacea (fresh)	-	4	11	-	2
Insects (terrestrial)	71	67	9	-	6
Mayflies	-	-	0	82	41
Diptera	-	-	8	55	47
Chironomid larvae	9	5	81	100	88
Fish	-	2	8	-	10
Number of stomachs sampled	55	114	53	11	51

[1]Nemeth et al. 2003

Table 9. Index of relative importance (IRI) of chum salmon food items, 2002-2004. The IRI is calculated by adding %N and %W, then multiplying the result by the frequency of occurrence.

	Safety Sound			Eldorado R.	Nome R.
Prey Item	2002[1]	2003	2004	2004	2004
Worms	9	-	0	-	-
Crustacea (marine)	8,351	9,694	3,485	9	4
Crustacea (fresh)	-	1	6	-	0
Insects (terrestrial)	4,424	1,317	8	-	3
Mayflies	-	-	0	6,870	519
Diptera	-	-	12	857	406
Chironomid larvae	100	45	6,870	16,040	15,041
Fish	-	2	28	-	64
Number of stomachs sampled	55	114	53	11	51

[1]Nemeth et al. 2003

Table 10. Percent available prey by number (%N) from zooplankton samples at various stations in Safety Sound and the Nome River from 2002 through 2004. Zooplankton samples represent prey found in the water column; sites are listed upstream to downstream.

Location and Prey Item	River (%)	Inlet (%)	West Bay (%)	Safety Sound (%)	Outlet (%)	Norton Sound (%)	All (%)
Safety Sound 2002[1]							
Worms		-			2		0
Crustacea (marine)		100			98		99
Crustacea (fresh)		0			0		0
Insects (terrestrial)		-			0		0
Mayflies		-			-		-
Diptera		-			-		-
Chironomid larvae		-			-		-
Fish		0			0		0
Number of prey		104,410			38,419		142,829
Safety Sound 2003							
Worms	0	1	2	13	16	15	7
Crustacea (marine)	78	84	95	86	82	82	83
Crustacea (fresh)	20	15	2	1	2	3	10
Insects (terrestrial)	-	-	-	-	-	-	-
Mayflies	-	-	-	-	-	-	-
Diptera	0	0	0	0	0	0	0
Chironomid larvae	1	0	0	-	0	0	0
Fish	-	0	0	0	0	0	0
Number of prey	6,686	19,402	20,709	13,815	11,983	8,513	81,108
Safety Sound 2004							
Worms	3	2	1	3	2	5	3
Crustacea (marine)	36	56	98	97	98	95	92
Crustacea (fresh)	47	8	0	0	0	0	3
Insects (terrestrial)	-	-	-	-	-	-	-
Mayflies	0	0	0	0	0	0	0
Diptera	0	-	-	-	-	-	0
Chironomid larvae	13	34	0	0	0	0	2
Fish	0	0	-	-	0	0	0
Number of prey	10,274	3,568	19,202	21,066	53,359	60,046	167,515
Nome River 2004		Upper (%)			Lower (%)		All (%)
Worms		14			-		10
Crustacea (marine)		3			15		6
Crustacea (fresh)		12			37		19
Insects (terrestrial)		-			-		-
Mayflies		-			4		1
Diptera		-			-		-
Chironomid larvae		71			44		63
Fish		-			-		-
Number of prey		66			27		93

[1]Categories amended from Nemeth et al. 2003

Table 11. Percent available prey by number (%N) from drop net samples in Safety Sound and the Nome River, 2004. Drop net samples represent available epi-benthic prey; sites are listed upstream to downstream.

	Safety Sound							Nome River		
Prey Item	River (%)	Inlet (%)	West Bay (%)	Safety Sound (%)	Outlet (%)	Norton Sound (%)	All (%)	Upper (%)	Lower (%)	All (%)
Worms (marine)	-	-	1	1	1	-	0	0	0	0
Worms (fresh)	2	13	20	84	20	-	12	2	1	1
Crustacea (marine)	5	10	27	7	35	22	9	2	1	1
Crustacea (fresh)	7	0	-	-	1	3	5	5	0	0
Insects	0	-	-	-	1	6	0	4	2	2
Molluscs	24	1	11	6	10	19	17	0	0	0
Chironomids	61	74	41	0	5	44	56	86	96	96
Jellyfish	-	-	0	2	9	6	1	-	-	-
Fish	0	1	0	1	18	-	1	0	0	0
Number of Prey	2,615	820	360	307	146	32	4,280	250	5,289	5,539

Table 12. Chum prey energy values reported in the literature. Average weight of each taxa was taken from zooplankton samples from Safety Sound in 2003.

Sample type	Location	Year	Taxa	Sample size (n)	% of sample	Mean weight (mg)	wet weight (cal/g)	Average cal/ organism	Estimated calories (cal)	Literature Sources
Drop Net										
	Safety Sound	2004	Chironomidae larvae	1,351	42%	0.36	1,095.7	0.39		11, 13
			Gastropoda	429	13%	0.54	337.0	0.18		4
			Ostracoda	289	9%	0.54	618.0	0.34		7, 12
			Nematoda	284	9%					
			Mysids	204	6%	0.36	901.1	0.32		3, 13
			Other	636	20%					
	Nome River	2004	Chironomidae larvae	5,313	96%	0.36	1,095.7	0.39		11, 13
			Arachnida	44	1%	0.06				
			Ephemeroptera	42	1%	0.54	1,083.1	0.59		5, 12
			Other	140	3%					
Zooplankton										
	Safety Sound	2003	Copepoda	50,793	63%	0.04	910.8	0.04		6, 8, 10, 12
			Echinodermata	8,438	10%	0.00	507.0	0.00		4
			Polychaeta	4,939	6%	3.62	849.0	3.07		4
			Harpacticoid	4,549	6%	0.27	910.8	0.25		6, 8, 10, 12
			Cladocera	4,047	5%	0.07	600.6	0.04		1, 12
			Other	8,342	10%					
	Safety Sound	2004	Copepoda	105,275	63%	0.04	910.8	0.04		6, 8, 10, 12
			Echinodermata	13,523	8%	0.00	507.0	0.00		4
			Cnidaria	12,640	8%	0.00	136.0	0.00		2, 10
			Cladocera	9,697	6%	0.07	600.7	0.04		1, 12
			Mollusca	5,394	3%	1.20	624.0	0.75		10
			Other	21,016	13%					
	Nome River	2004	Chironomidae larvae	61	62%	0.39	1,095.7	0.39		11, 13
			Oligochaeta	8	8%					
			Arachnida	7	7%					
			Rotifera	4	4%					
			Copepoda	3	3%	0.04	910.8	0.04		6, 8, 10, 12
			Other	16	16%					
Diet										
	Safety Sound	2003	Copepoda	729	48%	0.04	910.8	0.04	27	6, 8, 10, 12
			Amphipoda	292	19%	2.56	817.0	2.09	610	9
			Diptera adult	225	15%	0.54	1,083.1	0.59	132	5, 12
			Chironomidae larvae	108	7%	0.36	1,095.7	0.39	42	11, 13
			Cumacea	75	5%	0.56	592.5	0.33	25	11, 13
			Other	98	6%					
	Safety Sound	2004	Copepoda	6,391	67%	0.04	910.8	0.04	239	6, 8, 10, 12
			Chironomidae larvae	1,877	20%	0.36	1,095.7	0.39	730	11, 13
			Harpacticoida	715	7%	0.27	910.8	0.25	176	6, 8, 10, 12
			Cumacea	280	3%	0.56	592.5	0.33	93	11, 13
			Amphipoda	43	0%	2.56	817.0	2.09	90	9
			Other	239	3%					
	Nome River	2004	Chironomidae larvae	2,064	93%	0.36	1,095.7	0.39	803	11, 13
			Diptera adult	87	4%	0.54	1,083.1	0.59	51	12, 5
			Ephemeroptera	33	1%	0.54	1,083.1	0.59	19	5, 12
			Plecoptera	8	0%	0.54	1,083.1	0.59	5	5, 12
			Fish	7	0%	0.88	1,279.5	1.13	8	9, 10, 12
			Other	13	1%					

Literature Cited

1 Cummins and Wuychek 1971
2 Ikeda 1972
3 Tarverdiyeva 1972
4 Thayer et al. 1973
5 Griffiths 1977
6 Kosobokova 1980
7 Norrbin and Bamstedt 1984
8 Harris 1985
9 Ciannelli et al. 1998
10 Davis et al. 1998
11 Brey 2001(converted from dry weight using insect larvae ratio)
12 Boldt and Haldorson 2002
13 Cauffope and Heymans 2005

Table 13. Species richness, diversity (H'), and evenness in Safety Sound (2002-2004) and the Nome River (2004).

Site	S	H'	Hmax	J'
Safety Sound 2002[1]	22	2.04	3.09	0.66
Safety Sound 2003	28	2.29	3.33	0.69
Safety Sound 2004	28	1.12	3.33	0.34
Nome River 2004	27	1.81	3.30	0.55

Note: S = Species richness; H' = Shannon-Wiener index of diversity (-pi(ln pi); Hmax = ln(S); J' = Pielou's estimate of species evenness (H'/Hmax).

[1]Nemeth et al. 2003

Table 14. List of fish species for which CPUE differed by at least an order of magnitude between the Nome River and Safety Sound in June and July, 2004.

Apparent habitat association	Species	Freshwater habitat Nome River CPUE (fish/d)	Estuarine habitat Safety Sound CPUE (fish/d)	Difference (%)
Freshwater				
	Arctic grayling	9.05	0.01	66,465
	Coho salmon	60.51	0.27	22,540
	Dolly Varden	2.67	0.28	852
Estuarine				
	Arctic flounder	0.92	73.81	7,960
	Saffron cod	1.60	232.35	14,415
	Threespine stickleback	62.48	967.55	1,449
	Humpback whitefish	0	2.22	n/a
	Rainbow smelt	0.04	10.75	28,776
	Sculpin spp.	1.66	17.53	956
	Bering cisco	0.02	0.59	2,557
	Least cisco	0.83	85.25	10,215
Intermediate				
	Ninespine stickleback	11.23	17.04	52
	Round whitefish	7.90	5.80	36
	Pink salmon	0.10	0.06	53
	Chum salmon	0.31	0.54	74
	Starry flounder	22.98	9.97	131

Table 15. Total catch by species in nearshore Norton Sound trawls in 2003 and 2004.

Common name	Scientific name	August 2003	June 2004	July 2004
Chum salmon (juvenile)	*Onchorhynchus keta*	4	-	-
Saffron cod (juvenile)	*Eleginus navaga*	178	87	-
Sand lance	*Ammodytes hexapterus*	262	-	-
Threespine stickleback	*Gasterosteus aculeatus*	1,961	-	747
Tubenose poacher	*Pallasina barbata*	1	-	-
Unknown (larval/juvenile)		-	3,532	-
Shrimp	*Pandalus spp.*	10	-	-
Jellyfish		60	-	-
Total		2,406	3,619	747

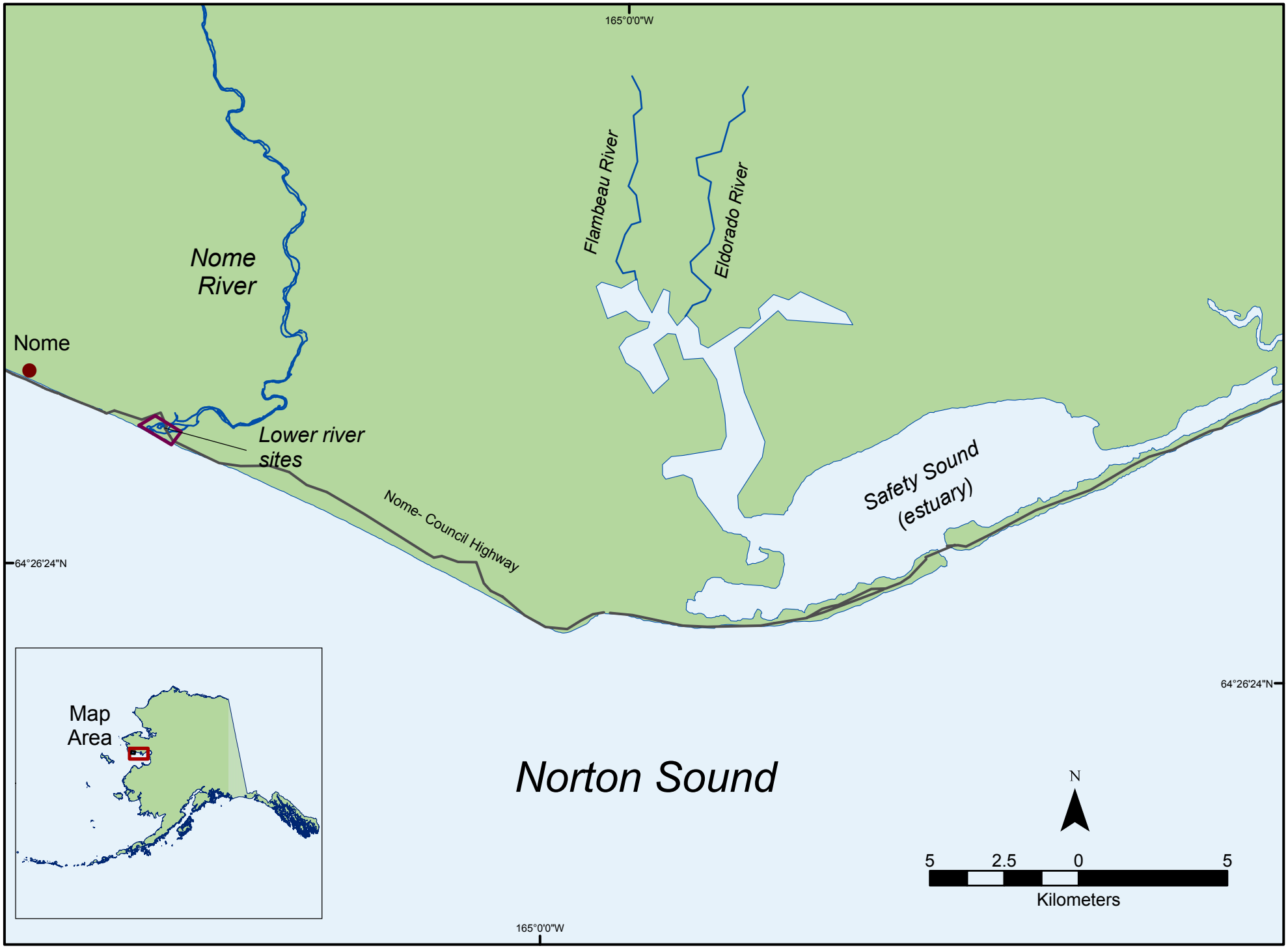

Figure 1. Map of study region showing Nome and Eldorado River watersheds.

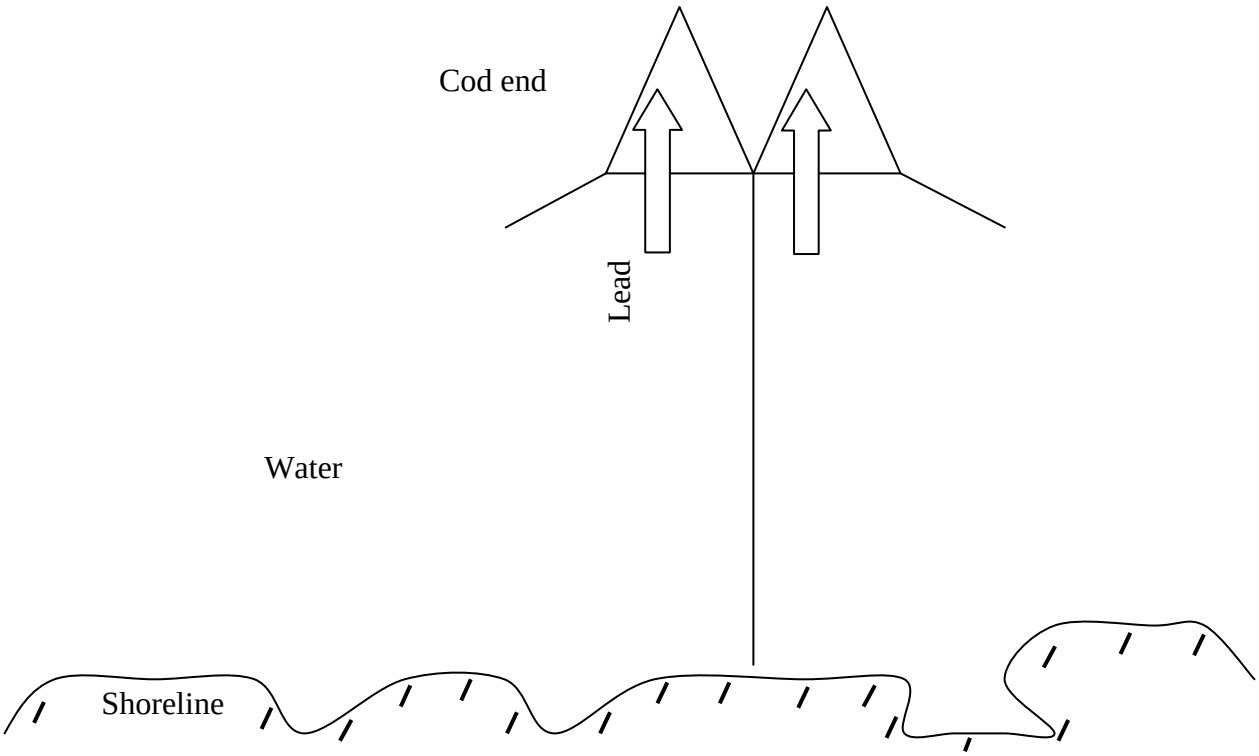

Figure 2. Design and arrangement of a typical fyke net used in Safety Sound and the Nome River, 2002-2004. Fish traveling along the lead enter the cod ends of nets at locations shown by arrows.

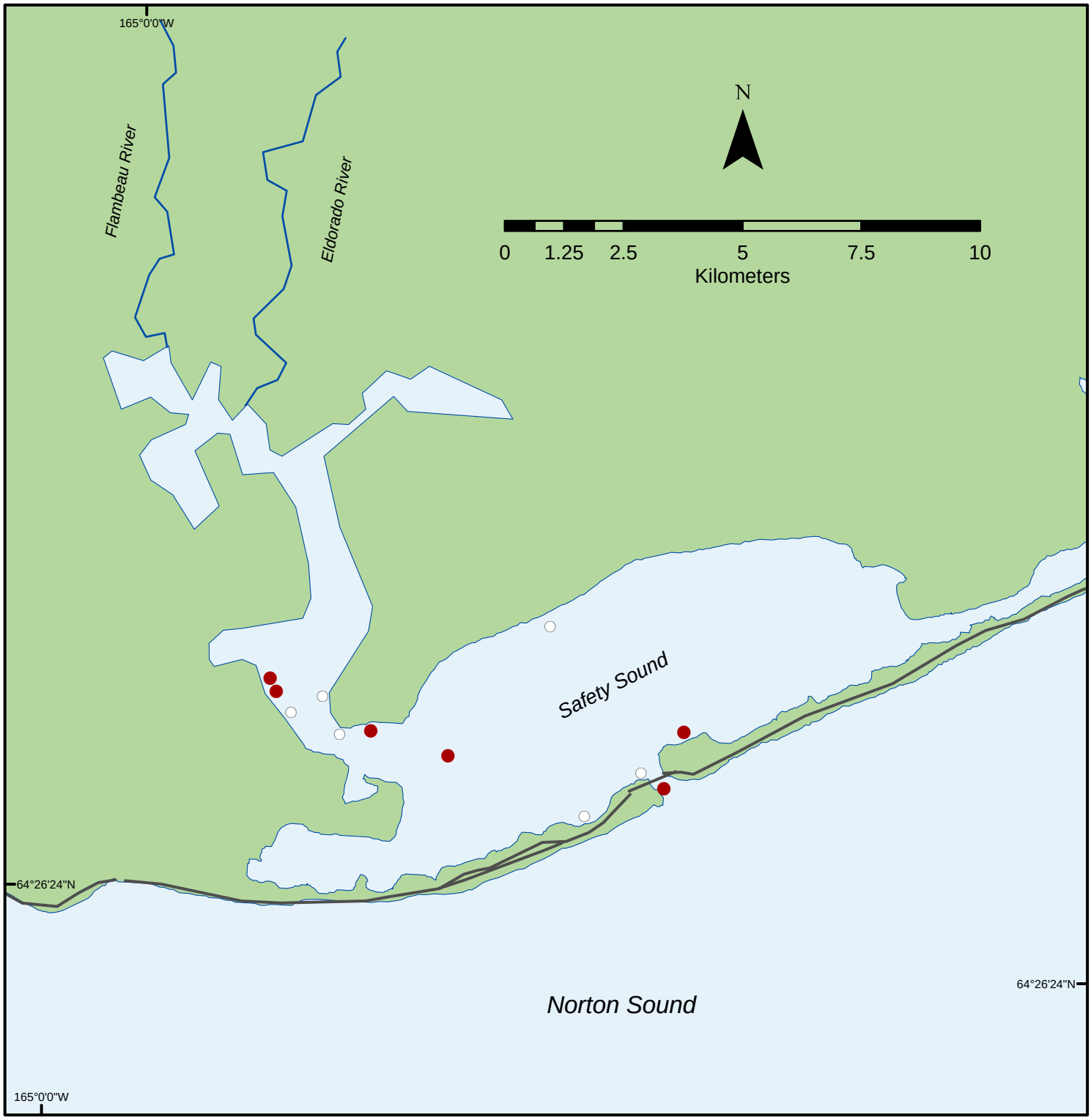

Figure 3. Locations at which juvenile chum salmon were sampled in the Eldorado River watershed, 2003. Fyke nets are solid dots and beach seines are open dots.

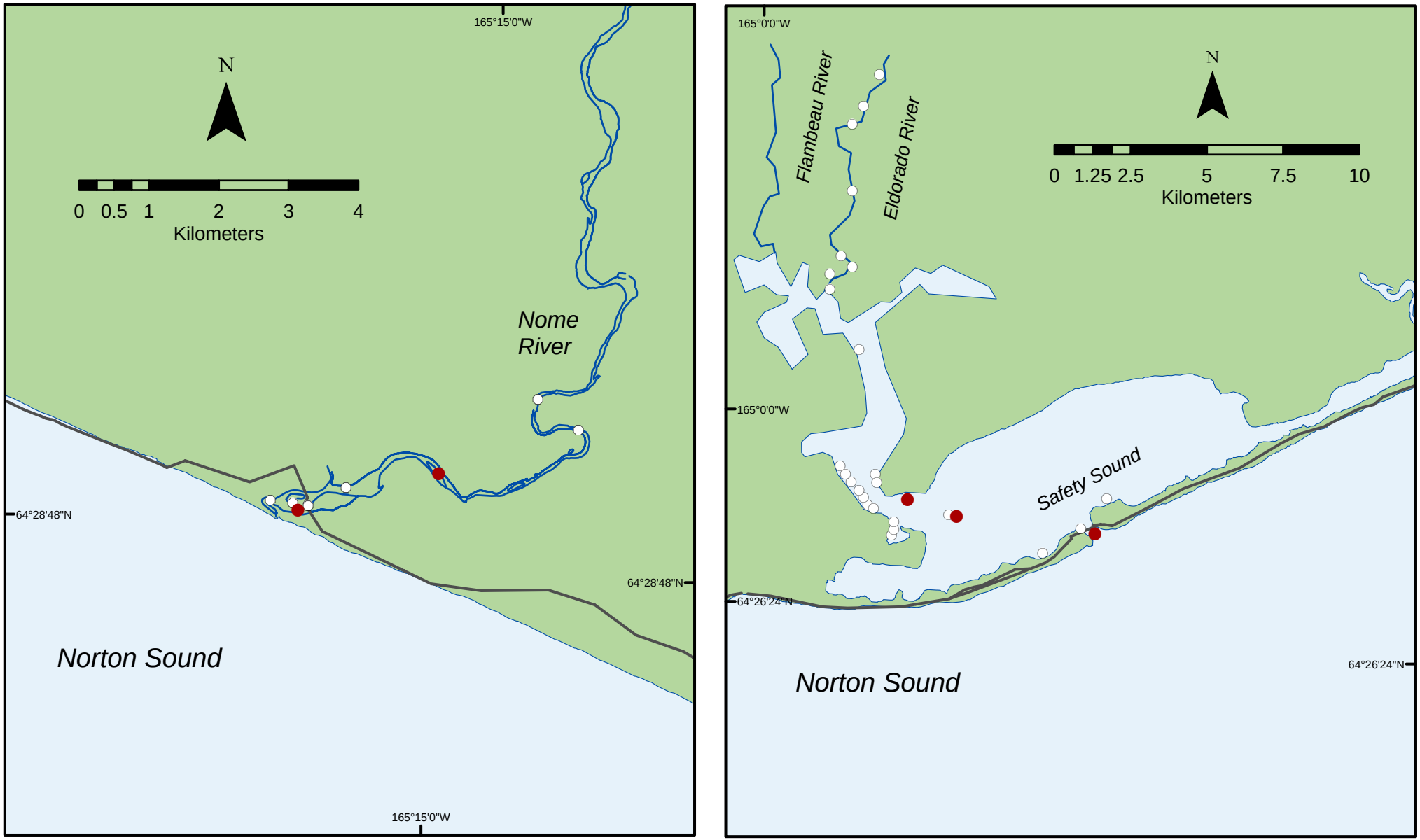

Figure 4. Locations at which juvenile chum salmon were sampled in the Nome and Eldorado River watersheds, 2004. Fyke nets are solid dots and beach seines are open dots.

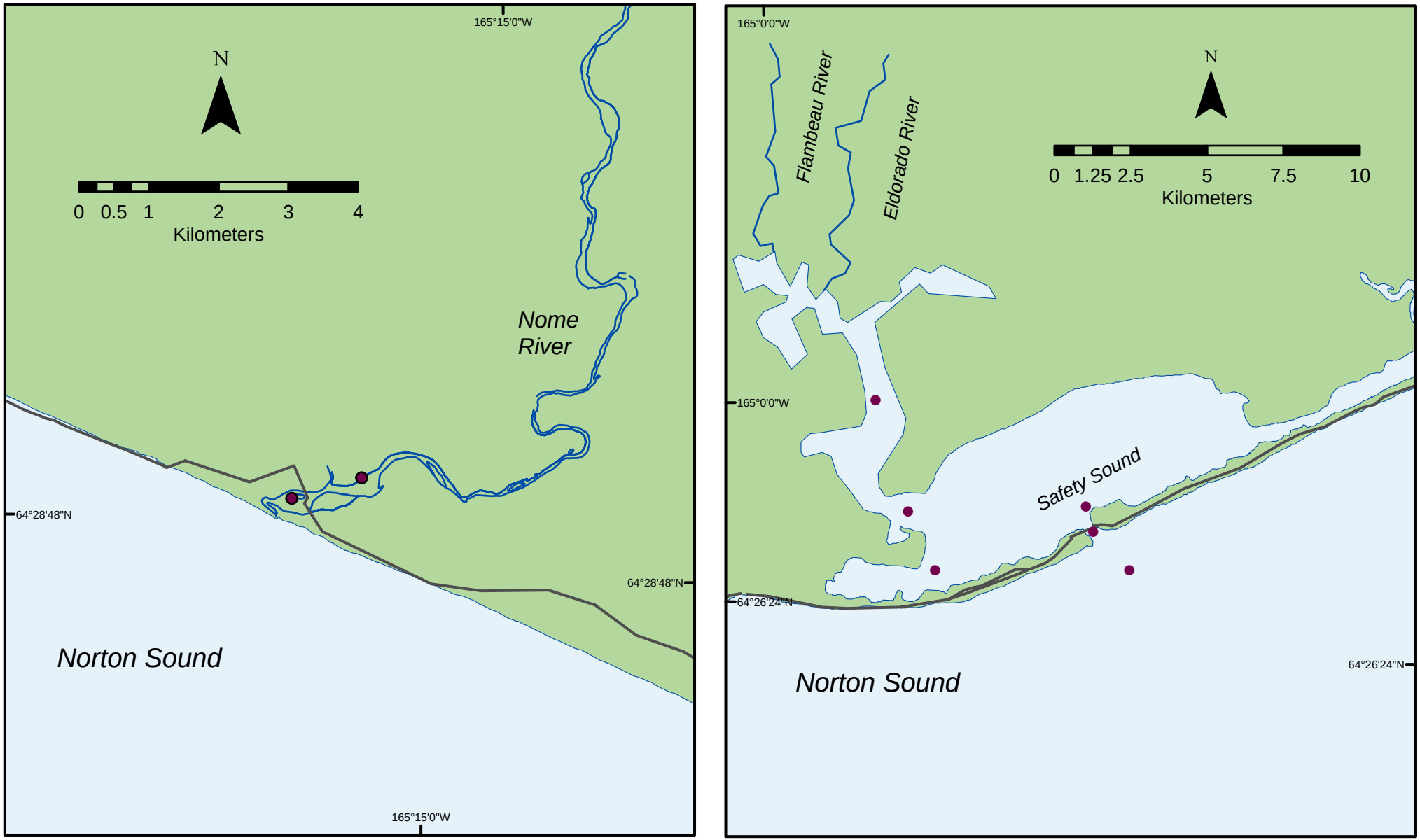

Figure 5. Locations at which invertebrates were sampled in the Nome (2004 only) and Eldorado (2003 and 2004) River watersheds.

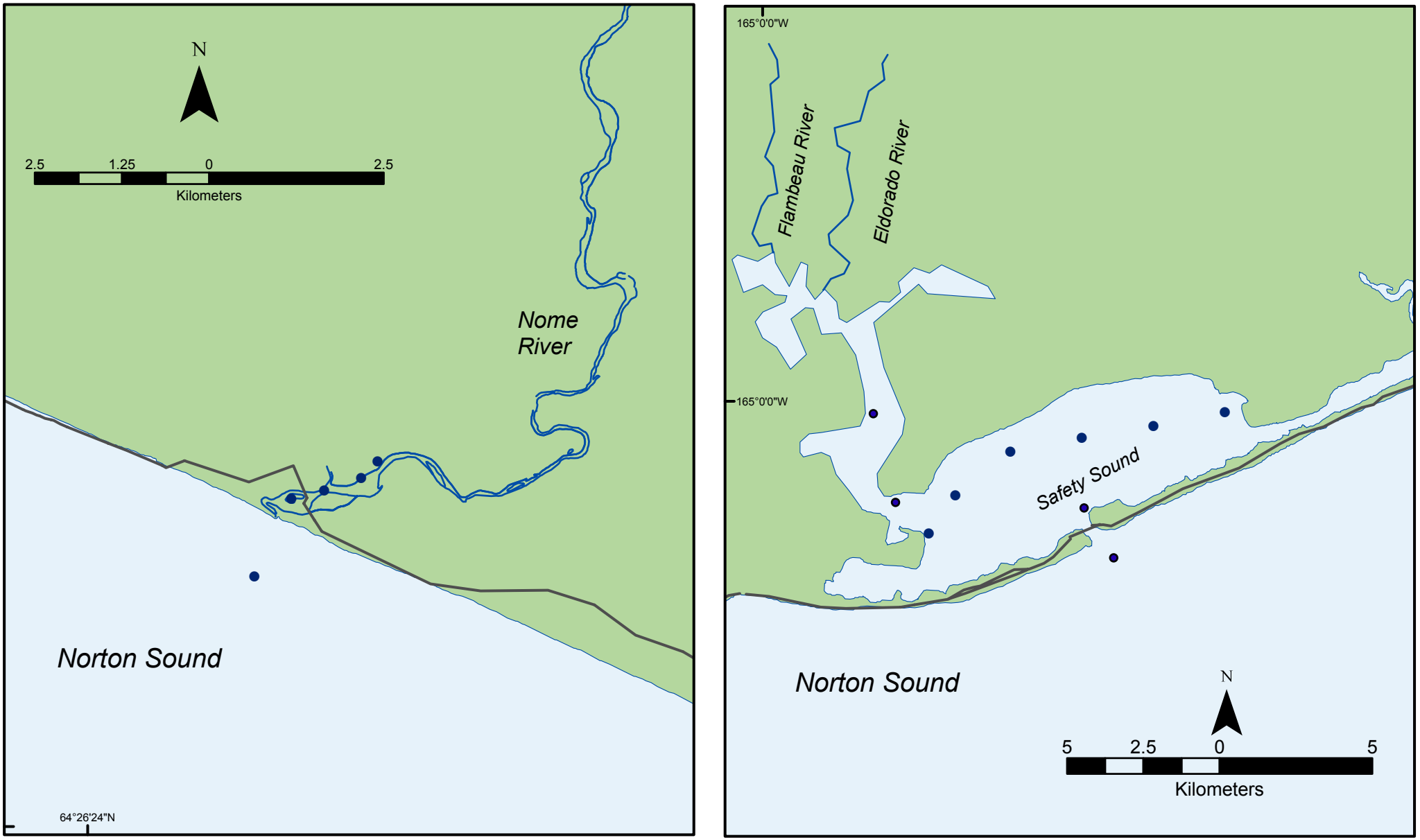

Figure 6. Temperature and salinity sampling locations in the Nome (2004) and Eldorado (2003 & 2004) River watersheds, 2004.

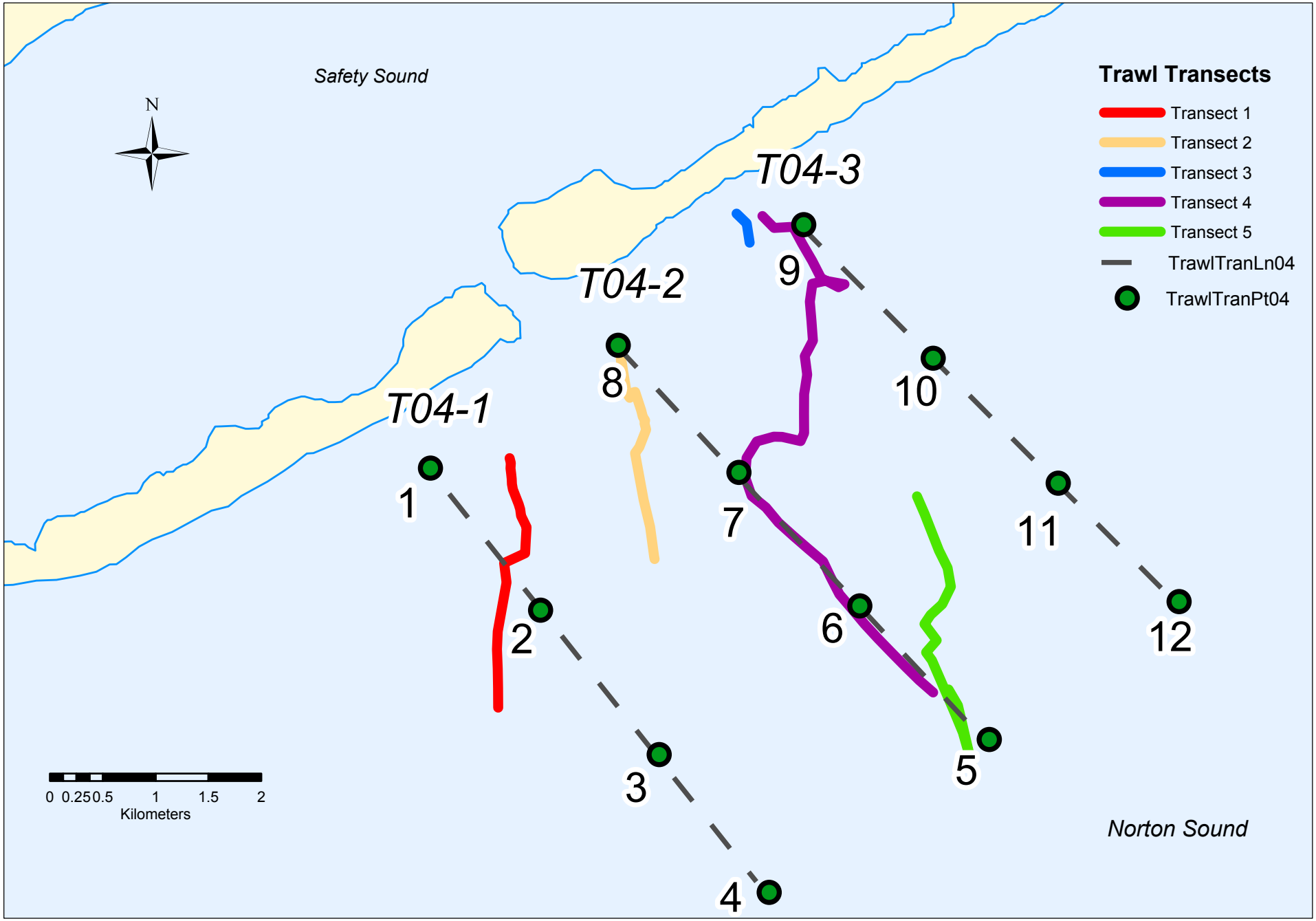

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Figure 7. Norton Sound trawl transect locations, 2004. Colored lines are 2003 transects; dashed lines are 2004 transects.

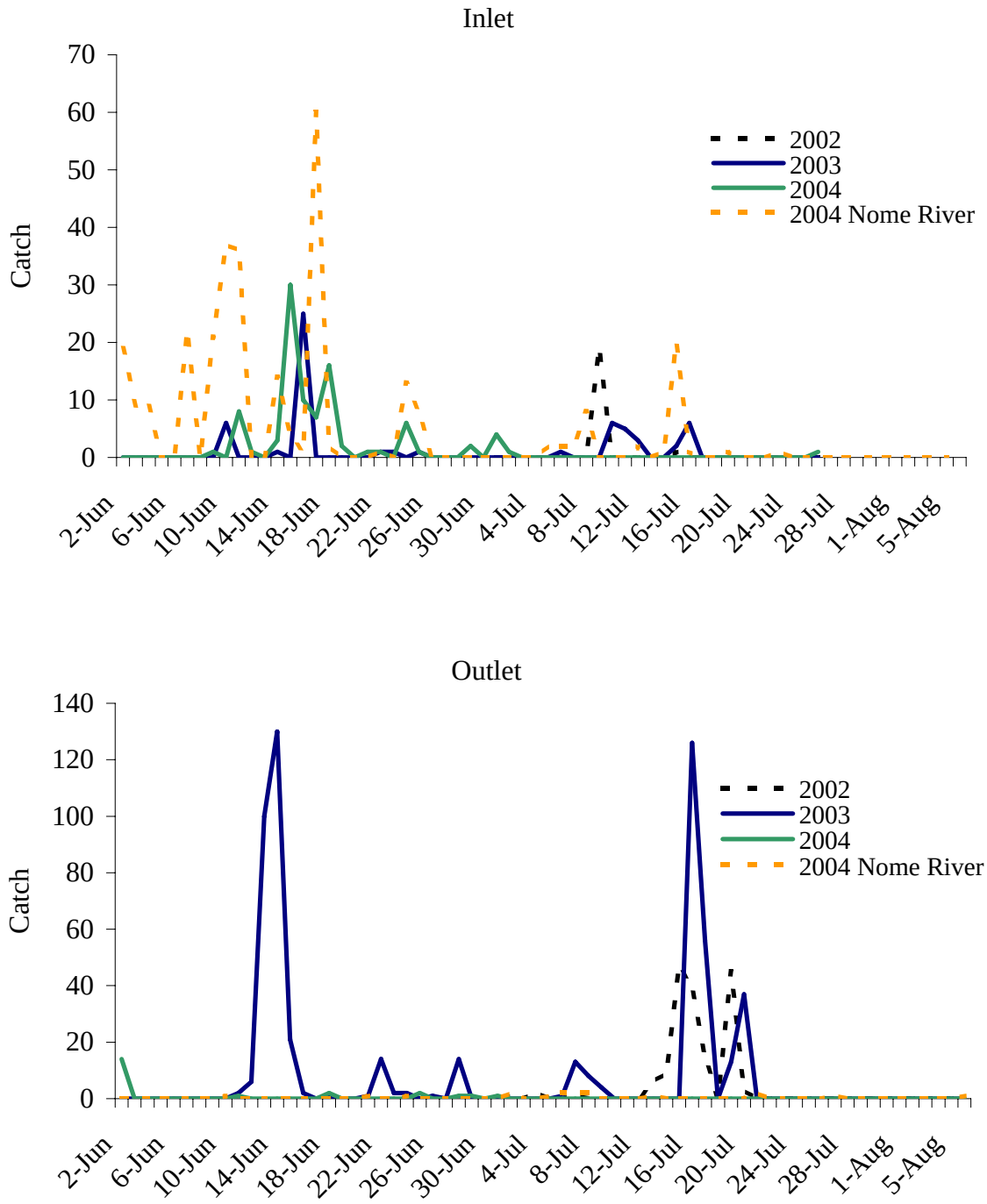

Figure 8. Chum salmon catch by date at the Safety Sound inlet, outlet, and Nome River, 2002-2004. 2002 data from Nemeth et al. (2003).

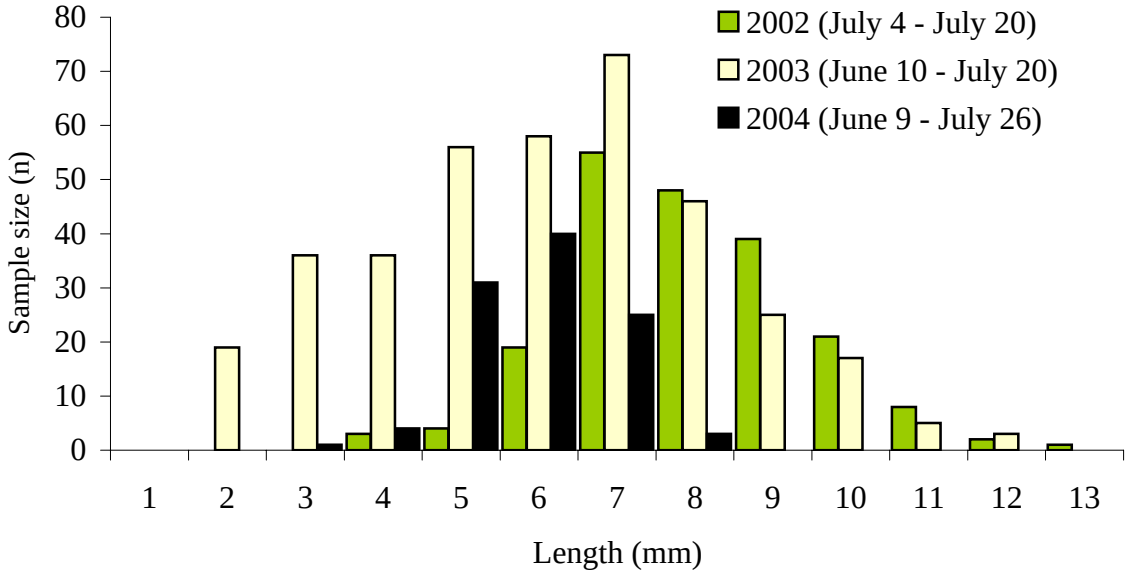

Figure 9. Histogram of chum salmon length frequencies for Safety Sound, 2002 - 2004. 2002 data from Nemeth et al. (2003).

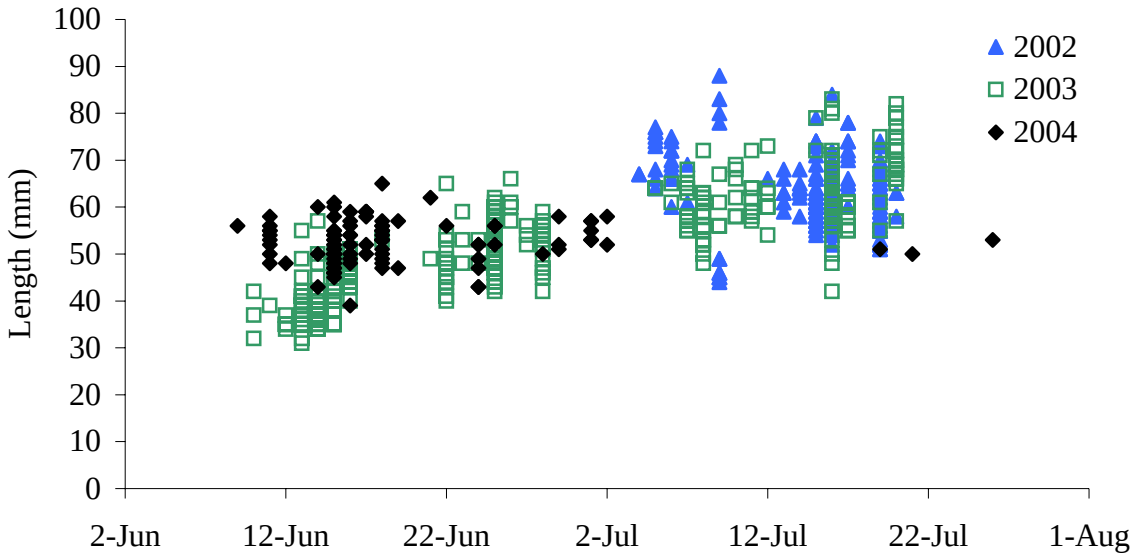

Figure 10. Chum salmon length by date in Safety Sound (2002 - 2004). 2002 data from Nemeth et al. (2003).

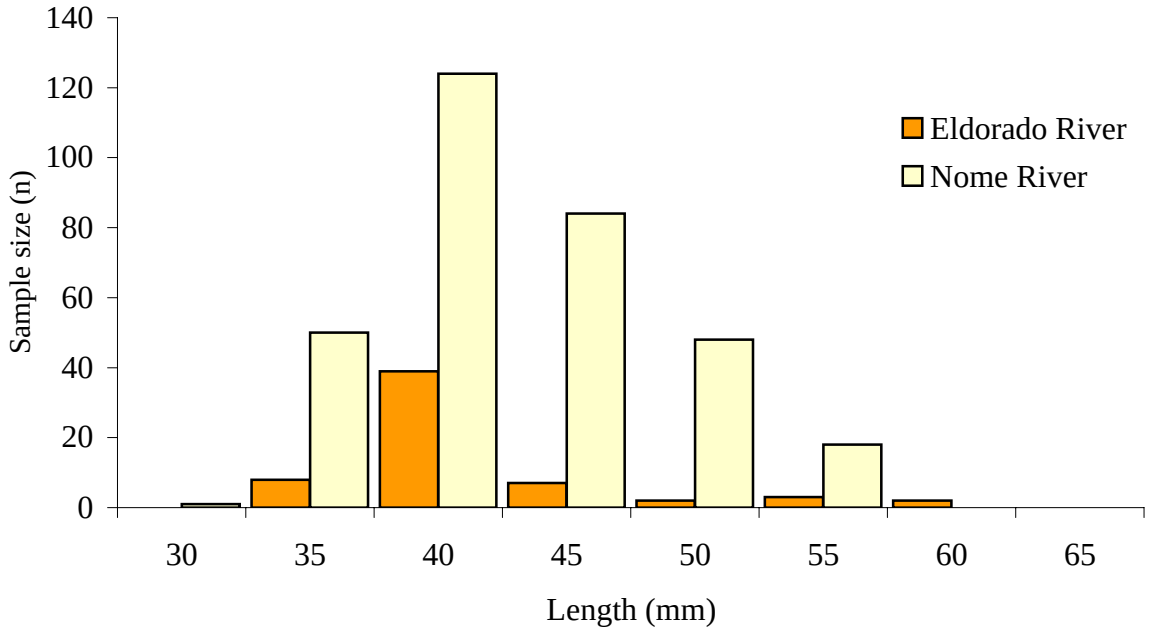

Figure 11. Histogram of chum salmon length frequencies for the Nome and Eldorado rivers, 2004.

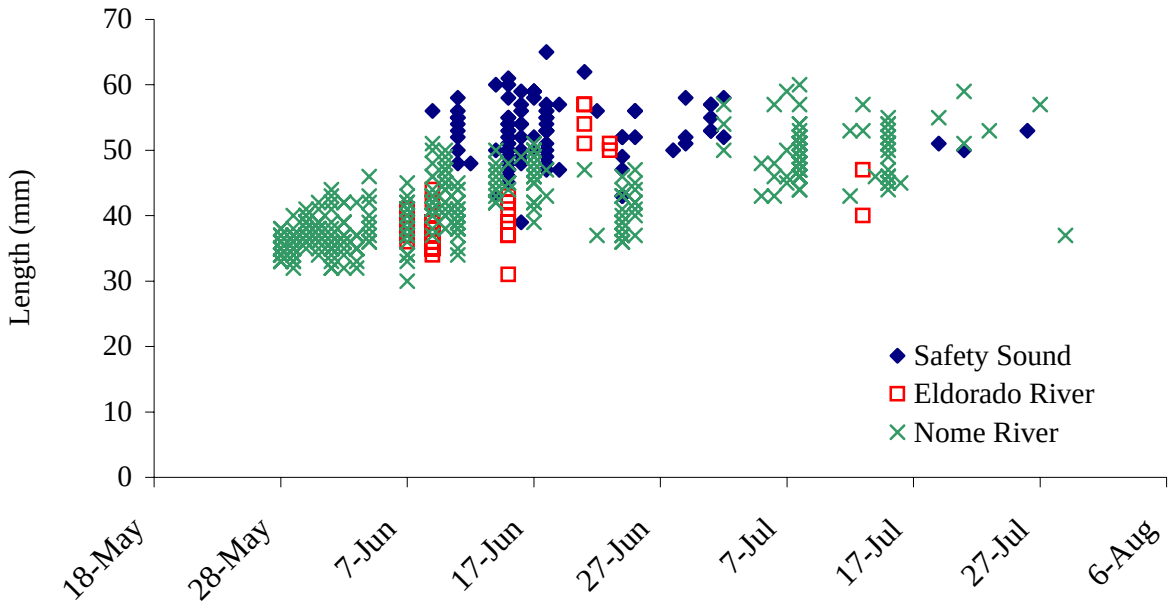

Figure 12. Chum salmon length by date, Safety Sound, Eldorado River, and Nome River, 2004.

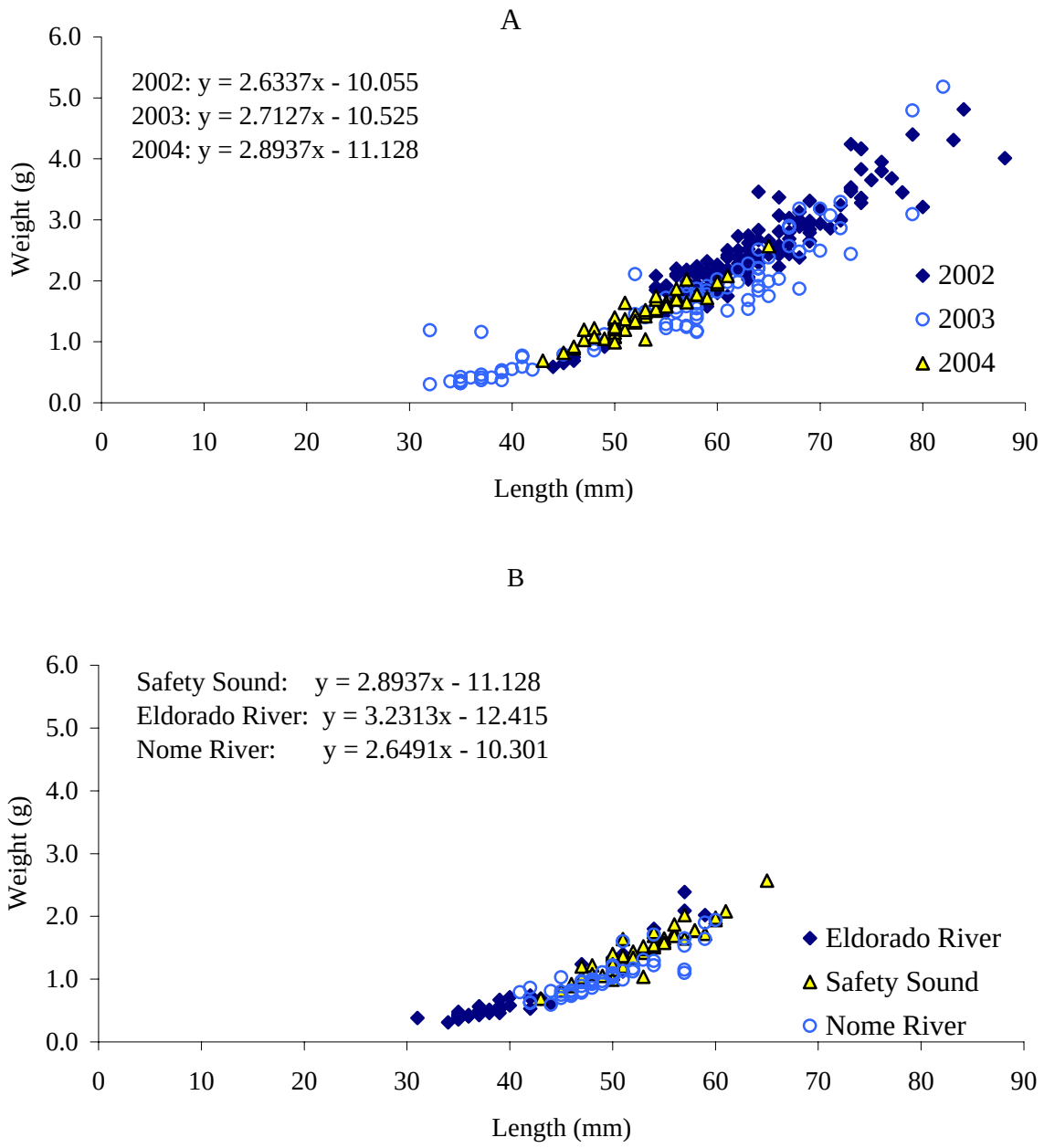

Figure 13. Chum salmon length vs. weight relationships. A-Safety Sound, 2002 - 2004; B-Safety Sound, and the Nome and Eldorado Rivers, 2004. Data points represent raw data, whereas linear regression equations are given for log transformed data. 2002 data from Nemeth et al. (2003).

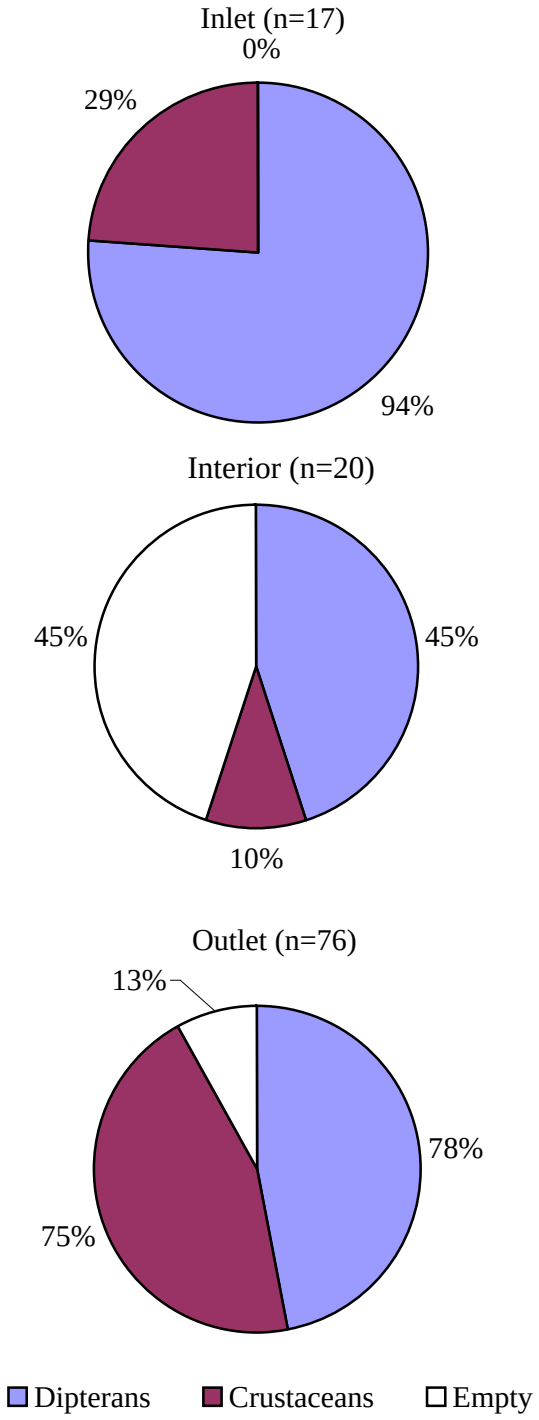

Figure 14. Frequency of occurrence (%FO) of prey in the diet of juvenile chum salmon caught in the inlet, interior, and outlet areas of Safety Sound in 2003. Totals may exceed 100% because some chum fed on more than one prey type.

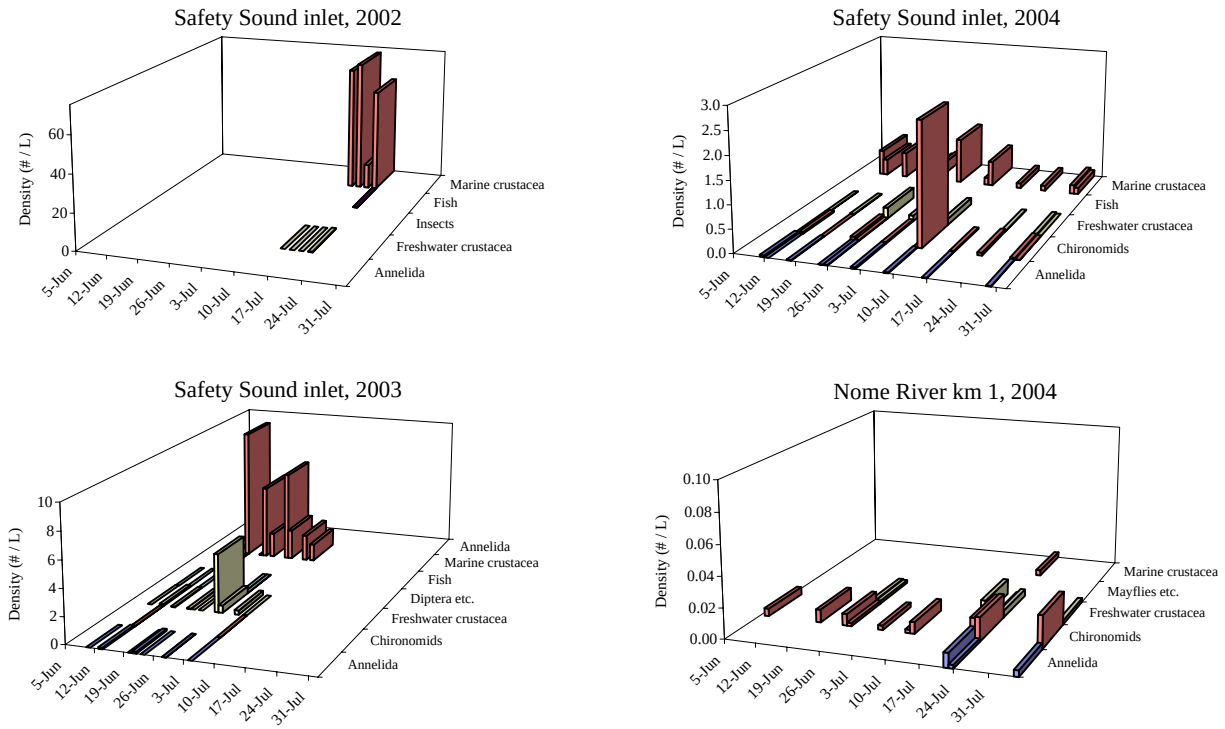

Figure 15a. Density of potential chum salmon prey, sampled with zooplankton nets, at the inlet stations in Safety Sound (2002-2004) and the upper Nome River (2004). 2002 data from Nemeth et al. 2003.

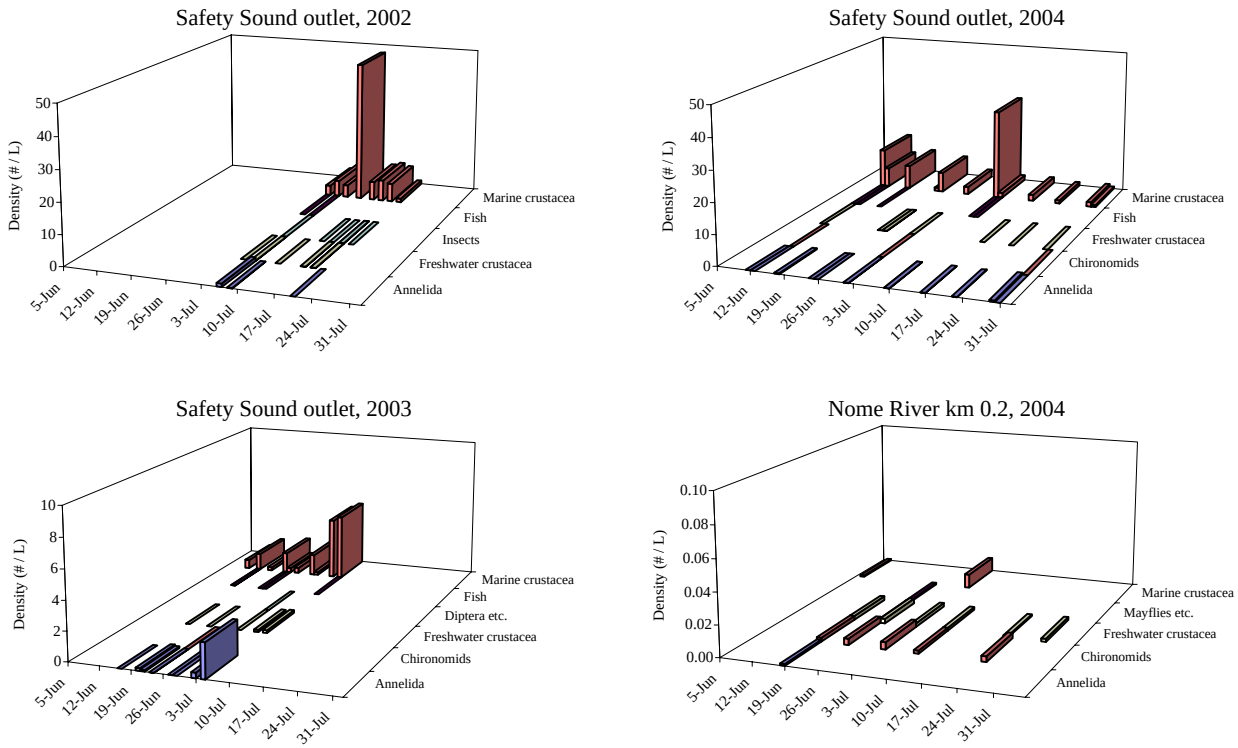

Figure 15b. Density of potential chum salmon prey, sampled with zooplankton nets, at the outlet stations in Safety Sound, 2002-2004 and the lower Nome River, 2004. 2002 data from Nemeth et al. (2003).

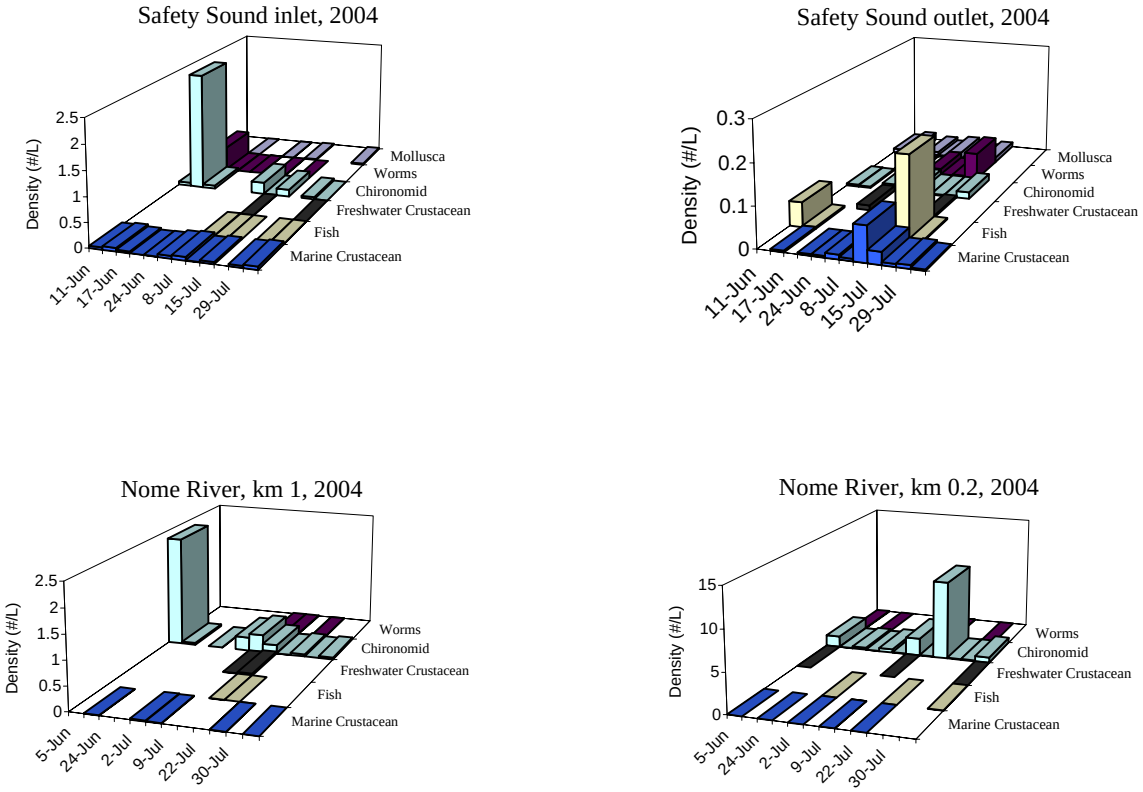

Figure 16. Density of potential chum salmon prey, at the inlet and outlet stations in Safety Sound and the upper and lower Nome River stations, captured in drop net samples in 2004.

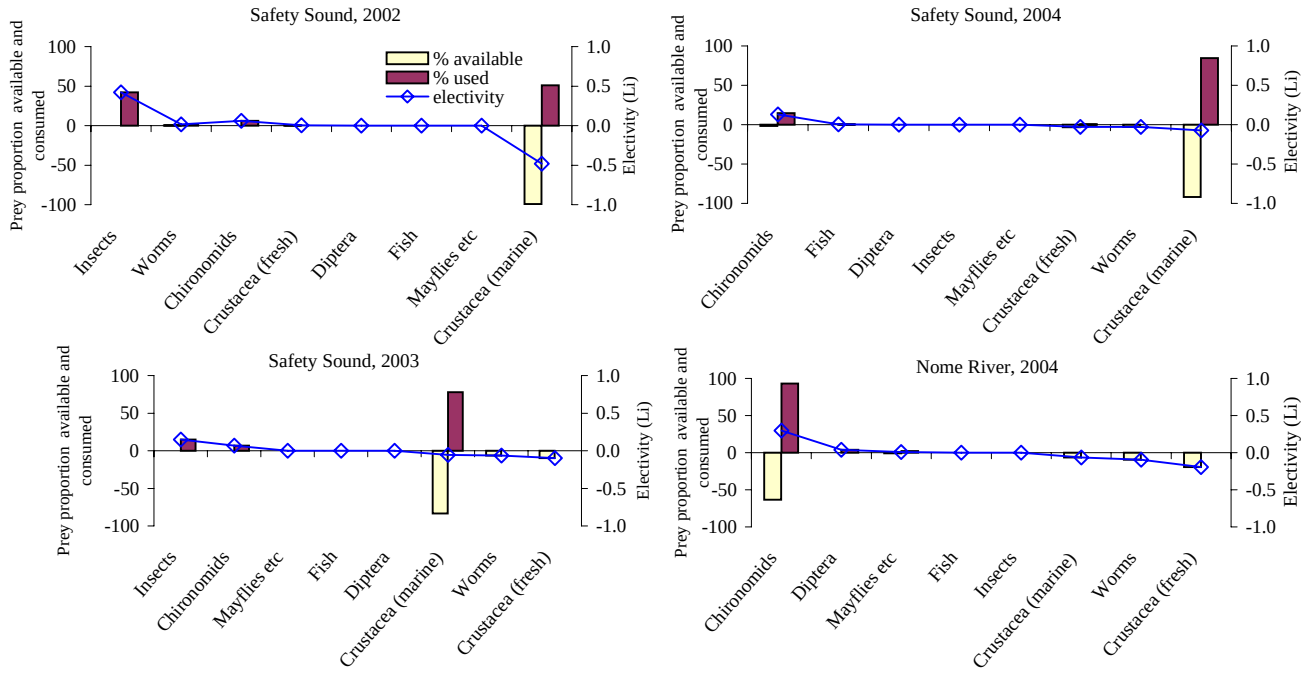

Figure 17. The proportion of prey consumed vs. prey availability, with resulting diet selectivity values in Safety Sound, 2002 - 2004, and the Nome River, 2004. Bars above the x-axis represent the proportion of the prey items represented in the diet, bars below the x-axis are the proportion of prey items available in the environment. A positive selectivity value implies targeted feeding upon that prey item, while a negative value implies a generalized feeding stategy or avoidance of that prey item. 2002 data from Nemeth et al. (2003).

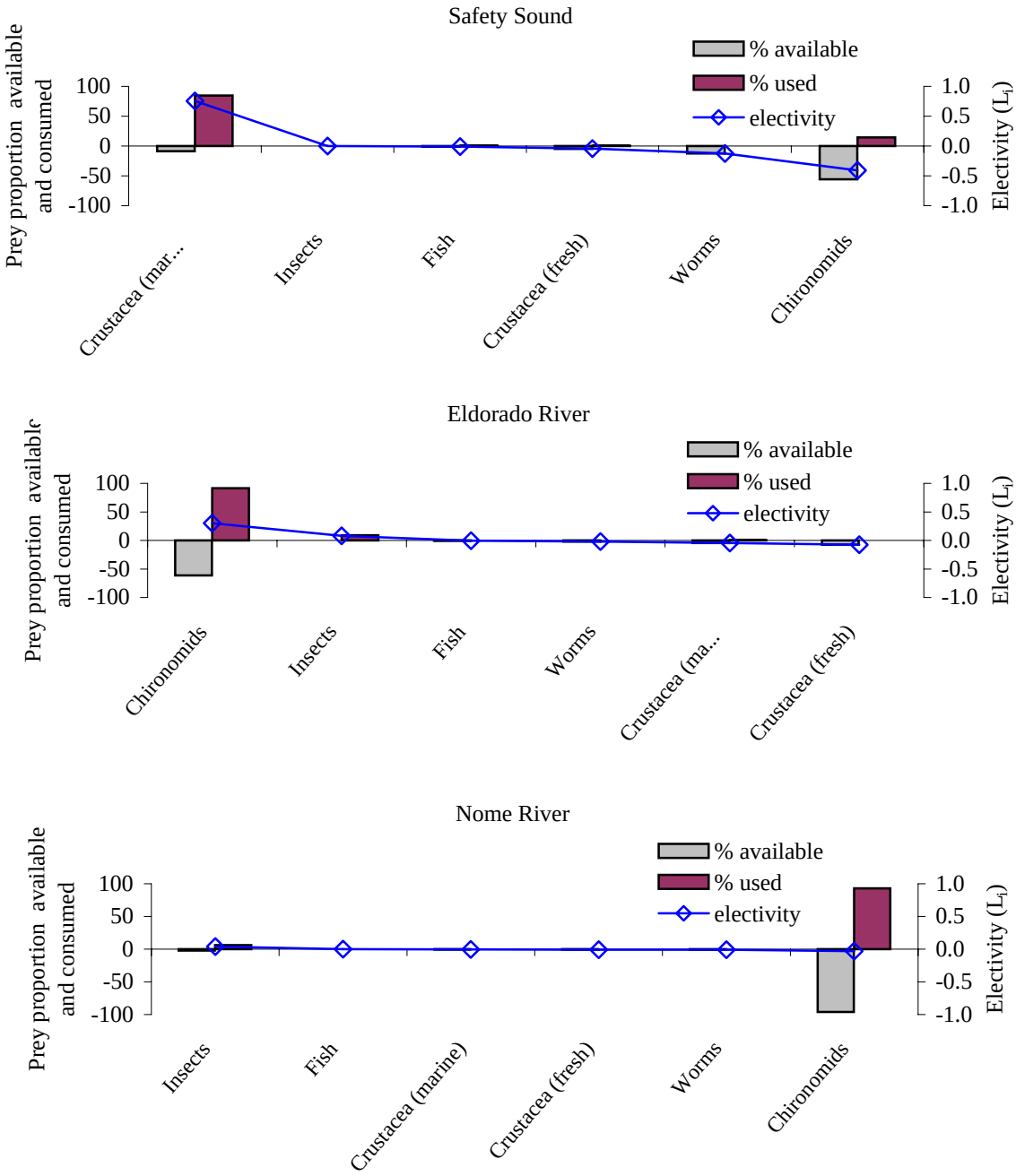

Figure 18. The proportion of prey consumed vs. epi-benthic prey availability, with resulting diet selectivity values in Safety Sound, the Eldorado R., and the Nome River, 2004. Bars above the x-axis represent the proportion of the prey items in the diet, while bars below the x-axis are the proportion of prey items available in the environment. A positive selectivity value implies targeted feeding upon that prey item, a negative value implies a generalized feeding stategy or avoidance of that prey item.

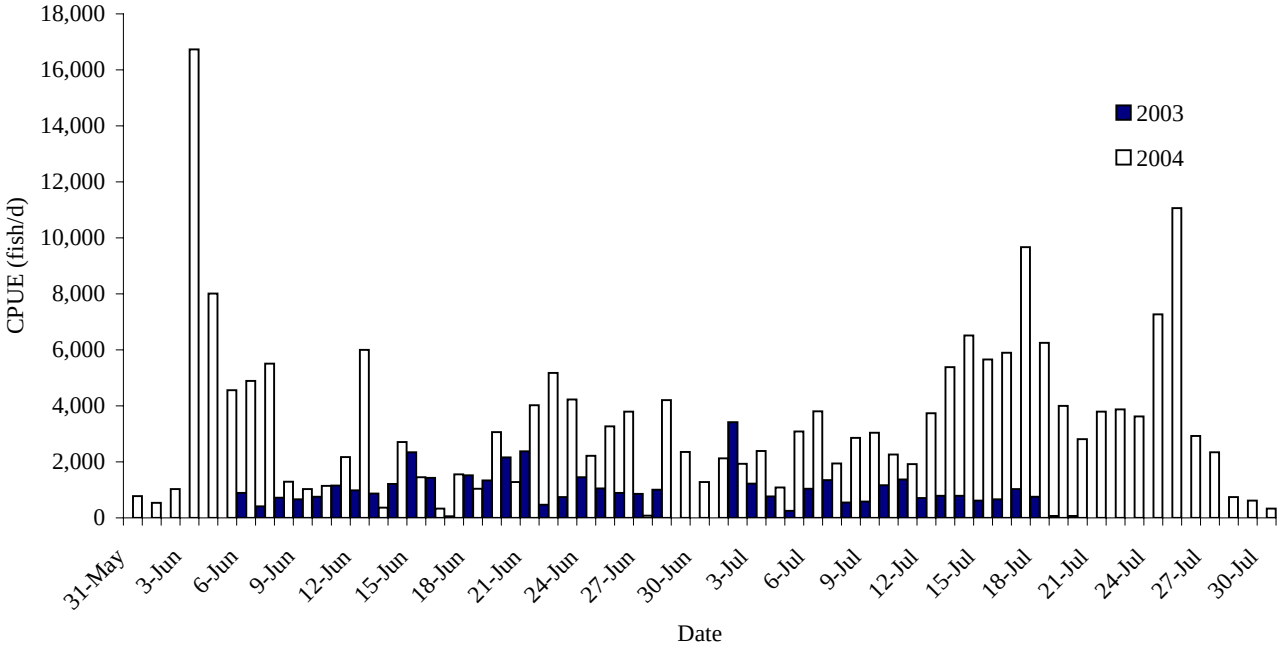

Figure 19. CPUE (fish/d) of all fish by date in Safety Sound, 2003 and 2004.

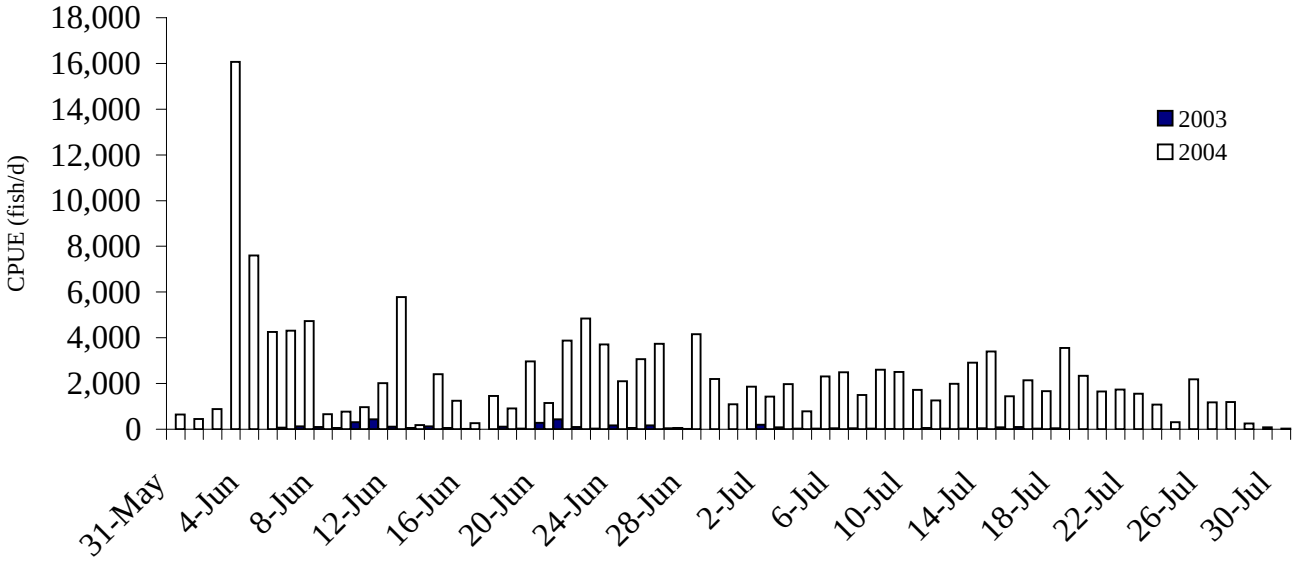

Figure 20. CPUE (fish/d) of threespine stickleback in Safety Sound, 2003 and 2004.

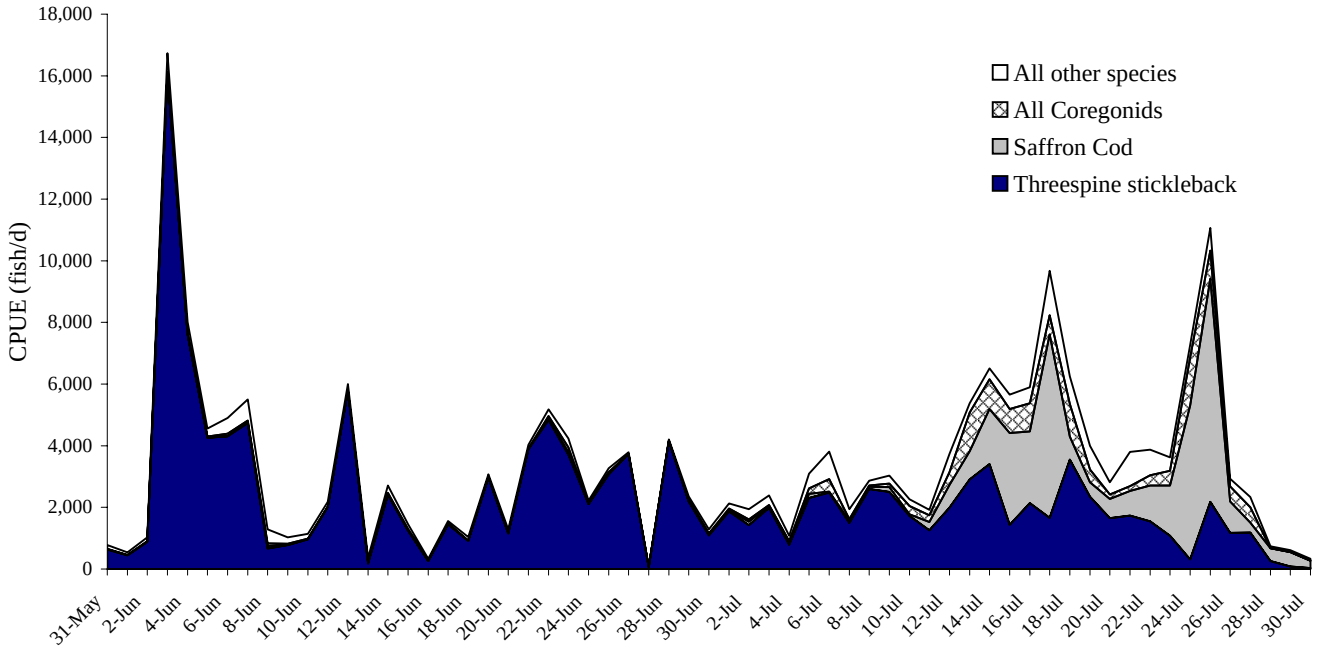

Figure 21. Fish species composition in Safety Sound as a proportion of total CPUE (fish/d) for all sites combined in 2004.

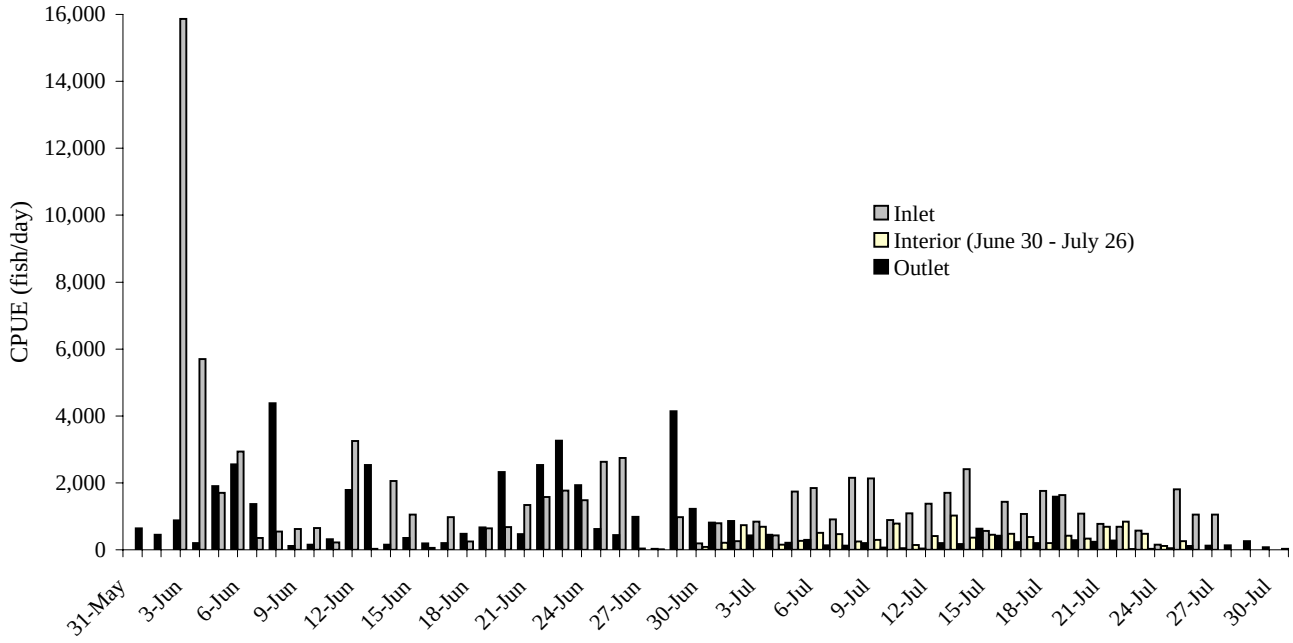

Figure 22. CPUE (fish/d) of threespine stickleback at three sampling locations in Safety Sound, 2004.

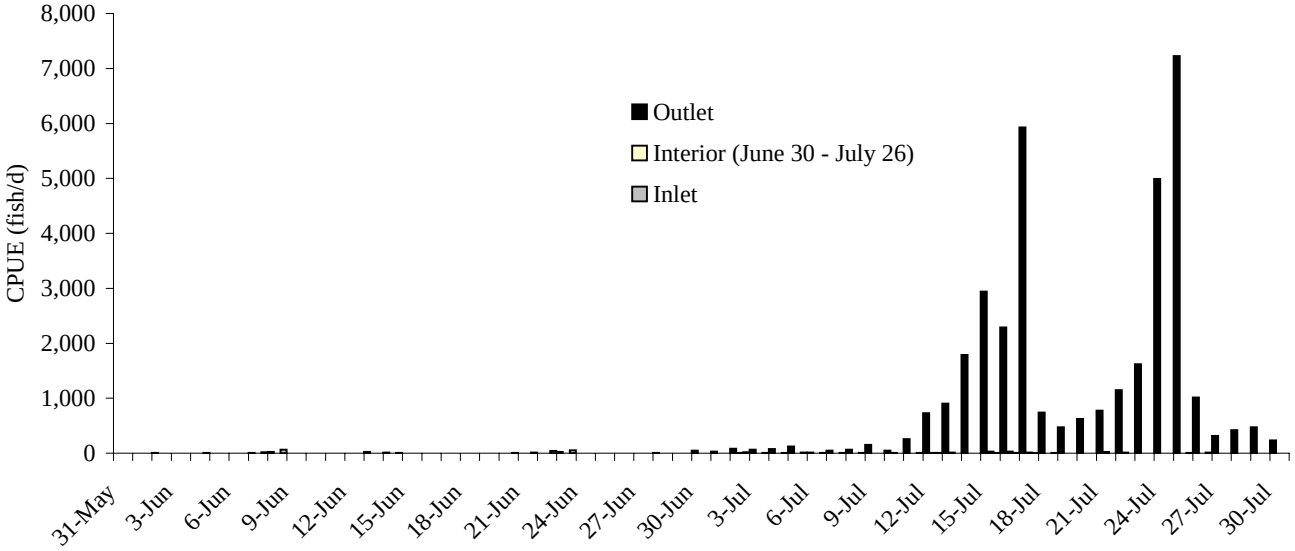

Figure 23. CPUE (fish/d) of saffron cod at three sampling locations in Safety Sound, 2004.

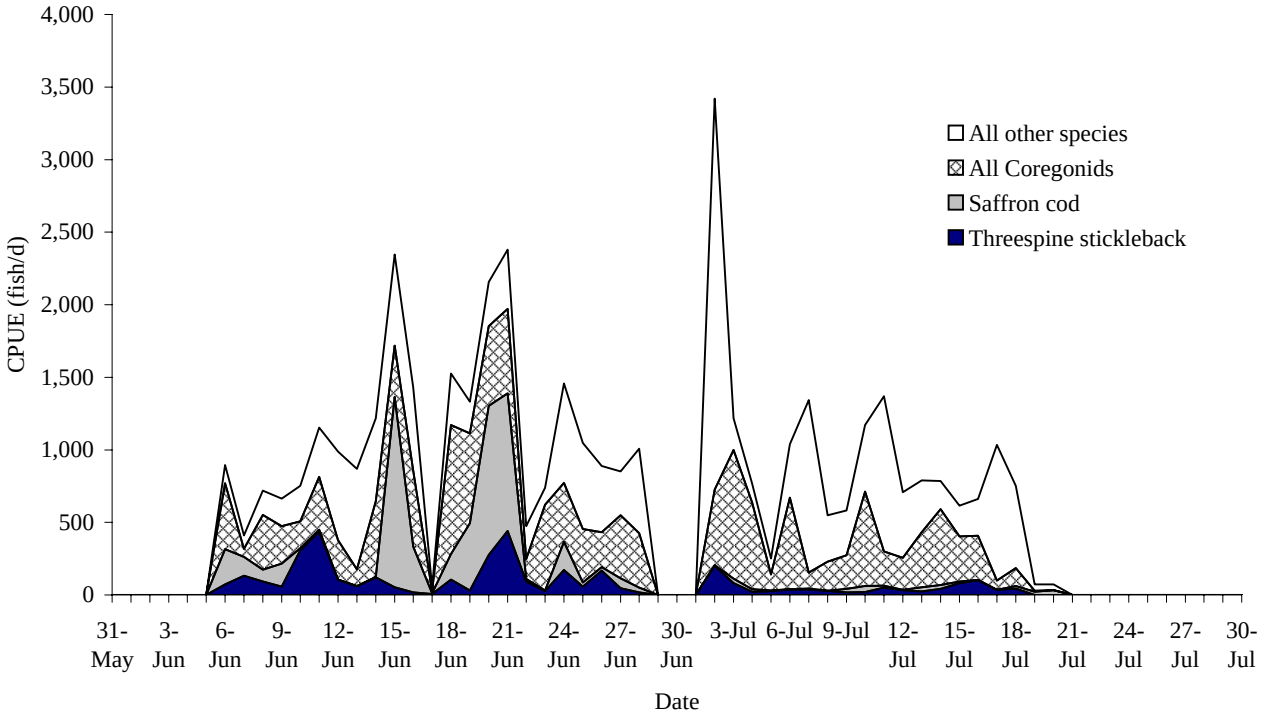

Figure 24. Fish species composition in Safety Sound as a proportion of total CPUE (fish/d) for all sites combined in 2003.

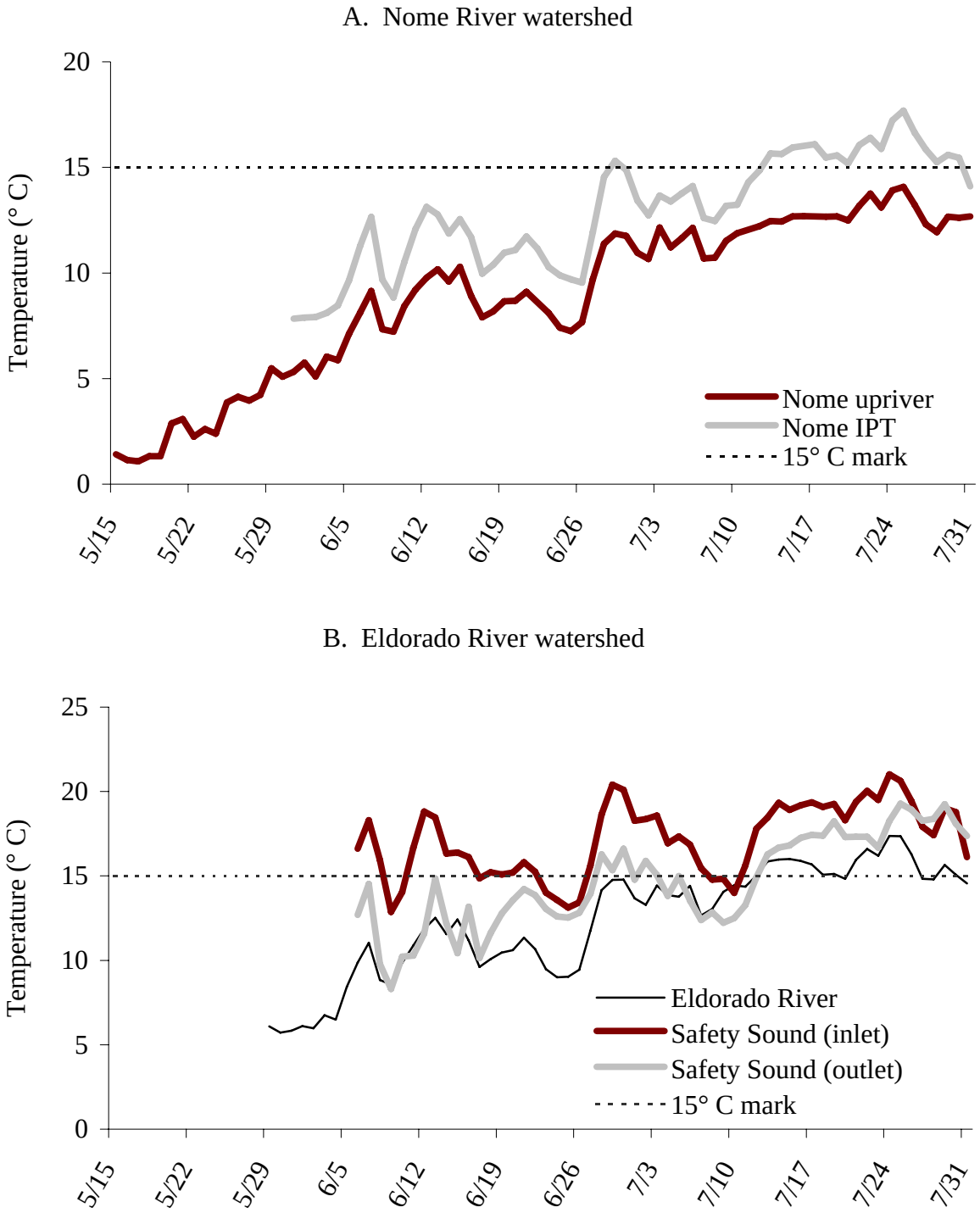

Figure 25. Mean daily temperature from continuous recorders in the (A) Nome River, and (B) Eldorado River watersheds, summer 2004. Dashed line shows 15° C for reference. Data for Nome River (upriver site) and Eldorado River from Kroeker and Dunmall (2005).

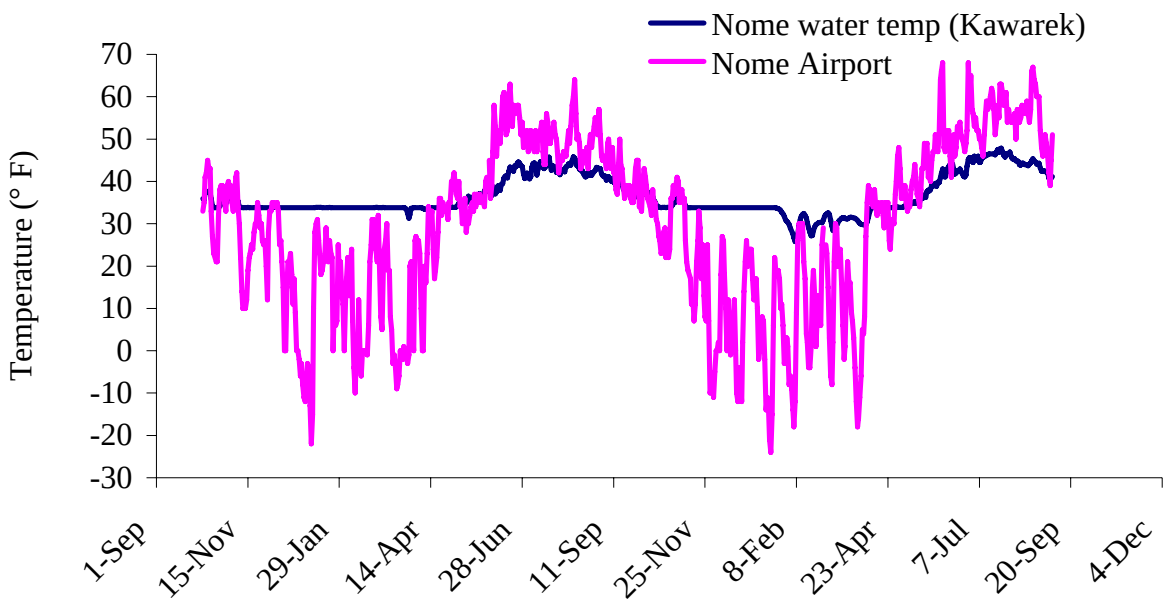

Figure 26. Nome airport mean daily air temperature and Nome River mean daily water temperature patterns, 2003 - 2004. Water temperature data are from Kroeker and Dunmall, (2005).

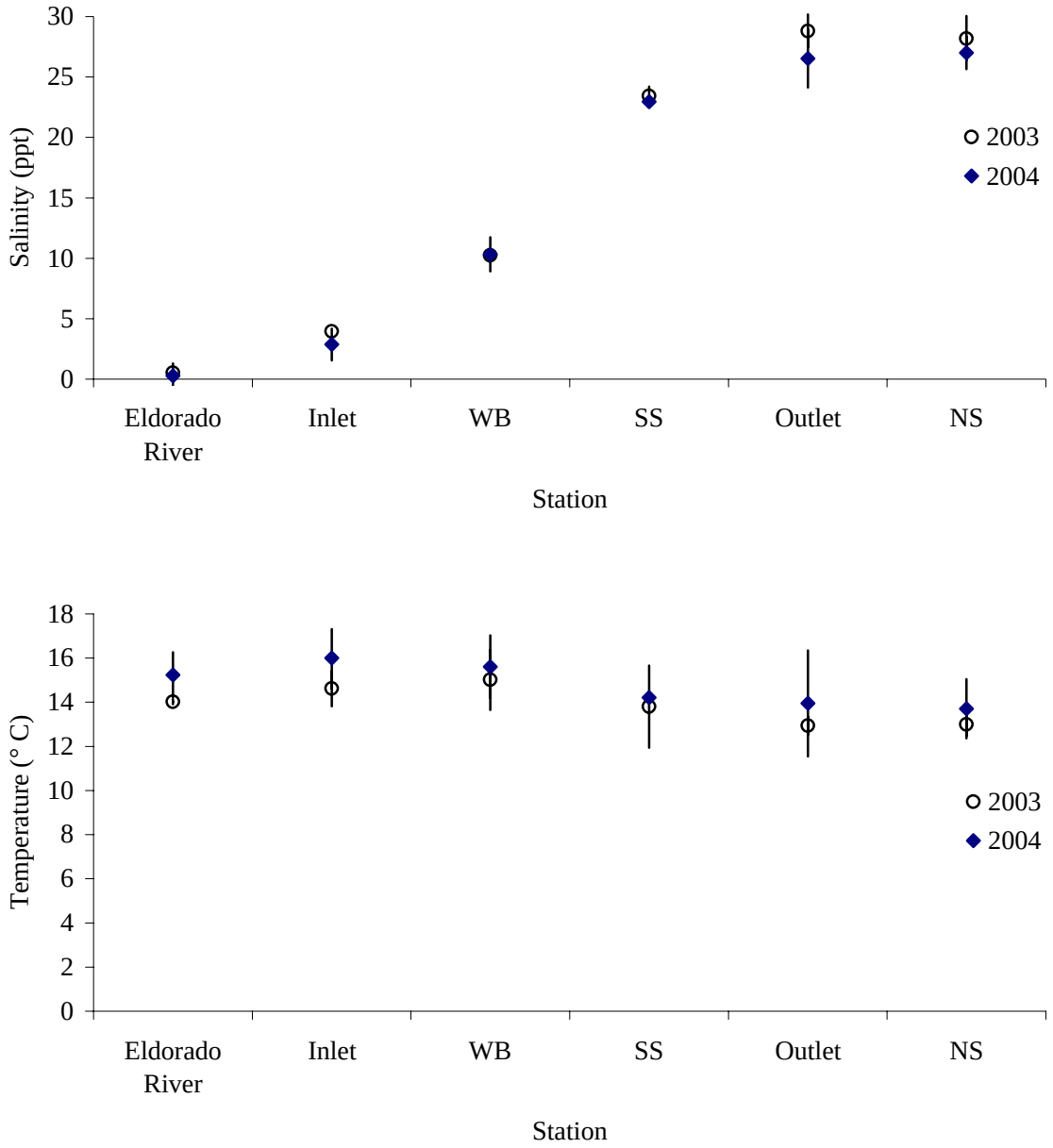

Figure 27. Mean water temperature and salinity throughout Safety Sound, 2003-2004. Sites listed from upstream to downstream. Vertical lines are 1 SE.

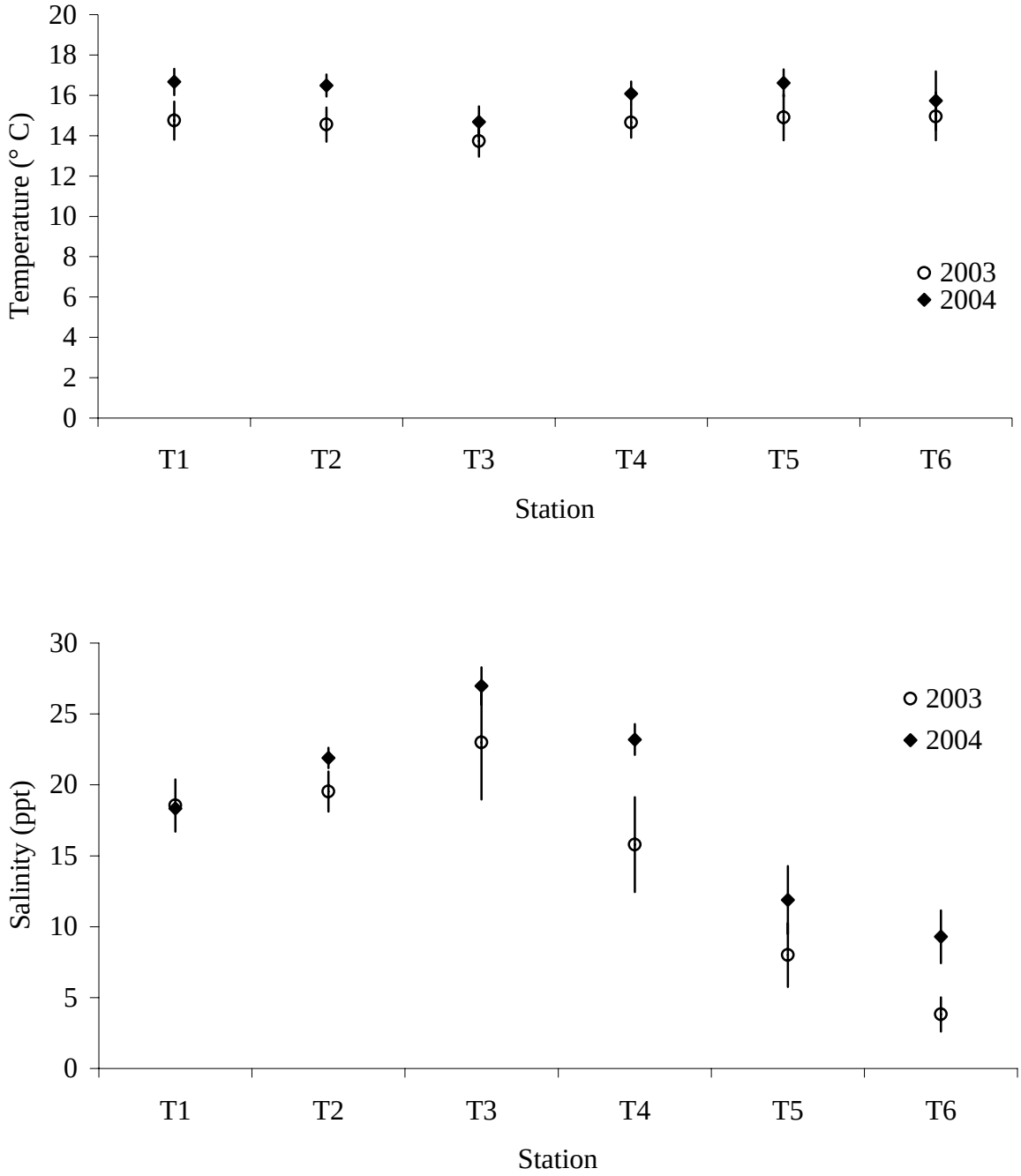

Figure 28. Mean water temperature and salinity across Safety Sound, 2003 and 2004. Stations are listed east to west. Vertical lines are 1 SE.

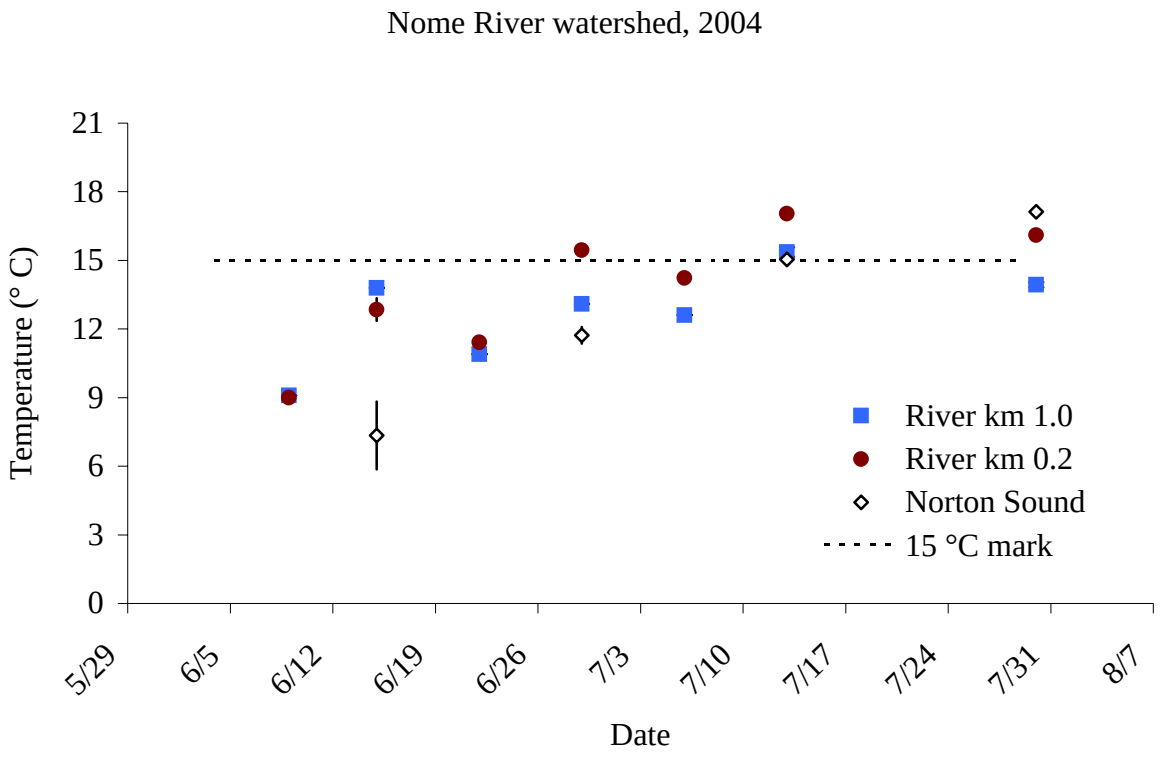

Figure 29. Mean water temperatures by date at select stations in the Nome River, and Norton Sound, 2004. Whiskers are 1 SE. Dashed line in indicates the 15°C temperature mark as a reference point.

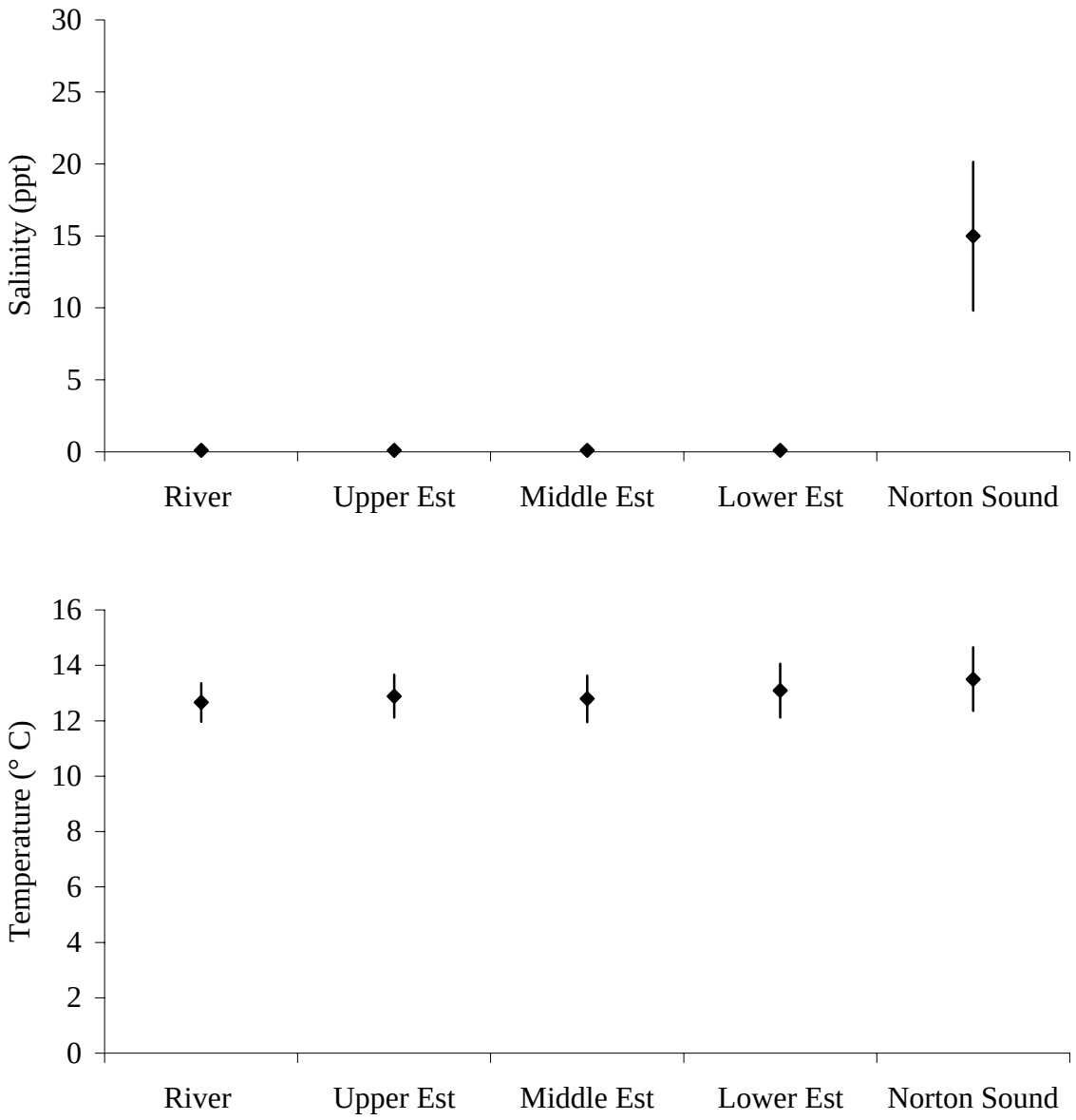

Figure 30. Mean watere temperature and salinity throughout the Nome River, 2004. Sites are listed from upstream to downstream. Vertical lines are 1 SE.

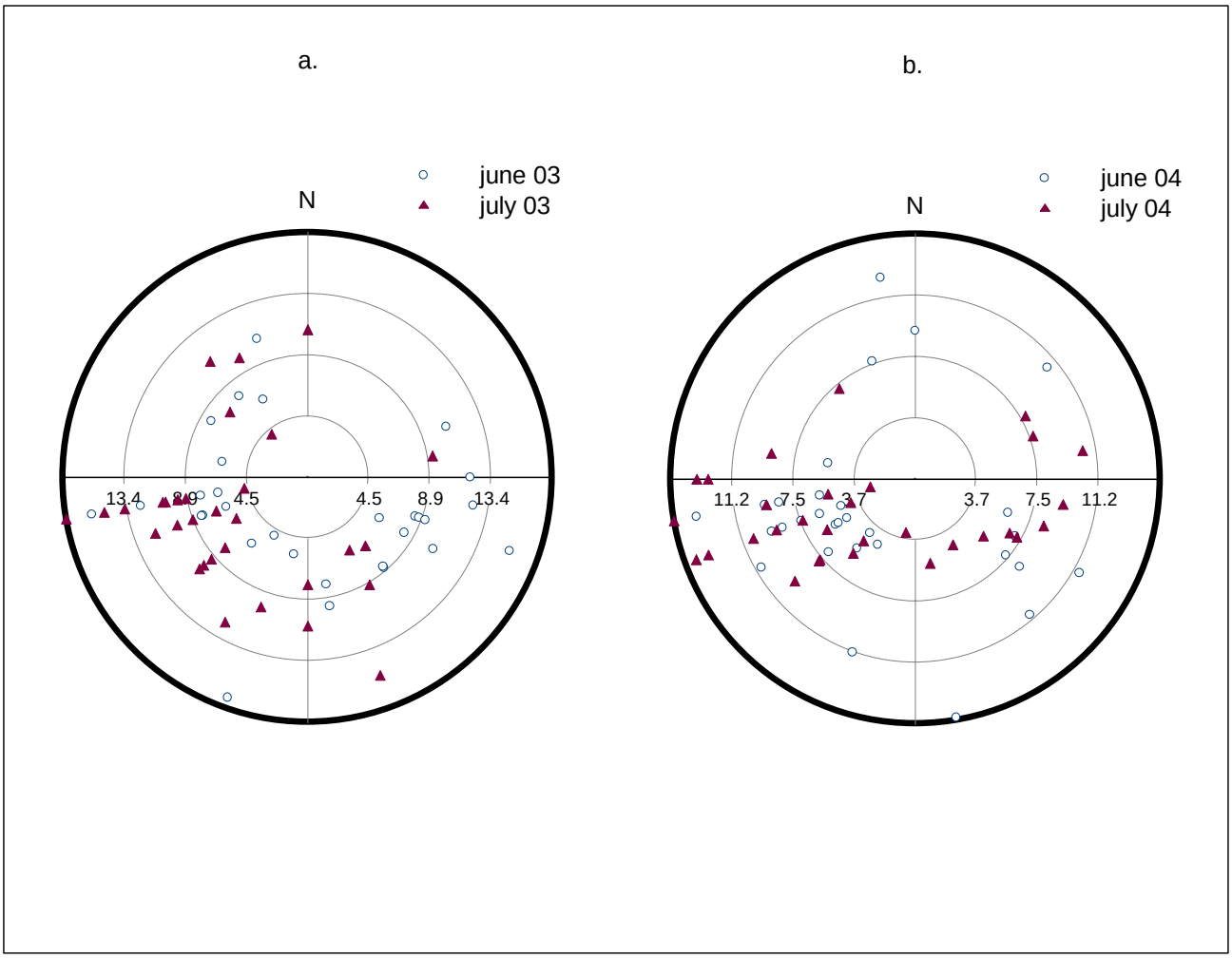

Figure 31. Average daily wind direction and speed (mph) recorded at the Nome airport. (a.) June - July, 2003 (b.) June - July, 2004.

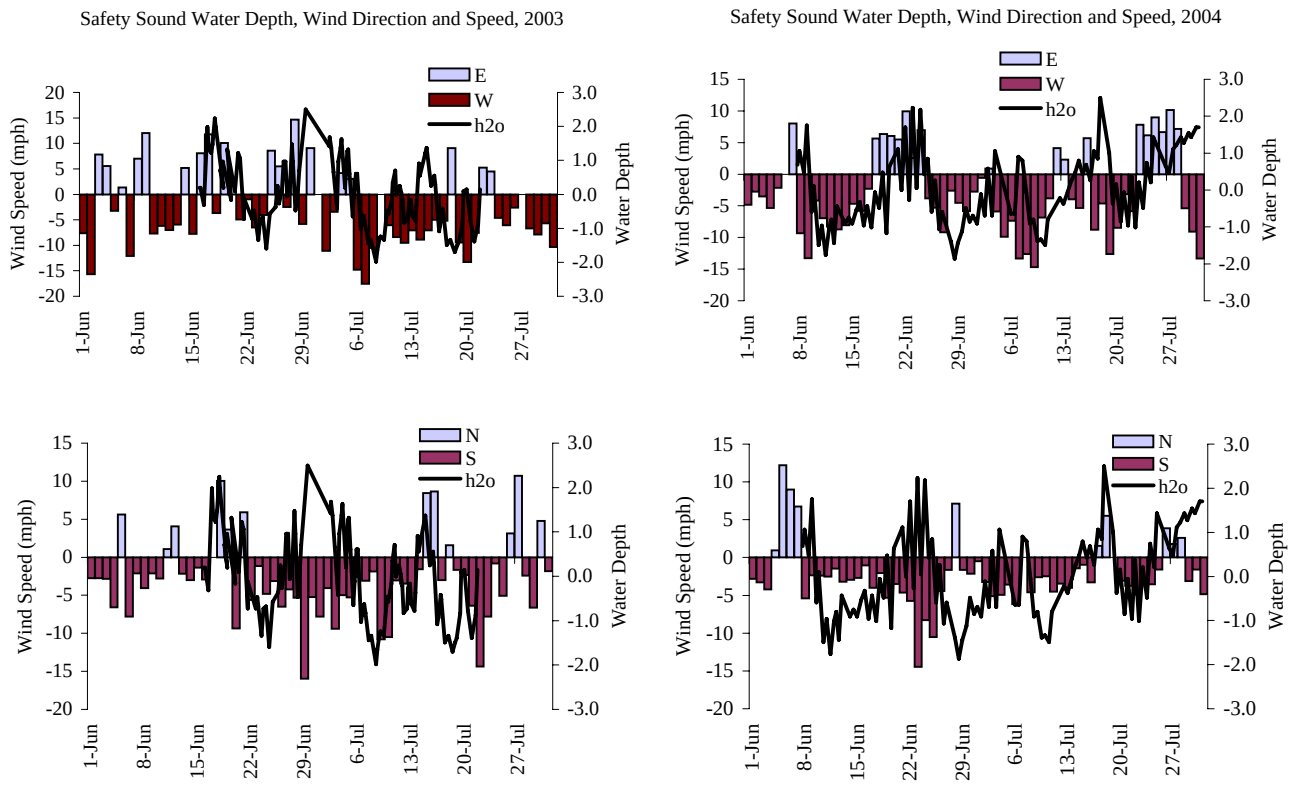

Figure 32. Safety Sound water depth and wind direction and speed recorded at the City of Nome airport in June and July, 2003 and 2004.

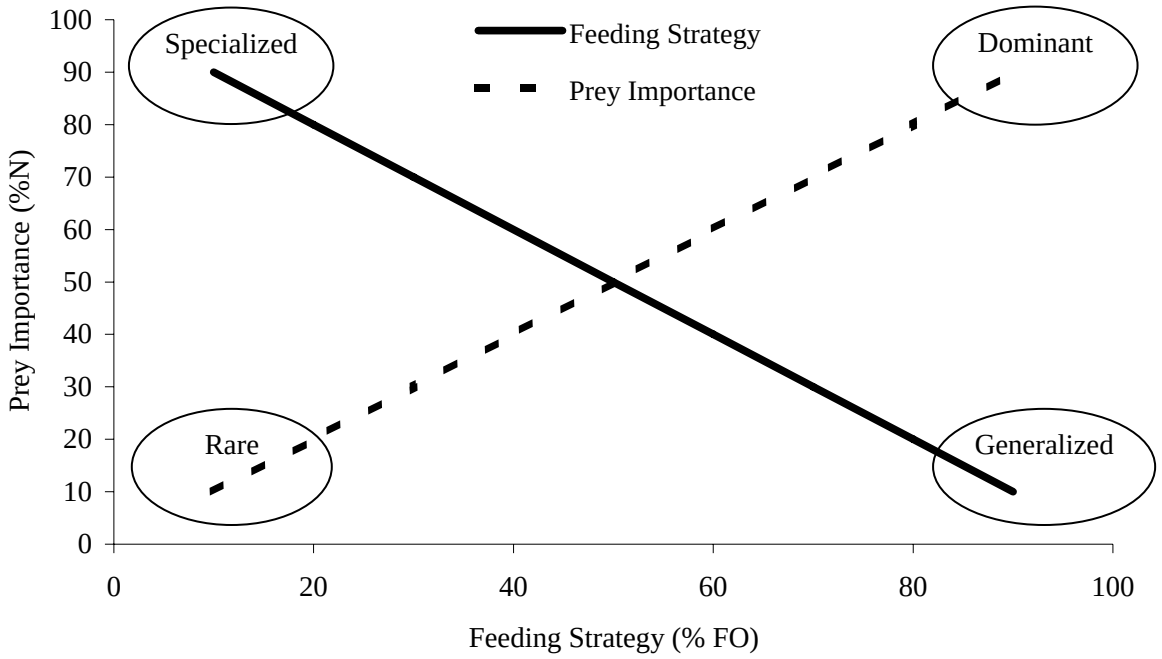

Figure 33. Conceptual diagram of feeding behavior, modeled after Costello (1990). A prey consumed in high quantity (%N, Y-axis) by a small proportion of predators (%FO, X-axis) represents a specialized feeding strategy. Prey consumed in low quanitities by many predators represent a generalized strategy. Total importance of a prey item increases from lower left to upper right of graph.

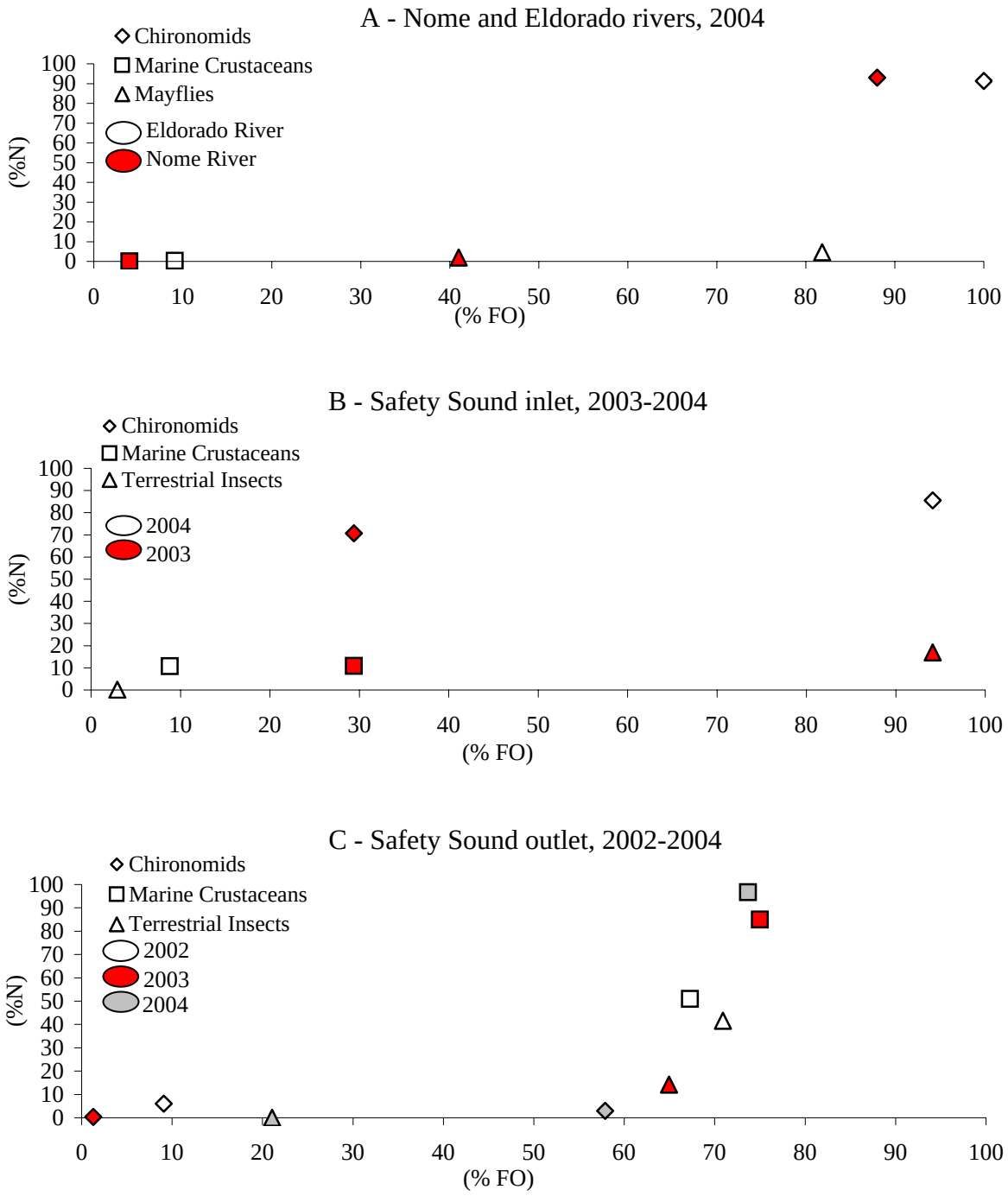

Figure 34. Conceptual diagram showing chum salmon feeding behavior on most important prey items. (A) the Nome and Eldorado rivers, 2004, (B) Safety Sound inlet 2003 - 2004, (C) Safety Sound outet 2002 - 2004.

Appendix A. Juvenile chum salmon catch by date and site in Safety Sound (2003 and 2004) and the Nome River (2004).

	Safety Sound 2003							Safety Sound 2004				
Date	Inlet	Outlet	Interior	Seine	SS3	Total	Date	Inlet	Outlet	Interior	Seine	Total
1-Jun							1-Jun					
2-Jun							2-Jun		14			14
3-Jun							3-Jun					
4-Jun							4-Jun					
5-Jun							5-Jun					
6-Jun							6-Jun					
7-Jun							7-Jun				17	17
8-Jun							8-Jun					
9-Jun							9-Jun	1			81	82
10-Jun	6					6	10-Jun					
11-Jun		2				2	11-Jun	8	1			9
12-Jun		6				6	12-Jun	1				1
13-Jun		100				100	13-Jun					
14-Jun	1	130				131	14-Jun	3				3
15-Jun		21				21	15-Jun	30			10	40
16-Jun	25	2				27	16-Jun	10				10
17-Jun							17-Jun	7				7
18-Jun		1				1	18-Jun	16	2			18
19-Jun							19-Jun	2				2
20-Jun							20-Jun					
21-Jun		1				1	21-Jun	1			4	5
22-Jun	1	14				15	22-Jun	1				1
23-Jun	1	2				3	23-Jun				2	2
24-Jun		2				2	24-Jun	6				6
25-Jun	1		65			66	25-Jun	1	2			3
26-Jun		1	3			4	26-Jun					
27-Jun		1	3			4	27-Jun					
28-Jun		14	1			15	28-Jun		1			1
29-Jun							29-Jun	2	1			3
30-Jun							30-Jun					
1-Jul							1-Jul	4	1			5
2-Jul							2-Jul	1		1		2
3-Jul							3-Jul					
4-Jul							4-Jul					
5-Jul			2			2	5-Jul					
6-Jul	1	1				2	6-Jul					
7-Jul		13				13	7-Jul					

Appendix A continued. Juvenile chum salmon catch by date and site in Safety Sound (2003 and 2004) and the Nome River (2004).

	Safety Sound 2003							Safety Sound 2004				
Date	Inlet	Outlet	Interior	Seine	SS3	Total	Date	Inlet	Outlet	Interior	Seine	Total
8-Jul		17			1	18	8-Jul					
9-Jul		4				4	9-Jul					
10-Jul	6					6	10-Jul					
11-Jul	5				3	8	11-Jul					
12-Jul	4				3	7	12-Jul					
13-Jul							13-Jul				2	2
14-Jul							14-Jul					
15-Jul			2			2	15-Jul					
16-Jul	6	126				132	16-Jul					
17-Jul		56				56	17-Jul					
18-Jul							18-Jul					1
19-Jul		13				13	19-Jul			1		1
20-Jul		37				37	20-Jul					
21-Jul							21-Jul			1		1
22-Jul							22-Jul					
23-Jul							23-Jul					
24-Jul							24-Jul					
25-Jul							25-Jul					
26-Jul							26-Jul	1				1
27-Jul							27-Jul					
28-Jul							28-Jul					
29-Jul							29-Jul					
30-Jul							30-Jul					
31-Jul							31-Jul					
2003 Total	57	564	76	0	7	704	2004 Total	95	22	3	116	237

Appendix A continued. Juvenile chum salmon catch by date and site in Safety Sound (2003 and 2004) and the Nome River (2004).

Nome River 2004

Date	IPT	Upper Fyke	Lower Fyke	Total	Date	IPT	Upper Fyke	Lower Fyke	Total
28-May	26			26	29-Jun		1		1
29-May	40			40	30-Jun				0
30-May	77			77	1-Jul				0
31-May	22			22	2-Jul			3	3
1-Jun	72			72	3-Jul				0
2-Jun	19			19	4-Jul				0
3-Jun	9			9	5-Jul	2		1	3
4-Jun	9			9	6-Jul	2		2	4
5-Jun					7-Jul	2		2	4
6-Jun					8-Jul	8		25	33
7-Jun	22			22	9-Jul				0
8-Jun					10-Jul				0
9-Jun	21			21	11-Jul				0
10-Jun	37		1	38	12-Jul	2			2
11-Jun	36			36	13-Jul			2	2
12-Jun					14-Jul	1			1
13-Jun					15-Jul	20			20
14-Jun	14			14	16-Jul	1			1
15-Jun	4			4	17-Jul				0
16-Jun	1			1	18-Jul				0
17-Jun	60			60	19-Jul	1			1
18-Jun	2			2	20-Jul				0
19-Jun					21-Jul			2	2
20-Jun					22-Jul				0
21-Jun			1	1	23-Jul	1			1
22-Jun	1			1	24-Jul				0
23-Jun					25-Jul				0
24-Jun	13		1	14	26-Jul				0
25-Jun	8			8	27-Jul			1	1
26-Jun					28-Jul				0
27-Jun					29-Jul				0
28-Jun					30-Jul				0
					2004 Total	533	1	41	575

Appendix B. Chum salmon diet index of relative importance (IRI) by site, month, year and gear type for Safety Sound and the Nome River.

	June - fyke nets				July - fyke nets		
Safety Sound 2002	River	Inlet	Rock Pile	Outlet	Inlet	Rock Pile	Outlet
Worms							9
Crustacea (marine)							8351
Crustacea (fresh)							-
Insects							4424
Mayflies etc							-
Diptera							-
Chironomids							100
Fish							-
# of stomachs							56
Safety Sound 2003							
Worms		-	-	-	-		-
Crustacea (marine)		4867	1434	11588	-		16528
Crustacea (fresh)		76	-	3	-		0
Insects		9073	2548	2976	1826		60
Mayflies etc		-	-	-	-		-
Diptera		-	-	-	-		-
Chironomids		948	-	1	3988		-
Fish		0	-	2	-		6
# of stomachs		8	20	51	9		26
Safety Sound 2004							
Worms	-	1	-	-	0	-	0
Crustacea (marine)	9	0	17276	8596	2127	5880	7519
Crustacea (fresh)	-	2	-	0	1139	-	0
Insects	-	2	17	68	0	47	299
Mayflies etc	1877	0	-	-	0	0	0
Diptera	857	2	17	-	179	67	1108
Chironomids	16040	18855	1679	928	9029	3770	2147
Fish	-	32	-	807	0	-	0
# of stomachs	11	28	6	6	6	5	2

Appendix B continued. Chum salmon diet index of relative importance (IRI) by site, month, year and gear type for Safety Sound and the Nome River.

	June		July
Nome River 2004	IPT	Fyke	Fyke
Worms	-	-	-
Crustacea (marine)	1	-	12
Crustacea (fresh)	-	-	-
Insects	993	-	10
Mayflies etc	2451	3823	6
Diptera	7038	6189	1003
Chironomids	2506	9988	13914
Fish	-	-	-
# of stomachs	22	2	27