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Availability of Juvenile Chinook Salmon to Predators Along the Margins of the Nechako and Stuart Rivers, B. C.

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June 1994

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2245

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178:67

Canadian Manuscript Report of

Fisheries and Aquatic Sciences No. 2245

June 1994

AVAILABILITY OF JUVENILE CHINOOK SALMON TO PREDATORS ALONG THE MARGINS OF THE NECHAKO AND STUART RIVERS, B.C.

by

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Cat. No. Fs 97-4/2245E ISSN 0706-6473

Correct citation for this publication:

Brown, T.G., E. White, D. Kelly, L. Rzen, and J. Rutten. 1994. Availability of juvenile chinook salmon to predators along the margins of the Nechako and Stuart rivers, B.C. Can. MS. Rep. Fish. Aquat. Sci. 2245: 34p.

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ABSTRACT

Brown, T.G., E. White, D. Kelly, L. Rzen, and J. Rutten. 1994. Availability of juvenile chinook salmon to predators along the margins of the Nechako and Stuart rivers, B.C. Can. MS. Rep. Fish. Aquat. Sci. 2245: 34p.

This study was carried out in partial fulfilment of the Department of Fisheries and Oceans commitment to an applied research program examining the impact of reduced flows and altered temperatures on predation of juvenile chinook salmon (*Oncorhynchus tshawytscha*) in the Nechako River. Juvenile chinook salmon; availability (seasonal and diel), size, age structure, distribution and relationship to environmental features was examined during the summer of 1991. Eight study locations along the margins of the Nechako River and two reference locations along the margins of the Stuart River were sampled by 3 m pole-seine, both day and night, for two sampling periods (May-June and Aug-Sept).

The availability of juvenile chinook to predators feeding along the margins of the Nechako and Stuart rivers varied seasonally, diurnally, and spatially. In May-June, juvenile chinook represented 30% of the fish numbers and 20% of the biomass present on the margins of the two rivers. Juvenile chinook estimates declined dramatically from 1.7 chinook/meter during the day in spring to 0.02 chinook/meter during the day in autumn. In May-June, juvenile chinook salmon were more abundant along the river margins of the Lower Nechako River than in either the Stuart or Upper Nechako rivers ($P < 0.05$), more were captured at night than during the day especially in the Upper Nechako River ($P < 0.01$), and those juvenile chinook captured at night were larger than those captured during the day ($P < 0.05$). In spring, the mean length of juvenile chinook salmon was similar to that of the entire fish community utilizing the river margins. We speculate that recently emerged chinook fry (46 mm or 1.0 g) were available to predators feeding along the river margins for only a short 30 to 40 day period in spring and if predators select their prey on the basis of size, chinook fry would not be preferentially selected.

Juvenile chinook salmon in the Lower Nechako River utilized flooded (vegetated) habitat in spring more than exposed sites whereas, in the Upper Nechako River more juveniles utilized the exposed sites compared to the flooded sites ($P < 0.05$). In autumn, more juvenile chinook utilized the exposed sites on both rivers than the vegetated sites ($P < 0.001$). Juvenile chinook salmon shifted from shallow sites in spring ($P < 0.001$) to deeper sites in autumn and appeared to occupy faster water.

RÉSUMÉ

Brown, T.G., E. White, D. Kelly, L. Rzen and J. Rutten. 1994. Availability of juvenile chinook salmon to predators along the margins of the Nechako and Stuart Rivers, B.C. Can. Manus. Rep. Fish. Aquat. Sci. 2245: 34 p.

Cette étude a été effectuée dans le cadre de l'exécution partielle de l'engagement du Ministère des Pêches et des Océans relativement à un programme de recherche appliquée sur les répercussions des faibles niveaux d'eau et des variations de températures sur la prédation des quinnats juvéniles (*Oncorhynchus tshawytscha*) dans la rivière Nechako. Au cours de l'été de 1991, on a examiné la capturabilité (saisonnaière et nycthémérale), la taille, la structure par âge, la répartition et la relation avec l'environnement du stock de saumons quinnats juvéniles. Pendant deux périodes d' échantillonnage (mai et juin, août et septembre), on a prélevé des echantillons au moyen de haveneaux de 3 m, tant le jour que la nuit, en points d'étude le long des berges de la rivière Nechako et deux lieux témoins le long des berges de la rivière Stuart.

Le nombre de quinnats juvéniles exposés aux prédateurs en quête de nourriture le long des berges de la Nechako et de la Stuart variait selon la saison, le moment (de jour ou de nuit) et le lieu. En mai et juin, le quinnat juvénile représentait 30 % des populations de poissons et 20 % de la boimasse présente sur les berges des deux rivières. Le nombre estimatif de quinnats juvéniles a chuté, passant de 1.7 quinnat/mètre durant la journée au printemps à 0.02 quinnat/mètre le jour en automne. En mai et juin, le quinnat juvénile était plus abondant le long des berges du cours inférieur de la rivière Nechako que dans la rivière Stuart ou le cours supérieur de la Nechako ($P < 0.05$), le nombre d'individus capturés était plus élevé la nuit que le jour, spécialement dans le cours supérieur de la rivière Nechako ($P < 0.01$), et les quinnats juvéniles capturés la nuit étaient plus gros que ceux qui étaient capturés la nuit étaient plus gros que ceux qui étaient capturés le jour ($P < 0.05$). Au printemps, la longueur moyenne des quinnats juvéniles correspondait à peu près à celle de poissons d'autres espèces qui fréquentaient les mêmes eaux. Nous supposons que les prédateurs se trouvant près de ces berges pouvaient se nourrir de nouveaux alevins quinnats (46 mm ou 1.0 g) pendant 30 à 40 jours à peine le printemps et que, si les prédateurs choisissaient leurs proies en fonction de la taille, les alevins quinnats n'auraient pas leur préférence.

Les quinnats juvéniles dans le cours inférieur de la rivière Nechako utilisaient plus les zones couvertes de végétation au printemps que les zones exposées, tandis que dans le cours supérieur de la rivière Nechako, on retrouvait plus de quinnats juvéniles dans les sites exposes que dans les zones couvertes ($P < 0.05$). L'automne, un plus grand nombre de quinnats juvéniles fréquentaient, dans les deux rivieres, les sites exposés que les zones couvertes
($P < 0.001$). Le quinnat juvénile a passé des sites peu profonds au printemps ($P < 0.001$) à des sites plus profonds a l'automne, et semblait préférer un courant plus fort.

INTRODUCTION

In respect to the Kemano Completion Project, an agreement was reached between the Federal Government, the Provincial Government, and Alcan Aluminium Ltd. on September 14, 1987. The terms of the agreement included a commitment that the Department of Fisheries and Oceans (DFO), on behalf of the Federal Government would conduct applied research on specific areas of concern. One of the areas of concern involved the impact of reduced flows and altered temperatures on predation and competition of juvenile chinook salmon (*Oncorhynchus tshawytscha*) in the Nechako River. This study was carried out in partial fulfilment of DFO's commitment to that applied research program.

This report summarizes the information on juvenile chinook salmon collected by pole-seine from the Nechako and Stuart rivers during summer 1991. These fish occupied the shallow margins of the two rivers and may have been consumed by birds (Brown et al. 1994) and larger piscivorous fish (Brown et al. 1992). Thus, it was important to determine their seasonal and diel abundance, age structure, distribution, size, and relationship to environmental features. Some of the findings from this report will be incorporated into a companion report (Brown et al. 1994) and used to estimate juvenile chinook consumption by piscivorous birds. Results will also assist in the planning of future studies on predator-prey and competition relationships within the Nechako and Stuart rivers.

METHODS

Juvenile chinook salmon were sampled at eight study locations on the Nechako River and two reference locations on the Stuart River (Figure 1). Age structure, seasonal abundance, size, biomass, diel movement, and relationship to environmental features such as; water depth, water velocity, vegetative cover, and substrate type were examined. The eight locations selected on the Nechako River were spaced from 13 to 34 km apart (mean of 20.5 km) and were representative of the river from Cheslatta Falls to the confluence of the Stuart River. The two locations on the Stuart River were the only ones that were readily accessible. Locations containing habitat improvement structures on the Nechako River (Anon. 1990) or large volumes of woody debris were not sampled during the course of this study. Locations were chosen subjectively based on ease of access, uniformity of shoreline, and general resemblance to river margin habitat within that river reach.

At each location, 4 sites of 25 m each were chosen randomly from approximately 250 m of river margin. The same sites were sampled day and night during both spring and fall. All daylight sampling was conducted in the late afternoon and completed at least 30 minutes prior to sundown and all night sampling was initiated at least 1 hour after sundown and conducted in the dark with the assistance of small battery powered head lamps. Fish sampling was conducted during spring (May-June) and autumn (Aug-Sept) of 1991 on both the Nechako and Stuart rivers. Sampling on the Nechako River in spring was from May 19 to June 25 and in autumn was from Sept 9 to Sept 25. Sampling on the Stuart River in spring was from June 14 to June 27 and in autumn was from Aug 19 to Sept 26. Each site was visited 4 times during the year.

Juvenile chinook salmon and other fish species were captured along the margins of the two rivers through the repetitive passage of a pole-

seine (width of 3 m and 2 mm mesh). All fish captured were removed from the net, anaesthetized with 2-4 phenoxyethanol and the numbers of each species and size (age) group were tallied. Fork-lengths and weights were measured from a representative sample of each species. Species with rare occurrences and all fish longer than approximately 10 cm were measured for length and weight. Fish ages were established from length frequency curves generated for each species of fish. No scales were taken from fish captured in the two rivers.

The number of juvenile chinook at each site was estimated by the removal method (Zippin 1958; Platts et al. 1983). A two person pole-seine was used for 3 passes of equal effort over the same area. Sites were not disturbed for a 15 min interval between passes. Fish were removed from the site and retained in buckets until all measurements from the captured fish for all three passes were completed. Nets were not used to enclose the sites, therefore emigration and immigration could have occurred.

The Zippen method (Zippin 1958) of population estimation is based on a maximum likelihood model for multiple step removal-depletion. The probabilities are reduced to easily used graphs in Platts et al (1983). The estimated probability of capture during a single removal ("P") is described by Platts et al (1983) as "the sum of the products of the number of fish captured during each successive removal and the number of the preceding removal to the total number of fish collected". Values of P were used to compare the relative efficiency of sampling different light conditions and different fish species, ages, and sizes. The greater the value of P the more efficient the capture method for a specific set of conditions.

To estimate biomass we first calculated the mean length of each size grouping (assumed different ages) of each species for each of the 4 sampling occasions from every site. Using length/weight curves generated from our Nechako and Stuart data, we then estimated the weight corresponding to the mean length. Finally, estimated numbers were multiplied by the estimated weight to yield the total weight for each species size grouping. The actual measured weights of larger fish or species with rare occurrences [ie. burbot (*Lota lota*), rainbow trout (*Oncorhynchus mykiss*), or chinook salmon juveniles captured in autumn] were used instead of estimated weights. Therefore, error in calculation of biomass is confined to the smaller sizes of the more numerous species.

The physical dimensions and habitat characteristics of each site were recorded during both the spring and fall sampling periods. All distance and depth measurements were made with a 30 m cloth tape. All sites were 25 m long and width was considered to be the maximum distance from shore sampled with the pole-seine. Sampling was confined to within approximately 4 m of shore (3.8 ± 0.2 m for May-June and 4.2 ± 0.3 m for Aug-Sept) and variation in distance from shore was dependent on site depth and gradient. Surface water velocity was the mean of three estimates of a floating chip of wood's velocity as measured at the maximum distance from shore sampled. Water depth was the mean of four depth measurements taken at the maximum distance from shore sampled with the pole-seine.

The vegetative and substrate characteristics of each site were estimated visually and are subjective. Sites were considered to be vegetated (flooded in spring) when 10% or greater of their surface was covered by either sedge, willow, or grass in spring and 10% or greater of

their surface was covered by a milfoil like plant (possibly *Elodea canadensis*; ECL 1991) in autumn. Substrate types were assigned using the surface visual analysis method (p 14-15, Platts et al. 1983). We assigned a dominate type and a sub-dominant type if no single substrate type covered more than 50% of the surface area. We also combined substrate size classes for silts and clays into one class, which we labelled "mud". The substrate types and the size ranges which we used to define them are; cobble >64 mm, gravel 63.9 mm to 2 mm, sand 1.9 mm to 0.06 mm, mud < 0.06 mm.

RESULTS

1. Pole-Seine Bias

Pole-seining was more effective at night than during the day. In May-June the estimated probability of capture during a single removal was 9% higher than during the day, while in Aug-Sept it was 7% higher (Figure 2). These differences in estimated probability of capture during a single removal produced a small difference in estimates of population size (approximately 5% higher estimates at night in May-June; calculated from Platts et al. 1983).

Pole-seining during the day was more efficient in capturing smaller fish (younger age groupings) then larger fish (older age groupings) however, this difference was not apparent for night pole-seining (Figure 3). There was only a slight difference in effectiveness of capture of the different species (P ranged from 56% to 62%; Figure 4). The species grouping "dace" [a combination of longnose (*Rhinichthys cataractae*) and leopard dace (*R. falcatus*)] had the lowest probability of capture (P = 56%; Figure 4), in spite of being the smallest fish. Therefore, when comparing catch and mean size estimates there is a bias towards higher estimates and larger fish at night.

The estimated probability of capture during a single removal was higher at night for chinook salmon only (Figure 5). In May-June these probabilities ranged from 48% during the day to 61% at night. In Aug-Sept these probabilities ranged from 54% during the day to 65% at night (Figure 5). These differences in estimated probability of capture during a single removal produced a bias towards higher estimates of chinook availability at night (approximately 7% in May-June and 5% in Aug-Sept; calculated from Platts et al. 1983).

The magnitude of bias towards selection of smaller juvenile chinook salmon during the day is unknown however, we speculated that the size selection bias is relatively small within any one sampling period. The size range of juvenile chinook was approximately 25 mm within a sampling period (May-June, 95% between 35 to 60 mm; Aug-Sept, 95% between 80 and 105 mm). We assumed that all chinook within such a narrow size range would have a similar ability to avoid capture.

2. Age Structure

One year old chinook salmon which presumably overwintered in the Nechako River, comprised 0.06% of the total juvenile chinook population utilizing the margins of the two rivers in spring. This estimate is based

on a sample size of 3,293 juvenile chinook salmon captured during May-June of which 621 were measured. All chinook larger than 75 mm were measured and this would have included all chinook we would have considered to be one year old. Only 2 juvenile chinook captured in May-June of 1991, were considered to be 1 year old (based on bimodality within length frequency distribution; see Figure 12 and 14) as they were at least 11 mm longer (87 and 97 mm) then the next largest juvenile chinook (76 mm). This age class division is also supported by the length measurements of juvenile chinook the following autumn. The smallest juvenile chinook captured in September of 1991 was 75 mm in length.

3. Relative Abundance

Juvenile chinook salmon were not the most abundant species captured within the Nechako and Stuart rivers. They represented 11.6% of the catch, estimated number, and biomass for all sampling occasions and sites combined (Figure 6). Northern squawfish (*Ptychocheilus oregonensis*), redside shiners (*Richardsonius balteatus*), suckers (*Catostomus sp.*), and the two dace species were more common than juvenile chinook salmon and represented 81% of the estimated numbers and 70% of the calculated biomass.

The estimated number (Table 1) and estimated biomass (Table 2) of each species, varied both diurnally and between the two sampling periods. Slightly more fish were present during the day (51% of May-June total and 55% of Aug-Sept total) and more biomass was captured at night (70% of May-June total and 73% of Aug-Sept total). More fish (62% of total) and more biomass (73% of total) were present during the Aug-Sept sampling period than in May-June. The nightly movement of older (larger) individuals from deeper water to the shallow margins would account for some of the diurnal differences. The presence of large numbers of small individuals in Aug-Sept (emerged after May-June) would account for some of the numerical differences detected between sampling periods.

The relative availability of juvenile chinook salmon to predators along the margins of the Nechako and Stuart rivers when compared to the total fish community, varied seasonally, diurnally, and spatially (Table 3). A greater relative number and a greater biomass of juvenile chinook utilized the margins of the two rivers in May-June (%N = 30%, %wt = 20%) then in Aug-Sept (%N = 0.4%, %wt = 3.9%). A greater relative number of juvenile chinook utilized the river margins at night (%N = 14%) then during the day (%N = 10%), however the relative juvenile chinook biomass was higher during the day (%wt = 14%) than at night (%wt = 11%). A greater relative number and biomass of juvenile chinook occupied the Lower Nechako River (Fort Fraser to confluence of Stuart River) than either the Upper Nechako River (Cheslatta Falls to Fort Fraser) or Stuart River (Table 3). The highest relative abundance of juvenile chinook occurred in May-June during the night in the Lower Nechako River. The lowest relative abundance was in Aug-Sept during the day in the Upper Nechako River.

The relative numbers and biomass of juvenile chinook salmon was not only dependent upon juvenile chinook movement but also upon movement by the other fish species. In May-June during the day, juvenile chinook salmon were the most abundant species numerically (Table 1), but shiners were on average larger and represented more biomass (Table 2). In May-June during the night, juvenile chinook salmon were the most abundant species

numerically (Table 1) and also represented the greatest biomass (Table 2). However, the older (larger) individuals of other species such as sculpins (*Cottus asper*), whitefish (*Prosopium williamsoni*), northern squawfish, sucker sp., redside shiner, rainbow trout, and dace species also exhibited strong nocturnal movements towards the river margins, resulting in much higher total biomass at night along the margins (Table 2).

4. Seasonal Numbers and Densities

The number of juvenile chinook salmon utilizing the margins of the Nechako and Stuart rivers declined rapidly in late May and early June (Figure 7). Numbers declined from over 5 chinook/m of river margin in mid-May to under 1 chinook/m of river margin in mid-June. Thus, chinook juveniles were abundant and available to predators feeding along the margins of the rivers for 30 to 40 days in spring.

The estimates of juvenile chinook numbers within the two rivers, declined dramatically from May-June to Aug-Sept (ANOVA, $N = 160$, $F = 24.27$, $P < 0.001$). The number of juvenile chinook utilizing the Nechako and Stuart river margins in May-June during the day (1.67 ± 0.71 chinook/m or 0.44 ± 0.19 chinook/m^2) when compared to numbers at night (1.95 ± 0.62 chinook/m or 0.47 ± 0.17 chinook/ m^2) was similar (ANOVA, $N = 80$, $F = 0.107$, $P = 0.744$). Far fewer chinook juveniles utilized the margins of the rivers in Aug-Sept, and those that did, used this habitat at night (0.072 ± 0.030 chinook/m or 0.017 ± 0.007 chinook/m^2) rather than during the day (0.0063 ± 0.0074 chinook/m or 0.0017 ± 0.0020 chinook/m^2; ANOVA, $N = 80$, $F = 19.770$, $P < .001$).

5. Distribution

There was no apparent relationship between numbers of juvenile chinook caught at each of the 10 locations during the two sample periods (Table 4). Water levels during May-June were much higher than during Aug-Sept (Figure 8; data from Water Survey of Canada, 1991). On the Nechako river 16 of 32 sites contained flooded terrestrial vegetation during spring. At low gradient sites, the shoreline receded as much as 20 m by Sept and the habitats were very different. The three locations where the most juvenile chinook were caught in the spring (14 km, 92 km, and 116 km; Figure 9) were not the locations where the most juvenile chinook were caught in autumn (46 km, 137 km, and 11 km Stuart; Figure 10).

Juvenile chinook in different regions of the rivers had different diel behaviour. In Aug-Sept, significantly more juvenile chinook utilized the 40 sites during the night than during the day (paired t-test, $t = -3.603$, $P < 0.001$; see Figure 10), while in May-June overall diel utilization was similar (paired t-test, $t = -0.600$, $P = 0.552$; see Figure 9). Although in May-June no differences in diel utilization of all the sites on the two rivers was apparent, differences were apparent for the river regions (Figure 11). In May-June, significantly more juvenile chinook were captured at night in the upper 16 sites on the Nechako than during the day (paired t-test, $t = -3.383$, $P < 0.01$), while similar numbers were captured at night and day from the Lower Nechako, (paired t-test, $t = 0.280$, $P = 0.793$) and less juvenile chinook were captured at night on the 8 Stuart River sites (paired t-test, $t = 1.761$, $P = .122$) although not

significantly less.

The differences in diurnal and seasonal juvenile chinook estimates for the Upper Nechako, Lower Nechako and Stuart rivers are summarized in Figure 11. Chinook were more abundant in the Lower Nechako than in either the Stuart or Upper Nechako (ANOVA, $N = 160$, $F = 3.869$, $P < 0.05$). There was also a significant interaction between season and location (ANOVA, $N = 160$, $F = 3.826$, $P < .05$). Juvenile chinook were more abundant at the 16 Lower Nechako River sites in May-June, while juvenile chinook were more abundant at the 8 Stuart River sites in Aug-Sept.

6. Size

Juvenile chinook length frequency distribution was similar to that of the fish community residing along the river margins in May-June (Figure 12). The length frequency distribution for chinook juveniles and for the entire fish community are markedly skewed with numbers declined rapidly at a fork-length of approximately 52 mm. The peak in length frequency between 20 and 50 mm is represented by fish which had emerged in summer 1990 (ie. dace, suckers, redside shiners, northern squawfish, and sculpins; Scott and Crossman 1973) as well as fish which had emerged in early spring 1991 (chinook salmon and whitefish; Scott and Crossman 1973). In May-June, the 621 measured juvenile chinook salmon had a mean fork-length of 46.0 ± 0.5 mm (weighing approximately 1.0 g), compared to a mean fork-length of 47.3 ± 0.6 mm for the entire fish population.

Juvenile chinook fork-lengths were to the extreme right of the length frequency distribution of the entire fish community residing along the margins of the Nechako and Stuart rivers in Aug-Sept (Figure 13). The 74 juvenile chinook captured had a mean fork-length of 88.1 ± 1.8 mm (approximately 7.5 g), compared to a mean fork-length of 45.7 ± 0.6 mm for the entire fish community. The large number of fish within the size range of approximately 20 to 40 mm (Figure 13), were represented by species such as; dace, suckers, redside shiners, northern squawfish and sculpins which emerged in summer, 1991 (Scott and Crossman 1973).

In May-June, juvenile chinook captured at the various locations along the river margins at night were significantly larger than those captured during the day (paired t-test, $t = -3.763$, $P < 0.05$). This diurnal difference in fork-length frequency (Figure 14), may be due to the immigration of larger juvenile chinook onto the river margins at night. Some of the diurnal difference in fork-length distribution may also be due to bias in capture method (Figure 6).

The mean length of juvenile chinook captured during the day was similar for the Upper Nechako, Lower Nechako, and Stuart rivers within each sample period (Figure 15). All three regions exhibited the same diurnal fork-length dichotomy, however the magnitude of the difference was not as great for the Stuart River (Figure 15). The lower magnitude of difference noted for the Stuart River may be an artifact of a small sample size and slightly earlier sampling time in autumn, or due to differences in habitat conditions, as the Stuart River appeared more turbid.

7. Relationship to Environmental Factors

Study sites were not determined on the basis of their habitat

features. Thus, experimental designs were very unbalanced. In the Stuart River, 7/8 sites were similar during both spring and autumn periods (mud bottom, emergent vegetation, and similar flow) and juvenile chinook abundance could not be correlated to different habitat types for that river. Also, few juvenile chinook (n = 76) were captured during Aug-Sept and analysis for this sampling period was difficult. We could however, compare juvenile chinook estimates in the Nechako River to; vegetative characteristics, water depth, surface water velocity, and substrate size.

a) Vegetative features

Water levels on the Nechako River were much higher in May-June than during September (Figure 8). Wetted perimeters at some sites receded as much as 20 meters, greatly altering the habitat features of the river margins. On the Nechako River, 16/32 sites were flooded into the succesional terrestrial vegetation during spring sampling. The 16 flooded sites (> 10% vegetation dominated by grasses, sedges, and small willows) were distributed evenly between the Upper and Lower Nechako River. In Sept, 8 sites exhibited dense beds of aquatic vegetation (possibly *Elodea canadensis*; ECL 1991), while 24 sites were considered to be exposed, without vegetation.

In spring, juvenile chinook salmon utilized both vegetated and exposed Nechako River shoreline habitat. More juvenile chinook salmon utilized the 16 vegetated sites than the 16 exposed sites, but this finding was not significant for the river as a whole (ANOVA, N = 64, F = 3.687, P = 0.060; see Figure 16). Differences in diel use of margin habitat has previously been noted, however comparison of diel use of vegetated versus exposed sites was not conclusive. More juvenile chinook utilized the 16 vegetated sites at night and during the day when compared to the 16 exposed sites under similar light conditions (Figure 16).

Differences in use of Upper and Lower Nechako River margin habitat were reported earlier and differences in use of vegetated versus exposed sites within the two river sections were apparent (ANOVA, N = 64, F = 4.408, P < 0.05). Within the Lower Nechako River more juvenile chinook utilized the 8 vegetated sites when compared to the 8 exposed sites for both day and night (Figure 16). However, this trend was reversed for the Upper Nechako River at night, where more juvenile chinook utilized the 8 exposed sites compared to the 8 vegetated sites. In autumn, more juvenile chinook utilized the exposed sites on both rivers compared to the vegetated sites (ANOVA, N = 80, F = 12.618, P < 0.001). During September, all 51 of the juvenile chinook salmon netted within the Nechako River were obtained from the 24 exposed sites, while no juvenile chinook were captured within the 8 sites containing dense beds of emergent vegetation. In the Stuart River 10 of the 25 juvenile chinook captured in Aug-Sept were from the single exposed site that was sampled.

b) Depth

Juvenile chinook shifted from occupying the shallowest sites in spring to deeper sites in autumn. In spring, juvenile chinook heavily utilized the 7 shallowest sites sampled on the Nechako River (independent t-test, P < .001) and were equally abundant during the day and night

(Figure 17, top). In autumn, deeper habitat was occupied (Figure 17, bottom). The 6 juvenile chinook captured during the day in autumn were taken from water over 0.5 meters in depth. These results are consistent with results reported by the Nechako River Project (1987) which noted that juvenile chinook occupied progressively deeper habitat through the season.

c) Surface Water Velocity

Juvenile chinook shifted to higher velocity habitat as the season progressed. In spring, juvenile chinook were most abundant at sites with an average surface flow of between 0.2 and 0.5 meters/sec (Figure 18, top). Also, there was a tendency for more fish to be present during the day in faster water (10 sites > 0.3 m/sec; independent t-test, $P = .08$) and to occupy slower water at night (22 sites < 0.3 m/sec; independent t-test, $P = .11$) however, these differences were not significant. In autumn, the sites with the highest water velocities (13 sites > 0.4 m/sec; independent t-test, $P = .11$) had a slightly greater abundance of juvenile chinook, but not significantly greater (Figure 18, bottom).

d) Substrate

During both May-June (Figure 19) and Aug-Sept (Figure 20), juvenile chinook were more abundant at sites with coarser substrate, but results were not significant. In spring the 16 sites with the coarsest substrate contained 66.4% of the estimated juvenile chinook (> gravel; independent t-test, $P = .11$) and in autumn the 17 sites with the coarsest substrate contained 90.2% of the estimated juvenile chinook (> gravel; independent t-test, $P = .11$). We did not examine the relationships between fish abundance and multiple environmental factors. Thus, we are uncertain if the abundance of juvenile chinook was directly related to the type of substrate or if they were simply attracted to habitat which had environmental features that are associated with this substrate (ie. higher velocity water).

DISCUSSION

Recently emerged, juvenile chinook salmon were abundant (1.8 chinook/meter) along the flooded margins of the Nechako and Stuart rivers during May-June. Lister et al. (1981) reported higher juvenile chinook abundance along the margins of Stuart River (4.2 chinook/meter; May 11 to June 14, 1980) however, they used a beach-seine capable of sampling more area and deeper water. Other studies within the Nechako River (Nechako River Project 1987; Russell et al. 1983) used catch per unit of effort estimations and their results are not comparable to ours.

The dramatic seasonal decline in abundance of juvenile chinook salmon along the margins of the two rivers that we observed was similar to that reported by these earlier studies (Lister et al. 1981; Russell et al. 1983; Nechako River Project 1987). The lack of juvenile chinook salmon along the margins of the two rivers later in the season does not prove they had emigrated from the river. Our capture method was only capable of sampling the river margins and not the deeper water located near the river thalweg. It is suspected that as their size increased the juvenile chinook moved

further away from the river margins (Nechako River Project 1987).

No clear explanation for differences in diurnal and seasonal juvenile chinook estimates for the Upper Nechako, Lower Nechako and Stuart rivers is apparent. Juvenile chinook captured at night were larger than those captured during the day and were more abundant in the Lower Nechako River than in the Upper Nechako River. In the Upper Nechako River juvenile chinook were significantly more abundant at night and significantly more abundant within exposed habitat. Within the Lower Nechako River significantly more juvenile chinook utilized flooded vegetation along the river margins, however there was no apparent difference in diurnal abundance.

In 1981, Russell et al. (1983) reported peak downstream movements of juvenile chinook occurred during, the 3rd week of April at Cutoff Creek, the 3rd week of June at Diamond Island, and the 1st week of July at Prince George. In the Stuart River peak downstream migration of under-yearling chinook salmon for 1980 was in mid-May (Lister et al. 1981). It is likely that by May-June of 1991, many of the juvenile chinook salmon had emigrated from the Upper Nechako River. This would account for the larger population estimates determined along the margins of the Lower Nechako River. It is also possible that differences in habitat (water clarity, velocity, and substrate) or differences in abundance of predators (birds and fish) between the Upper and Lower Nechako River may have accounted for some of the diel differences in utilization of river margins.

The flooded vegetation along the shoreline of the Lower Nechako River may have provided a refuge from predation or possibly a better source of food. We suspected that juvenile chinook occupying flooded habitat during the day and night would have received some protection from both avian and fish predators. They would have been protected from larger fish predators by the shallowness of the habitat and protected from bird predators during the day by the cover provided by the flooded vegetation. The utilization of shallow exposed sites at night within the Upper Nechako River would have provided protection from piscivorous fish. The movement into deeper water during the day by Upper Nechako River chinook would have reduced bird predation, while possibly increasing predation by piscivorous fish. We also suspected food acquisition patterns may have been involved, but the diurnal feeding habitats of juvenile chinook were not examined during the course of this study.

Juvenile chinook salmon which utilized the margins of the Nechako and Stuart rivers would have been preyed upon by both avian and fish predators (Gotceitas and Godin, 1993). They would have been most vulnerable to avian predators during the day and the largest fish residing along the shallow river margins would be selected by those predators (White 1953; Wood and Hand 1985; Slayer and Lager 1940). It would be advantageous to larger fish of all species to reside in deeper water during the day. Larger piscivorous fish such as rainbow trout, northern squawfish, and bull trout (*Salvelinus confluences*) which prey upon juvenile chinook within the Nechako River (Brown et al. 1992; Stallard 1992) would occupy deeper water during the day to avoid an increased risk of predation by birds. Therefore, it would be a survival advantage for small juvenile chinook fry to remain within shallow water during the day in spring. In May-June 1991, juvenile chinook salmon represented 30% of the fish numbers and 20% of the fish biomass utilizing river margin habitat. The small chinook fry (46 mm

or approximately 1.0 g) would have been available to avian predators feeding along the river margins during the day (mergansers and kingfishers; Brown et al. 1994) for only a 30 to 40 day period in early spring. Their fork-length distribution was similar to that of the total fish community occupying the river margins, thus it is unlikely that they would have been preferentially selected by piscivorous birds and fish because of their size (Brown et al. 1994).

By Aug-Sept, the larger juvenile chinook salmon (88 mm or approximately 7.5 g), occupied faster and deeper water; seemed to prefer exposed coarse substrate over weed-beds; and were more abundant during the night than during the day. At this time they were larger than the other members of the fish community which occupied the river margins and we suspect avian predators would have preferentially selected juvenile chinook, based on size, if they had utilized margin habitat during the day. A fish's ability to avoid larger piscivorous fish increases as the fish grows (salmonid sprint speed in the order of 9-12 * body length/sec; Webb 1975). Thus, as the juvenile chinook salmon grew the survival advantage of residing within shallow water during the day would decrease due to increased risk of predation and their ability to survive and maintain themselves in deeper and faster water would increase.

The apparent differences in catch effectiveness of pole-seining relative to light conditions indicates that all fish were able to avoid the pole-seine more easily during the day then at night. Also, the larger fish eluded the pole-seine better during the day than the smaller fish. We suspect that bias in our method of capturing juvenile chinook salmon (pole-seining), may have led to under-estimation of day-time population estimates compared to night estimates, under-estimation of day-time mean fork-lengths compared to night-time mean fork-lengths, and under-estimation of autumn population estimates compared to spring estimates. However, this bias would not account for all of the diurnal and seasonal differences in numbers and size we recorded.

ACKNOWLEDGMENTS

We would like to thank D. Duff for assistance in data collection and T.J. Brown for drafting the map used in this publication. We would also like to thank G. Faulkner, G.H. Hartman, C.V. Levings, C. Shirvel, and B. Riddell for reviewing this manuscript.

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Table 1. Estimated number of each fish species captured by pole-seine along the margins of the Nechako and Stuart rivers during 1991.

Common Name	Scientific Name	Estimated number/km			
		May - June		Aug - Sept	
		Day	Night	Day	Night
Burbot	*Lota lota*	0	2	3	1
Chinook	*Oncorhynchus tshawytscha*	1671	1950	6	70
Peamouth chub	*Mylocheilus caurinus*	96	16	5	0
Longnose dace	*Rhinichthys cataractae*	539	861	420	762
Leopard dace	*Rhinichthys falcatus*	929	702	1879	1092
Rainbow trout	*Oncorhynchus mykiss*	3	7	0	2
Sculpin	*Cottus asper*	153	458	363	484
Redside shiner	*Richardsonius balteatus*	1183	668	2535	2297
Sockeye	*Oncorhynchus nerka*	83	30	0	0
Northern squawfish	*Ptychocheilus oregonensis*	631	485	4323	1835
Suckers	*Catostomus sp.*	507	483	1498	2192
Unidentified		4	6	0	0
Whitefish	*Prosopium williamsoni*	403	213	1	143
Totals		6202	5881	11033	8878

Table 2. Estimated biomass of each fish species captured by pole-seine along the margins of the Nechako and Stuart rivers during 1991.

Species	Biomass (g/km)			
	May - June		Aug - Sept	
	Day	Night	Day	Night
Burbot	0.0	29.1	13.4	170.0
Chinook	1066.2	1628.9	32.4	560.6
Peamouth chub	91.4	45.9	8.0	0.0
Longnose dace	186.5	386.0	114.8	521.6
Leopard dace	312.1	649.3	297.6	542.3
Rainbow trout	15.6	246.1	0.0	214.9
Sculpin	151.6	1378.3	159.7	730.3
Redside shiner	1105.0	1116.7	1058.3	2343.2
Sockeye	10.0	3.13	0.0	0.0
N. Squawfish	506.9	1560.5	1569.9	2646.7
Sucker	305.4	1184.8	809.6	2102.8
Unidentified	5.8	6.0	0.0	0.0
Whitefish	175.5	1036.2	5.5	1361.9
Total	3931.9	9271.0	4069.1	11194.1

Table 3. Abundance of juvenile chinook salmon as percentage of total estimated number of all species (%N) and as percentage of total estimated biomass of all species (%wt).

	Upper Nechako		Lower Nechako		Stuart		Total Nechako	
	%N	%wt	%N	%wt	%N	%wt	%N	%wt
May-June								
Day	14.35	25.74	33.93	28.92	20.29	23.20	26.94	27.12
Night	30.98	26.40	36.77	16.75	24.52	7.94	33.18	17.57
Aug-Sept								
Day	0.00	0.00	0.11	2.00	0.15	0.67	0.05	0.80
Night	0.32	6.19	1.04	4.26	3.50	13.28	0.79	5.01

Table 4. Estimated number of juvenile chinook salmon for each site sampled along the margins of the Nechako and Stuart rivers during 1991.

Site	Location	Estimated number / 25 m (1 SE)			
		May - June		Aug - Sept	
		Day	Night	Day	Night
1	Nechako River	14(2)	154(6)	0	0
2	Cutoff Creek (14 km)	78(61)	202(7)	0	0
3		2(0)	54(4)	0	0
4		22(12)	58(4)	0	0
5	Nechako River	18(3)	21(3)	0	1(0)
6	Greer Creek (33 km)	1(1)	26(0)	0	0
7		4(1)	33(0)	0	0
8		2(1)	29(0)	0	0
9	Nechako River	0	39(0)	0	3(0)
10	Larson's (46 km)	0	51(3)	0	7(2)
11		0	5(0)	0	1(1)
12		20(10)	23(2)	0	5(1)
13	Nechako River	0	2(1)	0	0
14	Diamond Isl. (71 km)	0	7(2)	0	0
15		0	14(1)	0	0
16		0	5(0)	0	0
17	Nechako River	97(8)	23(3)	0	0
18	Below Nautley (92 km)	213(9)	46(4)	0	1(0)
19		2(1)	238(7)	0	2(0)
20		60(0)	123(7)	0	0
21	Nechako River	296(10)	95(4)	0	0
22	Braeside (116 km)	250(10)	212(6)	0	1(1)
23		18(2)	133(5)	0	3(1)
24		48(4)	33(0)	0	0
25	Nechako River	29(3)	21(0)	0	6(1)
26	Burners (137 km)	32(3)	10(0)	4(1)	4(1)
27		6(1)	37(3)	0	8(0)
28		1(1)	20(2)	0	5(1)
29	Nechako River	102(5)	16(2)	0	0
30	Hulatt (171 km)	23(2)	5(1)	0	0
31		4(0)	22(2)	0	0
32		11(2)	42(4)	0	0
33	Stuart River	72(0)	19(0)	0	9(2)
34	Upper (11 km)	93(5)	15(2)	0	10(1)
35		56(5)	46(0)	0	0
36		23(3)	38(3)	0	2(0)
37	Stuart River	4(1)	8(2)	0	0
38	Sturgeon Pt. (70 km)	22(3)	4(1)	1(0)	1(0)
39		42(18)	2(1)	1(1)	1(0)
40		6(1)	19(2)	0	0
Total		1671(188)	1950(92)	6(2)	70(11)
Mean		41.8	48.8	0.15	1.8

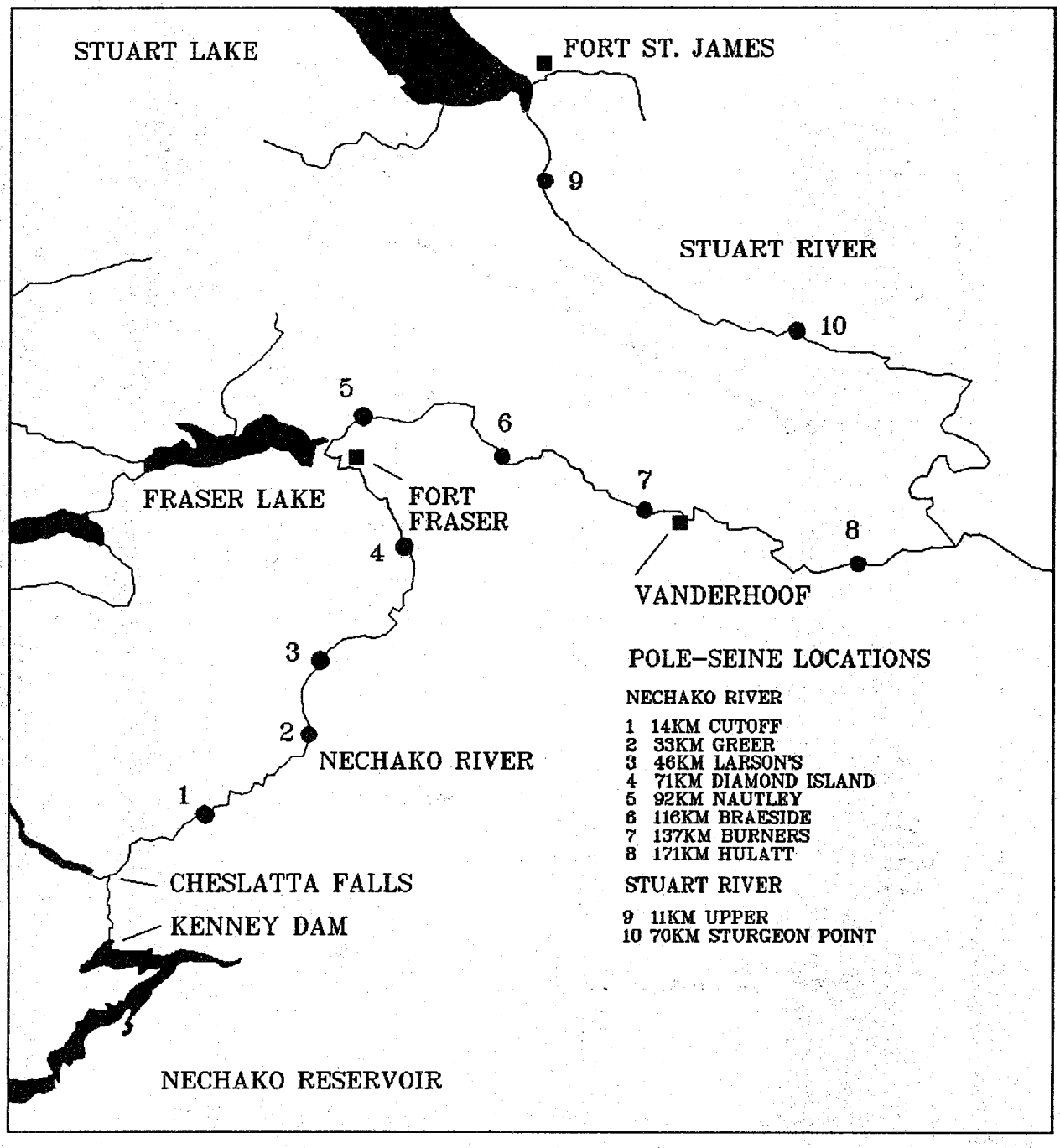


Figure 1. Map of Nechako and Stuart rivers identifying the 10 study locations.

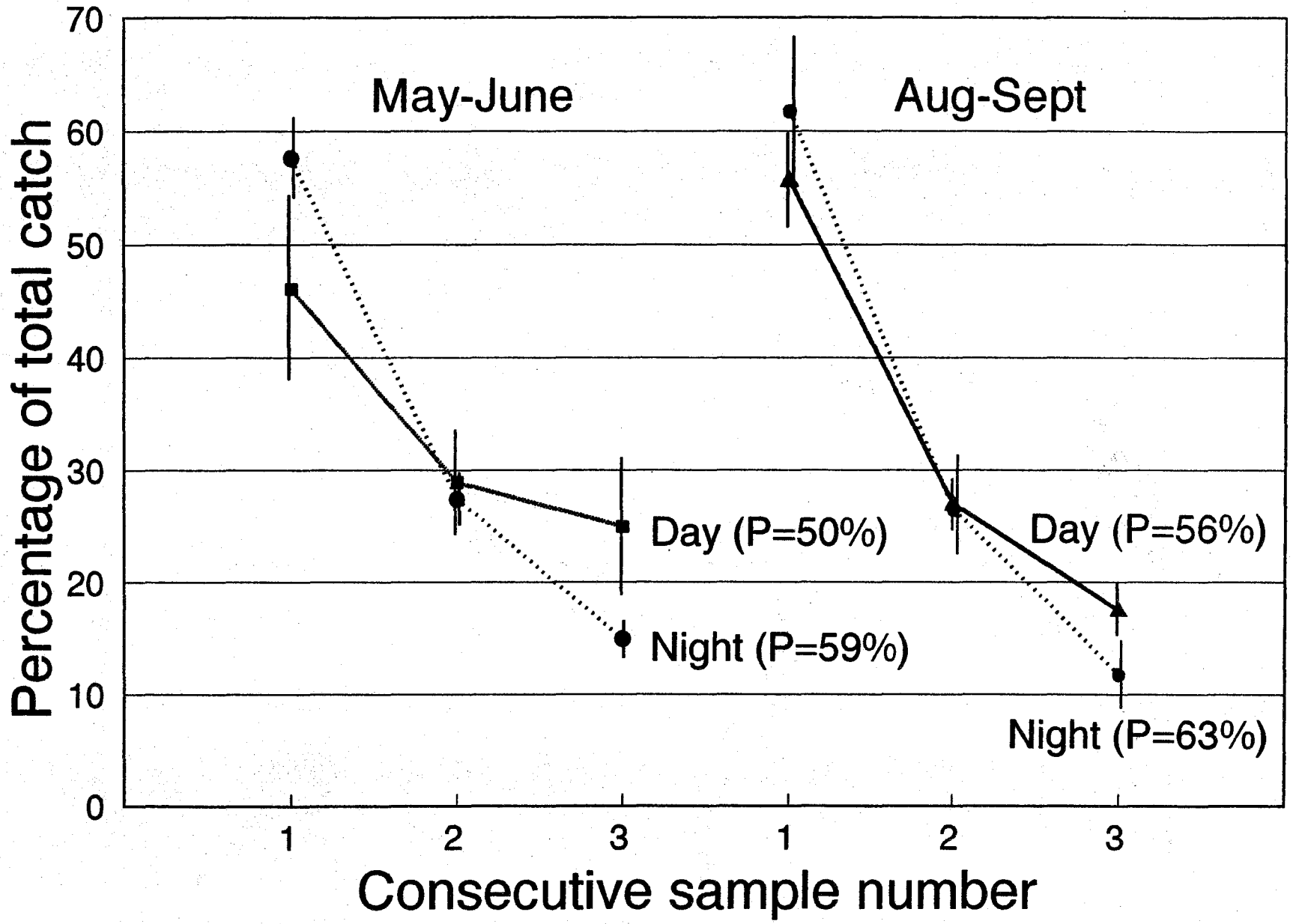


Figure 2. Catch efficiency of day and night sampling for two sampling periods; where, P equals the estimated probability of fish capture during a single removal for each location (95% C.L.).

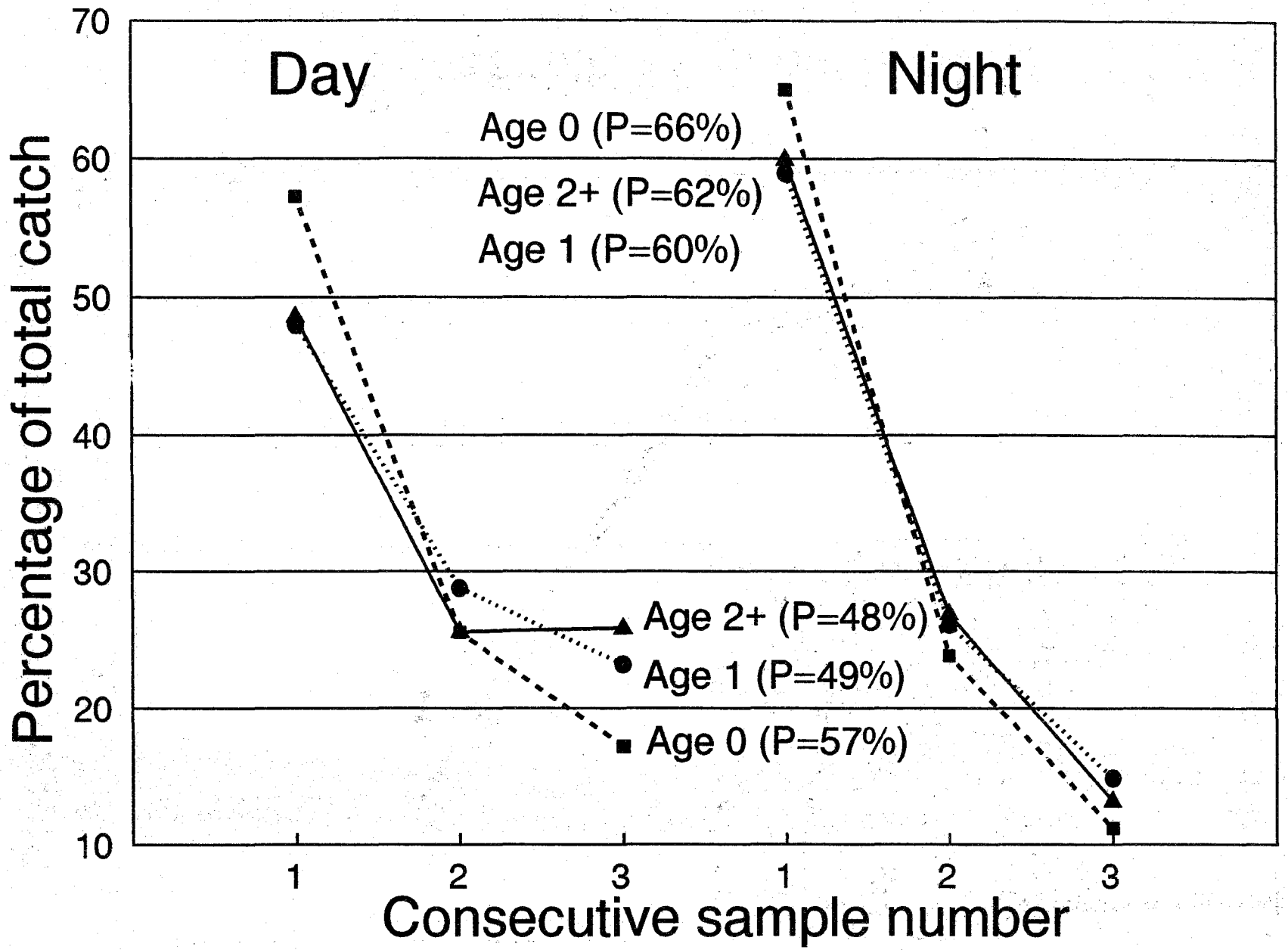


Figure 3. Catch efficiency of different fish age classes during the day and night; where, P equals the estimated probability of fish capture during a single removal from all sites and sampling periods, and age classes 2, 3, and 4 of all species are combined and are represented by 2+.

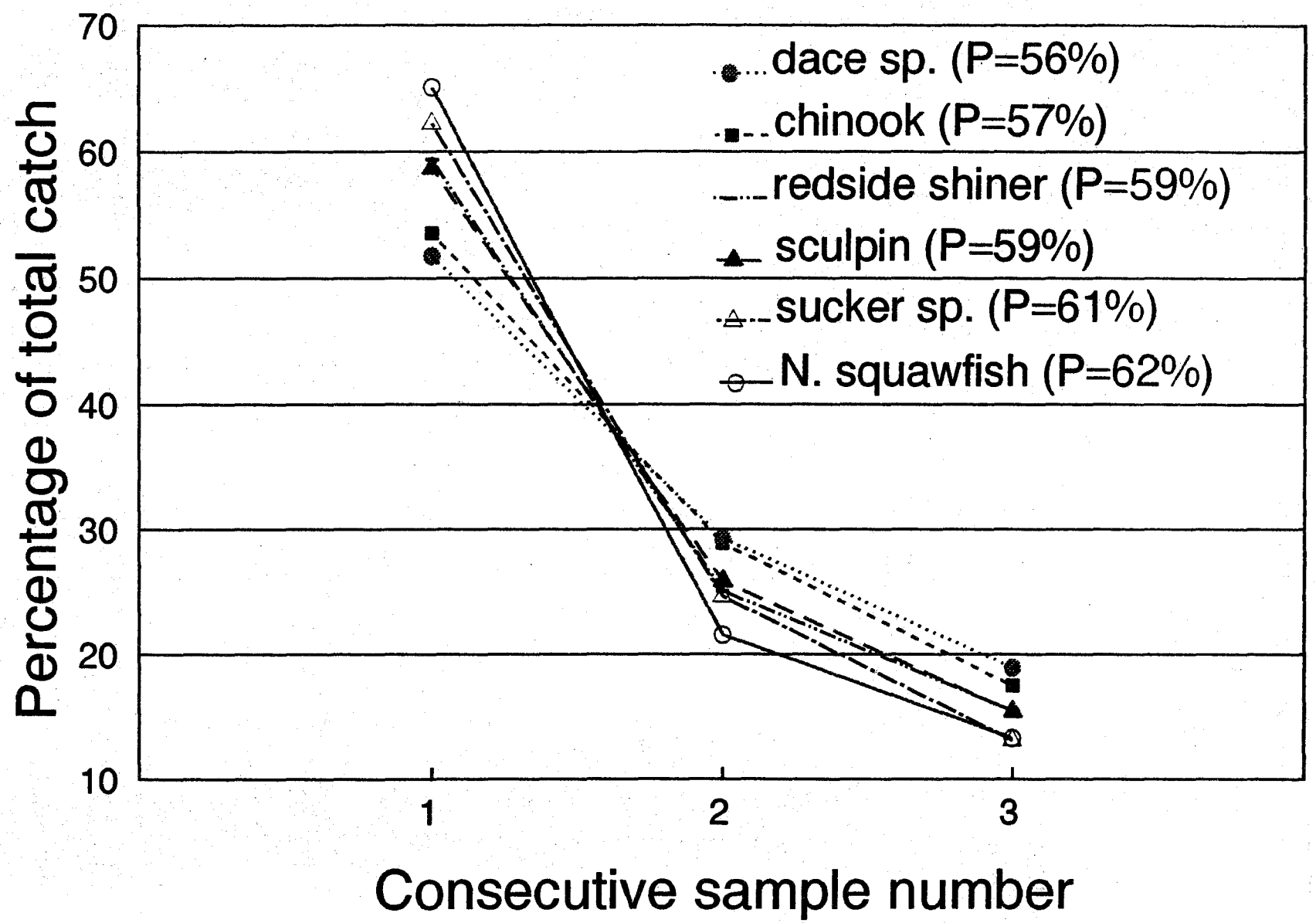


Figure 4. Catch efficiency of 6 fish species groupings which represent 97% of the total number of fish caught; where, P equals the estimated probability of capture during a single removal from all sites and sampling occasions combined.

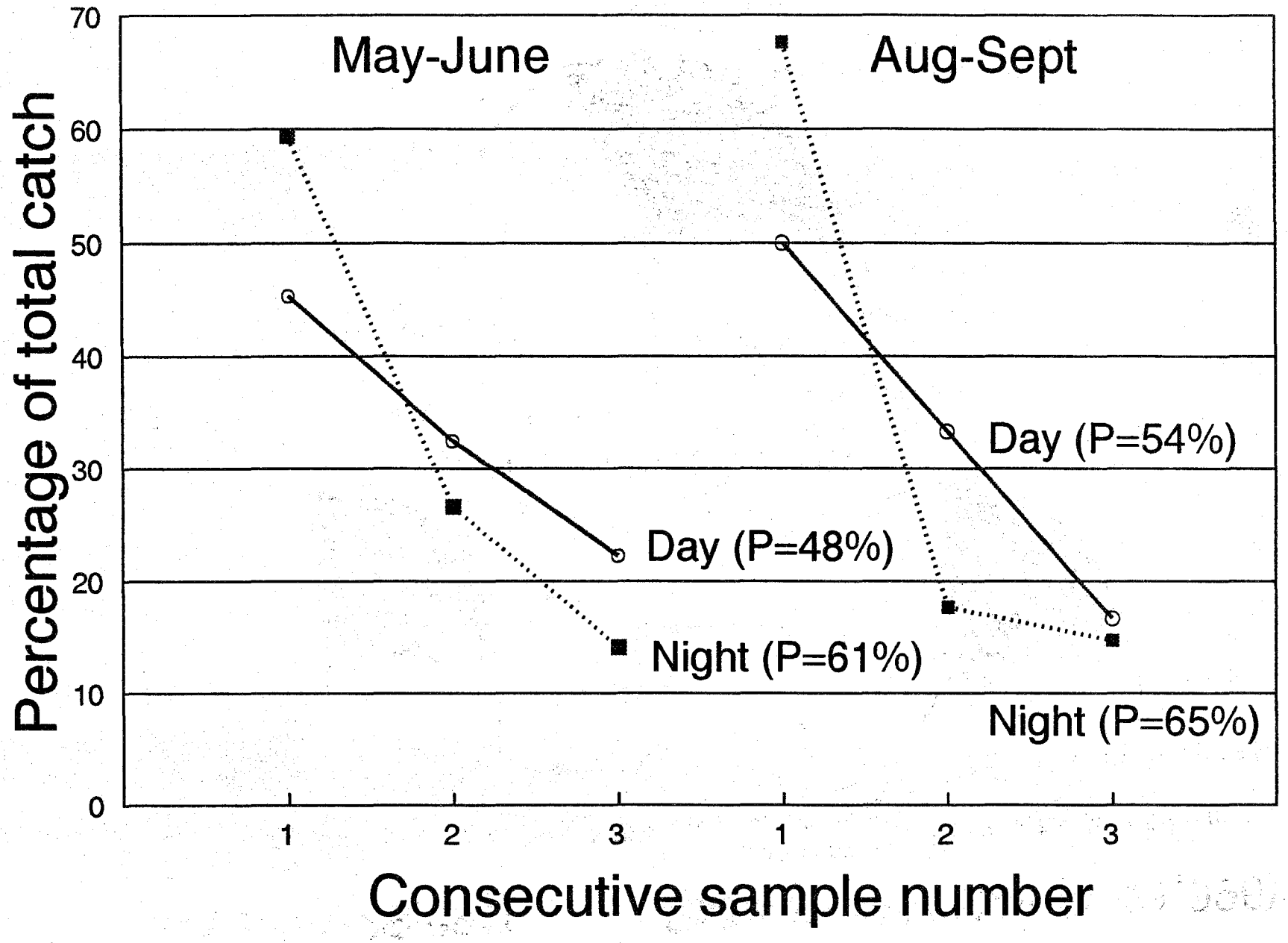


Figure 5. Catch efficiency of day and night sampling during two sampling periods for juvenile chinook salmon; where, P equals the estimated probability of capture during a single removal from all sites combined.

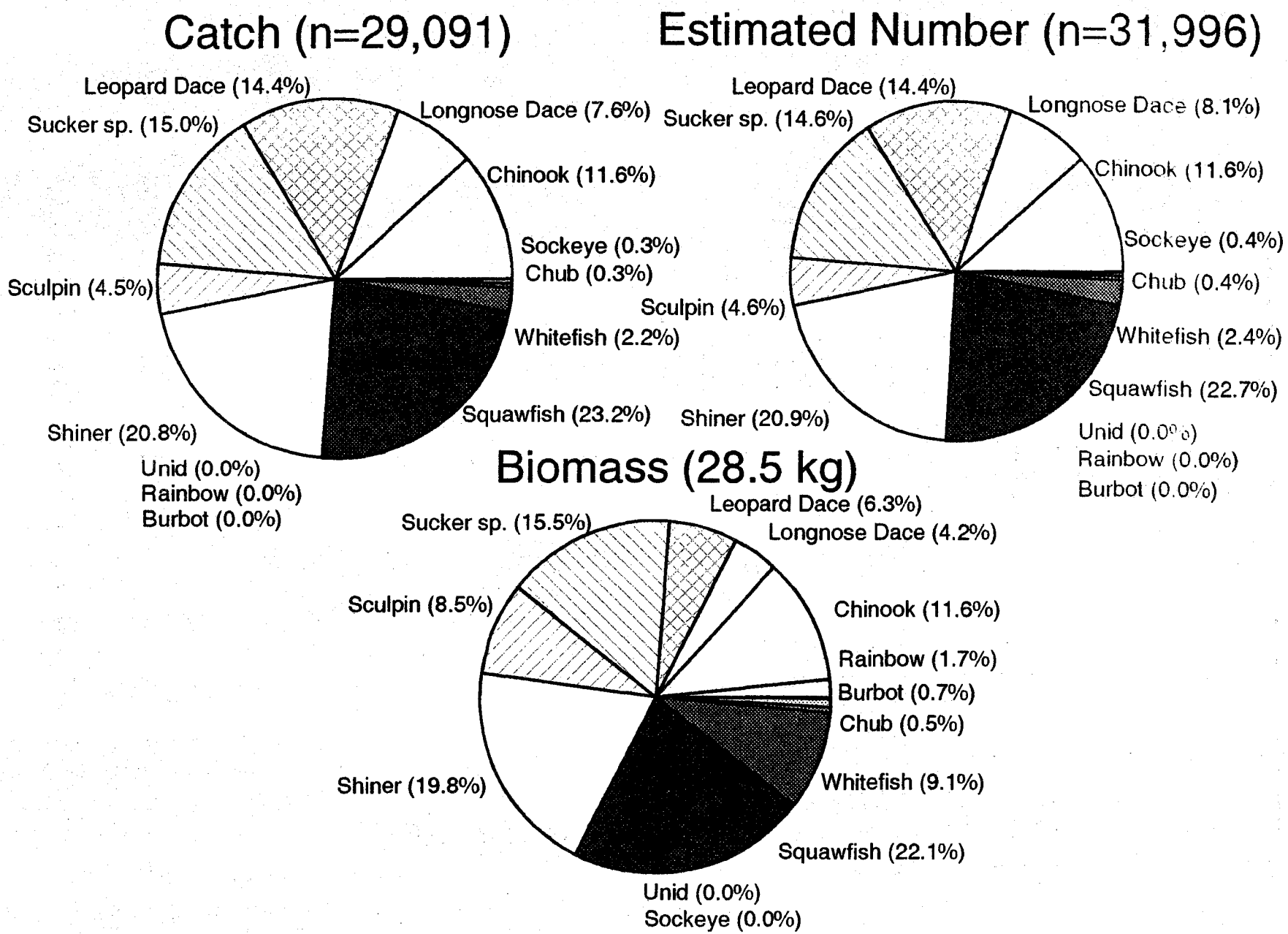


Figure 6. Abundance (catch, estimated number and biomass) of fish species along the margins of the Nechako and Stuart rivers during 1991.

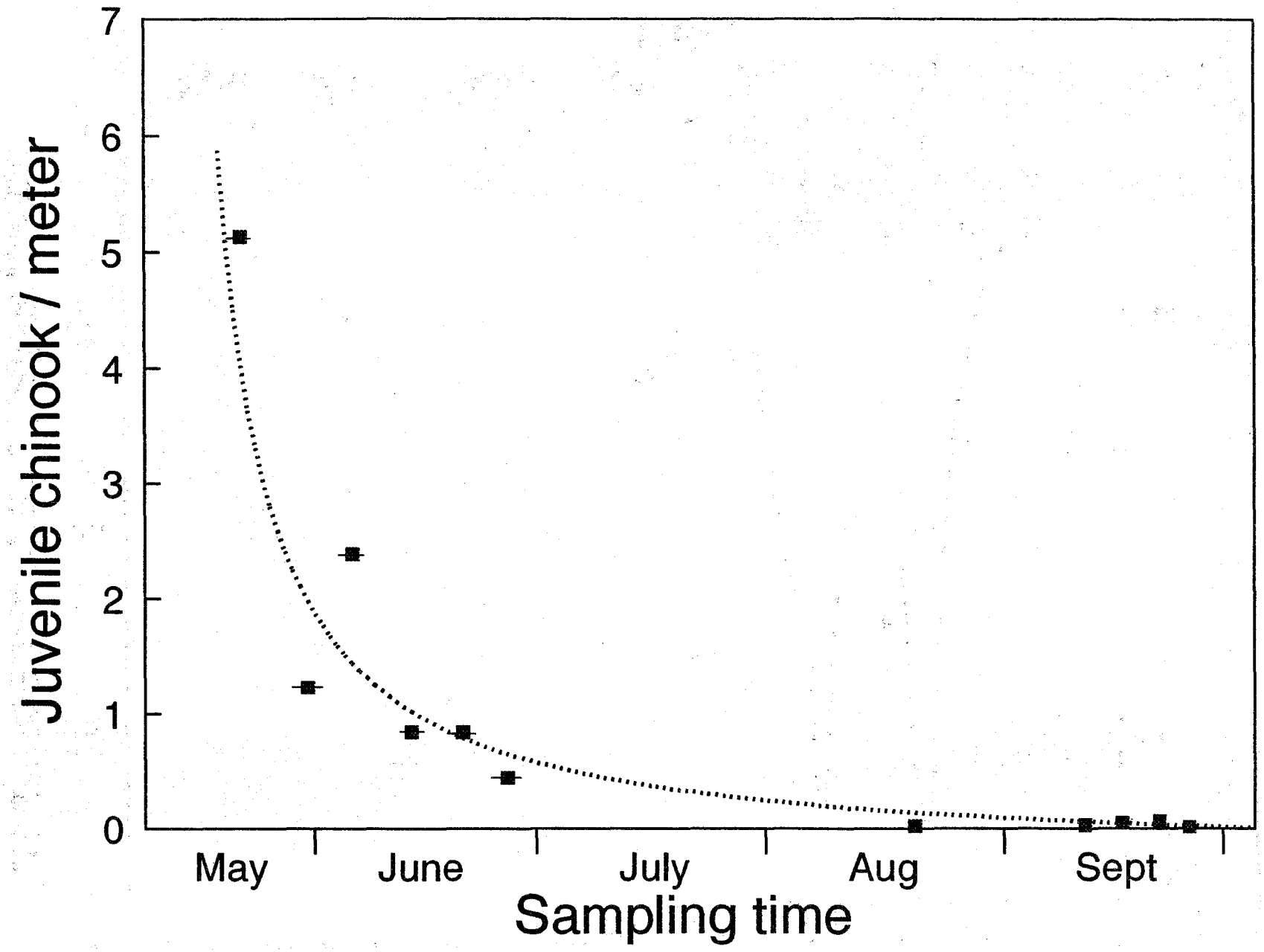


Figure 7. Catch of juvenile chinook salmon along the margins of the Nechako and Stuart rivers for 3 to 4 day intervals during 1991.

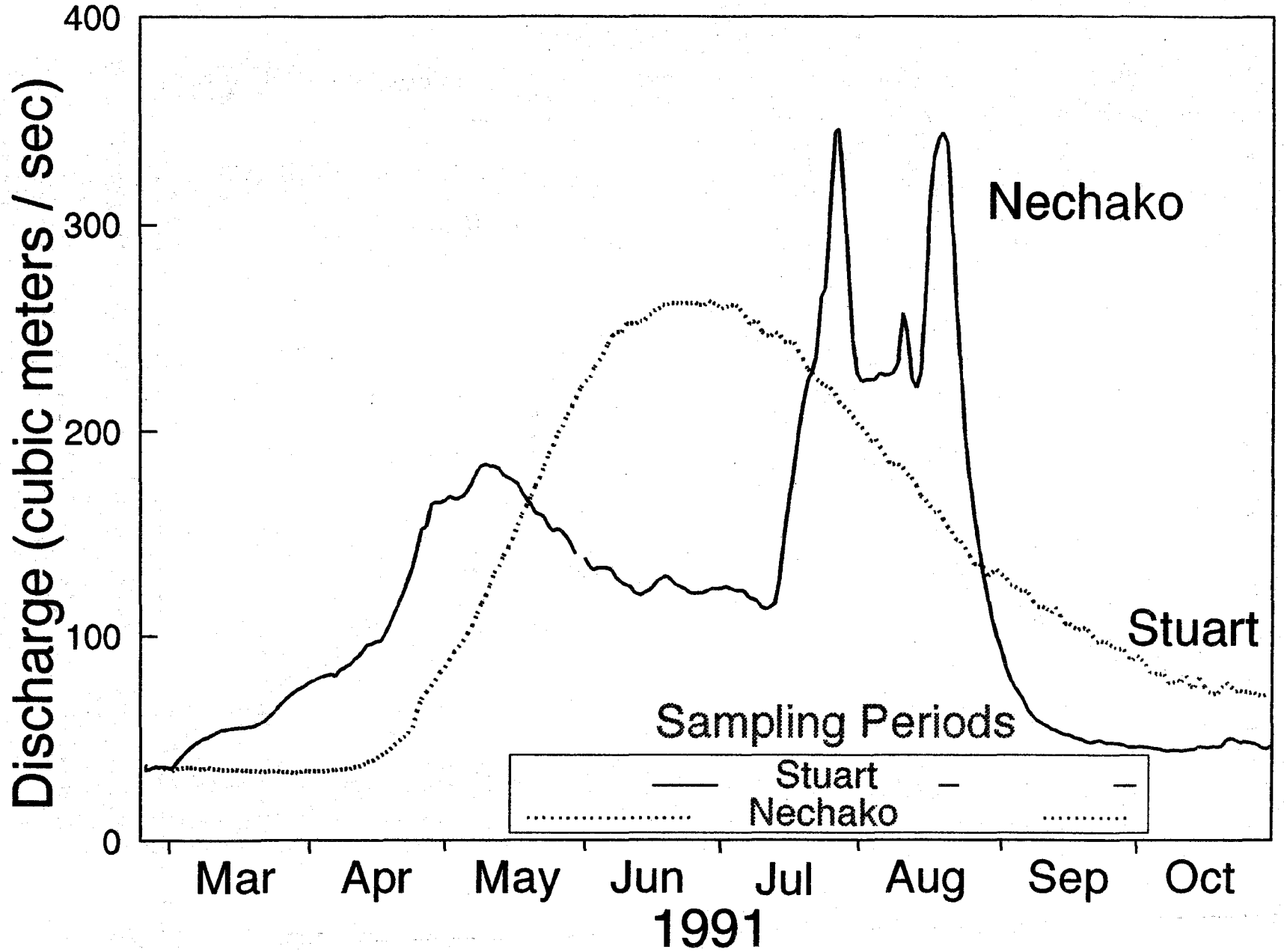


Figure 8. Nechako River (at Vanderhoof) and Stuart River (below Fort St. James) discharges (m^3/sec) for 1991.

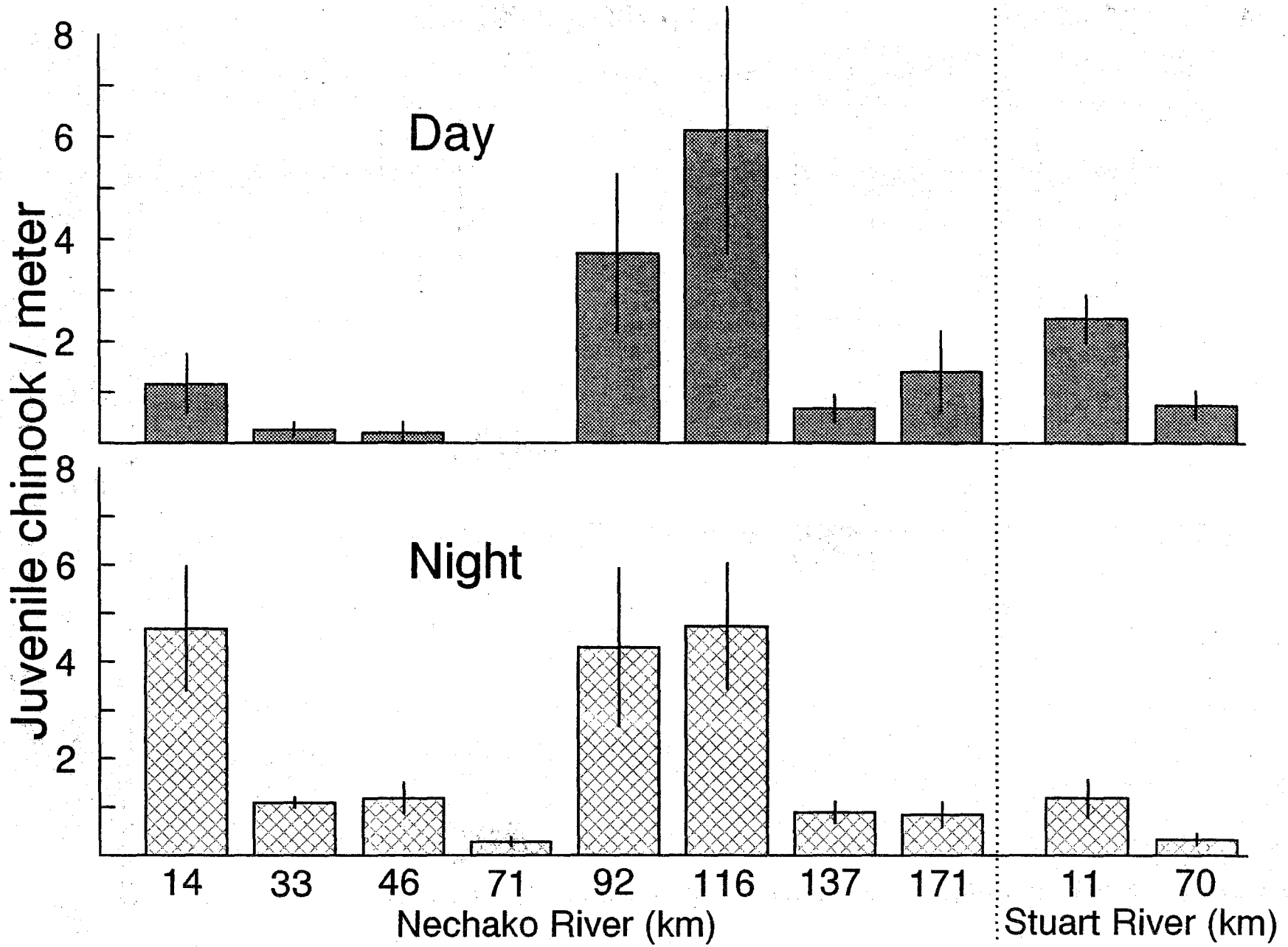


Figure 9. May-June, 1991 distribution of juvenile chinook salmon along the margins of the Nechako and Stuart rivers. The mean number of juvenile chinook/m of river margin (1 SE for 4 sites) for 10 locations is indicated for day (top) and night (bottom).

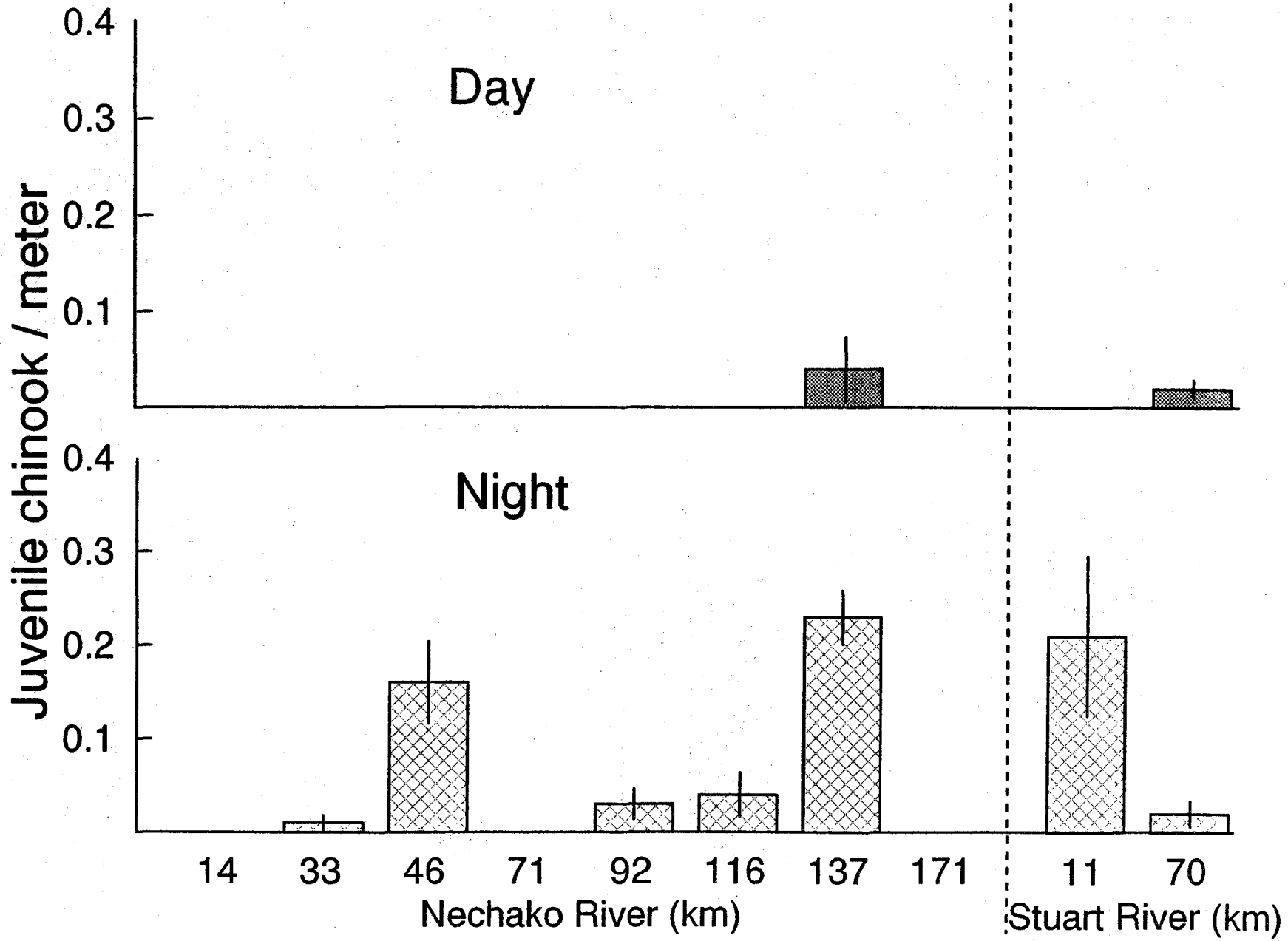


Figure 10. Aug-Sept, 1991 distribution of juvenile chinook salmon along the margins of the Nechako and Stuart rivers. The mean number of juvenile chinook salmon/m of river margin (1 SE for 4 sites) for 10 locations for day (top graph) and night (bottom graph).

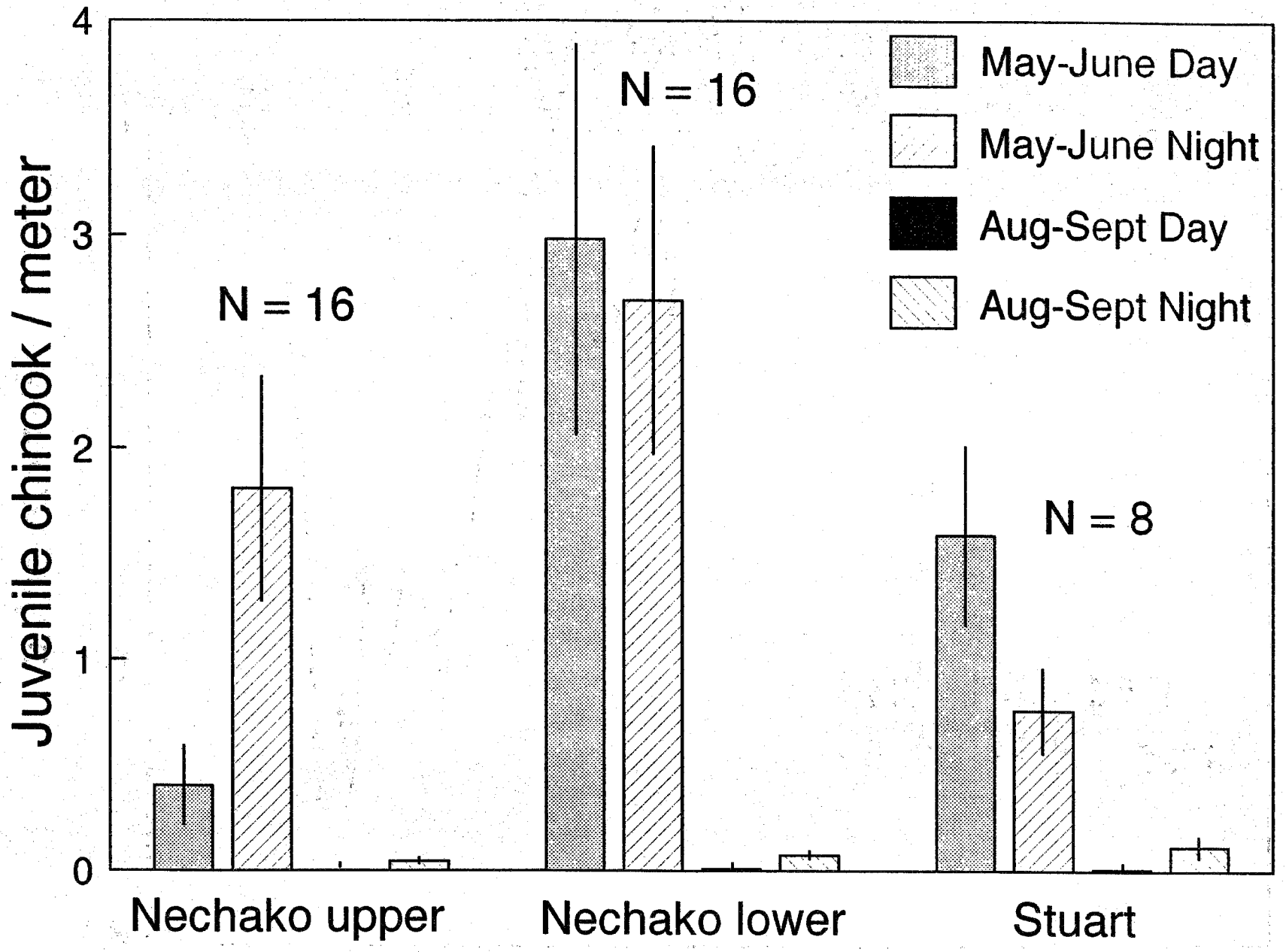


Figure 11. The mean estimated number of juvenile chinook salmon/m (95% C.L.) utilizing the Upper Nechako (Cheslatta Falls to Fort Fraser) Lower Nechako (Fort Fraser to Hulatt) and Stuart rivers (from 10 km below Stuart Lake to Sturgeion Point) for 4 sampling series. Where "N" equals the number of sites/series.

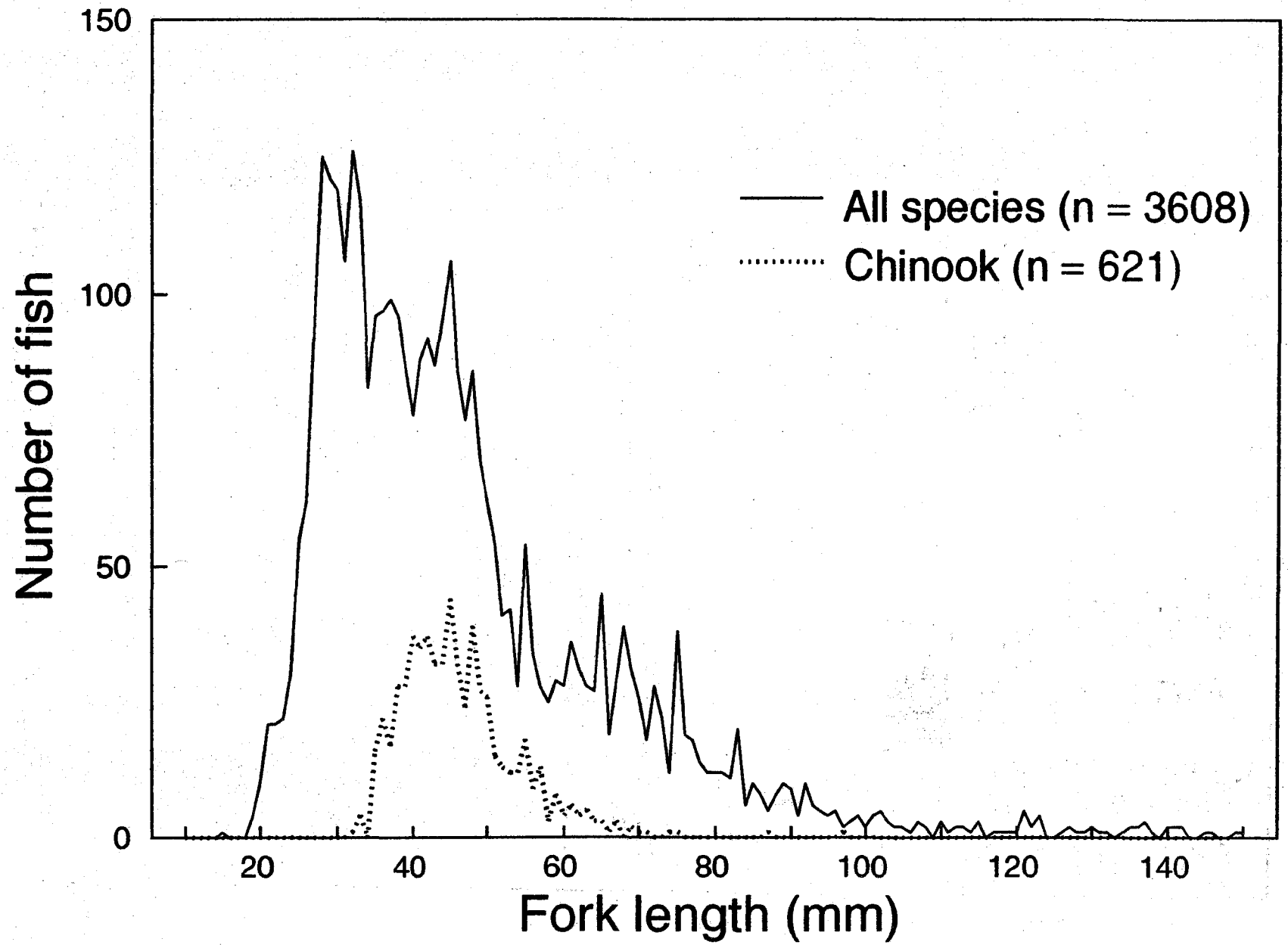


Figure 12. A comparison of May-June/91 fork-length frequencies of all fish (n = 3608) and of juvenile chinook salmon (n=621).

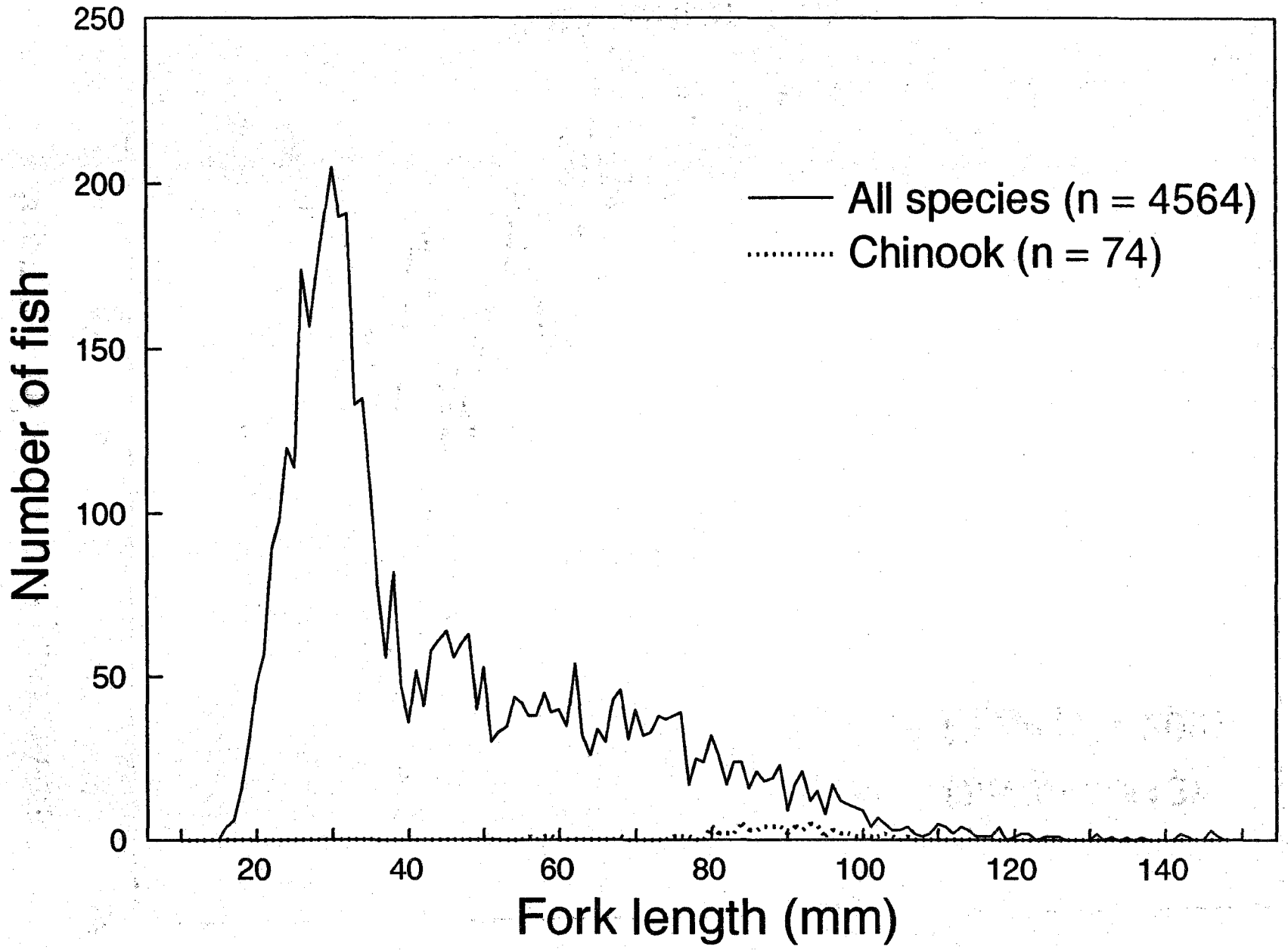


Figure 13. A comparison of Aug-Sept/91 fork-length frequencies of all fish (n = 4564) and of juvenile chinook salmon (n = 74).

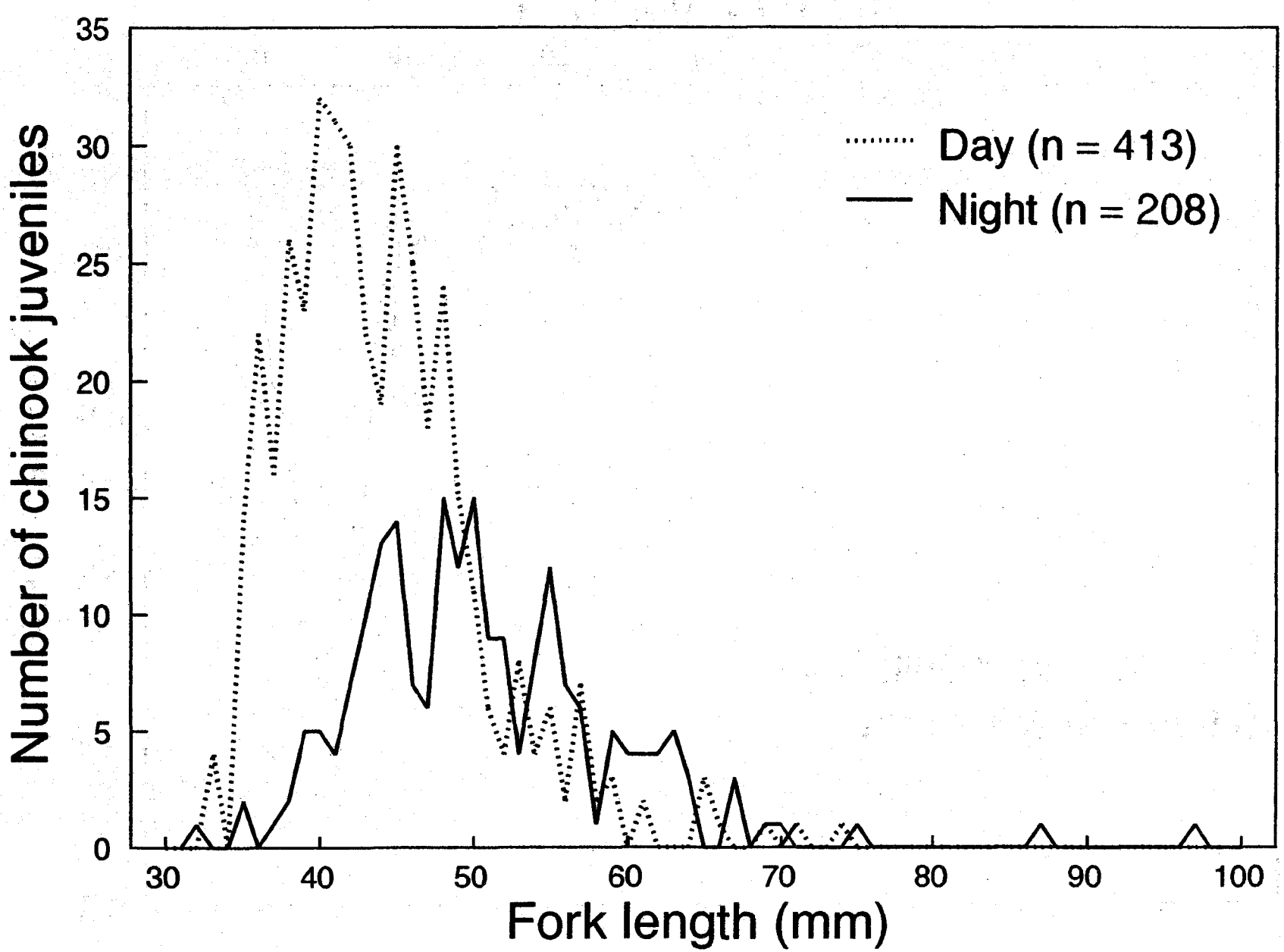


Figure 14. A comparison of May-June/91 fork-length frequencies of juvenile chinook salmon during the day (n = 413) and night (n=208).

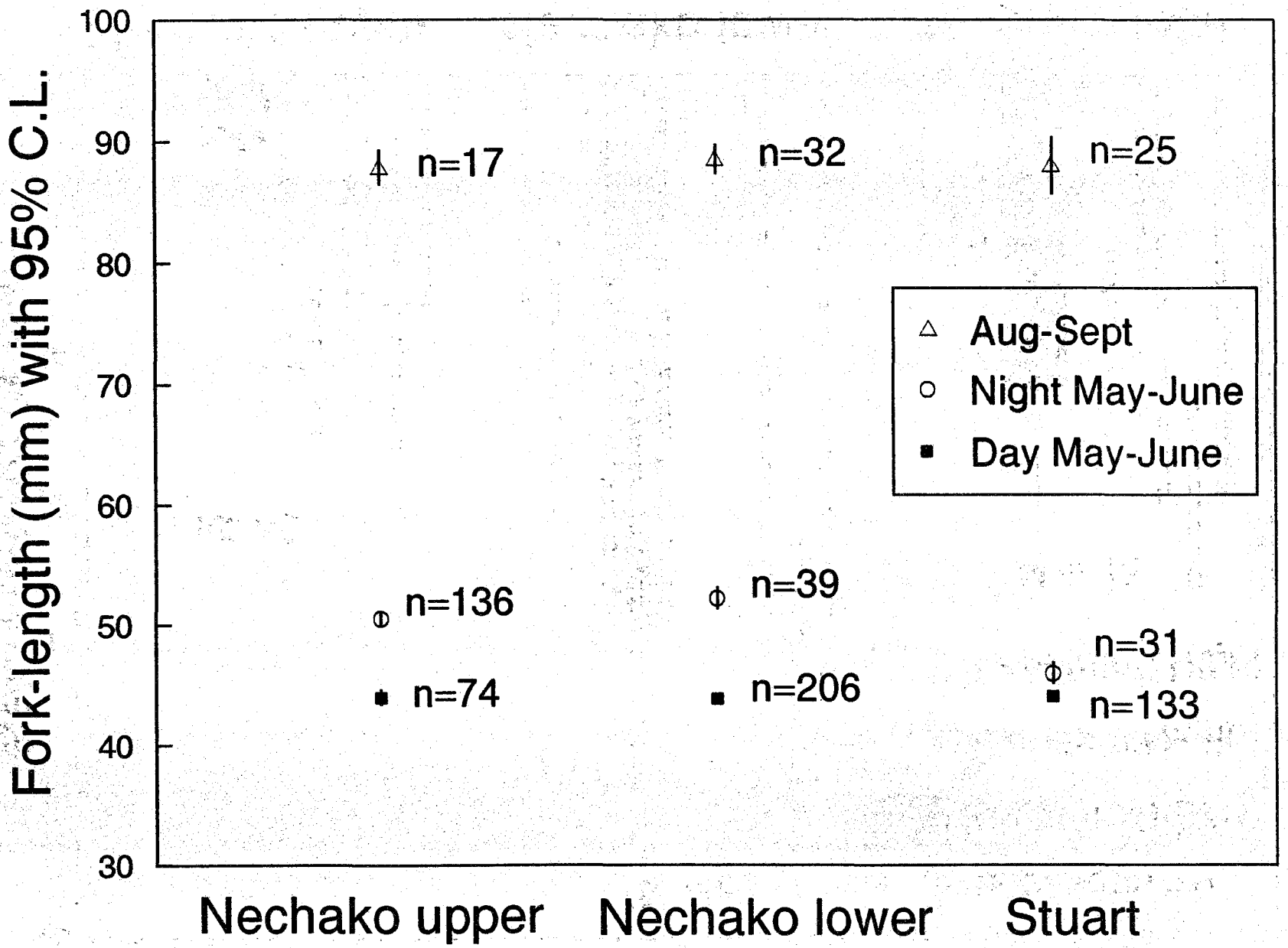


Figure 15. Comparison of mean fork-length (95% C.L.) of young of the year juvenile chinook salmon collected from the Upper Nechako (Cheslatta Falls to Fort Fraser) Lower Nechako (Fort Fraser to Hulatt) and Stuart rivers (10 km below Stuart Lake to Sturgeon Point). Number of fish measured is indicated by "n".

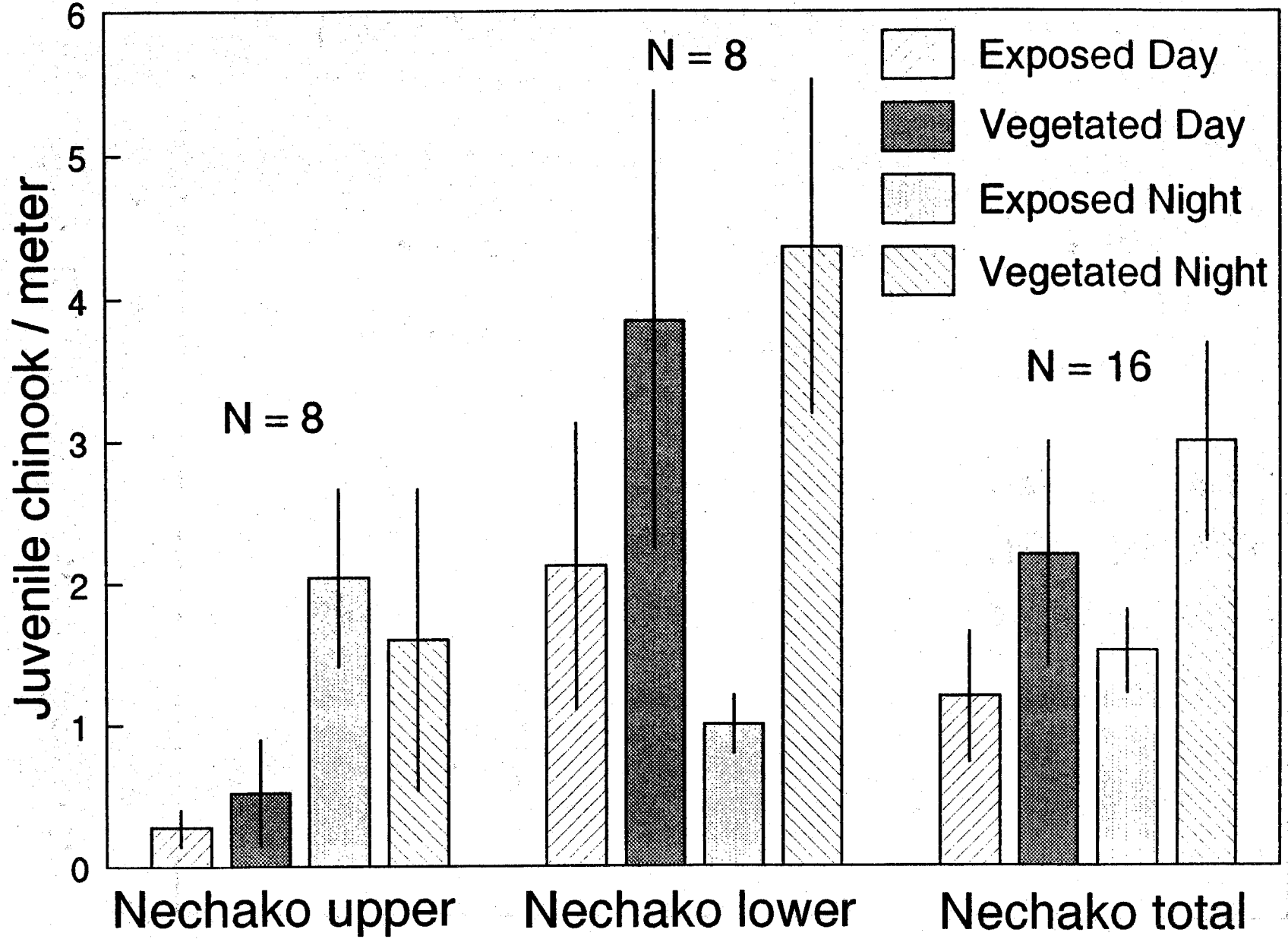


Figure 16. Diel use (juvenile chinook/m with 95% C.L.) of vegetated and exposed habitat along the margins of the Nechako River during May-June/91. Where "N" equals the number of sites/series.

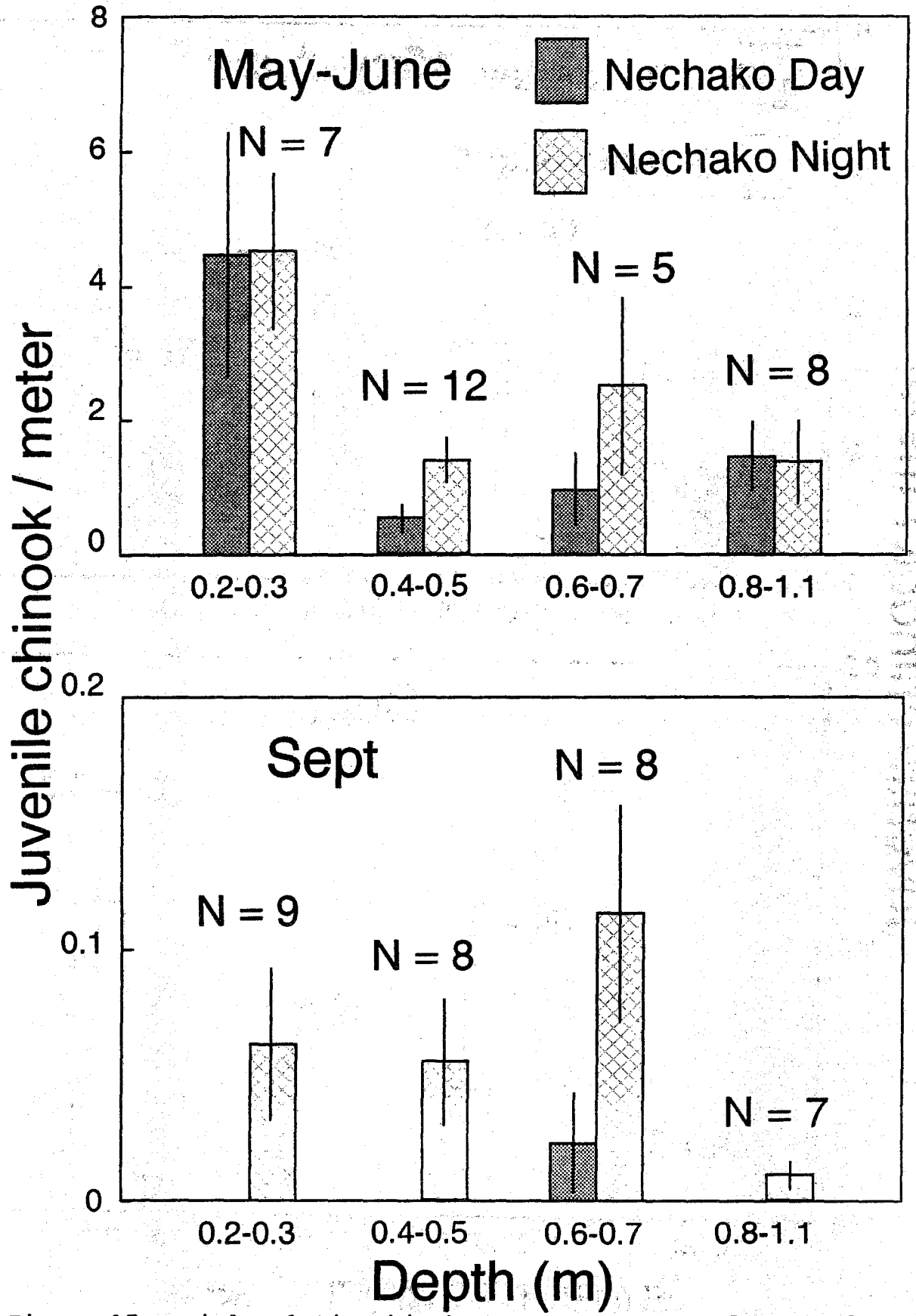


Figure 17. Diel relationship between mean water depth and number of juvenile chinook salmon (95% C.L.); where, "N" equals the number of sites. Two sampling periods are illustrated, May-June (top) and Sept. (bottom).

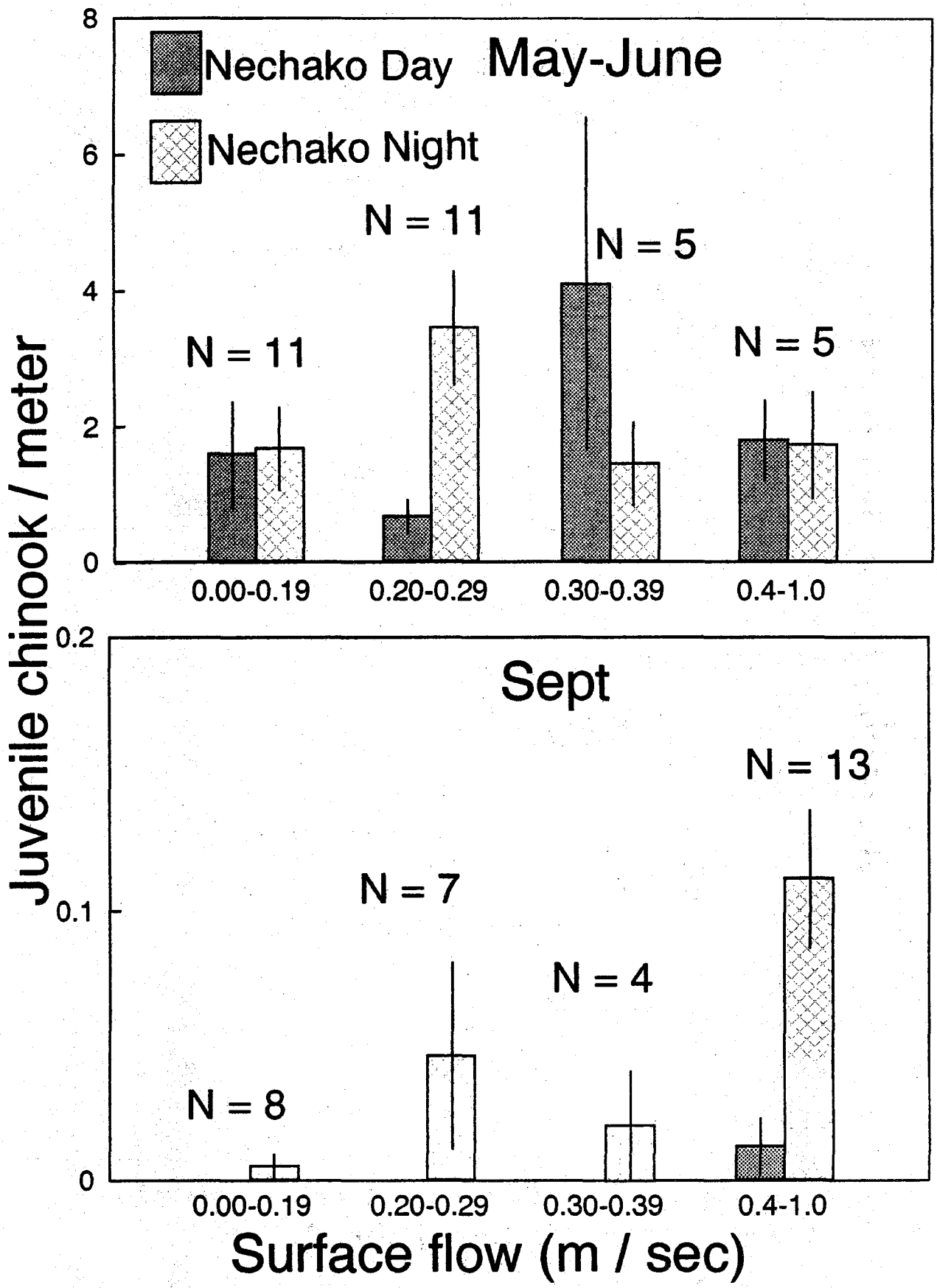


Figure 18. Diel relationship between mean surface water velocity and number of juvenile chinook salmon (95% C.L.); where "N" equals the number of sites. Two sampling periods are illustrated, May-June (top) and Sept. (bottom).

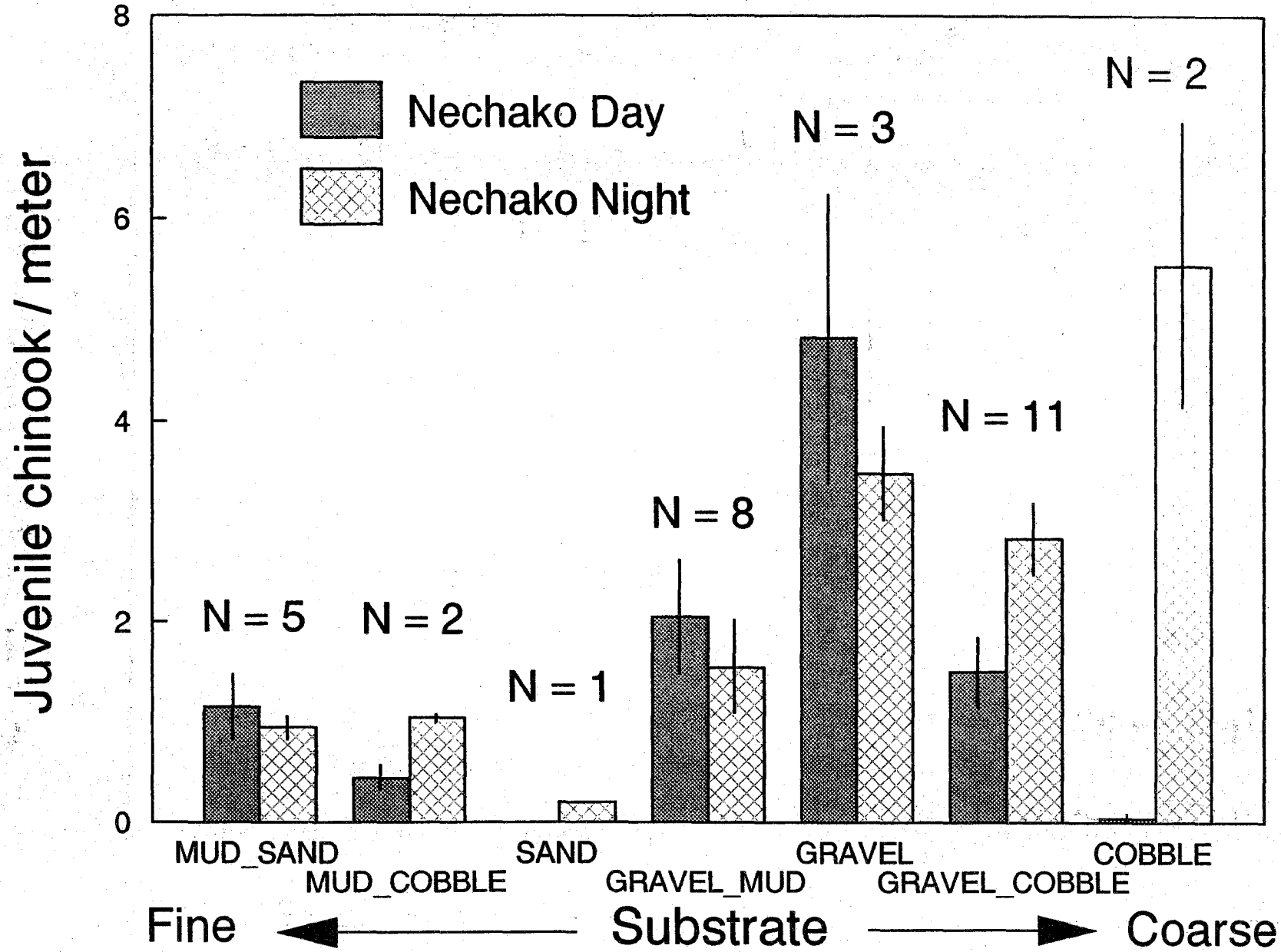


Figure 19. Diel relationship between substrate size and number of juvenile chinook salmon (95% C.L.) for May-June/91; where, "N" equals the number of sites for each substrate class.

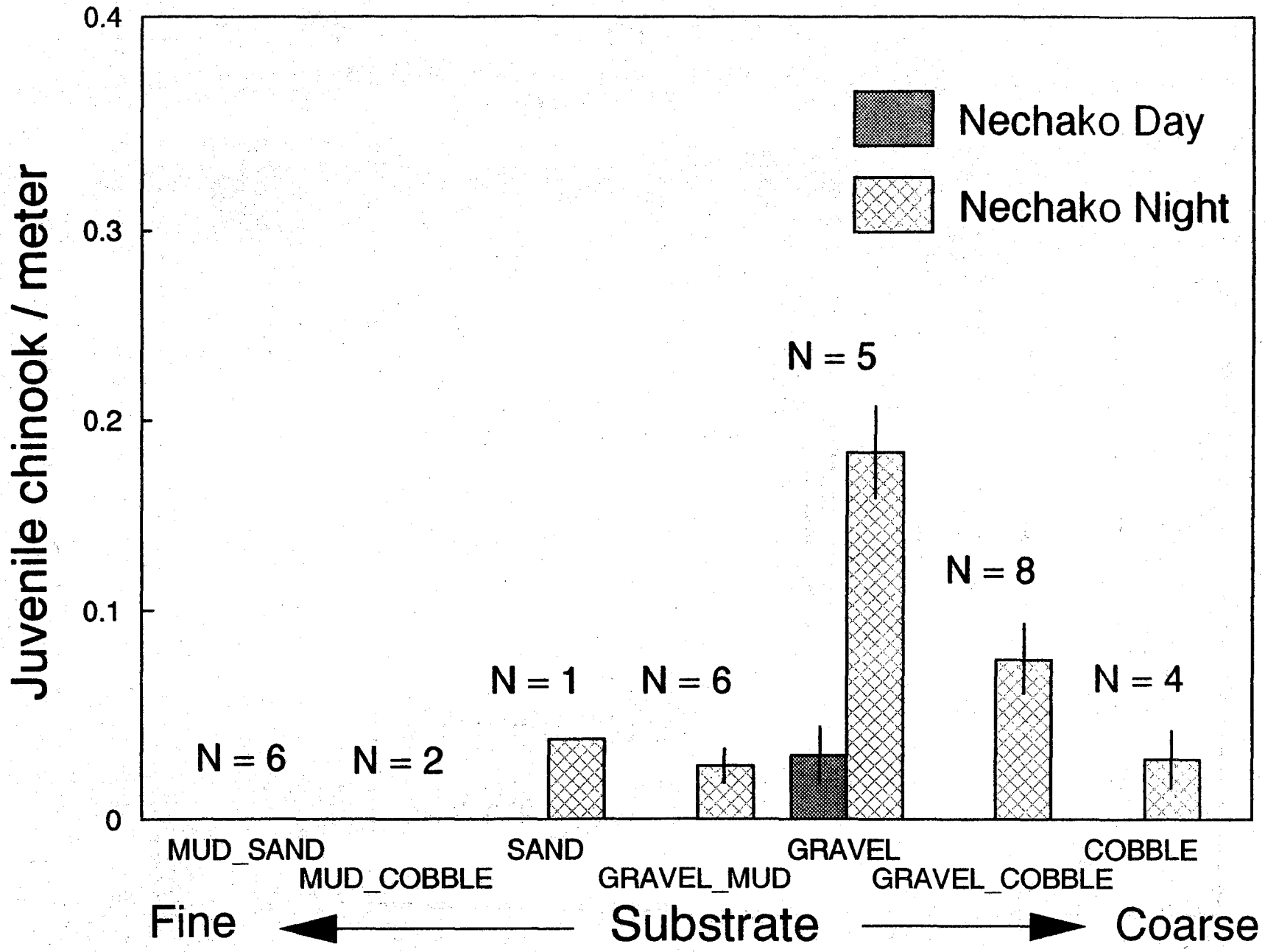


Figure 20. Diel relationship between substrate size and number of juvenile chinook salmon (95% C.L.) for Sept/91; where, "N" equals the number of sites for each substrate class.