Gerrard Rainbow Trout (*Oncorhynchus mykiss*) Spawner Migration and Residence Time as Estimated by Radio and Sonic Telemetry, 2004-2009

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EXECUTIVE SUMMARY

The effects of ecological alterations in the Kootenay Lake watershed on abundance of the highly valuable Gerrard-origin rainbow trout have been monitored by a time series of daily spawner counts extending from 1961 to the present. Escapement estimates have been derived since 1978 by expanding the peak count at the spawning area at Gerrard by a factor of 3.08. Alternative analyses integrating all of the count data in a season, such as the area-under-the-curve (AUC) methodology or maximum likelihood-based run timing models, are attractive relative to the peak count methodology in that they account for variability in the shape and breadth of the spawner abundance curve, which can be substantial. In 2004 we initiated a telemetry study of Gerrard rainbow trout spawner movements, utilizing sonic and radio tags, with a particular focus on acquiring the spawner residence time estimates necessary for both the AUC and maximum likelihood analyses.

Various fish capture methods were directed at the lower Duncan and Lardeau Rivers in 2004, with mixed success, but in 2005 and 2006 most tagged fish were captured using highly efficient tangle nets set in Kootenay Lake at the mouth of the lower Duncan River. A small number of captures using angling in the Lardeau River occurred during 2005-2007. We also monitored Gerrard rainbow trout tagged in Kootenay Lake as part of a separate study in 2008.

Abundance of Gerrard rainbow trout milling at the mouth of the Duncan River, as indicated by capture rate in the tangle net during spring 2005 and spring 2006, appeared to be at its highest in late March and the beginning of April. Radio-tagged fish migrated past the Lardeau/Duncan confluence and into the Lardeau River over an extended period between the last week of March and the first week of May. Radio-tagged spawners that migrated as far as Gerrard took between 5 and 20 days to travel between the Lardeau/Duncan confluence and the outlet of Trout Lake.

Several radio-tagged trout appeared to have spawned in locations other than Gerrard. Based on the total number of mature rainbow trout radio tagged at the mouth of the Duncan River in 2005 and 2006, and which went through the pattern of upstream migration followed by residence in a potential spawning stream and kelting past a fixed station (25 fish in total), 16% and 20% of radio-tagged trout spawned at other locations in the Lardeau River and at the Duncan Dam, respectively. Major, unexpected results of the study were the discovery of the population spawning below the tailrace of the Duncan Dam, and the discovery of potential methodologies for estimating their abundance including redd counts and nighttime boat surveys.

Residence time at Gerrard did not differ greatly for tagged male and female rainbow trout spawners (6.18 ± 1.33 days vs. 6.94 ± 1.16 days, respectively), and the overall residence time estimate for the six years' pooled telemetry data (including 2008 Kootenay Lake-tagged fish without sex data) was 6.94 days (n = 33, SE = 0.852 days). Spawning timing for radio- and sonic-tagged females appeared to be representative of untagged fish. However, males from the early part of the run timing curve appeared to be under-represented in our telemetry sample. We recommend, therefore, that additional

tagging and telemetry take place in future in order to increase representation of early-timed male rainbow trout spawners in the residence time estimate.

Two population estimation methodologies, based on (1) trapezoidal AUC calculations and (2) a maximum likelihood run timing model, which incorporated the pooled residence time estimate, an estimate of the variability of observer efficiency based on replicate counts, and periodic count data from 1961-2009, showed relatively good agreement in their estimates and comparable confidence intervals. Expanded peak counts were in reasonable agreement with estimates generated using the trapezoidal AUC and maximum likelihood approaches, being on average 9.3% and 8.3% higher, respectively. Expanded peak counts were however highly variable relative to population estimates based on all the count data, ranging from 70% (1966) to 176% (2008) of the maximum likelihood estimates. The ability of the trapezoidal AUC and ML approaches to account for variability in the form of the spawner abundance curve, as well as provide estimates of uncertainty for the population estimates, suggest that these approaches are preferable for future monitoring and analyses of Gerrard rainbow trout spawner abundance.

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BACKGROUND

The recreational fishery on Kootenay Lake, British Columbia, has long been one of North America's pre-eminent large lake fisheries, and it is a major contributor to the Kootenay region economy. Economic benefits to the area have not been evaluated in recent years (Andrusak 2005), but the value of the fishery in 1998 was estimated to be $2.74 million (Redfish Consulting 2001). Fishing effort is directed at kokanee salmon (*Oncorhynchus nerka*), bull trout (*Salvelinus confluentus*), and, particularly, a population of rainbow trout (*Oncorhynchus mykiss*) that are the world's largest, with individuals frequently obtaining sizes of 9 kg or more on a piscivorous diet (Cartwright 1961; Ashley et al. 1999; Redfish Consulting 2001). Most adults of this population spawn in the Lardeau River at Gerrard, located at the outlet of Trout Lake – fish belonging to the population are referred to as Gerrard rainbow trout.

The status of the Gerrard rainbow trout has been of interest for fishery managers for over 100 years. The first index of spawner abundance at Gerrard was provided by seine catch records of the hatchery that operated there from 1912 to 1952. Turning this index into a population estimate was challenging for fishery biologists, as the proportion of the run that was captured may have varied substantially (depending on water levels/debris jam conditions) and was ascertained only through opinions that could vary considerably between workers (reviewed in Irvine 1978). Daily, shore-based counts of spawners, the current method of enumeration at Gerrard, began in 1961 (some counts are available from the spawning periods of 1957-1960, and indicate very low abundance). The high quality of the viewing environment is well known (Northcote and Wilkie 1963; Irvine 1978). The spawning area at Gerrard is a local attraction for Kootenay region residents, who gather to watch the giant trout spawn in the clear outflow of Trout Lake each year. A time series of escapement data, therefore, exists since at least 1961 for evaluating the effects on the Gerrard rainbow trout of ecological alterations that include: 1) temporary cultural eutrophication from fertilizer plant operation; 2) the construction of Duncan and Libby dams; 3) hatchery supplementation of yearlings to the Gerrard population during the 1970s and 1980s; 4) introduction of more restrictive harvest regulations in 1987; and 5) experimental fertilization of the north arm of Kootenay Lake beginning in 1992.

The highest of these counts each year (annual peak counts) have frequently been used as an index of spawner abundance (e.g. Andrusak and Crowley 1976; Redfish Consulting 2001). Because a guardian employed by the British Columbia Ministry of Environment has been present to make adult rainbow trout counts at Gerrard throughout the spawning period, the area-under-the-curve (AUC) method (McNeil 1964; Hilborn et al. 1999), whereby the escapement estimate is calculated as the AUC (sum of the daily counts) divided by the average residence time, can also be applied to the count data. Peak counts at Gerrard from 1961-2009 are correlated ($r = 0.84$; Figure 1), but the AUC is attractive relative to the peak count as an index because the approach accounts for variability in the shape and breadth of the spawner abundance curve. This can be substantial at Gerrard. For example, the 1966 peak count of 249 was 2% greater than the 2001 peak count of 244, but the AUC index for 1966 is 97% larger (Table 5).

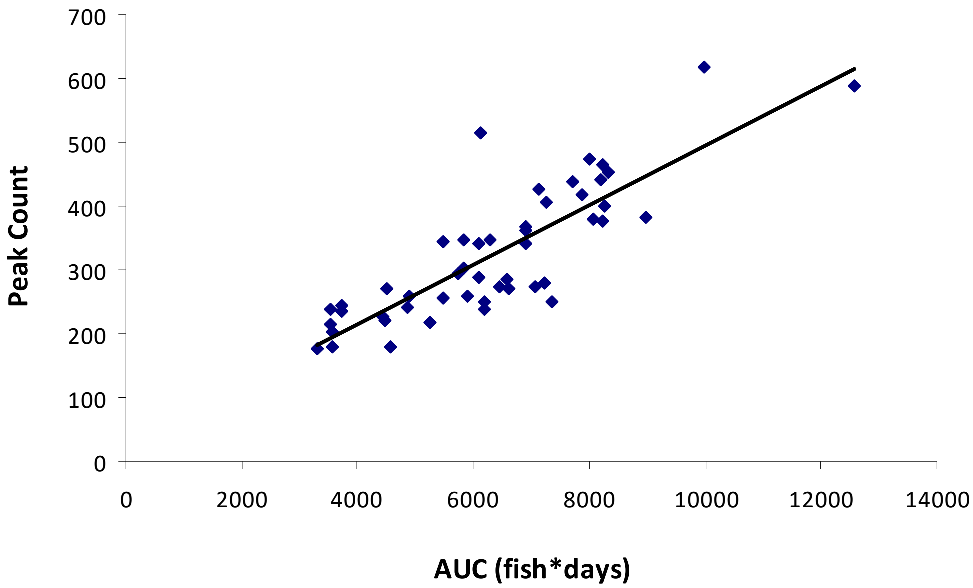

Figure 1. Correlation between peak count and area-under-the-curve (AUC) indices of abundance based on escapement data at Gerrard, 1961-2009.

Both the peak count and area-under-the-curve (fish*days) are indices of abundance and not escapement estimates. There are a number of reasons why it is desirable to know the actual escapement, such as i) monitoring population sizes relative to conservation guidelines, ii) exploitation rate monitoring, and iii) utilizing total adult recruitment (catch + escapement instead of an index of just one) for evaluating population abundance and responses to management actions. The estimation of the Gerrard population size has been identified as a specific, high priority objective in the recent Kootenay Lake Gerrard Rainbow Trout Management Plan (Andrusak 2005).

As part of the last review of the Gerrard rainbow trout escapement estimation procedure, Irvine (1978) developed an expansion factor for transforming the peak count index into an estimate of the total escapement. The expansion factor represented the average ratio of peak counts to population sizes for two years for which independent population estimates existed, 1966 and 1967. In 1966 the estimate of 650 fish was computed according to the AUC procedure in its simplest form (McNeil 1964; Hilborn et al. 1999), whereby the escapement estimate is calculated as the AUC (sum of the daily counts) divided by the average residence time. The estimate of average residence time (11.3 days) was acquired by observing individual fish with distinguishing features over the course of the spawning period (Hartman and Galbraith 1970; Irvine 1978). In 1967 spawners were enumerated as they passed through a counting fence in the lower Lardeau River. The estimate of 639 spawners was an expansion of the 574 fish counted reflecting the fact that the fence had to be removed before the spawning migration period had ended (Irvine 1978). Population estimate: Peak count ratios for 1966 and 1967 were, respectively, 2.61:1 and 3.55:1 - these were averaged to give the current expansion factor of 3.08.

Turning the AUC index into a population estimate requires estimates for two parameters, residence time or survey life *s* and observer efficiency *v* (Hilborn et al. 1999) as described above. A number of recent studies of steelhead (anadromous *Oncorhynchus mykiss*) abundance in British Columbia have made use of the innovative procedure of deploying radio tags in migrating adults to estimate *s* and *v* directly (Webb et al. 2001; Korman et al. 2002; Hagen 2001). Because each radio-tagged steelhead had also been outfitted with a large orange plastic spaghetti tag, observer efficiency in counting areas was estimated by comparing the number of spaghetti-tagged steelhead seen to the number known to be present from the telemetry record. The residence times of radio-tagged steelhead were the differences between times of entry into and exit from the counting area, which were estimated directly from frequent tracking observations and averaged for each sex.

We had two objectives at the outset of the study. First, we wished to make use of the technique of radio telemetry to estimate residence time of the rainbow trout spawners at Gerrard, by deploying a sample of radio tags in adult fish over a three-year period beginning in 2004. Second, we wished to evaluate movements of rainbow trout spawners along the length of the Lardeau and Duncan rivers. Beginning in 2005, a small sample of sonic tags were also deployed as part of this study and augmented residence time data. Sonic tags deployed during an experimental study of rainbow trout fishing mortality (Thorley and Andrusak 2009) provided additional residence time data between 2007 and 2009, with the prospect of additional information to come in future years. Results from the first six years of the study, conducted during consecutive spring spawner migrations between 2004 and 2009, are summarized in this report.

METHODS

Fish Capture, Tagging, and Sampling

The two primary fish capture methods we initially set out to evaluate for feasibility, during the first year of the project in spring 2004, were angling and tangle netting, which have proven successful for capturing steelhead and rainbow trout on spawning migrations elsewhere in British Columbia. Fish capture efforts took place during 5 field trips to the Lardeau/Duncan system in 2004: March 30 to April 1, April 6 to April 8, April 13 to April 15, April 20 to April 21, and April 26 to April 27. Prior to April 15, all fish capture activities took place in the lower Duncan River (downstream of the Lardeau confluence), because of our intention for learning about rainbow trout migration along the length of the Lardeau/Duncan system.

In 2004 we had two tangle nets manufactured specifically for this project, which consisted of 30 m and 15 m lengths, respectively, of 8.9 cm (3.5”) mesh monofilament gillnet of 2.4 m (8’) depth, with plastic floats and a leadline sufficient for use in heavy currents attached to each. The lower Duncan River appeared to be poorly suited for tangle netting, lacking deep eddy lines extending out from shore adjacent to potential holding and traveling water. We set the nets at three locations, choosing two for repeated efforts. One of these was the seam of potential holding water created by the merging of currents from the Lardeau and Duncan Rivers at their confluence, the other was a deep eddy line extending out from the head of a log jam and adjacent to faster water. The 30 m net was deployed at the Lardeau/Duncan confluence, and held in place by a rope attached to a 20 kg lead anchor. Ropes attached to logs protruding from the jam at the other location were used to suspend the 15 m net along the eddy line.

Poor success during spring 2004 using the anchored tangle nets prompted us to experiment with other netting methods. On April 6 the tangle nets were joined and set along the edge of the silt plume at the mouth of the Duncan River. On April 13 and 14 we drifted the tangle nets through runs in the lower Duncan of even flow and sufficient depth, until all panels had been destroyed on submerged but unseen wood debris.

We angled the lower Duncan River between March 30 and April 14, 2004 using three techniques: float fishing using salmon egg bait, casting lures (primarily large spoons), and trolling lures (plugs and spoons) by backing the boat down through potential holding water.

In response to poor capture success in the lower Duncan River, after April 15 in 2004 we conducted all fish capture activities in the Lardeau River itself, in an approximately 8 km section extending downstream of the spawning area to Hope Creek. Angling using bait and lure were employed exclusively.

During spring 2005 and spring 2006 we made concerted efforts to deploy radio tags at the mouth of the Duncan River in Kootenay Lake, to ensure that spawner movements throughout the system were investigated. We employed a specially-designed, 45 m (150’) long by 6 m (20’) deep, 11.4 cm (4.5”) mesh braided nylon gillnet as a tangle net set along the edge of the silt plume at the mouth of the Duncan River during eight visits between March 3 and April 28, 2005, and 14 visits between February 1 and April 19, 2006. The netting period was planned in advance to cover the entire run timing. The net, which had plastic floats and a leadline sufficient for use in current attached to the top and bottom edges of the net, respectively, was set at dusk and tended for a period of 1-4.5 hours. We patrolled along the net by spotlight-equipped boat at 15-20 minute intervals, retrieving fish that had become tangled in the net and transporting them to the beach in a plastic bin large enough to hold several adult rainbow trout. A crew of three was required for the simultaneous tasks of boat handling in the vicinity of the net, directing a spot light to illuminate the net, untangling fish from the net, and transferring fish untangled from the net to the plastic bin using a large landing net.

Because of relatively lower success capturing male Gerrard rainbow trout at the mouth of the Duncan River by tangle net in 2005 and 2006, we also expended a small amount of effort angling in the Lardeau River focused on collecting additional male samples, between April 12 and April 18 in 2005, on April 19 and April 20 in 2006, and on April 13 and April 18 in 2007. Twenty sonic tags were also surgically implanted in large rainbow trout caught by angling in Kootenay Lake, during a separate study; methods are presented in Thorley and Andrusak (2009).

No anaesthetic was used on individual Gerrard rainbow trout prior to handling, because of the cold water temperatures during the period of fish capture. The exceptions to this general approach were a single male rainbow trout that received a surgically implanted radio tag in 2005, and 1 female in 2005, 5 females in 2006, and 2 males and 1 female in 2007 that received surgically implanted sonic tags. To facilitate handling and reduce stress on the fish, trout were held in zippered tubes made from black, rubberized fabric with flow-through ends. The fish, already quieted from the exhaustion of being captured, were relatively docile when held in this manner. With the exception of anaesthetized fish receiving the surgically implanted radio and sonic transmitters, rainbow trout received radio transmitters inserted orally into the fish's stomach with the aid of a length of flexible, plastic tubing, with the antenna left to protrude from the fish's mouth. Radio tags utilized for this study were manufactured by Lotek Wireless Inc. (Newmarket, ON). Tags used were model MCFT-3A (16 mm diameter, 46 mm length, 16 g weight in air, operational life 761 days). Sonic tags used were Vemco Ltd. (Shad Bay, NS) model V9-2H-R256 (with a 50-150 off time, 9 mm diameter, 30 mm length, 5 g in air, operational life 147 days+).

Trout receiving surgically implanted radio and sonic tags were anaesthetized in water containing diluted clove oil at a concentration of 100 PPM (Prince and Powell 2000). Tags were inserted through a 3-4 cm incision in the abdominal cavity that was then sutured. The antenna of the radio tag protruded from the fish's side through a 16-guage-needle hole created in the abdominal wall posterior to the incision.

Biological sampling for all fish captured was standardized, with the exception of applying different visual tags during the three years. After inserting the radio tag, in 2004 a long white spaghetti tag was threaded and tied through a puncture across the fish's back, at the base of the dorsal fin, to aid visual identification on the spawning areas of Gerrard. The large size of the tag applied in 2004 was considered inappropriate for continued use, after learning that some radio-tagged fish were likely to be recaptured in Kootenay Lake, and that the tags were not highly visible at Gerrard unless the guardian spotted the fish at relatively close range. In 2005 and 2006 a pair of small, T-anchor tags were inserted into the fish's back along the base of the dorsal fin, to identify the fish in possible recapture events. During sampling in all years a small section of the adipose fin was removed and stored, along with a label, in a vial of 95% ethanol for genetic analysis. Following this a sample of at least 10 scales was removed for aging analysis, taken from a location two to three rows above the lateral line and between the posterior insertion of the dorsal fin and origin of the anal fin. Sex, fork length, girth, spaghetti or anchor tag number, radio tag frequency and code, genetic sample number, condition at time of release, and tagging location and time were recorded. In 2004 two fish were held after the completion of sampling for at least 45 minutes prior to release on the same day, the others caught in that year were released the following day after being held in the tube overnight. In 2005 and 2006 captured rainbow trout were held at the mouth of the Duncan River for 20-40 minutes after tagging, then released after the radio tag had been inspected a second time.

As the first step in scale analysis a suitable scale was identified under 47X magnification on a microfiche reader-printer, and photograph was made. Cleaning of scales in general was not required. Regions of closely spaced circuli were identified as annuli. Each photographed scale was measured along the focus-anterior axis, the radius of each annulus and the outer scale margin being recorded. Spawning checks on the scale, signalling a previous spawning event, were identified by patterns of broken or resorbed circuli at the annulus. We investigated the relationship between fish length and scale radius for Gerrard rainbow trout using ordinary least-squares regression. Juvenile rainbow trout scales included in the length/scale radius regression were collected in September 2005, April 2006, and September 2006 during a separate study of juvenile rainbow trout habitat use and abundance in the Lardeau River (Decker and Hagen 2009). Lengths-at-age were then back-calculated using the Fraser-Lee equation (Duncan 1980):

$$l_k = c + \frac{(L - c)r_k}{R}$$

where: l_k = the length at age k,
c = the constant of proportionality from the fish length/scale radius regression
L = the fish length at time of capture
r_k = the radius of the annulus at age k
R = the scale radius at the time of capture

Radio Telemetry

In the spring of 2004, all radio telemetry data was collected by mobile tracking. Radio reception for surveys by road or on foot along the river channel at Gerrard was through a two-element antenna attached directly to a portable receiver (Lotek Wireless Inc., Newmarket ON). Tracking from a pickup truck along the Meadow Creek-Trout Lake road, which took place on April 16 and April 21, 2004, was only partially successful and not pursued further. A helicopter survey of the entire Lardeau/lower Duncan system took place on April 27. A two-element antenna was attached to the base of one of the helicopter's skids, and was oriented with the elements perpendicular to the water surface. Radio telemetry observations at Gerrard were made daily by the guardian during the period that radio-tagged rainbow trout were using it, between April 21 and May 20, from the locations utilized to count spawners. The guardian determined carefully the direction of the strongest signal and recorded the power, in order to determine whether the radio signal was in fact coming from within the counting area.

During spring 2005, most fish captures were made at the mouth of the lower Duncan River, so the opportunity existed to observe passage of radio-tagged, adult rainbow trout through the lower Duncan River, and between the Lardeau/Duncan confluence and the spawning grounds at Gerrard. To ensure that the passage of radio-tagged fish past the confluence, or their residence in the vicinity of the Duncan Dam, could be recorded with certainty, we established a fixed station at the Lardeau/Duncan confluence on April 14. The fixed station consisted of a data-logging receiver, housed in a metal box screwed to a tree trunk at the confluence, connected to three, four-element directional antennae fixed to locations higher up the tree trunk. The antennae were directed: i) downstream in the lower Duncan River, ii) upstream in the Lardeau River, and iii) upstream at the tailrace of the Duncan Dam, where redds and a large, dead rainbow trout spawner had been observed for the first time in decades during our angling and netting efforts in the lower Duncan River in spring 2004. The fixed station remained operational until June 1, but it should be noted that due to a dead battery it was down between April 23 and April 26.

During spring 2006, the fixed station at the confluence of the Lardeau and Duncan Rivers was operational by March 23 and ran until May 29. To record entry of radio-tagged rainbow trout into the lower Duncan River, a fixed station with upstream and downstream antennae was erected approximately 300 m upstream of the mouth and operated from March 30 to May 5 when it was inundated by the rising level of Kootenay Lake. A third fixed station, designed to identify the passage of radio-tagged fish over the resistivity counter located approximately 3 km from Trout Lake, operated between April 14 and May 24 at a low gain setting with a single antenna pointed directly across the panels. Acoustic receivers (Vemco) located at Mobbs Creek (at the downstream extent of the Gerrard spawning area), at the bridge over the Lardeau River at the outlet of Trout Lake (the approximate upstream extent of spawning, and at the scaffolding used for counting purposes and were located such that presence of a sonic tagged fish in the counting area could be identified positively.

Mobile radio tracking of the lower Duncan River by boat took place on April 5 and April 12 in 2005, prior to the erection of the fixed station on April 14, and on March 29 and April 5, 6, and 20 in 2006. Tracking along the Meadow Creek to Trout Lake highway took place only in 2006, on April 8, 12, and 19. Mobile tracking between Kootenay Lake and Gerrard by helicopter took place on April 7 and April 22 in 2005, and on April 21 in 2006. Radio telemetry observations at Gerrard in 2005 and 2006 were made approximately once daily in the same manner that they were in 2004, on all dates that the guardian was present (2005: April 8 to May 15; 2006: April 14 to May 16).

Spawner abundance estimation

Spawner residence time. Spawner residence time for radio-tagged or sonic-tagged fish was estimated as the number of days on which they were present in the Gerrard counting area during the counting period. For radio-tagged fish, this was simply the number of days on which radio-tagged fish were detected, as radio telemetry observations were made daily at the same time as visual counts of spawners. For sonic-tagged fish, whose presence was recorded continuously on fixed receivers, their presence at Gerrard was only included in the residence time estimate if they were detected at a time of day coinciding with the morning or evening counting period. Although during most years the time of observations was not recorded, for the purposes of this analysis the counting periods were assumed to be 600-900 hrs and 1600-1900 hrs, daily.

Observer efficiency. An estimate of observer efficiency (the proportion of the total number of fish present that are visually detected) for spawning Gerrard rainbow trout is not yet available. Given the high level of water clarity at the site and good visibility of the large Gerrard rainbow trout spawners, an observer efficiency of 1 (100%) is assumed for this analysis.

Replicate spawner counts conducted by a second, experienced observer during 2008 and 2009, however, provide the basis for an estimate of inter-observer variability. Daily observer error was estimated as the average difference between the mean of the two counts (Hill 1997). This was assumed to be larger at larger abundances, so daily observer error estimates were standardized through division by the mean of the two counts. Squared, standardized daily error estimates were used as the basis for estimating standard deviation for the observer efficiency estimate (of mean = 1) in later steps.

Trapezoidal AUC methodology. A trapezoidal approximation to the area-under-the-curve (*AUC*) is given by:

$$AUC = \sum_{i=2}^{n} (t_i - t_{i-1}) \frac{(x_i + x_{i-1})}{2} \tag{1}$$

where t_i is the day of the year and x_i is the number of spawners observed for the i^{th} survey (Hilborn et al. 1999). At Gerrard, where counts are made daily where possible, the AUC over most of the spawner abundance curve is simply the sum of the average daily counts, with equation (1) being utilized only to estimate the AUC for dates where observations are missing. When the first or last counts are non-zero, which occurs frequently at Gerrard, the AUC for each of the unsurveyed tails of the spawner abundance curve is estimated as:

$$AUC_{tail} = \frac{x_{tail} s}{2} \tag{2}$$

where x_{tail} is the first or last count and s is the spawner residence time (survey life s in Hilborn et al. 1999). For the time series of Gerrard rainbow trout spawner counts, total escapement for each year was estimated by:

$$E = \frac{AUC}{s * v} \tag{3}$$

where v is the observer efficiency estimate (1 in our case).

Uncertainty in mean estimates of residence time (s) and observer efficiency (v) were incorporated into estimates of N using the method of stochastic (Monte Carlo, parametric bootstrap) simulation (Haddon 2001). Mean residence time and observer efficiency were stochastically simulated 2000 times based on standard deviation estimates for each parameter. For each iteration, stochastically generated mean s and v estimates were factored together and divided into the trapezoidal AUC estimate for each year. Upper and lower 95% confidence limits for the spawner escapement estimate (E) were identified as the 2.5% and 97.5% percentiles, respectively, of the 2000 iterations.

Hilborn et al. (1999) likelihood model. For comparative purposes, we also applied the spawning timing model of Hilborn et al. (1999), which provides a robust methodology for estimating uncertainty in the population estimates and performs well for instances where first or last counts are relatively high. The method assumes underlying models of fish arrival and departure (in the case of rainbow trout, which do not die after spawning) that are symmetrical, but with the departure model lagged by a period equal to one residence time (s). After trials of several candidate statistical distributions for modeling arrival and departure timing for Gerrard rainbow trout, we decided on the flexible beta distribution (Hilborn et al. 1999) as the most suitable. The number of fish present at any point in time (N_t) is given by:

$$N_t = A_t - D_t \tag{4}$$

where A_t and D_t are the cumulative numbers of arrivals and departures to day t, as predicted by the factoring estimated escapement (E) with models of arrival and departure timing, respectively (Hilborn et al. 1999). The predicted count of fish on a given day (C_t) is assumed to be equal to the number of fish present scaled by the observer efficiency v:

$$C_t = vN_t \tag{5}$$

For simplicity, the Hilborn et al. (1999) approach assumes deterministic dynamics, and that all error is in the observation process. The observation error model we used assumed a statistical distribution of count data relative to model predictions termed the pseudo-Poisson in Hilborn et al. (1999). Variance is assumed to be proportional to the expected value of the observation, as in the Poisson distribution, but the error is normally distributed:

$$\sigma^2{}_t = q\ C_t\ . \tag{6}$$

The constant q in equation 6 must be estimated. The likelihood of the observations (x_t), given the parameters, is given by

$$L(x \mid C) = \prod \frac{1}{\sigma_t \sqrt{2\pi}} \exp\left(\frac{(x_t - C_t)^2}{2\sigma^2{}_t} \right). \tag{7}$$

The Hilborn et al. (1999) maximum likelihood method also allows for the incorporation of uncertainty in residence time (s) and observer efficiency (v). Assuming normally distributed error with means of $\bar{s}$ and $\bar{v}$ and standard deviations of σ_s and σ_v, the likelihood components added to equation (7) are

$$L(s \mid \bar{s}, \sigma_s) = \prod \frac{1}{\sigma_m \sqrt{2\pi}} \exp\left(-\frac{(s - \bar{s})^2}{2\sigma^2{}_s} \right) \tag{8}$$

$$L(v \mid \bar{v}, \sigma_v) = \prod \frac{1}{\sigma_m \sqrt{2\pi}} \exp\left(-\frac{(v - \bar{v})^2}{2\sigma^2{}_v} \right)$$

$$L_{total} = L(x \mid C) L(s \mid \bar{s}, \sigma_s) L(v \mid \bar{v}, \sigma_v)$$

(Hilborn et al. 1999). The maximum likelihood fit of the model parameters E, q, s, v, and two parameters of the beta distribution, α and β, was conducted using the Solver non-linear iterative routine in Microsoft Excel.

We calculated confidence limits for estimates of spawner abundance using the method of likelihood profile, which is based on the observation that

$$2(L(E) - L(E)_{\min}) \tag{9}$$

is approximately Chi-square distributed with 1 df (Hilborn et al. 1999). For each level of spawner abundance, evaluated systematically at higher and lower values relative to the most likely spawner abundance estimate, we calculated the maximum likelihood as described above but with the level of spawner abundance E no longer free to vary. We identified upper and lower 95% confidence limits for the escapement estimate for each year using the Solver routine in Microsoft Excel, by searching for levels of E higher and lower than the maximum likelihood E, respectively, corresponding to a chi-square probability of 95%.

RESULTS AND DISCUSSION

Fish Capture

Captures in 2004. Our initial goal of capturing and radio-tagging Gerrard rainbow trout in the lower Duncan River was not feasible in 2004, as we had very poor success (Appendix 1a) capturing rainbow trout by either tangle net or angling. Suitable locations for deploying the tangle net were lacking, as the lower Duncan River has relatively poorly defined holding water with constrictions and large, fishable eddies notably absent. From three locations fished, no rainbow trout and only 2 bull trout, including one adfluvial adult, were captured in 11.5 hours total effort. It was also obvious that small floating debris was accumulating rapidly in the nets, making them substantially more visible in the water.

The fixed tangle net was also set for three hours along the edge of the silt plume at the mouth of the Duncan River in Kootenay Lake, on April 6, 2004. A single, 70 cm bull trout was captured. However, we felt at the time that the method could prove effective for Gerrard rainbow trout as well, perhaps with some modifications to the technique. We were concerned that the 2.4 m depth of the net may not be sufficient to intercept cruising Gerrard rainbow trout prior to entering the Duncan, and also felt that the net's effectiveness might be improved at night. At night debris particles clinging to the net would be less visible, and furthermore mature Gerrard rainbow trout had been observed near the Duncan River mouth at night before, swimming in shallow water at the time of burbot spawning surveys in March (BC MOE data on file). Destruction of the nets when used as drifting tangle nets in the lower Duncan River precluded further experimentation in spring 2004.

The only Gerrard rainbow trout captured in the lower Duncan River in 2004 was a female caught and tagged on April 13, in a 15 m section of tangle net stretched perpendicular to the current and drifted through the Lardeau/Duncan confluence pool (Appendix 1a). This was the first pass using the drifting tangle net, suggesting great promise for the method. However, we were only able to make a total of 11 passes with the tangle nets, capturing an additional three bull trout, before all three 15 m tangle net panels had been destroyed on the abundant, submerged wood in the lower Duncan channel. Stronger nets would be more durable, but routinely hooking them up on submerged wood debris in swift currents would also constitute a safety hazard. Therefore, we do not consider the method practical for the area.

Angling has proven to be an ideal method for collecting steelhead trout, which are of comparable body size, for tagging and biological sampling. The fish are highly catchable, the gear simple and portable, and the exertion associated with capture renders them temporarily docile, meaning that tagging and sampling can take place rapidly and without anesthetic at cold water temperatures. In the lower Duncan River, however, angling with salmon egg bait and lures was ineffective at catching Gerrard rainbow trout during spring, 2004. A total of 62 angler*hours (both methods combined) were expended between March 30 and April 14 on three different field trips, and the only captures were 35 bull trout (including adfluvial adults) and 6 mountain whitefish (Appendix 1a). Why angling was successful for bull trout and not Gerrard rainbow trout was unclear. In general, the lower Duncan River did not appear highly suitable for angling for low abundances of fish or for moving fish, as holding water was not well defined. A more important factor affecting our success may have been the fact that the water of the lower Duncan River was frequently high and turbid water in spring 2004, which may have affecting both the catchability of fish and their rate of movement through the area.

In contrast to our efforts in the lower Duncan River, angling with drifted salmon egg bait was an effective method for capturing Gerrard rainbow trout in the Lardeau River (Appendix 1a), particularly in the section between Mobbs Creek and Healey Creek, where potential holding water was most clearly defined. Three female Gerrard rainbow trout were captured and tagged in this section in three hours of angling with bait on April 15. On the April 20 and 21 field trip to the upper Lardeau, four Gerrard rainbow trout (two males, two females) were captured in 15 hours of angling with bait, although one female appeared to be kelting (post-spawning) and was released without a tag. No fish were captured on the April 26 and 27 field trip, in 21 hours of angling with bait, although one large fish was hooked and later lost. Angling with spoons and other lures did not appear to be effective for Gerrard rainbow trout, although it should be noted that spoons were frequently fished through holding water after bait had already been tried. No fish were captured on lures in a total of 13 hours effort between April 15 and April 26 (Appendix 1a).

Tangle net captures in 2005 and 2006. Fish capture efforts during the spawner migration periods of 2005 and 2006 were directed primarily at the mouth of the Duncan River in Kootenay Lake. Tangle netting at the mouth of the Duncan River was a highly effective and efficient method for capturing mature Gerrard rainbow trout in both years. Between March 10 and April 28, 2005, 24 mature rainbow trout were captured in approximately 25 hours of tangle netting effort, which took place approximately one night per week (Appendix 1b). In 2005 we deployed 15 radio tags, 4 in males and 11 in females, and a single sonic tag in fish captured at the mouth. In 2006, tangle netting at the mouth of the Duncan River took place twice weekly during the peak of the run timing period. Between February 1 and April 19, 2006, 44 mature rainbow trout were captured in approximately 28 hours of tangle netting effort. Radio tags were deployed in twenty of these fish, 12 females and 8 males, and sonic tags in three other females. Figure 2, which depicts run timing at the Duncan River mouth as indicated by tangle netting catch-per-effort, suggests that peak run timing into the lower Duncan River occurs in late March and the first half of April.

It appeared that our protocol of regular (every 15-20 minutes) patrols of the net was effective at retrieving adult fish in good condition - none were lost due to injuries sustained during netting in 2005. Small, immature rainbow trout captured in the net were tangled more severely and had substantial scale loss, although it should be noted that these fish were the minority of captures (Appendix 1b, 2c). In 2006, several mature rainbow trout captured at the mouth of the Duncan River were transported to the Meadow Creek spawning channel by staff of the Kootenay Trout Hatchery and held in specially designed boxes for broodstock purposes (Appendix 2c).

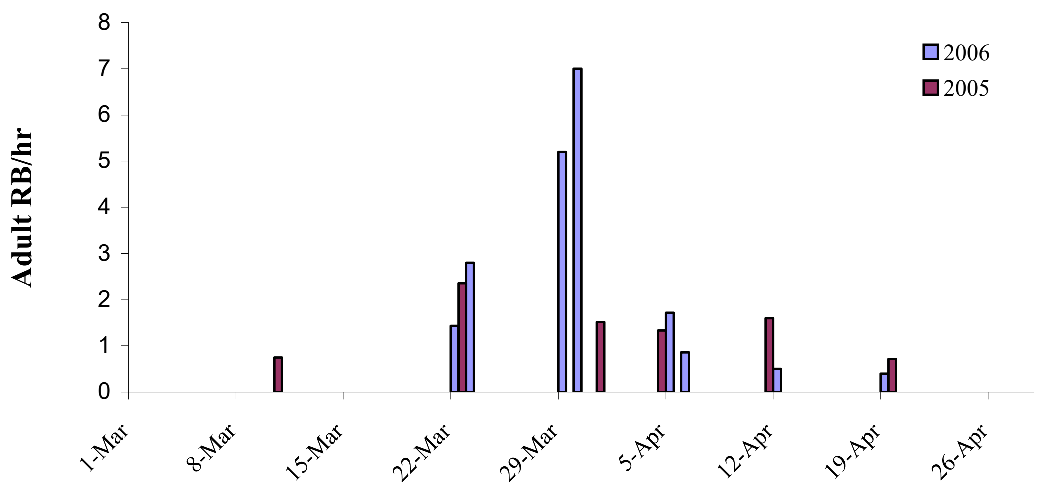

Figure 2. Rates of mature rainbow trout capture in March and April in a tangle net set at night at the mouth of the Duncan River in Kootenay Lake, 2005 and 2006. Note that data for the weeks of March 17 in 2005 and March 15 in 2006 were not available because of high winds, and the catches of mature rainbow trout for April 28 in 2005 and March 1 in 2006 were zero.

Angling captures 2005-2007. Because our sample of male Gerrard rainbow trout captured in the tangle net and successfully radio-tagged during 2005 was very small (Appendix 2b; *n* = 4), we also conducted one day of angling in the lower Duncan River and several days of angling in the Lardeau River (Appendix 1b). Unlike April 2004, angling success in the Lardeau River was poor, likely because of the very low and clear water conditions during the migration period. Only two mature rainbow trout, both males that we radio tagged, were captured during 33 angler hours of effort, one from the lower

Duncan River on March 10 and one from the Lardeau River on April 13. In 2006, 10.5 hours of angling effort in the Lardeau River were expended on April 19 and April 20 (Appendix 1c) with the goal of collecting additional male fish for hatchery purposes. Five mature rainbow trout were captured, two males and a female that were retained as broodstock and two females that received surgically-implanted sonic tags (Appendix 2c). In 2007, sonic tags were deployed in one female and two males captured during 8 angler hours of effort in the Lardeau River (Appendix 2d).

Age, Life History, and Growth

Adult rainbow trout sampling data and tag information is summarized in Appendices 3a-3d. Gerrard rainbow trout radio-tagged during this study in 2004 were, on average, smaller than fish that have been captured at Gerrard and utilized as brood stock for hatchery production in recent years (Table 1). We cannot speculate greatly on the 715 mm (SE = 40.0 mm) average male size (fork length) from 2004 captures because of the sample size of only two captures. The average size of the five radio-tagged females (731 mm, SE = 16.2 mm) is smaller than every recent year of hatchery brood stock collection except 1994 (Table 1).

Table 1. Gerrard rainbow trout captures from 2004-2006 versus hatchery sampling

Year	Average M FL (mm)	SE	Average F FL (mm)	SE	Average age F	Average age M
2006	912	26.2	807	14.2	6.3	6.5
2005	778*	58.8	762	21.0	7.1	6.1
2004	715	40.0	731	16.2	6.7	6
2000	858	18.3	776	12.9		
1998	855	11.6	771	10.0	6.4	
1994	784	22.0	717	13.5	6.0	
1992	850	31.9	750	13.7	6.7	
1991	861	9.7	782	24.9	6.7	
1982	872	11.2	813	20.6		
1981	817	68.3	784	13.9		
1980	857	31.8	809	26.2		
1979	853	32.5	797	8.0		
1949-1959**	663	22.9	675	13.5	5.3	

* Increases to 867 mm ± 8.3 mm if 2 fish <530 mm are excluded

**from surviving spawners captured in Kootenay Lake (Acara 1969).

Reproduction of rainbow trout in the Lardeau River, B.C.

Unpublished MS, BC Fish and Wildlife Branch, Nelson

The average female size from tangle net captures in 2005 (Table 1: 762 mm, SE = 21.0 mm) is comparable to previous hatchery sampling, but the average of all male captures is lower (778 mm, SE = 58.8 mm). It should be noted, however, that the male sample include 530 mm and 490 mm precocious males, and the average male size jumps to 867 mm (SE = 8.3 mm) if these fish are excluded, which is comparable to hatchery sampling. The 490 mm male was not radio-tagged, and the 530 mm male spent the spawning period in the vicinity of the Duncan Dam. Mature rainbow trout captured in 2006 were large relative to previous hatchery sampling. The 807 mm average female size is exceeded only by averages of 809 mm and 813 mm for 1980 and 1982, respectively (Table 1). The average male size of 912 mm is largest that we are aware of in recent sampling (Table 1), with nine of eleven fish sampled weighing 9.1 kg (20 pounds) or more (Appendix 2c).

A single female rainbow trout captured by angling in the Lardeau River in 2007 was 720 mm, and two males were 885 mm and 935 mm (Appendix 2d). These were not included in the above analysis because of the very small sample.

The analysis of Acara (1969), which investigated spawning checks on the scales of fish captured post-spawning in Kootenay Lake, found much smaller mean sizes and younger ages for both sexes (Table 1). Although this may reflect the population state at that time (1949-1959), it may also indicate that smaller, younger fish are more likely to survive spawning.

The large number of adult rainbow trout captured during this study, spanning sizes from 1.5 kg (3.3 lb) to 11.8 kg (26.0 lb) with many being of trophy size, presented a unique opportunity to develop an expansion factor for anglers wishing to know the weight of their catch without having to retain or weigh it. The best fit to length, girth, and weight data for Gerrard rainbow trout captured during this study was the equation:

$$Weight(lb) = \frac{Girth(inches)^2 \times Length(inches)}{720}, \qquad (10)$$

which can be distributed to anglers or used to print a table of predicted weights based on hypothetical length and girth data. Estimates of fish weight based on this equation explained 97% of the variation in actual measured fish weights for 55 Gerrard rainbow trout captured over the three years of this study for which the necessary length and girth data had been collected.

Appendix 3 presents a record of growth for 74 of 86 rainbow trout from which scales were collected during sampling in the spring of 2004, 2005, and 2006. Twelve of the scale samples contained only poor or regenerated scales, and could not be aged. Scales from juvenile Gerrard rainbow trout collected during two separate studies were included in the fork length/scale size regression used to back-calculate lengths-at-age for the Gerrard rainbow trout adults. Ages and back-calculated sizes of juvenile rainbow trout captured in the Lower Duncan in November 2004 (Hagen and Decker 2006), and in the Lardeau River during September 2005, April 2006, and August 2006 (Decker and Hagen 2007 in prep.), are presented in Appendix 4.

In all three years of sampling ages 6s and 7s, denoting spawning after the sixth and seventh winters of life, respectively, were the most common for mature fish. The tangle net sets in 2005 and 2006 sampled a greater diversity of ages than did angling in 2004, when the seven adult fish captured were all six or seven years old. Mature fish captured in the tangle net ranged from a 530 mm 4s male to seven fish (all females, six captured in 2005 and one in 2006) that had been alive for eight winters. Mean male age was younger than mean female age in 2004 and 2005 but not in 2006, when eleven males averaged an exceptional 912 mm fork length. Overall, female Gerrard rainbow trout captured during this study were of comparable age to those captured for hatchery purposes (Table 1).

Repeat spawning, where identified on scales, was on an annual basis, and rates for females were 14% (1 of 7), 29% (4 of 14, including a three-time repeat spawner), and 12% (3 of 26) for 2004 to 2006, respectively. With exception of the high rate of repeat spawning for sampled fish in 2005, these rates appear generally consistent with that recorded for a sample of 27 scales analyzed in 1992, when 3 repeat spawners (11%) were identified (BC Ministry of Environment, data on file). The large body size, advanced age, and, especially, relatively high proportion of repeat spawners among the 2005 sample may indicate a favourable situation for these fish with respect to spawner survival and exploitation rates in Kootenay Lake. The 735 mm, 5 kg female captured and tagged in the lower Duncan River (G04-002, Appendix 2a) is known to have spawned successfully, survived spawning, and begun feeding again in Kootenay Lake. The fish was captured by an angler in Kootenay Lake near Woodbury Creek on December 14, 2004, when it weighed 5.2 kg, and was later examined by Greg Andrusak of Redfish Consulting. She had regurgitated the radio tag and was feeding on kokanee at the time of capture. A small number (10) of old eggs left in the gut cavity indicated that the fish had spawned, and new skeins were forming presumably for repeat spawning in 2005.

Interestingly, one of two small, mature males captured during spring 2005, a 490 mm fish that did not receive a radio-tag, was the only male repeat spawner (Appendix 5: sample G05-002). Another 530 mm male did receive a radio tag, but spent the spawning period in the vicinity of the Duncan Dam (discussed below). These two fish were the first mature rainbow trout captured during 2005 sampling. Although spawner sizes have generally not been quantified, from our observations males of this size do not appear to be an important component of the spawning population at Gerrard. They are more frequently observed at the spawning area located at the tailrace of the Duncan Dam discussed below.

Repeat spawning among sonic-tagged Gerrard rainbow trout can be estimated following completion of the fishing and natural mortality study (Thorley and Andrusak 2009). To date, one sonic-tagged female rainbow trout has been detected on spawning migrations on two successive years (Tag 80; Appendix 2d).

For Gerrard rainbow trout sampled as adults, back-calculated lengths for their first winter (Appendix 3: 59-102 mm) are consistent with the range of lengths of young-of-the-year rainbow trout sampled in the lower Duncan River near the end of the growing season in November (Appendix 4: 60-87 mm, but note that this group does not necessarily comprise a random sample). However, scales sampled from adult rainbow trout show a highly variable second year growth increment relative to tributary rearing rainbow trout. Although not directly comparable because they had not finished growth for the year, juvenile rainbow trout in their second year captured in the Lardeau River in late September 2005 (Appendix 4) were of substantially smaller average size (128 mm, n = 43, range = 97-178 mm) than that indicated by back-calculated Gerrard scales for their second winter (180 mm, n = 74, range = 94-293), suggesting that many Gerrard rainbow trout do not spend a second year in the tributary rearing environment. Fish in the Lardeau River just coming out of their second winter in April 2006, which would be representative of Gerrard rainbow trout that had spent a second year instead of migrating earlier, had back-calculated lengths at their second annulus (at or near the scale margin and easy to detect) of 136-160 mm (Appendix 4: average = 145 mm, but note n = 3).

It is also interesting to note that among the 76 age-1+ (second growing season) rainbow trout sampled in the Lardeau system in September 2005, April 2006, and August 2006, back-calculated fork lengths during their first winter (mean = 64 mm, range = 45-89 mm) were significantly smaller than fork lengths back-calculated from the adult scales (mean = 82 mm; t = -10.504, df = 148, $P < 0.001$), suggesting that it is the smaller fish that are more likely to remain a second year in the stream. This trend continues for older juveniles, as well. Although the sample of tributary-rearing, age-2+ rainbows still present in the Lardeau River during fall sampling was very small (n = 5), the back-calculated mean fork length for their second winter (Appendix 4: mean = 102 mm), was smaller than even the September 2005 fork lengths of age-1+ fish captured at the same time (mean = 128 mm, see above). Even the largest of these back-calculated lengths for tributary-rearing, age-2+ fish (Appendix 4: 113 mm) was larger than only 3 of the 74 second-winter lengths back-calculated from the adult scales (Appendix 3). It is possible that these fish do not belong to the same population. An alternative explanation for this trend could be that larger juveniles were more difficult to capture by snorkelers.

Spawner Migration

2004 – Lardeau River. Tracking of radio-tagged Gerrard rainbow trout in 2004 began on April 16 (Appendix 5a). Of the seven radio-tagged fish, five were later tracked at Gerrard by the guardian, and two did not enter the counting area. One fish (frequency 151.760, Code 5), captured in the upper Lardeau River on April 15 (Appendix 2a), was detected only twice, once the day after capture at the capture location, then again on April 21 downstream of Tenderfoot Creek, which was well below the capture location. The fish appeared to have left the system, or the tag had malfunctioned, by April 27 when we conducted a tracking flight by helicopter. The other fish that did not enter the counting area at Gerrard (151.000, Code 9) may have spawned near Hope Creek in the upper Lardeau River. Although the fish was not seen on the helicopter tracking flight of April 27, the tag location was directly associated with a redd 1.5 km downstream of Hope Creek. A bald eagle was perched at the top of a tree beside the redd location, perhaps indicating the presence of fish or a carcass. This was the fish that was later recaptured in Kootenay Lake and found to have spawned successfully.

Spawning activity outside of the Gerrard counting area in 2004 was confirmed visually (completed redds) at other locations in the upper Lardeau River on the tracking flight as well. All spawning activity appeared to have occurred upstream of Poplar Creek. A total of seven redd locations were identified between the Poplar Creek and the Hope Creek bridges.

Radio-tagged rainbow trout captured in the Lardeau River in 2004 were first detected inside the Gerrard counting area 2-18 days after their capture dates. Four of five radio-tagged fish that entered the counting area in 2004 left the area after an initial, often short period, then returned for a second period. An important discovery was that one of these fish, a female (150.760, Code 3), was detected in Trout Lake near American Creek on the helicopter tracking flight of April 27, suggesting that the lake may be an important holding area for maturing spawners.

2005 and 2006 – Kootenay Lake to Gerrard. Most adult rainbow trout were tagged in 2005 and 2006 at the mouth of the Duncan River, at an earlier point in their migration. In 2005, for most fish the fixed station located at the Lardeau/Duncan confluence provided a record for entry into the Lardeau River from the lower Duncan River, to compare with tagging date and date of entry into the counting area at Gerrard, and also for emigration from the Lardeau system (Table 2). All radio tags deployed in mature, Gerrard rainbow trout in 2005 were detected at least once. One fish tagged on April 11 (Appendix 2b: frequency 151.000, code 16) was detected only once at the mouth of the lower Duncan River on April 22 and had an unknown fate. All other radio-tagged rainbow trout captured in Kootenay Lake were known to have migrated as far as the Lardeau/Duncan confluence, or beyond into the Lardeau River. For fish whose upstream migration to or past the fixed station was recorded in 2005, the amount of time that had passed between their capture date and time of arrival at the confluence was highly variable, ranging from 2 to 35 days (n = 9, mean = 15.9 days). The small amount of mobile telemetry data that exists from the lower Duncan River (Appendix 5b) prior to the establishment of the fixed station in 2005 also suggests that some fish may have an extended period of holding in the lower Duncan River itself. One fish (Appendix 5b: 151.000, code 17) appeared to be holding in the lower Duncan River over a minimum ten-day period between April 5 and April 14.

The fixed station located at the Lardeau/Duncan confluence was also in place for 2006, but two additional stations erected at the mouth of the Duncan River and at the resistivity counter located approximately 3 km from Trout Lake provided more precise movement data for the lower Duncan and upper Lardeau Rivers, respectively (Table 2). All fish radio tagged in Kootenay Lake in 2006, with the exception of one male (151.340, code 21) were detected later in the Lardeau/Duncan system at least as far as the Lardeau/Duncan confluence. The time between capture and arrival at the confluence was highly variable similar to 2005, ranging from 2-32 days (n = 18, mean = 17.2 days). Movements of most radio tagged fish into the lower Duncan River were recorded by the fixed station at the mouth (Table 3), and from a comparison of these with movements recorded on the Lardeau/Duncan confluence receiver it appears that rainbow trout spawners in 2006 did not have an extended residence time in the lower Duncan River. Radio-tagged trout took an average of 1.8 days (n = 13, range = 1-4 days) to travel from the mouth of the Duncan River to the confluence. Although data are very limited from 2005 (see above) for comparing to 2006, the lack of evidence for extended residence in 2006 suggests conditions were favourable for movement through the lower Duncan and into the Lardeau River in 2006, when the onset of snowmelt and higher water conditions occurred earlier in the year. The lack of a consistent pattern in migration of radio-tagged

Table 2. Movement of radio-tagged adult rainbow trout past the Lardeau/Duncan confluence, April 14 to June 1, 2005

Frequency	Code	Capture date	Direction past station	Dates past station	Arrival Gerrard	Departure Gerrard
151.000	7	10-Mar	Holding, moving in vicinity	14-Apr to 23-Apr; 26-Apr; 29-Apr to 13-May; 15-May to 18-May; 21-May; 23-May to 25-May; 27-May to 30-May	-	-
			Downstream	30-May		
151.320	22*	31-Mar	Upstream	15-Apr to 16-Apr	22-Apr	23-Apr
			Downstream	29-Apr		
151.000	20	11-Apr	Holding, moving in vicinity	18-Apr to 20-Apr; 26-Apr to 01-May	-	-
			Downstream	01-May		
151.320	23	31-Mar	Upstream	20-Apr	-	-
			Downstream	na		
150.760	14*	31-Mar	Upstream	20-Apr	27-Apr	07-May
			Downstream	08-May		
151.320	26*	19-Apr	Upstream	21-Apr	28-Apr	04-May
			Downstream	06-May		
151.000	18*	4-Apr	Upstream	23-Apr	04-May	09-May
			Downstream	10-May		
151.320	29*	19-Apr	Upstream	26-Apr	07-May	09-May
			Downstream	09-May		
150.760	13	23-Mar	Upstream	26-Apr	-	-
			Downstream	06-May		
150.760	15*	31-Mar	Upstream	na	20-Apr	28-Apr
			Downstream	29-Apr		
151.320	28*	11-Apr	Upstream	29-Apr	10-May	11-May
			Downstream	na		
150.760	11*	23-Mar	Upstream	na	26-Apr	27-Apr
			Downstream	03-May		
150.760	12*	23-Mar	Upstream	na	18-Apr	25-Apr
			Holding, then downstream	03-May to 06-May		

Note: fixed station was not in operation between 23-Apr and 26-Apr

* Detected at Gerrard during spawning period

Table 3. Movement of radio-tagged adult rainbow trout in the Lardeau-Duncan system, 2006

Frequency	Code	Capture date	Sex	Dates past past mouth	Dates past Lardeau-Duncan confluence	Dates past resistivity counter	Arrival Gerrard	Departure Gerrard
151.000	19	22-Mar	F	02-Apr; 12-Apr	04 to 07-Apr; 11, 12-Apr	-	-	-
151.320	24	22-Mar	M	before 30-Mar	24, 25-Mar	before 14-Apr	before 08-Apr	regurg. Trout L
151.320	25	22-Mar	F	19-Apr; 28-Apr	20 to 28-Apr	-	-	-
151.320	27	23-Mar	F	21-Apr; 09-May	22 to 24-Apr; 09-May	28-Apr	29-Apr	05-May
151.320	30	22-Mar	M	10-Apr	11-Apr	24-Apr; 06-May	24-Apr	02-May
151.440	12	23-Mar	F	09-Apr; 03, 08, 10-May	10-Apr; 03-May; 10 to 13 May	not detected	25-Apr	30-Apr
151.440	15	29-Mar	M	not detected	16-Apr	24-Apr; 28, 29-Apr	26-Apr	14-May
151.440	16	29-Mar	F	10-Apr; 09-May	11-Apr; 08-May	26-Apr	26-Apr	30-Apr
151.440	17	29-Mar	F	not detected; 06-May	27-Apr; 06-May	-	-	-
151.440	18	30-Mar	F	31-Mar; 28-Apr	03-Apr to 07-Apr	before 14-Apr?	19-Apr	25-Apr
151.440	19	30-Mar	M	18-Apr	21-Apr	-	-	-
151.440	20	5-Apr	F	not detected	03-May; 16-May	09-May; 15-May	12-May	13-May
151.460	22	30-Mar	M	09-Apr; 08, 09-May	10-Apr; 07, 08-May	25-Apr; 28-Apr	30-Apr	04-May
151.460	23	5-Apr	M	6, 10, 11-Apr	12-Apr	-	-	-
151.460	24	29-Mar	F	24-Apr; 3-May	26,30-Apr; 1 to 3-May	-	-	-
151.460	25	23-Mar	M	1-Apr; 2-May	3 to 7-Apr; 2-May	15-Apr; 30-Apr	21-Apr	30-Apr
151.460	26	5-Apr	F	not detected	7-May; 25-May	-	-	-
151.460	27	5-Apr	F	6-Apr; 23-Apr	10-Apr; 17,18,19, 22, 23-Apr	-	-	-
151.480	43	6-Apr	F	not detected; 14-Apr	12, 13-Apr	-	-	-

Note: fixed station at mouth was not in operation after 16-May fish from Kootenay Lake to the Lardeau/Duncan confluence suggests either that adult Gerrard rainbow trout mill at the mouth of the lower Duncan for an extended period prior to their entering the river, which is consistent with our high rate of capture of adult rainbow trout in the 45 m long tangle net set at the river mouth (Figure 2), or that handling had a substantial effect on migration timing that varied from fish to fish.

Migration of radio-tagged fish past the Lardeau/Duncan confluence and into the Lardeau River took place over an extended period in both 2005 and 2006. Movement of radio tagged fish into the Lardeau River appeared to peak in the second and third weeks of April in 2005 and was complete by April 29. From a comparison of the fixed station telemetry record (Table 2) with mobile telemetry data for 2005 (Appendix 5b), which was gathered by boat in the lower Duncan River on April 5 and April 12, and by helicopter along the length of the Duncan/Lardeau system on April 7 and April 22, it appeared that five radio-tagged rainbow trout had moved past the Lardeau/Duncan confluence into the Lardeau River prior to the establishment of the fixed station on April 14. Only one radio-tagged fish had entered the Lardeau by the time of the April 7 flight. It appeared also that no fish ascending the Lardeau had been missed during the April 23-26 period, when the station was down because of a low battery. All upstream movements of radio tagged rainbow trout into the Lardeau River were captured by the fixed station in 2006, and they extended over a longer period, without an obvious peak, from March 24 through to May 7 (Table 3).

Radio-tagged Gerrard rainbow trout took less time and showed less variability in their migrations between the Lardeau/Duncan confluence and Gerrard in 2005 relative to 2006, taking an average of 8.8 days to complete the journey (n = 6, range = 6-11days) in 2005 versus 12.6 days in 2006 (n = 9, range = 5-20 days).

In both years many of the fish that ascended the Lardeau River were not detected at Gerrard. Of the thirteen fish that ascended the Lardeau River in 2005, only nine were detected by the guardian. The radio tag deployed in the largest female captured in 2005 (Appendix 2b: 151.000, code 10) did not move from a location immediately downstream from the Howser Bridge (it was checked from the bridge on several locations), and appeared to have died or regurgitated its tag there. Tags belonging to two other Gerrard rainbow trout (Appendix 2b: male - 151.000, code 17; female - 151.320, code 23) were detected in the Lardeau River only once. They were never detected at Gerrard and failed to kelt past the fixed station. Whether these fish spawned at other locations in the Lardeau River or regurgitated their tags could not be determined. One other female (150.760, code 13) was known to have ascended the Lardeau River and kelted past the station ten days later, even though it was never detected at Gerrard. It appears likely that this fish spawned at another location in the Lardeau River. The one male captured in the Lardeau River in 2005 appeared to have died or regurgitated its tag shortly after it was captured (151.320, code 21). Two other fish, one male (151.000, Code 7) and one female (151.000, code 20), were not detected more than a short distance up the Lardeau River (Appendix 5b) and had extended periods of residence at the Duncan Dam, where they probably spawned.

Fifteen fish ascended the Lardeau River in 2006 and nine were detected at Gerrard. The earliest fish to enter the Lardeau River, on March 24, was a male captured on March 22 (151.320, code 24). This fish was detected in Trout Lake on April 8 prior to the initiation of daily telemetry at Gerrard, and was never detected again (Appendix 5c), suggesting that fish died or regurgitated its tag in the lake. Interestingly, on the helicopter flight of April 22, 2006 (Appendix 5c), two radio tags from 2004 (150.760, code 2 male and 150.760, code 3 female) were detected in Trout Lake in addition to one in a live fish from the current year that spawned at Gerrard. Whether tags lost in Trout Lake represent deaths or regurgitations is unknown, but a plausible mechanism for tag regurgitation may be a temporary resumption of feeding on fish prey in the lake, causing stomach expansion.

Two radio tagged male rainbow trout (Appendix 5c: 151.440, code 19 and 151.460, code 23) made limited progress up the Lardeau River and were not detected again, suggesting deaths or regurgitations. Two females (Table 3: 151.440, code 17 and 151.460, code 26) spent an extended period of time in the Lardeau before kelting out of the system but were not detected in the upper river (fixed station at resistivity counter or Gerrard), suggesting that they spawned lower in the system. The latter of these fish (code 26) was the last radio tagged fish to enter the Lardeau on May 7 – it is possible that it was not detected at the resistivity counter (the gain was turned very low, and other fish detected at Gerrard were missed by this fixed station) and reached Gerrard after daily tracking had ceased on May 16. A female trout (Appendix 5c: 151.460, code 27) made a migration of at least 8 km into the Lardeau River, over a seven-day period, before returning to the Duncan tailrace for a seven-day residence period, where it likely spawned. Another female (Table 3: 151.000, code 19) entered Lardeau River at least 6 km for a four-day period, then spent an additional two days at the Duncan tailrace. This fish may have spawned in either system. Two other radio tagged female rainbow trout (151.320, code 25 and 151.460, code 24) did not appear to enter the Lardeau River at all and stayed for extended residence periods at the tailrace of the Duncan Dam (Table 3), suggesting that they spawned there. One exceptional female (Table 3: 151.440, code 12) made a migration to Gerrard including a four-day residence period, then returned to Kootenay Lake only to re-enter the lower Duncan River and make a second migration to the Duncan Dam tailrace area, where it spent an additional four days. It is possible that spawning activity cannot be attributed to Gerrard alone for this fish.

Fixed stations in 2005 and 2006 allow a better evaluation of the success of tagging activities, as indicated by typical spawning behaviour of upstream migration followed by residence at a potential spawning area and/or kelting. Of the mature rainbow trout that were radio tagged in 2005 and 2006, males (6 of 14 fish – 43%) were more likely than females (3 of 23 – 13%) to die or regurgitate their tags (go missing) during their upstream migration prior to spawning. Fish regurgitating their tags or dying *after* their upstream migration to a spawning area are not included in these totals. The tagging crew noticed on several instances that tags were inserted much more deeply into the stomachs of large male trout than into the stomachs of females, and several tries were sometimes needed for the tag to seat properly.

Sixteen of the eighteen radio-tagged fish in total that were detected at Gerrard in 2005 and 2006 successfully kelted past the fixed station at the Lardeau/Duncan confluence (Table 2, Table 3). Most took four days or less. Interestingly, two of three fish that took six days or more (Table 2) to make their way down the Lardeau River in 2005 were females that had only spent one day at Gerrard. It may be possible that these fish were not detected while at Gerrard on other days, or that they spawned elsewhere. The radio-tagged fish detected at Gerrard that may not have survived spawning or regurgitated their tags were both males, one in each year (2005: 151.320, code 28; 2006: 151.440, code 15). The male from 2005 was detected at the counting area for only a single day at the tail end of the spawning period. This fish was the last radio-tagged rainbow trout to ascend the Lardeau River (Table 2).

Spawner Residence Time at Gerrard

Because of the relatively small number of radio- and sonic-tagged fish detected at Gerrard in each year, we combined the telemetry data for the 2004-2009 period before estimating residence time (Table 4). Average residence time in the counting area at Gerrard for eighteen female rainbow trout was 6.94 days (*SE* = 1.16 days)[1]. Dates of the peak spawner count at Gerrard over the study period were April 29, April 27, April 30, May 4, May 13, and May 10 for the years 2004-2009, respectively. A comparison between median dates of residence at Gerrard (Table 4) with corresponding peak count dates for the same year suggests that the female residence time data was representative for the two years of sampling. The median date of residence for one of the 18 fish fell right on the peak count date. Median dates of residence for 10 of the other 17 female spawners fell prior the peak count, while those of the remaining 7 fell after it.

Eleven male rainbow trout spawners had an average residence time at Gerrard of 6.18 days (*SE* = 1.33 days). For males, the median date of residence for one of the 11 fish fell right on the peak count date, while for the others median dates preceded the peak count for 4 fish and fell after it for 6 others (Table 4). Median dates of residence were very late in the spawning period for some of the male spawners (Table 4). Given the small sample size, and previous observations that spawner residence times may be shorter for later-timed spawners (Hilborn et al. 1999; Korman et al. 2002), we are concerned about the potential for underestimation of average male residence time. Although estimates are imprecise, male Gerrard rainbow trout with median dates of residence falling after the peak count did have shorter residence times on average (4.83 days, *SE* = 1.35) than males spawning earlier (9.00 days, *SE* = 2.68 days). Differential weighting of residence time estimates, such that early- and late-timed fish contribute equally to the overall residence time estimate, remains a possibility for future analyses. A better alternative is probably to generate more male residence time data from early in the spawning period. Early timed males have been captured in the tangle net sets in both 2005 and 2006, but unfortunately have had a high rate of death or regurgitation (we suspect the latter). In 2006 one of the earliest fish to arrive at Gerrard was a radio tagged male (Table 3: 151.320, code 24) that appeared to have regurgitated its tag in Trout Lake.

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[1] The sexes of Gerrard rainbow trout tagged in Kootenay Lake during May and June 2008, as part of the fishing and natural mortality study (Thorley and Andrusak 2009) were not recorded, and residence time data from these fish were therefore not included in the comparison between males and females.

Table 4. Residence time of radio- and sonic-tagged rainbow trout at Gerrard, 2004-2009

Year	Tag frequ.	Tag code	Sex	Dates in counting area	Median date in counting area	Residence time (d)
2004	150.760	1	M	8-May to 9-May, 16-May to 18-May	16-May	5
2004	150.760	2	M	30-Apr, 2-May to 10-May	5-May	10
2004	150.760	3	F	26-Apr, 30-Apr to 9-May	4-May	11
2004	150.760	4	F	22-Apr to 8-May	30-Apr	17
2004	151.000	8	F	23-Apr to 29-Apr, 08-May to 14-May	29-Apr	14
2005	150.760	11	F	26-Apr	26-Apr	1
2005	150.760	12	F	18-Apr to 20-Apr, 22-Apr to 24-Apr	20-Apr	6
2005	150.760	15	M	20-Apr to 27-Apr	23-Apr	8
2005	151.320	22	F	22-Apr	22-Apr	1
2005	150.760	14	F	27-Apr, 29-Apr to 06-May	2-May	9
2005	151.320	26	F	28-Apr to 03-May	30-Apr	6
2005	151.000	18	F	04-May to 08-May	6-May	5
2005	151.320	29	M	07-May to 08-May	7-May	2
2005	151.320	28	M	10-May	10-May	1
2006	151.320	27	F	29-Apr, 1-May to 04-May	2-May	5
2006	151.320	30	M	24-Apr, 30-Apr, 01-May	30-Apr	3
2006	151.440	12	F	25-Apr, 27 to 29-Apr	27-Apr	4
2006	151.440	15	M	26-Apr to 27-Apr, 13-May	27-Apr	3
2006	151.440	16	F	26-Apr to 29-Apr	27-Apr	4
2006	151.440	18	F	19-Apr, 23-Apr to 24-Apr	23-Apr	3
2006	151.440	20	F	12-May	12-May	1
2006	151.460	22	M	30-Apr to 03-May	1-May	4
2006	151.460	25	M	21-Apr to 29-Apr	25-Apr	9
2006	Acoustic	169	F	24-Apr to 25-Apr, 26-Apr to 27-Apr	26-Apr	4
2006	Acoustic	172	F	21-Apr to 29-Apr, 30-Apr to 1-May	26-Apr	11
2007	Acoustic	80	F	20-Apr to 28-Apr, 4-May to 8-May, 2-Jun	27-Apr	15
2007	Acoustic	150	M	6-May to 12-May	9-May	7
2007	Acoustic	152	M	19-Apr, 21-Apr to 5-May	28-Apr	16
2008	Acoustic	80	F	12-May to 13-May, 15-May to 21-May	18-May	8
2009	Acoustic	321	na	13-May	13-May	1
2009	Acoustic	323	na	16-May to 17-May, 19-May to 1-Jun	25-May	16
2009	Acoustic	324	na	4-May to 7-May, 9-May, 12-May to 19-May	13-May	13
2009	Acoustic	326	na	27-Apr to 2-May	30-Apr	6

Extreme residence times for Gerrard rainbow trout (with distinguishing marks) observed by the guardian have been 30 and 23 days for males and females, respectively (R. Gates, pers. comm. 2005). Given that early-timed males with longer residence times appear to be under-represented in our telemetry record, additional efforts to deploy tags in early-timed males appear to be warranted.

Of the 33 radio- and sonic-tagged fish that were detected at Gerrard over the six-year study period, 17 fish, after having arrived at Gerrard, left the spawning area for periods of 1 to 16 days before returning for a second stay. Some of these fish were detected in Trout Lake. The fixed station located at the resistivity counter 3 km from Trout Lake (Table 3) detected one radio tagged male fish (151.440, code 15) dropping down from Gerrard. This was the fish that returned to Gerrard 16 days after having left the first time. Its behaviour suggests spawning at other locations in the upper river, and perhaps that movement to and from the Gerrard spawning area may be more extensive than previously thought. The use of fixed receivers, which record over a 24-hour period, is recommended for all future telemetry at Gerrard. This has been the norm since 2006.

Given that male and female residence time estimates exhibit comparable averages (see above) and ranges (females: 1-17 days; males 1-16 days; Table 4), we pooled residence time data for both sexes to generate the overall residence time estimate of 6.94 days (n = 33, SE = 0.852 days).[2]

Rainbow Trout Spawners at Other Locations

It has become clear during the course of this study that adult rainbow trout spawn at other locations in the Lardeau/Duncan system than Gerrard. During the three radio telemetry years 2004-2006 redds (nests dug into the gravel) were observed in the Lardeau River downstream of Gerrard, during either fish capture activities or helicopter tracking flights. Clarity is not always suitable for observing redds in downstream locations, and this may have precluded the discovery of spawning activities in the past. The telemetry flight of April 21, 2006 was conducted during exceptional viewing conditions, and a redd count was attempted. Redds were identified as low in the system as the lower Duncan River (Appendix 5c: 4 redds), and from the Howser Bridge over the Lardeau River five kilometres upstream of Meadow Creek to Gerrard. At least 45 redds were counted on the flight, which is likely to be a substantial underestimate of actual redd abundance (Hagen 2001; Decker and Hagen 2007). Given that the date of the flight was well in advance of the April 30 peak count at Gerrard, it appears that the proportion of the population that spawned at locations in the Lardeau/Duncan system other than Gerrard is substantial.

Mature rainbow trout radio-tagged at the mouth of the Duncan River in 2005 and 2006, and which went through the full migration pattern expected for spawners[3] (25 fish in total), provide an indication of the relative importance of other spawning locations. Sixteen fish (eight in each year) that had residence recorded at Gerrard successfully kelted from the system (Tables 2 and 3; 64% of total). For comparison with this number,

[2] Residence time data from fish captured during the fishing and mortality study, (Thorley and Andrusak 2009), which were not sexed, are also included.

[3] Upstream migration and residence in a potential spawning stream, followed kelting past a fixed station.

we estimate that four fish (three in 2006) spawned at other locations in the Lardeau River before kelting (16%), and five (three in 2006) spawned at the Duncan Dam tailrace (20%).

A major discovery of the 2004 study was the population of large rainbow trout spawning on the tailrace of the Duncan Dam. On March 30, 2004 we inspected a 760 mm, ripe female that appeared to have been killed by an eagle and partially eaten on a gravel bar in the spillway plunge pool (Appendix 3). No other fish were seen, but a total of seven completed redds were counted in the Duncan River in a braided section immediately downstream of the tailrace. We monitored this section of the Duncan River regularly after March 30, but high, coloured water in April made observations of redds difficult and spawners were never observed.

A method for enumerating lower Duncan River spawners was discovered by accident on the evening of April 6, 2005 by a crew involved in a separate study in the lower Duncan River that employed nighttime snorkeling counts and boat travel at night (Hagen and Decker 2007). Crewmembers in a boat passing over the tailout of the Duncan Dam tailrace and through the braided section of the lower Duncan River immediately downstream, and holding powerful floodlights, observed approximately 20-40 large, adult rainbow trout spawners shortly after dusk. We repeated their survey twice more on following weeks. Redds were also counted during daylight hours, when no fish were observed except for the last redd survey on April 18, when four males were observed in the vicinity of the redds.

In 2006 the night count of spawners and day count of redds was repeated as a protocol approximately once weekly. The final redd count, on April 20, was conducted during a period of reduced discharge from the Duncan Dam, which greatly facilitated the count. As mentioned above, it appears that two and three radio tagged rainbow trout spawned at the Duncan Dam tailrace in 2005 and 2006, respectively. Our telemetry record indicates that spawning activity at the Duncan Dam tailrace may continue until as late as May 3 (Table 3: 151.460, code 24), indicating our redd count in 2006 was an underestimate.

Rainbow trout population estimation at the Duncan Dam tailrace has continued annually using a periodic spawner and redd count methodology similar to the above, as a component of the BC Hydro Water Use Plan study DDMMON#2 - Lower Duncan River Habitat Use Monitoring (Thorley 2010). Analysis using area-under-the-curve (AUC) methods indicated roughly 125 fish spawned there during spring 2009 (Thorley 2010). This estimate does not support the estimate of 20% of the total spawning population utilizing the lower Duncan River for spawning (from the proportion of radio tags above), but is substantial nonetheless.

Whether this population is related to the population that once spawned at the outlet of Duncan Lake, and is now thought to be extinct (Andrusak 2005), is unknown. Reproductive isolation between Duncan River spawners and those at Gerrard may never have been very great. Even prior to the construction of the Duncan Dam, spawning areas at the outlet of Duncan Lake would have been a short journey out of the way for male rainbow trout traveling to Gerrard, and the late-March to mid-May spawning timing in the Duncan River (Thorley 2010) appears to coincide with the migration of Gerrard rainbow trout into the Lardeau River (Tables 2, 3). Tissue samples collected from Duncan tailrace spawners in future may provide insight into the genetic relations between these stocks. Tissue samples collected from the dead spawner observed on the tailrace in 2004 and from rainbow trout young-of-the-year collected in side channel habitats of the lower Duncan River in a separate study (Hagen and Decker 2007, have been analyzed in the lab of Eric Taylor at the University of British Columbia. Rainbow trout utilizing the lower Duncan River for rearing appear to be indistinguishable from Gerrard rainbow trout, which may reflect the documented emigration of rainbow trout juveniles from the Lardeau system (Irvine 1978), but which is also consistent with the notion that the Duncan River spawners should be considered a part of the Gerrard population.

Spawner Population Size at Gerrard

Using the pooled (both sexes) residence time estimate (6.94 days, *SE* = 0.852 days) and the estimate of observer error (v = 1, *SE* = 0.0259), along with periodic count data from 1961-2009 (Appendix 6), we generated time series of Gerrard rainbow trout spawner population estimates based on (1) trapezoidal AUC calculations and (2) the Hilborn et al. (1999) maximum likelihood (ML) approach for comparison with expanded peak counts. Our two population estimation procedures exhibit relatively good agreement and comparable levels of precision across the 49-year time series (Table 5).

Confidence bounds for all estimates of spawner population size *N* made using the trapezoidal method were proportional to the estimate (see Methods). Percent relative error (average half confidence interval divided by the estimate; Krebs 1999) was 26% for each year's estimate, approaching the minimum target of 25% suggested by Robson and Regier (1964) for the monitoring of management experiments. Percent relative error for population estimates generated using the maximum likelihood methodology ranged from 20% to 33%, but was also 26% on average (*SE* = 0.42%). Mean estimated spawner abundance for the 1961-2009 period was *N* = 912 (*SE* = 39) using the trapezoidal method, and a comparable 920 (*SE* = 40) for the ML approach. The good agreement suggests that the periodic count data cover the spawning period thoroughly enough that the trapezoidal method, with its simpler annual calculation, can be utilized with minimal underestimation bias relative to the more computationally-intensive ML method. However, even though precision is comparable for the two approaches on average, reduced confidence in a particular year's estimate resulting from high first or last counts, or widely varying daily counts caused by variable conditions, will only be detected using the ML approach, in which quantitative analysis is specific to each year.

Expanded peak counts (by a factor of 3.08; Irvine 1978) are on average 9.3% and 8.3% higher than estimates generated using the trapezoidal AUC and ML approaches, respectively. Although agreement is relatively good on average, expanded peak counts are highly variable relative to population estimates based on all the count data, ranging from 70% (1966) to 176% (2008) of the ML estimates (Table 5). The time series of expanded peak counts has to date been a useful index of abundance for the Gerrard population. However, the ability of the trapezoidal AUC and ML approaches to account for variability in the form of the spawner abundance curve, as well as provide estimates of uncertainty for the population estimates, suggest that these approaches are preferable for future monitoring and analyses of Gerrard rainbow trout spawner abundance.

Table 5. Population estimates derived from periodic counts of rainbow trout spawners at Gerrard, 1961-2009.

Year	Peak count	Peak x3.08	AUC (fish*days)	Trapezoidal *N*	Trapezoidal *LCL*	Trapezoidal *UCL*	ML *N*	ML *LCL*	ML *UCL*
2009	589	1814	12565	1811	1453	2397	1846	1487	2403
2008	514	1583	6117	881	707	1167	902	735	1160
2007	464	1429	8229	1186	951	1570	1203	974	1557
2006	438	1349	7701	1110	890	1469	1093	831	1561
2005	426	1312	7141	1029	826	1362	1016	804	1369
2004	406	1250	7254	1045	839	1384	1017	807	1366
2003	303	933	5847	843	676	1115	823	665	1074
2002	227	699	4446	641	514	848	698	542	962
2001	244	752	3713	535	429	708	523	417	694
2000	340	1047	6892	993	797	1315	998	793	1337
1999	399	1229	8258	1190	955	1575	1190	962	1554
1998	367	1130	6912	996	799	1319	1000	787	1360
1997	344	1060	5469	788	632	1043	755	604	997
1996	275	847	6463	931	747	1233	923	753	1184
1995	286	881	6573	947	760	1254	958	771	1260
1994	275	847	7060	1017	816	1347	1066	859	1396
1993	257	792	5486	791	634	1046	836	642	1184
1992	219	675	5242	755	606	1000	773	618	1030
1991	280	862	7242	1044	837	1381	1124	895	1496
1990	382	1177	8967	1292	1037	1711	1310	1061	1694
1989	363	1118	6888	993	796	1314	983	800	1268
1988	340	1047	6097	879	705	1163	870	680	1200
1987	294	906	5749	828	665	1097	848	671	1143
1986	378	1164	8054	1161	931	1536	1252	983	1715
1985	241	742	4849	699	561	925	743	598	974
1984	220	678	4481	646	518	855	626	495	843
1983	270	832	4505	649	521	859	659	524	881
1982	417	1284	7865	1133	909	1500	1109	897	1435
1981	453	1395	8313	1198	961	1586	1209	953	1607
1980	440	1355	8204	1182	949	1565	1277	992	1760
1979	618	1903	9994	1440	1155	1906	1429	1171	1824
1978	473	1457	8006	1154	926	1527	1164	936	1522
1977	347	1069	5830	840	674	1112	851	698	1082
1976	272	838	6617	953	765	1262	963	787	1234
1975	346	1066	6294	907	728	1201	878	696	1185
1974	287	884	6098	879	705	1163	850	692	1098
1973	258	795	4909	707	568	936	709	561	959
1972	238	733	3547	511	410	677	482	375	662
1971	176	542	3319	478	384	633	457	364	609
1970	203	625	3567	514	412	680	505	405	660
1969	237	730	6174	890	714	1178	904	731	1175
1968	178	548	4585	661	530	875	648	542	806
1967	180	554	3557	513	411	679	516	425	647
1966	249	767	7370	1062	852	1406	1094	911	1360
1965	377	1161	8243	1188	953	1572	1184	978	1483
1964	234	721	3715	535	430	709	528	430	676
1963	251	773	6194	893	716	1182	915	756	1150
1962	258	795	5896	850	682	1125	860	700	1111
1961	214	659	3516	507	407	671	513	416	661

Recommendations and Conclusions

The use of radio telemetry, and, to a lesser extent, sonic tagging to estimate residence time of rainbow trout at Gerrard has provided important research data to date in addition to spawner residence time, such as the discovery of rainbow trout spawning at locations other than Gerrard, and in particular the discovery of the population of rainbow trout spawning at the Duncan Dam tailrace. Development of a method for estimating the size of this population is ongoing as part of the BC Hydro Water Use Plan study DDMMON#2 - Lower Duncan River Habitat Use Monitoring (Thorley 2010). It is important to note that this study will not be continuing past spring 2011 at the latest, and to take measures to ensure that continued monitoring takes place. Current dam operations may be seriously compromising the productivity of the lower Duncan rainbow population and its likelihood of long-term persistence. Stagnant flows and sedimentation of redds below the Duncan Dam have been observed regularly since the re-discovery of spawning activity in 2004. Some juvenile rainbow trout rearing habitats have also been eliminated and otherwise adversely affected by flow regulation in the lower Duncan River (Hagen and Decker 2007 and references therein). Monitoring of rainbow trout abundance in the lower Duncan River is essential for evaluating measures in the Water Use Plan designed to mitigate the effects of dam operation on this rainbow trout population.

A primary purpose of the study was to generate a residence time estimate for use in an area-under-the-curve population estimation procedure. We have established a residence time estimate for the population of rainbow trout spawning at Gerrard, and have used it to build a time series of population estimates extending back to 1961 (Table 5). Currently, it appears that we have been successful at gathering residence time information from across the spawning period for female rainbow trout, although the high degree of variability in the residence time data suggests that a larger sample would be beneficial. With respect to male Gerrard rainbow trout spawners, however, the residence time estimate is based on relatively few data from the early part of the spawning period. curve. We recommend that efforts be continued to increase the sample of male residence time data, from early-timed fish in particular. Nighttime tangle netting at the mouth of the lower Duncan River in Kootenay Lake has proven to be a highly efficient method for sampling Gerrard rainbow trout spawners, and on some years angling in the upper Lardeau River can also be effective. Tangle netting should occur during the final two weeks of March to target early-timed Gerrard spawners, and tags distributed only to males until the sample of male residence time estimates is comparable to the sample of females. The use to date of surgically-implanted sonic tags and fixed receivers at Gerrard appears to be the ideal methodology for acquiring the residence time data.

Observer efficiency, or the proportion of the true number of fish present that are actually observed, would normally be an important parameter in calculating AUC-based population estimates. Because of relatively low flows out of Trout Lake, combined with good visibility of the large, coloured rainbow trout spawners, we assume currently that observer efficiency for Gerrard rainbow trout spawners is very high. Trials of several methods of evaluating this assumption, and providing quantitative estimates of observer efficiency, have not yielded usable data to date.

In 2004 a long white spaghetti tag was threaded and tied through a puncture across each radio-tagged fish's back, at the base of the dorsal fin, to aid visual identification of tagged fish on the spawning areas of Gerrard. The tags did not appear to be highly visible at Gerrard, however, meaning that it could not be reliably determined whether radio-tagged fish could be seen during the counting procedure or not. As mentioned previously, after 2004 the tags were also considered inappropriate for continued use because of their large size.

A pilot project utilizing a resistivity counter was undertaken during 2004-2006, with the goal of establishing an independent and more accurate estimate of total abundance with which to calibrate the visual methods. The pilot indicated that the detection probability of migrating Gerrard rainbow trout was high, and that the resistivity counter was a potentially powerful population estimation tool (McCubbing and Andrusak 2006). However, counter operation and the proportion of the spawning population detected annually appeared to be affected by counter design, flow conditions, and fish behaviour. This was suggested by observations of increased counter reliability with design changes implemented year-to-year, loss of data during high discharge periods or counter malfunction, and a substantially greater estimate of the number of Gerrard rainbow trout spawners passing over the counter relative to visual counts in 2006 than observed during the previous year (over the period it was functional; McCubbing and Andrusak 2005). The latter observation was attributed in part to a pair of Gerrard rainbow trout holding in the area over an extended period in 2006, and necessitated introduction of a critical assumption about the pattern of fish migration during the population estimation procedure (McCubbing and Andrusak 2006). The use of counter data to quantify observer efficiency and its uncertainty will require a time series of accurate, precise population estimates. Although the resistivity counter has been demonstrated to be a powerful fish population estimation technique, we are not currently aware whether quantitative estimates of all parameters necessary for generating population estimates annually, along with uncertainty estimates for these parameters, are feasible without significant additional study. If the expectation can be reasonably established that counter-based population estimates will be significantly less biased and of greater precision than current estimates based on periodic counts, it may still be desirable to pursue a time series of independent population estimates using the resistivity counter.

We have also been exploring options for inexpensive, low-level aerial photography to document fish populations and habitat use (Spence 2009a, 2009b), and in early trials the methodology appears to have great potential at Gerrard. In trials during spring 2009, a tethered, helium-filled blimp did not disturb Gerrard rainbow trout spawners, and recorded images demonstrated good potential for fish enumeration, habitat use assessment, and size estimation. More extensive field trials are scheduled for 2010, during which the potential for estimating observer efficiency will be specifically investigated.

Currently, it is thought that during the early part of the run timing, when arriving spawners cruise spawning areas as well as areas of deeper water, the chance of not seeing rainbow trout that are actually present in the counting area is greatest. Resistivity counter data during the early portion of the run timing, when counter reliability appears to be high, exhibit relatively good agreement with the count at Gerrard (McCubbing and Andrusak 2005). Under the assumptions that limited emigration occurs during this period and the counter reliability was high, then it would appear that even during the early portion of the run timing that observer efficiency at Gerrard is very high. Under this scenario improvements to estimates of residence time may be the most efficient means of improving levels of confidence for the population estimates.

A snorkeling-based methodology for estimating juvenile rainbow trout populations in the Lardeau River has been developed, and annual estimates of total fry and parr abundance in the system are available beginning in 2007 (Decker and Hagen 2009). In concert with reliable estimates of brood spawner abundance, juvenile abundance data collected over a sufficiently long time period may permit estimates of the carrying capacity of the Lardeau system for rainbow trout production. An evaluation of the relative importance of density-dependent versus stochastic environmental mortality factors in regulating population size early in life is also possible, and has implications for habitat enhancement planning. Importantly, knowledge of juvenile year-class strength will also improve the power of the Gerrard spawner index as a tool for continued evaluation of the effects of ecological or management changes in the lacustrine environment. To enable an age-structured analysis that integrates the effects of year-class strength, annual estimates of the age structure of the spawning population are required by 2011 at the latest. The most efficient means of gathering this information may be through non-invasive sampling of fish size at the spawning grounds, and estimating age composition in a secondary analysis. As mentioned above, low-level aerial photography appears to have high potential for spawner size estimation at Gerrard (Spence 2009b). We recommend, therefore, that size-based estimates of spawner population age structure, in addition to the estimates of observer efficiency, be pursued beginning as soon as possible using the aerial photography program.

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Appendix 1a. Fish sampling success in Duncan/Lardeau system, 2004

Date	Location	Method	Effort (h)	Adult RB	BT	Other
30-Mar	Lower Duncan	angling lure	2	0	1	
		angling bait	4	0	3	
31-Mar	Lower Duncan	angling lure	4	0	4	
		angling bait	4	0	3	
		fixed tangle net	0.5	0	2	
1-Apr	Lower Duncan,	angling lure	9	0	4	
	Dam-Arg. Bridge	angling bait	6.5	0	3	1 MW
06-Apr	Lower Duncan,	angling lure	5	0	2	
	Dam-Mill	angling bait	7	0	3	1 MW
	- Note: recapture BT P2027 (pink), 76 cm					
06-Apr	River mouth	fixed tangle net	3	0	1	
	- along eddy line at edge of plume befor dark; 70 cm BT					
07-Apr	Lower Duncan	angling lure	6	0	3	
		angling bait	6	0	3	3 MW
		fixed tangle net	5	0		
08-Apr	Lower Duncan	angling lure	6	0	2	
		angling bait	5	0	4	1 MW
		fixed tangle net	6	0	0	
13-Apr	Lower Duncan,	drifted tangle net	8 drifts	1	3	
	Dam-Arg. Bridge	angling lure	1	0	0	
		angling bait	1	0	0	
	- Net hung up badly and torn on submerged woody debris @ dog leg					
14-Apr	Lower Duncan,	drifted tangle net	3 drifts	0	0	
	Dam-Arg. Bridge	angling lure	2	0	0	
		angling bait	3	0	0	
	- Net destroyed on last drift; no fish caught - both rivers high and turbid					
15-Apr	Lardeau River,	angling lure	6	0	0	
	Gerrard to	angling bait	6	3	0	
	Tenderfoot C					
	- 1 fish captured @ km 49; 2 @ Healy C bridge					
20-Apr	Lardeau River,	angling lure	3	0	0	
	resistivity counter	angling bait	3	3	1	
	to Healey C					
21-Apr	Lardeau River,	angling lure	2	0	0	
	km 49-Healey C	angling bait	12	1	0	
	- Bright female, consensus was that fish may be kelting; estimate that 3 RB lost					
26-Apr	Lardeau River,	angling lure	2	0	0	
	km 49-Hope C	angling bait	19	0	0	
	- No fish captured; 1 fish lost @ Healey C					
27-Apr	Lardeau River,	angling bait	2	0	0	
	Healey C					
	- No fish captured; none seen in angled areas					

Appendix 1b. Fish sampling success in Duncan/Lardeau system, 2005

Date	Location	Method	Effort (h)	Adult RB	BT	Other
3-Mar	Duncan mouth	Tangle net	3.0	0	0	
10-Mar	Lower Duncan	angling bait	2.0	1	2	
	Duncan mouth	Tangle net	4.0	3	6	2 SU
17-Mar	Duncan mouth	Poor weather, no set				
23-Mar	Duncan mouth	Tangle net	1.7	4	0	
31-Mar	Duncan mouth	Tangle net	3.3	5	1	
	- One additional RB ~70 cm escaped					
4-Apr	Duncan mouth	Tangle net	4.5	6	1	
11-Apr	Duncan mouth	Tangle net	2.5	4	0	
12-Apr	Upper Lardeau	angling bait	6	0	0	
13-Apr	Upper Lardeau	angling bait	5	1	0	
14-Apr	Upper Lardeau	angling bait	8	0	1	2 MW
		angling lure	4	0	1	
18-Apr	Upper Lardeau	angling bait	6	0	0	
		angling lure	2	0	0	
19-Apr	Duncan mouth	Tangle net	2.8	2	0	3 Imm. RB
28-Apr	Duncan mouth	Tangle net	3	0	1	4 NPM
	- No rainbow caught					

Appendix 1c. Fish sampling success in Duncan/Lardeau system, 2006

Date	Location	Method	Effort (h)	Adult RB	BT	Other
1-Feb	Duncan mouth	Tangle net	1.5	0	0	2 pygmy whitefish
8-Feb	Duncan mouth	Tangle net	1.5	0	0	1 imm. RB
15-Feb	Duncan mouth	Tangle net	1.5	0	2	
22-Feb	Duncan mouth	Poor weather, no set				
1-Mar	Duncan mouth	Tangle net	1.5	0	2	1 imm. RB
15-Mar	Duncan mouth	Poor weather, no set				
22-Mar	Duncan mouth	Tangle net	3.5	5	1	1 Su
23-Mar	Duncan mouth	Tangle net	2.5	7	1	
29-Mar	Duncan mouth	Tangle net	2.5	13	0	-
30-Mar	Duncan mouth	Tangle net	1	7	0	2 imm. RB
4-Apr	Duncan Dam	Tangle net	1	1	-	
5-Apr	Duncan mouth	Tangle net	3.5	6	0	1 imm. RB
6-Apr	Duncan mouth	Tangle net	3.5	3	5	
12-Apr	Duncan mouth	Tangle net	2	1	1	1 su, 1 npm
19-Apr	upper Lardeau R	Angling	2.5	2	0	
19-Apr	Duncan mouth	Tangle net	2.5	1	1	4 imm RB, 4 npm
20-Apr	upper Lardeau R	Angling	8	3	0	

Appendix 2a. Adult Gerrard rainbow trout captures, Lardeau/Duncan system 2004

Sample number	Date captured	Sex	L (mm)	G (mm)	Wt (kg)	Tag frequ.	Tag code	Floy tag number	
G04-001	30-Mar-04	F	760	-	-	-	-	-	-
	- Observed dead on spillway plunge pool bar below Duncan Dam; talon marks on back								
G04-002	13-Apr-04	F	735	390	5.0	151.000	9	Y00247	Y00248
	- at Lardeau/Duncan confluence pool 1430h; released 14-April 1300h in excellent cond.								
G04-003	15-Apr-04	F	740	420	5.2	151.000	8	Y00245	Y00246
	- at km 49, approx 600 m u/s of resistivity counter; 1145h released 45 min. later in good cond.								
G04-004	15-Apr-04	F	720	400	5.0	150.760	3	Y00243	Y00244
	- at Healy Creek bridge 1415h; released at 1545 same day								
G04-005	15-Apr-04	F	780	415	5.7	150.760	5	Y00241	Y00242
	- at Healy Creek bridge 1445h; released at 1545 same day								
G04-006	20-Apr-04	M	675	330	3.2	150.760	1	Y00239	Y00240
	- at Healy Creek bridge 1400h; released at 1050h 21-Apr; had turned around in bag								
G04-007	20-Apr-04	M	755	415	5.2	150.760	2	Y00237	Y00238
	- at Healy Creek bridge 1435h; released at 1050h 21-Apr; had turned around in bag								
G04-008	20-Apr-04	F	680	360	3.6	150.760	4	Y00235	Y00236
	- at road km 48 1700h; released at 1030h 21-Apr.								
G04-009	21-Apr-04	F	610	285	2.3	No tag			
	- Consesus decision was that fish had already been spawning, therefore released untagged								

Appendix 2b. Adult Gerrard rainbow trout captures, Lardeau/Duncan system 2005

Sample number	Date captured	Sex	L (mm)	G (mm)	Wt (kg)	Tag frequ.	Tag code	Floy tag number	
G05-001	10-Mar-05	M	530	-	1.6	151.000	7	OR00601	-
	- Angled from pool at deer farm on whitefish gear, surgically implanted tag								
G05-002	10-Mar-05	M	490	-	-	-	-	-	-
	- Small mature fish tangle netted at Duncan mouth, not tagged								
G05-003	10-Mar-05	F	510	-	-	-	-	-	-
	- Caudal fin worn and fungus present. Possibly spawned?								
G05-004	10-Mar-05	F	830	-	9.5	151.000	10	OR00624	-
G05-005	23-Mar-05	F	760	-	-	150.760	11	P2826	P2827
G05-006	23-Mar-05	F	765	-	-	150.760	12	P2828	P2829
	- Fish attempting to regurgitate tag on release								
G05-007	23-Mar-05	F	835	-	-	150.760	13	P2830	P2831
	- One other rainbow captured in poor condition, released without being sampled								
G05-008	31-Mar-05	M	860	470	8.2	150.760	15	P2832	P2833
G05-009	31-Mar-05	F	780	420	6.4	150.760	14	P2834	P2835
G05-010	31-Mar-05	M	900	510	9.1	lost during tagging			
G05-011	31-Mar-05	F	810	440	6.8	151.320	23	P2847	P2848
G05-012	31-Mar-05	F	760	410	-	151.320	22	P2845	P2846
	- One other rainbow captured ~70 cm escaped								
G05-013	04-Apr-05	M	845	545	9.1	151.000	17	P2843	P2844
G05-014	04-Apr-05	F	830	435	6.8	-	-	P2842	-
G05-015	04-Apr-05	F	660	360	3.2	-	-	-	-
G05-016	04-Apr-05	F	670	395	3.6	-	-	P2841	-
G05-017	04-Apr-05	F	840	495	8.6	151.000	18	P2839	P2840
G05-018	04-Apr-05	F	860	465	8.2	-	-	P2837	P2838
	- Kokanee present in stomach of P2841, so not tagged								
G05-019	11-Apr-05	F	785	465	7.0	151.000	16	P2801	P2802
G05-020	11-Apr-05	M	865	500	8.2	151.320	28	P2803	P2804
G05-021	11-Apr-05	F	800	455	7.3	151.000	20	P2805	P2806
G05-022	11-Apr-05	F	760	410	5.7	-	-	P2807	-
G05-023	13-Apr-05	M	850	500	-	151.320	21	P2809	P2810
G05-024	19-Apr-05	Imm	600	340	2.5	-	-	P2811	-
G05-025	19-Apr-05	F	820	430	6.4	151.320	26	P2812	P2813
G05-026	19-Apr-05	Imm	530	260	1.5	-	-	-	-
G05-027	19-Apr-05	M	880	540	9.1	151.320	29	P2815	P2817
G05-028	19-Apr-05	Imm	560	280	1.8	-	-	-	-

Appendix 2c. Adult Gerrard rainbow trout captures, Lardeau/Duncan system 2006

Sample number	Date captured	Sex	L (mm)	G (mm)	Wt (kg)	Tag frequ.	Tag code	Floy tag number	
#1Feb8	08-Feb-06	M?	495	-	1.4	-	7	B0274	Scales
#1Mar1	01-Mar-06	Imm	540	-	-	-	-	-	Scales
	- Small immature fish tangle netted at Duncan mouth, not tagged								
#1Mar22	22-Mar-06	Imm?	462	-	-	-	-	-	-
#2Mar22	22-Mar-06	F	745	-	5.2	151.320	25	B0273	B0272
#3Mar22	22-Mar-06	F	695	-	4.8	151.000	19	B0271	B0270
#4Mar22	22-Mar-06	M	961	530	9.3	151.320	30	B0269	B0268
#5Mar22	22-Mar-06	M	1003	530	11.4	151.320	24	B0266	B0267
#1Mar23	23-Mar-06	F	930	-	8.6	-	-	-	-
#2Mar23	23-Mar-06	F	760	400	5.0	151.320	27	B0265	B0264
#3Mar23	23-Mar-06	F	825	-	7.7	-	-	-	-
#4Mar23	23-Mar-06	F	860	-	7.7	151.440	12	B0263	B0262
#5Mar23	23-Mar-06	F	905	525	9.5	-	-	-	-
#6Mar23	23-Mar-06	Imm	490	-	-	-	-	-	-
#7Mar23	23-Mar-06	M	985	580	11.8	151.460	25	B0251	B0252
#1Mar29	29-Mar-06	F	810	450	-	151.440	17	B0276	B0279
#2Mar29	29-Mar-06	F	810	445	6.3	151.440	16	B0282	B0281
#3Mar29	29-Mar-06	F	860	490	-	-	-	-	-
#4Mar29	29-Mar-06	F	875	470	-	-	-	-	-
	- #3 and #4 retained for hatchery brood stock								
#5Mar29	29-Mar-06	F	810	425	6.1	-	-	-	-
#6Mar29	29-Mar-06	F	820	440	6.4	-	-	-	-
#7Mar29	29-Mar-06	F	630	315	2.7	-	-	-	-
#8Mar29	29-Mar-06	F	920	525	9.3	151.460	24	B0283	B0284
#9Mar29	29-Mar-06	M	950	565	11.5	151.440	15	B0287	B0285
	- Two additonal females retained for hatchery broodstock, not sampled								
	- Two additional females released without being sampled								

Appendix 2c, continued

Sample number	Date captured	Sex	L (mm)	G (mm)	Wt (kg)	Tag frequ.	Tag code	Floy tag number	
#1Mar30	30-Mar-06	M	920	530	9.8	151.440	19	B0288	B0289
#2Mar30	30-Mar-06	F	805	440	5.9	151.440	18	B0290	B0291
#3Mar30	30-Mar-06	F	865	505	9.1	Acoustic	168	B0348	B0347
#4Mar30	30-Mar-06	M	690	380	3.4	151.460	22	B0349	B0350
#5Mar30	30-Mar-06	Imm	630	330	2.5	-	-	-	-
#6Mar30	30-Mar-06	Imm	575	265	1.6	-	-	-	-
#7Mar30	30-Mar-06	F	780	435	5.9	Acoustic	169	B0346	B0345
-	Two additonal females retained for hatchery broodstock, not sampled								
#1Dunc	04-Apr-06	M	920	530	9.8	-	-	B0288	B0289
#1Apr5	05-Apr-06	F	800	460	-	151.440	20	B0342	B0341
#2Apr5	05-Apr-06	M	960	600	11.4	-	-	-	-
-	retained for hatchery brood stock								
#3Apr5	05-Apr-06	M	890	560	10.0	151.440	21	B0340	B0339
#4Apr5	05-Apr-06	M	835	460	6.8	151.460	23	B0338	B0337
#5Apr5	05-Apr-06	F	790	445	5.9	151.460	26	B0336	B0335
#6Apr5	05-Apr-06	F	810	470	7.0	151.460	27	B0334	B0333
#7Apr5	05-Apr-06	Imm	540	305	1.8	-	-	B0332	B0331
#1Apr6	06-Apr-06	F	689	375	4.0	151.480	43	B0329	B0327
#2Apr6	06-Apr-06	F	755	435	5.5	Acoustic	170	B0352	B0351
#3Apr6	06-Apr-06	M	920	525	9.5	-	-	-	-
-	retained for hatchery brood stock								
#1Apr19	19-Apr-06	F	845	440	-	Acoustic	171	B0028	B0027
#2Apr19	19-Apr-06	F	775	380	-	Acoustic	172	B0030	B0353
-	19-Apr-06	M	retained for hatchery broodstock						
-	20-Apr-06	M	retained for hatchery broodstock						
-	20-Apr-06	M	retained for hatchery broodstock						
-	20-Apr-06	F	retained for hatchery broodstock						

Appendix 2d. Adult Gerrard rainbow trout captures, Lardeau River 2007

Fish ID	Date captured	Sex	L (mm)	G (mm)	Wt (kg)	Tag frequ.	Tag code	Floy tag number	
767	12-Apr-07	M	885	na	na	Acoustic	150	na	-
686	19-Apr-07	F	720	na	na	Acoustic	80	Y00437	-
769	19-Apr-07	M	935	na	na	Acoustic	152	Y00438	-

Appendix 3. Back-calculated lengths-at-annuli, Gerrard rainbow trout, 2004-2006

Site/					Back-calculated length-at-annulus							
sample	Year	Fork l.	Sex	Age	1	2	3	4	5	6	7	8
G04-007	2004	755	M	6s	99.76	161.3	284.5	385.6	662.7	755		
G04-009	2004	610	F	6ss	68.98	113	240.5	363.7	478	579.2	610	
G04-002	2004	735	F	6s	69.87	209.5	381.9	550.2	652.9	735		
G04-003	2004	740	F	6s	86.71	234.5	374.5	483.3	642.8	740		
G04-008	2004	680	F	7s	85.73	248.5	317.7	439.8	509	590.5	680	
G04-005	2004	780	F	7s	84.26	202.5	288.9	388.9	561.7	684.5	780	
G04-006	2004	675	M	6s	63.94	124.6	280.6	410.6	558	675		
G05-027	2005	880	M	6s	70.32	240.8	443.2	624.3	777	880		
G05-021	2005	800	F	8s	72.56	131	238.2	325.9	452.5	605.2	744.8	800
G05-017	2005	840	F	8s	92.48	175.1	265	351.2	469.8	631.6	786.1	840
G05-001	2005	530	M	4s	96.38	231.1	420.5	530				
G05-012	2005	760	F	6s	87.18	251.9	420.1	556.8	686.4	760		
G05-002	2005	490	M	4ss	74.91	117.6	362	462.8	490			
G05-014	2005	830	F	6s	82.86	125.7	351.4	549.8	736.6	830		
G05-003	2005	510	F	5s?	77.92	192.6	289.5	395.4	510			
G05-006	2005	765	F	6sss	71.8	193.9	327.8	509	658.7	713.8	749.2	765
G05-009	2005	780	F	6ss	90.54	237.1	313.7	516.9	666.8	736.7	780	
G05-011	2005	810	F	8s	65.61	114.1	211	325.3	456.8	633.4	744.2	810
G05-004	2005	830	F	7s	78.41	161	247.7	458.3	627.7	792.8	830	
G05-013	2005	845	M	7s	83.73	187.7	299.1	403.1	611	726.2	845	
G05-016	2005	670	F	5ss	95.24	285.6	416.2	531.9	632.7	670		
G05-007	2005	835	F	6s	80.48	172.3	340	531.6	719.2	835		
G05-018	2005	860	F	8s	70.82	135.4	246.6	390.1	580.2	695	813.4	860
G05-008	2005	860	M	7s	79.51	219.4	374	547.1	664.9	793.7	860	
G05-005	2005	760	F	6s	81.54	223.7	398.4	520.3	642.2	760		
G05-025	2005	820	F	7ss	60.91	144.9	316.2	413.6	547.9	668.9	779.7	820
G05-020	2005	865	M	7s	65.84	171.4	261.9	469.2	627.5	793.4	865	
G05-024	2005	600	Imm	5+	82.45	163.8	303.8	479.6	600			
G05-022	2005	760	F	7s	72.56	144.5	332.3	420.3	568.2	668.1	760	
G05-023	2005	850	M	7s	80.65	159.5	313.3	474.7	613.6	774.9	850	
G05-028	2005	560	Imm	5+	78.64	153.7	286.9	392.7	560			
G05-0??	2005	530	Imm	4+	81.58	235.8	397.3	530				
Acoust#2	2006	755	F	6s	98	173	266	430	616	755		
#7Mar30	2006	780	F	6s	69	108	241	414	664	780		
#2Apr19	2006	775	F	6s	99	183	379	579	750	775		
#9Mar29	2006	950	M	7s	86	157	293	525	732	894	950	
#5Mar29	2006	810	F	7ss	79	155	231	325	498	682	782	810
#5Mar23	2006	905	F	6s	74	223	419	641	837	905		
#1Mar22	2006	462	Imm	5+	82	160	297	384	462			
#1Feb8	2006	495	M?	5+ or 5s	64	94	285	375	495			
#1Mar23	2006	930	F	7s	85	187	329	522	715	890	930	

Appendix 3, continued

Site/ sample	Year	Fork l.	Sex	Age	Back-calculated length-at-annulus 1	2	3	4	5	6	7	8
#2Mar23	2006	760	F	6s	65	115	263	474	675	760		
#6Mar23	2006	490	Imm	6s	84	140	231	356	447	490		
#3Mar30	2006	865	F	6s	71	124	267	447	694	837	865	
#2Apr5	2006	960	M	6s	87	202	306	520	760	960		
#4Apr5	2006	835	M	6s	91	202	365	584	771	835		
#1Apr5	2006	800	F	5s	97	293	506	681	800			
#3Mar22	2006	695	F	6s	82	145	237	411	581	695		
#1Apr6	2006	689	F	6s	81	135	240	367	559	689		
#2Mar22	2006	745	F	5s	91	270	441	604	745			
#3Apr6	2006	920	F	7s	93	178	294	522	719	885	920	
#5Mar22	2006	1003	M	6s	85	192	327	576	803	1003		
#3Apr5	2006	890	M	7s	83	228	285	439	638	827	890	
#6Apr5	2006	810	F	7s	82	162	246	434	563	733	810	
#6Mar30	2006	575	Imm?	5+	68	130	234	440	575			
#3Mar23	2006	825	F	7s	89	161	288	439	612	760	825	
#1Mar29	2006	810	F	6ss	97	164	284	442	643	760	810	
#8Mar29	2006	920	F	7s	89	152	316	479	667	850	920	
#6Mar29	2006	820	F	7s	59	31	73	134	185	186	187	
#4Mar23	2006	860	F	6s	90	249	376	595	765	860		
*Apr12	2006	910	M	7s	88	145	296	472	666	853	910	
*Mar29	2006	775	F	6ss	85	218	304	432	639	728	775	
#5Mar30	2006	630	Imm	4+	91	292	448	630				
*Mar29	2006	775	F	6s	86	161	265	488	686	775		
*Mar29/30	2006	830	F	6s	97	261	413	592	744	830		
*Mar29	2006	820	F	6s	89	198	231	454	701	820		
*Apr19	2006	860	M	7s	75	147	278	338	513	732	860	
*Apr19	2006	870	M	6s	86	149	262	505	756	870		
*Mar29/30	2006	850	F	7s	82	154	299	398	611	742	850	
#4Mar30	2006	690	M	6s	87	168	263	327	532	690		
#2Mar29	2006	810	F	6s	102	288	395	592	746	810		
#5Apr5	2006	790	F	6s	94	261	407	485	723	790		
#1Mar30	2006	920	M	7s	66	116	173	330	534	806	920	
#7Apr5	2006	540	Imm	6+	59	112	269	380	440	519		

Appendix 4. Back-calculated lengths-at-annuli, Lardeau/Duncan rainbow trout juveniles, 2004-2006

Site/ sample	Year	Month	Fork l.	Sex	Age	Back-calculated length-at-annulus 1	2
Duncan side channel	2004	Nov	80	Imm.	0+		
Duncan side channel	2004	Nov	65	Imm.	0+		
Duncan side channel	2004	Nov	70	Imm.	0+		
Duncan side channel	2004	Nov	139	Imm.	1+	70	
Duncan side channel	2004	Nov	124	Imm.	1+	67	
Duncan side channel	2004	Nov	78	Imm.	0+		
Duncan side channel	2004	Nov	77	Imm.	0+		
Duncan side channel	2004	Nov	60	Imm.	0+		
Duncan side channel	2004	Nov	67	Imm.	0+		
Duncan side channel	2004	Nov	75	Imm.	1+	53	
Duncan side channel	2004	Nov	69	Imm.	0+		
Duncan side channel	2004	Nov	87	Imm.	0+		
Duncan side channel	2004	Nov	80	Imm.	0+		
Duncan side channel	2004	Nov	70	Imm.	0+		
Duncan side channel	2004	Nov	87	Imm.	0+		
La-13.5	2005	Sep	61	Imm.	0+		
La-13.5	2005	Sep	65	Imm.	0+		
La-13.5	2005	Sep	61	Imm.	0+		
La-29.3	2005	Sep	36	Imm.	0+		
La-29.3	2005	Sep	33	Imm.	0+		
La-29.3	2005	Sep	44	Imm.	0+		
La-12.0	2005	Sep	59	Imm.	0+		
La-12.0	2005	Sep	55	Imm.	0+		
La-12.0	2005	Sep	62	Imm.	0+		
La-?	2005	Sep	109	Imm.	1+	54	
La-?	2005	Sep	126	Imm.	1+	61	
La-?	2005	Sep	118	Imm.	1+	53	
La-?	2005	Sep	112	Imm.	1+	58	
La-18.8	2005	Sep	178	Imm.	1+	78	
La-18.8	2005	Sep	47	Imm.	0+		
La-18.8	2005	Sep	57	Imm.	0+		
La-12.05	2005	Sep	119	Imm.	1+	59	
La-15.2b	2005	Sep	126	Imm.	1+	54	
La-15.2b	2005	Sep	155	Imm.	1+	68	
La-15.2b	2005	Sep	127	Imm.	1+	55	
La-15.2b	2005	Sep	125	Imm.	1+	53	
La-18.8	2005	Sep	78	Imm.	0+		
La-18.8	2005	Sep	118	Imm.	1+	54	
La 26.6	2005	Sep	107	Imm.	1+	62	
La 26.5	2005	Sep	133	Imm.	1+	65	
La 26.5	2005	Sep	102	Imm.	1+	54	
La 4.4d	2005	Sep	151	Imm.	2+	71	101
La 26.5	2005	Sep	152	Imm.	2+	69	113
La 26.5	2005	Sep	172	Imm.	2+	62	96
La 26.5	2005	Sep	157	Imm.	1+	66	
La 34.7	2005	Sep	115	Imm.	1+	45	
La 34.7	2005	Sep	72	Imm.	0+		

Appendix 4, continued. Back-calculated lengths-at-annuli for juvenile trout

Site/ sample	Year	Month	Fork l.	Sex	Age	Back-calculated length-at-annulus 1	2
La 34.7	2005	Sep	107	Imm.	1+	51	
La 13.7	2005	Sep	72	Imm.	0+		
La 13.7	2005	Sep	66	Imm.	0+		
La 13.7	2005	Sep	110	Imm.	1+	53	
La 15.6b	2005	Sep	99	Imm.	1+	50	
La 15.6b	2005	Sep	128	Imm.	1+	52	
La 15.2b	2005	Sep	97	Imm.	1+	52	
La 15.2b	2005	Sep	121	Imm.	1+	57	
La 15.2b	2005	Sep	124	Imm.	1+	69	
La 15.2b	2005	Sep	124	Imm.	1+	60	
La31.6d	2005	Sep	125	Imm.	1+	53	
La 18.8	2005	Sep	121	Imm.	1+	65	
La 18.8	2005	Sep	110	Imm.	1+	54	
La 18.8	2005	Sep	78	Imm.	0+		
La 24.4	2005	Sep	115	Imm.	1+	68	
La 24.4	2005	Sep	132	Imm.	1+	74	
La 29.8	2005	Sep	74	Imm.	0+		
La 29.8	2005	Sep	60	Imm.	0+		
La 17.9	2005	Sep	79	Imm.	0+		
La 13.7	2005	Sep	67	Imm.	0+		
La 13.7	2005	Sep	65	Imm.	0+		
La 13.7	2005	Sep	61	Imm.	0+		
La 10.9	2005	Sep	53	Imm.	0+		
La 10.9	2005	Sep	47	Imm.	0+		
La 7.4	2005	Sep	56	Imm.	0+		
La 7.4	2005	Sep	54	Imm.	0+		
La 7.4	2005	Sep	76	Imm.	0+		
La 24.4a	2005	Sep	63	Imm.	0+		
La 24.4a	2005	Sep	66	Imm.	0+		
La 10.9	2005	Sep	75	Imm.	0+		
La 10.9	2005	Sep	70	Imm.	0+		
La 10.9	2005	Sep	72	Imm.	0+		
La 10.9	2005	Sep	82	Imm.	0+		
La 7.4	2005	Sep	60	Imm.	0+		
La 7.4	2005	Sep	58	Imm.	0+		
La 7.4	2005	Sep	56	Imm.	0+		
La 33.8	2005	Sep	142	Imm.	1+	57	
La 33.8	2005	Sep	129	Imm.	1+	65	
La 33.8	2005	Sep	152	Imm.	1+	70	
La 33.8	2005	Sep	128	Imm.	1+	64	
La 33.8	2005	Sep	140	Imm.	1+	63	
La 33.8	2005	Sep	187	Imm.	2+	65	90
La 33.8	2005	Sep	140	Imm.	1+	80	
La 17.9	2005	Sep	104	Imm.	1+	62	
La 17.9	2005	Sep	122	Imm.	1+	64	
La 29.8	2005	Sep	121	Imm.	1+	65	

Appendix 4, continued. Back-calculated lengths-at-annuli for juvenile trout

Site/ sample	Year	Month	Fork l.	Sex	Age	Back-calculated length-at-annulus 1	 2
La 24.4	2005	Sep	153	Imm.	2+	65	113
La 15.6b	2005	Sep	150	Imm.	1+	63	
La 19.5b	2005	Sep	168	Imm.	1+	80	
La 34.7	2005	Sep	158	Imm.	1+	64	
La 12.05	2005	Sep	148	Imm.	1+	60	
La 18.8	2005	Sep	145	Imm.	1+	72	
6.4b	2006	Apr	64	Imm.	1+	57	
6.4b	2006	Apr	74	Imm.	1+	74	
24.4b2	2006	Apr	98	Imm.	1+	77	
24.4b2	2006	Apr	101	Imm.	1+	81	
24.4b2	2006	Apr	94	Imm.	1+	77	
36.4d	2006	Apr	94	Imm.	1+	76	
36.4d	2006	Apr	145	Imm.	2+	73	136
36.4d	2006	Apr	138	Imm.	2+	69	138
36.4d	2006	Apr	98	Imm.	1+	87	
36.4d	2006	Apr	178	Imm.	2+	81	160
36.4d	2006	Apr	106	Imm.	1+	89	
6.4b	2006	Apr	87	Imm.	1+	77	
6.4b	2006	Apr	88	Imm.	1+	74	
6.4b	2006	Apr	78	Imm.	1+	78	
33.8s	2006	Apr	87	Imm.	1+	77	
33.8s	2006	Apr	104	Imm.	1+	75	
33.8s	2006	Apr	101	Imm.	1+	76	
na	2006	Apr	78	Imm.	1+	70	
30.1s	2006	Aug	108	Imm.	1+	61	
30.1s	2006	Aug	122	Imm.	1+	60	
30.1s	2006	Aug	111	Imm.	1+	60	
na	2006	Aug	130	Imm.	1+	66	
na	2006	Aug	130	Imm.	1+	73	
30.1s	2006	Aug	100	Imm.	1+	58	
30.1s	2006	Aug	100	Imm.	1+	52	
30.1s	2006	Aug	100	Imm.	1+	55	
12.0b	2006	Aug	135	Imm.	1+	77	
12.0b	2006	Aug	124	Imm.	1+	68	
12.0b	2006	Aug	103	Imm.	1+	55	
na	2006	Aug	143	Imm.	1+	74	
na	2006	Aug	100	Imm.	1+	55	
29.8s	2006	Aug	91	Imm.	1+	51	
29.8s	2006	Aug	122	Imm.	1+	58	
29.8s	2006	Aug	94	Imm.	1+	48	
29.3b	2006	Aug	93	Imm.	1+	53	
29.3b	2006	Aug	90	Imm.	1+	55	

Appendix 5a. Radio telemetry observations of rainbow trout spawners in the Lardeau River, 2004

Date	Tag frequ.	Tag code	Time	Location	Power	Comment
16-Apr-04	150.760	5	1100	Healy C bridge		
	150.760	3	1345	0.5 km d/s Mobbs C		
21-Apr-04	151.000	-	830	faint @ rd. km 30		probably Code 9
	150.760	5	1135	1 km d/s Tenderfoot C		d/s of tagging loc.
22-Apr-04	151.000	-	1030	from Mobbs C		not coded
	150.760	4	1700	above Mobbs C	174	
23-Apr-04	151.000	8	830	above Gerrard bridge	158	visual
	150.760	4	900	above Mobbs C	171	
24-Apr-04	151.000	8	1700	from observation deck	201	
	150.760	4	1730	from Mobbs C	169	
25-Apr-04	151.000	8	930	from observation deck	220	
	150.760	4	1100	above Mobbs C	180	
26-Apr-04	150.760	3	1300	trailer	103	
	150.760	4	1300	Mobbs		
	151.000	8	1300	bridge	188	
27-Apr-04	151.000	8	1100	bridge		
	150.760	4	1100	Mobbs		
by helicopter:						
	150.760	3		American C, Trout L		in lake
	151.000	9		1.5 km d/s Hope C		at redd loc.
28-Apr-04	150.760	4	1300	Mobbs	109	
	151.000	8	1300	bridge	110	
29-Apr-04	151.000	8	930	bridge	165	
	150.760	4	930	Mobbs	161	
30-Apr-04	150.760	4	1330	trailer	139	
	150.760	3	1330	trailer	170	
	150.760	2	1330	trailer	169	
	151.000	-				not coded, d/s section?
01-May-04	150.760	3	1300	trailer		
	150.760	4	1300	Mobbs		
02-May-04	150.760	2	1100	trailer		
	150.760	3	1100	bridge		
	150.760	4	1100	Mobbs		
03-May-04	150.760	2	1000	bridge		
	150.760	3	1000	bridge		
	150.760	4	1000	Mobbs		

Appendix 5a, continued

Date	Tag frequ.	Tag Code	Time	Location	Power	Comment
04-May-04	150.760	2	900	bridge		
	150.760	3	900	trailer		
	150.760	4	900	Mobbs		
05-May-04	150.760	2	1400	bridge		
	150.760	3	1400	trailer		
	150.760	4	1400	Mobbs		
06-May-04	150.760	2	900	trailer		
	150.760	3	900	Mobbs		
	150.760	4	900	Mobbs		
07-May-04	150.760	2	900	bridge		
	150.760	3	900	Mobbs		
	150.760	4	900	Mobbs		
	151.000	-				not coded, d/s section?
08-May-04	151.000	8	1600	trailer	190	
	150.760	1	1600	bridge	213	
	150.760	2	1600	trailer	166	
	150.760	3	1600	trailer	187	
	150.760	4	1600	Mobbs	91	
09-May-04	151.000	8	1800	trailer	160	
	150.760	1	1800	trailer	192	
	150.760	2	1800	trailer	177	
	150.760	3	1800	trailer	166	
10-May-04	151.000	8	930	trailer	115	
	150.760	2	930	trailer	181	
11-May-04	151.000	8	900	trailer	189	
12-May-04	151.000	8	1300	trailer	135	
13-May-04	151.000	8	830	trailer	182	
14-May-04	151.000	8	900	trailer	219	
15-May-04	151.000	8	1000	trailer	204	
16-May-04	151.000	8	900	trailer	190	
	150.760	1	900	trailer	178	
17-May-04	151.000	8	900	trailer	230	not vis. at max. power
	150.760	1	900	trailer	161	
18-May-04	151.000	8	830	trailer	228	otter kill?
	150.760	1	830	trailer	140	
19-May-04	151.000	8	1120	trailer	230	
20-May-04	151.000	8	1230	trailer	230	
23-May-04	151.000	8	700	trailer		

Appendix 5b. Mobile telemetry of adult rainbow trout in the Lardeau/Duncan system, 2005

Date	Tag frequ.	Tag code	Location/comment
Lower Duncan River by boat			
05-Apr-05	151.000	17	7.8 km d/s of Lardeau confluence in lower Duncan River
	150.760	15	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.320	22	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.000	7	1.5 km d/s of Lardeau confluence at WSC station
	150.760	12	Lardeau/Duncan confluence
Kootenay Lake to Gerrard by helicopter			
07-Apr-05	151.000	17	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.320	22	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	150.760	15	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.000	7	Lardeau/Duncan confluence
	150.760	12	Lardeau/Duncan confluence
	151.000	10	200 m d/s Howser Bridge, Lardeau R; UTM: 0502764;5570743
	151.000	8	2004 mortality at Gerrard
Lower Duncan River by boat			
12-Apr-05	151.000	20	300 m u/s in lower Duncan River
	151.000	17	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.000	7	1.5 km d/s of Lardeau confluence at WSC station
	151.000	10	200 m d/s Howser Bridge, Lardeau R
Gerrard			
18-Apr-05	150.760	12	
19-Apr-05	150.760	12	
20-Apr-05	150.760	15	
	150.760	12	
21-Apr-05	150.760	15	
22-Apr-05	150.760	15	
	150.760	12	
	151.320	22	
Kootenay Lake to Gerrard by helicopter			
22-Apr-05	151.320	29	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.000	18	Kootenay Lake
	151.000	16	500 m u/s of Kootenay Lake
	151.000	7	Duncan Dam tailrace
	151.000	20	d/s of marblehead dump, Lardeau River; WP 24
	151.320	26	200 m d/s Howser Bridge; WP 25
	151.000	10	200 m d/s Howser Bridge; WP 25
	151.320	23	Howser road turnoff; WP 27
	150.760	14	Goldhill bridge area; WP 28
	151.320	21	Goldhill bridge area; WP 29

Appendix 5b, continued

Date	Tag frequ.	Tag code	Location/comment
Kootenay Lake to Gerrard by helicopter, continued			
22-Apr-05	150.760	15	Gerrard
	151.320	22	Gerrard
	151.000	17	Healy C bridge
	150.760	12	Gerrard
Gerrard			
23-Apr-05	150.760	15	From bank between Gerrard and Mobbs Creek
	150.760	12	
24-Apr-05	150.760	15	
	150.760	12	
25-Apr-05	150.760	15	
26-Apr-05	150.760	15	
	150.760	11	
27-Apr-05	150.760	15	
	150.760	14	
28-Apr-05	151.320	26	
29-Apr-05	150.760	14	
30-Apr-05	150.760	14	
	151.320	26	
01-May-05	150.760	14	
	151.320	26	
02-May-05	150.760	14	
	151.320	26	
03-May-05	150.760	14	
	151.320	26	
04-May-05	150.760	14	
	151.000	18	
05-May-05	150.760	14	
	151.000	18	
06-May-05	150.760	14	
	151.000	18	
07-May-05	151.000	18	
	151.320	29	
08-May-05	151.000	18	
	151.320	29	
10-May-05	151.320	28	

Appendix 5c. Mobile telemetry of adult rainbow trout in the Lardeau/Duncan system, 2006

Date	Tag frequ.	Tag code	Location/comment
Lower Duncan River by boat			
29-Mar-06	151.000	7	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.320	24	Duncan dam tailrace near spillway confluence
05-Apr-06	151.000	7	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.000	19	Duncan Dam tailrace
	151.440	18	Duncan Dam tailrace
06-Apr-06	151.000	19	first pool below Duncan Dam tailrace
	151.440	18	at base of Duncan Dam
	151.460	25	250 m d/s of Duncan Dam
Lardeau River by road			
08-Apr-06	151.000	10	old tag d/s of Howser bridge
	151.320	23	old tag under Howser bridge
	151.000	19	at road km 19 (Howser turn off)
	151.460	25	at road km 25
	151.440	18	at road km 26
	151.320	21	at road km 29
	151.320	24	upstream of Gerrard in Trout Lake
12-Apr-06	151.440	12	at road km 19 (Howser turn off)
	151.460	27	at road km 21.5
	151.460	22	at road km 22
	151.460	25	at road km 40
	151.440	16	at road km 17
	151.000	19	300m d/s of Duncan Dam in tailrace
19-Apr-06	151.320	24	upstream of Gerrard in Trout Lake
	151.440	18	at Gerrard bridge
	151.440	16	at road km 34 (Poplar C)
	151.320	21	at road km 29.5 (last year's)
	151.440	15	at road km 29.5 (d/s of Goldhill bridge)
	151.320	23	old tag at road km 18 (under Howser bridge)
	151.460	23	at road km 16
Lower Duncan River by boat			
20-Apr-06	150.760	12	mouth of Duncan R
	151.440	19	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.000	7	4.5 km d/s of Lardeau confluence in Meadow Creek channel
	151.320	25	Lardeau/Duncan confluence

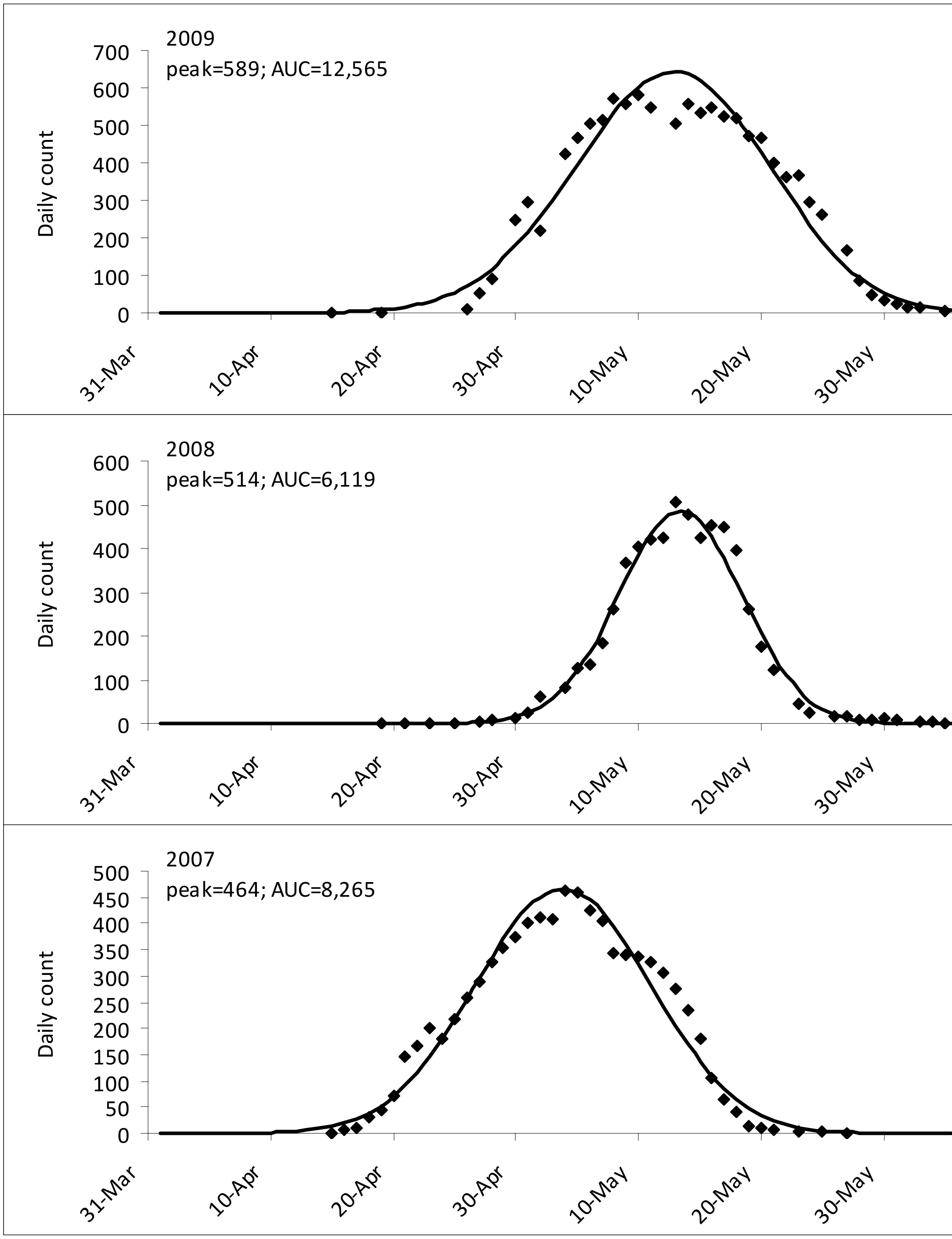
Appendix 5c, continued

Date	Tag frequ.	Tag code	Location/comment
Kootenay Lake to Gerrard by helicopter			
21-Apr-06	151.320	29	Kootnay Lake, possible eagle nest: 50^o 02.986'; 116^o 54.403'
	150.760	12	Kootenay L: 50^o 10.038'; 116^o 55.501'
	151.000	7	plus redd in Meadow C back channel: 50^o 12.461'; 116^o 57.081'
	-	-	4 redds at deer farm: 50^o 13.298'; 116^{o}57.449'
	151.320	23	old tag; 50^o 17.207';116^o 57.627'
	151.440	19	Lardeau landfill: 50^o 16.451'; 116^o 57.884'
	151.000	10	Howser bridge (last year's)
	151.460	27	u/s of Howser bridge: 50^o 20.014'; 116^o 59.856'
	-	-	several redds: 50^o 21.028'; 117^o 01.687'
	151.320	21	50^o 22.376'; 117^o 03.334'
	-	-	several redds: 50^o 23.535'; 117^o 05.065'
	-	-	1 redd: 50^o 24.868'; 117^o 06.592'
	-	-	3 redds at Poplar C: 50^o 24.971'; 117^o 07.250'
	-	-	3 redds u/s of Poplar C: 50^o 25.119'; 117^o 07.802'
	-	-	1 redd: 50^o 25.452'; 117^o 08.348'
	151.440	15	Between Poplar and Rapid C: 50^o 25.979'; 117^o 08.665'
	151.440	16	u/s of Rapid C: 50^o 26.651'; 117^o 09.834'
	151.440	12	: 50^o 26.864'; 117^o 10.263'
	-	-	3 redds: 50^o 27.221'; 117^o 11.056'
	151.460	22	: 50^o 27.247'; 117^o 11.092'
	-	-	1 redd: 50^o 27.370'; 117^o 11.320'
	-	-	9 redds Hope C bridge
	-	-	4 redds Hope-Healy C
	-	-	40-50 fish Healy C bridge
	-	-	10 redds Healy C to Gerrard
	151.460	25	Gerrard
	150.760	3	Trout L
	151.440	18	Trout L
	150.760	2	Wilkie C
Gerrard			
22-Apr-06	151.460	25	
23-Apr-06	151.460	25	
	151.440	18	
24-Apr-06	151.000	30	
	151.460	25	
	151.440	18	

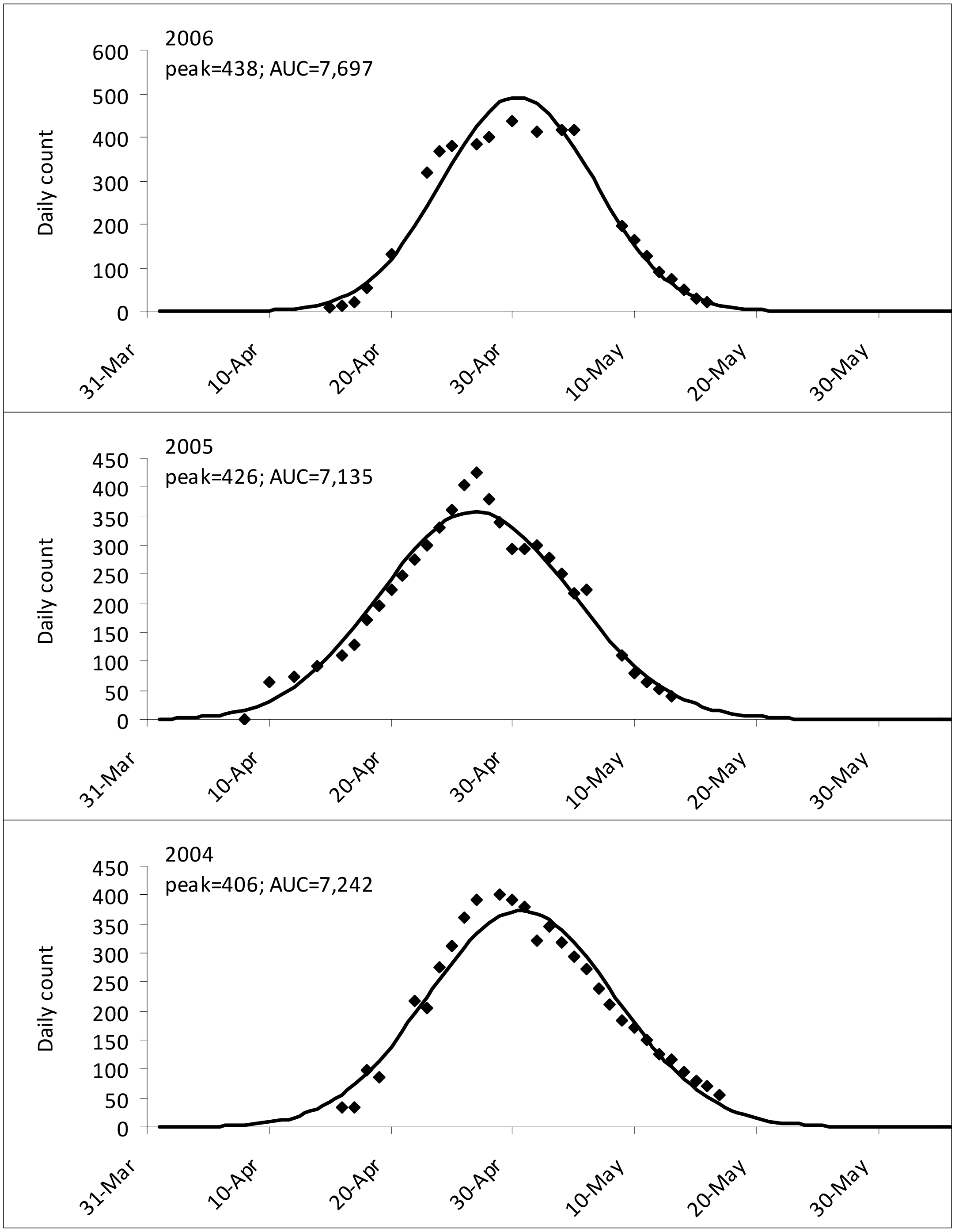
Appendix 5c, continued

Date	Tag frequ.	Tag code	Location/comment
Gerrard, continued			
25-Apr-06	151.460	25	
	151.440	12	
26-Apr-06	151.460	25	
	151.440	16	
	151.440	15	
27-Apr-06	151.460	25	
	151.440	16	
	151.440	15	
	151.440	12	
28-Apr-06	151.460	25	
	151.440	16	
	151.440	12	
29-Apr-06	151.460	25	
	151.440	16	
	151.440	12	
	151.000	27	
30-Apr-06	151.460	22	
	151.000	30	
01-May-06	151.460	22	
	151.000	30	
	151.000	27	
02-May-06	151.460	22	
	151.000	27	
03-May-06	151.460	22	
	151.000	27	
04-May-06	151.000	27	
12-May-06	151.440	20	
13-May-06	151.440	15	

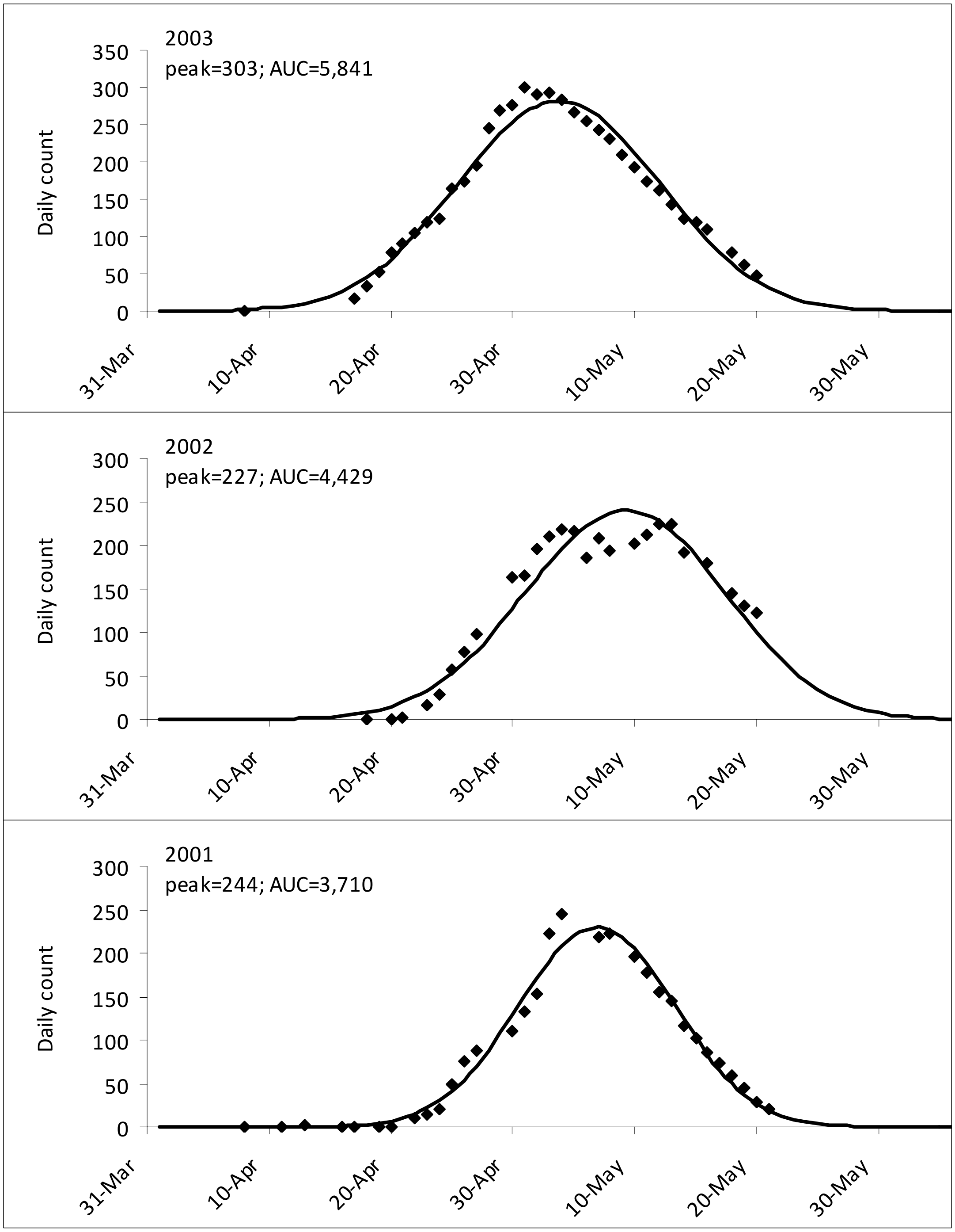
Appendix 6. Periodic counts of rainbow trout spawners at Gerrard, 1961-2009, with maximum likelihood fit of beta distribution run timing model (see methods).



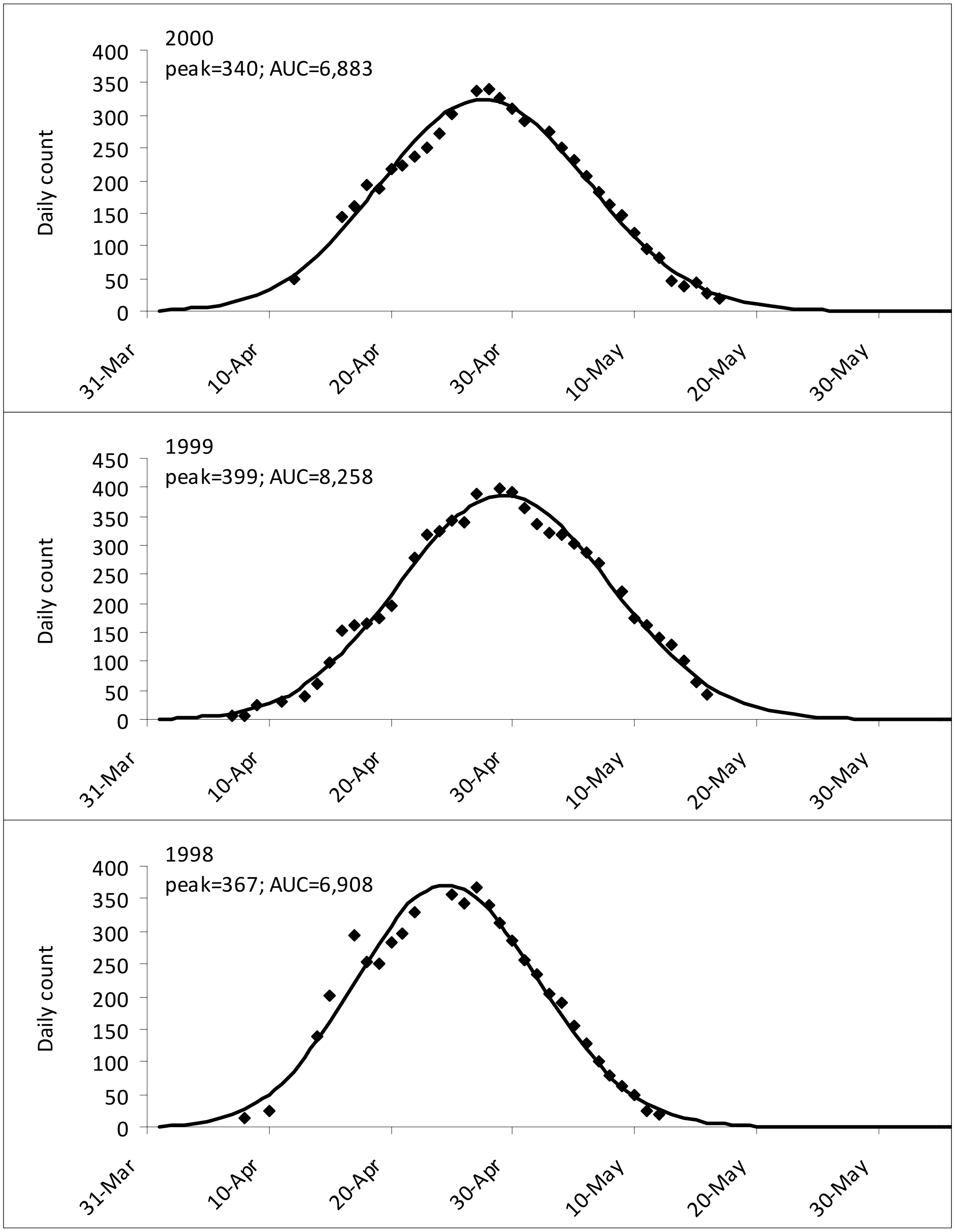
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



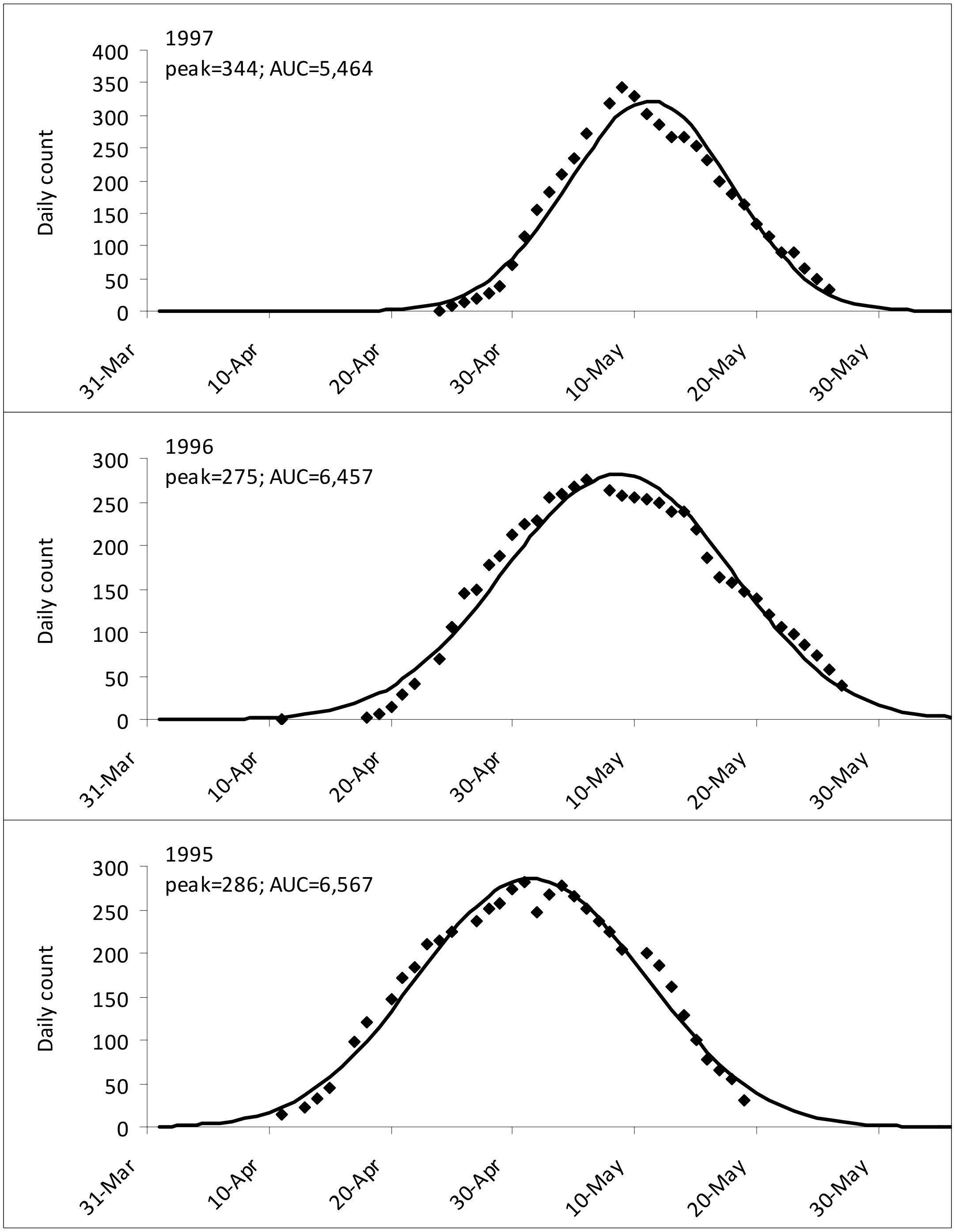
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



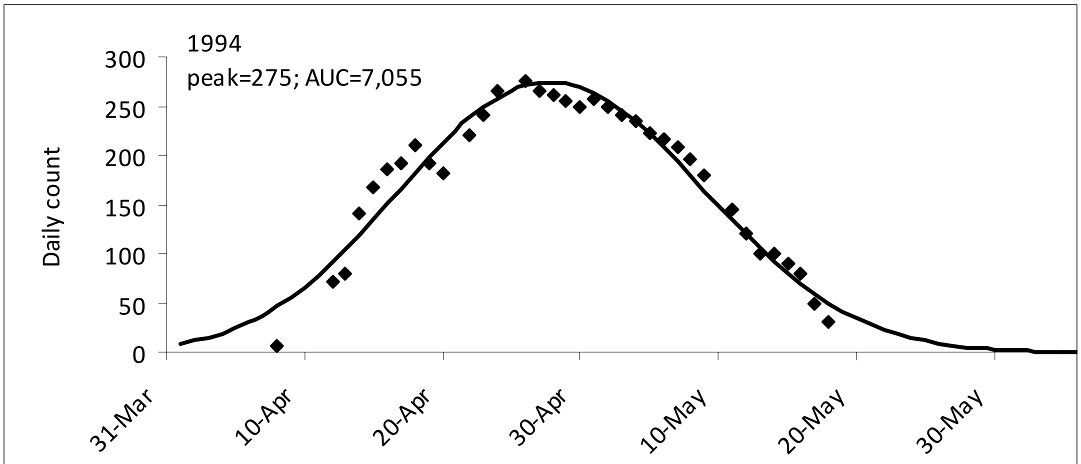
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.

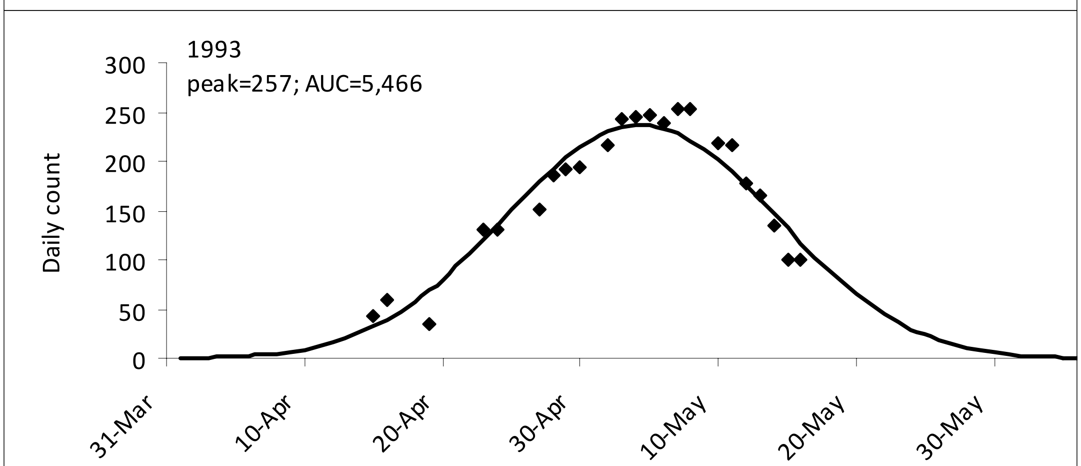


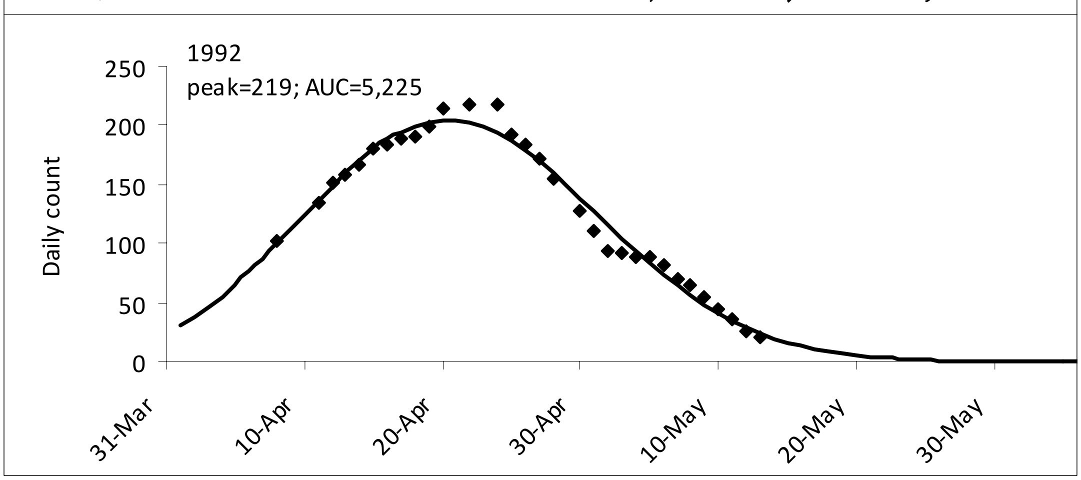
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



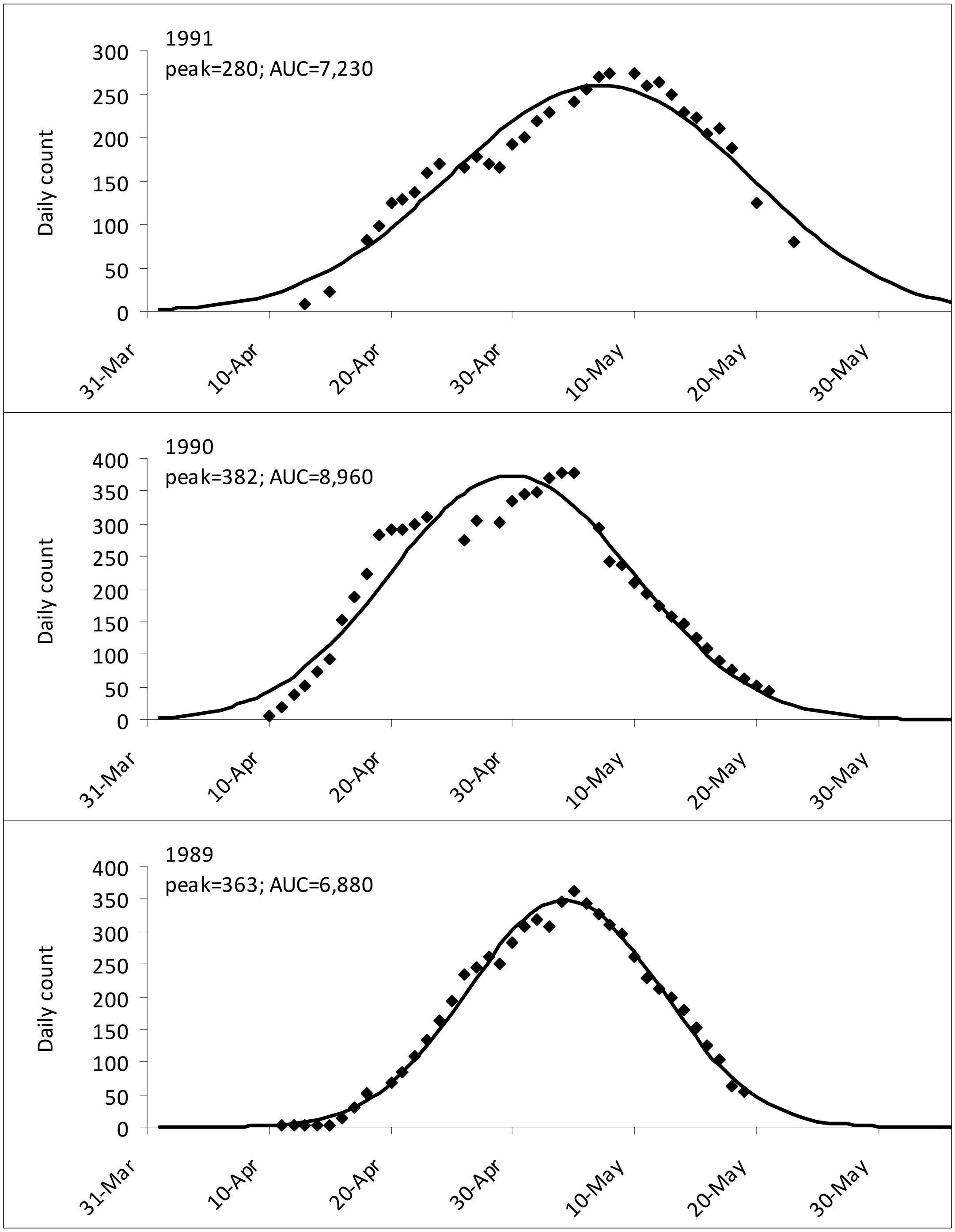
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



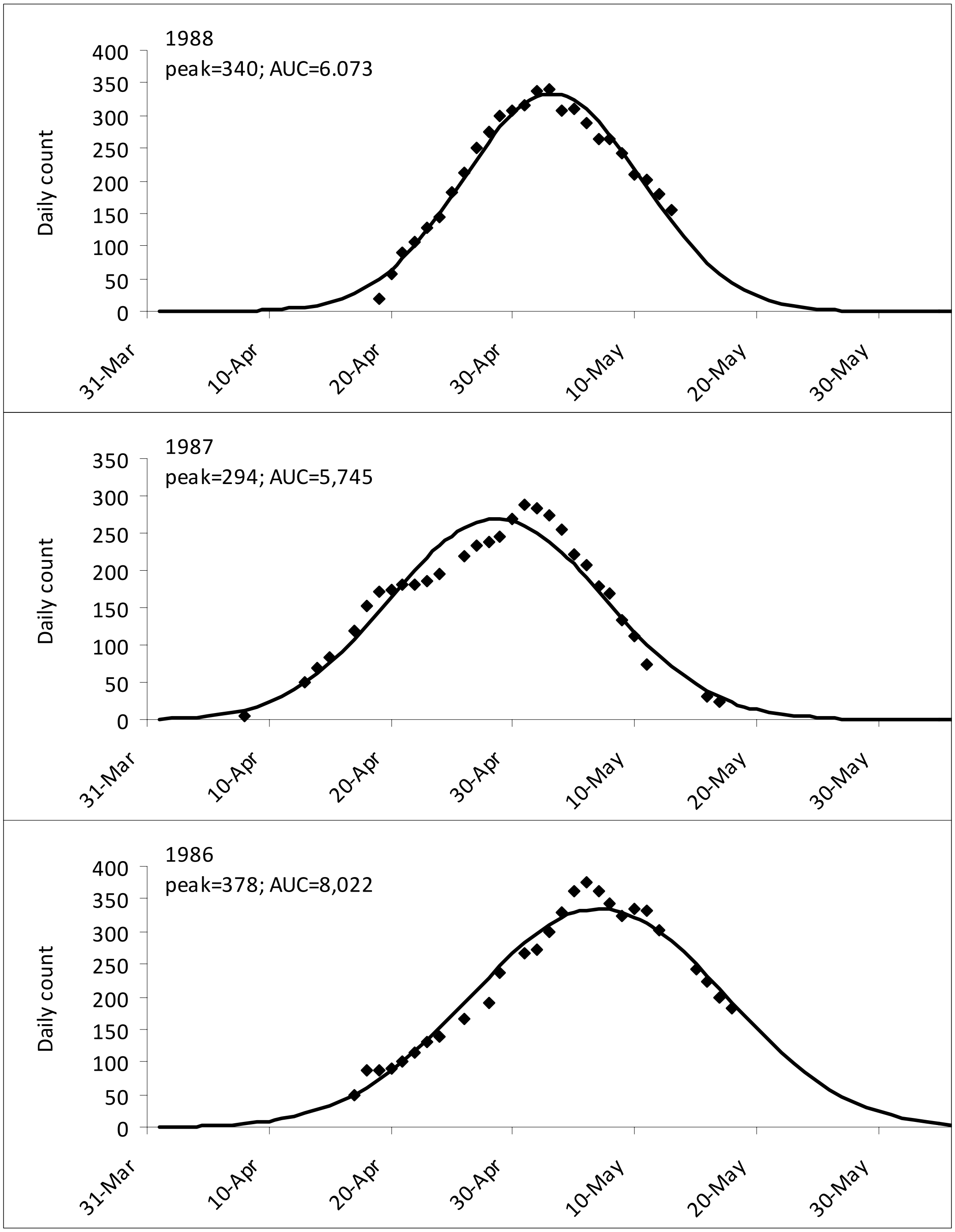




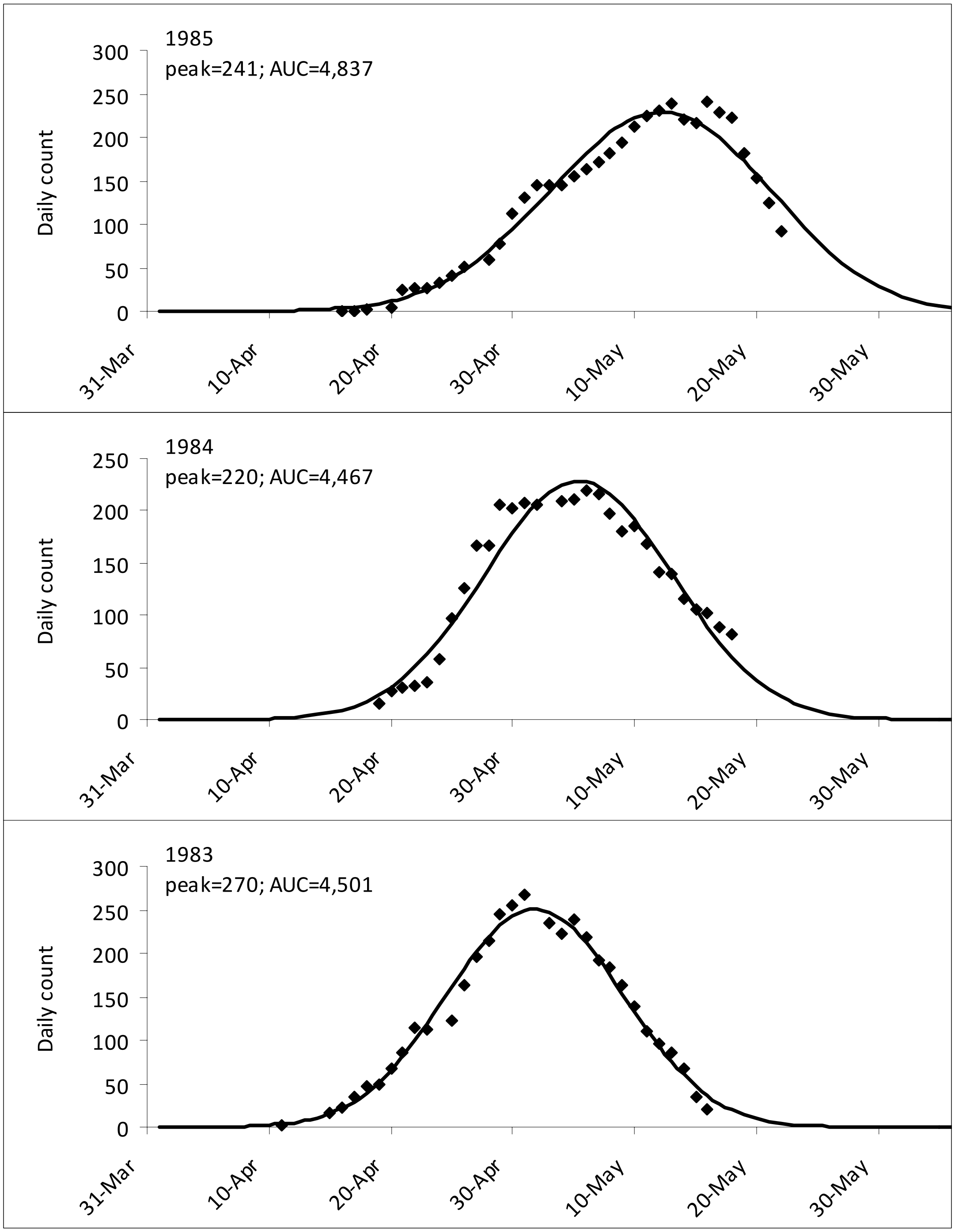
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



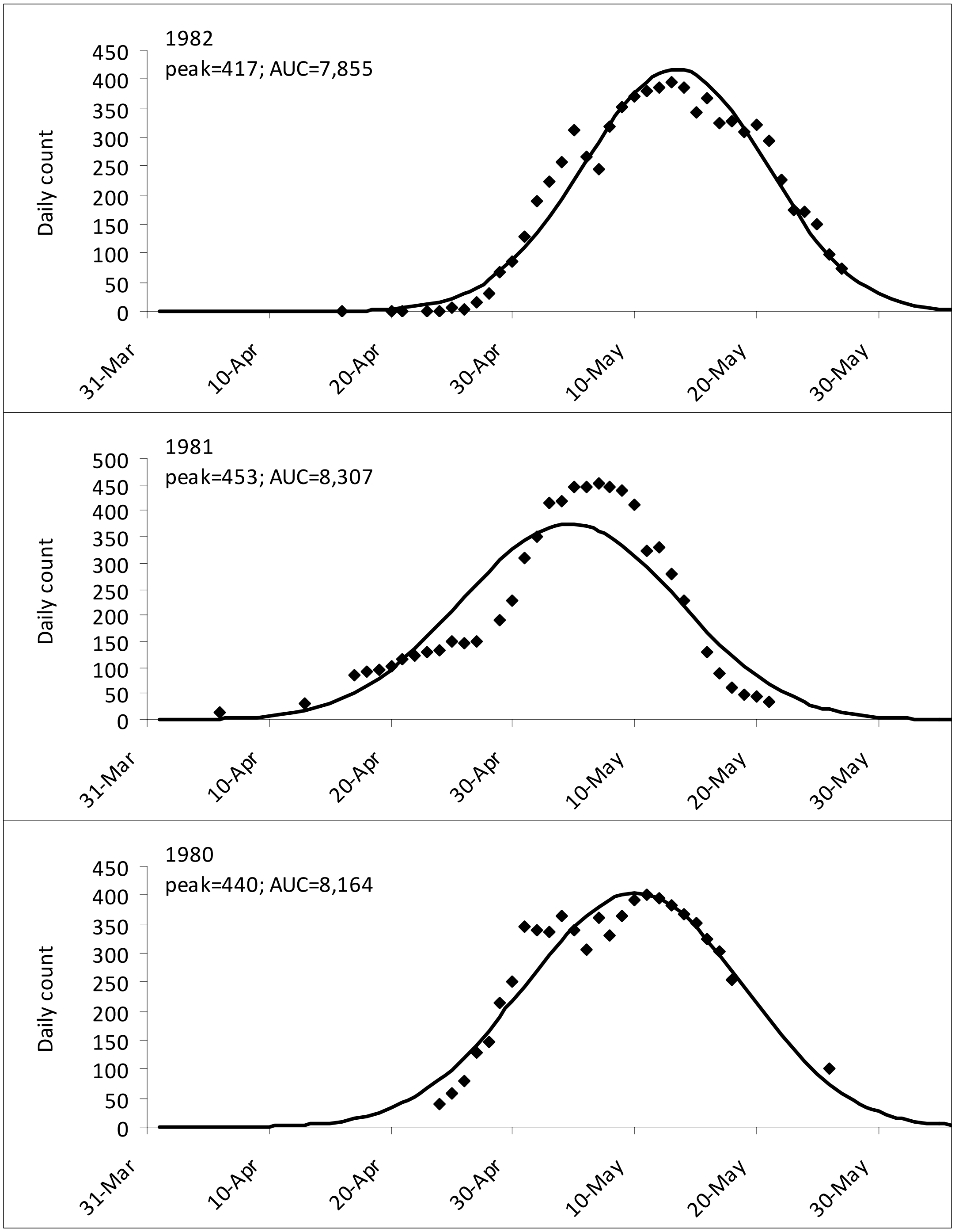
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



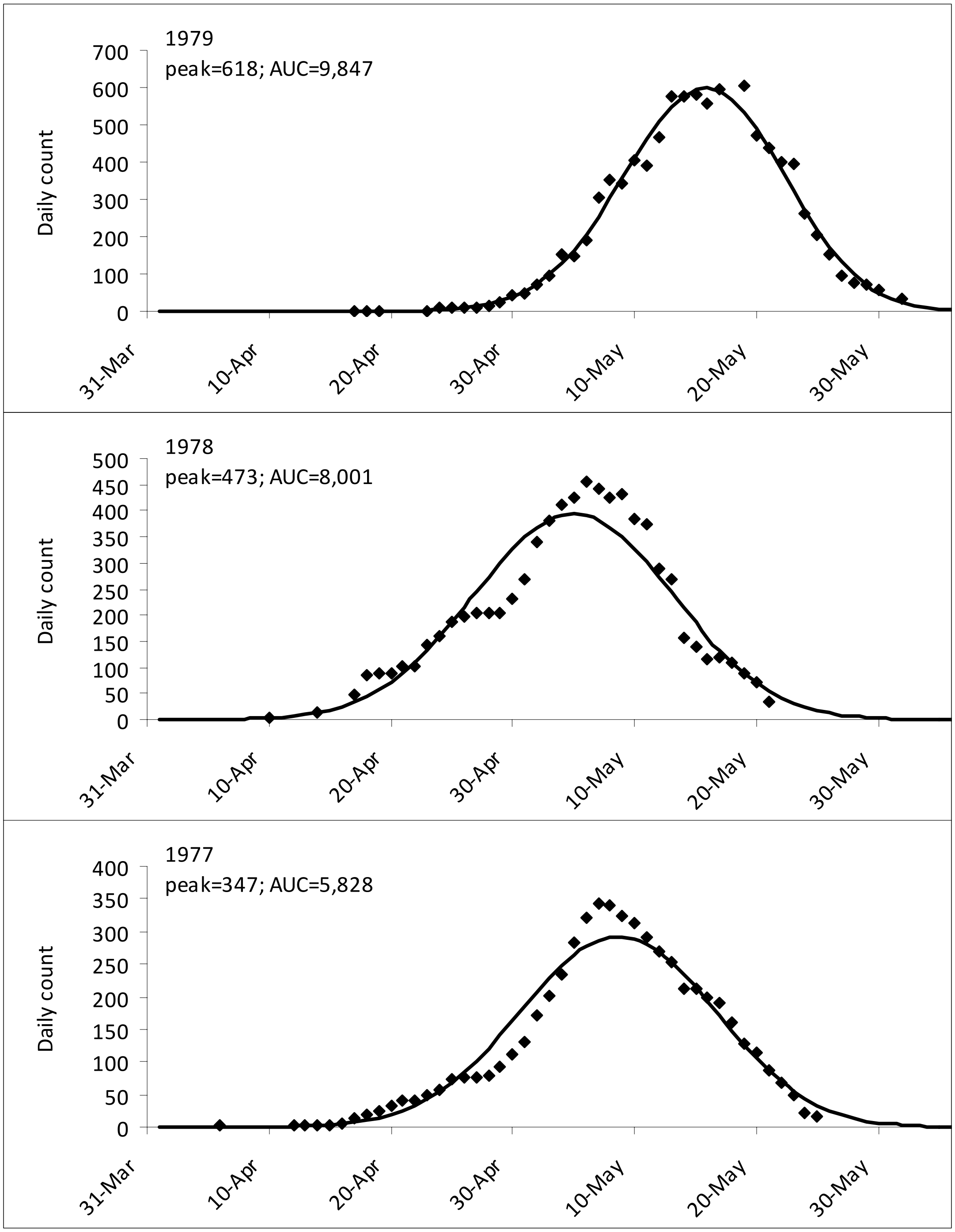
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



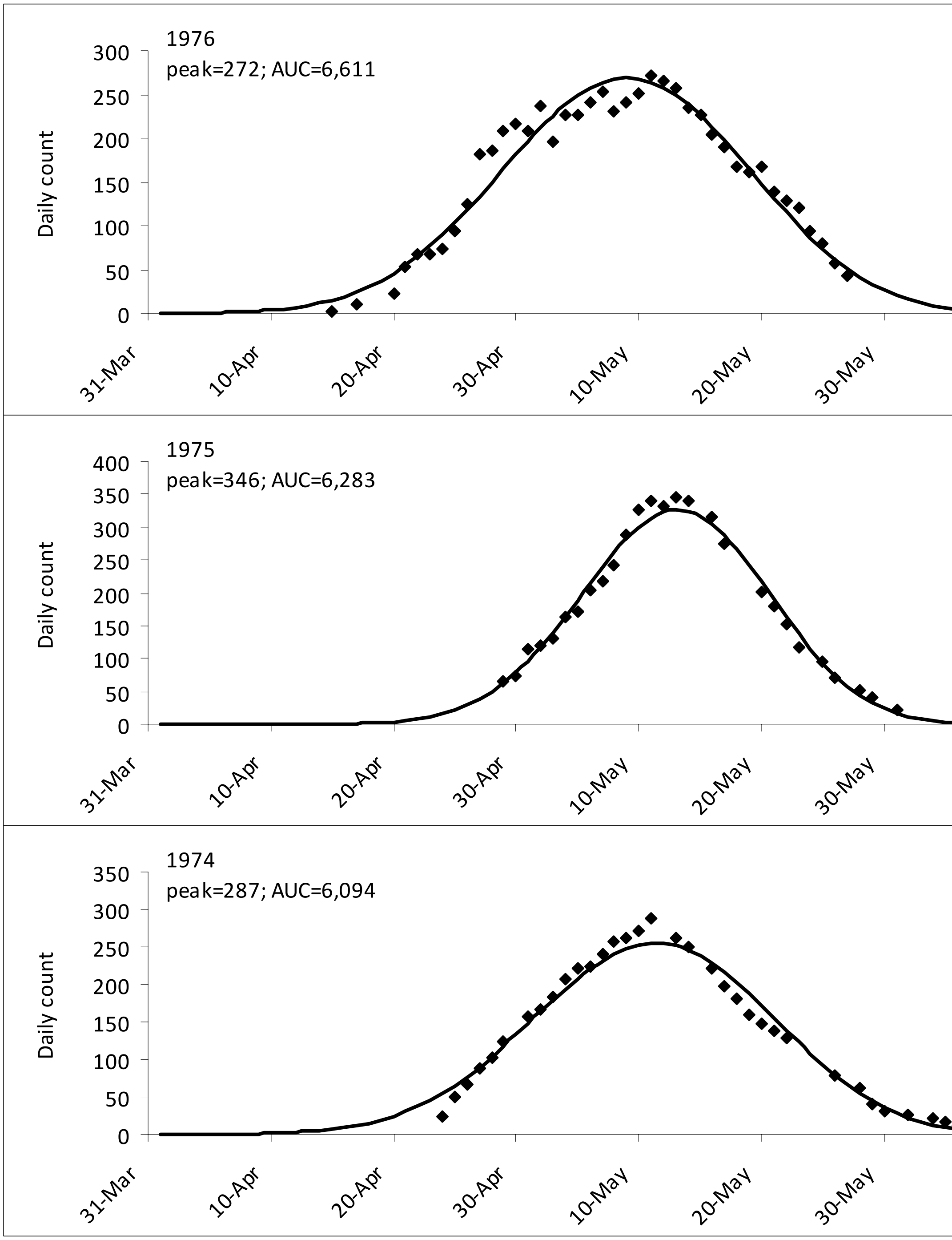
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



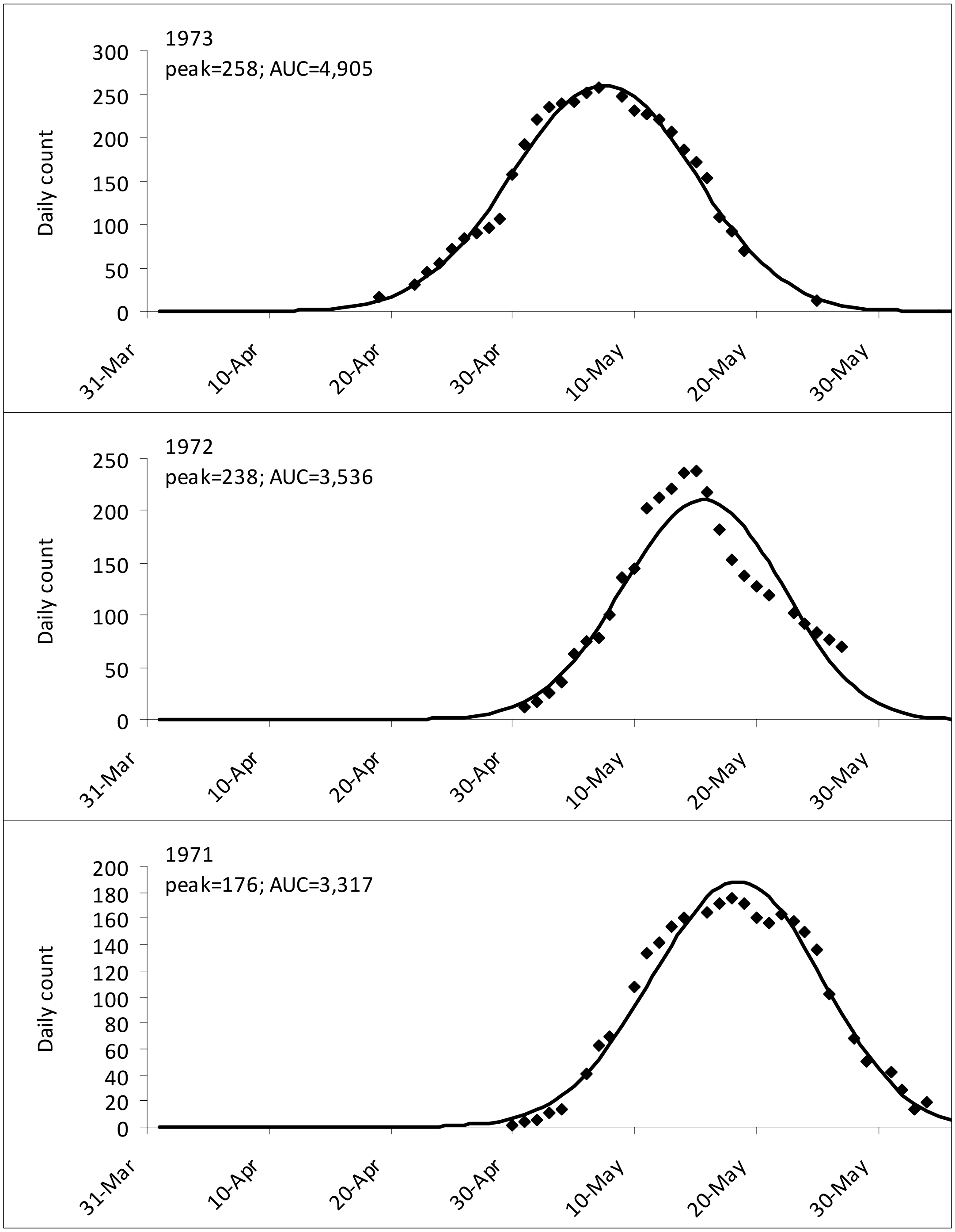
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



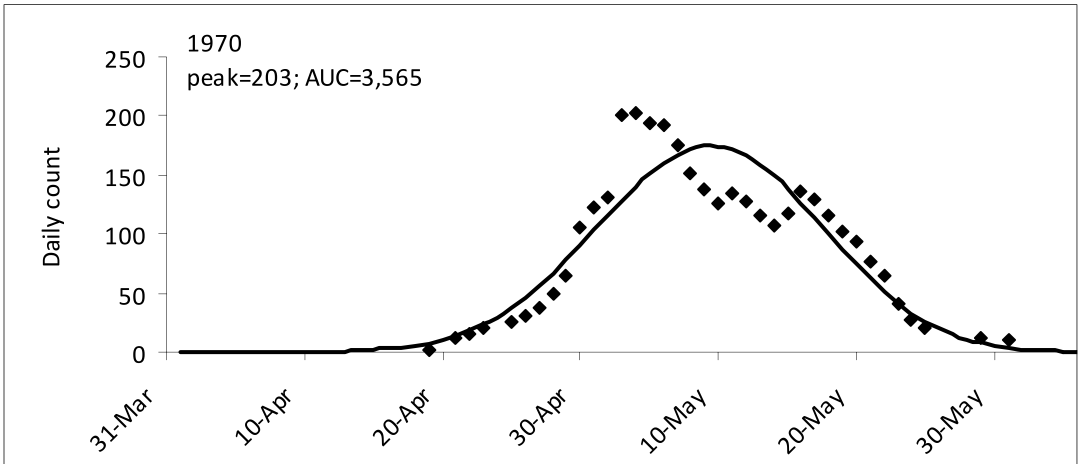
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.

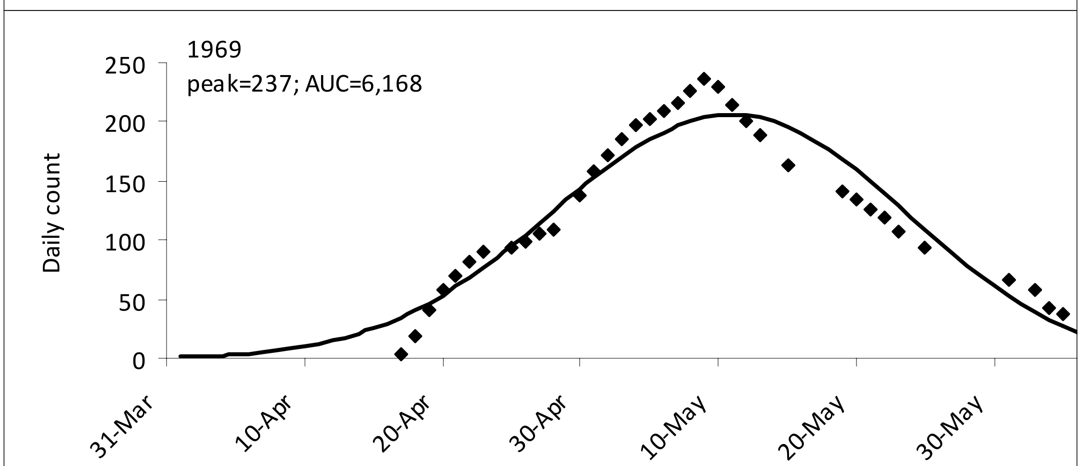


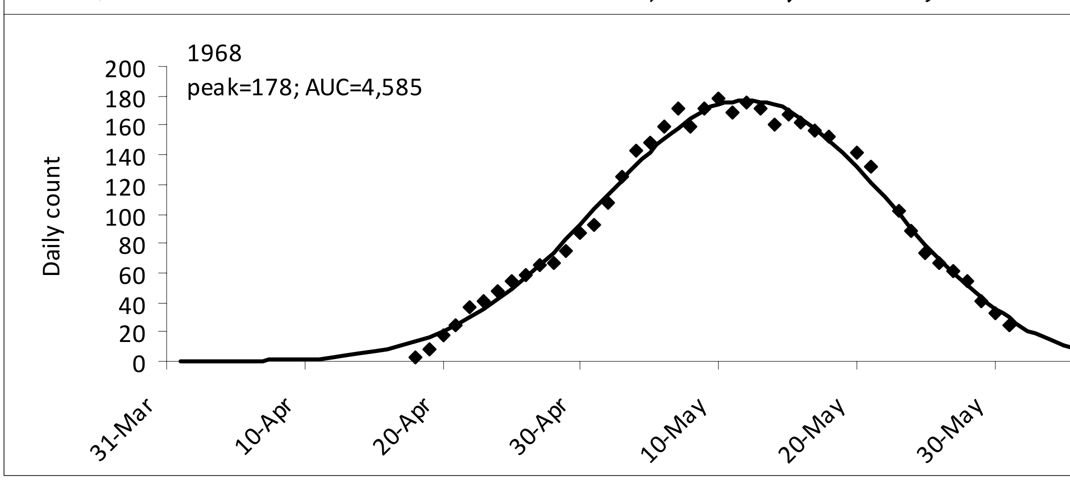
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.



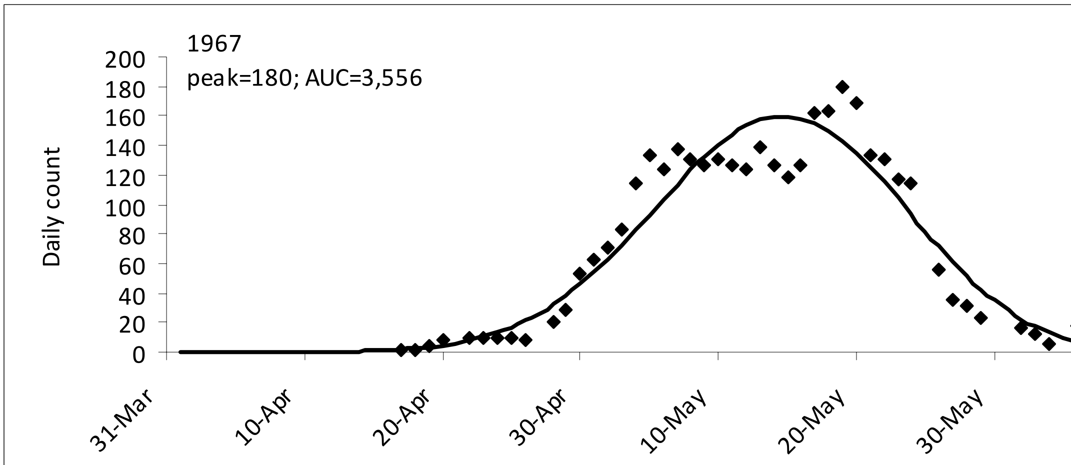
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.

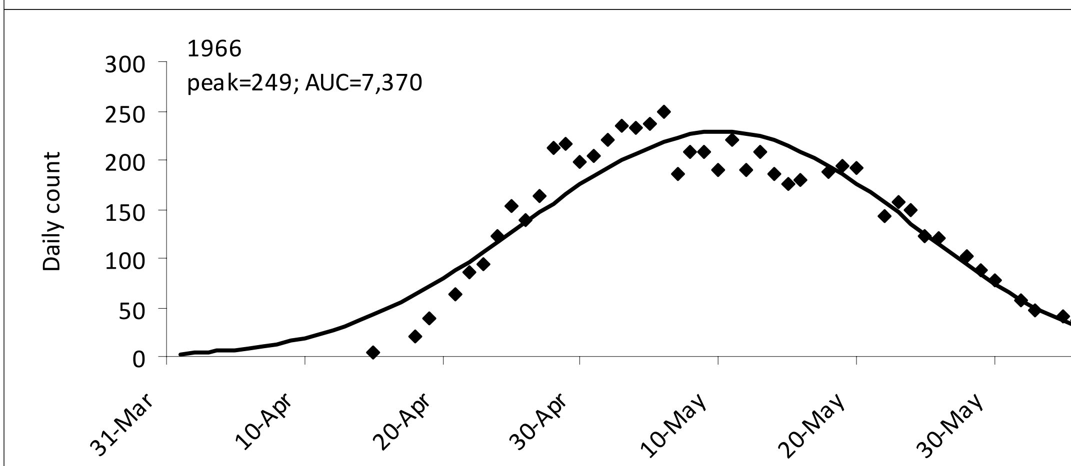


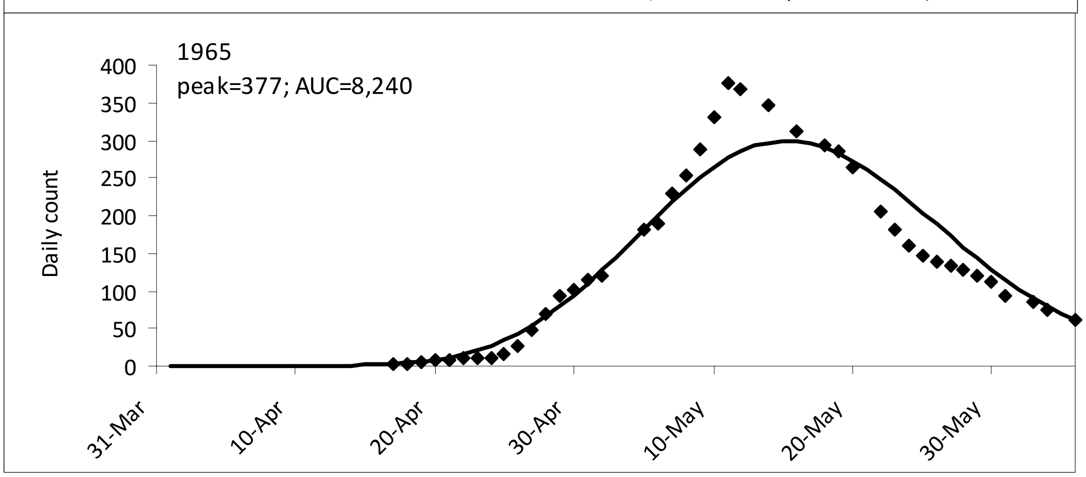




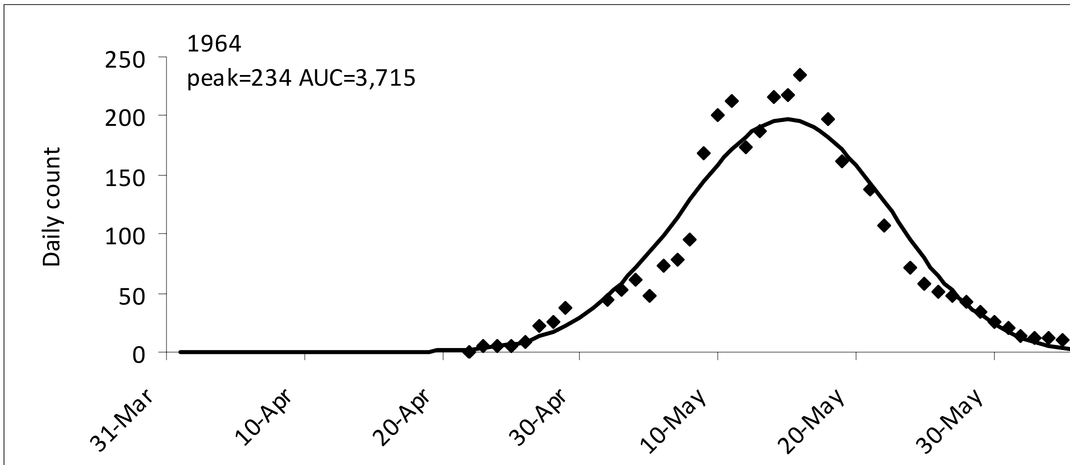
Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.

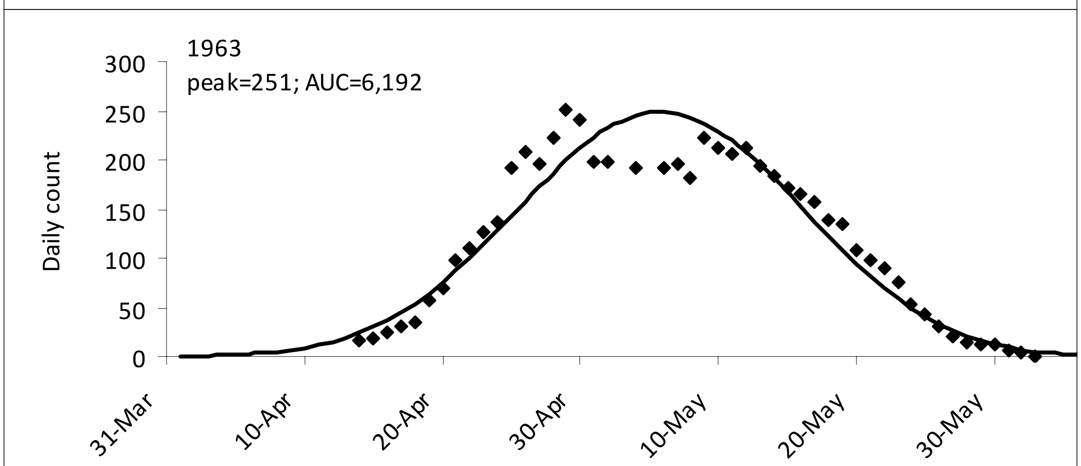


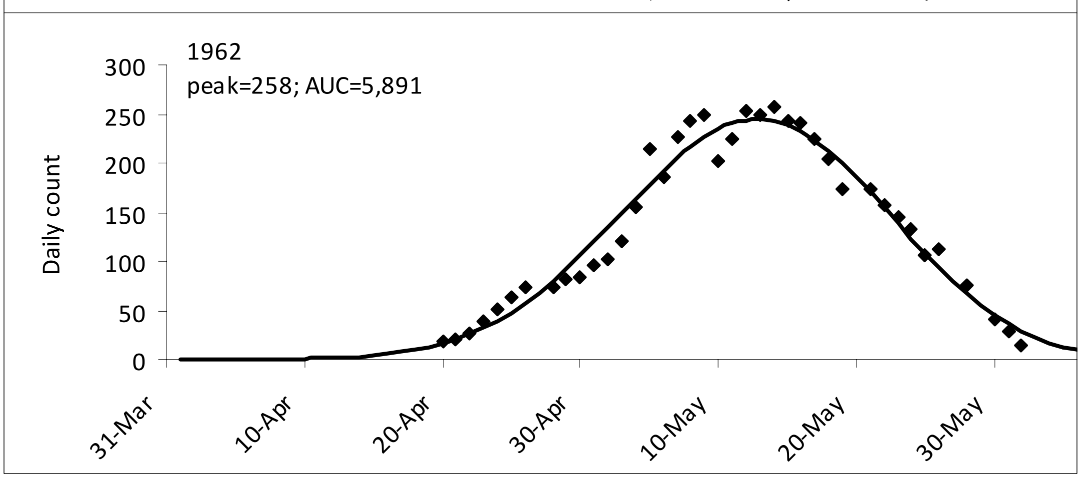




Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.







Appendix 6, continued. Periodic counts of rainbow trout spawners at Gerrard.