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# NUSHAGAK BAY SALMON FISHERY MODEL

by

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FINAL REPORT

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# BACKGROUND

Among the world's salmon fisheries, those of Alaska and specifically of Bristol Bay are among the largest and best-researched in the world. The Bristol Bay fishery is composed of five fishing districts. The Nushagak Bay fishery has the widest diversity of species harvested and is the largest salmon fishery of Bristol Bay, except for cyclical extremes of abundance of sockeye salmon migrating to the Kvichak River. As with many fisheries, the Nushagak Bay salmon fishery has declined drastically since the turn of the century.

Because of this decline a rigorous research program was developed during the post-war period by W. F. Thompson, at that time Director of the School of Fisheries, University of Washington, with financial support from the salmon industry. As a result, a data base of extraordinarily high quality and detail was generated which provides a rational basis for salmon management.

Consistent management depends on objective decisions preceded by analysis and evaluation of alternative strategies. Computerized models represent the fastest method of processing diverse data for such a decision-making process.

# OBJECTIVES

This contract served as the first step in the development of a comprehensive management model of the salmon fisheries of Nushagak Bay. The final product will be a realistic and verifiable model of the Nushagak fishery which managers can use to evaluate alternative harvest stretegies for their biological as well as conomic objectives. The specific objectives of this contract were to 1) evaluate the utility of migratory time density functions (entry-exit models) of sockeye salmon migrating to Nushagak Bay for intraseason abundance estimation and 2) to develop migratory time density functions for sockeye salmon migrating to the Wood, Igushik and Nuyakuk Rivers for 1979. These objectives were accomplished by:

A. Estimating the total return of sockeye salmon to Nushagak Bay employing:

1. historic migratory time density functions of fish bound for the Wood, Igushik and Nuyakuk Rivers
2. absolute abundance from visual counts from river side towers
3. indices of abundance from inside test fishing programs[1]
4. indices of abundance from outside test fishing programs[2]
5. estimates of abundance from aerial surveys
6. estimates of migratory timing from tagging experiments.

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[1]Inside test fishing programs refer to gill net sampling programs conducted within the Nushagak Bay District and includes both CPUE data supplied by the set-net fishermen and the ADF & G sampling programs conducted in the Igushik and Nuyakuk River to estimate escapement several days in advance of the absolute counts from the river side towers.

[2]Outside test fishing programs refer to sampling projects conducted seaward from the Nushagak Bay fishing district and include both the existing sampling program conducted in the vicinity of Port Moller and the tentative sampling program to be conducted just beyond the Nushagak Bay fishing district.

B. Evaluating alternative catch allocation procedures to allow formulation of migratory time-density functions for individual river systems.

# ABUNDANCE ESTIMATION OF SOCKEYE SALMON IN NUSHAGAK BAY, 1979

## INTRODUCTION

Accurate knowledge of the abundance of fish returning to a fishing district is fundamental to decisions regarding fishing periods. The objective of such control is the achievement of a predetermined spawning escapement goal. Since spawning escapement represents the difference between the total number of fish entering the fishery and those caught, knowledge of abundance is critical input into harvest control decisions. Information concerning total abundance allows the manager to develop an overall harvest strategy, while knowledge of daily abundance provides him with the opportunity to differentially harvest fish as they enter the fishery.

Prior to 1979, the abundance estimates for Nushagak Bay were developed approximately 9 months in advance of the subsequent fishery. These forecasts were based primarily on age structure of returning fish coupled with estimates of return per spawner. From 1955 through 1977, the accuracy of the forecasted returns ranged from approximately .5 to 2 times the observed return. During 1979, development of an intraseason abundance estimation procedure for Nushagak Bay was initiated to reduce the variance of the total abundance estimates and provide estimates of daily abundance.

## METHODS

The abundance estimation process for Nushagak Bay sockeye salmon is a dynamic procedure. At present, the process is comprised of three phases. The first phase involves the long-range forecast that was mentioned previously. The second phase involves the intraseason abundance estimate of total return to Bristol Bay as measured by the Port Moller outside test net fishery. Phase 3 involves the intraseason abundance estimate developed specifically for Nushagak Bay. This was comprised of two elements: 1. estimates based on observed daily abundance calculated from catch and spawning escapement generated from within the Nushagak Bay district, and 2. estimates based on catch per unit of effort data (CPUE) obtained from set net fishermen hired to report their daily catch and effort. A prospective third source of input is being considered which would incorporate CPUE data generated from a test net boat fishing outside the Nushagak Bay fishing district. The role of each of these phases in the abundance estimation process will be mentioned; however, intraseason abundance estimates based on observed abundance and CPUE data generated by set net fishermen will be reviewed thoroughly.

Phase 1: Long-Range Forecast of Abundance

The long-range forecast for all rivers of Bristol Bay is developed by the Alaska Department of Fish and Game (ADF&G) approximately 9 months in advance of the subsequent fishery. This forecast provides managers and industry representatives with the first estimate of the return to any fishing district. The potential errors of the estimate detract from the applicability of these estimates for intraseason harvest control decisions.

Phase 2: Port Moller Outside Test Fishing Program

The Port Moller outside test fishing program was first described by Paulus (1969). Mundy and Mathisen (1978, 1979) and Mundy (1979) developed more exact procedures to estimate total sockeye salmon return to Bristol Bay about one week in advance of the entry of salmon into the fishing districts.

In addition estimates of daily abundance for Bristol Bay were prepared from the Port Moller data.

These data and estimates are relevant to the intraseason abundance estimation process for Nushagak Bay because they represent the first observations of abundance since the smolts emmigrated from the fishing district. These observations of total abundance coupled with preseason forecasts for each district allow managers to formulate harvest strategies for the initial phase of the migration. For example, if the total abundance estimate from Port Moller is lower than the sum of the preseason forecasts (Phase 1) for the districts, then the managers will adopt a more conservative harvest strategy especially if the estimate from Port Moller approximates the number of fish required for spawning escapement to the individual rivers. In addition to measures of abundance, these data aid in defining the mean of the migratory time density function for the individual fishing districts. This is critical for the intraseason abundance estimation procedure.

## Phase 3: Intraseason Abundance Estimation for Nushagak Bay

### Element 1: Intraseason Abundance Estimation Based on Observed Catch and Escapement

The primary basis for the intraseason abundance estimation procedure was association of observed daily catch and escapement data with historic migratory time density functions (Table 1). The estimation techniques were based on those described by Mundy and Mathisen (1978 and 1979) and Mundy (1979).

The merits of this estimation procedure are improved if accurate catch and escapement statistics are obtained quickly. There is, unfortunately, a lag of two or three days from the time the fish enter the fishing district

Table 1[1]. Yearly time density statistics for the Nushagak fishing district, sockeye salmon.

| YEAR | MEAN DAYS | MEAN[2] (MONTH/DAY) | VARIANCE DAYS |
|---|---|---|---|
| 1959 | 21.52 | 7/06 | 39.54 |
| 1960 | 21.87 | 7/06 | 40.24 |
| 1961 | 20.96 | 7/05 | 36.68 |
| 1962 | 21.18 | 7/05 | 26.16 |
| 1963 | 20.47 | 7/04 | 27.94 |
| 1964 | 21.97 | 7/06 | 29.61 |
| 1965 | 21.70 | 7/06 | 32.34 |
| 1966 | 22.08 | 7/06 | 21.30 |
| 1967 | 17.35 | 7/01 | 30.36 |
| 1968 | 17.43 | 7/01 | 30.72 |
| 1969 | 20.48 | 7/04 | 19.16 |
| 1970 | 21.23 | 7/05 | 16.14 |
| 1971 | 27.02 | 7/11 | 24.36 |
| 1972 | 22.85 | 7/07 | 15.94 |
| 1973 | 21.17 | 7/05 | 33.80 |
| 1974 | 18.87 | 7/03 | 24.75 |
| 1975 | 23.96 | 7/08 | 13.06 |

1 Adapted from Mundy (1979).

2 The mean (month/day) are based on an initial day of the migration of 6/15.

until reliable estimates of spawning escapement can be obtained. Escapement data were provided by inside gillnet sampling programs (Mills, 1979; Pahlke, 1979), a side-scanning sonar project (Pahlke, 1979), aerial surveys (Nelson, personal communication), and counts from observation towers (presented later in Tables 6, 7 and 8). Until the inside test fishing programs and sonar programs were established on the Igushik and Nushagak Rivers, reliable estimates of spawning escapement were substantially delayed. About five days are required for the fish to swim from the fishing district past the observation tower on the Igushik River. Travel from the fishing district past the Nuyakuk tower requires approximately 10 days and these latter counts do not include fish migrating to the Nushagak-Malchatna river systems, which are subsequently counted on the spawning grounds during aerial surveys.

Element 2: Intraseason Abundance Estimation Based on CPUE Data Generated from Commercial Set Nets

During the 1979 Nushagak Bay sockeye salmon migration, three commercial set net fishermen were contracted to report set net catches so that catch per unit of effort (CPUE) could be calculated and employed in calculating the total return of sockeye salmon to Nushagak Bay. The sites selected were Etolin Point, Ekuk Bluff and Nichol's Hills. The procedure for calculating total abundance was the same as that described for the Port Moller estimates. The relationship

$$C/f = qN$$

where C represents catch

f represents effort in 10 fathom hours

q represents catchability

N represents abundance of sockeye salmon passing the net path

served as the algorithm for the estimation process.

Element 3: Proposed Outside Test Fishing Boat

The outside transect proposed by ADF & G and associated test fishery would add critical information on daily abundance, which could also be employed to yield an estimate of total abundance in advance of the procedure based on observed catch plus escapement. The gain in time depends on the location of the transect and the ability to accurately estimate the catchability coefficient, q.

Although the abundance estimation process is composed of three phases only elements 1 and 2 of phase 3 were evaluated during 1979.

## RESULTS

### Phase 3, Element 1: Intraseason Abundance Estimation Based on Observed Catch and Escapement

During 1979, four estimates[3] of the sockeye salmon run size were prepared as follows:

| Date | Stage of migration (% of total) | Estimate (millions) | % error |
|---|---|---|---|
| 6/28 | 16 | 5.5 | - 10 |
| 6/30 | 25 | 3.6 | - 40 |
| 7/5 | 68 | 4.4 | - 30 |
| 7/9 | 78 | 5.5 | - 10 |

These results suggest that the intraseason abundance estimates based on historic migratory time density functions can serve as an effective basis for

[3]Details of these estimates were prepared for ADF & G in July and submitted to the chief fishery scientist's office in Juneau, Alaska.

predicting total seasonal abundance in spite of large daily errors (Table 2 and Figure 1). These daily errors compensate for one another so that the cumulative observed abundance is remarkably similar to the expected (Figure 2).

Phase 3, Element 2: Intraseason Abundance Estimation Based on CPUE Data Generated from Commercial Set Nets

The outside test fishing projects were primarily designed to provide CPUE data for intraseason abundance estimation. Because the estimation process is based on cumulative CPUE data, data collection is a daily procedure. Failure to maintain a continuous data base disrupts the total abundance estimation process. In theory, discontinuous data can be used for daily abundance estimation. During the 1979 season, only data from Nichol's Hills were sufficiently consistent to provide a basis for intraseason total abundance estimates (Tables 3 and 4). However, the large CPUE reported on June 30 from Ekuk Bluff was the first evidence that fish were moving into the district after several days of reduced catches and escapements. These data were instrumental in the decision to open the fishery, reducing the overescapement into the Wood River. Because of the extremely limited data, the utility of these sites cannot be effectively evaluated. Therefore all three sites should be reexamined during 1980.

Each of the sites has inherent advantages and disadvantages. The Etolin Point location is near the outside line of the fishing district and as such is subject to the least interference from the fishing fleet. This area, however, possibly represents a milling area for the sockeye and where fish from other districts may be caught (Straty, 1969). Sockeye that pass Ekuk Bluff are primarily Wood River and Nuyakuk-Nushagak-Mulchatna River fish (Straty, 1969). There is considerable commercial harvest in this area and from there seaward. The catch of the Nichol's Hills site is probably largely composed of Igushik

Table 2. Observed and expected proportions of total abundance for the 1979 migration of sockeye salmon to Nushagak Bay.

| Day of the migration[1] | Observed[2] daily proportion of total abundance | Observed cumulative proportion of total abundance | Expected[3] daily proportion of total abundance | Expected cumulative proportion of total abundance |
|---|---|---|---|---|
| 1. | .003894 | .00389 | .0064893 | .006490 |
| 2. | .001136 | .00503 | .0093501 | .015840 |
| 3. | .003245 | .00827 | .0130677 | .028910 |
| 4. | .006976 | .01525 | .0177149 | .046620 |
| 5. | .032122 | .04737 | .0232935 | .069920 |
| 6. | .048994 | .09637 | .0297092 | .099620 |
| 7. | .056295 | .15266 | .0367541 | .136380 |
| 8. | .017359 | .17002 | .0441040 | .180480 |
| 9. | .087605 | .25762 | .0513344 | .231820 |
| 10. | .086308 | .34393 | .0579559 | .289770 |
| 11. | .086794 | .43073 | .0634665 | .353240 |
| 12. | .102693 | .53342 | .0674140 | .420650 |
| 13. | .049481 | .58290 | .0694566 | .490110 |
| 14. | .024659 | .60756 | .0694122 | .559520 |
| 15. | .046561 | .65412 | .0672846 | .626810 |
| 16. | .079981 | .73410 | .0632636 | .690070 |
| 17. | .049968 | .78407 | .0576967 | .747770 |
| 18. | .025146 | .80921 | .0510394 | .798810 |
| 19. | .021252 | .83047 | .0437945 | .842600 |
| 20. | .016385 | .84685 | .0364494 | .879050 |
| 21. | .030337 | .87719 | .0294253 | .908480 |
| 22. | .034555 | .91175 | .0230414 | .931520 |
| 23. | .027093 | .93884 | .0175007 | .949020 |
| 24. | .018170 | .95701 | .0128932 | .961910 |
| 25. | .013790 | .97080 | .0092134 | .971120 |
| 26. | .008436 | .97923 | .0063862 | .977510 |
| 27. | .007138 | .98637 | .0042936 | .981800 |
| 28. | .005516 | .99189 | .0028000 | .984600 |
| 29. | .004056 | .99594 | .0017712 | .986380 |
| 30. | .002433 | .99838 | .0010867 | .987460 |
| 31. | .001622 | 1.00000 | .0006467 | .988110 |

[1] Day 1 represents all days up to and including 19 June 1979. Day 2 represents 20 June 1979, etc.

[2] Proportions are based on a preliminary estimated total abundance of 6.164 million sockeye salmon calculated from catch and escapement data at the end of the fishing season.

[3] Expected values were calculated based on the techniques described by Mundy (1979) where $\bar{x} = 13.5$ and $\sigma = 5.73$.

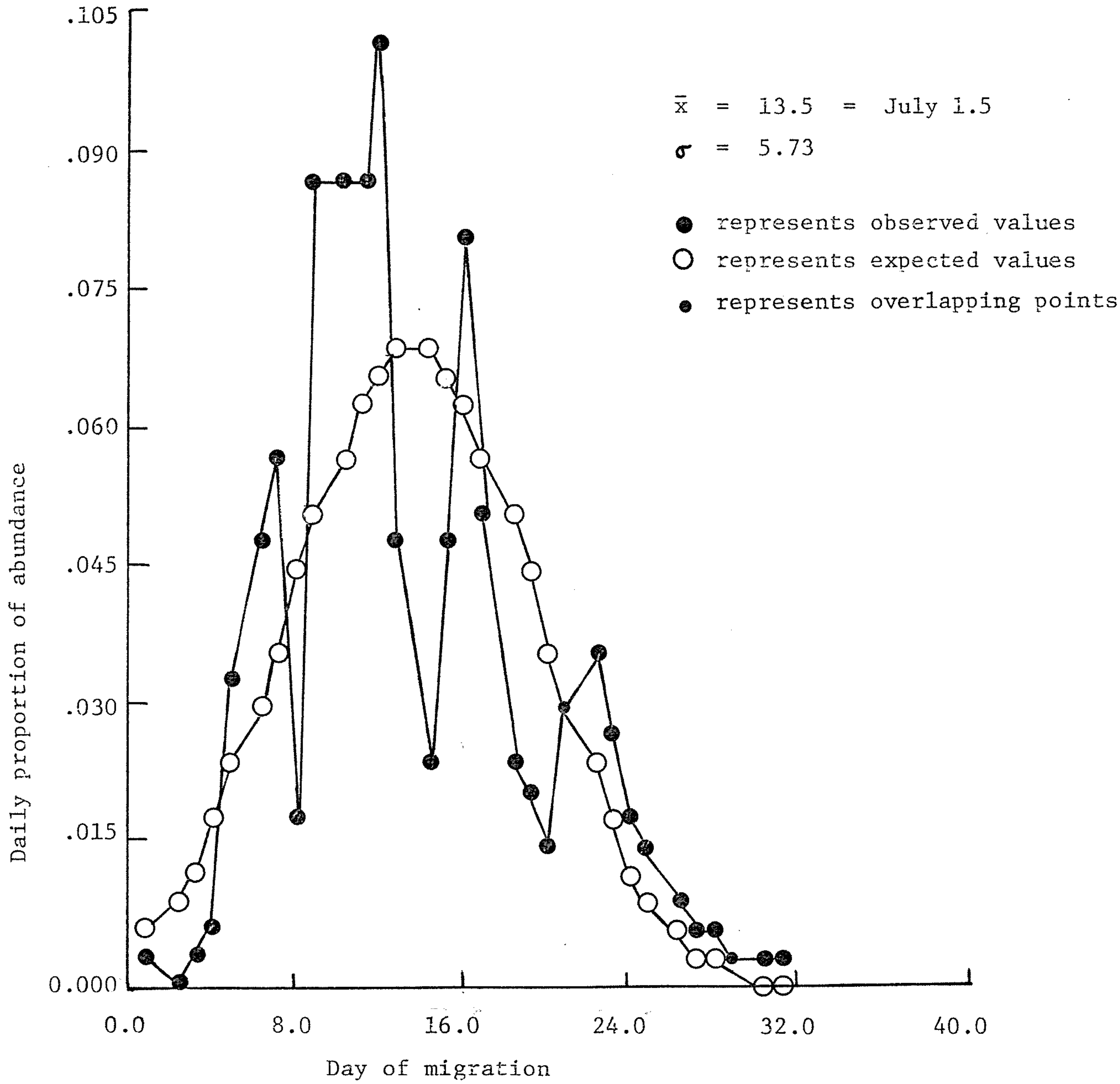


Figure 1. Observed and expected daily proportions of total abundance for the 1979 migration of sockeye salmon to Nushagak Bay.

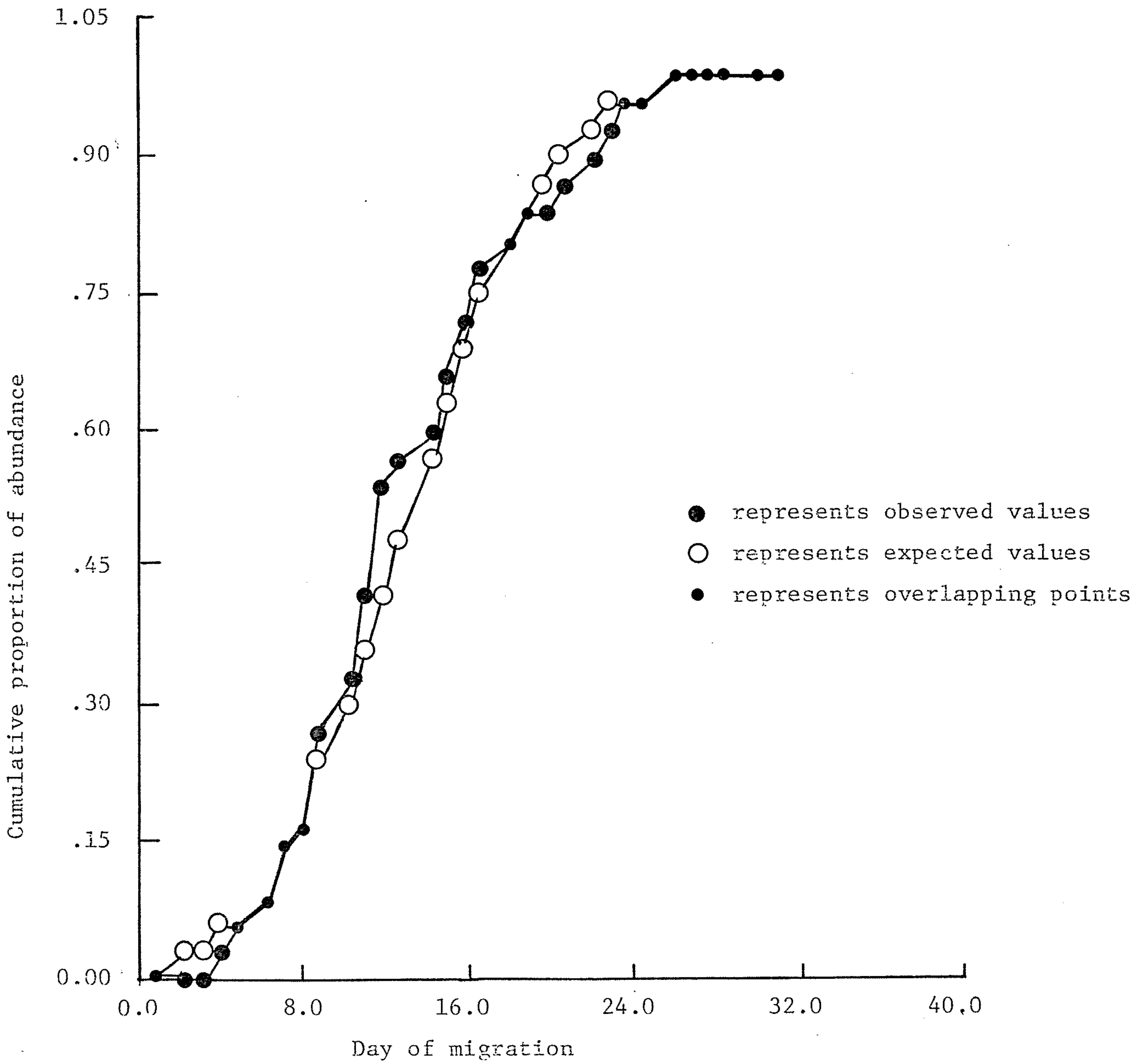


Figure 2. Observed and expected cumulative proportions of total abundance for the 1979 migration of sockeye salmon to Nushagak Bay.

Table 3. Summary of Nushagak Bay outside set-net test fishing, 1979

| Date | Day | Test-Fish Indices (Sockeye)[1] | | |
|---|---|---|---|---|
| | | Etolin Point | Ekuk Bluff | Nichol's Hills |
| June 19 | 1 | - | - | |
| 20 | 2 | 0 | 0 | |
| 21 | 3 | 52 | | 15 |
| 22 | 4 | 0 | 1161 | 109[2] |
| 23 | 5 | - | | 91 |
| 24 | 6 | - | 4652 | 285 |
| 25 | 7 | 253 | 296 | 97 |
| 26 | 8 | 1240 | 2416 | 11 |
| 27 | 9 | - | | 112 |
| 28 | 10 | 477 | | 43 |
| 29 | 11 | 38 | | 671 |
| 30 | 12 | - | 3480 | 924 |
| July 1 | 13 | 2930 | | 1619[2] |
| 2 | 14 | 296 | | 28 |
| 3 | 15 | | | 86 |
| 4 | 16 | | | 496[2] |
| 5 | 17 | | | 3636[2] |
| 6 | 18 | | | ND[3] |
| 7 | 19 | | | ND |
| 8 | 20 | | | 212 |
| 9 | 21 | | | 226 |
| 10 | 22 | | | 187 |
| 11 | 23 | | | 3200[2] |
| 12 | 24 | | | 117 |
| 13 | 25 | | | 74 |
| 14 | 26 | | | 20 |
| 15 | 27 | | | 80 |

[1] Fish/10 fathom hours

[2] Hired fishermen only were fishing

[3] ND represents no data

Table 4. Observed abundance and test fish indices from Nichol's Hills set-net site during the first 16 days of the migration.

| Day[1] of migration | District migration[2] daily number | cumulative number | Nichol's Hills daily index (Fish/10 fathom hrs) | Nichol's Hills cumulative index (Fish/10 fathom hrs) |
|---|---|---|---|---|
| | (Thousands of fish) | | | |
| 1. | 24. | 24.00 | 0.00 | 0.00 |
| 2. | 7. | 31.00 | 0.00 | 0.00 |
| 3. | 20. | 51.00 | 15.00 | 15.00 |
| 4. | 43. | 94.00 | 109.00 | 124.00 |
| 5. | 198. | 292.00 | 91.00 | 215.00 |
| 6. | 302. | 594.00 | 285.00 | 500.00 |
| 7. | 347. | 941.00 | 97.00 | 597.00 |
| 8. | 107. | 1048.00 | 11.00 | 608.00 |
| 9. | 540. | 1588.00 | 112.00 | 720.00 |
| 10. | 532. | 2120.00 | 43.00 | 763.00 |
| 11. | 535. | 2655.00 | 671.00 | 1434.00 |
| 12. | 633. | 3288.00 | 924.00 | 2358.00 |
| 13. | 305. | 3593.00 | 1619.00 | 3977.00 |
| 14. | 152. | 3745.00 | 28.00 | 4005.00 |
| 15. | 287. | 4032.00 | 86.00 | 4091.00 |
| 16. | 493. | 4525.00 | 497.00 | 4588.00 |
| 17. | 308. | 4833.00 | 3636.00 | 8224.00 |
| 18. | 155. | 4988.00 | ND[3] | |
| 19. | 131. | 5119.00 | ND | |
| 20. | 101. | 5220.00 | 212.00 | |
| 21. | 187. | 5407.00 | 226.00 | |
| 22. | 213. | 5620.00 | 187.00 | |
| 23. | 167. | 5787.00 | 3200.00 | |
| 24. | 112. | 5899.00 | 117.00 | |
| 25. | 85. | 5984.00 | 74.00 | |
| 26. | 52. | 6036.00 | 20.00 | |
| 27. | 44. | 6080.00 | 80.00 | |
| 28. | 34. | 6114.00 | | |
| 29. | 25. | 6139.00 | | |
| 30. | 15. | 6154.00 | | |
| 31. | 10. | 6160.00 | | |

[1] Day 1 represents data from 19 June 1979 and all previous days
Day 2 represents data from 20 June 1979, etc.

[2] These are preliminary data generated from adding catch and escapement. The escapements were lagged to the fishery, 2 days for Wood River, 5 days for Igushik River and 10 days for Nuyakuk River.

[3] ND represents no data.

River fish (Straty, 1969). This location also is well within the fishing district and CPUE data are subject to the influence of the fishing fleet. One additional site should be considered either at Coffee Point or Clark's Point so that movement of fish through the fishing district can be followed more closely.

The Nichol's Hills project produced consistent data until 5 July 1979. The daily and cumulative CPUE reflected the daily and cumulative abundance (Figures 3 and 4). However, there were several extraordinarily large CPUE values which corresponded to days when only the hired fisherman was fishing (Table 3).

## DISCUSSION

### Phase 3, Element 1: Intraseason Abundance Estimation Based on Observed Catch and Escapement

All estimates were low; however, accurate abundance estimates were produced with less than 20% of the total return tabulated. The drop in estimates from 5.5 to 3.6 million fish was caused by several factors. First, the mean date of the migration was not well defined because of a lack of precise knowledge of the status of the observed abundance relative to the historic migratory time-density functions. Secondly, catches were generally underestimated because of incomplete reports from processors. Consequently, the abundance was underestimated. Finally, since catch and escapement had dropped sharply for about two days, human concern for overestimation biased the estimation procedure especially when the estimate was revised. This emotional element must be eliminated in order for the estimation process to be consistent.

Post-season estimates of total abundance for the 1979 season employing the migratory time density function generated from observed data served as an

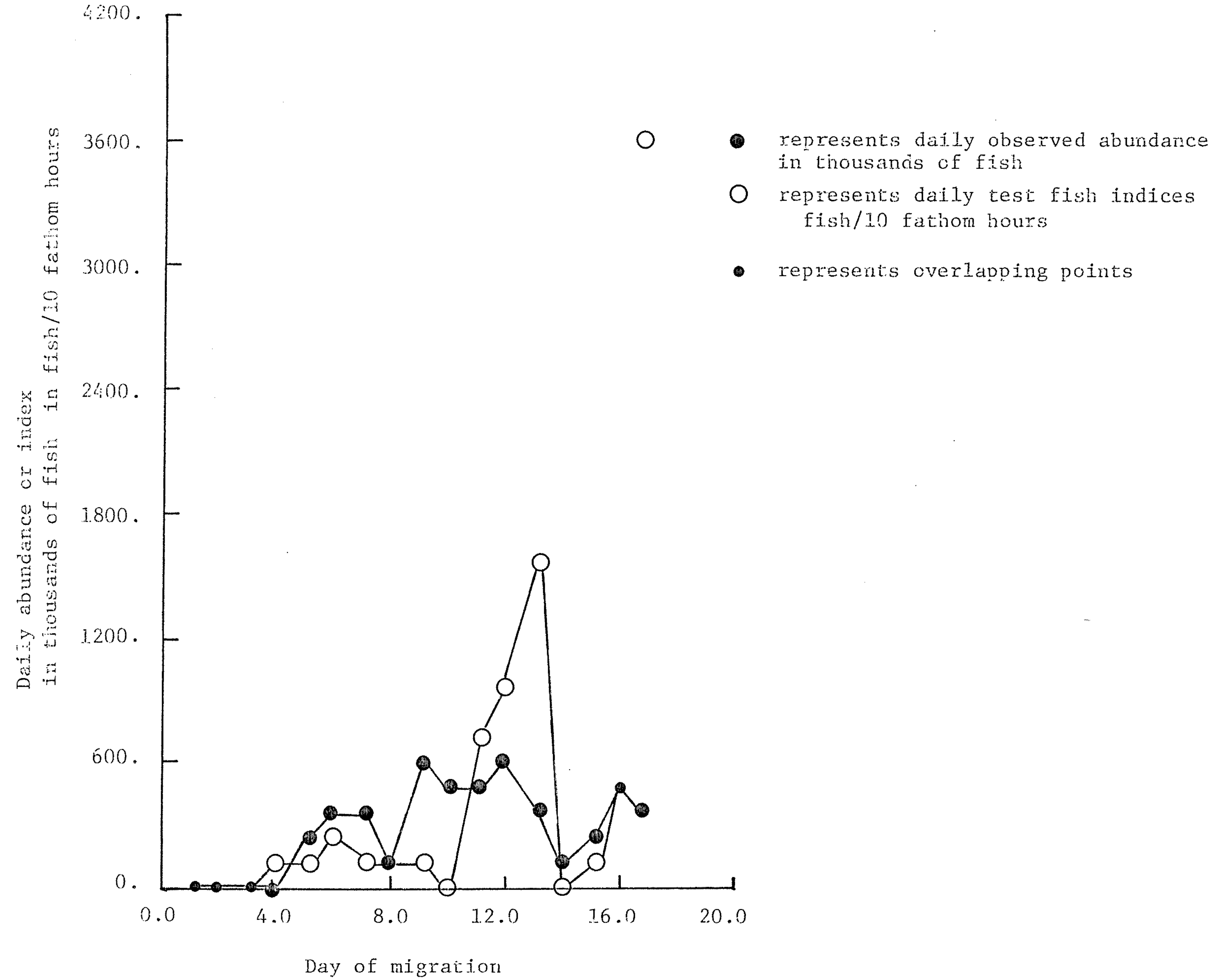


Figure 3. Observed daily abundance and test fish indices from Nichol's Hills set net sites.

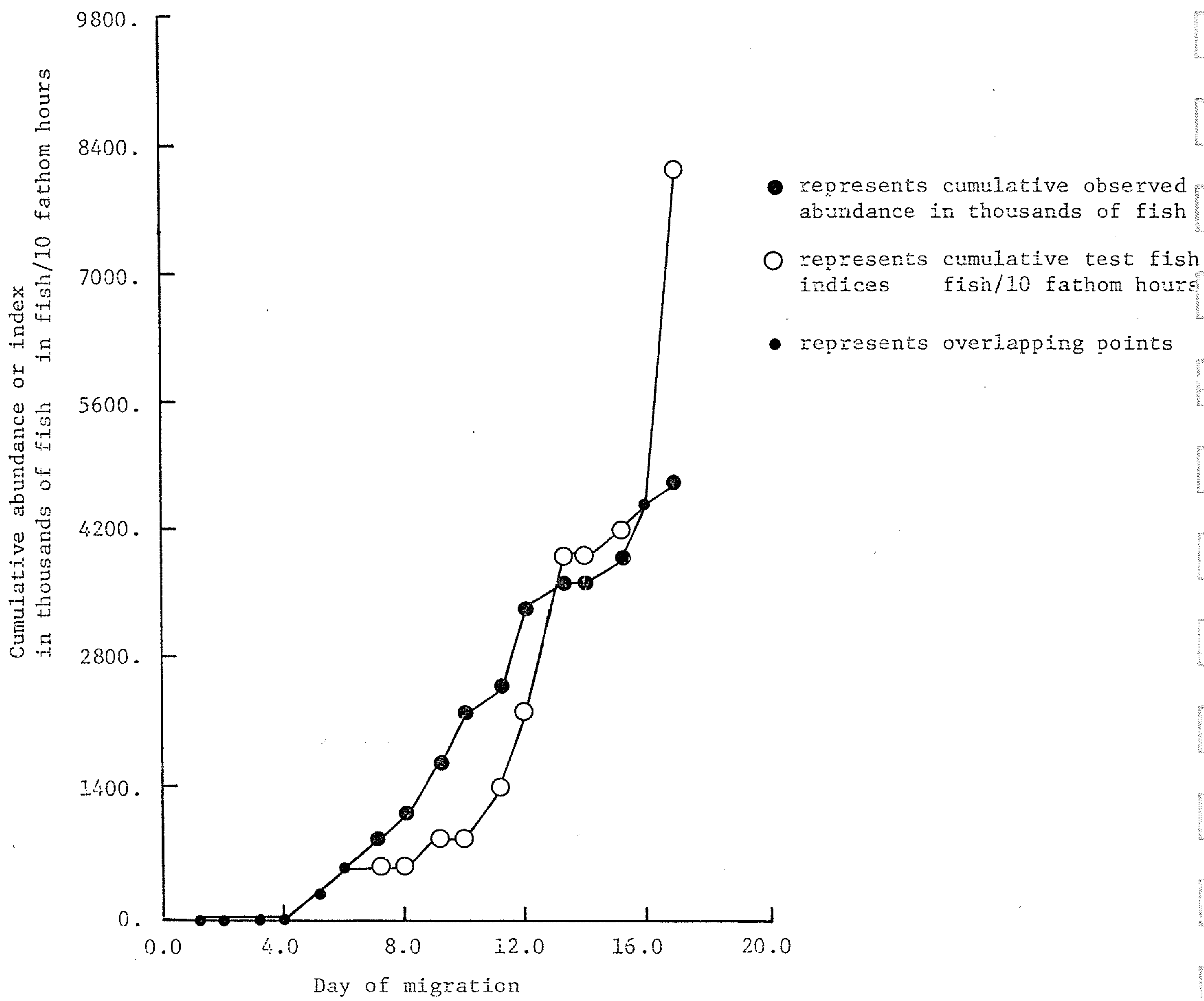


Figure 4. Observed cumulative abundance and test indices from Nichol's Hills set net sites.

excellent measure of total abundance (Table 5). The majority of the estimates were remarkably close to the preliminary observed total abundance of 6.164 million fish. These results demonstrate the potential of estimating total abundance from the existing data base and abundance monitoring from within the fishing district. Then, too, after 10% of the fish had migrated through the fishing district, the accuracy of the estimated was within 15% of the true value. Finally, following day 6, the estimates were within 20% of the observed total abundance.

Phase 3, Element 2: Intraseason Abundance Estimation Based on CPUE Data Generated from Commercial Set Net

Although this was the first year that set net fishermen were hired to report catch and effort, the potential of the program can be assessed. Among the numerous advantages of this outside test fishing program are the following:

1. Beyond the value provided for intraseason abundance estimation, the CPUE data supply managers with a measure of the presence or absence of fish which aid in determining whether or not to open the fishery.
2. Such a program would be cheaper than data obtained from a boat fishing outside the fishing district; however, CPUE from a vessel outside the fishing district would not be influenced by the commercial fishery and would supply more reliable information on daily passage rate.

The primary disadvantage of a test fishing program within the fishing district is that CPUE indices are subject to the influence of the fishing fleet as well as shifts in the migratory path of the fish. These sources of error must be evaluated if the utility of such a program is to be accurately assessed.

Table 5. Estimates of abundance for the 1979 sockeye salmon returning to Nushagak Bay in 1979.

| Day[1] of Migration | Observed Abundance[2] Cumulative Numbers (N) (thousands) | $N^2$ | $\Sigma N^2$ | Expected[3] Cumulative Proportion (P) | NP | $\Sigma NP$ | $\frac{\Sigma N^2}{\Sigma NP}$ (thousands) |
|---|---|---|---|---|---|---|---|
| 1. | 24.00 | 576. | 576. | .006489 | .16 | .2 | 3698.57 |
| 2. | 31.00 | 961. | 1537. | .015839 | .49 | .6 | 2376.52 |
| 3. | 51.00 | 2601. | 4138. | .028907 | 1.47 | 2.1 | 1950.96 |
| 4. | 94.00 | 8836. | 12974. | .046622 | 4.38 | 6.5 | 1994.94 |
| 5. | 292.00 | 85264. | 98238. | .069915 | 20.42 | 26.9 | 3649.44 |
| 6. | 594.00 | 352836. | 451074. | .099625 | 59.18 | 86.1 | 5239.20 |
| 7. | 941.00 | 885481. | 1336555. | .136379 | 128.33 | 214.4 | 6233.10 |
| 8. | 1048.00 | 1098304. | 2434859. | .180483 | 189.15 | 403.6 | 6033.23 |
| 9. | 1588.00 | 2521744. | 4956603. | .231817 | 368.13 | 771.7 | 6422.97 |
| 10. | 2120.00 | 4494400. | 9451003. | .289773 | 614.32 | 1386.0 | 6818.81 |
| 11. | 2655.00 | 7049025. | 16500028. | .353240 | 937.85 | 2323.9 | 7100.23 |
| 12. | 3288.00 | 10810944. | 27310972. | .420654 | 1383.1[illegible] | 3707.0 | 7367.44 |
| 13. | 3593.00 | 12909649. | 40220621. | .490110 | 1760.97 | 5467.9 | 7355.71 |
| 14. | 3745.00 | 14025025. | 54245646. | .559522 | 2095.4[illegible] | 7563.4 | 7172.17 |
| 15. | 4032.00 | 16257024. | 70502670. | .626807 | 2527.29 | 10090.6 | 6986.94 |
| 16. | 4525.00 | 20475625. | 90978295. | .690071 | 3122.57 | 13213.2 | 6885.40 |
| 17. | 4833.00 | 23357889. | 114336184. | .747767 | 3613.96 | 16827.2 | 6794.74 |
| 18. | 4988.00 | 24880144. | 139216328. | .798807 | 3984.45 | 20811.6 | 6689.36 |
| 19. | 5119.00 | 26204161. | 165420489. | .842601 | 4313.27 | 25124.9 | 6583.93 |
| 20. | 5220.00 | 27248400. | 192668889. | .879051 | 4588.65 | 29713.5 | 6484.21 |
| 21. | 5407.00 | 29235649. | 221904538. | .908476 | 4912.13 | 34625.7 | 6408.67 |
| 22. | 5620.00 | 31584400. | 253488938. | .931517 | 5235.13 | 39860.8 | 6359.35 |
| 23. | 5787.00 | 33489369. | 286978307. | .949018 | 5491.97 | 45352.8 | 6327.69 |
| 24. | 5899.00 | 34798201. | 321776508. | .961911 | 5674.3[illegible] | 51027.1 | 6306.00 |
| 25. | 5984.00 | 35808256. | 357584764. | .971125 | 5811.2[illegible] | 56838.3 | 6291.27 |
| 26. | 6036.00 | 36433296. | 394018060. | .977511 | 5900.26 | 62738.5 | 6280.32 |
| 27. | 6080.00 | 36966400. | 430984460. | .981804 | 5969.37 | 68707.9 | 6272.70 |
| 28. | 6114.00 | 37380996. | 468365456. | .984604 | 6019.87 | 74727.8 | 6267.62 |
| 29. | 6139.00 | 37687321. | 506052777. | .986375 | 6055.36 | 80783.1 | 6264.34 |
| 30. | 6154.00 | 37871716. | 543924493. | .987462 | 6076.84 | 86860.0 | 6262.08 |
| 31. | 6164.00 | 37994896. | 581919389. | .988109 | 6090.70 | 92950.7 | 6260.52 |

[1] Day 1 represents all time prior to and including 19 June 1979; Day 2 represents 20 June 1979, etc.

[2] Observed abundance based on catch plus escapement where escapement was lagged to the fishery 2 days for Wood River, 5 days for Igushik River and 10 days for Nuyakuk River.

[3] Expected proportions were developed according to techniques described by Mundy and Mathisen (1978, 1979) and Mundy (1979)

# CATCH ALLOCATION AND MIGRATORY TIME DENSITIES FOR SOCKEYE SALMON FROM WOOD, IGUSHIK AND NUYAKUK RIVERS FOR 1979.

## INTRODUCTION

Allocation of fishes caught in a fishing district to their respective river of origin has been a continuous problem for salmon fishery managers throughout Bristol Bay. Partitioning the catch by scale pattern analysis has not been successful for Nushagak Bay primarily because of the large variability in growth of sockeye within a system and limited sample sizes during the migration. Within Nushagak District, the variation in scale patterns for fish from the Wood River system is as large or larger than for the other systems in Nushagak Bay (Robertson, personal communication). Therefore, in 1979 catches were allocated on the assumption that they were proportional to escapements. This permitted construction of migratory time-density functions for each of the river systems by techniques similar to those described by Mundy (1979).

## METHODS

First, the catch was apportioned employing total escapement to the respective river systems as the partitioning coefficient. The equations employed follow:

$$TE = \left( \sum_{i=1}^{n} \sum_{j=1}^{m} E_{ij} \right) + NM \qquad [2]$$

where $TE$ = total Nushagak escapement

$E_{ij}$ = escapement counted on day i to river j.

$i$ = 1, 2, ..., n.

$j$ = 1, 2, ..., m.

NM = total estimated escapement into Nushagak-Mulchatna from aerial surveys.

$n_j$ = total number of days during the spawning escapement into river j.

m = total number of rivers, m = 3.

It follows that:

$$WE = \sum_{i=1}^{n_1} E_{ij} \qquad [3]$$

when j = 1 (Wood River)

WE represents Wood River total escapement.

$$IE = \sum_{i=1}^{n_2} E_{ij} \qquad [4]$$

when j = 2 (Igushik River)

IE represents Igushik River total escapement.

$$NE = \left(\sum_{i=1}^{n_3} E_{ij}\right) + NM \qquad [5]$$

when j = 3 (Nuyakuk River total escapement)

NE represents Nushagak-Nuyakuk-Mulchatna River total escapement.

The following allocation of mixed stock catch assumes that the catch from river system j on day i, $C_{ij}$, is proportional to total daily catch, $C_{i.}$. The proportionality factor is the ratio of the annual escapement to river j, $E_{.j}$ to the total annual escapement to all rivers, TE, or symbolically,

$$C_{ij} = C_{i.} \frac{E_{.j}}{TE} \qquad [6]$$

For 1979 the values (in thousands of fish) based on Tables 6-8, were as follows:

| | | | |
|---|---|---|---|
| TE | = 3001 | | |
| WE | = 1705 | WE/TE | = .57 |
| IE | = 839 | IE/TE | = .28 |
| NE | = 457 | NE/TE | = .15 |
| NM | = 100 | | |

The preceding calculations assume that the migratory time density functions for the fish from all river systems are the same and that the harvest rate, numbers harvested per numbers vulnerable to harvest, is equal for the populations from each river system each day. Shifts in gear deployment caused by regulatory shifts, shifts in processor demand, or shifts in the migratory path of the majority of fish leads to violation of this assumption. From the 11th through the 13th day of the migration, 29 June through 1 July, the apportionment of catch was altered to reflect a shift in the fishing fleet to the eastern side of the district. The movement of the fleet, coupled with suspensions by processors on Igushik Beach and minimal observed set net fishing activity (observed during aerial surveys, Nelson pers. comm.) justify this, setting the catch associated with Igushik River to zero while the remainder of the catch was apportioned as follows:

$$\text{adjusted } C_{ij} = C_{i\cdot} \left(\frac{E_{\cdot j}}{WE + NE}\right) \qquad [7]$$

where $i = 11, 12, 13$

$j \neq 2$ except

$C_{11,2} = C_{12,2} = C_{13,2} = 0$

Table 6. Preliminary escapement data for the Wood River system, 1979.

| DAY[1] OF MIGRATION | WOOD RIVER ESCAPEMENT DAILY[2] NUMBER | DAILY PROPORTION | CUMULATIVE NUMBER | CUMULATIVE PROPORTION |
|---|---|---|---|---|
| 1. | 1. | .000587 | 1.00 | .00059 |
| 2. | 0. | 0.000000 | 1.00 | .00059 |
| 3. | 0. | 0.000000 | 1.00 | .00059 |
| 4. | 0. | 0.000000 | 1.00 | .00059 |
| 5. | 55. | .032258 | 56.00 | .03284 |
| 6. | 246. | .144282 | 302.00 | .17713 |
| 7. | 160. | .093842 | 462.00 | .27097 |
| 8. | 18. | .010557 | 480.00 | .28152 |
| 9. | 12. | .007038 | 492.00 | .28856 |
| 10. | 9. | .005279 | 501.00 | .29384 |
| 11. | 264. | .154839 | 765.00 | .44868 |
| 12. | 530. | .310850 | 1295.00 | .75953 |
| 13. | 39. | .022874 | 1334.00 | .78240 |
| 14. | 9. | .005279 | 1343.00 | .78768 |
| 15. | 19. | .011144 | 1362.00 | .79883 |
| 16. | 167. | .097947 | 1529.00 | .89677 |
| 17. | 116. | .068035 | 1645.00 | .96481 |
| 18. | 18. | .010557 | 1663.00 | .97537 |
| 19. | 6. | .003519 | 1669.00 | .97889 |
| 20. | 5. | .002933 | 1674.00 | .98182 |
| 21. | 4. | .002346 | 1678.00 | .98416 |
| 22. | 8. | .004692 | 1686.00 | .98886 |
| 23. | 5. | .002933 | 1691.00 | .99179 |
| 24. | 4. | .002346 | 1695.00 | .99413 |
| 25. | 5. | .002933 | 1700.00 | .99707 |
| 26. | 5. | .002933 | 1705.00 | 1.00000 |
| 27. | 0. | 0.000000 | 1705.00 | 1.00000 |
| 28. | 0. | 0.000000 | 1705.00 | 1.00000 |
| 29. | 0. | 0.000000 | 1705.00 | 1.00000 |
| 30. | 0. | 0.000000 | 1705.00 | 1.00000 |
| 31. | 0. | 0.000000 | 1705.00 | 1.00000 |

[1] Day 1 represents all data prior to and including 19 June 1979. Day 2 represents data from 20 June 1979.

[2] The escapement was lagged 2 days to the reference frame of the fishery and represents thousands of fish.

Table 7. Preliminary escapement data for the Igushik River system, 1979.

IGUSHIK RIVER ESCAPEMENT

| DAY[1] OF MIGRATION | DAILY NUMBER[2] | DAILY PROPORTION | CUMULATIVE NUMBER | CUMULATIVE PROPORTION |
|---|---|---|---|---|
| 1. | 4. | .004768 | 4. | .00477 |
| 2. | 2. | .002384 | 6. | .00715 |
| 3. | 5. | .005959 | 11. | .01311 |
| 4. | 19. | .022646 | 30. | .03576 |
| 5. | 28. | .033373 | 58. | .06913 |
| 6. | 30. | .035757 | 88. | .10489 |
| 7. | 30. | .035757 | 118. | .14064 |
| 8. | 27. | .032181 | 145. | .17282 |
| 9. | 64. | .076281 | 209. | .24911 |
| 10. | 89. | .106079 | 298. | .35518 |
| 11. | 64. | .076281 | 362. | .43147 |
| 12. | 72. | .085816 | 434. | .51728 |
| 13. | 57. | .067938 | 491. | .58522 |
| 14. | 46. | .054827 | 537. | .64005 |
| 15. | 59. | .070322 | 596. | .71037 |
| 16. | 53. | .063170 | 649. | .77354 |
| 17. | 40. | .047676 | 689. | .82122 |
| 18. | 25. | .029797 | 714. | .85101 |
| 19. | 23. | .027414 | 737. | .87843 |
| 20. | 21. | .025030 | 758. | .90346 |
| 21. | 13. | .015495 | 771. | .91895 |
| 22. | 15. | .017878 | 786. | .93683 |
| 23. | 12. | .014303 | 798. | .95113 |
| 24. | 8. | .009535 | 806. | .96067 |
| 25. | 6. | .007151 | 812. | .96782 |
| 26. | 5. | .005959 | 817. | .97378 |
| 27. | 4. | .004768 | 821. | .97855 |
| 28. | 4. | .004768 | 825. | .98331 |
| 29. | 5. | .005959 | 830. | .98927 |
| 30. | 5. | .005959 | 835. | .99523 |
| 31. | 4. | .004768 | 839. | 1.00000 |

1 Day 1 represents all the data prior to and including 19 June 1979. Day 2 represents data from 20 June 1979, etc.

2 The escapement was lagged 5 days to the reference frame of the fishery and represents thousands of fish.

Table 8. Preliminary escapement data for the Nuyakuk River system, 1979.

| DAY[1] OF MIGRATION | NUYAKUK RIVER ESCAPEMENT DAILY[2] NUMBER | DAILY PROPORTION | CUMULATIVE NUMBER | CUMULATIVE PROPORTION |
|---|---|---|---|---|
| 1. | 0. | 0.000000 | 0. | 0.00000 |
| 2. | 0. | 0.000000 | 0. | 0.00000 |
| 3. | 4. | .011204 | 4. | .01120 |
| 4. | 24. | .067227 | 28. | .07843 |
| 5. | 47. | .131653 | 75. | .21008 |
| 6. | 26. | .072829 | 101. | .28291 |
| 7. | 12. | .033613 | 113. | .31653 |
| 8. | 49. | .137255 | 162. | .45378 |
| 9. | 55. | .154062 | 217. | .60784 |
| 10. | 38. | .106443 | 255. | .71429 |
| 11. | 17. | .047619 | 272. | .76190 |
| 12. | 11. | .030812 | 283. | .79272 |
| 13. | 33. | .092437 | 316. | .88515 |
| 14. | 22. | .061625 | 338. | .94678 |
| 15. | 9. | .025210 | 347. | .97199 |
| 16. | 3. | .008403 | 350. | .98039 |
| 17. | 2. | .005602 | 352. | .98599 |
| 18. | 2. | .005602 | 354. | .99160 |
| 19. | 2. | .005602 | 356. | .99720 |
| 20. | 1. | .002801 | 357. | 1.00000 |
| 21. | 0. | 0.000000 | 357. | 1.00000 |
| 22. | 0. | 0.000000 | 357. | 1.00000 |
| 23. | 0. | 0.000000 | 357. | 1.00000 |
| 24. | 0. | 0.000000 | 357. | 1.00000 |
| 25. | 0. | 0.000000 | 357. | 1.00000 |
| 26. | 0. | 0.000000 | 357. | 1.00000 |
| 27. | 0. | 0.000000 | 357. | 1.00000 |
| 28. | 0. | 0.000000 | 357. | 1.00000 |
| 29. | 0. | 0.000000 | 357. | 1.00000 |
| 30. | 0. | 0.000000 | 357. | 1.00000 |
| 31. | 0. | 0.000000 | 357. | 1.00000 |

[1] Day 1 represents all the data prior to and including 19 June 1979. Day 2 represents data from 20 June 1979.

[2] The escapement was lagged 10 days to the reference frame of the fishery and represents thousands of fish.

and $$\frac{WE}{WE + NE} = .79$$

$$\frac{NE}{WE + NE} = .21$$

An alternate approach was based on apportionment of catch according to the daily escapement to each river system. This procedure, as the previous one, assumes that the catch from river system j on day i, $C'_{ij}$, is proportional to daily catch, $C_{i.}$ The proportionality factor is the ratio of the escapement to river j on day i, $E_{ij}$, to the total daily escapement to all rivers, $E_{i.}$ Symbolically

$$C'_{ij} = C_{i.} \frac{E_{ij}}{E_{i.}} \qquad [8]$$

Values of $\frac{E_{ij}}{E_{.j}}$ are presented in Table 9.

Equation 8 is subject to the same assumptions as equation 6 except that the migratory time density functions are not assumed to be the same. The apportioned catch was adjusted from day 9 through day 13, 27 June through 1 July. Days 9 and 10 were included in the adjustment because of substantial observed catches from the eastern and northern portions of the district where the majority of the fleet was fishing. Observed catches from the Igushik River set net fishery were also substantial, which prevented the associated catch from being set to zero as was the case for days 11-13. The best measure of catch from the Igushik River for days 9 and 10 was assumed to be that derived from equation 6. The remaining catch was then allocated to the Wood River and the Nuyakuk River based on daily escapement to only those two river systems. Symbolically,

Table 9. Preliminary relative escapements into the three major river systems of Nushagak Bay, 1979.

| DAY OF MIGRATION[1] | ESCAPEMENT PROPORTION OF DISTRICT WOOD R. | IGUSHIK R. | NUYAKUK R. |
|---|---|---|---|
| 1. | .200000 | .80000 | 0.000000 |
| 2. | 0.000000 | 1.00000 | 0.000000 |
| 3. | 0.000000 | .55556 | .444444 |
| 4. | 0.000000 | .44186 | .558140 |
| 5. | .423077 | .21538 | .361538 |
| 6. | .814570 | .09934 | .086093 |
| 7. | .792079 | .14851 | .059406 |
| 8. | .191489 | .28723 | .521277 |
| 9. | .091603 | .48855 | .419847 |
| 10. | .066176 | .65441 | .279412 |
| 11. | .765217 | .18551 | .049275 |
| 12. | .864600 | .11746 | .017945 |
| 13. | .302326 | .44186 | .255814 |
| 14. | .116883 | .59740 | .285714 |
| 15. | .218391 | .67816 | .103448 |
| 16. | .748879 | .23767 | .013453 |
| 17. | .734177 | .25316 | .012658 |
| 18. | .400000 | .55556 | .044444 |
| 19. | .193548 | .74194 | .064516 |
| 20. | .185185 | .77778 | .037037 |
| 21. | .235294 | .76471 | 0.000000 |
| 22. | .347826 | .65217 | 0.000000 |
| 23. | .294118 | .70588 | 0.000000 |
| 24. | .333333 | .66667 | 0.000000 |
| 25. | .454545 | .54545 | 0.000000 |
| 26. | .500000 | .50000 | 0.000000 |
| 27. | 0.000000 | 1.00000 | 0.000000 |
| 28. | 0.000000 | 1.00000 | 0.000000 |
| 29. | 0.000000 | 1.00000 | 0.000000 |
| 30. | 0.000000 | 1.00000 | 0.000000 |
| 31. | 0.000000 | 1.00000 | 0.000000 |

[1] Day 1 represents 19 June 1979 and all previous dates, day 2 represents 20 June 1979, etc.

$$\text{adjusted } C'_{ij} = (C_{i.} - C_{i2}) \frac{E_{ij}}{E_{i.}} \qquad [9]$$

$i = 9, 10, \ldots, 13$ and $j \neq 2$

$j = 2$

$C'_{9,2} = C_{9,2}$

$C'_{10,2} = C_{10,2}$

$C'_{11,2} = C'_{12,2} = C'_{13,2} = 0$

Once the catch was apportioned to the respective river systems, the escapement for that day ($E_{ij}$) was added to the catch ($\overline{\underline{C}}_{ij}$) to establish the daily abundance as follows:

$$N_{ij} = (\overline{\underline{C}}_{ij} + E_{ij}) \qquad [10]$$

where $N_{ij}$ = abundance associated with river j on day i

$\overline{\underline{C}}_{ij}$ = either $C_{ij}$

or $C_{ij}$ and appropriate adjusted $C_{ij}$

or $C'_{ij}$

or $C'_{ij}$ and appropriate adjusted $C'_{ij}$

$i = d_j - t_j$

$t_j$ = the time needed for the fish to swim from the fishing district past the counting tower of the respective river; $t_j = 0$ when the fish were within the fishing district

$d_j$ = the day the fish swam past the counting tower

The $E_{ij}$ were based on counts from counting towers on each of the rivers. The basis for determining time (t) between the fishing district and counting towers was tagging studies conducted by ADF&G and represents a mean (McBride 1978, 1979; Mills 1979; Pahlke 1979).

The abundance ($N_{ij}$) was established for each river system by the two methods described. The mean date, $\bar{x}$, and variance, $s^2$, were calculated for the two abundances developed for each river system according to techniques reported by Mundy and Mathisen (1978, 1979) and Mundy (1979). After $\bar{x}$ and $s^2$ were calculated the expected migratory time density functions were formulated according to theories and techniques described by Mundy and Mathisen (1978, 1979) and Mundy (1979). The normal probability density served as the model for the migratory time density function.

$$N(x;\bar{x},s^2) = \frac{1}{s\sqrt{2\pi}} e^{-\frac{1}{2}\frac{(x-\bar{x})^2}{s}} \qquad [11]$$

where N represents normal distribution

x represents day of the migration

$\bar{x}$ represents the mean

$s^2$ represents the variance

RESULTS

The alternative techniques for apportioning catch produced substantially different estimates of total abundance to individual river systems (Table 10) as well as differences in $\bar{x}$ and s (Table 11). The two estimates of daily and cumulative abundance differed considerably (Appendix A). Because of the differences in $\bar{x}$ and s, the calculated migratory time densities differed

Table 10. Catch and abundance apportioned to Wood, Igushik and Nuyakuk River systems for 1979.

| Catch allocated to river system (in thousands) | | | Total abundance by river system (in thousands) | | |
|---|---|---|---|---|---|
| Wood | Igushik | Nuyakuk | Wood | Igushik | Nuyakuk |
| 1919[1] | 943 | 401 | 3624 | 1782 | 758 |
| 1985[2] | 747 | 531 | 3686 | 1580 | 887 |
| 1110[3] | 1710 | 444 | 2815 | 2549 | 801 |
| 1264[4] | 1360 | 642 | 2969 | 2199 | 999 |

1 Catch was based on $\sum_{i=1}^{n} C_{ij}$, equation 6

2 Catch was based on $\sum_{i=1}^{n}$ ($C_{ij}$ and adjusted $C_{ij}$, equations 6 and 7)

3 Catch was based on the $\sum_{i=1}^{n} C'_{ij}$, equation 8

4 Catch was based on the $\sum_{i=1}^{n}$ ($C'_{ij}$ and adjusted $C'_{ij}$, equations 8 and 9)

Table 11. Estimated means and variances for migratory time density functions for the Wood, Igushik and Nuyakuk River systems based on alternative catch allocation strategies for 1979.

| | Based on $\sum_{i=1}^{n}$ ($C_{ij}$ and adjusted $C_{ij}$) | | Based on $\sum_{i=1}^{n}$ ($C'_{ij}$ and adjusted $C'_{ij}$) | |
|---|---|---|---|---|
| | $\bar{x}$[1] | s | $\bar{x}$ | s |
| Wood River | 13.43 | 5.54 | 12.78 | 4.90 |
| Igushik River | 14.02 | 5.59 | 16.11 | 6.47 |
| Nuyakuk River | 12.73 | 5.98 | 9.74 | 2.87 |

1 $\bar{x}$ represents mean day with $x_1$ defined as 19 June 1979.

(Figures 5 and 6). There were noticeable differences between expected daily proportion of abundances and the observed in both cases (Appendix B). The expected cumulative proportion of abundance, in both cases, however, patterned the observed cumulative proportions closely (Appendix B).

DISCUSSION

The differences in total abundance and migratory time-density functions for the Wood, Igushik and Nuyakuk Rivers reflect the inadequacies of assuming that catch is proportional to abundance. Another fundamental flaw of catch apportionment based on seasonal spawning escapement for each river system was the implication that the migratory time density functions for fish inhabiting the various systems were similar in mean and variance. The validity of such an assumption is questionable. If the migratory time density functions were similar, the observed daily proportions of spawning escapement should remain constant. Such is not the case (Table 9). Some differences could be attributed to shifts of the fishing fleet or differences in catchability of fish from different systems, however, the observed variation cannot be explained by this alone. If the patterns of observed spawning escapement reflect the observed abundance, then the expected migratory time densities should reflect observed spawning escapement at least in terms of duration of the migration. The duration of escapement to the individual river systems, however, differs substantially from the migratory time density functions based on apportioning the catch according to total spawning escapement. The duration of the observed spawning escapement to the Nuyakuk River was short, and the majority of sockeye salmon entered the river over a 10-day

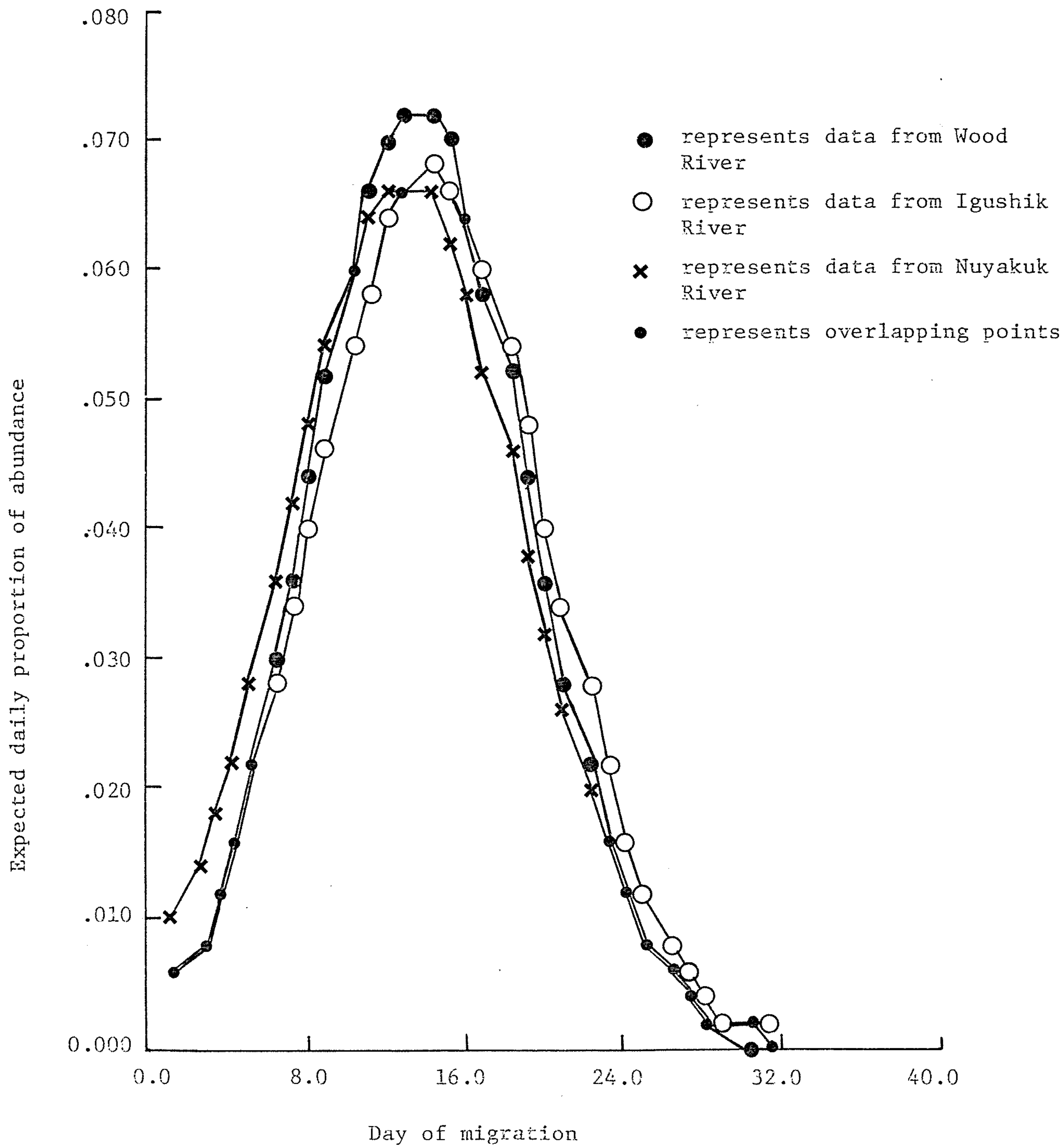


Figure 5. Migrating time density functions for total abundance by river system based on catch allocated according to $C_{ij}$ and adjusted $C_{ij}$.

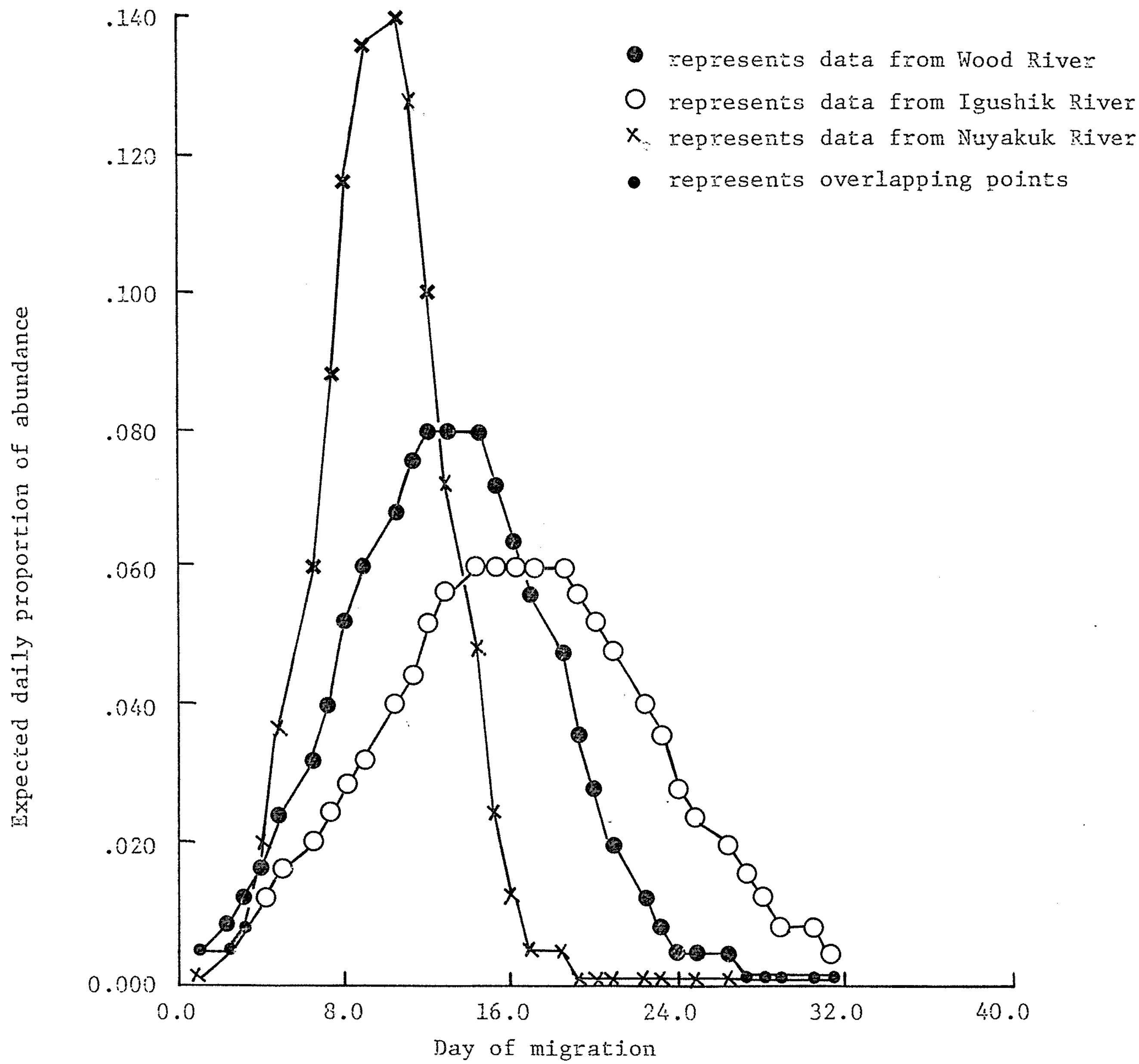


Figure 6. Migratory time density functions for the total abundance by river system based on catch allocated according to $C'_{ij}$ and adjusted $C'_{ij}$.

period (Table 8). The observed spawning escapement in the Wood River was more prolonged than that of the Nuyakuk; however, it was less prolonged than that for observed spawning escapement to the Igushik (Tables 6, 7 and 8). Such differences in observed spawning escapement were not reflected as well in the migratory time densities developed by allocating catch according to total escapement proportions as opposed to those formulated by employing proportions of daily escapement.

The relative timing of the observed spawning escapement should also be reflected in the migratory time density functions. That is, the time from the beginning to the end of the observed spawning escapement should correspond to the expected based on the migratory time density functions. Although the chronology of the migratory time density functions is the same for both techniques of catch allocation, the migratory time density functions generated by apportioning catch according to daily escapement corresponded more closely to the observed spawning escapement.

Finally, basic biological theory contradicts the assumption that migratory time density functions should be uniform. In a system as complex as the Nushagak, supplied by three major river systems inhabited by numerous stocks, the probability that the migratory time density functions are uniform is marginal. The variability in migratory time density functions between stocks has been well documented (Mundy 1979, Smith 1964).

The fundamental discrepancy associated with catch allocation based on daily proportions of spawning escapement is the assumption that fish from all systems are harvested at the same rate. Since catchability is a function of fish weight in size selective gear and the weight distributions of fish migrating to individual rivers differ, the fish are not harvested in equal porportions. Secondly, the sockeye salmon of Nushagak Bay are not randomly distributed (Straty, 1969). Thus as the fishing fleet shifts, so does the proportion of fish harvested from the individual river systems. Exposure to equal fishing effort is especially problematic because the Igushik River fish primarily confined to the east side of the district do not penetrate as deeply as the Wood and Nuyakuk River fish (Straty, 1969). At times when the fishing fleet is on the west side of the district, harvest of Igushik River fish is especially light and the relative escapement is probably disproportionate. As a consequence, catch apportionment to the Igushik system based on daily spawning escapement is overestimated. The escapement of fish into the Wood and Nushagak, however, probably very closely reflects the daily abundance of fish migrating to those two rivers. In spite of errors, the migratory time density functions developed by apportioning catch according to daily escapements were consistent with observed data and demonstrate their potential utility in catch allocation.

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# APPENDIX A

## Preliminary Catch Allocation and Total Abundance of Sockeye Salmon from Wood, Igushik and Nuyakuk Rivers, 1979

Table A1. Preliminary sockeye salmon catch allocation based on proportions of total escapement (Equations 6 and 7).

| DAY OF MIGRATION | WOOD RIVER CATCH (No. in thousands) | IGUSHIK RIVER CATCH (No. in thousands) | NUYAKUK RIVER CATCH (No. in thousands) |
|---|---|---|---|
| 1. | 10.792 | 5.320 | 2.8880 |
| 2. | 2.840 | 1.400 | .7600 |
| 3. | 6.248 | 3.080 | 1.6720 |
| 4. | 0.000 | 0.000 | 0.0000 |
| 5. | 38.624 | 19.040 | 10.3360 |
| 6. | 0.000 | 0.000 | 0.0000 |
| 7. | 82.360 | 40.600 | 22.0400 |
| 8. | 7.384 | 3.640 | 1.9760 |
| 9. | 232.312 | 114.520 | 62.1680 |
| 10. | 224.928 | 110.880 | 60.1920 |
| 11. | 150.000 | 0.000 | 40.0000 |
| 12. | 16.000 | 0.000 | 4.0000 |
| 13. | 138.000 | 0.000 | 38.0000 |
| 14. | 42.600 | 21.000 | 11.4000 |
| 15. | 113.600 | 56.000 | 30.4000 |
| 16. | 153.360 | 75.600 | 41.0400 |
| 17. | 85.200 | 42.000 | 22.8000 |
| 18. | 62.480 | 30.800 | 16.7200 |
| 19. | 56.800 | 28.000 | 15.2000 |
| 20. | 42.032 | 20.720 | 11.2480 |
| 21. | 96.560 | 47.600 | 25.8400 |
| 22. | 150.000 | 0.000 | 40.0000 |
| 23. | 85.200 | 42.000 | 22.8000 |
| 24. | 56.800 | 28.000 | 15.2000 |
| 25. | 42.032 | 20.720 | 11.2480 |
| 26. | 23.856 | 11.760 | 6.3840 |
| 27. | 22.720 | 11.200 | 6.0800 |
| 28. | 17.040 | 8.400 | 4.5600 |
| 29. | 16.000 | 0.000 | 4.0000 |
| 30. | 5.680 | 2.800 | 1.5200 |
| 31. | 3.408 | 1.680 | .9120 |

Table A2. Preliminary sockeye salmon daily abundance with estimate of catch based on proportions of total escapement (Equations 6, 7 and 10).

| DAY OF MIGRATION | WOOD R. DAILY ABUNDANCE (No. in thousands) | IGUSHIK R. DAILY ABUNDANCE (No. in thousands) | NUYAKUK R. DAILY ABUNDANCE (No. in thousands) |
|---|---|---|---|
| 1. | 11.792 | 9.320 | 2.888 |
| 2. | 2.840 | 3.400 | .760 |
| 3. | 6.248 | 8.080 | 5.672 |
| 4. | 0.000 | 19.000 | 24.000 |
| 5. | 93.624 | 47.040 | 57.336 |
| 6. | 246.000 | 30.000 | 26.000 |
| 7. | 242.360 | 70.600 | 34.040 |
| 8. | 25.384 | 30.640 | 50.976 |
| 9. | 244.312 | 178.520 | 117.168 |
| 10. | 233.928 | 199.880 | 98.192 |
| 11. | 414.000 | 64.000 | 57.000 |
| 12. | 546.000 | 72.000 | 15.000 |
| 13. | 177.000 | 57.000 | 71.000 |
| 14. | 51.600 | 67.000 | 33.400 |
| 15. | 132.600 | 115.000 | 39.400 |
| 16. | 320.360 | 128.600 | 44.040 |
| 17. | 201.200 | 82.000 | 24.800 |
| 18. | 80.480 | 55.800 | 18.720 |
| 19. | 62.800 | 51.000 | 17.200 |
| 20. | 47.032 | 41.720 | 12.248 |
| 21. | 100.560 | 60.600 | 25.840 |
| 22. | 158.000 | 15.000 | 40.000 |
| 23. | 90.200 | 54.000 | 22.800 |
| 24. | 60.800 | 36.000 | 15.200 |
| 25. | 47.032 | 26.720 | 11.248 |
| 26. | 28.856 | 16.760 | 6.384 |
| 27. | 22.720 | 15.200 | 6.080 |
| 28. | 17.040 | 12.400 | 4.560 |
| 29. | 16.000 | 5.000 | 4.000 |
| 30. | 5.680 | 7.800 | 1.520 |
| 31. | 3.408 | 5.680 | .912 |

Table A3. Preliminary sockeye salmon daily proportions of abundance with estimates of catch based on proportions of total escapement (Equations 6, 7, 10).

| DAY OF MIGRATION | WOOD R. ABUNDANCE DAILY PROPORTION | IGUSHIK R. ABUNDANCE DAILY PROPORTION | NUYAKUK R. ABUNDANCE DAILY PROPORTION |
|---|---|---|---|
| 1. | .003196 | .005877 | .003251 |
| 2. | .000770 | .002144 | .000855 |
| 3. | .001693 | .005095 | .006385 |
| 4. | 0.000000 | .011981 | .027015 |
| 5. | .025373 | .029663 | .064540 |
| 6. | .066668 | .018918 | .029267 |
| 7. | .065682 | .044520 | .038317 |
| 8. | .006879 | .019321 | .057381 |
| 9. | .066211 | .112574 | .131890 |
| 10. | .063397 | .126044 | .110529 |
| 11. | .112198 | .040358 | .064162 |
| 12. | .147971 | .045403 | .016885 |
| 13. | .047969 | .035944 | .079921 |
| 14. | .013984 | .042250 | .037597 |
| 15. | .035936 | .072519 | .044350 |
| 16. | .086821 | .081095 | .049573 |
| 17. | .054527 | .051709 | .027916 |
| 18. | .021811 | .035187 | .021072 |
| 19. | .017019 | .032160 | .019361 |
| 20. | .012746 | .026308 | .013787 |
| 21. | .027253 | .038214 | .029087 |
| 22. | .042820 | .009459 | .045026 |
| 23. | .024445 | .034052 | .025665 |
| 24. | .016477 | .022701 | .017110 |
| 25. | .012746 | .016850 | .012661 |
| 26. | .007820 | .010569 | .007186 |
| 27. | .006157 | .009585 | .006844 |
| 28. | .004618 | .007819 | .005133 |
| 29. | .004336 | .003153 | .004503 |
| 30. | .001539 | .004919 | .001711 |
| 31. | .000924 | .003582 | .001027 |

Table A4. Preliminary sockeye salmon cumulative abundance with estimates of catch based on proportions of total escapement (Equations 6, 7 and 10).

| DAY OF MIGRATION | WOOD R. ABUNDANCE CUMULATIVE NUMBER IN THOUSANDS | IGUSHIK R. ABUNDANCE CUMULATIVE NUMBER IN THOUSANDS | NUYAKUK R. ABUNDANCE CUMULATIVE NUMBER IN THOUSANDS |
|---|---|---|---|
| 1. | 11.79 | 9.32 | 2.890 |
| 2. | 14.63 | 12.72 | 3.650 |
| 3. | 20.88 | 20.80 | 9.320 |
| 4. | 20.88 | 39.80 | 33.320 |
| 5. | 114.50 | 86.84 | 90.660 |
| 6. | 360.50 | 116.84 | 116.660 |
| 7. | 602.86 | 187.44 | 150.700 |
| 8. | 628.25 | 218.08 | 201.670 |
| 9. | 872.56 | 396.60 | 318.840 |
| 10. | 1106.49 | 596.48 | 417.030 |
| 11. | 1520.49 | 660.48 | 474.030 |
| 12. | 2066.49 | 732.48 | 489.030 |
| 13. | 2243.49 | 789.48 | 560.030 |
| 14. | 2295.09 | 856.48 | 593.430 |
| 15. | 2427.69 | 971.48 | 632.830 |
| 16. | 2748.05 | 1100.08 | 676.870 |
| 17. | 2949.25 | 1182.08 | 701.670 |
| 18. | 3029.73 | 1237.88 | 720.390 |
| 19. | 3092.53 | 1288.88 | 737.590 |
| 20. | 3139.56 | 1330.60 | 749.840 |
| 21. | 3240.12 | 1391.20 | 775.680 |
| 22. | 3398.12 | 1406.20 | 815.680 |
| 23. | 3488.32 | 1460.20 | 838.480 |
| 24. | 3549.12 | 1496.20 | 853.680 |
| 25. | 3596.15 | 1522.92 | 864.930 |
| 26. | 3625.01 | 1539.68 | 871.310 |
| 27. | 3647.73 | 1554.88 | 877.390 |
| 28. | 3664.77 | 1567.28 | 881.950 |
| 29. | 3680.77 | 1572.28 | 885.950 |
| 30. | 3686.45 | 1580.08 | 887.470 |
| 31. | 3689.86 | 1585.76 | 888.380 |

Table A5. Preliminary sockeye salmon cumulative proportions of abundance with estimates of catch based on proportions of total escapement (Equations 6, 7 and 10).

| DAY OF MIGRATION | WOOD R. ABUNDANCE CUMULATIVE PROPORTION | IGUSHIK R. ABUNDANCE CUMULATIVE PROPORTION | NUYAKUK R. ABUNDANCE CUMULATIVE PROPORTION |
|---|---|---|---|
| 1. | .00320 | .00588 | .00325 |
| 2. | .00397 | .00802 | .00411 |
| 3. | .00566 | .01312 | .01049 |
| 4. | .00566 | .02510 | .03751 |
| 5. | .03103 | .05476 | .10205 |
| 6. | .09770 | .07368 | .13131 |
| 7. | .16338 | .11820 | .16963 |
| 8. | .17026 | .13752 | .22701 |
| 9. | .23647 | .25009 | .35890 |
| 10. | .29987 | .37614 | .46943 |
| 11. | .41207 | .41650 | .53359 |
| 12. | .56004 | .46190 | .55048 |
| 13. | .60801 | .49784 | .63040 |
| 14. | .62199 | .54009 | .66799 |
| 15. | .65793 | .61261 | .71234 |
| 16. | .74475 | .69371 | .76192 |
| 17. | .79928 | .74542 | .78983 |
| 18. | .82109 | .78060 | .81091 |
| 19. | .83811 | .81276 | .83027 |
| 20. | .85085 | .83907 | .84405 |
| 21. | .87811 | .87729 | .87314 |
| 22. | .92092 | .88674 | .91817 |
| 23. | .94537 | .92080 | .94383 |
| 24. | .96185 | .94350 | .96094 |
| 25. | .97459 | .96035 | .97360 |
| 26. | .98241 | .97092 | .98079 |
| 27. | .98857 | .98050 | .98763 |
| 28. | .99319 | .98832 | .99276 |
| 29. | .99753 | .99147 | .99727 |
| 30. | .99906 | .99639 | .99898 |
| 31. | .99999 | .99997 | 1.00000 |

Table A6. Preliminary sockeye salmon catch allocation based on proportions of daily escapement (Equations 8, 9 and 10).

| DAY OF MIGRATION | WOOD R. CATCH DAILY (No. in thousands) | IGUSHIK R. CATCH DAILY (No. in thousands) | NUYAKUK R. CATCH DAILY (No. in thousands) |
|---|---|---|---|
| 1. | 3.800 | 15.200 | 0.000 |
| 2. | 0.000 | 5.000 | 0.000 |
| 3. | 0.000 | 6.111 | 4.889 |
| 4. | 0.000 | 0.000 | 0.000 |
| 5. | 28.769 | 14.646 | 24.585 |
| 6. | 0.000 | 0.000 | 0.000 |
| 7. | 114.851 | 21.535 | 8.614 |
| 8. | 2.489 | 3.734 | 6.777 |
| 9. | 80.000 | 114.520 | 219.000 |
| 10. | 51.000 | 110.880 | 235.000 |
| 11. | 150.000 | 0.000 | 40.000 |
| 12. | 16.000 | 0.000 | 4.000 |
| 13. | 138.000 | 0.000 | 38.000 |
| 14. | 8.766 | 44.805 | 21.429 |
| 15. | 43.678 | 135.632 | 20.690 |
| 16. | 202.197 | 64.170 | 3.632 |
| 17. | 110.127 | 37.975 | 1.899 |
| 18. | 44.000 | 61.111 | 4.889 |
| 19. | 19.355 | 74.194 | 6.452 |
| 20. | 13.704 | 57.556 | 2.741 |
| 21. | 40.000 | 130.000 | 0.000 |
| 22. | 66.087 | 123.913 | 0.000 |
| 23. | 44.118 | 105.882 | 0.000 |
| 24. | 33.333 | 66.667 | 0.000 |
| 25. | 33.636 | 40.364 | 0.000 |
| 26. | 21.000 | 21.000 | 0.000 |
| 27. | 0.000 | 40.000 | 0.000 |
| 28. | 0.000 | 30.000 | 0.000 |
| 29. | 0.000 | 20.000 | 0.000 |
| 30. | 0.000 | 10.000 | 0.000 |
| 31. | 0.000 | 6.000 | 0.000 |

Table A7. Preliminary sockeye salmon daily abundance with estimates of catch based on proportions of daily escapement (Equations 8, 9 and 10).

| DAY OF MIGRATION | WOOD R. ABUNDANCE DAILY (No. in thousands) | IGUSHIK R. ABUNDANCE DAILY (No. in thousands) | NUYAKUK R. ABUNDANCE DAILY (No. in thousands) |
|---|---|---|---|
| 1. | 4.800 | 19.200 | 0.000 |
| 2. | 0.000 | 7.000 | 0.000 |
| 3. | 0.000 | 11.111 | 8.889 |
| 4. | 0.000 | 19.000 | 24.000 |
| 5. | 83.769 | 42.646 | 71.585 |
| 6. | 246.000 | 30.000 | 26.000 |
| 7. | 274.851 | 51.535 | 20.614 |
| 8. | 20.489 | 30.734 | 55.777 |
| 9. | 92.000 | 178.520 | 274.000 |
| 10. | 60.000 | 199.880 | 273.000 |
| 11. | 414.000 | 64.000 | 57.000 |
| 12. | 546.000 | 72.000 | 15.000 |
| 13. | 177.000 | 57.000 | 71.000 |
| 14. | 17.766 | 90.805 | 43.429 |
| 15. | 62.678 | 194.632 | 29.690 |
| 16. | 369.197 | 117.170 | 6.632 |
| 17. | 226.127 | 77.975 | 3.899 |
| 18. | 62.000 | 86.111 | 6.889 |
| 19. | 25.355 | 97.194 | 8.452 |
| 20. | 18.704 | 78.556 | 3.741 |
| 21. | 44.000 | 143.000 | 0.000 |
| 22. | 74.087 | 138.913 | 0.000 |
| 23. | 49.118 | 117.882 | 0.000 |
| 24. | 37.333 | 74.667 | 0.000 |
| 25. | 38.636 | 46.364 | 0.000 |
| 26. | 26.000 | 26.000 | 0.000 |
| 27. | 0.000 | 44.000 | 0.000 |
| 28. | 0.000 | 34.000 | 0.000 |
| 29. | 0.000 | 25.000 | 0.000 |
| 30. | 0.000 | 15.000 | 0.000 |
| 31. | 0.000 | 10.000 | 0.000 |

Table A8. Preliminary sockeye salmon daily proportions of abundance with estimates of catch based on proportions of daily escapement (Equations 8, 9 and 10).

| DAY OF MIGRATION | WOOD R. ABUNDANCE DAILY PROPORTION | IGUSHIK R. ABUNDANCE DAILY PROPORTION | NUYAKUK R. ABUNDANCE DAILY PROPORTION |
|---|---|---|---|
| 1. | .001616 | .0087277 | 0.000000 |
| 2. | 0.000000 | .0031820 | 0.000000 |
| 3. | 0.000000 | .0050507 | .008893 |
| 4. | 0.000000 | .0086368 | .024010 |
| 5. | .028206 | .0193855 | .071614 |
| 6. | .082831 | .0136370 | .026011 |
| 7. | .092546 | .0234259 | .020622 |
| 8. | .006899 | .0139707 | .055799 |
| 9. | .030977 | .0811491 | .274112 |
| 10. | .020203 | .0908587 | .273112 |
| 11. | .139399 | .0290922 | .057023 |
| 12. | .183845 | .0327288 | .015006 |
| 13. | .059598 | .0259103 | .071029 |
| 14. | .005982 | .0412770 | .043446 |
| 15. | .021104 | .0884732 | .029702 |
| 16. | .124313 | .0532617 | .006635 |
| 17. | .076139 | .0354446 | .003900 |
| 18. | .020876 | .0391432 | .006892 |
| 19. | .008537 | .0441809 | .008455 |
| 20. | .006298 | .0357087 | .003742 |
| 21. | .014815 | .0650030 | 0.000000 |
| 22. | .024946 | .0631452 | 0.000000 |
| 23. | .016538 | .0535853 | 0.000000 |
| 24. | .012571 | .0339409 | 0.000000 |
| 25. | .013009 | .0210753 | 0.000000 |
| 26. | .008755 | .0118187 | 0.000000 |
| 27. | 0.000000 | .0200009 | 0.000000 |
| 28. | 0.000000 | .0154552 | 0.000000 |
| 29. | 0.000000 | .0113642 | 0.000000 |
| 30. | 0.000000 | .0068185 | 0.000000 |
| 31. | 0.000000 | .0045457 | 0.000000 |

Table A9. Preliminary sockeye salmon cumulative abundance with estimates of catch based on proportions of total escapement (Equations 8, 9 and 10).

| DAY OF MIGRATION | WOOD R. ABUNDANCE CUMULATIVE NUMBER IN THOUSANDS | IGUSHIK R. ABUNDANCE CUMULATIVE NUMBER IN THOUSANDS | NUYAKUK R. ABUNDANCE CUMULATIVE NUMBER IN THOUSANDS |
|---|---|---|---|
| 1. | 4.80 | 19.20 | 0.000 |
| 2. | 4.80 | 26.20 | 0.000 |
| 3. | 4.80 | 37.31 | 8.890 |
| 4. | 4.80 | 56.31 | 32.890 |
| 5. | 88.57 | 98.96 | 104.470 |
| 6. | 334.57 | 128.96 | 130.470 |
| 7. | 609.42 | 180.49 | 151.090 |
| 8. | 629.91 | 211.23 | 206.860 |
| 9. | 721.91 | 389.75 | 480.860 |
| 10. | 781.91 | 589.63 | 753.860 |
| 11. | 1195.91 | 653.63 | 810.860 |
| 12. | 1741.91 | 725.63 | 825.860 |
| 13. | 1918.91 | 782.63 | 896.860 |
| 14. | 1936.68 | 873.43 | 940.290 |
| 15. | 1999.35 | 1068.06 | 969.980 |
| 16. | 2368.55 | 1185.23 | 976.610 |
| 17. | 2594.68 | 1263.21 | 980.510 |
| 18. | 2656.68 | 1349.32 | 987.400 |
| 19. | 2682.03 | 1446.51 | 995.850 |
| 20. | 2700.74 | 1525.07 | 999.590 |
| 21. | 2744.74 | 1668.07 | 999.590 |
| 22. | 2818.82 | 1806.98 | 999.590 |
| 23. | 2867.94 | 1924.86 | 999.590 |
| 24. | 2905.27 | 1999.53 | 999.590 |
| 25. | 2943.91 | 2045.89 | 999.590 |
| 26. | 2969.91 | 2071.89 | 999.590 |
| 27. | 2969.91 | 2115.89 | 999.590 |
| 28. | 2969.91 | 2149.89 | 999.590 |
| 29. | 2969.91 | 2174.89 | 999.590 |
| 30. | 2969.91 | 2189.89 | 999.590 |
| 31. | 2969.91 | 2199.89 | 999.590 |

Table A10. Preliminary sockeye salmon cumulative proportions of abundance with estimates of catch based on proportions of total escapement (Equations 8, 9 and 10).

| DAY OF MIGRATION | WOOD R. ABUNDANCE CUMULATIVE PROPORTION | IGUSHIK R. ABUNDANCE CUMULATIVE PROPORTION | NUYAKUK R. ABUNDANCE CUMULATIVE PROPORTION |
|---|---|---|---|
| 1. | .00162 | .00873 | 0.00000 |
| 2. | .00162 | .01191 | 0.00000 |
| 3. | .00162 | .01696 | .00889 |
| 4. | .00162 | .02560 | .03290 |
| 5. | .02982 | .04498 | .10452 |
| 6. | .11265 | .05862 | .13053 |
| 7. | .20520 | .08205 | .15115 |
| 8. | .21210 | .09602 | .20695 |
| 9. | .24308 | .17717 | .48106 |
| 10. | .26328 | .26802 | .75417 |
| 11. | .40268 | .29712 | .81120 |
| 12. | .58652 | .32984 | .82620 |
| 13. | .64612 | .35576 | .89723 |
| 14. | .65210 | .39703 | .94068 |
| 15. | .67321 | .48551 | .97038 |
| 16. | .79752 | .53877 | .97702 |
| 17. | .87366 | .57421 | .98092 |
| 18. | .89453 | .61335 | .98781 |
| 19. | .90307 | .65754 | .99626 |
| 20. | .90937 | .69324 | 1.00000 |
| 21. | .92418 | .75825 | 1.00000 |
| 22. | .94913 | .82139 | 1.00000 |
| 23. | .96567 | .87498 | 1.00000 |
| 24. | .97824 | .90892 | 1.00000 |
| 25. | .99125 | .92999 | 1.00000 |
| 26. | 1.00000 | .94181 | 1.00000 |
| 27. | 1.00000 | .96181 | 1.00000 |
| 28. | 1.00000 | .97727 | 1.00000 |
| 29. | 1.00000 | .98863 | 1.00000 |
| 30. | 1.00000 | .99545 | 1.00000 |
| 31. | 1.00000 | 1.00000 | 1.00000 |

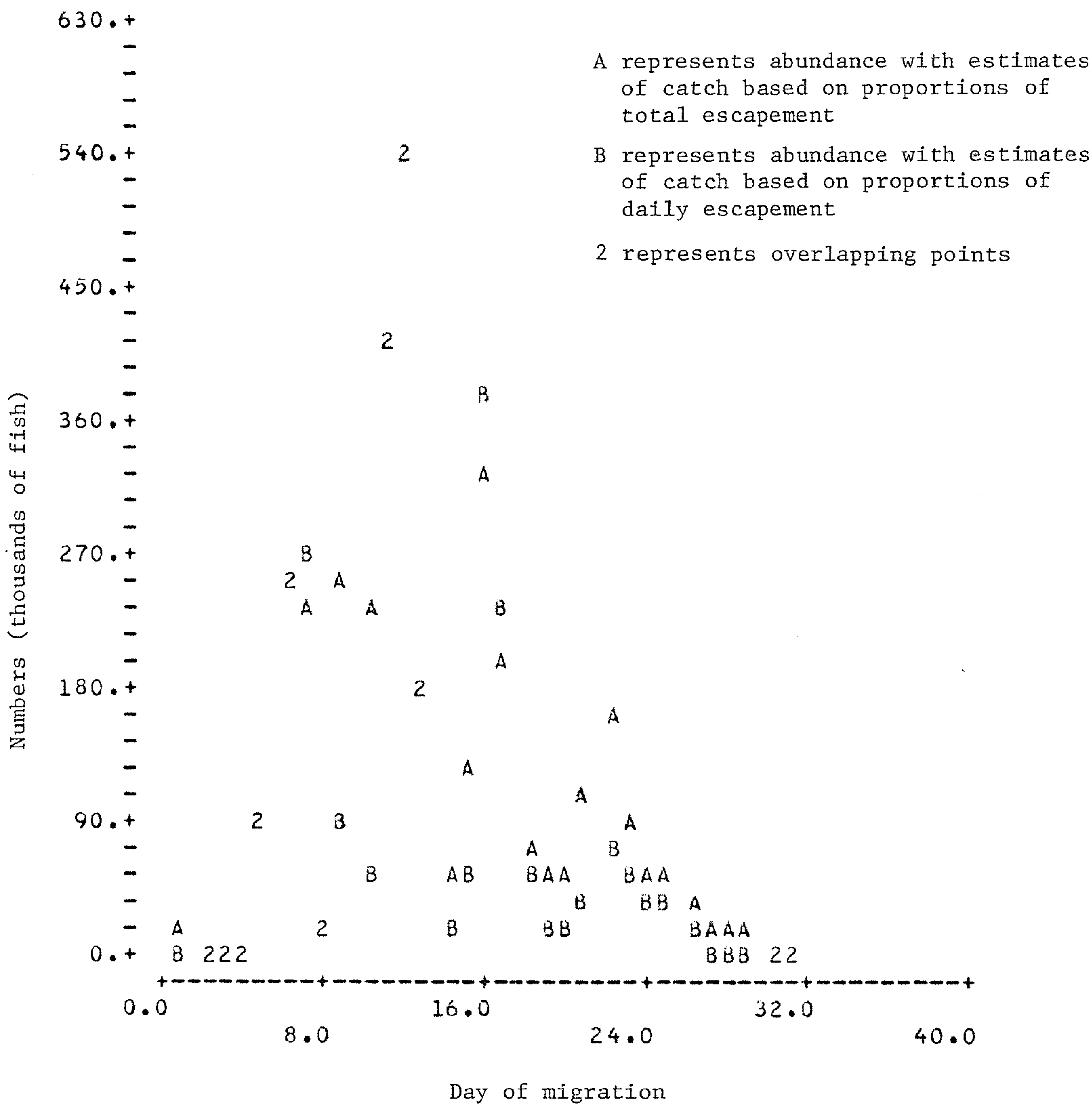


Figure A1. Preliminary sockeye salmon daily abundance for the Wood River, 1979.

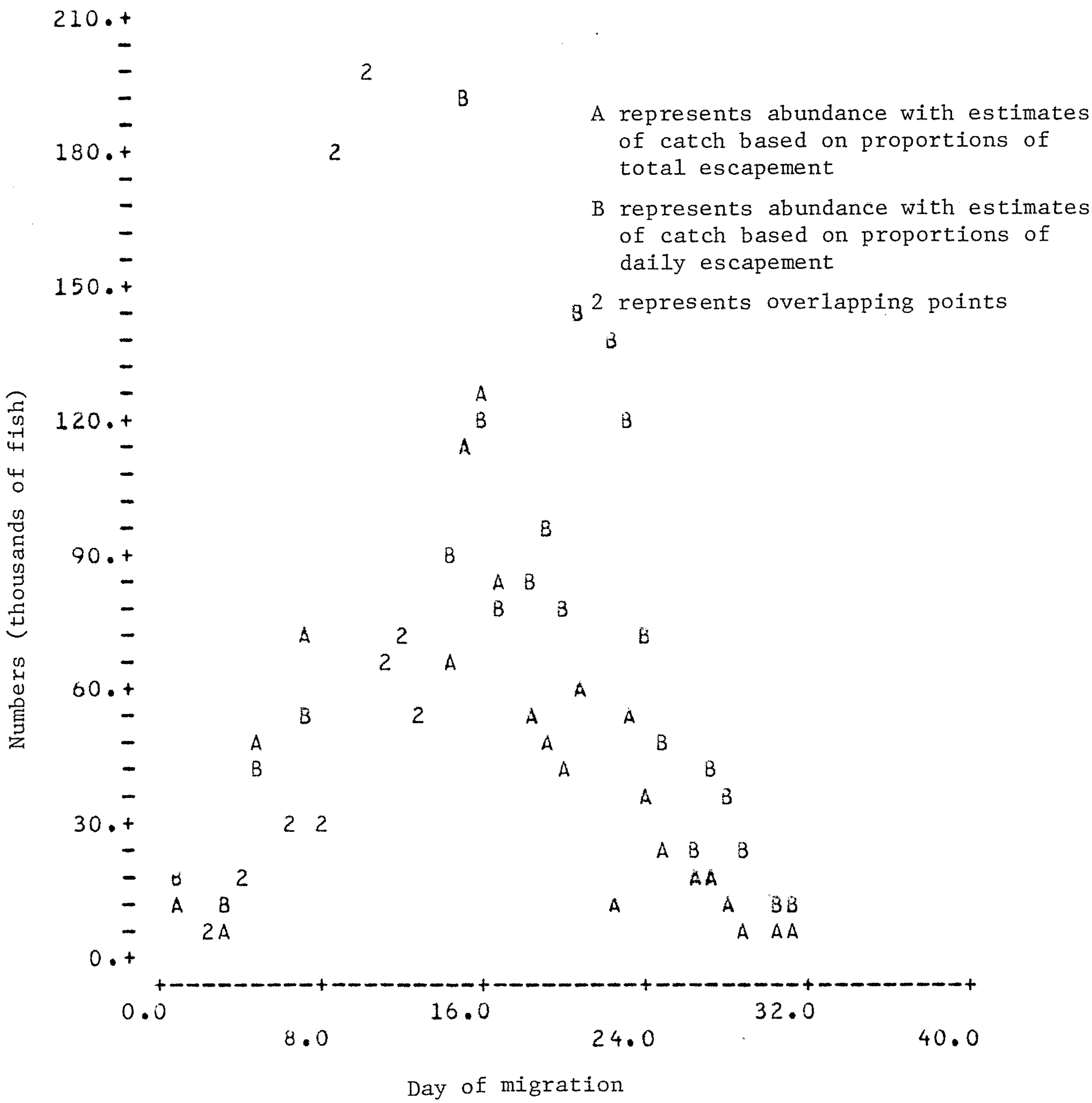


Figure A2. Preliminary sockeye salmon daily abundance for the Igushik River, 1979.

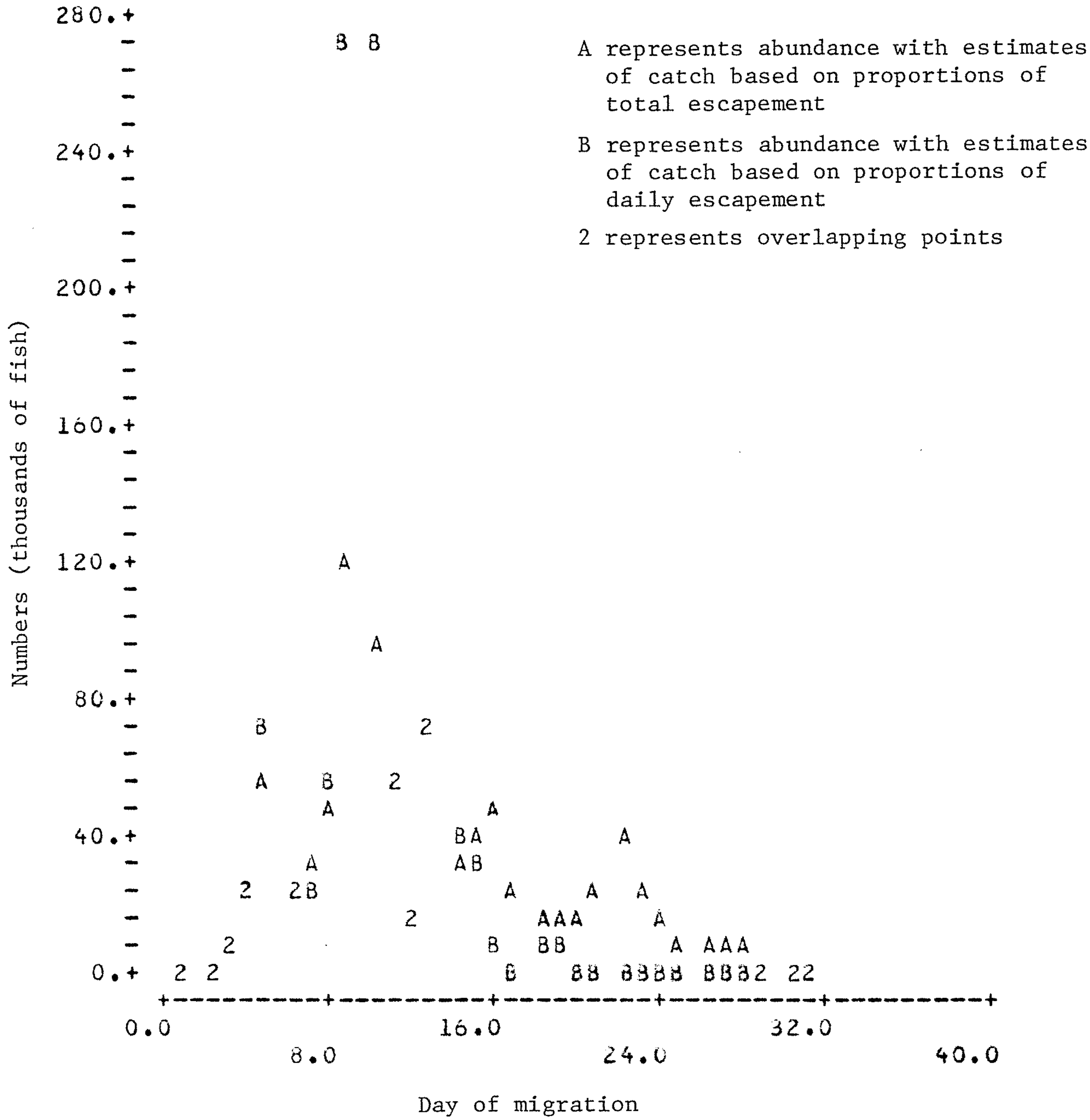


Figure A3. Preliminary sockeye salmon daily abundance for the Nuyakuk River, 1979.

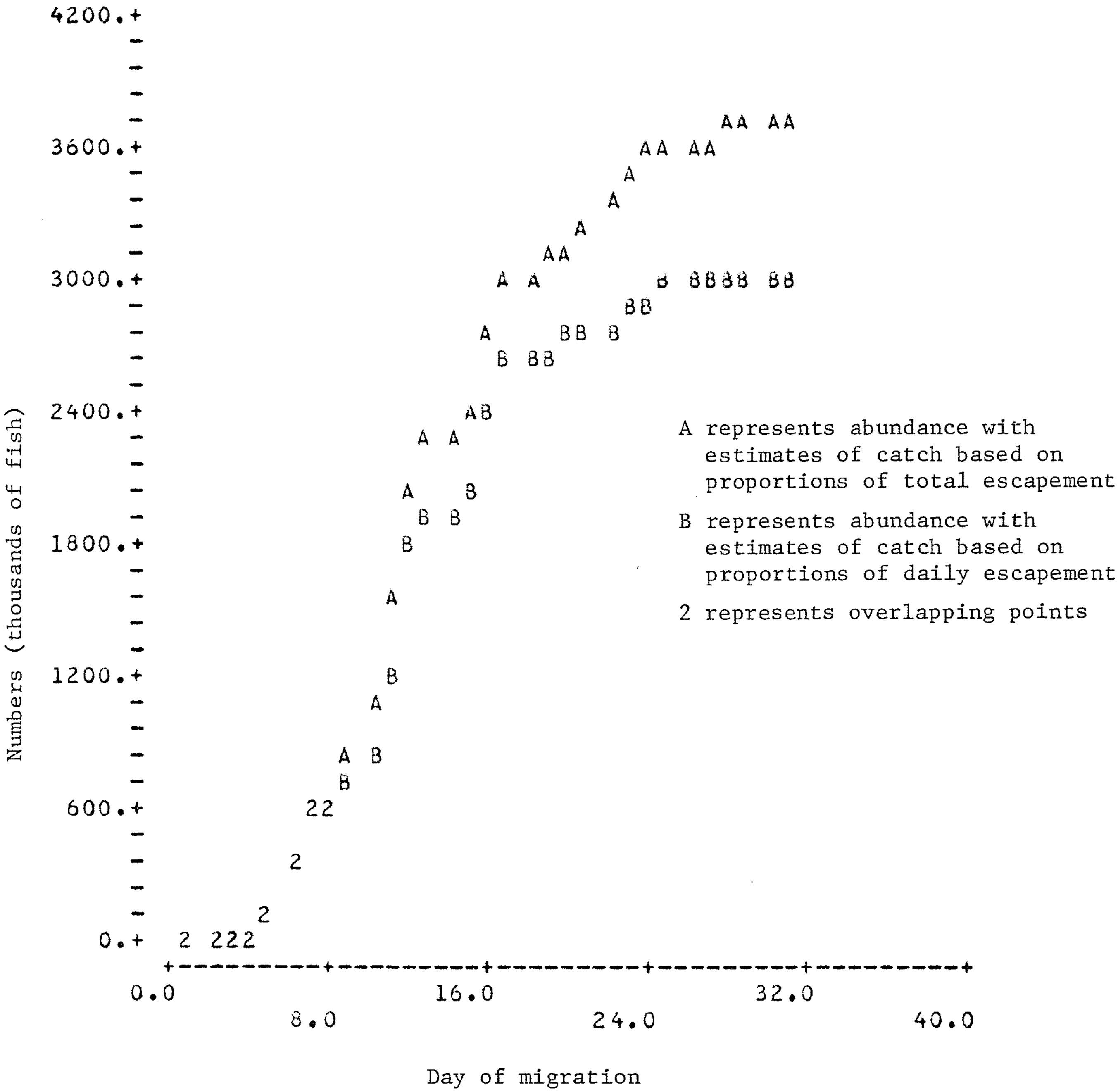


Figure A4. Preliminary sockeye salmon cumulative abundance for the Wood River, 1979.

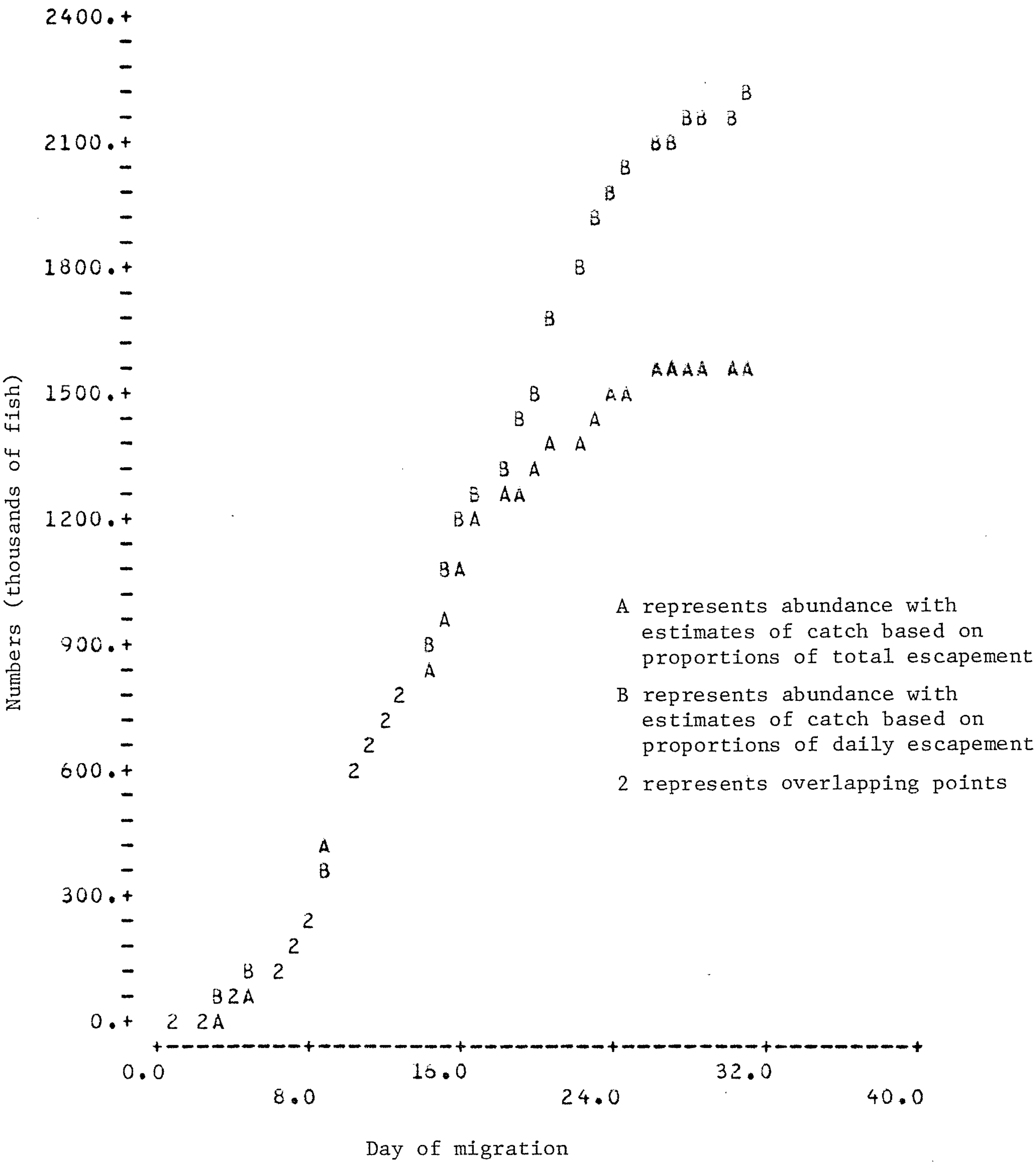


Figure A5. Preliminary sockeye salmon daily abundance for the Igushik River, 1979.

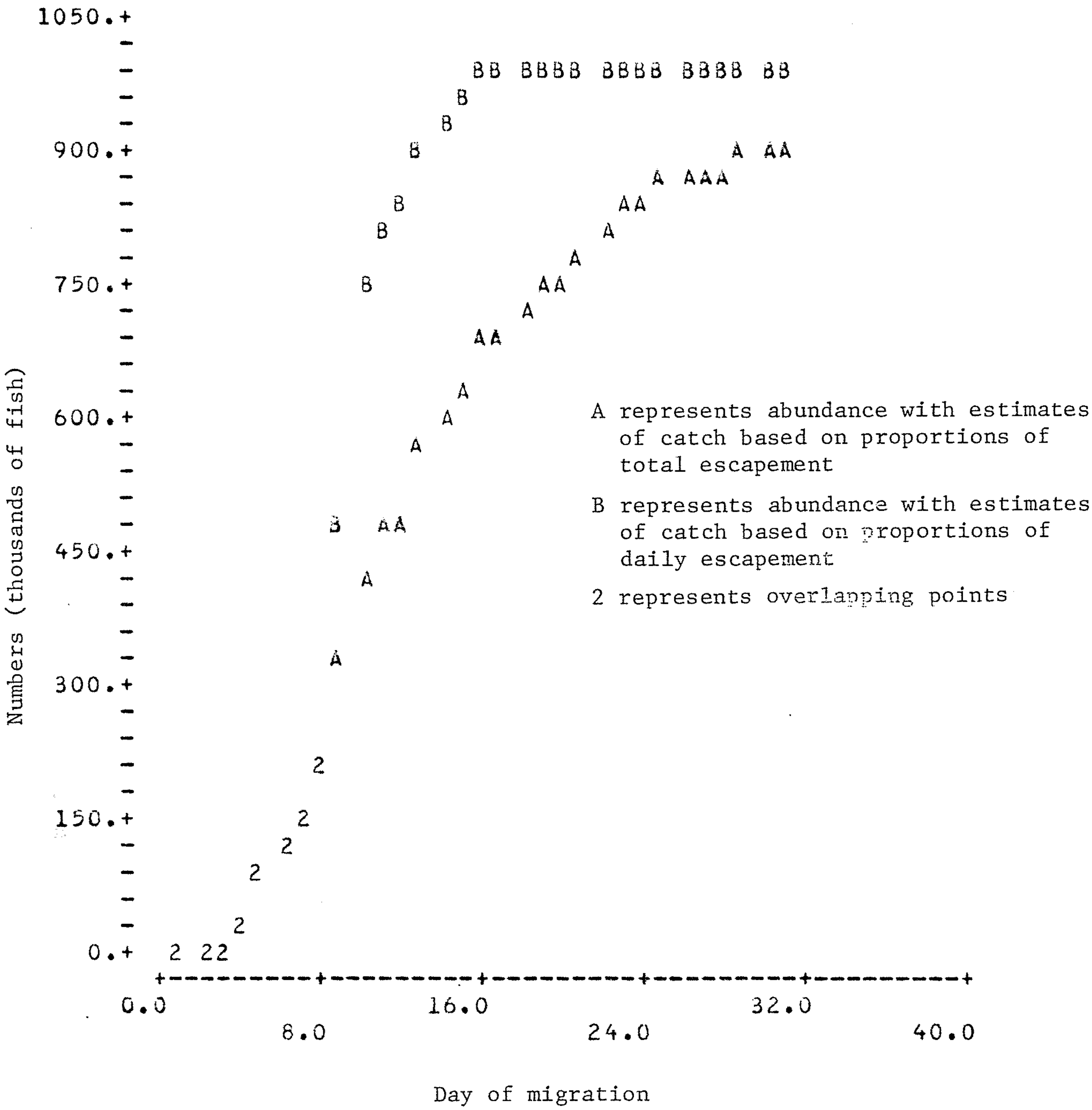


Figure A6. Preliminary sockeye salmon daily abundance for the Nuyakuk River, 1979.

# APPENDIX B

Observed Abundance and Migratory Time-Density Functions for Sockeye Salmon from Wood, Igushik and Nuyakuk Rivers, 1979

Table B1. Observed proportions of abundance with estimates of catch based on proportions of total escapement and expected proportions of abundance based on migratory time density functions for the Wood River, 1979.

| DAY OF MIGRATION | WOOD R. ABUNDANCE DAILY PROPORTION OBSERVED | WOOD R. ABUNDANCE DAILY PROPORTION EXPECTED | WOOD R. ABUNDANCE CUMULATIVE PROPORTION OBSERVED | WOOD R. ABUNDANCE CUMULATIVE PROPORTION EXPECTED |
|---|---|---|---|---|
| 1. | .003196 | .0058198 | .00320 | .005820 |
| 2. | .000770 | .0085834 | .00397 | .014400 |
| 3. | .001693 | .0122534 | .00566 | .026660 |
| 4. | 0.000000 | .0169319 | .00566 | .043590 |
| 5. | .025373 | .0226467 | .03103 | .066240 |
| 6. | .066668 | .0293197 | .09770 | .095550 |
| 7. | .065682 | .0367421 | .16338 | .132300 |
| 8. | .006879 | .0445677 | .17026 | .176860 |
| 9. | .066211 | .0523273 | .23647 | .229190 |
| 10. | .063397 | .0594687 | .29987 | .288660 |
| 11. | .112198 | .0654185 | .41207 | .354080 |
| 12. | .147971 | .0696569 | .56004 | .423740 |
| 13. | .047969 | .0717926 | .60801 | .495530 |
| 14. | .013984 | .0716220 | .62199 | .567150 |
| 15. | .035936 | .0691617 | .65793 | .636310 |
| 16. | .086821 | .0646452 | .74475 | .700960 |
| 17. | .054527 | .0584869 | .79928 | .759440 |
| 18. | .021811 | .0512192 | .82109 | .810660 |
| 19. | .017019 | .0434169 | .83811 | .854080 |
| 20. | .012746 | .0356235 | .85085 | .889700 |
| 21. | .027253 | .0282922 | .87811 | .918000 |
| 22. | .042820 | .0217494 | .92092 | .939750 |
| 23. | .024445 | .0161838 | .94537 | .955930 |
| 24. | .016477 | .0116564 | .96185 | .967590 |
| 25. | .012746 | .0081265 | .97459 | .975710 |
| 26. | .007820 | .0054839 | .98241 | .981200 |
| 27. | .006157 | .0035820 | .98857 | .984780 |
| 28. | .004618 | .0022648 | .99319 | .987040 |
| 29. | .004336 | .0013860 | .99753 | .988430 |
| 30. | .001539 | .0008210 | .99906 | .989250 |
| 31. | .000924 | .0004708 | .99999 | .989720 |

Table B2. Observed proportions of abundance with estimates of catch based on proportions of total escapement and expected proportions of abundance based on migratory time density functions for the Igushik River, 1979.

| DAY OF MIGRATION | IGUSHIK R. ABUNDANCE DAILY PROPORTION OBSERVED | IGUSHIK R. ABUNDANCE DAILY PROPORTION EXPECTED | IGUSHIK R. ABUNDANCE CUMULATIVE PROPORTION OBSERVED | IGUSHIK R. ABUNDANCE CUMULATIVE PROPORTION EXPECTED |
|---|---|---|---|---|
| 1. | .005877 | .0061231 | .00588 | .006120 |
| 2. | .002144 | .0087195 | .00802 | .014840 |
| 3. | .005095 | .0120711 | .01312 | .026910 |
| 4. | .011981 | .0162459 | .02510 | .043160 |
| 5. | .029663 | .0212559 | .05476 | .064420 |
| 6. | .018918 | .0270365 | .07368 | .091450 |
| 7. | .044520 | .0334319 | .11820 | .124880 |
| 8. | .019321 | .0401892 | .13752 | .165070 |
| 9. | .112574 | .0469672 | .25009 | .212040 |
| 10. | .126044 | .0533604 | .37614 | .265400 |
| 11. | .040358 | .0589361 | .41650 | .324340 |
| 12. | .045403 | .0632822 | .46190 | .387620 |
| 13. | .035944 | .0660571 | .49784 | .453680 |
| 14. | .042250 | .0670341 | .54009 | .520710 |
| 15. | .072519 | .0661318 | .61261 | .586840 |
| 16. | .081095 | .0634253 | .69371 | .650270 |
| 17. | .051709 | .0591361 | .74542 | .709400 |
| 18. | .035187 | .0536020 | .78060 | .763010 |
| 19. | .032160 | .0472332 | .81276 | .810240 |
| 20. | .026308 | .0404624 | .83907 | .850700 |
| 21. | .038214 | .0336972 | .87729 | .884400 |
| 22. | .009459 | .0272819 | .88674 | .911680 |
| 23. | .034052 | .0214730 | .92080 | .933150 |
| 24. | .022701 | .0164304 | .94350 | .949580 |
| 25. | .016850 | .0122220 | .96035 | .961810 |
| 26. | .010569 | .0088385 | .97092 | .970640 |
| 27. | .009585 | .0062136 | .98050 | .976860 |
| 28. | .007819 | .0042467 | .98832 | .981100 |
| 29. | .003153 | .0028216 | .99147 | .983930 |
| 30. | .004919 | .0018226 | .99639 | .985750 |
| 31. | .003582 | .0011445 | .99997 | .986890 |

Table B3. Observed proportions of abundance with estimates of catch based on proportions of total escapement and expected proportions of abundance based on migratory time density functions for the Nuyakuk River, 1979

| DAY OF MIGRATION | NUYAKUK R. ABUNDANCE DAILY PROPORTION OBSERVED | NUYAKUK R. ABUNDANCE DAILY PROPORTION EXPECTED | NUYAKUK R. ABUNDANCE CUMULATIVE PROPORTION OBSERVED | NUYAKUK R. ABUNDANCE CUMULATIVE PROPORTION EXPECTED |
|---|---|---|---|---|
| 1. | .003251 | .0097446 | .00325 | .009745 |
| 2. | .000855 | .0133405 | .00411 | .023085 |
| 3. | .006385 | .0177596 | .01049 | .040845 |
| 4. | .027015 | .0229903 | .03751 | .063835 |
| 5. | .064540 | .0289406 | .10205 | .092776 |
| 6. | .029267 | .0354258 | .13131 | .128201 |
| 7. | .038317 | .0421681 | .16963 | .170370 |
| 8. | .057381 | .0488090 | .22701 | .219179 |
| 9. | .131890 | .0549371 | .35890 | .274116 |
| 10. | .110529 | .0601288 | .46943 | .334244 |
| 11. | .064162 | .0639957 | .53359 | .398240 |
| 12. | .016885 | .0662323 | .55048 | .464473 |
| 13. | .079921 | .0666561 | .63040 | .531129 |
| 14. | .037597 | .0652320 | .66799 | .596361 |
| 15. | .044350 | .0620773 | .71234 | .658438 |
| 16. | .049573 | .0574454 | .76192 | .715883 |
| 17. | .027916 | .0516927 | .78983 | .767576 |
| 18. | .021072 | .0452329 | .81091 | .812809 |
| 19. | .019361 | .0384884 | .83027 | .851297 |
| 20. | .013787 | .0318461 | .84405 | .883143 |
| 21. | .029087 | .0256233 | .87314 | .908767 |
| 22. | .045026 | .0200476 | .91817 | .928814 |
| 23. | .025665 | .0152526 | .94383 | .944067 |
| 24. | .017110 | .0112843 | .96094 | .955351 |
| 25. | .012661 | .0081181 | .97360 | .963469 |
| 26. | .007186 | .0056792 | .98079 | .969149 |
| 27. | .006844 | .0038634 | .98763 | .973012 |
| 28. | .005133 | .0025557 | .99276 | .975568 |
| 29. | .004503 | .0016440 | .99727 | .977212 |
| 30. | .001711 | .0010283 | .99898 | .978240 |
| 31. | .001027 | .0006255 | 1.00000 | .978865 |

Table B4. Observed proportions of abundance with estimates of catch based on proportions of daily escapement and expected proportions of abundance based on migratory time density functions for the Wood River, 1979.

| DAY OF MIGRATION | WOOD R. ABUNDANCE DAILY PROPORTION OBSERVED | WOOD R. ABUNDANCE DAILY PROPORTION EXPECTED | WOOD R. ABUNDANCE CUMULATIVE PROPORTION OBSERVED | WOOD R. ABUNDANCE CUMULATIVE PROPORTION EXPECTED |
|---|---|---|---|---|
| 1. | .001616 | .0045363 | .00162 | .004540 |
| 2. | 0.000000 | .0072533 | .00162 | .011790 |
| 3. | 0.000000 | .0111250 | .00162 | .022910 |
| 4. | 0.000000 | .0163679 | .00162 | .039280 |
| 5. | .028206 | .0231002 | .02982 | .062380 |
| 6. | .082831 | .0312730 | .11265 | .093660 |
| 7. | .092546 | .0406117 | .20520 | .134270 |
| 8. | .006899 | .0505897 | .21210 | .184860 |
| 9. | .030977 | .0604510 | .24308 | .245310 |
| 10. | .020203 | .0692906 | .26328 | .314600 |
| 11. | .139399 | .0761859 | .40268 | .390780 |
| 12. | .183845 | .0803535 | .58652 | .471140 |
| 13. | .059598 | .0812951 | .64612 | .552430 |
| 14. | .005982 | .0788958 | .65210 | .631330 |
| 15. | .021104 | .0734468 | .67321 | .704780 |
| 16. | .124313 | .0655875 | .79752 | .770360 |
| 17. | .076139 | .0561823 | .87366 | .826550 |
| 18. | .020876 | .0461644 | .89453 | .872710 |
| 19. | .008537 | .0363869 | .90307 | .909100 |
| 20. | .006298 | .0275114 | .90937 | .936610 |
| 21. | .014815 | .0199530 | .92418 | .956560 |
| 22. | .024946 | .0138815 | .94913 | .970440 |
| 23. | .016538 | .0092639 | .96567 | .979710 |
| 24. | .012571 | .0059303 | .97824 | .985640 |
| 25. | .013009 | .0036416 | .99125 | .989280 |
| 26. | .008755 | .0021451 | 1.00000 | .991420 |
| 27. | 0.000000 | .0012120 | 1.00000 | .992640 |
| 28. | 0.000000 | .0006569 | 1.00000 | .993290 |
| 29. | 0.000000 | .0003415 | 1.00000 | .993630 |
| 30. | 0.000000 | .0001703 | 1.00000 | .993800 |
| 31. | 0.000000 | .0000815 | 1.00000 | .993890 |

Table B5. Observed proportions of abundance with estimates of catch based on proportions of daily escapement and expected proportions of abundance based on migratory time density functions for the Igushik River, 1979.

| DAY OF MIGRATION | IGUSHIK R. ABUNDANCE DAILY PROPORTION OBSERVED | IGUSHIK R. ABUNDANCE DAILY PROPORTION EXPECTED | IGUSHIK R. ABUNDANCE CUMULATIVE PROPORTION OBSERVED | IGUSHIK R. ABUNDANCE CUMULATIVE PROPORTION EXPECTED |
|---|---|---|---|---|
| 1. | .0087277 | .0040282 | .00873 | .004030 |
| 2. | .0031820 | .0057120 | .01191 | .009740 |
| 3. | .0050507 | .0079082 | .01696 | .017650 |
| 4. | .0086368 | .0106903 | .02560 | .028340 |
| 5. | .0193855 | .0141098 | .04498 | .042450 |
| 6. | .0136370 | .0181831 | .05862 | .060630 |
| 7. | .0234259 | .0228788 | .08205 | .083510 |
| 8. | .0139707 | .0281070 | .09602 | .111620 |
| 9. | .0811491 | .0337143 | .17717 | .145330 |
| 10. | .0908587 | .0394850 | .26802 | .184820 |
| 11. | .0290922 | .0451509 | .29712 | .229970 |
| 12. | .0327288 | .0504103 | .32984 | .280380 |
| 13. | .0259103 | .0549527 | .35576 | .335330 |
| 14. | .0412770 | .0584894 | .39703 | .393820 |
| 15. | .0884732 | .0607830 | .48551 | .454600 |
| 16. | .0532617 | .0616744 | .53877 | .516280 |
| 17. | .0354446 | .0611006 | .57421 | .577380 |
| 18. | .0391432 | .0591022 | .61335 | .636480 |
| 19. | .0441809 | .0558187 | .65754 | .692300 |
| 20. | .0357087 | .0514722 | .69324 | .743770 |
| 21. | .0650030 | .0463429 | .75825 | .790110 |
| 22. | .0631452 | .0407392 | .82139 | .830850 |
| 23. | .0535853 | .0349670 | .87498 | .865820 |
| 24. | .0339409 | .0293036 | .90892 | .895120 |
| 25. | .0210753 | .0239774 | .92999 | .919100 |
| 26. | .0118187 | .0191559 | .94181 | .938260 |
| 27. | .0200009 | .0149423 | .96181 | .953200 |
| 28. | .0154552 | .0113803 | .97727 | .964580 |
| 29. | .0113642 | .0084626 | .98863 | .973040 |
| 30. | .0068185 | .0061443 | .99545 | .979190 |
| 31. | .0045457 | .0043557 | 1.00000 | .983540 |

Table B6. Observed proportions of abundance with estimates of catch based on proportions of daily escapement and expected proportions of abundance based on migratory time density functions for the Nuyakuk River, 1979.

| DAY OF MIGRATION | NUYAKUK R. ABUNDANCE DAILY PROPORTION OBSERVED | NUYAKUK R. ABUNDANCE DAILY PROPORTION EXPECTED | NUYAKUK R. ABUNDANCE CUMULATIVE PROPORTION OBSERVED | NUYAKUK R. ABUNDANCE CUMULATIVE PROPORTION EXPECTED |
|---|---|---|---|---|
| 1. | 0.000000 | .001350 | 0.00000 | .001350 |
| 2. | 0.000000 | .003669 | 0.00000 | .005020 |
| 3. | .008893 | .008828 | .00889 | .013850 |
| 4. | .024010 | .018819 | .03290 | .032670 |
| 5. | .071614 | .035534 | .10452 | .068200 |
| 6. | .026011 | .059434 | .13053 | .127630 |
| 7. | .020622 | .088057 | .15115 | .215690 |
| 8. | .055799 | .115568 | .20695 | .331260 |
| 9. | .274112 | .134354 | .48106 | .465610 |
| 10. | .273112 | .138358 | .75417 | .603970 |
| 11. | .057023 | .126212 | .81120 | .730180 |
| 12. | .015006 | .101985 | .82620 | .832170 |
| 13. | .071029 | .072998 | .89723 | .905170 |
| 14. | .043446 | .046284 | .94068 | .951450 |
| 15. | .029702 | .025995 | .97038 | .977440 |
| 16. | .006635 | .012933 | .97702 | .990380 |
| 17. | .003900 | .005699 | .98092 | .996080 |
| 18. | .006892 | .002225 | .98781 | .998300 |
| 19. | .008455 | .000769 | .99626 | .999070 |
| 20. | .003742 | .000236 | 1.00000 | .999310 |
| 21. | 0.000000 | .000064 | 1.00000 | .999370 |
| 22. | 0.000000 | .000015 | 1.00000 | .999390 |
| 23. | 0.000000 | .000003 | 1.00000 | .999390 |
| 24. | 0.000000 | .000001 | 1.00000 | .999390 |
| 25. | 0.000000 | 0.000000 | 1.00000 | .999390 |
| 26. | 0.000000 | 0.000000 | 1.00000 | .999390 |
| 27. | 0.000000 | 0.000000 | 1.00000 | .999390 |
| 28. | 0.000000 | 0.000000 | 1.00000 | .999390 |
| 29. | 0.000000 | 0.000000 | 1.00000 | .999390 |
| 30. | 0.000000 | 0.000000 | 1.00000 | .999390 |
| 31. | 0.000000 | 0.000000 | 1.00000 | .999390 |

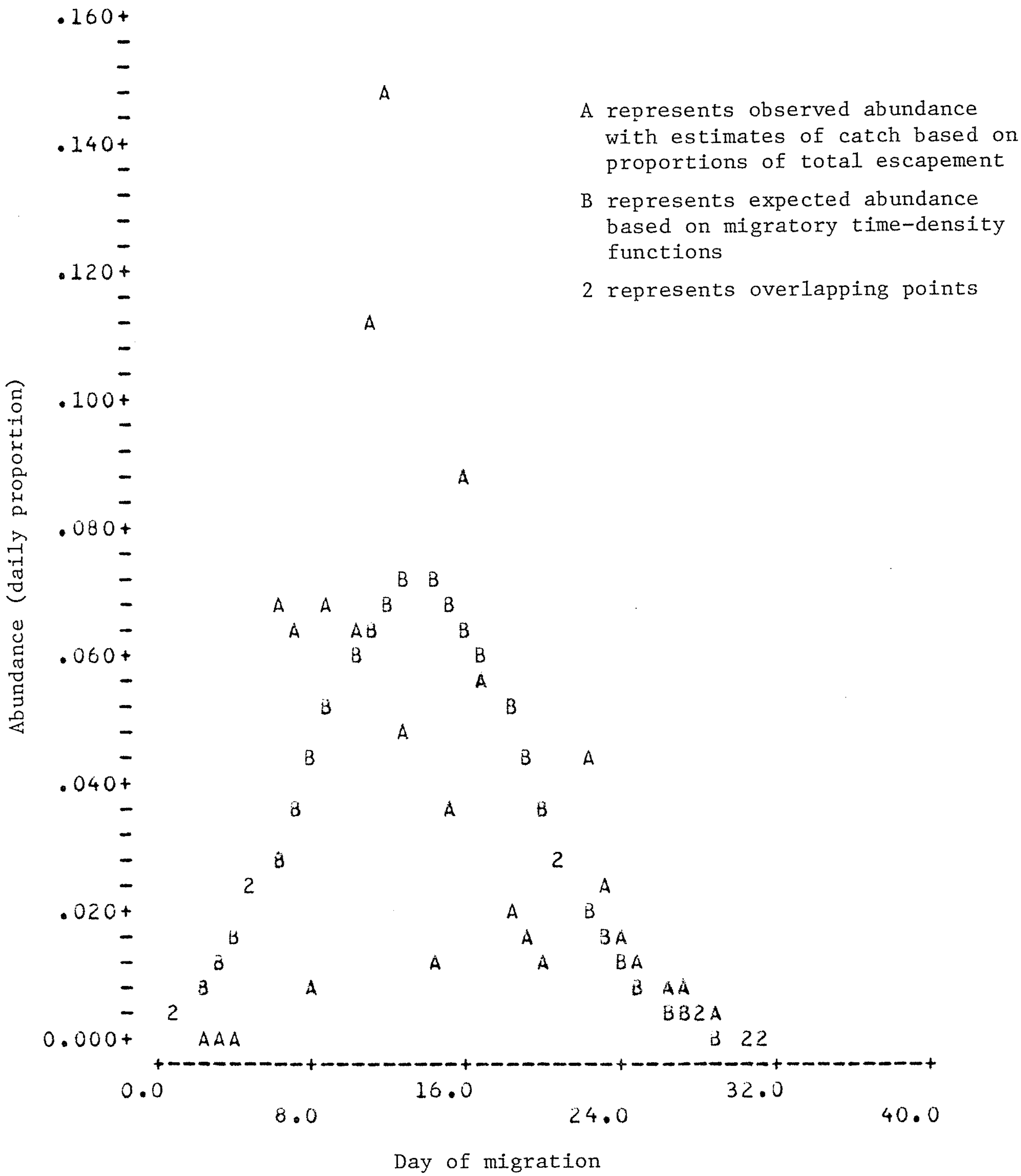


Figure B1. Observed daily abundance with estimates of catch based on proportions of total escapement and expected abundance based on migratory time-density functions for the Wood River, 1979.

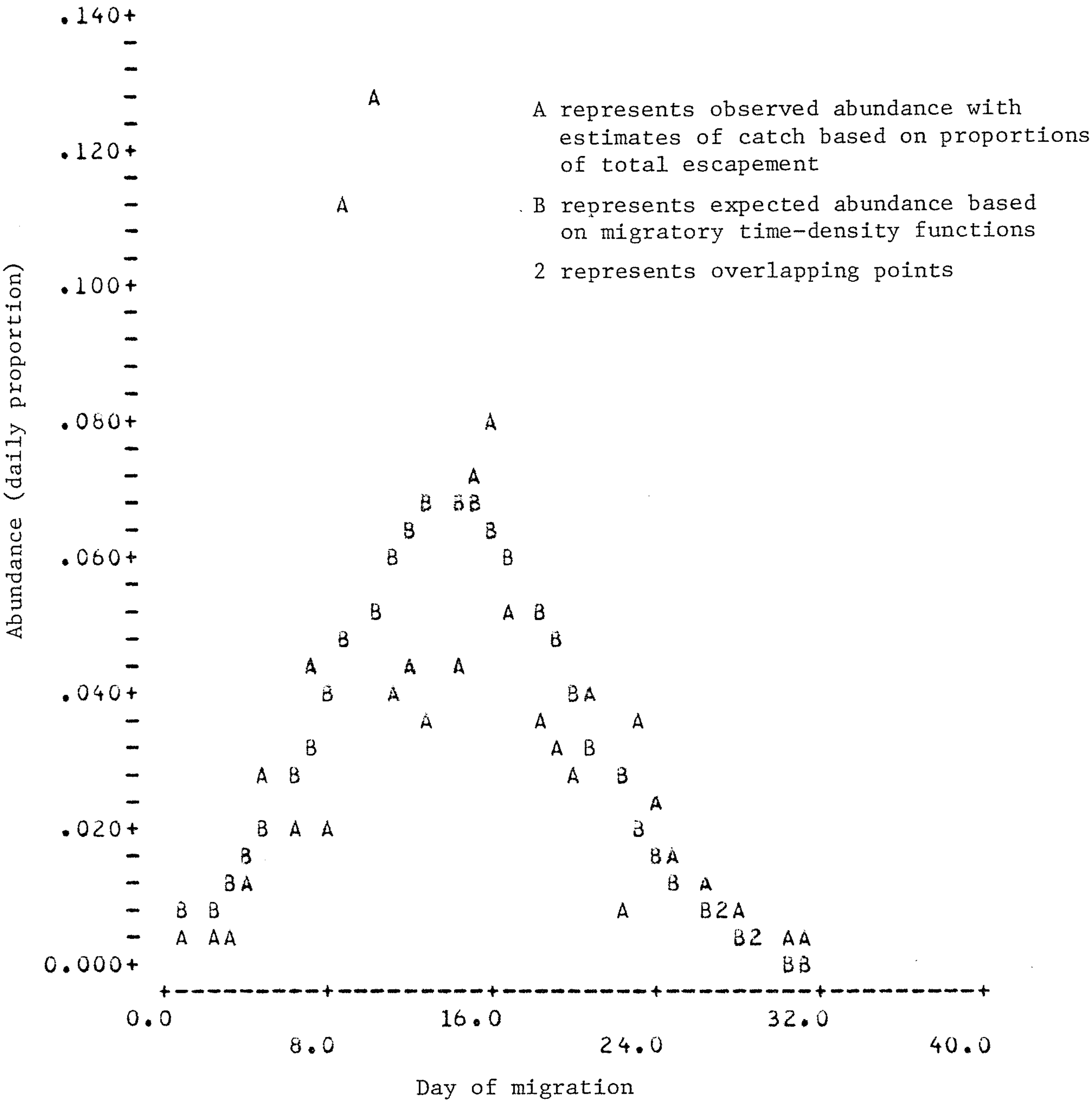


Figure B2. Observed daily abundance with estimates of catch based on proportions of total escapement and expected abundance based on migratory time-density functions for the Igushik River, 1979.

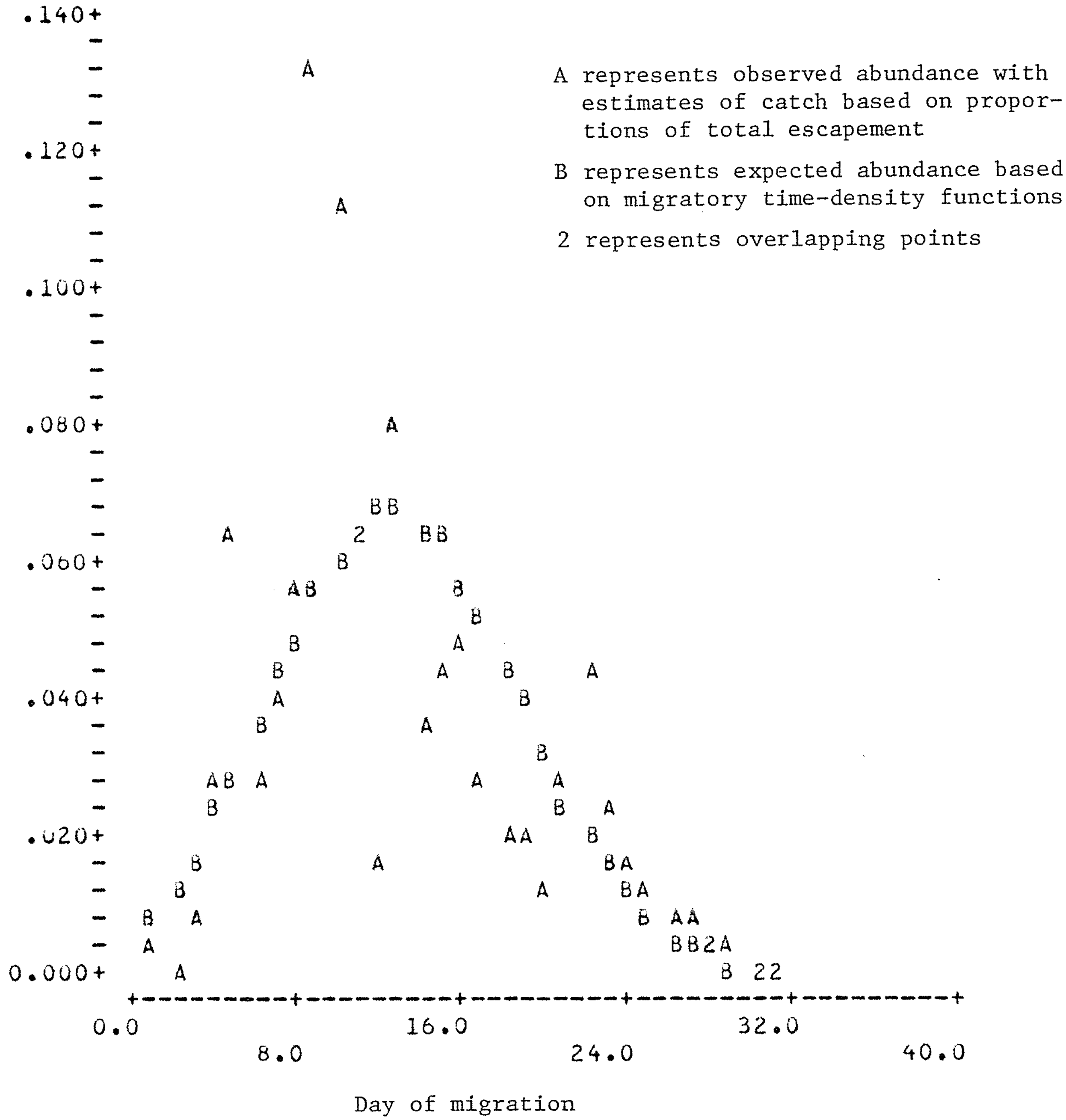


Figure B3. Observed daily abundance with estimates of catch based on proportions of total escapement and expected abundance based on migratory time-density functions for the Nuyakuk River, 1979.

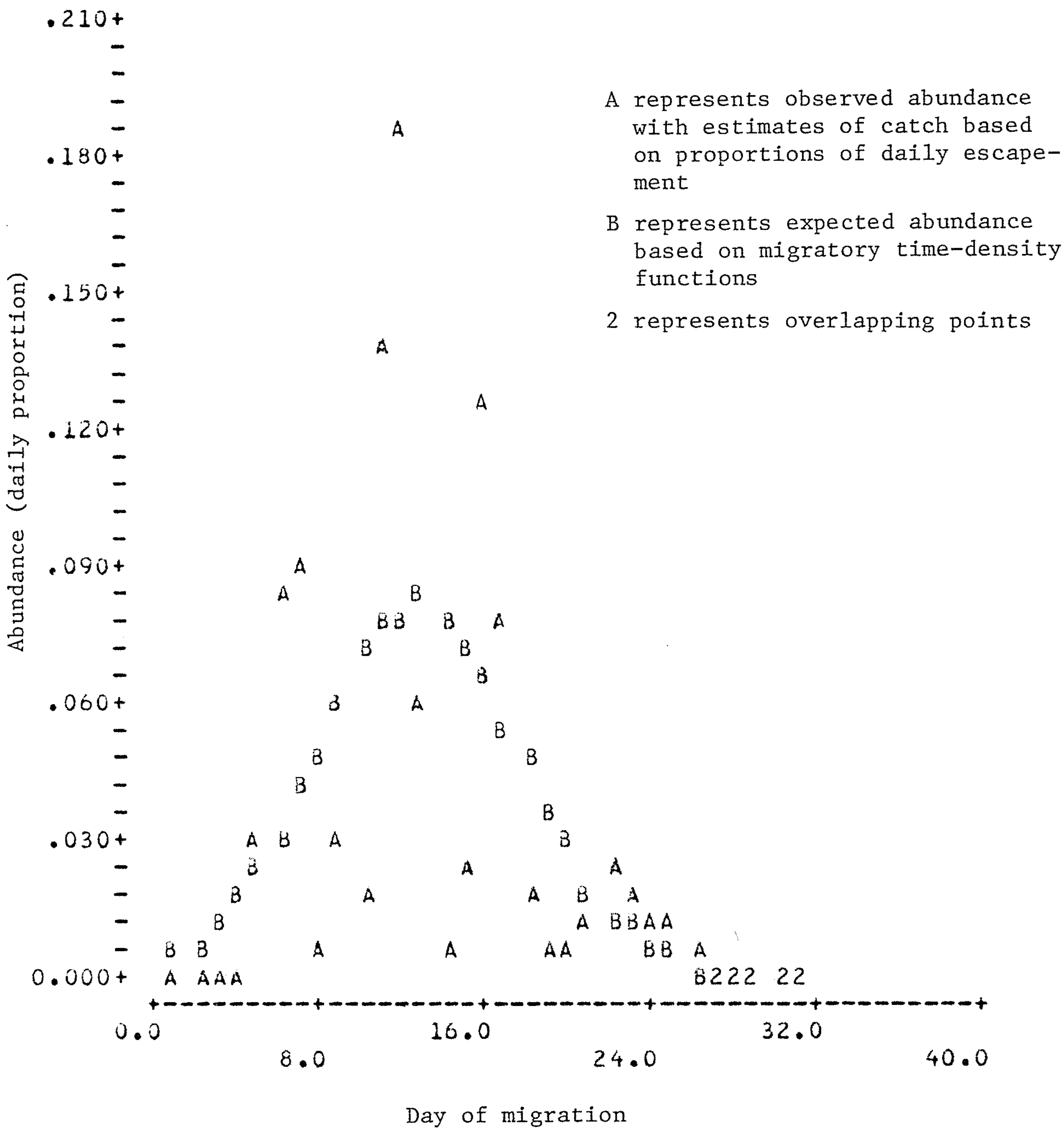


Figure B4. Observed daily abundance with estimates of catch based on proportions of daily escapement and expected abundance based on migratory time-density functions for the Wood River, 1979.

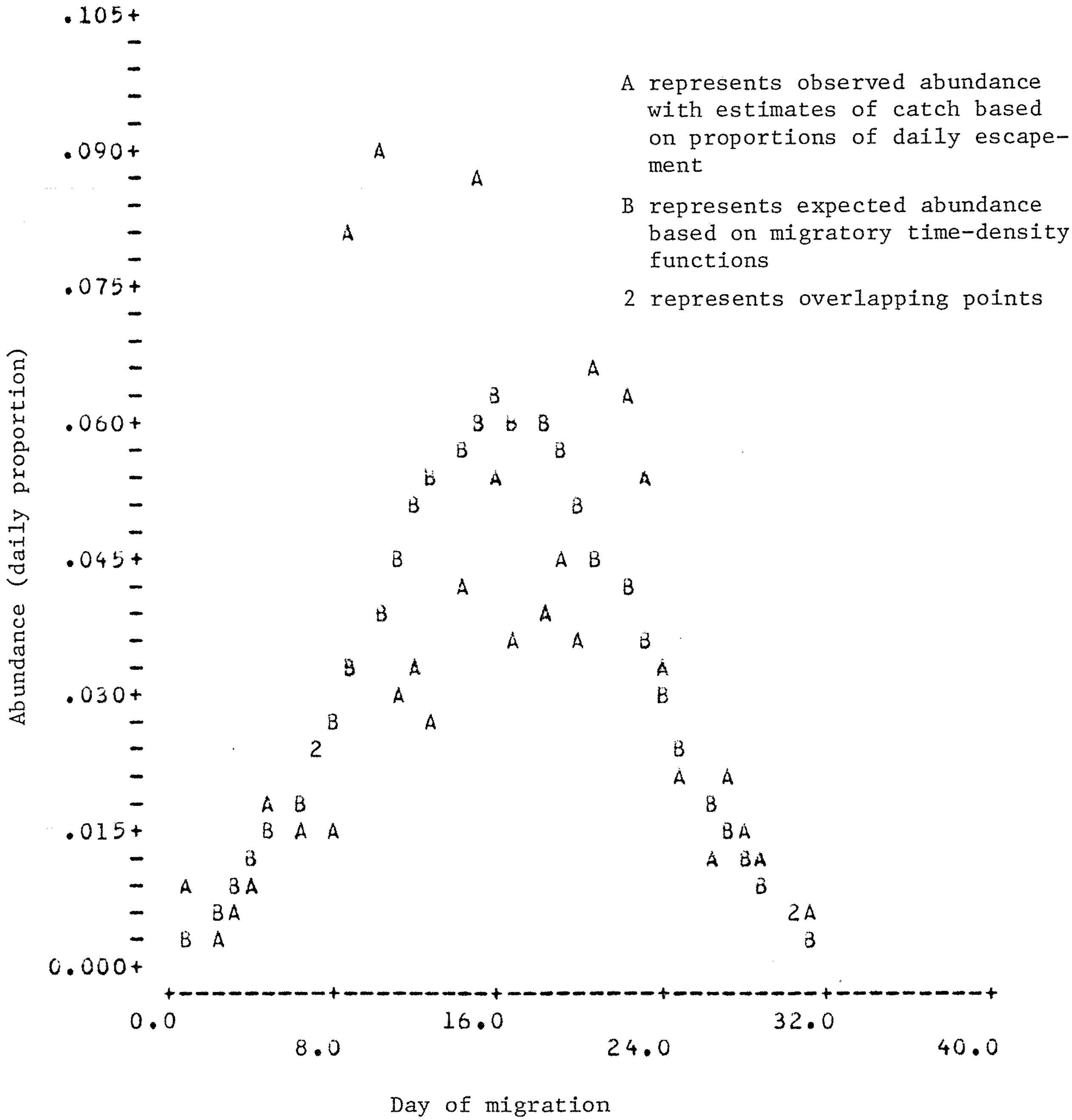


Figure B5. Observed daily abundance with estimates of catch based on proportions of daily escapement and expected abundance based on migratory time-density functions for the Igushik River, 1979.

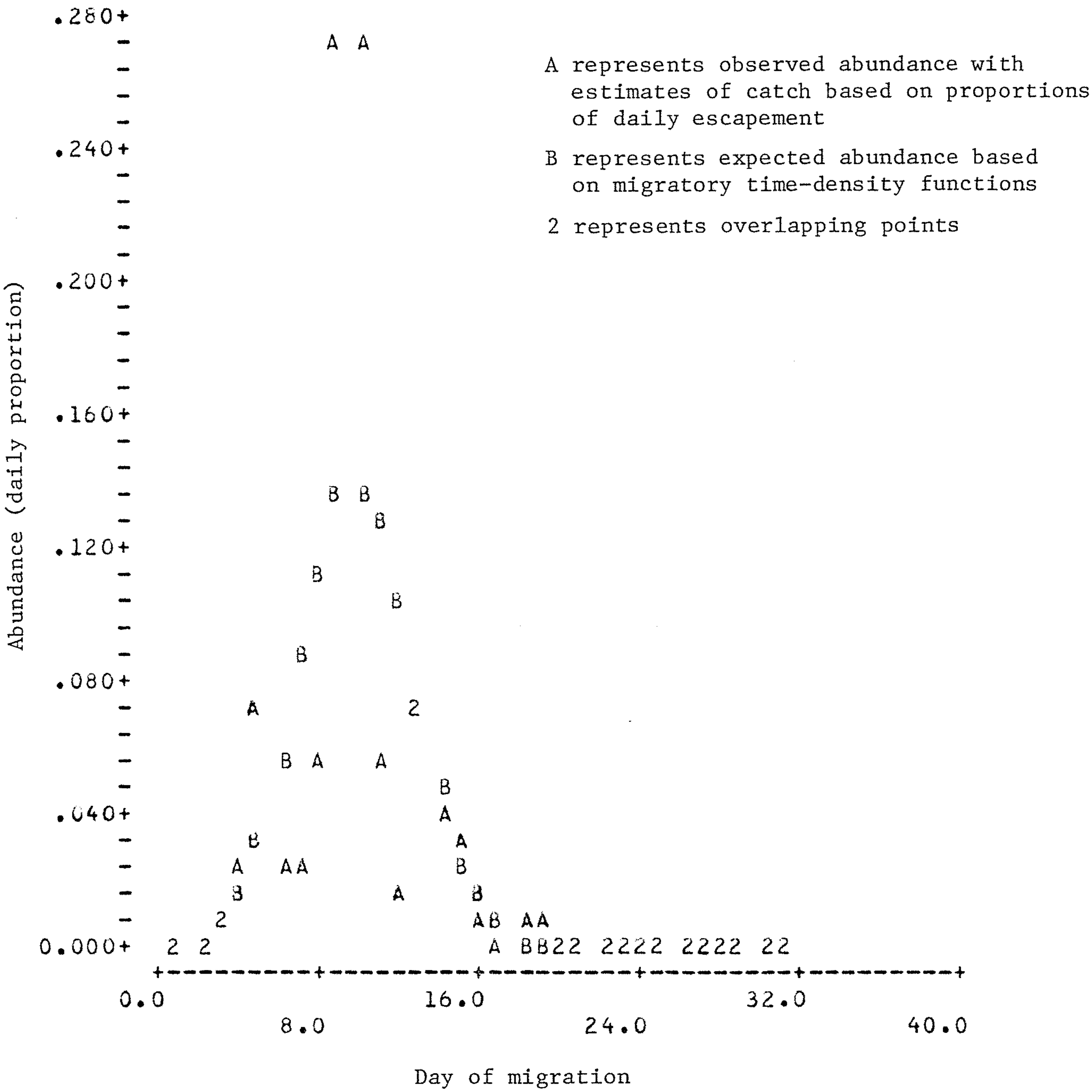


Figure B6. Observed daily abundance with estimates of catch based on proportions of daily escapement and expected abundance based on migratory time-density functions for the Nuyakuk River, 1979.

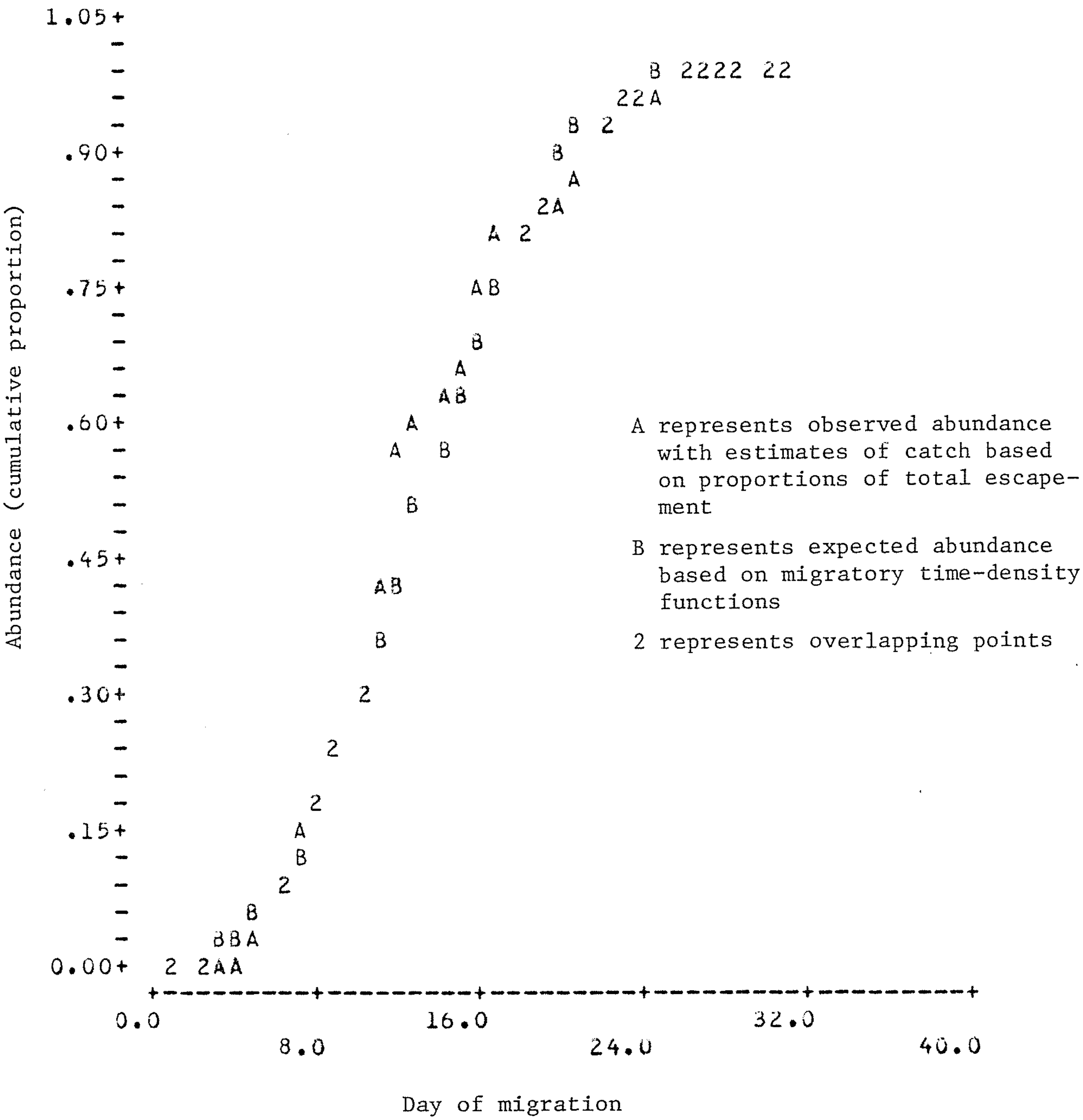


Figure B7. Observed cumulative abundance with estimates of catch based on proportions of total escapement and expected abundance based on migratory time-density functions for the Wood River, 1979.

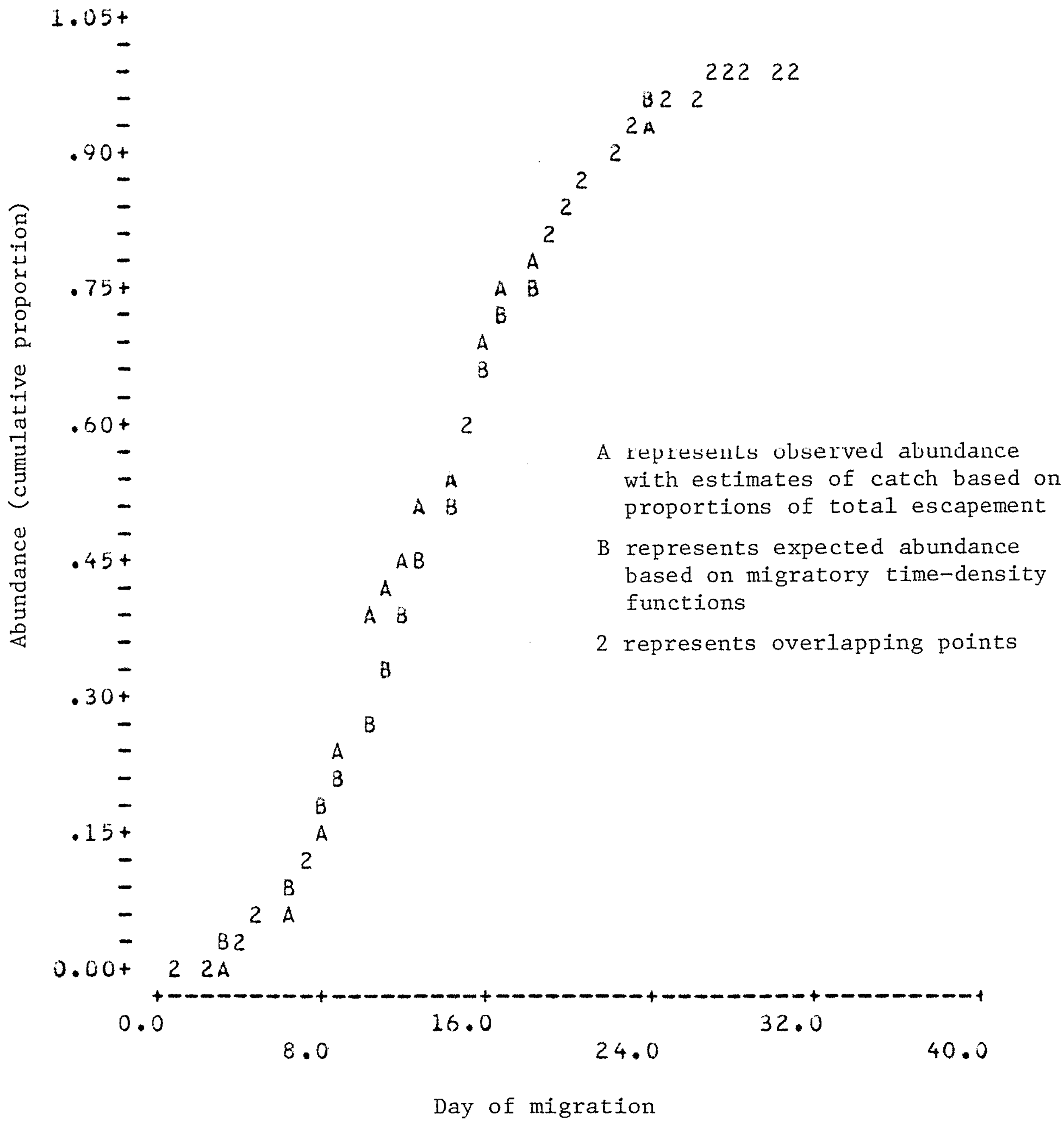


Figure B8. Observed cumulative abundance with estimates of catch based on proportions of total escapement and expected abundance based on migratory time-density functions for the Igushik River, 1979.

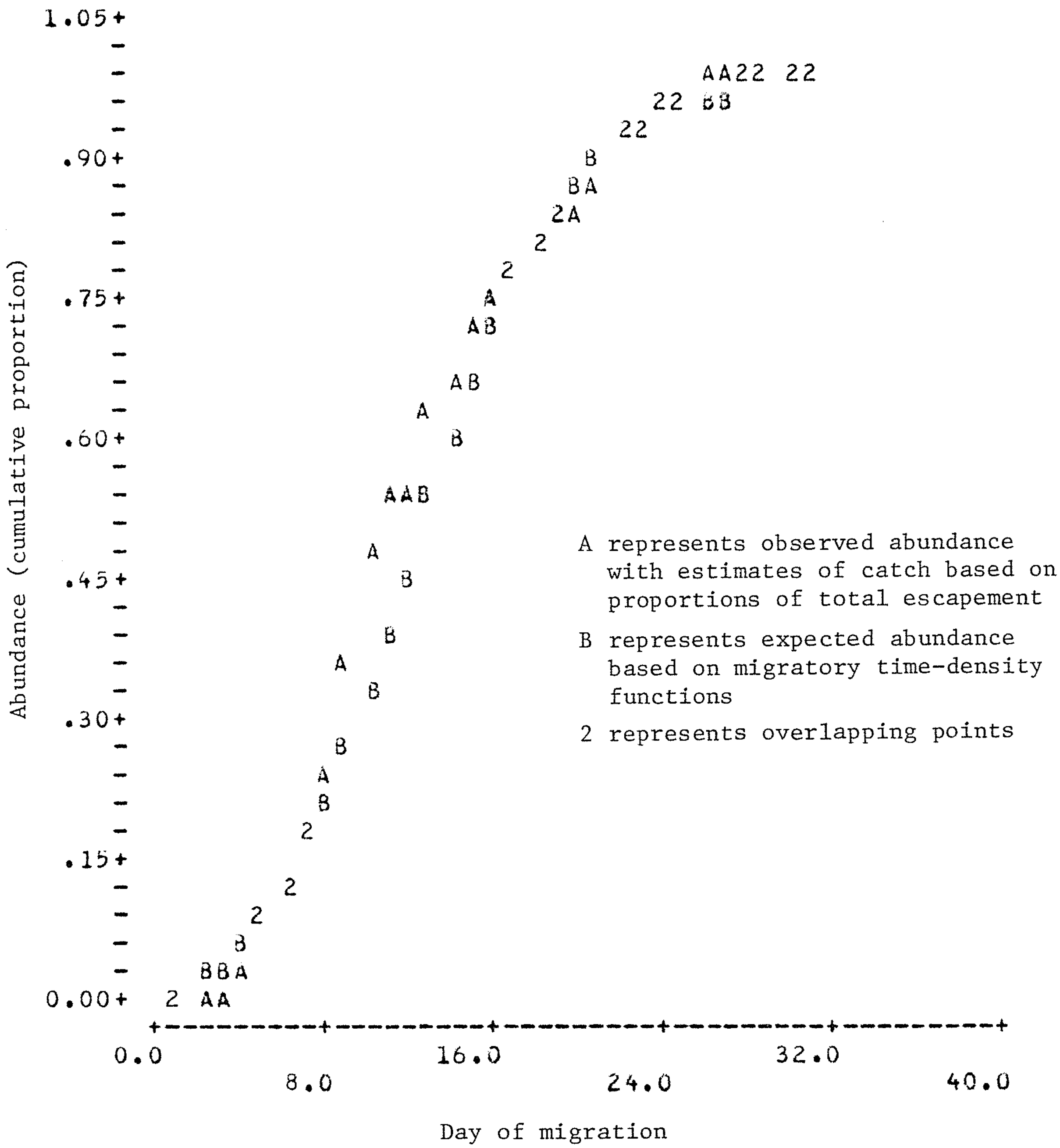


Table B9. Observed cumulative abundance with estimates of catch based on proportions of total escapement and expected abundance based on migratory time-density functions for the Nuyakuk River, 1979.

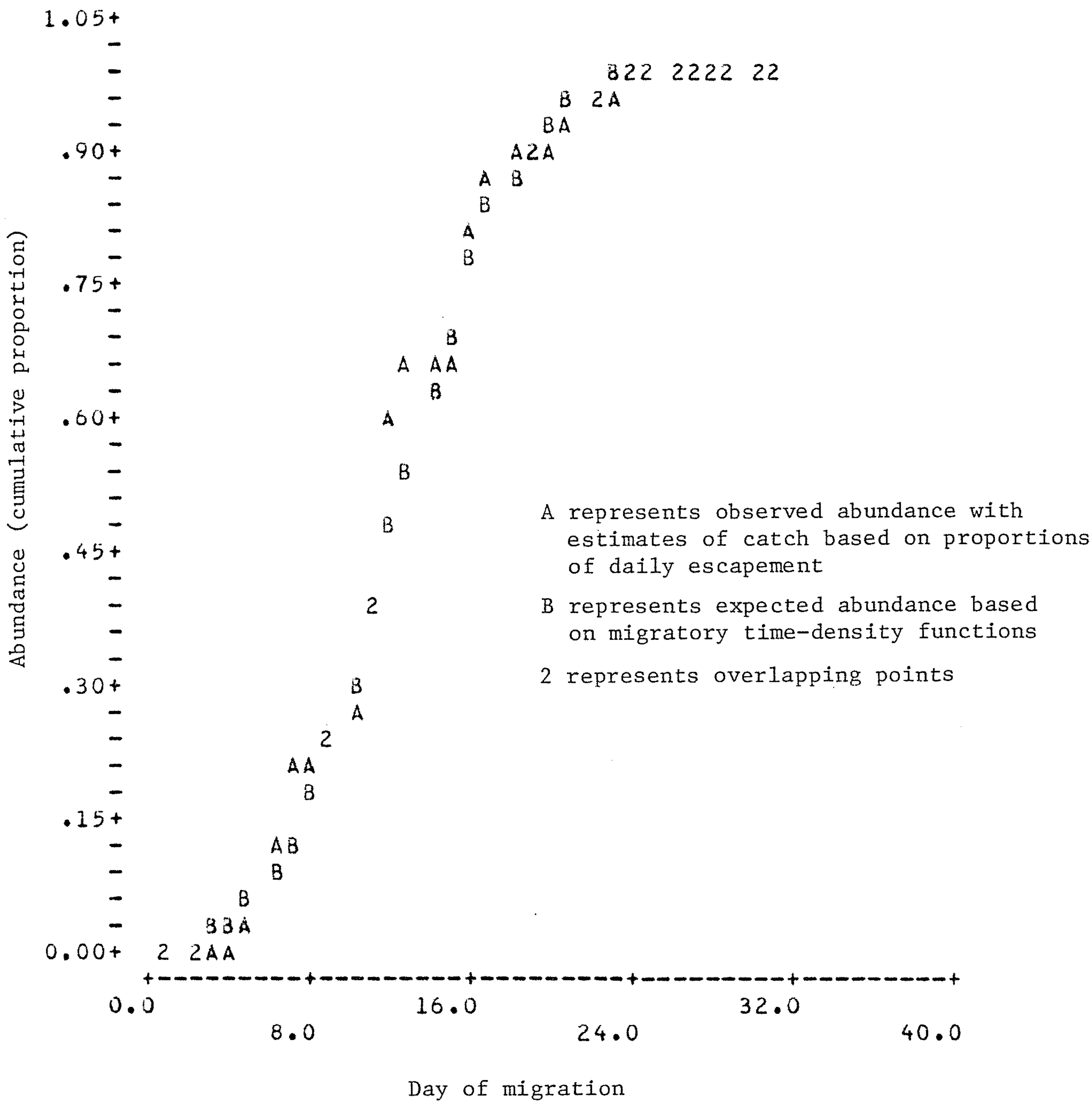


Figure B10. Observed cumulative abundance with estimates of catch based on proportions of daily escapement and expected abundance based on migratory time-density functions for the Wood River, 1979.

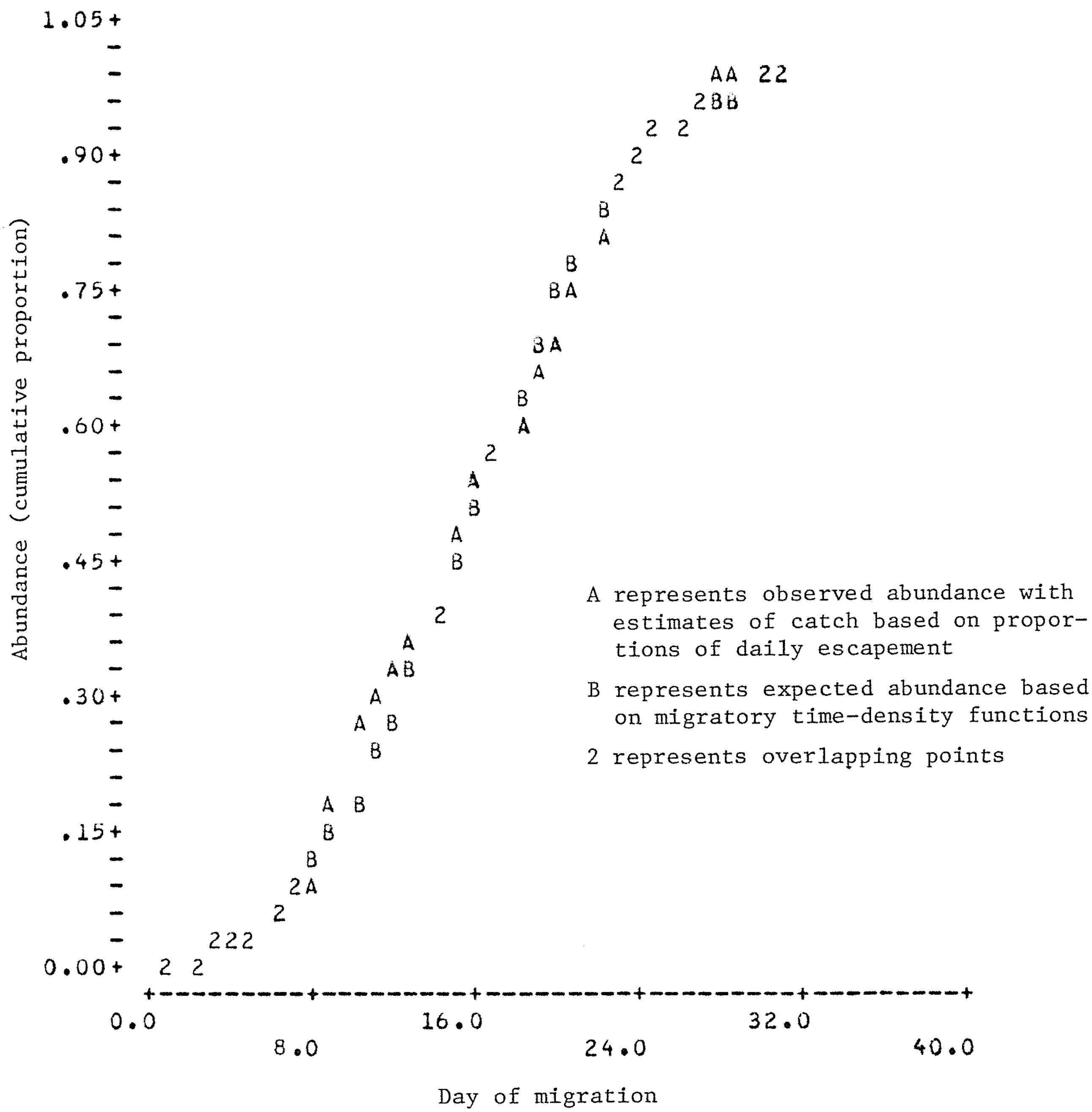


Figure B11. Observed daily abundance with estimates of catch based on proportions of daily escapement and expected abundance based on migratory time-density functions for the Igushik River, 1979.

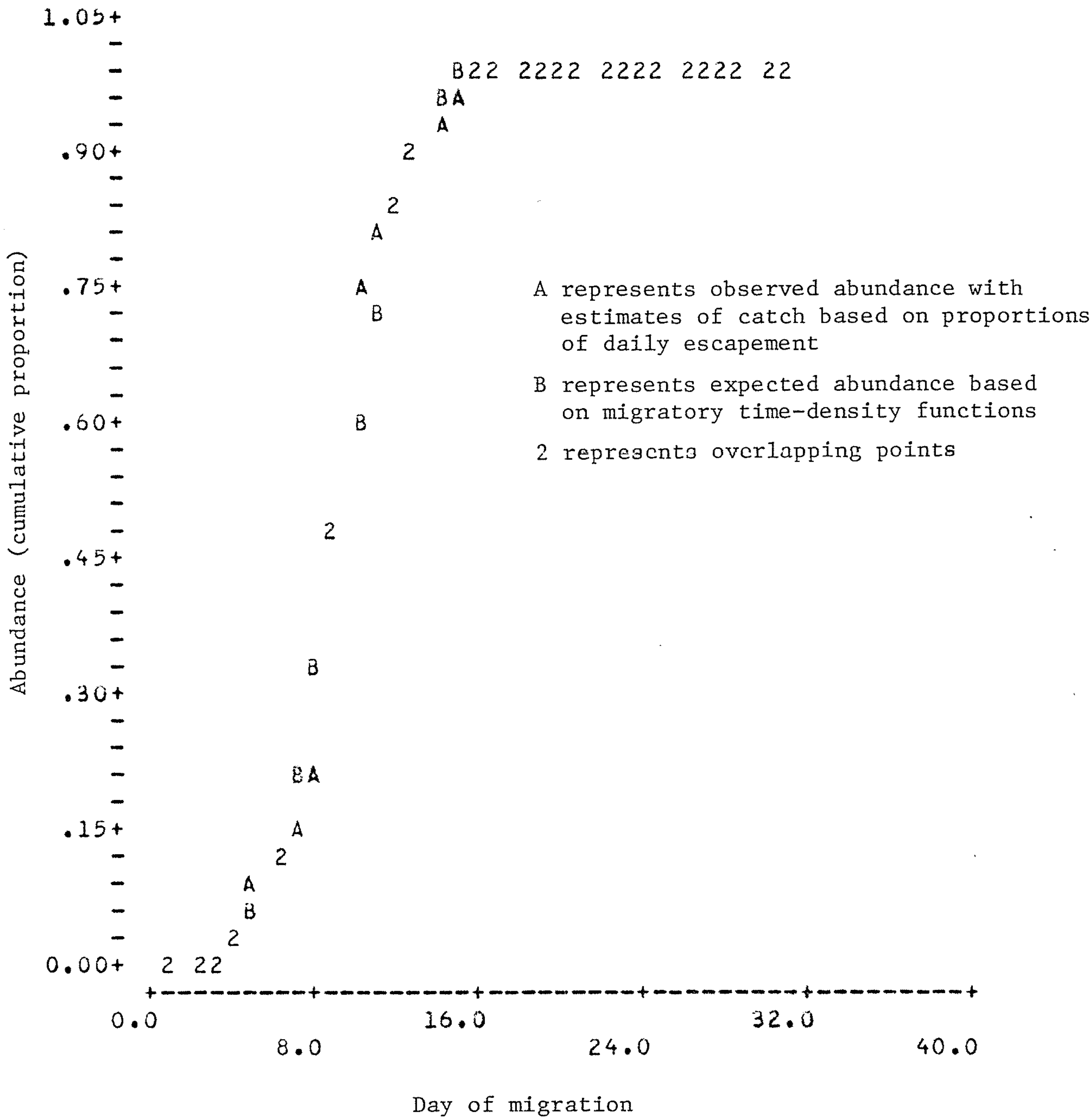


Figure B12. Observed daily abundance with estimates of catch based on proportions of daily escapement and expected abundance based on migratory time-density functions for the Nuyakuk River, 1979.