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STATE/FEDERAL NATURAL RESOURCE DAMAGE ASSESSMENT
DRAFT PRELIMINARY STATUS REPORT

Project Title:	INJURY TO PINK/CHUM SALMON SPAWNING AREAS OUTSIDE PRINCE WILLIAM SOUND
Study ID Number:	Fish/Shellfish Study Number 7a
Lead Agency:	State of Alaska, ADF&G; Commercial Fisheries Division
Cooperating Agency(ies):	Federal: NPS, USFS, USFWS State: DNR
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EXECUTIVE SUMMARY

Wild stocks of pink (Oncorhynchus gorbuscha) and chum (O. keta) salmon are important to the ecosystems and fisheries in lower Cook Inlet and on the Gulf of Alaska side of the Kenai Peninsula. Both species spawn in the intertidal zone making them vulnerable to the detrimental effects of an oil spill. To show injury from exposure to oil, the presence of oil coupled with a reduction in survival in some life history stage of the salmon must be shown. The focus of this study was therefore on 1) the presence of hydrocarbons in an indicator species, specifically blue mussels (*Mytilus sp.*), collected at the mouth of salmon spawning streams, 2) lesions and tumors in salmon induced by oil contamination, 3) a reduction in numbers of spawning salmon, and 4) a change in the proportion of salmon spawning in the intertidal zone.

Ground surveys for numbers and distribution of spawning pink and chum salmon in oiled and control streams were made during the summers of 1989 and 1990. Twelve streams were surveyed on the Cook Inlet and Gulf of Alaska side of the Kenai Peninsula (i.e., ADF&G Lower Cook Inlet Management Area). All of the oiled study streams were on the Gulf of Alaska side.

No dramatic difference in numbers of pink salmon spawners or their distribution within the stream (intertidal vs. upstream) occurred for the 1989 and 1990 returns (Yuen and Swanton 1990, Tables 1 and 2). Stream life estimate for Humpy Creek based on weir counts was 21 days. Fish in both streams that were tagged early in the season also exhibited a 21 day stream life. Neither agreed with the historical 17.5 day estimate used in this study. While shorter stream life is associated with tags applied later in the season, that may have been a function of unintentionally tagging fish already in stream residence for some time.

The hydrocarbon and histopathological analysis are still in progress. Methods and strategies for restoration are not yet identified.

OBJECTIVES

The objectives of this project were to:

1. determine the presence or absence of crude oil contamination on intertidal habitat used by spawning pink and chum salmon within Lower Cook inlet-Gulf of Alaska area streams through:

    a. visual observation,
    b. hydrocarbon analysis of tissue samples from an indicator species, specifically blue mussels (Mytilus sp.), collected in the immediate area of each sampled stream, and
    c. histopathological examination of olfactory, kidney, spleen, and liver tissues from pink salmon that migrated to sea during the oil spill.

2. estimate the number of pink and chum salmon spawning in standardized intertidal and upstream zones of test (oiled) and control (unoiled) streams;

3. determine whether crude oil contamination affected spawning distribution of either pink or chum salmon;

4. produce a catalog of aerial photographs and detailed maps of pink and chum salmon spawner distribution within all surveyed streams. This will be used in designing Natural Resource Damage Assessment (NRDA) Plan Study 8a, concerning egg and preemergent fry survival (hereafter called NRDA Study 8a);

5. identify potential methods and strategies for restoration of lost use, spawning populations, or habitat adversely affected by crude oil contamination.

Objectives 1a, 1b, 2, 4, and 5 correspond to objectives 3, 1, 2, and 4, respectively, listed in the Detailed Study Plan (Anonymous 1989). Objectives 1c and 3 were added after publication of the Detailed Study Plan.

INTRODUCTION

Wild stocks of pink and chum salmon provide major fisheries in Lower Cook Inlet and on the Gulf of Alaska side of the Kenai Peninsula. In 1988, the year before the oil spill, the exvessel value of the commercial catch of wild and hatchery salmon stocks from these areas was more than $8.2 million. These salmon stocks are also very important to the sport, subsistence, and personal use fisheries. The study area in this report stretches from Kachemak Bay in Lower Cook Inlet to Resurrection Bay on the Gulf of Alaska.

STUDY METHODOLOGY

Study Sites

Twelve streams in the Lower Cook Inlet-Gulf of Alaska area were examined during this study. Streams were selected using the following criteria:

1. Crude oil contamination.
2. Historical use of the intertidal area by spawning salmon.
3. Availability of historical ground and aerial survey data for pink and chum salmon spawning.
4. Availability of historical alevin density indices.
5. Freedom from confounding effects of logging (Rocky River) and development.

6. Accessibility and personnel safety since these streams were to be visited during winter and spring to sample egg and preemergent fry (NRDA Study 8a).

The nine streams studied during 1989 were Windy Creek Left, Windy Creek Right, Port Dick Creek and Island Creek on the Gulf of Alaska and Humpy Creek, China Poot Creek, Seldovia River, Tutka Lagoon Creek, and Port Graham Creek in lower Cook Inlet (Figure 1). The 1989 Detailed Study Plan proposed surveys for only eight streams. By stretching available labor and time, a ninth stream was added to the study. Although it was more desirable to add an oiled stream to the study, logistical constraints made it difficult.

In 1990 some changes were made in the streams selected. China Poot Creek was dropped from the survey due to its very small intertidal Tutka and Seldovia Creeks were also dropped because their intertidal areas faced north, resulting in late thaws which caused problems during the spring of 1990. To increase the number of study streams on the Gulf of Alaska, three new streams were added; Tonsina (in Resurrection Bay), South Nuka and James Lagoon Creeks (Figure 1). All three of the new streams had been sampled for fry density during past years.

The Spill Response Staff, Alaska Department of Environmental Conservation (ADEC 1990) ranked five of these streams by degree of oiling. Windy Creek Right was lightly oiled, Port Dick, Island, and South Nuka Creeks very lightly oiled, and Windy Creek Left as unoiled (ADEC 1990). ADEC did not classify the remaining streams by degree of oiling and are considered unoiled for purposes of this study (Table 3).

All of the oiled streams are on the Gulf of Alaska side of the Kenai Peninsula and most of the unoiled streams on the Cook Inlet side. Therefore, effects of geographic location on spawner distribution must be considered when comparing oiled and unoiled streams.

Tide Zones

Tidal areas are divided into four survey zones: (1) 1.8 m-1.2 m below mean high tide, (2) 1.2 m-0.6 m below mean high tide, (3) 0.6 m-0.0 m below mean high tide, (4) 0.0 m-extent of upstream spawning (delineated by a natural barrier to salmon passage, the start of the stream, or the absence of spawning salmon). Fluorescent orange 0.3 m^2 plywood rectangles attached to trees growing along the stream bed, identified the zone boundaries. Each marker was placed in relation to mean high tide level, since a large difference in mean tide height exists between the Gulf of Alaska (4 m) and lower Cook Inlet (6 m) (Figure 2). Markers were placed during August 1989 and replaced in June 1990. Tide level was determined by walking along the stream bed ahead of the incoming tide with a hand held tide level computer (TF-20 Tidefinder from Corex Electro-systems, Inc.) and placing markers at the appropriate levels. Marker number 1 was placed furthest downstream (1.8 m below mean high tide) Stream length was measured between markers. Stream widths were measured at 25 m intervals between markers. A level and stadia rod was used to place some of the number 3 markers after positioning the number 1 and 2 markers with the tide computer.

Schematic diagrams of the intertidal zones were drawn for each stream. Information was obtained from oblique aerial photographs of study streams made from fixed wing aircraft, a vertical aerial photograph of Windy Left Stream purchased from Aeromap US (2014 Merrill Field Drive, Anchorage, AK), and from notes collected when the markers were installed. The location of zone boundary markers, length of each stream survey zone, width of each zone at the upper and lower boundaries, and prominent landmarks were included in the diagrams. Since areas used by spawning salmon were generally uniformly populated, only areas within each stream not used by spawning salmon were shown. This information was used to design and conduct NRDA Fish/Shellfish Study Number 8 concerning egg and preemergent fry survival.

Spawning Distribution

The percent of the total pink or chum salmon spawning population that occurred below mean high tide was

$$P = \frac{\sum_{z=1}^{3} \hat{E}_z}{\hat{E}},$$

where

$\hat{E}_z$ = total number of pink or chum salmon that entered the study stream to spawn in zone z during the season.

Spawning distribution data from previous years will be compared with those collected during 1989 and 1990 to determine if a change occurred.

Spawner Abundance

To estimate the number of pink and chum salmon spawning within a study stream, two crews of two people each surveyed each study stream at least once every seven days. During each stream survey, field crews counted the number of live and dead pink and chum salmon within each of the four zones. All surveys began at low tide. Counting always began at marker 1 and progressed upstream. This facilitated counting, since spawning salmon are disturbed less by a person walking upstream than by a person walking downstream. Counts of both live and dead pink and chum salmon were completed for each survey zone before continuing on to the next zone. Hand held tally counters were used to record counts. Crew members periodically rotated between crews to minimize counting biases.

During 1989, surveys were made between 10 July and 7 September. Both crew members surveyed each of the three zones located below mean high tide as well as all single channel stream areas in the zone above mean high tide. Upon completing a zone or channel survey, both crew members compared their counts. Surveys of zones or channels were repeated until differences were 10% or less. The average of each crew member's final zone or channel count was used as the best estimate of live and dead pink and chum salmon. In areas where the stream branched, the crew split up and surveyed separate areas. When counting large numbers of more than one species, one crew member sometimes counted only live salmon while the other counted only the carcasses.

During 1990, surveys were made between 10 July and 2 October. Two streams, Humpy and Port Dick Creek were surveyed daily. The rest of the streams were surveyed once a week, as in 1989. Crew members counted independently in 1990. They walked on opposite banks of intertidal and single channel stream areas where possible. Before each survey both crew members had the option of a 'practice count' for a measured distance. If their counts differed by more than 10%, they retraced their steps and searched for the cause of the difference (fish in a deep pool on one bank not clearly visible to the other, sun glare, deep shadow, overhanging vegetation, etc.). They recounted as many times as necessary until satisfied that they could compensate for visibility problems peculiar to their vantage points. Similarly, when crews approached an area with difficult visibility, either crew member could request as many as 3 recounts of the problem area until that observer was satisfied that visibility problems had been overcome or accounted for to the extent possible. Each observer counted and recorded independently unless either felt that their count was invalid due to visibility problems. The separate counts were used to estimate counting variance while the average was used to estimate escapement.

During each stream survey observers recorded the following data was recorded on standard forms:

1. stream name;
2. date and time;
3. counts of live and dead salmon by observer, species and location in the stream [(1) 1.8-1.2 m below mean high tide, (2) 1.2-0.6 m below mean high tide, and (3) 0.6 m below mean high tide-mean high tide (0.0), (4) the upstream egg-fry dig area (above tidal inundation), and (5) the upstream area above the egg-fry dig area];
4. comments or a rank on the quality of the survey: visibility, completeness of survey, etc.
5. observer's name(s).

Total spawning populations of pink and chum salmon within each study stream were estimated using a geometric approach similar to that described by Johnson and Barrett (1988). A 17.5 day stream life was used to allow comparisons with the data base published in the annual management reports. The total number of live pink and chum salmon in the stream between adjacent survey dates was estimated using the following formula:

$$\hat{c}_i = \frac{(d_i - d_{i-1})\,x_i - \dfrac{(d_i - d_{i-1})\,(x_i - x_{i-1})}{2}}{17.5},$$

where
- $\hat{c}_i$ = estimated number of pink or chum salmon that entered the study stream between survey i-1 and survey i;
- d_i = Julian calendar day of survey i ($1 < d < 365$);
- x_i = number of live pink or chum salmon observed in the study stream during survey i;
- s = stream life (in days) for pink or chum salmon (defined in the next section).

Total spawning population estimates of pink and chum salmon for the study stream were then calculated as:

$$\hat{E} = \hat{C}_a + \sum_{i=1}^{n} \hat{C}_i,$$

where

$\hat{E}$ = total estimated number of pink or chum salmon which entered the study stream to spawn during the season;

n = number of surveys made of the study stream during the season.

$\hat{C}_a$ = estimated number of pink or chum salmon that entered the study stream between the last (n^{th}) survey and 15 September 1989:

$$\hat{C}_a = \frac{\frac{(258-d_n)x_n}{2}}{17.5},$$

During 1989, no pink or chum salmon were assumed to enter the study stream on or after 15 September (Julian day 258). During 1990, surveys were continued until the number of salmon remaining in the stream was less than or equal to 1% of the peak count. The number of live pink and chum salmon within the study stream was considered to be zero on or prior to 10 July (Julian day 191) for both study years.

Stream Life

Stream life, the number of days that a salmon was alive in the spawning stream, was estimated from analysis of spawner and carcass counts, tagging data, and weir counts. In Lower Cook Inlet, stream life is estimated to be 17.5 days (Davis and Valentine 1970) but not verified. The original source of the 17.5 day estimate is unknown.

Pink salmon in Humpy Creek, which flows into Kachemak Bay, and Port Dick Creek on the Gulf of Alaska, (Figure 1) were tagged during 1990. Daily foot surveys were conducted on both streams. The observers counted the number of live spawners, carcasses, and tagged fish. Location, sex, tag type and numbers of live and dead tagged salmon were recorded. Some tags were recovered that separated from the salmon or carcass. In many cases, a carcass with its tag attached, washed out of the stream into the ocean and was not recovered.

Weir

A weir was operated on Humpy Creek to provide an estimate of total escapement. Carcasses that washed up against the weir were counted and placed on the other side of the weir.

Tagging

A beach seine was used to collect salmon arriving within the lower intertidal area of each stream. Only fish not excessively "water-marked" and free of external injuries received tags. Four tagging events were spread over a two month period in each stream. All salmon were tagged with a unique number or color-bar combination code. Different tag colors for each sex and distinctive tag types for each tagging event were used. Between 25 and 50 fish of each sex from a single tide were tagged during each tagging event.

Tag types were selected to provide individual fish with a 3 digit number or a 3 position color-bar combination code. Readability in moving and cloudy water was a major concern. Five tag types bearing either a 3-digit number or a 3-position color code were used to identify individual fish (Table 4 and Figure 3).

1) Numbered disk tag on back. A Peterson disk tag, 2.5 cm diameter with 1 cm high numbers attached immediately below the dorsal fin.

2) Numbered surveyor's tape on tail. Made from strips of 2.5 x 15 cm flagging tape tied around a cinch or cable tie. The tag was attached to the fish by fastening the cinch tie around the fish's tail. Excess cable tie was cut off before release of the fish. Tape extended behind the tail so its numbers could be read from either side of the fish. The 2.0 cm high numbers were marked on the tape with a black waterproof felt tip marker.

3) Numbered adhesive tape on tail. Same as 2) except 16.0 cm strips of 2.5 cm plastic waterproof adhesive tape (sold by 3M as suitable for repairing plastic swimming pools) were folded over a cinch or cable tie, (adhesive side on the inside). This formed an 8.0 cm tag. The tag was attached to the fish in the same manner as in 2) such that the tag extended behind the tail so the numbers could be read from either side of the fish. The 2.0 cm high numbers were marked on the tape with a black waterproof felt tip marker.

4a) Color-bar coded tag on tail. Same as 3) except that the completed tag was 6.3 cm long with combinations of 1.9 cm wide bars of a middle value color (i.e. red) and 0.8 cm wide bars of a dark value color (i.e. blue) instead of numbers. Again, the tag extended behind the tail so the color-bar code could be read from either side of the fish. This version was reinforced with a toothpick.

4b) Same as 4a) but without the toothpick reinforcement.

5) Color-bar coded tag on back. Same as 4a) but folded over a Floy spaghetti anchor tag instead of a cinch tie and attached below the dorsal fin.

Tag types 1, 4b and 5 were used at both Humpy Creek and Port Dick. Other tag types were not successful. The numbered surveyor's tape (type 2) originally used at Port Dick was fragile, ripping easily during and after application. This tag was redesigned with waterproof adhesive tape to create tag type 3. The toothpick-reinforced color-bar coded tag (type 4a) used at Humpy Creek was too rigid, breaking apart within a few days. That tag was redesigned as tag type 4b before being used at Port Dick.

Observed tags were recorded on a daily basis by tag number or by code. Tagged fish were considered to be alive on the dates (1) between live sightings and (2) between the date of tag release and the first live sighting. Thus, the daily count of live tags included both observed and unobserved tags. Daily counts of unreadable live tags were also recorded. If the daily unreadable tag count exceeded the unobserved tag count, then the daily tag count was the observed count plus the greater of either the unreadable or unobserved count.

Unreadable tags were considered unobserved tags. However, the number of unreadable tags frequently exceeded those of unobserved tags, especially in Port Dick. This suggests that some tags numbers were not read at least once, e.g., Appendix Table A7 and A8. Thus, the daily count curve includes interpolations between peaks whenever the unreadable count is used instead of the unobserved count. This has the effect of slowing down the decay rate of the live counts.

Sightings of tagged carcasses were recorded on a daily basis by tag number or code. The daily tagged carcass count included only the initial carcass sighting.

The status of a tagged fish is considered unknown on the dates between the last live and the first carcass sighting. They are not included in either the daily tag or the daily tagged carcass count.

Tags having neither live nor carcass sightings are considered lost or strayed and not included in the analysis.

Stream Life Equations

Seven methods of estimating stream life are used in this study. Method 1 uses the median number of days between the date of tag release and the date of initial tagged carcass sighting. Only tags where one day or less elapse between the last live sighting and the first carcass sighting are considered.

$$S = \begin{cases} t_{\frac{n+1}{2}}, & n \text{ odd} \\ \dfrac{t_{\frac{n}{2}} + t_{\frac{n}{2}+1}}{2}, & n \text{ even} \end{cases}$$

where: S = stream life,
t = number of days from date of tag release to date of first carcass sighting, sorted into ascending order. This data set includes only observations where no more than one day elapsed between the date of last live sighting and the date of first carcass sighting.
n = number to tagged fish meeting above criteria.

Method 2 is similar to method 1 but used all initial carcass sightings, ignoring date of last live sighting.

Method 3 is the half life of all observed tags. This method differs from methods 1 and 2 in that it can be estimated in the absence of (1) carcass sightings or (2) individual tag numbers.

$$S = t_{\frac{T}{2}},$$

where T = total number of tags sighted after release, and
$t_{T/2}$ = number of days from date of release to the date when the number of tagged fish still alive was equal to T/2.

Method 4 is an average statistic based on the total number of tagged fish in the stream and the cumulative number of tag-days. This can be calculated in the absence of (1) individual tag numbers or (2) carcasses.

$$S = \frac{C}{T},$$

where T = total number of tags sighted after release including unobserved tags (i.e. presumed to be alive between live sighting when marked fish were not observed on consecutive dates), and
C = cumulated tag sighting including unobserved tags. With daily data, C = tag-days.

Method 5 is the number of days between modes in the 3-day moving average of daily live and carcass counts, independent of tagging data.

$$S = d_c - d_l,$$

where d_l = date of live count mode (3-day moving average) and
d_c = date of carcass count mode (3-day moving average).

By way of comparison, method 6 is the historical stream life estimate, where

$$S = 17.5 \text{ days}.$$

Method 7 is the seasonal average stream life estimate derived from the daily weir and foot survey counts, i.e.

$$S = \frac{\sum f}{\sum w},$$

where f = accumulated daily foot survey counts, including interpolation for missed counts, expressed as fish days, and
w = total number of fish counted through the weir.

Hydrocarbon Analysis

Mussels were collected near the mouth of each stream to be analyzed for hydrocarbon content for corroborating visual observations by field crews concerning the level of crude oil contamination sustained by each stream. Unfortunately, mussels collected at the start of the study, in July 1989, could not be used for hydrocarbon analyses because a commercial shipper failed to keep them frozen. Therefore, a second sample of mussels was obtained in November 1989.

A field blank (sample container opened at the collection site, closed and stored as if it contained a sample) and two replicate mussel samples were collected at each study site. Each sample consisted of enough mussels to provide 10 grams of tissue for analysis. Collectors gathered specimens with washed bare hands to avoid adding additional hydrocarbons (i.e., hydrocarbons not originating from the Exxon Valdez spill) to samples. Also, only mussels above water were collected to avoid contamination of tissues with hydrocarbons floating on the water surface. Glass jars pre-rinsed with dicloromethane and having teflon lined lids were used as sample containers. Samples were stored in padlocked containers and kept in a freezer at the State Department of Fish and Game office in Homer, Alaska. Chain of custody forms accompanied each sample. Samples were hand carried to Anchorage for shipment to the National Marine Fisheries Service Auke Bay Laboratory, Juneau, Alaska, for analyses by contracted laboratories.

Histopathological Analysis

Pink salmon returning to spawn during the summer of 1990 are from the same cohort that migrated through Exxon Valdez crude oil during the spring and summer of 1989 as fry. To detect sublethal effects of their exposure, tissue samples for histopathological analysis were collected from pink salmon entering each of the study streams except Tonsina. Olfactory organ, spleen, kidney, and liver tissue samples were taken from 20 males and 20 females immediately after they were killed. Spawned out fish were avoided. Organs were examined in the field for lesions, tumors, and abnormalities in shape or color and replicate 2mm tissue sections were preserved in a phosphate buffered 10% formalin solution. Chain of custody forms accompanied each sample. All samples were shipped directly to Dr. David Hinton, Department of Medicine, School of Veterinary Medicine, University of California, Davis for analysis.

STUDY RESULTS

The study streams in the Lower Cook Inlet-Gulf of Alaska area were surveyed between 10 July and 6 September 1989, and 10 July and 2 October 1990. These dates bracket pink salmon spawning runs fairly well. For most streams, observed numbers of pink salmon increased from 10 July to a peak sometime in mid to late August after which numbers of live pink salmon decreased and dead pink salmon increased. An exception was Island Creek in 1989 where the peak survey occurred on the last day. Surveys for chum salmon should have been started earlier in the year for many streams. Relatively large numbers of chum salmon were usually observed during the earliest surveys while peak numbers were generally observed in late July.

Although attempts were made to survey each stream at least once every seven days, the interval between study stream survey ranged from 4 to 26 days with a median value of 9 days during 1989. Most delays were caused by high winds which prevented travel by aircraft to the more remote study streams. Unfortunately, the intervals between successive surveys of most study streams were too long to allow for reliable estimates of stream life.

Tide Zones

All stream zone maps required by NRDA Study 8a were completed. Schematic diagrams showing markers, stream measurements, and major landmarks were done for each.

Spawner Distribution

The proportion of pink salmon intertidal spawners during 1989 was well within the range of historical observations, i.e., between the .25 and .75 quartiles, in all but two stream (Table 1). During 1990, only three streams were within the two quartiles. A similar analysis for chum salmon is in progress. During 1989, a greater percentage of both pink and chum salmon spawned below mean high tide within oiled (pink salmon: 64%; chum salmon 52%) than within unoiled (pink salmon: 48%; chum salmon: 45%) streams. These differences probably reflected inherent differences between the distribution of spawners in the Gulf of Alaska (oiled) and lower Cook Inlet (unoiled) streams rather than effects of crude oil contamination.

Spawner Abundance

With one exception, pink salmon escapement estimates for oiled and control streams were either within or above the range of historical observations (greater than or equal to the .25 quartile, Table 2). The 1989 escapement in Tonsina Creek, an unoiled stream in Resurrection Bay, was below its historical range. A similar analysis for chum salmon is in progress. Total estimates of the 1989 pink salmon spawning escapements ranged from 4,821 for Island Creek to 89,987 for Humpy Creek (Table 3). Total estimates of chum salmon spawning escapements ranged from 17 in Windy Creek Left to 4,431 in Island Creek. Some spawning escapement estimates appeared to be low when compared to peak numbers of salmon observed during ground surveys. This was most obvious for three study streams; Port Dick Creek (pink and chum salmon), Windy Creek Right (chum salmon), and Tutka Lagoon Creek (chum salmon). Total estimates for these systems would be larger, if stream life values used in calculations be smaller.

Stream Life

Tagging

Tagging dates in relation to run timing as well as the 3-day moving averages are depicted in **Figures** 3 and 4.

Numbered Disk Tag on Back. Fifty males and 50 females were tagged at Port Dick on July 18. Another 50 males and 50 females were tagged at Humpy Creek on July 19. The Port Dick males had orange tags numbered 1-50. Females had yellow tags numbered 51-100. The Humpy Creek males had orange tags numbered 201-250. Females were marked with yellow tags numbered 251-300. These tags (type 1), remained attached throughout the life of the fish and remained attached to the carcass. It was often difficult to determine the tag number of a live fish that was swimming or that was stationary in moving water. Some fish were "chased" in an attempt to read the tag. This tag type also caught floating debris in the stream. Several tags and pins were recovered from debris suggesting that the tags may have been torn off the fish.

Numbered Surveyor's Tape on Tail. On July 21, 50 red tags, numbered 1-50, and 50 yellow tags, number 51-100, were attached to the tails of male and female pink salmon with cinch ties at Port Dick Creek. These tags (type 2) ripped easily and were difficult to read. This tag type was redesigned with different materials (type 3) before being used at Humpy Creek.

Numbered Adhesive Tape on Tail. On July 26, 50 red tags, numbered 1-50, and 50 yellow tags, numbered 51-100, were attached to the tails to male and female pink salmon in Humpy Creek. The numbers on these tags (type 3) were easier to see than those on the Peterson disk. However, the tag numbers often wore off before the fish died. The tag type was not repeated at Port Dick.

Color-Bar Coded Tag on Tail. To improve readability over the other tag designs, the color-bar combination coded tags had three colors in three positions to produce 24 unique combinations (three red or three yellow bars in succession were not used as it could be confused with the numbered adhesive tape tags). Two of the colors, red and blue, were of different bar widths to enhance readability in low light conditions. The third color was the base color used for each sex: red for males and yellow for females.

On August 2, 24 male and 24 female pink salmon were tagged on the tail with a color-bar coded tags at Humpy Creek. Readability was good in moving water and on swimming fish. These tags (type 4a) had a center rib, i.e. a tooth pick to stiffen the tag and make it easier to read. However, it also created a weak point at the base of the tooth pick. Most of the tags broke off at the base of the toothpick within 24-48 hours.

The tags were redesigned without the longitudinal toothpick brace (type 4b). On August 3-4, 25 male and 25 female pink salmon were tagged with white and yellow color-bar coded tags respectively at Port Dick Creek.

Color-Bar Coded Tag on Back. As a final enhancement, the color-bar coded tags were built around a standard floy anchor tag instead of the cable tie to improve tag durability and readability (type 5). On August 13, 25 green and 25 yellow color-bar tags were attached the backs of male and female pink salmon respectively at Humpy Creek. On August 14, 25 white and 25 yellow tags were applied to male and female pink salmon at Port Dick Creek. Despite the floy anchor design having some problems with one half of the T-shaped anchor breaking off and the tag subsequently pulling out, this design proved to be, under a variety of conditions, the most readable of all designs due to 1) conspicuous color-coding (Yuen and Bechtol 1991) and 2) placement high on the back.

Stream Life Estimates

Stream life estimates varied among the methods used and became progressively shorter for fish tagged later in the season (Table 5). However, fish tagged later in the season may have been from the same group of fish tagged earlier as suggested by a common date when carcasses were first observed. There was no consistent pattern to indicate one sex had a longer stream life than the other. None of the stream life estimates agreed with the historical 17.5 day estimate.

At Humpy Creek, 24,699 pink salmon were counted as they passed through the weir. The corresponding accumulated daily foot survey count, including linear interpolations for missed counts, was 215,550. The seasonal average Humpy Creek stream life was therefore 20.9 days (method 7). Only the results from the first tagging event agreed with this estimate. Stream life estimates in the absence of tagging data, i.e., number of days between peak live and peak carcass counts, are not reliable.

The 21 day stream life estimate derived in this study suggests the historical escapement estimates based on 17.5 days may be biased high. However, we do not know if 1990 was a representative year or if it was an anomaly nor do we know how stream life estimates vary between years. By way of comparison, the preliminary estimates for Prince William Sound pink salmon are less than 17.5 days, the opposite of what we found.

Humpy Creek. Of the four sets of tags (types 1, 3, 4a, and 5) released in Humpy Creek (Table 4) only three were successful (1, 3, and 5). Males initially appeared to have a longer stream life but the pattern was not consistent across methods or dates (Table 5). Therefore, only the estimates for sex combined are presented. All tags were applied before the large influx of spawners on August 15 (Figure 4).

The July 19 tag release led to estimates of a median stream life of 24 days (method 1), a tagged fish half life of 20 days (method 2), 19 days for method 3, and a median date to initial carcass sighting of 23 days (method 4; Figures 12 and 13). The average of all four estimates weighted by sample size (n) was 20.8 days (Table 5), a very close agreement with the seasonal average estimate (method 7).

The July 26 tag release produced estimates of a median stream life of 16 days (method 1), a tagged fish half life of 9 days (method 2), 11 days for method 3, and a median first carcass date of 21 days (method 4; Figures 14 and 15). The mean weighted estimate was 11.7 days (Table 5). The July 26 results were suspect because fish tagged on that date may have been from the same group tagged on July 19, despite efforts to tag only those fish that did not fully exhibit the coloration of an actively spawning fish. While the second tag release trailed the first by 7 days, the two stream lives ended within 2 days of each other (August 9 and 7). The mean dates when tagged carcasses first appeared (method 1) occurred within a day of each other (August 10 and 11; Figure 5) as was the projected end of lives from method 3 (August 5 and 6; Figure 7). The half life date of the tags was also only 4 days apart (August 3 and August 7; Figure 6).

The August 13 tag release produced estimates of a median stream life of 8 days (method 1), a half life estimate of 10 days (method 2), 9 days for method 3, and a median carcass date of 8 days (method 4; Figures 16 and 17). The weighted mean was 9.4 days (Table 5). It is not clear why these result differed from the seasonal average estimate (method 7). While it appears the August 13 tagging occurred after most of the fish from the two earlier taggings had died (Figures 5-8), there was the possibility that the fish being tagged had been in stream residence for some time. Had the tagging occurred several days later, we would have been more confident working with new fish from the large influx that began in mid-August (Figure 4).

Only one mode was observed in the 3-day moving average of live and peak carcass counts as opposed to two in the daily weir counts (Figure 4). The 11 days between the midpoint of the plateau in live count on August 24 and the peak carcass on September 4 (Figure 18; method 5) did not approximate the seasonal average stream life (method 7).

Port Dick. There were four tag releases employing tag types 1, 3, 4b, and 5 in Port Dick. Only three tag designs, 1, 4b, and 5, were successful (Table 4). Females initially appeared to have a longer stream life but the pattern was not always consistent across methods (Table 5). To be consistent with the Humpy Creek results, only estimates for combined sex will be presented below. Only methods 2-4 were used for tagging data due to the low number of live tag sightings followed within a day by a corresponding carcass sighting.

The July 18 tag release had no carcass observations that fell within one day of the most recent live observation. Therefore equation 1 could not be used. The other estimates yielded tag half life estimates of 21 days (method 2) and 19 days (method 3), and a median carcass date of 24 days (method 4; Figures 19 and 20). The weighted mean was 20.3 days (Table 5).

The August 3 tag release had no carcass observations that fell within one day of the most recent live observation. Therefore equation 1 could not be used. The other estimates yielded tag half life estimates of 6 days (method 2) and 7 days (method 3). Only one female carcass was observed, 21 days after the tag was released, (Equation 4; Figures 21 and 22). The weighted mean was 7 days (Table 5).

The tag release of August 14 (Type 5) led to tag sightings but no carcass recoveries. Stream life estimates yielded a tag half life of 11 days (method 2) and 10 days (method 3; Figures 23 and 24). The weighted mean was 10.6 days (Table 2).

There are two peaks in the 3-day moving average of live and peak carcass counts (equation 4). Twenty days passed between the first peak live count on August 8 and the first peak in carcass counts on August 28. Seven days passed between the midpoint of the plateau in live counts on August 26 and the second peak in carcass counts on September 2 (Figure 25).

The August 3 tagging results may not be biased. The dates when half of the fish from the July 18 tagging should be dead (August 8 and 9; Figure 9) suggest that the same fish were unintentionally tagged 16 days apart. Likewise, the August 14 tags appeared to have been applied too late for the fish in the first mode but too early for those the second, hence the short stream life of 10.6 days (Figure 4). If the latter two tagging results are discounted, then both streams had stream lives, within a day of each other, that were about 2.5 days greater than the historical 17.5 day estimate.

Strays

There were three known strays, all in Port Dick. A female tagged on July 18, number 96, was later caught by a commercial fishing boat in Port Dick Bay. A male tagged on August 3, color code red-blue-blue, was seen in Slide Creek, another stream flowing into Port Dick. This fish was not included in the stream life analysis. Another male, tagged on August 14, color code white-red-blue, was also seen in Slide Creek on August 20. The same fish later returned to Port Dick and was seen on August 22 and 23. This fish was included in the stream life analysis.

Carcass Life

All 3 tag releases in Humpy Creek resulted in tagged carcasses sightings but only the first two tag releases led to any tagged carcass sightings. Carcass life was considerably shorter in Port Dick, 2 days compared to about a week in Humpy Creek (Table 6).

Tagged carcasses could readily be seen in Humpy Creek because it is a smaller stream than Port Dick Creek. Humpy Creek also had fewer fish to sort through (27,000 escapement between the intertidal and upstream zones of Humpy Creek compared to 42,000 concentrated in the intertidal area of Port Dick). The ability of observers to find tagged fish was influenced by those two variables.

Port Dick carcass lives are shorter than those in Humpy Creek. The gradient in the intertidal area of Port Dick Creek is such that the stream is almost a straight line to the ocean. Tidal flushing quickly removes any carcasses. Humpy Creek, on the other hand, meanders stream throughout the intertidal area. Carcasses are deposited on gravel bars by the receding tide and could be counted for several days.

Hydrocarbon Analysis

Mussel samples have been collected but the results are not yet available from the laboratory performing the analysis.

Histopathological Analysis

Tissue samples have been collected but the results are not yet available from the laboratory performing the analysis.

STATUS OF INJURY ASSESSMENT

Four of the five stated objectives have been addressed and at least partially met at this time. 1) The status of crude oil contamination to intertidal areas in the study streams has been or is in the process of being quantified using a variety of methods. The laboratory analyses of mussels for hydrocarbons and pink salmon tissues for histopathological analysis are not complete. 2) Preliminary estimates of numbers of pink and chum salmon spawning within the oiled and control streams have been made for 1989 and 1990. Comparisons with the pink salmon historical data have been completed but comparisons with the chum salmon historical data are not complete. No analysis has been made with a stream life estimate other than 17.5 days. 3) A comparison of pink salmon spawning distribution in 1989 and 1990 with those in previous years using published historical data base is complete. The analysis for chum salmon is not complete. All of the analyses in this report are based on the 17.5 day stream life estimate. The weir and tagging results in this study, however, do not support the 17.5 day stream life estimate. The computerized historical escapement data base is still being verified. It has not been used for any analyses. 4) A series of aerial photographs, maps, and schematic diagrams of pink and chum salmon spawning streams has been developed for use in designing and implementing NRDA Study 8a, which concerns egg and preemergent fry survival. 5) Potential methods and strategies for restoration of lost use, populations, or habitat in areas that have been adversely affected by crude oil contamination have not been identified at this time. It is too early in the damage assessment process to address this issue in this report.

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Yuen, H.J. and W. Bechtol. 1991. Easy to read tag for pink and chum salmon stream life studies. Presentation at 15th Northeast Pacific Pink and Chum Salmon Workshop. February 27-March 1, 1991. Tigh-Na-Mara Resort. Parksville, British Columbia.

Table 1. Historical quartiles of intertidal spawning and the 1989 and 1990 percentage of intertidal spawning.

Stream	Quartile .25	Quartile .50	Quartile .75	1989 Escapement	1989 Within Q(.25)-Q(.75)?	1990 Escapement	1990 Within Q(.25)-Q(.75)?
Humpy Creek	9%	13%	17%	10%	yes	56%	no
Island Creek	74%	79%	87%	47%	no	71%	no
James Lagoon	64%	82%	100%	n/a	n/a	85%	yes
Port Dick Creek	34%	85%	94%	87%	yes	97%	no
Port Graham Creek	38%	57%	66%	51%	yes	67%	no
Seldovia River	61%	67%	70%	59%	yes	82%	no
South Nuka Creek	32%	39%	39%	39%	yes	18%	no
Tonsina Creek	n/a	n/a	n/a	n/a	n/a	100%	n/a
Tutka Lagoon	90%	91%	96%	n/a	n/a	90%	yes
Windy Creek Left	29%	35%	53%	19%	no	41%	yes
Windy Creek Right	43%	54%	81%	74%	yes	84%	no

Table 2. Historical escapement quartiles and the 1989 and 1990 escapement size.

Stream	Quartile .25	Quartile .50	Quartile .75	1989 Escapement	1989 Within Q(.25)-Q(.75)?	1990 Escapement	1990 Within Q(.25)-Q(.75)?
Humpy Creek	22,600	31,900	64,000	93,000	no	27,042	yes
Island Creek	500	2,100	15,300	6,700	yes	25,000	no
James Lagoon	1,700	5,100	9,000	4,900	yes	3,787	yes
Port Dick Creek	14,000	35,000	62,800	55,400	yes	41,704	yes
Port Graham Creek	4,000	10,900	24,400	19,100	yes	20,053	yes
Seldovia River	16,900	27,900	50,000	26,200	yes	27,782	yes
South Nuka Creek	1,200	10,000	16,000	7,300	yes	13,299	yes
Tonsina Creek	700	2,200	6,000	500	no	1,180	yes
Tutka Lagoon	7,000	12,900	17,300	11,900	yes	38,500	no
Windy Creek Left	2,200	5,000	11,900	25,200	no	7,521	yes
Windy Creek Right	2,000	4,300	8,000	6,600	yes	7,095	yes

Table 3. Streams surveyed for spawning pink and chum salmon for NRDA Study 7a, Lower Cook Inlet and Gulf of Alaska, 1989 and 1990.

Stream	Degree of Oiling[a]	Study Year
Gulf of Alaska:		
Island Creek	very lightly oiled	1989, 1990
Port Dick Creek	very lightly oiled	1989, 1990
Windy Creek Left	unoiled	1989, 1990
Windy Creek Right	lightly oiled	1989, 1990
James Lagoon	unoiled	1990
South Nuka Island Creek	very lightly oiled	1990
Tonsina Creek	unoiled	1990
Lower Cook Inlet:		
China Poot Creek	unoiled	1989
Seldovia River	unoiled	1989
Tutka Lagoon Creek	unoiled	1989
Humpy Creek	unoiled	1989, 1990
Port Graham Creek	unoiled	1989, 1990

[a] Source: ADEC 1989.

Table 4. Tagging dates, tag type, color, and numbers used to estimate stream life of pink salmon on Port Dick and Humpy Creeks, Lower Cook Inlet, 1990.

Stream	Tag Type	Point of Attachment	Method of Attachment	Number	Color	Sex	Date
Humpy Creek	Numbered Disc	Back	Pin	201-250	Orange	Male	July 19
	Numbered Disc	Back	Pin	251-300	Yellow	Female	July 19
	Numbered Adhesive Tape	Tail	Cinch-Tie	1-50	Red	Male	July 26
	Numbered Adhesive Tape	Tail	Cinch-Tie	51-100	Yellow	Female	July 26
	Color-Bar Coded Tag[a]	Tail	Cinch-tie	N/A	White	Male	August 2
	Color-Bar Coded Tag[a]	Tail	Cinch-tie	N/A	Yellow	Female	August 2
	Color-Bar Coded Tag	Back	Floy Anchor	N/A	Green	Male	August 13
	Color-Bar Coded Tag	Back	Floy Anchor	N/A	Yellow	Female	August 13
Port Dick Creek	Numbered Disc	Back	Pin	1-50	Orange	Male	July 18
	Numbered Disc	Back	Pin	51-100	Yellow	Female	July 18
	Numbered Survey Tape	Tail	Cinch-Tie	1-50	Red	Male	July 21
	Numbered Survey Tape	Tail	Cinch-Tie	51-100	Yellow	Female	July 21
	Color-Bar Coded Tag	Tail	Cinch-Tie	N/A	White	Male	August 3
	Color-Bar Coded Tag	Tail	Cinch-Tie	N/A	Yellow	Female	August 3
	Color-Bar Coded Tag	Back	Floy Anchor	N/A	White	Male	August 14
	Color-Bar Coded Tag	Back	Floy Anchor	N/A	Yellow	Female	August 14

[a] with toothpick reinforcement

Table 5. Summary of stream life estimates by date, stream, sex, and method.

Stream	Date of Tag or peak live count	sex	Method 1: # days until tagged carcass observed	Method 2: No. days until only half of all tagged fish remaining	Method 3: tag-days /tags sighted	Method 4: median carcass date	mean weighted by sample size (n)	Method 5: No. days between peak live and peak carcass count
			Stream life estimates[a]					
Humpy	Jul 19	male	25 (n=11)	22 (n=45)	20 (n=45)	23 (n=32)	21.7	
		female	23 (n= 7)	19 (n=37)	19 (n=37)	23 (n=30)	18.8	
		both sex	24 (n=18)	20 (n=82)	19 (n=82)	23 (n=62)	20.8	
	Jul 26	male	17 (n= 2)	11 (n=25)	11 (n=25)	21 (n=10)	12.1	
		female	16 (n= 1)	9 (n=27)	11 (n=27)	23 (n=13)	12.0	
		both sex	16 (n= 3)	9 (n=52)	11 (n=52)	21 (n=23)	11.7	
	Aug 13	male	no data	9 (n=23)	9 (n=23)	no data	8.5	
		female	8 (n= 2)	11 (n=21)	10 (n=21)	8 (n= 2)	10.1	
		both sex	8 (n= 2)	10 (n=44)	9 (n=44)	8 (n= 2)	9.4	
	Aug 24	both sex						11 (Aug 24-Sep 4)
Port Dick	Jul 18	male	no data	17 (n=31)	17 (n=31)	30 (n= 7)	18.3	
		female	no data	21 (n=17)	22 (n=17)	23 (n= 5)	21.8	
		both sex	no data	21 (n=48)	19 (n=48)	24 (n=12)	20.3	
	Aug 3	male	no data	6 (n=15)	6 (n=15)	no data	5.8	
		female	no data	6 (n= 8)	9 (n= 8)	21 (n= 1)	8.1	
		both sex	no data	6 (n=23)	7 (n=23)	21 (n= 1)	6.6	
	Aug 8	both sex						20 (Aug 8-Aug 28)
	Aug 14	male	no data	10 (n=20)	9 (n=20)	no data	4.4	
		female	no data	12 (n=21)	11 (n=21)	no data	5.7	
		both sex	no data	11 (n=41)	10 (n=41)	no data	10.6	
	Aug 26	both sex						7 (Aug 26-Sep 2)

[a] method 6: 17.5 days historical estimate for both sex.

Table 6. Summary of carcass life estimates by tag date and stream.

Stream	Tag Date	Location	Mean Carcass Life (days)	n
Humpy	Jul 19	Intertidal (below weir)	7.7	18
		Intertidal (above weir)	9.9	13
		Stream	7.3	31
Humpy	Jul 26	Intertidal (below weir)	1.0	2
		Intertidal (above weir)	5.0	5
		Stream	5.2	16
Humpy	Aug 13	Stream	1.0	2
Port Dick	Jul 18	Intertidal	1.8	12
Port Dick	Aug 3	Intertidal	2.0	1

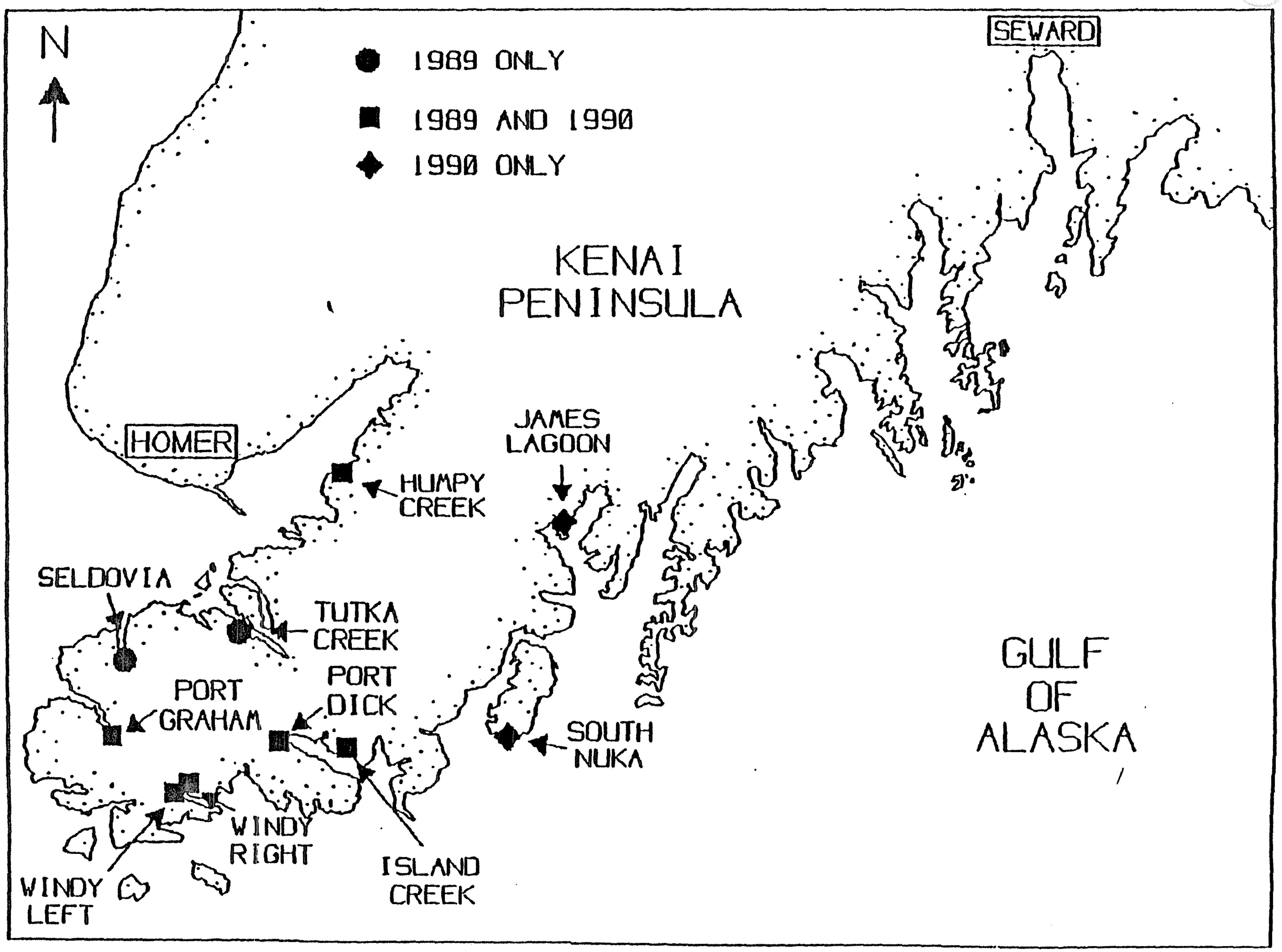


Figure 1. Study streams in lower Cook Inlet and the Gulf of Alaska

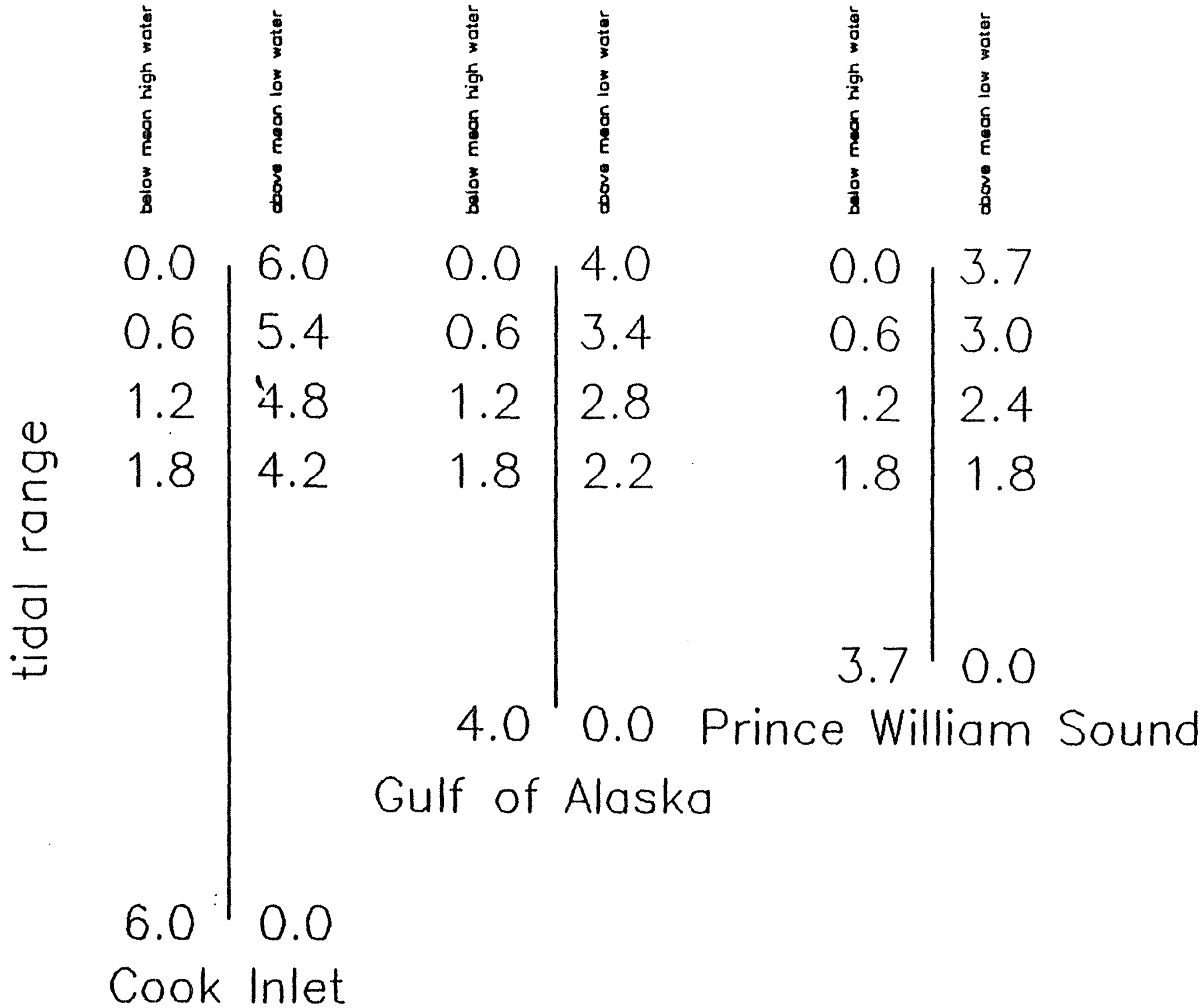


Figure 2. Tidal range and stream zones.

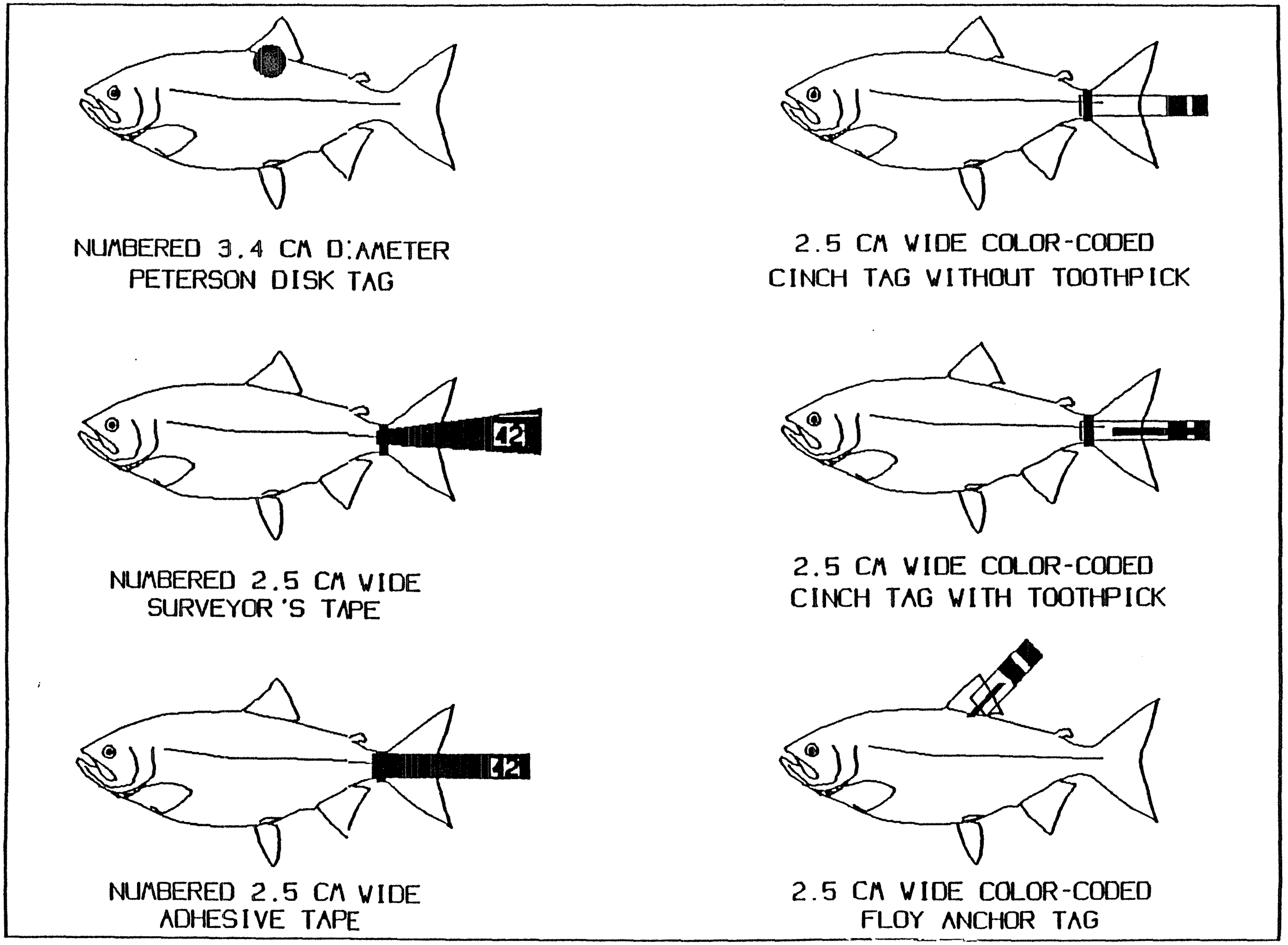
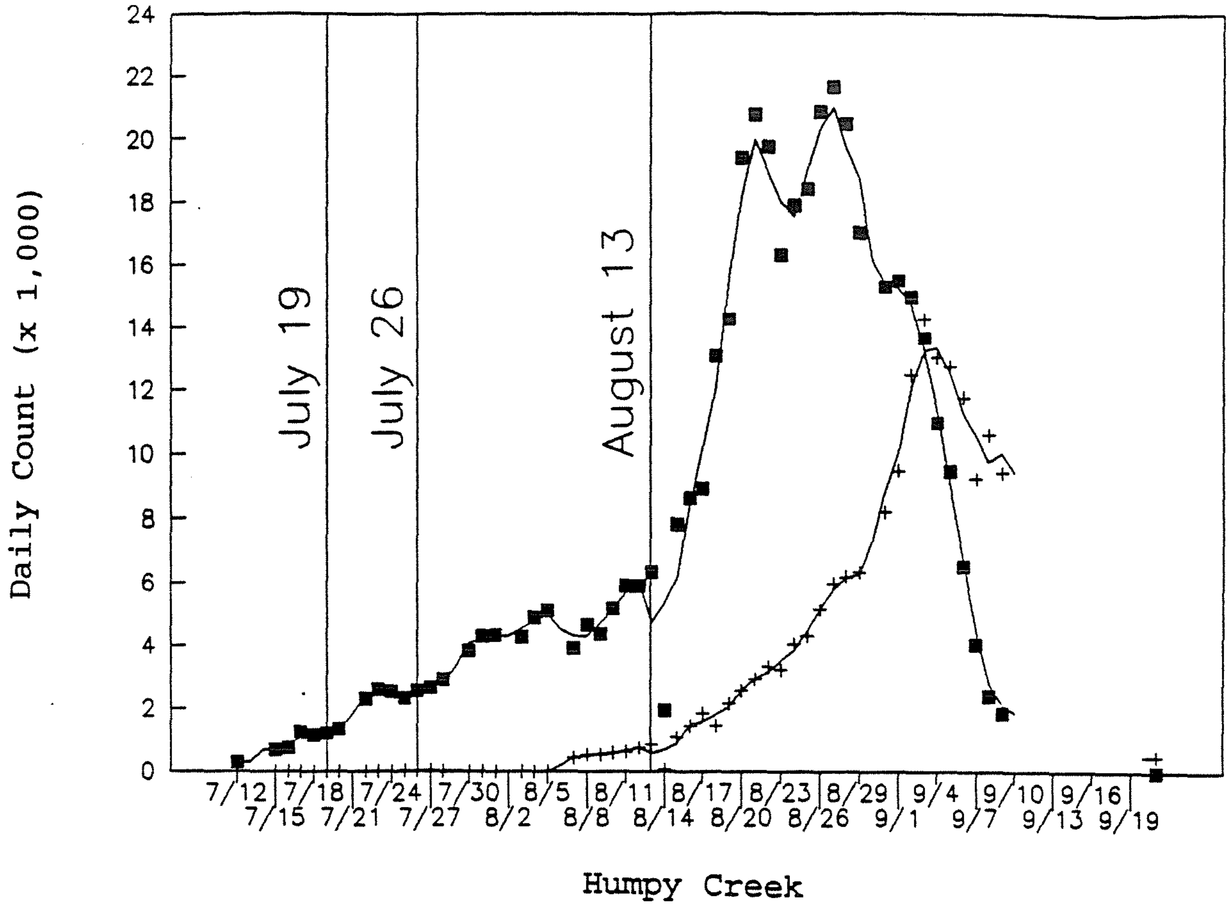


Figure 3. Tag types used in NRDA Study 7a.



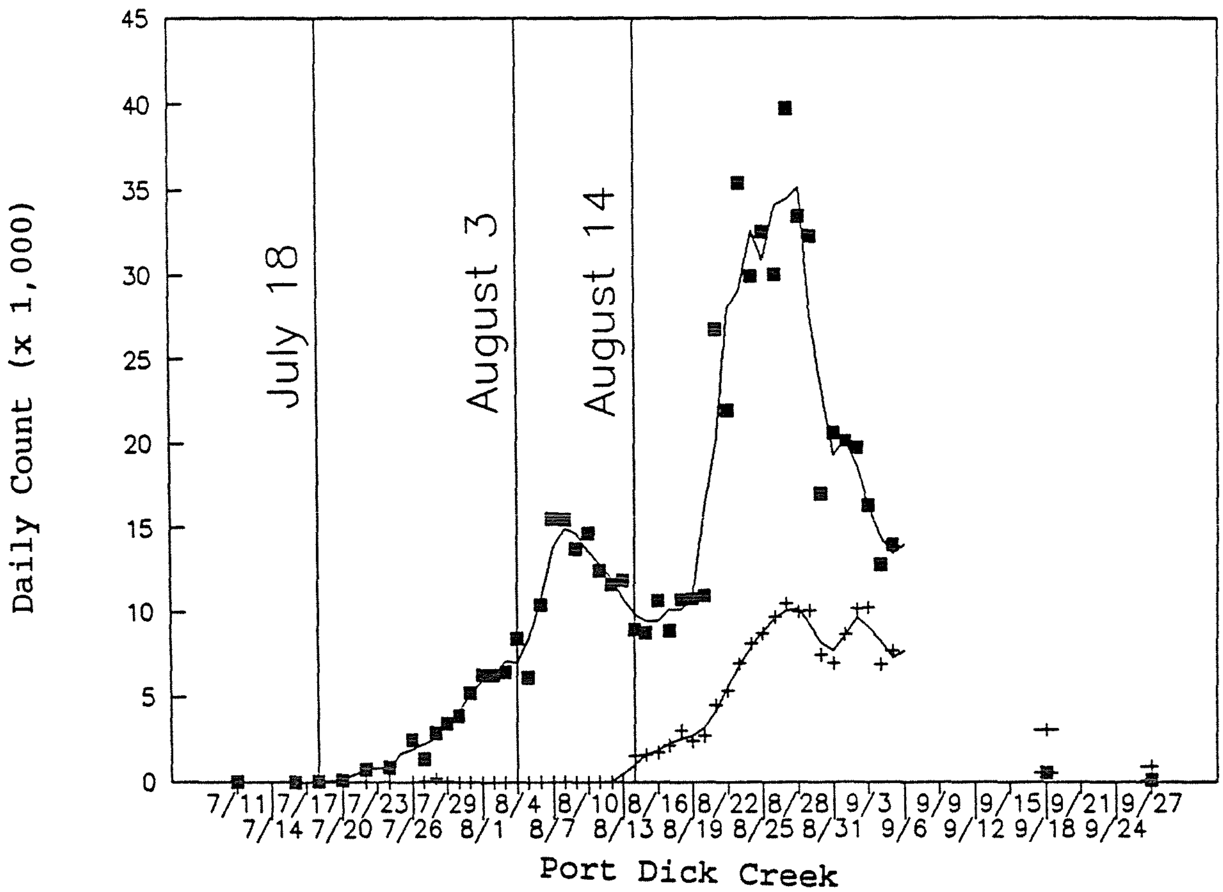


Figure 4. Daily live and carcass counts, 3-day moving average, and tagging dates, Humpy and Port Dick Creek, 1990

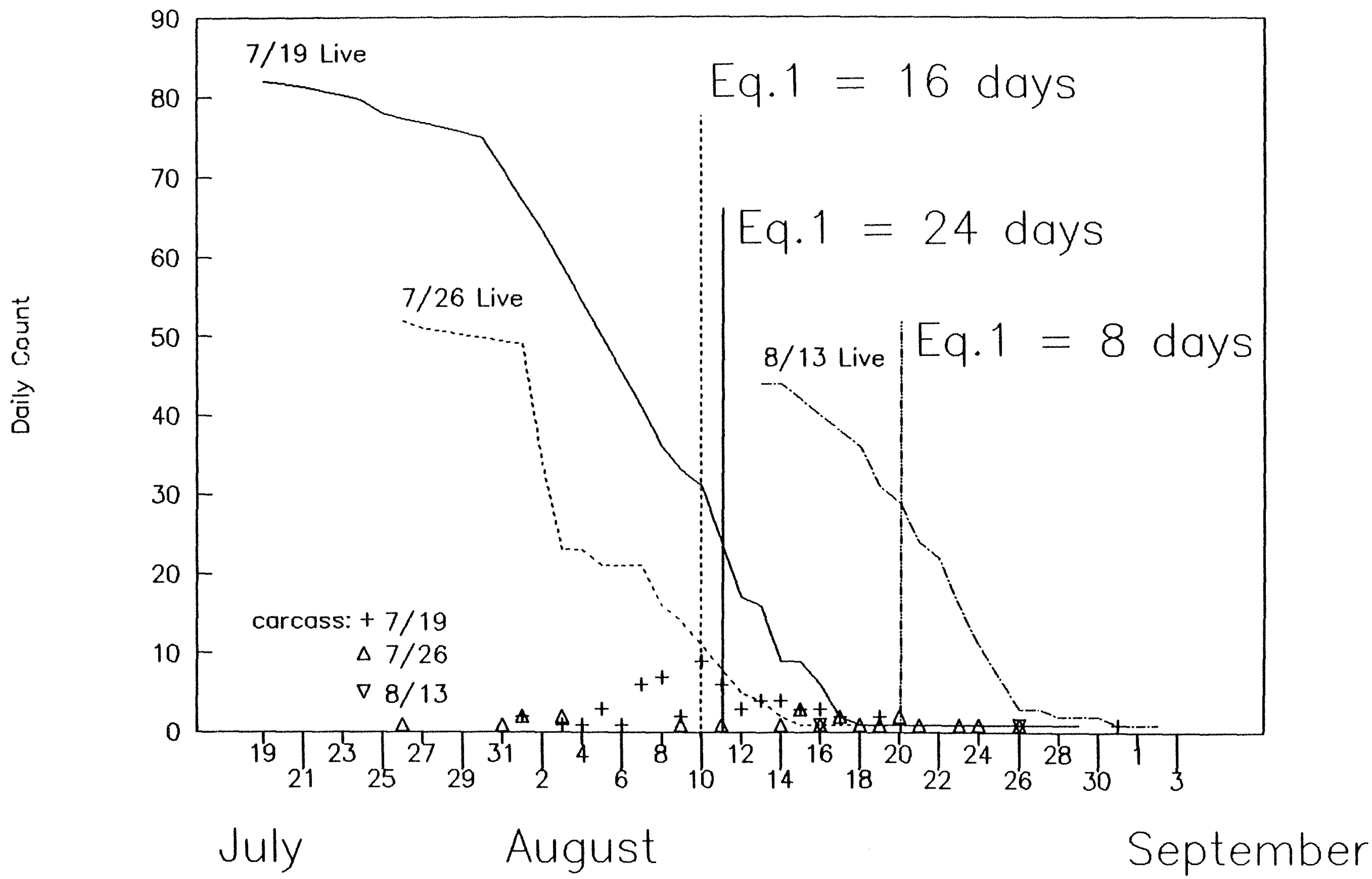


Figure 5. Estimates of stream life from method 1, all tag releases, both sex pink salmon, Humpy Creek, 1990.

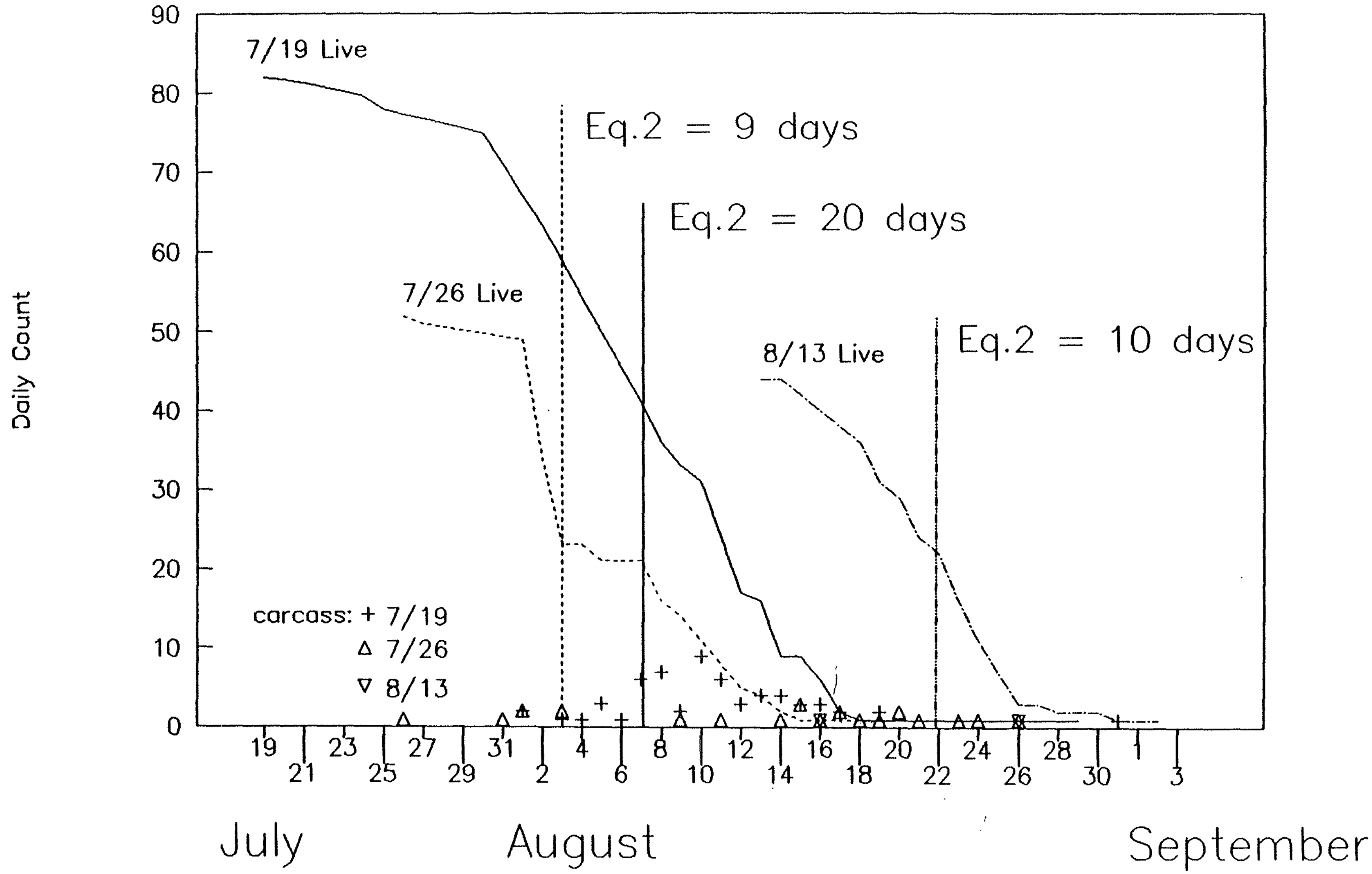


Figure 6. Estimates of stream life from method 2, all tag releases, both sex pink salmon, Humpy Creek, 1990.

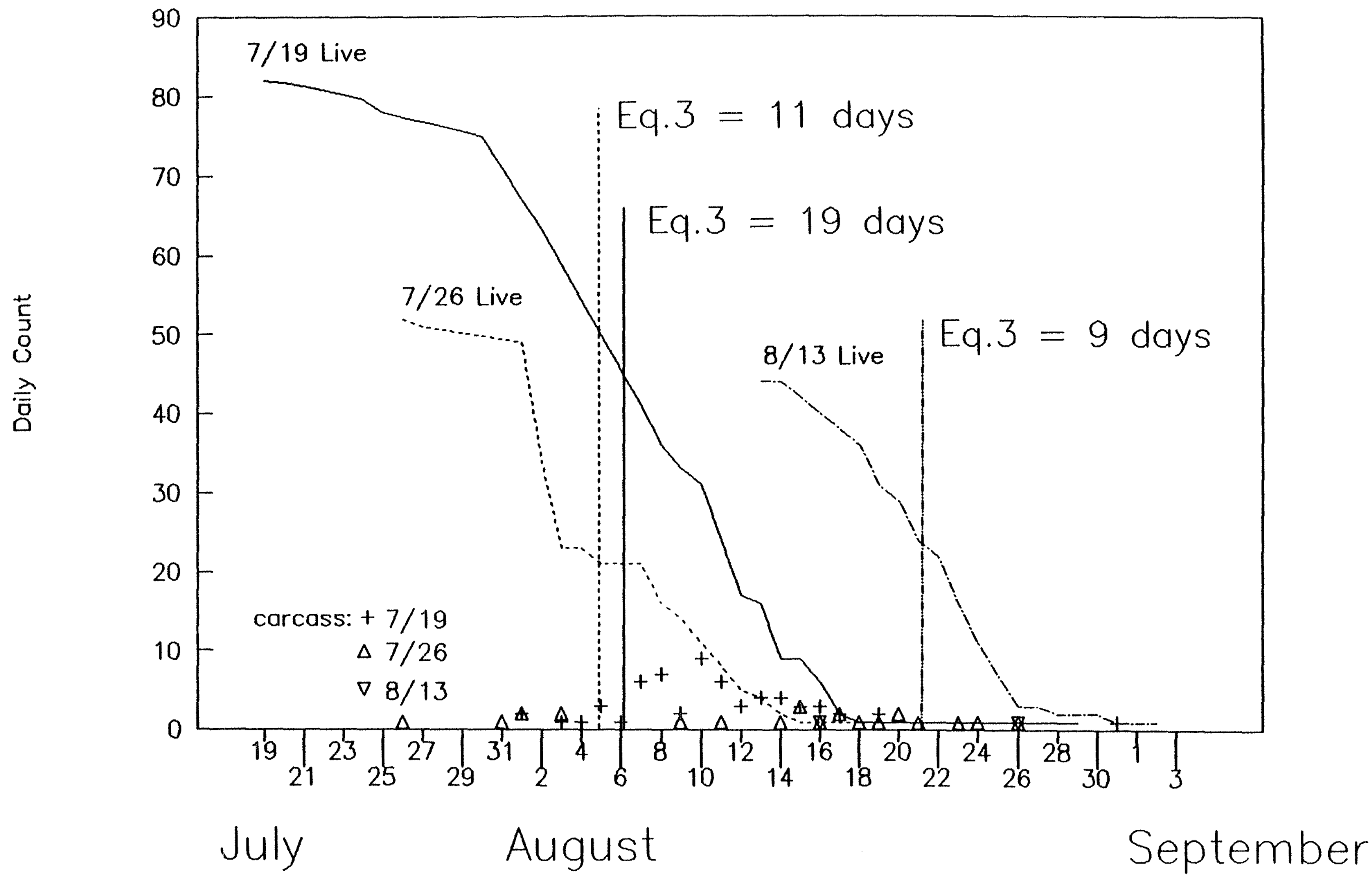


Figure 7. Estimates of stream life from method 3, all tag releases, both sex pink salmon, Humpy Creek, 1990.

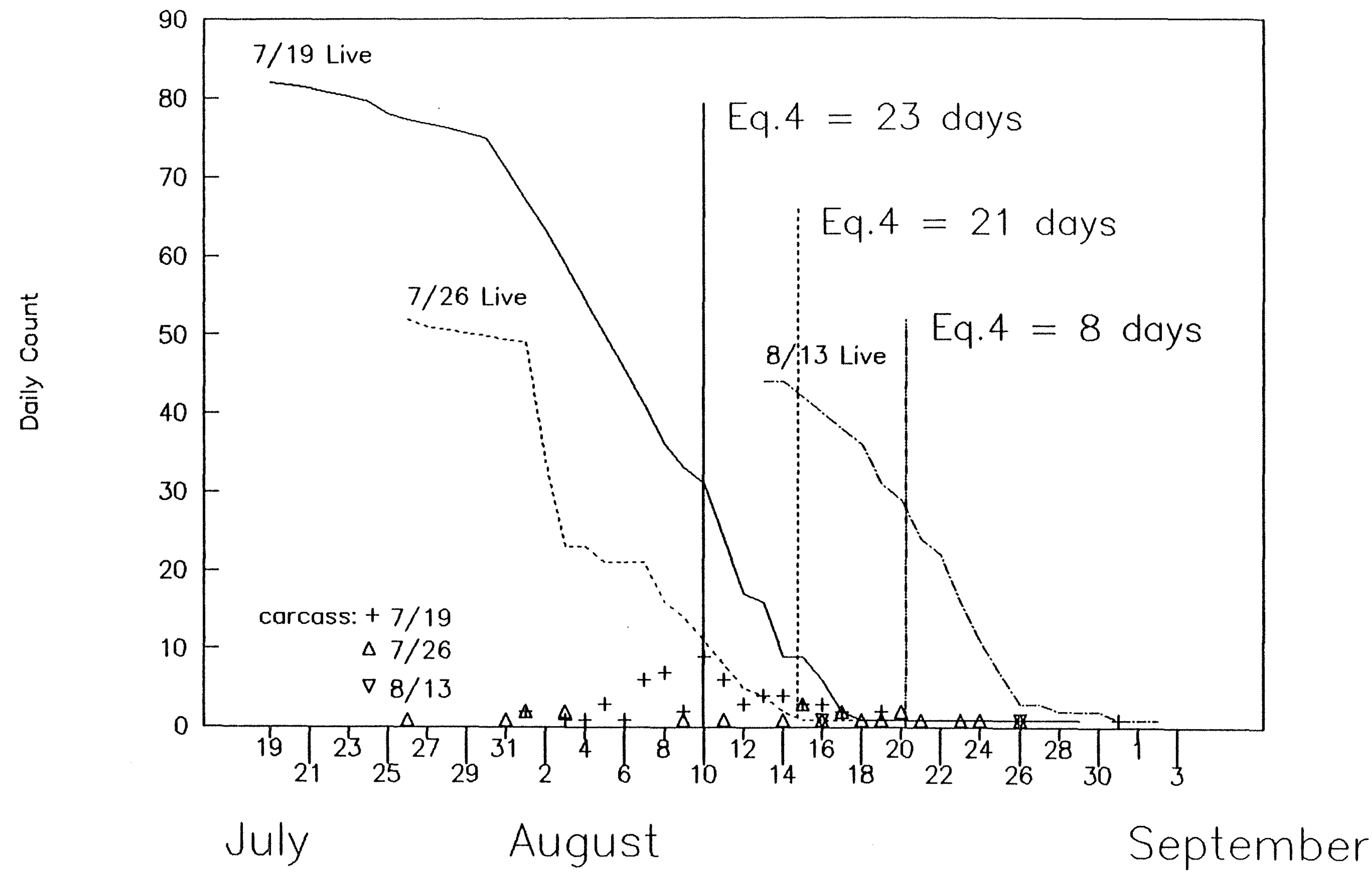


Figure 8. Estimates of stream life from method 4, all tag releases, both sex pink salmon, Humpy Creek, 1990.

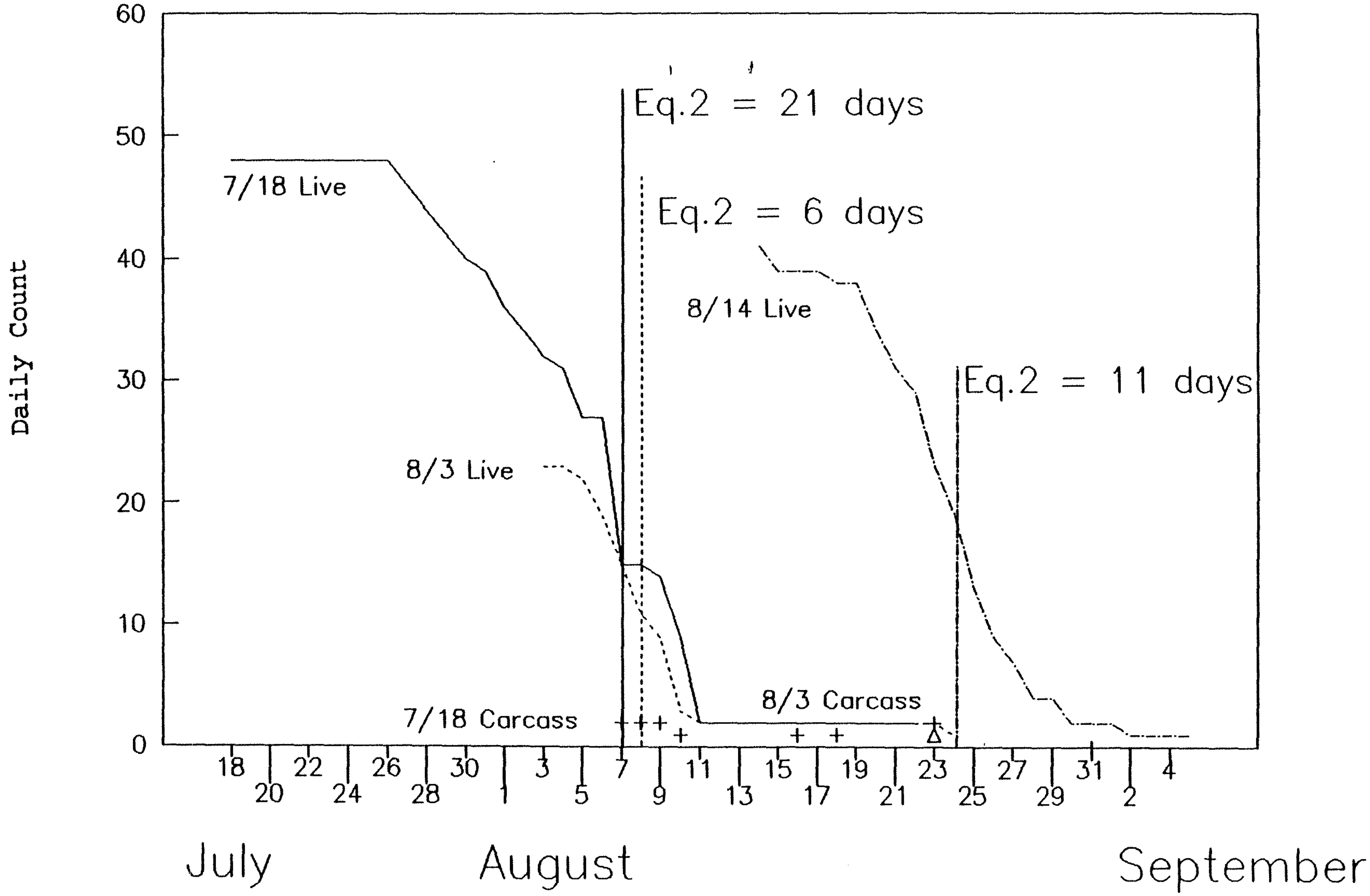


Figure 9. Estimates of stream life from method 2, all tag releases, both sex pink salmon, Port Dick, 1990.

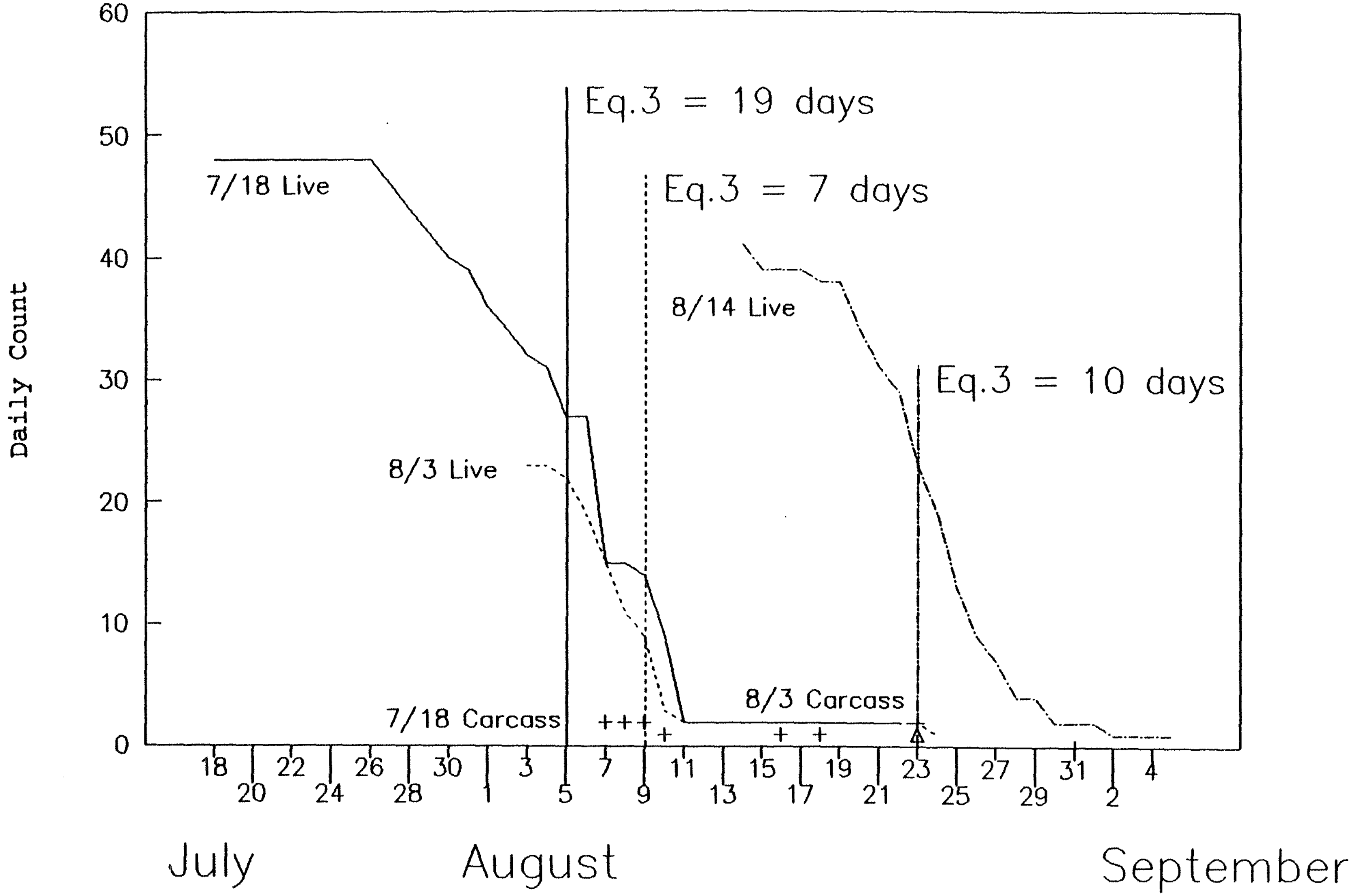


Figure 10. Estimates of stream life from method 3, all tag releases, both sex pink salmon, Humpy Creek, 1990.

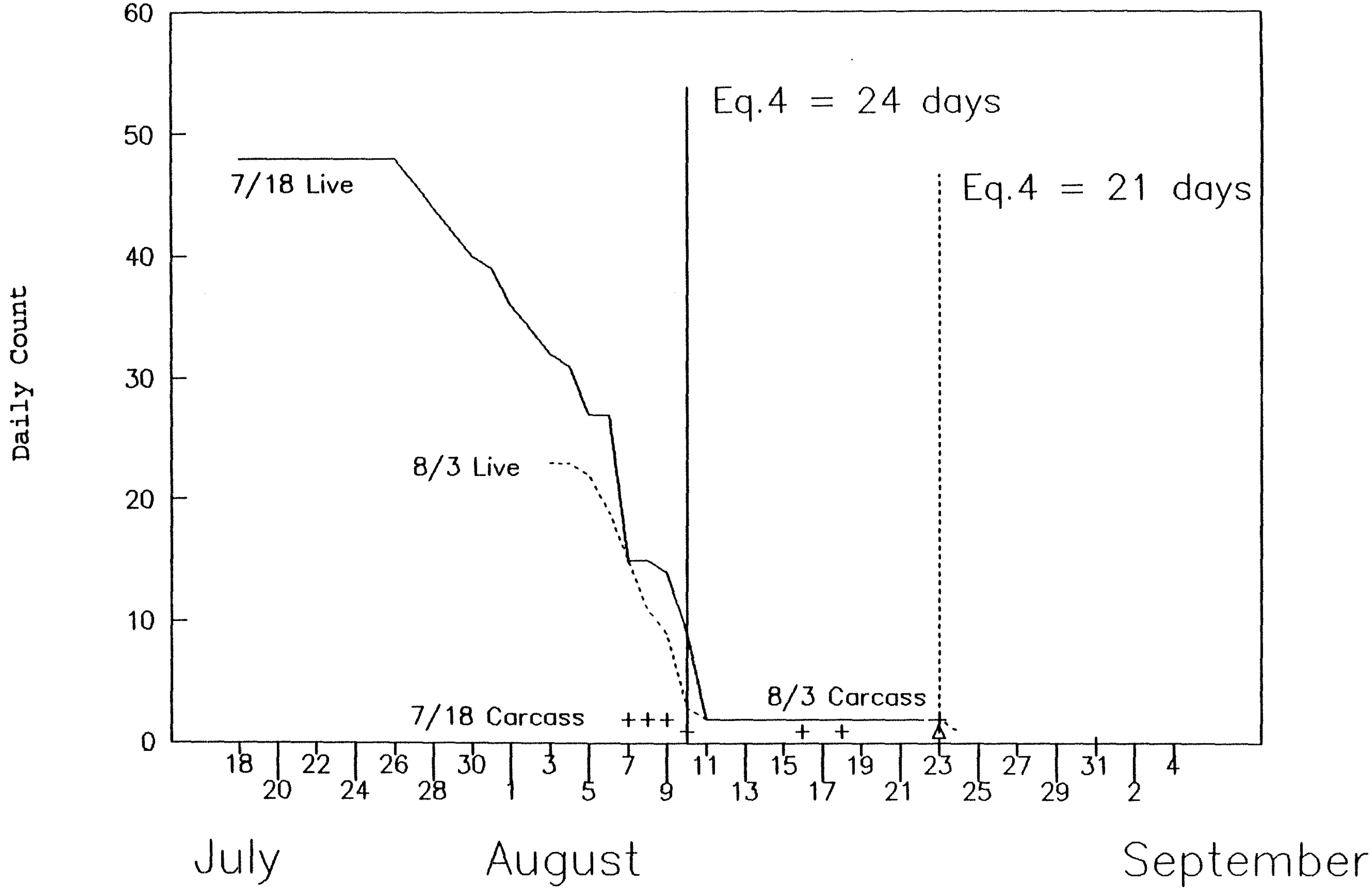


Figure 11. Estimates of stream life from method 4, all tag releases, both sex pink salmon, Humpy Creek, 1990.

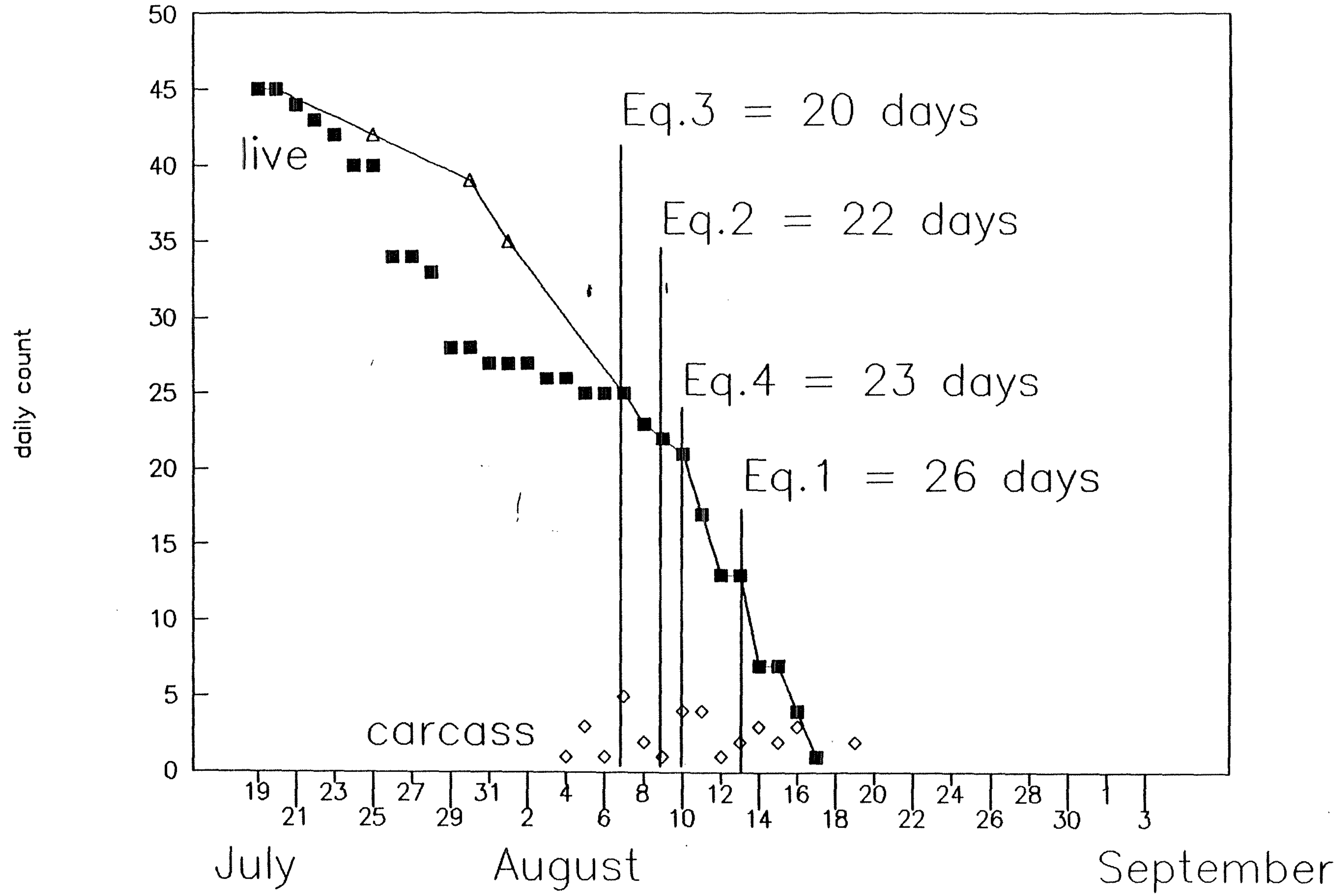


Figure 12. Estimates of stream life from July 19 tag release of male pink salmon, Humpy Creek, 1990.

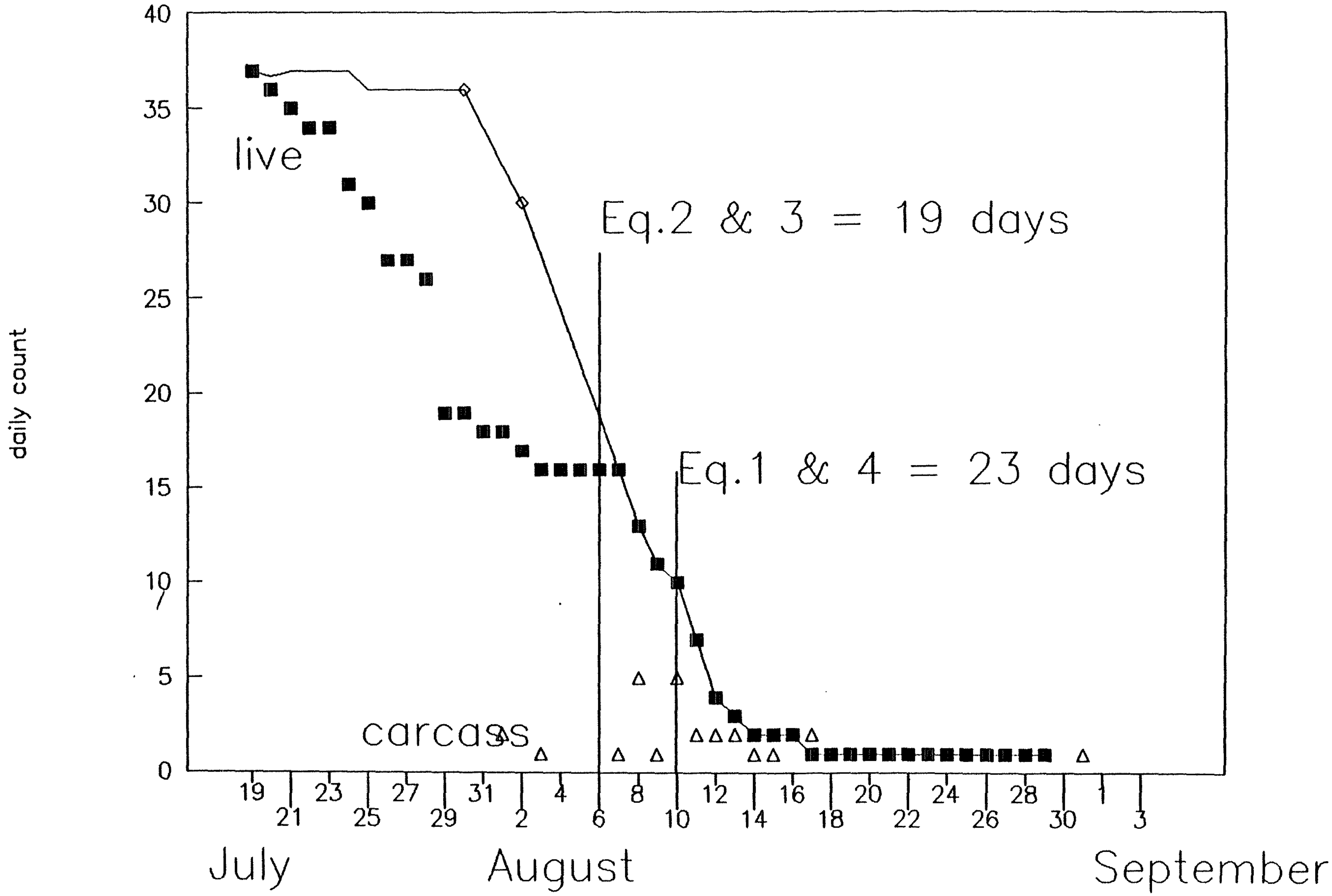


Figure 13. Estimates of stream life from July 19 tag release of female pink salmon, Humpy Creek, 1990.

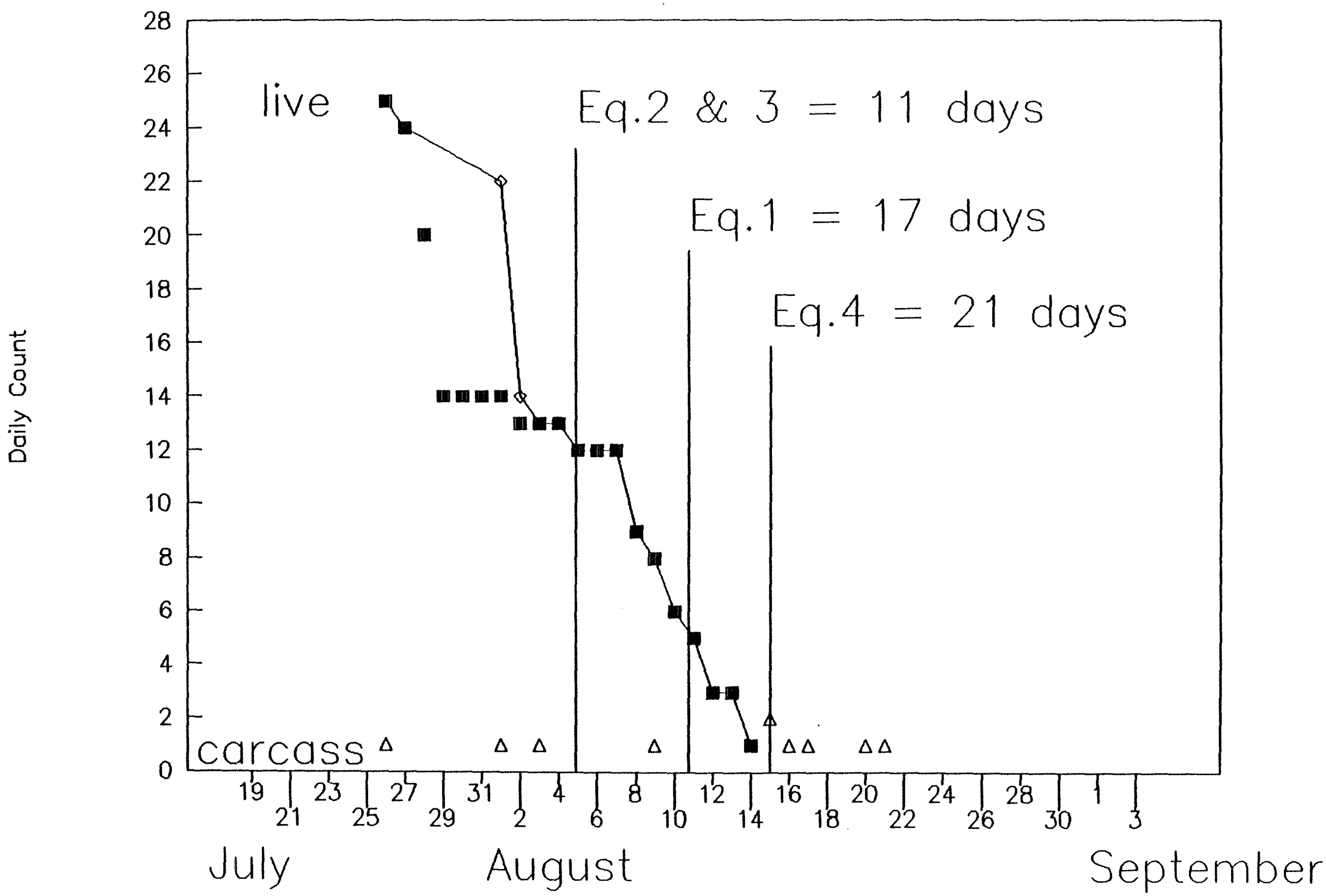


Figure 14. Estimates of stream life from July 26 tag release of male pink salmon, Humpy Creek, 1990.

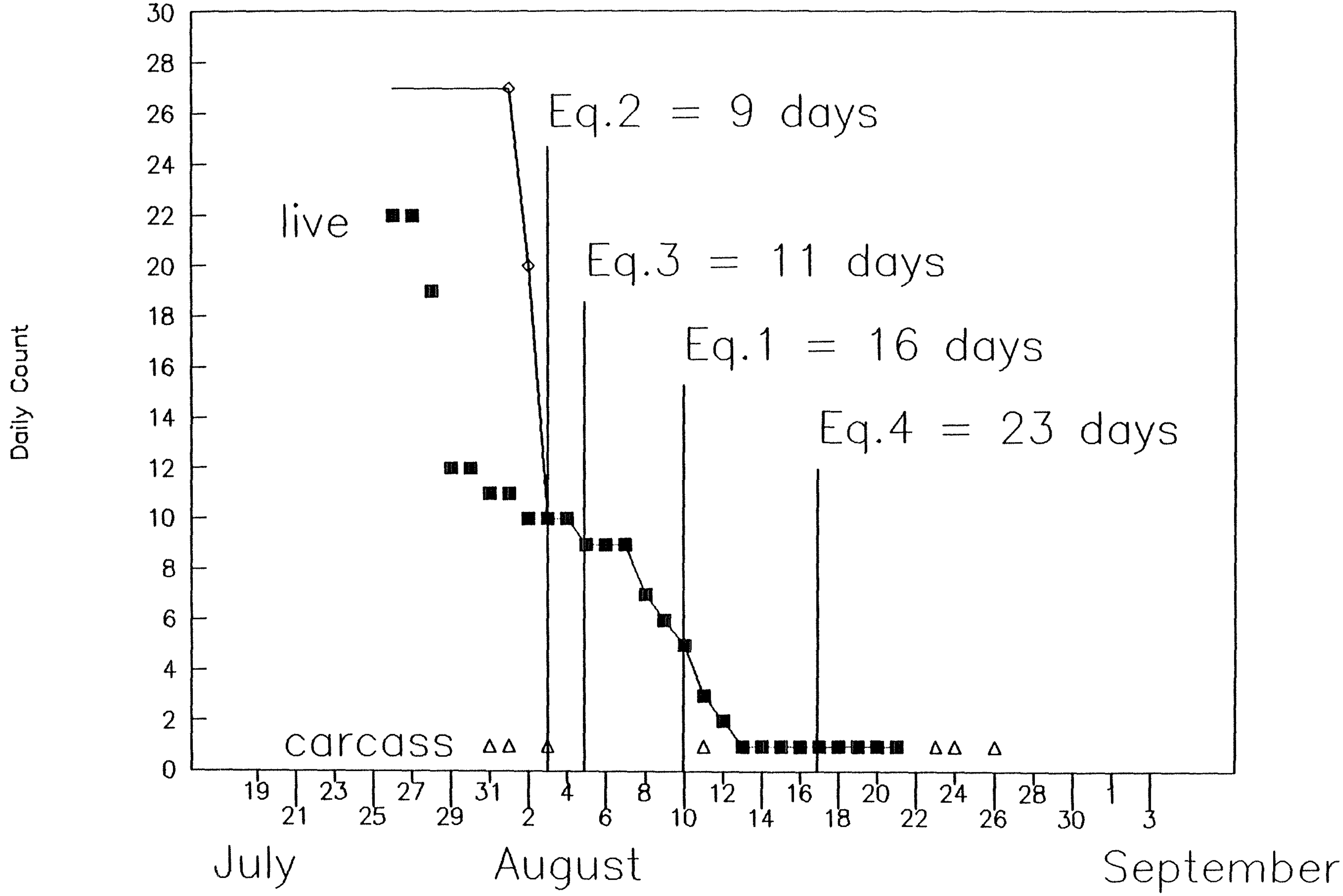


Figure 15. Estimates of stream life from July 26 tag release of female pink salmon, Humpy Creek, 1990.

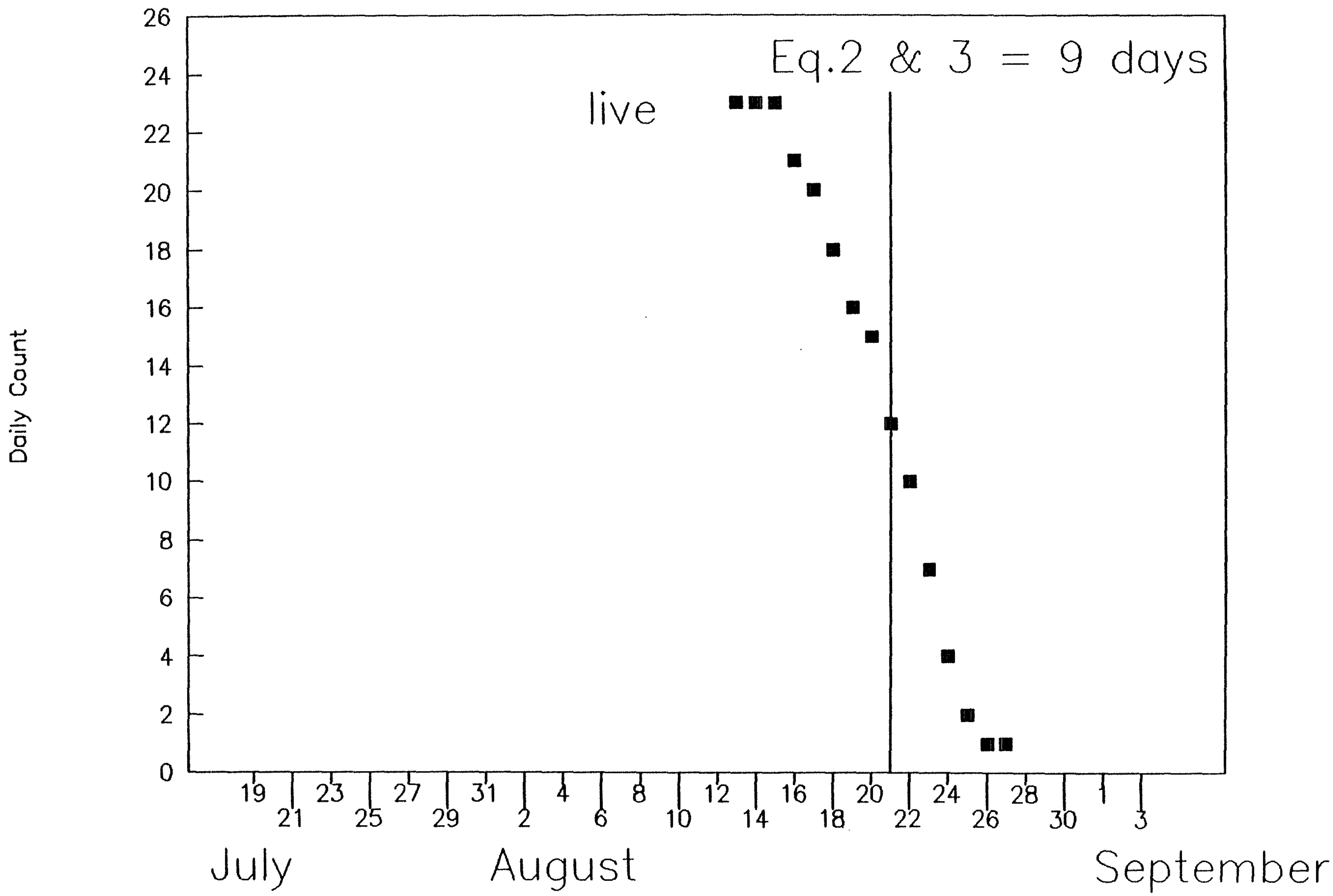


Figure 16. Estimates of stream life from August 13 tag release of male pink salmon, Humpy Creek, 1990.

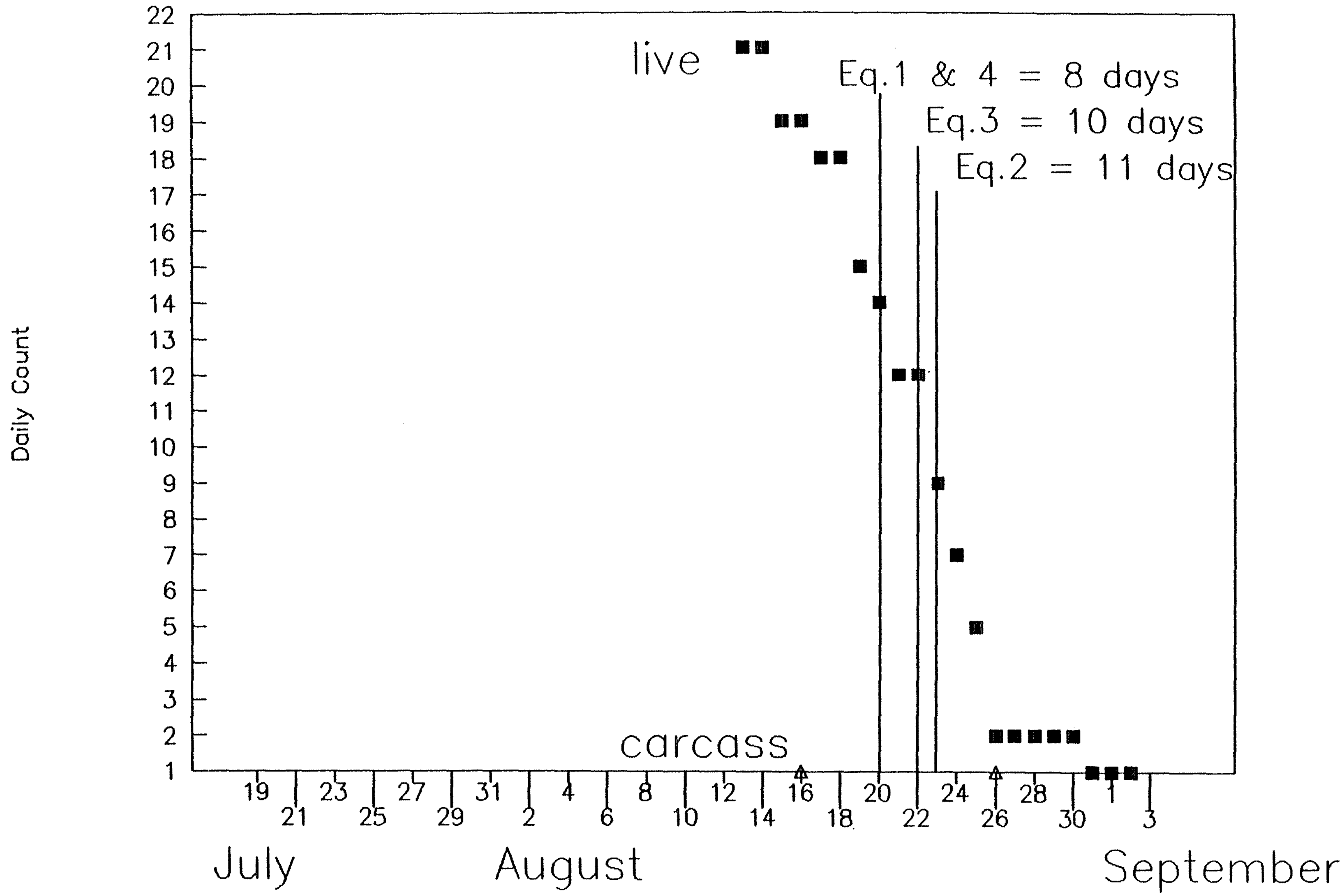


Figure 17. Estimates of stream life from August 13 tag release of female pink salmon, Humpy Creek, 1990.

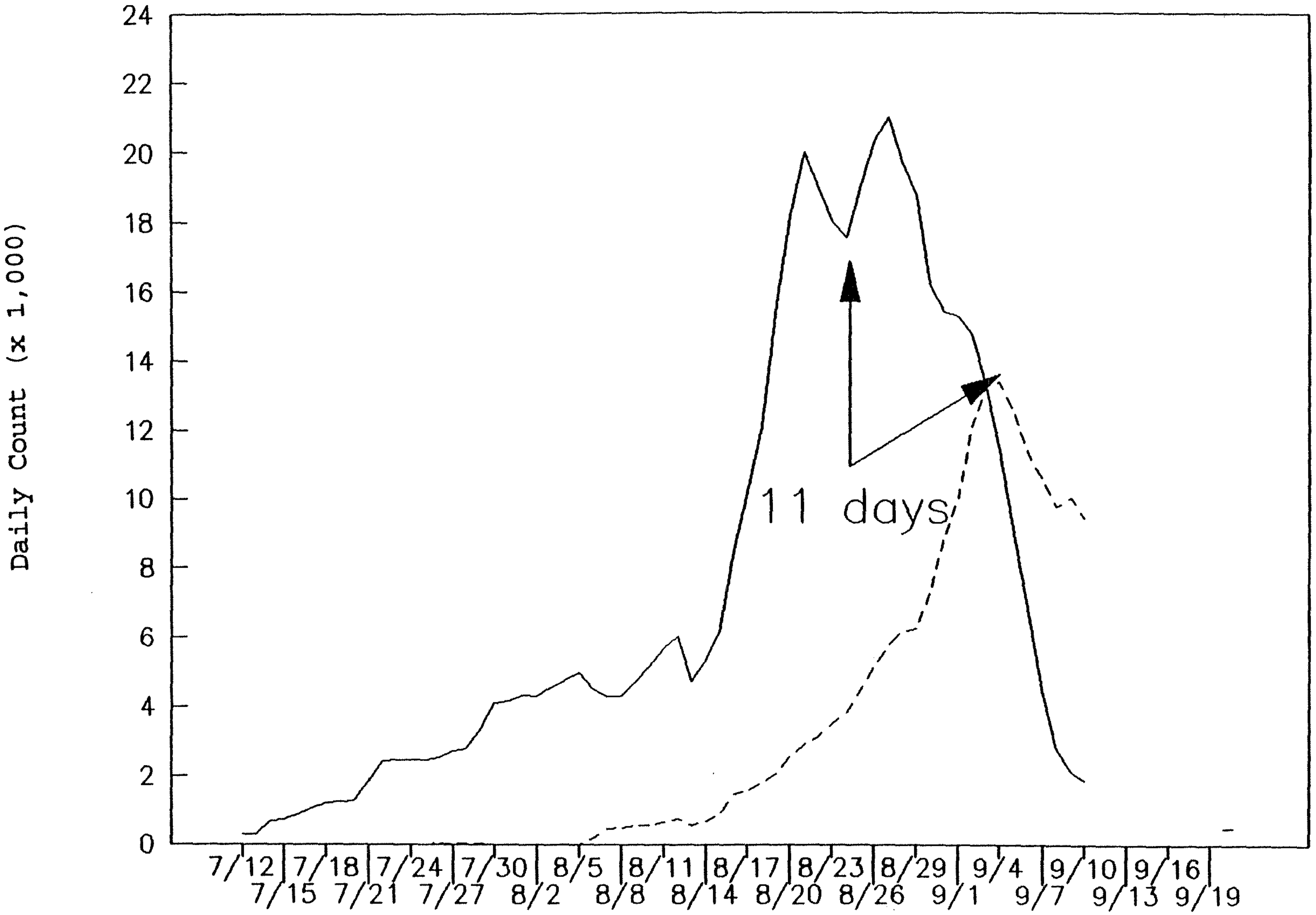


Figure 18. Estimates of stream life from 3-day moving average of live and carcass counts and number of days between peaks, Humpy Creek, 1990.

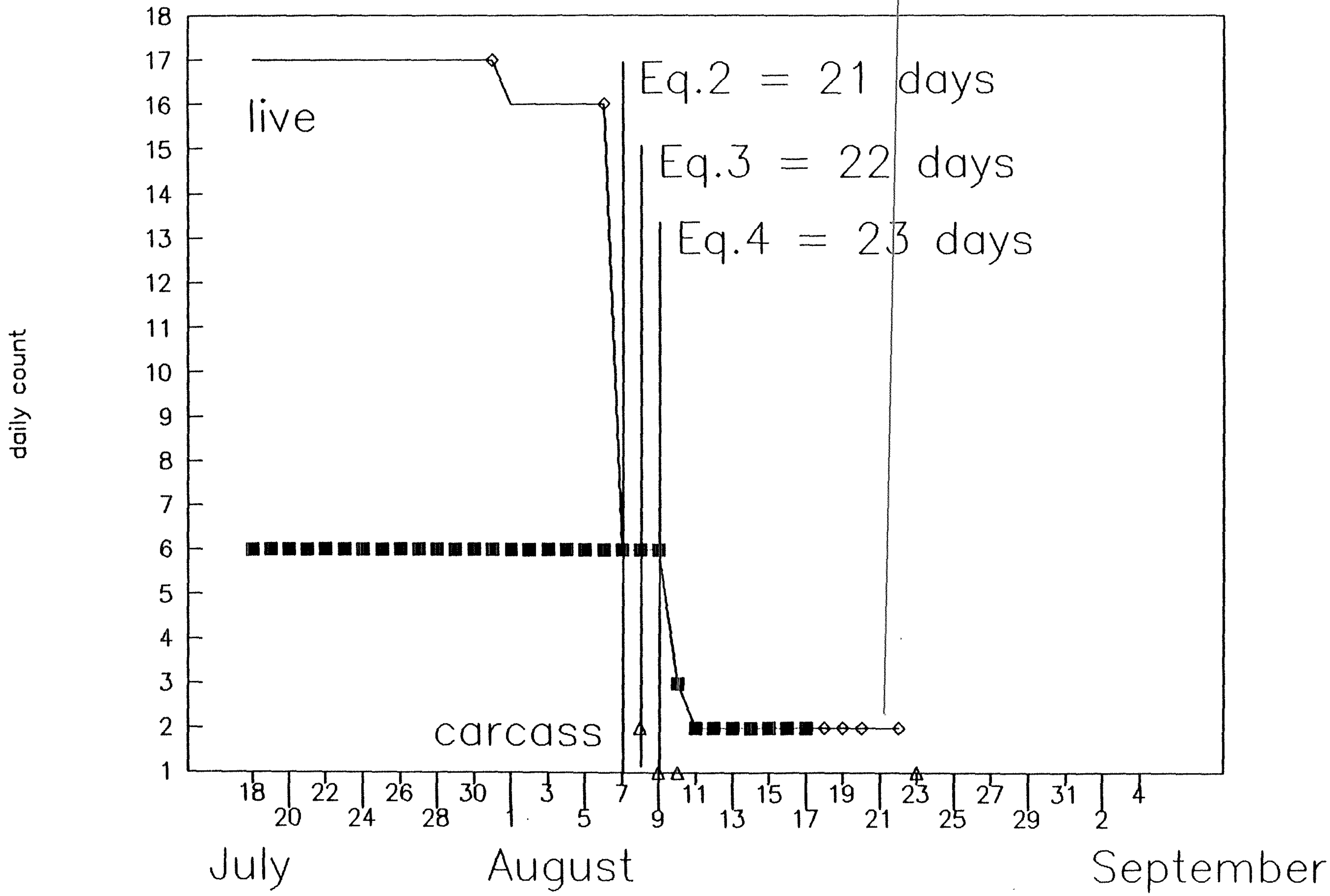


Figure 19. Estimates of stream life from July 18 tag release of male pink salmon, Port Dick, 1990.

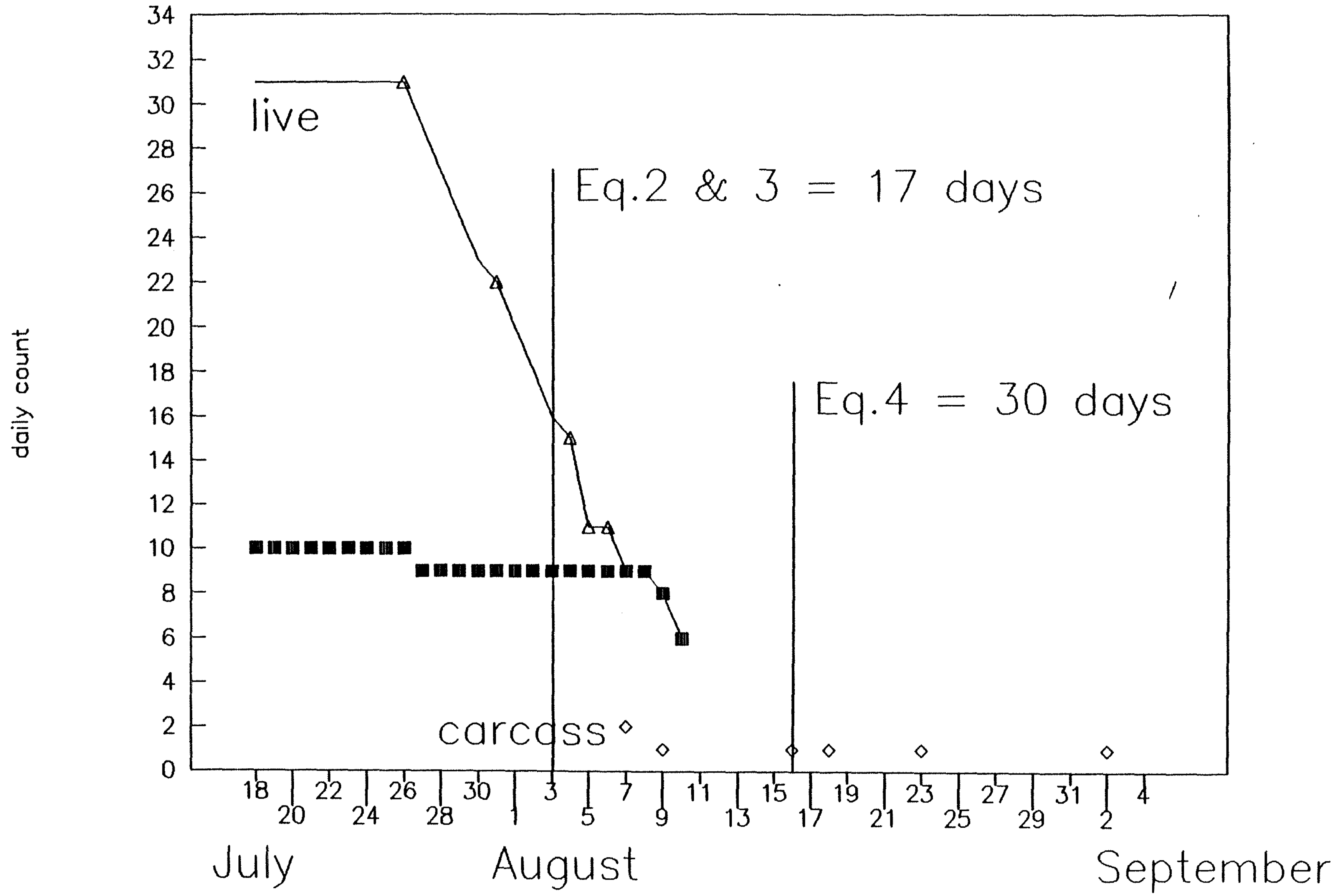


Figure 20. Estimates of stream life from July 18 tag release of female pink salmon, Port Dick, 1990.

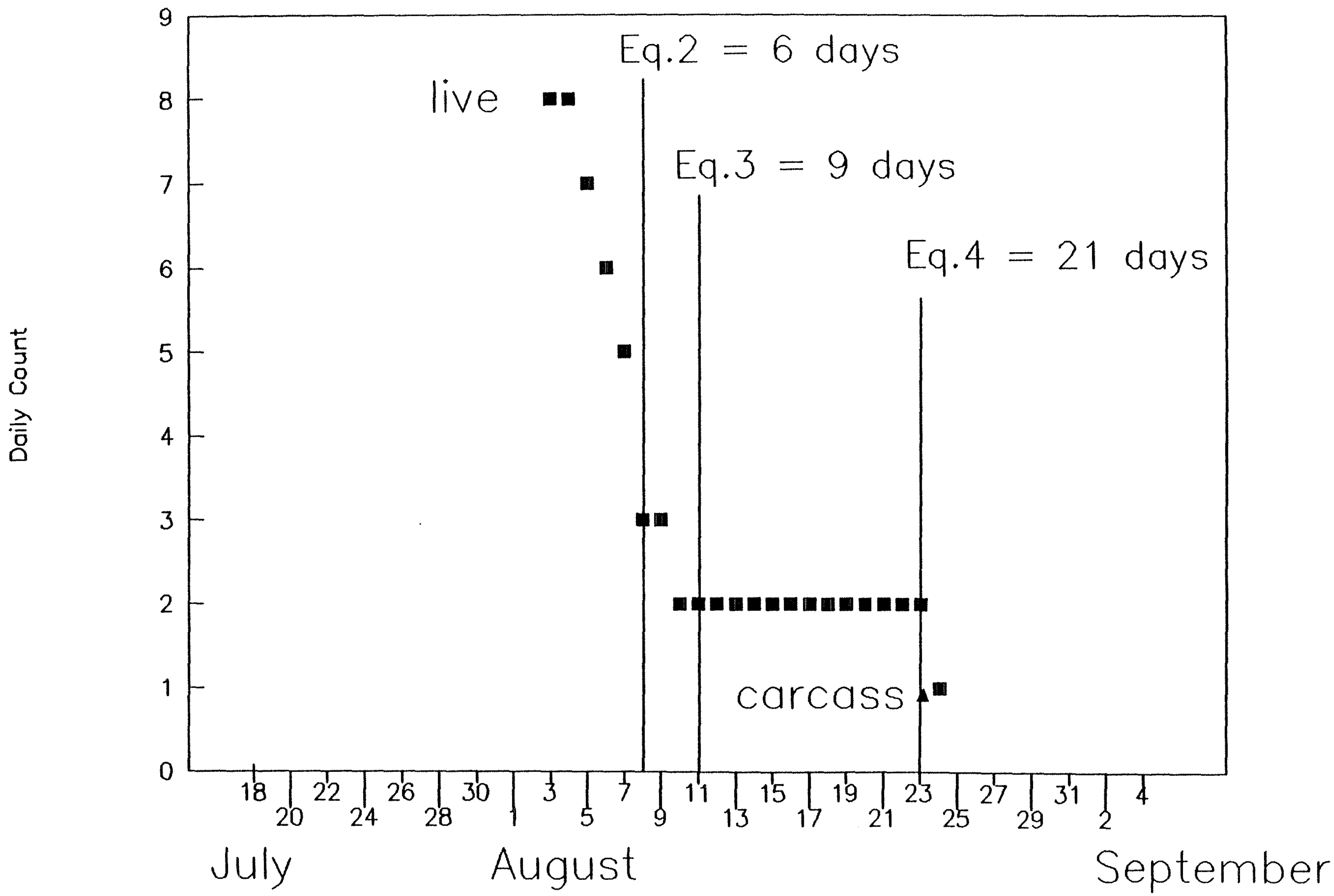


Figure 21. Estimates of stream life from August 3 tag release of male pink salmon, Port Dick, 1990.

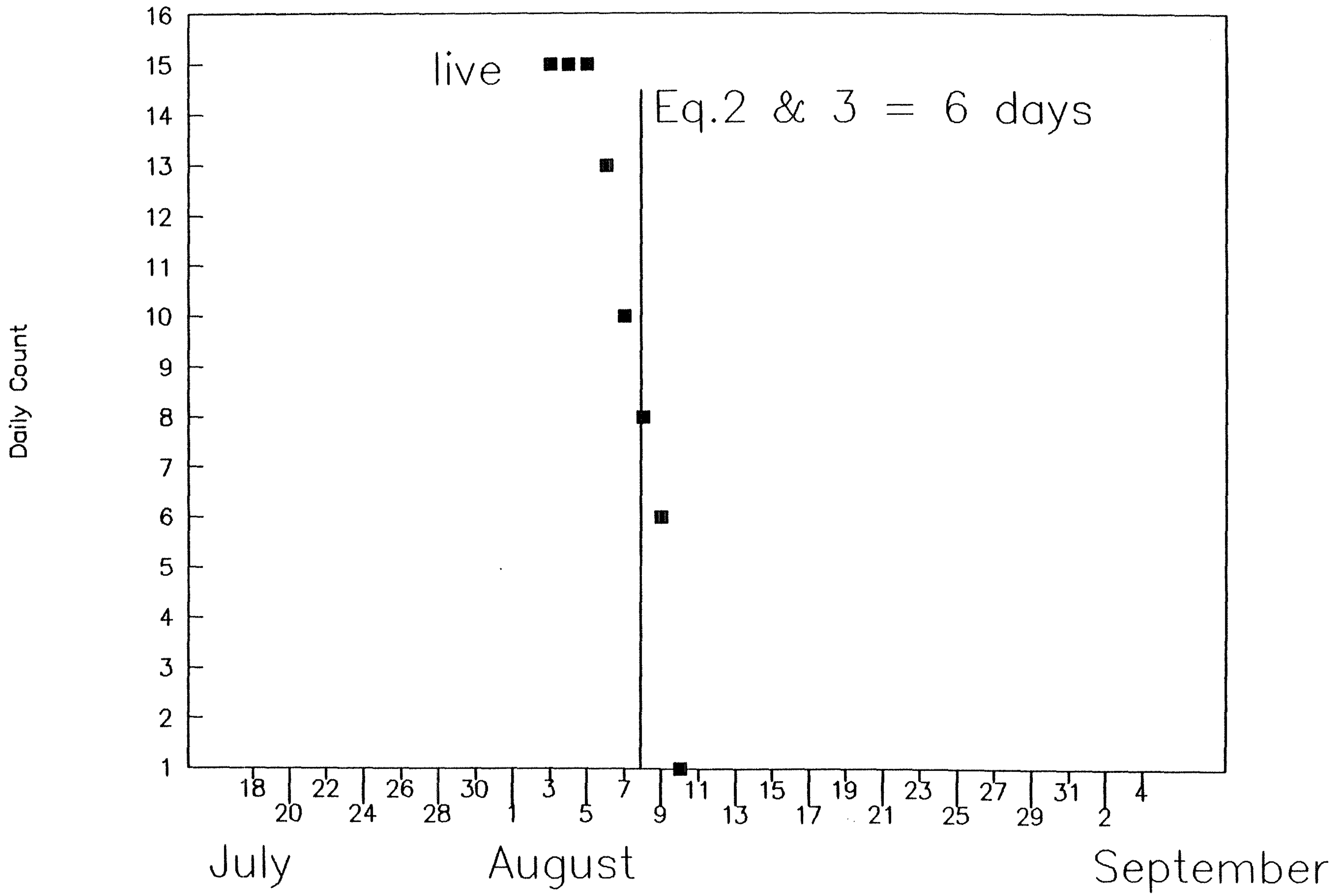


Figure 22. Estimates of stream life from August 3 tag release of female pink salmon, Port Dick, 1990.

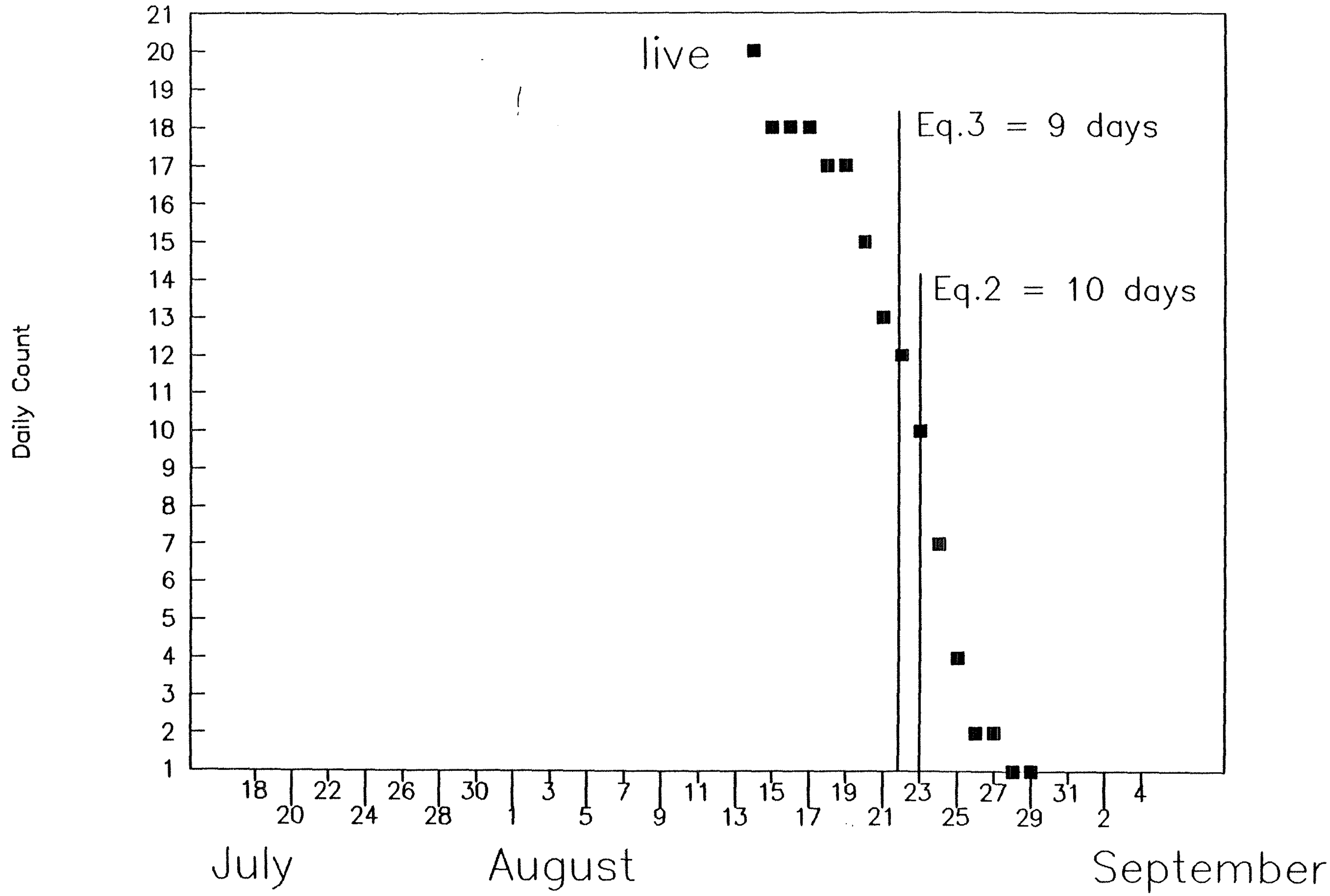


Figure 23. Estimates of stream life from August 14 tag release of male pink salmon, Port Dick, 1990.

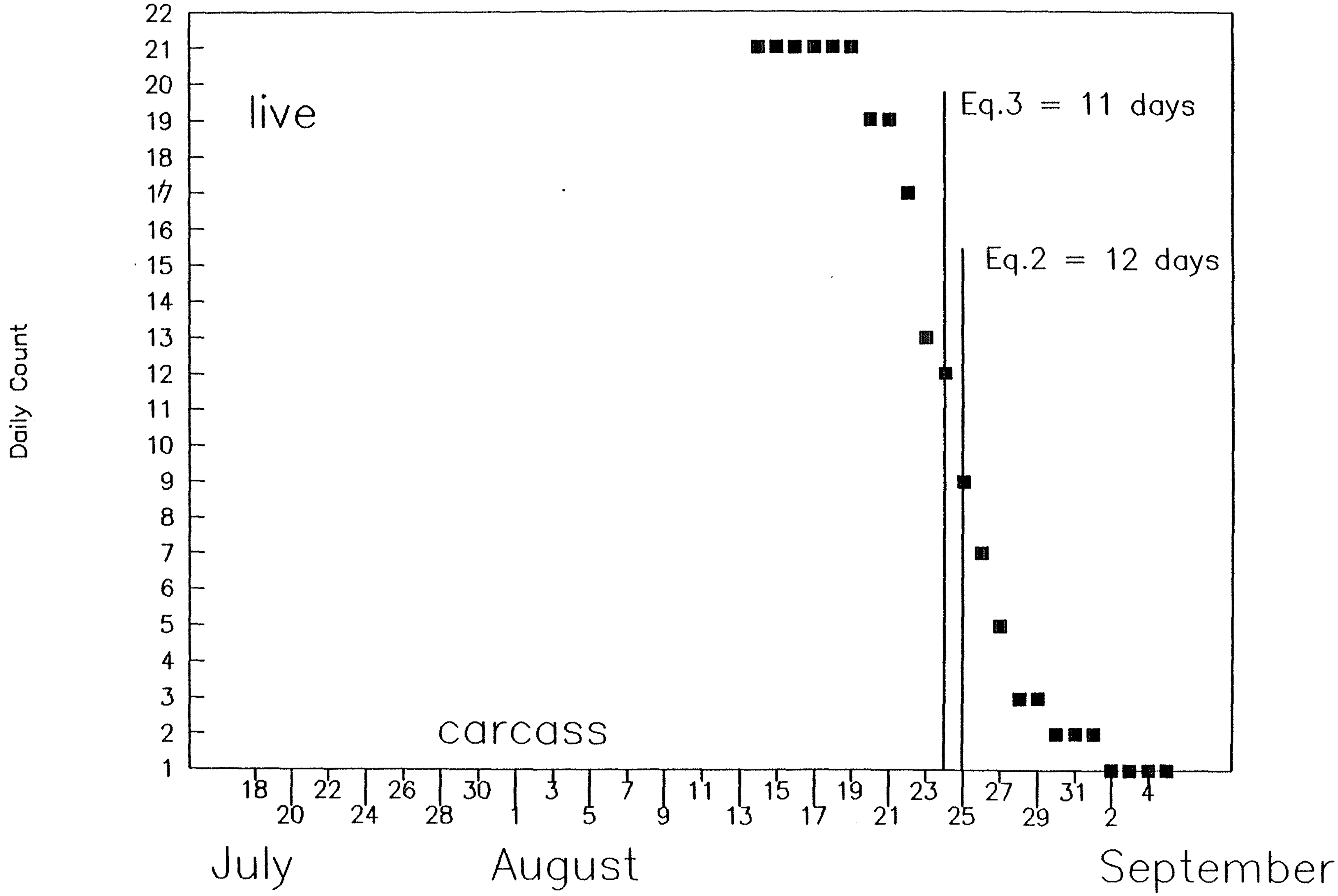


Figure 24. Estimates of stream life from August 14 tag release of female pink salmon, Port Dick, 1990.

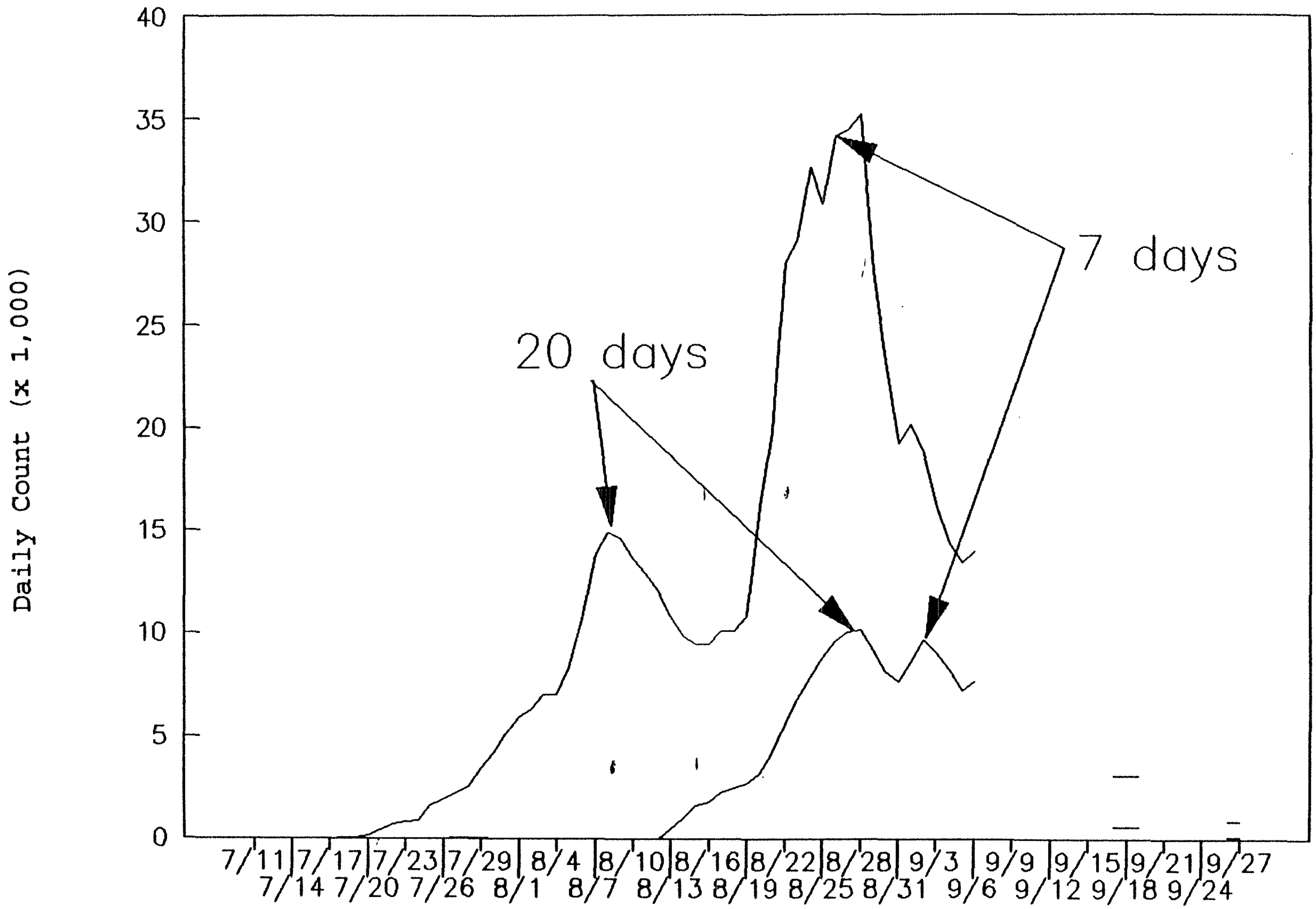


Figure 25. Estimates of stream life from 3-day moving average of live and carcass counts and number of days between peaks, Port Dick, 1990