Freshwater habitat as a predictor of coho salmon smolt production in two Norton Sound rivers: an initial study to support the development of habitat-based escapement goals

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Freshwater habitat as a predictor of coho salmon smolt production in two Norton Sound rivers: an initial study to support the development of habitat-based escapement goals

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by

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Cover photo:
Investigating habitat use by juvenile coho salmon above and below a beaver dam on Buster Creek, Nome River drainage.

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TABLE OF CONTENTS

TABLE OF CONTENTS iii
LIST OF TABLES iv
LIST OF FIGURES iv
LIST OF APENDICES v
EXECUTIVE SUMMARY vi
INTRODUCTION 1
METHODS 3
Study area 3
Estimates of juvenile coho salmon habitat use and habitat quantity 4
Coho biosampling – length and age 5
Juvenile coho salmon production in Osborn Creek, Nome River watershed 5
Model estimates of coho salmon smolt abundance 6
Adult spawners needed to produce the predicted ranges of coho smolt production 6
RESULTS 6
Estimates of juvenile coho salmon habitat use and habitat quantity 6
Coho biosampling – length and age 8
Juvenile coho salmon production in Osborn Creek, Nome River watershed 9
Model estimates of coho salmon smolt abundance 10
Adult spawners needed to produce the predicted ranges of coho smolt production 10
DISCUSSION 11
CONLCUSION AND RECOMMENDATIONS 15
ACKNOWLEDGEMENTS 16
REFERENCES 17

LIST OF TABLES

Table 1 Historical escapement of coho salmon to the Nome and North Rivers, Norton Sound Alaska…….....20

Table 2 Locations and dates of sampling sites on the Nome River, 2003. 21

Table 3 Locations and dates of sampling sites on the North River, 2003.....22

Table 4 Catch per unit effort (minnow traps only) of juvenile coho salmon captured at Nome River sampling sites, 2003 23

Table 5 Catch per unit effort (minnow traps only) of juvenile coho salmon captured at North River sampling sites, 2003.....24

Table 6 Length (mm) at age for juvenile coho salmon captured at Nome and North river sampling stations in 2003.....25

Table 7 Age structure of juvenile coho salmon captured in Osborn Creek area in June and August, 2003.....26

Table 8 Accessible stream length and smolt yield estimates for North and Nome rivers using 3 different models 27

Table 9 Estimate of the required number of coho spawners needed to produce range of smolts predicted by 3 habitat-based production models.....28

Table 10 Comparison of observed adult coho salmon escapements estimated number needed to seed the habitat in the Nome and North river watersheds.....29

Table 11 Age composition of Nome and North River adult salmon, 2001-2003 30

LIST OF FIGURES

Figure 1 Smolt yield as a function of stream length by different geographical groups 31

Figure 2 Location of Nome and North rivers in Norton Sound. 32

Figure 3 Stream order classifications in the Nome River drainage.....33

Figure 4 Stream order classifications in the North River drainage 34

Figure 5 Sampling sites in the Nome River drainage, 2003.....35

Figure 6 Sampling sites in the North River drainage, 2003 36

Figure 7 Ages and locations of juvenile coho salmon in the Nome River drainage, June 2003 37

Figure 8 Ages and locations of juvenile coho salmon in the Nome River drainage, August 2003 38

Figure 9 Ages and locations of juvenile coho salmon in the North River drainage, June 2003 39

Figure 10 Ages and locations of juvenile coho salmon in the North River drainage, August 2003 40

Figure 11 Sizes of juvenile coho salmon by month and habitat type in the Nome and North rivers, 2003 41

Figure 12 Water level and juvenile coho salmon catch at the Osborn Creek fence traps, June 2003. 42

Figure 13 Water temperature and juvenile coho salmon catch at the Osborn Creek fence traps, June 2003. 43

Figure 14 Sizes of juvenile coho salmon by location and gear type in Osborn Creek, June 2003 44

Figure 15 Estimated quantity of coho salmon rearing habitat by sub-basin in the Nome and North river watersheds 45

Figure 16 Estimated quantity of coho salmon rearing habitat by gradient class in the Nome and North river watersheds 46

LIST OF APENDICES

Appendix A Mean annual yield of coho smolts and accessible stream length data from Bocking and Peacock (2004), adapted from Bradford et al. (1997). 47

Appendix B Appendix B. Stream lengths (m) predicted to be accessible to juvenile coho salmon in the North and Nome rivers, stratified by gradient and stream order...49

EXECUTIVE SUMMARY

This report describes work done through 2003 to assess the potential for habitat-based models of coho salmon smolt production in the Norton Sound region of Alaska. One purpose of smolt production models is to estimate the number of adult spawners needed to produce these smolts. In 2003, freshwater rearing habitat suitable for juvenile coho salmon was estimated from topographic maps for the Nome and North rivers. The rivers were then sampled (electrofishing and/or minnow trapping) to ground-truth assumptions of juvenile coho distribution, habitat use, and age structure. A revised estimate of freshwater rearing habitat was then generated for each river and classified by stream order and gradient class. Also in 2003, an intensive sampling program was carried out on Osborn Creek, a tributary to the Nome River, to investigate long-term potential for a field study to measure juvenile coho production.

Major findings in 2003 were that 1) Distribution of juvenile coho salmon was consistent with predictions from the literature, 2) The total lineal km of rearing habitat in each watershed was estimated at 277 km on the North River and 83 km on the Nome River, and 3) Coho fry appeared to swim up from the gravel in late June, grew little between September and June, appeared to temporarily move into tributaries within two months of hatching, and differed in size among stream reach types and habitats.

Smolt production was then modeled based on rearing habitat and relationships between habitat quantity and smolt production observed in other studies outside the region. Three models of coho smolt production were then used to illustrate future steps needed to generate estimates of adult coho spawner abundance. Models derived from average and median smolt production per km of stream for British Columbia and Southeast Alaskan streams yielded spawner abundance estimates within the range of adult escapements seen in both the Nome and North rivers. Although there is an extensive body of work relating coho production to habitat, all of this work has been outside the Norton Sound region. The next step for this study should be to collect smolt production data from Norton Sound streams to determine regional associations between habitat and smolt production.

Results to date have implications for estimates of total production of coho salmon smolts in Norton Sound watersheds; the development of escapement goals for adult coho; improved understanding of the freshwater life history of coho in the region; and habitat assessment, conservation, and prioritization of recovery efforts for Norton Sound coho salmon.

INTRODUCTION

This report describes the study of juvenile coho salmon habitat use in two tributaries to Norton Sound, Alaska, in 2003. The study was conducted as the preliminary part of a proposed four-year project assessing the potential for habitat-based escapement goals for coho salmon in Norton Sound. The first step in the development of these goals is to estimate the amount of habitat available at critical life stages. In 2003, we used literature data, remote mapping, and field surveys to estimate the total amount of rearing habitat – based on gradient, stream order, and lineal stream length – used by juvenile coho in the Nome and North rivers. To demonstrate how this information can be used in habitat-based escapement goals, we then combined the habitat data with literature estimates of smolt production, egg deposition and coho survival data to estimate the number of adult coho needed to seed the spawning habitat. The specific objectives in 2003 were to:

1. Estimate the quantity of rearing habitat accessible to juvenile coho salmon in the Nome and North river drainages from digital topographic maps;
2. Conduct field surveys to ground-truth assumptions about juvenile coho habitat use and to collect detailed information on juvenile coho salmon age structure and seasonal distribution;
3. Estimate a range of predicted smolt abundances on the Nome and North Rivers based on habitat quantity and coho distribution (Objectives 1 and 2, above) and reported relationships between habitat and smolt abundance (Bradford et al. 1997);
4. Use a range of data from the literature to model the number of spawners needed to produce the predicted range of smolt abundance.

Escapement goals are developed to help manage salmon according to the sustained yield principle mandated by the State of Alaska (ADF&G 2001). Escapement goals are management targets that represent a balance between long-term sustainability of salmon populations and harvest by humans. One of the challenges in developing escapement goals is thus to determine how many adult salmon spawners are needed to produce future generations. Intuitively, this number must be related to the ability of the ecosystem to support salmon. The need to incorporate ecosystem factors into escapement goals or harvest management has thus recently received increased attention (e.g., Bradford et al. 1997; Nickelson 1998; Bradford et al. 2000; Knudsen 2000), and is a fundamental part of the concept of habitat-based escapement goals.

Incorporation of freshwater habitat into escapement goals holds promise for coho salmon in particular because of coho life history and the consistent relationship between freshwater habitat and coho abundance across different geographic regions. The proportion of freshwater to saltwater time is much greater for coho than for other salmon species, and the freshwater environment thus has a relatively large opportunity to influence eventual adult coho abundance. Coho salmon may spend up to three years (winters) in freshwater, but typically spend only 18 months in saltwater before returning to freshwater to spawn (Sandercock 1991). Coho marine survival is high relative to other salmon species due to the large size at which coho enter the ocean and the short amount of time they spend there (Bradford 1995). Empirical data indicate that coho smolt production is poorly correlated with parent spawner abundance, and is instead most likely a function of freshwater rearing habitat quantity and quality (Bradford et al. 1997).

As a result, freshwater environmental factors that influence juvenile coho abundance and condition can be expected to have a relatively large influence on eventual adult coho abundance.

Juvenile coho salmon production – defined here as the number of smolts migrating to saltwater – appears closely linked to a few landscape-level variables. Numerous studies have detected correlations between juvenile coho production and freshwater habitat features such as stream length (Marshall and Britton 1990; Bradford et al. 1997), valley slope and stream gradient (Sharma and Hilborn 2001), and stream area (Holtby et al. 1990). In one of the more extensive studies of juvenile coho and freshwater habitat, Bradford et al. (1997) reviewed data from 484 annual estimates of coho smolt abundance (covering 86 streams) and found stream length to be a useful predictor of smolt production at a regional level. Collectively, these studies demonstrate that the correlation between freshwater habitat features and coho smolt abundance is consistent at different scales and across geographic regions (Figure 1).

The linkage between large-scale habitat features and coho smolt production indicates that quantification of basic habitat features may be an effective way to estimate smolt production within a watershed. After accounting for unusable stream reaches (e.g., due to migration barriers), coho smolt production should correlate with features such as stream length or area. Many habitat features can be estimated from maps and photos, making it a cost-effective way to generate smolt abundance estimates over a large geographic area. In large watersheds, smolt production could be estimated by combining habitat measurements of the entire watershed with estimates of smolt or pre-smolt abundance in representative study reaches.

If average smolt production in a watershed can be estimated, then the number of adults needed to produce the smolts can be taken as a starting point for determining the number of adult coho needed to seed the spawning grounds. Burns (1971) defined carrying capacity as the average production over the long term, around which production may fluctuate annually. Shaul et al. (2003) suggested that the mean annual coho salmon smolt production (excluding low escapement years) was the best estimator of a watershed's smolt production capability, and that this production capability could be used to estimate the number of adult coho needed to seed the spawning grounds. Generating adult spawner estimates from smolt abundance estimates requires testable assumptions about egg deposition and survival from egg to smolt. These assumptions must be taken from values reported in the literature until local empirical data are generated.

An evaluation of the number of adult coho spawners needed to seed the habitat is a timely one in Norton Sound, a high-latitude region of Alaska that is near the northern edge of coho salmon distribution. Funding has been made available for the research and restoration of regional salmon stocks, and the Steering Committee that directs these funds has identified the need to improve escapement estimates and the overall knowledge of coho salmon life history in Norton Sound (NSRRP 2002). Stock-recruit analyses are currently used to set escapement goals, but analyses for most systems are constrained by insufficient data for all regional salmon stocks (Clark 2001). Adult coho escapement is difficult to estimate because coho return late in the year when counting conditions are poor, and because coho typically return in low numbers to a large number of streams. Developing escapement goals on all Norton Sound rivers using spawner-recruit models would require either quantifying adult coho returns on each stream for many years (an impossible or prohibitively expensive task), or making inferences for many streams based on

returns to a few. Such inferences would not include habitat factors, a notable omission given the demonstrated role of habitat in coho production. In contrast, estimating juvenile salmon production based on stream habitat features would be relatively inexpensive and would yield estimates of spawner seeding levels that accounts for differences in habitat among streams.

Several steps are needed to estimate the number of adult coho spawners needed to seed Norton Sound spawning grounds. First, juvenile coho distribution and habitat use should be predicted from other studies, then ground-truthed with field surveys. Second, the total amount of juvenile coho rearing habitat in the watershed should be predicted from maps of large-scale habitat features, using methods such as those of Bradford et al (1997). Third, coho abundance per habitat unit should be measured, then multiplied by the habitat quantity to predict a range of juvenile coho salmon (smolts or pre-smolts) produced in Norton Sound streams. Fourth, literature estimates of egg deposition and juvenile coho survival can be applied to estimate the number of adult spawners needed to produce the number of smolts predicted by the habitat models (e.g., Nickelson and Lawson 1998). Fifth, studies of juvenile coho production, survival, and habitat use need to be developed within Norton Sound to replace literature values with regional, empirical data. These steps are best taken under a directed, hypothesis-driven research program such as the NSRRP, which is dedicated to assisting salmon management by addressing critical research gaps (NSRRP 2002).

Our work to date goes through the collection of empirical distribution data and subsequent estimation of total available rearing habitat (Step 2). Our future work on this project will be to measure juvenile coho production per habitat unit to estimate total smolt production (Step 3), and then use this estimate to model the number of adults needed to seed the habitat (Step 4). Although we have not yet undertaken Step 3, (measuring juvenile coho production per habitat unit), we model adult coho spawners in this report to illustrate how the data will ultimately be applied. To do this, we have imported a range of production data (coho smolts per km of habitat) from the literature. The resulting range of adults spawner estimates should be interpreted cautiously until empirical data can be collected from within Norton Sound.

METHODS

Study area

The 2003 study was conducted on the Nome and North rivers, in northwestern Alaska. The Nome River empties directly into Norton Sound 5 km east of the town of Nome. The North River empties into the Unalakleet River approximately 8 km upstream from where the Unalakleet River empties into Norton Sound at the town of Unalakleet (Figure 2). Both rivers have an annual high water event in June from snowmelt and again in August or September from rainfall. Ice thaws earlier and forms later on the North River compared to the Nome River; ice-out time in 2003 was mid-May in the North River and late May in the Nome River.

The Nome River is a 4th order watershed (at 1:63,360 scale) approximately 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 has three 3rd-order sub-basins. The largest of these is Osborn Creek, which joins the Nome River 13.5 km upstream from Norton Sound (Figure 5).

The Alaska Department of Fish and game (ADF&G) has operated a weir on the Nome River since 1996. The weir project was originally developed to count chum salmon and thus not operated late enough in the season to count the entire coho run. From 1996 through 2000, the weir operated for a portion of the coho run (median date of August 25), and counts ranged from 66 to 696 fish (mean = 319). From 2001 through 2003, the weir operated until at least Sept 10, and counts ranged from 548 to 3418, with a mean of 2,128 (Kohler 2003; Table 1). The count of 548 fish came in 2003, when coho returns to the Nome subdistrict were classified as "very poor" (Menard 2003), and counts at the Nome River weir were an order of magnitude less than in 2001 and 2002 (Table 1). The years 2001 and 2002 were thus taken as the most reliable estimates of Nome River coho escapement because the weir ran late into the coho run, and the run itself did not seem atypical based on local knowledge and experience. The mean coho salmon escapement in 2001 and 2002 was 2,918 fish.

The North River is a 5th-order tributary that empties into the Unalakleet River near the town of Unalakleet, Alaska (Figure 6). The North River has two 4th order sub-basins and ten 3rd order sub-basins. The largest tributary is the Little North River, which enters the mainstem North River approximately 6.5 km upstream from the confluence of the North and Unalakleet rivers (Figure 6). A counting tower has been operated at (approximately) river km 5 on the North River since 1996. As with the Nome weir, the North River tower operation has operated for varying lengths each year. In the three years (1997, 1999, 2002) when the tower was operated until late August, adult counts ranged from 3,210 to 5,746 (Mean = 4,590). The tower operated longer (until mid-September) in 2001 and 2003, so these years were considered to be the most reliable estimates of coho salmon escapement to the North River. Coho counts averaged 9,110 in these two years (range = 5,837 to 12,383; Table 1).

Estimates of juvenile coho salmon habitat use and habitat quantity

The expected distribution of coho rearing habitat within the Nome and North River drainages was estimated from topographical maps and existing reports and information (Scott and Webb 1985; Webb and McLean 1991) following the methods of Bradford et al. (1997). The total kilometers of stream (including mainstem and tributaries) meeting model criteria was calculated for both rivers using digital topographic maps (scale=1:63,360) and ArcView 3.1 (ESRI, Redlands CA). To be considered potential coho rearing habitat, stream reaches were required to be 3rd order or higher (Strahler 1957), have gradients less than 8%, and be no more than 2 branches off the mainstem Nome or North rivers (Bocking and Peacock 2004). The number of branches off the mainstem is referred to hereafter as the *B* value.

Representative 3rd and 4th-order tributary streams were then identified and targeted for field surveys to ground-truth assumptions about coho distribution. Field surveys were conducted in June and in August of 2003 on each stream. Data from these surveys were then used to adjust the map-based estimates of available coho habitat.

Field surveys were also designed to collect biological information that would be useful for describing habitat use at multiple scales and age classes in both June and August. A number of target sampling "groups" were identified *a priori*. Sampling groups were established at the tributary scale, and were each comprised of 4 separate sampling sites. Within a group, sites were arranged so that one site was on the mainstem river near a tributary, one site was on the tributary

itself, and one site was in each branch of the upstream forks of the tributary (Figures 5 and 6). Sites were thus categorized as mainstem, tributary, or tributary forks. Within a site, sampling was conducted at several (2 to 8) sampling locations. Spatially, sampling groups were spaced between 5 and 20 km apart, sampling sites within each group were spaced between 1 and 5 km apart, and sampling locations within a site were generally within 100 m of each other. This sampling design allowed comparisons of coho caught in tributaries and mainstem habitats.

Sites were initially sampled in June; most sites were then re-sampled in August, along with new ones made possible by improved access (higher water for boat travel), and improved knowledge and equipment. All sampling in June was with minnow traps (both 1/4" and 1/8" mesh). Most sites in August were sampled with the same minnow traps, and a few were sampled with a backpack electrofisher (Tables 2 and 3). Channel wetted width, water depth, and stream flow (orange float method) were measured on all tributaries.

Coho biosampling – length and age

Captured coho salmon were measured to the nearest mm (fork length). In most capture events, all the coho captured were able to be measured. In a few events, coho were subsampled for lengths. These subsamples were chosen randomly from a holding tank containing all fish captured during that event. Coho ages were estimated by either aging fish directly from scale pattern analysis or by inferring ages by applying length statistics associated with fish that were aged by scale pattern analysis.

For the scale pattern aging, scale samples were taken from subsamples of captured coho and placed on gum cards. The cards were then sent to Birkenhead Scale Analysis (Lone Butte, British Columbia), where the ages were estimated based on annuli and plus growth. Scales from early June were re-evaluated in late summer, after scales from newly emerged juvenile coho could be used for comparison.

For the length-assigned aging, the mean, range, standard deviation, and 95% confidence intervals of the length were calculated from the scaled-aged fish. These statistics were calculated for each age group of coho, classified by river and sampling month. The minimum length of any age-1 fish, for each combination of river and sampling month, was taken as the cutoff point for assigning ages to coho that had been measured but not scale-aged. Coho below this minimum size were considered age-0, whereas coho above this size were considered age-1 or older. On Osborn Creek, we also used statistics from scale-aged coho to separate age-1 from age-2 coho. Coho measuring within 2 standard deviations of the mean of an age group were assigned to that group.

Juvenile coho salmon production in Osborn Creek, Nome River watershed

Two temporary V-style smolt traps were established on Osborn Creek, 0.25 km and 0.5 km upstream from the confluence with the Nome River (Figure 5). The upstream trap was installed on June 3 and operated daily until June 30, and then operated 2 days/week until July 15. The downstream trap was installed on June 10 and operated daily until June 24. Each trap consisted of a fish-tight plywood live box fed by an intake hose. The intake hose ran 3m upstream to the point of the "V" formed by two upstream-facing leads. Each lead was made of lumber lined with

hardware cloth small enough to divert age-1 juvenile coho salmon into the point of the V, through the intake hose, and into the live box. Once caught, juvenile coho were sampled for scales and weights. Subsamples of fish were also weighed.

Minnow traps were also set in the vicinities of the traps to compare juvenile coho caught in the trap to those rearing nearby. Water levels were monitored with a staff gauge placed at the downstream trap.

Model estimates of coho salmon smolt abundance

Once the available coho rearing habitat had been identified, quantified, and modified by ground-truthing, three models were used to predict coho salmon smolt abundance in each watershed. All of the models used relationships between habitat and observed smolt production from a dataset of 113 streams developed over 40 years in southeast Alaska, British Columbia, Oregon, and Washington (Appendix A; Bocking and Peacock 2004). For Model 1, the smolt production from the Nome and North rivers was predicted from the log-linear relationship between stream length and smolt production derived from this 113-stream dataset (Appendix A). For Model 2, smolt production on both rivers was predicted by the median smolt production per km from the 113-stream dataset. Finally, Model 3 was generated as an alternative to account for the hypothesized lower coho productivity in Norton Sound streams. Model 3 was derived from the 25% quartile for the 113-stream data set (Appendix A).

Adult spawners needed to produce the predicted ranges of coho smolt production

The number of adult coho salmon needed to produce the range of smolts predicted by each model was then estimated using estimates of coho fecundity, egg deposition, and the survival rates from egg to fry and from fry to smolt (e.g., Nickelson and Lawson 1998). Survival estimates from egg to fry and fry to smolt were taken from Bradford (1995). Fecundity estimates were taken from female coho salmon returning to the Unalakleet River in 2002 (Nemeth et al. 2003). Egg deposition by spawning females was considered to be 100%, an unrealistically high number chosen because there are no data to help indicate actual egg deposition rates. Although idealistic, an estimate of 100% provided a bias in a known direction.

RESULTS

Estimates of juvenile coho salmon habitat use and habitat quantity

Based on stream order, gradient, and known barriers, the length of stream habitat available to rearing coho was estimated at 83 km in the Nome River and 277 km in the North River (Table 8). This habitat consisted of the mainstem and 3 sub-basins on the Nome River and the mainstem and 12 sub-basins on the North River (Figure 15; Appendix B). The mainstem of the Nome River accounted for 77% of the available coho rearing in the Nome River drainage. The three 3rd order sub-basins, Osborn, Buster, and Elk, accounted for the remaining 23% with Osborn Creek being the largest (Figure 15).

The mainstem of the North River accounted for 57% of the available coho rearing habitat in the North River drainage. The Little North River and tributaries G and J each accounted for approximately 10% of the available rearing habitat, and the remaining 9 sub-basins accounted for the remaining rearing habitat (Figure 15).

Nearly all of the rearing habitat included in the model was less than 2% gradient. On the Nome River, 94% of the rearing habitat was less than 2% gradient, 5% of the habitat was between 2% and 4% gradient, and a small amount of habitat (less than 1%) was between 4% and 6% gradient. On the North River, 84% of the rearing habitat was less than 2% gradient, 15% of the habitat was between 2% and 4% gradient, and the remaining 1% was between 4% and 6% (Figure 16). Although gradients of up to 8% were allowed to be included in the model, all potential reaches between 6 and 8% were excluded by high *B* or low stream order.

Sampling was conducted at 24 sites on the Nome River, with a total number of 1,073 minnow trap hours (Table 4). In June, twelve sites were sampled (Figure 5), using a total of 680 hours of minnow trap fishing time. Several sites originally targeted were not sampled because of high, swift water with no holding habitat for juvenile coho. Juvenile coho salmon were captured in two of the three tributaries (Buster and Osborn creeks; Figure 7) that were predicted to have juvenile coho habitat. In these two streams, juvenile coho were captured only in the tributary mainstem and not upstream in either of the tributary forks. No coho were captured in Banner Creek, the third tributary predicted to have coho rearing habitat. Juvenile coho salmon were also captured in three of the seven sites sampled on the mainstem Nome River. Scale-aged fish were age-1 at all sites except in Osborn Creek, where limited numbers of age-2 fish were also caught. Based on lengths, one potential age-0 fish (length=48 mm) was caught in the mainstem Nome River on June 2.

Sampling was repeated at eight of the Nome River sites in August. In addition, 12 new sites were sampled, for a total of 393 hours of minnow trap time. Juvenile coho salmon were captured in 4 of 7 tributaries sampled and in all eight of the sites sampled in the mainstem Nome River (Figure 8). Of the eight sites that were re-sampled, all four of the ones that had juvenile coho in June also had fish in August; of the four sites that did not have juvenile coho in June, three had fish in August. Coho salmon captured in August were ages 0, 1, and 2, and the catch per unit effort (CPUE) of each age class was higher in August than in June. Electrofishing was also used to sample for fish in Sulphur Creek and in the mainstem Nome at the Sulphur Creek confluence and the Triple Creek confluence.

Age-0 fish were not captured in June (Figure 7), and were not seen until June 25. In August, age-0 fish were caught in high numbers in streams that had no holding habitat during high water events in June (e.g., Basin Creek), and that are thought to freeze solid in the winter (Figure 8). Age-1 fish were caught in both June and August, in both the mainstem Nome River and its tributaries. Age-2 coho were identified from scale ages in both June and August, but only from a beaver dam impoundment on Osborn Creek. In addition, likely age-2 fish (based on length) were also captured from a beaver dam impoundment on the mainstem Nome River in August.

On the North River, 21 sites were sampled, with a total of 1,187 hours of minnow trap effort (Table 5). In June, fourteen sites were sampled, using a total of 1011 hours of minnow trap

fishing time. Most target sites had habitat that appeared suitable for juvenile coho. Juvenile coho salmon were captured in three of the four tributary streams predicted to have juvenile coho (Figure 9). In these streams, juvenile coho were captured in a mixture of mainstem tributaries and tributary forks. Juvenile coho salmon were also captured in two of the four sites on the mainstem North River that were sampled. All coho captured were estimated as age-1 fish (both scale age and length-assigned ages). All sampling in June was conducted with minnow traps.

Sampling was repeated at thirteen of the North River sites in August. In addition, eight new sites were sampled, for a total of 176 hours of minnow trap time (Table 5). Juvenile coho salmon were captured in 5 of 8 tributaries sampled and in all six of the sites sampled in the mainstem North River (Figure 10). Of the thirteen sites that were re-sampled, all six of the ones that had juvenile coho in June also had juveniles in August; of the seven sites that did not have juvenile coho in June, three had juveniles in August. Coho salmon captured in August were aged at age-0 and age-1; of the unaged fish, ages assigned by lengths were also age-0 and age-1. Electrofishing was used to sample for juvenile coho at eight sites in August. Three of these sites had yielded no coho when trapped with minnow traps; when re-sampled with electrofishing equipment, juvenile coho were captured at one of these three sites.

In the mainstem North River, juvenile coho salmon were captured at the highest upriver site sampled, which was 79 km above the confluence with the Unalakleet River (Figure 10). Coho caught at km 79 included both age-1 (scale ages) and age-0 (inferred from length at date: mean length = 47.1 mm on August 26). In the North River tributaries, juvenile coho salmon were caught as far upstream as H (North River km 68), but were not captured in I (North River km 76; Figure 10). Juvenile coho were caught in H in both June and August; in June, all coho caught in H were age-1 (scale-aged), and in August all coho caught in H were estimated at age-0 (inferred from length at date: mean length = 35 mm on August 27).

The majority of 3rd order and higher streams that were surveyed had juvenile coho; the majority of 2nd order and lower streams that were surveyed did not (Figures 7 through 10). Exceptions such as Basin (2nd order) and Darling (1st order) creeks on the Nome River indicate that some lower-order streams may need to be considered under certain conditions. The inclusion of 2nd order streams would substantially increase the amount of habitat, so these streams should only be included in future models after considering attributes such as distance up watershed and valley slope (Sharma and Hilborn 2001). Overall, distribution sampling for juvenile coho supported the inclusion of 3rd order and higher streams in the model estimates of smolt production.

Coho biosampling – length and age

In the Nome River watershed, mean lengths of juvenile coho in June averaged 65 mm in tributary and mainstem habitats and had an overall range of 35 to 117 mm (Table 5; Figure 11). Coho were not captured in any of the tributary fork habitat in June, and no sampling was conducted in beaver ponds or rehabilitation quarries. In August, mean coho lengths in the Nome river tributaries (mean = 57 mm) and the mainstem (mean = 56 mm) were again similar to one another, but were decreased from June due to the emergence of age-0 coho in July. The range of fish sizes was larger in the mainstem (32 to 159 mm) than in the tributaries (37 to 99 mm). Coho lengths were larger in other habitats (Figure 11), averaging 89 mm in beaver ponds (range = 54 to 125 mm) and 80 mm in the rehabilitation quarries (range = 43 to 102 mm).

In the North River watershed, a few fish were caught in each of three habitat types in June (Table 7; Figure 11). Coho averaged 56 mm in the mainstem habitat (range = 50 to 65 mm), 72 mm in the tributary habitat (range = 54 to 103 mm), and 54 mm in the tributary forks habitat (range = 50 to 56 mm), but samples sizes were too small (23 coho caught total) for meaningful comparisons among habitat types. In August (Figure 11), coho averaged 51 mm in the mainstem habitat (range = 32 to 107 mm), 55 mm in the tributary habitat (range = 35 to 84 mm), and 42 mm in the tributary forks (range = 34 to 65 mm).

Juvenile coho salmon production in Osborn Creek, Nome River watershed

The uppermost trap on Osborn Creek was installed before complete ice-out and fished from June 3 to June 27. The fence extended across 75% of the stream and up to the thalweg, which was close to the bank in that section of the stream. On June 13, the trap was shut down for the day so that the fence could be adjusted as the thalweg moved with dropping water levels. The lower trap was installed on June 5, knocked down by high water levels on June 7, and fished continuously from June 7 to June 27. The lower fence extended out to the edge of thalweg, covering about 60% of the stream width. Minnow traps were fished throughout the area during the time the fences operated. Water levels in Osborn Creek were relatively stable from May 24 to May 30, rose sharply on May 31, fluctuated from June 1 to June 6, and declined steadily throughout the rest of June (Figure 12). By June 13, the water level had declined to the same levels as first seen on May 24; by June 28, it had dropped to about half of the June 13 level. Ice remained in the stream until June 6.

A total of 164 juvenile coho were captured at the fences, 231 in minnow traps nearby in Osborn Creek, and 43 in minnow traps placed downstream in the Nome River at the confluence with Osborn Creek (Table 7). The combined catch from the two fences peaked from June 11 to 14, during a period of relatively stable water levels that began 5 days after the last peak water level (Figure 12). The upper fence was the only one that operated from June 3 to June 7; during this time, the only day that fish were not caught was June 7, when water level peaked. Water temperatures averaged less than 1° C in late May when fence construction began. Coho salmon began to be captured in the fence on June 3, when mean daily water temperatures were still less than 2° C (Figure 13). There was a pronounced increase in the combined catch at both fences from June 10 to June 11; this increased catch coincided with an increase in water temperature (increasing from 3.9 to 7.2; Figure 13), but not with a marked change in water level (Figure 12).

Of the juvenile coho captured in the Osborn Creek group in June (including the Nome River minnow traps), 146 were aged from scales and another 312 were assigned ages based on their lengths. Coho captured in Osborn Creek in June were 98% age-1 and 2% age-2 (Table 7). All of the coho captured in the fence traps (n=158) were age-1. Coho captured in the Nome River minnow traps were 81% age-1 and 19% age-2 (Table 7). In late June, a beaver pond 1 km upstream of the fences was also sampled with minnow traps. Of the 37 juvenile coho caught, 62% were age-1 and 36% were age-2 (Table 7).

Coho lengths averaged 57.1 mm (SE=0.4) in the Osborn Creek fences, 62.5 mm (SE=0.7) in the Osborn Creek minnow traps, and 69.6 mm (SE=2.2) in the Nome River minnow traps (Figure 14). Based on 95% confidence intervals, fish caught at the Osborn Creek fences were significantly smaller than fish caught in the Osborn Creek and Nome River minnow traps (Figure

14).

When the same sites were sampled with minnow traps in August, the age composition in Osborn Creek (not including the beaver dam) was 88% age-0 and 12% age-1 (Table 7). Based on the age structure seen earlier in June, we would predict at least some of these age-0 fish to overwinter in Osborn Creek and then migrate out as age-1 fish the next June. Most of the age-1 coho would be expected to migrate from Osborn Creek down into the Nome River sometime before the winter, such as in the fall when water levels rise. In the Nome River, at the confluence with Osborn Creek, only age-0 coho were captured in minnow traps in August. In the beaver pond in Osborn Creek, the age structure in August was 47% age-1 and 53% age-2 (Table 7).

The Osborn Creek beaver pond was sampled in February of 2004. Juvenile coho were captured in minnow traps inserted through holes in the ice. Length and scale information was not recorded, but all coho captured were similar in size to those captured at the same site in August of 2003.

Model estimates of coho salmon smolt abundance

Model 1, generated from the log-linear relationship between stream length and smolt production for British Columbia and Southeast Alaska coho streams (Figure 1; Appendix A), estimated smolt production on the Nome River at 146,098 smolts (95% CI: 110,567 – 181,629) and smolt production on the North River at 419,593 (95% CI: 307,392 – 531,794). Model 2, which used the median smolt production per km from the same data set, estimated smolt production on the Nome River at 105,370 (95% CI = 72,179 – 170-836 smolts) and smolt production on the North River at 350,934 smolts (95%CI=240,390 – 568,964 smolts). Model 3, which was the most conservative estimate and was derived from the 25% quartile of the same 40-year data set, estimated smolt production on the Nome River at 54,917 smolts and smolt production on the North River at 182,899 smolts (Table 8). Note that no estimate of variance was derived for Model 3.

Adult spawners needed to produce the predicted ranges of coho smolt production

Based on predicted smolt abundance from each model and literature values for fecundity and survival, the number of adult coho salmon needed to produce the estimated number of smolts ranged from 1,331 (Model 3) to 3,540 (Model 1) on the Nome River and 4,431 (Model 3) to 10,166 (Model 1) on the North River (Table 9). For the Nome River, these estimates are 25% greater (Model 1), 10% less (Model 2), and 53% less (Model 3) than the 2,918 average coho escapement observed from 2001 and 2002 (Table 10). For the North River, these estimates are 15% greater, 4% less, and 50% less than the 9,110 average coho escapement observed in 2001 and 2003 (Table 10). The average escapements to the Nome River for 2001 to 2003 and the North River in 2001 and 2003 were within the 95% confidence interval for Model 2. The average North River escapement (2001 and 2003) was also within the 95% confidence interval for Model 1, but the average Nome River escapement (2001 to 2003, inclusive) was below the 95% confidence interval for Model 1 (Table 9).

DISCUSSION

The distribution surveys indicated that habitat use associations from other regions were useful for predicting summer habitat use by juvenile coho salmon in Norton Sound watersheds. In the Nome River, coho salmon were present in all of the sampled 3rd and 4th order reaches, and also relatively high in the mainstem river (river km 55). In the North River, juvenile coho salmon were present in all of the 4th and 5th order reaches (mainstem and tributaries) sampled, and in all but two of the 3rd order tributaries (one high-gradient stream in the upper drainage and one that had been blocked by a large, defunct, beaver dam) sampled. Coho salmon were present in the mainstem river as high as we could access by boat (river km 79). It therefore appears defensible to include all 3rd-order and higher tributaries in the estimates of total available habitat, and to assume that, despite the cold winters, coho rear high in the mainstems of the rivers. Some 2nd order habitat may also need to be included in the models; juvenile coho were present in about half of the 2nd order streams sampled in the Nome River watershed (Figure 8). The factors that determine use of 2nd order habitat may be difficult to determine, however, and these waters were thus left out of the current estimates of habitat (thereby imparting some bias). Future coho rearing habitat models will need to consider how and when to include these streams in estimates of habitat quantity.

A sensitivity analysis that assesses the effects of including different stream reach types in the model will also be important for refining future estimates of habitat quantity. Bocking and Peacock (2004) found that total rearing habitat estimates within the watershed were affected more by increasing the number of tributaries off the mainstem (the *B* value) than by increasing the gradient of stream reaches that could be included. Future revisions to the habitat quantity model should focus on sensitivity analyses of including different reach categories (i.e., *B* value, stream order, and stream gradient); these analyses can be used to prioritize future coho survey reaches.

Distributions of juvenile coho salmon in the Nome and North rivers in 2003 were consistent with two surveys conducted in prior years. Webb and McLean (1991) electrofished several tributaries to the Nome River in early August of 1990. We electrofished three of these streams in August of 2003. In Darling Creek, coho salmon were present in both 1990 and 2003, and sampled fish included both age-0 and age-1 fish (ages estimated from lengths). In David Creek, coho salmon were not found in 1990 or in 2003. In Sulphur Creek juvenile coho were captured in 1990 but not in 2003. The difference in Sulphur Creek (coho found in 1990 but not in 2003) may have been due to changes in habitat from 1991 to 2003. Webb and McLean (1991) suggested that juvenile coho used tributaries seasonally, moving from the Nome River up into tributaries in early summer, then back down into the Nome River in the late summer or fall. In 1990, habitat classifications indicated Sulphur Creek had relatively poor rearing habitat (high gradient, high water velocity, and low pool abundance), and few coho were caught (Webb and McLean, 1991). In 2003, our field crews noted the same poor habitat characteristics (M. Nemeth, personal observation) and counted only 3 pools in the first 1.1 km upstream from the Nome River. The absence of juvenile coho in 2003 could be explained by poor conditions for coho migrating from the Nome River into Sulphur Creek in early summer (e.g., water velocity barrier in lower creek), by degraded habitat conditions since 1991, or by such low abundance that the coho were not detected in 2003.

Scott and Webb (1985) surveyed the upper North River (upstream of km 39) with minnow traps in July of 1985. Six sites had juvenile coho and two did not. We sampled seven of these eight sites in 2003. Of the six sites that had coho in 1985, coho were found in four in 2003 (two sites in the mainstem North River, two in tributaries), no coho were found in a fifth (a tributary), and the sixth was not sampled in 2003. Both of the sites that did not have coho in 1985 had coho in 2003. Both of these were 4th-order tributaries. Scott and Webb (1985) also reported that additional sites were sampled in 1985, but coho were not captured and the numbers and locations of these sites were not reported. Overall, the two sampling events show consistency in coho use of upper tributaries and mainstem North River in 1985 and 2003. We do not know why one tributary had coho in 1985 but not in 2003. The site that had coho in 1985 but not in 2003 was a 3rd-order tributary that had many active beaver dams in 2003. The absence of coho in 2003 came despite a substantial amount of catch effort – multiple locations were sampled in June (minnow traps only) and August (minnow traps and electrofishing), both in the tributary mainstem and in its upper forks. This was in the smallest class of tributaries sampled (3rd order) and had a B=2. As on the Nome, B=1 tributaries always had coho while B=2 tributaries only sometimes had coho, underscoring the need to determine how and when to include these tributaries in the model.

Region-wide estimates of juvenile coho rearing habitat may be able to be refined by adding smaller-scale variables to the models. Sharma and Hilborn (2001) reported correlations between coho smolt production and habitat factors that are smaller-scale than the ones we used, and found these factors to be useful predictors at the local (watershed) scale. Now that juvenile coho presence has been confirmed in B=1 streams, for example, other landscape-level variables such as valley slope (Sharma and Hilborn 2001) can be applied to estimate production within sub-basins. In addition, habitat assessments that are planned for the Nome River in 2004 will classify habitat units such as pools and ponds. Sharma and Hilborn (2001) found these habitat types to be useful predictors of smolt production in small watersheds. These measurements of habitat types can be combined with the distribution data from 2003 to further refine estimates of juvenile coho abundance in the Nome River.

The presence of multiple age classes of juvenile coho in Norton Sound rivers may need to be factored into models of coho salmon rearing habitat. Freezing or drying causes seasonal contractions of useable rearing habitat; the life stages at the times of such contractions are thought to be the stages that limit eventual smolt production (Bocking and Peacock 2004). Bradford et al. (2000) felt that the limiting stage for coho was during the transition from yearling parr to smolt, when low water and freezing temperatures reduced the total amount of rearing habitat. Most habitat-based production estimates have been for populations that spend one winter in freshwater (e.g., Nickelson and Lawson 1998), and correlations between coho smolt production and habitat have thus not accounted for age-specific habitat use (Bradford et al. 1997; Sharma and Hilborn 2001). The majority of Norton Sound coho salmon spend two winters in freshwater (Table 11), and there are no studies to indicate which age class is most affected by winter habitat contractions. If winter habitat contractions in Norton Sound have the largest effect on coho in their first winter, there may be little difference in habitat models from Norton Sound and other places. Further studies should evaluate habitat use by age class to help determine which life stage limits smolt production.

The results from the 2003 surveys yielded basic life history information that will be useful for

directing future work. Juvenile coho salmon were difficult to catch in minnow traps in all waters of the Nome and North Rivers in June. Age-0 coho had not yet emerged, and high flows with low water temperatures may have kept age-1 from being active enough to catch in traps. By August, water levels had dropped, temperatures had risen, and juvenile coho were caught in higher numbers and at a greater proportion of the sites. Several tributaries that did not appear to have spawning habitat had age-0 coho in August but not in June, suggesting that age-0 coho, although small, move into the tributaries in the summer and return to the mainstem river sometime before June (presumably by the beginning of winter). In tributaries of the Nome and North rivers, maximum coho size decreased from June to August. In mainstem habitat of both rivers, however, maximum coho size increased from June to August. These trends are consistent with the movement of larger, older fish from the tributaries into mainstem habitat over the course of the summer.

In the North River, the capture of age-1 coho salmon (mean = 54 mm) from the tributary forks in June suggest that age-0 coho are able to overwinter in small (3rd order) streams relatively high in the drainage (river km 68). This size class of coho was not captured at these sites in August, but smaller, age-0 fish (mean = 42 mm) were present instead. The most likely life history model appears to be one in which coho spawn in the tributary forks in the late fall and emerge from the gravel in June. At least some of these coho then overwinter in the tributary forks for a year, resulting in the presence of the 42 mm coho in August and the 54 mm coho in June in our study. These coho then migrate down into the lower tributary or the mainstem North River at age-1 and spend another winter. Headwater habitats may have less predators and competition for space, thereby conferring an advantage to coho that are able to remain there until growing large enough to compete for food and space with larger fish downstream. A pattern of gradual downstream movement into different areas at different ages has been documented for other coho populations (e.g., Murphy et al. 1997; Brown et al. 1999). The alternative would be that age-1 coho migrate from the lower reaches of a tributary up into the headwaters in early June. This would require migrating upstream against high, cold water driven by snowmelt (daytime high water temperatures of 1 to 4 C°) and seems unlikely. Consequently, the potential of these small headwater habitats for overwintering and juvenile rearing needs to be considered.

Age and size structure of juvenile coho salmon varied among habitat types in 2003, providing initial insight into age-specific habitat use by juvenile coho salmon in Norton Sound. In the Nome River, the largest juvenile coho captured in August were consistently in impoundments (beaver ponds and rehabilitation quarries; Figure 11). Age-2 coho were captured only in beaver ponds. Juvenile coho were also present under the ice in these ponds in February, indicating that at least some of the coho remain there overwinter instead of moving in from the mainstem in the spring. These observations are consistent with detailed studies by Nickelson et al. (1992), who reported that winter densities of juvenile coho were highest in beaver ponds (as compared to glides, riffles, and other kinds of pools).

Results from Osborn Creek in June and August suggest that age-1 coho may migrate from Osborn Creek into the Nome River as age-1 fish, then overwinter for a year somewhere else in the Nome River watershed before migrating to sea as age-2 smolts. At the Osborn Creek fences in June, the distinct pulse of fish that came in the middle of the month (Figure 12) in June consisted entirely of age-1 coho. Because this site was low in the Osborn Creek system (within 1

km of the Nome River), these fish were assumed to have been emigrating from upstream in Osborn Creek down into the Nome River. A few age-2 coho were present in Osborn Creek in June (2% of catch), but not nearly as many as in the Nome River (16%) or the beaver pond (38%; Table 7).

When the June minnow trapping sites were re-sampled in August, age-2 coho were entirely absent in the mainstem Nome River and Osborn Creek. Age-0 coho comprised the entire catch in the Nome River, and the lower Osborn Creek had both age-0 and age-1 coho. Based on the age structures seen earlier in June (i.e., many age-1 coho emigrating downstream, no age-2 coho) we would predict at least some of these age-0 fish to overwinter in Osborn Creek and then migrate out as age-1 fish the next June. Most of the age-1 present in August coho would be expected to migrate from Osborn Creek down into the Nome River sometime before the winter, such as in the fall when water levels rise.

In the beaver pond on Osborn Creek, the proportion of age-2 coho was relatively high in both June and August. At least some coho overwintered in the pond from 2003 to 2004, and would not have been able to leave until the ice broke up in mid-May of 2004. The presence of age-2 coho in August and of large, albeit unaged, coho in February suggests that this beaver pond produces some of few coho from the Nome River watershed that spend 3 years in freshwater (an estimated 0.6% of the Nome River escapement in 2001; Kohler and Knuepfer 2001).

At this stage of the project, the biological data needed to estimate smolt production or adult spawner abundance must be transferred from coho salmon data collected outside the region. In the interim, we use this report to provide example models of smolt production and adult spawner abundance. Although preliminary, there are several useful reasons for doing so. First, these models help indicate how data will be used, and which are most important for generating habitat-based production (juvenile or adult) estimates – the value of survival, fecundity, egg deposition, and juvenile production data is demonstrated by the models presented in Tables 8 and 9. Second, the models allow analyses of the sensitivity of the estimates to data inputs. Predictions based on habitat quantity alone (Model 1) and on an assumed median smolt production per km in Norton Sound (Model 2) yielded overlapping estimates for smolt quantity (Table 8). Predictions based on an unusually low level of smolt production per km (Model 3) yielded a point estimate that was not within the 95% range of the other models. Third, the models provide an early bridge between our measurements of habitat and known escapements of adult coho salmon, thereby allowing highly unrealistic scenarios to be identified. Model 3, developed to explore the implications of inherently low smolt production in Norton Sound, substantially underestimated the number of adult coho spawners that have been observed in both rivers in years with the most reliable escapement estimates (Table 10).

Measurements of juvenile coho density at the watershed or habitat unit level will be an important next step in the development of habitat-based production models. Such measurements will provide empirical data from within Norton Sound that can be used in the models. They will also provide some measure of how well larger datasets from outside the region can be transferred into the region. Given the growing body of literature relating production to habitat (e.g., Nickelson et al. 1992; Nickelson 1998; Anderson and Hetrick 2003) and the potential for using this relationship to develop escapement goals (e.g., Nickelson 1998; Bradford et al. 2000; Sharma

and Hilborn 2001; Bocking and Peacock 2004), there is clearly a need to begin measuring coho smolt or pre-smolt production somewhere in western Alaska.

An important aspect of future studies will also be to describe the emigration patterns of coho smolts. Evidence from 2003 suggests that juvenile coho did not smolt directly from the largest tributary (Osborn Creek), and instead may have moved into the Nome River at age-1. If coho smolts migrate from the lower river in a relatively compressed pulse, future studies should attempt to estimate smolt production for the entire Nome River watershed. If smolts do not migrate in a distinct pulse (such as instead smolting over a lengthy time from a range of locations upriver), future studies may need to estimate smolt production by estimating abundance per habitat type of age-1 coho.

CONCLUSION AND RECOMMENDATIONS

The 2003 work provided two of the initial components needed to develop habitat-based estimates of coho salmon smolt production in Norton Sound. The total amount of potential coho salmon rearing habitat in the Nome and North River watershed was estimated and stratified by stream order, gradient, and elevation. A substantial amount of information on juvenile coho salmon age structure and distribution was then collected in field surveys, helping to refine the estimates of habitat quantity while guiding future population studies. The initial habitat estimates were also applied to biological data from the literature to illustrate model development and identify future data needs. Future efforts should be divided in two general categories: refining the understanding of the linkage between habitat and juvenile coho in Norton Sound, and measuring smolt production or pre-smolt abundance in Norton Sound streams.

To understand the linkage between habitat and juvenile coho in Norton Sound, future work should emphasize refining our knowledge of habitat use by season and age groups, and of the factors governing use of certain subsets of streams (such as those with B=2). Bradford et al. (1997) found a useful correlation between coho smolt production and regional level habitat features, but cautioned that more detailed observations were needed to predict smolt production at the watershed level. Sharma and Hilborn (2001) later demonstrated such watershed-level linkages, finding smolt production correlated with watershed features such as valley slope and instream variables such as microhabitat types and large woody debris. Such features should be examined now that we have a better understanding of juvenile coho distribution in Norton Sound. Specific recommendations in subsequent years are to:

- Conduct additional field surveys to refine coho distribution estimates and to evaluate differences among years;
- Measure smaller-scale habitat features (e.g., pool frequency) for future linkage with juvenile coho production; and,
- Identify habitat use by life stage.

Coho salmon production needs to be measured, or estimated, in at least one Norton Sound stream. Such estimates would provide empirical data to replace the literature values used in the models, while indicating how comparable Norton Sound coho smolt production is to larger

datasets developed outside the region. Specific recommendations in subsequent years are to:

- Describe smolt migration patterns for the purpose of designing abundance studies;
- Estimate juvenile coho abundance in different habitat types to better understand habitat factors that influence abundance; and,
- Measure total smolt production from one watershed or from one or more tributaries.

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Table 1. Historical escapement of coho salmon to the Nome and North rivers, Norton Sound, Alaska

	Nome River[1]		North River[2]	
Year	Count	Operation End Date	Count	Operation End Date
1985	-	-	2,045	31-Aug
1993	4,349	28-Aug	-	-
1994	726	15-Aug	-	-
1995	1,650	06-Sep	-	-
1996	66	23-Jul	1,229	25-Jul
1997	321	27-Aug	5,768	26-Aug
1998	96	11-Aug	3,361	12-Aug
1999	417	25-Aug	4,792	31-Aug
2000	696	25-Aug	6,961	12-Aug
2001	2,418	11-Sep	12,383	15-Sep
2002	3,418	11-Sep	3,210	30-Aug
2003	548	10-Sep	5,837	13-Sep

[1] Tower counts for 1993-95 and then weir counts from 1996-2003.

[2] Tower counts for all years listed.

Nome River count data from Kohler (2003)

North River escapement data from unpublished ADF&G data, 2004

Table 2. Locations and dates of sampling sites on the Nome River, 2003.

Group (Figure 3)	Site number	Habitat Type	River Km[1]	Sampling method	Latitude (ºN)	Longitude (ºW)	Sampling Date 1	Sampling Date 2
Osborn	1	Mainstem Nome	13.5	Minnow trap	64.549084	165.220605	07-Jun	23-Aug
Osborn	2	Tributary	0.5	Minnow trap	64.548721	165.208595	07-Jun	23-Aug
Osborn	3	Tributary Fork	3.2	Minnow trap	64.5441	165.16689	06-Jun	-
Osborn	4	Tributary Fork	3.5	Minnow trap	64.54427	165.16016	06-Jun	-
Estuary	1a	Estuary	0.7	Minnow trap	64.48653	165.296567	14-Jun	24-Aug
Estuary	1b	Estuary	1.3	Minnow trap	64.485401	165.284943	-	24-Aug
Estuary	1c	Estuary	1.7	Minnow trap	64.487555	165.280726	14-Jun	24-Aug
Nome Lower	1a	Nome mainstem	7.2	Minnow trap	64.501869	165.227067	-	24-Aug
Nome Lower	1b	Nome mainstem	8.0	Minnow trap	64.504385	165.212209	-	24-Aug
Nome Lower	1c	Nome mainstem	8.5	Minnow trap	64.509019	165.210316	-	24-Aug
Nome Lower	1d	Nome mainstem	9.2	Minnow trap	64.514727	165.204847	-	24-Aug
Nome Lower	1e	Nome mainstem	9.8	Minnow trap	64.517329	165.212585	-	24-Aug
Nome Lower	1f	Nome mainstem	10.2	Electrofishing	64.517082	165.219199	-	24-Aug
Buster	1	Mainstem Nome	20.3	Minnow trap	64.588671	165.262743	07-Jun	22-Aug
Buster	2	Tributary	0.3	Minnow trap	64.589795	165.260408	08-Jun	22-Aug
Buster	3	Tributary Fork	2.5	Minnow trap	64.600655	165.241039	08-Jun	-
Buster	4	Tributary Fork	2.4	Minnow trap	64.600949	165.244084	08-Jun	-
Banner	1	Mainstem Nome	27.9	Minnow trap	64.636074	165.292273	09-Jun	-
Banner	2	Tributary	1.9	Minnow trap, electrofishing	64.647736	165.312221	09-Jun	23-Aug
Nome Flats (bridge)	1a	Mainstem Nome	30.3	Minnow trap	64.649367	165.294017	01-Jun	18-Aug
Nome Flats	1b	Mainstem Nome	30.5	Minnow trap	64.650892	165.294567	-	18-Aug
Nome Flats	1c	Mainstem Nome	31.2	Minnow trap	64.656949	165.296255	-	18-Aug
Nome Flats	1d	Mainstem Nome	31.9	Minnow trap	64.6618	165.295439	-	23-Aug
Nome Flats	1e	Mainstem Nome	32.2	Minnow trap	64.664567	165.3001	12-Jun	18-Aug
Basin	1	Mainstem Nome	34.4	Minnow trap	64.681666	165.306038	-	19-Aug
Basin	2	Tributary	0.4	Minnow trap	64.683676	165.299804	-	19-Aug
Kink Corner	1	Tributary	0.3	Minnow trap	64.730917	165.264256	-	18-Aug
Darling	1	Mainstem Nome	45.7	Minnow trap	64.738518	165.237858	-	19-Aug
Darling	2	Tributary	0.9	Minnow trap	64.74142	165.220495	-	19-Aug
Sulphur	1	Mainstem Nome	54.9	Electrofishing	64.809181	165.219598	-	23-Aug
Sulphur	2	Tributary	1.1	Electrofishing	64.816126	165.204205	-	23-Aug
David	1	Mainstem Nome	59.4	Electrofishing	64.839013	165.263249	-	21-Aug
David	2	Tributary	1.0	Minnow trap	64.846424	165.252156	-	21-Aug

[1] Mainstem sites are km from Norton Sound; tributary and tributary forks sites are km from mainstem Nome River.

Table 3. Locations and dates of sampling sites on the North River, 2003.

Group (Fig 4)	Site number	Habitat Type	River Km[1]	Sampling method	Latitude (ºN)	Longitude (ºW)	Sampling Date 1	Sampling Date 2
Little North R	not sampled	NA	6.4	-	-	-	-	-
Little North R	2	Tributary	7.6	Minnow traps	63.8987	160.536467	29-Jun	27-Aug
Waypoint 91	1	Mainstem	8.2	Electrofishing	63.9043	160.612050	-	29-Aug
Waypoint 90	2	Mainstem	12.7	Electrofishing	63.9236	160.605786	26-Jun	-
V	not sampled	NA	31.5	-	-	-	-	-
V	2	Tributary	0.1	Minnow traps	64.0328	160.467037	-	29-Aug
D	1	Mainstem	39.5	Minnow traps	64.0830	160.363234	-	29-Aug
D	2	Tributary	0.4	Electrofishing	64.0802	160.369386	-	29-Aug
3190	1	Mainstem	39.8	Minnow traps	64.0821	160.360364	-	28-Aug
3190	2	Tributary	0.7	Minnow traps	64.0828	160.360319	-	28-Aug
E	1	Mainstem	50.4	Minnow traps	64.1556	160.260930	28-Jun	27-Aug
E	2	Tributary	0.3	Minnow traps	64.1551	160.256632	28-Jun	28-Aug
E	3	Tributary fork	2.3	Minnow traps	64.1438	160.228531	28-Jun	28-Aug
E	4	Tributary fork	2.3	Minnow traps	64.1446	160.227427	28-Jun	28-Aug
G	1	Mainstem	60.7	Minnow traps	64.2261	160.170485	26-Jun	26-Aug
G	2	Tributary	0.1	Minnow traps	64.2259	160.168157	26-Jun	26-Aug
G	3	Tributary fork	1.6	Minnow traps	64.2224	160.141125	26-Jun	26-Aug
G	4	Tributary fork	1.7	Minnow traps	64.2228	160.139266	26-Jun	26-Aug
H	1	Mainstem	68.4	Minnow traps	64.2817	160.107638	27-Jun	26-Aug
H	2	Tributary	2.1	Minnow traps	64.2864	160.131235	27-Jun	26-Aug
H	3	Tributary fork	2.7	Minnow traps	64.2882	160.138831	27-Jun	27-Aug
H	4	Tributary fork	3.1	Minnow traps	64.2928	160.135509	27-Jun	27-Aug
I	1a	Mainstem	76.2	Minnow traps	64.3351	160.034772	-	26-Aug
I	1b	Tributary	0.4	Electrofishing	64.3373	160.039184	-	26-Aug
North R	1c	Mainstem	78.3	Minnow traps	64.3418	160.021573	-	26-Aug
North R	1d	Mainstem	79.0	Minnow traps	64.3468	160.012076	-	26-Aug

[1]Mainstem sites are km from Unalakleet River; tributary sites are km from North River.

Table 4. Catch per unit effort (minnow traps only) of juvenile coho salmon captured at Nome River sampling stations, 2003.

				June			August			Total		
Group	Site	Stream type	River Km[1]	Effort (hrs)	Catch (n)	CPUE (n per hr)	Effort (hrs)	Catch (n)	CPUE (n per hr)	Effort (hrs)	Catch (n)	CPUE (n per hr)
Osborn	1	Mainstem Nome	13.5	69.87	7	0.100	15.88	68	4.3	85.75	75	0.9
Osborn	2	Tributary	0.5	208.75	6	0.029	24	122	5.1	232.75	128	0.5
Osborn	3	Tributary Fork	3.2	18.1	0	0.000	0	0	NA	18.1	0	0.0
Osborn	4	Tributary Fork	3.5	19.78	0	0.000	0	0	NA	19.78	0	0.0
Nome R. Estuary	A-C	Estuary	0.7 - 1.2	40.78	0	0.000	32.13	6	0.2	72.91	6	0.1
Lower Nome R.	A-D	Nome mainstem	7.2 - 10.2	NA	NA	NA	44.28	161	3.6	44.28	161	3.6
Buster	1	Mainstem Nome	20.3	102.63	0	0.000	28.47	127	4.5	131.1	127	1.0
Buster	2	Tributary	0.3	31.85	182	5.714	29.07	265	9.1	60.92	447	7.3
Buster	3	Tributary Fork	2.5	7.18	0	0.000	0	0	NA	7.18	0	0.0
Buster	4	Tributary Fork	2.4	6.82	0	0.000	0	0	NA	6.82	0	0.0
Banner	1	Mainstem Nome	27.9	0	0	NA	0	0	NA	0	0	NA
Banner	2	Tributary (2 places)	0.1 and 1.9	80.7	0	0.000	17.6	0	0.0	98.3	0	0.0
Nome R. Bridge	1	Mainstem Nome	30.3	72.07	13	0.180	16.55	30	1.8	88.62	43	0.5
Nome R. flats	A-F	Mainstem Nome	30.5 - 32.2	21.43	0	0.000	94.72	22	0.2	116.15	22	0.2
Basin	1	Mainstem Nome	34.4	0	0	NA	10.53	45	4.3	10.53	45	4.3
Basin	2	Tributary	0.4	0	0	NA	22.62	39	1.7	22.62	39	1.7
Kink Corner	1	Tributary	0.3	0	0	NA	2.25	33	14.7	2.25	33	14.7
Darling	1	Mainstem Nome	45.7	0	0	NA	18.88	162	8.6	18.88	162	8.6
Darling	2	Tributary	0.9	0	0	NA	17.43	4	0.2	17.43	4	0.2
Sulphur	1	Mainstem Nome	54.9	0	0	NA	0	0	NA	0	0	NA
Sulphur	2	Tributary	1.1	0	0	NA	0	0	NA	0	0	NA
David	1	Mainstem Nome	59.4	0	0	NA	0	0	NA	0	0	NA
David	2	Tributary	1.0	0	0	NA	18.97	0	0.0	18.97	0	0.0
Total				680	208	0.31	393	1084	2.76	1073	1292	1.20

[1] Mainstem sites are km from Norton Sound; tributary and tributary forks sites are km from mainstem Nome River.

Table 5. Catch per unit effort (minnow traps only) of juvenile coho salmon captured at North River sampling stations, 2003.

				June			August			Total		
Group	Site	Stream type	River Km[1]	Effort (hrs)	Catch (n)	CPUE (n per hr)	Effort (hrs)	Catch (n)	CPUE (n per hr)	Effort (hrs)	Catch (n)	CPUE (n per hr)
Little North R	not sampled	NA	6.4	0	0	NA	0	0	NA	0	0	NA
Little North R	2	Tributary	7.6	101.98	4	0.0	8.2	7	0.9	110.18	11	0.1
Waypoint 91	1	Mainstem	8.2	0	0	NA	0	0	NA	0	0	NA
Waypoint 90	2	Mainstem	12.7	2.8	0	0.0	0	0	NA	2.8	0	0.0
V	not sampled	NA	31.5	0	0	NA	0	0	NA	0	0	NA
V	2	Tributary	0.1	0	0	NA	0.25	0	0.0	0.25	0	0.0
D	1	Mainstem	39.5	0	0	NA	7.7	3	0.4	7.7	3	0.4
D	2	Tributary	0.4	0	0	NA	0	0	NA	0	0	NA
3190	1	Mainstem	39.8	0	0	NA	4	1	0.3	4	1	0.3
3190	2	Tributary	0.7	0	0	NA	1.47	0	0.0	1.47	0	0.0
E	1	Mainstem	50.4	56.37	0	0.0	11.5	17	1.5	67.87	17	0.3
E	2	Tributary	0.3	114.23	0	0.0	20.47	0	0.0	134.7	0	0.0
E	3	Tributary fork	2.3	80.52	0	0.0	8.27	0	0.0	88.79	0	0.0
E	4	Tributary fork	2.3	85.93	0	0.0	6.2	0	0.0	92.13	0	0.0
G	1	Mainstem	60.7	51.55	1	0.0	16.68	2	0.1	68.23	3	0.0
G	2	Tributary	0.1	146.7	6	0.0	20.87	4	0.2	167.57	10	0.1
G	3	Tributary fork	1.6	16.6	0	0.0	8.1	0	0.0	24.7	0	0.0
G	4	Tributary fork	1.7	15.63	0	0.0	7.55	1	0.1	23.18	1	0.0
H	1	Mainstem	68.4	53.6	9	0.2	10.47	5	0.5	64.07	14	0.2
H	2	Tributary	2.1	114.78	0	0.0	18.57	2	0.1	133.35	2	0.0
H	3	Tributary fork	2.7	84.5	2	0.0	2.82	1	0.4	87.32	3	0.0
H	4	Tributary fork	3.1	85.72	3	0.0	4.92	0	0.0	90.64	3	0.0
I	A-C	Mainstem	76.2 - 79.0	0	0	NA	17.93	47	2.6	17.93	47	2.6
I	2	Tributary	0.4	0	0	NA	0	0	NA	0	0	NA
Total				1011	25	0.02	176	90	0.51	1187	115	0.10

[1] Mainstem sites are km from Norton Sound; tributary and tributary forks sites are km from mainstem Nome River.

Table 6. Length (mm) at age for juvenile coho salmon captured at Nome and North River sampling stations in the summer of 2003. All ages are from scale-aged fish.

		Age group				
Group	Data	0	1	2	Not aged	Total
Nome River						
Basin	Mean length (mm)	57.5	73.4		50.4	52.5
	Sample size (n)	2	5		54	61
Buster	Mean length (mm)	62.3	89.6		50.5	57.2
	Sample size (n)	10	21		108	139
Darling	Mean length (mm)	62.0	69.0		42.9	44.8
	Sample size (n)	1	1		22	24
G	Mean length (mm)		62.0		43.3	52.6
	Sample size (n)		8		8	16
I	Mean length (mm)		77.5		47.1	49.6
	Sample size (n)		2		23	25
Nome-Bridge	Mean length (mm)	47.7	73.0		60.3	64.5
	Sample size (n)	3	13		14	30
Nome-Estuary	Mean length (mm)	68.0	83.0			75.5
	Sample size (n)	1	1			2
Nome-Flats	Mean length (mm)		135.2		61.3	94.9
	Sample size (n)		10		12	22
Osborn	Mean length (mm)	48.8	65.5	102.0	60.9	66.0
	Sample size (n)	5	157	18	91	271
Kink corner	Mean length (mm)	54.3	83.7		84.2	79.6
	Sample size (n)	7	17		23	47
Sulphur	Mean length (mm)				48	48.0
	Sample size (n)				5	5
Total	Mean length (mm)	56.4	72.9	102.0	56.5	63.9
	Sample size (n)	29	225	18	336	608
North River						
D	Mean length (mm)		73.0		34.0	49.6
	Sample size (n)		2		3	5
E	Mean length (mm)	59.0	71.0		51.7	53.3
	Sample size (n)	1	1		15	17
H	Mean length (mm)		55.2		38.0	47.0
	Sample size (n)		12		11	23
Little North	Mean length (mm)	57.2	74.7	101.5		70.0
	Sample size (n)	6	3	2		11
North MS	Mean length (mm)		96.3			96.3
	Sample size (n)		3			3
3190	Mean length (mm)	55				55.0
	Sample size (n)	1				1
Total, Nome & North R.	Mean length (mm)	57.1	65.9	101.5	45.4	53.7
	Sample size (n)	8	31	2	60	101

Table 7. Ages of juvenile coho salmon captured in Osborn Creek area in 2003. Ages estimated from fish length, based on subsamples of scale-aged fish.

	Osborn Creek		Beaver Pond (on Osborn Creek)		Nome River	
	June	August	June	August	June	August
Number sampled (n)	370	41	37	36	51	32
Age 0 (%)	0%	88%	0%	0%	0%	100%
Age 1 (%)	98%	12%	62%	47%	84%	0%
Age 2 (%)	2%	0%	38%	53%	16%	0%

Table 8. Accessible stream length and predicted smolt production for North and Nome rivers using 3 different models (only 3rd order of higher tributaries are included).

			Total Smolts							
			Model 1			Model 2			Model 3*	
Watershed	Stream order	Accessible stream length (m)	Estimate	Lower 95% CI	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI	Estimate	St. Dev.
North River	5	277,219	419,593	307,392	531,794	350,934	240,390	568,964	182,899	
Nome River	4	83,237	146,098	110,567	181,629	105,370	72,179	170,836	54,917	

Model 1 = Log-linear relation between stream length and smolt density for streams from British Columbia and Southeast Alaska, Bradford et al. (1997).
Model 2 = Median smolt density for streams from British Columbia and Southeast Alaska, Bradford et al. (1997).
Model 3 = 25% quartile of smolt density for streams from British Columbia and Southeast Alaska, Bradford et al. (1997).
*No 95% confidence interval available for the 25th percentile

Table 9. Estimate of the required number of coho spawners needed to produce range of smolts predicted by 3 habitat-based production models.

Watershed	Stream Length (km)	Stream Order	Statistic	Estimated smolt production	[1] Required fry production	[2] Required egg deposition	Female[3] fecundity	Required spawners	Spawners / km
Model 1				fry-smolt = 7.6%	egg-fry = 19.8%				
North River	277	5	Mean	419,593	5,535,524	27,957,193	5335	10,481	38
			Upper 95% CI	531,794	7,015,748	35,433,068	5335	13,283	48
			Lower 95% CI	307,392	4,055,301	20,481,317	5335	7,678	28
Nome River	83	4	Mean	146,098	1,927,417	9,734,429	5335	3,649	44
			Upper 95% CI	181,629	2,396,163	12,101,833	5335	4,537	55
			Lower 95% CI	110,567	1,458,671	7,367,026	5335	2,762	33
Model 2									
North River	277	5	Mean	350,934	4,629,737	23,382,510	5335	8,766	32
			Upper 95% CI	568,964	7,506,121	37,909,704	5335	14,212	51
			Lower 95% CI	240,390	3,171,377	16,017,056	5335	6,005	22
Nome River	83	4	Mean	105,370	1,390,112	7,020,767	5335	2,632	32
			Upper 95% CI	170,836	2,253,767	11,382,661	5335	4,267	51
			Lower 95% CI	72,179	952,229	4,809,236	5335	1,803	22
Model 3									
North River	277	5	Mean	182,899	2,412,915	12,186,437	5335	4,568	16
Nome River	83	4	Mean	54,917	724,495	3,659,066	5335	1,372	16

[1]Assumes a 7.6 % survival rate from fry to smolt (Bradford 1995).
[2]Assumes a 19.8 survival rate from egg to fry (Bradford 1995).
[3]Data from Unalakleet River (Nemeth et al. 2003).

Table 10. Comparison of observed returns of adult coho salmon to the Nome and North Rivers compared to model estimates of the adult coho escapement needed to produce the predicted number of smolts in each river.

River	Model	Predicted	[1] Mean observed	Difference	Over / under (%)
Nome	1	3649	2918	731	25%
	2	2632	2918	-286	-10%
	3	1372	2918	-1546	-53%
North	1	10481	9110	1371	15%
	2	8766	9110	-344	-4%
	3	4568	9110	-4542	-50%

[1]Nome River - based on 2001 and 2002 weir counts

[1]North River - based on 2001 and 2003 tower counts

Table 11. Age composition of Nome and North River adult salmon, 2001-2003[1].

		Age			
Year	River	1.1	2.1	3.1	4.1
2001	Nome	NA	NA	NA	NA
	North	4.3%	82.3%	13.4%	0.0%
2002	Nome	1.4%	80.6%	17.1%	0.7%
	North	12.8%	74.0%	13.1%	0.0%
2003	Nome	14.7%	79.0%	6.3%	0.0%
	North	15.5%	78.4%	6.1%	0.0%

[1]Nome River data are from weir, North River data are from Unalakleet River test fishery.

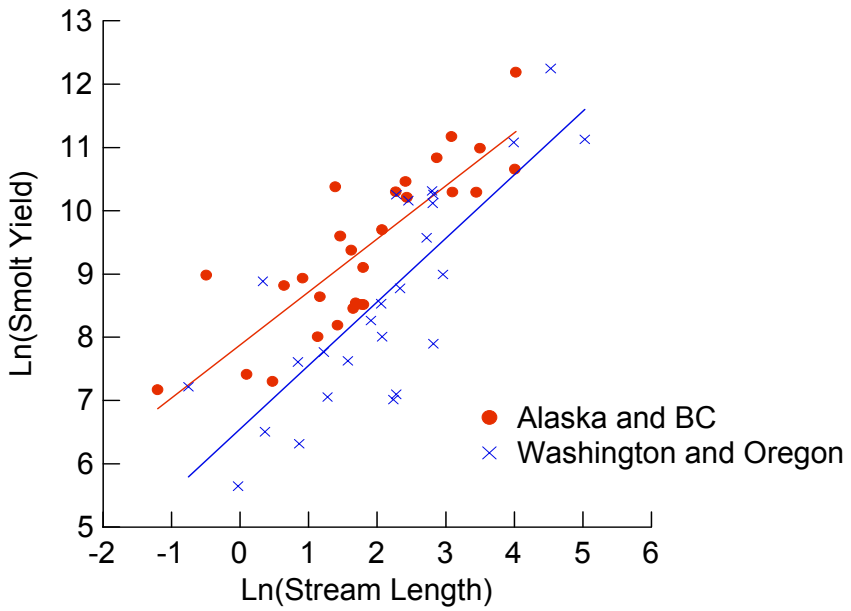


Figure 1. Smolt yield as a function of stream length by geographical group. Data from Bocking and Peacock (2004), using data from Bradford et al. (1997).

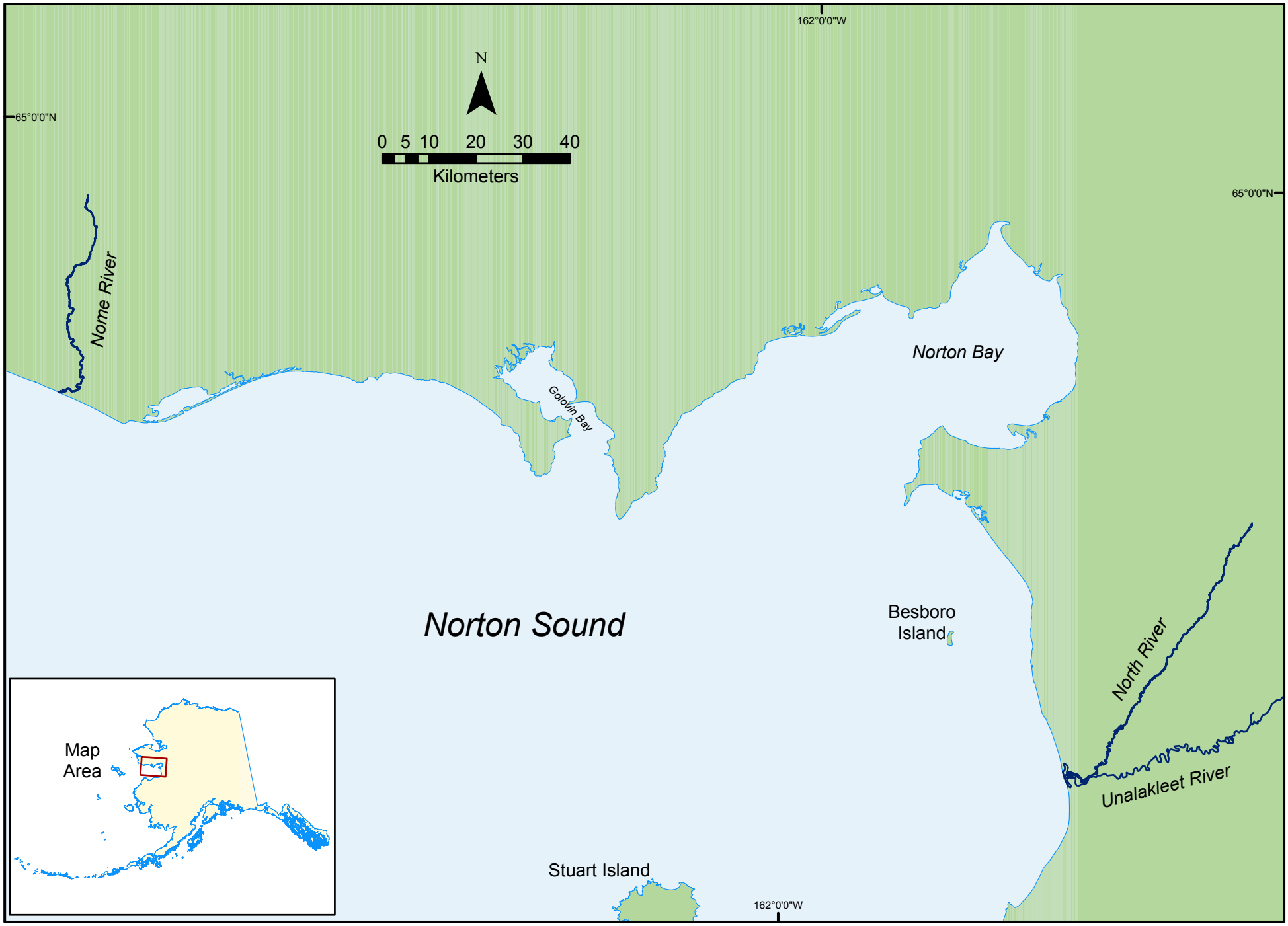


Figure 2. Map of Norton Sound, Alaska, showing the North and Nome rivers.

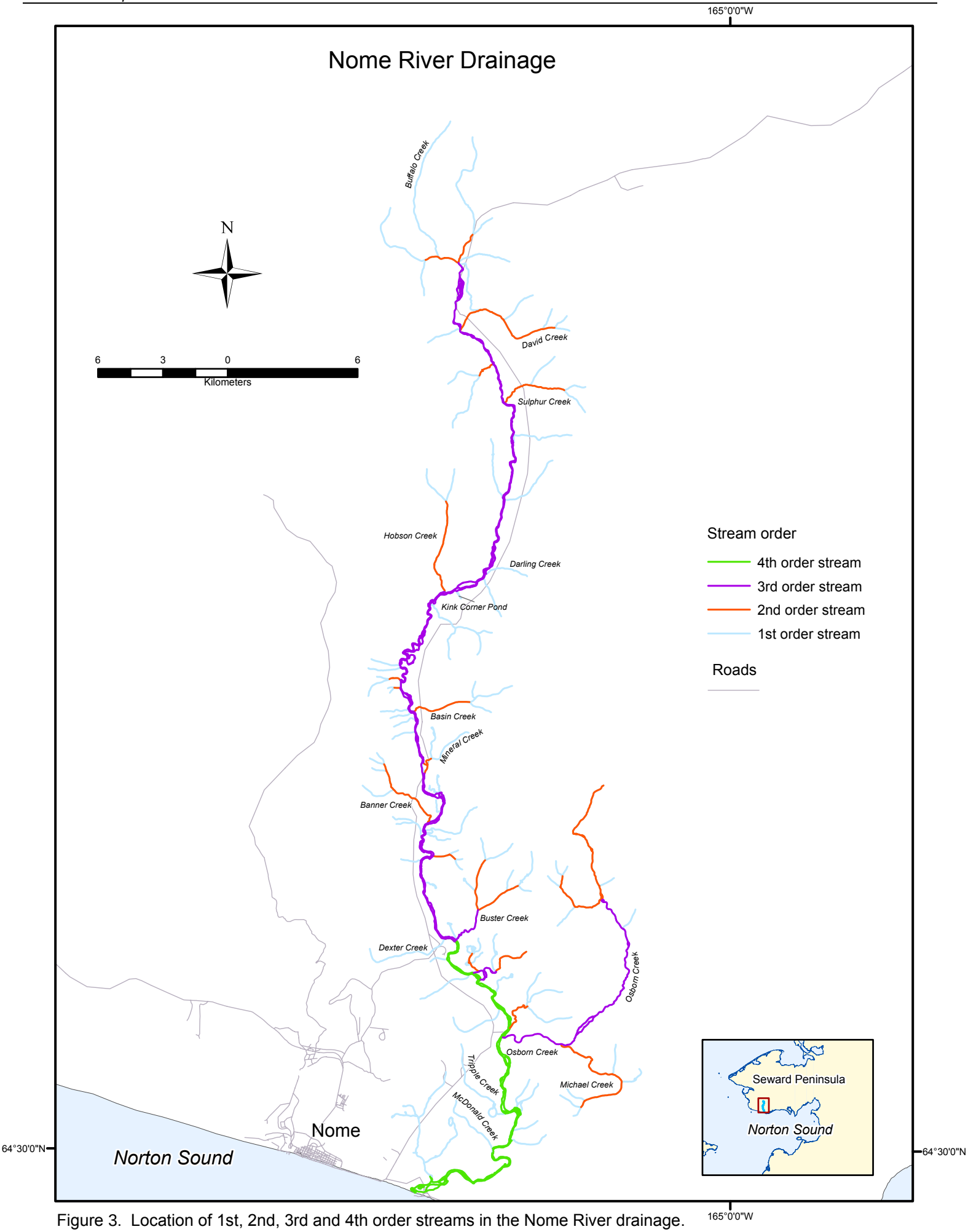


Figure 3. Location of 1st, 2nd, 3rd and 4th order streams in the Nome River drainage.

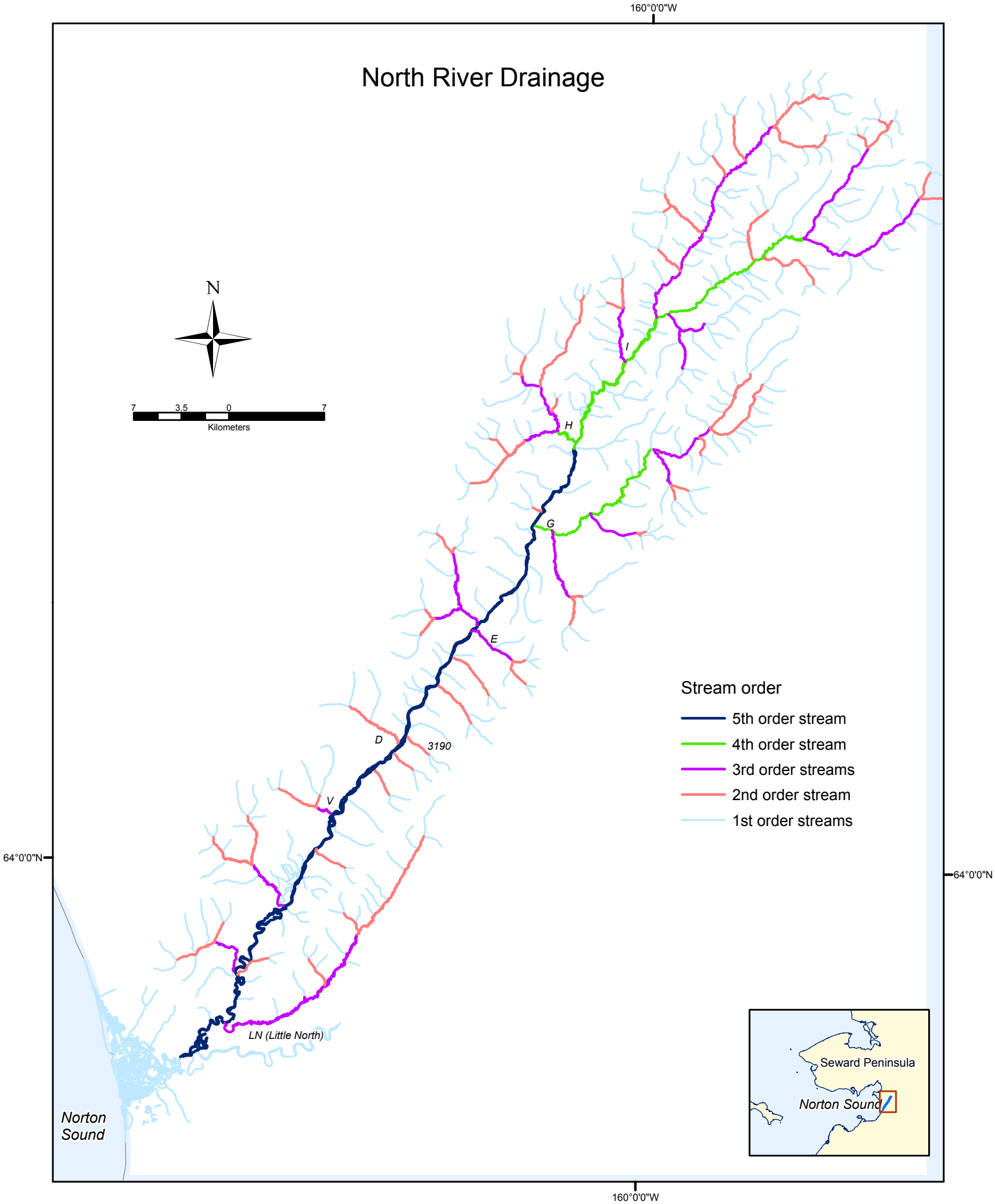


Figure 4. Location of 1st, 2nd, 3rd, 4th and 5th order streams in the North River drainage, 2003.

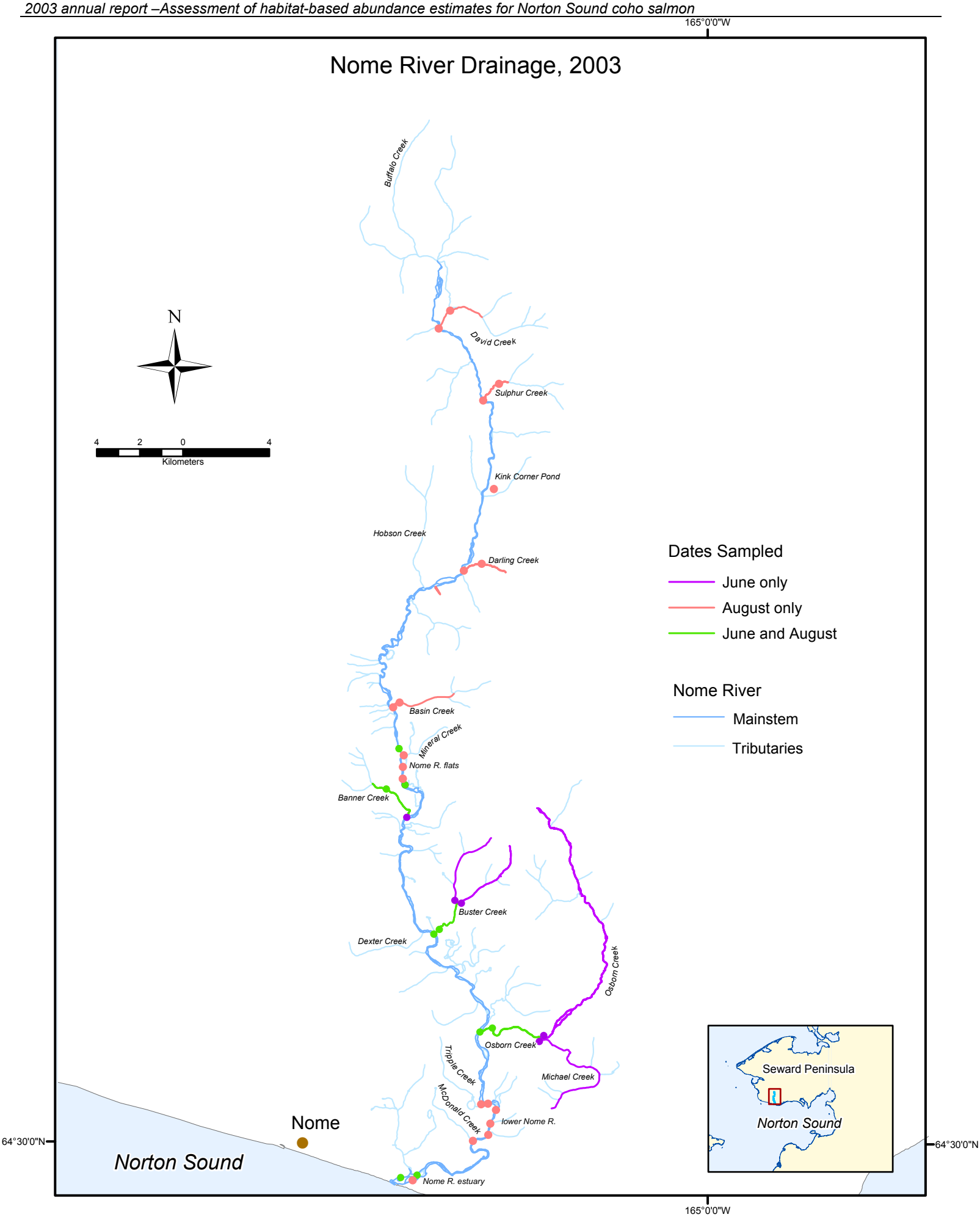


Figure 5. Sampling locations and months in the Nome River drainage, 2003.

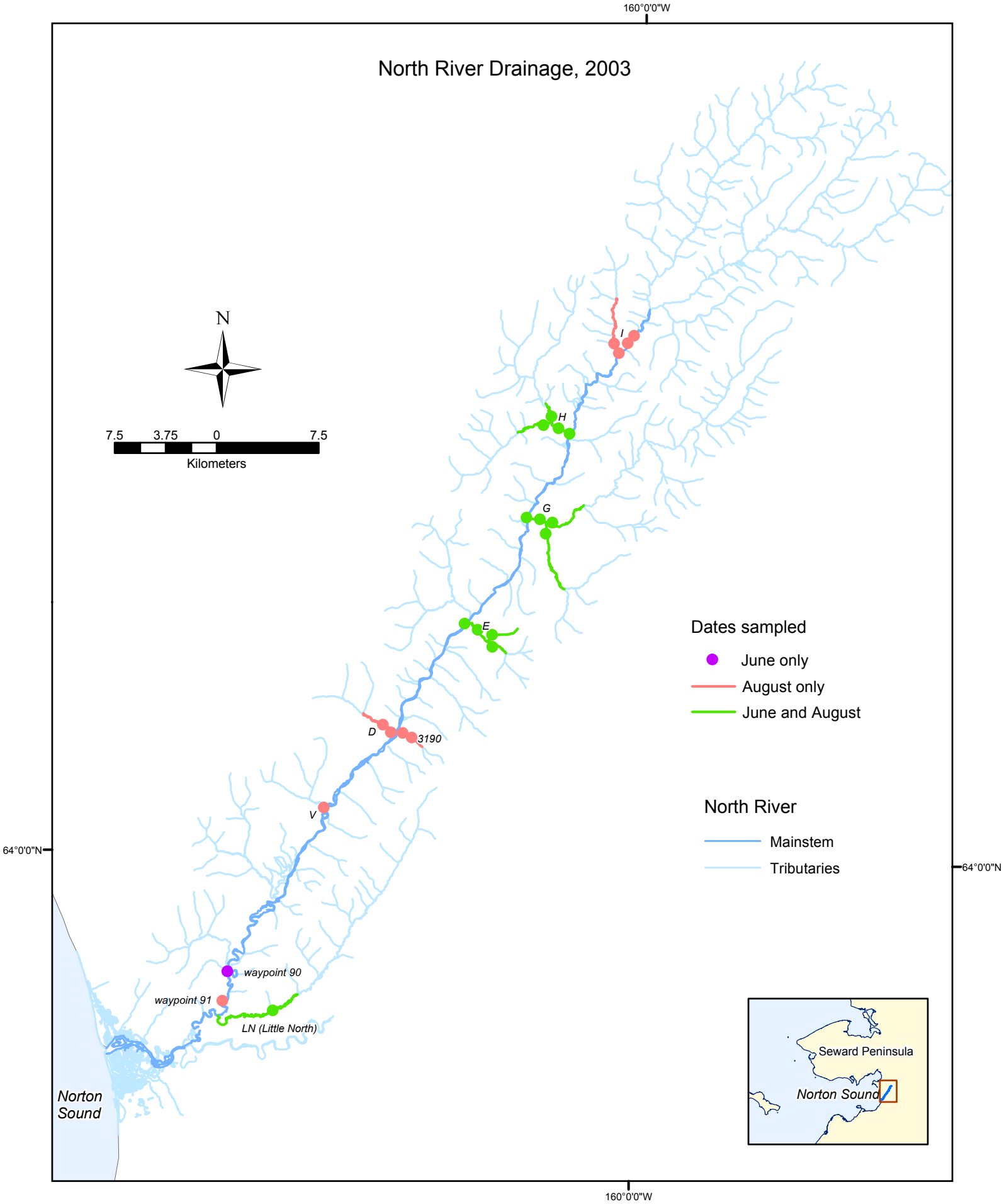


Figure 6. Sampling locations and months in the North River drainage, 2003.

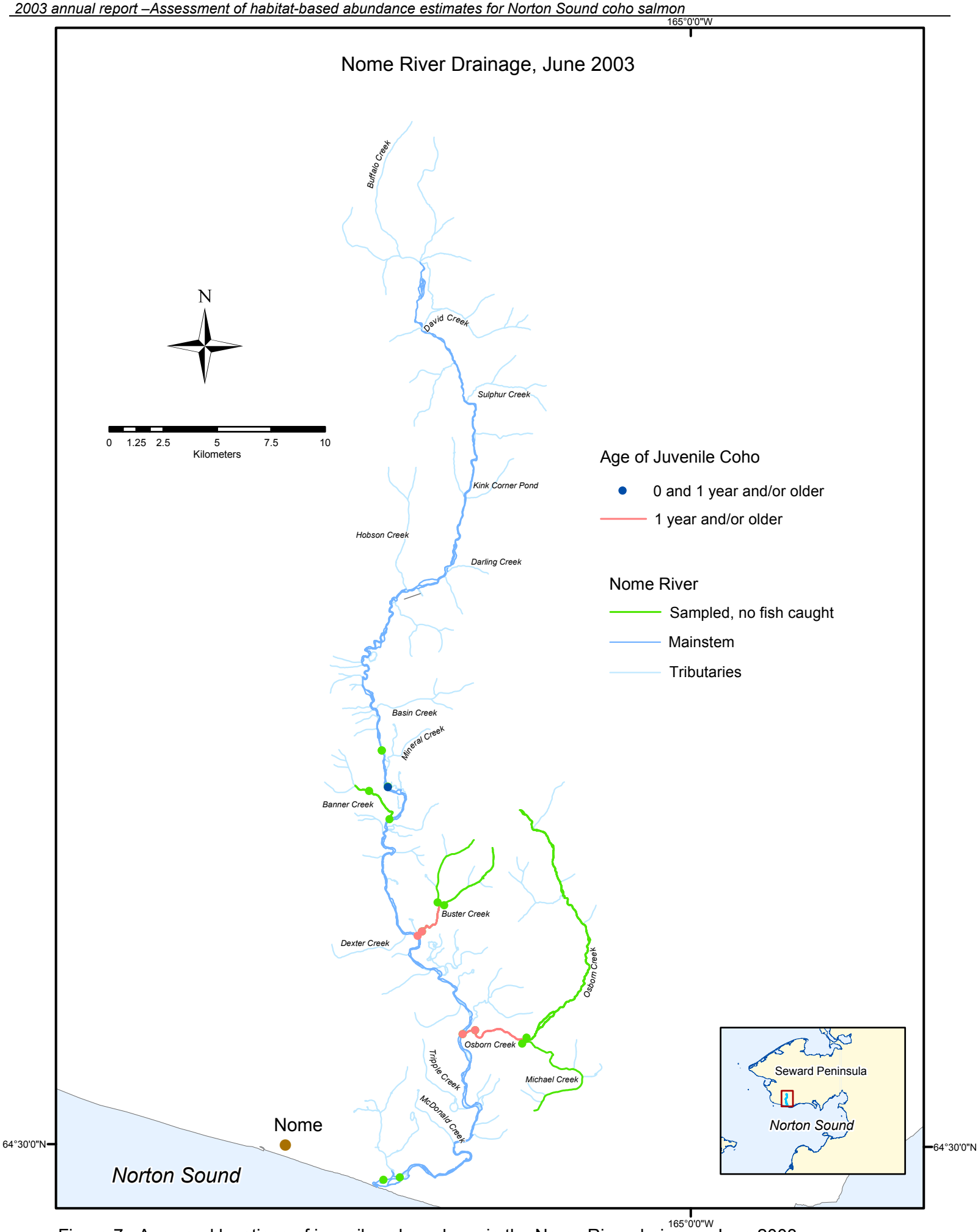


Figure 7. Ages and locations of juvenile coho salmon in the Nome River drainage, June 2003.

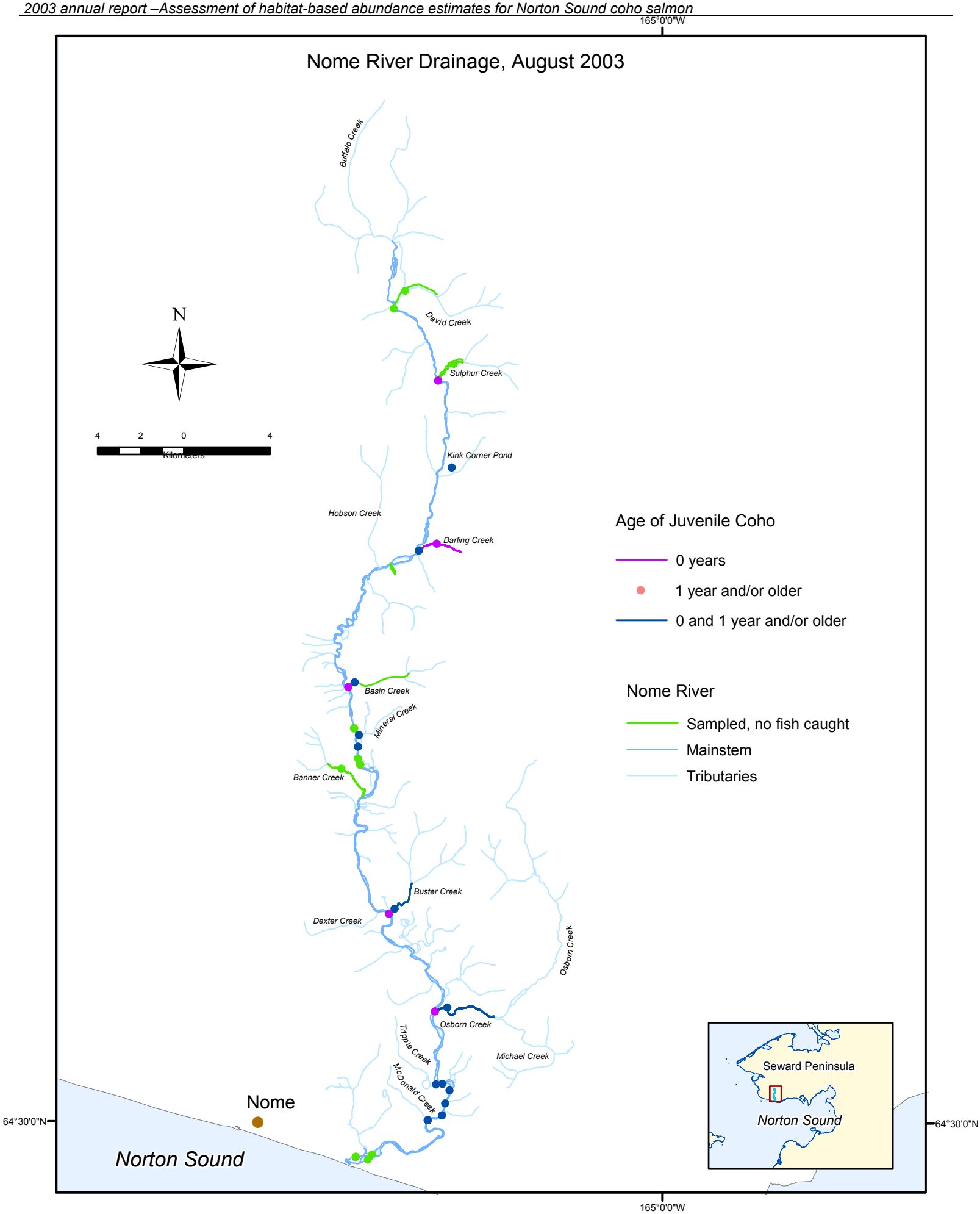


Figure 8. Ages and locations of juvenile coho salmon in the Nome River drainage, August 2003.

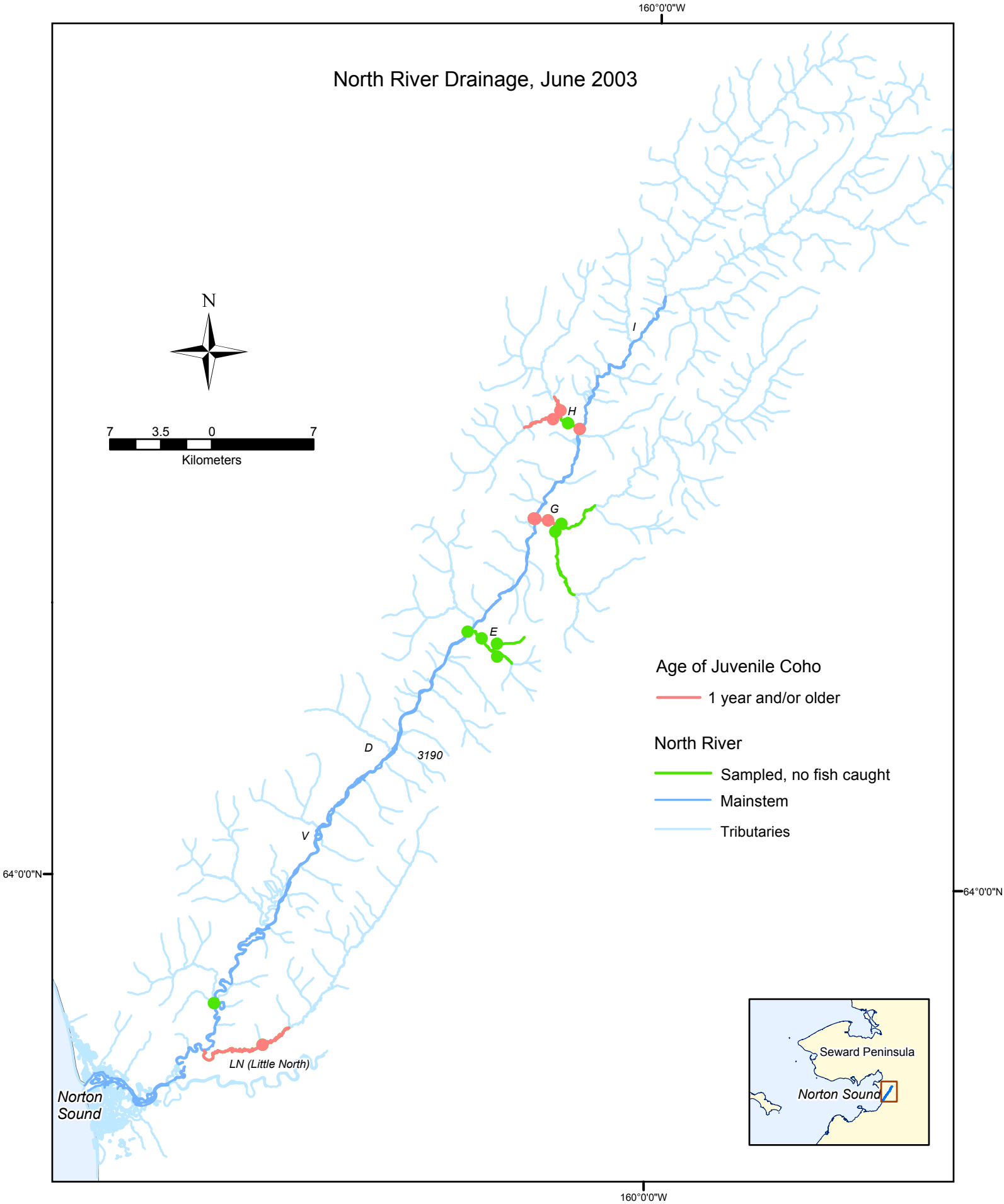


Figure 9. Ages and locations of juvenile coho salmon in the North River drainage, June 2003.

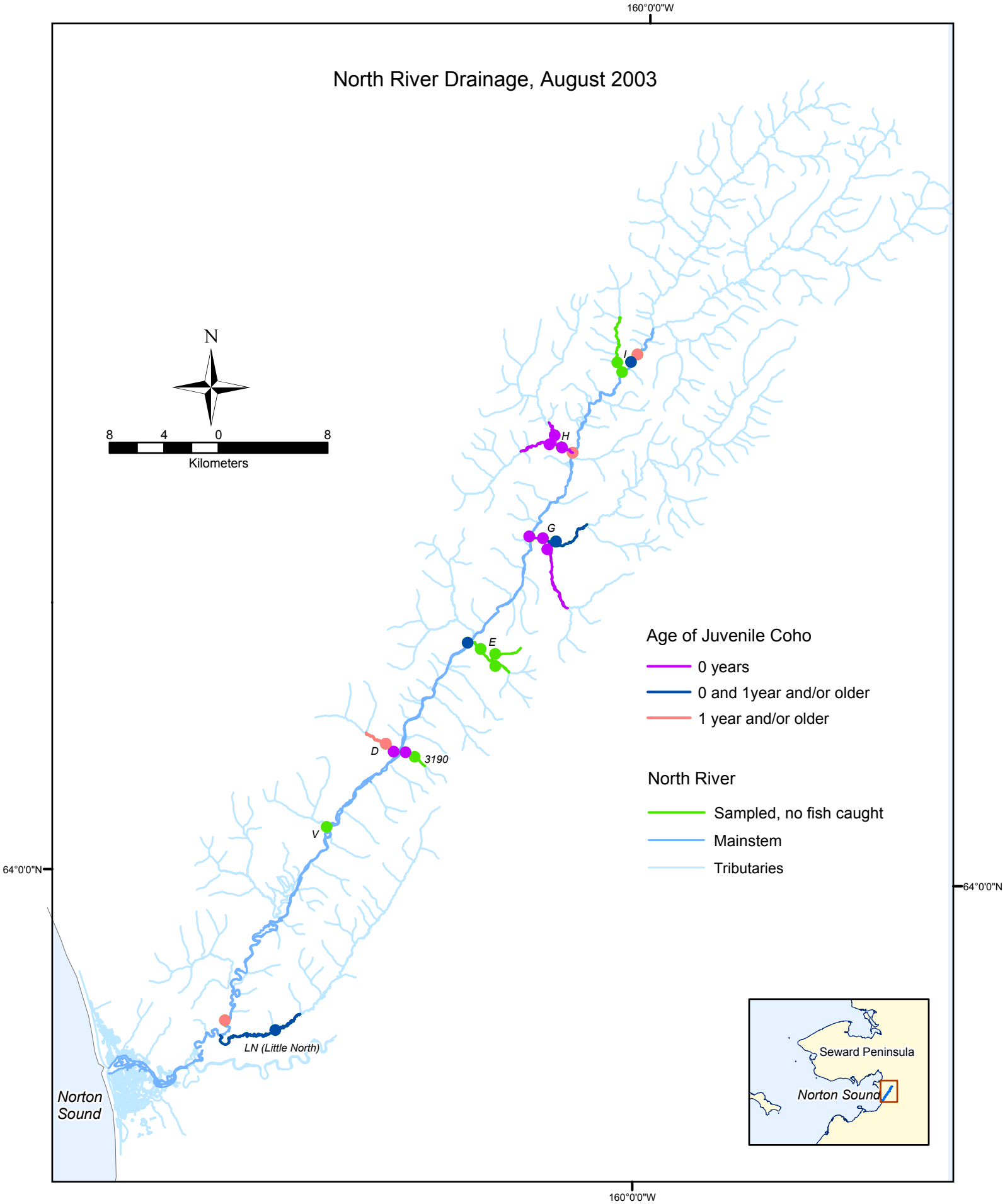


Figure 10. Ages and locations of juvenile coho salmon in the North River drainage, August 2003.

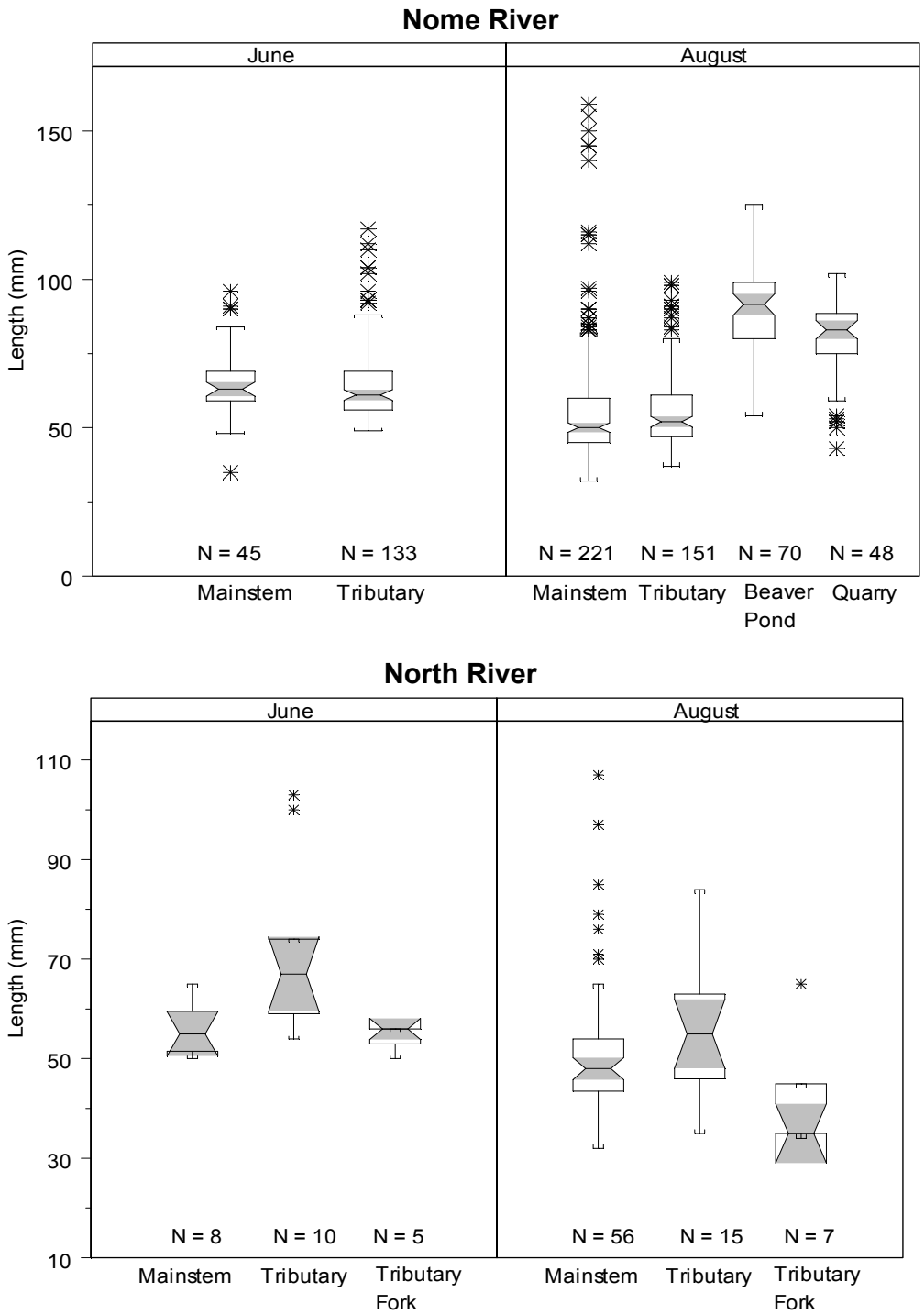
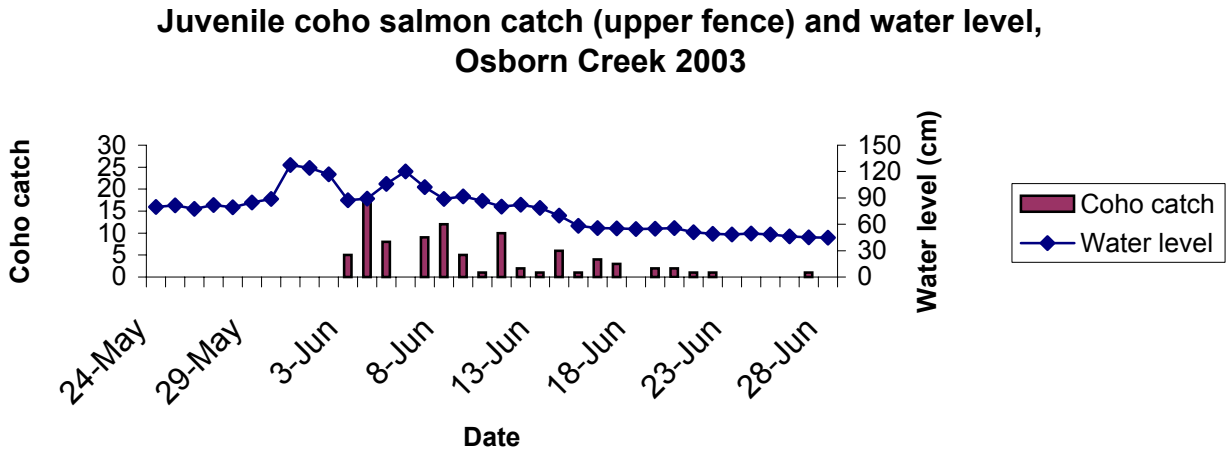


Figure 11. Sizes of juvenile coho salmon by month and habitat type in the Nome and North rivers, 2003. Center horizontal line is sample median, box edges are 1st and 3rd quartiles, whiskers extend 1.5 times the inter-quartile range, shaded areas represent 95% confidence intervals.



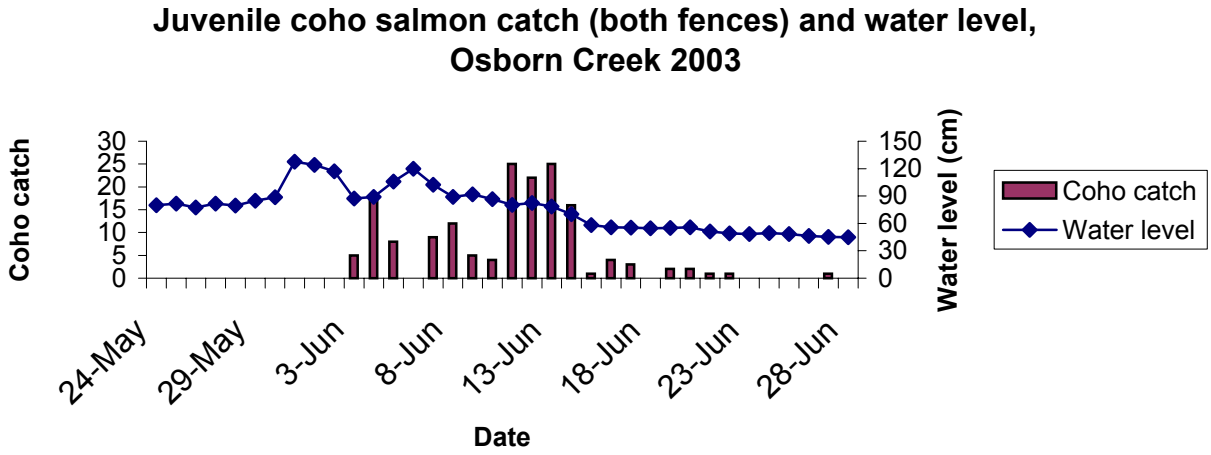


Figure 12. Juvenile coho salmon catch and water level in Osborn Creek for the upper fence (upper panel) and both fences combined (lower panel).

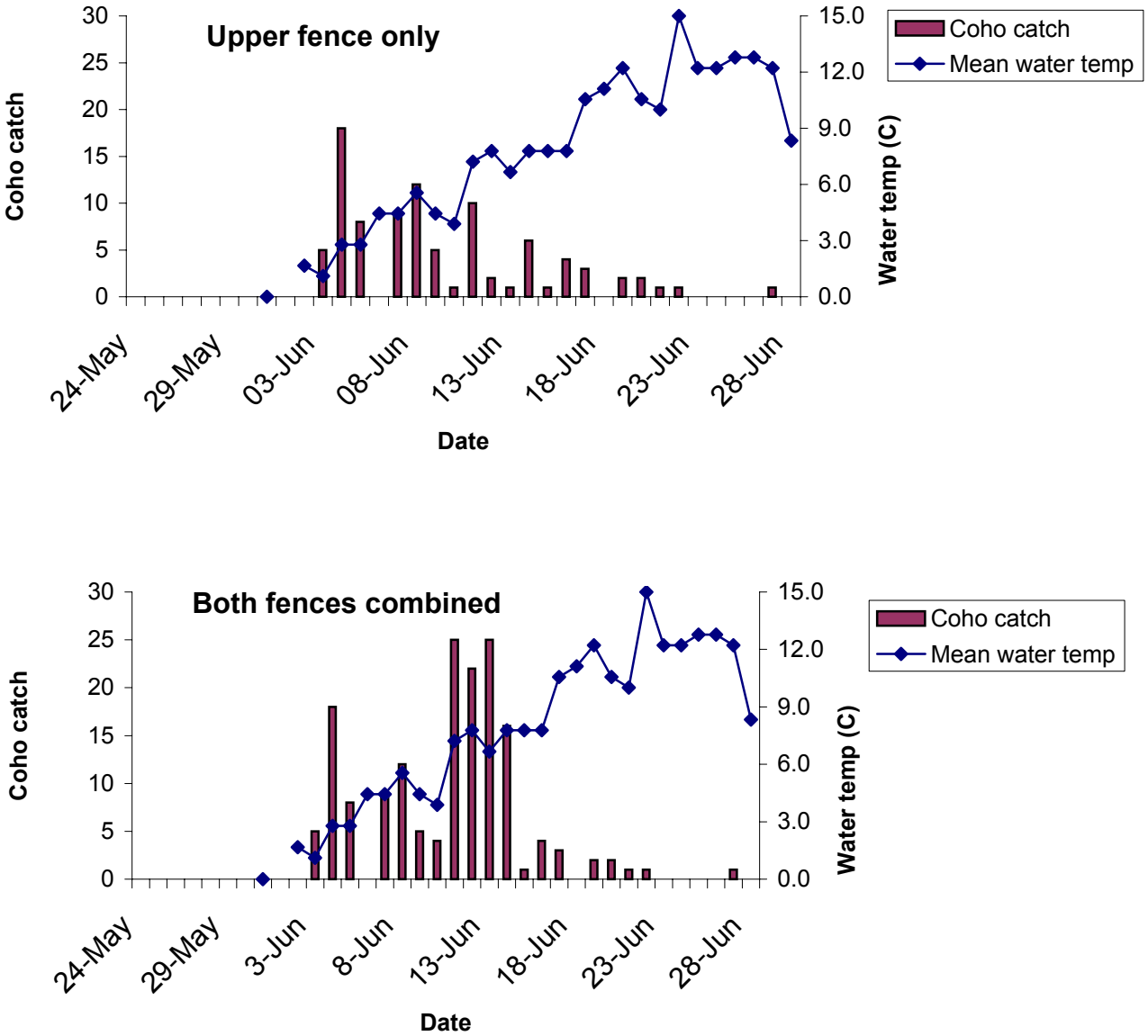


Figure 13. Juvenile coho salmon catch and water temperature in Osborn Creek for the upper fence (upper panel) and both fences combined (lower panel).

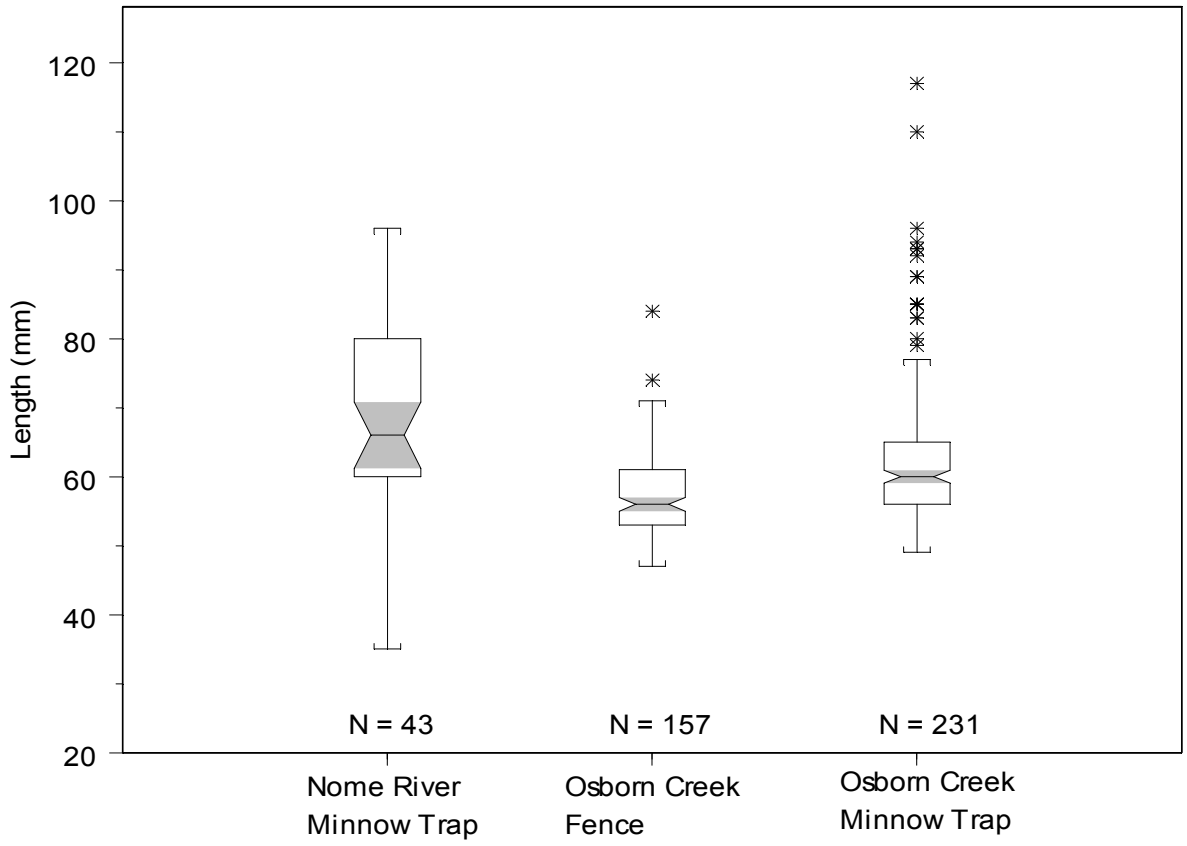
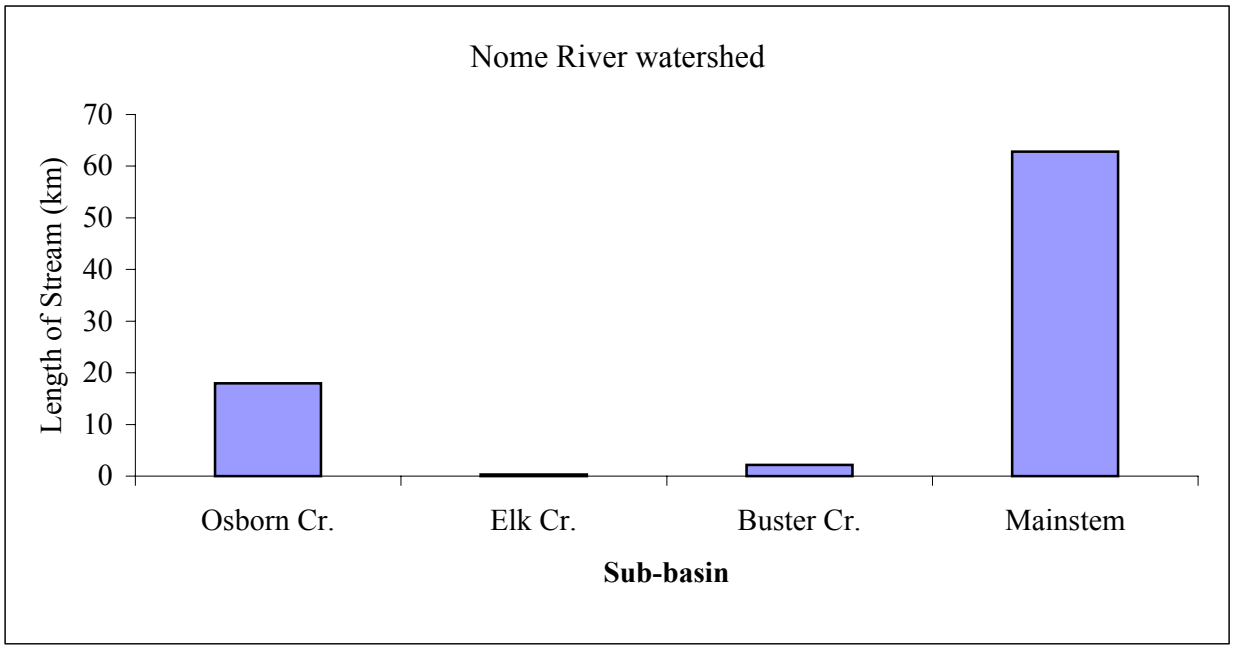


Figure 14. Sizes of juvenile coho salmon by location and gear type in Osborn Creek, June 2003. Center horizontal line is sample median, shaded areas represent 95% confidence intervals, box edges are 1st and 3rd quartiles, and whiskers extend 1.5 times the inter-quartile range.



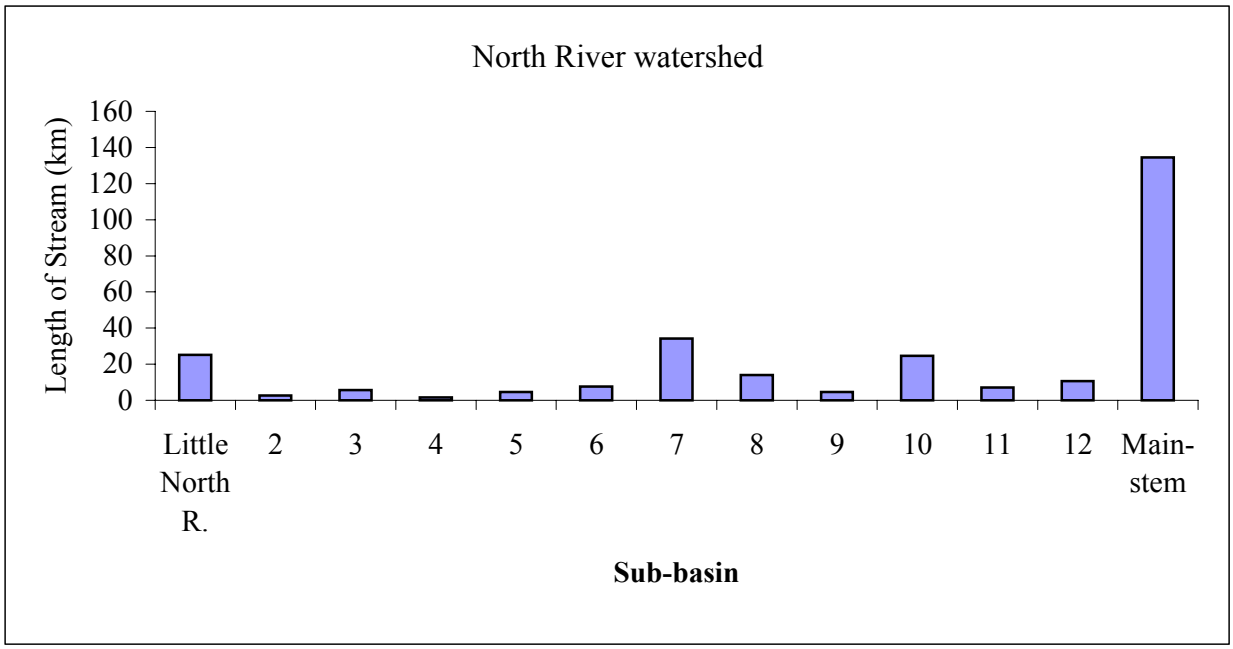


Figure 15. Estimated quantity of coho salmon rearing habitat, by sub-basin, in the Nome and North river watersheds.

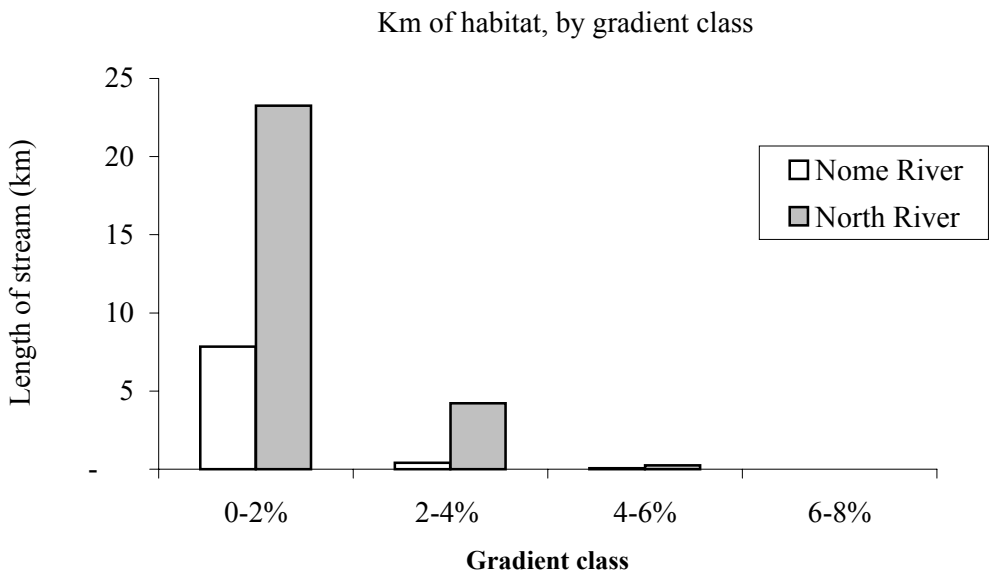


Figure 16. Estimated quantity of habitat available in the Nome and North rivers, classified by gradient category.

Appendix A. Mean annual yield of coho smolts and accessible stream length data, modified from Bradford et al. (1997).

(BC, Alaska, Washington and Oregon streams).

Stream / Side Channel	Latitude	Geographic Region	Years of Data	Accessible Length (km)	Mean Smolt Yield	SD	CV	Yield per km
Porcupine Creek	56 11	SEAK	4	5.2	4,694	915	0.19	903
Sashin Creek	55 23	SEAK	10	1.1	1,654	621	0.38	1,504
Berners River		SEAK	11	55.7	196,283			3,524
Auke Creek		SEAK	21	1.9	6,727			3,541
Hugh Smith Lake		SEAK	17	4.0	32,036			8,009
Toboggan[2]		NBC	10	17.5	50,724	23595	0.47	2,892
Zolzap Creek[3]	55 15	NBC	9	9.7	29,833	15452	0.52	3,088
Lachmach River[1]	54 17	NBC	10	11.4	27,163	12942	0.48	2,383
Hooknose Creek	52 08	NBC	10	5.8	4,987	1,618	0.32	855
Keogh River	50 40	SBC	11	21.8	71,062	15,706	0.22	3,260
Quinsam River	49 59	SBC	5	54.9	42,388	9,353	0.22	772
Tenderfoot Creek	49 55	SBC	3	0.6	7,923	2,546	0.32	12,989
Black Creek	49 52	SBC	10	33.0	59,065	24,314	0.41	1,790
Meighn Creek	49 45	SBC	3	3.2	5,634	2,917	0.52	1,761
Trent River	49 38	SBC	6	7.9	16,255	5,210	0.32	2,052
Chef Creek	49 27	SBC	3	4.3	14,708	3,305	0.22	3,420
Nile Creek	49 25	SBC	9	6.0	4,973	1,381	0.28	823
Hunt's Creek[4]	49 23	SBC	12	5.4	5,110	2,086	0.41	946
Qualicum River	49 23	SBC	15	11.2	34,807	14,659	0.42	3,122
French Creek	49 21	SBC	5	22.1	29,471	10,364	0.35	1,334
Salmon River	49 08	SBC	7	31.3	29,369	11,927	0.41	939
Coghlan Creek	49 07	SBC	7	5.1	11,787	3,222	0.27	2,334
Hopedale Creek	49 06	SBC	3	2.5	7,554	3,590	0.48	3,034
Rust Creek	49 06	SBC	3	0.3	1,295	690	0.53	4,317
Ryder Creek	49 06	SBC	3	4.1	3,590	1,923	0.54	867
Street Creek	49 06	SBC	3	1.6	1,479	326	0.22	924
Salwein Creek	49 06	SBC	4	6.0	8,955	3,169	0.35	1,493
Carnation Creek	48 56	SBC	20	3.1	2,996	905	0.30	966
Little Pilchuck Creek	47 59	WA	13	9.7	28,307	7,069	0.25	2,906
South Fork Skykomi	47 50	WA	5	92.4	208,758	29,278	0.14	2,259
Lost Creek	47 39	WA	9	3.4	2,355	1,278	0.54	697
Wildcat Creek	47 39	WA	9	6.7	3,873	1,553	0.40	576
Christmas Creek	47 39	WA	10	9.3	1,110	762	0.69	119
Big Beef Creek	47 39	WA	12	16.4	30,072	9,530	0.32	1,834
Snahapish Creek	47 39	WA	13	19.2	8,038	3,274	0.41	419
Shale Creek	47 38	WA	11	7.9	3,000	1,439	0.48	380

Appendix A. Mean annual yield of coho smolts and accessible stream length data, modified from Bradford et al. (1997).

(BC, Alaska, Washington and Oregon streams).

Stream / Side Channel	Latitude	Geographic Region	Years of Data	Accessible Length (km)	Mean Smolt Yield	SD	CV	Yield per km
Hurst Creek	47 34	WA	12	7.8	5,050	5,050	1.00	647
Clearwater River	47 33	WA	4	151.7	67,971	16,769	0.25	448
Bear Creek	47 29	WA	10	2.4	552	233	0.42	234
Courtney Creek	47 28	WA	10	3.6	1,156	369	0.32	324
Little Tahuya Creek	47 27	WA	10	1.4	7,208	3,266	0.45	5,186
Mission Creek	47 26	WA	7	15.2	14,307	5,048	0.35	944
Minter Creek	47 22	WA	11	16.7	28,456	7,337	0.26	1,704
Harris Creek	47 21	WA	9	11.6	25,772	7,718	0.30	2,220
Mill Creek	47 12	WA	12	16.5	24,809	7,997	0.32	1,503
Deschutes River	46 57	WA	6	54.0	64,675	25,825	0.40	1,198
Gnat Creek	46 12	OR	5	4.8	2,048	1,041	0.51	427
Spring Creek	45 37	OR	10	0.5	1,360	583	0.43	2,894
Sand Creek	45 17	OR	3	9.7	1,207	133	0.11	124
Fish Creek	45 09	OR	3	16.7	2,689	373	0.14	161
Deer Creek	44 32	OR	15	2.3	2,014	617	0.31	868
Flynn Creek	44 31	OR	14	1.4	667	366	0.55	466
Needle Branch Creek	44 31	OR	14	1.0	283	138	0.49	292
Waddell Creek	37 06	CA	4	10.3	6,445	4,266	0.66	626
SEAK Mean			12.6	13.6			0.29	3,496
NBC Mean			9.8	11.1			0.45	2,305
SBC Mean			6.9	11.8			0.36	2,481
BC Mean			7.4	11.7			0.37	2,451
WA Mean			9.6	24.8			0.41	1,311
OR Mean			9.1	5.2			0.36	747
Overall Mean			8.8	15.4			0.39	1,913

[1] Lachmach mean for smolt years 1991-2000 (source).

[2] Toboggan Creek mean for smolt years 1991-2000 (source).

[3] Zolzap Creek mean for smolt years 1992-2000 (Baxter..)

[4] Length modified according to Myers

Appendix B. Stream lengths (m) predicted to be accessible to coho salmon smolts in North and Nome rivers, stratified by gradient and stream order.

Watershed	Sub-basin	>3rd Order				>4th Order				>5th Order				Side Channels (<2%)			
		<2%	<4%	<6%	<8%	<2%	<4%	<6%	<8%	<2%	<4%	<6%	<8%	<2%	<4%	<6%	<8%
North	1 (Little North R)	25,229	25,229	25,229	25,229	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	2,735	2,735	2,735	-	-	-	-	-	-	-	-	-	-	-	-
	3	4,733	5,679	5,679	5,679	-	-	-	-	-	-	-	-	-	-	-	-
	4	1,596	1,596	1,596	1,596	-	-	-	-	-	-	-	-	-	-	-	-
	5	1,571	4,575	4,575	4,575	-	-	-	-	-	-	-	-	-	-	-	-
	6	3,629	6,482	7,674	7,674	-	-	-	-	-	-	-	-	-	-	-	-
	7	22,100	34,140	34,140	34,140	13,042	14,395	14,395	14,395	-	-	-	-	-	-	-	-
	8	6,246	13,414	14,084	14,084	2,287	2,287	2,287	2,287	-	-	-	-	-	-	-	-
	9	-	4,665	4,665	4,665	-	-	-	-	-	-	-	-	-	-	-	-
	10	21,813	24,563	24,563	24,563	-	-	-	-	-	-	-	-	-	-	-	-
	11	5,609	6,587	7,110	7,110	-	-	-	-	-	-	-	-	-	-	-	-
	12	8,222	10,692	10,692	10,692	-	-	-	-	-	-	-	-	-	-	-	-
	13 (Mainstem North R.)	131,936	134,474	134,474	134,474	122,301	122,301	122,301	122,301	69,782	69,782	69,782	69,782	23,756	23,756	23,756	23,756
	North R. total	232,684	274,832	277,219	277,219	137,630	138,983	138,983	138,983	69,782	69,782	69,782	69,782	23,756	23,756	23,756	23,756
Nome																	
	Osborn Creek	15,845	17,324	17,975	17,975	-	-	-	-	-	-	-	-	-	-	-	-
	Elk Creek	302	302	302	302	-	-	-	-	-	-	-	-	-	-	-	-
	Buster Creek	2,146	2,146	2,146	2,146	-	-	-	-	-	-	-	-	-	-	-	-
	Mainstem Nome R.	60,206	62,814	62,814	62,814	20,684	20,684	20,684	20,684	-	-	-	-	-	-	-	-
	Nome R. total	78,499	82,586	83,237	83,237	20,684	20,684	20,684	20,684	-	-	-	-	-	-	-	-
Totak, Nome & North R.		311,183	357,418	360,456	360,456	158,314	159,667	159,667	159,667	69,782	69,782	69,782	69,782	23,756	23,756	23,756	23,756