DIVISION OF COMMERCIAL FISHERIES

INTERIM REPORT

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BY BRIAN L. LYNCH

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**ABSTRACT**

A gill net test fishery was conducted in upper Clarence Strait in the fall of 1988. The objective was to compare the catch-per-unit-effort (CPUE) of coho and chum salmon between gill net sets made during three phases of ambient light. The results of analysis of variance tests showed that for this fishery no statistically significant differences between the CPUE for coho and chum salmon occurred between sets made during hours of daylight, twilight, and darkness.

KEYWORDS: Coho salmon, chum salmon, gill net, catch-per-unit-effort, ambient light.

## INTRODUCTION

Coho salmon (*Oncorhynchus kisutch*) are often harvested in fall mixed stock drift gill net fisheries that are targeting on chum salmon (*O. keta*), a subject of concern in years of low coho abundance. Observations by fishermen have suggested that coho may be more susceptible to capture at night, when they seem to be found offshore in greater abundance, than during daylight hours. This study examines the possibility of using light-specific gill net closures as an effective management tool to reduce catches of coho salmon in mixed stock fisheries.

An experimental fishery using drift gill net gear was conducted in upper Clarence Strait along the west coast of Etolin Island at Marsh Island in Southeast Alaska (Figure 1) to determine whether ambient light affected catch rates of coho and chum salmon. Catch-per-unit-effort (CPUE) of coho and chum salmon taken in drift gill net sets made during daylight, twilight, and dark hours were compared to determine if light-specific gill net closures could be used as an effective management tool to minimize catches of coho salmon while still maintaining fisheries for other species. This tool would be especially useful during periods of low coho abundance. Night closures are not currently employed in the management of the Upper Clarence Strait/Sumner Strait commercial drift gill net area (District 106).

A large segment of the coho commercial gill net catch in Southeast Alaska are caught in fall fisheries in regulatory District 106 (Clarence and Sumner Straits). The majority of fall commercial drift gill net fishing in District 106 occurs near Macnamara Point, Point Colpoys, Kashevarof Passage, and Marsh Island (Figure 1). The bulk of the fishing takes place during daylight hours and the nets are set perpendicular to shore so that they are often "crowding" the beach on the onshore end throughout the drift. Daylight fishing predominates because fisherman generally are unable to visually observe their nets in the dark, and at this time of year longer periods of darkness occur. Darkness, tidal action, weather, and debris can combine to make night fishing extremely hazardous. When night fishing does occur, it often takes place offshore, to a distance of one mile from shore, which minimizes the possibility of entangling the net on rocks, in debris, or in tidal whirlpools. Near Marsh Island, coho salmon are often found in good abundance offshore where night fisheries can operate.

The test fishery was designed to emulate typical commercial fishing used by fall gill net fishermen in District 106.

## METHODS

### *Sampling Methods*

The fishery occurred during a four week period between August 24 and September 16, 1988. Fishing was done from the F/V *Fairhaven*, a 35-ft commercial Southeast Alaskan gill net vessel, using a standard fall commercial 300 fathom gill net made of 6.25-in stretched mesh "mono-twist with center core" webbing, 60 meshes deep. An attempt was made to keep the duration of each set near 2.0 h. The entire net was used on each set and the sets actually averaged 1.9 h., with a range from 0.48 to 3.16 h. The duration of each set depended upon its proximity to shore, drift speed and direction, debris, water and wind conditions. Fishing time was calculated using the standard formula employed in Bristol Bay test fisheries (Van Alen 1981):

$$\text{Fishing Time (Hrs)} = (IN_s - OUT_f) + 1/2\ [(OUT_f - OUT_s) + (IN_f - IN_s)]$$

Where: $OUT_s$ = the time at the beginning of the set
$OUT_f$ = the time at which the net was fully set
$IN_s$ = the time at the beginning of net retrieval
$IN_f$ = the time at which the net was fully retrieved onboard the vessel

The catch of each species was divided by the fishing time to obtain the CPUE for each set.

The gill net sets were classified as to their occurrence during the three phases of ambient light (twilight, full daylight, and full darkness) based on the time when the net retrieval began. The phases of light were determined as follows: (1) Twilight--the period between sunset and astronomical twilight, (2) Daylight--the period between sunrise and sunset, and (3) Darkness--the period between evening and morning astronomical twilight. The times for sunrise, sunset and twilight each week were obtained from standard nautical tables (USNO 1987).

Offshore fishing was initially scheduled to occur approximately 50% of the total test fishing time. This was intended to ensure that the location normally fished at night would be sufficiently represented. However, high winds and rough seas occurred during much of the test fishing period and only 39.7% of the sets and 40.3% of the fishing time occurred in the offshore location. The offshore location was much more exposed to SE winds than the onshore location. Also, the period from midnight to 0300 hours was not normally sampled in order to provide a rest period for the skipper and crew.

Data recorded for each set included date, set number, location, fishing time, catch by species, weather conditions, and tidal stage. Additionally, all fish were examined for coded-wire tags (CWT), measured from mid-eye to fork-of-tail, and the sex was determined for the majority of coho captured. These data were ancillary to the study and are not included in the results.

### *Analytical Methods*

To test for differences in CPUE between the three ambient light phases the Kruskal-Wallis Test, a non-parametric ANOVA based on ranking (Zar 1984), was used due to non-normality of the CPUE data (Figure 2). The CPUE values during each light phase were ranked in ascending order, the rank sums obtained and the corrected H statistic, $H_c$, calculated and tested for significance with tabled chi-square ($X^2$) values at the 90% confidence level ($\alpha$=.10). Because the study was designed to show and act on no significant differences, the 90% level was used to reduce the chance of concluding no differences when, in fact, there were.

When significant differences were detected, nonparametric Tukey-type comparisons of the CPUE data from the Kruskal-Wallis test were to be used to determine between which light phases the significant differences occurred (Zar 1984).

Notched box plots were used to graphically compare the CPUE distributions at the three different ambient light phases for each species. The plots display the distribution of all points: the box represents the 25% and 75% range; the horizontal mid-line, the median; the straight vertical line, the 10% and 90% range; values outside the 10% - 90% range are represented as points; and the width of the box is proportional to the square root of the number of observations. The notched section of the box represents 95% confidence intervals around the median. This information may be used to compare pairs of distributions; if the 95% confidence intervals do not overlap, one may be fairly confident that the medians of the two distributions are different. If the box is folded over, this indicates that the 95% confidence interval is larger than the 25% - 75% range. This may often happen when sample sizes are small and when it does happen, little confidence should be placed in the interpretation of the box.

Tidal effects were not included in the analysis. Both flood and ebb tides were fished randomly and were represented within each light phase, so sets during all tidal stages within each light phase were combined. Weather and wave conditions were also not included in the analysis because various weather conditions were randomly distributed throughout each of the three ambient light conditions and because of the difficulties in quantifying these effects.

## RESULTS

Thirty-eight of the 63 sets made at Marsh Island were sets made onshore, while 25 of the sets were made in the offshore location. The onshore sets were comprised of 22 daylight sets, 11 twilight sets, and 5 sets during the hours of darkness. The offshore sets were comprised of 13 daylight sets, 9 twilight sets, and 3 sets during the dark period.

A total of 412 coho and 598 chum salmon were caught in 63 sets during the test fishery. Catch, fishing times, and CPUE are given for each set in Appendices A and B for coho and chum salmon, respectively. In addition to the coho and chum, 112 pink salmon (*O. gorbuscha*), 16 sockeye salmon (*O. nerka*), and 10 chinook salmon (*O. tshawytscha*) were also caught during the course of the fishery.

### *Coho Salmon*

The onshore daylight median coho CPUE of 4.36 coho/h was the highest coho CPUE of all ambient light phases in the separate fishing locations while the onshore twilight median coho CPUE of 1.90 coho/h was the lowest (Table 1). From the notched box plot (Figure 3), it is seen that the 95% confidence interval around the median (notched portion of box) overlaps for any paired comparison, suggesting no significant difference in median values. However, as the boxes display folding over for both twilight and dark sets, little significance should be placed on these results. The Kruskal-Wallis test also detected no significant differences in coho CPUE between the three phases of ambient light in the separate fishing locations ($H_C$=7.37; $X^2_{.10,2}$=9.24). Coho CPUE values, ranks, and resultant statistics for ambient light phases in the separate fishing locations are presented in Appendix C.

The highest median coho CPUE for fishing locations combined occurred during daylight at 3.13 coho/h, while the median CPUE for the twilight and dark periods were 2.99 coho/h and 2.34 coho/h, respectively (Table 1). The notched box plot (Figure 4) shows no significant differences in median values between ambient light phases. The Kruskal-Wallis test also detected no significant differences between the three light phases for combined fishing locations ($H_C$=1.63; $X^2_{.10,2}$=4.61). Coho CPUE values, ranks and resultant statistics for ambient light periods with fishing locations combined are presented in Appendix D.

### *Chum Salmon*

The onshore daylight median chum CPUE of 6.42 chum/h was the highest chum CPUE of all ambient light phases in the separate fishing locations, while the onshore twilight chum CPUE of 2.83 chum/h was the lowest (Table 2). The notched box plot (Figure 5) shows no significant differences in median values between locations or ambient light phases. The Kruskal-Wallis test also detected no significant differences in chum CPUE between the three phases of ambient light in the separate fishing locations ($H_C$=6.08; $X^2_{.10,2}$=9.24). Chum CPUE values, ranks and resultant statistics for ambient light phases in the separate fishing locations are presented in Appendix E.

The highest median chum CPUE for fishing locations combined occurred during daylight at 4.44 chum/h, while the median CPUE for the dark and twilight periods were 4.06 chum/h and 3.43 chum/h, respectively (Table 2). The notched box plot (Figure 6) shows no significant differences in median values between ambient light phases. The Kruskal-Wallis test also detected no significant differences between the three light phases for combined fishing locations ($H_C$=2.07;

$X^2_{.10,2}$=4.61). Chum CPUE values, ranks and resultant statistics for ambient light periods with fishing locations combined are presented in Appendix F.

## DISCUSSION

The results indicate that ambient light is apparently not a major influence upon coho or chum salmon gill net CPUE in the District 6 gill net areas. In the fall gill net fisheries the use of night fishing closures as a management option to reduce coho harvests during years of reduced coho abundance, while targeting on chum salmon, would not be effective. Furthermore, if night closures were implemented, total fishing time reductions might be necessary as night closures would provide a rest period for fishermen which could result in increased fishing effort during the open daylight periods.

Although no statistically significant differences existed between CPUE during the three phases of ambient light, catch rates for coho between individual sets did demonstrate distinct differences. The large variation in CPUE between individual sets combined with the small sample size for full darkness sets may have essentially masked any detectable differences in CPUE between the three ambient light phases. Different results than were seen in this study may have been obtained had the number of sets made during full darkness been greater. Increasing the number of night sets by including sets during the 0100-0300 period would have given us a more representative sample of catches during the full darkness period.

A more thorough project utilizing a greater number of sets in all three light phases was conducted in 1989. The data is currently undergoing analysis. It is hoped that by increasing the number of sets more conclusive information about the actual effects of light conditions on catches of coho, chum, and other salmon species can be obtained.

## LITERATURE CITED


USNO (United States Naval Observatory). 1987. The astronomical almanac for the year 1988. U.S. Government Printing Office. Washington, D.C.

Van Alen, B. W. 1981. 1980 Nushagak Bay offshore test fishing. Pages 15-41 in H. Yuen, ed. 1980 Bristol Bay sockeye salmon test fishing projects. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 65, Juneau.

Zar, J. H. 1984. Biostatistical analysis. 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Table 1. Coho salmon catches, median CPUE (coho/h), number of sets and hours fished by ambient light phase and fishing location for the 1988 Clarence Strait test fishery.

| | DAYLIGHT | TWILIGHT | DARK |
|---|---|---|---|
| | ONSHORE | | |
| Catch | 193 | 51 | 24 |
| Median CPUE | 4.36 | 1.90 | 3.53 |
| Sets | 22 | 11 | 5 |
| Hours Fished | 39.72 | 21.04 | 7.44 |
| | OFFSHORE | | |
| Catch | 57 | 76 | 11 |
| Median CPUE | 2.10 | 2.13 | 2.44 |
| Sets | 12 | 10 | 3 |
| Hours Fished | 24.22 | 23.89 | 5.23 |
| | LOCATIONS COMBINED | | |
| Catch | 250 | 127 | 35 |
| Median CPUE | 3.13 | 1.98 | 2.98 |
| Sets | 34 | 21 | 8 |
| Hours Fished | 63.94 | 44.93 | 12.67 |

Table 2. Chum salmon catches, median CPUE (coho/h), number of sets and hours fished by ambient light phase and fishing location for the 1988 Clarence Strait test fishery.

| | DAYLIGHT | TWILIGHT | DARK |
|---|---|---|---|
| | ---------------ONSHORE----------- | | |
| Catch | 266 | 83 | 35 |
| Median CPUE | 6.42 | 2.83 | 4.74 |
| Sets | 22 | 11 | 5 |
| Hours Fished | 39.72 | 21.04 | 7.44 |
| | ---------------OFFSHORE----------- | | |
| Catch | 99 | 100 | 15 |
| Median CPUE | 3.32 | 4.06 | 3.38 |
| Sets | 12 | 10 | 3 |
| Hours Fished | 24.22 | 23.89 | 5.23 |
| | --------LOCATIONS COMBINED-------- | | |
| Catch | 365 | 183 | 50 |
| Median CPUE | 4.44 | 3.43 | 4.06 |
| Sets | 34 | 21 | 8 |
| Hours Fished | 63.94 | 44.93 | 12.67 |

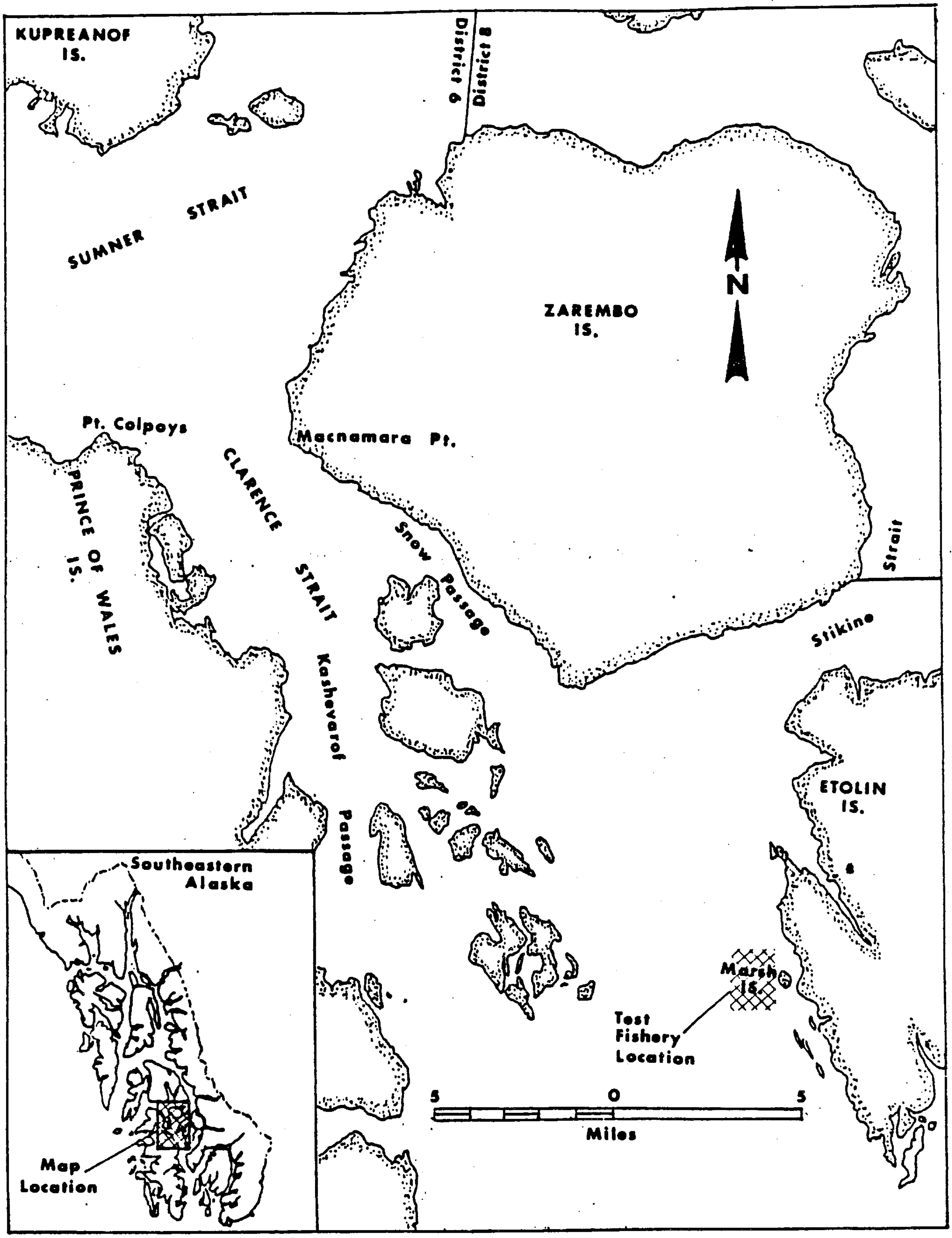



Figure 1. Sumner and upper Clarence Straits showing the 1988 Clarence Strait gill net test fishery location.

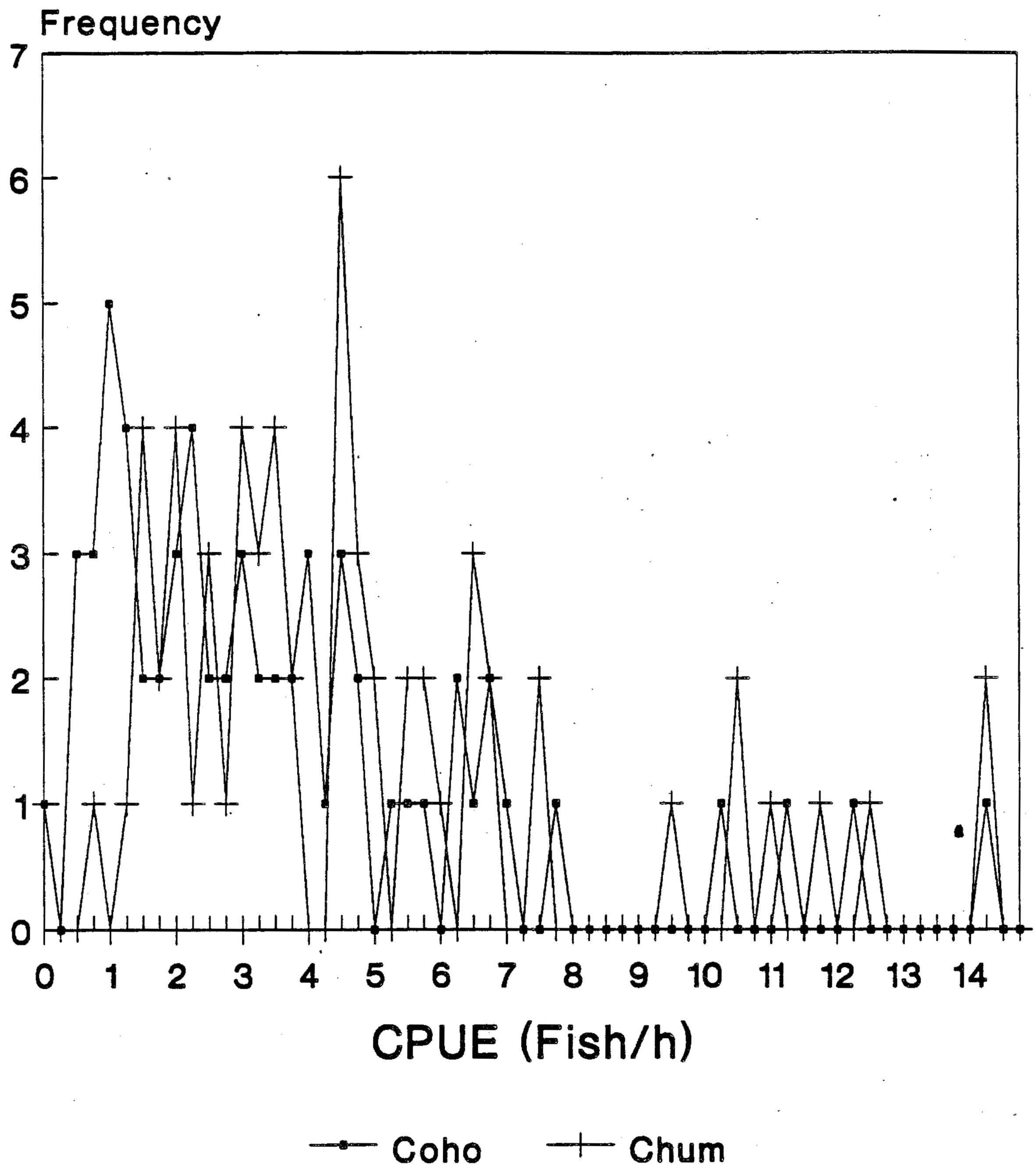
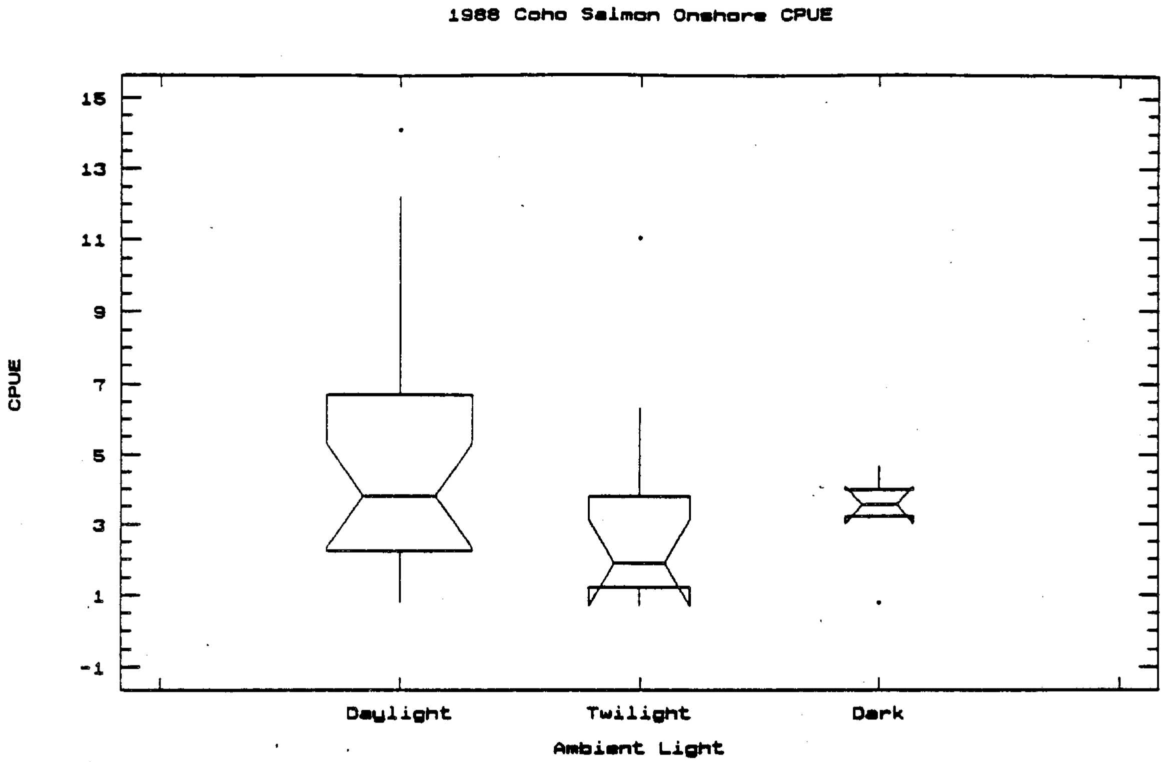



Figure 2. Distribution of the CPUE for coho and chum salmon in the Clarence Strait gill net test fishery.



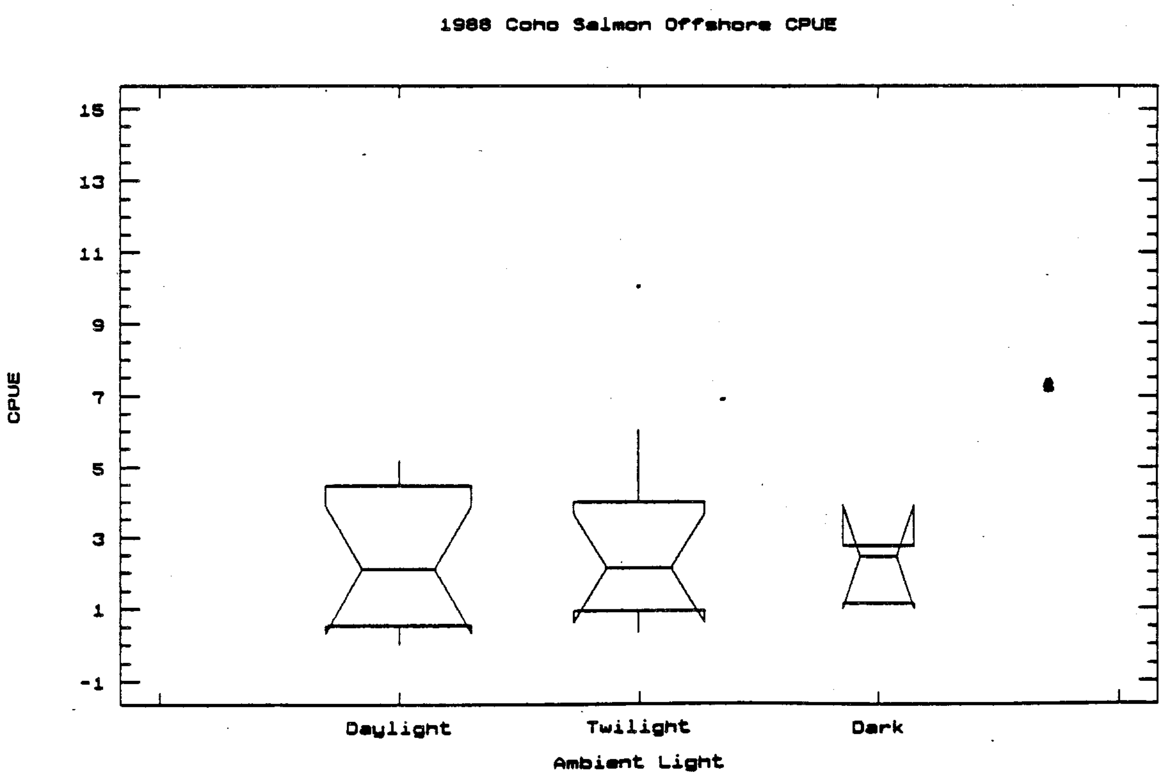




Figure 3. Box plots of the coho CPUE showing the median and range (vertical bar and points) for ambient light phases in separate fishing locations.

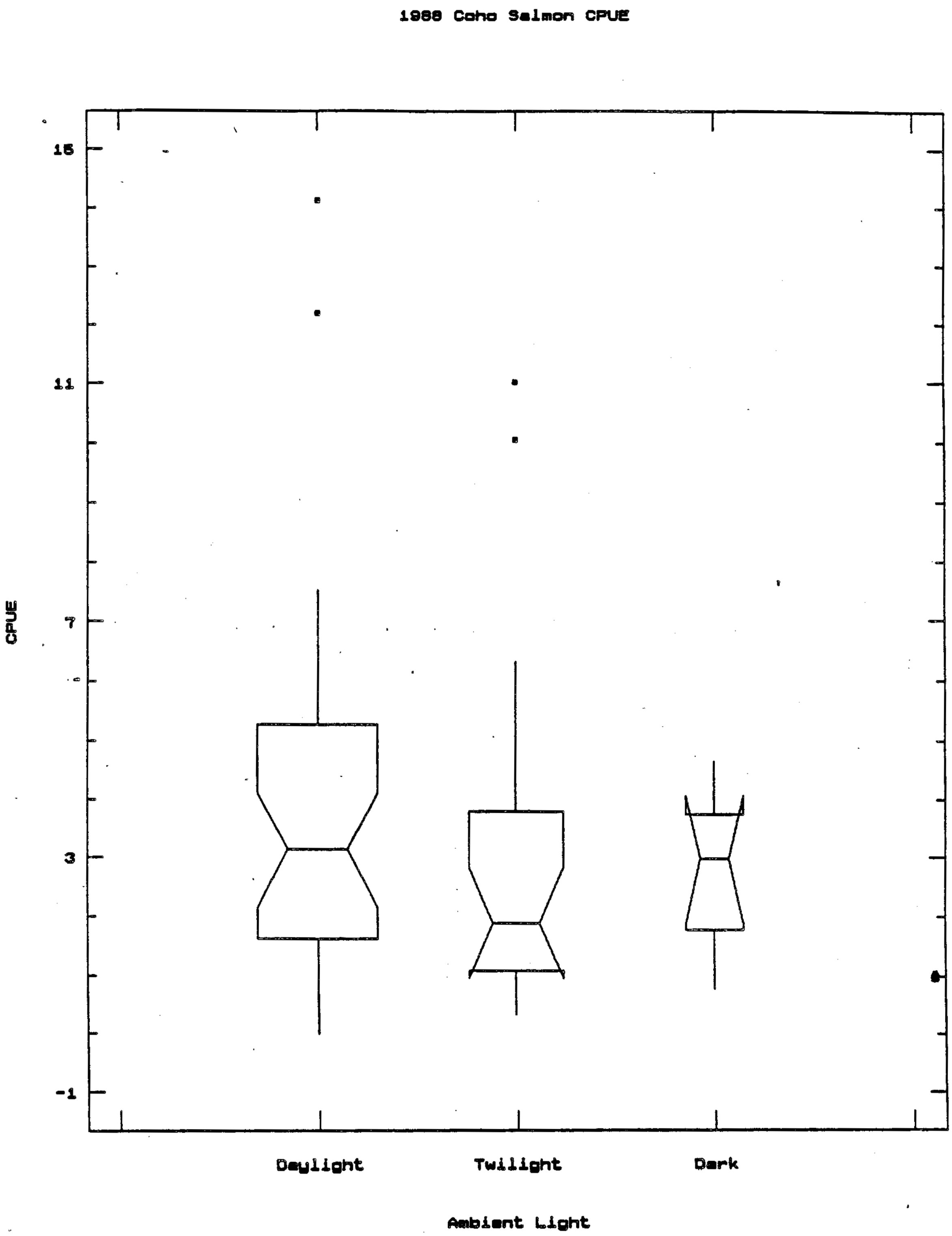
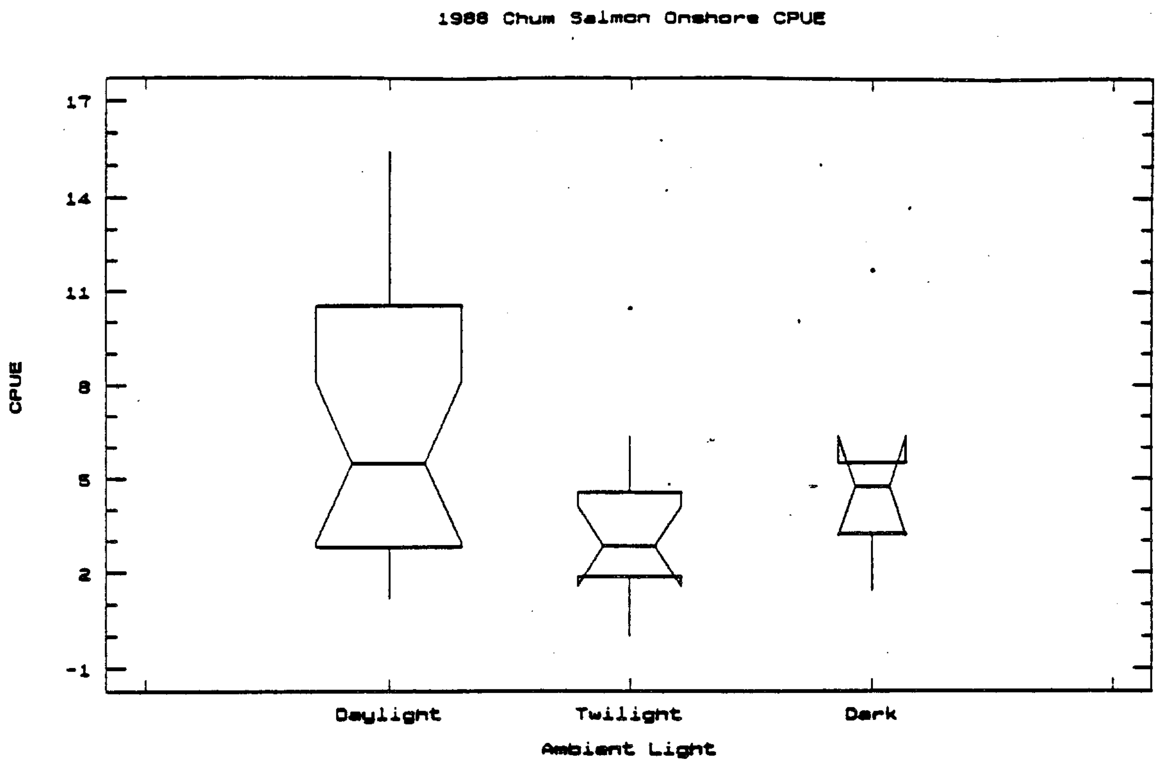



Figure 4. Box plots of the coho CPUE showing the median and range (vertical bar and points) for ambient light phases and combined fishing locations.



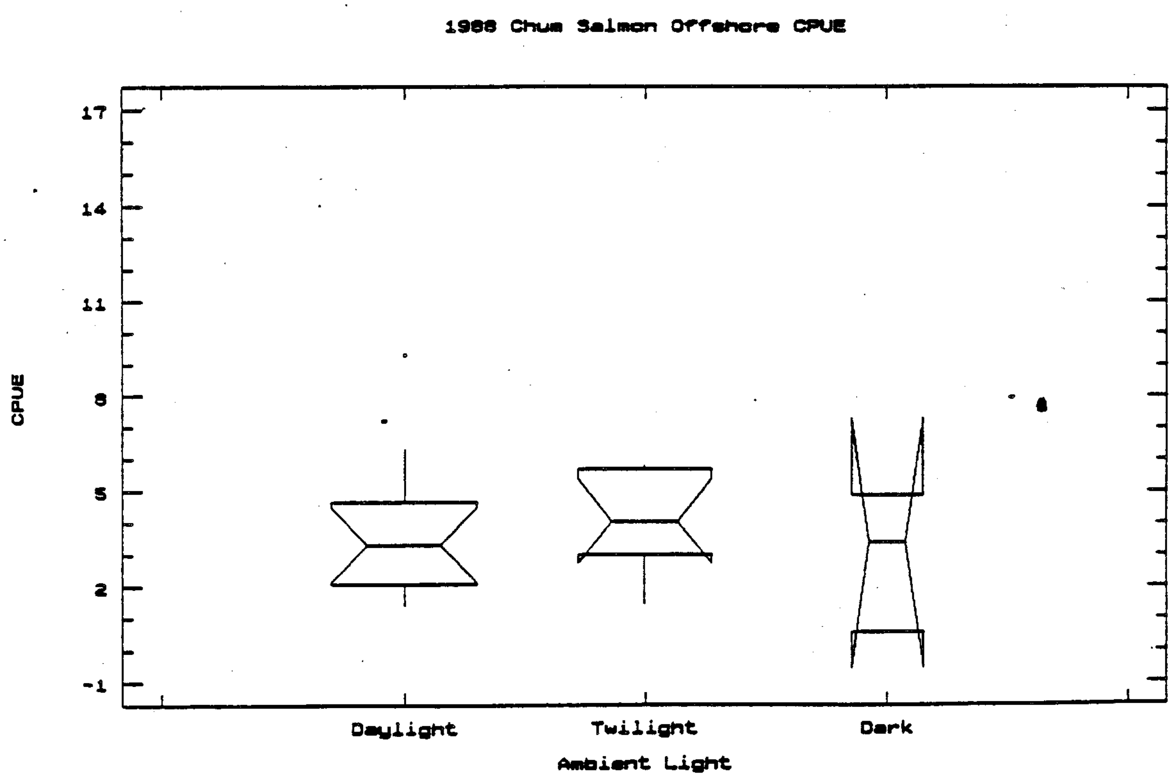




Figure 5. Box plots of the chum CPUE showing the median and range (vertical bar and points) for ambient light phases in separate fishing locations.

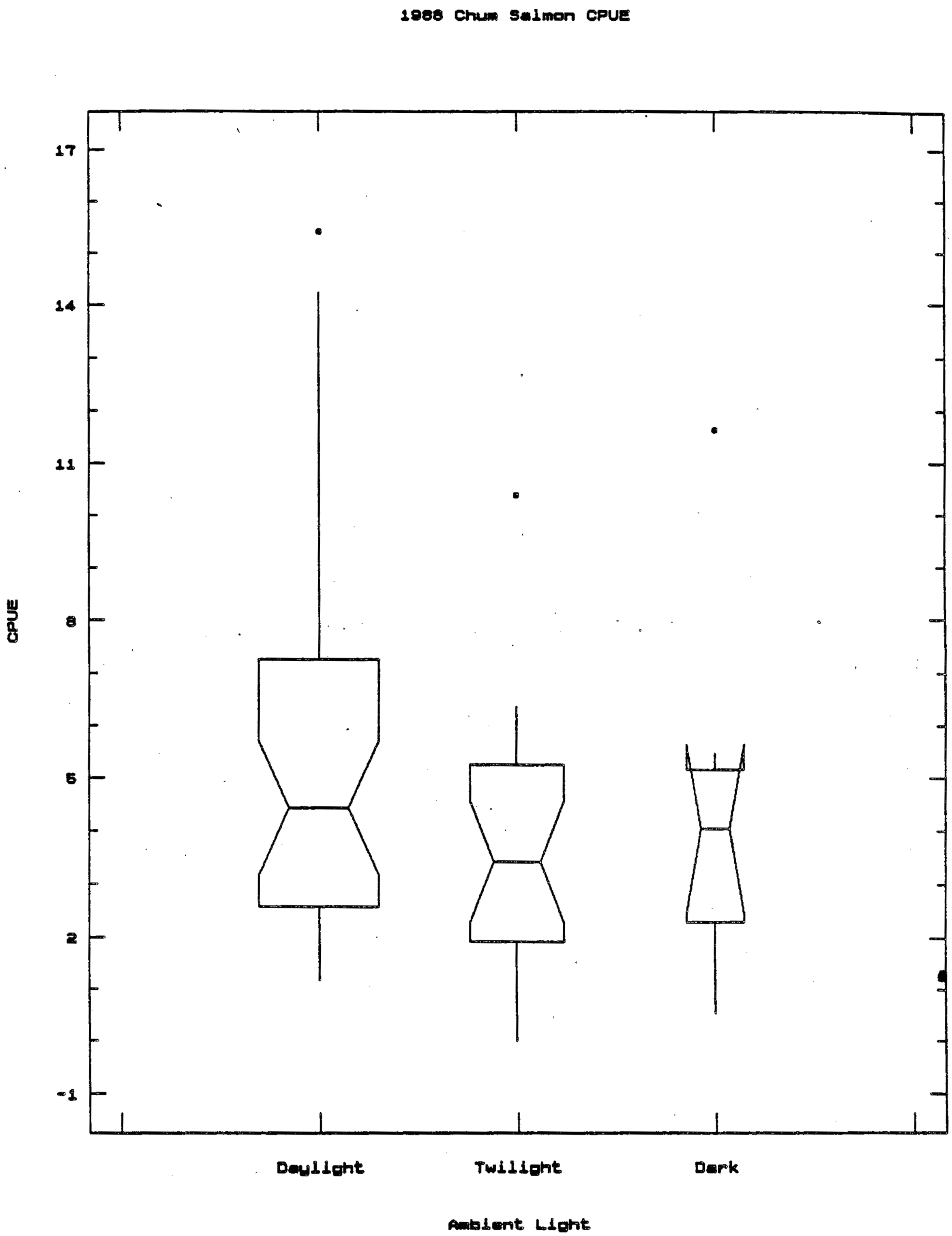



Figure 6. Box plots of the chum CPUE showing the median and range (vertical bar and points) for ambient light phases and combined fishing locations.

# APPENDICES

Appendix A. Coho salmon catches, CPUE (coho/h), fishing hours, ambient light phase, and date of sets by fishing location and time for the 1988 Clarence Strait gill net test fishery.

| Date | Coho Catch | Start Net Out | Net Full Out | Start Net In | Net Full In | Fishing Time (Hours) | CPUE | Ambient Light Phase |
|---|---|---|---|---|---|---|---|---|
| ONSHORE | | | | | | | | |
| 09/02 | 4 | 326 | 338 | 548 | 613 | 2.48 | 1.62 | Twilight |
| 08/26 | 9 | 455 | 503 | 536 | 600 | 0.82 | 11.02 | Twilight |
| 09/07 | 3 | 407 | 432 | 632 | 701 | 2.45 | 1.22 | Twilight |
| 09/02 | 3 | 623 | 632 | 745 | 752 | 1.35 | 2.22 | Daylight |
| 08/26 | 4 | 611 | 619 | 740 | 756 | 1.55 | 2.58 | Daylight |
| 09/07 | 2 | 705 | 732 | 800 | 815 | 0.82 | 2.45 | Daylight |
| 09/16 | 16 | 713 | 721 | 916 | 954 | 2.30 | 6.96 | Daylight |
| 08/26 | 1 | 813 | 819 | 924 | 940 | 1.27 | 0.79 | Daylight |
| 09/02 | 12 | 755 | 803 | 941 | 1008 | 1.93 | 6.23 | Daylight |
| 08/24 | 18 | 812 | 822 | 931 | 1000 | 1.48 | 12.20 | Daylight |
| 09/14 | 3 | 805 | 820 | 1033 | 1100 | 2.57 | 1.17 | Daylight |
| 09/07 | 6 | 825 | 840 | 1035 | 1105 | 2.29 | 2.62 | Daylight |
| 09/15 | 6 | 1008 | 1016 | 1142 | 1210 | 1.73 | 3.46 | Daylight |
| 09/02 | 3 | 1014 | 1022 | 1137 | 1152 | 1.44 | 2.08 | Daylight |
| 08/24 | 8 | 1003 | 1010 | 1150 | 1215 | 1.93 | 4.14 | Daylight |
| 09/07 | 22 | 1110 | 1118 | 1230 | 1305 | 1.56 | 14.12 | Daylight |
| 09/02 | 2 | 1201 | 1211 | 1319 | 1337 | 1.37 | 1.46 | Daylight |
| 09/16 | 16 | 1224 | 1233 | 1435 | 1508 | 2.38 | 6.71 | Daylight |
| 08/24 | 19 | 1217 | 1225 | 1457 | 1527 | 2.85 | 6.67 | Daylight |
| 09/02 | 2 | 1346 | 1354 | 1455 | 1512 | 1.23 | 1.63 | Daylight |
| 08/24 | 9 | 1530 | 1537 | 1705 | 1727 | 1.71 | 5.27 | Daylight |
| 09/16 | 6 | 1515 | 1520 | 1715 | 1737 | 2.14 | 2.80 | Daylight |
| 09/02 | 9 | 1525 | 1532 | 1652 | 1719 | 1.62 | 5.57 | Daylight |
| 09/14 | 17 | 1532 | 1540 | 1730 | 1813 | 2.26 | 7.53 | Daylight |
| 09/07 | 9 | 1617 | 1624 | 1805 | 1832 | 1.97 | 4.58 | Daylight |
| 09/06 | 4 | 1805 | 1825 | 2010 | 2040 | 2.17 | 1.85 | Twilight |
| 09/01 | 1 | 1836 | 1843 | 1958 | 2016 | 1.46 | 0.69 | Twilight |
| 08/24 | 9 | 1730 | 1734 | 1957 | 2019 | 2.60 | 3.46 | Twilight |
| 08/25 | 3 | 2029 | 2037 | 2052 | 2111 | 0.48 | 6.32 | Twilight |
| 09/15 | 5 | 1837 | 1850 | 2043 | 2121 | 2.31 | 2.17 | Twilight |
| 08/30 | 5 | 1825 | 1845 | 2055 | 2130 | 2.63 | 1.90 | Twilight |
| 09/01 | 2 | 2023 | 2032 | 2215 | 2245 | 2.04 | 0.98 | Twilight |
| 08/24 | 6 | 2025 | 2033 | 2152 | 2216 | 1.58 | 3.79 | Twilight |
| 09/06 | 6 | 2045 | 2110 | 2235 | 2305 | 1.88 | 3.20 | Dark |
| 08/30 | 8 | 2137 | 2152 | 2328 | 2402 | 2.01 | 3.98 | Dark |
| 08/24 | 1 | 2220 | 2228 | 2329 | 2351 | 1.27 | 0.79 | Dark |
| 09/01 | 4 | 2254 | 2303 | 2340 | 2400 | 0.86 | 4.66 | Dark |
| 09/06 | 5 | 2315 | 2330 | 2435 | 2500 | 1.42 | 3.53 | Dark |
| OFFSHORE | | | | | | | | |
| 08/25 | 23 | 317 | 332 | 523 | 600 | 2.28 | 10.07 | Twilight |
| 09/15 | 3 | 350 | 407 | 630 | 657 | 2.75 | 1.09 | Twilight |
| 09/16 | 1 | 345 | 404 | 640 | 704 | 2.96 | 0.34 | Twilight |
| 09/08 | 19 | 342 | 405 | 644 | 722 | 3.16 | 6.02 | Twilight |
| 09/09 | 9 | 403 | 417 | 650 | 725 | 2.96 | 3.04 | Twilight |
| 08/25 | 2 | 606 | 613 | 807 | 852 | 2.33 | 0.86 | Daylight |
| 09/09 | 5 | 728 | 735 | 930 | 1000 | 2.23 | 2.25 | Daylight |
| 09/15 | 11 | 707 | 718 | 921 | 1001 | 2.48 | 4.44 | Daylight |
| 09/08 | 1 | 732 | 749 | 955 | 1023 | 2.48 | 0.40 | Daylight |
| 08/25 | 1 | 852 | 900 | 1050 | 1108 | 2.05 | 0.49 | Daylight |
| 09/16 | 9 | 1000 | 1009 | 1153 | 1217 | 2.01 | 4.48 | Daylight |
| 09/09 | 4 | 1008 | 1015 | 1201 | 1229 | 2.06 | 1.94 | Daylight |
| 08/25 | 1 | 1108 | 1117 | 1253 | 1309 | 1.81 | 0.55 | Daylight |
| 09/14 | 0 | 1110 | 1128 | 1237 | 1254 | 1.44 | 0.00 | Daylight |
| 09/15 | 8 | 1216 | 1223 | 1343 | 1402 | 1.55 | 5.16 | Daylight |
| 09/09 | 7 | 1230 | 1238 | 1353 | 1423 | 1.57 | 4.47 | Daylight |
| 09/14 | 8 | 1256 | 1304 | 1458 | 1527 | 2.21 | 3.62 | Daylight |
| 09/08 | 2 | 1729 | 1737 | 1850 | 1912 | 1.47 | 1.36 | Twilight |
| 08/25 | 1 | 1901 | 1908 | 2000 | 2018 | 1.08 | 0.93 | Twilight |
| 09/14 | 2 | 1824 | 1833 | 2052 | 2123 | 2.65 | 0.75 | Twilight |
| 09/07 | 6 | 1906 | 1914 | 2102 | 2127 | 2.08 | 2.89 | Twilight |
| 09/08 | 10 | 1918 | 1925 | 2139 | 2204 | 2.50 | 4.00 | Twilight |
| 09/15 | 5 | 2133 | 2147 | 2319 | 2338 | 1.81 | 2.76 | Dark |
| 09/14 | 4 | 2126 | 2137 | 2259 | 2321 | 1.64 | 2.44 | Dark |
| 09/07 | 2 | 2127 | 2138 | 2308 | 2330 | 1.78 | 1.13 | Dark |

Appendix B. Chum salmon catches, CPUE (chum/h), fishing hours, ambient light phase, and date of sets by fishing location and time for the 1988 Clarence Strait gill net test fishery.

| Date | Chum Catch | Start Net Out | Net Full Out | Start Net In | Net Full In | Fishing Time (Hour) | CPUE | Ambient Light Phase |
|---|---|---|---|---|---|---|---|---|
| ONSHORE | | | | | | | | |
| 09/02 | 7 | 326 | 338 | 548 | 613 | 2.48 | 2.83 | Twilight |
| 08/26 | 2 | 455 | 503 | 536 | 600 | 0.82 | 2.45 | Twilight |
| 09/07 | 4 | 407 | 432 | 632 | 701 | 2.45 | 1.63 | Twilight |
| 09/02 | 4 | 611 | 619 | 740 | 756 | 1.55 | 2.58 | Daylight |
| 08/26 | 6 | 623 | 632 | 745 | 752 | 1.35 | 4.44 | Daylight |
| 09/07 | 2 | 705 | 732 | 800 | 815 | 0.82 | 2.45 | Daylight |
| 09/16 | 17 | 713 | 721 | 916 | 954 | 2.30 | 7.39 | Daylight |
| 08/26 | 14 | 755 | 803 | 941 | 1008 | 1.93 | 7.27 | Daylight |
| 09/02 | 21 | 812 | 822 | 931 | 1000 | 1.48 | 14.24 | Daylight |
| 08/24 | 3 | 813 | 819 | 924 | 940 | 1.27 | 2.37 | Daylight |
| 09/14 | 3 | 805 | 820 | 1033 | 1100 | 2.57 | 1.17 | Daylight |
| 09/07 | 24 | 825 | 840 | 1035 | 1105 | 2.29 | 10.47 | Daylight |
| 09/15 | 21 | 1003 | 1010 | 1150 | 1215 | 1.93 | 10.86 | Daylight |
| 09/02 | 5 | 1008 | 1016 | 1142 | 1210 | 1.73 | 2.88 | Daylight |
| 08/24 | 2 | 1014 | 1022 | 1137 | 1152 | 1.44 | 1.39 | Daylight |
| 09/07 | 24 | 1110 | 1118 | 1230 | 1305 | 1.56 | 15.40 | Daylight |
| 09/02 | 6 | 1201 | 1211 | 1319 | 1337 | 1.37 | 4.39 | Daylight |
| 09/16 | 18 | 1217 | 1225 | 1457 | 1527 | 2.85 | 6.32 | Daylight |
| 08/24 | 16 | 1224 | 1233 | 1435 | 1508 | 2.38 | 6.71 | Daylight |
| 09/02 | 8 | 1346 | 1354 | 1455 | 1512 | 1.23 | 6.53 | Daylight |
| 08/24 | 6 | 1515 | 1520 | 1715 | 1737 | 2.14 | 2.80 | Daylight |
| 09/16 | 23 | 1525 | 1532 | 1652 | 1719 | 1.62 | 14.23 | Daylight |
| 09/02 | 8 | 1530 | 1537 | 1705 | 1727 | 1.71 | 4.68 | Daylight |
| 09/14 | 28 | 1532 | 1540 | 1730 | 1813 | 2.26 | 12.40 | Daylight |
| 09/07 | 7 | 1617 | 1624 | 1805 | 1832 | 1.97 | 3.56 | Daylight |
| 09/06 | 5 | 1730 | 1734 | 1957 | 2019 | 2.60 | 1.92 | Twilight |
| 09/01 | 4 | 1805 | 1825 | 2010 | 2040 | 2.17 | 1.85 | Twilight |
| 08/24 | 5 | 1836 | 1843 | 1958 | 2016 | 1.46 | 3.43 | Twilight |
| 08/25 | 12 | 1825 | 1845 | 2055 | 2130 | 2.63 | 4.57 | Twilight |
| 09/15 | 24 | 1837 | 1850 | 2043 | 2121 | 2.31 | 10.40 | Twilight |
| 08/30 | 0 | 2029 | 2037 | 2052 | 2111 | 0.48 | 0.00 | Twilight |
| 09/01 | 13 | 2023 | 2032 | 2215 | 2245 | 2.04 | 6.37 | Twilight |
| 08/24 | 7 | 2025 | 2033 | 2152 | 2216 | 1.58 | 4.42 | Twilight |
| 09/06 | 6 | 2045 | 2110 | 2235 | 2305 | 1.88 | 3.20 | Dark |
| 08/30 | 11 | 2137 | 2152 | 2328 | 2402 | 2.01 | 5.48 | Dark |
| 08/24 | 6 | 2220 | 2228 | 2329 | 2351 | 1.27 | 4.74 | Dark |
| 09/01 | 10 | 2254 | 2303 | 2340 | 2400 | 0.86 | 11.65 | Dark |
| 09/06 | 2 | 2315 | 2330 | 2435 | 2500 | 1.42 | 1.41 | Dark |
| OFFSHORE | | | | | | | | |
| 08/25 | 12 | 317 | 332 | 523 | 600 | 2.28 | 5.26 | Twilight |
| 09/15 | 18 | 342 | 405 | 644 | 722 | 3.16 | 5.70 | Twilight |
| 09/16 | 13 | 345 | 404 | 640 | 704 | 2.96 | 4.39 | Twilight |
| 09/08 | 16 | 350 | 407 | 630 | 657 | 2.75 | 5.82 | Twilight |
| 09/09 | 17 | 403 | 417 | 650 | 725 | 2.96 | 5.75 | Twilight |
| 08/25 | 7 | 606 | 613 | 807 | 852 | 2.33 | 3.00 | Daylight |
| 09/09 | 23 | 707 | 718 | 921 | 1001 | 2.48 | 9.29 | Daylight |
| 09/15 | 7 | 728 | 735 | 930 | 1000 | 2.23 | 3.15 | Daylight |
| 09/08 | 11 | 732 | 749 | 955 | 1023 | 2.48 | 4.44 | Daylight |
| 08/25 | 4 | 852 | 900 | 1050 | 1108 | 2.05 | 1.95 | Daylight |
| 09/16 | 7 | 1000 | 1009 | 1153 | 1217 | 2.01 | 3.49 | Daylight |
| 09/09 | 10 | 1008 | 1015 | 1201 | 1229 | 2.06 | 4.86 | Daylight |
| 08/25 | 4 | 1108 | 1117 | 1253 | 1309 | 1.81 | 2.21 | Daylight |
| 09/14 | 2 | 1110 | 1128 | 1237 | 1254 | 1.44 | 1.39 | Daylight |
| 09/15 | 3 | 1216 | 1223 | 1343 | 1402 | 1.55 | 1.94 | Daylight |
| 09/09 | 7 | 1230 | 1238 | 1353 | 1423 | 1.57 | 4.47 | Daylight |
| 09/14 | 14 | 1256 | 1304 | 1458 | 1527 | 2.21 | 6.34 | Daylight |
| 09/08 | 5 | 1729 | 1737 | 1850 | 1912 | 1.47 | 3.41 | Twilight |
| 08/25 | 4 | 1901 | 1908 | 2000 | 2018 | 1.08 | 3.72 | Twilight |
| 09/14 | 8 | 1824 | 1833 | 2052 | 2123 | 2.65 | 3.02 | Twilight |
| 09/07 | 3 | 1906 | 1914 | 2102 | 2127 | 2.08 | 1.45 | Twilight |
| 09/08 | 4 | 1918 | 1925 | 2139 | 2204 | 2.50 | 1.60 | Twilight |
| 09/15 | 8 | 2126 | 2137 | 2259 | 2321 | 1.64 | 4.87 | Dark |
| 09/14 | 6 | 2127 | 2138 | 2308 | 2330 | 1.78 | 3.38 | Dark |
| 09/07 | 1 | 2133 | 2147 | 2319 | 2338 | 1.81 | 0.55 | Dark |

Appendix C. Coho salmon CPUE values, ranks, and resultant statistics from the Kruskal-Wallis test for ambient light phases in separate fishing locations.

| | ONSHORE DAYLIGHT | | OFFSHORE DAYLIGHT | | ONSHORE TWILIGHT | | OFFSHORE TWILIGHT | | ONSHORE DARK | | OFFSHORE DARK | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CPUE | Rank | CPUE | Rank | CPUE | Rank | CPUE | Rank | CPUE | Rank | CPUE | Rank |
| | 0.79 | 8.5 | 0.00 | 1 | 0.69 | 6 | 0.34 | 2 | 0.79 | 8.5 | 1.13 | 14 |
| | 1.17 | 15 | 0.40 | 3 | 0.98 | 12 | 0.75 | 7 | 3.20 | 36 | 2.44 | 28.5 |
| | 1.46 | 18 | 0.49 | 4 | 1.22 | 16 | 0.93 | 11 | 3.53 | 39 | 2.76 | 32 |
| | 1.63 | 19.5 | 0.55 | 5 | 1.62 | 19.5 | 1.09 | 13 | 3.98 | 42 | | |
| | 2.08 | 24 | 0.86 | 10 | 1.85 | 21 | 1.36 | 17 | 4.66 | 49 | | |
| | 2.22 | 26 | 1.94 | 23 | 1.90 | 22 | 2.89 | 34 | | | | |
| | 2.45 | 28.5 | 2.25 | 27 | 2.17 | 25 | 3.04 | 35 | | | | |
| | 2.58 | 30 | 3.62 | 40 | 3.46 | 37.5 | 4.00 | 43 | | | | |
| | 2.62 | 31 | 4.44 | 45 | 3.79 | 41 | 6.02 | 53 | | | | |
| | 2.80 | 33 | 4.47 | 46.5 | 6.32 | 55 | 10.07 | 61 | | | | |
| | 3.46 | 37.5 | 6.48 | 46.5 | 11.02 | 60 | | | | | | |
| | 4.14 | 44 | 5.16 | 50 | | | | | | | | |
| | 4.58 | 48 | | | | | | | | | | |
| | 5.27 | 51 | | | | | | | | | | |
| | 5.57 | 52 | | | | | | | | | | |
| | 6.23 | 54 | | | | | | | | | | |
| | 6.67 | 56 | | | | | | | | | | |
| | 6.71 | 57 | | | | | | | | | | |
| | 6.96 | 58 | | | | | | | | | | |
| | 7.53 | 59 | | | | | | | | | | |
| | 12.20 | 62 | | | | | | | | | | |
| | 14.12 | 63 | | | | | | | | | | |
| SUM (Ri) | | 875 | | 301 | | 316 | | 276 | | 174.5 | | 74.5 |
| ni | | 22 | | 12 | | 11 | | 10 | | 5 | | 3 |
| MEDIAN | 4.36 | | 2.10 | | 1.90 | | 2.13 | | 3.53 | | 2.44 | |
| MEAN | 4.69 | | 2.39 | | 3.18 | | 3.05 | | 3.23 | | 2.11 | |
| SD | 3.45 | | 1.93 | | 3.06 | | 3.05 | | 3.22 | | 0.87 | |

$H_o$: $CPUE_{ondaylight} = CPUE_{offdaylight} = CPUE_{ontwilight} = CPUE_{offtwilight} = CPUE_{ondark} = CPUE_{offdark}$

$H_A$: $CPUE_{ondaylight} \neq CPUE_{offdaylight} \neq CPUE_{ontwilight} \neq CPUE_{offtwilight} \neq CPUE_{ondark} \neq CPUE_{offdark}$

Combined Locations and Light Phases:

N 63
MEDIAN 2.76
MEAN 3.49
SD 2.91

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1) = 7.365$$

$$C = 1 - \frac{\Sigma T}{N^3 - N} = .9999$$

$$\Sigma T = \sum_{i=1}^{m} (t_i^3 - t_i) = 30$$

$H = 7.365$
$H_C = H/C = 7.366$
$v = k - 1 = 5$
$(X^2_{.10,5} = 9.236)$
Accept $H_o$
$.10 < P$

where: $t_i$ = number of ties in the $i^{th}$ group of ties
m = number of groups of tied ranks = 5
C = correction factor for tied ranks
$H_c$ = corrected H statistic

Appendix D. Coho salmon CPUE values, ranks, and resultant statistics from the Kruskal-Wallis test for ambient light phases in combined fishing locations.

| | Daylight CPUE | Daylight Rank | Twilight CPUE | Twilight Rank | Dark CPUE | Dark Rank |
|---|---|---|---|---|---|---|
| | 0.00 | 1 | 0.34 | 2 | 0.79 | 8.5 |
| | 0.40 | 3 | 0.69 | 6 | 1.13 | 14 |
| | 0.49 | 4 | 0.75 | 7 | 2.44 | 28.5 |
| | 0.55 | 5 | 0.93 | 11 | 2.76 | 32 |
| | 0.79 | 8.5 | 0.98 | 12 | 3.20 | 36 |
| | 0.86 | 10 | 1.09 | 13 | 3.53 | 39 |
| | 1.17 | 15 | 1.22 | 16 | 3.98 | 42 |
| | 1.46 | 18 | 1.36 | 17 | 4.66 | 49 |
| | 1.63 | 19.5 | 1.62 | 19.5 | | |
| | 1.94 | 23 | 1.85 | 21 | | |
| | 2.08 | 24 | 1.90 | 22 | | |
| | 2.22 | 26 | 2.17 | 25 | | |
| | 2.25 | 27 | 2.89 | 34 | | |
| | 2.45 | 28.5 | 3.04 | 35 | | |
| | 2.58 | 30 | 3.46 | 37.5 | | |
| | 2.62 | 31 | 3.79 | 41 | | |
| | 2.80 | 33 | 4.00 | 43 | | |
| | 3.46 | 37.5 | 6.02 | 53 | | |
| | 3.62 | 40 | 6.32 | 55 | | |
| | 4.14 | 44 | 10.07 | 60 | | |
| | 4.44 | 45 | 11.02 | 61 | | |
| | 4.47 | 46.5 | | | | |
| | 4.48 | 46.5 | | | | |
| | 4.58 | 48 | | | | |
| | 5.16 | 50 | | | | |
| | 5.27 | 51 | | | | |
| | 5.57 | 52 | | | | |
| | 6.23 | 54 | | | | |
| | 6.67 | 56 | | | | |
| | 6.71 | 57 | | | | |
| | 6.96 | 58 | | | | |
| | 7.53 | 59 | | | | |
| | 12.20 | 62 | | | | |
| | 14.12 | 63 | | | | |
| SUM (Ri) | | 1176 | | 591 | | 249 |
| ni | | 34 | | 21 | | 8 |
| MEDIAN | 3.13 | | 1.98 | | 2.98 | |
| MEAN | 3.88 | | 3.12 | | 2.81 | |
| SD | 3.17 | | 2.97 | | 1.34 | |

$H_o$: $CPUE_{Daylight} = CPUE_{twilight} = CPUE_{dark}$

$H_A$: $CPUE_{Daylight} \neq CPUE_{twilight} \neq CPUE_{dark}$

Light Phases Combined:

N 63
MEDIAN 2.76
MEAN 3.49
SD 2.91

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1) = 1.626$$

$H = 1.63$
$H_c = H/C = 1.63$

$$C = 1 - \frac{\Sigma T}{N^3 - N} = .9999$$

$v = k - 1 = 2$
$(X^2_{.10,2} = 4.605)$
Accept $H_o$
$.10 < P$

$$\Sigma T = \sum_{i=1}^{m} (t_i^3 - t_i) = 30$$

where: $t_i$ = number of ties in the $i^{th}$ group of ties
$m$ = number of groups of tied ranks = 5
$C$ = correction factor for tied ranks
$H_c$ = corrected H statistic

## Appendix E. Chum salmon CPUE values, ranks, and resultant statistics from the Kruskal-Wallis test for ambient light phases in separate fishing locations.

| | ONSHORE DAYLIGHT CPUE | ONSHORE DAYLIGHT Rank | OFFSHORE DAYLIGHT CPUE | OFFSHORE DAYLIGHT Rank | ONSHORE TWILIGHT CPUE | ONSHORE TWILIGHT Rank | OFFSHORE TWILIGHT CPUE | OFFSHORE TWILIGHT Rank | ONSHORE DARK CPUE | ONSHORE DARK Rank | OFFSHORE DARK CPUE | OFFSHORE DARK Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.17 | 3 | 1.39 | 4.5 | 0.00 | 1 | 1.45 | 7 | 1.41 | 6 | 0.55 | 2 |
| | 1.39 | 4.5 | 1.94 | 12.5 | 1.63 | 9 | 1.60 | 8 | 3.20 | 25 | 3.38 | 26 |
| | 2.37 | 15 | 1.95 | 12.5 | 1.85 | 10 | 3.02 | 23 | 4.74 | 40 | 4.87 | 41.5 |
| | 2.45 | 16.5 | 2.21 | 14 | 1.92 | 11 | 3.41 | 27 | 5.48 | 44 | | |
| | 2.58 | 18 | 3.00 | 22 | 2.45 | 16.5 | 3.72 | 31 | 11.65 | 59 | | |
| | 2.80 | 19 | 3.15 | 24 | 2.83 | 20 | 4.39 | 32.5 | | | | |
| | 2.88 | 21 | 3.49 | 29 | 3.43 | 28 | 5.26 | 43 | | | | |
| | 3.56 | 30 | 4.44 | 35.5 | 4.42 | 34 | 5.70 | 45 | | | | |
| | 4.39 | 32.5 | 4.47 | 37 | 4.57 | 38 | 5.75 | 46 | | | | |
| | 4.44 | 35.5 | 4.86 | 41.5 | 6.37 | 50 | 5.82 | 47 | | | | |
| | 4.68 | 39 | 6.34 | 49 | 10.40 | 56 | | | | | | |
| | 6.32 | 48 | 9.29 | 55 | | | | | | | | |
| | 6.53 | 51 | | | | | | | | | | |
| | 6.71 | 52 | | | | | | | | | | |
| | 7.27 | 53 | | | | | | | | | | |
| | 7.39 | 54 | | | | | | | | | | |
| | 10.47 | 57 | | | | | | | | | | |
| | 10.86 | 58 | | | | | | | | | | |
| | 12.40 | 60 | | | | | | | | | | |
| | 14.23 | 61.5 | | | | | | | | | | |
| | 14.24 | 61.5 | | | | | | | | | | |
| | 15.40 | 63 | | | | | | | | | | |
| SUM (Ri) | | 853 | | 336.5 | | 273.5 | | 309.5 | | 174 | | 69.5 |
| ni | | 22 | | 12 | | 11 | | 10 | | 5 | | 3 |
| MEDIAN | 6.42 | | 3.32 | | 2.83 | | 4.06 | | 4.74 | | 3.38 | |
| MEAN | 6.57 | | 3.88 | | 3.62 | | 4.01 | | 5.30 | | 2.94 | |
| SD | 4.48 | | 2.23 | | 2.83 | | 1.67 | | 1.76 | | 2.19 | |

$H_o$: $CPUE_{ondaylight} = CPUE_{offdaylight} = CPUE_{ontwilight} = CPUE_{offtwilight} = CPUE_{ondark} = CPUE_{offdark}$

$H_A$: $CPUE_{ondaylight} \neq CPUE_{offdaylight} \neq CPUE_{ontwilight} \neq CPUE_{offtwilight} \neq CPUE_{ondark} \neq CPUE_{offdark}$

Combined Locations and Light Phases:

N 63
MEDIAN 4.39
MEAN 4.862
SD 3.478
SE 0.438

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1) = 6.076$$

$$C = 1 - \frac{\Sigma T}{N^3 - N} = .9999$$

$$\Sigma T = \sum_{i=1}^{m} (t_i^3 - t_i) = 36$$

$H = 6.076$
$H_c = H/C = 6.077$
$v = k - 1 = 5$
$(X^2_{.10,5} = 9.236)$
Accept $H_o$
$.10 < P$

where: $t_i$ = number of ties in the $i^{th}$ group of ties
$m$ = number of groups of tied ranks = 6
$C$ = correction factor for tied ranks
$H_c$ = corrected H statistic

Appendix F. Chum salmon CPUE values, ranks, and resultant statistics from the Kruskal-Wallis test for ambient light phases in combined fishing locations.

| | Daylight | | Twilight | | Dark | |
|---|---|---|---|---|---|---|
| | CPUE | Rank | CPUE | Rank | CPUE | Rank |
| | 1.17 | 3 | 0.00 | 1 | 0.55 | 2 |
| | 1.39 | 4.5 | 1.45 | 7 | 1.41 | 6 |
| | 1.39 | 4.5 | 1.60 | 8 | 3.20 | 25 |
| | 1.94 | 12.5 | 1.63 | 9 | 3.38 | 26 |
| | 1.95 | 12.5 | 1.85 | 10 | 4.74 | 40 |
| | 2.21 | 14 | 1.92 | 11 | 4.87 | 42 |
| | 2.37 | 15 | 2.45 | 16.5 | 5.48 | 44 |
| | 2.45 | 16.5 | 2.83 | 20 | 11.65 | 59 |
| | 2.58 | 18 | 3.02 | 23 | | |
| | 2.80 | 19 | 3.41 | 27 | | |
| | 2.88 | 21 | 3.43 | 28 | | |
| | 3.00 | 22 | 3.72 | 31 | | |
| | 3.15 | 24 | 4.39 | 32.5 | | |
| | 3.49 | 29 | 4.42 | 34 | | |
| | 3.56 | 30 | 4.57 | 38 | | |
| | 4.39 | 32.5 | 5.26 | 43 | | |
| | 4.44 | 35.5 | 5.70 | 45 | | |
| | 4.44 | 35.5 | 5.75 | 46 | | |
| | 4.47 | 37 | 5.82 | 47 | | |
| | 4.68 | 39 | 6.37 | 50 | | |
| | 4.86 | 41 | 10.40 | 56 | | |
| | 6.32 | 48 | | | | |
| | 6.34 | 49 | | | | |
| | 6.53 | 51 | | | | |
| | 6.71 | 52 | | | | |
| | 7.27 | 53 | | | | |
| | 7.39 | 54 | | | | |
| | 9.29 | 55 | | | | |
| | 10.47 | 57 | | | | |
| | 10.86 | 58 | | | | |
| | 12.40 | 60 | | | | |
| | 14.23 | 61.5 | | | | |
| | 14.24 | 61.5 | | | | |
| | 15.40 | 63 | | | | |
| SUM (Ri) | | 1189 | | 583 | | 244 |
| ni | | 34 | | 21 | | 8 |
| MEDIAN | 4.44 | | 3.43 | | 4.06 | |
| MEAN | 5.62 | | 3.81 | | 4.41 | |
| SD | 4.01 | | 2.30 | | 3.39 | |

$H_o$: $CPUE_{Daylight} = CPUE_{twilight} = CPUE_{dark}$

$H_A$: $CPUE_{Daylight} \neq CPUE_{twilight} \neq CPUE_{dark}$

Light Phases Combined:

| | |
|---|---|
| N | 63 |
| MEDIAN | 4.39 |
| MEAN | 4.83 |
| SD | 3.48 |
| | 0.44 |

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1) = 2.07$$

$$C = 1 - \frac{\Sigma T}{N^3 - N} = .9999$$

$$\Sigma T = \sum_{i=1}^{m} (t_i^3 - t_i) = 36$$

$H = 2.07$
$H_c = 2.07$
$v = k - 1 = 2$
$(X^2_{.10,2} = 4.605)$
Accept $H_o$
$.10 < P$

where: $t_i$ = number of ties in the $i^{th}$ group of ties
m = number of groups of tied ranks = 5
C = correction factor for tied ranks
$H_c$ = corrected H statistic