Movements and Habitat Selection of Native Fishes and Spiny Softshells in the Yellowstone River, Montana

M. E. Jaeger, R. G. Bramblett, B. J. Tornabene, N. McClenning, M. Nelson, T. Watson, A. Ankrum, M. Webb

ABSTRACT

The Yellowstone River retains some of the least-altered large river habitat remaining in the Rocky Mountains and Great Plains because it is the longest unimpounded river in the contiguous United States. Several Species of Concern and culturally important species occur in the Yellowstone River; however, sparse information exists regarding their movements and habitat selection, which precludes science-based management and conservation. We studied movements and habitat selection of Blue Suckers, Shovelnose Sturgeon, Burbot, Channel Catfish, and Spiny Softshells over 600 km of the Yellowstone River from the Clarks Fork downstream to the confluence with the Missouri River. Blue Suckers and Shovelnose Sturgeon had long home ranges and extensive movements whereas Burbot, Channel Catfish, and Spiny Softshells had smaller home ranges. Blue Suckers used the Yellowstone River in spring through autumn and emigrated to the Missouri River for overwintering while all other species remained in the Yellowstone River year round. Aggregations during spawning and nesting seasons were observed, but their wide spatial dispersion and overall paucity suggests that suitable spawning and nesting habitats occur at multiple locations along the river. All species readily passed upstream of natural rapids, but passage at diversion dams varied among structures, species, and discharge levels. Blue Suckers passed most diversions while Shovelnose Sturgeon only rarely passed one diversion (Intake) and were blocked by other diversions (Cartersville). Burbot, Channel Catfish, and Spiny Softshells encountered diversion dams less often because of their smaller home ranges, but were able to pass diversions on some occasions and were blocked during others. Habitats used by our study species were spatially and temporally diverse with respect to geomorphology. For example, main channels and side channels, reaches with varied geological confinement, and reaches with and without islands were all selected by one or more of our study species during one or more seasons of each year. Blue Suckers and Shovelnose Sturgeon largely avoided unconfined reach types and used main channel habitats. Burbot and Channel Catfish largely avoided confined reaches and also used main channel habitats. Spiny Softshells preferred secondary channels in all seasons but winter, when they preferred bluff pools. We observed little use of tributaries by all species. The overall diversity of habitat use and habitat availability is likely attributable to the lack of main-stem impoundments and channelization and the relatively natural flow regime that makes the Yellowstone River

unique among large rivers in the Rocky Mountains and Great Plains. Preservation of riverine processes that maintain this habitat diversity will increase the likelihood that the Yellowstone River retains an intact aquatic assemblage.

INTRODUCTION

The Yellowstone River is the longest unimpounded river in the contiguous United States and represents some of the most pristine large-river habitat remaining in the Rocky Mountains and Great Plains (Figure 1). The fish assemblage includes 36 native species from 10 families (White and Bramblett 1993); six species are state-listed Species of Special Concern and the pallid sturgeon *Scaphirhynchus albus* is a federally-listed endangered species (Montana Natural Heritage Program 2014). The river also supports a diverse wildlife assemblage that includes Spiny Softshell turtles *Apalone spinifera*, Bald Eagles *Haliaeetus leucocephalus*, and two federally-endangered bird species, the Interior Least Tern *Sternula antillarum*, and the Piping Plover *Charadrius melodus*. This faunally-rich ecosystem has considerable ecological value and supports a culturally-important recreational fishery resulting in designation as an Aquatic Conservation Focus Area by Montana Fish, Wildlife & Parks (FWP). Accordingly, the relatively intact hydrology and ecological processes in the Yellowstone River provide a unique setting to determine movements and habitat selection of fishes in a comparatively unaltered river and inform management and restoration direction occurring in more altered systems.

Despite the ecological and cultural values associated with the Yellowstone River ecosystem, limited life history and behavioral information currently exists for most native species, thereby restricting management and conservation options and effectiveness. Moreover, although the Yellowstone River lacks any large main-stem impoundments, it is spanned by six low-head diversion dams (Figure 1), and the degree to which these structures limit passage of fish is not well understood. Therefore, the goal of this study was to increase the knowledge base for ecologically and culturally-important native Yellowstone River fish and wildlife to help guide the formulation of management and conservation strategies that will benefit both this unique ecosystem and more altered large prairie rivers. Specific emphasis was placed on Blue Suckers *Cycleptus elongatus*, Burbot *Lota lota*, Channel Catfish *Ictalurus punctatus*, Shovelnose Sturgeon *Scaphirhynchus platorynchus*, and Spiny Softshells because of scarcity, recreational and cultural importance, and a limited knowledge base.

Blue Suckers are a Montana Species of Special Concern (Montana Natural Heritage Program 2014), and a Federal Endangered Species Act category 2 species (listing as endangered or threatened was possibly appropriate, but sufficient data were not currently available) by the U.S. Fish and Wildlife Service because of range-wide habitat alteration and fragmentation. Potential threats to Blue Suckers in Montana are thought to include habitat fragmentation by high- and low-head dams and dewatering of critical tributary spawning habitats (Gardner 1998). Blue Suckers may be especially vulnerable to migratory barriers and loss of spawning and rearing habitats because of their migratory nature, high spawning habitat specificity, and perceived poor reproductive success and recruitment (Gardner 1998). Loss and fragmentation of Blue Sucker habitat may be especially prevalent in the Yellowstone River, where diversion dams potentially restrict movements and chronic dewatering of tributaries may eliminate scarce spawning and rearing habitats, but information gaps regarding basic ecology prevent assessment of the extent of habitat disruption. Heretofore, management and research efforts have been limited to routine monitoring. Blue Suckers are known to emigrate from the Missouri River in early summer and enter the Yellowstone River (Fuller and Braaten 2012); however, no studies have focused on Blue Sucker movements or habitat use within the Yellowstone River.

Shovelnose sturgeon are abundant in reaches of the Yellowstone River downstream of Cartersville Diversion but are thought to be functionally absent upstream of this dam. Previous sampling efforts, angler photographs, and other anecdotal evidence suggests this species was historically present and abundant well upstream of Cartersville Diversion but has likely been extirpated by the cumulative effects of flow alteration of the Bighorn River and installation of barriers (low-head diversion dams) on the Yellowstone River. Similar anthropogenically influenced declines in Shovelnose Sturgeon distribution and abundance have occurred throughout their range in other large-river ecosystems; however, the relatively pristine reaches of the lower Yellowstone River likely support the highest densities of Shovelnose Sturgeon range-wide making it an ideal location to characterize the ecology and habitat requirements of this species and gain insights into how they could be restored to upstream reaches.

Burbot (a FWP species of Greatest Conservation Need) and Channel Catfish support a culturally-valuable recreational fishery on the Yellowstone River, but information gaps regarding movements and habitat selection limit effective management of these species (Montana Fish, Wildlife, & Parks 1997; Jones-Wuellner and Guy 2004). Highly variable results of drainage-wide inter- and intra-annual sampling efforts for Burbot (Jones-Wuellner and Guy 2004) suggest dynamic seasonal and annual migration patterns, although no information regarding movement patterns and habitat use in the Yellowstone River exists. The potential for long distance migrations and discrete spawning aggregations of Burbot and Channel Catfish in the Yellowstone River necessitates a better understanding of seasonal movements and habitat use, including the potential fragmentary effects of diversion dams, to guide management decisions.

Spiny Softshells, a Montana Species of Special Concern (Montana Natural Heritage Program 2014), occur in the study area, yet little is known about their populations, distribution, movements, or habitat use in the Yellowstone River. Describing this life history information will benefit managers in the Yellowstone corridor and can help guide conservation efforts for the species in other altered and fragmented large-river systems (e.g., Missouri and Mississippi rivers).

Therefore, to address the aforementioned information gaps our objectives were to:

1) Describe seasonal home ranges, movement patterns, and habitat selection of adult Blue Suckers, Shovelnose Sturgeon, Burbot, Channel Catfish, and Spiny Softshells in a relatively pristine large river.

2) Determine whether any target species used Yellowstone River tributaries or tributary confluences.

3) Identify potential spawning reaches of all target fish species and nesting locations of Spiny Softshells.

4) Determine whether, at what time of year, and under what discharge range diversion dams or natural rapids blocked passage of any target species, and if telemetered species that passed upstream of Intake Diversion used main or side channel routes.

METHODS

Fish and turtle capture and telemetry.—Forty Blue Suckers, 37 Shovelnose Sturgeon, 124 Burbot, 105 Channel Catfish, and 54 Spiny Softshell Turtles were collected by electrofishing, drifting trammel nets, or setting baited hoop nets from April 2005 to May 2008 between Park City, Montana (river kilometer [rkm] 632.5) and the confluence with the Missouri River (rkm 0; Figure 2-3; Appendix Tables 1-5). This section of river was divided into the following seven reaches predicated on geomorphic differences and the presence of potential migratory barriers: (1) Park City to Huntley Diversion, (2) Huntley Diversion to Rancher Diversion, (3) Rancher Diversion to Cartersville Diversion, (4) Cartersville Diversion to Miles City, (5) Miles City to Fallon, (6) Fallon to Intake Diversion, (7) Intake Diversion to the confluence with the Missouri River. Within each reach, sampling points were randomly selected and sampled in the order of their selection. Gears were deployed within no more than five kilometers of each selected sampling point and a maximum of three fish or turtles were collected for telemeterization at each sampling point with the exception of channel catfish in reach 1 where all fish that met minimum size requirements were telemetered because of low abundances. Only adult fish were used as determined by established species-specific lengths at sexual maturity or the expression of gametes. Only adult turtles were selected for telemeter attachment as determined by sex-specific straight carapace length; we identified males based on tail length (extending beyond the carapace) and the presence of ocelli on their carapace. In 2005, ten fish of each species and eight turtles were telemetered in reaches 3–7, with the exception of shovelnose sturgeon and blue suckers which only occurred in reaches 4–7. In 2006 and 2007 fifteen burbot, fifteen channel catfish, and ten turtles were collected from reaches 1 and 2. Additional transmitters were implanted into new individuals each year as needed to replace expelled transmitters.

Radio transmitters of two sizes were used to maximize battery life while avoiding transmitter-to-body-weight ratios in excess of 2% (Winter 1996). Blue sucker, channel catfish, shovelnose sturgeon and spiny softshell turtles received transmitters that were 73 mm long and 16 mm in diameter, weighed 26 g, and had a minimum battery life of 1686 days. Burbot received transmitters that were 46 mm long and 16 mm in diameter, weighed 16 g, and had a minimum battery life of 761 days. Transmitters were implanted in fish immediately following capture using procedures modified from Hart and Summerfelt (1975). Incisions were closed using size 35W stainless steel surgical staples and transmitter antennae trailed externally (Ross and Kleiner 1982; Pegg et al. 1997). Transmitters were attached to turtles externally with stainless steel surgical wire threaded through holes made at the base of the carapace. Transmitters were labeled with a return address and phone number to facilitate return if fish were harvested or found dead. Following surgery, fish and turtles were briefly placed (< 15 minutes) in a holding tank until they recovered and released near the point of capture.

Fish and turtles in reaches 3–7 were relocated by boat at least twice per month from April through November and by aircraft once every three weeks from December through March in 2005–2008. Fish and turtles in reaches 1 and 2 were relocated by boat or aircraft at least once per month from May through February from 2006 to 2008. The entire length of all reaches was traversed during each relocation period. Following detection, exact location of fish and turtles was determined by triangulation coordinates of the location were determined using a hand-held global positioning unit (Winter 1996), and the location was converted to rkm using geographic information system (GIS) software. Fixed, continuously-monitoring receiving stations were placed at the Missouri, Powder, Tongue, and Bighorn river confluences with the Yellowstone River to assess tributary use and emigration, and at Intake and Cartersville diversions.

Habitat quantification.—The availability of habitat in our study area was quantified at three scales: from the largest to the smallest scale the classifications were degree of channel confinement (reach type I), geomorphic reach type (reach type II), and habitat unit. First, to assign reaches to reach type I, we used an existing classification of channel confinement for the Yellowstone River from Springdale to the confluence with the Missouri River (Boyd and Thatcher 2007). Channel confinement was classified as confined, partially confined, or unconfined. Confined reaches had channel margins dominated by bedrock, partially confined reaches had channel margins that intermittently contacted the bedrock valley wall, and unconfined reaches did not contact the bedrock valley wall (Appendix Table 6; Boyd and Thatcher 2004).

Second, to assign reaches to reach type II, we used an existing reach classification that further separated reaches into 10 geomorphic reach categories based on channel planform, degree of confinement, and presence of islands (Boyd and Thatcher 2004). Reach types were categorized as confined meandering (CM), confined straight (CS), partially confined anabranching (PCA), partially confined braided (PCB), partially confined meandering (PCM), partially confined meandering with islands (PCM/I), partially confined straight (PCS), unconfined anabranching (UA), unconfined braided (UB), and unconfined straight with islands (US/I; Appendix Table 6).

Third, habitat units were delineated using low-level 1:24,000 scale color infrared aerial photographs taken during baseflow conditions and physical features inventory (Natural Resources Conservation Service 2002), geologic maps (Montana Bureau of Mines and Geology 1979–2001b), and GIS software. Pool type classification occurred for baseflow and runoff periods and was predicated on geomorphic function (i.e. pool, crossover, secondary channel) and bank material (i.e., bedrock, terrace, alluvium, riprap) as described by Jaeger et al. (2005). Pool types were bluff (the pool contacted bedrock valley margin) terrace (the pool contacted geologic terrace valley margin), alluvial (the pool did not contact bedrock or terrace valley margin), riprap bluff (bluff pools stabilized with riprap), riprap alluvial (alluvial pools stabilized with riprap), crossover ("riffles" where the channel crossed from one outside bend to another), and secondary channel (channels that contained < 50% of the discharge). Total availability of each habitat type during base flow and runoff periods was quantified using GIS software. Availability at base flow was calculated as the amount of habitat provided by all habitat types except seasonally-inundated side channels. Availability during runoff included seasonally-inundated side channels.

Physical characteristics of each habitat unit type were determined using a stratified random sampling design. Within reaches 3-6 one of each pool type and two channel crossovers and secondary channels were randomly selected for physical characterization. Reach 7 was subdivided near Sidney, MT (rkm 49.1) because of a change in predominate substrate and habitats were selected as described above within each sub reach. Each selected habitat unit was divided into 5 evenly spaced transects and depth, velocity, and substrate were measured at 20 points along each transect, except for channel crossovers where only 10 measurements were taken along each transect. Depth was measured with a Lowrance sonar depth finder or stadia rod. Bottom and average velocity were recorded using a boat-mounted USGS model AA current meter at each sample site. Average velocity was measured at 60% depth for sample sites that were less 1.2 meters deep and at 20% and 80% depth for sites that were greater than 1.2 meters deep. Substrate was characterized as sand-silt, gravel-cobble, or bedrock-boulders using a steel conduit (Bramblett and White 2001). Width of each transect was recorded using a hand-held range finder and transects were averaged to estimate average width of each habitat unit. Length of each habitat unit was determined using GIS software. All measurements occurred during baseflow conditions (August-October).

Data Analysis

Seasons.—Each year was divided into seasons based primarily on hydrograph (Figure 4) for analysis of habitat use and movement rates. Spring was defined as the period from

April 1 to the date at which discharge at Miles City increased to above 15,000 cfs and encompassed lowland runoff. Runoff was defined by the period during which discharge was greater than 15,000 cfs at Miles City and encompassed mountain runoff. Summer was defined as the period during which discharge was less than 15,000 cfs to September 30. Winter was defined as the period from October 1 to March 30.

Home range.—Linear home range (LHR) of each telemetered animal was calculated by subtracting its farthest downstream rkm location from its farthest upstream rkm location, both overall and by season (i.e., seasonal home range [SHR]). The number and percent of tagged individuals of each species whose home ranges were in FWP Region 5, 7, or both was calculated.

We investigated differences in overall median LHR among species, and SHR within species and among seasons, with Kruskal-Wallis one-way analysis of variance tests (ANOVA) and pairwise Wilcoxon rank sum tests (Zar 1999). Relationships between LHR and monitoring period and number of locations for each species were examined using Spearman's rank-order correlation.

Because female shovelnose sturgeon were not expected to spawn annually, movements during spawning years were analyzed separately from non-spawning years. Spawning and non-spawning years were assigned by histological analysis of gonad samples and radioimmunoassay of plasma samples collected from recaptured telemetered sturgeon throughout the study. Individuals were assigned spawning years based on the minimum physiological duration required between spawning events (one year for males and two years for females) unless physiological data suggested otherwise. Linear home ranges between periods were compared with a Wilcoxon signed-rank test.

Longitudinal distribution.—Longitudinal distribution was evaluated by dividing each species' maximum linear home range into 15-rkm segments, summing point locations per segment, and dividing by total number of point locations within the maximum linear home range for each species to achieve frequencies per segment. This was done for each species by season and for their original tagging and spawning distributions. We visually inspected plots to assess when and where the highest frequencies of individuals were located by species and seasonal, origin, and spawning distributions.

Movement.—Movement patterns were visualized by plotting relocation histories of all telemetered fish and turtles by species. Overall and seasonal net movement rates (km/d) were calculated by dividing the change in rkm between successive relocations by the number of days that elapsed between relocations such that a positive rate indicates upstream movement and a negative rate indicates downstream movement (Bramblett 1996). Overall and seasonal total movement rates were calculated by taking the absolute value of daily net movement rates. Calculated movement rates represent the minimum movement for the time period between relocations because additional movement may have occurred between relocations.

We compared overall movement rates among species and seasonal movement rates among and within species using Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests (Zar 1999). Overall and seasonal upstream and downstream movement rates within species were compared using Mann-Whitney-U tests.

Habitat selection.—Seasonal selection of habitats (reach types I and II, and habitat unit) by telemetered animals was determined by comparing telemetry relocation frequencies to proportional availability of each habitat by species in each season (including spawning season for reach types I and II). Habitat use frequencies for individual fish were calculated for each season as the proportion of relocations that were made within each habitat type (Manly et al. 2002). Use was determined using GPS coordinates of each relocation, field notes, color infrared aerial photographs and physical features inventory (Natural Resources Conservation Service 2002), geologic maps (Montana Bureau of Mines and Geology 1979–2001b), and GIS software. Selection ratios with 90% (95% for habitat units) simultaneous Bonferroni confidence intervals were calculated to identify preference (selection ratio significantly > 1) or avoidance (selection ratio significantly < 1) of habitats, compared among seasons within species for each habitat comparison, and tested the null hypothesis of seasonal selection in proportion to availability for different habitat types using program R v3.1.2 and package adehabitat (Manly et al. 2002; Rogers and White 2006; R Development Core, 2014). Alpha level for all habitat selection comparisons was 0.05.

Use of tributaries and confluences.—We documented the occurrences of animals relocated in or within 1.6 rkm (i.e., in vicinity) of selected tributaries. The tributaries were the Powder, Tongue, and Bighorn rivers, and O'Fallon and Rosebud creeks. We summarized when animals were located in or in vicinity of tributaries by month and year, which tributaries they were in or near, and how long (duration in days) they remained in or near them.

Aggregations.—We identified aggregations of three or more individuals of the same species within 1 rkm of each other on the same day throughout the entire monitoring period for all species. We classified aggregations as spawning (or nesting in the case of Spiny Softshells) or non-spawning.

Putative spawning periods (Table 1) were identified for each species and each year by matching literature reports for spawning temperatures and unpublished water temperature data for the Yellowstone River at Sidney, Montana. Blue Suckers have been reported to spawn in spring and early summer (Bednarski and Scarnecchia 2005) at temperatures varying from 12° to 23° C throughout their range (Moss et al. 1983; Rupprect and Jahn 1980; Vokoun et al. 2003; Neeley et al. 2010). Shovelnose Sturgeon optimal spawning periods have been described as being from 16 to 20° C (Goodman et al. 2013; Kappenman et al. 2013). Spawning temperature reports for Burbot were sparse and we were unable to locate winter Yellowstone River temperatures; however, Burbot are known to spawn in winter (Scott and Crossman 1973) when river temperatures are usually near freezing. Brown (1971) stated that ripe individuals have been reported as early as December, but that spawning in Montana probably occurs during February. Channel Catfish are reported to spawn from 21.1° C to 30° C but 26.7° C appears to be optimal (Tucker and Robinson 1990). Spiny Softshells on the Missouri River nested post-peak runoff and nesting lasted about 24 days in an a year with average runoff (Tornabene 2014).

Passage at diversions and rapids.—Passage or blockage (apparent failure to pass upstream of diversion dam or rapid) at Intake, Cartersville, Myers (also known as Yellowstone), Rancher, Waco, and Huntley diversions was assessed. We also assessed whether animals were able to pass or were blocked at two natural rapids, Wolf (rkm 230.0) and Matthews (rkm 277.8) rapids. These rapids were selected because they had previously been surveyed to assess hydraulic conditions potentially faced by Shovelnose Sturgeon during documented passage events as a design analog for a rock ramp for Cartersville Diversion (Dowl HKM et al. 2010).

We used plots of individual animal rkm locations across time with the location of diversion dams and rapids indicated with horizontal lines to initially identify potential passage or blockage events. We characterized passage as movement towards a structure with successful passing over the dam or rapid (i.e., relocations below and then above the structure). Blockage was interpreted as successive animal telemetry relocations within 1.6 rkm downstream of the diversion dam or rapid, but without subsequent relocations upstream of the diversion dam or rapid.

We also evaluated whether animals passing Intake Diversion did so by way of side-channel or main channel route by comparing relocations obtained by manual tracking and fixed telemetry stations at Intake Diversion. Passage events were classified as main-channel passage (over the diversion dam) if the animal's transmitter was picked up continuously by the remote telemetry station as they moved upstream. In contrast, passage events were classified as side-channel passage if they were either picked up by the fixed station only briefly while moving upstream or were not picked up by the fixed station but were located below and subsequently above Intake Diversion (animals using the side channel were not within range of the fixed telemetry station).

We determined the range of dates and discharges under which passage or blockage events occurred and calculated summary statistics for discharge (minimum, maximum, and mean daily discharge) for each event. Discharge data was obtained from the USGS Yellowstone River flow gage nearest to the diversion dam or rapid (Billings, Forsyth, Miles City, or Sidney, Montana). We summarized and tabulated passage and blockage events for each species at each structure by month.

We used Mann-Whitney-U tests to compare discharge statistics during passage and blockage events for those species and structures for which there were sufficient observations for statistical testing. Kruskal-Wallis ANOVAs were used to compare discharge statistics during passage via the main channel, via the side channel, and during blockage events at Intake Diversion for those species with sufficient numbers of observations.

We used binomial logistic regression to investigate the ability of species to pass over diversion dams compared to riffles, how this varied among species, the influence of different discharge statistics (i.e., maximum, minimum, and mean discharge) in passage over these structures, and if species passage depended on different discharge levels. We started with a full model including all the aforementioned variables and interaction terms, used backwards elimination variable selection by removing uninformative parameters ($\alpha > 0.05$), created multiple competing models, and compared models using Akaike information criterion (AIC). We also calculated and visualized probabilities of passage over diversion dams and riffles for each species as a function of Yellowstone River discharge.

RESULTS

Home range.—Most individuals of all species remained in the FWP region in which they were tagged (Table 2, Figures 5-9). Monitoring period and number of locations varied among species and among animals that retained transmitters or expelled transmitters (Tables 3 and 4). Some significant correlations existed between LHR and monitoring period, and LHR and number of locations for Blue Suckers, Burbot, and Channel Catfish (Table 5). These relationships were similar within species for those animals that retained transmitters and those that expelled transmitters, except for Blue Suckers and Burbot (Table 5). There were no significant relationships between LHR and monitoring period and LHR and number of relocations for Shovelnose Sturgeon or Spiny Softshells (Table 5). To avoid bias related to transmitter expulsion, animals that expelled transmitters before the end of a year or season were removed from LHR or SHR analyses.

Median linear home range varied among species ($P < 0.001$; Table 6; Figure 10). Blue Sucker LHRs were largest, and were significantly different from all other species. Shovelnose Sturgeon LHRs were next largest, and were significantly different from all other species. Burbot, Channel Catfish, and Spiny Softshell LHRs were smallest and did not differ significantly from one another. Shovelnose sturgeon LHRs were significantly larger during spawning years than non-spawning years ($P = 0.003$; Table 7; Figure 11)

Seasonal home ranges were significantly different within species, except for Channel Catfish (Table 8). Median seasonal home range of Blue Sucker was smallest in spring; runoff, summer, and winter home ranges were not significantly different. Median SHR of Burbot was greatest in winter, but not significantly different than runoff. Median SHR of Shovelnose Sturgeon was greatest in summer, but not significantly different than during spring and runoff. Median SHR of Spiny Softshells was greatest in summer and significantly different than spring, runoff, and winter (Table 9; Figures 12–16).

Longitudinal distribution.—Telemetered Blue Suckers occupied reaches from the confluence of the Missouri River to rkm 465, which is 9 rkm below the Bighorn River and 5 rkm below Rancher diversion (Figure 17). Longitudinal distribution during spawning season was dispersed, but the reach with the highest frequency of relocations during spawning season was rkm 105–120 (Figure 17), which includes Intake Diversion. The second highest frequency of spawning season relocations occurred from rkm 0–15, just above the confluence with the Missouri River.

Telemetered Shovelnose Sturgeon occupied reaches from the confluence of the Missouri River to rkm 375, which is just below Cartersville Diversion (Figure 18). Longitudinal distribution during spawning season was dispersed, but a cluster of relocations occurred at rkm 225–240, which includes the confluence of the Powder River (rkm 236; Figure 18).

Telemetered Burbot occupied reaches from the confluence of the Missouri River to rkm 645, which is above the Clarks Fork River (rkm 609; Figure 19). Longitudinal distribution during spawning season was dispersed, but a cluster of relocations occurred from rkm 90–120, which includes Intake Diversion (rkm 115). A second cluster of relocations occurred from rkm 600–615, which was below the Clarks Fork River (Figure 19).

Telemetered Channel Catfish occupied reaches from the confluence of the Missouri River to rkm 540, which is below Huntley Diversion (rkm 566; Figure 20). Longitudinal distribution during spawning season was dispersed, but two clusters of relocations occurred below rkm 75, which is below Intake Diversion (Figure 20).

Telemetered Spiny Softshells occupied reaches from rkms 60–615, which is from near Sidney, Montana to above the Clarks Fork River (Figure 21). Longitudinal distribution during nesting season was dispersed, but most relocations occurred below rkm 420 (Figure 21).

Movement.— Overall (Table 10; Figure 22) and seasonal (Tables 11 and 12) total movement rates were significantly different among most species. Overall median net movement rates were close to zero and not significantly different among the five species that were monitored (Table 13; Figure 23); however, seasonal net movement rates varied significantly for all species except Spiny Softshells (Tables 14 and 15).

Blue Suckers exhibited strong directional movement trends. Most individual Blue Suckers moved into the Yellowstone River from the Missouri River below the confluence in June, coincident with runoff, and moved back downstream and out of the Yellowstone River in October (Figure 24). Seasonal total movement rates varied significantly (Table 11) with faster movements occurring in runoff and winter (Table 12; Figure 25). Seasonal net movement rates of Blue Suckers varied significantly (Table 14), and each season was significantly different than all other seasons (Table 15; Figure 26). Upstream and downstream movements occurred during all seasons, and upstream and downstream movement rates were significantly different from each other in runoff and winter (Tables 16 and 17; Figures 27 and 28). Runoff movement rates were primarily upstream whereas winter movement rates were primarily downstream.

Shovelnose Sturgeon had variable movement trends, and many individuals moved considerable distances between summer and winter locations (Figure 29). At least 46% of individuals had winter locations upstream of summer locations; moreover 30% of individuals had winter locations in the reach immediately downstream of Cartersville Diversion. Twenty two percent of individuals had winter locations downstream of summer locations; others were relatively sedentary or had no discernible pattern.

Seasonal total (Table 11) and net (Table 14) movement rates of Shovelnose Sturgeon varied significantly among seasons. Similar rates of movement occurred during spring, runoff and summer (Table 12; Figure 30). Upstream and downstream movements occurred during all seasons, although median seasonal net movement rates were slightly downstream during runoff and winter and upstream during spring and summer (Table 15; Figure 31). Upstream and downstream net movement rates were not significantly different from each other during any season (Table 16). No significant differences in overall or seasonal total and net movements rates of male, spawning female, and non-spawning females occurred except for total movement rates in spring (Table 18). Spawning female sturgeon had significantly higher median total movement rates than non-spawning female sturgeon during spring (Table 19, Figure 32). Male Shovelnose Sturgeon also had higher median total movement rates than nonspawning females, although they were not significantly different. Total movement rates during the runoff period and net movement rates during the spring or runoff seasons did not differ, even though these included the putative spawning period (Table 19-20, Figure 32-33).

Burbot movement trends were variable; many individuals were relatively sedentary whereas others exhibited modest upstream and downstream movements (Figure 34). No differences in total movement rate were observed among seasons (Table 11and 12; Figure 35); however, directionality of movements varied among seasons (Table 14 and 15; Figure 36). Upstream and downstream movements occurred during all seasons, but median net movement rates during summer were slightly downstream compared to in spring and winter, when seasonal net movements were close to zero (Table 15; Figure 36). Downstream movement rates were significantly greater than upstream movement rates during runoff and summer (Tables 16 and 17; Figures 37 and 38).

Channel Catfish movement trends were variable; many individuals were relatively sedentary whereas others exhibited small upstream and downstream movements (Figure 39). Seasonal total movement rates were similar in all seasons other than winter, when movement rates were significantly lower (Tables 11 and 12; Figure 40). Seasonal net movement rates of Channel Catfish varied (Tables 14 and 15; Figure 41). Upstream and downstream movements occurred during all seasons. However, median seasonal net movement rates were close to zero during all seasons, and movement rates in summer were significantly different than in spring and winter, when seasonal net movements were slightly downstream (Table 15; Figure 41). Downstream movement rates were greater than upstream movement rates in winter (Tables 16 and 17; Figure 42).

Most Spiny Softshells were relatively sedentary (Figure 43). Total movement rates were lower in the winter than during other seasons (Tables 11 and 12; Figure 44). Net movement rates of Spiny Softshells did not vary among seasons (Tables 14 and 15; Figure 45). Upstream and downstream movements occurred during all seasons, although median seasonal net movement rates were near zero during all seasons (Table 15; Figure 45). Upstream and downstream net movement rates were different from each other during spring, when downstream movement rates were greater (Tables 16 and 17; Figure 46).

Physical habitat.—Differences in length, width, average and maximum depth, average column and bottom velocity, and percentage of boulder and bedrock substrate were observed among habitat types ($P < 0.001$, Table 21). Main-stem pools at the valley margin (bluff, riprap bluff) were generally longer and had lower average and bottom velocities than pools away from the valley margin (alluvial, riprap alluvial). Armored pools (riprap valley margin, riprap alluvial) generally had higher maximum and average depths, greater variability of depths, and a higher percentage of boulder and bedrock substrates than their unarmored equivalents (bluff pool, alluvial pool). Terrace pools had characteristics that were generally intermediate between alluvial and bluff pools (Table 21). Channel crossovers were shorter, shallower, had higher velocities, and a lower percentage of boulder and bedrock substrates than other main-stem habitat types.

Habitat selection.—Partially confined reaches composed the majority of available reach type I lengths (rkms) in the total range of each of the five species (Table 22). Unconfined reaches were second most available for Burbot, Channel Catfish, and Spiny Softshells, whereas confined reaches were second most available for Blue Suckers and Shovelnose Sturgeon. Reach type II availability was more variable among species (Table 23).

Blue Suckers avoided reach type I unconfined reaches overall (considering all seasons simultaneously; Figure 47; Appendix Table 7). Blue Suckers preferred partially confined reaches during spawning season and avoided unconfined reaches during runoff, summer, and spawning seasons (Figure 48; Appendix Table 8).

Blue Suckers avoided reach type II partially confined braided, unconfined anabranching, and unconfined braided reaches overall (Figure 49; Appendix Table 9). Blue Suckers did not prefer any reach type II habitats during any season, but they avoided partially confined braided, partially confined meandering, unconfined anabranching, and unconfined braided reaches in most seasons, including spawning season (Figure 50; Appendix Table 10).

Blue Suckers did not use all habitat units in proportion to their availability during any season (Figure 51). During spring, alluvial pools were preferred and diversion dam pools were avoided. During runoff, diversion dam pools were preferred and secondary channels were avoided. All habitats were used in proportion to their availability during summer and winter except secondary channels, which were avoided.

Shovelnose Sturgeon avoided type I unconfined reaches overall and during all seasons (Figure 47 and 52; Appendix Table 7 and 11).

Shovelnose Sturgeon avoided type II confined straight and unconfined straight with islands reaches overall (Figure 49; Appendix Table 9). Shovelnose Sturgeon preferred confined meandering reaches during winter and avoided confined straight and unconfined straight with islands reaches in most seasons, including spawning season (Figure 53; Appendix Table 12).

Shovelnose sturgeon did not use all habitats in proportion to their availability during any season ($P < 0.05$; Figure 54). Sturgeon preferred channel crossovers, avoided secondary channels, and all other habitat types were used in proportion to their availability. During runoff and summer, secondary channels were avoided and during winter channel crossovers and secondary channels were avoided.

Burbot avoided type I confined reaches overall (Figure 47; Appendix Table 7). Burbot preferred partially confined reaches during spring and runoff and avoided confined reaches during spring, runoff, summer, and winter. (Figure 55; Appendix Table 13).

Burbot avoided type II confined straight and unconfined straight with islands reaches overall (Figure 49; Appendix Table 9). During spawning season, Burbot avoided unconfined straight reaches with islands (Figure 56; Appendix Table 14). Burbot preferred unconfined braided reaches in summer, and largely avoided confined meandering, confined straight, partially confined braided, unconfined anabranching, and unconfined straight with island reaches during spring, summer, and runoff. During winter, Burbot avoided confined straight and unconfined straight with islands reaches.

Burbot did not use all habitat units in proportion to their availability during any season (Figure 57). During spring, runoff, and summer Burbot preferred bluff and riprap alluvial pools, avoided alluvial pools, channel crossovers, and secondary channels. During winter, riprap alluvial pools were preferred.

Channel Catfish avoided type I confined reaches overall (Figure 47; Appendix Table 7). Channel Catfish exhibited no preference or avoidance of any Reach Type I reaches in any season (Figure 58; Appendix Table 15).

Channel Catfish avoided type II confined straight reaches overall (Figure 49; Appendix Table 9). Channel Catfish did not prefer any reach type II habitats during any season, but they largely avoided confined straight, partially confined braided, partially confined meandering, and partially confined straight reaches in spring, runoff, and summer. During spawning season and winter, Channel Catfish avoided confined straight reaches (Figure 59; Appendix Table 16). Channel catfish did not use all habitat units in proportion to their availability during spring and runoff (Figure 60). During spring channel crossovers were avoided and all other habitat types were used in proportion to their availability. During runoff channel crossovers were preferred

Spiny Softshells exhibited no preference or avoidance of any Type I reaches overall (Figure 47; Appendix Table 7). Spiny Softshells also exhibited no preference or avoidance of any Reach Type I reaches in any season (Figure 61; Appendix Table 17).

Spiny Softshells avoided type II partially confined braided reaches overall (Figure 49; Appendix Table 9). Spiny Softshells avoided partially confined braided reaches in all seasons except runoff, partially confined meandering reaches in summer and winter, and confined meandering in the nesting season. During runoff, Spiny Softshells exhibited no preference or avoidance of any type II reaches (Figure 62; Appendix Table 18).

Spiny Softshells did not use habitats in proportion to their availability during any season ($P < 0.05$; Figure 63). Secondary channels were preferred during all seasons other than winter. Spiny Softshells generally demonstrated higher preference of unarmored pools (bluff, terrace, alluvial) than their armored equivalents (riprap bluff and riprap alluvial). During winter bluff pools were preferred. Diversion dams were avoided during all seasons.

Use of tributaries and confluences.—Telemetered animals were occasionally relocated in the vicinity of, or in tributaries (Table 24). A total of 15% of individual telemetered Blue Sucker and 13% of Shovelnose Sturgeon were relocated in the vicinity of tributaries (Table 24). From 7% to 8% of telemetered Burbot, Channel Catfish, and Spiny Softshells were relocated in the vicinity of tributaries (Table 24). Channel Catfish were relocated in tributaries more often (7% of individuals) than other telemetered species. The months with the highest number of relocations of telemetered animals in the vicinity of or in tributaries were May and June, respectively (Table 25). The tributaries with the highest number of relocations of telemetered animals in the vicinity of or in tributaries were the Powder, Tongue, Bighorn, and Clarks Fork rivers, and O'Fallon and Rosebud creeks, respectively (Table 26).

Aggregations.—We documented spawning and non-spawning aggregations for all five species (Table 27; Figures 64-68; Appendix Tables 19-26). Aggregations were more easily and commonly identified at remote stations because they were constantly scanning at these locations. Blue Sucker aggregations were common at rkm 0, at the mouth of the

Yellowstone River, and near Intake Diversion (Figure 64; Appendix Table 22). A total of 10 aggregations were observed during putative Blue Sucker spawning seasons; one Blue Sucker aggregation was observed at rkm 0.8, which is just above the confluence with the Missouri River, and 9 were at rkm 114.4–115.0, which is just above Intake Diversion (Appendix Table 22).

Shovelnose Sturgeon aggregations were common below Cartersville Diversion (Figure 65; Appendix Table 23). A total of nine aggregations were observed during putative Shovelnose Sturgeon spawning seasons, dispersed from rkm 43.9–294.5 (Appendix Table 23). Two putative Shovelnose Sturgeon spawning aggregations were at rkm 43.9–44.0 below Sidney, Montana, four putative spawning aggregations were at rkm 225.9–236.6 below Wolf Rapids to above the mouth of the Powder River, and two were at rkm 293.7–294.5 near the Tongue River confluence (Appendix Table 23).

Burbot aggregations were common below Intake Diversion, above Cartersville Diversion, and near the Clarks Fork River (Figure 66; Appendix Table 24). Two aggregations were observed during putative Burbot spawning seasons; one aggregation was at rkm 223.4, which is below Wolf Rapids and above O'Fallon Creek, and one was at rkm 604, which is below the confluence of the Clarks Fork River (Appendix Table 24).

Channel Catfish aggregations were less common, but five occurred at rkm 68.9–69.9, which is about 45 rkm below Intake Diversion (Figure 67; Appendix Table 25). Nine aggregations were observed during putative Channel Catfish spawning seasons and these aggregations were dispersed from rkm 69.4–420.1 (Appendix Table 25).

Spiny Softshell aggregations occurred about 55 rkm above Intake Diversion, and about 23 rkm above Cartersville Diversion (Figure 68; Appendix Table 26). Four putative Spiny Softshell nesting aggregations were located from rkm 44.0–104.7, which is from below Intake Diversion to above Cartersville Diversion (Appendix Table 26).

Passage at diversions and rapids.—Most telemetered Blue Suckers and Shovelnose Sturgeon encountered diversion dams or rapids and most Burbot, Channel Catfish, and Spiny Softshells did not (Table 28). Telemetered animals were blocked at 36% of events at diversion dams but only 3% of events at rapids (Table 29). Most passage and blockage events were at Intake and Cartersville diversions and at Matthews and Wolf rapids; telemetered animals rarely encountered Myers, Rancher, Waco, or Huntley diversions (Table 30). Passage irrespective of species was lower at Cartersville (45%) than at Intake (73%; Table 30). Most passage events at Intake Diversion were via the main channel (89%; presumably over the diversion dam), rather than via the side channel (11%; Table 31). The month with the greatest number of encounters at diversion dams and rapids was June, followed by May, July, and April, respectively (Table 32; Appendix Tables 27–33).

Blue Suckers passed upstream at 69 of 75 (92%) events at Intake Diversion (Table 33), passing upstream by way of the main channel (presumably over the diversion dam) on 60 of 66 (91%) passage events and by way of the side channel on 6 of 66 (9%) events (Table 34). Median discharge was not significantly different ($P < 0.05$) during periods when Blue Suckers passed Intake via the main channel, the side channel, or were blocked. The ranges of discharge when Blue Suckers passed Intake via the main channel and via the side channel did not differ but the maximum discharge was lower when Blue Suckers were blocked (Table 35). Blue Suckers passed upstream at 17 of 18 (94%) events at Cartersville Diversion and at 4 of 4 events at Myers Diversion (Table 33). The minimum, mean, and maximum discharge were higher during periods when Blue Suckers passed Cartersville than during the one blockage event at Cartersville Diversion (Table 36). Telemetered Blue Suckers did not encounter any diversion dams upstream of Myers Diversion (Table 33)

Shovelnose Sturgeon passed upstream at 3 of 19 (16%) events at Intake Diversion (Table 33), passing upstream by way of the main channel on two passage events (Table 34); we were unable to determine the route of passage during the other event. Maximum discharge was lower during the periods when Shovelnose Sturgeon passed Intake via the main channel than during the blockage events (Table 35). Shovelnose Sturgeon were blocked at 15 of 15 events at Cartersville Diversion (Table 33), when discharge ranged from 3,790 to 23,600 cfs (Table 36). Shovelnose Sturgeon did not encounter any of the diversion dams upstream of Cartersville Diversion (Table 33).

Burbot passed upstream at 2 of 9 (22%) events at Intake Diversion (Table 33), passing upstream via the main channel on one occasion (Table 34); we were unable to determine the route of passage during the other event. Discharge was higher during the period when a Burbot passed Intake via the main channel than when they were blocked (Table 35). Burbot passed upstream at 6 of 14 (43%) events at Cartersville Diversion (Table 33). Median discharge was similar ($P > 0.05$), and range of discharge was also similar (Table 36), during periods when Burbot passed and when they were blocked at Cartersville. We documented one passage event and one blockage event at Waco Diversion; maximum discharge was higher during the blockage event period than during the passage event period (Table 36).

Channel Catfish passed upstream during three events and were blocked during one event at Intake Diversion (Table 33), passing upstream via the main channel on two occasions, and via the side channel on one occasion (Table 34). Maximum discharge was higher during the period when a Channel Catfish passed Intake via the side channel than when they passed via the main channel, and much higher than when they were blocked (Table 35). Channel Catfish were blocked at three of four events at Cartersville Diversion (Table 33). Maximum discharge was the same during periods when Channel Catfish passed and when they were blocked at Cartersville (Table 36). We documented two Channel Catfish passage events and one blockage event at Myers Diversion, one passage event at Rancher Diversion, and one passage and one blockage event at Waco Diversion (Table 33).

Spiny Softshell turtles passed upstream at two of two events at Intake Diversion (Table 33). Passage occurred by way of the side channel on one passage event and we were unable to determine the route of passage during the other event (Table 34). Discharge ranged from 17,200 cfs to 25,900 cfs during this event (Table 35). Spiny Softshells passed upstream at one of five events at Cartersville Diversion (Table 33). Mean, minimum, and maximum discharge was lower during the period when the Spiny Softshell passed than when they were blocked at Cartersville Diversion (Table 36). Telemetered Spiny Softshells did not encounter any of the diversion dams upstream of Cartersville Diversion (Table 33).

The probability of upstream passage for all species was higher at rapids than at diversion dams and increased with increasing maximum discharge except for Spiny Softshells, which had a lower probability of passage with increasing discharge (Figures 69 and 70). The relationship between increasing discharge and probability of passage was most pronounced for Channel Catfish. Blue Suckers had the highest and Shovelnose Sturgeon had the lowest probability of passage at diversion dams (Figure 69).

DISCUSSION

We described movements and habitat use of Blue Suckers, Burbot, Channel Catfish, Shovelnose Sturgeon, and Spiny Softshells on the Yellowstone River in Montana and North Dakota. Home ranges, movement patterns, ability to pass diversion dams, habitat use, use of tributaries, and putative spawning locations varied among the five species we studied and among individuals of each species. However, we observed two general movement patterns: Blue Suckers and Shovelnose Sturgeon had long home ranges and rapid movement rates whereas Burbot, Channel Catfish, and Spiny Softshells had smaller home ranges and slower movement rates.

Our results conform to the tenets of the Flood Pulse Concept (FPC; Junk et al. 1989) and the Natural Flow Paradigm (Poff et al. 1997). Lateral floodplain connectivity and habitat heterogeneity provided by side channels are thought to provide critical habitats for lotic fishes (Junk et al. 1989; Schlosser 1991; Fausch et al., 2002). However, widespread anthropogenic alterations of most large, temperate rivers have caused extensive floodplain contraction (Tockner and Stanford 2002) and side-channel loss. The quasi-natural flood pulse on the Yellowstone River provided cues for movements of Blue Sucker and Shovelnose Sturgeon and created and maintained diverse habitats (i.e., meanders, islands, pools, crossovers, and side channels).

The Highway Analogy of the FPC posits that main-stem channels are primarily used as refuges in low water, and as a route for accessing feeding, spawning, and rearing habitats on the floodplain during high water (Junk et al. 1989). Spiny Softshells used side channels extensively in our study, as well as in the Missouri River above Fort Peck

Reservoir (Tornabene 2014). Floodplains and topologically diverse habitats are important for larval Blue Suckers (Adams et al. 2006) and other components of the fish assemblage and food web such as pelagophils (e.g. Flathead Chub, Western Silvery Minnow; Perkin and Gido 2011). Moreover, many of the other species in the Yellowstone River fish assemblage—particularly small fishes—extensively used side channel habitat, particularly during runoff (Reinhold et al., in press). However, as we expected this was not the case for adult Blue Sucker and Shovelnose Sturgeon, which are fluvial specialist fish species (Galat and Zweimuller 2001).

Our observations of intermediate to large-scale movements support riverine ecology paradigms that emphasize the importance of directed movement by fish across landscape scales to occupy patches of critical habitat required to fulfill their life cycle (i.e., Dynamic Landscape Model, Schlosser 1991; and Riverscapes Concept, Fausch et al. 2002). For example, Blue Suckers moved hundreds of kilometers between the Yellowstone and Missouri rivers among overwintering, spawning, and summer habitats. Shovelnose Sturgeon also had long-range movements that were presumably required to complete their life cycle. The Stream Hydraulics Concept posits that stream hydraulics (e.g., velocity, depth, substrate, and roughness) are the most vital environmental components regulating zonation patterns of benthic macroinvertebrates (Statzner and Hilger 1986). Accordingly, the use of different habitats in summer (gravel and cobble substrate in the Yellowstone River) and winter (sandy substrate in the Missouri River) by Blue Suckers may be related to invertebrate food availability (Rupprecht and Jahn 1980; Moss et al. 1983). Bluff pools may be critical habitat patches in the Yellowstone River landscape because these areas have more abundant large substrate such as boulders, slower current velocities than alluvial pools, and are focal points for overwintering Spiny Softshells (Tornabene 2014), spawning Sauger (Jaeger et al. 2005), and rearing habitat for juvenile Pallid Sturgeon (Jaeger, unpublished data).

Blue Suckers.—Blue Suckers annually migrated into the Yellowstone River from the Missouri River during summer. Movements were in a directed manner at faster rates and over longer distances than the other species. Most Blue Suckers migrated into the Yellowstone River during runoff associated with the annual peak in the hydrograph in May or June, rapidly moved upstream to locations between Intake Diversion and the confluence of the Bighorn River where they were relatively sedentary during summer, then moved downstream and returned to the Missouri River in autumn or early winter (typically October). These movements do not appear to be associated with spawning; gonadal biopsy of 25 females captured during immigration into the Yellowstone River immediately prior to the putative spawning period indicated that none had mature eggs (Jaeger, unpublished data). Additionally, few aggregations of Blue Suckers were observed during the putative spawning season, except those detected at fixed receiving stations where the probability of detecting aggregations was higher than from boat-based relocation surveys. However, non-telemetered gravid and spent male and female Blue Sucker aggregations were observed in the Tongue River during most years of this study

(Backes, unpublished data), which suggests there may be a subpopulation that uses the Tongue River for spawning that we did not characterize during this study.

Blue Sucker migration into the Yellowstone River was probably associated with selection of specific habitats because their post-migration (summer) movement rates were significantly lower than in other seasons. Although Blue Suckers were widely distributed during summer they avoided unconfined reaches in general, and laterally complex geomorphic reach types prone to braiding and side channel development (i.e., unconfined braided, partially confined braided, and unconfined anabranching) in particular. Similarly, secondary channels were avoided whereas main-stem habitat types were used in proportion to availability. Secondary channels were narrower and shallower than main-stem habitat types. Main-stem pool types with the highest selection ratios (terrace and alluvial pools) had higher average and bottom velocities than other main-stem pools, although selection of these habitats relative to the availability was not statistically significant. However, periodic Yellowstone River surveys with drifting trammel nets also captured the highest density of blue suckers in relatively deep, swift habitats (Jaeger, unpublished data). All reaches and habitat types used during summer had predominately gravel and cobble substrates whereas areas with predominately sand or silt substrate, such as the Yellowstone River downstream of Sidney and the Missouri River were avoided. Therefore, relatively deep and swift main-stem habitats with gravel and cobble substrates occurring in reaches that are not prone to side channel development are likely important adult Blue Sucker habitat during warm seasons.

Our observations combined with previous observations of Blue Sucker movements on the Missouri River above the confluence of the Yellowstone River (MRATC; Fuller and Braaten 2012) indicate that some individuals in the Yellowstone River, the MRATC, and the Milk River are part of the same population. Blue Suckers in this population had the following movement patterns: (1) most Blue Suckers overwinter in the MRATC; (2) a discharge-dependent portion of the population enters the Milk River primarily in May, and emigrates as Milk River discharge recedes in May, June, or July; (3) about half of the Blue Suckers remain in the MRATC during summer and the other half (including some Blue Suckers that entered the Milk River) move over 200 rkm downstream to the confluence, then enter the Yellowstone River primarily in May and June and move upstream from 10 to over 450 rkm; (4) most Blue Suckers emigrate from the Yellowstone River in September and October and return to overwinter in the MRATC. Apparently few Blue Suckers tagged in the MRATC use the Missouri River below the confluence of the Yellowstone River (MRBTC) because Fuller and Braaten (2012) do not report any relocations for Blue Suckers from this part of their study area.

The use of the Yellowstone River during summer by Blue Suckers is similar to that observed for Pallid Sturgeon in this ecosystem with some exceptions. First, most Pallid Sturgeon entered the Yellowstone River in April or May rather than May or June, and resided in the MRBTC, rather than the MRATC upon emigration from the Yellowstone River in late summer or fall (Bramblett and White 2001; Fuller and Braaten 2012). Second, most Pallid Sturgeon remained in the lower 20 rkm of the Yellowstone River and did not pass Intake Diversion (Bramblett and White 2001), whereas Blue Suckers ranged up to 450 rkm up the Yellowstone River and individuals passed Intake, Cartersville, and Myers diversions. When moving upstream from the MRBTC and passing upstream of the Yellowstone-Missouri river confluence, Pallid Sturgeon usually entered the river with the higher discharge–which was usually the Yellowstone River (Bramblett and White 2001). However, Blue Suckers must first move downstream from the MRATC to the confluence before they can perceive the magnitude of Yellowstone River discharge. This suggests that Blue Suckers emigrate from the Missouri River because discharge is too low, and because Fort Peck dam blocks upstream movement. Alternatively, Blue Suckers may have instinctive fidelity to the Yellowstone River.

The relative importance of laterally complex reach types to Blue Suckers in the Yellowstone River remains ambiguous. The avoidance of laterally complex reach types and secondary channel habitats during summer periods on the Yellowstone River suggests they may not be important to adult Blue Suckers in summer; however, these habitats were used as migration corridors when Blue Suckers migrated into and out of the Yellowstone River. Shallow, slow water associated with islands and side channels are important habitat for larval and juvenile Blue Suckers (Adams et al. 2006) and slow current areas are important adult Blue Sucker habitat in autumn (Neely et al. 2010). Seasonal changes in distribution and habitat use by Blue Suckers indicate that they require a diversity of habitats to complete their life cycle (Moss et al. 1983; Peterson et al. 2000; Adams 2006; Neely et al. 2010).

Our results suggest that the Yellowstone River is probably not the predominant spawning habitat for Blue Suckers in the Yellowstone/Missouri River system; however, some spawning may occur in the Yellowstone River. Some Blue Suckers remained in the Yellowstone River year-round or throughout the putative spawning period and spawning-site fidelity has been noted for the closely-related Southeastern Blue Sucker (Mettee et al. 2004). We observed that Blue Suckers preferred reaches with some degree of geological confinement during their putative spawning periods concordant with reports of Blue Suckers spawning adhesive eggs over bedrock and cobble in 1–2-m deep riffles with swift current velocities (about 1.8 m/s; Rupprect and Jahn 1980; Moss et al. 1983; Vokoun et al. 2003; Neely et al. 2010). Geologically-confined reaches (such as Matthews and Wolf rapids) have abundant bedrock substrate (Jaeger et al. 2005) and probably provide swift currents that are suitable for Blue Sucker spawning. The long-distance movements that we documented in the Yellowstone River (> 450 km), the movements between the Missouri River and Yellowstone River (> 200 km; Fuller and Braaten 2012), and the unknown river lengths needed for larval ichthyoplankton drift illustrate the importance of very long, unfragmented rivers for this species.

Most Blue Suckers showed interannual fidelity to the Yellowstone River regardless of annual variation in peak discharge (35,300–56,500 cfs). We did not observe Blue Suckers using tributaries such as the Powder or Tongue rivers. The Powder River may lack suitable spawning habitat because its substrate is primarily sand (Hubert 1993) and the Tongue and Bighorn rivers are impounded and may no longer provide adequate hydrological cues to stimulate the entrance of Blue Suckers. In the Missouri River in Montana, the number of Blue Suckers that entered the Milk River was discharge-dependent (Fuller and Braaten 2012). Therefore, some Blue Suckers may opportunistically spawn in tributaries when discharge is high, as has been reported elsewhere in the species range (Moss et al. 1983; Vokoun et al. 2003; Neely et al. 2010), whereas other portions of the population exhibit interannual spawning fidelity to main-stem rivers.

Shovelnose Sturgeon.—Shovelnose Sturgeon movements occurred primarily during the runoff season and were presumably spawning migrations associated with high flows and . Unlike Blue Suckers, most Shovelnose Sturgeon had small home ranges winter and remained in the Yellowstone River as was previously observed (Bramblett and White 2001). Home ranges and movements of spawning female Shovelnose Sturgeon were larger than those of non-spawning fish, which is consistent with observations in the Missouri River (Richards et al. 2013). However, movements of male Shovelnose Sturgeon were generally higher than those of non-spawning females as was observed in the Missouri River, although this may simply be related to different resolution of data and delineation of seasons between studies. Spawning aggregations were distributed over a wider area in the Yellowstone River (250.6 km) than in the Missouri River (75 km; Richards et al. 2013) despite Shovelnose Sturgeon having similar overall distributions in both studies. This combined with comparatively shorter distance movements of spawning Shovelnose Sturgeon in the Yellowstone River may indicate that suitable spawning habitats are more widely available or distributed than in the more hydrologically altered Missouri River. In the lower Missouri River, gravid female Shovelnose Sturgeon used areas with high variability in depth and current velocity (Bonnot et al. 2011). Diverse habitats such as these are likely available in many areas of the Yellowstone River, which is unchannelized and unimpounded. Contrary to previous studies, we did not observe aggregations below Intake Diversion (Bramblett and White 2001). However, all of their Shovelnose Sturgeon were telemetered below Intake Diversion whereas most of ours were telemetered above Intake Diversion.

We speculate that most Shovelnose Sturgeon in the Yellowstone River move downstream for spawning because summer locations were downstream of winter locations and spawning occurs in summer. This general pattern was previously observed for

Shovelnose Sturgeon in the Yellowstone and Missouri rivers (Bramblett and White 2001) and in the Missouri River above Fort Peck Reservoir (Richards 2012), but differs from the upstream spawning migrations observed in the lower Missouri River (Wildhaber et al. 2011). Downstream migration for spawning was also observed for Sauger in the Yellowstone River (Jaeger et al. 2005). Migration for spawning is an adaptive strategy that maximizes evolutionary fitness (Bronmark et al. 2014). Many riverine fish spawning migrations are in an upstream direction which prevents downstream population displacement, particularly for those species with drifting eggs or larvae, by allowing time for early life stage development (Braaten et al. 2008; Perkin and Gido 2011; Walters et al. 2014). However, downstream spawning migrations have been noted in other large river fishes, such as Colorado Pikeminnow (Tyus and McAda 1984). We posit that some Shovelnose Sturgeon in the Yellowstone River migrate downstream to spawn because suitable adult habitat exists upstream of spawning habitat, and that the suitability of spawning habitat is a combination of adequate spawning microhabitat conditions (i.e., substrate and current velocities) and a location that facilitates the 6 d post-hatch drift (covering an estimated distance of 94 to 250 km; Braaten et al. 2008) of larvae to nursery habitats.

Shovelnose Sturgeon were found near tributaries (primarily the Powder River) fairly often as was observed on the Missouri River (Wildhaber 2012; Wildhaber et al. 2014). However, we rarely documented instances of Shovelnose Sturgeon entering tributaries. Shovelnose Sturgeon are known to migrate hundreds of kilometers up the Powder River to the vicinity of Crazy Woman Creek in Wyoming, presumably for spawning (Annear 1992), but we did not observe many Shovelnose Sturgeon entering the Powder River. Similarly, long-term sampling data from tagged fish indicates that the Tongue River up to the T&Y Diversion is annually used for spawning, despite our low number of observations in this study.

Habitat use by Shovelnose Sturgeon during this study was generally consistent with previous findings. Avoidance of unconfined reaches suggests that Shovelnose Sturgeon avoid areas without deep main channels, which is congruent with other observations in the Missouri River (Gerrity et al. 2008; Wildhaber et al. 2014). In our study, similar to previous observations in the Yellowstone River, Shovelnose Sturgeon avoided boulder substrates and used depths greater than 0.9-m deep (Bramblett and White 2001). Shovelnose Sturgeon can negotiate fast current velocities, up to 1.5 m/s in the Yellowstone River (Bramblett and White 2001) and up to 1.8 m/s in laboratory swimming trials (White and Mefford 2002). However, swimming performance was best over smooth substrates with laminar flow, and declined when baffles created turbulence and eddies (White and Mefford 2002).

Outside of the spawning season, Shovelnose Sturgeon were often located in confined meandering reaches and channel crossovers. Use of these habitats may increase foraging efficiency because they likely have laminar flow and gravel and cobble substrates. Shovelnose Sturgeon hold position in laminar flow with very little energetic expenditure (White and Mefford 2002) and gravel and cobble substrates with little fine substrate typically have higher diversity and abundance of benthic invertebrates. Thus, sturgeon may be able to optimally forage in these reach and habitat types. Reach and habitat types that were avoided were more likely to have turbulent flow and laterally heterogeneous bed forms that are comprised of high proportions of shallow, off-channel habitat. Shovelnose Sturgeon avoided the only two confined straight reaches in our study area, which are geologically confined and have relatively high gradients with moderate bedrock rapids (e.g., Matthews and Wolf rapids), perhaps to avoid turbulent flows that occur there. Unconfined reaches, which typically have a high degree of meandering, multiple flow channels and complex lateral habitats such as side channels and anabranches, were avoided during all seasons. Similarly, secondary channel habitat types, that are shallower than main-stem habitat types were avoided during all seasons.

Although Yellowstone River rapids did not block Shovelnose Sturgeon passage, they were used disproportionately less than their availability. A contributing factor may be that these reaches are above the Powder River confluence and are consequently often less turbid than those below the Powder River confluence, which may contribute to their reduced use by the turbidity-loving Shovelnose Sturgeon. The unconfined Yellowstone River reach located just above the confluence with the Missouri River was also avoided by Shovelnose Sturgeon, and the substrate in this reach is comprised almost completely of sand (Bramblett and White 2001). The avoidance of a sandy reach is congruent with previous findings in the Yellowstone River where Shovelnose Sturgeon used gravel and cobble substrates more often than sand substrates (Bramblett and White 2001), but differs from a Missouri River study above Fort Peck Reservoir (Gerrity et al. 2008), and a Kansas River study, where sand and silt was used more often than gravel and cobble. However, gravel and cobble were more available in our study area than in the Missouri and Kansas rivers study areas, and Shovelnose Sturgeon use sand substrates when their home range is dominated by sand (Quist et al. 1999; Bramblett and White 2001; Gerrity et al. 2008). The avoidance of channel crossovers in winter may be due to temperature-related decreases in metabolism that make these areas too swift for overwintering habitat. Avoidance of crossovers during winter in our study differs from results on the Kansas River, where Shovelnose Sturgeon preferred channel crossovers, and avoided outside bends in winter (Quist et al. 1999). However, mean current velocities at fish locations were slower on the Kansas River (mean = 0.34 m/s) than on the Yellowstone River (mean = 0.78 m/s; Bramblett and White 2001). Secondary channels were avoided in all seasons, further indicating that main channels are the primary habitat for Shovelnose Sturgeon as was also observed in the Missouri River (Gerrity et al. 2008; Wildhaber et al. 2014).

Burbot.—Burbot movements appeared to be related to spawning and habitat use was otherwise similar throughout the year. Although movements among habitats were observed during all seasons, the largest home ranges occurred during winter, which includes the putative spawning season. Only riprap alluvial pools were selected during the spawning period although most reach types and habitats were also used. During non-spawning periods when movements were rare, pools with relatively high depths and proportions of boulder and bedrock substrate (bluff, riprap alluvial) were selected and shallow habitats (crossovers, secondary channels, alluvial pools) were avoided. However, relatively simple confined reaches, where frequent contact with the valley margin results in creation of deep rocky bluff pools, were avoided. Some reaches with high proportions of shallow habitats were selected (unconfined anabranching) or used in proportion to their availability while others (partially confined braided) were avoided. Overall it appears that Burbot preferred deep, rocky habitats that occurred in reaches with relatively high complexity and habitat diversity.

Most Burbot were relatively sedentary, with linear home ranges less than 25 rkm; however, others had home ranges up to 281 rkm and this was similar to observations from previous studies (Paragamian et al. 2005). Our observation of variability in Burbot home range size is similar to observations of resident individuals with small home ranges and mobile individuals with large home ranges in a reservoir in British Columbia (Harrison et al. 2014).

Winter movements, when Burbot home ranges were longest, are likely spawning-related movements because Burbot are nocturnal, synchronous, winter spawners (Scott and Crossman 1973). We only observed two aggregations during the putative spawning period of February (Brown 1971); one aggregation was located 6 km below the mouth of the Clarks Fork and the other was near Terry, Montana. Expanding our putative spawning season (February; Brown 1971) to include December, January, and March increases the number of putative spawning aggregations to 11. Five of these were within 7 km below the confluence of the Clarks Fork, and the other 6 were distributed from Terry, Montana to below Huntley Diversion. The rarity of detected spawning aggregations was unexpected because Burbot are known to aggregate for spawning (Scott and Crossman 1973). However, the spawning period for Burbot has been reported as only one to three weeks in duration (Boag 1989; Evenson 2000). Therefore, we may have failed to detect some spawning aggregations using infrequent aircraft-based telemetry runs occurring once every three weeks.

Burbot movement was often downstream during runoff suggesting that they sometimes use runoff to facilitate downstream movements following winter spawning because they are thought to be poor endurance swimmers (McPhail and Paragamian 2000). Downstream movement rates were faster than upstream movement rates in runoff and summer, and these rates were similar to those described for Burbot in the Kootenai River in Idaho and in British Columbia, Canada (Paragamian et al. 2005).

Burbot were rarely relocated in the vicinity of or within tributaries. This was somewhat unexpected because Burbot are known to occupy tributaries in other parts of their range (Jude et al. 2013; Stephenson et al. 2013). However, Burbot are coldwater fish and most Yellowstone River tributaries that we monitored may be too warm. Moreover, Burbot were not captured during extensive sampling of Montana prairie streams during 1999-2007; most of these were warmwater streams (Bramblett 2009; Mullen et al. 2011). The only tributary where we relocated Burbot was the Clarks Fork, which is the farthest upstream and coldest tributary in our study area.

Burbot preferred reach types with some degree of geological confinement, but avoided fully confined reaches, similar to our observations for Shovelnose Sturgeon. Burbot inhabit areas with large boulder and bedrock substrates (Edsal et al. 1993; Dixon and Vokoun 2009; Eick 2013); and partially confined reaches where river bends contact bluffs (Jaeger et al. 2005) provide these substrates. Burbot avoided the reach above the Missouri River confluence, perhaps because the substrate in this reach is comprised almost entirely of sand (Bramblett and White 2001). At the habitat unit scale, Burbot preference for riprap alluvial pools during winter suggests that Burbot may spawn on or near riprap boulders. Burbot are thought to spawn on cobble or boulder habitats in the Great Lakes (Jude et al. 2014).

Channel Catfish.—Use of most habitats and reaches in proportion to availability suggests Channel Catfish were generalists with low habitat specificity despite having diverse movements and home ranges among individuals. Channel Catfish are the only species we studied in which home ranges were generally equal in all seasons, although net downstream movement rates in winter were greater than upstream rates. Long-range movements of over 300 km by Channel Catfish have been reported from the lower Missouri River (Dames et al. 1989). Many Channel Catfish in our study were essentially sedentary whereas others had home ranges of over 200 rkm. However, relative to the other fish species studied it is unclear what prompted these movements since most habitats and reaches were used in proportion to their availability throughout the year and most individuals had smaller home ranges. Although Channel Catfish are known to exhibit expulsion rates of surgically implanted transmitters as high as 71% (Summerfelt and Mosier 1984) that may contribute to perceived disparities in movements among individuals, our expulsion rate was less than 50%. Overall it appeared that suitable geomorphic conditions and habitats for channel catfish existed throughout most of the study area. The only geomorphic reaches avoided were confined reaches. Similar to Burbot and Shovelnose Sturgeon, Channel Catfish may avoid these reaches because they are too shallow, swift, steep, turbulent, or a combination thereof. Channel Catfish avoided channel crossovers in spring, and preferred them during runoff. The reasons for seasonal disparity in channel crossover use are not clear; however, depths are shallower in channel crossovers than in pools and higher turbidity during runoff may provide security from aerial predators.

Channel Catfish were relocated in tributaries more often than other species, yet only 7% of telemetered individuals used tributaries. We expected more use of tributaries because Channel Catfish often use tributaries for spawning or other purposes in the Powder River (Gerhardt and Hubert 1990; Smith and Hubert 1989), Grand River (Vokoun and Rabeni 2002), and Missouri River (Dames et al. 1989) basins. Channel Catfish spawning and habitat use is typically associated with cover in the form of large substrate, cavities, or large woody debris (Gerhardt and Hubert 1990; Kelsch and Wendel 2004). Perhaps Channel Catfish seek spawning habitat in tributaries when main-stem rivers are naturally (Powder River; Hubert 1993) or anthropogenically simplified (Missouri River; Dames et al. 1989, Grand River; Vokoun and Rabeni 2002), but less so in the Yellowstone River that contains diverse habitats.

Spiny Softshell Turtles.—Spiny Softshells generally made small movements but had clear patterns of seasonal habitat selection. Spiny Softshells preferred secondary channels or bluff pools in most seasons, except winter when they preferred only bluff pools. However, avoidance of reach types prone to side channel development and relatively small home ranges suggests that the presence of bluff pools and secondary channels proximal to each other may be an important delineator of preferred habitat.

Bluff pools and secondary channels combine to provide most annual needs of Spiny Softshells. Secondary channels may offer warmer water temperatures during spring, refugia from high flows during runoff, and proximity to nesting habitat (generally islands and shorelines with scant vegetation) during summer (Tornabene 2014). During winter, Spiny Softshells preferred bluff pools indicating that many turtles hibernated in these habitats similar to Spiny Softshells in the Missouri River that overwintered in outside bends with moderate depth and water velocity (Tornabene 2014). Bluff pools were deeper and slower than alluvial pools, and greater depth probably provided security from ice scour. Moreover, moderate current velocities may have prevented displacement while providing adequate oxygen, which facilitates survival of overwintering turtles (Ultsch 2006). Over half of the Spiny Softshell aggregations that we observed occurred from October through April, indicating that these were mostly hibernacula, and were from six locations ranging from above Intake Diversion to above Cartersville Diversion. One of these hibernacula was used on three separate winters, indicating fidelity to this hibernaculum. Similar observations of overwintering aggregations and interannual hibernaculum fidelity were observed in the Missouri River and this may indicate that overwintering habitats are generally sparse or of particular importance to the annual survival of the population (Ultsch 2006; Tornabene 2014). Moreover, because of an often-truncated active season in the northern range of the species, male and female Spiny

Softshells may aggregate at overwintering sites as a means to expedite finding mates and reproducing in the following year (Tornabene 2014).

Spiny Softshell home ranges were the smallest of all species, but not significantly different from those of Burbot or Channel Catfish. Most Spiny Softshells were quite sedentary (median home range = 6.5 rkm) although one individual moved almost 300 km. Our observations were similar those on the Missouri River in Montana where median home range was small (7.0 rkm), ranged to almost 300 km, and was largest in summer (Tornabene 2014). Spiny Softshell movements in summer were probably associated with departing from nesting habitats and movement towards hibernacula, which also was documented on the Missouri River in Montana (Tornabene 2014).

Spiny Softshells were not captured or relocated below rkm 60, which is near Sidney, Montana. This is congruent with previous sampling of the Yellowstone River that identified a longitudinal distribution of softshell catch per unit effort in the Yellowstone and Missouri rivers. The distribution generally increased from coolwater, mid-river reaches downstream to warmwater reaches, but declined abruptly as substrate transitioned to sand on the Yellowstone River near Sidney, Montana, and on the Missouri River above Fort Peck Reservoir. Additionally, no turtles were captured on the Missouri River below Fort Peck Reservoir and this also may be related to cold hydrostatic release form Fort Peck Dam (Dood et al. 2009). Spiny Softshells may prefer substrates with some gravel or cobble because incubation temperatures in simulated nests in gravel substrates were warmer, acquired more degree days for incubation, and were more consistent than in sand substrates (Tornabene 2014). Thus, choosing gravel over sand substrates could be important in maximizing degree-days for incubation in the northern range of the species.

Spiny Softshells were only documented in one tributary of the Yellowstone River, the Bighorn River, which differed from observations on the Missouri River above Fort Peck (Tornabene 2014). Spiny Softshells on the Missouri River were commonly found in, and showed interannual fidelity to, backwatered tributaries often during spring and the ascending limb of snowmelt runoff (Tornabene 2014). However, the Missouri River study area is largely canyon-bound, and tributaries are small intermittent or ephemeral creeks. These backwatered tributaries provided some of the only off-channel lateral habitats (Tornabene 2014). In contrast, secondary channels are more common on the Yellowstone River than on the Missouri River and may offer areas with similar habitat qualities.

We documented four putative nesting aggregations of Spiny Softshells ranging from below Intake Diversion to above Cartersville Diversion. Spiny Softshells may not aggregate if preferred nesting habitat is widely available. On the Missouri River, most Spiny Softshells nested on sparsely-vegetated islands where nest depredation rates were lower than on mainland shorelines (Tornabene 2014). Such islands are seemingly more common on the Yellowstone River than on the Missouri River; therefore, Spiny Softshells may not need to aggregate on nesting islands on the Yellowstone River (RG Bramblett and BJ Tornabene, personal observations). However, years with high runoff can also necessitate aggregation in sparse locations by limiting spatiotemporally distributed nesting habitats (Tornabene 2014). Confined meandering reaches, which consisted of three reaches near the Powder River confluence, were avoided during Spiny Softshell nesting season and this is probably because islands were rare in these reaches.

Conclusions.—Blue Suckers and Shovelnose Sturgeon had long home ranges and extensive movements whereas Burbot, Channel Catfish, and Spiny Softshells had smaller home ranges. Blue Suckers used the Yellowstone River in spring through autumn and emigrated to the Missouri River for overwintering while all other species remained in the Yellowstone River throughout the year.

All species readily passed upstream of Matthews and Wolf Rapids, but passage at diversion dams varied among structures and species. Individual Blue Suckers passed Intake, Cartersville, and Myers diversions and were rarely blocked at these structures. Conversely, Shovelnose Sturgeon rarely passed upstream at Intake Diversion and never passed upstream at Cartersville Diversion. Burbot, Channel Catfish, and Spiny Softshells encountered diversion dams less often because of their smaller home ranges, but were able to pass Intake and Cartersville diversions on some occasions, and were blocked on other occasions. We collected little information on passage at diversion dams upstream of Carterville Diversion because there were few observations of telemetered animals encountering these structures. Most passage events at Intake Diversion were via the main channel, rather than via the side channel. However, non-telemetered animals may have used the side channel for passage and these side channels may provide nursery and backwater refugia for several species. Passage irrespective of species was lower at Cartersville Diversion than at Intake Diversion. There was little evidence that discharge was the primary factor that influenced passage success at diversion dams. Passage at diversion dams is probably also influenced by animal morphology and motivation, diversion configuration, hydraulic conditions, or a combination thereof. Facilitating passage at diversions would probably benefit Shovelnose Sturgeon populations by making habitat available upstream of Cartersville Diversion. However, the effect of altered riverine processes, resulting from damming of the Bighorn River on the suitability of reaches upstream of Cartersville Diversion is not known. Further study is needed to determine the degree to which diversion dams upstream of Cartersville Diversion block fish movements. Moreover, information on the effect of all diversion dams on the entire fish assemblage which includes over 50 species is sparse.

Large tributaries were not frequently used by our study species. However, the Tongue and Bighorn rivers are impounded and hydrological cues may be lacking. Moreover, fish may remain in the Yellowstone River because natural riverine processes and habitat are more intact in the Yellowstone River than in dammed tributaries (Tongue and Bighorn rivers). The limited use of Yellowstone River tributaries we observed contrasts with a study using otolith microchemistry data for three cyprinid species on the lower Yellowstone that indicated about two thirds of individuals used tributaries at some point in their life history (Duncan et al. 2012). Perhaps cyprinids naturally use tributaries more than the larger fish and the turtle species that we studied, or the small tributaries that were included in the Duncan et al. (2012) study were more ecologically intact than the large tributaries we studied, or a combination thereof.

Habitat selection varied widely among species; Blue Suckers and Shovelnose Sturgeon largely avoided unconfined reach types and used main channel habitats and Burbot and Channel Catfish largely avoided confined reaches and also used main channel habitats. Spiny Softshells preferred secondary channels in all seasons but winter, when they preferred bluff pools. Aggregations during spawning and nesting seasons were observed, but they were rare and widely dispersed, suggesting that suitable spawning and nesting habitats occur at multiple locations along the river.

Habitats used by our study species were spatially, temporally, and geomorphically diverse. For example, main channels and side channels, reaches with varying degrees of geological confinement, and reaches with and without islands were all selected by one or more of our study species during one or more seasons. The spatial dispersion and overall paucity of aggregations during spawning and nesting seasons suggests that suitable spawning and nesting habitats occur at multiple locations along the river. This diversity of habitat use and habitat availability is probably attributable to the lack of main-stem impoundments and channelization and the relatively natural flow regime that makes the Yellowstone River unique among large rivers in the Rocky Mountains and Great Plains. Preservation of riverine processes that maintain habitat diversity will enhance the probability that the Yellowstone River retains an intact aquatic assemblage. Our study has inference with regard to management and restoration of similar large temperate riverine ecosystems such as the Missouri River. The long range movements we observed add to the consensus that longitudinal fragmentation of rivers is a threat because fluvial specialist fishes use reaches on the scale of hundreds of kilometers (Bramblett and White 2001; Braaten et al. 2008; Perkin and Gido 2011). Moreover, fluvial generalists and mostly sedentary species also make large exploratory or temporally irregular movements in search of shelter, food, mates, and to colonize new areas. The use of diverse habitats at multiple scales by the species we studied reinforces the ecological theory stressing the importance of preservation and restoration of riverscapes (Schlosser 1991; Fausch et al. 2002) and natural flow regimes (Hesse 1987; Poff et al. 1997; Poff et al. 2010) in the conservation of riverine biodiversity.

Acknowledgements: Special recognition and thanks are owed to Drew Pearson, John Hunziker, Shane Schulze, Rosa McIver, Michael Burt, Will Riggs, and Brad Tribby for the hundreds of hours they spent in the field collecting the information presented in this report. Karin Boyd and Tony Thatcher provided considerable thought, delineation, interpretation, and integration of habitat and geomorphic information. Brad Schmitz, Vic Riggs, Jim Darling, Ken Frazer, George Jordan, Sue Camp, and Ken McDonald were invaluable to the planning and funding of this work. This work was funded in part by a U.S. Fish and Wildlife Service State Grant and Montana Fish, Wildlife & Parks.

REFERENCES

Adams, S. R., M. B. Flinn, B. M. Burr, M. R. Whiles, and J. E. Garvey. 2006. Ecology of larval Blue Sucker (Cycleptus elongatus) in the Mississippi River. Ecology of Freshwater Fish 15:291–300.

Annear, T. C. 1992. Shovelnose sturgeon investigations; summary report 1983 to 1991. Wyoming Game and Fish Department Administrative Report, Cheyenne, WY.

Bednarski, J., and D. L. Scarnecchia. 2006. Age structure and reproductive activity of Blue Sucker in the Milk River, Missouri River drainage, Montana. Prairie Naturalist 38:167–182.

Boag, T. D. 1989. Growth and fecundity of Burbot, Lota lota L., in two Alberta lakes. Master's Thesis, University of Alberta, Edmonton.

Bonnot, T. W., M. L. Wildhaber, J. J. Millspaugh, A. J. DeLonay, R. B. Jacobson, and J. L. Bryan. 2011. Discrete choice modeling of Shovelnose Sturgeon habitat selection in the Lower Missouri River. Journal of Applied Ichthyology 27:291–300.

Boyd, K., and T. Thatcher. 2004. Geomorphic reconnaissance and GIS development Yellowstone River, Montana: Springdale to the Missouri River confluence. Final Report to the Yellowstone River Conservation Districts Council, Billings, Montana.

Braaten, P. J., and D. B. Fuller. 2004. Fort Peck flow modification biological data collection plan, summary of 2003 activities. U.S. Army Corps of Engineers, Fort Peck.

Braaten, P. J., D. B. Fuller, L. D. Holte, R. D. Lott, W. Viste, T. F. Brandt, and R. G. Legare. 2008. Drift dynamics of larval pallid sturgeon and Shovelnose Sturgeon in a natural side channel of the upper Missouri River, Montana. North American Journal of Fisheries Management 28:808–826.

Bramblett, R. G. 1996. Habitats and movements of Pallid and Shovelnose Sturgeon in the Yellowstone and Missouri Rivers, Montana and North Dakota. Ph.D. dissertation, Montana State University, Bozeman.

Bramblett, R. G. 2009. Synthesis of Montana Prairie Stream Fish Surveys, 1999–2007. Report to Montana Fish, Wildlife, and Parks, Helena.

Bramblett, R. G., and R. G. White. 2001. Habitat use and movements of Pallid and Shovelnose Sturgeon in the Yellowstone and Missouri Rivers in Montana and North Dakota. Transactions of the American Fisheries Society 130: 1006–1025.

Brönmark, C., Hulthén, K., Nilsson, P. A., Skov, C., Hansson, L. A., Brodersen, J., & Chapman, B. B. 2013. There and back again: migration in freshwater fishes. Canadian Journal of Zoology, 92:467–479.

Brown, C. J. D. 1971. Fishes of Montana. Big Sky Books, Montana State University, Bozeman.

Bureau of Reclamation and U. S. Army Corps of Engineers. 2014. Intake Diversion Dam Modification Lower Yellowstone Project, Montana Draft Supplement to the 2010 Final Environmental Assessment. Billings.

Butler, S. E., and D. H. Wahl. 2011. Distribution, movements and habitat use of Channel Catfish in a river with multiple low-head dams. River Research and Applications 27: 1182–1191.

Carlson, J. 2003. Montana animal species of special concern. Montana Natural Heritage Program and Montana Fish, Wildlife and Parks Report, Helena.

Dames, H. R., T. G. Coon, and J. W. Robinson. 1989. Movements of channel and flathead catfish between the Missouri River and a tributary, Perche Creek. Transactions of the American Fisheries Society 118:670–679.

Dixon, C. J., and J. C. Vokoun. 2009. Burbot resource selection in small streams near the southern extent of the species range. Ecology of Freshwater Fish 18:234–246.

Dood, A. R., B. Schmitz, V. Riggs, N. McClenning, M. Jaeger, D. Fuller, R. Rauscher, S. Leathe, D. Moore, J. Dullum, J. Ensign, S. Story, and M. Backes. 2009. Relative abundance of Spiny Softshell turtles (Apalone spinifera) on the Missouri and Yellowstone rivers in Montana, Final Report. Montana Fish, Wildlife & Parks, Helena, Montana.

Dowl HKM. 2010. Cartersville irrigation dam fish passage alternative analysis and environmental assessment. Submitted to Montana Fish, Wildlife, and Parks.

Duncan M. B., R. G. Bramblett, and A. V. Zale. 2012. Distribution, habitats, and tributary linkages of small and nongame fishes in the lower Yellowstone River. Montana Fish, Wildlife and Parks University Research Completion Report Series Number 2012-01.

Edsall, T. A., G. W. Kennedy, and W. H. Horns. 1993. Distribution, abundance, and resting microhabitat of Burbot on Julian's Reef, southwestern Lake Michigan. Transactions of the American Fisheries Society 122:560–574.

Eick, D. 2013. Habitat preferences of the Burbot (Lota lota) from the River Elbe: an experimental approach. Journal of Applied Ichthyology 29:541–548.

Evenson, M. J. 2000. Reproductive traits of Burbot in the Tanana River, Alaska. Pages 61–70 in V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda.

Fausch, K. D., Torgersen, C. E., Baxter, C. V. and Li, H. W. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes a continuous view of the river is needed to understand how processes interacting among scales set the context for stream fishes and their habitat. BioScience, 52(6).

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:199–214.

Fuller, D. B. and P. J. Braaten. 2012. Fort Peck flow modification biological data collection plan compendium, summary of 2001–2009 activities. U.S. Army Corps of Engineers, Fort Peck.

Galat D. L., Zweimüller I. 2001. Conserving large-river fishes: is the highway analogy an appropriate paradigm?. Journal of the North American Benthological Society. 20(2):266-79.

Gardner, W. M. 1998. Blue Sucker. Montana Chapter of the American Fisheries Society. Available: http://www.fisheries.org/AFSmontana/SSCpages/Bluesuckstatus.htm (October 2004).

Gerhardt D. R. and W. A. Hubert. 1990. Spawning habitat of Channel Catfish in the Powder River system Wyoming-Montana USA. Prairie Naturalist 22:155–164.

Gerrity, P. C., C. S. Guy, and W. M. Gardner. 2008. Habitat use of juvenile pallid sturgeon and Shovelnose Sturgeon with implications for water-level management in a downstream reservoir. North American Journal of Fisheries Management 28:832–843.

Goodman, B. J., C. S. Guy, S. L. Camp, W. M. Gardner, K. M. Kappenman, and M. A. H. Webb. 2013. Shovelnose sturgeon spawning in relation to varying discharge treatments in a Missouri River tributary. River Research and Applications, 29:1004–1015.

Harrison, P. M., L. F. G. Gutowsky, E. G. Martins, D. A. Patterson, S. J. Cooke, and M. Power. 2014. Personality-dependent spatial ecology occurs independently from dispersal in wild Burbot (Lota lota). Behavioral Ecology.

Hart, L. G., and R. C. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into flathead catfish (Pylodictis olivaris). Transactions of the American Fisheries Society, 104, 56–59.

Helfrich, L. A., C. Liston, S. Hiebert, M. Albers, and K. Frazer. 1999. Influence of low-head diversion dams on fish passage, community composition, and abundance in the Yellowstone River, Montana. Rivers 7:21–32.

Hubert, W. The Powder River: a relatively pristine stream on the Great Plains. 1993. in L. W. Hesse, C. B. Stalnaker, N. G. Benson, J. R. Zuboy, editors. Restoration planning for the rivers of the Mississippi River ecosystem. Biological Report 19, National Biological Survey, Washington, D.C.

Jaeger, M. E., A. V. Zale, T. E. McMahon, and B. J. Schmitz. 2005. Seasonal movements, habitat use, aggregation, exploitation, and entrainment of Sauger in the lower Yellowstone River: an empirical assessment of factors affecting population recovery. North American Journal of Fisheries Management 25:1550–1568.

Jones-Wuellner, M. R. and C. S. Guy. 2004. Status of Burbot in Montana. Report of Montana Cooperative Fishery Research Unit. Received by Montana Fish, Wildlife and Parks, Helena.

Jude, D. J., Y. Wang, S. R. Hensler, and J. Jans. 2013. 2013. Burbot early life history strategies in the Great Lakes. Transactions of the American Fisheries Society. 142:1733–1745.

Junk, W.J., Bayley, P.B., and Sparks, R.E. 1989. The flood pulse concept in river-floodplain systems. Pages 110-127 in D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Kappenman, K. M., M. A. H. Webb, and M. Greenwood. 2013. The effect of temperature on embryo survival and development in pallid sturgeon Scaphirhynchus albus (Forbes & Richardson 1905) and Shovelnose Sturgeon S. platorynchus (Rafinesque, 1820). Journal of Applied Ichthyology 292013:1193–1203.

Kelsch, S. W., and J. L. Wendel. 2004. Lotic habitat availability and use by Channel Catfish in the Red River of the North. Journal of Freshwater Ecology 19:473–484.

Koch, J. D., and M. C. Quist. 2010. Current status and trends in Shovelnose Sturgeon (Scaphirhynchus platorynchus) management and conservation. Journal of Applied Ichthyology 26: 491–498.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1992. Fluvial processes in geomorphology. Dover Publications, Mineola.

Luiselli, L. 2008. Resource partitioning in freshwater turtle communities: A null model meta-analysis of available data. Acta Oecologica 34:80–88.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals. Kluwer Academic Press, Dordrecht.

Maurice F. Mettee, Thomas E. Shepard, Patrick E. O'Neil, Stuart W. McGregor, and Wiley P. Henderson, Jr. 2004. Status survey of the southeastern Blue Sucker (Cycleptus meridionalis) in the Alabama River, 1995–2004. Open File Report 0504, Geological Survey of Alabama, Tuscaloosa.

McPhail, J. D. and , V. L. Paragamian. 2000. Burbot biology and life history. In Burbot: Biology, Ecology, and Management (Paragamian, V. L. and D. W. Willis editors), pp. 11–23. Bethesda: American Fisheries Society.

Montana Bureau of Mines and Geology. 1979. Geologic map of the Hysham 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 371. Butte.

Montana Bureau of Mines and Geology. 1980. Geologic map of the Terry 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 284. Butte.

Montana Bureau of Mines and Geology. 1981a. Geologic map of the Sidney 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 277. Butte.

Montana Bureau of Mines and Geology. 1981b. Geologic map of the Wibaux 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 282. Butte.

Montana Bureau of Mines and Geology. 1998. Geologic map of the Glendive 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 371. Butte.

Montana Bureau of Mines and Geology. 2000. Geologic map of the Billings 30' x 60' quadrangle, Montana. 1:100,000. Geologic map series no. 59. Butte.

Montana Bureau of Mines and Geology. 2001a. Geologic map of the Miles City 30’ x 60’ quadrangle, Montana. 1:100,000. Open-file report no. 426. Butte.

Montana Bureau of Mines and Geology. 2001b. Geologic map of the Forsyth 30’ x 60’ quadrangle, Montana. 1:100,000. Open-file report no. 425. Butte.

Montana Fish, Wildlife and Parks. 1997. Montana warmwater fisheries management plan, 1997–2006. Montana Fish, Wildlife and Parks, Helena.

Montana Natural Heritage Program. 2014. Animal species of concern. Available: http://mtnhp.org/SpeciesOfConcern/?AorP=a. (October 2014).

Moss, R. E., J. W. Scanlan, and C. S. Anderson. 1983. Observations on the natural history of the Blue Sucker (Cycleptus elongatus Le Sueur) in the Neosho River. American Midland Naturalist 1983:15–22.

Mullen, J. A., R. G. Bramblett, C. S. Guy, A. V. Zale, and D. W. Roberts. 2011. Determinants of Fish Assemblage Structure in Northwestern Great Plains Streams. Transactions of the American Fisheries Society 140:271–281.

Natural Resources and Conservation Service. 2002. Lower Yellowstone River Corridor Color Infrared Digital Orthophotography, Montana. Natural Resources and Conservation Service, Bozeman. Available: www.nris.state.mt.us/yellowstone/LowerYel/LowerYelPhotos.html (April 2004).

Neely, B. C., M. A. Pegg, and G. E. Mestl. 2010. Seasonal resource selection by Blue Suckers Cycleptus elongatus. Journal of Fish Biology 76:836–851.

O’Driscoll, R. L. 1998. Description of spatial pattern in seabird distributions along line transects using neighbor K statistics. Marine Ecology Progress Series 165:81–94.

Paakkonen, J. P., M. Laitinen, T. J. Marjomaki. 2000. Total activity in Burbot measured with a bioelectric monitoring system: seasonal differences in activity length. Pages 38–47 in V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology, and management. American Fisheries Society, Fisheries Management Section, Publication number 1, Bethesda.

Paragamian, V. L., R. Hardy, and B. Gunderman. 2005. Effects of regulated discharge on Burbot migration. Journal of Fish Biology 66:1199–1213.

Pegg, M. A., P. W. Bettoli, and J. B. Layzer. 1997. Movement of saugers in the lower Tennessee River determined by radio telemetry, and implications for management. North American Journal of Fisheries Management 17:763–768

Perkin, J. S., and K. B. Gido. 2011. Stream fragmentation thresholds for a reproductive guild of Great Plains fishes. Fisheries 36:371–383.

Peterson, M. S., Nicholson, L. C., Fulling, G. L., and Snyder, D. J. 2000. Catch-per-unit-effort, environmental conditions and spawning migration of Cycleptus meridionalis Burr and Mayden in two coastal rivers of the northern Gulf of Mexico. The American Midland Naturalist, 143:414–421.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., and Stromberg, J.C. 1997. The natural flow regime. BioScience 47:769-784.

Poff, N.L., Richter, B.D., Arthington, A.H., Bunn, S.E., Naiman, R.J., Kendy, E., Acreman, E. et al. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology 55:147-170.

Quist, M. C., J. S. Tillma, M. N. Burlingame, and C. S. Guy. 1997. Overwinter habitat use of Shovelnose Sturgeon in the Kansas River. Transactions of the American Fisheries Society 128: 522–527.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.Rproject.org/.

Richards, R. R. 2012. Movement of Scaphirhynchus species in the Missouri River above Fort Peck reservoir, Montana. M.S. Thesis, Montana State University, Bozeman.

Richards, R. R., C. S. Guy, M. A. Webb, W. M. Gardner, C. B. Jensen. 2013. Spawning related movement of shovelnose sturgeon in the Missouri River above Fort Peck Reservoir, Montana.   Journal of Applied Ichthyology 2013: 1-12.

Rogers, K. B., and G. C. White. 2007. Analysis of movement and habitat use from telemetry data, pp. 625–676. In: Analysis and interpretation of freshwater fisheries data. C.S. Guy, and M.L. Brown (eds). American Fisheries Society, Bethesda, Maryland.

Ross, M. J., and C. F. Kleiner. 1982. Shielded-needle technique for surgically implanting radio-frequency transmitters in fish. Progressive Fish-Culturist 44:41–43.

Rupprecht, R. J., and L. A. Jahn. 1980. Biological notes on Blue Suckers in the Mississippi River. Transactions of the American Fisheries Society 109:323–326.

Schlosser, I. J. Stream fish ecology: a landscape perspective. BioScience. 1991 41(10):704-12.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board Canada, Bulletin 173: Ottawa.

Simon, J. R. 1951. Wyoming fishes. Wyoming Game and Fish Department Bulletin Number 4. Cheyenne.

Smith, J. B. and W. A. Hubert. 1989. Use of a tributary by fishes in a Great Plains river system. Prairie Naturalist 21:27–38.

Statzner, B. and Higler, B., 1986. Stream hydraulics as a major determinant of benthic invertebrate zonation patterns. Freshwater biology, 16:127-139.

Stewart, P. A. 1998. Southeastern Montana fisheries investigations. Montana Fish, Wildlife and Parks Report F-78-R-4, Helena.

Summerfelt, R. C., and D. Mosier. 1984. Transintestinal expulsion of surgically implanted dummy transmitters by Channel Catfish. Transactions of the American Fisheries Society 113:760–766.

Tockner K., Stanford J. A. 2002. Riverine flood plains: present state and future trends. Environmental conservation. 29(03):308-30.

Tornabene, B. J. 2014. Movements, habitats, and nesting ecology of Spiny Softshells in the Missouri River: The influence of natural and anthropogenic factors. Master's Thesis, Montana State University-Bozeman.

Tucker, C. C., and E. H. Robinson. 1990. Channel catfish farming handbook. Springer Science and Business Media.

Tyus, H. M., and C. W. McAda. 1984. Migration, movements and habitat preferences of Colorado squawfish, Ptychocheilus lucius, in the Green, White and Yampa rivers, Colorado and Utah. The Southwestern Naturalist 1984:289–299.

Ultsch, G.R. 2006. The ecology of overwintering among turtles: where turtles overwinter and its consequences. Biological Reviews 81:339–367.

Vokoun, J. C., and C. F. Rabeni. 2002. Distribution of Channel Catfish life stages in a prairie river basin. The Prairie Naturalist 34:47–59.

Vokoun, J. C., T. L. Guerrant, and C. F. Rabeni. 2003. Demographics and chronology of a spawning aggregation of Blue Sucker (Cycleptus elongatus) in the Grand River, Missouri, USA. Journal of Freshwater Ecology 18:567–575.

Walters, D. M., R. E. Zuellig, H. J. Crockett, J. F. Bruce, P. M. Lukacs, and R. M. Fitzpatrick. 2014. Barriers impede upstream spawning migration of Flathead Chub. Transactions of the American Fisheries Society 143:17–25.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego.

White, R. G. and B. Mefford. 2002. Assessment of behavior and swimming ability of Yellowstone River sturgeon for designing fish passage devices. Bureau of Reclamation, Water Resources Research Laboratory. Denver, Colorado.

White, R. G., and R. G. Bramblett. 1993. The Yellowstone River: its fish and fisheries. Pages 396–414 in L. W. Hesse, C. B. Stalnaker, N. G. Benson, J. R. Zuboy, editors. Restoration planning for the rivers of the Mississippi River ecosystem. Biological Report 19, National Biological Survey, Washington, D.C.

Wildhaber, M. L., D. W. Gladish, and A. Arab. 2012. Distribution and habitat use of the Missouri River and lower Yellowstone River benthic fishes from 1996 to 1998: a baseline for fish community recovery. River Research and Applications 28:1780–1803.

Wildhaber, M. L., S. H. Holan, G. M. Davis, D. W. Gladish, A. J. DeLonay, Diana M. Papoulias, and D. K. Sommerhauser. 2011. Evaluating spawning migration patterns and predicting spawning success of Shovelnose Sturgeon in the lower Missouri River. Journal of Applied Ichthyology 27:301–308.

Wildhaber, M. L., W-H. Yang, and A. Arab. 2014. Population trends, bend use relative to available habitat and within-river-bend habitat use of eight indicator species of Missouri and lower Kansas rivers benthic fishes: 15 years after baseline assessment. River Research and Applications. wileyonlinelibrary.com, DOI: 10.1002/rra.2846.

Winter, J. D. 1996. Advances in underwater biotelemetry. Pages 555–590 in B. R. Murphy and D. W. Willis, editors. Fisheries techniques. American Fisheries Society, Bethesda.

Zar, J. H. 1999. Biostatistical Analysis. Prentice Hall, Upper Saddle River.

Table 1. Beginning, end, and number of days for potential spawning periods for Blue Suckers (BLSU), Burbot (BURB), Channel catfish (CHCA), Shovelnose sturgeon (SHST), and Spiny Softshells (SPSO) in the Yellowstone River from 2005–2009.

	2005			2006			2007		
	Days	Begin	End	Days	Begin	End	Days	Begin	End
BLSU	30	17-May	19-Jun	43	27-Apr	29-Jun	41	17-Apr	23-Jun
BURB	28	1-Feb	28-Feb	28	1-Feb	28-Feb	28	1-Feb	28-Feb
CHCA	41	2-Jul	12-Aug	77	15-Jun	31-Aug	76	21-Jun	5-Sep
SHST	30	18-May	17-Jun	43	14-May	26-Jun	41	11-May	21-Jun
SPSO	23	27-Jun	20-Jul	23	14-Jun	7-Jul	23	11-Jun	4-Jul

	2008			2009		
	Days	Begin	End	Days	Begin	End
BLSU	35	5-May	24-Jul	64	5-May	26-Jul
BURB	28	1-Feb	28-Feb	28	1-Feb	28-Feb
CHCA	55	2-Jul	26-Aug	68	2-Jul	8-Sep
SHST	35	16-May	20-Jun	64	20-May	23-Jul
SPSO	23	15-Jul	7-Aug	23	12-Jul	4-Aug

Table 2. Number of total individuals per species (*N*) and number (n) and percent (%) of individuals of each species monitored in the Yellowstone River from 2005–2009 originally tagged in (tagging location) and whose home ranges were in region 5, 7, or both regions.

		Tagging location		Home range		
		R5	R7	R5	R7	Both
Species	*N*	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
BLSU	40	0 (0)	40 (100)	0 (0)	40 (100)	0 (0)
BURB	124	31 (25)	93 (75)	31 (25)	93 (75)	0 (0)
CHCA	105	0 (0)	105 (100)	0 (0)	104 (99)	1 (1)
SHST	37	0 (0)	37 (100)	0 (0)	37 (100)	0 (0)
SPSO	54	16 (30)	38 (70)	16 (30)	38 (70)	0 (0)

Table 3. Summary statistics (SD = standard deviation) for monitoring period (d) for Blue Suckers, Burbot, Channel catfish, Shovelnose sturgeon, and Spiny Softshells separated by active (A) and known expelled (E) transmittered animals monitored in the Yellowstone River from 2005–2009.

	N		Minimum		Mean		SE		Maximum	
	A	E	A	E	A	E	A	E	A	E
BLSU	37	3	15	75	897	182	63	92	1178	365
BRBT	110	14	0	49	214	118	13	11	878	197
CHCA	82	23	7	33	309	213	33	34	1142	674
SHST	35	2	47	103	1079	235	38	132	1178	367
SPSO	54		2		685		45		1167	

Table 4. Summary statistics (SD = standard deviation) for number of locations for Blue Suckers Burbot, Channel catfish, Shovelnose sturgeon, and Spiny Softshells separated by active (A) and known expelled (E) transmittered animals monitored in the Yellowstone River from 2005–2009.

	N		Minimum		Mean		SE		Maximum	
	A	E	A	E	A	E	A	E	A	E
BLSU	37	3	2	2	31	4	3	1	54	6
BRBT	110	14	1	5	11	11	1	1	37	23
CHCA	82	23	2	2	12	9	1	2	55	27
SHST	35	2	2	3	46	13	2	9	59	22
SPSO	54		2		25		2		47	

Table 5. Relationship between linear home range (km) and monitoring period (d) or number of locations for each species monitored in the Yellowstone River from 2005–2009 using Spearman's Rank-Order Correlation (S = test statistic, *P* = p-value, and *rho* = Spearman's rank correlation coefficient).

		Monitoring period			Number of locations		
	N	S	*P*	*rho*	S	*P*	*rho*
BLSU							
Overall	40	3933.32	**> 0.01**	0.63	3315.74	**> 0.01**	0.69
Expelled	3	0.00	0.33	1.00	2.00	1.00	0.50
Active	37	3806.06	**> 0.01**	0.55	3191.41	**> 0.01**	0.62
BURB							
Overall	124	210784.70	**> 0.01**	0.34	191263.60	**> 0.01**	0.40
Expelled	14	205.73	**0.04**	0.55	258.92	0.12	0.43
Active	110	145720.90	**> 0.01**	0.34	134667.00	**> 0.01**	0.39
CHCA							
Overall	105	138291.70	**> 0.01**	0.28	170032.30	0.22	0.12
Expelled	23	986.0.00	**> 0.01**	0.51	1601.70	0.34	0.21
Active	82	68614.09	**0.02**	0.25	83042.60	0.39	0.10
SHST							
Overall	37	9206.30	0.60	-0.09	7569.30	0.54	0.10
Expelled	2	0.00	1.00	1.00	0.00	1.00	1.00
Active	35	8345.60	0.30	-0.16	6761.10	0.76	0.05
SPSO							
Overall	54	20691.80	0.10	0.21	23499.10	0.45	0.10
Expelled	0	NA	NA	NA	NA	NA	NA
Active	54	20691.80	0.10	0.21	23499.10	0.45	0.10

Table 6. Summary statistics for linear home range (km) of all species monitored in the Yellowstone River from 2005–2009. Significance (Sig) indicates significant differences (χ^2 = 114.09, df =4, and $P < 0.0001$) in median linear home range among species; species with the same letter are not significantly different.

Species	N	Minimum	Mean	SE	Median	Maximum	Sig
BLSU	37	9.81	232.47	20.78	235.72	464.04	A
BRBT	110	0.00	33.99	6.77	8.96	281.30	B
CHCA	82	0.03	38.09	6.39	7.02	217.81	B
SHST	35	3.30	133.12	15.82	129.66	377.50	C
SPSO	54	0.56	17.56	5.83	6.28	298.92	B

Table 7. Summary statistics for linear home range (km) of Shovelnose Sturgeon during spawning and nonspawning periods, monitored in the Yellowstone River from 2006–2007. Standard error is 'SE'. Linear home ranges between periods were compared with a Wilcoxon signed-rank test.

	N	Min	Mean	SE	Median	Max
Spawning	19	10.1	125.6	16.1	129.3	264.7
Nonspawning	19	4.23	67.9	9.4	64.5	139.7

Table 8. Results of Kruskal-Wallis one-way analysis of variance tests comparing seasonal home ranges (km) of Blue Suckers, Burbot, Channel catfish, Shovelnose sturgeon, and Spiny Softshells monitored in the Yellowstone River from 2005–2009.

	χ^2	df	*P*
BLSU	11.56	3	0.009
BRBT	21.92	3	< 0.001
CHCA	0.49	3	0.92
SHST	13.15	3	0.004
SPSO	48.92	3	< 0.001

Table 9. Summary statistics for seasonal home ranges of Blue Suckers, Burbot, Channel catfish, Shovelnose sturgeon, and Spiny Softshells monitored in the Yellowstone River from 2005–2009. Significance (Sig.) indicates statistically significant differences in median seasonal home range among seasons for each species; seasons under each species sharing the same letter are not significantly different.

		N	Min	Mean	SE	Median	Max	Sig
BLSU	Spring	11	0.0	63.6	22.3	8.0	190.4	A
	Runoff	35	0.0	171.1	20.3	174.9	377.9	B
	Summer	38	9.8	143.1	16.3	129.3	380.0	B
	Winter	29	0.0	200.5	24.4	235.7	362.3	B
BRBT	Spring	113	0.0	2.5	0.7	0.2	57.9	A
	Runoff	115	0.0	5.5	1.9	0.6	178.3	A
	Summer	78	0.0	10.4	4.2	0.1	280.8	A
	Winter	87	0.0	17.4	3.0	3.8	137.7	B
CHCA	Spring	64	0.0	12.6	4.5	0.5	154.7	A
	Runoff	93	0.0	17.9	4.6	0.3	217.8	A
	Summer	94	0.0	7.9	2.3	0.4	162.9	A
	Winter	57	0.0	8.3	4.1	0.4	179.4	A
SHST	Spring	35	0.1	72.2	14.5	40.4	370.0	A,B
	Runoff	36	0.0	100.5	15.8	69.0	372.1	A
	Summer	37	0.1	86.4	14.3	71.7	377.5	A
	Winter	35	0.3	46.1	11.5	23.1	260.4	B
SPSO	Spring	48	0.0	3.0	0.9	1.1	32.6	A
	Runoff	48	0.0	4.8	1.4	2.0	60.1	A
	Summer	53	0.6	15.6	5.9	4.2	298.9	B
	Winter	51	0.0	1.9	0.7	0.7	32.8	A

Table 10. Summary statistics for total movement rates (km/d) of each species monitored in the Yellowstone River from 2005–2009. Standard error is 'SE'. Significance (Sig) indicates significant differences in median net movement rate among species using a Kruskal-Wallis one-way analysis of variance ($\chi^2 = 706.16$, df = 4, $P < 0.0001$) and pairwise Wilcoxon rank sum tests; species sharing the same letter are not significantly different.

Species	N	Minimum	Mean	SE	Median	Maximum	Sig
BLSU	310	0.00	4.31	0.40	1.43	39.79	A
BRBT	412	0.00	0.23	0.04	0.02	9.80	B
CHCA	503	0.00	0.20	0.03	0.02	5.55	B
SHST	430	0.00	0.45	0.04	0.14	12.72	C
SPSO	426	0.00	0.06	0.02	0.01	6.56	D

Table 11. Results of Kruskal-Wallis one-way analysis of variance tests comparing seasonal total movement rates for each species monitored in the Yellowstone River from 2005–2009 (χ^2 = chi-squared, df = degrees of freedom, and P = p-value).

Species	χ^2	df	P
BLSU	55.89	3	< 0.0001
BRBT	2.81	3	0.42
CHCA	41.59	3	< 0.0001
SHST	1116.89	3	< 0.0001
SPSO	104.88	3	< 0.0001

Table 12. Summary statistics for total movement rates (km/d) by season of each species monitored in the Yellowstone River from 2005–2009. Standard error is ‘SE’. Significance (Sig) indicates significant differences in median net movement rate among seasons for each species using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons under each species sharing the same letter are not significantly different.

Species	Season	N	Minimum	Mean	SE	Median	Maximum	Sig
BLSU	Spring	36	0.00	2.28	1.07	0.49	37.92	A
	Run off	83	0.00	4.95	0.63	3.89	37.92	B
	Summer	117	0.00	1.60	0.31	0.82	27.56	A
	Winter	74	0.00	8.86	1.14	4.84	39.79	B
BRBT	Spring	123	0.00	0.13	0.03	0.02	1.79	A
	Run off	121	0.00	0.31	0.12	0.02	9.80	A
	Summer	80	0.00	0.36	0.11	0.02	6.31	A
	Winter	88	0.00	0.13	0.03	0.03	1.47	A
CHCA	Spring	122	0.00	0.24	0.06	0.04	4.07	A
	Run off	158	0.00	0.37	0.07	0.03	3.93	A
	Summer	118	0.00	0.16	0.04	0.02	5.55	A
	Winter	105	0.00	0.03	0.01	0.00	0.52	B
SHST	Spring	101	0.00	0.50	0.07	0.24	4.28	A
	Run off	100	0.00	0.60	0.08	0.32	4.49	A
	Summer	128	0.00	0.62	0.11	0.29	12.72	A
	Winter	101	0.00	0.05	0.01	0.02	0.40	B
SPSO	Spring	98	0.00	0.07	0.01	0.02	0.66	A
	Run off	92	0.00	0.05	0.01	0.02	0.66	A
	Summer	130	0.00	0.11	0.05	0.03	6.56	A
	Winter	106	0.00	0.01	0.00	0.00	0.18	B

Table 13. Summary statistics for overall net movement rates (km/d) of each species monitored in the Yellowstone River from 2005–2009. Significance (Sig) indicates significant differences in median net movement rate among species using a Kruskal-Wallis one-way analysis of variance (χ^2 = 9.43, df = 4, P = 0.05) and pairwise Wilcoxon rank sum tests; species with the same letter are not significantly different.

Species	*N*	Minimum	Mean	SE	Median	Maximum	Sig
BLSU	310	-39.795	-0.839	0.463	0.007	37.920	A
BURB	412	-9.801	-0.134	0.042	-0.002	1.470	A
CHCA	503	-3.926	0.002	0.027	0.000	5.551	A
SHST	430	-12.725	-0.047	0.049	0.003	4.280	A
SPSO	426	-0.657	0.012	0.016	0.000	6.557	A

Table 14. Results of Kruskal-Wallis one-way analysis of variance tests comparing seasonal net movement rates for each species monitored in the Yellowstone River from 2005–2009 (χ^2 = chi-squared, df = degrees of freedom, and P = p-value).

Species	χ^2	df	*P*
BLSU	172.63	3	**< 0.01**
BURB	26.58	3	**< 0.01**
CHCA	16.14	3	**< 0.01**
SHST	10.51	3	**0.01**
SPSO	0.56	3	0.91

Table 15. Summary statistics for net movement rates (km/d) by season of each species monitored in the Yellowstone River from 2005–2009. Significance (Sig) indicates significant differences in median net movement rate among seasons for each species using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different.

Species	Season	*N*	Minimum	Mean	SE	Median	Maximum	Sig
BLSU	Spring	36	-1.307	2.034	1.082	0.429	37.920	A
	Runoff	83	-1.307	4.899	0.631	3.889	37.920	B
	Summer	117	-27.560	-0.762	0.333	-0.191	4.371	C
	Winter	74	-39.795	-8.794	1.151	-4.840	0.873	D
BURB	Spring	123	-1.790	0.003	0.029	0.000	1.390	A
	Runoff	121	-9.801	-0.263	0.117	-0.004	0.513	A, B
	Summer	80	-6.313	-0.333	0.107	-0.017	0.784	B
	Winter	88	-0.751	0.031	0.032	0.001	1.470	A
CHCA	Spring	122	-3.386	-0.059	0.060	-0.001	4.073	A
	Runoff	158	-3.926	-0.014	0.062	0.000	3.649	A, B
	Summer	118	-0.515	0.101	0.052	0.001	5.551	B
	Winter	105	-0.484	-0.015	0.008	-0.001	0.518	A
SHST	Spring	101	-3.349	-0.058	0.088	0.003	4.280	A, B
	Runoff	100	-4.493	-0.061	0.101	-0.041	4.187	A, B
	Summer	128	-12.725	-0.070	0.126	0.041	1.931	A
	Winter	101	-0.178	0.006	0.008	-0.002	0.396	B
SPSO	Spring	98	-0.657	-0.016	0.013	0.000	0.323	A
	Runoff	92	-0.657	-0.006	0.012	-0.001	0.381	A
	Summer	130	-0.325	0.056	0.051	0.000	6.557	A
	Winter	106	-0.089	0.000	0.002	0.000	0.179	A

Table 16. Results of Mann-Whitney-U tests comparing upstream and downstream net movement rate overall and by season for each species monitored in the Yellowstone River from 2005–2009 (*W* = test statistic and *P* = p-value).

	Overall		Spring		Runoff		Summer		Winter	
Species	*W*	*P*	*W*	*P*	*W*	*P*	*W*	*P*	*W*	*P*
BLSU	12043	0.96	127	0.59	509	**< 0.01**	1484	0.37	51	**< 0.01**
BURB	17525	**< 0.01**	1946	0.78	1236	**< 0.01**	330	**0.003**	921	0.75
CHCA	32109	0.77	1773	0.53	1990	0.31	3171	0.86	890	**< 0.01**
SHST	23687	0.7	1314	0.79	1203	0.92	1572	0.14	1496.5	0.17
SPSO	21570	0.37	929	**0.05**	1081	0.86	2245	0.54	1444	0.94

Table 17. Summary statistics for upstream and downstream net movement rates (km/d) by season for each species monitored in the Yellowstone River from 2005–2009. Only summary statistics of parameters from MWU tests that exhibited significant differences (Table 13; SE = standard error).

		Spring				Runoff			
Species	Direction	*N*	Mean	Median	SE	*N*	Mean	Median	SE
BLSU	Up					76	5.378	4.087	0.663
	Down					7	-0.300	-0.044	0.180
BURB	Up					49	0.056	0.008	0.015
	Down					72	-0.480	-0.030	0.193
CHCA	Up								
	Down								
SPSO	Up	50	0.050	0.015	0.011				
	Down	48	-0.084	-0.031	0.019				

		Summer				Winter			
Species	Direction	*N*	Mean	Median	SE	*N*	Mean	Median	SE
BLSU	Up					8	0.292	0.271	0.103
	Down					66	-9.895	-7.523	1.223
BURB	Up	20	0.052	0.007	0.039				
	Down	60	-0.462	-0.047	0.139				
CHCA	Up					39	0.023	0.002	0.014
	Down					67	-0.036	-0.011	0.009
SHST	Up								
	Down								
SPSO	Up								
	Down								

Table 18. Results of Kruskal–Wallis one-way analysis of variance tests comparing total and net movement rates of spawning male, spawning female, and nonspawning female Shovelnose Sturgeon overall ("Pooled") and in runoff, spring, and summer seasons monitored in the Yellowstone River from 2006–2007. Bold font indicates a difference among median total movement rates for that comparison.

Movement rate	Season	χ^2	df	*P*
Total	Pooled	3.16	2	0.20
	Spring	**6.64**	2	**0.04**
	Runoff	4.37	2	0.11
	Summer	1.97	2	0.37
Net	Pooled	0.41	2	0.82
	Spring	0.41	2	0.81

Runoff	1.20	2	0.55
Summer	0.22	2	0.89

Table 19. Summary statistics for total movement rates (km/d) of spawning male, spawning female, and nonspawning female Shovelnose Sturgeon monitored in the Yellowstone River from 2006–2007 by season. Standard error is 'SE', Minimum is 'Min', and Maximum is 'Max'. 'Sig.' indicates significant differences among groups; groups sharing the same letter are not significantly different from one another.

Season	Class	N	Min	Mean	SE	Median	Max	Sig.
Spring	Spawning Males	18	0.00	0.57	0.24	0.21	4.28	A,B
	Spawning Females	15	0.02	0.50	0.07	0.52	0.85	A
	Nonspawning Females	13	0.01	0.23	0.09	0.06	1.13	B
Runoff	Spawning Males	17	0.01	0.34	0.11	0.14	1.62	A
	Spawning Females	15	0.04	0.44	0.09	0.39	1.28	A
	Nonspawning Females	13	0.02	0.48	0.09	0.42	1.01	A
Summer	Spawning Males	18	0.01	0.41	0.09	0.32	1.31	A
	Spawning Females	15	0.00	0.42	0.10	0.34	1.17	A
	Nonspawning Females	13	0.02	0.63	0.14	0.48	1.53	A

Table 20. Summary statistics for net movement rates (km/d) of spawning male, spawning female, and nonspawning female Shovelnose Sturgeon monitored in the Yellowstone River from 2006–2007 by season. Standard error is 'SE', Minimum is 'Min', and Maximum is 'Max'. 'Sig.' indicates significant differences among groups; groups sharing the same letter are not significantly different from one another.

Season	Class	N	Min	Mean	SE	Median	Max	Sig.
Spring	Spawning Males	18	-1.74	0.19	0.27	0.06	4.28	A
	Spawning Females	15	-0.85	0.01	0.15	-0.02	0.78	A
	Nonspawning Females	13	-1.13	-0.04	0.11	-0.01	0.60	A
Runoff	Spawning Males	17	-1.28	-0.08	0.14	-0.04	1.62	A
	Spawning Females	15	-0.97	-0.09	0.15	-0.20	1.28	A
	Nonspawning Females	13	-1.01	-0.25	0.15	-0.32	0.67	A
Summer	Spawning Males	18	-0.35	0.29	0.11	0.16	1.31	A
	Spawning Females	15	-1.17	0.23	0.13	0.29	1.05	A
	Nonspawning Females	13	-1.53	0.26	0.22	0.33	1.40	A

Table 21. Characteristics of habitat types in the Yellowstone River from 2005–2009. Bluff, alluvial, terrace are pool types. Pool types with rip-rap are abbreviated as RR. Standard errors are displayed in parentheses.

Habitat	Mean length (km)	Mean width (m)	Mean depth (m)	Mean max. depth (m)	Mean velocity (m/s)	Mean bottom velocity (m/s)	Mean % ≥Bldr.
Bluff	1.3	147 (1.71)	1.48 (0.04)	3.36 (0.31)	0.69 (0.02)	0.53 (0.01)	19.4 (6.43)
Terrace	0.9	138 (2.98)	1.52 (0.03)	3.11 (0.35)	0.92 (0.02)	0.72 (0.02)	16.6 (2.60)
Alluvial	0.7	115 (1.09)	1.27 0.23)	2.35 (0.22)	0.92 (0.02)	0.73 (0.01)	3.2 (3.17)
RR bluff	1.3	156 (0.56)	1.83 (0.46)	4.25 (0.48)	0.68 (0.01)	0.52 (0.01)	27.3 (7.68)
RR alluvial	0.9	156 (1.00)	1.67 (0.41)	3.68 (0.56)	0.81 (0.02)	0.65 (0.02)	18.8 (9.82)
Crossover	0.4	145 (1.64)	0.96 (0.02)	1.96 (0.20)	1.16 (0.02)	0.95 (0.02)	1.0 (0.67)
Secondary Channel	0.8	82 (0.84)	0.64 (0.01)	1.51 (0.13)	0.78 (0.01)	0.61 (0.01)	3.5 (2.30)

Table 22. Summary of reach type I lengths (km) and percent of total range (%) for telemetered species monitored in the Yellowstone River from 2005–2009. For type: C =confined, P = partially confined, and U = unconfined.

	BLSU		BURB		CHCA		SHST		SPSO	
	km	%	km	%	km	%	km	%	km	%
C	81.9	17.1	81.9	12.7	81.9	14.1	81.9	21.7	81.9	14.5
P	325.7	67.8	403.0	62.5	390.5	67.2	284.3	75.2	344.4	61.1
U	72.5	15.1	159.6	24.8	108.3	18.6	12.0	3.2	137.1	24.3
Total	480.1	100.0	644.5	100.0	580.7	100.0	378.2	100.0	563.4	100.0

Table 23. Summary of reach type lengths (km) and percent of total range (%) for telemetered species monitored in the Yellowstone River from 2005–2009. For type: CM = confined meandering, CM = confined straight, PCA = partially confined anabranching, PCB = partially confined braided, PCM = partially confined meandering, PCM/I = partially confined meandering with islands, PCS = partially confined straight, UA = unconfined anabranching, UB = unconfined braided, US/I = unconfined straight with islands.

	BLSU		BURB		CHCA		SHST		SPSO	
Type	km	%	km	%	km	%	km	%	km	%
CM	51.8	10.8	51.8	8.0	51.8	8.9	51.8	13.7	51.8	9.2
CS	30.1	6.3	30.1	4.7	30.1	5.2	30.1	8.0	30.1	5.3
PCA	97.4	20.3	137.2	21.3	124.7	21.5	97.4	25.8	124.7	22.1
PCB	14.8	3.1	34.7	5.4	34.7	6.0			34.7	6.2
PCM	11.0	2.3	22.5	3.5	22.5	3.9			22.5	4.0
PCM/I	155.3	32.3	155.3	24.1	155.3	26.7	155.3	41.1	109.2	19.4
PCS	47.2	9.8	53.3	8.3	53.3	9.2	31.6	8.4	53.3	9.5
UA	60.5	12.6	101.6	15.8	87.3	15.0			91.1	16.2
UB	12.0	2.5	46.0	7.1	21.0	3.6			46.0	8.2
US/I			12.0	1.9			12.0	3.2		
TOTAL	480.1	100.0	644.5	100.0	580.7	100.0	378.2	100.0	563.4	100.0

Table 24. Number of telemetered individuals (*N*), number of individuals in the vicinity of tributaries V (*N*), percent of individuals in the vicinity of tributaries V (%), number of individuals known to be in tributaries T (*N*), percent of individuals known to be in tributaries T (%), and number of individuals both in the vicinity of, and in tributaries *N* both in the Yellowstone River from 2005–2009.

	N	V (*N*)	V (%)	T (*N*)	T (%)	*N* both
BLSU	40	6	15	0	0	0
BURB	124	10	8	2	2	1
CHCA	105	8	8	7	7	0
SHST	37	18	49	3	8	1
SPSO	54	4	7	1	2	1
Totals	460	46	-	13	-	3

Table 25. Number of instances for telemetered species located in the vicinity of (V) and in tributaries (T) by month in the Yellowstone River from 2005–2009.

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T
BLSU							1				1		4											
BURB	2	2	1				1		1		2								1		1		1	
CHCA					1				3	5	3	1	1	1										
SHST			1		2		6		17	3	5		1		2		3		1		1			
SPSO	1														4	1		1						
Total	3	2	2		3		8		21	8	11	1	6	1	6	1	3	1	2		2		1	

Table 26. Number of instances for telemetered species and total located in vicinity of (V) and in each tributary (T) in the Yellowstone River from 2005–2009.

	Clarks Fork		Bighorn		Rosebud		Tongue		Powder		O'Fallon	
	V	T	V	T	V	T	V	T	V	T	V	T
BLSU							3		2		1	
BURB	5	2	1				2		2			
CHCA					1		3	5	4	2		
SHST					1		8	1	25	2	5	
SPSO			5	2								
Total	5	2	6	2	2		16	6	33	4	6	

Table 27. Number of aggregations during potential spawning periods of telemetered species, during non-spawning, and total in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered animals present on the same day.

	Spawning	Other	Total
BLSU	11	20	31
BURB	2	55	57
CHCA	9	10	19
SHST	9	44	53
SPSO	4	39	43
Pooled	35	168	203

Table 28. Number of telemetered animals that passed, were blocked by, both passed and were blocked, or were not in vicinity of diversions or riffles in the Yellowstone River from 2005–2009.

	Passed (%)	Blocked (%)	Both	Not in vicinity
BLSU	30 (79)	8 (21)	8	10
BURB	12 (50)	12 (50)	3	103
CHCA	15 (71)	6 (29)	3	87
SHST	34 (69)	15 (31)	11	9
SPSO	3 (75)	1 (25)	0	50
Total	84	42	25	259

Table 29. Number of passage and blockage events at diversions or riffles by telemetered animals in the Yellowstone River from 2005–2009.

	Passage (%)	Blocked (%)
Diversions	113 (64)	62 (36)
Riffles	154 (97)	5 (3)

Table 30. Number of events of passage and blockage by structure (Type; D = diversion dam and R = natural rapids) at diversions or rapids by telemetered animals in the Yellowstone River from 2005–2009.

Structure	Type	Passage (%)	Blocked (%)
Huntley	D	0 (0)	0 (0)
Waco	D	2 (67)	1 (33)
Rancher	D	1 (100)	0 (0)
Myers	D	6 (100)	0 (0)
Cartersville	D	25 (45)	31 (55)
Matthews Rapids	R	59 (95)	3 (5)
Wolf Rapids	R	95 (98)	2 (2)
Intake	D	79 (73)	30 (27)
Total		267	67

Table 31. Number of occurrences of each species and pooled by season using main (M) or side channel (S) to pass above or that were blocked (B) by Intake Diversion in the Yellowstone River from 2005–2009.

	Spring			Runoff			Summer			Winter		
	M	S	B	M	S	B	M	S	B	M	S	B
BLSU	3			47	3	6	5	2		5	1	
BURB	1		5									1
CHCA				2	1				1			
SHST	1		2	1		9			4			
SPSO					1							
Pooled	5	0	7	50	5	15	5	2	5	5	1	1

Table 32. Number of passage and blockage events by month at diversions or riffles by all telemetered animals in the Yellowstone River from 2005–2009.

Month	Blocked	Passage	Total
1	0	1	1
2	0	2	2
3	4	7	11
4	13	16	29
5	13	52	65
6	16	98	114
7	9	57	66
8	5	12	17
9	4	9	13
10	1	9	10
11	1	2	3
12	1	2	3
Total	67	267	334

Table 33. Number of events of passage and blockage by structure (Type; D = diversion dam and R = natural rapids) at diversions or rapids by all telemetered animals in the Yellowstone River from 2005–2009.

Structure	Type	Species	Passage	Blockage	Species total	Structure total
Huntley	D					
Waco	D					3
		BURB	1	1	2	
		CHCA	1	0	1	
Rancher	D					1
		CHCA	1	0	1	
Myers	D					6
		BLSU	4	0	4	
		CHCA	2	0	2	
Cartersville	D					56
		BLSU	17	1	18	
		BURB	6	8	14	
		CHCA	1	3	4	
		SHST	0	15	15	
		SPSO	1	4	5	
Matthews Rapids	R					62
		BLSU	33	3	36	
		BURB	2	0	2	
		CHCA	6	0	6	
		SHST	17	0	17	
		SPSO	1	0	1	
Wolf Rapids	R					97
		BLSU	46	0	46	
		BURB	6	0	6	
		CHCA	8	2	10	
		SHST	32	0	32	
		SPSO	3	0	3	
Intake	D					109
		BLSU	69	6	75	
		BURB	2	7	9	
		CHCA	3	1	4	
		SHST	3	16	19	
		SPSO	2	0	2	

Table 34. Number of individuals of each species passing above Intake Diversion (*N*), number of occurrences and individuals using main or side channel or both to pass Intake Diversion, and frequency (%) using main or side channel or both to pass above Intake in the Yellowstone River from 2005–2009.

		Occurrences		Individuals			Individuals (%)		
	N	Main	Side	Main	Side	Both	Main	Side	Both
BLSU	28	60	6	25	5	2	78	16	6
BURB	1	1		1			100		
CHCA	3	2	1	2	1		66	33	
SHST	2	2		2			100		
SPSO	1		1		1			100	

Table 35. Number of observations (*N*), minimum (Min), mean, standard error (SE), and maximum (Max) discharge (cubic feet per second) during passage by way of main or side channel or being blocked by Intake Diversion for each species monitored in the Yellowstone River from 2005–2009.

	Main					Side Channel					Blocked				
	N	Min	Mean	SE	Max	*N*	Min	Mean	SE	Max	*N*	Min	Mean	SE	Max
Total	65	1,800	16,252	11,262	56,500	8	1,800	22,844	14,249	56,500	28	1,800	20,858	9,912	56,500
BLSU	60	1,800	23,381	1,463	56,500	6	1,800	22,251	6,504	56,500	6	1,800	23,159	3,977	32,900
BURB	1	9,190	17,218		32,900						6	6,370	9,134	439	17,400
CHCA	2	6,220	18,598	5,240	40,100	1	3,010	12,077		42,900	1	3,110	4,901		7,210
SHST	2	6,220	13,781	415	40,100						15	3,010	17,092	2,496	56,500
SPSO						1	17,200	21,286		25,900					

Table 36. Number of observations (*N*), minimum (Min), mean, standard deviation (SD), and maximum (Max) discharge (cubic feet per second) during passage and blockage events by each species for each structure (natural rapids and diversion dams) in the Yellowstone River from 2005–2009.

		Blockage					Passage				
Structure	Species	*N*	Min	Mean	SE	Max	*N*	Min	Mean	SE	Max
Huntley	Pooled										
	BLSU										
	BURB										
	CHCA										
	SHST										
	SPSO										
Waco	Pooled	1	7,440	24,341	NA	45,700	2	1,900	14,207	8,237	33,500
	BLSU										
	BURB	1	7,440	24,341	NA	45,700	1	5,560	22,445	NA	33,500
	CHCA						1	1,900	5,970	NA	31,900
	SHST										
	SPSO										
Rancher	Pooled						1	3,880	8,585	NA	34,200
	BLSU										
	BURB										
	CHCA						1	3,880	8,585	NA	34,200
	SHST										
	SPSO										
Myers	Pooled						6	3,810	9,658	2,358	48,500

	BLSU						4	3,810	9,457	3,674	48,500
	BURB										
	CHCA						2	3,880	10,061	1,475	37,300
	SHST										
	SPSO										
Cartersville	Pooled	31	3,790	12,422	1,468	34,200	25	3,810	12,733	1,842	48,500
	BLSU	1	10,500	10,940	NA	11,400	17	3,810	11,519	1,768	48,500
	BURB	8	4,700	13,696	3,141	34,200	6	4,700	18,143	5,506	33,900
	CHCA	3	6,070	16,020	4,975	34,200	1	3,880	8,585	NA	34,200
	SHST	15	3,790	8,337	1,435	23,600					
	SPSO	4	15,300	22,867	3,292	30,700	1	3,880	5,041	NA	7,480
Matthews Rapids	Pooled	3	4,150	7,320	2,177	20,500	59	3,420	16,398	1,355	57,400
	BLSU	3	4,150	7,320	2,177	20,500	33	3,420	16,784	1,890	57,400
	BURB						2	4,340	6,297	1,478	10,300
	CHCA						6	4,360	16,194	3.853	37,700
	SHST						17	3,950	17,568	2.502	57,400
	SPSO						1	3,950	5,207	NA	8,130
Wolf Rapids	Pooled	2	2,430	4,361	1,931	10,900	95	900	14,785	1,229	56,500
	BLSU						46	2,600	20,808	1,930	56,500
	BURB						6	900	5,791	392	8,870
	CHCA	2	2,430	4,361	1,931	10,900	8	3,010	16,938	3,993	56,500
	SHST						32	900	8,305	999	40,100
	SPSO						3	1,800	3,801	830	7,710
Intake	Pooled	30	1,800	15,588	1,756	56,500	79	1,800	21,556	1,344	56,500

BLSU	6	1,800	23,159	3,440	32,900	69	1,800	22,560	1,444	56,500
BURB	7	5,000	8,598	740	17,400	2	9,190	17,218	NA	32,900
CHCA	1	3,110	4,901	NA	7,210	3	3,010	16,424	4,042	42,900
SHST	16	3,010	16,474	2,494	56,500	3	3,010	10,597	4,562	40,100
SPSO						2	3,010	12,726	8,560	25,900

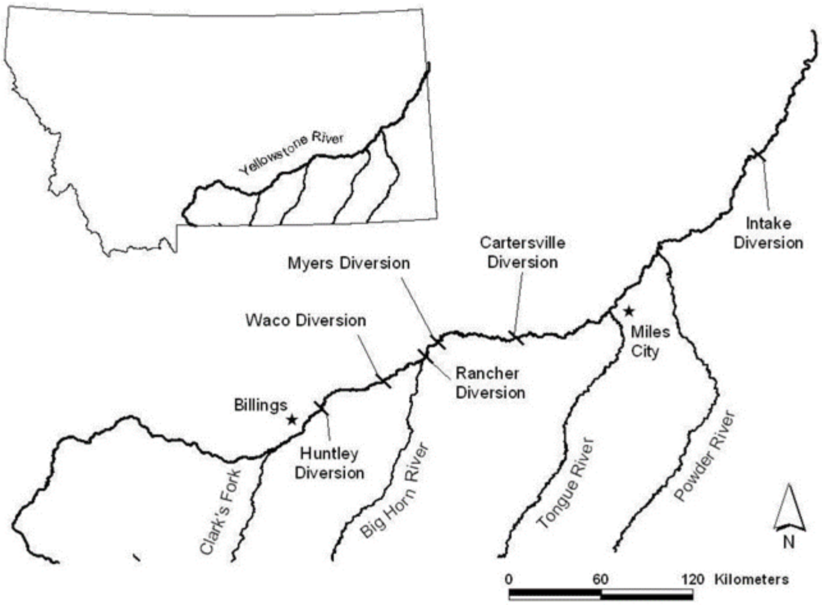

Figure 1. The lower Yellowstone River, its major tributaries, and diversion dams.

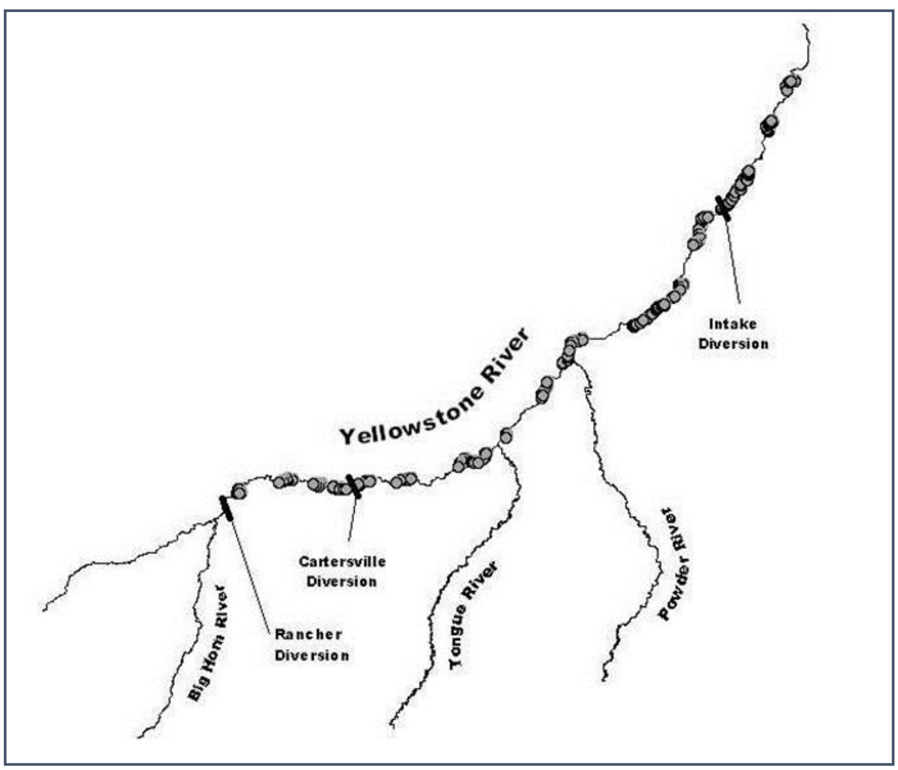

Figure 2. Locations sampled during 2005 in the Yellowstone River. Shaded circles indicate location where at least one radio transmitter was implanted into a target species.

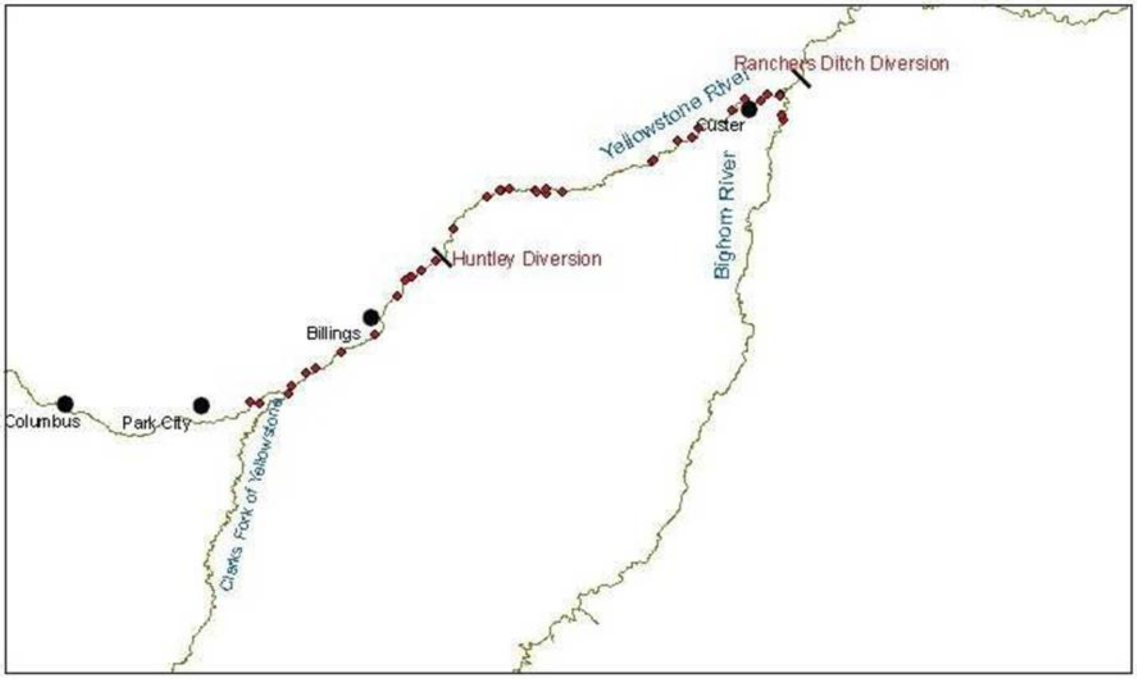

Figure 3. Locations sampled during 2006 in the Yellowstone River. Shaded diamonds indicate locations where at least one radio transmitter was implanted into a target species.

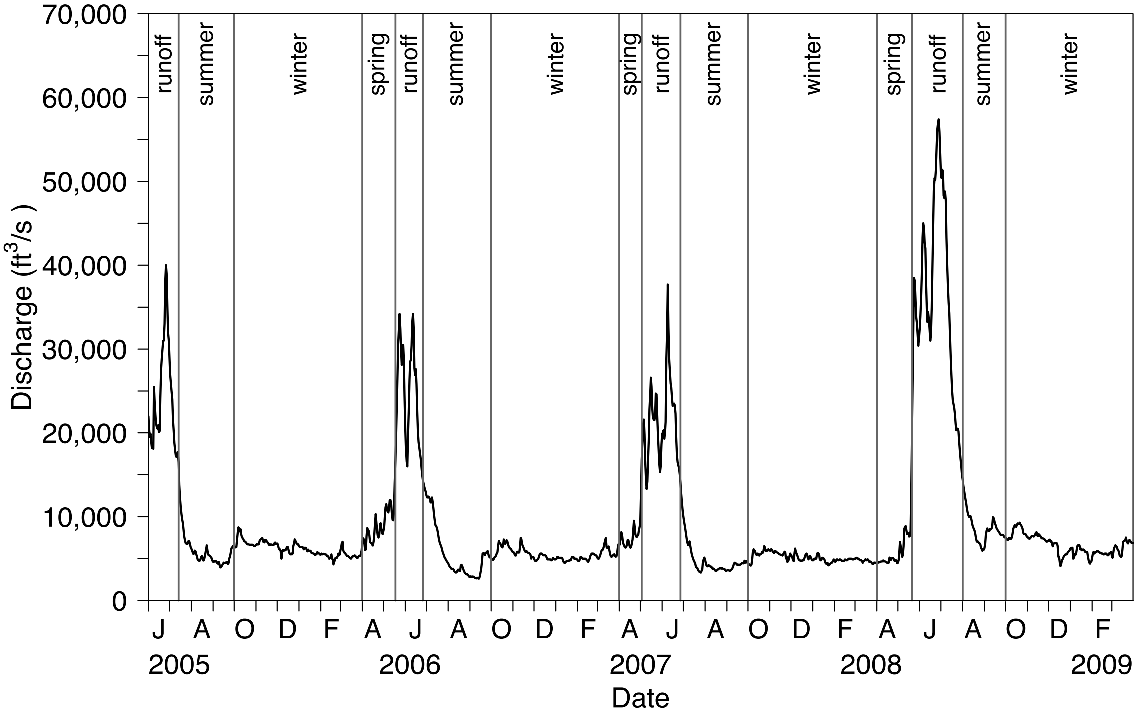

Figure 4. Discharge at Miles City, Montana and season delineation in the Yellowstone River from 2005–2009.

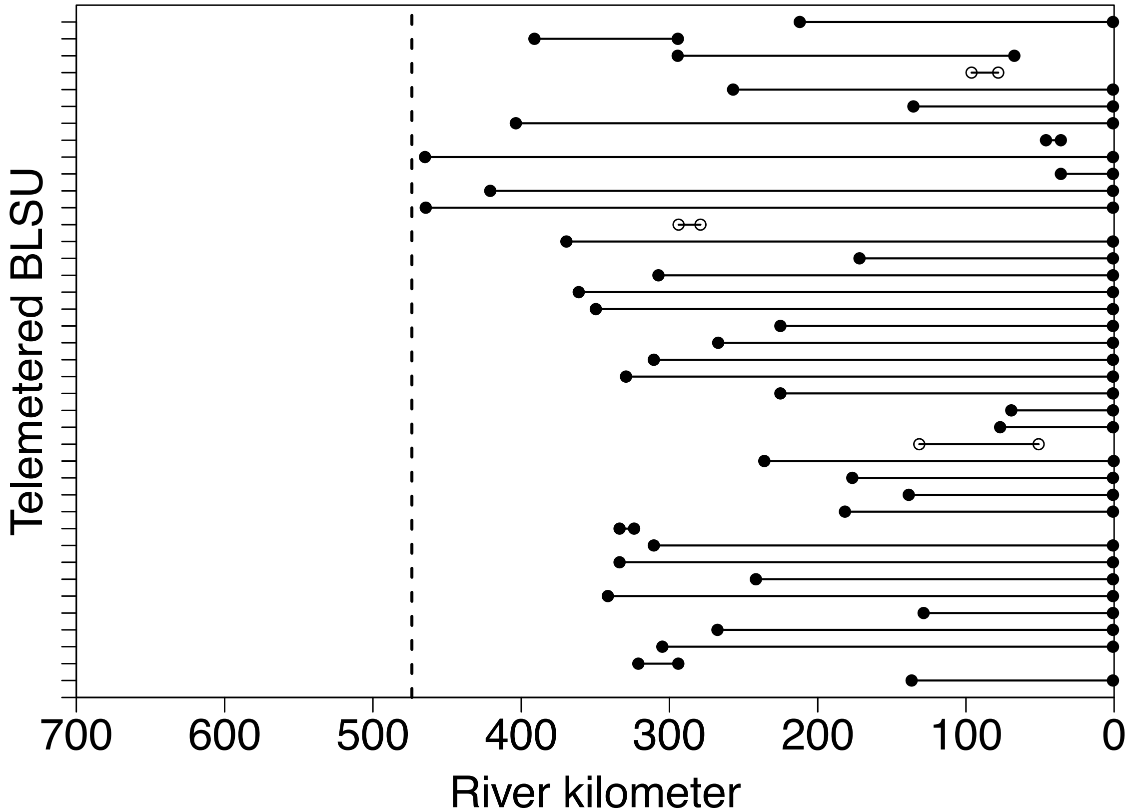

Figure 5. Linear home ranges of individual telemetered Blue Suckers ($N = 40$) in the Yellowstone River from 2005–2009, each individual is represented by two points and a horizontal solid line; open points depict home ranges of fish that expelled their transmitter. River kilometer represents distance from the confluence with the Missouri River (river kilometer 0). Points that occur at river kilometer 0 depict fish that moved out of the Yellowstone River at the confluence of the Missouri River. The vertical dashed line represents the location of the Bighorn River and division between Montana Fish, Wildlife & Parks Regions 5 (left) and 7 (right).

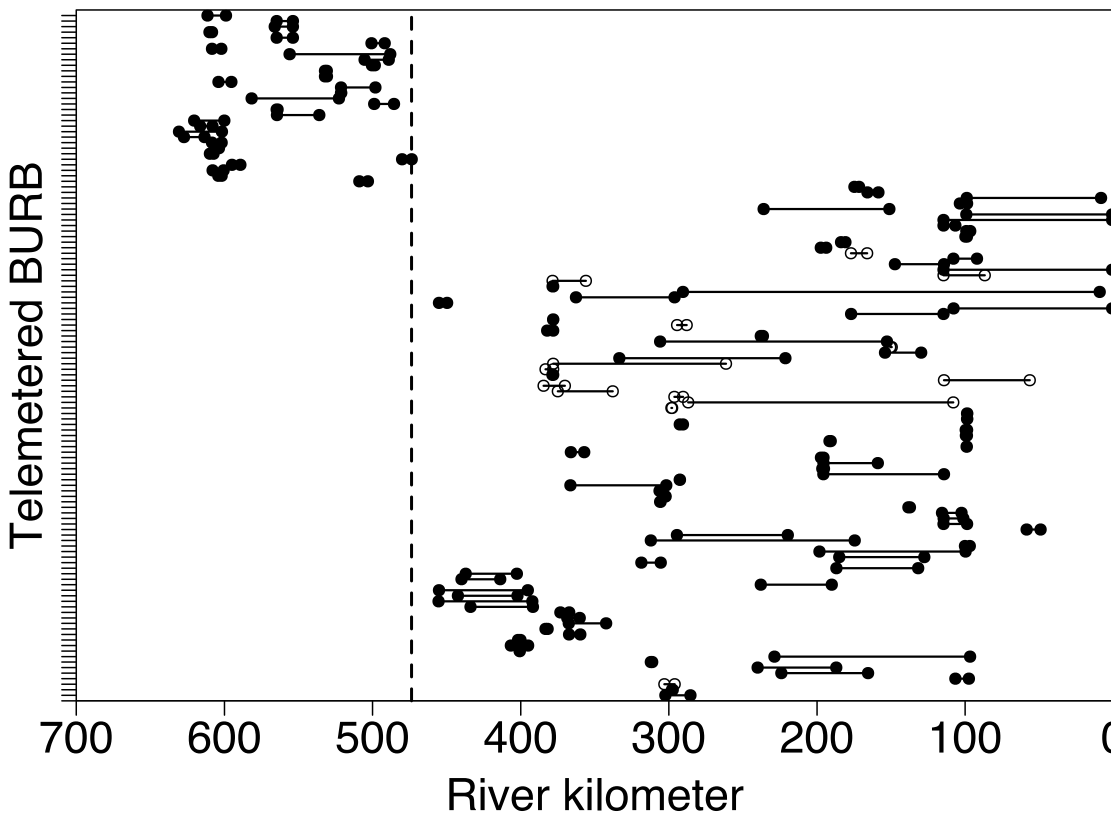

Figure 6. Linear home ranges of individual telemetered Burbot (*N* = 124) in the Yellowstone River from 2005–2009, each individual is represented by two points and a horizontal solid line; open points depict home ranges of fish that expelled their transmitter. River kilometer represents distance from the confluence with the Missouri River (river kilometer 0). Points that occur at river kilometer 0 depict fish that moved out of the Yellowstone River at the confluence of the Missouri River. The vertical dashed line represents the location of the Bighorn River and division between Montana Fish, Wildlife & Parks Regions 5 (left) and 7 (right).

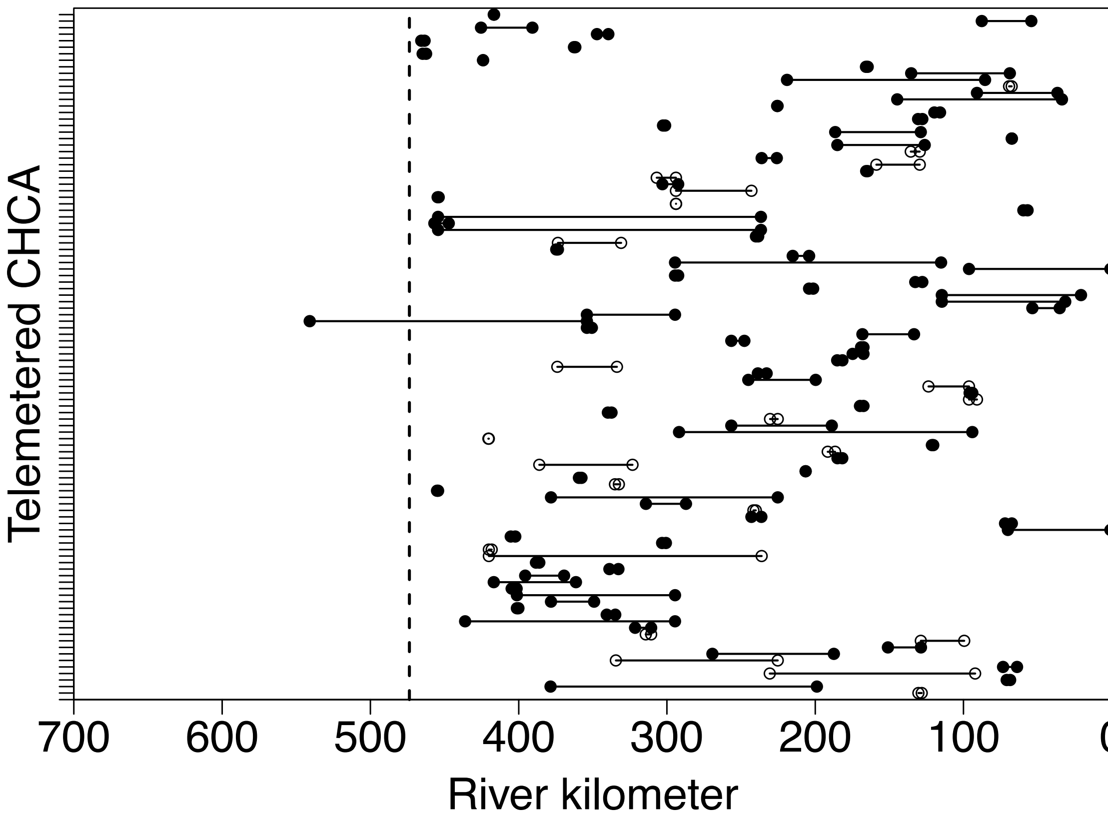

Figure 7. Linear home ranges of individual telemetered Channel Catfish (*N* = 105) in the Yellowstone River from 2005–2009, each individual is represented by two points and a horizontal solid line; open points depict home ranges of fish that expelled their transmitter. River kilometer represents distance from the confluence with the Missouri River (river kilometer 0). Points that occur at river kilometer 0 depict fish that moved out of the Yellowstone River at the confluence of the Missouri River. The vertical dashed line represents the location of the Bighorn River and division between Montana Fish, Wildlife & Parks Regions 5 (left) and 7 (right).

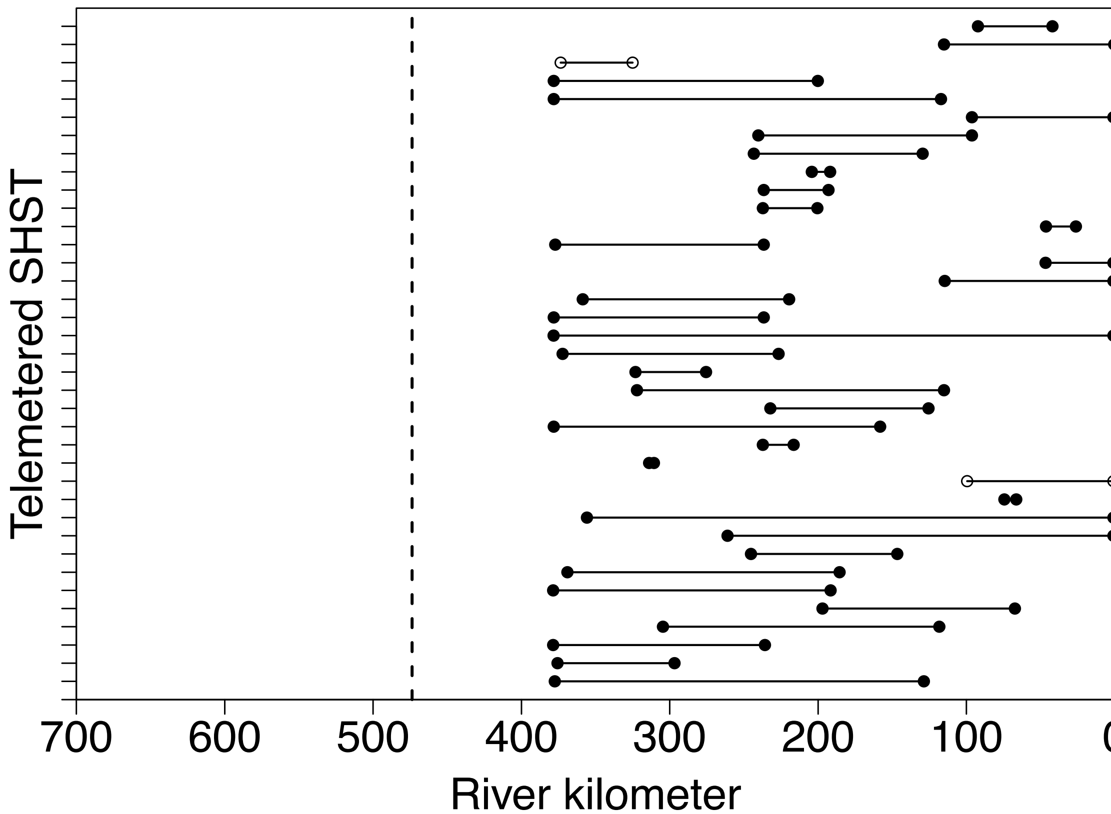

Figure 8. Linear home ranges of individual telemetered Shovelnose Sturgeon (*N* = 37) in the Yellowstone River from 2005–2009, each individual is represented by two points and a horizontal solid line; open points depict home ranges of fish that expelled their transmitter. River kilometer represents distance from the confluence with the Missouri River (river kilometer 0). Points that occur at river kilometer 0 depict fish that moved out of the Yellowstone River at the confluence of the Missouri River. The vertical dashed line represents the location of the Bighorn River and division between Montana Fish, Wildlife & Parks Regions 5 (left) and 7 (right).

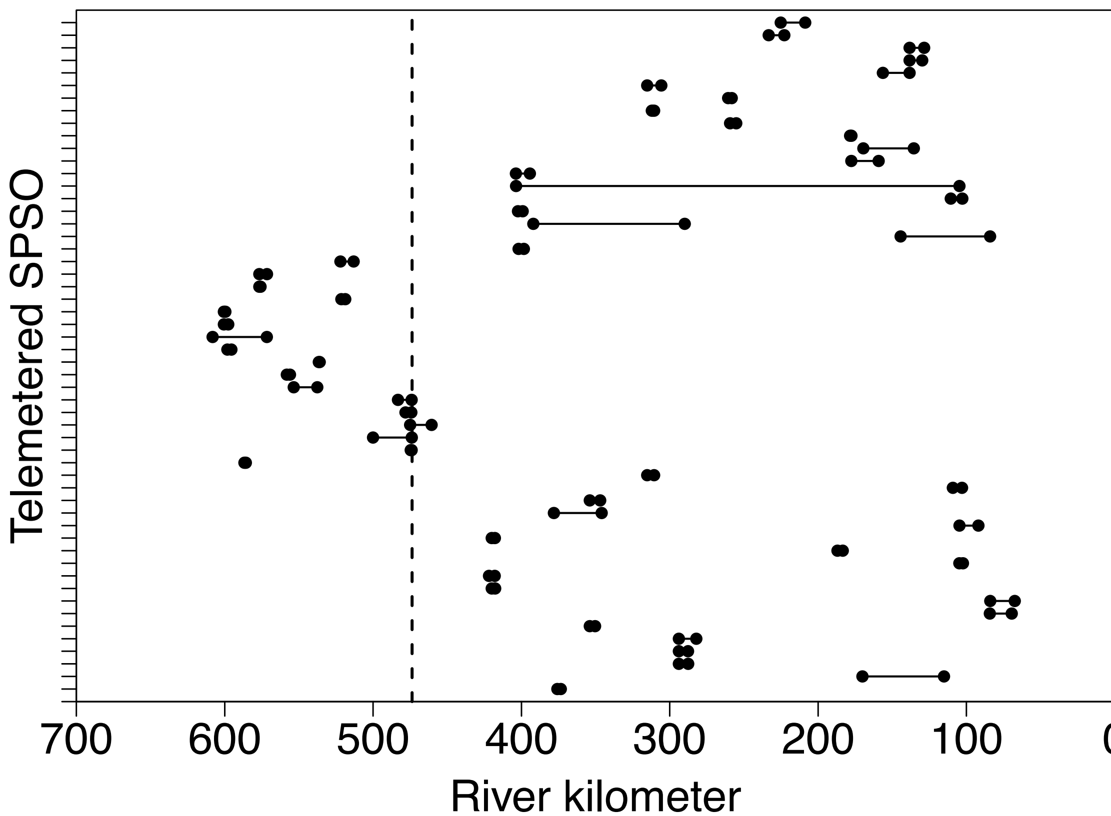

Figure 9. Linear home ranges of individual telemetered Spiny Softshells (*N* = 54) in the Yellowstone River from 2005–2009, each individual is represented by two points and a horizontal solid line; open points depict home ranges of fish that expelled their transmitter. River kilometer represents distance from the confluence with the Missouri River (river kilometer 0). Points that occur at river kilometer 0 depict fish that moved out of the Yellowstone River at the confluence of the Missouri River. The vertical dashed line represents the location of the Bighorn River and division between Montana Fish, Wildlife & Parks Regions 5 (left) and 7 (right).

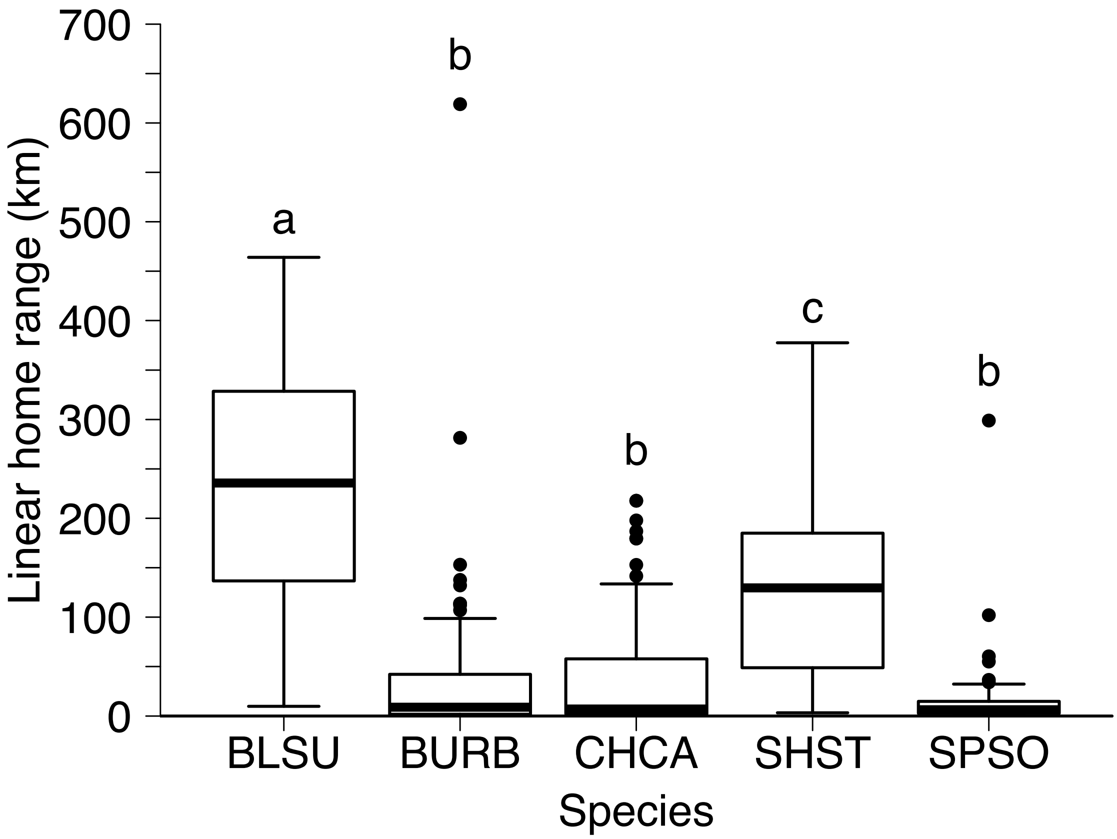

Figure 10. Linear home ranges of telemetered species monitored in the Yellowstone River from 2005–2009. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median linear home range among species; species with the same letter are not significantly different.

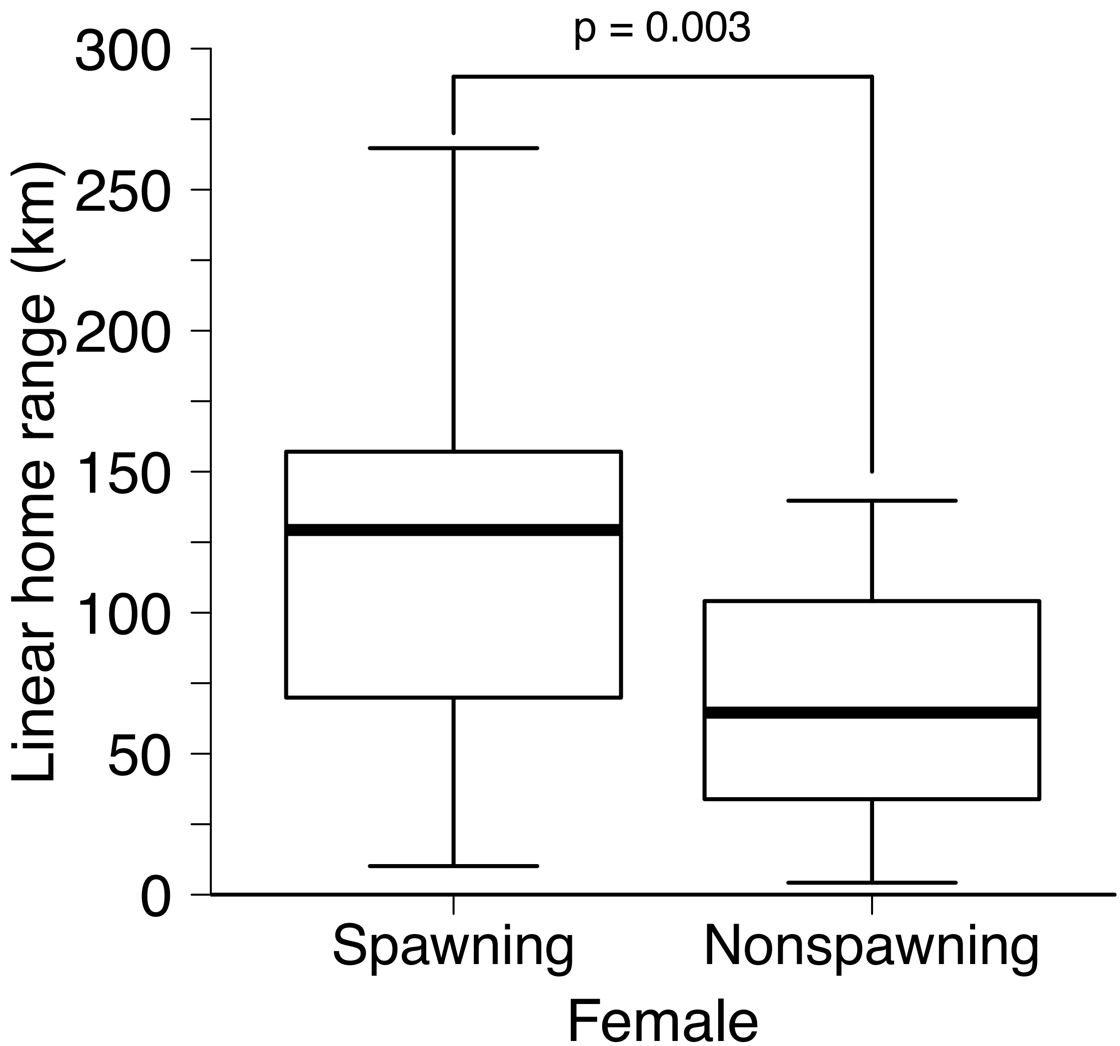

Figure 11. Linear home range of female Shovelnose sturgeon during spawning and nonspawning periods, indicated by histological and RIA data, monitored in the Yellowstone River from 2006–2007. Linear home ranges are compared among periods with a Wilcoxon signed-rank test.

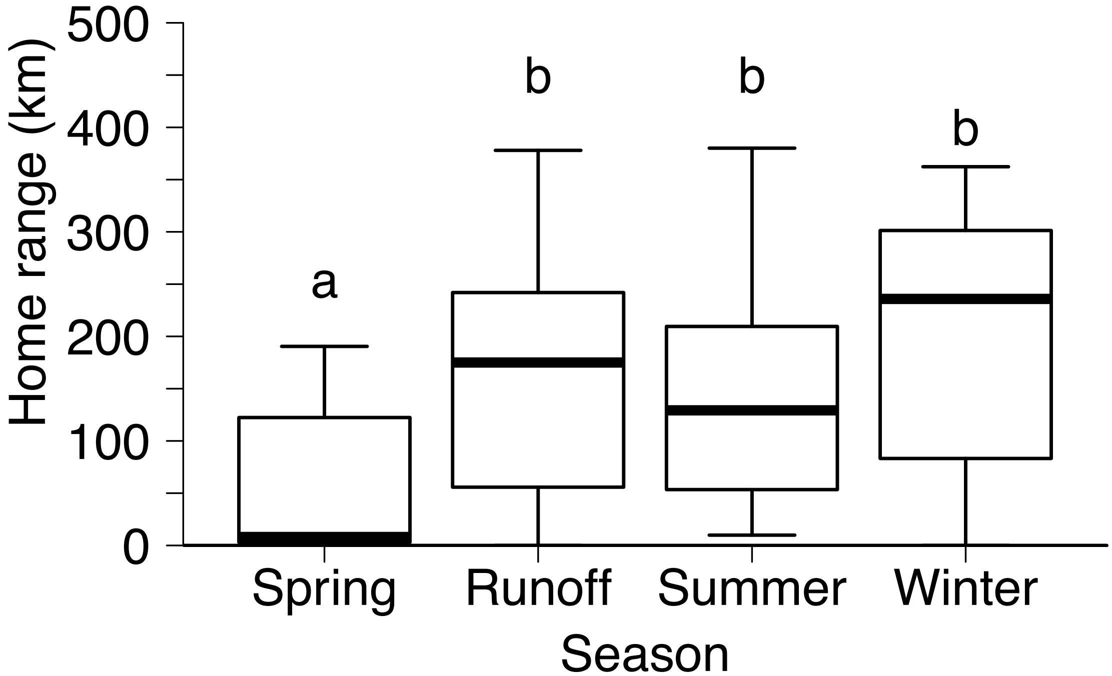

Figure 12. Seasonal linear home ranges of Blue Sucker monitored in the Yellowstone River from 2005–2009. Letters above bars indicate significant differences in median linear home range among seasons; seasons with the same letter are not significantly different.

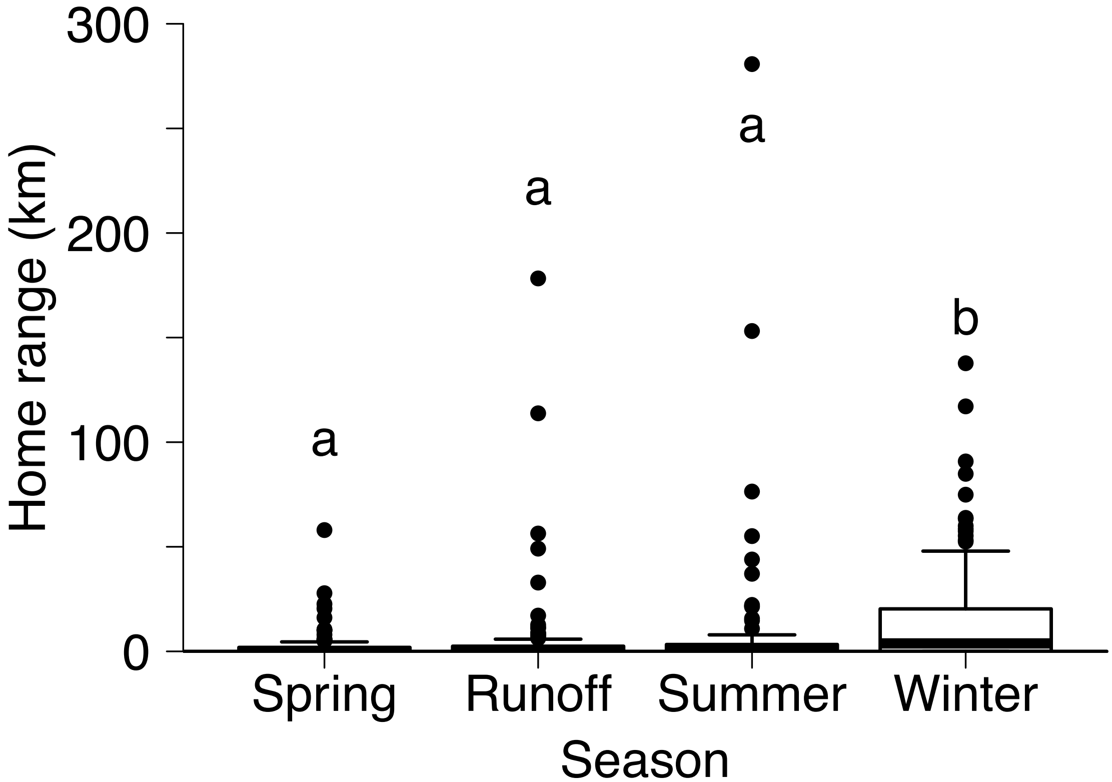

Figure 13. Seasonal linear home ranges of Burbot monitored in the Yellowstone River from 2005–2009. Letters above bars indicate significant differences in median linear home range among seasons; seasons with the same letter are not significantly different.

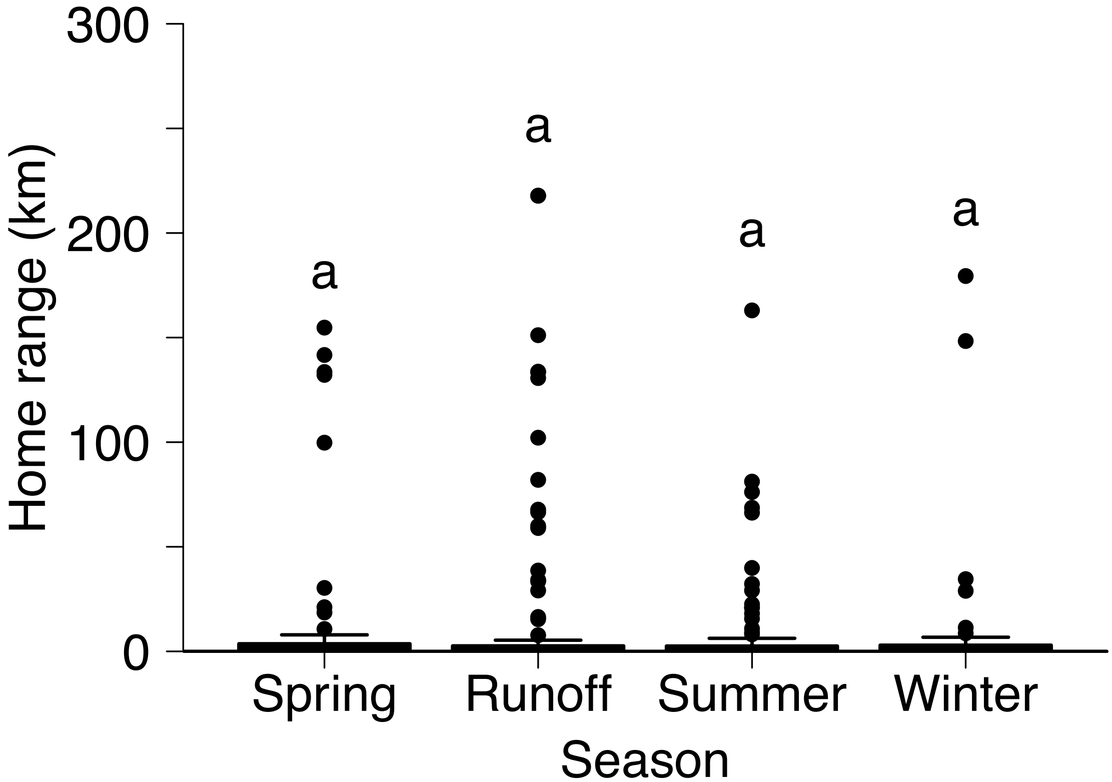

Figure 14. Seasonal linear home ranges of Channel Catfish monitored in the Yellowstone River from 2005–2009. Letters above bars indicate significant differences in median linear home range among seasons; seasons with the same letter are not significantly different.

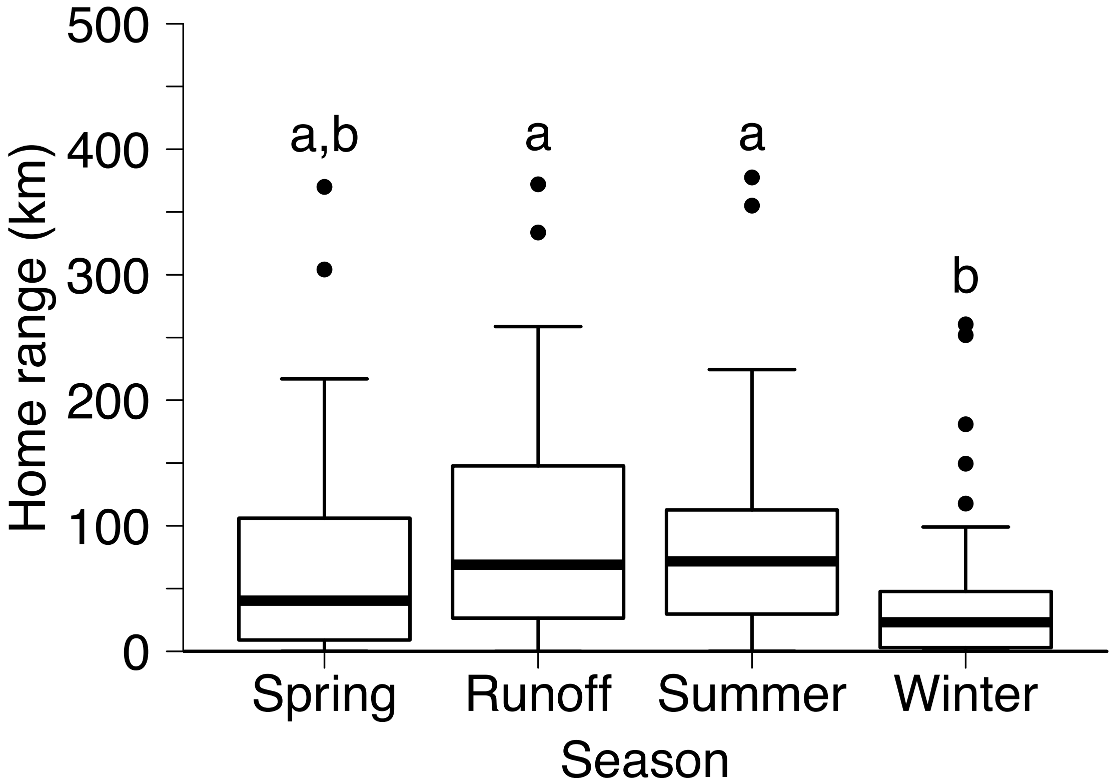

Figure 15. Seasonal linear home ranges of Shovelnose Sturgeon monitored in the Yellowstone River from 2005–2009. Letters above bars indicate significant differences in median linear home range among seasons; seasons with the same letter are not significantly different.

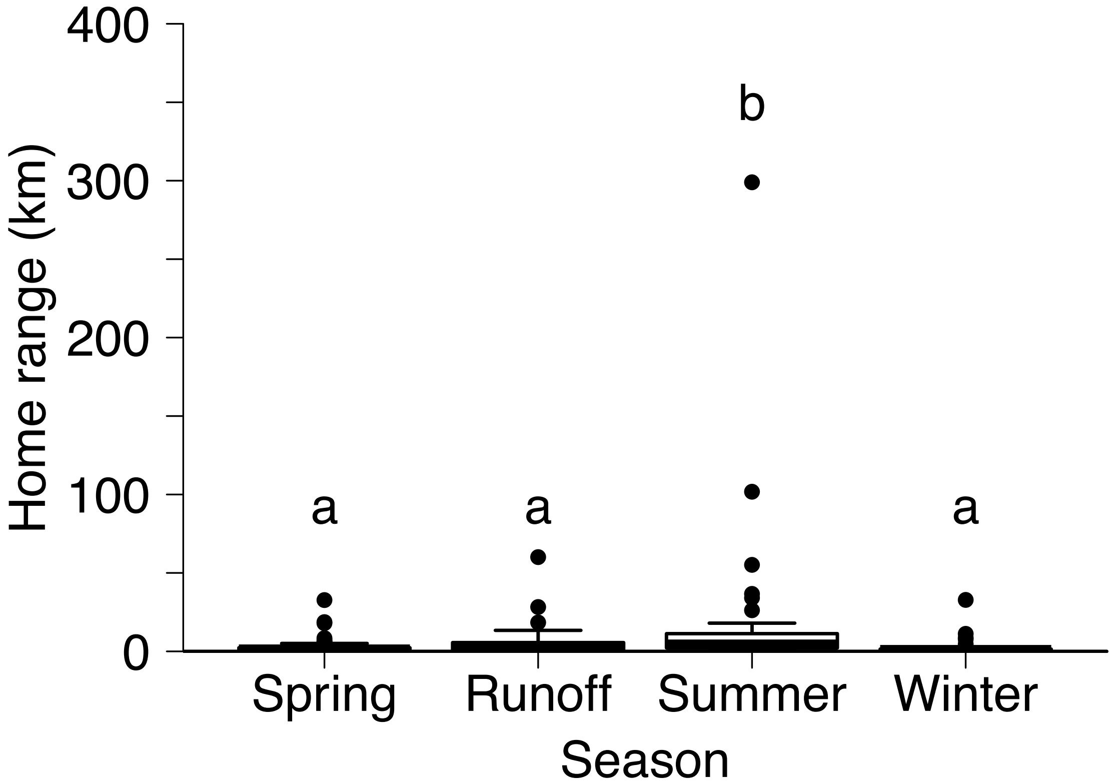

Figure 16. Seasonal linear home ranges of Spiny Softshells monitored in the Yellowstone River from 2005–2009. Letters above bars indicate significant differences in median linear home range among seasons; seasons with the same letter are not significantly different.

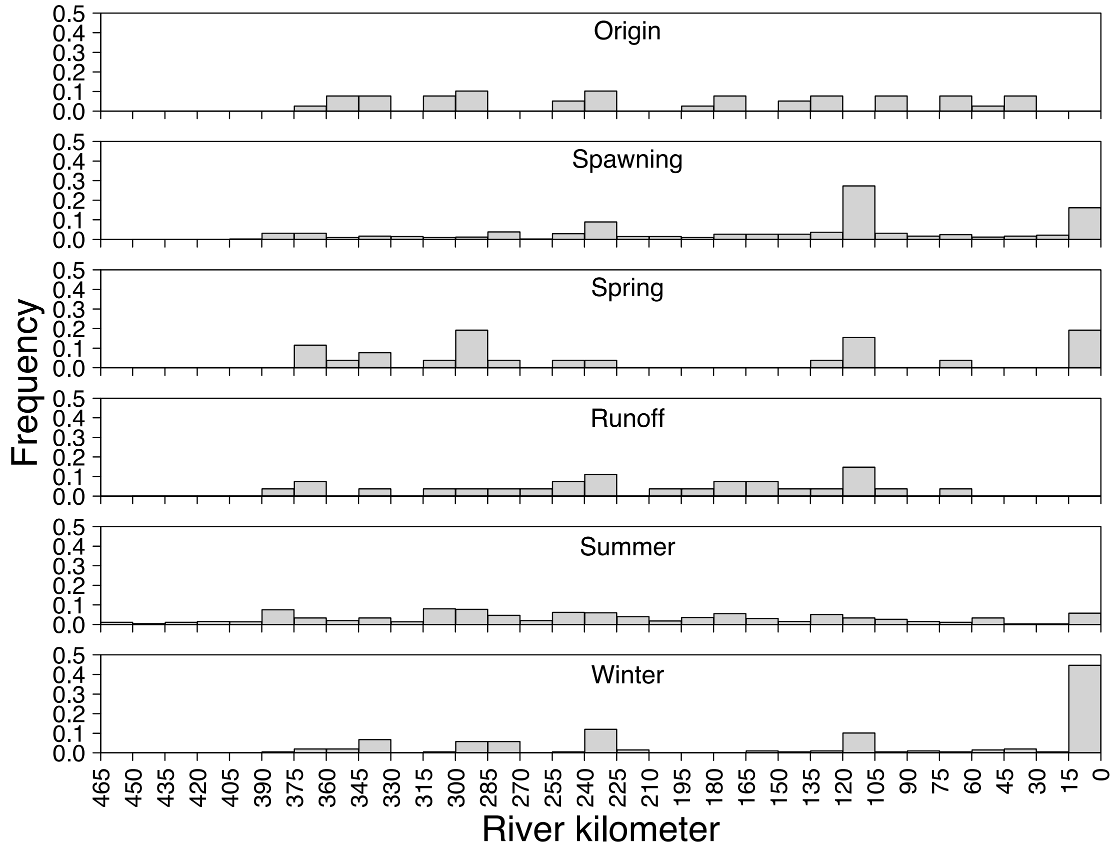

Figure 17. Longitudinal frequency distribution of telemetered Blue Suckers in the Yellowstone River from 2005–2009 binned by 15-river kilometer segments when captured (origin), potentially spawning, and by season.

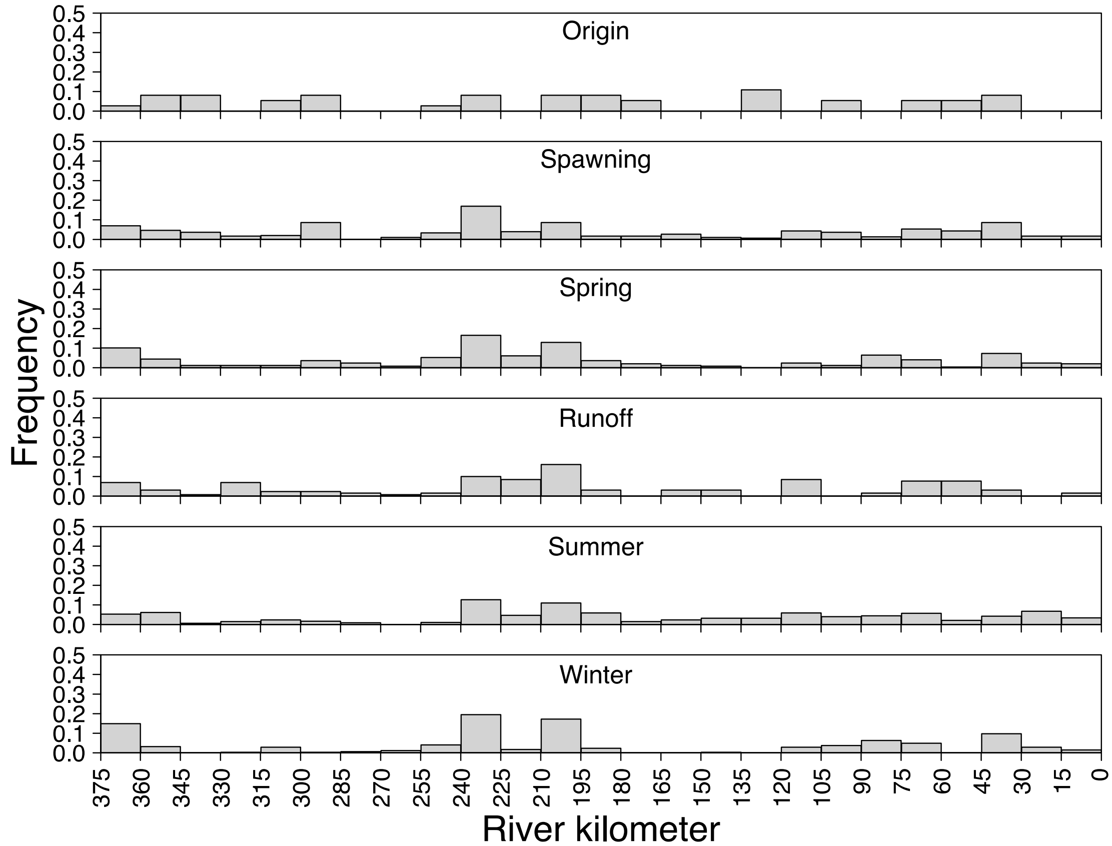

Figure 18. Longitudinal frequency distribution of telemetered Shovelnose sturgeon in the Yellowstone River from 2005–2009 binned by 15-river kilometer segments when captured (origin), potentially spawning, and by season.

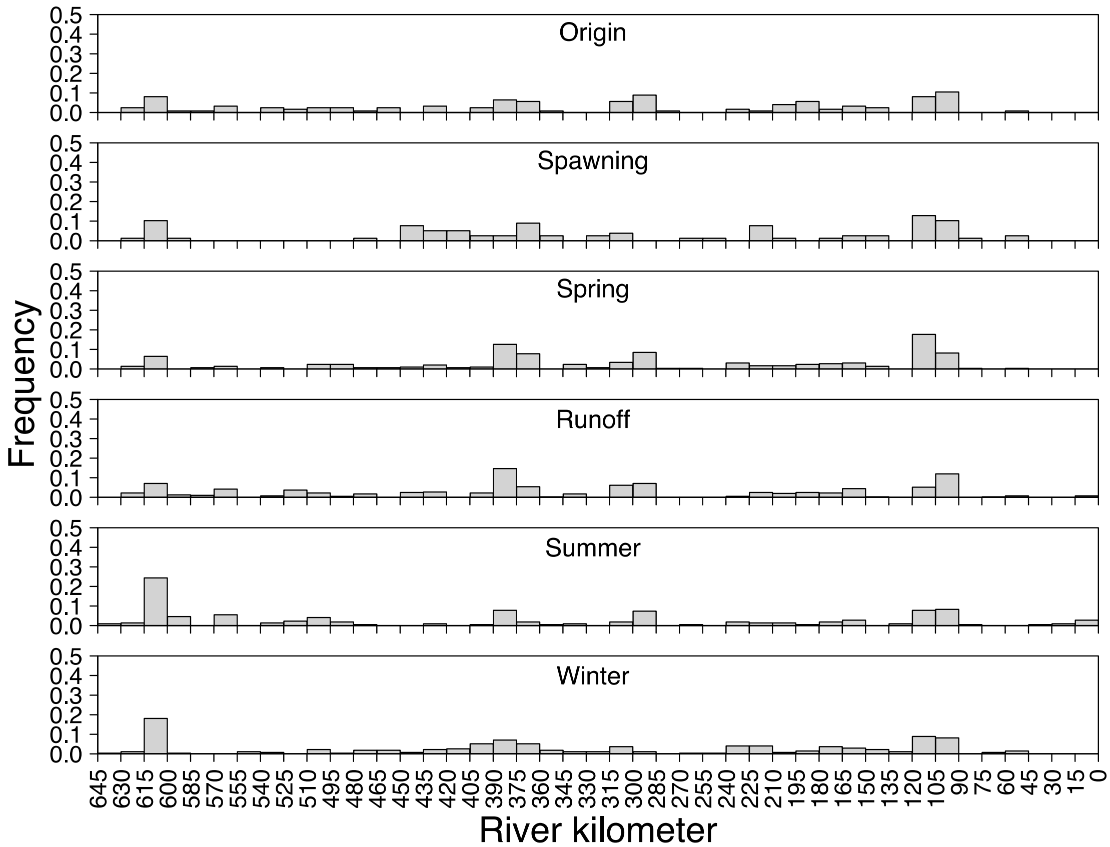

Figure 19. Longitudinal frequency distribution of telemetered Burbot in the Yellowstone River from 2005–2009 binned by 15-river kilometer segments when captured (origin), potentially spawning, and by season.

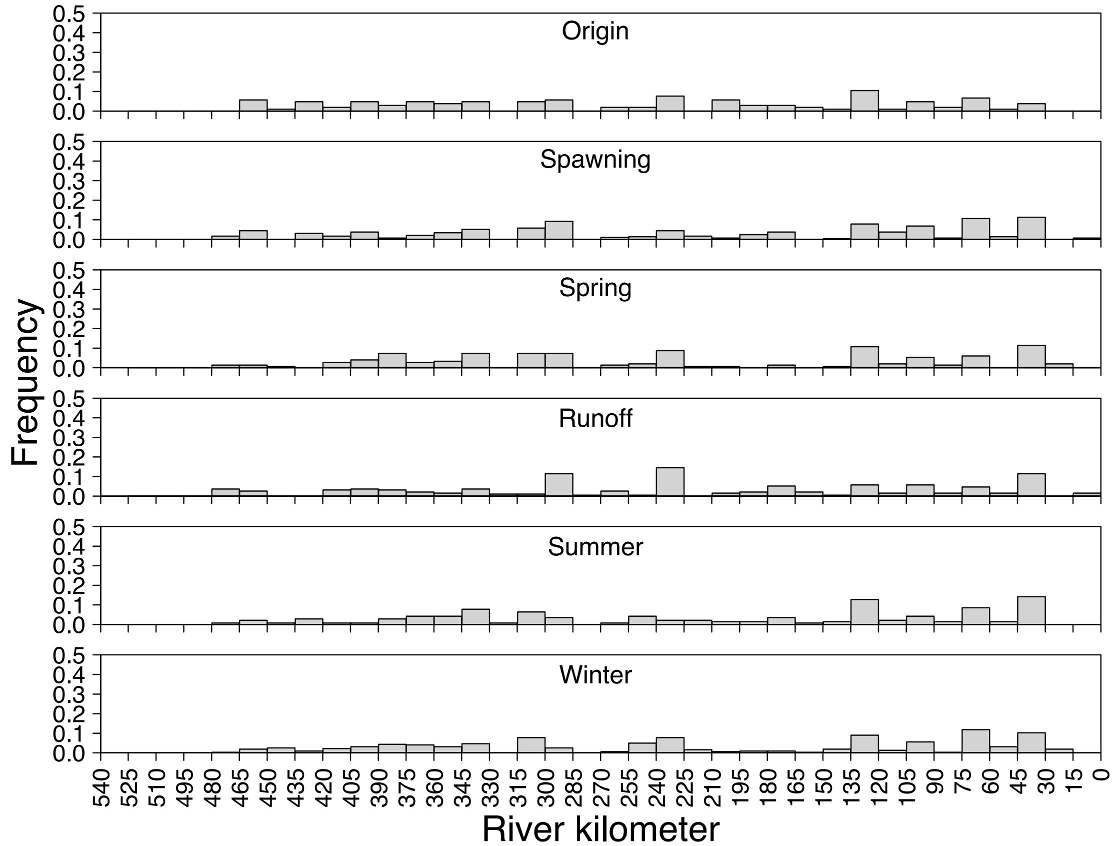

Figure 20. Longitudinal frequency distribution of telemetered Channel Catfish in the Yellowstone River from 2005–2009 binned by 15-river kilometer segments when captured (origin), potentially spawning, and by season.

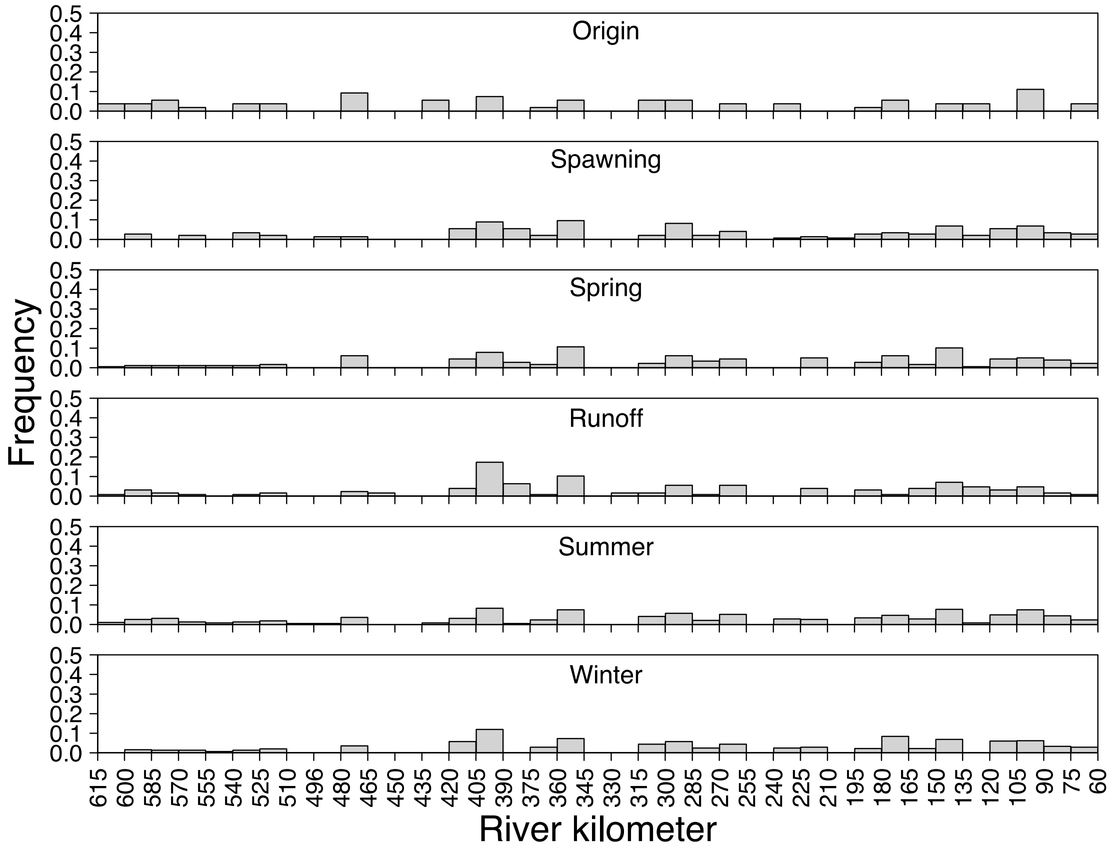

Figure 21. Longitudinal frequency distribution of telemetered Spiny Softshells in the Yellowstone River from 2005–2009 binned by 15-river kilometer segments when captured (origin), potentially spawning and by season.

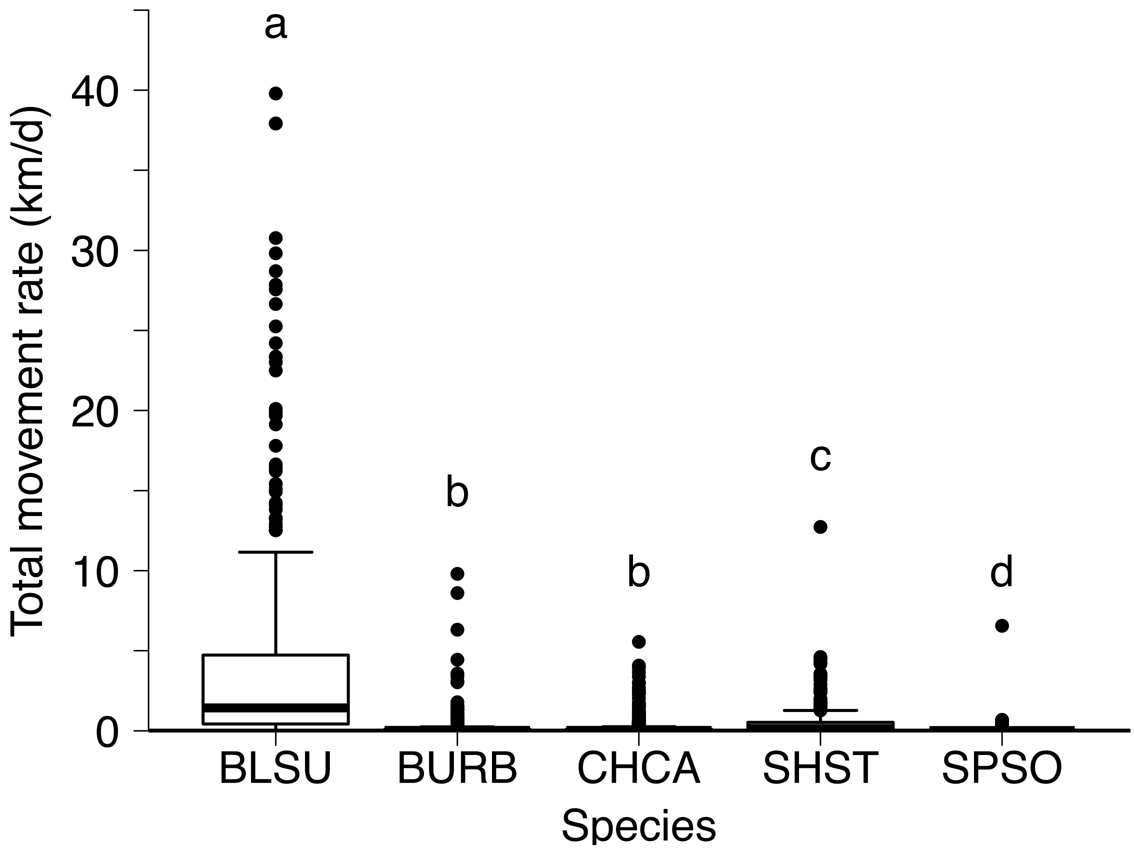

Figure 22. Overall total movement rates for telemetered species monitored in the Yellowstone River from 2005–2009. Bold lines within boxes represent medians, bottom and top of boxes are first and third quantiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among species using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; species with the same letter are not significantly different.

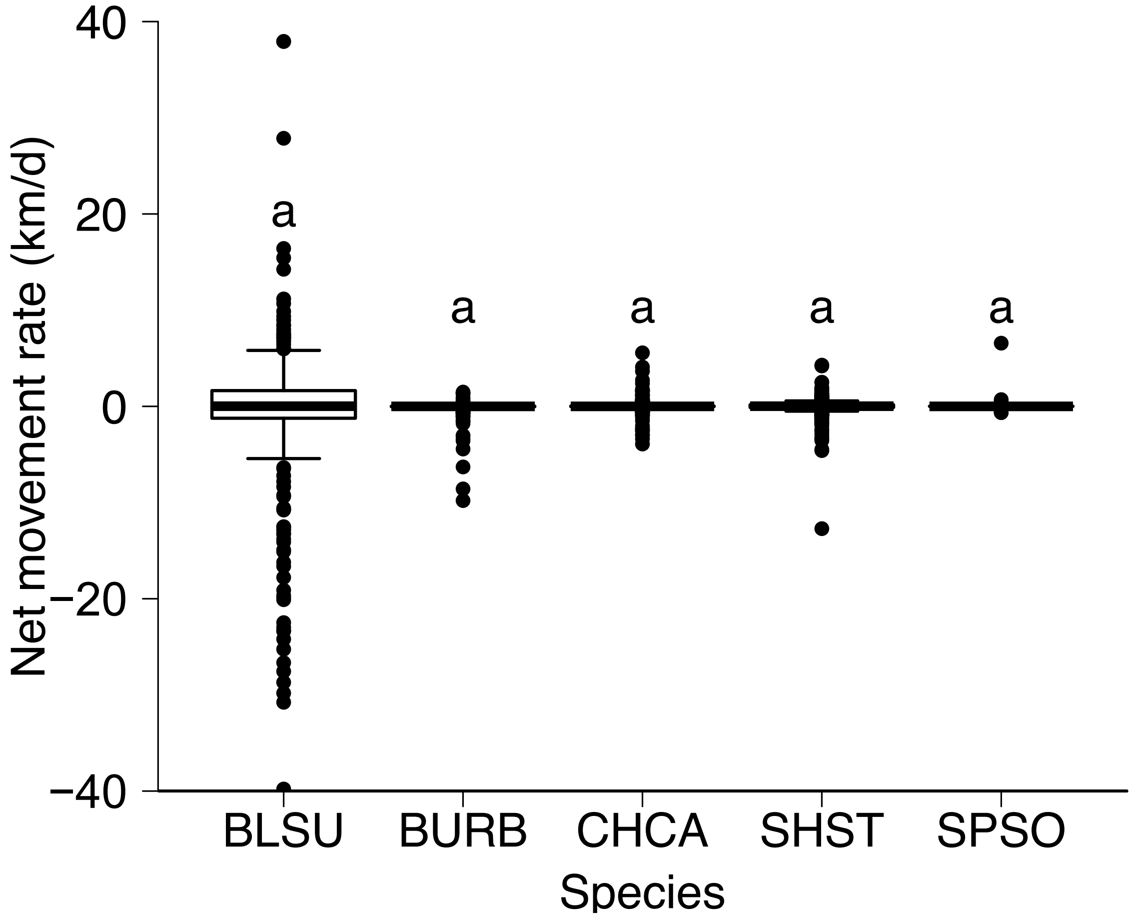

Figure 23. Overall net movement rates for telemetered species monitored in the Yellowstone River from 2005–2009. Bold lines within boxes represent medians, bottom and top of boxes are first and third quantiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among species using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; species with the same letter are not significantly different. Negative values indicate downstream movements and positive values indicate upstream movements.

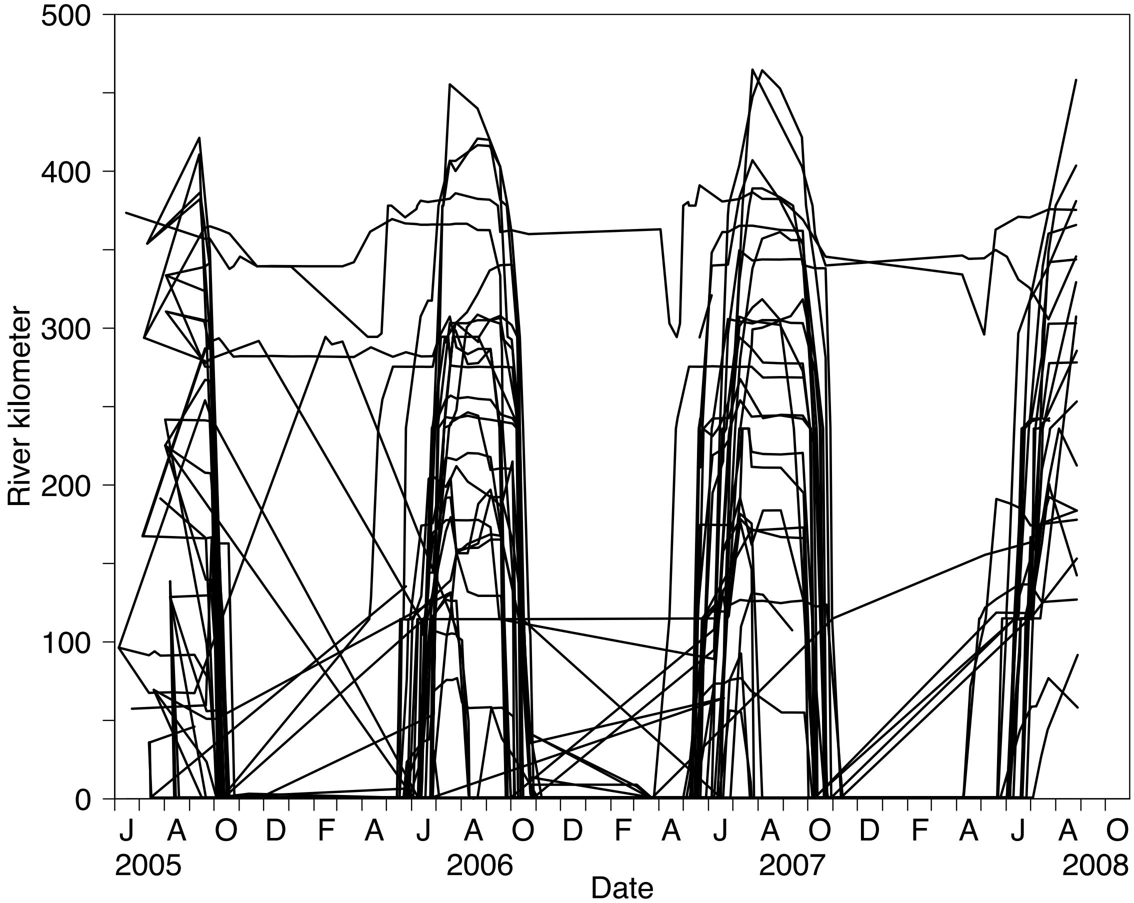

Figure 24. Movements of all telemetered Blue Suckers in the Yellowstone River from 2005–2009.

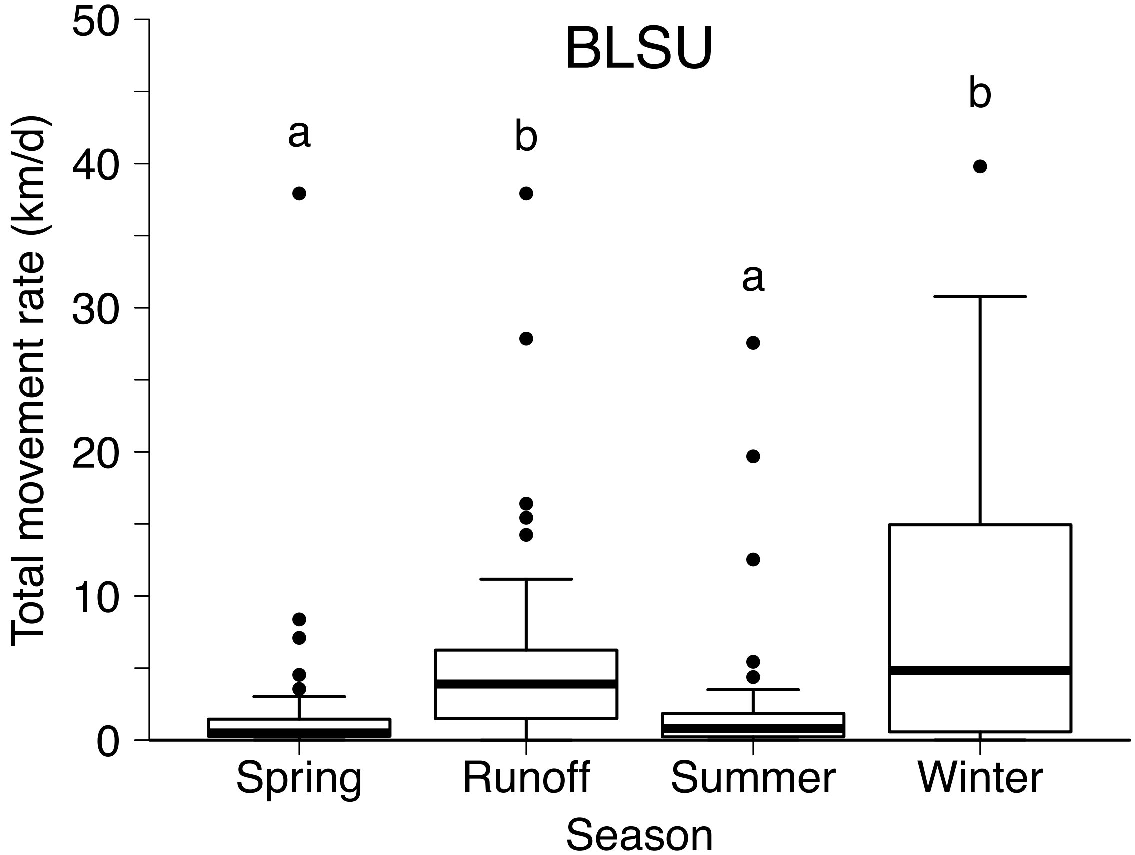

Figure 25. Total movement rate of telemetered Blue Suckers (*N* = 36) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different.

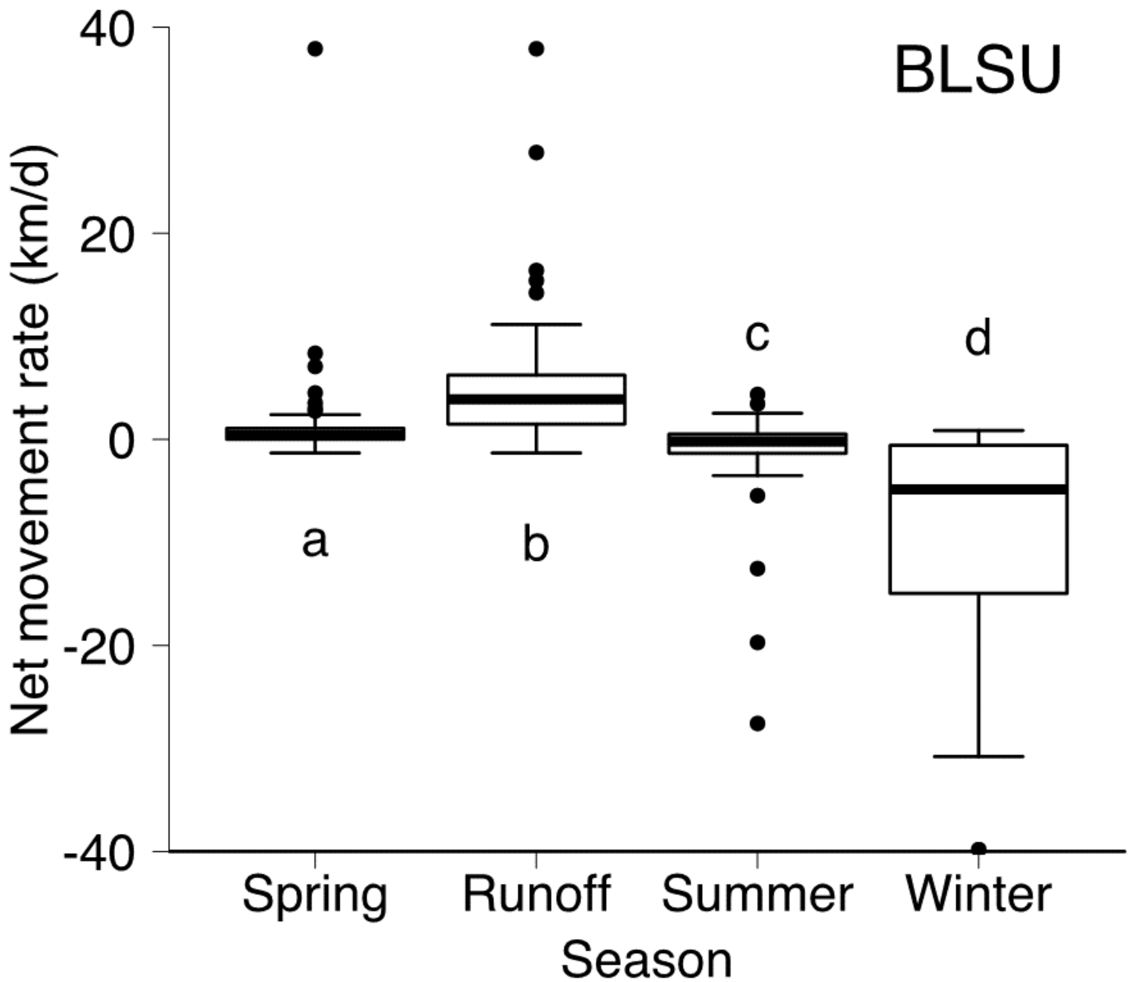

Figure 26. Net movement rate of telemetered Blue Suckers (*N* = 36) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different. Negative values indicate downstream movements and positive values indicate upstream movements.

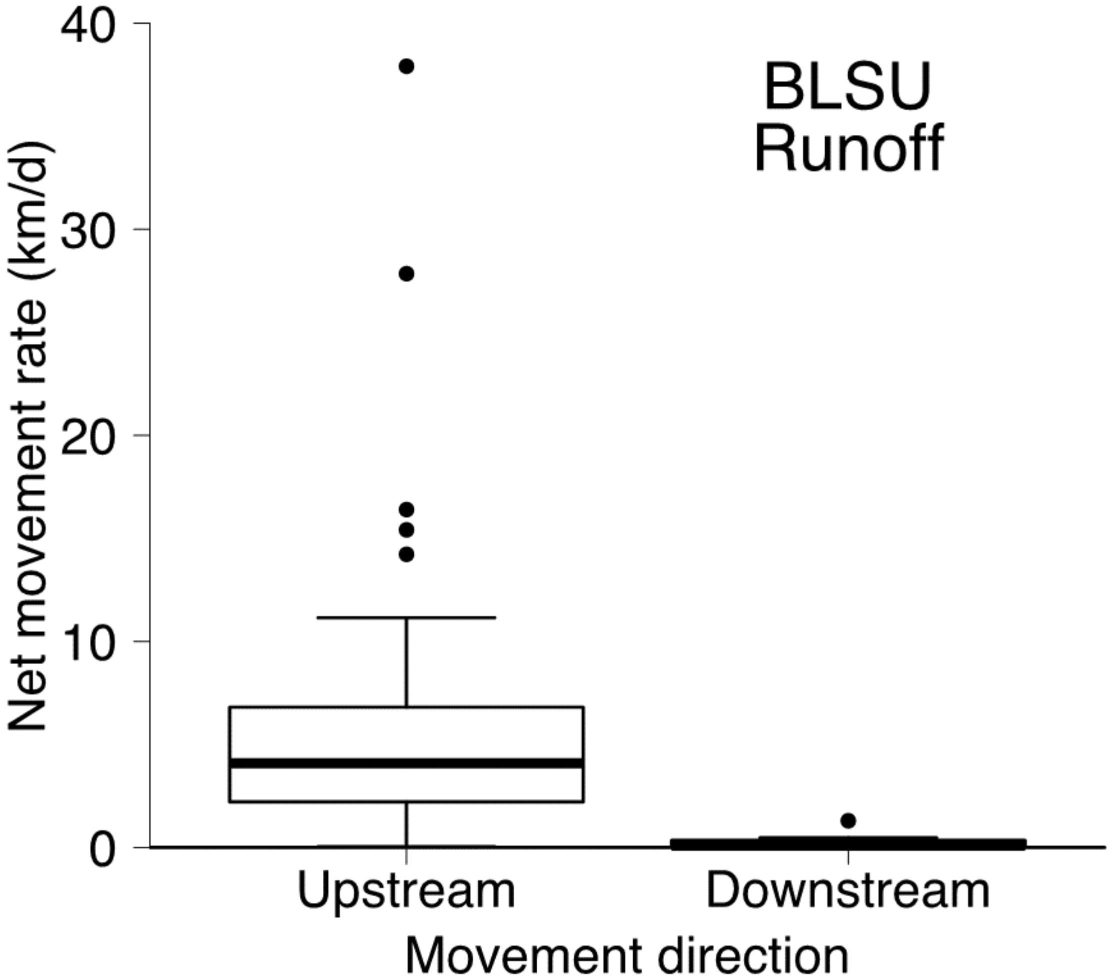

Figure 27. Absolute values of net upstream and downstream movement rates of Blue Suckers (*N* = 36) in the Yellowstone River from 2005–2009 during runoff. The absolute values of net downstream movement rates are displayed for clarity. Net upstream and downstream movement rates were significantly different from each other using a Mann-Whitney-U test.

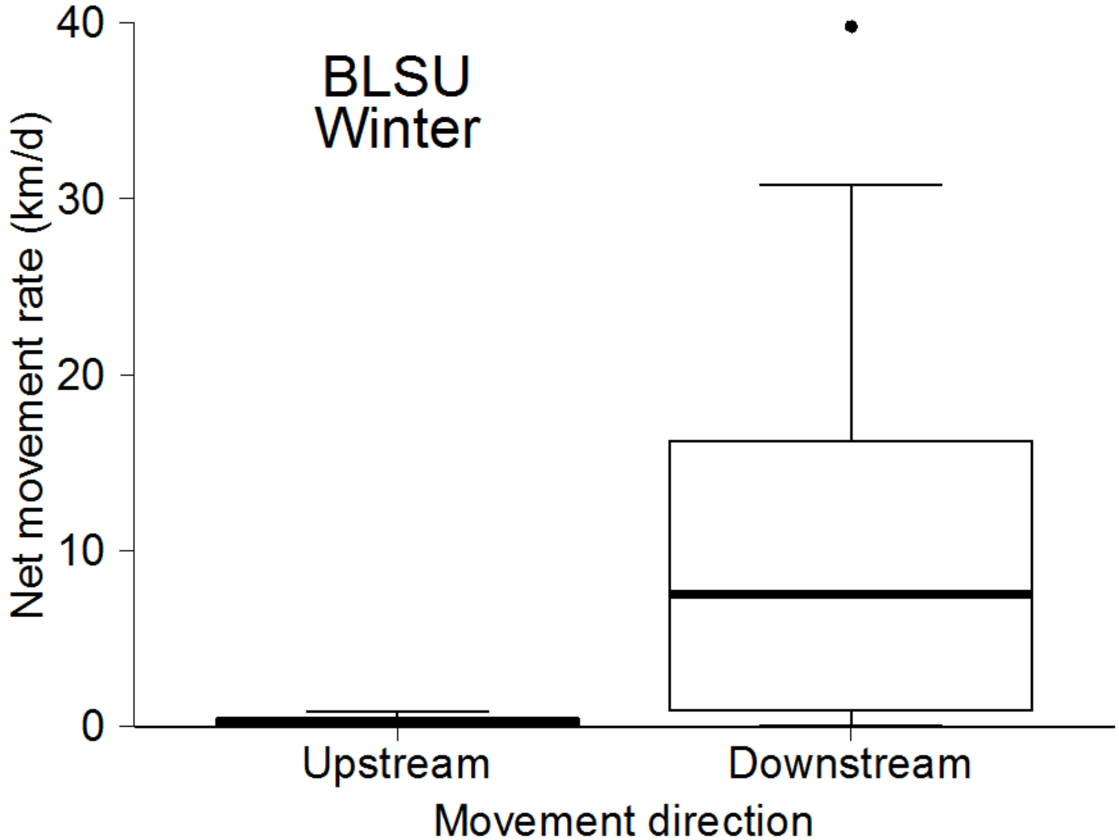

Figure 28. Absolute values of net upstream and downstream movement rates of Blue Suckers (*N* = 36) in the Yellowstone River from 2005–2009 during winter. The absolute values of net downstream movement rates are displayed for clarity. Net upstream and downstream movement rates were significantly different from each other using a Mann-Whitney-U test.

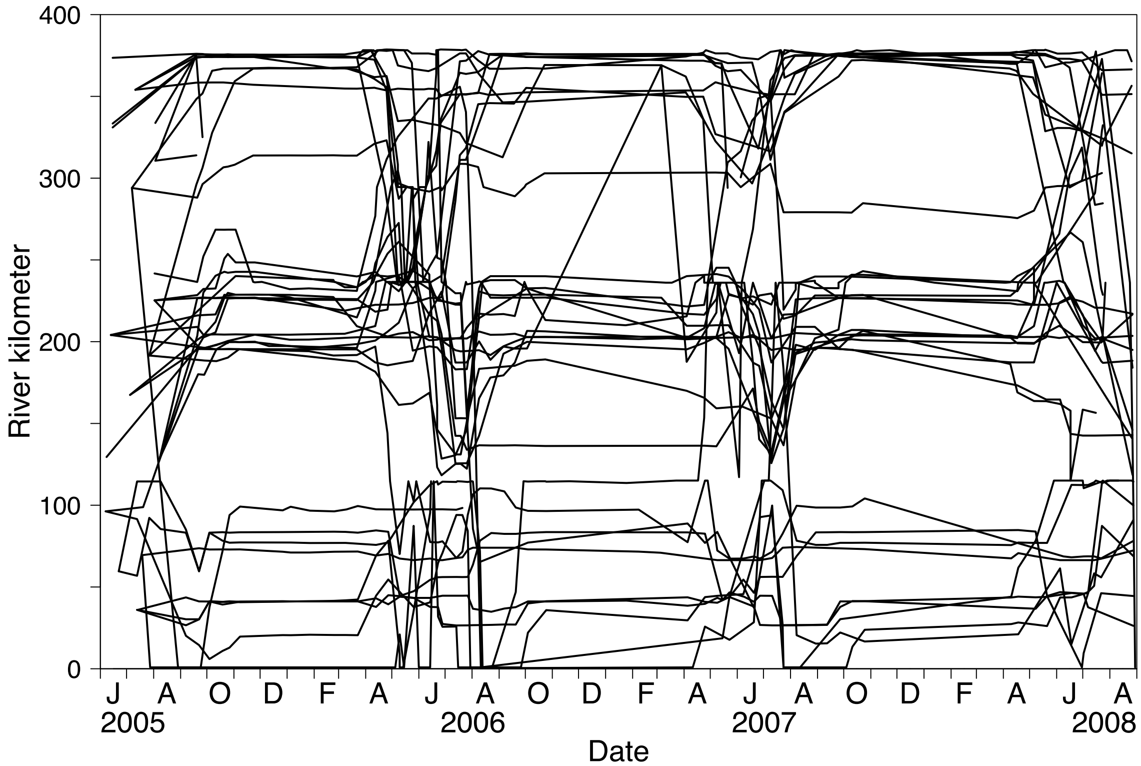

Figure 29. Movements of all telemetered Shovelnose Sturgeon in the Yellowstone River from 2005–2009.

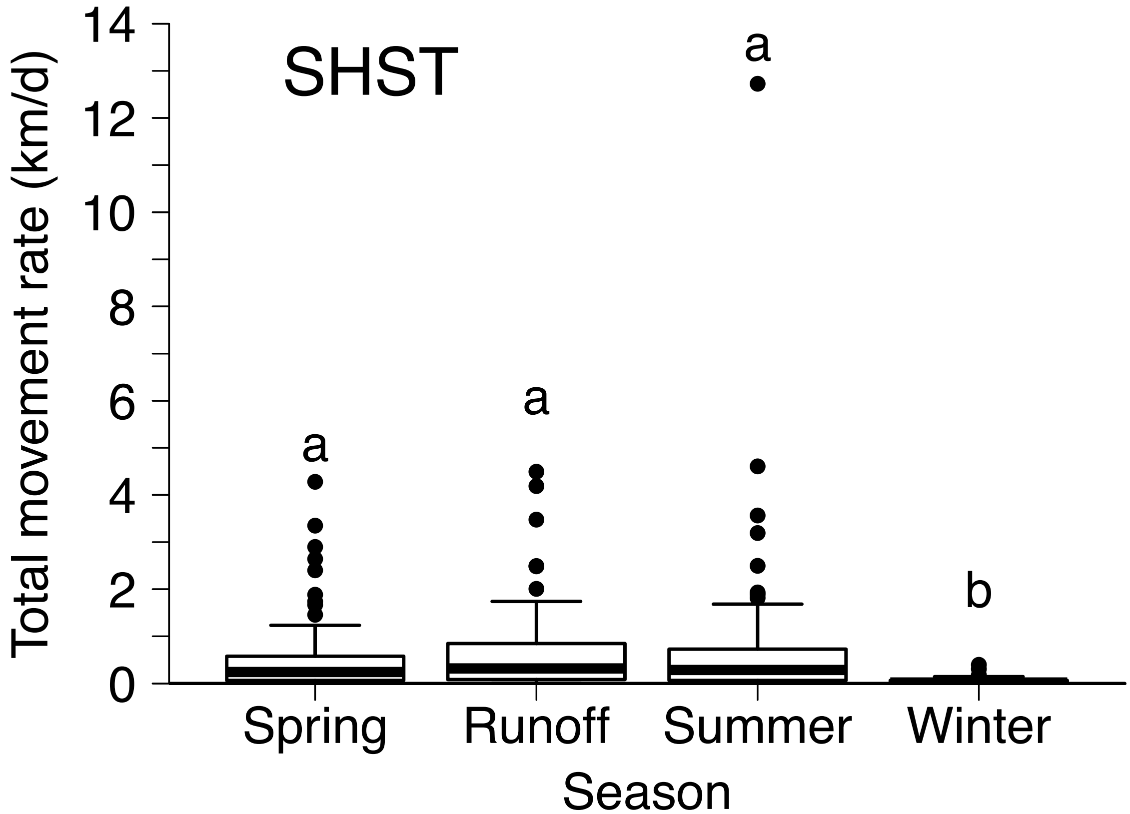

Figure 30. Total movement rate of telemetered Shovelnose Sturgeon (N = 33) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different.

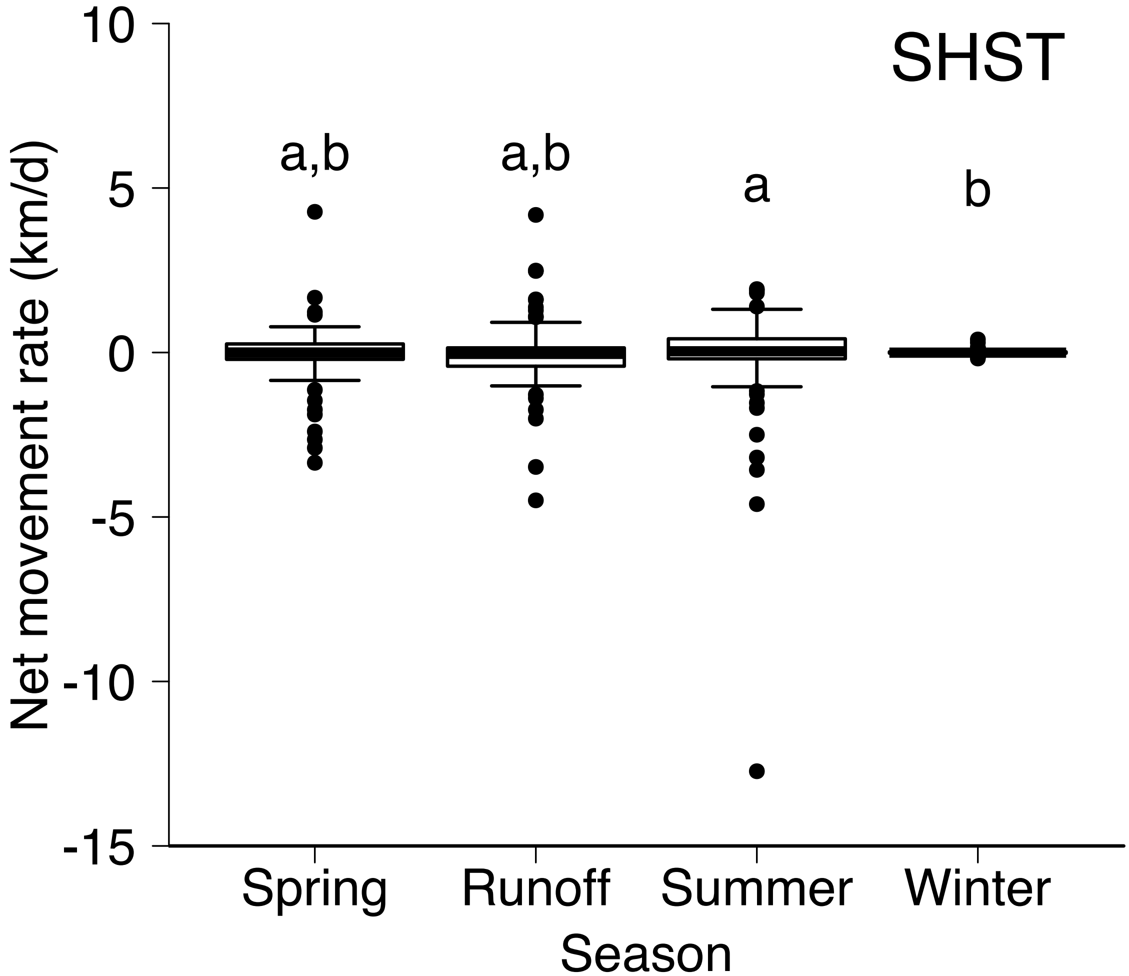

Figure 31. Net movement rate of telemetered Shovelnose Sturgeon (N = 33) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different. Negative values indicate downstream movements and positive values indicate upstream movements.

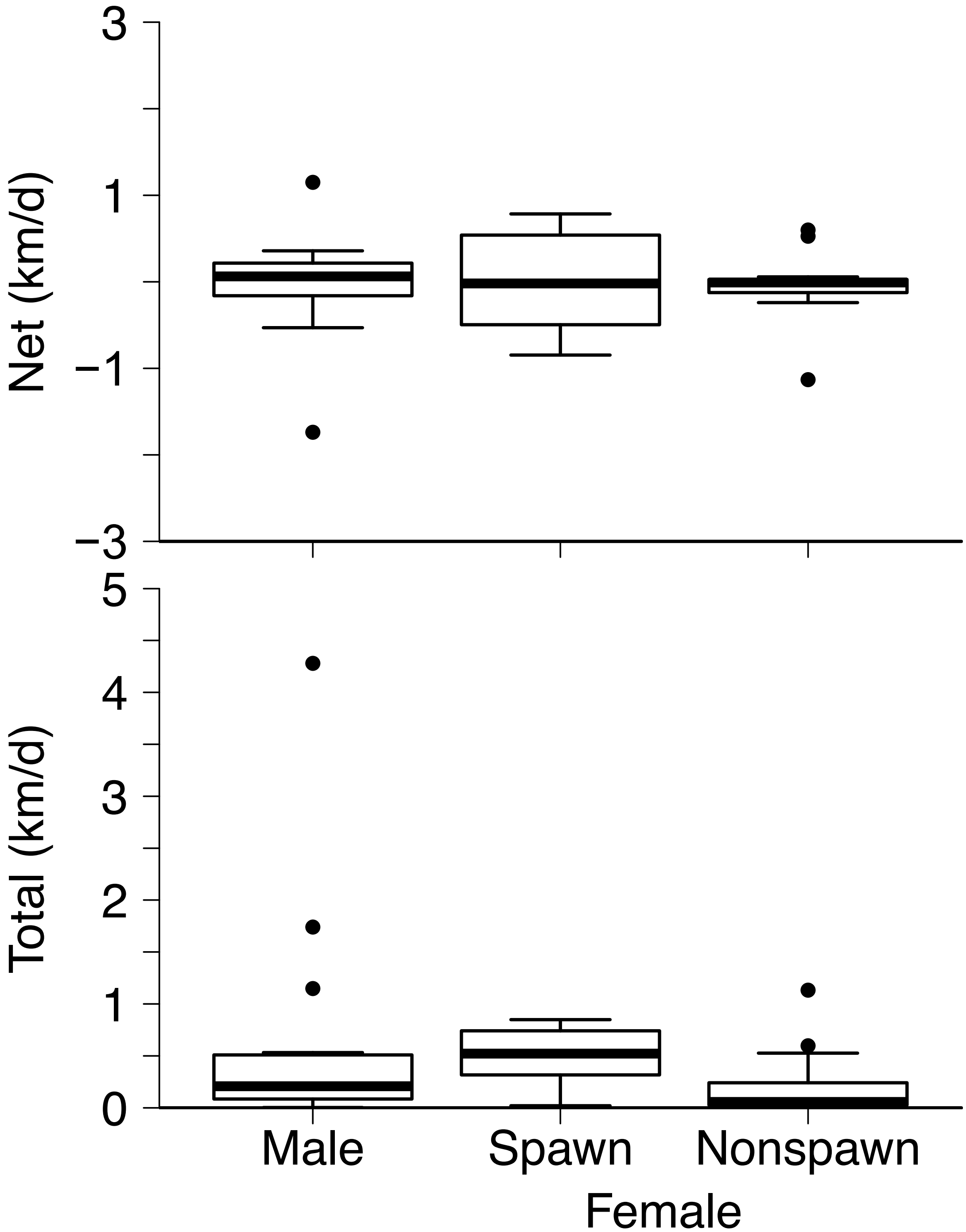

Figure 32. Net and total movement rates (km/d) of telemetered spawning male ('Male'), spawning female ('Spawn'), and nonspawning female ('Nonspawn') Shovelnose Sturgeon in spring monitored in the Yellowstone River from 2006–2007. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range.

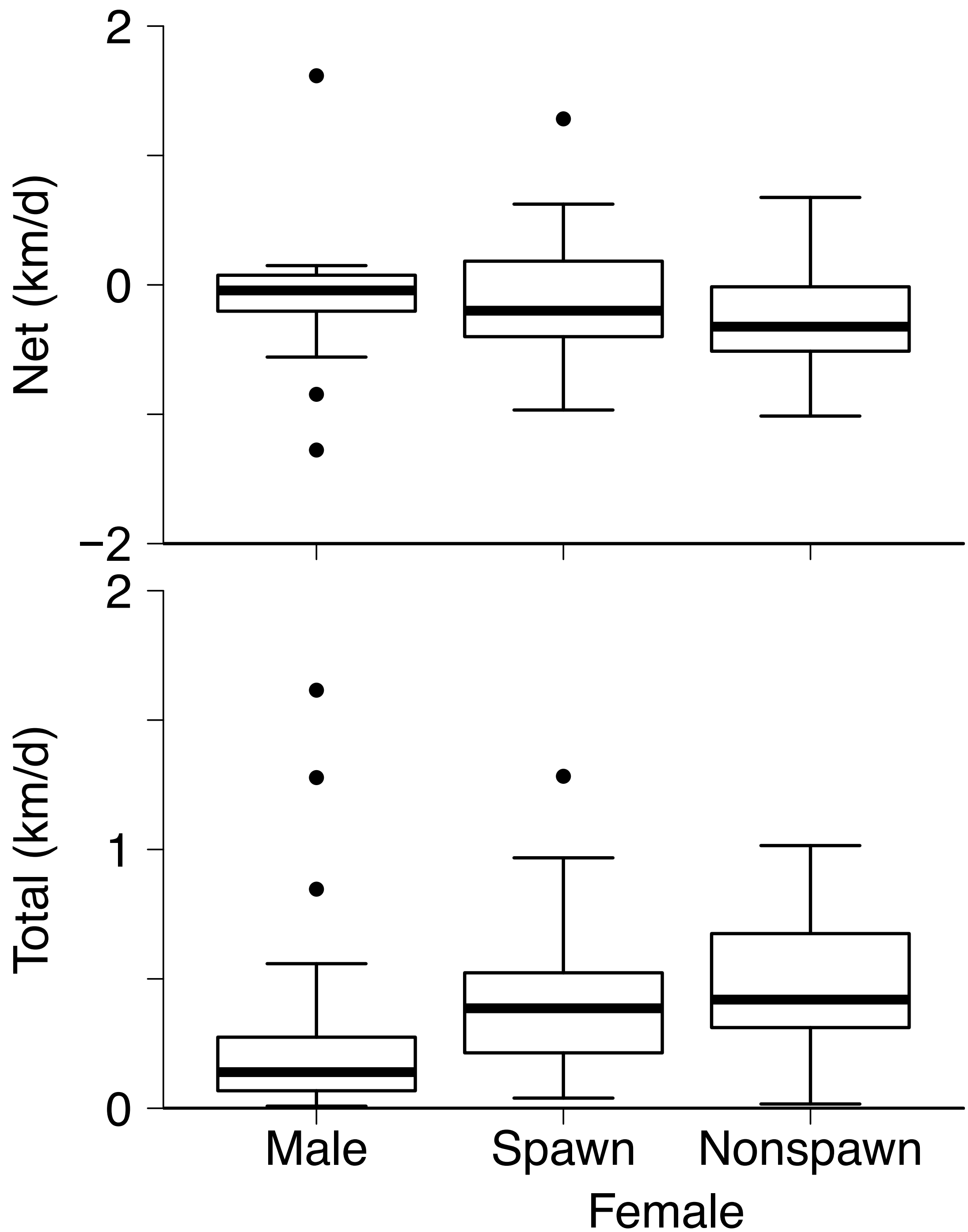

Figure 33. Net and total movement rates (km/d) of telemetered spawning male (‘Male’), spawning female (‘Spawn’), and nonspawning (‘Nonspawn’) female Shovelnose Sturgeon in runoff monitored in the Yellowstone River from 2006–2007. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range.

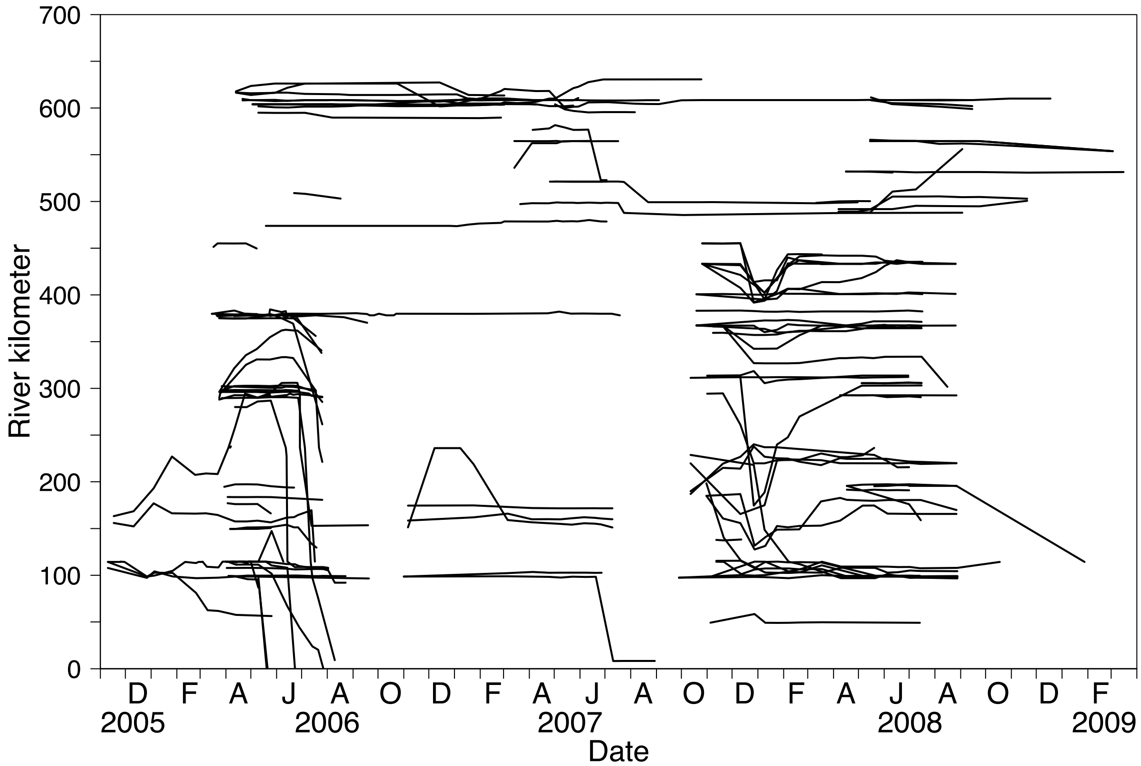

Figure 34. Movements of all telemetered Burbot in the Yellowstone River from 2005–2009.

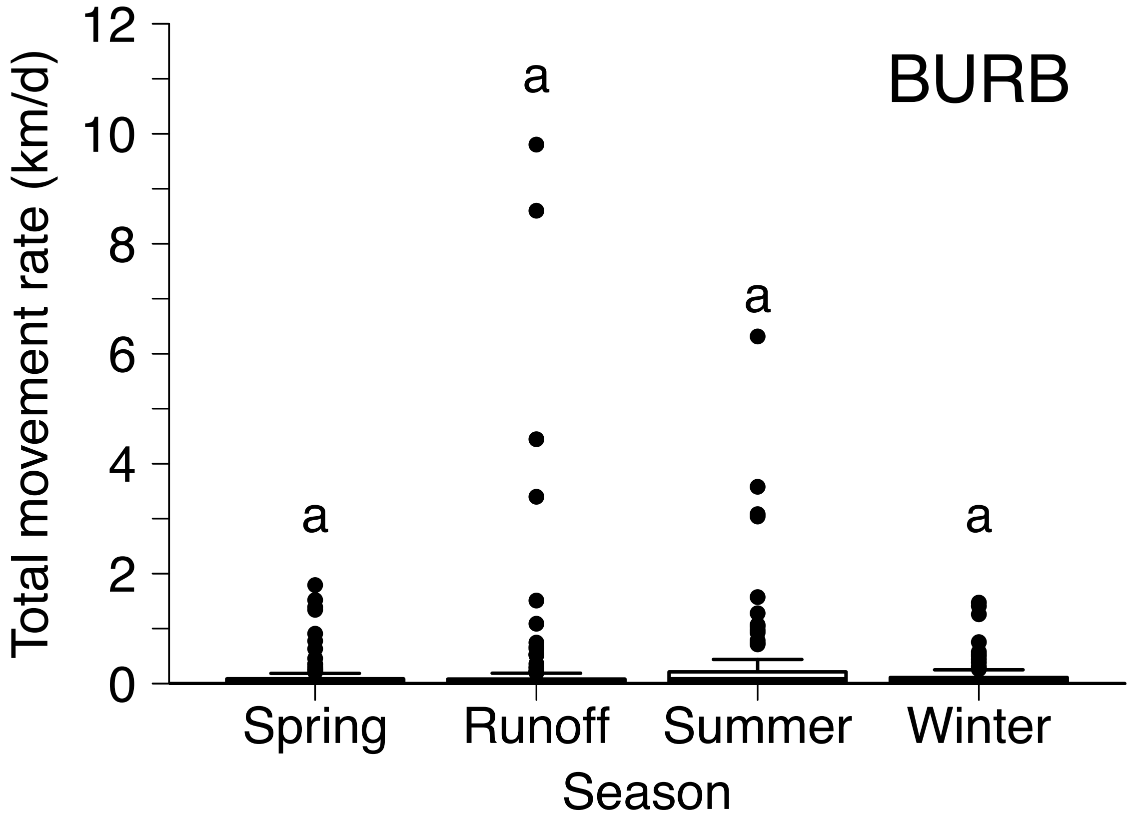

Figure 35. Total movement rate of telemetered Burbot (*N* = 81) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different.

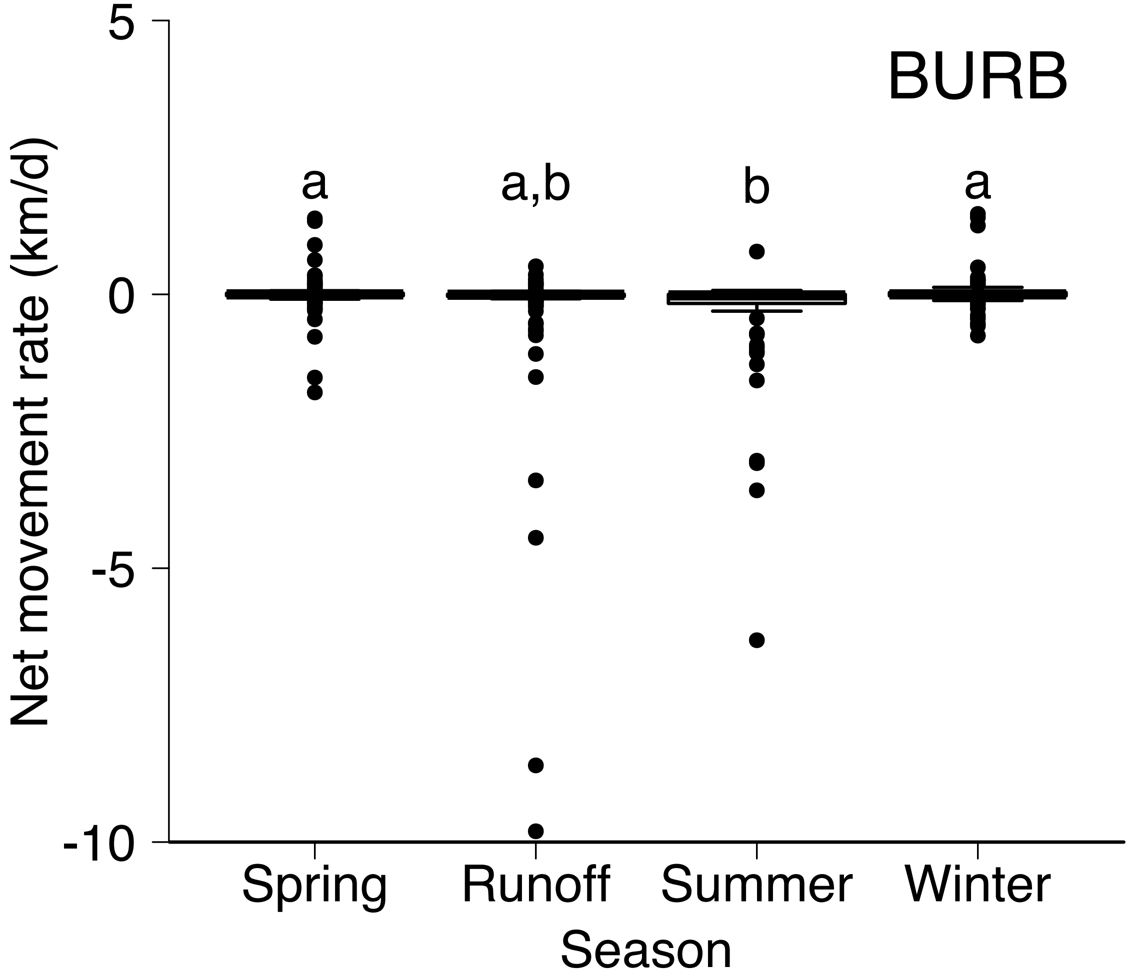

Figure 36. Net movement rate of telemetered Burbot (*N* = 81) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different. Negative values indicate downstream movements and positive values indicate upstream movements.

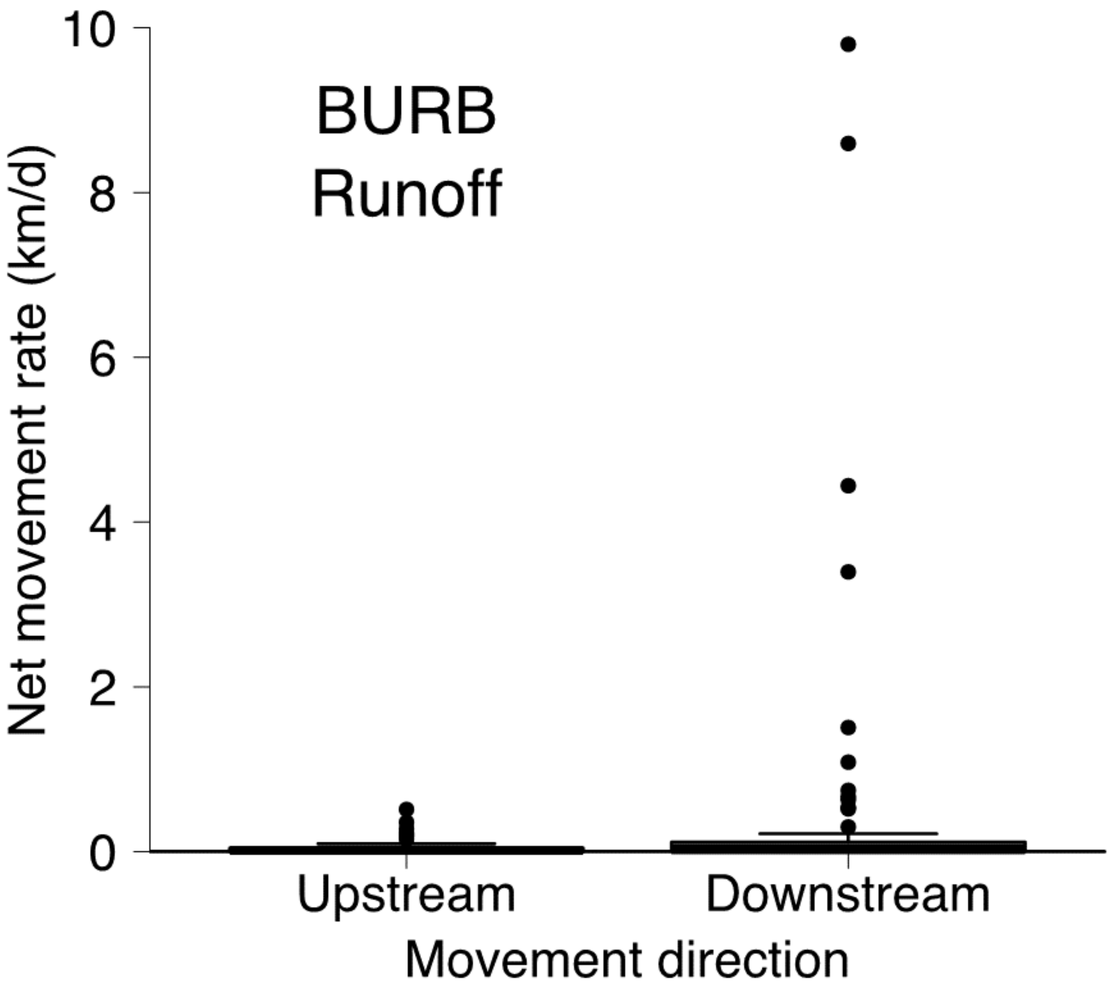

Figure 37. Absolute values of net upstream and downstream movement rates of Burbot (*N* = 81) in the Yellowstone River from 2005–2009 during runoff. Net upstream and downstream movement rates were significantly different from each other using a Mann-Whitney-U test.

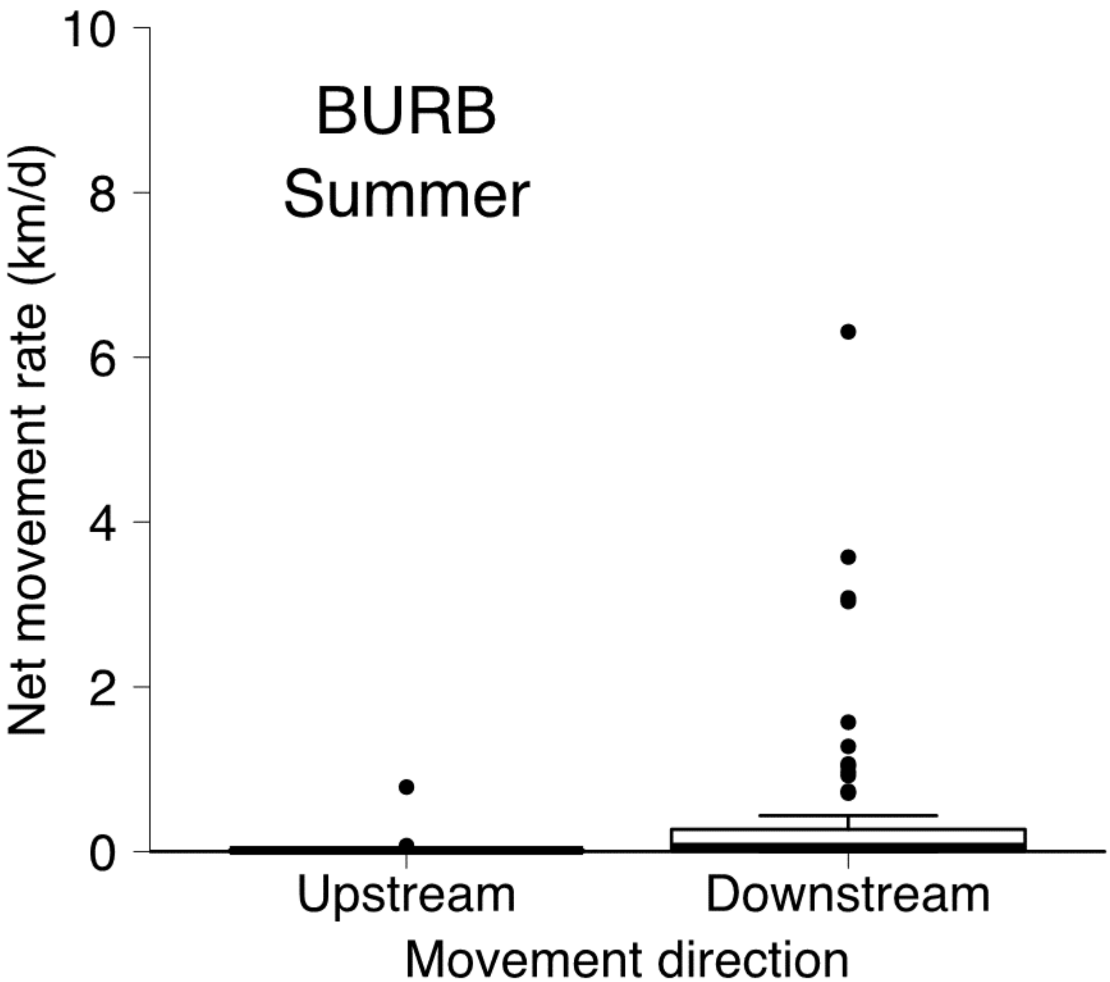

Figure 38. Absolute values of net upstream and downstream movement rates of Burbot ($N = 81$) in the Yellowstone River from 2005–2009 during summer. Net upstream and downstream movement rates were significantly different from each other using a Mann-Whitney-U test.

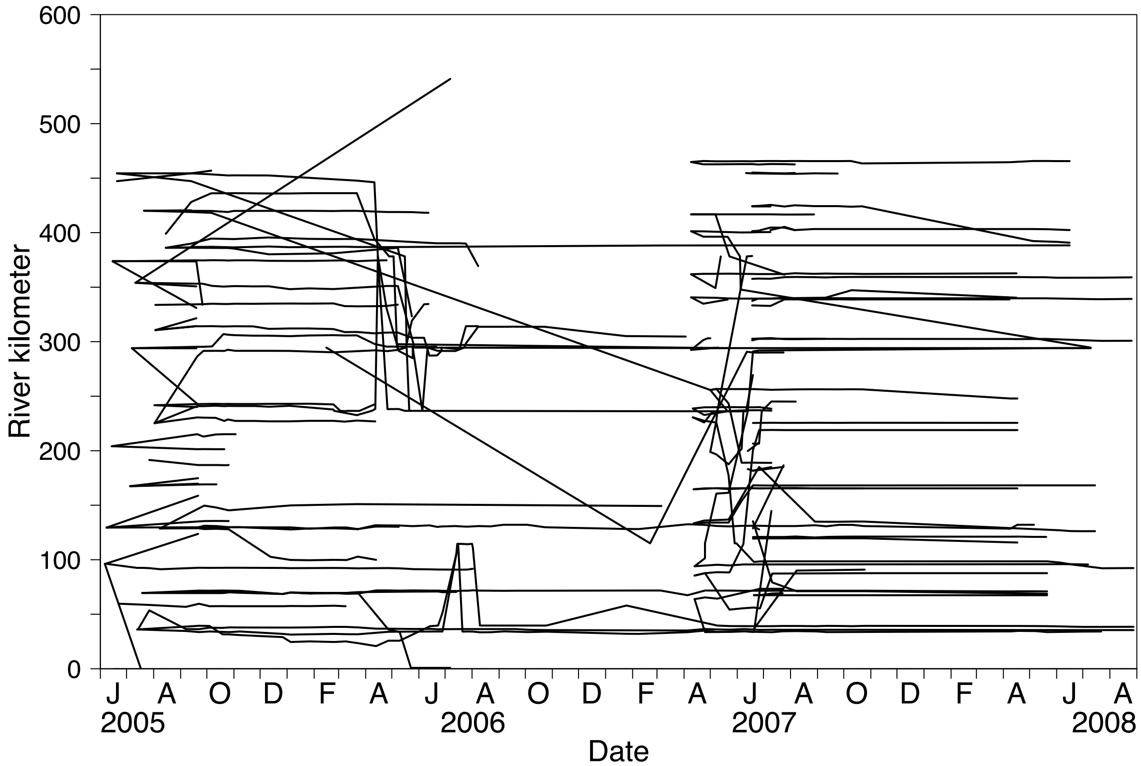

Figure 39. Movements of all telemetered Channel Catfish in the Yellowstone River from 2005–2009.

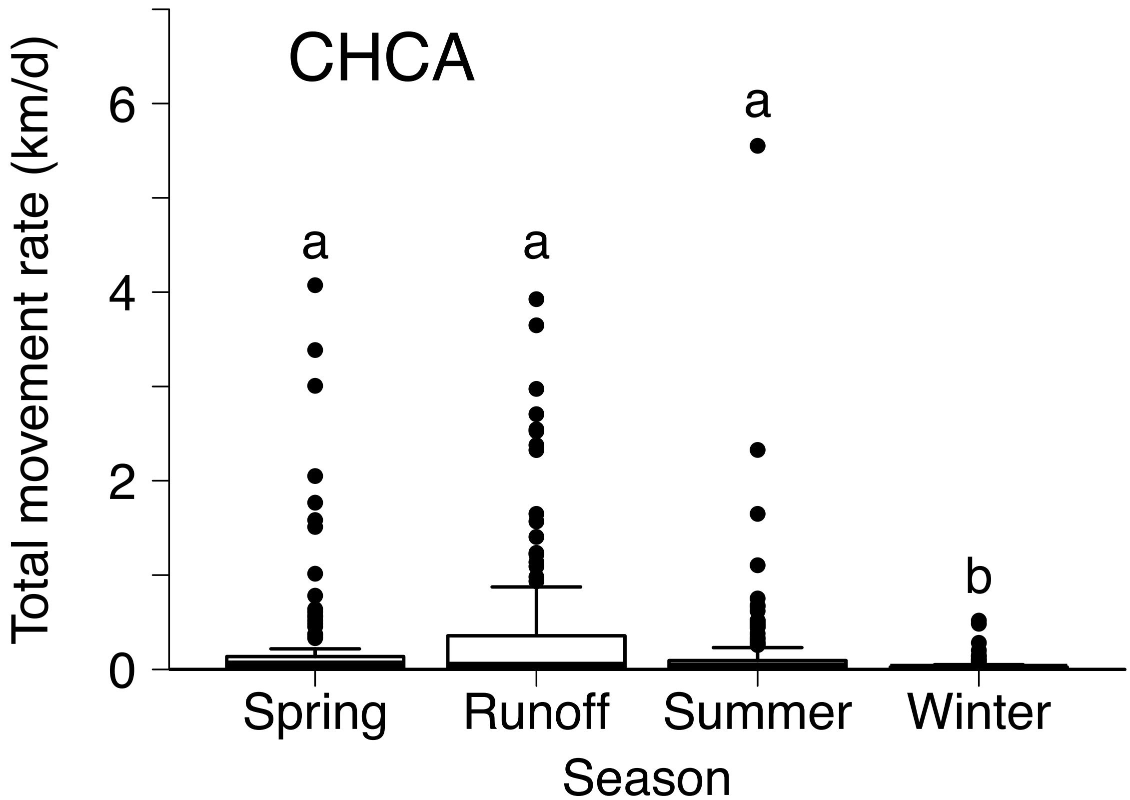

Figure 40. Total movement rate of telemetered Channel Catfish (*N* = 82) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different.

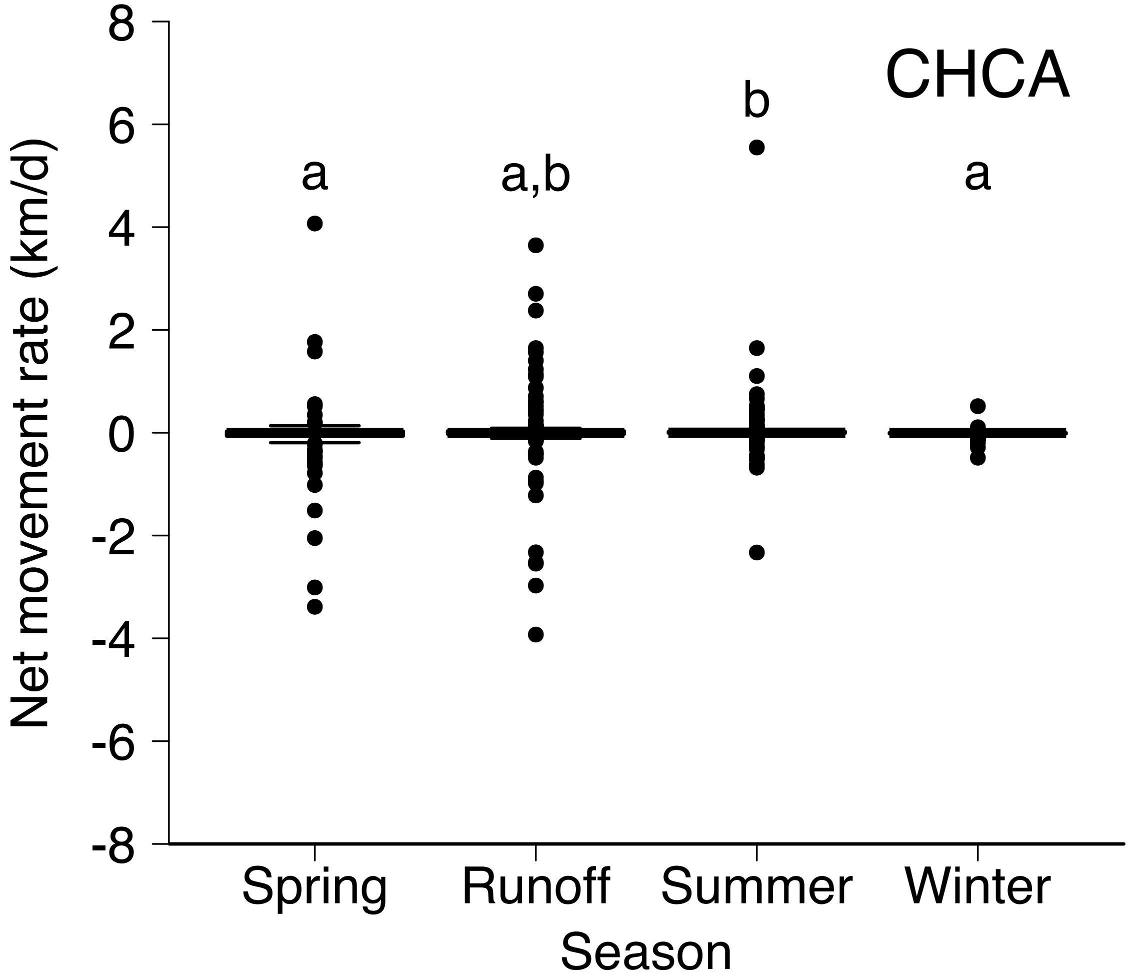

Figure 41. Net movement rate of telemetered Channel Catfish (*N* = 82) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different. Negative values indicate downstream movements and positive values indicate upstream movements.

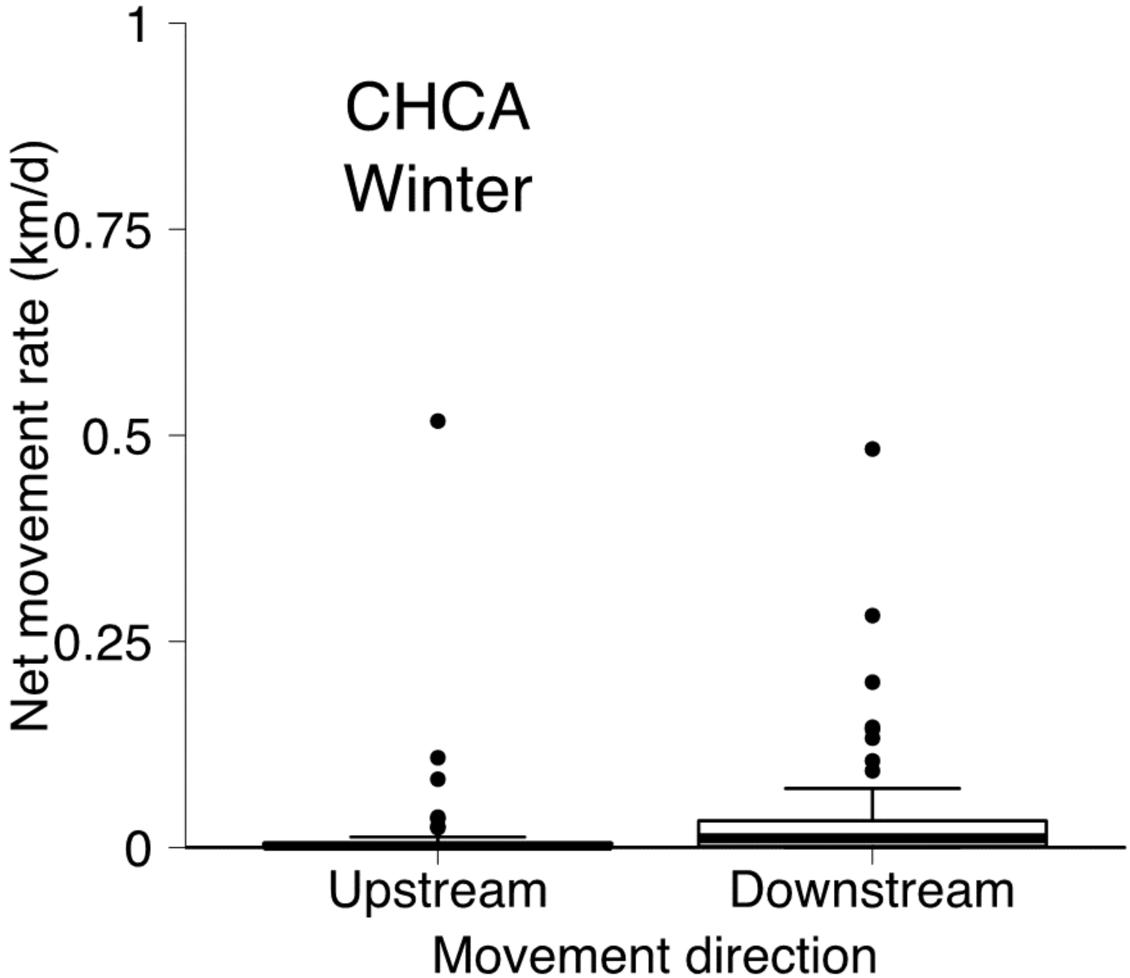

Figure 42. Absolute values of net upstream and downstream movement rates of Channel Catfish (*N* = 82) in the in the Yellowstone River from 2005–2009 during winter. Net upstream and downstream movement rates were significantly different from each other using a Mann-Whitney-U test.

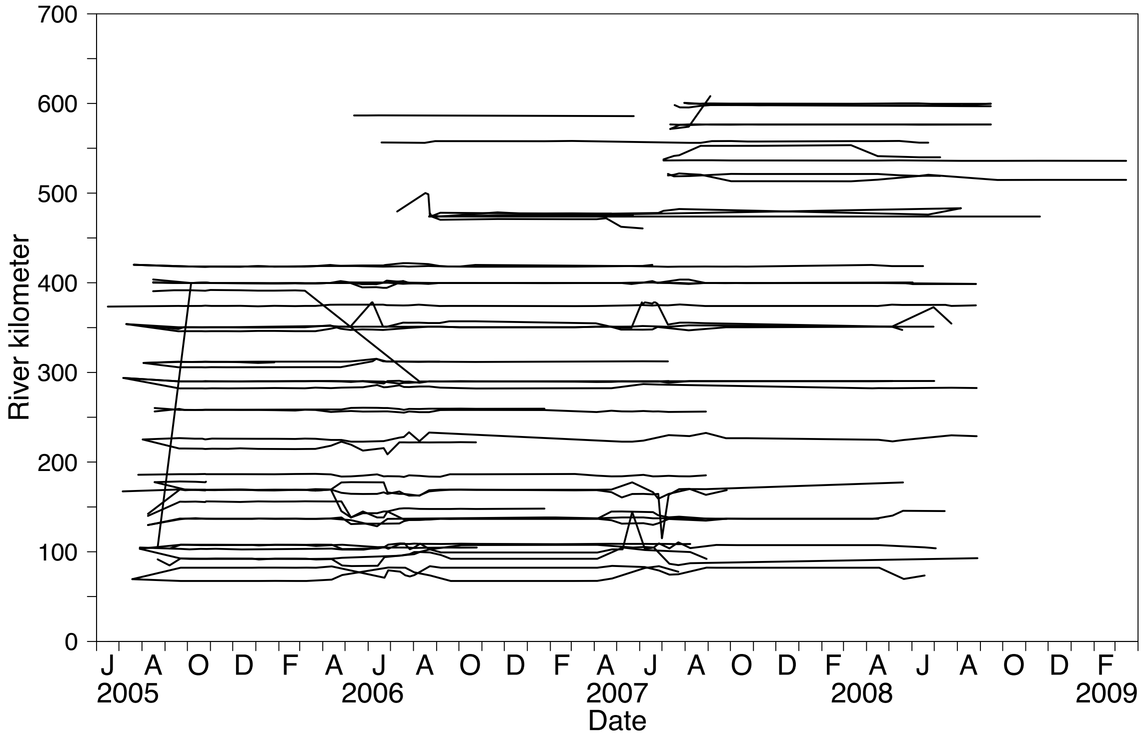

Figure 43. Movements of all telemetered Spiny Softshells in the Yellowstone River from 2005–2009.

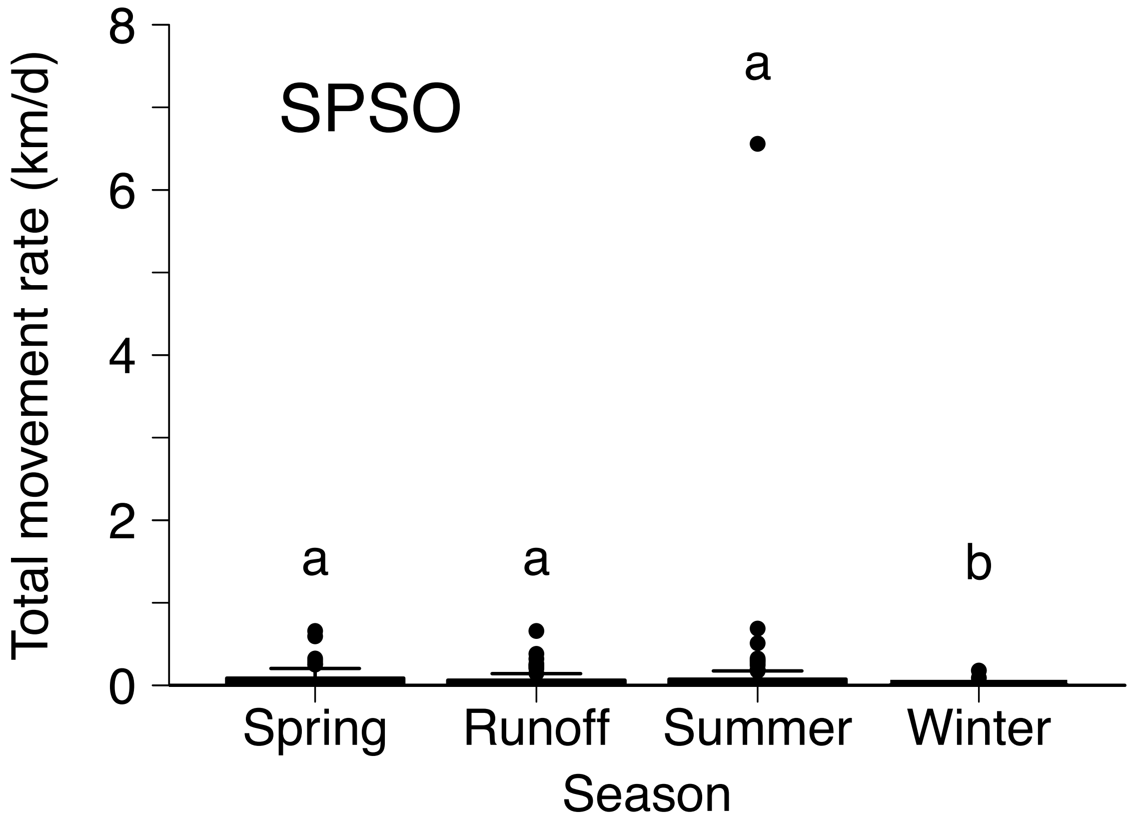

Figure 44. Total movement rate of telemetered Spiny Softshells (*N* = 37) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different.

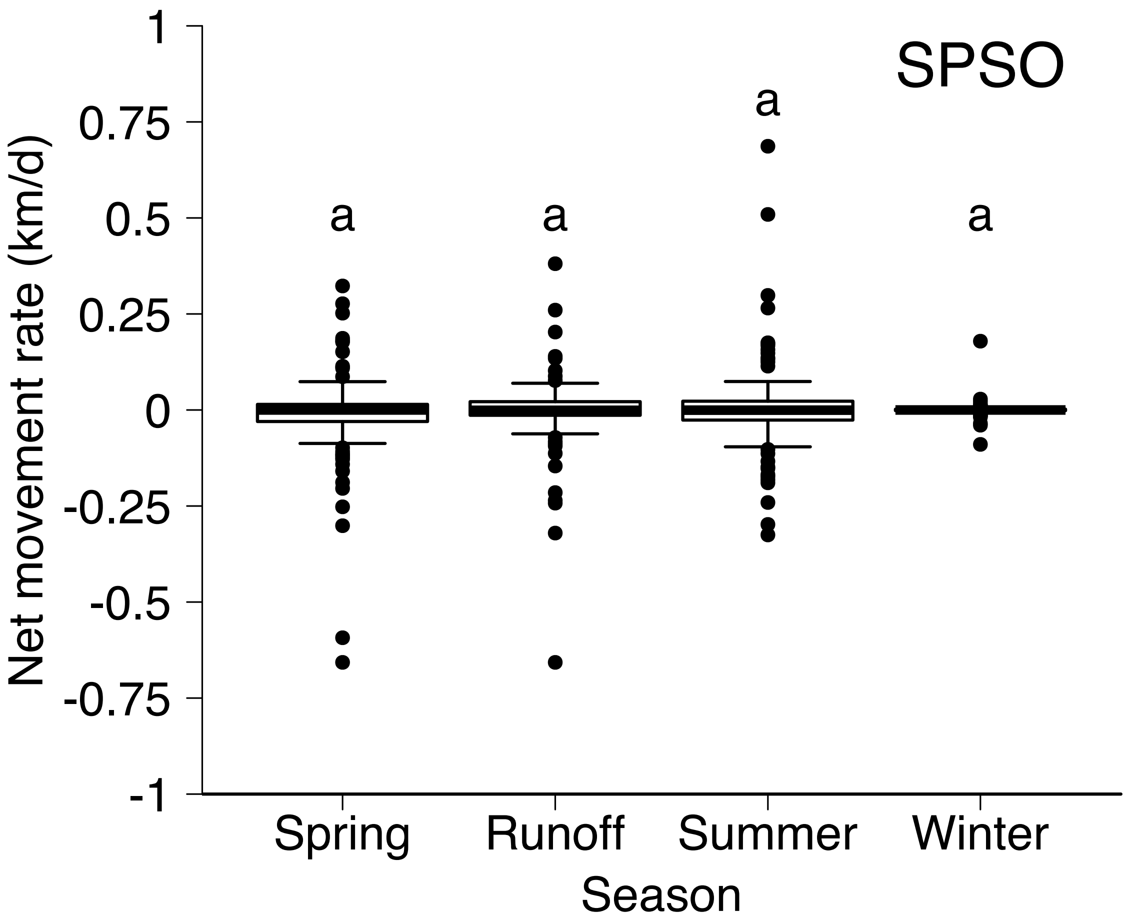

Figure 45. Net movement rate of telemetered Spiny Softshells (*N* = 37) in the Yellowstone River from 2005–2009 by season. Bold lines within boxes represent medians, bottom and top of boxes are first and third quartiles, and whiskers are 1.5 times interquartile range. Letters above bars indicate significant differences in median net movement rate among seasons using a Kruskal-Wallis one-way analysis of variance and pairwise Wilcoxon rank sum tests; seasons with the same letter are not significantly different. Negative values indicate downstream movements and positive values indicate upstream movements.

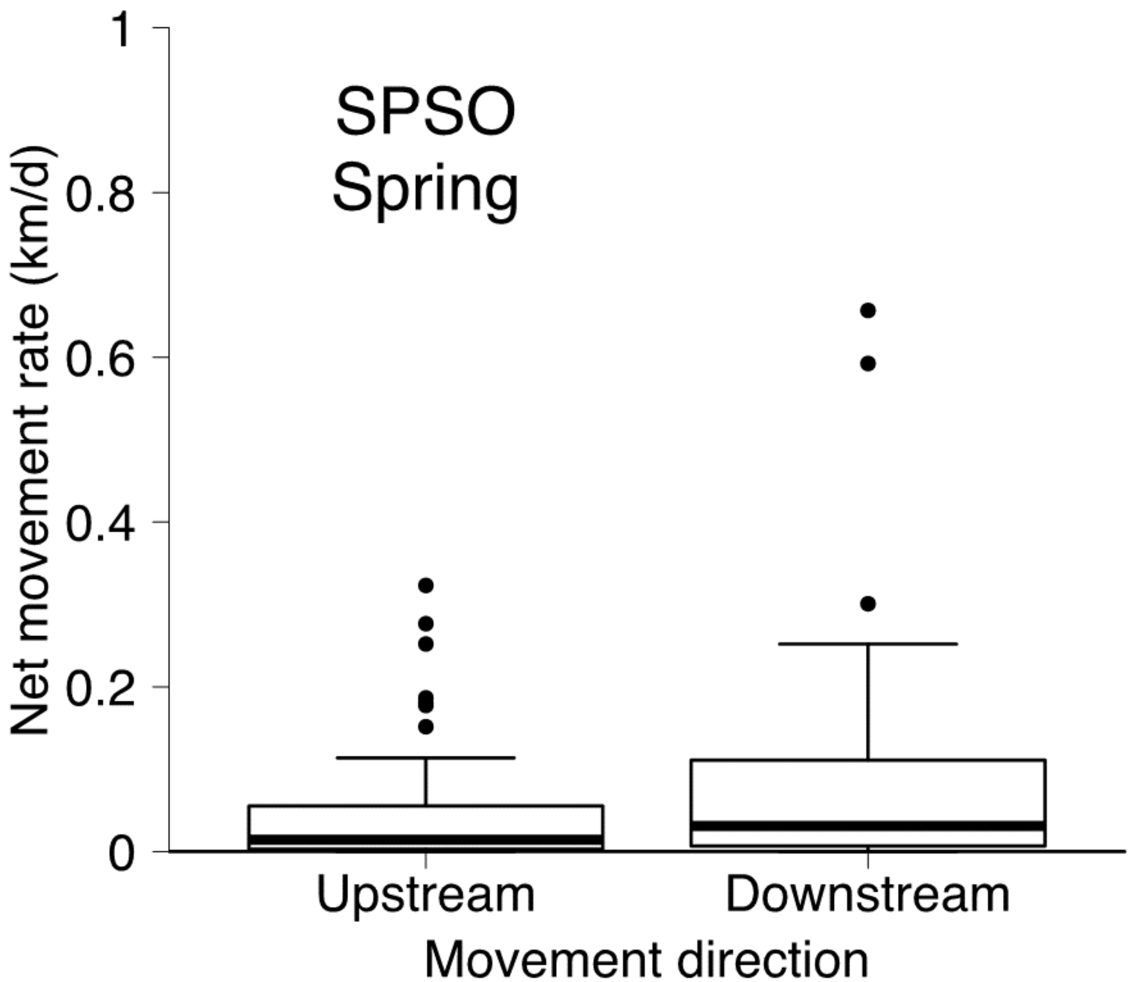

Figure 46. Absolute values of net upstream and downstream movement rates of spiny Softshells (*N* = 37) in the Yellowstone River from 2005–2009 during spring. Net upstream and downstream movement rates were weakly significantly different from each other using a Mann-Whitney-U test.

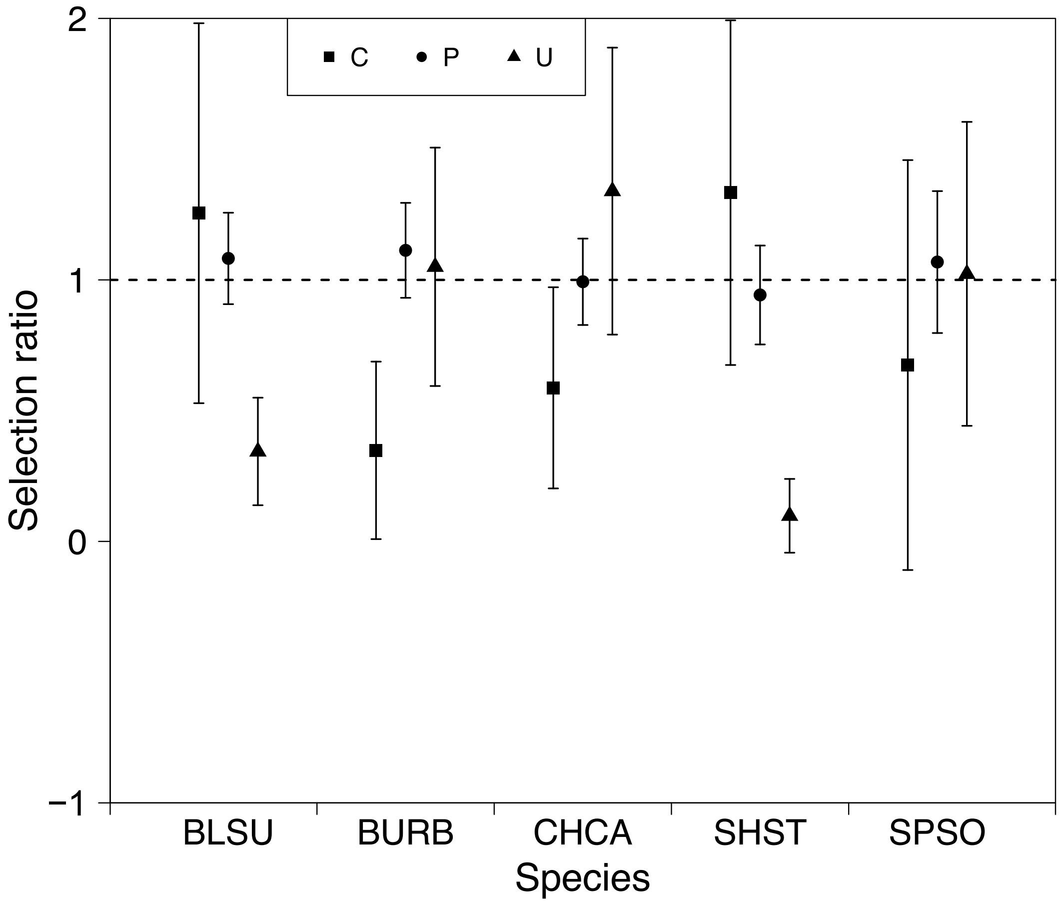

Figure 47. Overall geomorphic reach type I selection by telemetered species in the Yellowstone River from 2005–2009. C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

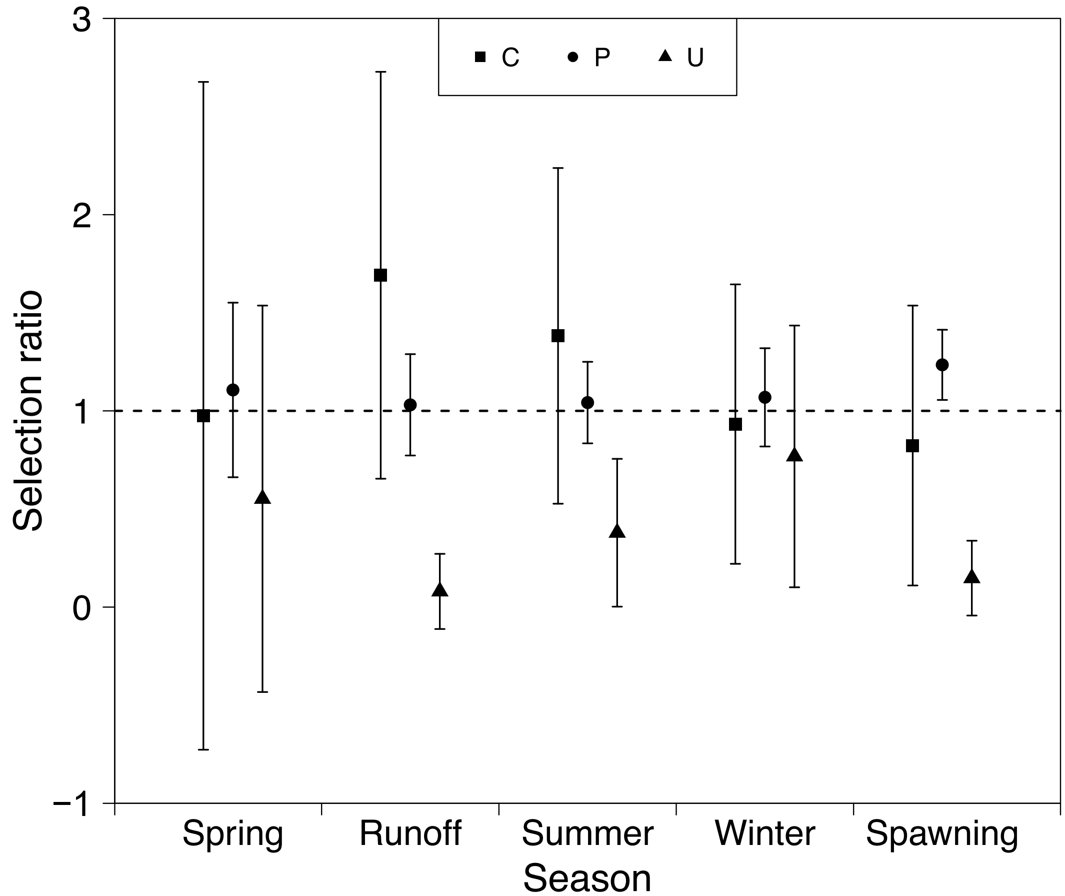

Figure 48. Seasonal geomorphic reach type I selection by telemetered Blue Suckers in the Yellowstone River from 2005–2009. C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

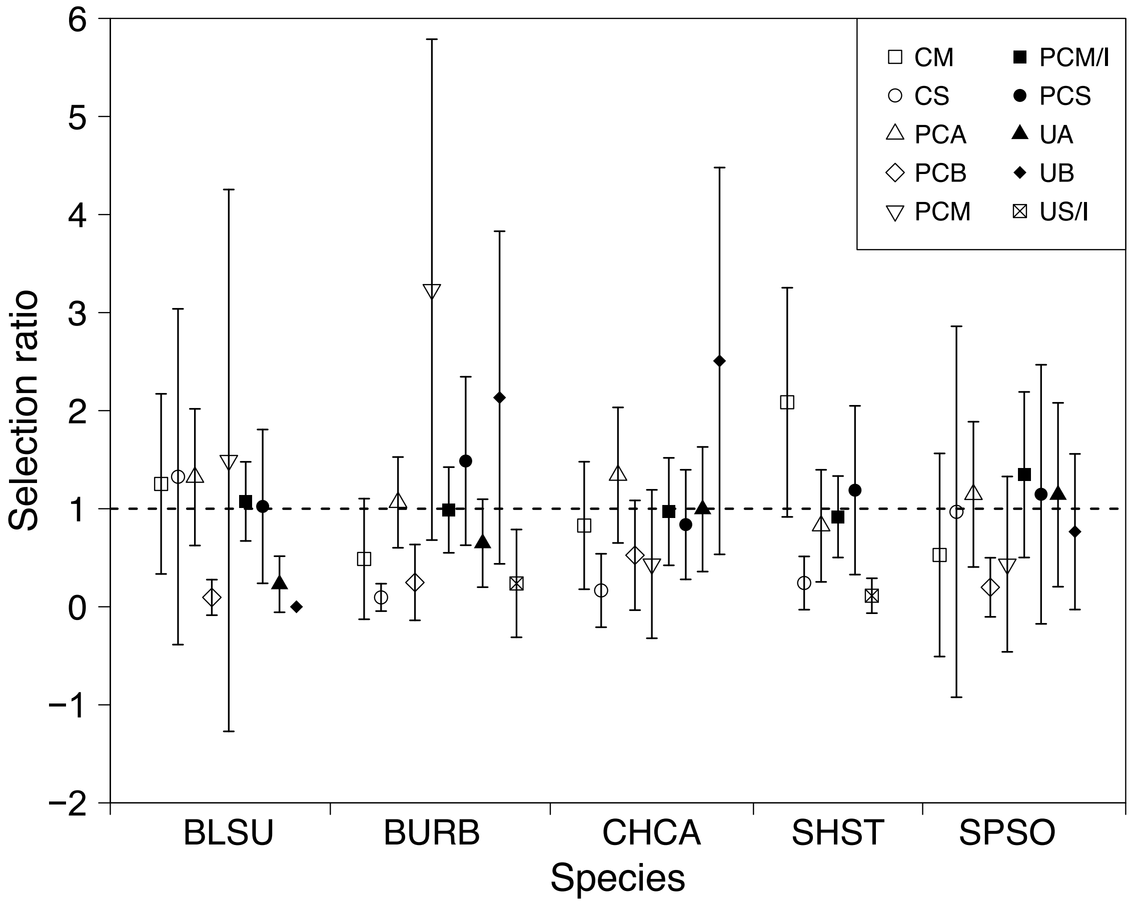

Figure 49. Overall geomorphic reach type II selection by telemetered species in the Yellowstone River from 2005–2009. CM (open squares) = confined meandering, CM (open circles) = confined straight, PCA (open triangles) = partially confined anabranching, PCB (open diamonds) = partially confined braided, PCM (open upside down triangles) = partially confined meandering, PCM/I (closed squares) = partially confined meandering with islands, PCS (closed circles) = partially confined straight, UA (closed triangles) = unconfined anabranching, and UB (closed diamonds) = unconfined braided. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

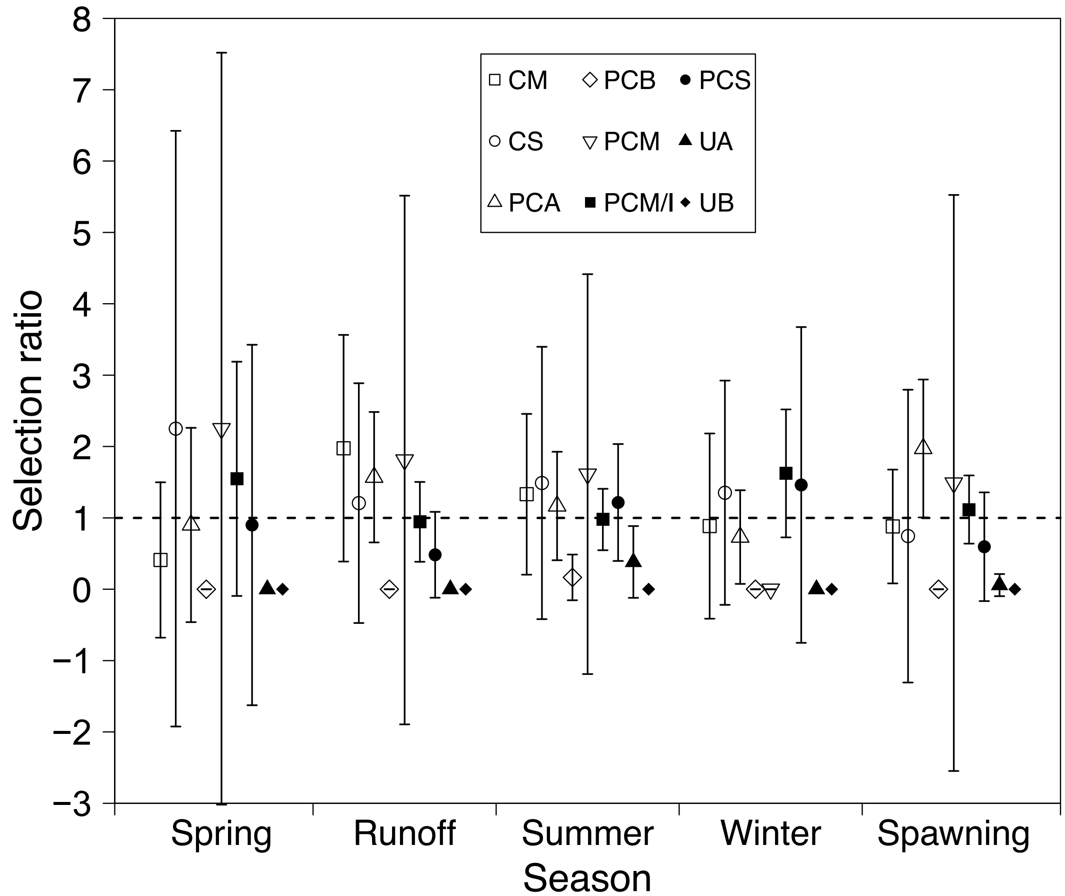

Figure 50. Seasonal geomorphic reach type II selection by telemetered Blue Suckers in the Yellowstone River from 2005–2009. CM (open squares) = confined meandering, CM (open circles) = confined straight, PCA (open triangles) = partially confined anabranching, PCB (open diamonds) = partially confined braided, PCM (open upside down triangles) = partially confined meandering, PCM/I (closed squares) = partially confined meandering with islands, PCS (closed circles) = partially confined straight, UA (closed triangles) = unconfined anabranching, and UB (closed diamonds) = unconfined braided. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

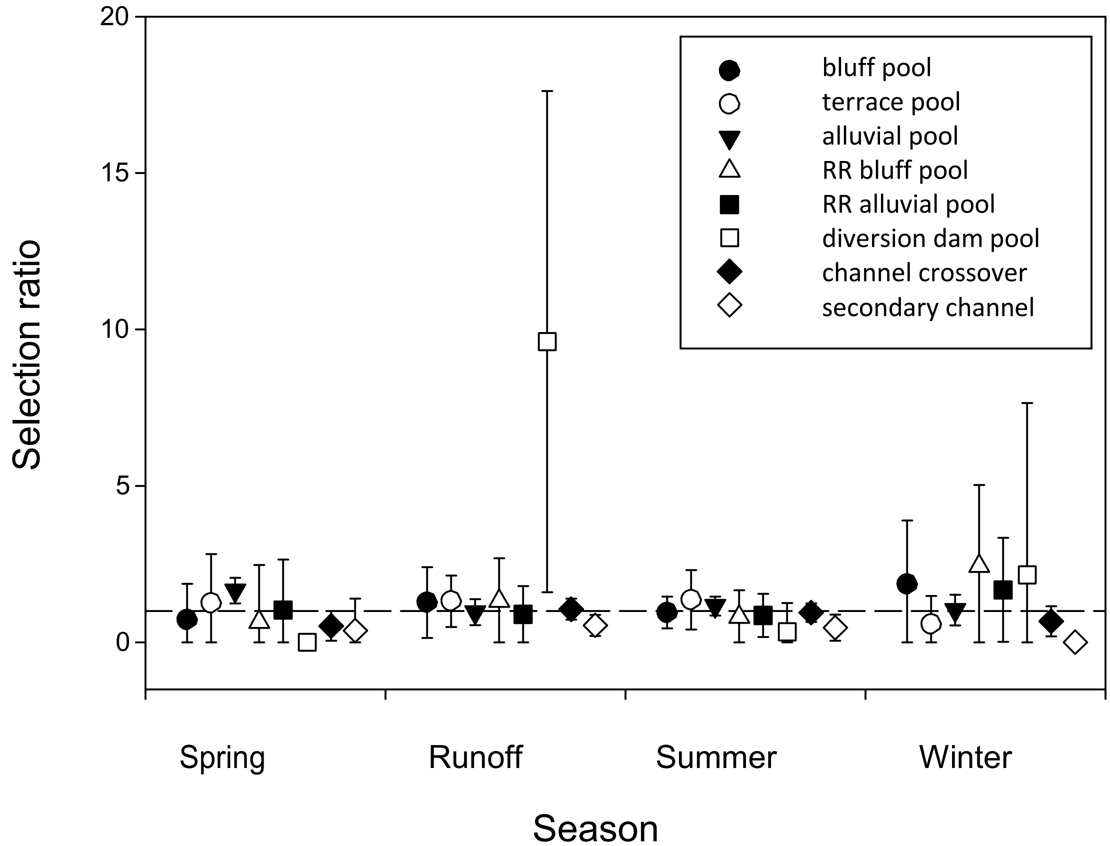

Figure 51. Seasonal selection ratios of habitat types by telemetered Blue Suckers in the Yellowstone River from 2004-2009. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 95% Bonferroni confidence intervals.

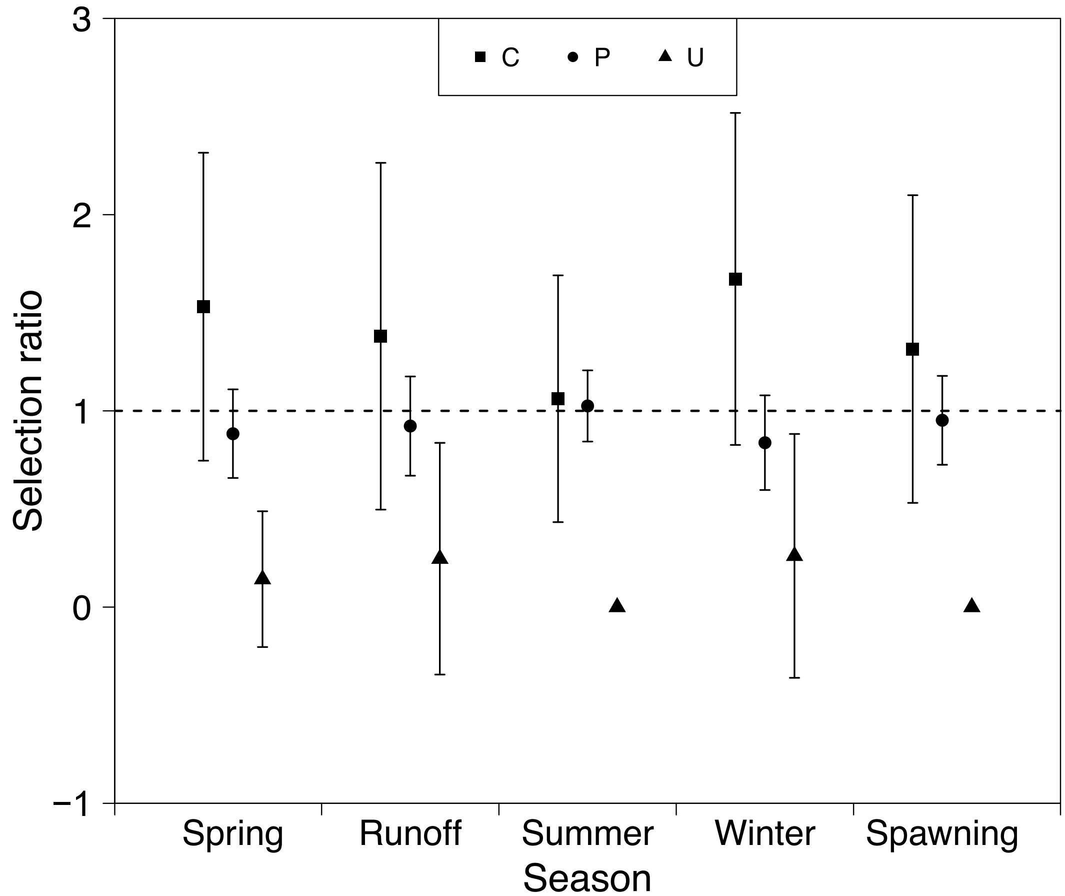

Figure 52. Seasonal geomorphic reach type I selection by telemetered Shovelnose sturgeon in the Yellowstone River from 2005–2009. C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

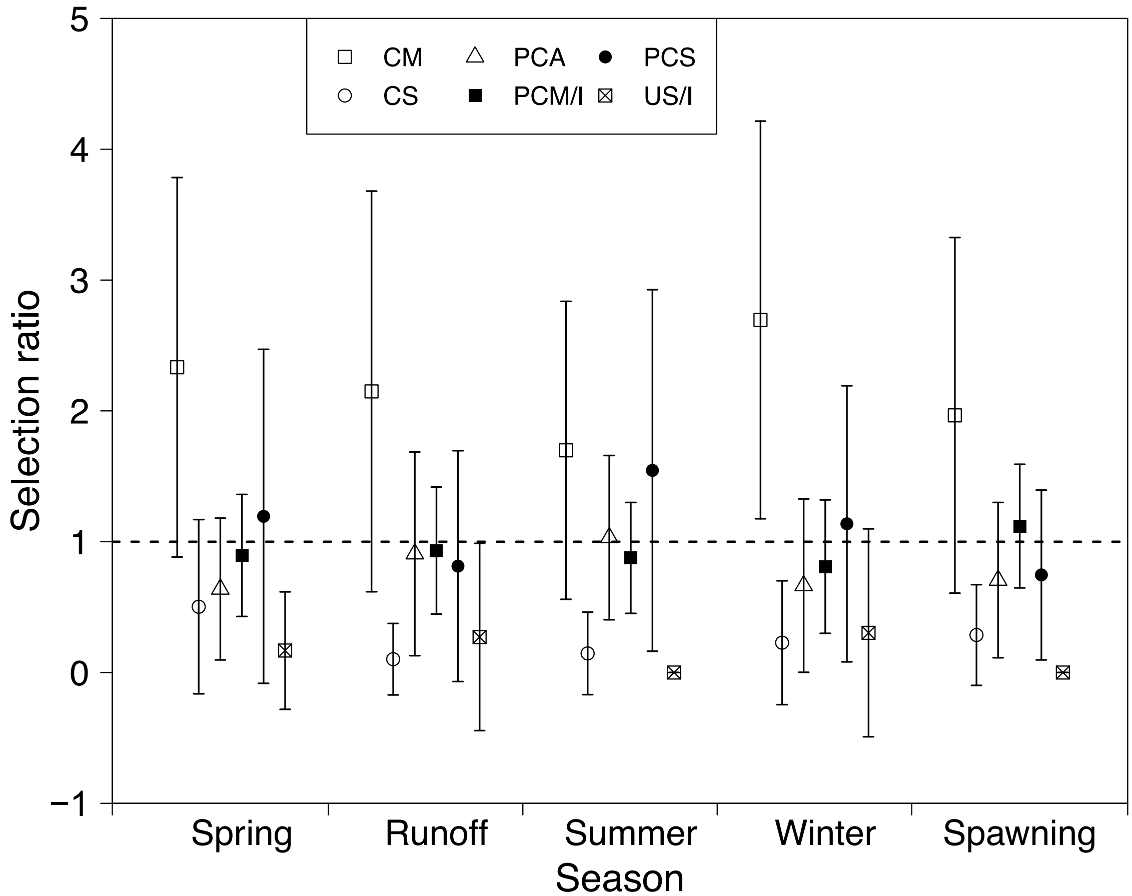

Figure 53. Seasonal geomorphic reach type II selection by telemetered Shovelnose Sturgeon in the Yellowstone River from 2005–2009. CM (open squares) = confined meandering, CM (open circles) = confined straight, PCA (open triangles) = partially confined anabranching, PCM/I (closed squares) = partially confined meandering with islands, PCS (closed circles) = partially confined straight, and US/I (crossed open rectangle) = unconfined straight with islands. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

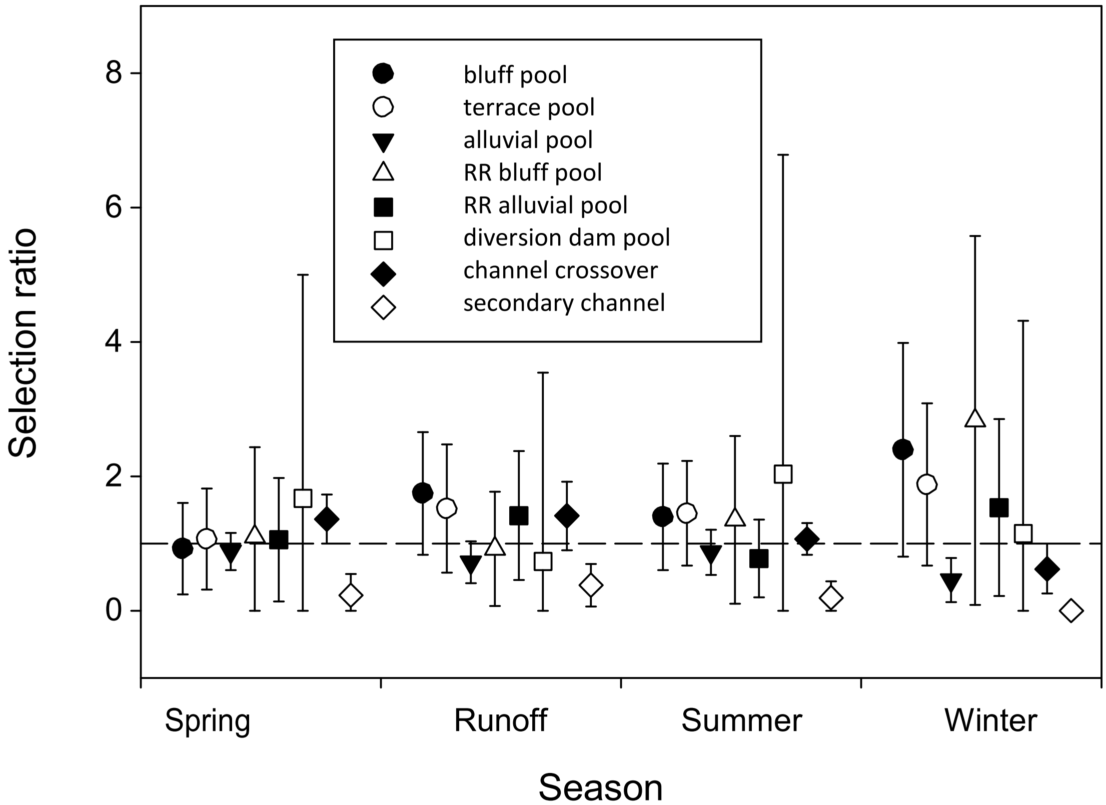

Figure 54. Seasonal selection ratios of habitat types by telemetered Shovelnose Sturgeon in the Yellowstone River from 2005–2009. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 95% Bonferroni confidence intervals.

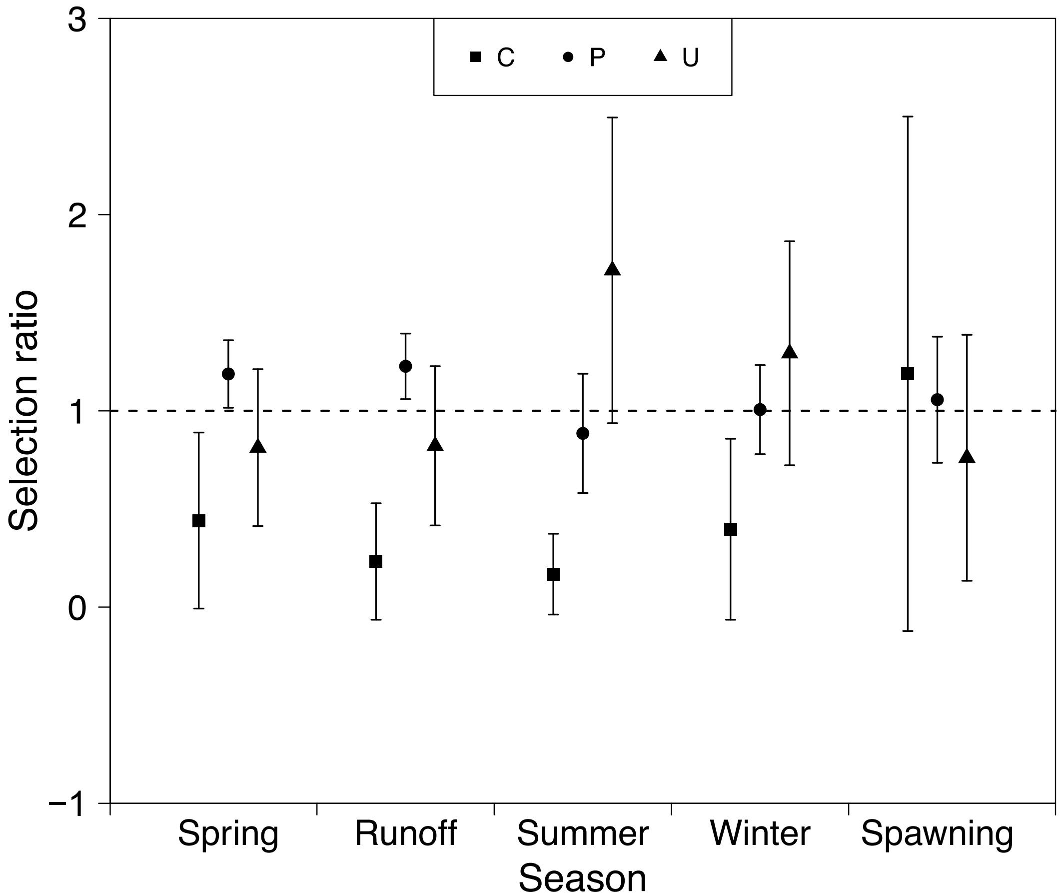

Figure 55. Seasonal geomorphic reach type I selection by telemetered Burbot in the Yellowstone River from 2005–2009. C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

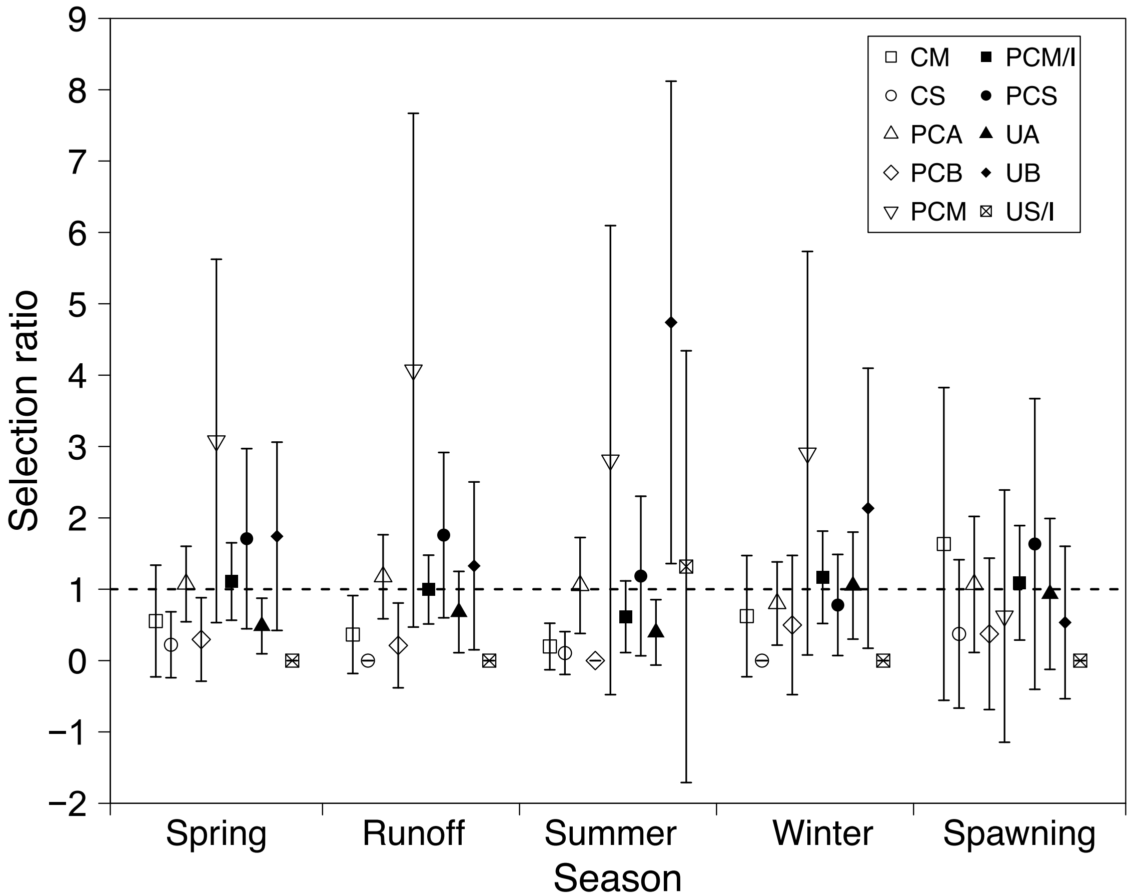

Figure 56. Seasonal geomorphic reach type II selection by telemetered Burbot in the Yellowstone River from 2005–2009. CM (open squares) = confined meandering, CM (open circles) = confined straight, PCA (open triangles) = partially confined anabranching, PCB (open diamonds) = partially confined braided, PCM (open upside down triangles) = partially confined meandering, PCM/I (closed squares) = partially confined meandering with islands, PCS (closed circles) = partially confined straight, UA (closed triangles) = unconfined anabranching, UB (closed diamonds) = unconfined braided, US/I (crossed open rectangle) = unconfined straight with islands. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

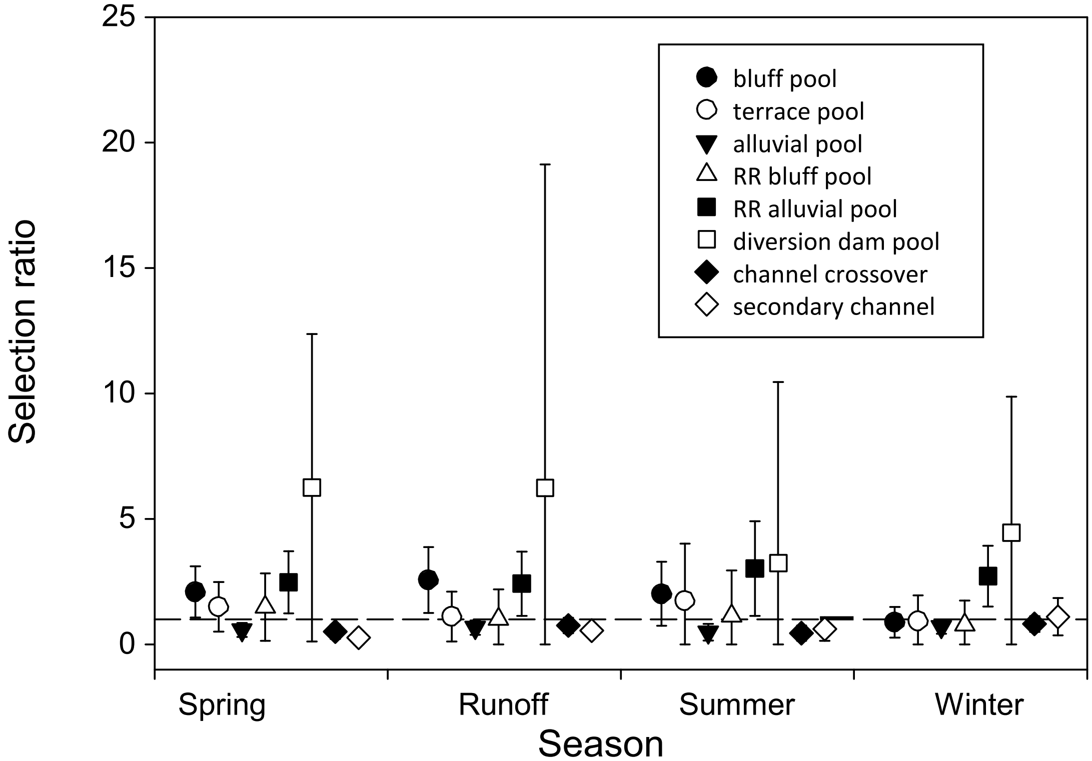

Figure 57. Seasonal selection ratios of habitat types by telemetered Burbot in the Yellowstone River from 2004–2009. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 95% Bonferroni confidence intervals.

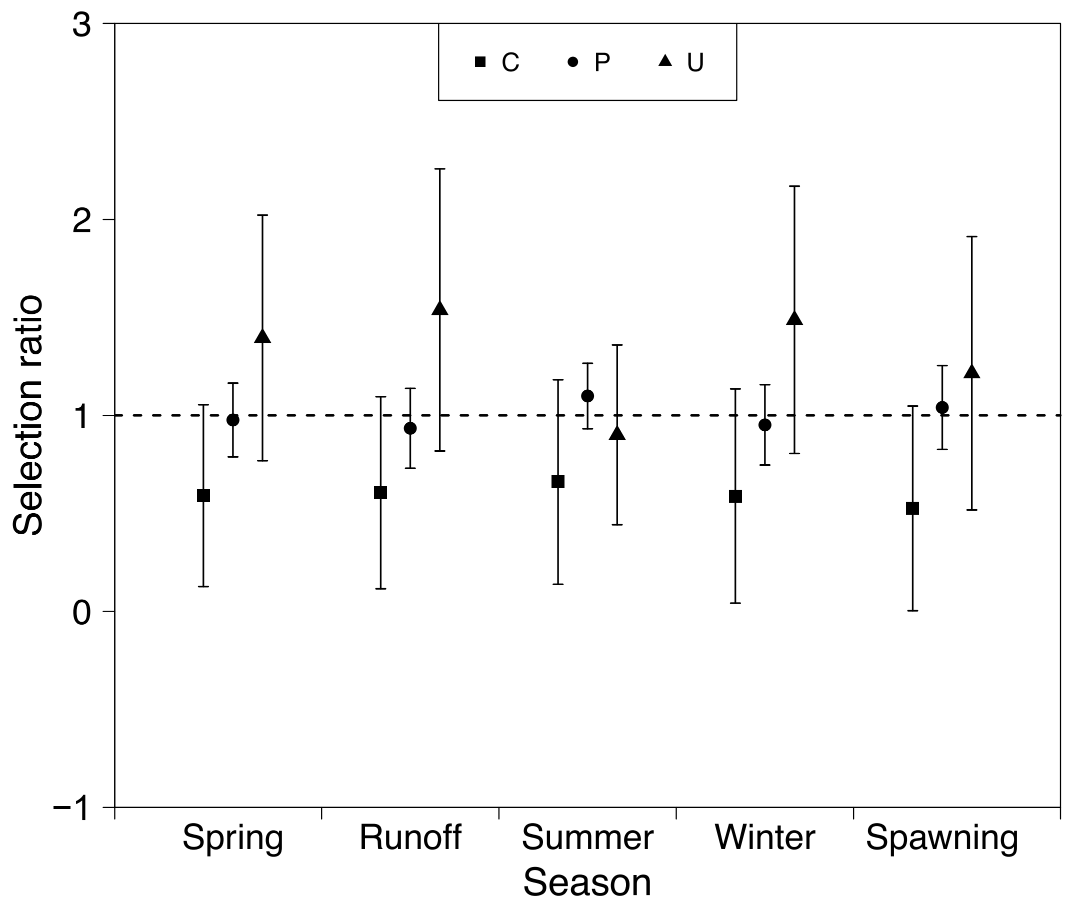

Figure 58. Seasonal geomorphic reach type I selection by telemetered Channel catfish in the Yellowstone River from 2005–2009. C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

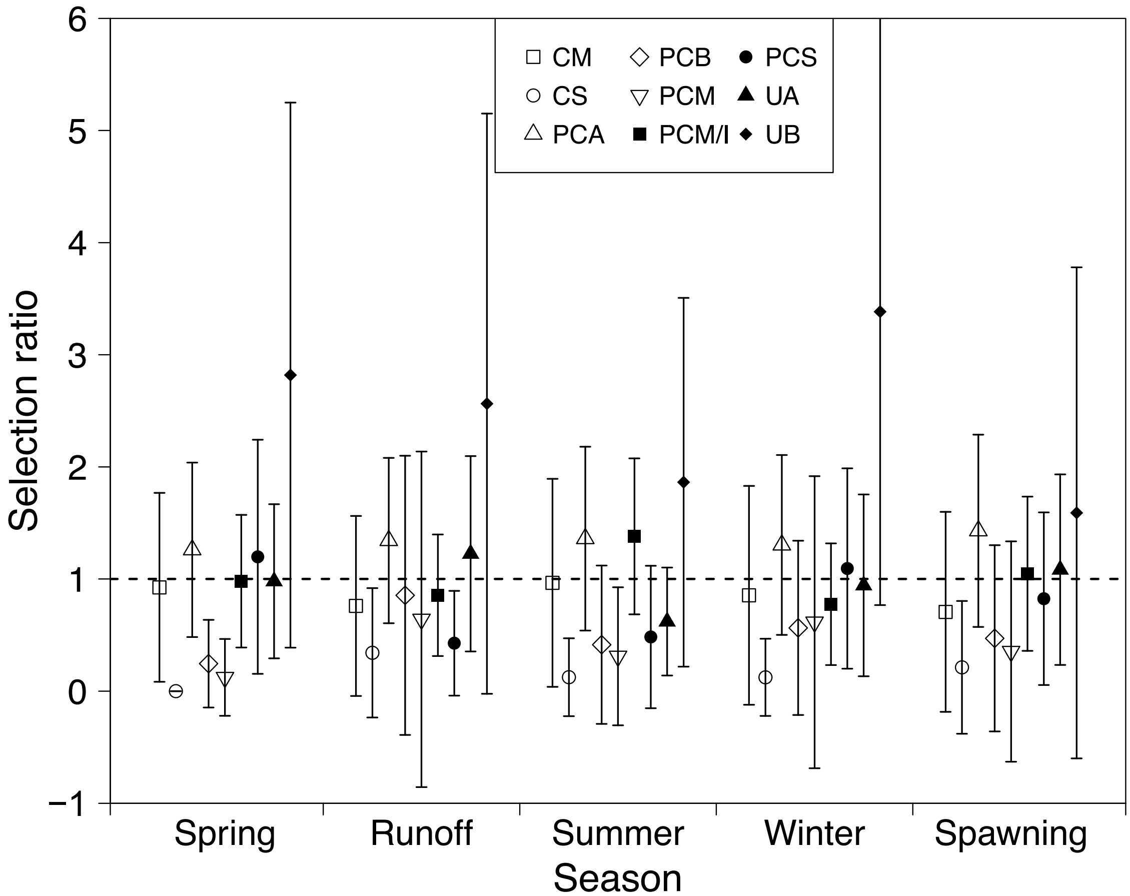

Figure 59. Seasonal geomorphic reach type II selection by telemetered Channel catfish in the Yellowstone River from 2005–2009. CM (open squares) = confined meandering, CM (open circles) = confined straight, PCA (open triangles) = partially confined anabranching, PCB (open diamonds) = partially confined braided, PCM (open upside down triangles) = partially confined meandering, PCM/I (closed squares) = partially confined meandering with islands, PCS (closed circles) = partially confined straight, UA (closed triangles) = unconfined anabranching, and UB (closed diamonds) = unconfined braided. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

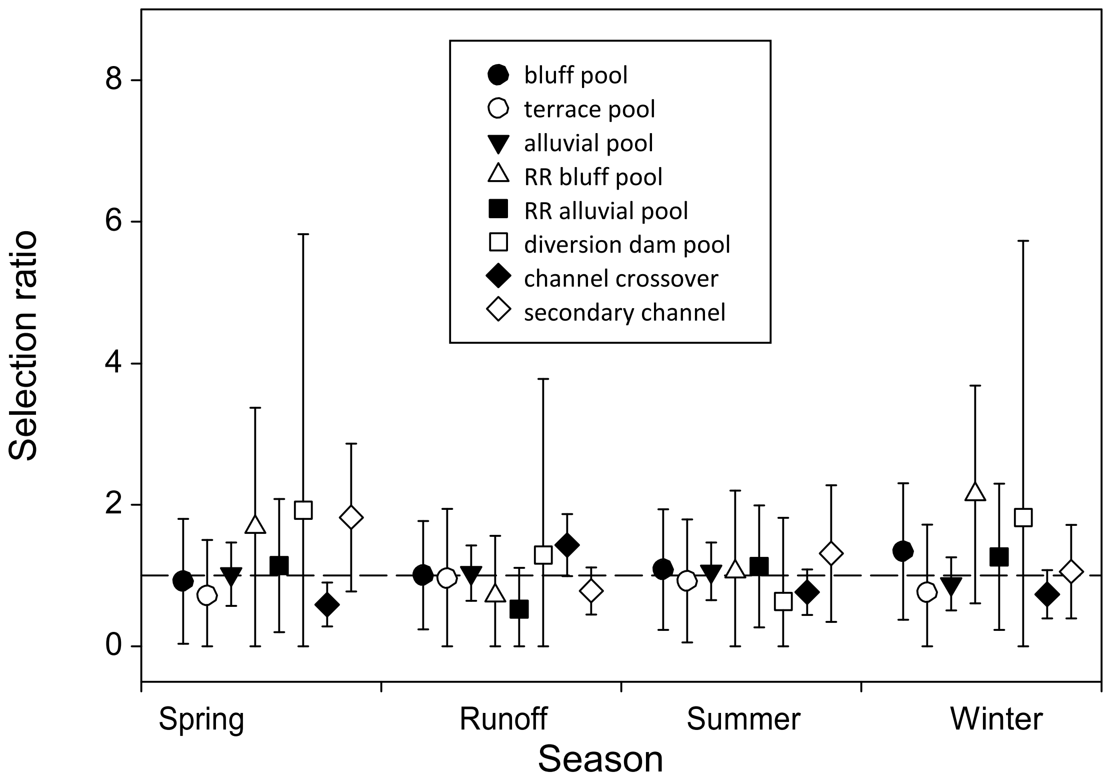

Figure 60. Seasonal selection ratios of habitat types by telemetered Channel Catfish in the Yellowstone River from 2004–2009. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

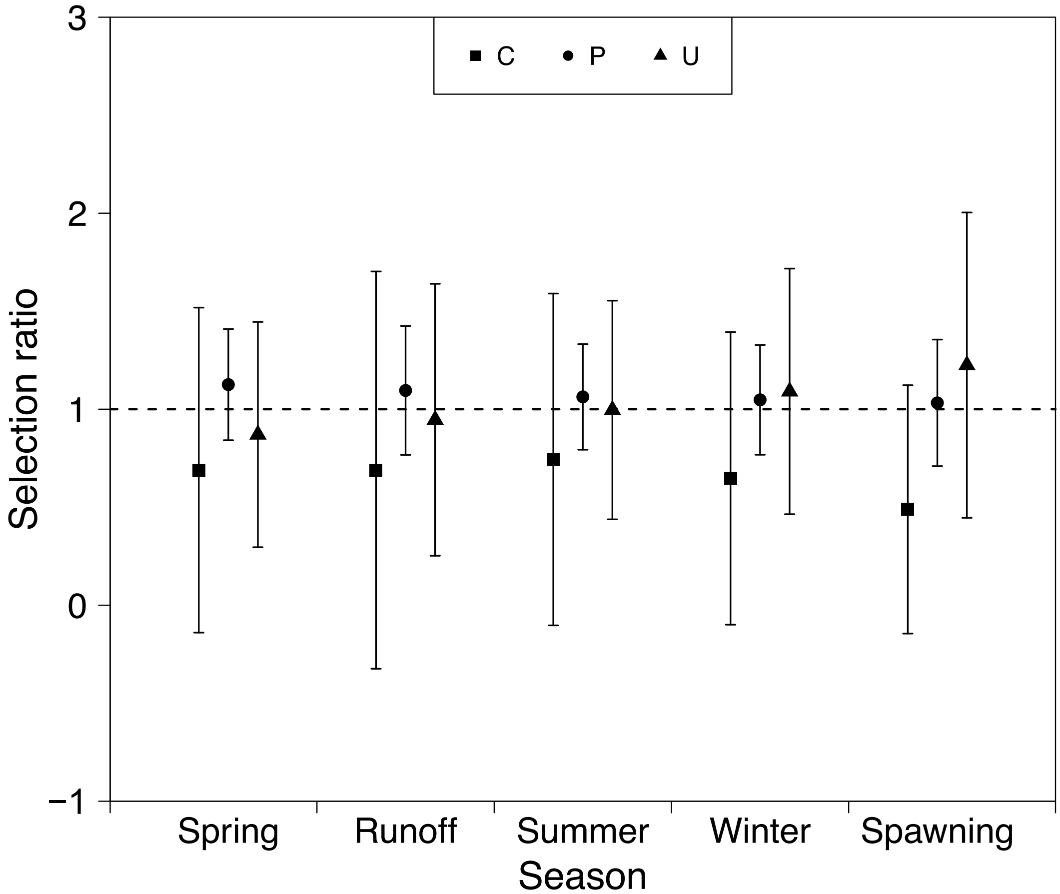

Figure 61. Seasonal geomorphic reach type I selection by telemetered Spiny Softshells in the Yellowstone River from 2005–2009. C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

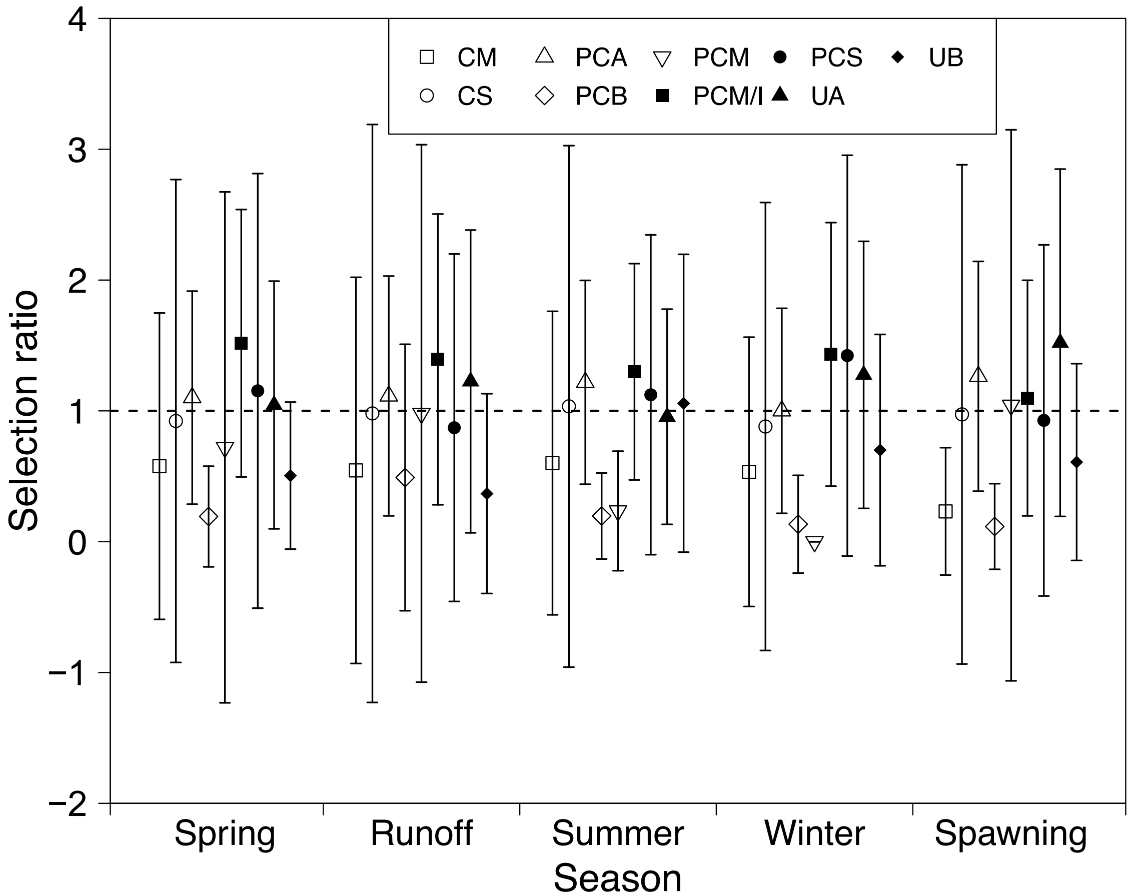

Figure 62. Seasonal geomorphic reach type II selection by telemetered Spiny Softshells in the Yellowstone River from 2005–2009. CM (open squares) = confined meandering, CM (open circles) = confined straight, PCA (open triangles) = partially confined anabranching, PCB (open diamonds) = partially confined braided, PCM (open upside down triangles) = partially confined meandering, PCM/I (closed squares) = partially confined meandering with islands, PCS (closed circles) = partially confined straight, UA (closed triangles) = unconfined anabranching, and UB (closed diamonds) = unconfined braided. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

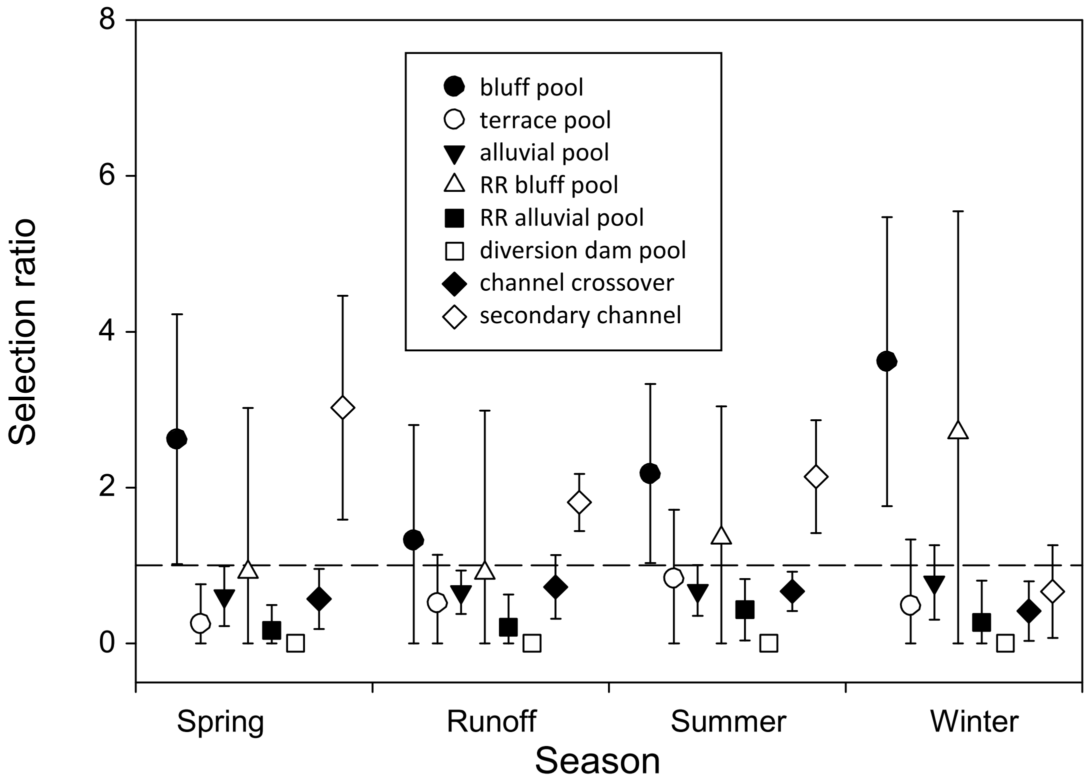

Figure 63. Seasonal selection ratios of habitat types by telemetered Spiny Softshells in the Yellowstone River from 2005–2009. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 95% Bonferroni confidence intervals.

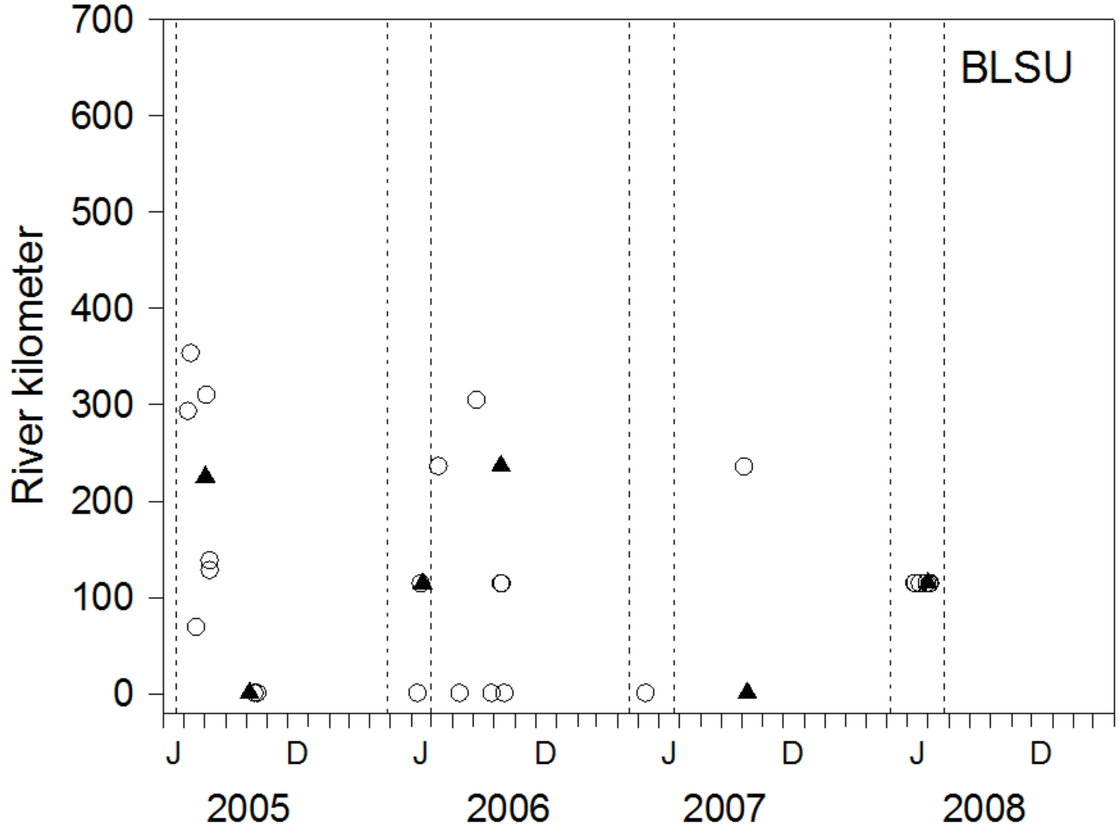

Figure 64. Aggregations of Blue Suckers in the Yellowstone River from 2005–2009 (J = June and D = December). Open circles represent aggregations of 3 telemetered individuals and closed triangles represent aggregations of 3 or more telemetered individuals within 1 km of each other on the same day. Dashed lines represent potential spawning periods for each year.

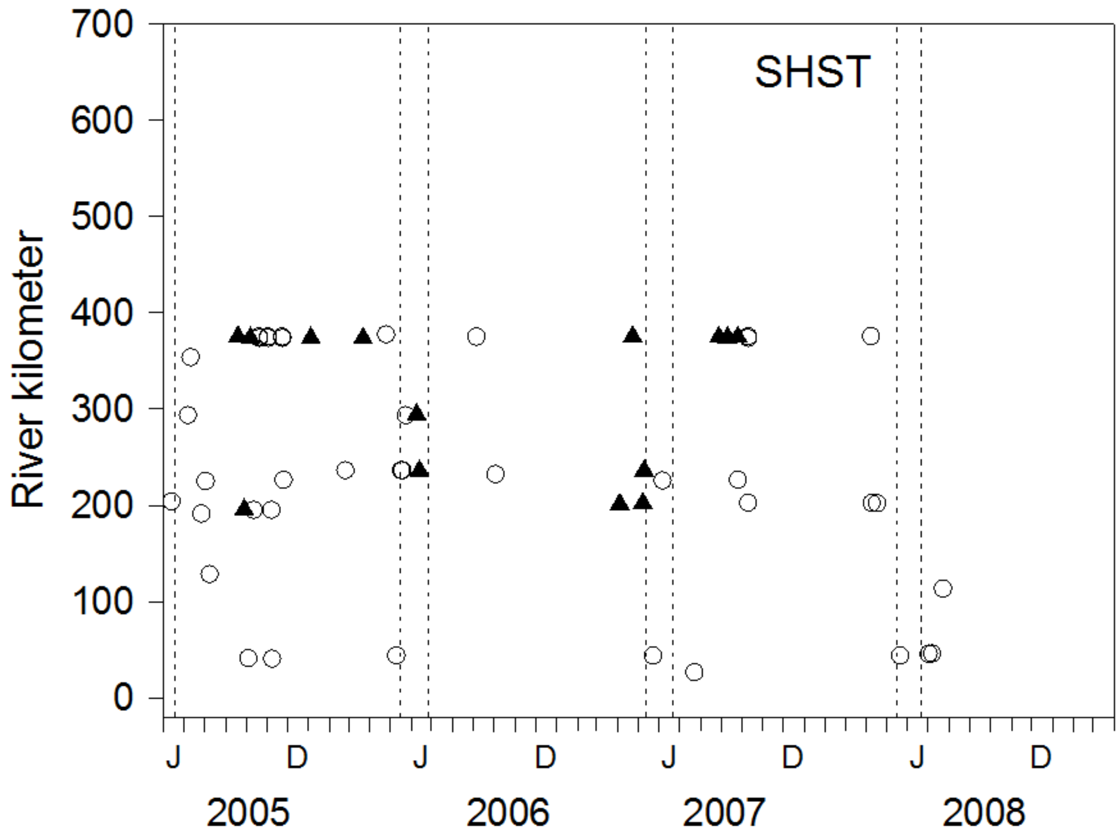

Figure 65. Aggregations of Shovelnose sturgeon in the Yellowstone River from 2005–2009 (J = June and D = December). Open circles represent aggregations of 3 telemetered individuals and closed triangles represent aggregations of 3 or more telemetered individuals within 1 km of each other on the same day. Dashed lines represent potential spawning periods for each year.

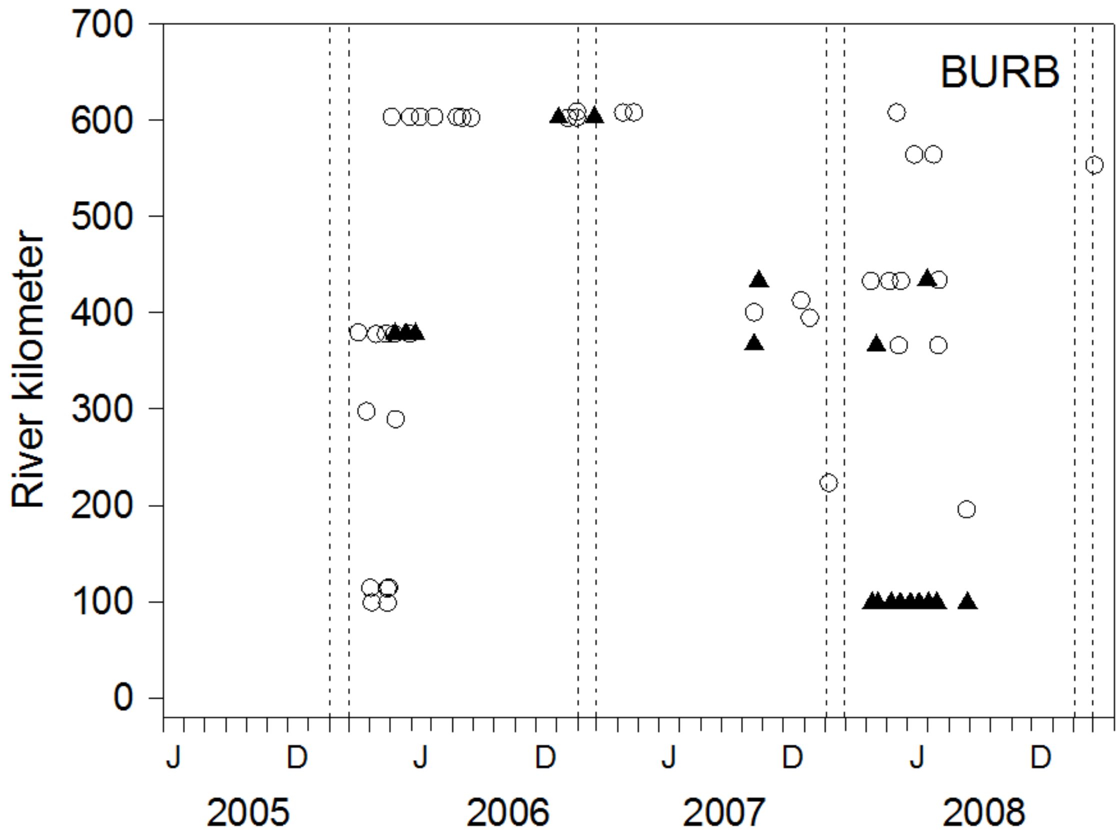

Figure 66. Aggregations of Burbot in the Yellowstone River from 2005–2009 (J = June and D = December). Open circles represent aggregations of 3 telemetered individuals and closed triangles represent aggregations of 3 or more telemetered individuals within 1 km of each other on the same day. Dashed lines represent potential spawning periods for each year.

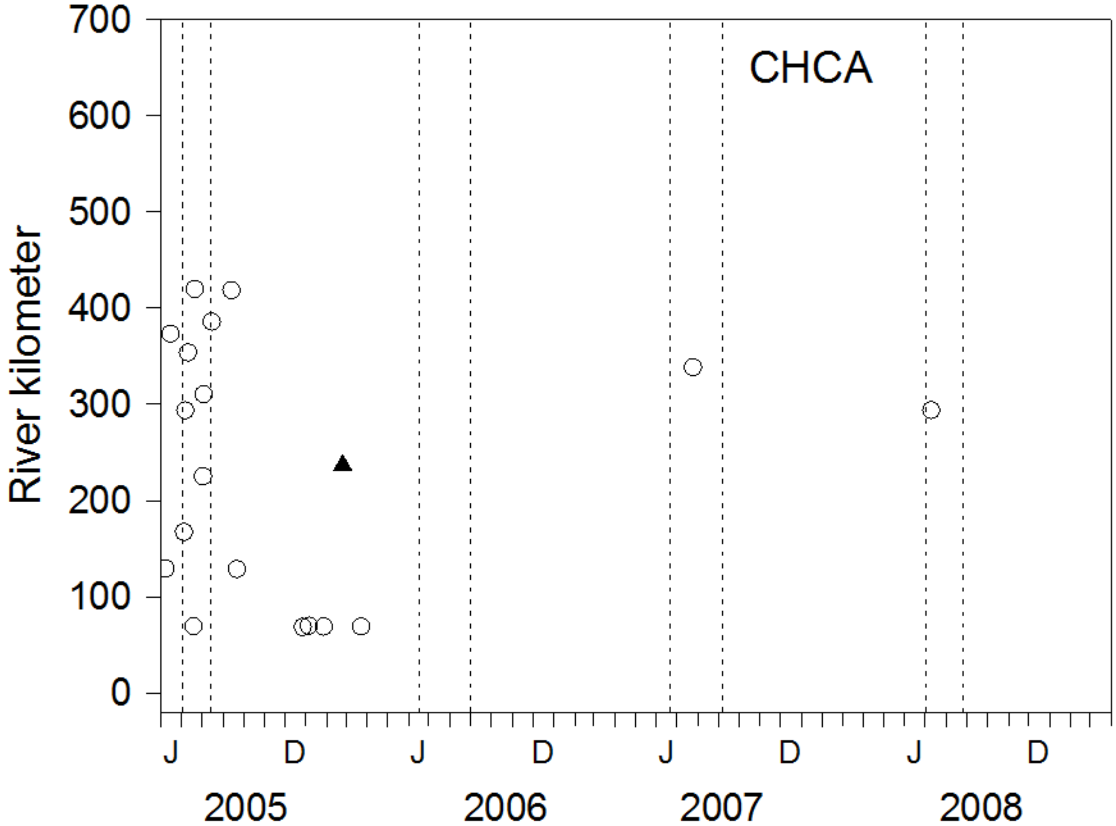

Figure 67. Aggregations of Channel catfish in the Yellowstone River from 2005–2009 (J = June and D = December). Open circles represent aggregations of 3 telemetered individuals and closed triangles represent aggregations of 3 or more telemetered individuals within 1 km of each other on the same day. Dashed lines represent potential spawning periods for each year.

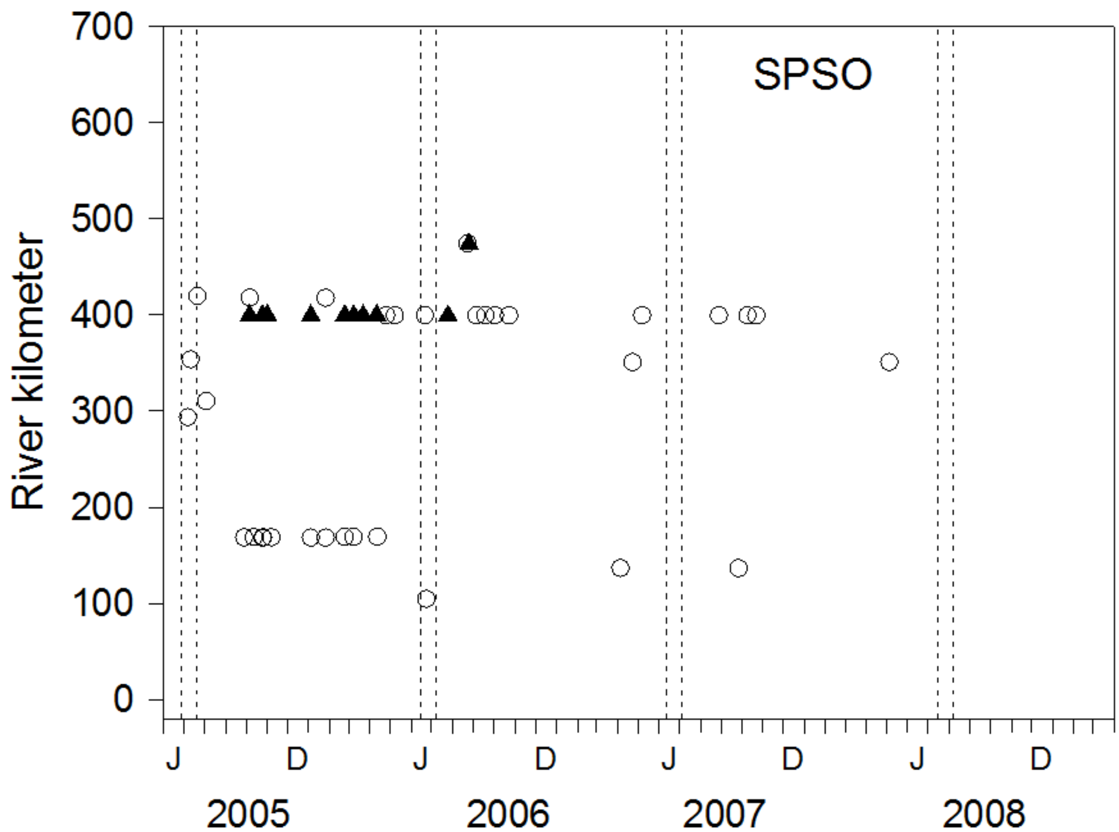

Figure 68. Aggregations of Spiny Softshell Turtles in the Yellowstone River from 2005–2009 (J = June and D = December). Open circles represent aggregations of 3 telemetered individuals and closed triangles represent aggregation of 3 or more telemetered individuals within 1 km of each other on the same day. Dashed lines represent potential spawning periods for each year.

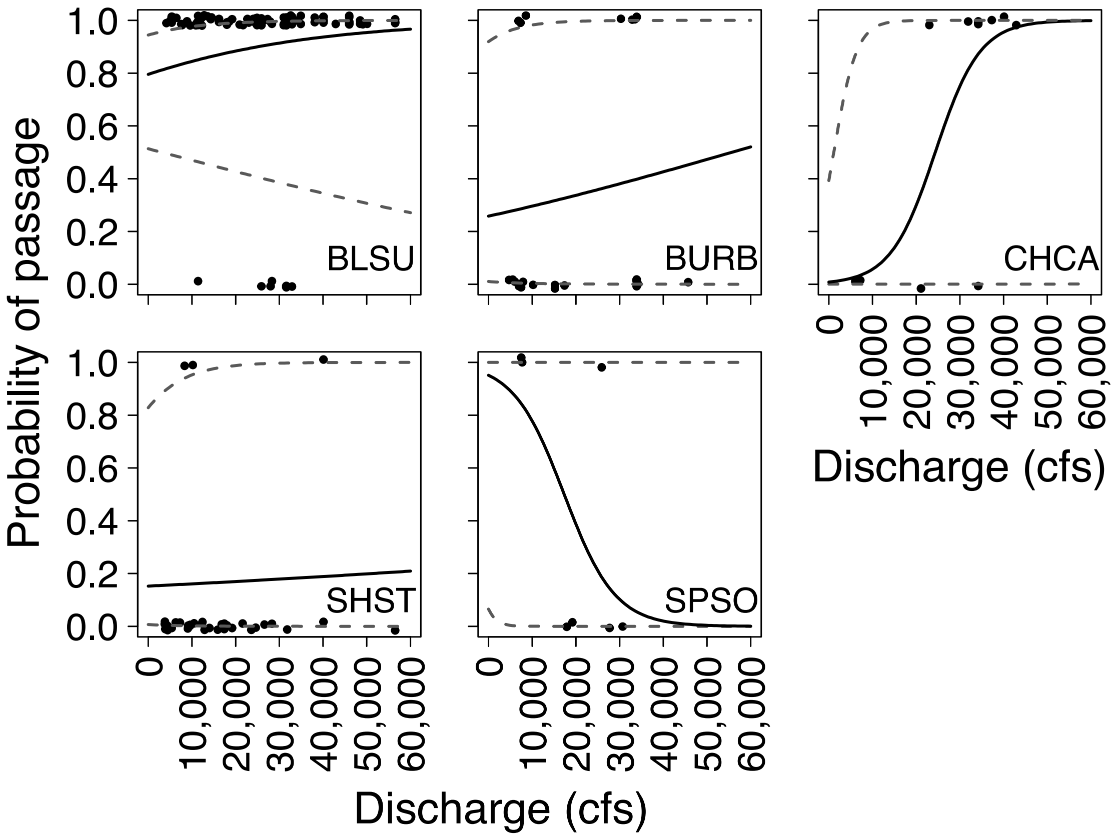

Figure 69. Predicted probability of passage (solid line) over diversion dams, and associated upper and lower confidence 95% confidence intervals (dotted lines), by telemetered species at increasing discharge levels in the Yellowstone River from 2005–2009. Points are jittered and represent actual data points collected for each species passing diversion dams.

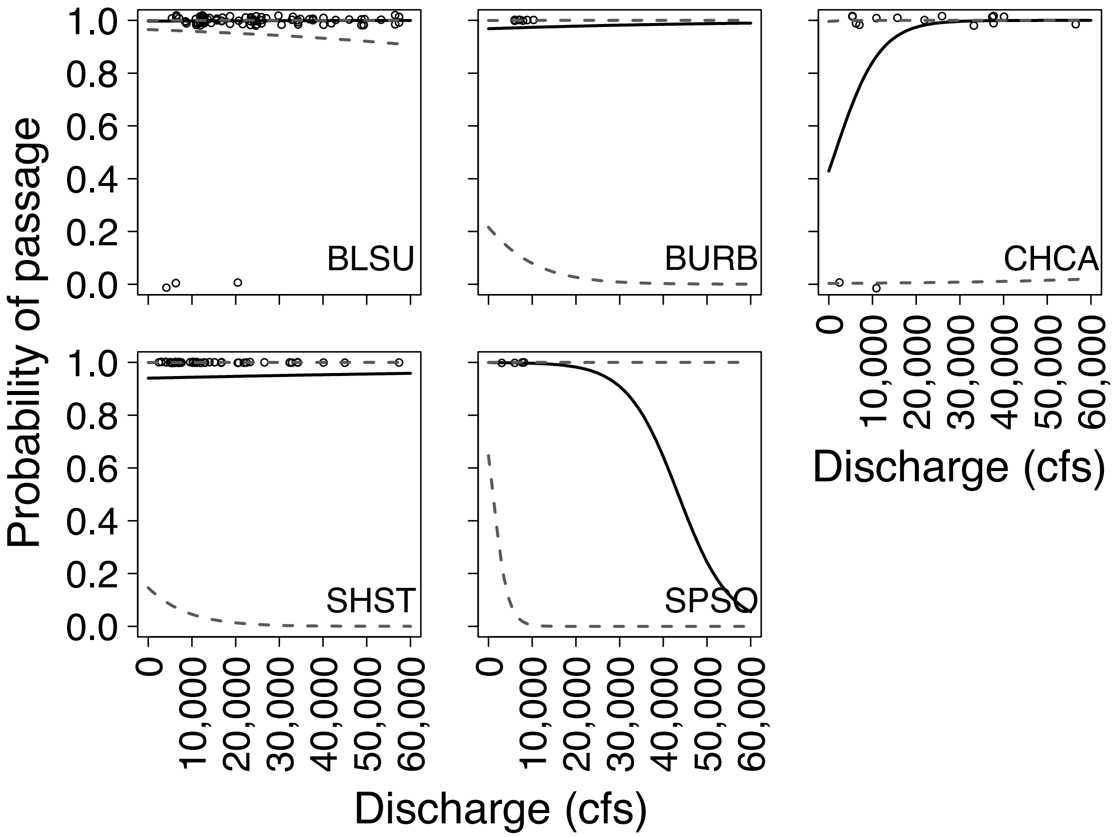

Figure 70. Predicted probability of passage (solid line) over natural riffles, and associated upper and lower confidence 95% confidence intervals (dotted lines), by telemetered species at increasing discharge levels in the Yellowstone River from 2005–2009. Points are jittered and represent actual data points collected for each species passing natural riffles.

APPENDIX I

Appendix Table 1. Code, frequency, number of observations (*N* obs.), monitoring period (Mon. period), if the animal expelled the transmitter (Expel, A = active for entire monitoring period and E = expelled) and linear home range (LHR) for each telemetered Blue Sucker (BLSU) monitored in the Yellowstone River from 2005–2009.

Sp.	Num.	Code	Freq.	*N* obs.	Mon. period	Expel	LHR
BLSU	1	12	420	45	1115	A	136.60
BLSU	2	13	420	2	15	A	26.90
BLSU	3	15	420	44	1115	A	304.00
BLSU	4	16	420	42	1087	A	266.76
BLSU	5	18	420	2	44	A	127.80
BLSU	6	19	420	32	1086	A	340.71
BLSU	7	20	420	45	1121	A	240.85
BLSU	8	22	420	39	783	A	332.84
BLSU	9	24	420	42	1119	A	309.75
BLSU	10	25	420	2	47	A	9.81
BLSU	11	29	420	26	1116	A	180.80
BLSU	12	32	420	19	713	A	137.79
BLSU	13	33	420	8	718	A	175.83
BLSU	14	49	420	35	1127	A	235.72
BLSU	15	57	420	4	365	E	80.55
BLSU	16	58	420	41	1136	A	76.14
BLSU	17	63	420	7	735	A	68.61
BLSU	18	65	420	38	1121	A	224.39
BLSU	19	69	420	45	1119	A	328.48
BLSU	20	72	420	42	1120	A	309.75
BLSU	21	74	420	22	771	A	266.27
BLSU	22	75	420	31	1121	A	224.39
BLSU	23	77	420	47	1120	A	348.86
BLSU	24	15	480	46	1148	A	360.42
BLSU	25	18	480	51	1148	A	306.59
BLSU	26	19	480	39	1148	A	170.97
BLSU	27	23	480	54	1146	A	368.70
BLSU	28	27	480	2	75	E	14.83
BLSU	29	28	480	41	1146	A	463.54
BLSU	30	30	480	46	1142	A	420.06
BLSU	31	32	480	6	357	A	35.16
BLSU	32	34	480	44	1142	A	464.04

BLSU	33	35	480	2	55	A	10.02
BLSU	34	36	480	31	1142	A	402.78
BLSU	35	46	480	3	315	A	134.66
BLSU	36	47	480	48	1178	A	256.23
BLSU	37	61	480	6	107	E	17.99
BLSU	38	64	480	9	416	A	227.08
BLSU	39	67	480	52	1168	A	96.68
BLSU	40	79	480	22	1105	A	211.26

Appendix Table 2. Code, frequency, number of observations (*N* obs.), monitoring period (Mon. period), if the animal expelled the transmitter (Expel, A = active for entire monitoring period and E = expelled) and linear home range (LHR) for each telemetered Shovelnose Sturgeon (SHST) monitored in the Yellowstone River from 2005–2009.

Sp.	Num.	Code	Freq.	*N* obs.	Mon. period	Expel	LHR
SHST	1	11	420	41	1115	A	248.84
SHST	2	21	420	36	1119	A	78.91
SHST	3	27	420	40	1086	A	142.80
SHST	4	30	420	49	1115	A	186.33
SHST	5	31	420	52	1116	A	129.66
SHST	6	47	420	57	1126	A	187.12
SHST	7	48	420	39	1127	A	183.47
SHST	8	50	420	46	1014	A	98.65
SHST	9	53	420	47	1122	A	260.26
SHST	10	54	420	46	1105	A	355.02
SHST	11	59	420	53	1136	A	8.06
SHST	12	61	420	22	367	E	98.68
SHST	13	67	420	2	47	A	3.30
SHST	14	79	420	51	1121	A	20.78
SHST	15	80	420	53	1087	A	220.09
SHST	16	16	480	48	1149	A	106.68
SHST	17	17	480	51	1107	A	207.04
SHST	18	20	480	46	1112	A	47.62
SHST	19	21	480	42	1146	A	145.66
SHST	20	25	480	53	1150	A	377.50
SHST	21	29	480	46	1108	A	141.62
SHST	22	33	480	43	1109	A	139.08
SHST	23	37	480	20	337	A	113.78
SHST	24	39	480	50	1141	A	45.85
SHST	25	41	480	53	1142	A	140.59
SHST	26	44	480	49	1142	A	20.08
SHST	27	50	480	51	1171	A	36.74

SHST	28	51	480	50	1171	A	43.65
SHST	29	52	480	47	1171	A	12.39
SHST	30	53	480	41	1176	A	113.89
SHST	31	57	480	45	1177	A	144.07
SHST	32	60	480	49	1178	A	95.43
SHST	33	66	480	56	1168	A	261.10
SHST	34	70	480	48	1138	A	178.07
SHST	35	72	480	3	103	E	48.54
SHST	36	76	480	59	1163	A	114.75
SHST	37	80	480	58	1163	A	50.20

Appendix Table 3. Code, frequency, number of observations (*N* obs.), monitoring period (Mon. period), if the animal expelled the transmitter (Expel, A = active for entire monitoring period and E = expelled) and linear home range (LHR) for each telemetered Burbot (BURB) monitored in the Yellowstone River from 2005–2009.

Sp.	Num.	Code	Freq.	*N* obs.	Mon. period	Expel	LHR
BURB	1	38	420	9	121	A	16.93
BURB	2	44	420	7	91	A	0.47
BURB	3	45	420	10	113	E	7.03
BURB	4	11	500	12	335	A	9.19
BURB	5	12	500	14	320	A	58.50
BURB	6	13	500	10	263	A	53.11
BURB	7	14	500	13	262	A	0.90
BURB	8	15	500	12	321	A	132.08
BURB	9	16	500	1	0	A	0.00
BURB	10	17	500	12	312	A	11.71
BURB	11	18	500	12	272	A	1.59
BURB	12	19	500	14	271	A	7.58
BURB	13	20	500	13	272	A	1.46
BURB	14	21	500	14	271	A	25.23
BURB	15	22	500	16	312	A	8.45
BURB	16	23	500	12	271	A	5.89
BURB	17	24	500	10	209	A	42.09
BURB	18	25	500	16	265	A	63.39
BURB	19	26	500	15	265	A	40.21
BURB	20	27	500	9	144	A	59.95
BURB	21	28	500	17	320	A	47.93
BURB	22	29	500	16	305	A	26.16
BURB	23	30	500	13	305	A	34.56
BURB	24	31	500	18	301	A	55.22

BURB	25	32	500	10	242	A	13.08
BURB	26	33	500	16	301	A	57.44
BURB	27	34	500	10	203	A	98.70
BURB	28	35	500	15	335	A	3.23
BURB	29	36	500	11	258	A	137.67
BURB	30	37	500	13	201	A	74.85
BURB	31	38	500	8	252	A	9.46
BURB	32	39	500	13	296	A	15.88
BURB	33	40	500	17	341	A	13.31
BURB	34	41	500	14	290	A	13.08
BURB	35	42	500	3	30	A	0.95
BURB	36	43	500	5	72	A	0.24
BURB	37	44	500	1	0	A	0.00
BURB	38	45	500	6	72	A	1.00
BURB	39	47	500	14	282	A	64.71
BURB	40	48	500	10	140	A	0.10
BURB	41	49	500	4	211	A	81.45
BURB	42	50	500	5	99	A	1.08
BURB	43	51	500	3	89	A	36.75
BURB	44	52	500	7	132	A	1.79
BURB	45	53	500	11	251	A	8.99
BURB	46	54	500	8	140	A	0.11
BURB	47	55	500	6	75	A	0.80
BURB	48	56	500	5	95	A	0.66
BURB	49	57	500	6	87	A	0.98
BURB	50	58	500	9	97	A	2.12
BURB	51	59	500	8	140	A	0.02
BURB	52	60	500	2	42	A	0.03
BURB	53	11	600	7	86	E	0.53
BURB	54	12	600	13	112	E	178.99
BURB	55	13	600	12	121	E	5.86
BURB	56	14	600	11	123	E	37.12
BURB	57	15	600	12	165	E	14.30
BURB	58	16	600	9	197	E	57.89
BURB	59	17	600	30	110	A	0.50
BURB	60	18	600	9	84	E	5.15
BURB	61	19	600	10	124	E	116.67
BURB	62	20	600	11	124	A	112.20
BURB	63	21	600	10	104	A	24.46
BURB	64	22	600	5	49	E	1.01
BURB	65	23	600	22	306	A	153.13

BURB	66	24	600	2	1	A	1.38
BURB	67	25	600	33	491	A	4.01
BURB	68	26	600	13	124	E	6.44
BURB	69	27	600	7	67	A	0.00
BURB	70	28	600	16	242	A	62.43
BURB	71	29	600	11	192	A	107.00
BURB	72	30	600	5	52	A	5.44
BURB	73	31	600	11	123	A	66.58
BURB	74	32	600	14	136	A	281.35
BURB	75	33	600	19	71	A	0.42
BURB	76	34	600	17	119	E	22.45
BURB	77	35	600	23	181	E	27.79
BURB	78	36	600	23	83	A	113.76
BURB	79	37	600	16	69	A	33.18
BURB	80	38	600	13	143	A	15.88
BURB	81	39	600	5	52	E	10.96
BURB	82	40	600	7	84	A	3.62
BURB	83	41	600	6	114	A	2.94
BURB	84	42	600	12	141	A	0.93
BURB	85	43	600	3	169	A	2.59
BURB	86	44	600	12	104	A	7.95
BURB	87	45	600	13	115	A	113.76
BURB	88	46	600	4	46	A	98.37
BURB	89	47	600	12	246	A	84.94
BURB	90	48	600	9	238	A	4.92
BURB	91	49	600	11	302	A	90.68
BURB	92	50	600	11	246	A	7.30
BURB	93	51	600	8	246	A	3.20
BURB	94	74	600	3	56	A	5.79
BURB	95	75	600	19	386	A	2.25
BURB	96	76	600	14	296	A	7.48
BURB	97	77	600	9	292	A	5.71
BURB	98	78	600	18	410	A	6.52
BURB	99	79	600	29	501	A	2.41
BURB	100	80	600	15	341	A	2.57
BURB	101	81	600	16	357	A	6.52
BURB	102	82	600	10	323	A	13.92
BURB	103	83	600	20	560	A	29.04
BURB	104	84	600	20	412	A	8.29
BURB	105	85	600	37	878	A	20.35
BURB	106	86	600	11	125	A	28.56

BURB	107	87	600	8	90	A	0.64
BURB	108	89	600	15	532	A	13.44
BURB	109	90	600	9	89	A	58.89
BURB	110	93	600	8	68	A	0.08
BURB	111	94	600	18	370	A	23.25
BURB	112	95	600	9	96	A	8.69
BURB	113	108	600	9	334	A	1.29
BURB	114	110	600	3	56	A	1.13
BURB	115	111	600	4	65	A	1.93
BURB	116	112	600	9	227	A	16.25
BURB	117	113	600	6	149	A	67.90
BURB	118	114	600	4	122	A	6.32
BURB	119	115	600	8	227	A	8.93
BURB	120	117	600	7	292	A	10.94
BURB	121	120	600	6	216	A	1.77
BURB	122	122	600	7	292	A	12.23
BURB	123	123	600	7	292	A	10.94
BURB	124	124	600	4	122	A	12.47

Appendix Table 4. Code, frequency, number of observations (*N* obs.), monitoring period (Mon. period), if the animal expelled the transmitter (Expel, A = active for entire monitoring period and E = expelled) and linear home range (LHR) for each telemetered Channel Catfish (CHCA) monitored in the Yellowstone River from 2005–2009.

Sp.	Num.	Code	Freq.	*N* obs.	Mon. period	Expel	LHR
CHCA	1	13a	420	14	274	E	2.29
CHCA	2	13b	420	5	48	A	179.63
CHCA	3	60a	420	15	360	A	2.27
CHCA	4	60b	420	25	505	E	138.45
CHCA	5	66b	420	6	101	A	9.48
CHCA	6	71a	420	17	314	E	109.26
CHCA	7	71b	420	8	49	A	81.93
CHCA	8	14	420	7	575	A	22.32
CHCA	9	17	420	12	248	E	29.31
CHCA	10	26	420	2	47	E	3.69
CHCA	11	28	420	2	47	A	10.81
CHCA	12	34	420	20	644	A	141.64
CHCA	13	35	420	3	42	A	5.78
CHCA	14	36	420	6	91	A	1.06
CHCA	15	37	420	3	34	A	29.08
CHCA	16	39	420	8	458	A	106.72

CHCA	17	40	420	5	49	A	3.32
CHCA	18	41	420	5	107	A	55.41
CHCA	19	42	420	14	358	A	26.22
CHCA	20	45	420	10	295	A	6.08
CHCA	21	46	420	16	1036	A	2.22
CHCA	22	55	420	6	674	E	184.03
CHCA	23	56	420	14	326	E	1.95
CHCA	24	57	420	16	435	A	2.59
CHCA	25	61	420	11	343	A	2.96
CHCA	26	62	420	18	353	A	69.25
CHCA	27	64	420	45	1037	A	4.57
CHCA	28	66	420	21	253	A	6.73
CHCA	29	70	420	2	49	E	1.69
CHCA	30	73	420	29	370	A	27.04
CHCA	31	78	420	23	670	A	152.95
CHCA	32	17b	420	5	49	A	0.71
CHCA	33	23a	420	17	278	E	2.61
CHCA	34	23b	420	16	435	A	1.77
CHCA	35	26b	420	2	7	A	0.03
CHCA	36	43a	420	9	282	E	62.83
CHCA	37	43b	420	2	21	A	3.23
CHCA	38	51a	420	6	91	E	4.92
CHCA	39	51b	420	15	336	A	0.90
CHCA	40	52a	420	2	54	E	0.34
CHCA	41	52b	420	13	454	A	197.85
CHCA	42	55b	420	8	70	A	67.72
CHCA	43	76a	420	15	253	E	5.20
CHCA	44	76b	420	19	435	A	2.45
CHCA	45	11	480	2	78	A	2.32
CHCA	46	58a	480	27	421	E	5.36
CHCA	47	58b	480	9	451	A	1.90
CHCA	48	59a	480	2	106	E	27.39
CHCA	49	59b	480	5	55	A	45.40
CHCA	50	69b	480	8	90	A	5.87
CHCA	51	71a	480	3	103	E	40.23
CHCA	52	71b	480	3	41	A	3.51
CHCA	53	12	480	2	78	A	7.31
CHCA	54	13	480	4	99	A	1.64
CHCA	55	14	480	12	352	A	8.77
CHCA	56	27	480	11	460	A	34.84
CHCA	57	31	480	2	70	A	3.32
CHCA	58	38	480	2	361	A	186.93

CHCA	59	40	480	17	1095	A	59.50
CHCA	60	42	480	39	1141	A	18.46
CHCA	61	43	480	46	1104	A	83.25
CHCA	62	45	480	55	1142	A	93.89
CHCA	63	48	480	5	129	A	2.72
CHCA	64	54	480	49	1063	A	4.80
CHCA	65	61	480	3	31	A	2.09
CHCA	66	63	480	2	41	A	95.43
CHCA	67	64	480	8	524	A	179.44
CHCA	68	65	480	6	142	A	11.02
CHCA	69	68	480	16	314	A	1.13
CHCA	70	69	480	2	96	E	42.63
CHCA	71	72	480	8	90	A	1.48
CHCA	72	73	480	6	337	A	217.81
CHCA	73	74	480	3	108	A	9.70
CHCA	74	77	480	33	652	A	217.81
CHCA	75	78	480	13	259	A	2.88
CHCA	76	22a	480	2	74	E	0.06
CHCA	77	22b	480	8	105	A	0.76
CHCA	78	24a	480	2	75	E	50.95
CHCA	79	24b	480	4	22	A	10.62
CHCA	80	26a	480	20	349	E	12.99
CHCA	81	26b	480	6	195	A	1.01
CHCA	82	55a	480	2	105	E	29.26
CHCA	83	55b	480	9	56	A	10.20
CHCA	84	56a	480	4	140	E	6.07
CHCA	85	56b	480	14	460	A	58.95
CHCA	86	11	600	12	336	A	0.03
CHCA	87	12	600	2	35	A	57.74
CHCA	88	13	600	6	84	A	1.43
CHCA	89	15	600	2	7	A	2.91
CHCA	90	16	600	9	303	A	3.81
CHCA	91	18	600	10	303	A	0.21
CHCA	92	19	600	6	88	A	111.16
CHCA	93	26	600	3	127	A	54.30
CHCA	94	27	600	4	33	E	1.74
CHCA	95	34	600	15	370	A	133.54
CHCA	96	39	600	10	337	A	66.48
CHCA	97	52	600	13	371	A	1.19
CHCA	98	53	600	2	21	A	0.05
CHCA	99	54	600	10	119	A	2.25
CHCA	100	55	600	16	373	A	0.93

CHCA	101	56	600	19	434	A	2.17
CHCA	102	57	600	10	373	A	7.71
CHCA	103	58	600	12	364	A	34.63
CHCA	104	59	600	11	404	A	33.47
CHCA	105	60	600	8	141	A	0.23

Appendix Table 5. Code, frequency, number of observations (*N* obs.), monitoring period (Mon. period), if the animal expelled the transmitter (Expel, A = active for entire monitoring period and E = expelled) and linear home range (LHR) for each telemetered Spiny Softshells (SPSO) monitored in the Yellowstone River from 2005–2009.

Sp.	Num.	Code	Freq.	*N* obs.	Mon. period	Expel	LHR
SPSO	1	102	480	4	376	A	0.9
SPSO	2	106	480	2	2	A	0.7
SPSO	3	107	480	18	317	A	26.2
SPSO	4	108	480	9	286	A	14.4
SPSO	5	109	480	8	244	A	3.9
SPSO	6	110	480	22	820	A	9.2
SPSO	7	111	480	12	372	A	15.9
SPSO	8	113	480	17	735	A	2.2
SPSO	9	116	480	15	622	A	0.6
SPSO	10	117	480	10	425	A	2.7
SPSO	11	118	480	4	54	A	36.6
SPSO	12	119	480	11	412	A	3.0
SPSO	13	120	480	11	412	A	1.0
SPSO	14	121	480	12	366	A	2.7
SPSO	15	122	480	11	431	A	0.8
SPSO	16	123	480	11	431	A	5.1
SPSO	17	124	480	14	616	A	8.9
SPSO	18	81	420	43	1167	A	2.3
SPSO	19	82	420	42	812	A	55.1
SPSO	20	83	420	36	733	A	6.3
SPSO	21	84	420	35	1034	A	6.2
SPSO	22	85	420	34	1147	A	11.8
SPSO	23	87	420	33	1085	A	3.6
SPSO	24	88	420	42	1065	A	14.8
SPSO	25	89	420	28	734	A	16.6
SPSO	26	91	420	17	340	A	2.3
SPSO	27	92	420	17	697	A	3.9
SPSO	28	93	420	22	453	A	2.4
SPSO	29	94	420	37	763	A	3.5
SPSO	30	95	420	31	1061	A	2.2

SPSO	31	96	420	26	762	A	12.8
SPSO	32	97	420	47	1109	A	32.3
SPSO	33	98	420	38	1043	A	7.0
SPSO	34	99	420	38	740	A	6.1
SPSO	35	100	420	21	705	A	4.7
SPSO	36	81	480	40	1106	A	3.5
SPSO	37	82	480	33	1102	A	60.4
SPSO	38	83	480	12	1050	A	102.0
SPSO	39	84	480	21	343	A	3.2
SPSO	40	85	480	41	1030	A	7.8
SPSO	41	86	480	35	1015	A	298.9
SPSO	42	87	480	34	1106	A	9.4
SPSO	43	88	480	34	1006	A	18.5
SPSO	44	89	480	44	1071	A	34.1
SPSO	45	90	480	6	69	A	0.9
SPSO	46	91	480	40	741	A	4.2
SPSO	47	92	480	11	176	A	1.5
SPSO	48	93	480	23	524	A	2.4
SPSO	49	94	480	18	398	A	9.5
SPSO	50	95	480	30	533	A	18.0
SPSO	51	96	480	40	982	A	8.5
SPSO	52	97	480	27	778	A	9.8
SPSO	53	98	480	36	1121	A	10.5
SPSO	54	99	480	29	448	A	16.6

Appendix Table 6. Summary of reaches, reach type I, reach type II, length (km), distance from confluence (Dist., km), braiding parameter (Braiding), and river complexity index per km (RCI/km) within the Yellowstone River study site from the Clark's Fork of the Yellowstone (A18) to the confluence with the Missouri River (D16). For type I: CM = confined meandering, CM = confined straight, PCA = partially confined anabranching, PCB = partially confined braided, PCM = partially confined meandering, PCM/I = partially confined meandering with islands, PCS = partially confined straight, UA = unconfined anabranching, UB = unconfined braided, US/I = unconfined straight with islands. For type II: P = partially confined, U = unconfined, and C = confined. Adapted from Table A-1 and B-2 from Boyd and Thatcher (2007).

Reach	Type I	Type II	Length	Dist.	Braiding	RCI/km
A16	P	PCA	12.5	644.5	2.9	5.7
A17	U	UA	10.5	632.0	2.8	5.5
A18	U	UA	3.8	621.5	3.3	8.0
B1	U	UB	25.0	617.7	2.4	3.7
B2	P	PCB	9.9	592.7	2.2	3.9
B3	U	UB	7.0	582.8	2.9	4.0
B4	P	PCS	6.1	575.8	1.8	1.7
B5	U	UA	12.1	569.7	3.5	8.3
B6	P	PCB	10.0	557.6	2.5	3.5
B7	U	UB	14.0	547.6	2.8	4.3
B8	P	PCA	14.4	533.6	3.0	4.3
B9	U	UA	7.5	519.2	3.4	7.5
B10	P	PCM	11.5	511.7	2.6	5.4
B11	P	PCA	12.9	500.2	3.1	4.9
B12	U	UA	7.2	487.3	3.5	6.6
C1	U	UA	9.5	480.1	3.0	5.5
C2	P	PCB	8.9	470.6	2.6	3.4
C3	U	UA	7.5	461.7	2.9	5.6
C4	P	PCB	5.9	454.2	1.7	2.5
C5	P	PCS	5.1	448.3	2.0	2.4
C6	U	UA	9.1	443.2	2.0	3.5
C7	U	UA	15.3	434.1	3.2	7.6
C8	P	PCS	10.5	418.8	2.1	2.9
C9	U	UA	19.1	408.3	2.3	3.2
C10	P	PCM	11.0	389.2	1.8	2.0
C11	P	PCM/I	18.8	378.2	2.1	3.6
C12	P	PCM/I	16.1	359.4	1.9	2.8
C13	P	PCM/I	10.8	343.3	1.9	2.2
C14	P	PCM/I	19.6	332.5	1.9	3.0
C15	P	PCS	6.0	312.9	1.7	1.4
C16	P	PCM/I	11.6	306.9	2.6	3.7

C17	P	PCS	7.1	295.3	2.1	2.2
C18	P	PCS	5.2	288.2	1.1	0.6
C19	C	CS	17.9	283.0	1.4	0.8
C20	C	CS	12.2	265.1	1.8	2.0
C21	C	CM	15.3	252.9	1.9	2.2
D1	C	CM	19.5	237.6	1.6	2.4
D2	C	CM	17.0	218.1	1.1	0.3
D3	P	PCS	13.3	201.1	1.6	1.0
D4	P	PCM/I	17.7	187.8	2.3	2.9
D5	P	PCA	18.2	170.1	3.3	5.3
D6	P	PCM/I	9.0	151.9	2.2	2.7
D7	P	PCA	12.2	142.9	3.3	5.1
D8	P	PCA	16.4	130.7	2.6	4.4
D9	P	PCM/I	5.6	114.3	2.5	3.8
D10	P	PCA	18.6	108.7	3.0	4.3
D11	P	PCA	10.4	90.1	3.5	6.7
D12	P	PCA	21.6	79.7	2.9	4.0
D13	P	PCM/I	13.5	58.1	2.3	2.6
D14	P	PCM/I	23.1	44.6	2.1	2.3
D15	P	PCM/I	9.5	21.5	2.3	2.1
D16	U	US/I	12.0	12.0	2.6	2.8

Appendix Table 7. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for overall geomorphic reach types used by all telemetered species in the Yellowstone River from 2005–2009. C = confined, P = partially confined, and U = unconfined reaches.

Species	Reach type II	% Avail.	% Used	Ratio	SE	LCI	UCI
BLSU	C	0.17	0.21	1.25	0.30	0.53	1.98
	P	0.68	0.73	1.08	0.07	0.91	1.26
	U	0.15	0.05	0.34	0.09	0.14	0.55
BURB	C	0.13	0.04	0.35	0.14	0.01	0.69
	P	0.63	0.70	1.11	0.08	0.93	1.29
	U	0.25	0.26	1.05	0.19	0.59	1.51
CHCA	C	0.14	0.08	0.59	0.16	0.20	0.97
	P	0.67	0.67	0.99	0.07	0.83	1.16
	U	0.19	0.25	1.34	0.23	0.79	1.89
SHST	C	0.22	0.29	1.33	0.28	0.67	1.99
	P	0.75	0.71	0.94	0.08	0.75	1.13
	U	0.03	0.00	0.10	0.06	-0.04	0.24
SPSO	C	0.15	0.10	0.67	0.33	-0.11	1.46
	P	0.61	0.65	1.07	0.11	0.80	1.34
	U	0.24	0.25	1.02	0.24	0.44	1.60

Appendix Table 8. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for reach type I used by telemetered Blue Suckers in the Yellowstone River from the Clark's Fork of the Yellowstone to the confluence with the Missouri River from 2005–2009.

Season	Reach type I	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	C	0.17	0.17	0.97	0.71	-0.73	2.68
	P	0.68	0.75	1.11	0.19	0.66	1.55
	U	0.15	0.08	0.55	0.41	-0.43	1.54
Runoff	C	0.17	0.29	1.69	0.43	0.65	2.73
	P	0.68	0.70	1.03	0.11	0.77	1.29
	U	0.15	0.01	0.08	0.08	-0.11	0.27
Summer	C	0.17	0.24	1.38	0.36	0.53	2.24
	P	0.68	0.71	1.04	0.09	0.83	1.25
	U	0.15	0.06	0.38	0.16	0.00	0.76
Winter	C	0.17	0.16	0.93	0.30	0.22	1.64
	P	0.68	0.72	1.07	0.10	0.82	1.32
	U	0.15	0.12	0.77	0.28	0.10	1.43
Spawning	C	0.17	0.14	0.82	0.30	0.11	1.54
	P	0.68	0.84	1.23	0.07	1.06	1.41
	U	0.15	0.02	0.15	0.08	-0.04	0.34

Appendix Table 9. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for overall geomorphic reach type II used by telemetered species in the Yellowstone River from 2005–2009. CM = confined meandering, CM = confined straight, PCA = partially confined anabranching, PCB = partially confined braided, PCM = partially confined meandering, PCM/I = partially confined meandering with islands, PCS = partially confined straight, UA = unconfined anabranching, and UB = unconfined braided.

Species	Reach Type II	% Avail.	% Used	Ratio	SE	LCI	UCI
BLSU	CM	0.11	0.14	1.25	0.33	0.33	2.17
	CS	0.06	0.08	1.33	0.62	-0.39	3.04
	PCA	0.20	0.27	1.32	0.25	0.62	2.02
	PCB	0.03	0.00	0.09	0.07	-0.09	0.28
	PCM	0.02	0.03	1.49	1.00	-1.27	4.25
	PCM/I	0.32	0.35	1.07	0.15	0.67	1.48
	PCS	0.10	0.10	1.02	0.28	0.24	1.81
	UA	0.13	0.03	0.23	0.10	-0.06	0.52
	UB	0.02	0.00	0.00	0.00	0.00	0.00
BURB	CM	0.08	0.04	0.49	0.22	-0.13	1.10
	CS	0.05	0.00	0.10	0.05	-0.04	0.23
	PCA	0.21	0.23	1.06	0.16	0.60	1.53
	PCB	0.05	0.01	0.25	0.14	-0.14	0.63
	PCM	0.03	0.10	3.23	0.91	0.68	5.79
	PCM/I	0.24	0.24	0.99	0.16	0.55	1.42
	PCS	0.08	0.12	1.49	0.31	0.63	2.34
	UA	0.16	0.10	0.65	0.16	0.20	1.10
	UB	0.07	0.15	2.13	0.60	0.44	3.83
	US/I	0.02	0.00	0.24	0.20	-0.31	0.79
CHCA	CM	0.09	0.07	0.83	0.23	0.18	1.48
	CS	0.05	0.01	0.17	0.13	-0.21	0.54
	PCA	0.21	0.28	1.34	0.25	0.65	2.03
	PCB	0.06	0.03	0.52	0.20	-0.03	1.08
	PCM	0.04	0.02	0.43	0.27	-0.32	1.19
	PCM/I	0.27	0.26	0.97	0.20	0.42	1.52
	PCS	0.09	0.08	0.84	0.20	0.28	1.40
	UA	0.15	0.15	0.99	0.23	0.36	1.63
	UB	0.04	0.10	2.51	0.71	0.53	4.48
SHST	CM	0.14	0.29	2.08	0.44	0.92	3.25
	CS	0.08	0.02	0.24	0.10	-0.03	0.51

	PCA	0.26	0.21	0.82	0.22	0.25	1.40
	PCM/I	0.41	0.38	0.92	0.16	0.50	1.33
	PCS	0.08	0.10	1.19	0.33	0.33	2.05
	US/I	0.03	0.00	0.11	0.07	-0.07	0.29
SPSO	CM	0.09	0.05	0.53	0.37	-0.51	1.56
	CS	0.05	0.05	0.97	0.68	-0.92	2.86
	PCA	0.22	0.26	1.15	0.27	0.41	1.89
	PCB	0.06	0.01	0.20	0.11	-0.10	0.50
	PCM	0.04	0.02	0.43	0.32	-0.46	1.33
	PCM/I	0.19	0.26	1.35	0.30	0.50	2.19
	PCS	0.09	0.11	1.15	0.48	-0.17	2.47
	UA	0.16	0.19	1.14	0.34	0.20	2.08
	UB	0.08	0.06	0.76	0.29	-0.03	1.56

Appendix Table 10. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for seasonal geomorphic reach types used by telemetered Blue Suckers in the Yellowstone River from 2005–2009. CM = confined meandering, CM = confined straight, PCA = partially confined anabranching, PCB = partially confined braided, PCM = partially confined meandering, PCM/I = partially confined meandering with islands, PCS = partially confined straight, UA = unconfined anabranching, and UB = unconfined braided.

Season	Reach type	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	CM	0.11	0.05	0.41	0.39	-0.68	1.50
	CS	0.06	0.14	2.25	1.51	-1.92	6.42
	PCA	0.20	0.18	0.90	0.49	-0.46	2.26
	PCB	0.03	0.00	0.00	0.00	0.00	0.00
	PCM	0.02	0.05	2.25	1.90	-3.02	7.52
	PCM/I	0.32	0.50	1.55	0.59	-0.09	3.19
	PCS	0.10	0.09	0.90	0.91	-1.63	3.43
	UA	0.13	0.00	0.00	0.00	0.00	0.00
	UB	0.02	0.00	0.00	0.00	0.00	0.00
Runoff	CM	0.11	0.05	0.41	0.39	-0.68	1.50
	CS	0.06	0.14	2.25	1.51	-1.92	6.42
	PCA	0.20	0.18	0.90	0.49	-0.46	2.26
	PCB	0.03	0.00	0.00	0.00	0.00	0.00
	PCM	0.02	0.05	2.25	1.90	-3.02	7.52
	PCM/I	0.32	0.50	1.55	0.59	-0.09	3.19
	PCS	0.10	0.09	0.90	0.91	-1.63	3.43
	UA	0.13	0.00	0.00	0.00	0.00	0.00
	UB	0.02	0.00	0.00	0.00	0.00	0.00
Summer	CM	0.11	0.15	1.33	0.41	0.20	2.46
	CS	0.06	0.09	1.49	0.69	-0.42	3.40
	PCA	0.20	0.24	1.17	0.27	0.41	1.93
	PCB	0.03	0.01	0.17	0.12	-0.15	0.49
	PCM	0.02	0.03	1.61	1.01	-1.19	4.42
	PCM/I	0.32	0.32	0.98	0.16	0.55	1.41
	PCS	0.10	0.12	1.22	0.30	0.40	2.03
	UA	0.13	0.05	0.38	0.18	-0.12	0.88
	UB	0.02	0.00	0.00	0.00	0.00	0.00
Winter	CM	0.11	0.10	0.89	0.47	-0.41	2.18
	CS	0.06	0.08	1.35	0.57	-0.22	2.92
	PCA	0.20	0.15	0.73	0.24	0.07	1.39

	PCB	0.03	0.00	0.00	0.00	0.00	0.00
	PCM	0.02	0.00	0.00	0.00	0.00	0.00
	PCM/I	0.32	0.52	1.62	0.32	0.73	2.52
	PCS	0.10	0.15	1.46	0.80	-0.75	3.67
	UA	0.13	0.00	0.00	0.00	0.00	0.00
	UB	0.02	0.00	0.00	0.00	0.00	0.00
Spawning	CM	0.11	0.10	0.88	0.29	0.08	1.68
	CS	0.06	0.05	0.74	0.74	-1.31	2.80
	PCA	0.20	0.40	1.97	0.35	1.01	2.94
	PCB	0.03	0.00	0.00	0.00	0.00	0.00
	PCM	0.02	0.03	1.49	1.46	-2.55	5.53
	PCM/I	0.32	0.36	1.12	0.17	0.64	1.59
	PCS	0.10	0.06	0.60	0.27	-0.17	1.36
	UA	0.13	0.01	0.06	0.06	-0.10	0.21
	UB	0.02	0.00	0.00	0.00	0.00	0.00

Appendix Table 11. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for geomorphic reach type I used by telemetered Shovelnose in the Yellowstone River from 2005–2009. For reach type II: C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches.

Season	Reach type I	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	C	0.22	0.33	1.53	0.33	0.75	2.32
	P	0.75	0.66	0.88	0.09	0.66	1.11
	U	0.03	0.00	0.14	0.14	-0.20	0.49
Runoff	C	0.22	0.30	1.38	0.37	0.50	2.26
	P	0.75	0.69	0.92	0.11	0.67	1.18
	U	0.03	0.01	0.25	0.25	-0.34	0.84
Summer	C	0.22	0.23	1.06	0.26	0.43	1.69
	P	0.75	0.77	1.02	0.08	0.84	1.21
	U	0.03	0.00	0.00	0.00	0.00	0.00
Winter	C	0.22	0.36	1.67	0.35	0.83	2.52
	P	0.75	0.63	0.84	0.10	0.60	1.08
	U	0.03	0.01	0.26	0.26	-0.36	0.88
Spawning	C	0.22	0.29	1.32	0.33	0.53	2.10
	P	0.75	0.71	0.95	0.09	0.73	1.18

U	0.03	0.00	0.00	0.00	0.00	0.00

Appendix Table 12. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for seasonal geomorphic reach type II used by telemetered Shovelnose Sturgeon in the Yellowstone River from 2005–2009. CM = confined meandering, CS = confined straight, PCA = partially confined anabranching, PCM/I = partially confined meandering with islands, PCS = partially confined straight, and US/I = unconfined straight with islands.

Season	Reach type	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	CM	0.14	0.33	2.33	0.55	0.88	3.78
	CS	0.08	0.04	0.50	0.25	-0.16	1.17
	PCA	0.26	0.17	0.64	0.21	0.10	1.18
	PCM/I	0.41	0.37	0.89	0.18	0.43	1.36
	PCS	0.08	0.10	1.19	0.48	-0.08	2.47
	US/I	0.03	0.01	0.17	0.17	-0.28	0.62
Runoff	CM	0.14	0.30	2.15	0.58	0.62	3.68
	CS	0.08	0.01	0.10	0.10	-0.17	0.37
	PCA	0.26	0.24	0.91	0.30	0.13	1.69
	PCM/I	0.41	0.38	0.93	0.18	0.45	1.42
	PCS	0.08	0.07	0.81	0.33	-0.07	1.70
	US/I	0.03	0.01	0.27	0.27	-0.44	0.99
Summer	CM	0.14	0.24	1.70	0.43	0.56	2.84
	CS	0.08	0.01	0.15	0.12	-0.17	0.46
	PCA	0.26	0.27	1.03	0.24	0.40	1.66
	PCM/I	0.41	0.36	0.88	0.16	0.45	1.30
	PCS	0.08	0.12	1.54	0.52	0.16	2.93
	US/I	0.03	0.00	0.00	0.00	0.00	0.00
Winter	CM	0.14	0.38	2.69	0.58	1.18	4.21
	CS	0.08	0.02	0.23	0.18	-0.25	0.70
	PCA	0.26	0.17	0.66	0.25	0.00	1.33
	PCM/I	0.41	0.33	0.81	0.19	0.30	1.32
	PCS	0.08	0.09	1.14	0.40	0.08	2.19
	US/I	0.03	0.01	0.30	0.30	-0.49	1.10
Spawning	CM	0.14	0.28	1.97	0.52	0.61	3.33
	CS	0.08	0.02	0.29	0.15	-0.10	0.67
	PCA	0.26	0.18	0.71	0.22	0.11	1.30
	PCM/I	0.41	0.46	1.12	0.18	0.65	1.59
	PCS	0.08	0.06	0.75	0.25	0.10	1.39
	US/I	0.03	0.00	0.00	0.00	0.00	0.00

Appendix Table 13. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for geomorphic reach types used by telemetered Burbot in the Yellowstone River from 2005–2009. For reach type II: C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches.

Season	Reach type I	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	C	0.13	0.06	0.44	0.19	-0.01	0.89
	P	0.63	0.74	1.19	0.07	1.02	1.36
	U	0.25	0.20	0.81	0.17	0.41	1.21
Runoff	C	0.13	0.03	0.23	0.12	-0.06	0.53
	P	0.63	0.77	1.23	0.07	1.06	1.39
	U	0.25	0.20	0.82	0.17	0.42	1.23
Summer	C	0.13	0.02	0.17	0.09	-0.04	0.37
	P	0.63	0.55	0.89	0.13	0.58	1.19
	U	0.25	0.43	1.72	0.33	0.94	2.49
Winter	C	0.13	0.05	0.40	0.19	-0.06	0.86
	P	0.63	0.63	1.01	0.09	0.78	1.23
	U	0.25	0.32	1.29	0.24	0.72	1.86
Spawning	C	0.13	0.15	1.19	0.55	-0.12	2.50
	P	0.63	0.66	1.06	0.13	0.74	1.38
	U	0.25	0.19	0.76	0.26	0.13	1.39

Appendix Table 14. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for seasonal geomorphic reach type II used by telemetered Burbot in the Yellowstone River from 2005–2009. CM = confined meandering, CM = confined straight, PCA = partially confined anabranching, PCB = partially confined braided, PCM = partially confined meandering, PCM/I = partially confined meandering with islands, PCS = partially confined straight, UA = unconfined anabranching, UB = unconfined braided, and US/I = unconfined straight with islands.

Season	Reach type	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	CM	0.08	0.04	0.55	0.28	-0.23	1.34
	CS	0.05	0.01	0.22	0.16	-0.24	0.68
	PCA	0.21	0.23	1.07	0.19	0.54	1.60
	PCB	0.05	0.01	0.30	0.21	-0.29	0.88
	PCM	0.03	0.09	3.08	0.91	0.53	5.62
	PCM/I	0.24	0.27	1.11	0.19	0.57	1.65
	PCS	0.08	0.14	1.71	0.45	0.45	2.97
	UA	0.16	0.08	0.48	0.14	0.10	0.87
	UB	0.07	0.12	1.74	0.47	0.42	3.06
	US/I	0.02	0.00	0.00	0.00	0.00	0.00
Runoff	CM	0.08	0.03	0.36	0.19	-0.18	0.91
	CS	0.05	0.00	0.00	0.00	0.00	0.00
	PCA	0.21	0.25	1.18	0.21	0.59	1.76
	PCB	0.05	0.01	0.21	0.21	-0.38	0.81
	PCM	0.03	0.12	4.07	1.28	0.47	7.67
	PCM/I	0.24	0.24	1.00	0.17	0.51	1.48
	PCS	0.08	0.14	1.76	0.41	0.60	2.92
	UA	0.16	0.11	0.68	0.20	0.11	1.25
	UB	0.07	0.09	1.33	0.42	0.15	2.50
	US/I	0.02	0.00	0.00	0.00	0.00	0.00
Summer	CM	0.08	0.02	0.20	0.12	-0.13	0.52
	CS	0.05	0.01	0.11	0.11	-0.19	0.40
	PCA	0.21	0.22	1.05	0.24	0.38	1.73
	PCB	0.05	0.00	0.00	0.00	0.00	0.00
	PCM	0.03	0.09	2.81	1.17	-0.48	6.10
	PCM/I	0.24	0.15	0.61	0.18	0.11	1.12
	PCS	0.08	0.10	1.18	0.40	0.07	2.30
	UA	0.16	0.06	0.39	0.16	-0.06	0.85
	UB	0.07	0.34	4.74	1.20	1.36	8.12
	US/I	0.02	0.03	1.32	1.08	-1.71	4.34

Winter	CM	0.08	0.05	0.62	0.30	-0.23	1.47
	CS	0.05	0.00	0.00	0.00	0.00	0.00
	PCA	0.21	0.17	0.80	0.21	0.22	1.38
	PCB	0.05	0.03	0.50	0.35	-0.48	1.47
	PCM	0.03	0.09	2.91	1.01	0.08	5.73
	PCM/I	0.24	0.28	1.17	0.23	0.52	1.82
	PCS	0.08	0.06	0.78	0.25	0.07	1.49
	UA	0.16	0.17	1.05	0.27	0.30	1.80
	UB	0.07	0.15	2.13	0.70	0.17	4.10
	US/I	0.02	0.00	0.00	0.00	0.00	0.00
Spawning	CM	0.08	0.13	1.63	0.78	-0.56	3.83
	CS	0.05	0.02	0.37	0.37	-0.67	1.41
	PCA	0.21	0.23	1.07	0.34	0.11	2.02
	PCB	0.05	0.02	0.37	0.38	-0.69	1.43
	PCM	0.03	0.02	0.62	0.63	-1.15	2.39
	PCM/I	0.24	0.26	1.09	0.29	0.29	1.89
	PCS	0.08	0.13	1.63	0.73	-0.40	3.67
	UA	0.16	0.15	0.93	0.38	-0.12	1.99
	UB	0.07	0.04	0.53	0.38	-0.53	1.60
	US/I	0.02	0.00	0.00	0.00	0.00	0.00

Appendix Table 15. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for geomorphic reach type I used by telemetered Channel Catfish in the Yellowstone River from 2005–2009. For reach type II: C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches.

Season	Reach type II	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	C	0.14	0.08	0.59	0.19	0.13	1.05
	P	0.67	0.66	0.98	0.08	0.79	1.16
	U	0.19	0.26	1.40	0.26	0.77	2.02
Runoff	C	0.14	0.09	0.61	0.20	0.12	1.10
	P	0.67	0.63	0.93	0.09	0.73	1.14
	U	0.19	0.29	1.54	0.30	0.82	2.26
Summer	C	0.14	0.09	0.66	0.22	0.14	1.18
	P	0.67	0.74	1.10	0.07	0.93	1.27
	U	0.19	0.17	0.90	0.19	0.44	1.36
Winter	C	0.14	0.08	0.59	0.23	0.04	1.14
	P	0.67	0.64	0.95	0.09	0.75	1.16
	U	0.19	0.28	1.49	0.28	0.81	2.17
Spawning	C	0.14	0.07	0.53	0.22	0.00	1.05
	P	0.67	0.70	1.04	0.09	0.83	1.25
	U	0.19	0.23	1.21	0.29	0.52	1.91

Appendix Table 16. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for seasonal geomorphic reach type II used by telemetered Channel Catfish in the Yellowstone River from 2005–2009. CM = confined meandering, CM = confined straight, PCA = partially confined anabranching, PCB = partially confined braided, PCM = partially confined meandering, PCM/I = partially confined meandering with islands, PCS = partially confined straight, UA = unconfined anabranching, and UB = unconfined braided.

Season	Reach type	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	CM	0.09	0.08	0.93	0.30	0.08	1.77
	CS	0.05	0.00	0.00	0.00	0.00	0.00
	PCA	0.21	0.26	1.26	0.28	0.48	2.04
	PCB	0.06	0.01	0.25	0.14	-0.15	0.64
	PCM	0.04	0.00	0.12	0.12	-0.22	0.47
	PCM/I	0.27	0.26	0.98	0.21	0.39	1.57
	PCS	0.09	0.11	1.20	0.38	0.15	2.24
	UA	0.15	0.15	0.98	0.25	0.29	1.67
	UB	0.04	0.11	2.82	0.88	0.39	5.25
Runoff	CM	0.09	0.07	0.76	0.29	-0.04	1.56
	CS	0.05	0.02	0.34	0.21	-0.24	0.92
	PCA	0.21	0.28	1.34	0.27	0.61	2.08
	PCB	0.06	0.05	0.85	0.45	-0.39	2.10
	PCM	0.04	0.03	0.64	0.54	-0.86	2.14
	PCM/I	0.27	0.23	0.85	0.20	0.31	1.40
	PCS	0.09	0.04	0.43	0.17	-0.04	0.89
	UA	0.15	0.18	1.23	0.31	0.35	2.10
	UB	0.04	0.10	2.56	0.93	-0.02	5.15
Summer	CM	0.09	0.09	0.97	0.33	0.04	1.89
	CS	0.05	0.01	0.12	0.13	-0.22	0.47
	PCA	0.21	0.29	1.36	0.30	0.54	2.18
	PCB	0.06	0.02	0.41	0.25	-0.29	1.12
	PCM	0.04	0.01	0.31	0.22	-0.30	0.93
	PCM/I	0.27	0.37	1.38	0.25	0.69	2.08
	PCS	0.09	0.04	0.48	0.23	-0.15	1.12
	UA	0.15	0.09	0.62	0.17	0.14	1.10
	UB	0.04	0.07	1.86	0.59	0.22	3.51
Winter	CM	0.09	0.08	0.85	0.35	-0.12	1.83
	CS	0.05	0.01	0.12	0.12	-0.22	0.47
	PCA	0.21	0.27	1.30	0.29	0.50	2.11

	PCB	0.06	0.03	0.56	0.28	-0.21	1.34
	PCM	0.04	0.02	0.62	0.47	-0.69	1.92
	PCM/I	0.27	0.21	0.77	0.20	0.23	1.32
	PCS	0.09	0.10	1.09	0.32	0.20	1.99
	UA	0.15	0.14	0.94	0.29	0.13	1.75
	UB	0.04	0.14	3.38	0.94	0.77	6.00
Spawning	CM	0.09	0.06	0.71	0.32	-0.18	1.60
	CS	0.05	0.01	0.21	0.21	-0.38	0.80
	PCA	0.21	0.30	1.43	0.31	0.57	2.29
	PCB	0.06	0.03	0.47	0.30	-0.36	1.30
	PCM	0.04	0.01	0.35	0.35	-0.63	1.34
	PCM/I	0.27	0.28	1.05	0.25	0.36	1.73
	PCS	0.09	0.07	0.82	0.28	0.05	1.59
	UA	0.15	0.16	1.08	0.31	0.23	1.93
	UB	0.04	0.06	1.59	0.79	-0.60	3.78

Appendix Table 17. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for geomorphic reach types used by telemetered Spiny Softshells in the Yellowstone River from 2005–2009. For reach type I: C (closed rectangles) = confined, P (closed circles) = partially confined, and U (closed triangles) = unconfined reaches. The dashed line represents a selection ratio of 1 (i.e., no preference), values less than zero indicate a reach is used less than expected (avoidance), and values greater than zero indicate a reach is used more than expected (preference). Error bars describe 90% Bonferroni confidence intervals.

Season	Reach type I	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	C	0.15	0.10	0.69	0.35	-0.14	1.5179
	P	0.61	0.69	1.13	0.12	0.84	1.4088
	U	0.24	0.21	0.87	0.24	0.30	1.4454
Runoff	C	0.15	0.10	0.69	0.42	-0.32	1.70
	P	0.61	0.67	1.10	0.14	0.77	1.42
	U	0.24	0.23	0.95	0.29	0.25	1.64
Summer	C	0.15	0.11	0.74	0.35	-0.10	1.59
	P	0.61	0.65	1.06	0.11	0.79	1.33
	U	0.24	0.24	1.00	0.23	0.44	1.55
Winter	C	0.15	0.09	0.65	0.31	-0.10	1.39

	P	0.61	0.64	1.05	0.12	0.77	1.33
	U	0.24	0.27	1.09	0.26	0.46	1.72
Spawning	C	0.15	0.07	0.49	0.26	-0.14	1.12
	P	0.61	0.63	1.03	0.13	0.71	1.35
	U	0.24	0.30	1.22	0.33	0.45	2.00

Appendix Table 18. Length, percent available (% Avail.) and used, selection ratio, standard error for selection ratio, and lower and upper confidence intervals on the selection ratio for seasonal geomorphic reach type II used by telemetered Spiny Softshells in the Yellowstone River from 2005–2009. CM = confined meandering, CM = confined straight, PCA = partially confined anabranching, PCB = partially confined braided, PCM = partially confined meandering, PCM/I = partially confined meandering with islands, PCS = partially confined straight, UA = unconfined anabranching, and UB = unconfined braided.

Season	Reach type	% Avail.	% Used	Ratio	SE	LCI	UCI
Spring	CM	0.09	0.05	0.58	0.42	-0.59	1.75
	CS	0.05	0.05	0.92	0.67	-0.92	2.77
	PCA	0.22	0.25	1.10	0.29	0.29	1.92
	PCB	0.06	0.01	0.19	0.14	-0.19	0.58
	PCM	0.04	0.03	0.72	0.70	-1.23	2.67
	PCM/I	0.19	0.29	1.52	0.37	0.50	2.54
	PCS	0.09	0.11	1.15	0.60	-0.51	2.81
	UA	0.16	0.17	1.04	0.34	0.10	1.99
	UB	0.08	0.04	0.50	0.20	-0.06	1.07
Runoff	CM	0.09	0.05	0.54	0.53	-0.93	2.02
	CS	0.05	0.05	0.98	0.80	-1.23	3.19
	PCA	0.22	0.25	1.11	0.33	0.20	2.03
	PCB	0.06	0.03	0.49	0.37	-0.53	1.51
	PCM	0.04	0.04	0.98	0.74	-1.07	3.03
	PCM/I	0.19	0.27	1.39	0.40	0.28	2.50
	PCS	0.09	0.08	0.87	0.48	-0.46	2.20
	UA	0.16	0.20	1.23	0.42	0.07	2.38
	UB	0.08	0.03	0.37	0.28	-0.40	1.13
Summer	CM	0.09	0.06	0.60	0.42	-0.56	1.76
	CS	0.05	0.05	1.03	0.72	-0.96	3.03
	PCA	0.22	0.27	1.22	0.28	0.44	2.00
	PCB	0.06	0.01	0.20	0.12	-0.13	0.52

	PCM	0.04	0.01	0.24	0.16	-0.22	0.69
	PCM/I	0.19	0.25	1.30	0.30	0.47	2.13
	PCS	0.09	0.10	1.12	0.44	-0.10	2.35
	UA	0.16	0.16	0.95	0.30	0.13	1.78
	UB	0.08	0.09	1.06	0.41	-0.08	2.20
Winter	CM	0.09	0.05	0.53	0.37	-0.50	1.56
	CS	0.05	0.04	0.88	0.62	-0.83	2.59
	PCA	0.22	0.22	1.00	0.28	0.22	1.78
	PCB	0.06	0.01	0.13	0.13	-0.24	0.51
	PCM	0.04	0.00	0.00	0.00	0.00	0.00
	PCM/I	0.19	0.28	1.43	0.36	0.42	2.44
	PCS	0.09	0.13	1.42	0.55	-0.11	2.95
	UA	0.16	0.21	1.28	0.37	0.25	2.30
	UB	0.08	0.06	0.70	0.32	-0.18	1.58
Spawning	CM	0.09	0.02	0.23	0.18	-0.26	0.72
	CS	0.05	0.05	0.97	0.69	-0.94	2.88
	PCA	0.22	0.28	1.26	0.32	0.39	2.14
	PCB	0.06	0.01	0.12	0.12	-0.21	0.44
	PCM	0.04	0.04	1.04	0.76	-1.06	3.15
	PCM/I	0.19	0.21	1.10	0.32	0.20	2.00
	PCS	0.09	0.09	0.93	0.48	-0.42	2.27
	UA	0.16	0.25	1.52	0.48	0.19	2.85
	UB	0.08	0.05	0.61	0.27	-0.14	1.36

Appendix Table 19. Number of aggregations by year and total by species in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered animals present on the same day.

	2005	2006	2007	2008	2009	Total
BLSU	10	11	3	7		31
BURB		22	11	23	1	57
CHCA	13	4	1	1		19
SHST	20	12	14	7		53
SPSO	13	22	7	1		43
Pooled	56	71	36	39	1	203

Appendix Table 20. Number of aggregations by month and total by species in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered animals present on the same day.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

BLSU					1	7	7	5	2	9		
BRBT	5	2	3	13	13	6	6	5		3		1
CHCA	2	1	1			2	7	3	2			1
SHST	1	1	1	6	8	4	7	3	6	9	7	
SPSO	4	2	3	5	3	2	4	4	4	10	2	
Pooled	12	6	8	24	25	21	31	20	14	31	9	2

Appendix Table 21. Minimum, mean, and maximum number in aggregation and length of reach inhabited by aggregation by species in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered animals present on the same day.

		Number in aggregation			Length of reach		
	N	Min	Mean	Max	Min	Mean	Max
BLSU	31	3	3.23	5	0	0.01	0.37
BURB	57	3	3.58	8	0	0.37	1
CHCA	19	3	3.05	4	0	0.25	1
SHST	53	3	3.28	5	0	0.37	1
SPSO	43	3	3.26	5	0	0.15	0.59

Appendix Table 22. Aggregations of Blue Suckers in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered Blue Suckers present on the same day. Spawning denotes if an aggregation occurred during the potential spawning period.

Date	RKM	Number in Aggregation	Length of Reach	During spawning
7/7/05	293.88	3	0	
7/11/05	353.93	3	0	
7/19/05	69.41	3	0	
8/2/05	225.20	4	0	
8/3/05	310.55	3	0	
8/8/05	138.60	3	0	
8/8/05	128.61	3	0	
10/6/05	0.80	4	0	
10/13/05	0.80	3	0	
10/17/05	0.80	3	0	
6/10/06	0.80	3	0	Y
6/15/06	114.56	3	0	Y
6/18/06	114.56	4	0	Y
7/11/06	236.52	3	0	
8/11/06	0.80	3	0	
9/5/06	305.11	3	0.03	
9/27/06	0.80	3	0	
10/11/06	236.52	4	0	
10/11/06	114.56	3	0	
10/12/06	114.56	3	0	
10/16/06	0.80	3	0	
5/12/07	0.80	3	0	Y
10/4/07	236.04	3	0	
10/9/07	0.80	4	0	
6/11/08	115.04	3	0	Y
6/12/08	115.04	3	0	Y
6/19/08	115.04	3	0	Y
6/29/08	115.04	3	0	Y
7/1/08	115.04	5	0.37	Y
7/3/08	114.38	3	0.01	Y
7/4/08	115.04	3	0	Y

Appendix Table 23. Aggregations of Shovelnose Sturgeon in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered Shovelnose Sturgeon present on the same day. Spawning denotes if an aggregation occurred during the potential spawning period.

Date	RKM	Number in Aggregation	Length of Reach	During spawning
6/13/05	204.1	3	0	Y
7/7/05	293.95	3	0	
7/11/05	354.01	3	0	
7/27/05	191.51	3	0	
8/2/05	225.24	3	0	
8/8/05	128.63	3	0	
9/19/05	375.52	4	0.32	
9/28/05	195.45	4	0.65	
10/4/05	41.07	3	0.18	
10/7/05	373.96	5	0.93	
10/12/05	195.31	3	0.02	
10/20/05	374.06	3	0.11	
10/20/05	375.44	3	0.03	
11/2/05	374.04	3	0.07	
11/2/05	375.43	3	0.05	
11/7/05	195.33	3	0.06	
11/8/05	40.67	3	0.32	
11/23/05	374.12	3	0.08	
11/23/05	375.49	3	0.03	
11/25/05	226.6	3	0.21	
1/4/06	374.03	4	0.14	
2/24/06	236.57	3	0	
3/22/06	373.72	4	0.28	
4/25/06	377.79	3	0.86	
5/10/06	44.05	3	0.38	
5/17/06	236.57	3	0	Y
5/19/06	236.57	3	0	Y
5/24/06	293.67	3	0.84	Y
6/9/06	294.51	4	0	Y
6/13/06	235.85	4	0.28	Y
9/5/06	375.4	3	0.27	
10/3/06	232.47	3	0.11	
4/4/07	201.43	4	0.58	
4/23/07	375.27	4	0.88	
5/8/07	202.25	4	0.70	
5/10/07	236.09	4	0	
5/23/07	43.85	3	0.09	Y

6/6/07	225.87	3	0.90	Y
7/23/07	26.52	3	0.44	
8/28/07	374.85	4	0.98	
9/10/07	374.49	4	0.95	
9/25/07	226.68	3	0.40	
9/25/07	375.01	4	0.74	
10/10/07	202.79	3	1.00	
10/10/07	374.04	3	0.01	
10/10/07	375.6	3	0.92	
4/8/08	375.85	3	0.49	
4/9/08	202.5	3	1.00	
4/17/08	202.2	3	0.67	
5/21/08	43.97	3	0.51	Y
7/2/08	45.75	3	0.18	
7/7/08	46.04	3	0.86	
7/23/08	113.54	3	0.93	

Appendix Table 24. Aggregations of Burbot in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered Burbot present on the same day. Spawning denotes if an aggregation occurred during the potential spawning period.

Date	RKM	Number in Aggregation	Length of Reach	During spawning
3/15/06	379.72	3	0	
3/27/06	297.86	3	0	
4/2/06	114.24	3	0.20	
4/4/06	99.18	3	0	
4/10/06	378.12	3	0	
4/25/06	378.53	3	0	
4/27/06	98.71	3	0.02	
4/27/06	113.61	3	0.82	
4/29/06	114.56	3	0	
5/3/06	603.94	3	0	
5/7/06	378.12	3	0	
5/8/06	378.12	4	0	
5/9/06	289.76	3	0.15	
5/24/06	378.49	6	1.00	
5/30/06	378.12	3	0	
5/30/06	603.94	3	0	
6/7/06	378.21	4	1.00	
6/14/06	603.86	3	0.24	
7/5/06	603.86	3	0.16	

8/7/06	603.86	3	0.16	
8/15/06	603.05	3	0.73	
8/28/06	603.05	3	0.73	
1/4/07	602.73	5	1.00	
1/18/07	602.73	3	0.56	
1/31/07	602.97	3	0	
1/31/07	609.41	3	0.08	
2/26/07	603.46	4	0.40	Y
4/9/07	608.28	3	0.16	
4/25/07	608.44	3	0	
10/19/07	367.33	4	0	
10/19/07	400.69	3	0	
10/26/07	433.24	4	0	
12/27/07	413.09	3	0.57	
1/9/08	394.98	3	0.22	
2/6/08	223.36	3	0.66	Y
4/8/08	433.22	3	0.08	
4/10/08	98.63	4	0.71	
4/16/08	366.14	4	0.94	
4/18/08	98.65	6	1.00	
5/5/08	433.19	3	0.11	
5/8/08	98.71	4	0.58	
5/16/08	608.36	3	0.05	
5/19/08	366.27	3	0.79	
5/21/08	98.65	6	1.00	
5/22/08	433.32	3	0.92	
6/5/08	98.65	4	0.98	
6/11/08	564.6	3	0.4	
6/18/08	98.65	6	0.96	
6/30/08	434.54	4	0.43	
7/2/08	98.63	8	1.00	
7/9/08	564.68	3	0.08	
7/14/08	98.65	6	0.51	
7/16/08	366.37	3	0.63	
7/17/08	434.24	3	0.74	
8/27/08	195.59	3	0.07	
8/28/08	98.65	4	0.23	
3/3/09	553.82	3	0	

Appendix Table 25. Aggregations of Channel Catfish in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered Channel Catfish present on the same day. Spawning denotes if an aggregation occurred during the potential spawning period.

Date	RKM	Number in Aggregation	Length of Reach	During spawning
6/8/05	129.44	3	0	
6/15/05	373.56	3	0.41	
7/5/05	167.42	3	0	Y
7/7/05	293.95	3	0	Y
7/11/05	354.01	3	0	Y
7/19/05	69.43	3	0	Y
7/21/05	420.12	3	0	Y
8/2/05	225.24	3	0	Y
8/3/05	310.62	3	0	Y
8/15/05	386.07	3	0	
9/13/05	418.88	3	0.98	
9/21/05	128.78	3	1.00	
12/27/05	68.53	3	0	
1/5/06	69.86	3	0	
1/27/06	68.99	3	0.59	
2/24/06	236.57	4	0	
3/23/06	68.88	3	1.00	
7/25/07	338.75	3	0.84	Y
7/10/08	294.11	3	0	Y

Appendix Table 26. Aggregations of Spiny Softshells in the Yellowstone River from 2005–2009. Aggregations are defined as reaches < 1 km with 3 or more telemetered Spiny Softshells present on the same day. Spawning denotes if an aggregation occurred during the potential spawning period.

Date	RKM	Number in Aggregation	Length of Reach	During nesting
7/7/05	293.88	3	0	Y
7/11/05	353.93	3	0	Y
7/21/05	420.03	3	0	
8/3/05	310.55	3	0	
9/28/05	168.67	3	0.40	
10/6/05	399.74	4	0	
10/6/05	418.11	3	0.02	
10/12/05	168.93	3	0.19	
10/25/05	168.41	3	0.51	
10/25/05	399.72	4	0.41	
10/26/05	168.8	3	0.14	
11/1/05	399.71	4	0.42	
11/7/05	168.78	3	0.26	
1/4/06	168.48	3	0.34	
1/4/06	399.48	4	0	
1/26/06	168.4	3	0.34	
1/26/06	418	3	0	
2/23/06	169.04	3	0.09	
2/23/06	399.55	4	0	
3/8/06	169.01	3	0.02	
3/8/06	399.34	4	0	
3/22/06	399.34	4	0	
4/11/06	399.79	4	0.04	
4/12/06	169.41	3	0.02	
4/25/06	399.84	3	0	
5/8/06	399.8	3	0.43	
6/21/06	400.03	3	0.11	Y
6/23/06	104.68	3	0.42	Y
7/25/06	399.21	4	0.59	
8/23/06	474.66	3	0.33	
8/25/06	474.01	5	0.16	
9/5/06	399.76	3	0.04	
9/18/06	399.79	3	0.04	
10/2/06	399.79	3	0.01	
10/23/06	399.79	3	0.03	

4/5/07	136.8	3	0.56
4/23/07	351.05	3	0
5/7/07	399.84	3	0
8/28/07	399.8	3	0
9/26/07	136.64	3	0.24
10/9/07	399.74	3	0.05
10/22/07	399.61	3	0.13
5/5/08	351.05	3	0

Appendix Table 27. Timing and frequency of passing or being blocked by Huntley Diversion in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB												
CHCA												
SHST												
SPSO												
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB												
CHCA												
SHST												
SPSO												

Appendix Table 28. Timing and frequency of passing or being blocked by Waco Diversion in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB					1							
CHCA							1					
SHST												
SPSO												
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB						1						
CHCA												
SHST												

SPSO												

Appendix Table 29. Timing and frequency of passing or being blocked by Rancher Diversion in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB												
CHCA							1					
SHST												
SPSO												
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB												
CHCA												
SHST												
SPSO												

Appendix Table 30. Timing and frequency of passing or being blocked by Myers Diversion in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU						1	3					
BURB												
CHCA						1	1					
SHST												
SPSO												
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB												
CHCA												
SHST												
SPSO												

Appendix Table 31. Timing and frequency of passing or being blocked by Cartersville Diversion in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU					2	5	9	1				
BURB			1	1	3					1		
CHCA							1					
SHST												
SPSO								1				
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU					1							
BURB			3	1	2				1	1		
CHCA				1	2							
SHST				5	2	2	3	2	1			
SPSO						4						

Appendix Table 32. Timing and frequency of passing or being blocked by Matthew's Rapids in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU					4	14	14		1			
BURB		1		1								
CHCA		1		1	1	2			1			
SHST				4	6	4	2			1		
SPSO								1				
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU							2	1				
BURB												
CHCA												
SHST												
SPSO												

Appendix Table 33. Timing and frequency of passing or being blocked by Wolf rapids in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU					6	26	12	1	1			
BURB	1		1		1						1	2
CHCA					3	2		2	1			
SHST			3	7	4	4	7	3	3	1		
SPSO							1	2				
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU												
BURB												
CHCA								1	1			
SHST												
SPSO												

Appendix Table 14. Timing and frequency of passing or being blocked by Intake Diversion in the Yellowstone River from 2005–2009.

	Passing											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU			2	1	17	37	4		2	5	1	
BURB					1					1		
CHCA					1	2						
SHST				1	1		1					
SPSO					1			1				
	Blocked											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BLSU					2	4						
BURB				5							1	1
CHCA							1					
SHST			1	1	4	5	3	1	1			
SPSO												

APPENDIX II

The following are individual movement plots for each monitored animal plotted against mean daily discharge from 2005 through 2009 in the Yellowstone River in Montana. The first y-axis (left vertical axis) shows river kilometer (rkm) location, solid circles connected by a dashed line represent movements of the individual animal, and solid triangles represent when animals were located in tributaries. The second y-axis (right vertical axis) and the solid gray line show mean daily discharge in cubic feet per second (cfs). The x-axis represents time in months and years–and extent of time varies by species (Table 1, below). Solid horizontal lines within the plots represent the locations of diversions, dotted horizontal lines represent the locations of select tributaries (Table 2, below), and not all species plots contain all horizontal lines (Table 1, below).

Table 1. Month and year for the beginning (Begin) and end (End) of the monitoring period (Mon. per.) and river kilometer (rkm) maximum for each species.

Species	Species code	Mon. per. Begin	Mon. per. End	Species maximum
Blue Sucker	BLSU	June 2005	October 2008	455.4
Burbot	BURB	November 2005	March 2009	630.7
Channel Catfish	CHCA	June 2005	August 2008	576.8
Shovelnose Sturgeon	SHST	June 2005	August 2008	378.6
Spiny Softshell Turtle	SPSO	June 2005	March 2009	608.2

Table 2. River mile (RM) and river kilometer (RKM) locations of structures included in individual movement plots from the upper (top) to lower (bottom) Yellowstone River.

Location	RM	RKM	Structure type
Clarks Fork	378.6	609.4	Tributary
Huntley	351.8	566.2	Diversion
Waco	316.2	508.9	Diversion
Bighorn River	294.5	474.0	Tributary
Rancher	292.0	469.9	Diversion
Myers	278.1	447.6	Diversion
Cartersville	235.5	379.0	Diversion
Tongue River	182.8	294.2	Tributary
Powder River	146.9	236.4	Tributary
Intake	71.2	114.6	Diversion

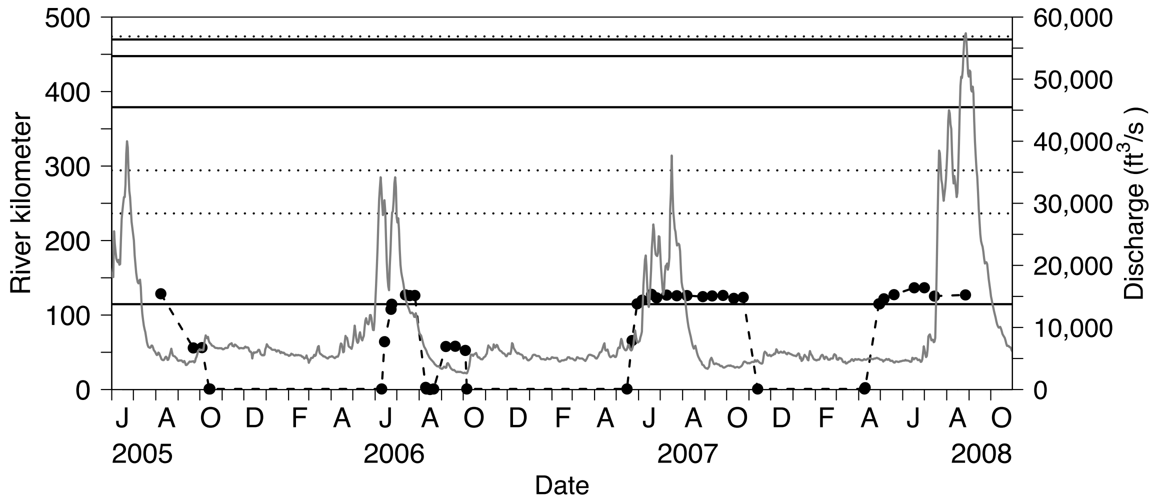

Figure 1. Movements of BLSU #1 (frequency = 420, code = 12, N = 45)

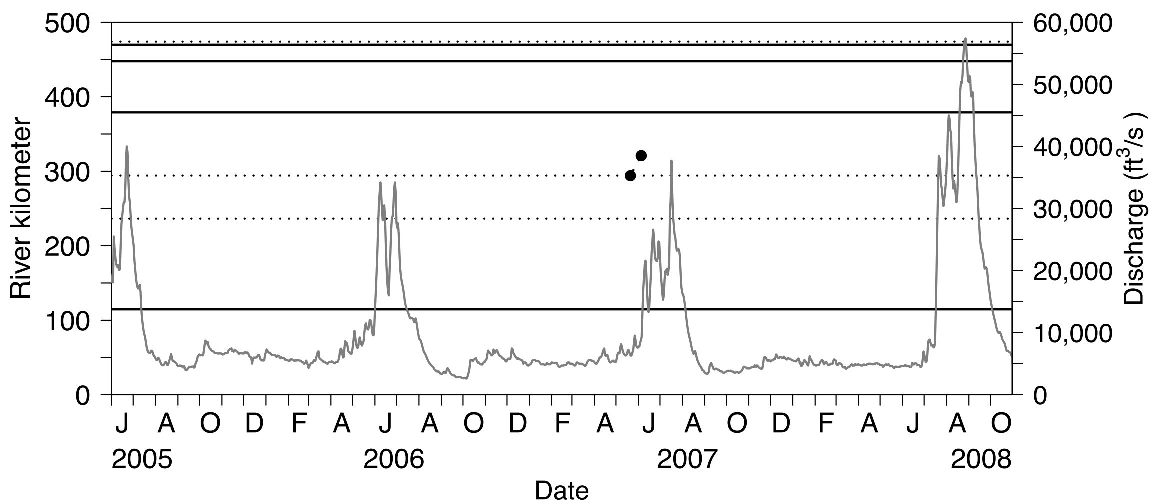

Figure 2. Movements of BLSU #2 (frequency = 420, code = 13, N = 2)

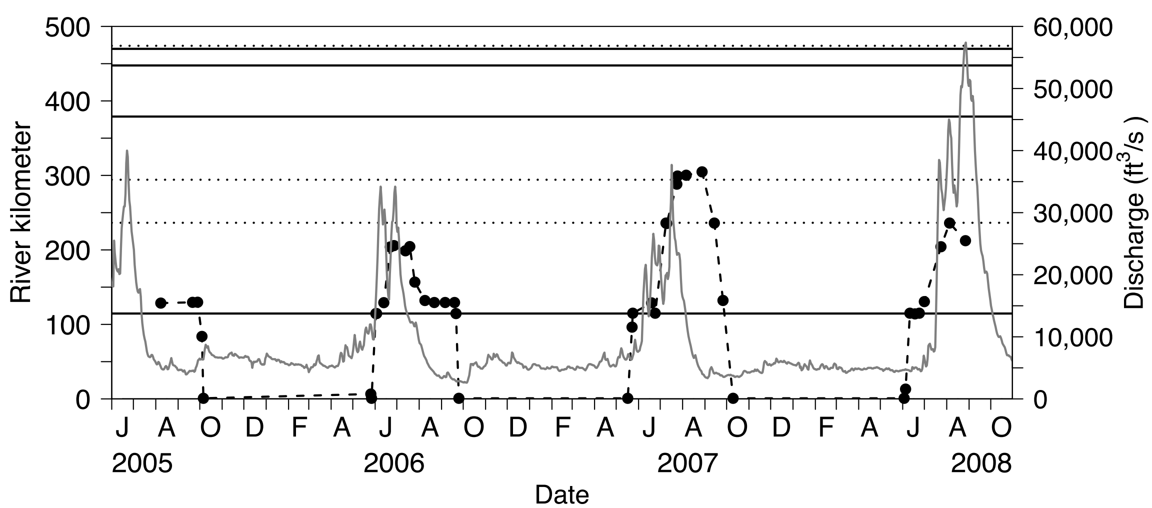

Figure 3. Movements of BLSU #3 (frequency = 420, code = 15, N = 44)

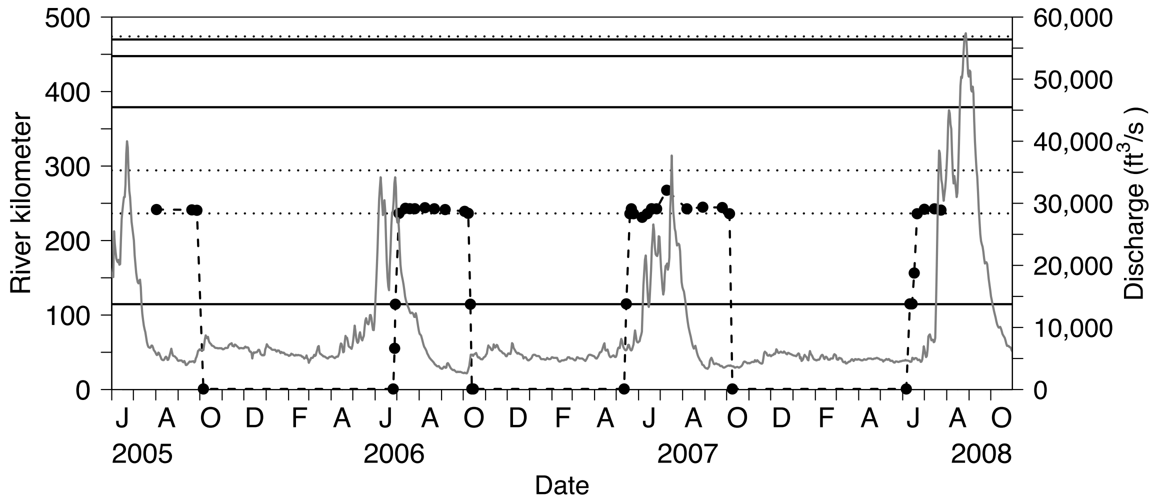

Figure 4. Movements of BLSU #4 (frequency = 420, code = 16, N = 42)

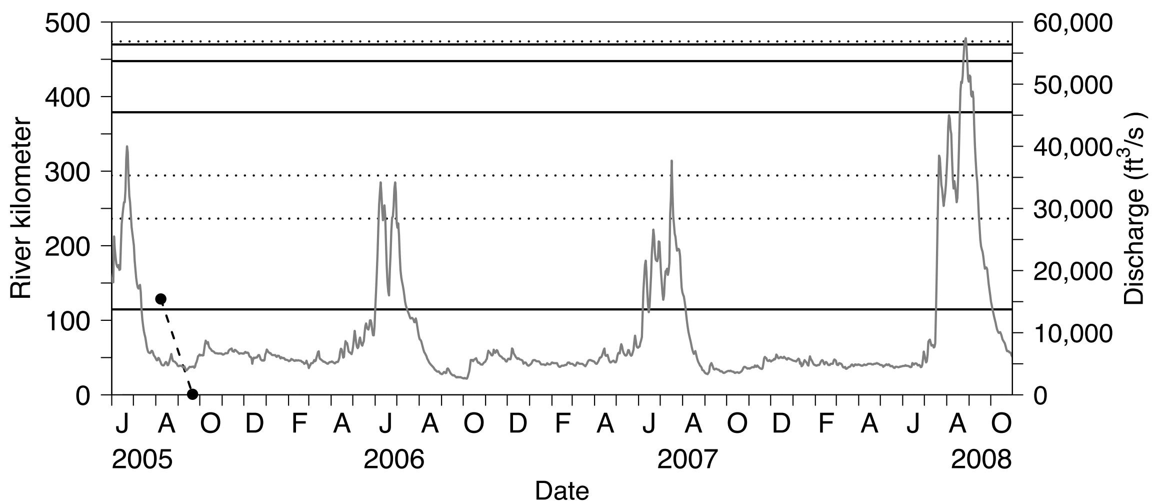

Figure 5. Movements of BLSU #5 (frequency = 420, code = 18, N = 2)

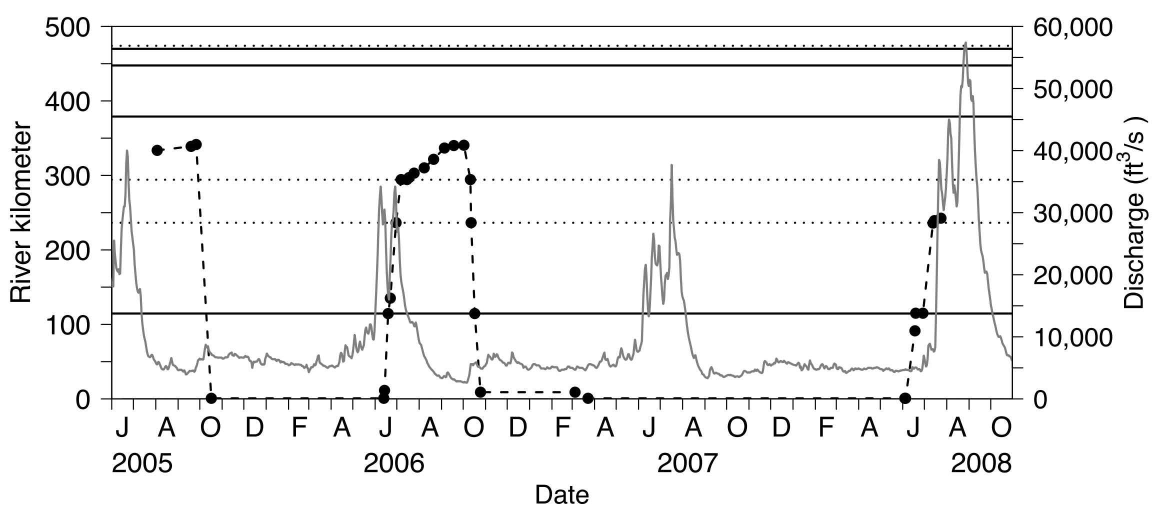

Figure 6. Movements of BLSU #6 (frequency = 420, code = 19, N = 32)

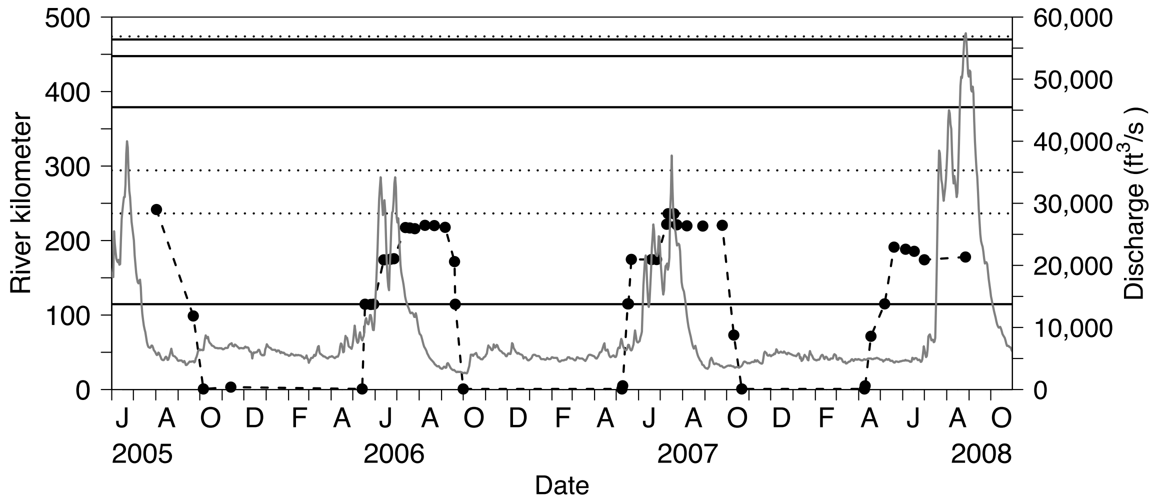

Figure 7. Movements of BLSU #7 (frequency = 420, code = 20, N = 45)

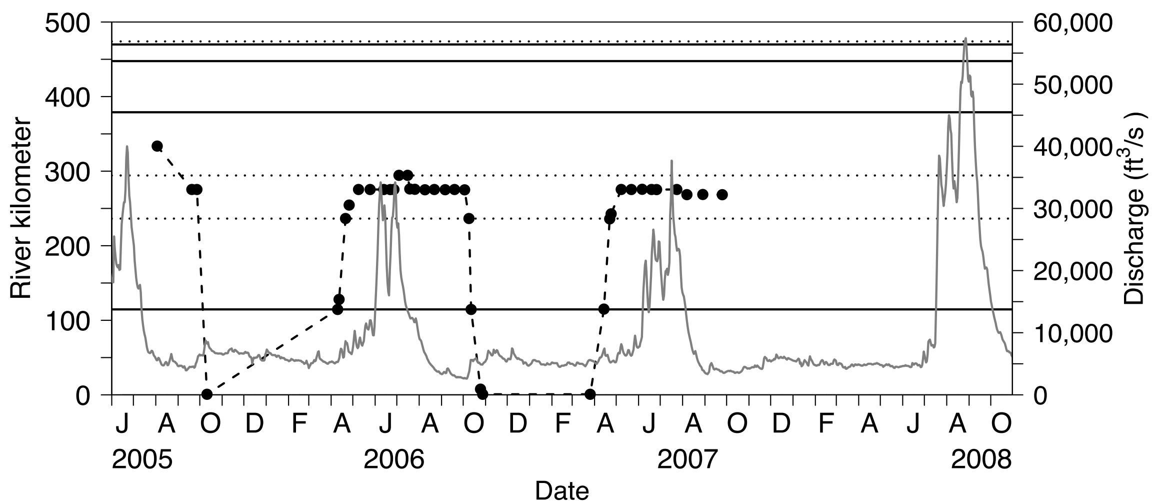

Figure 8. Movements of BLSU #8 (frequency = 420, code = 22, N = 39)

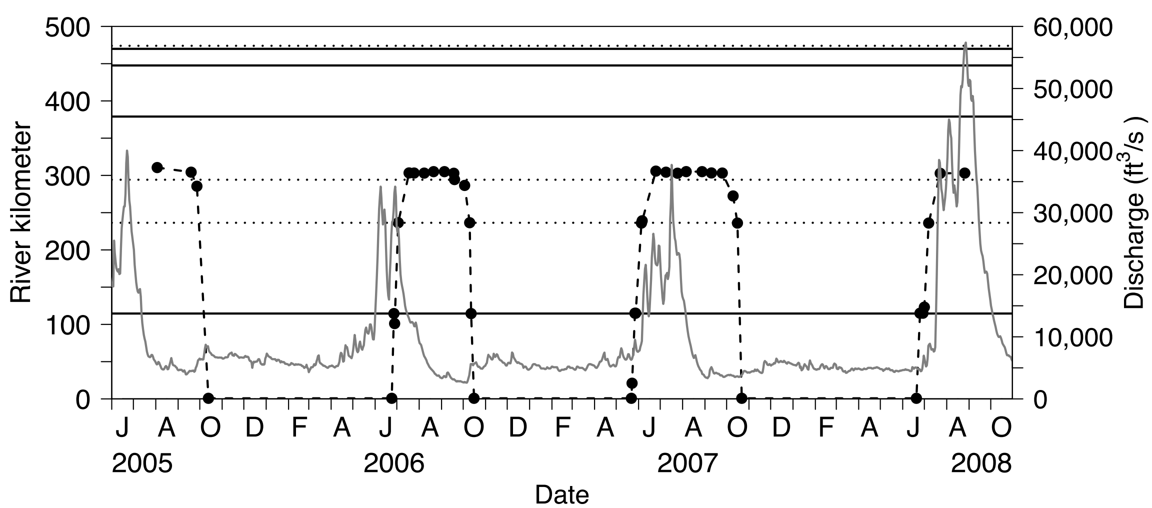

Figure 9. Movements of BLSU #9 (frequency = 420, code = 24, N = 42)

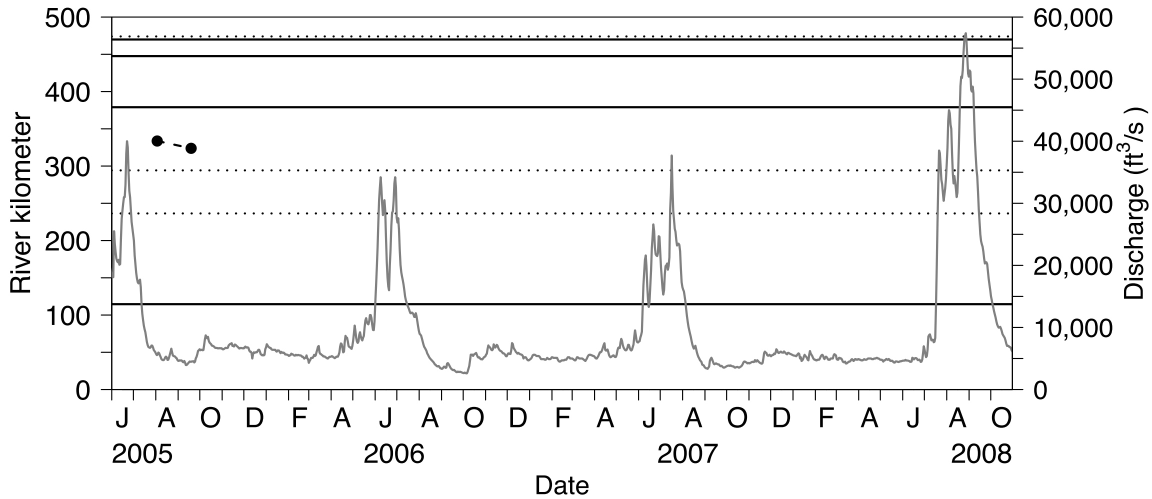

Figure 10. Movements of BLSU #10 (frequency = 420, code = 25, N = 2)

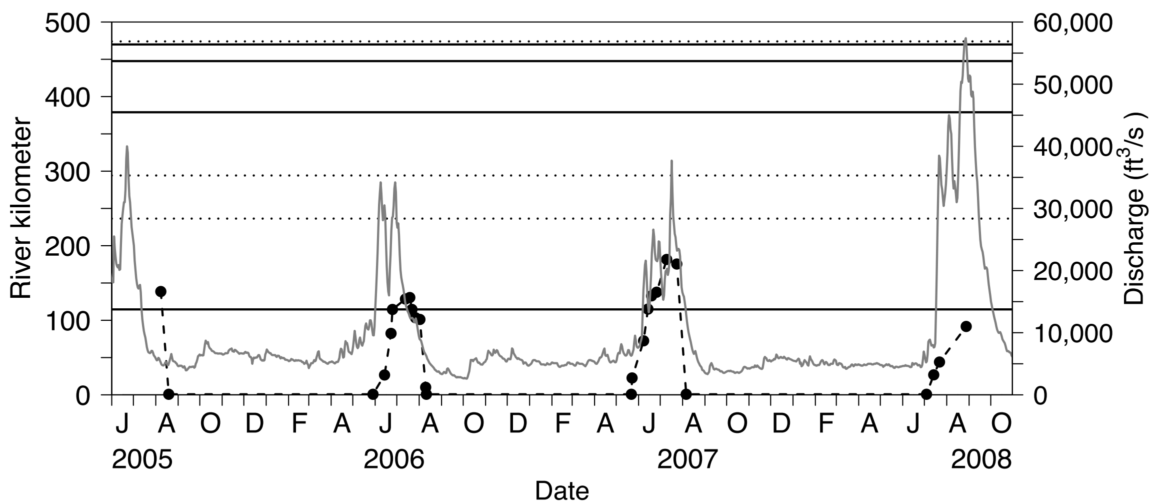

Figure 11. Movements of BLSU #11 (frequency = 420, code = 29, N = 26)

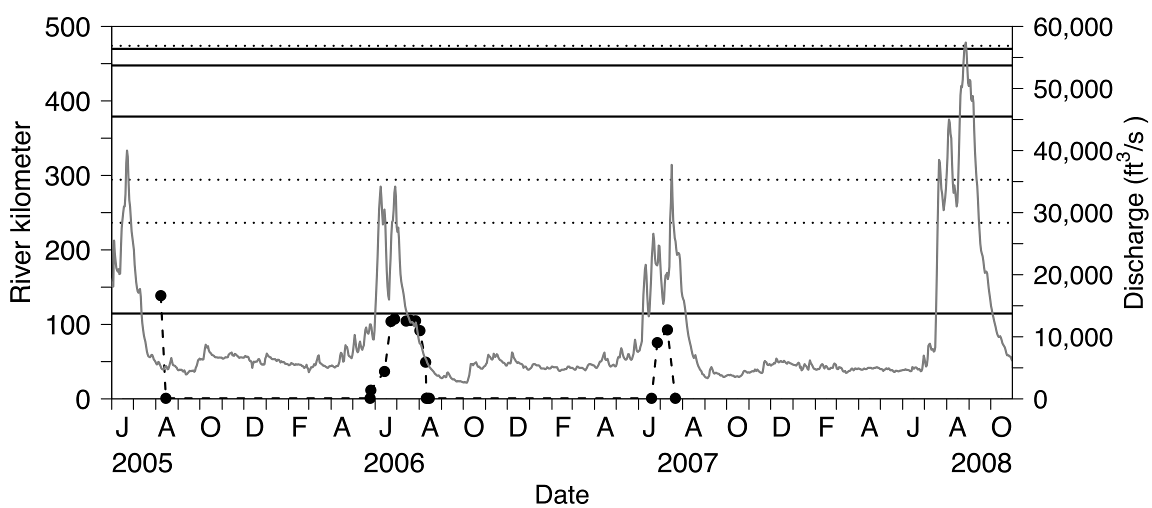

Figure 12. Movements of BLSU #12 (frequency = 420, code = 32, N = 19)

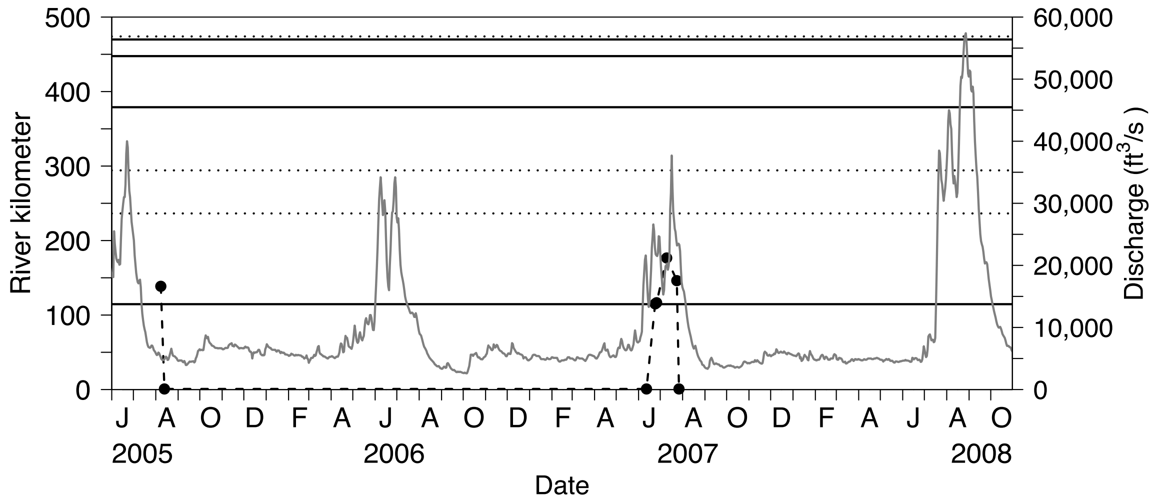

Figure 13. Movements of BLSU #13 (frequency = 420, code = 33, N = 8)

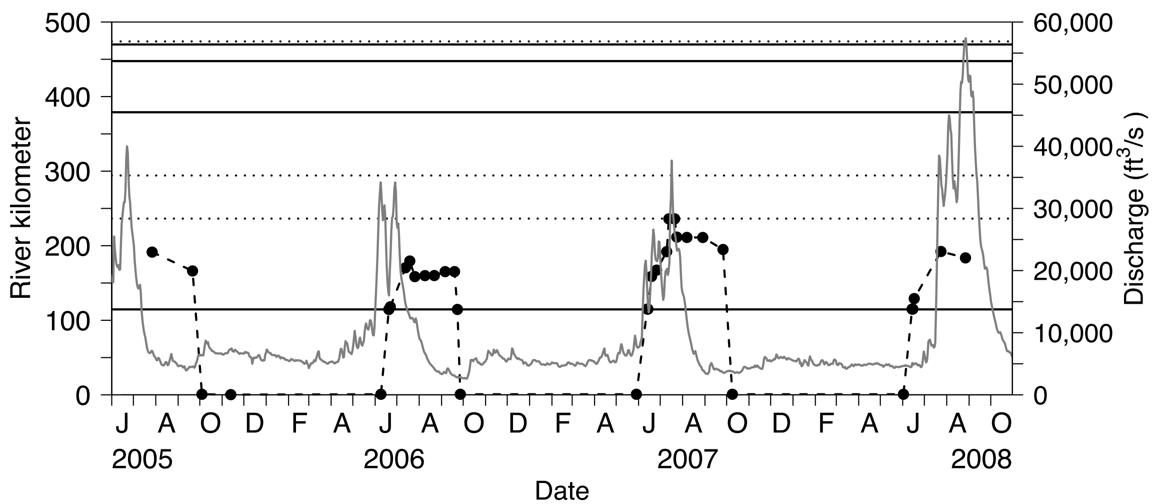

Figure 14. Movements of BLSU #14 (frequency = 420, code = 49, N = 35)

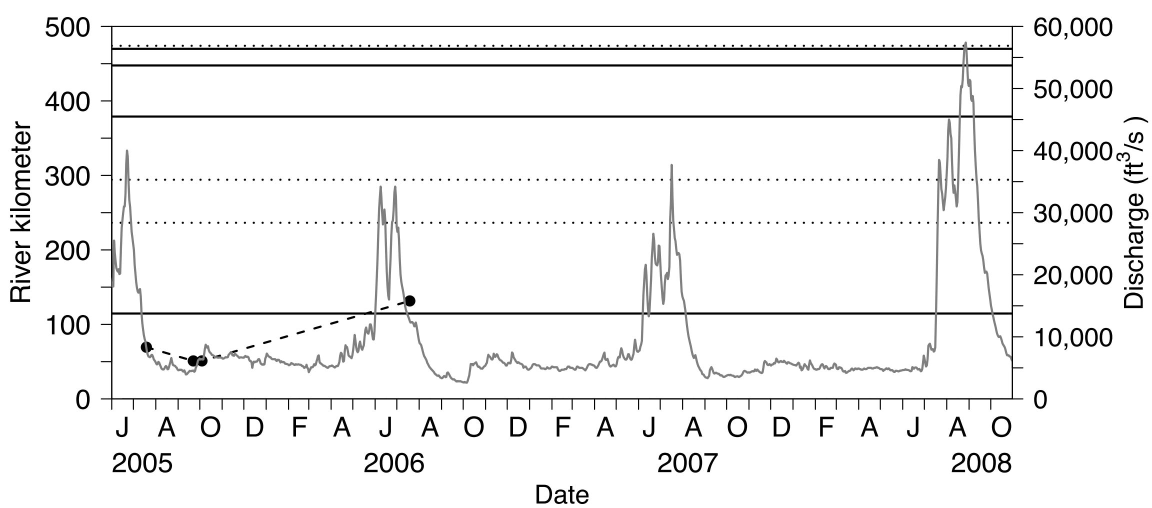

Figure 15. Movements of BLSU #15 (frequency = 420, code = 57, N = 4)

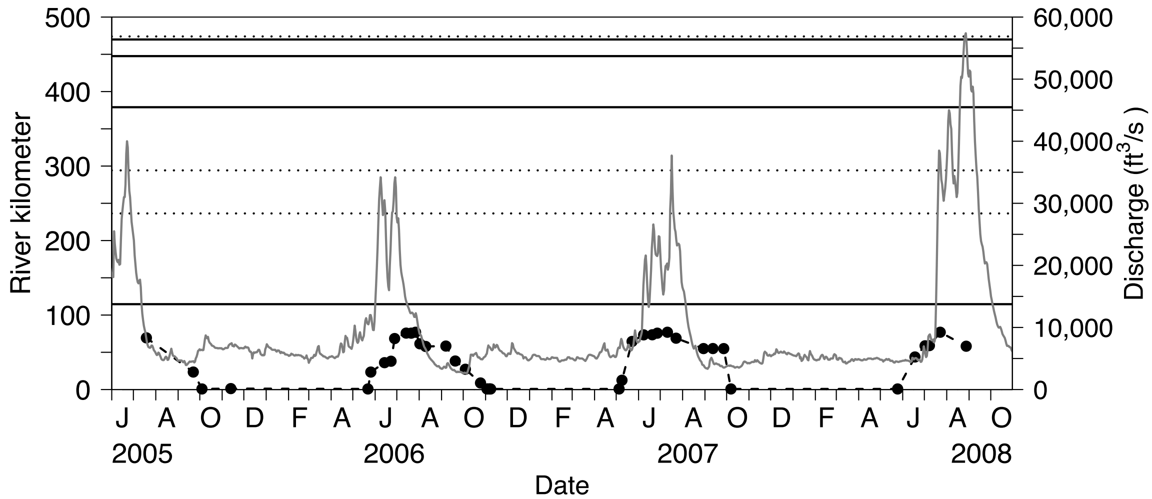

Figure 16. Movements of BLSU #16 (frequency = 420, code = 58, N = 41)

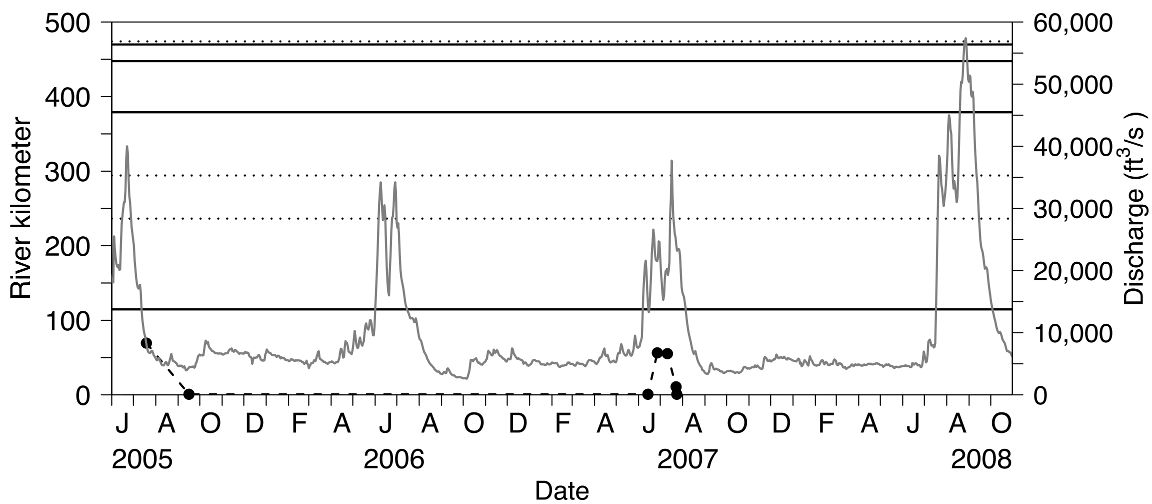

Figure 17. Movements of BLSU #17 (frequency = 420, code = 63, N = 7)

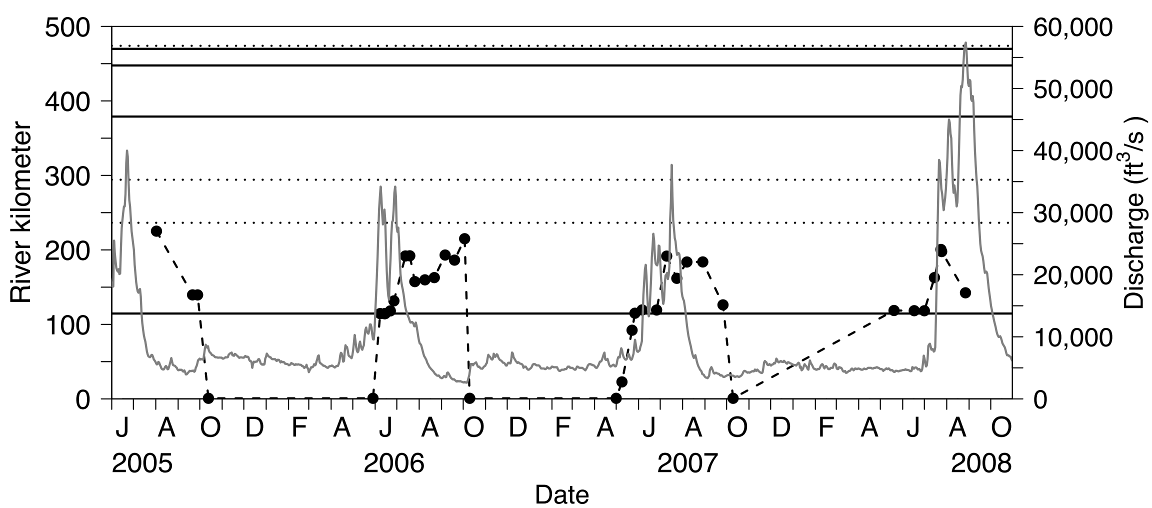

Figure 18. Movements of BLSU #18 (frequency = 420, code = 65, N = 38)

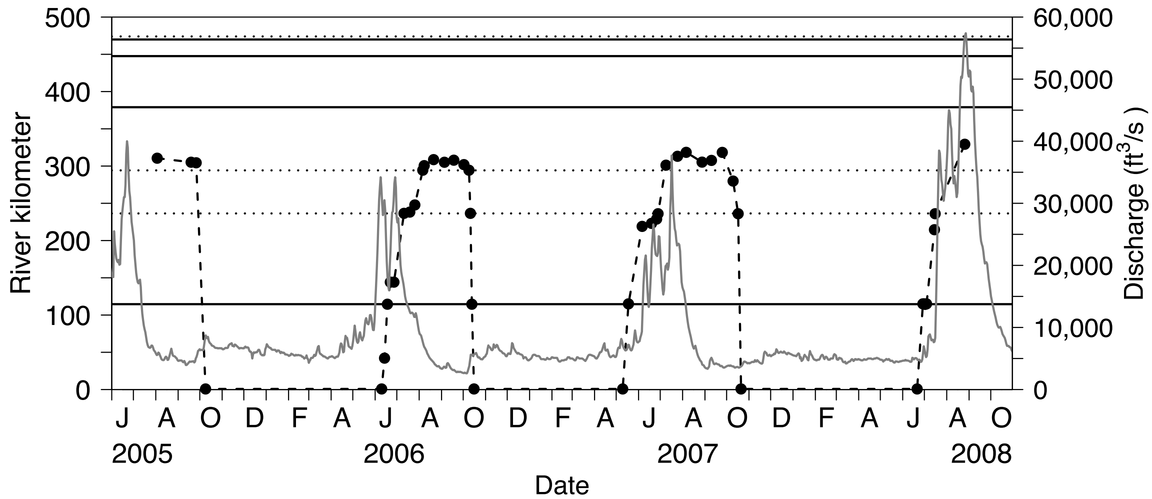

Figure 19. Movements of BLSU #19 (frequency = 420, code = 69, N = 45)

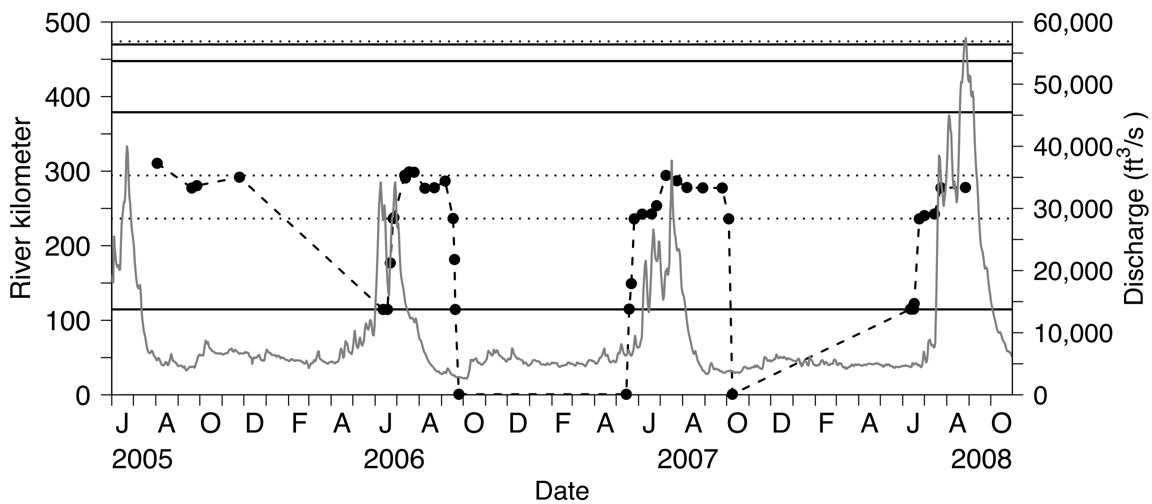

Figure 20. Movements of BLSU #20 (frequency = 420, code = 72, N = 42)

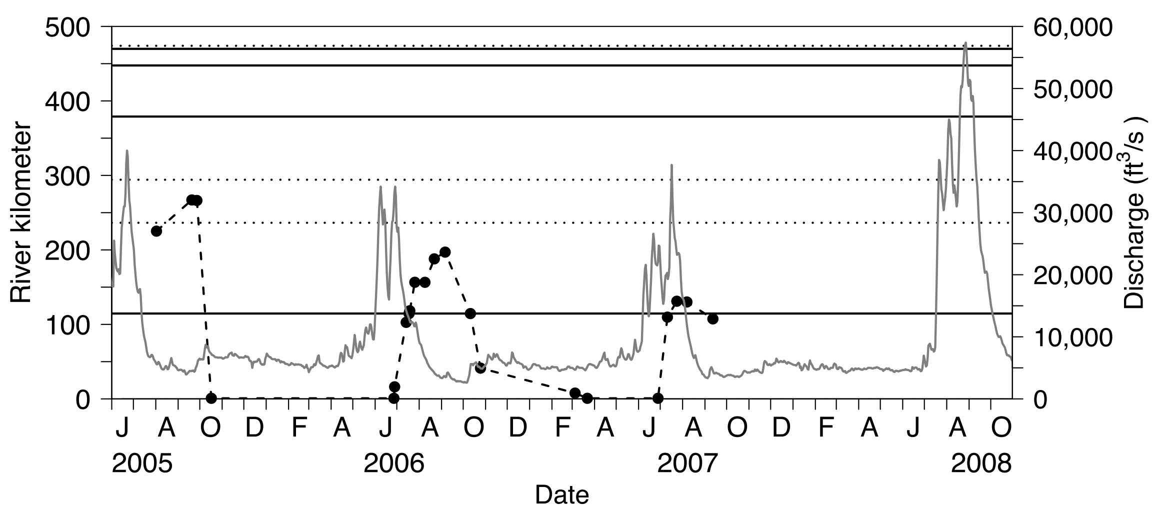

Figure 21. Movements of BLSU #21 (frequency = 420, code = 74, N = 22)

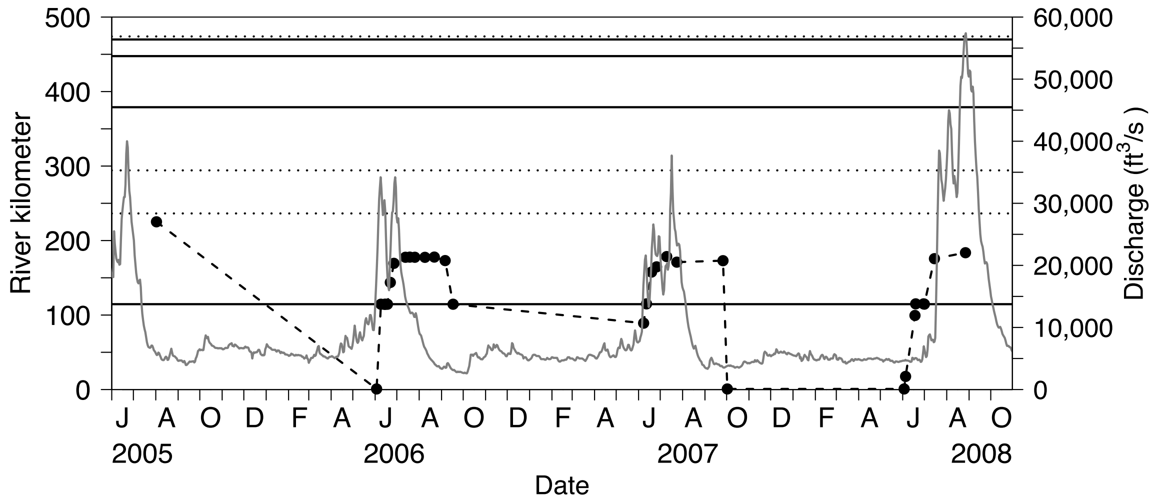

Figure 22. Movements of BLSU #22 (frequency = 420, code = 75, N = 31)

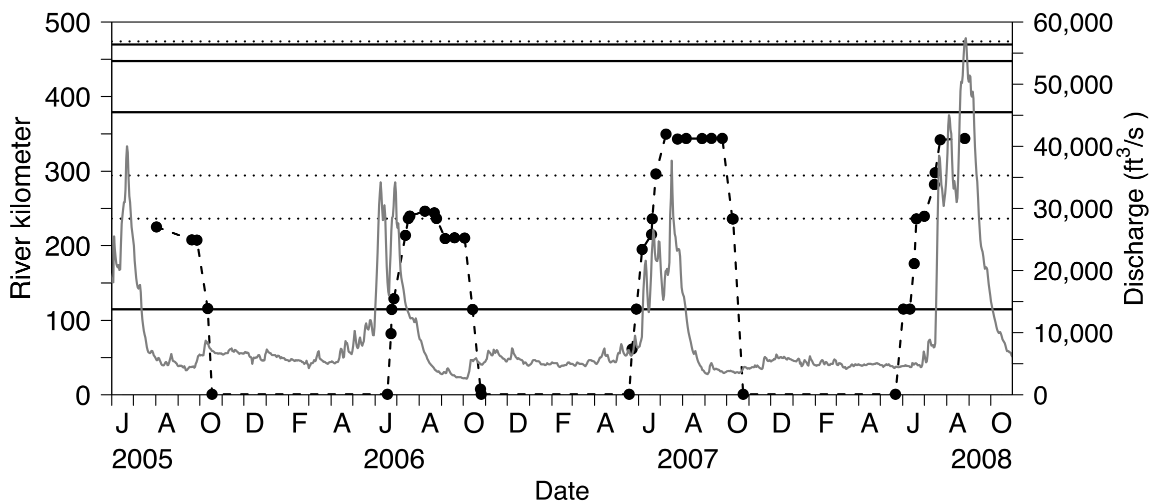

Figure 23. Movements of BLSU #23 (frequency = 420, code = 77, N = 47)

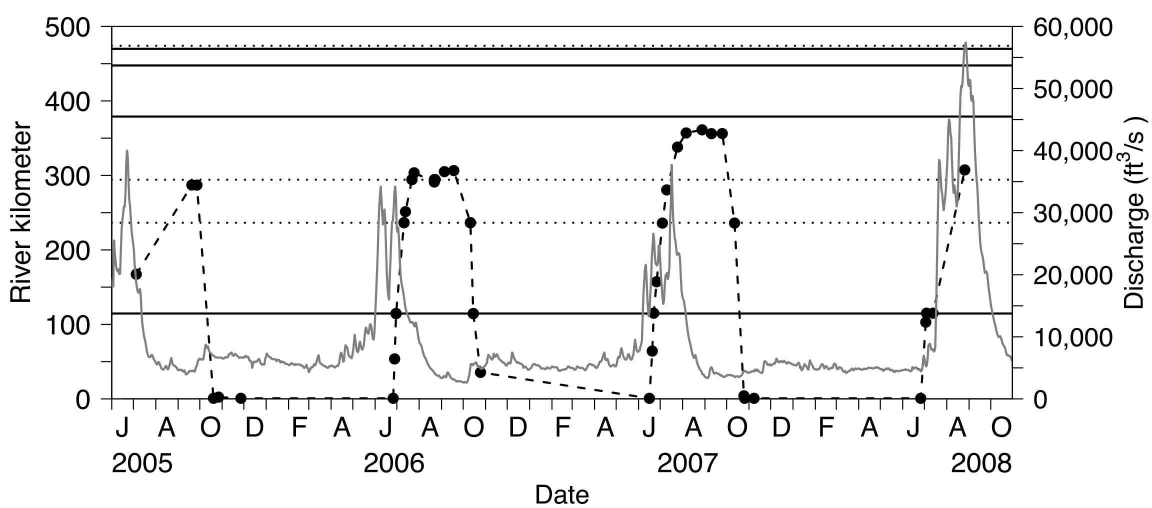

Figure 24. Movements of BLSU #24 (frequency = 480, code = 15, N = 46)

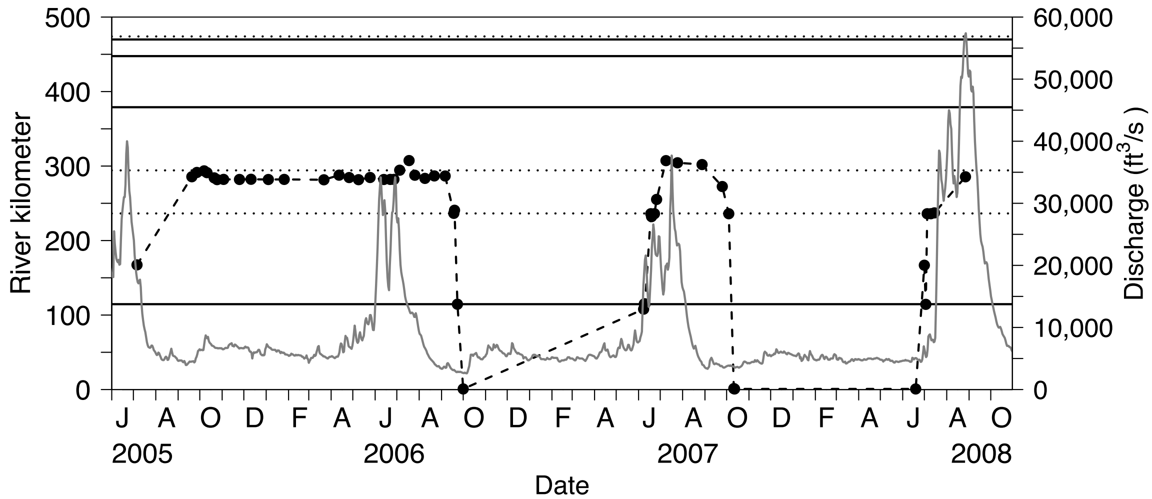

Figure 25. Movements of BLSU #25 (frequency = 480, code = 18, N = 51)

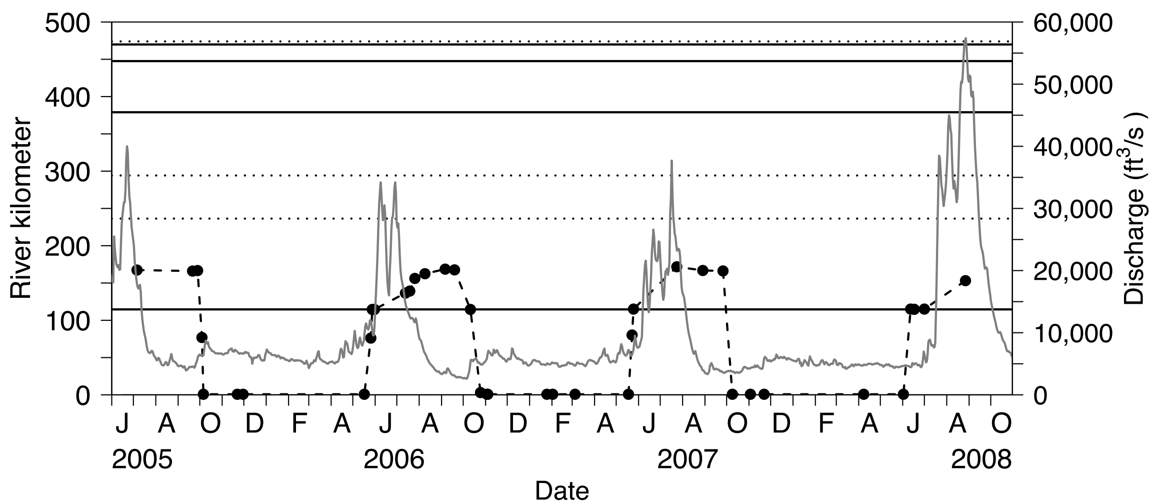

Figure 26. Movements of BLSU #26 (frequency = 480, code = 19, N = 39)

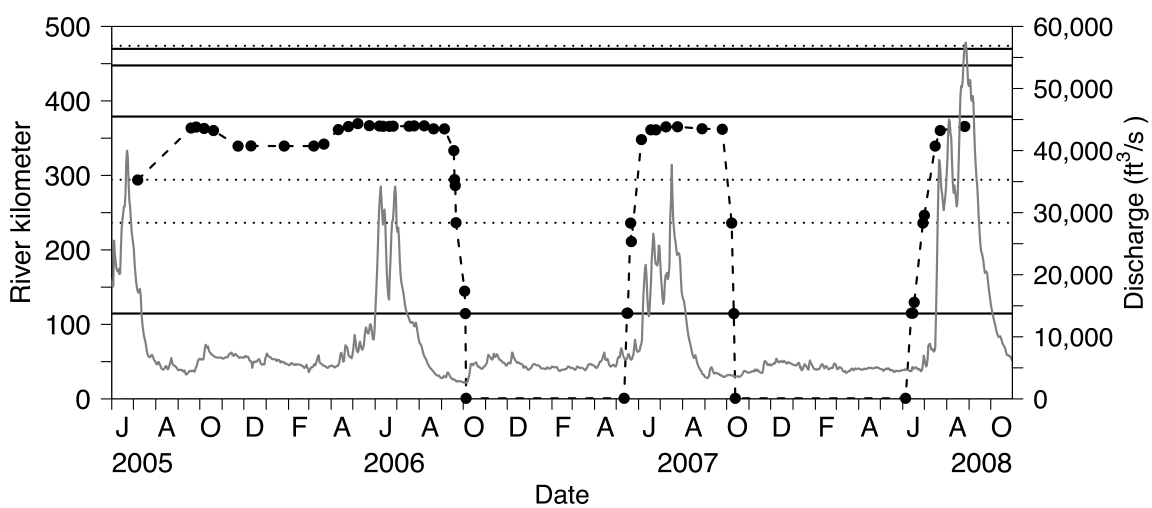

Figure 27. Movements of BLSU #27 (frequency = 480, code = 23, N = 54)

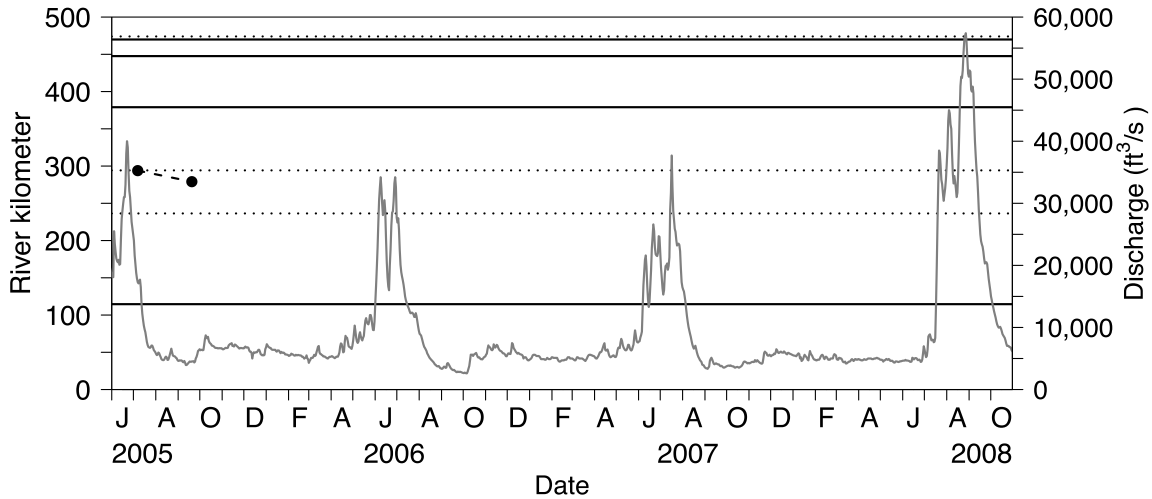

Figure 28. Movements of BLSU #28 (frequency = 480, code = 27, N = 2)

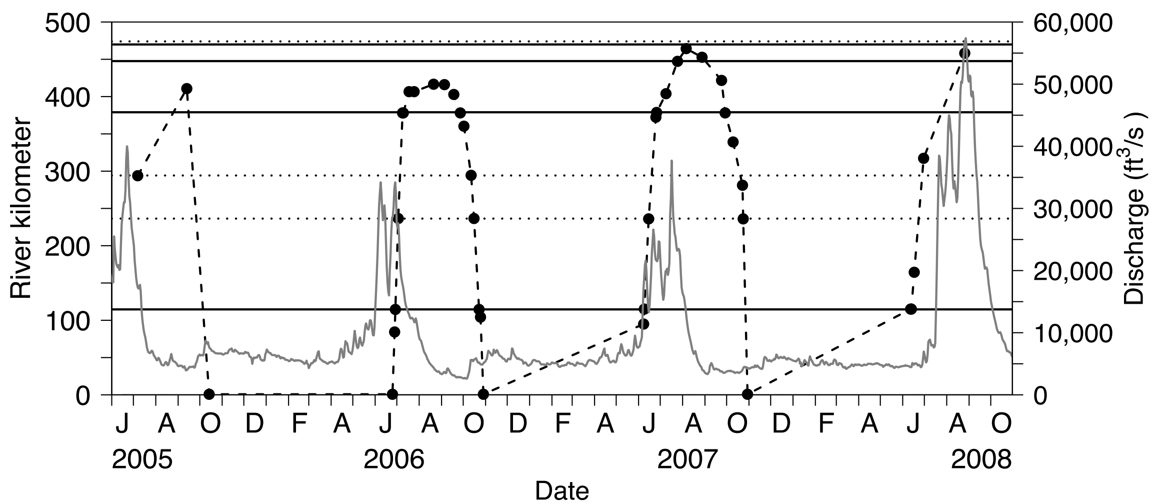

Figure 29. Movements of BLSU #29 (frequency = 480, code = 28, N = 41)

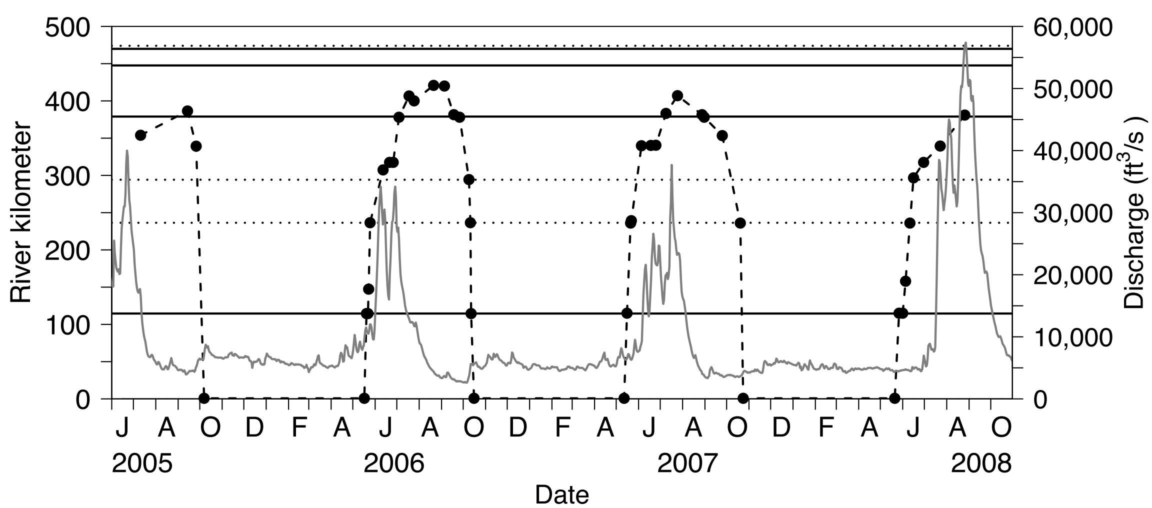

Figure 30. Movements of BLSU #30 (frequency = 480, code = 30, N = 46)

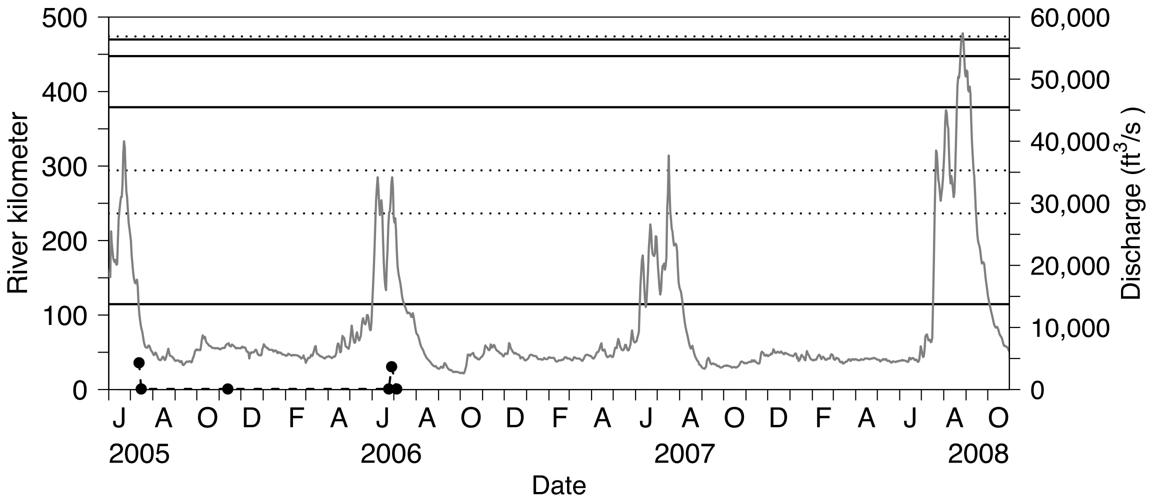

Figure 31. Movements of BLSU #31 (frequency = 480, code = 32, N = 6)

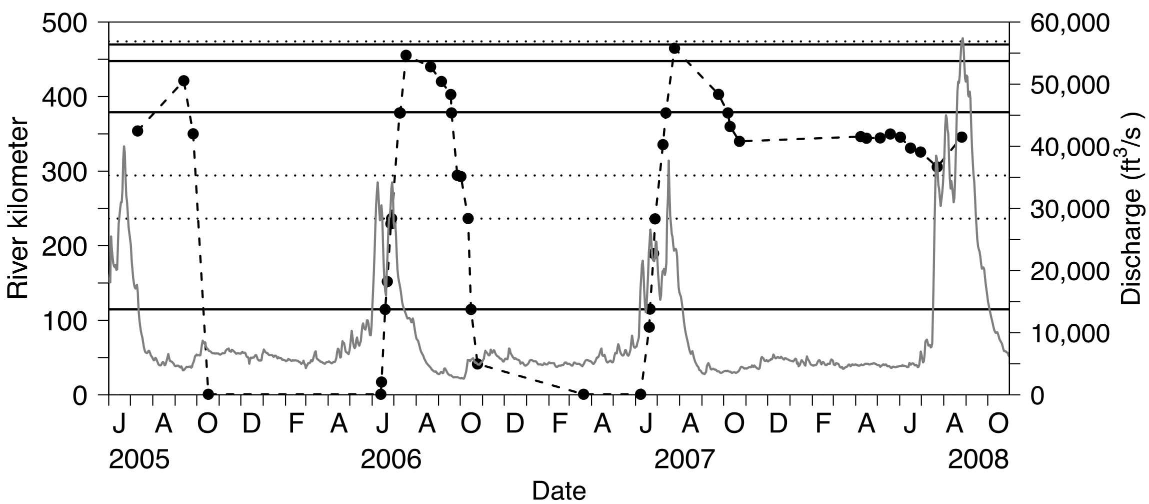

Figure 32. Movements of BLSU #32 (frequency = 480, code = 34, N = 44)

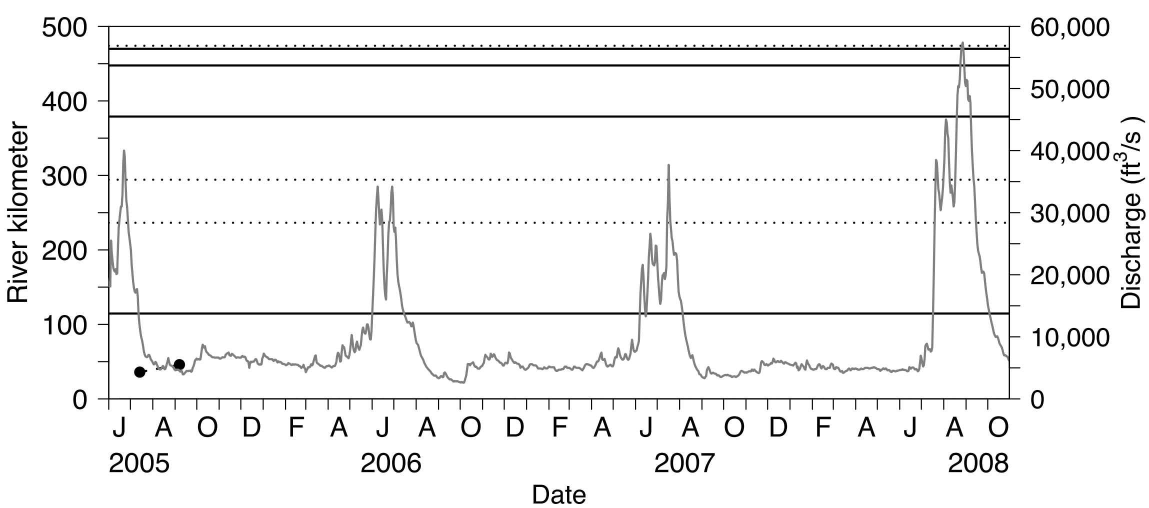

Figure 33. Movements of BLSU #33 (frequency = 480, code = 35, N = 2)

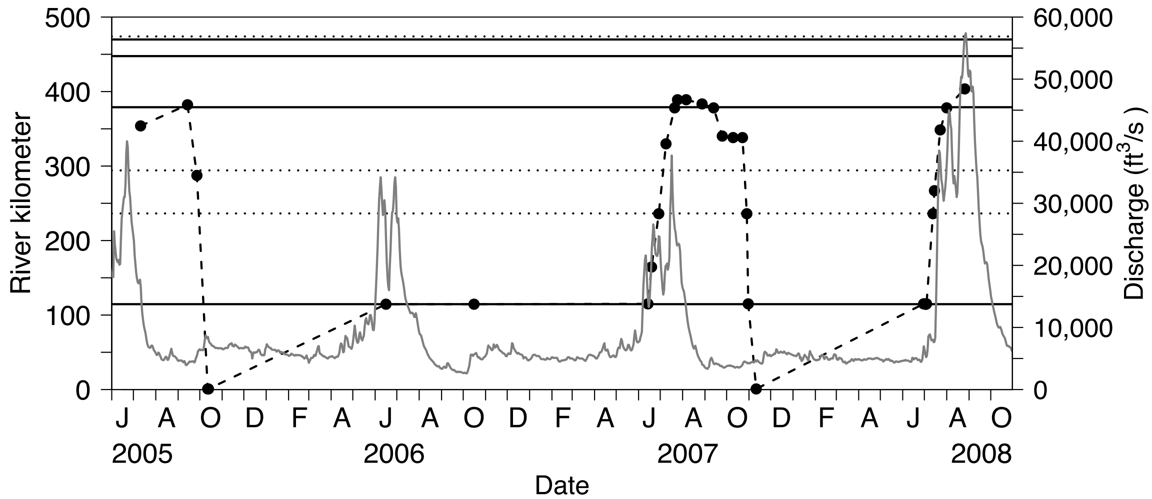

Figure 34. Movements of BLSU #34 (frequency = 480, code = 36, N = 31)

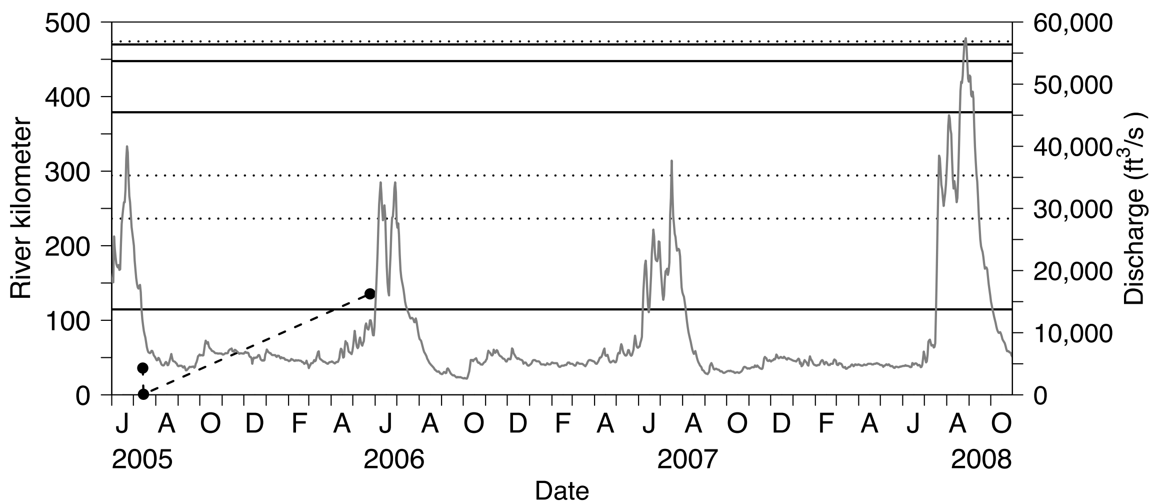

Figure 35. Movements of BLSU #35 (frequency = 480, code = 46, N = 3)

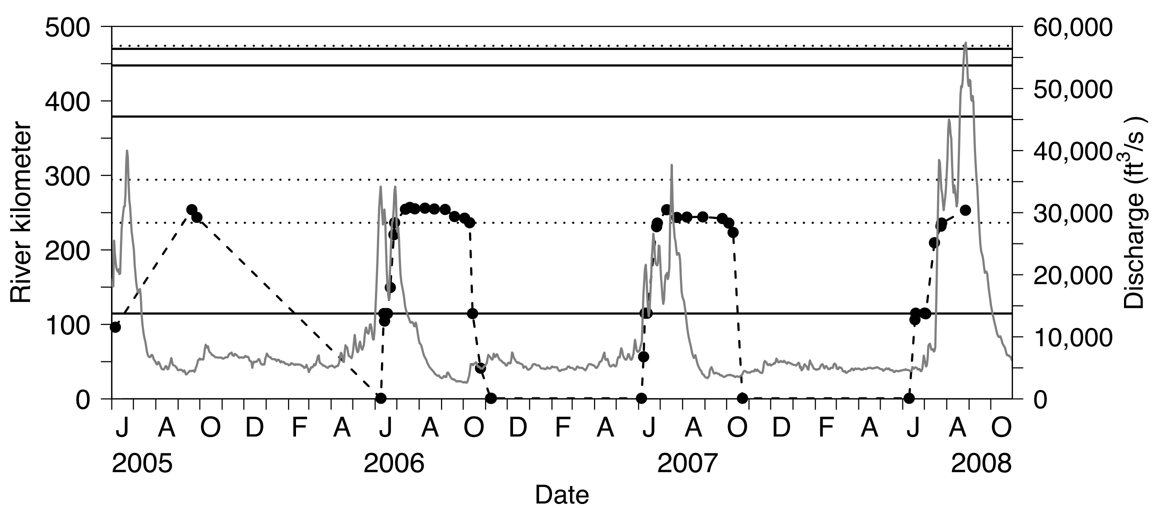

Figure 36. Movements of BLSU #36 (frequency = 480, code = 47, N = 48)

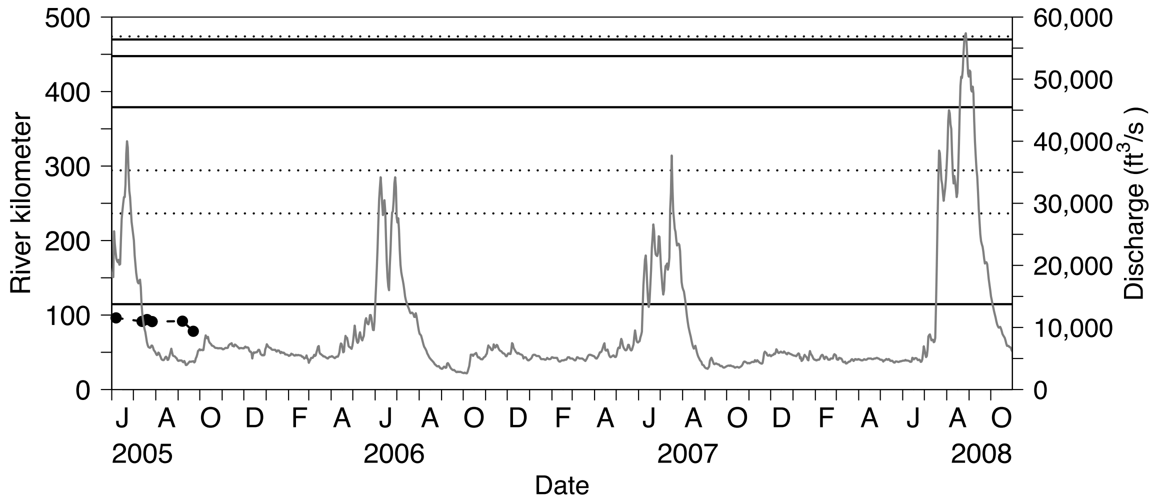

Figure 37. Movements of BLSU #37 (frequency = 480, code = 61, N = 6)

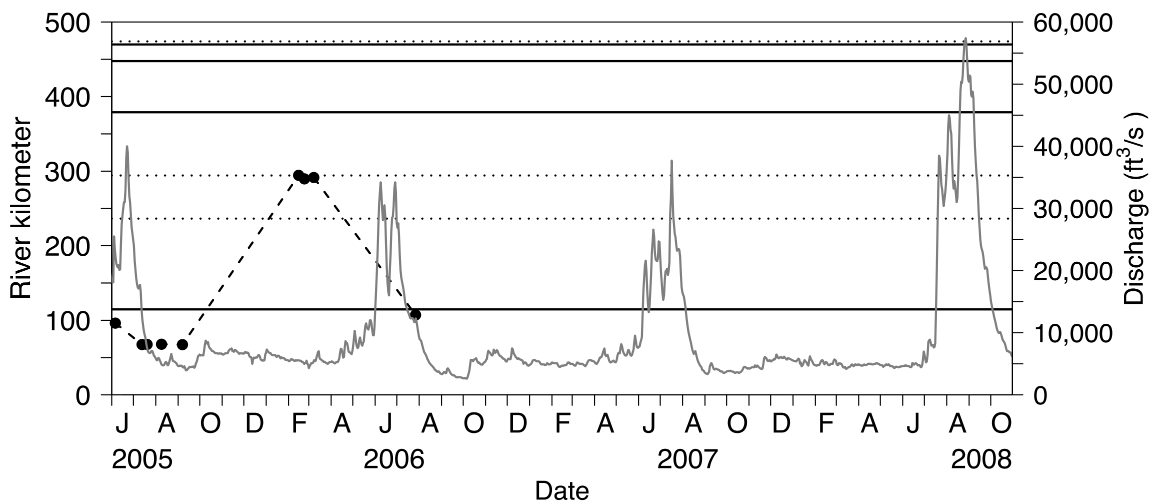

Figure 38. Movements of BLSU #38 (frequency = 480, code = 64, N = 9)

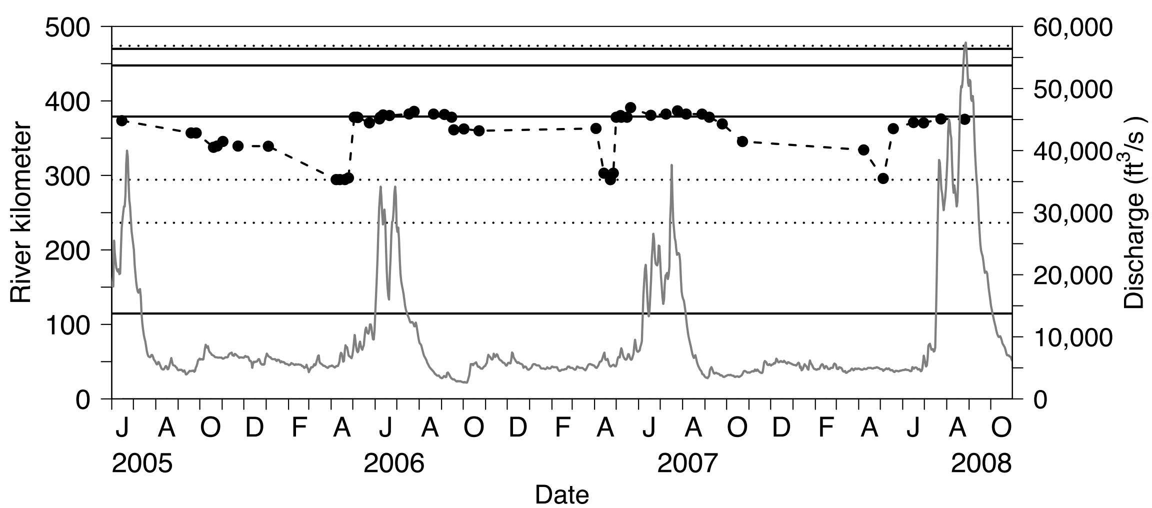

Figure 39. Movements of BLSU #39 (frequency = 480, code = 67, N = 52)

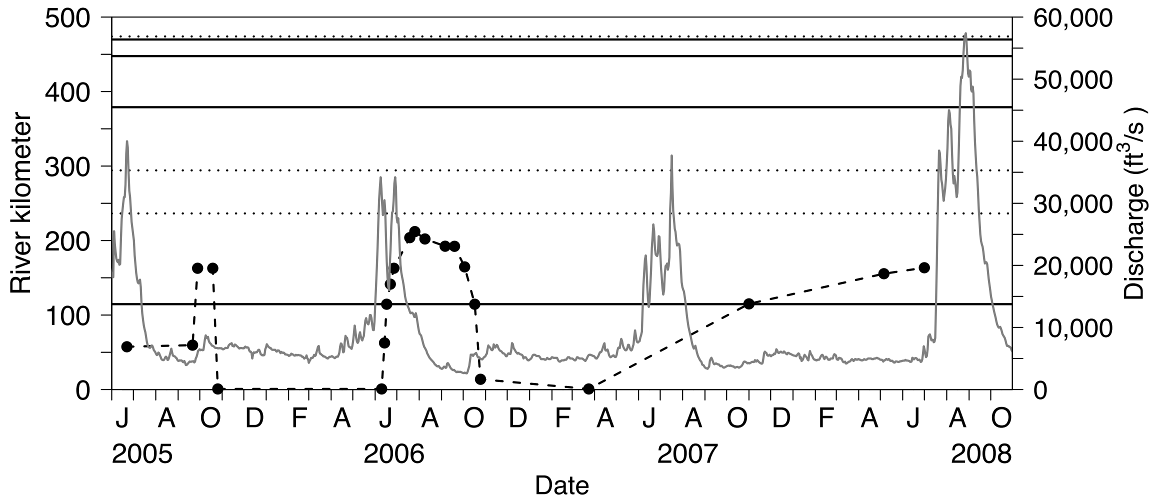

Figure 40. Movements of BLSU #40 (frequency = 480, code = 79, N = 22)

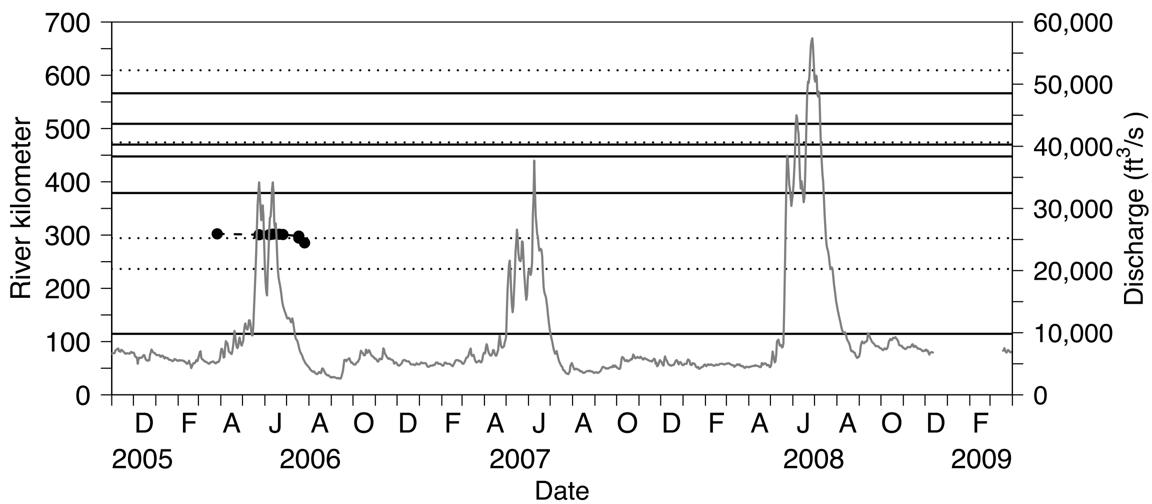

Figure 41. Movements of BURB #1 (frequency = 420, code = 38, N = 9)

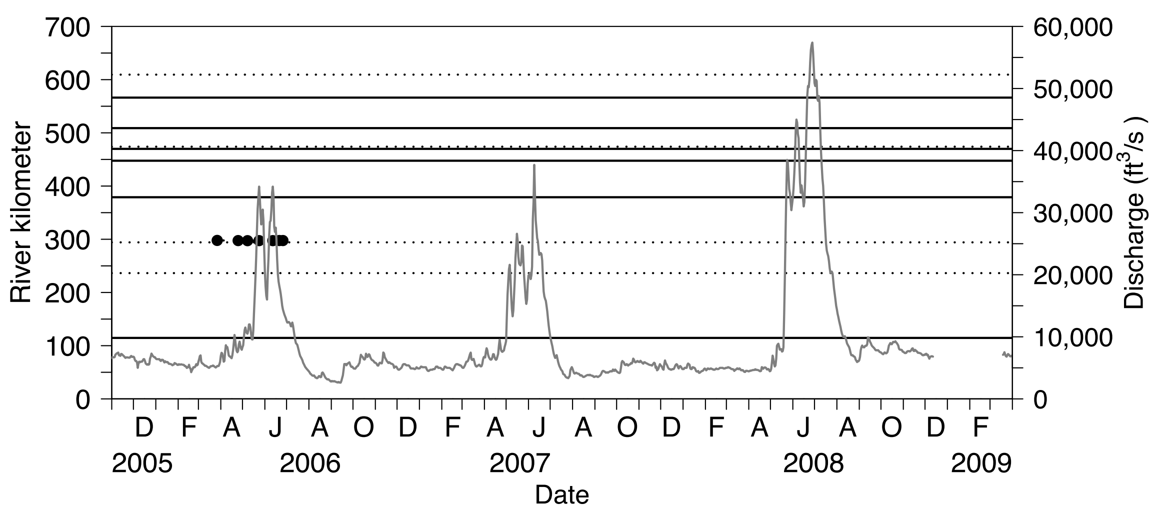

Figure 42. Movements of BURB #2 (frequency = 420, code = 44, N = 7)

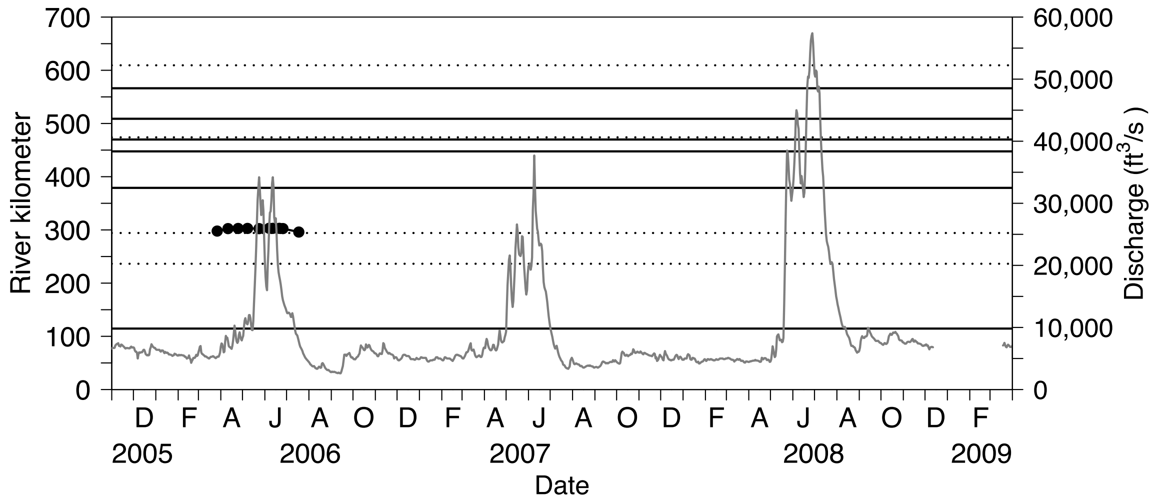

Figure 43. Movements of BURB #3 (frequency = 420, code = 45, N = 10)

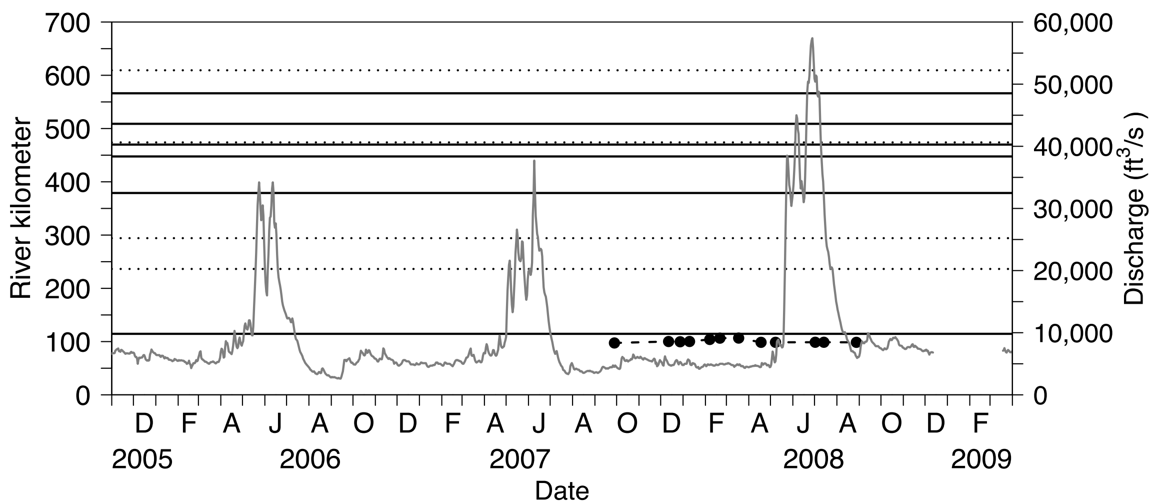

Figure 44. Movements of BURB #4 (frequency = 500, code = 11, N = 12)

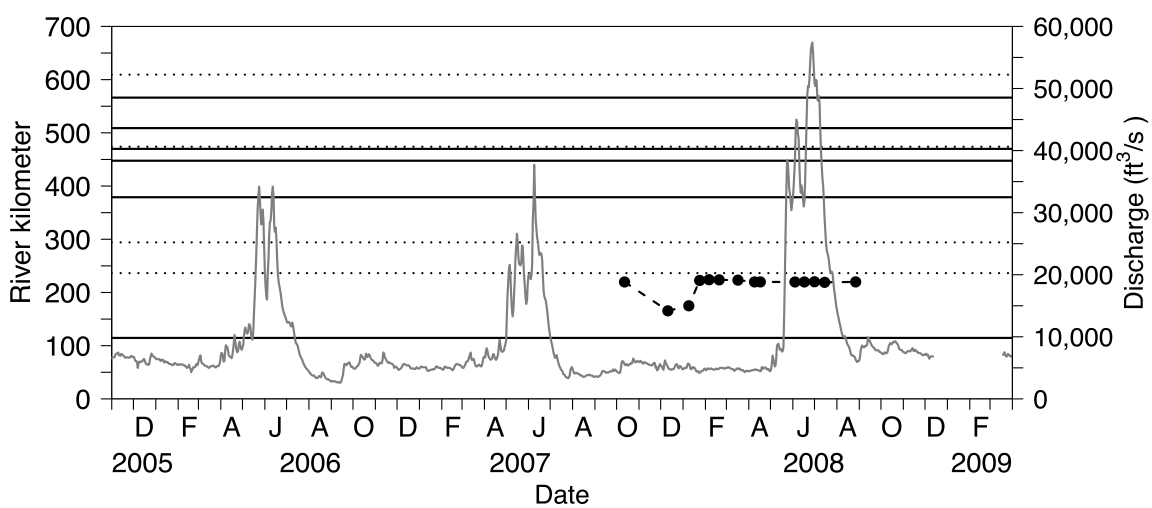

Figure 45. Movements of BURB #5 (frequency = 500, code = 12, N = 14)

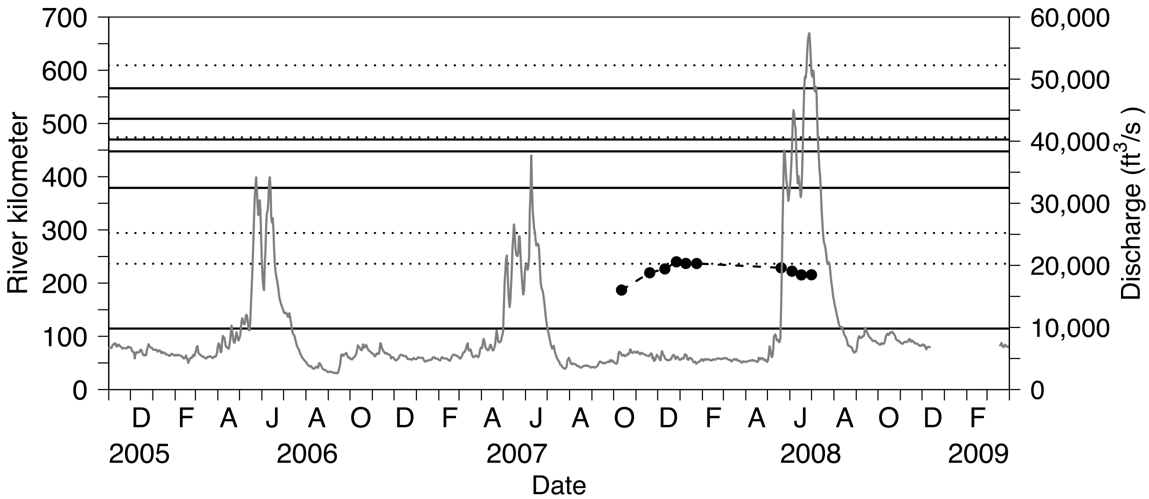

Figure 46. Movements of BURB #6 (frequency = 500, code = 13, N = 10)

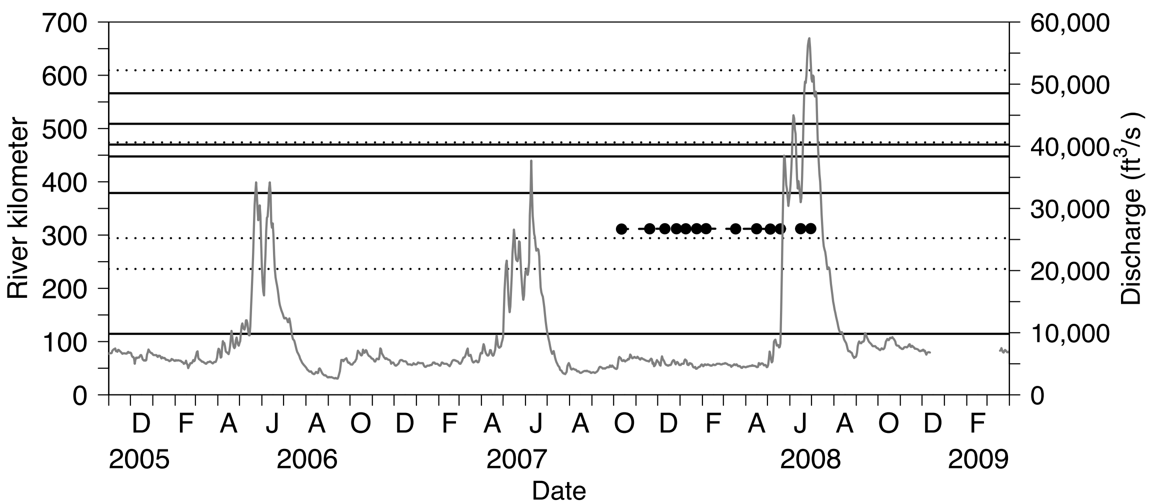

Figure 47. Movements of BURB #7 (frequency = 500, code = 14, N = 13)

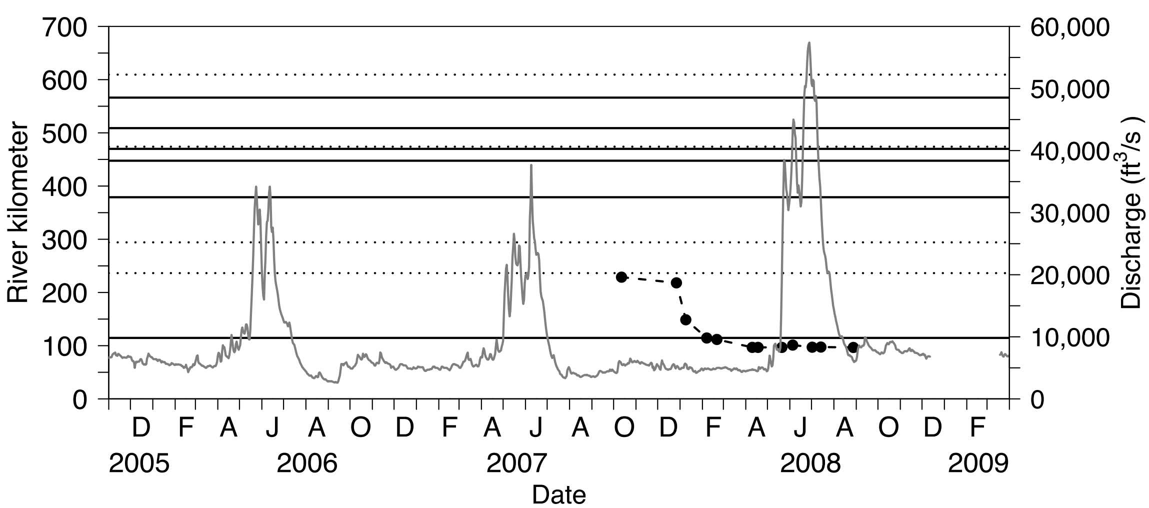

Figure 48. Movements of BURB #8 (frequency = 500, code = 15, N = 12)

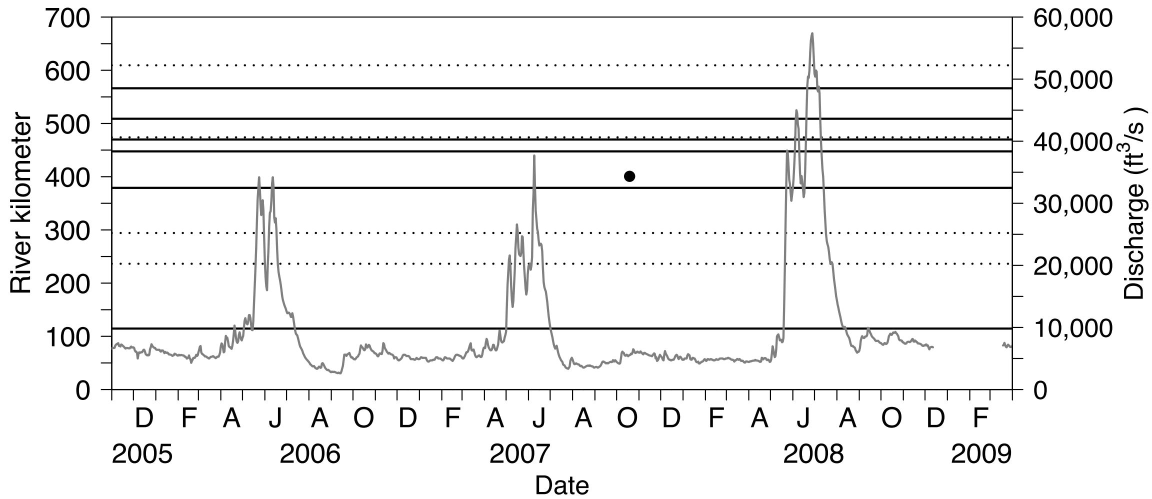

Figure 49. Movements of BURB #9 (frequency = 500, code = 16, N = 1)

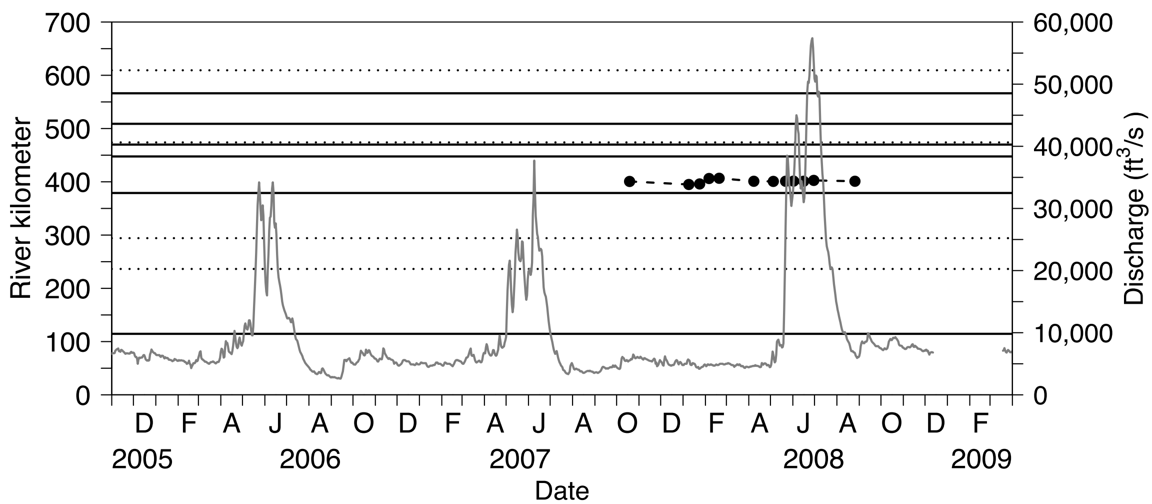

Figure 50. Movements of BURB #10 (frequency = 500, code = 17, N = 12)

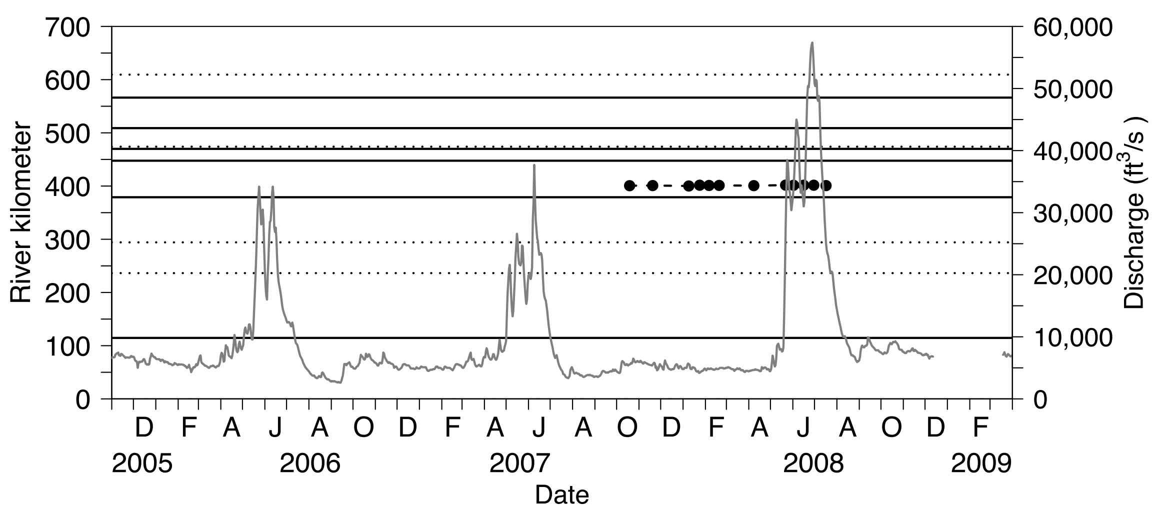

Figure 51. Movements of BURB #11 (frequency = 500, code = 18, N = 12)

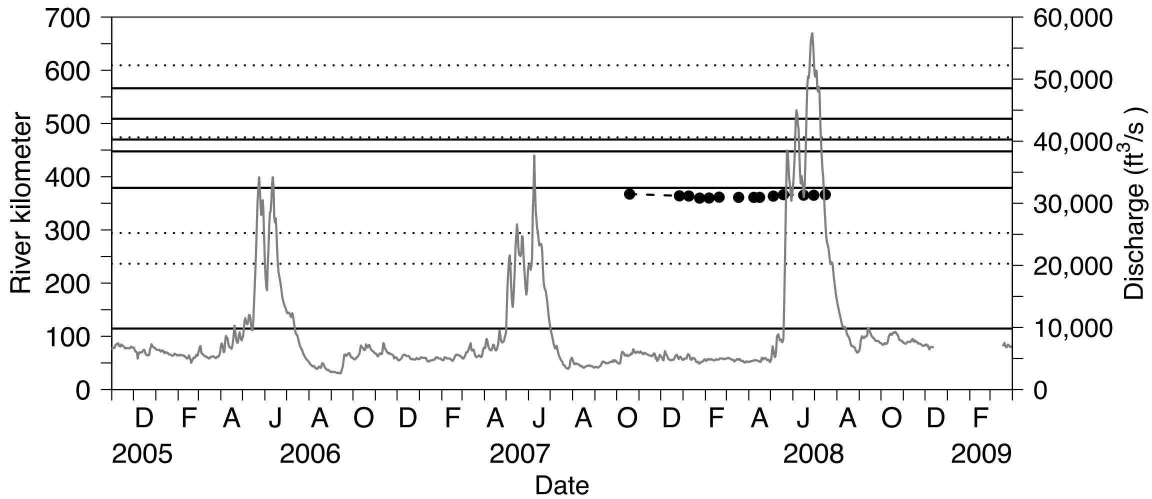

Figure 52. Movements of BURB #12 (frequency = 500, code = 19, N = 14)

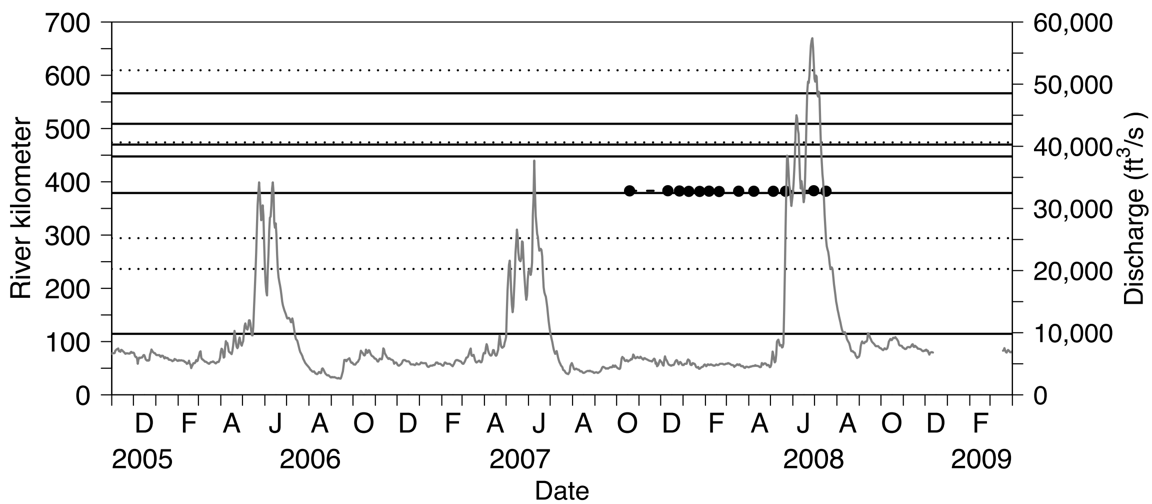

Figure 53. Movements of BURB #13 (frequency = 500, code = 20, N = 13)

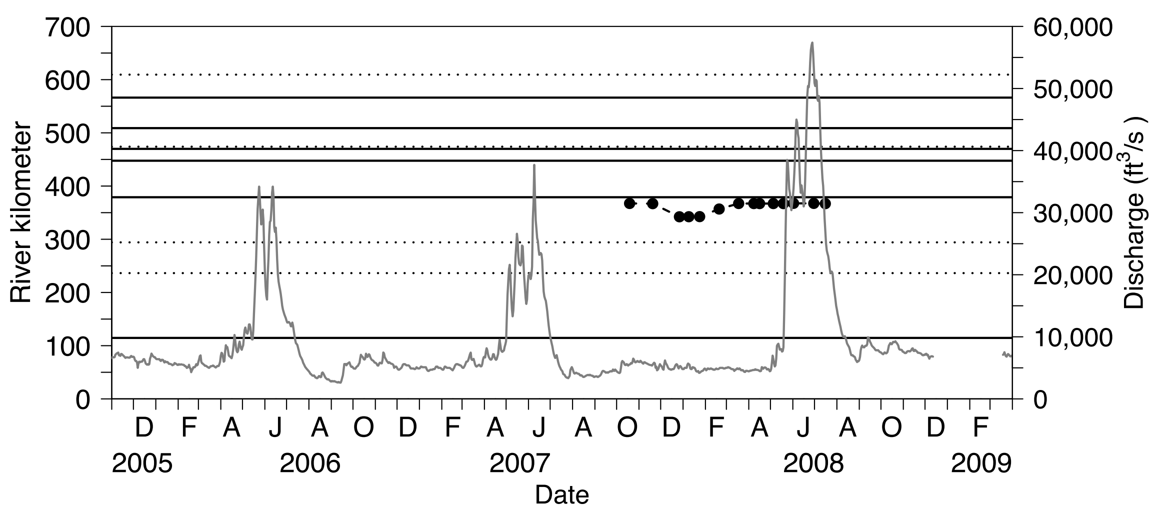

Figure 54. Movements of BURB #14 (frequency = 500, code = 21, N = 14)

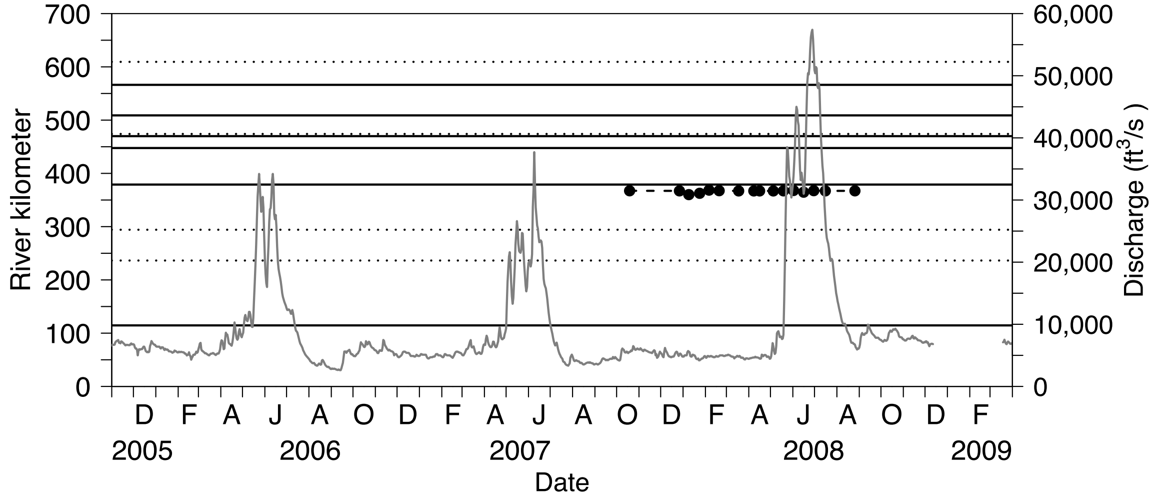

Figure 55. Movements of BURB #15 (frequency = 500, code = 22, N = 16)

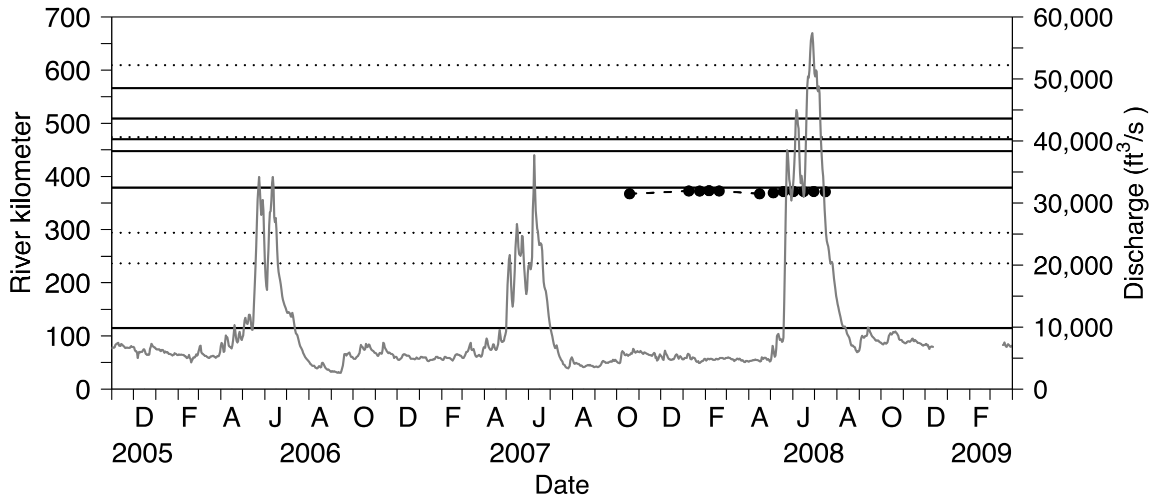

Figure 56. Movements of BURB #16 (frequency = 500, code = 23, N = 12)

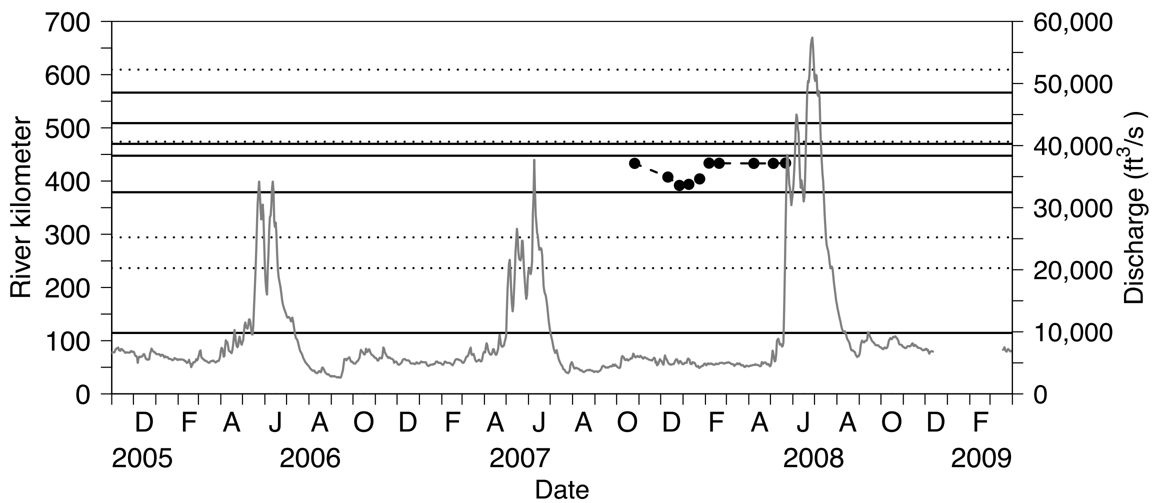

Figure 57. Movements of BURB #17 (frequency = 500, code = 24, N = 10)

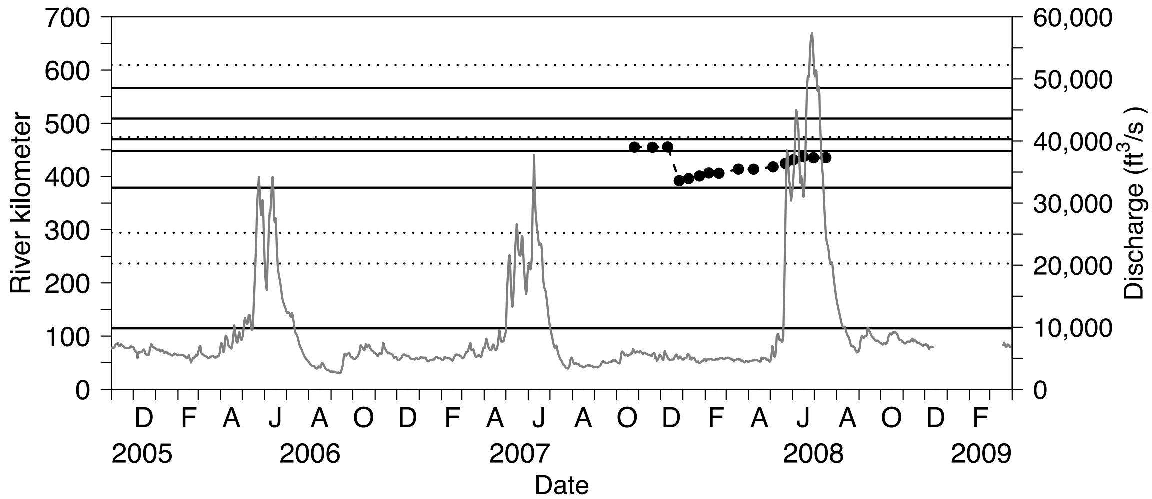

Figure 58. Movements of BURB #18 (frequency = 500, code = 25, N = 16)

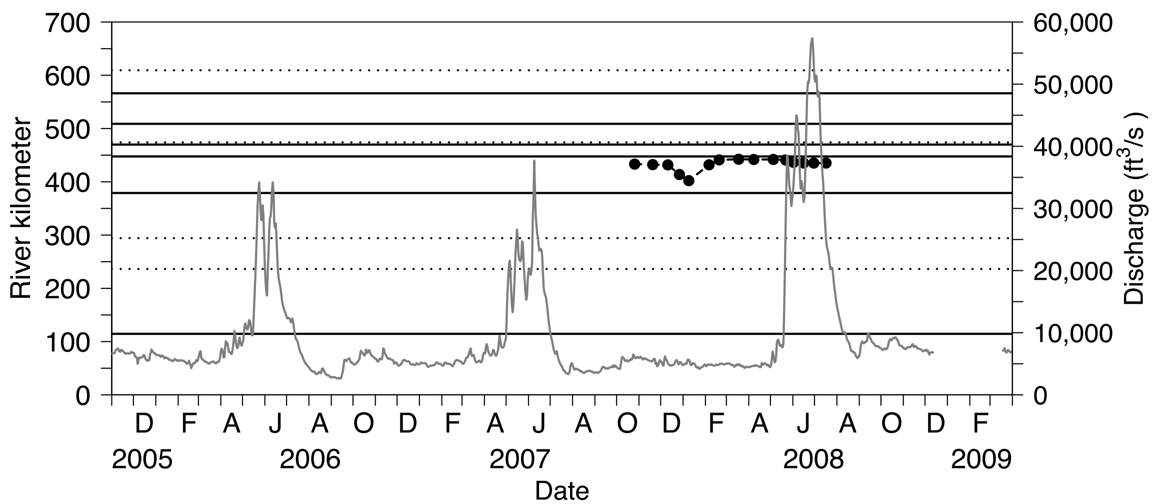

Figure 59. Movements of BURB #19 (frequency = 500, code = 26, N = 15)

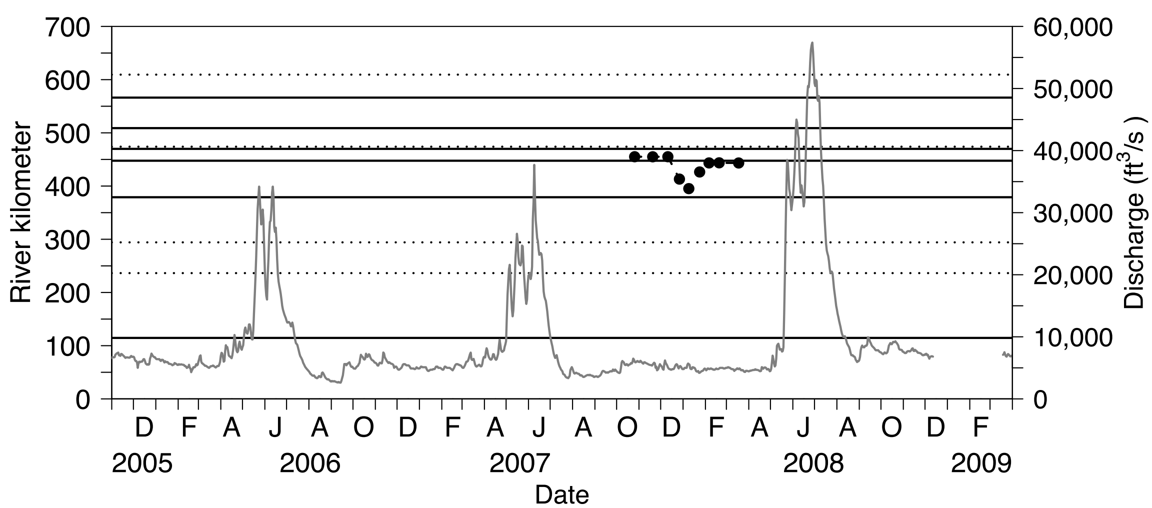

Figure 60. Movements of BURB #20 (frequency = 500, code = 27, N = 9)

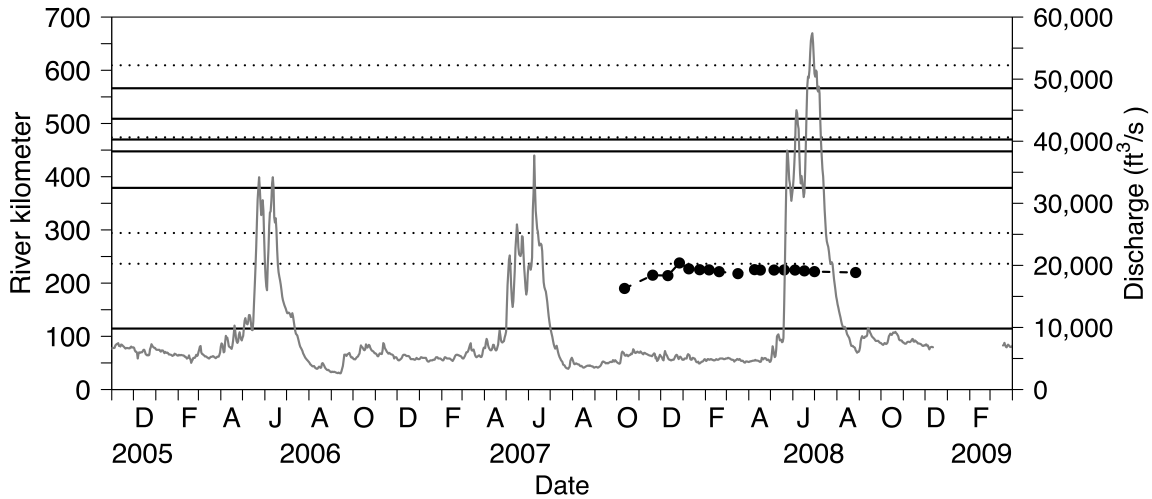

Figure 61. Movements of BURB #21 (frequency = 500, code = 28, N = 17)

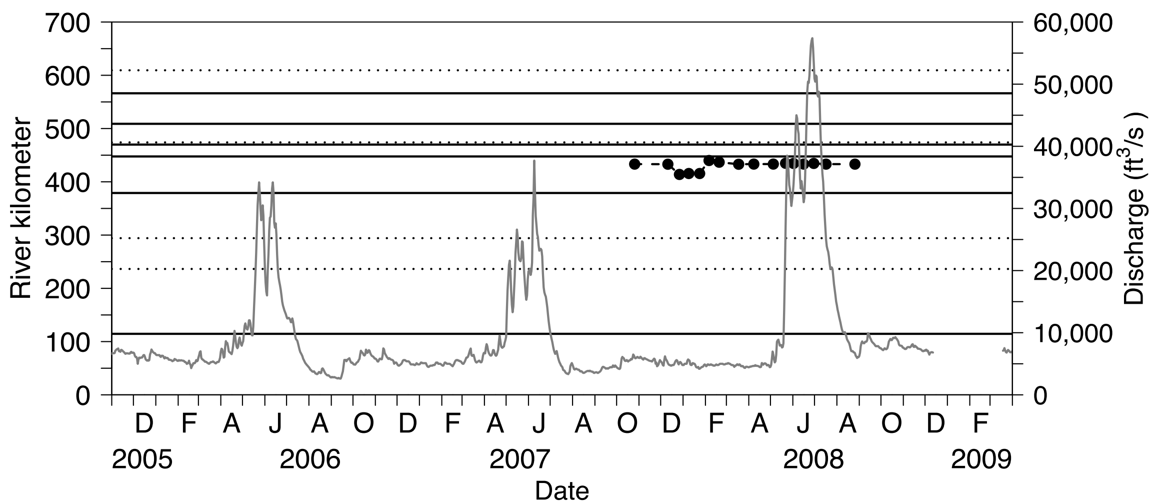

Figure 62. Movements of BURB #22 (frequency = 500, code = 29, N = 16)

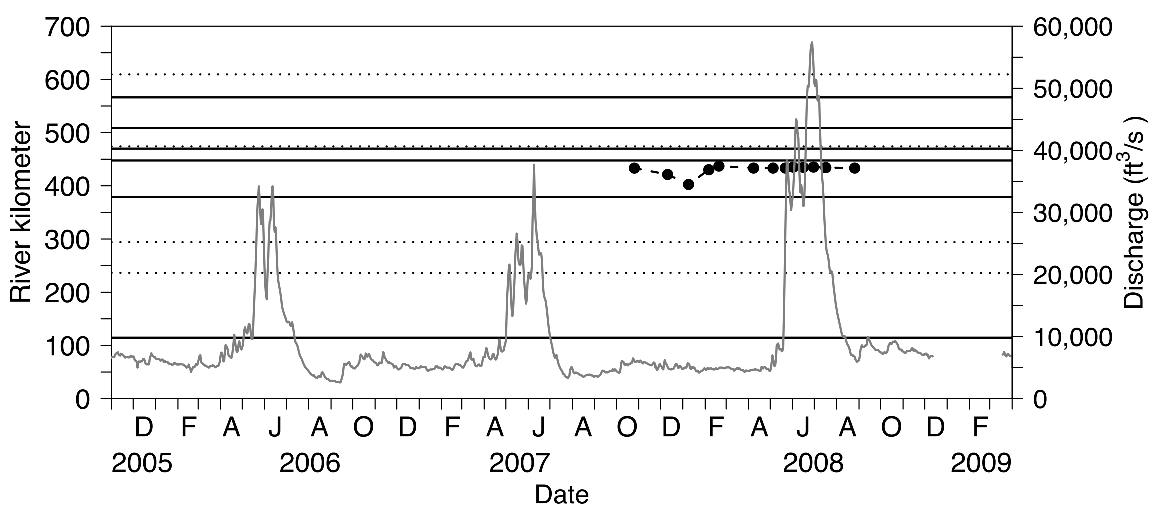

Figure 63. Movements of BURB #23 (frequency = 500, code = 30, N = 13)

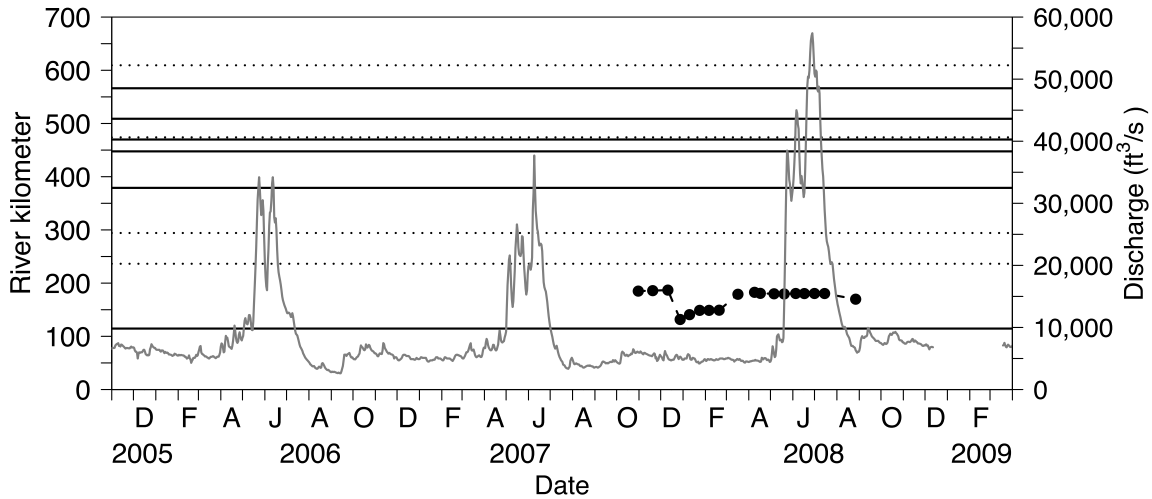

Figure 64. Movements of BURB #24 (frequency = 500, code = 31, N = 18)

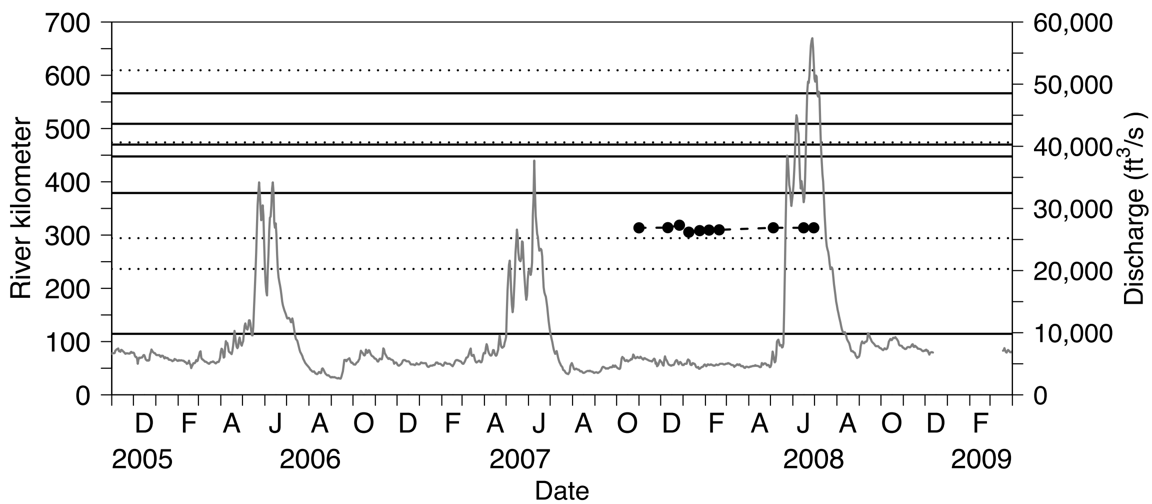

Figure 65. Movements of BURB #25 (frequency = 500, code = 32, N = 10)

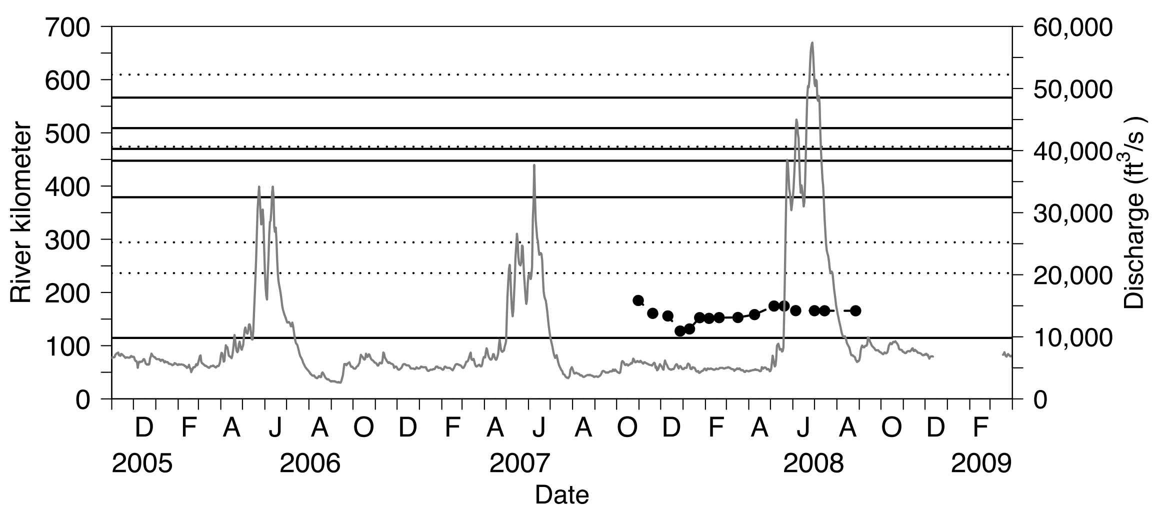

Figure 66. Movements of BURB #26 (frequency = 500, code = 33, N = 16)

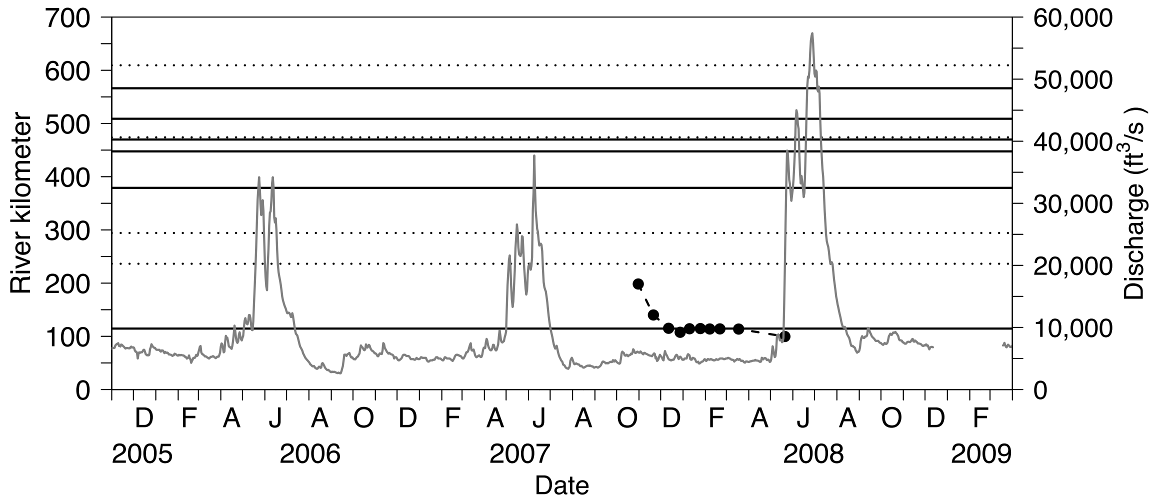

Figure 67. Movements of BURB #27 (frequency = 500, code = 34, N = 10)

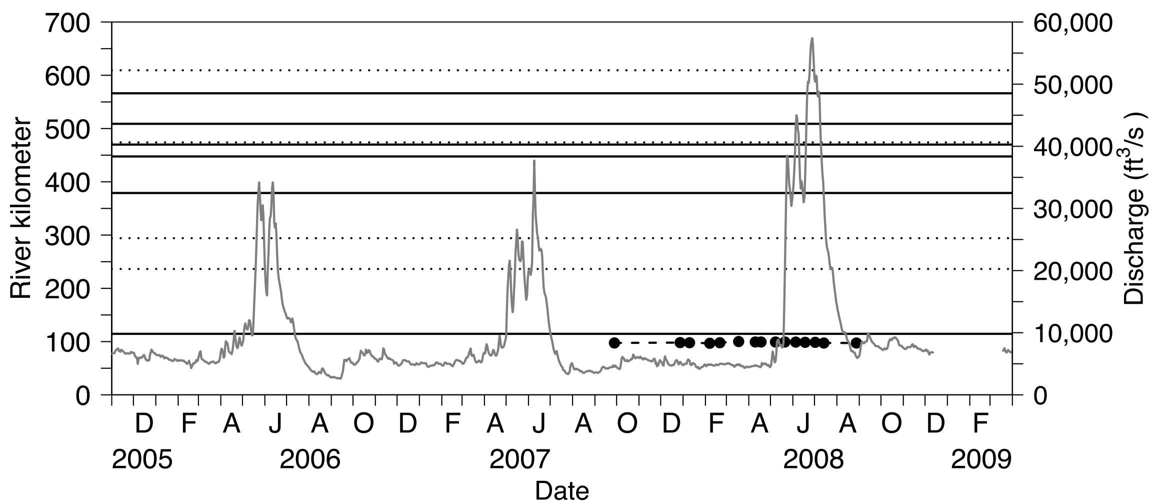

Figure 68. Movements of BURB #28 (frequency = 500, code = 35, N = 15)

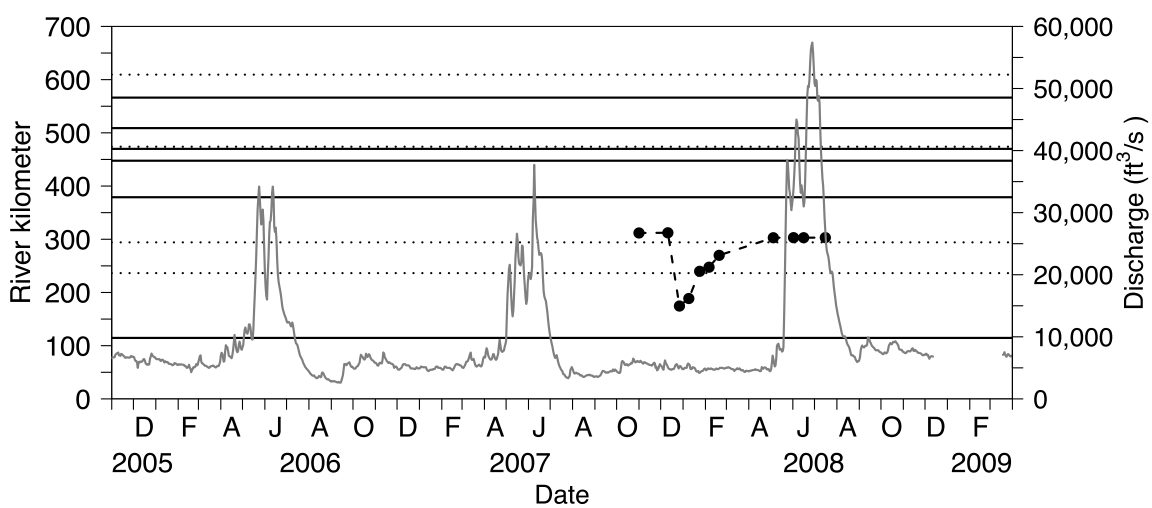

Figure 69. Movements of BURB #29 (frequency = 500, code = 36, N = 11)

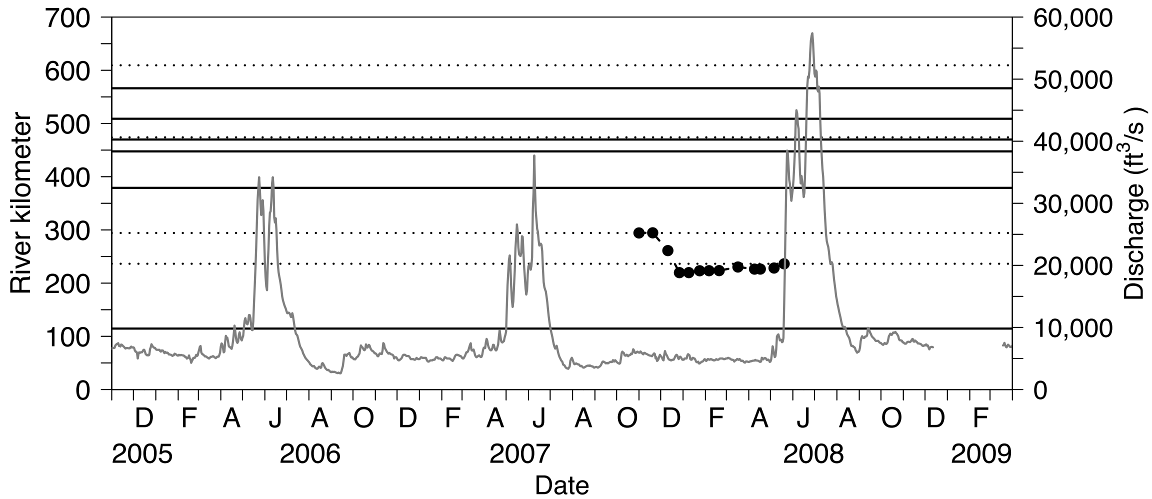

Figure 70. Movements of BURB #30 (frequency = 500, code = 37, N = 13)

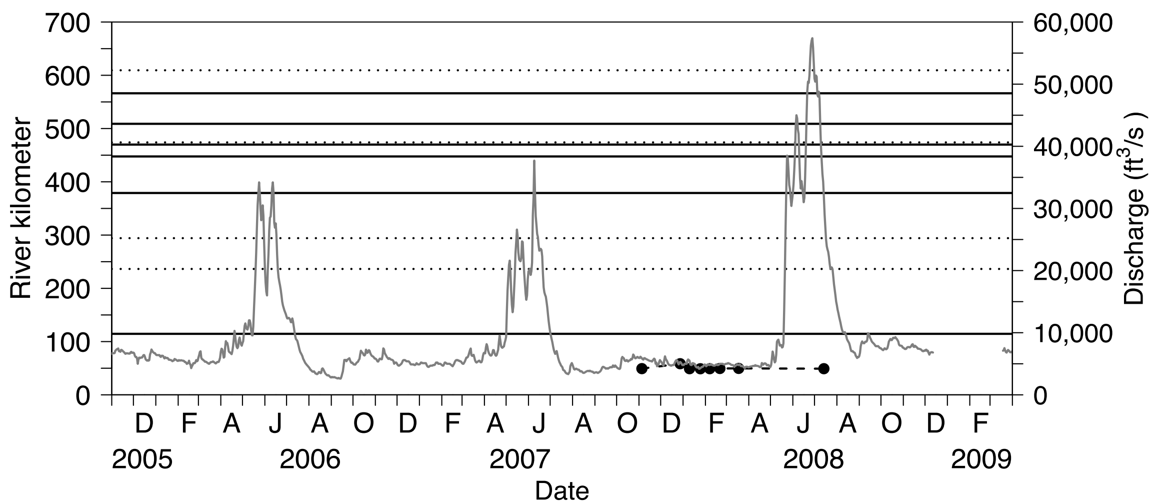

Figure 71. Movements of BURB #31 (frequency = 500, code = 38, N = 8)

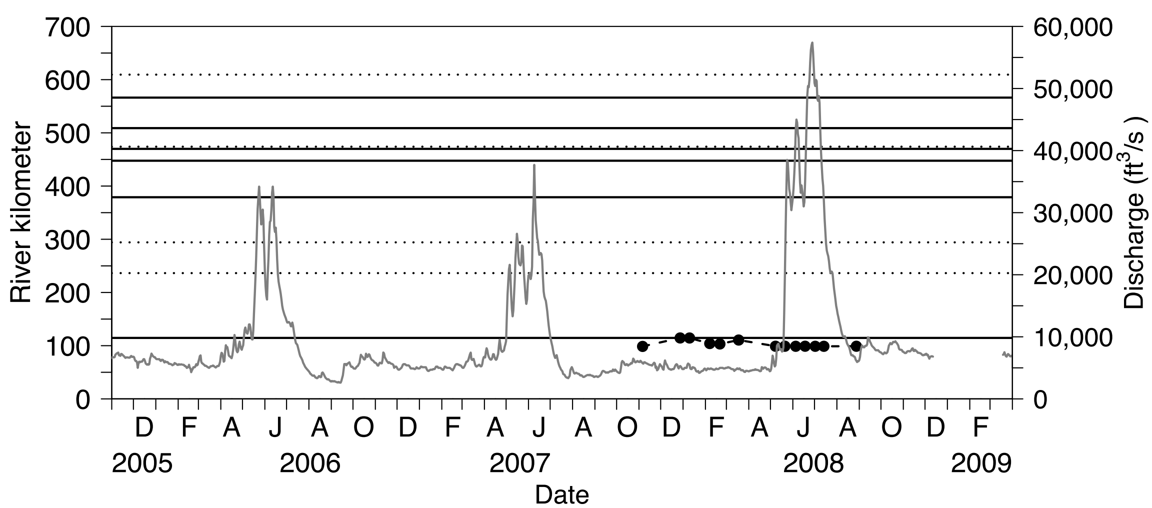

Figure 72. Movements of BURB #32 (frequency = 500, code = 39, N = 13)

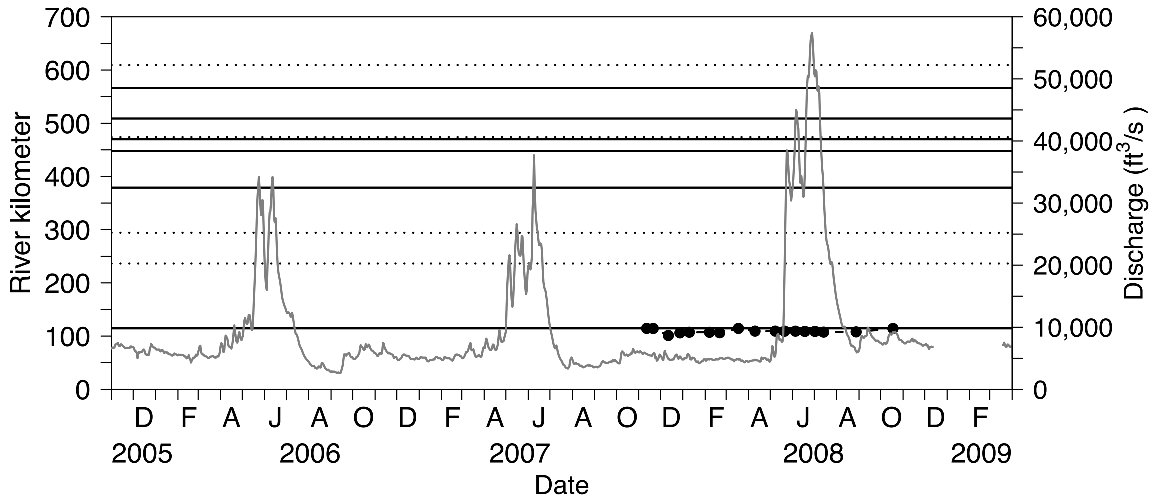

Figure 73. Movements of BURB #33 (frequency = 500, code = 40, N = 17)

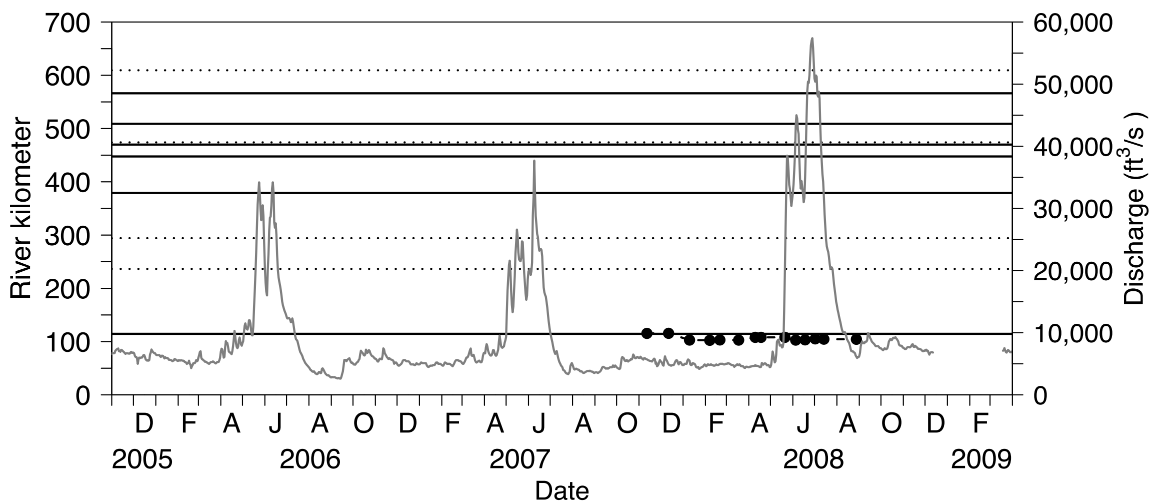

Figure 74. Movements of BURB #34 (frequency = 500, code = 41, N = 14)

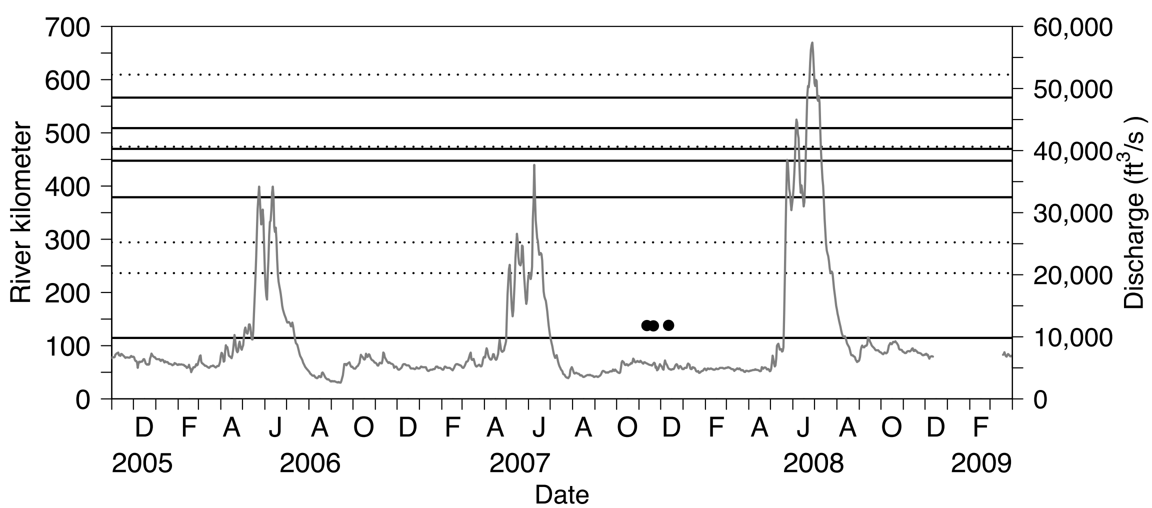

Figure 75. Movements of BURB #35 (frequency = 500, code = 42, N = 3)

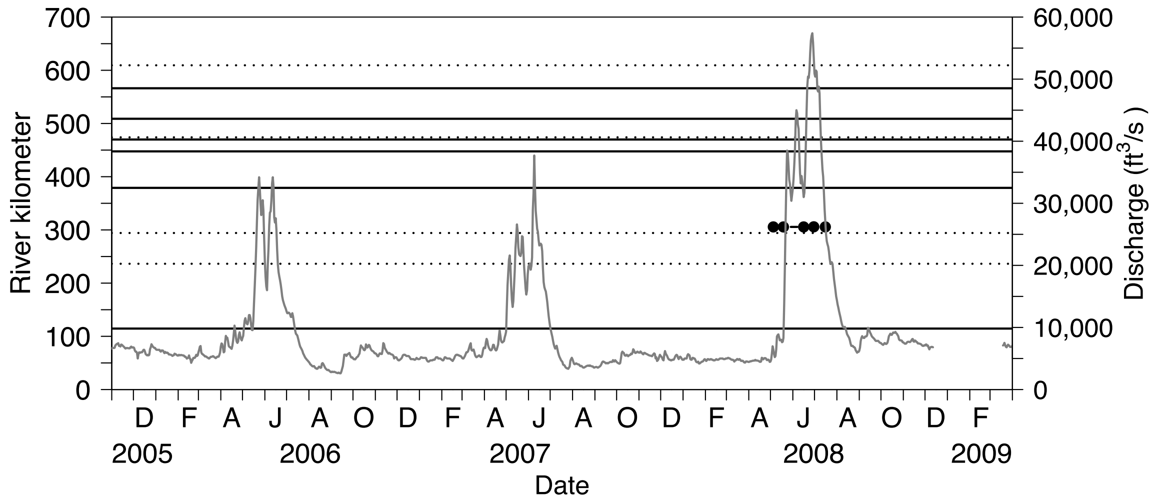

Figure 76. Movements of BURB #36 (frequency = 500, code = 43, N = 5)

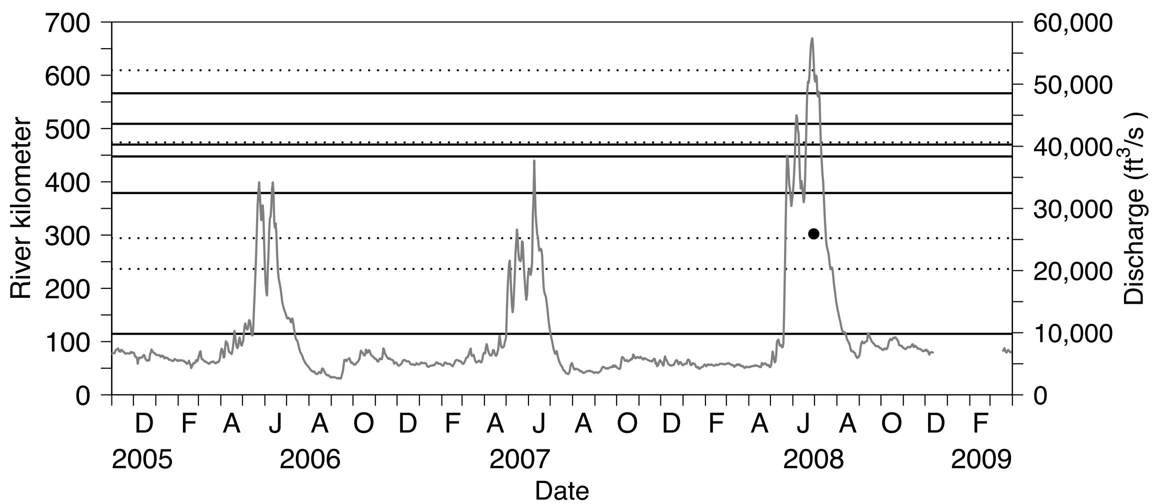

Figure 77. Movements of BURB #37 (frequency = 500, code = 44, N = 1)

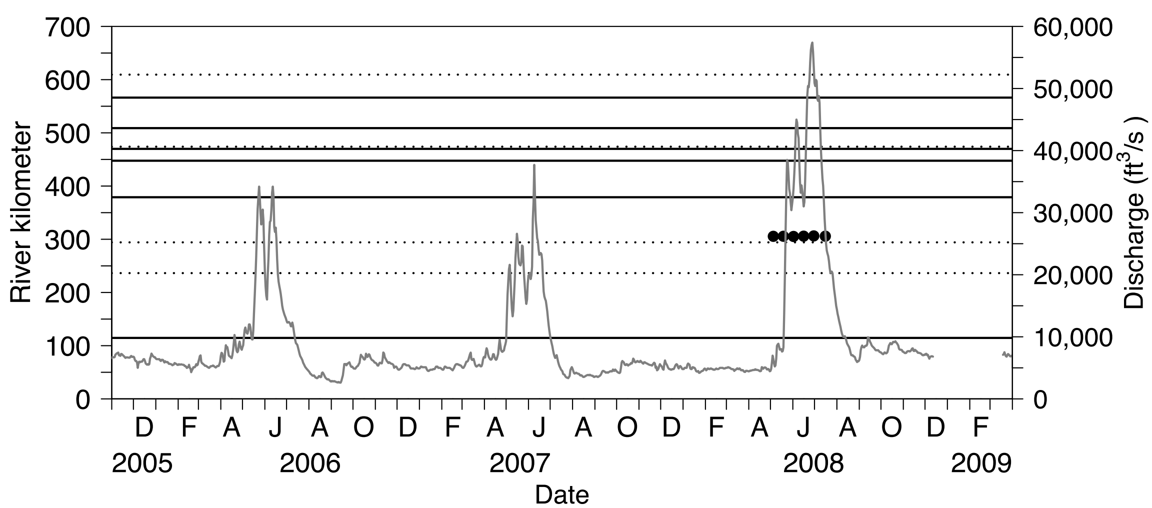

Figure 78. Movements of BURB #38 (frequency = 500, code = 45, N = 6)

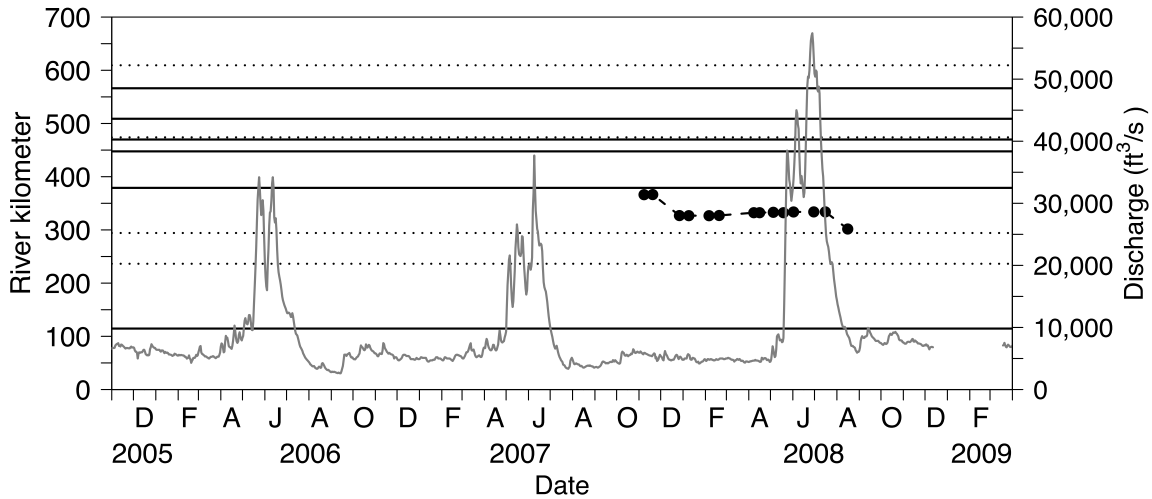

Figure 79. Movements of BURB #39 (frequency = 500, code = 47, N = 14)

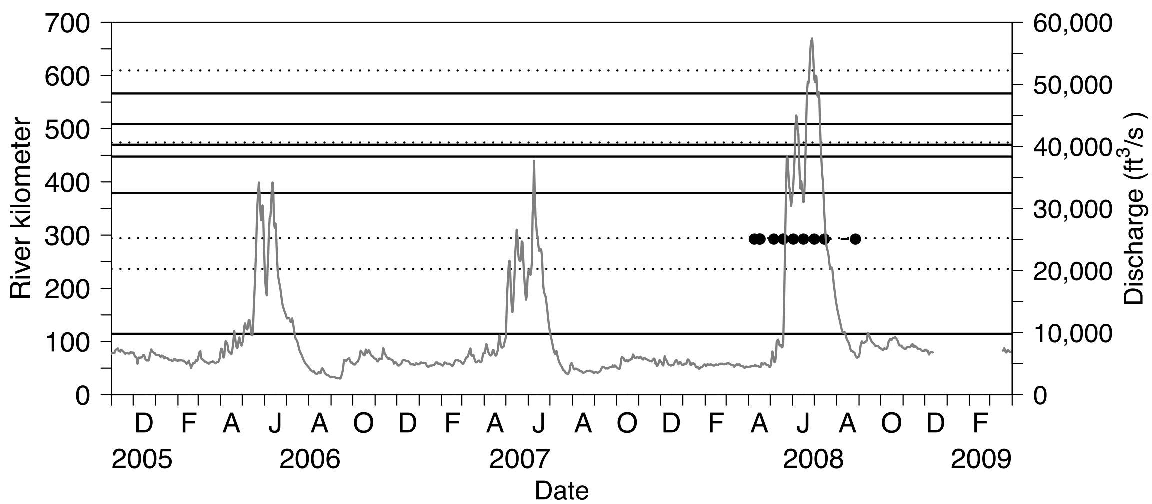

Figure 80. Movements of BURB #40 (frequency = 500, code = 48, N = 10)

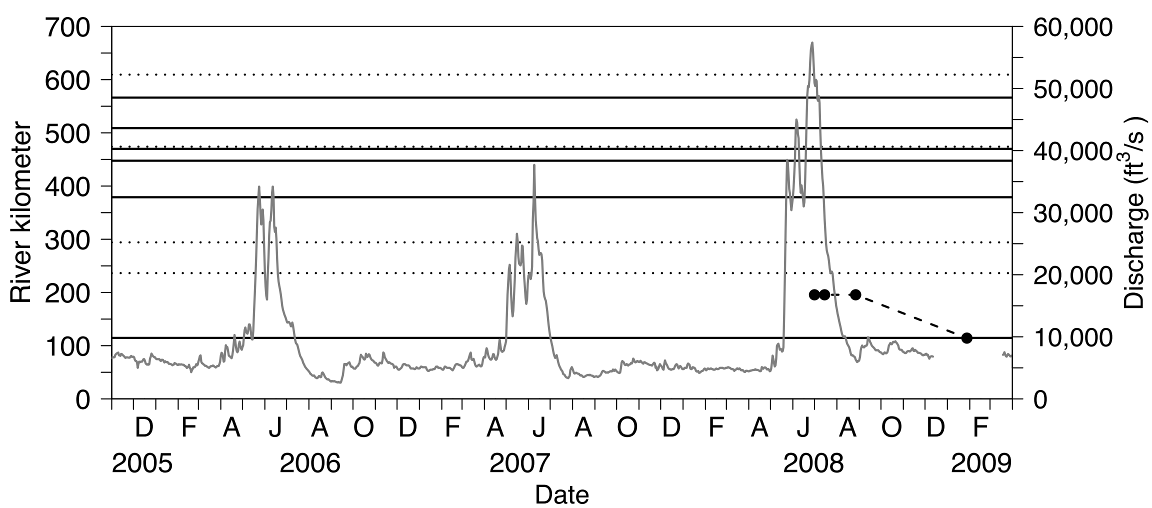

Figure 81. Movements of BURB #41 (frequency = 500, code = 49, N = 4)

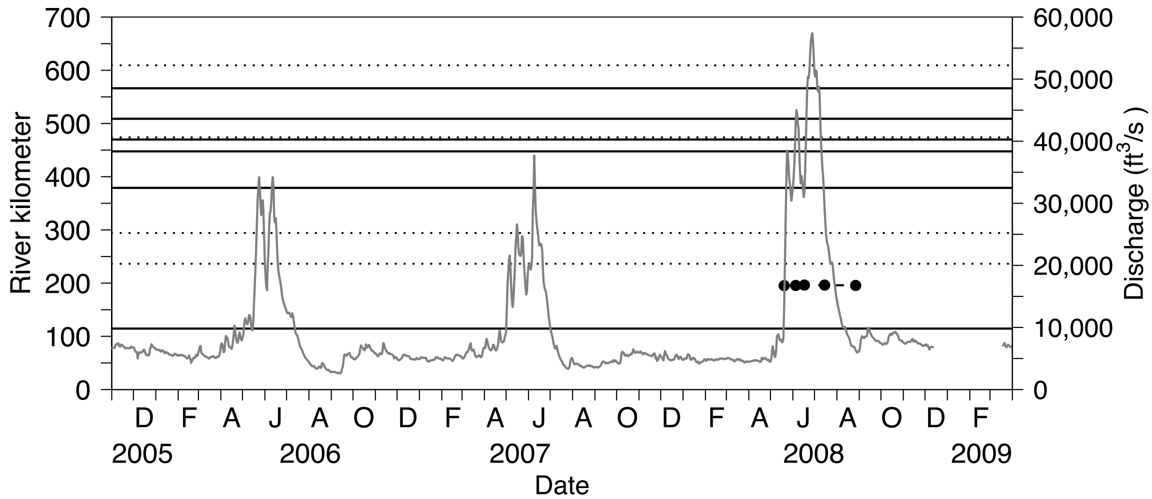

Figure 82. Movements of BURB #42 (frequency = 500, code = 50, N = 5)

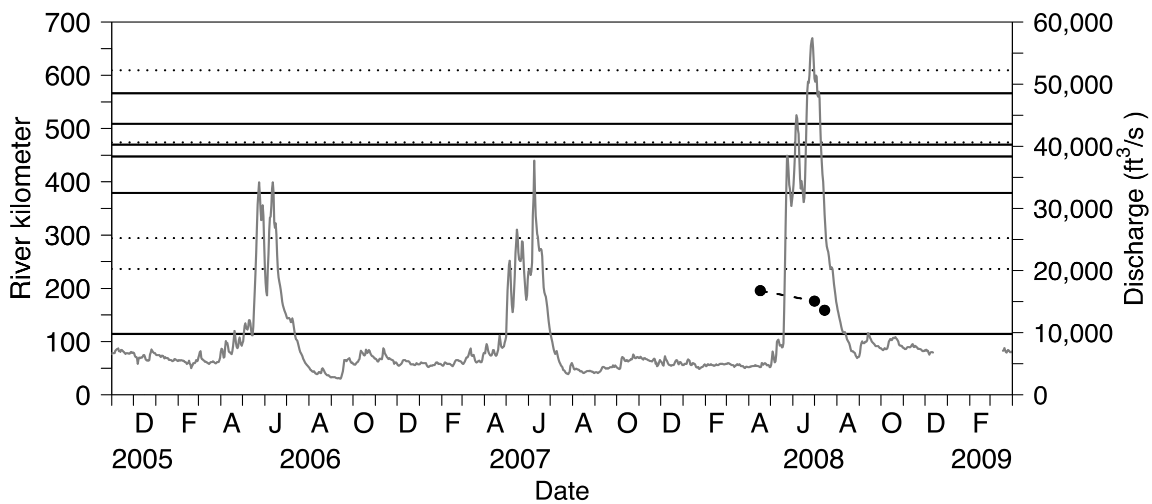

Figure 83. Movements of BURB #43 (frequency = 500, code = 51, N = 3)

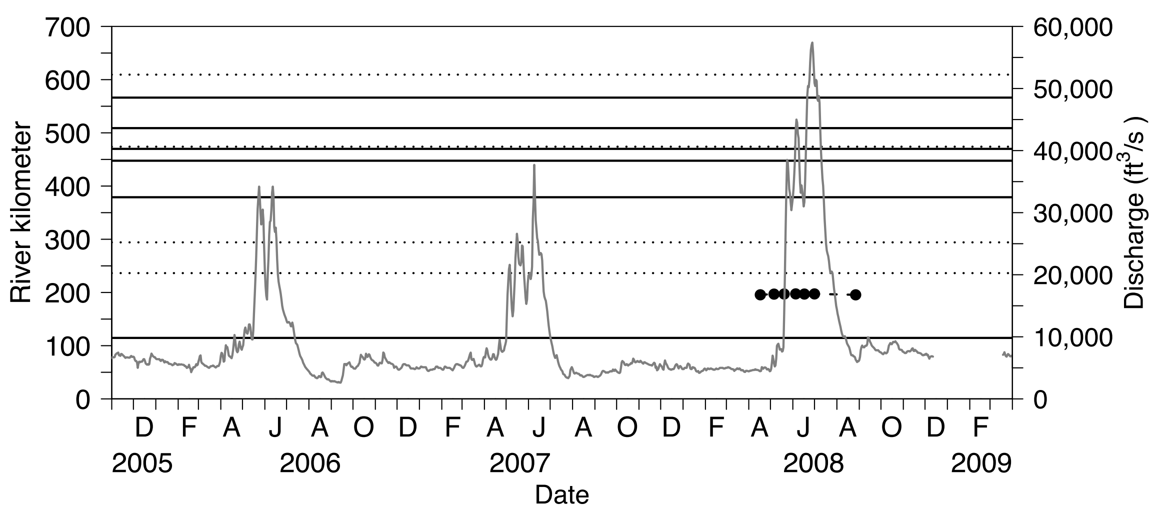

Figure 84. Movements of BURB #44 (frequency = 500, code = 52, N = 7)

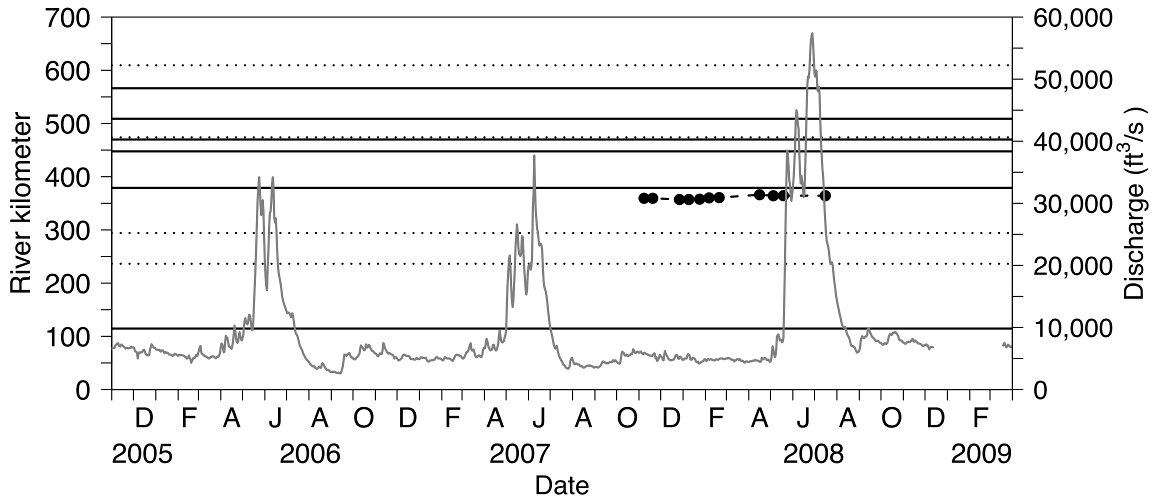

Figure 85. Movements of BURB #45 (frequency = 500, code = 53, N = 11)

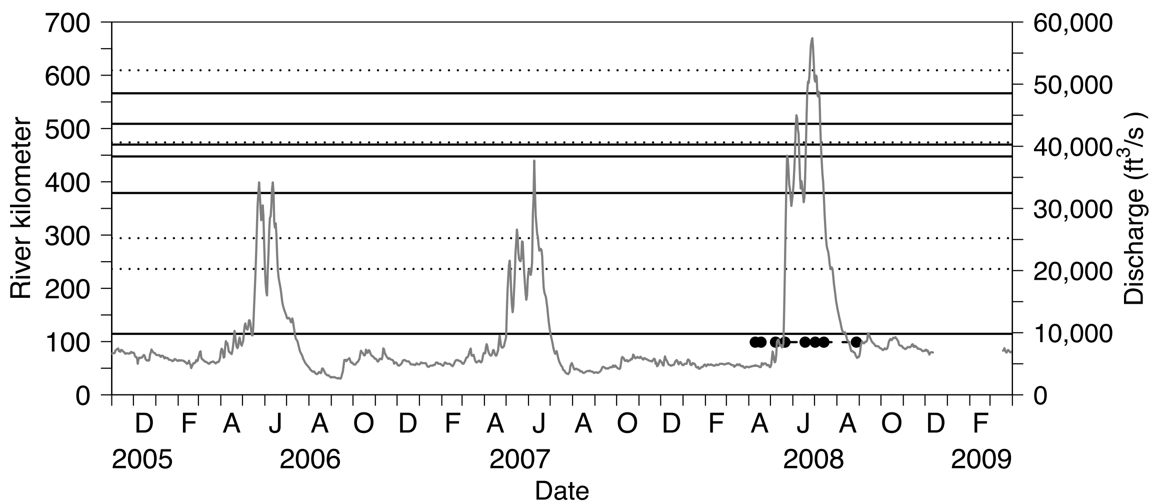

Figure 86. Movements of BURB #46 (frequency = 500, code = 54, N = 8)

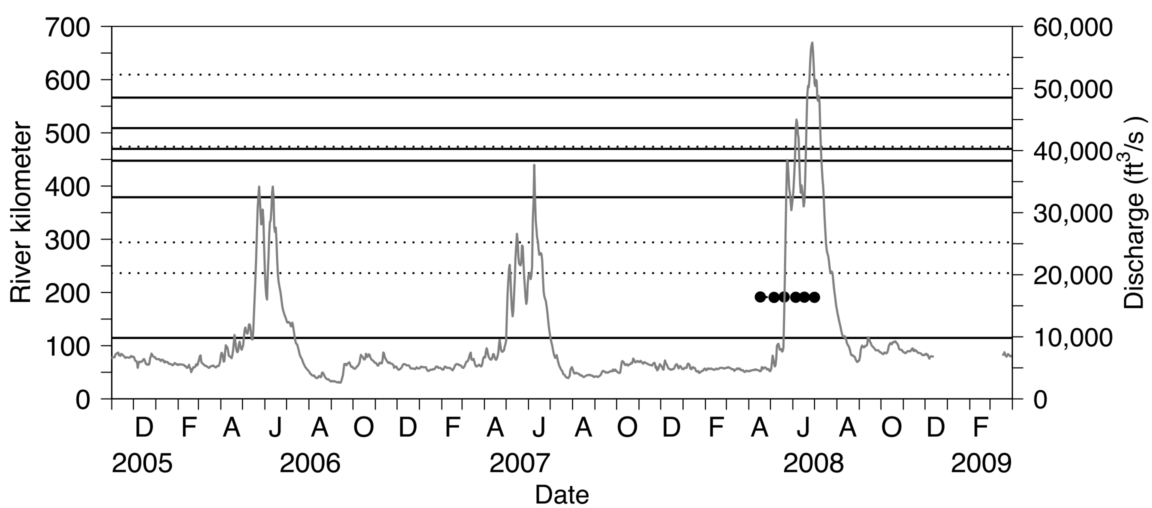

Figure 87. Movements of BURB #47 (frequency = 500, code = 55, N = 6)

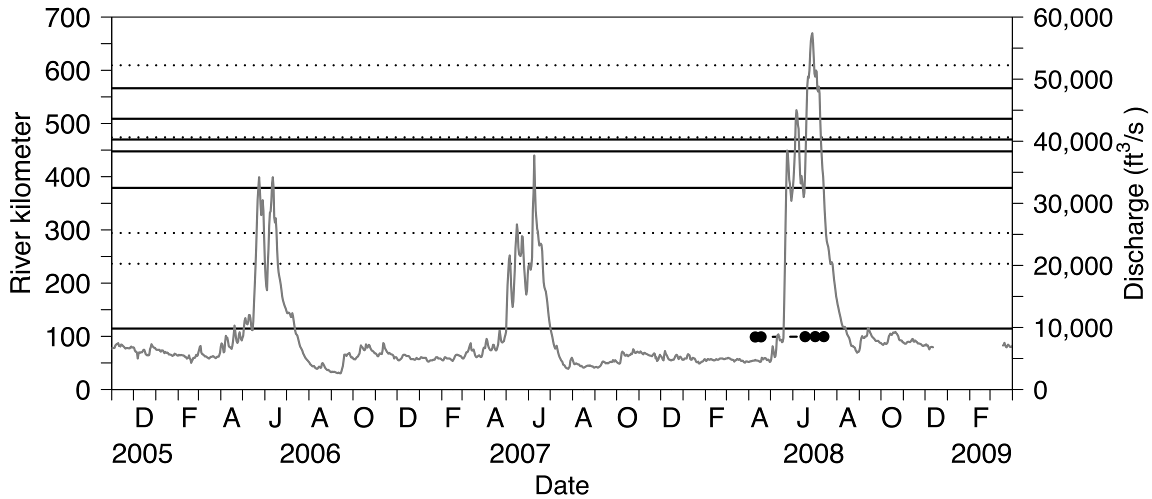

Figure 88. Movements of BURB #48 (frequency = 500, code = 56, N = 5)

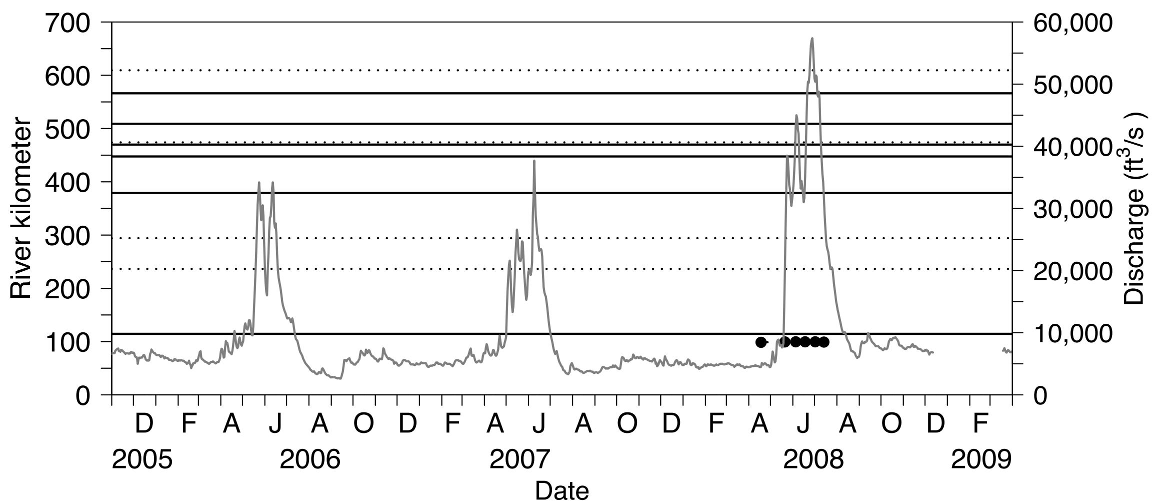

Figure 89. Movements of BURB #49 (frequency = 500, code = 57, N = 6)

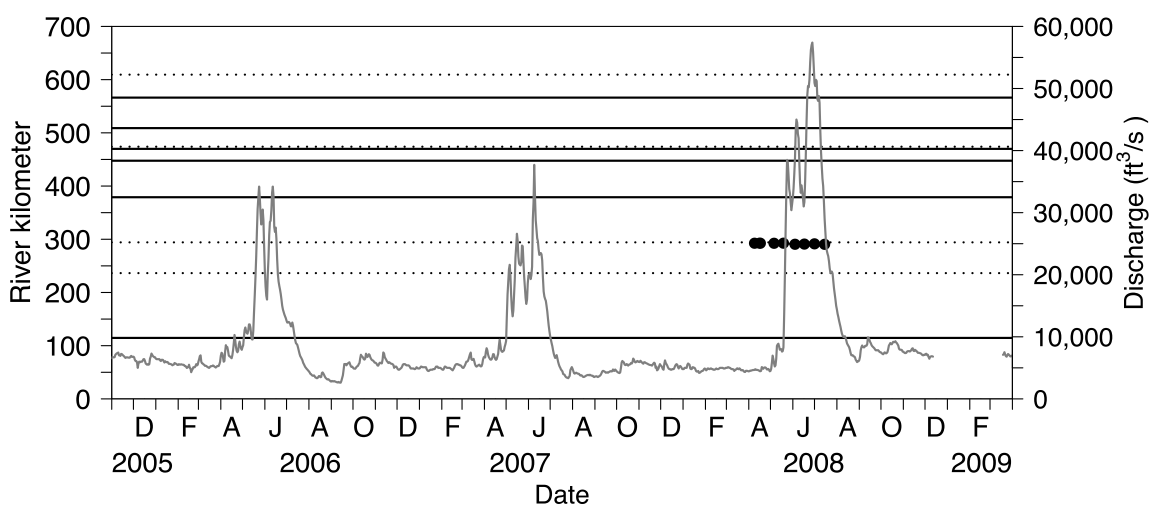

Figure 90. Movements of BURB #50 (frequency = 500, code = 58, N = 9)

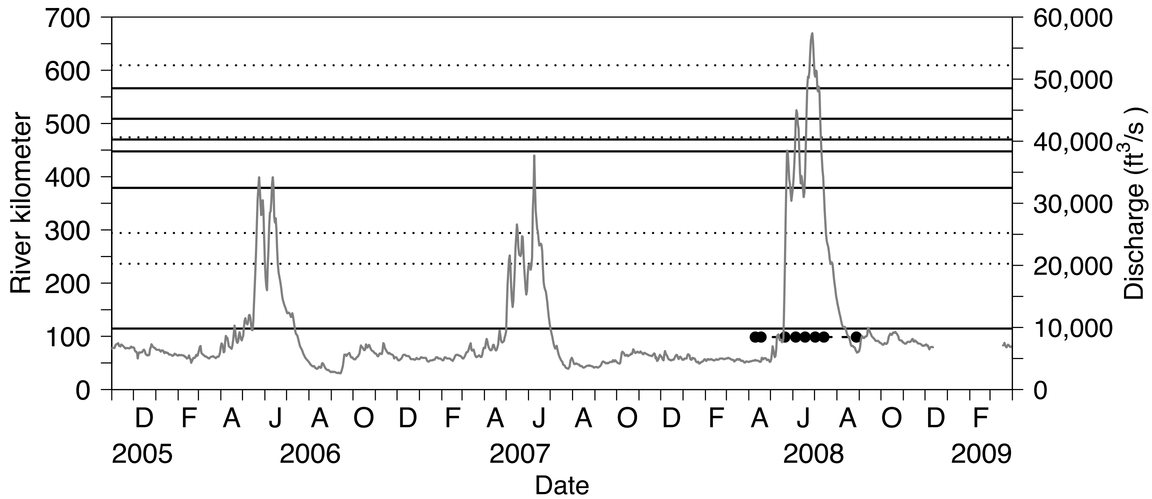

Figure 91. Movements of BURB #51 (frequency = 500, code = 59, N = 8)

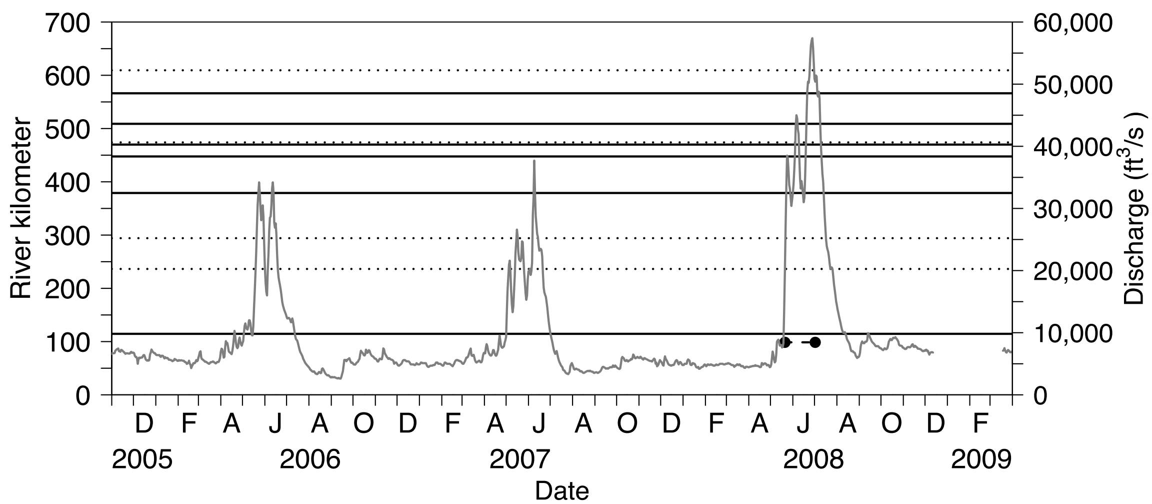

Figure 92. Movements of BURB #52 (frequency = 500, code = 60, N = 2)

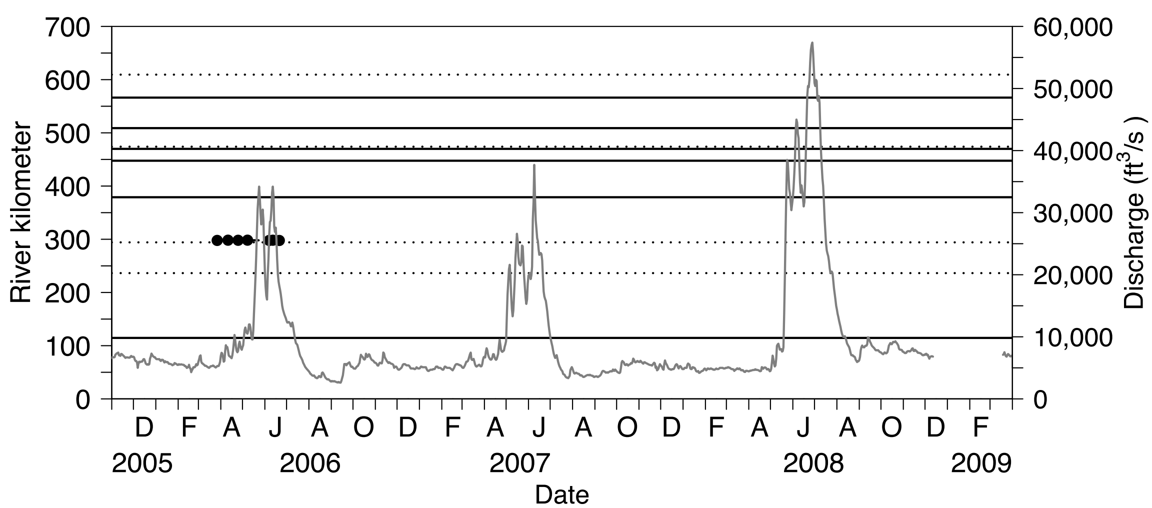

Figure 93. Movements of BURB #53 (frequency = 600, code = 11, N = 7)

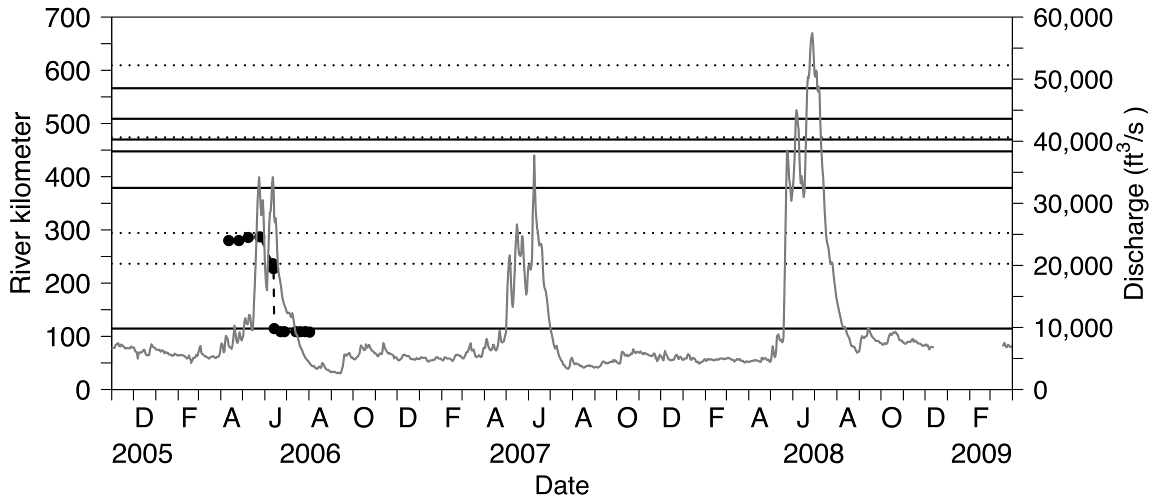

Figure 94. Movements of BURB #54 (frequency = 600, code = 12, N = 13)

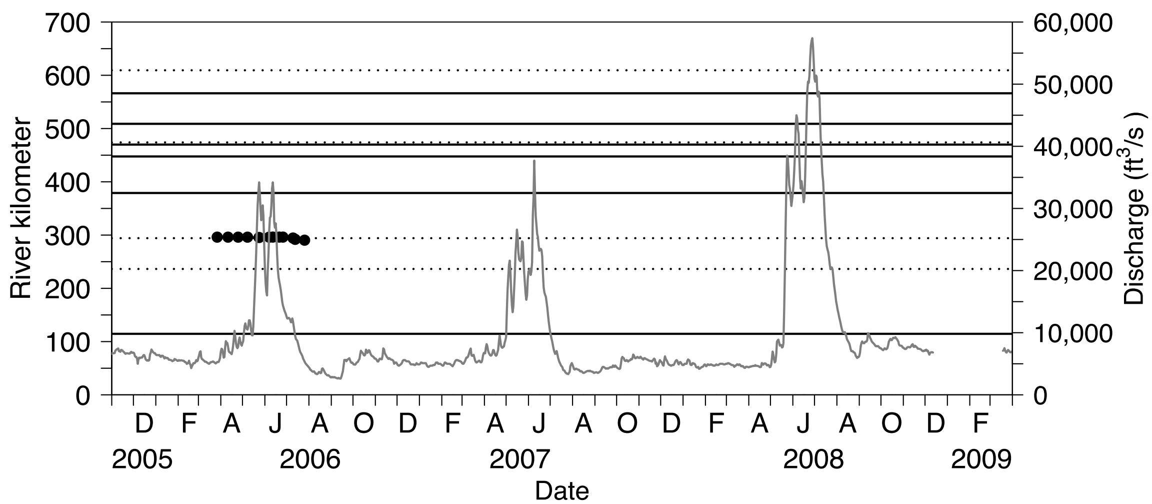

Figure 95. Movements of BURB #55 (frequency = 600, code = 13, N = 12)

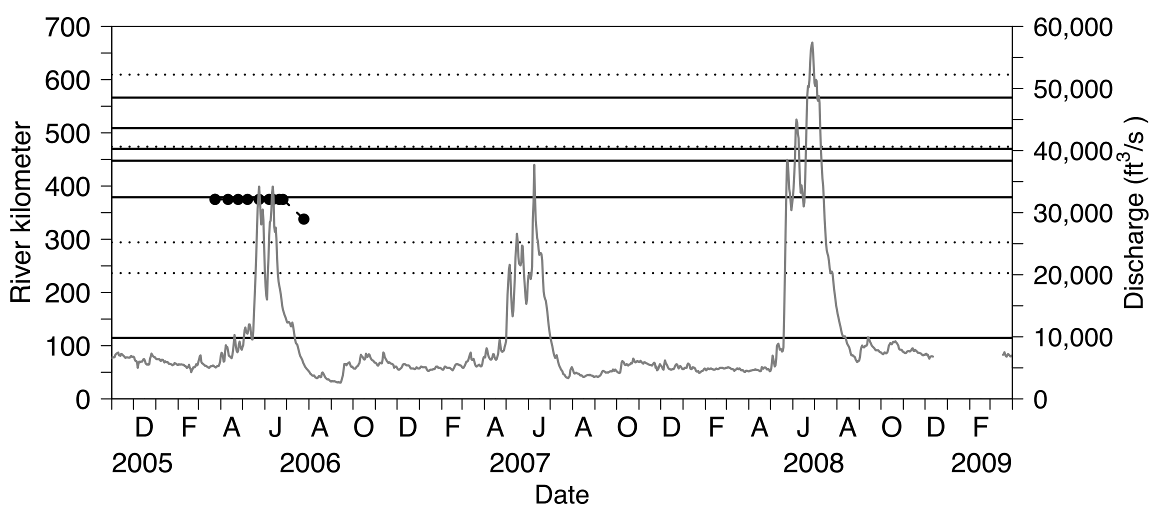

Figure 96. Movements of BURB #56 (frequency = 600, code = 14, N = 11)

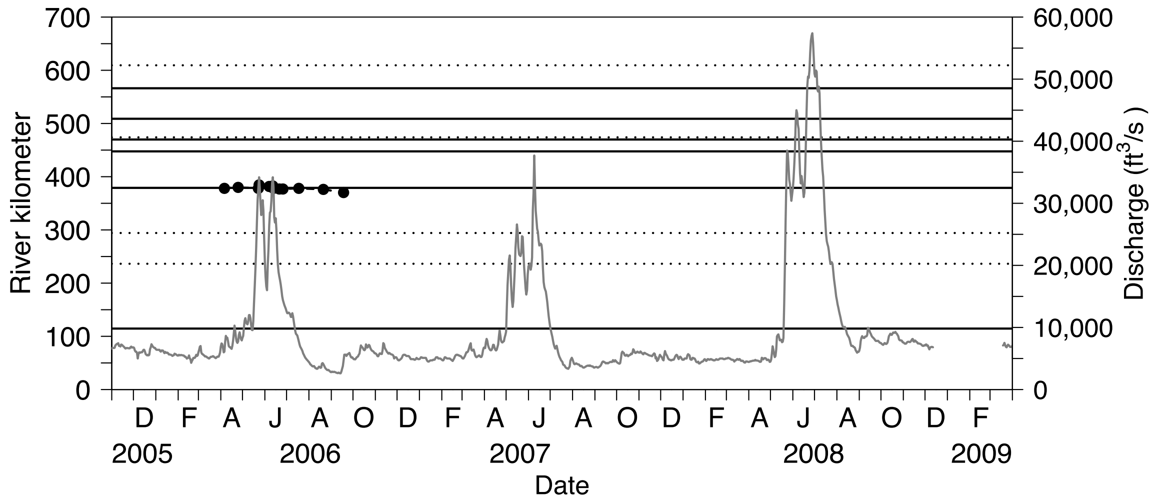

Figure 97. Movements of BURB #57 (frequency = 600, code = 15, N = 12)

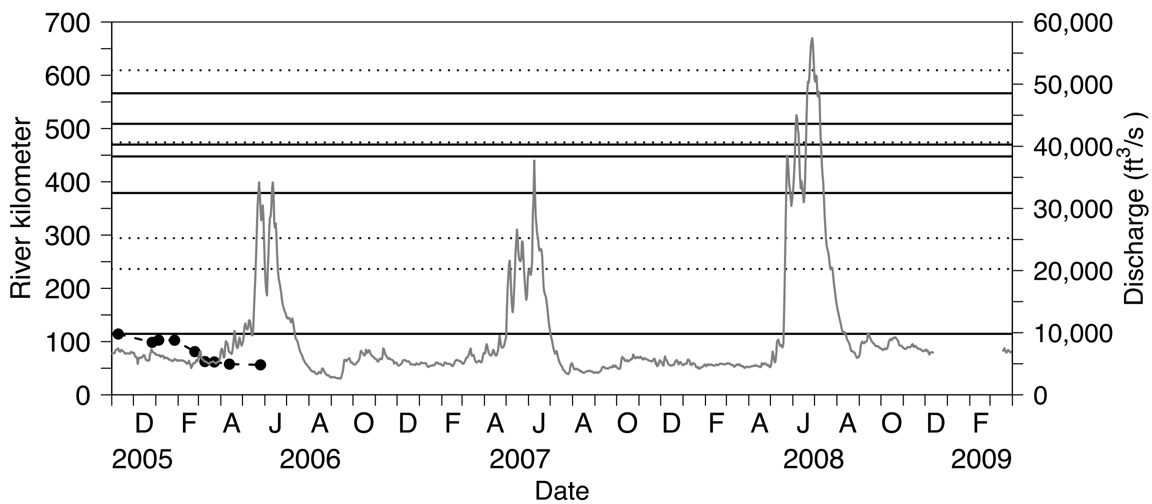

Figure 98. Movements of BURB #58 (frequency = 600, code = 16, N = 9)

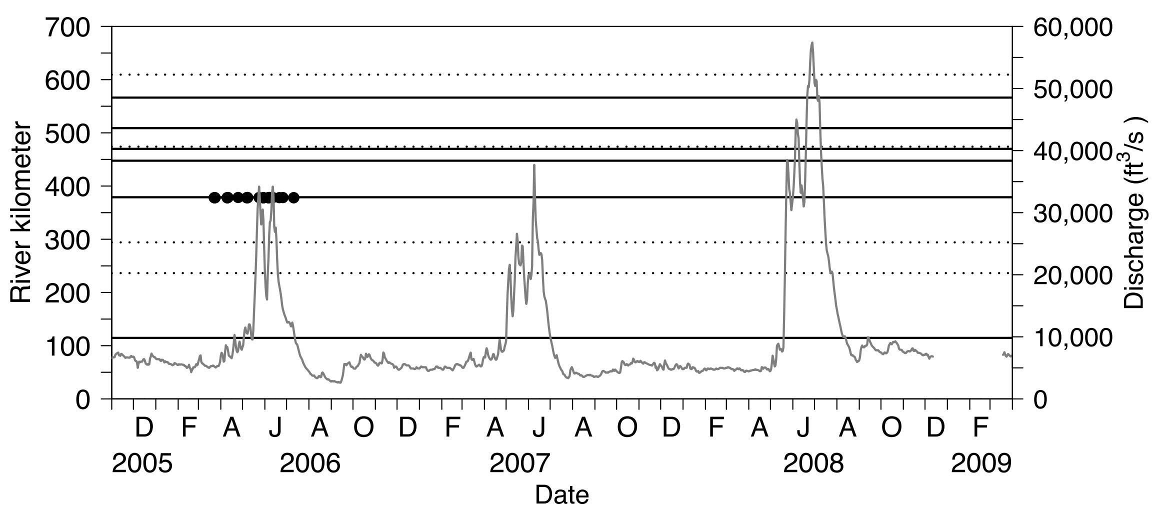

Figure 99. Movements of BURB #59 (frequency = 600, code = 17, N = 30)

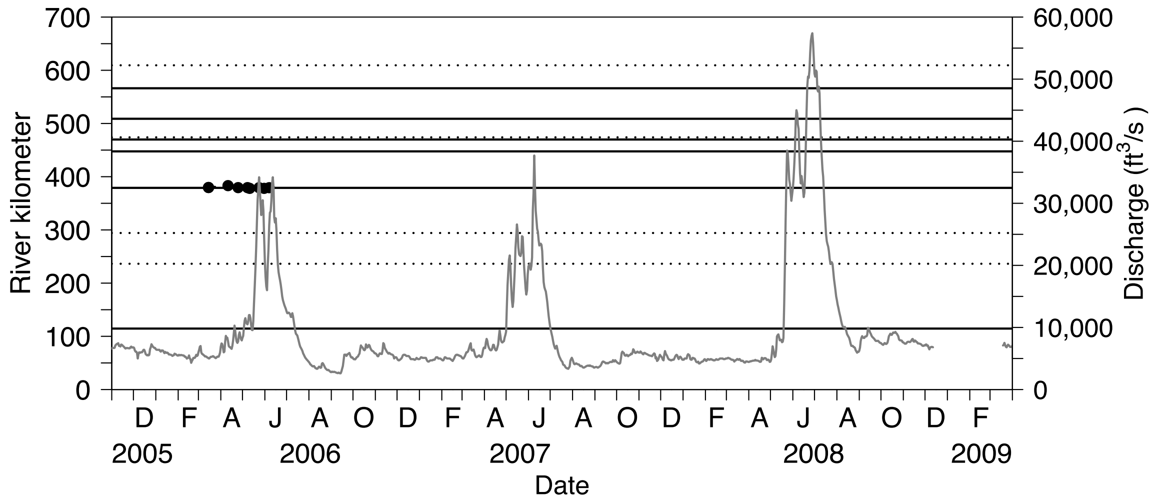

Figure 100. Movements of BURB #60 (frequency = 600, code = 18, N = 9)

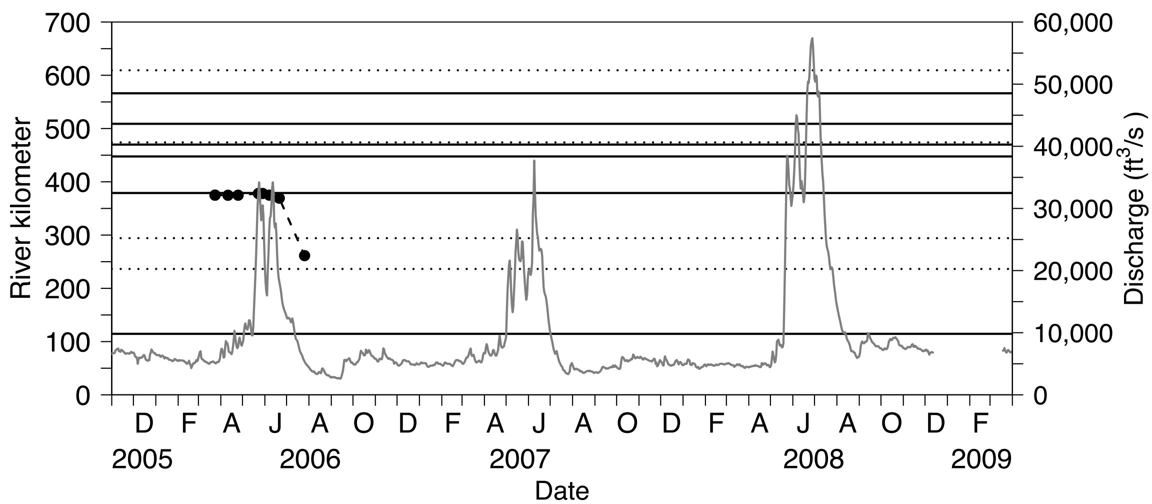

Figure 101. Movements of BURB #61 (frequency = 600, code = 19, N = 10)

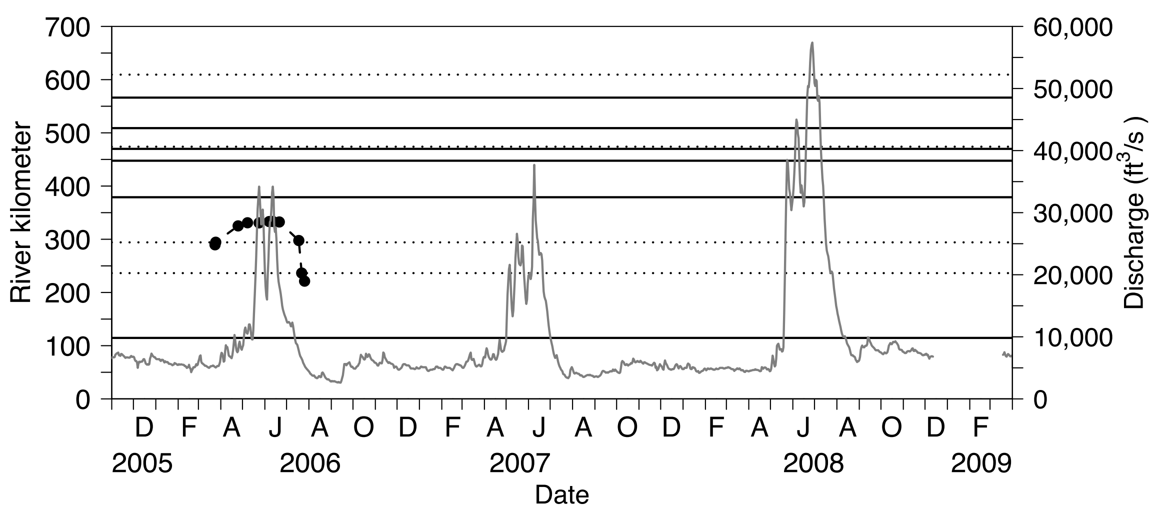

Figure 102. Movements of BURB #62 (frequency = 600, code = 20, N = 11)

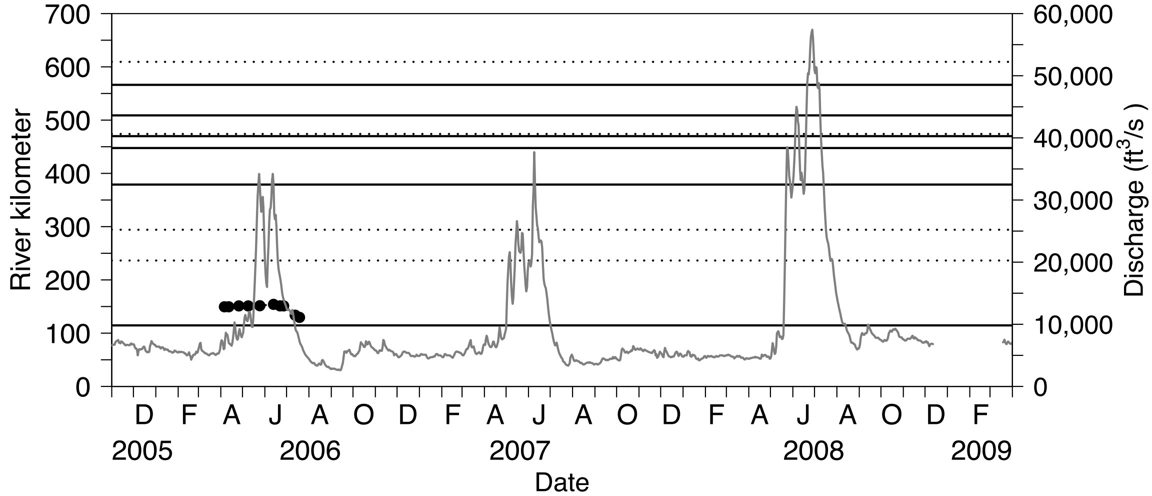

Figure 103. Movements of BURB #63 (frequency = 600, code = 21, N = 10)

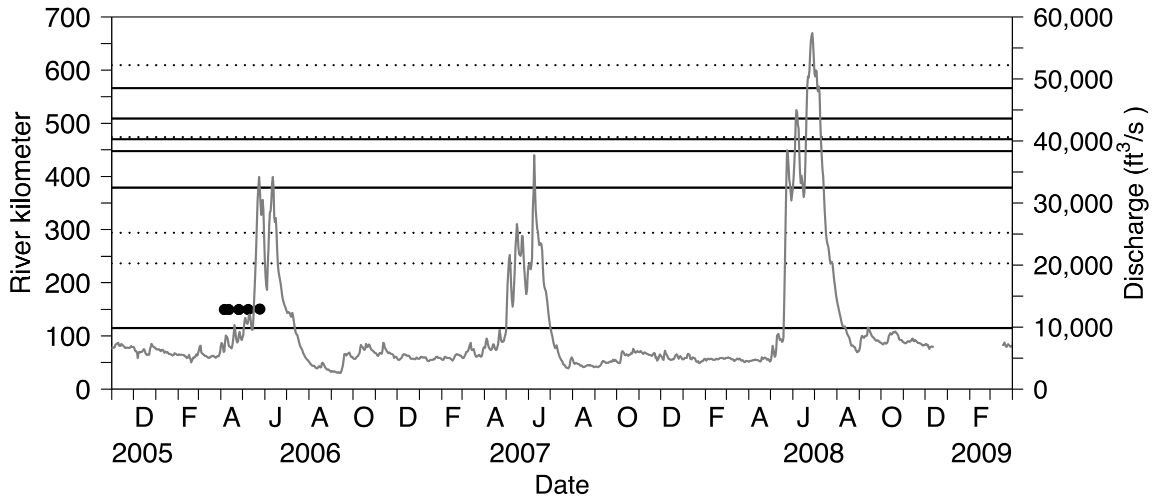

Figure 104. Movements of BURB #64 (frequency = 600, code = 22, N = 5)

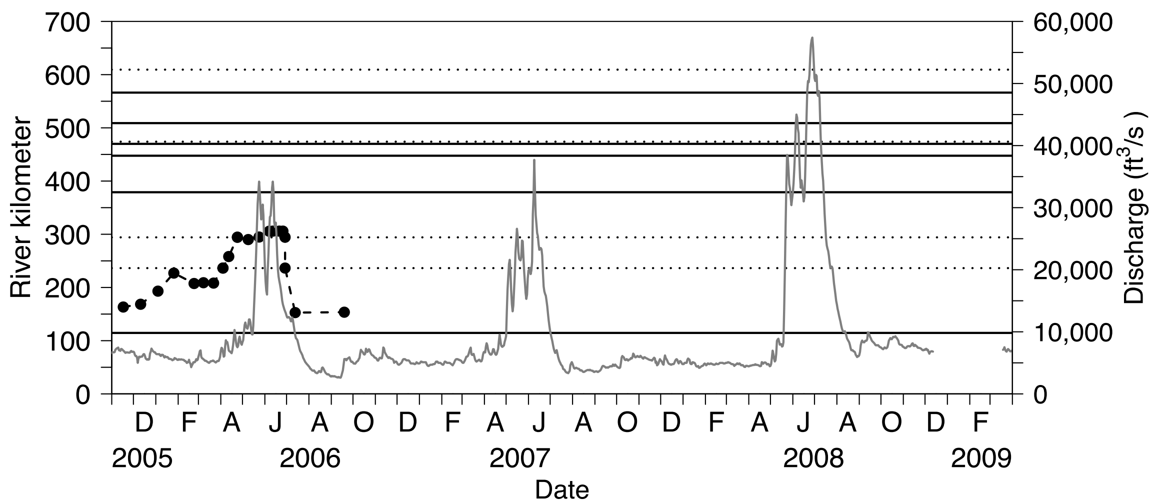

Figure 105. Movements of BURB #65 (frequency = 600, code = 23, N = 22)

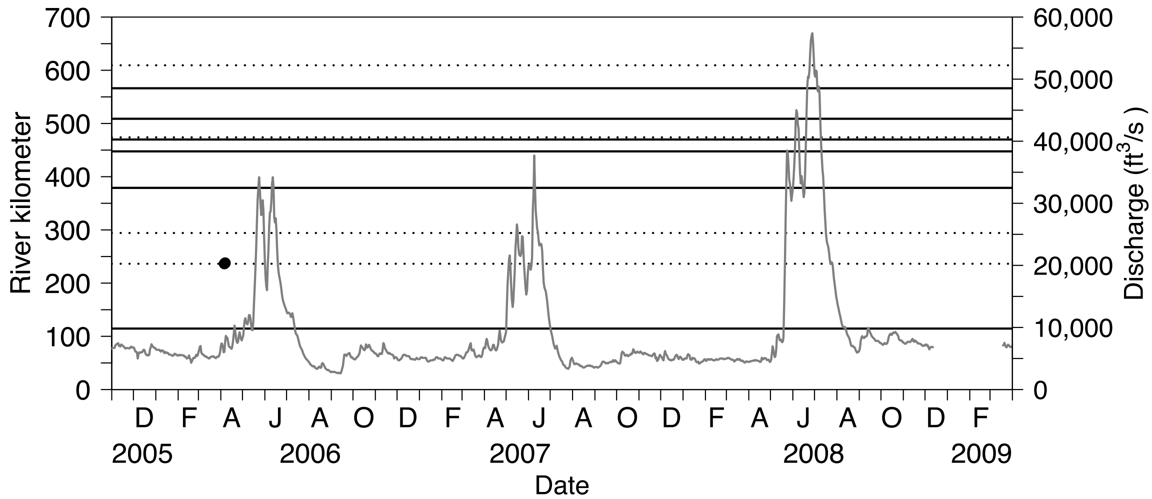

Figure 106. Movements of BURB #66 (frequency = 600, code = 24, N = 2)

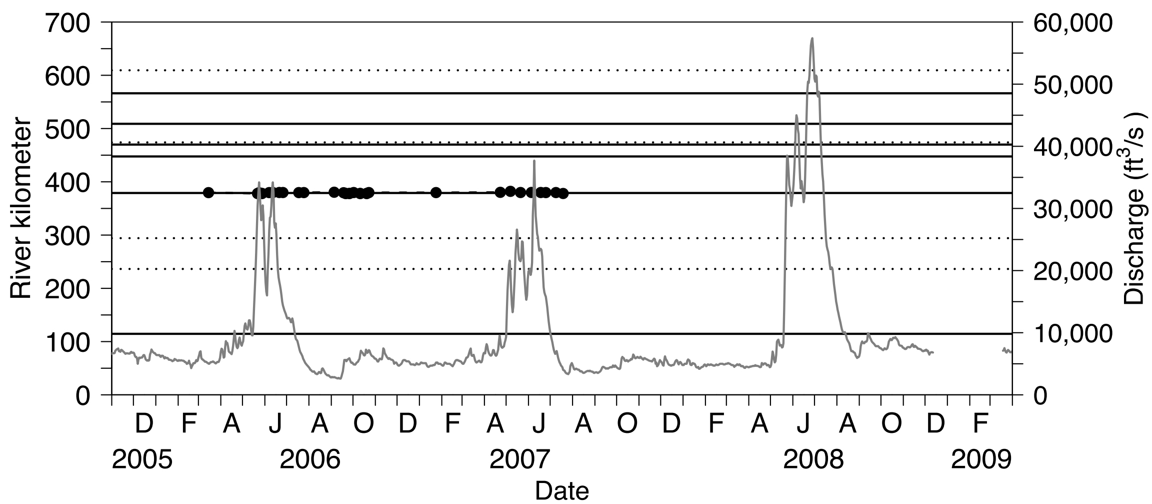

Figure 107. Movements of BURB #67 (frequency = 600, code = 25, N = 33)

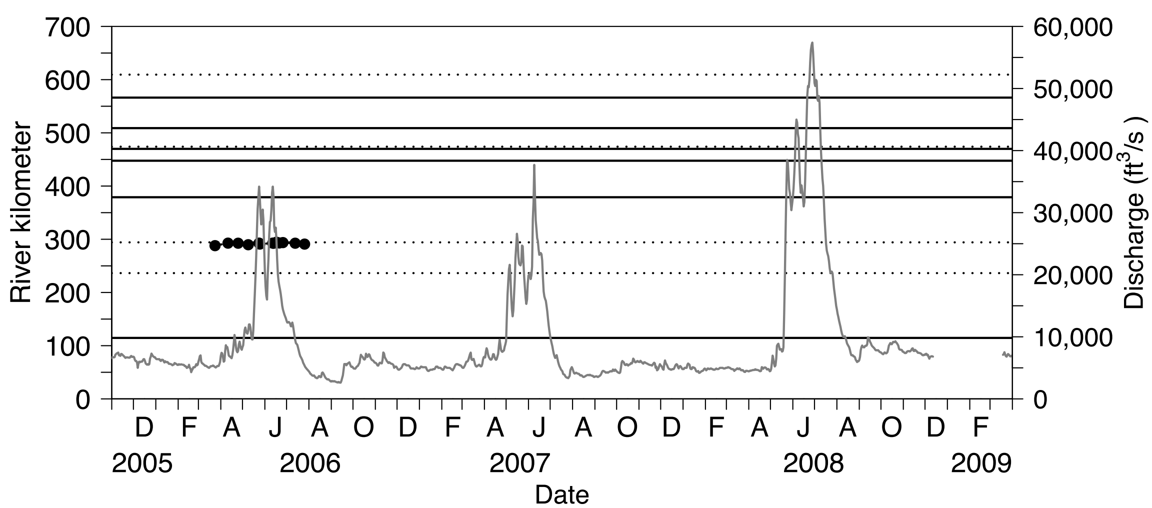

Figure 108. Movements of BURB #68 (frequency = 600, code = 26, N = 13)

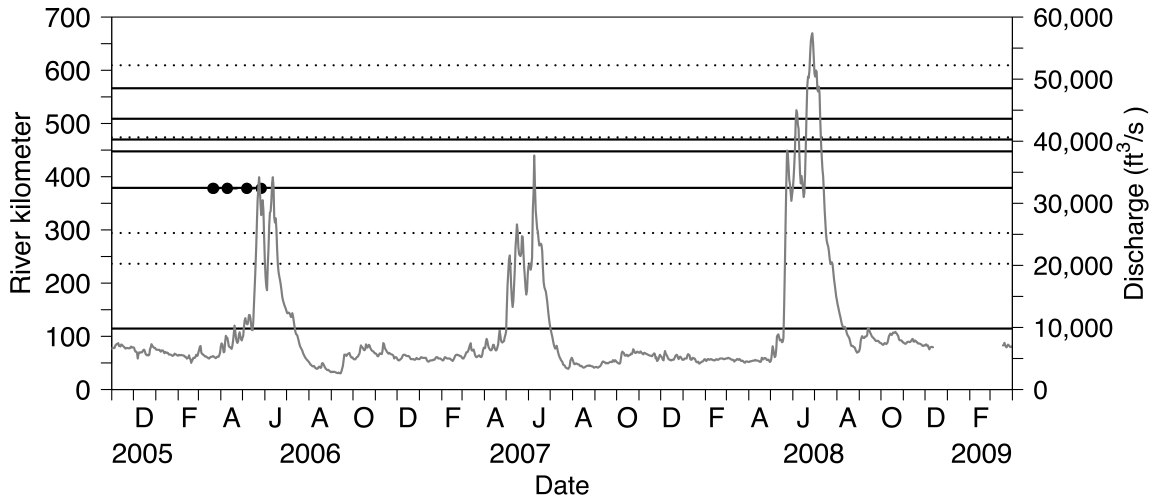

Figure 109. Movements of BURB #69 (frequency = 600, code = 27, N = 7)

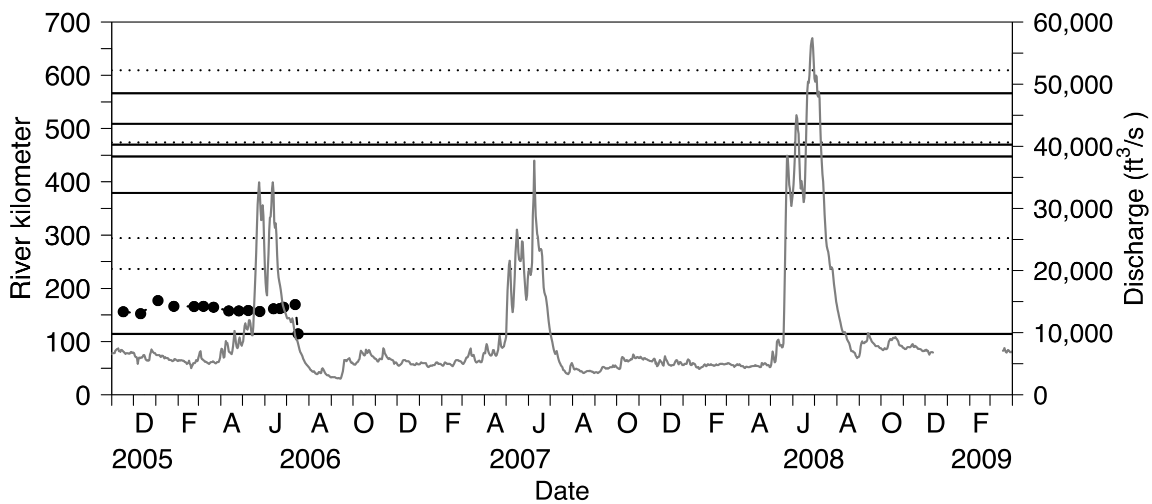

Figure 110. Movements of BURB #70 (frequency = 600, code = 28, N = 16)

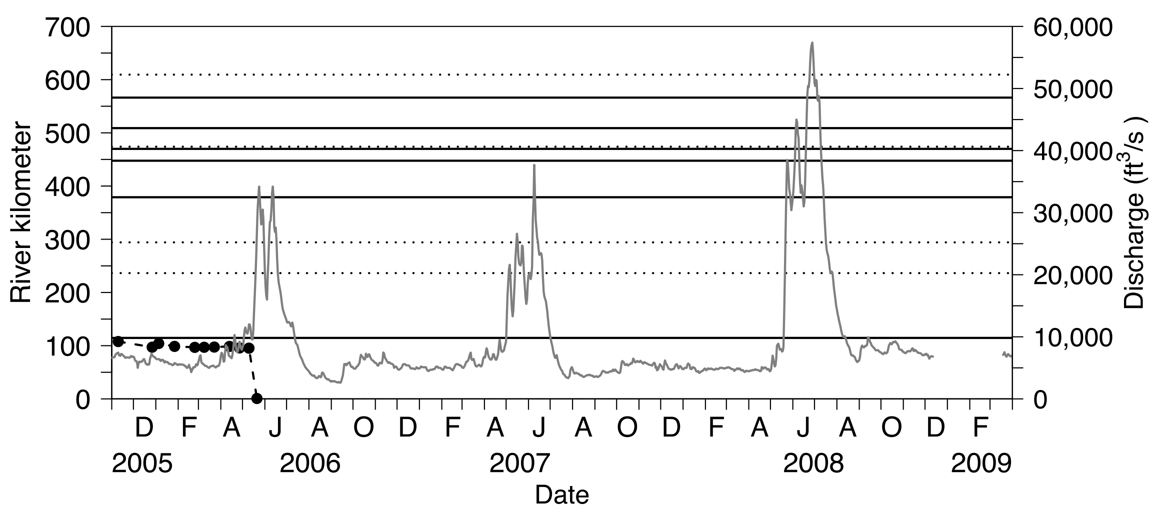

Figure 111. Movements of BURB #71 (frequency = 600, code = 29, N = 11)

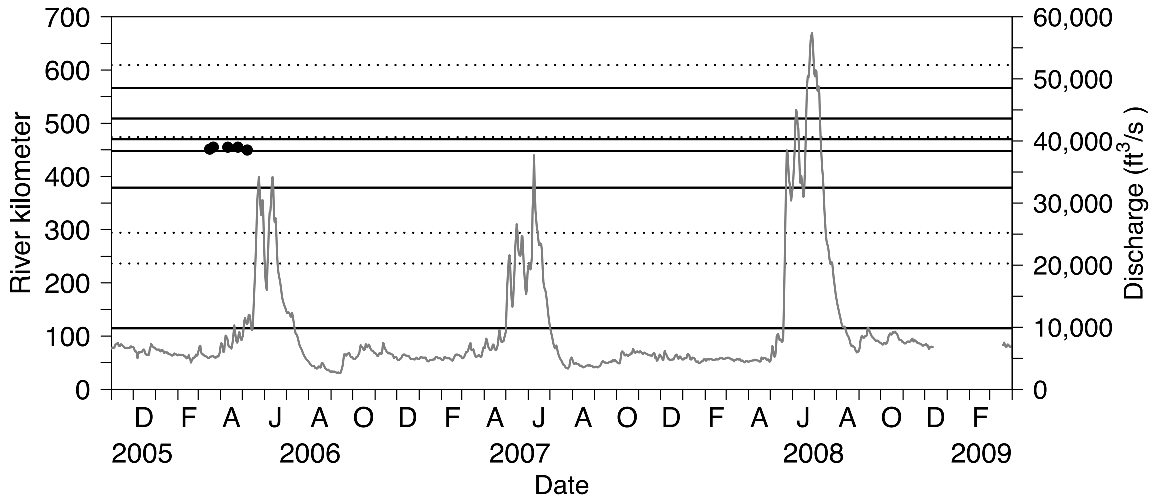

Figure 112. Movements of BURB #72 (frequency = 600, code = 30, N = 5)

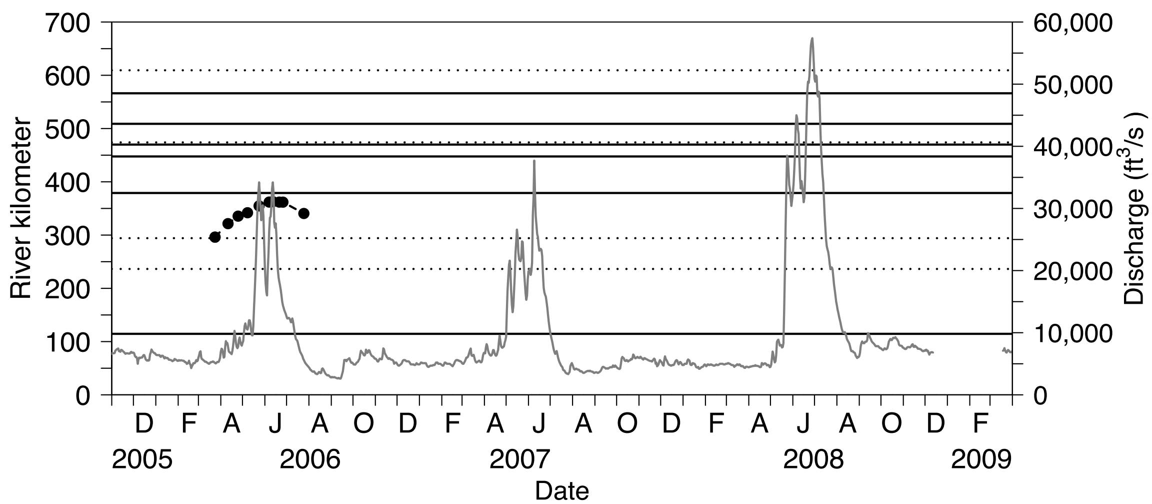

Figure 113. Movements of BURB #73 (frequency = 600, code = 31, N = 11)

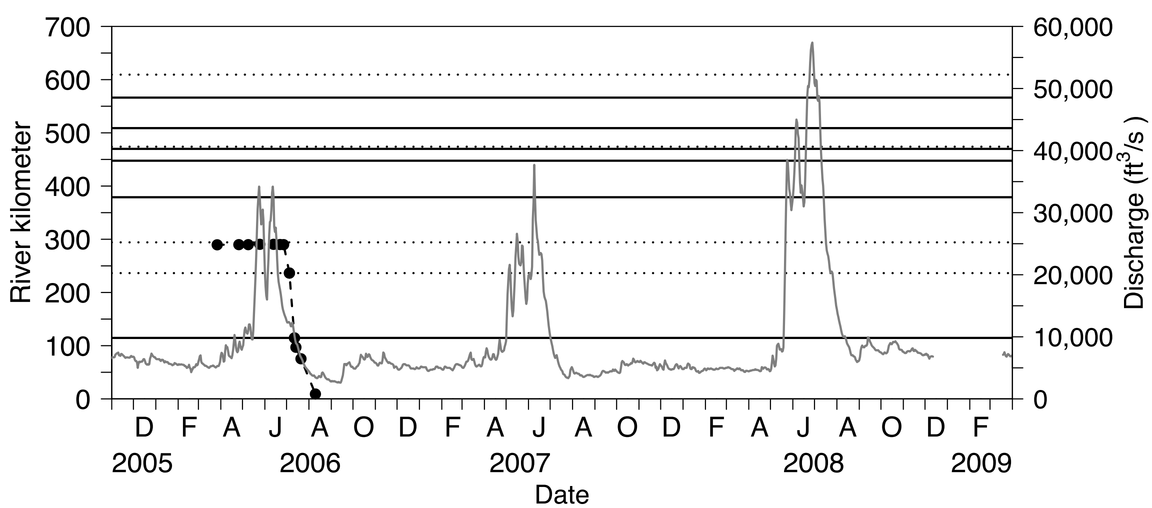

Figure 114. Movements of BURB #74 (frequency = 600, code = 32, N = 14)

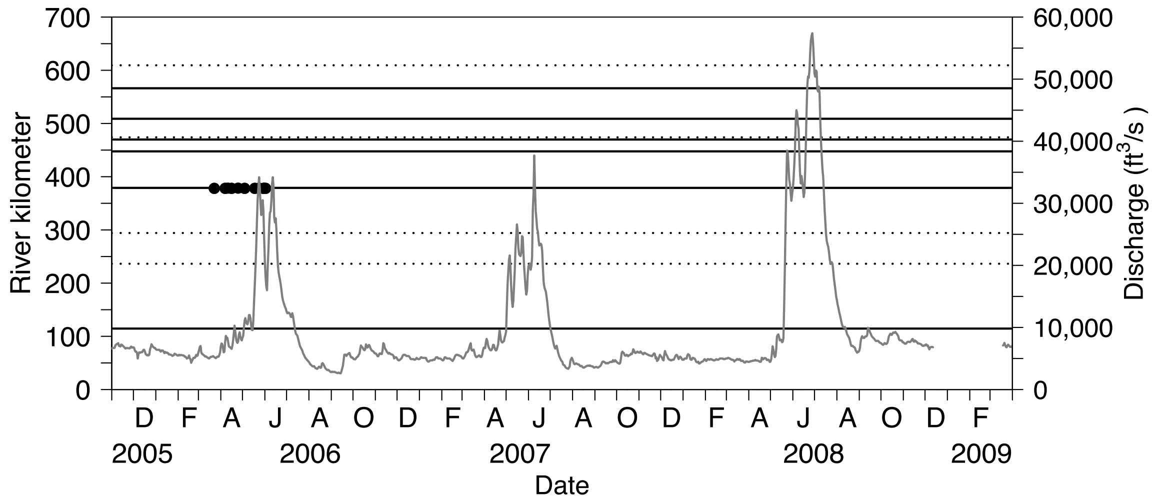

Figure 115. Movements of BURB #75 (frequency = 600, code = 33, N = 19)

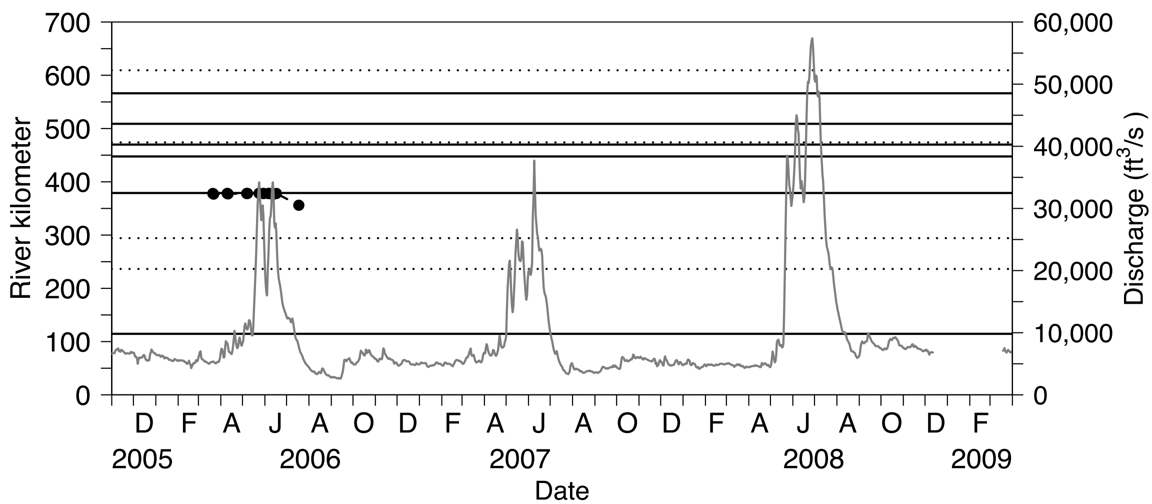

Figure 116. Movements of BURB #76 (frequency = 600, code = 34, N = 17)

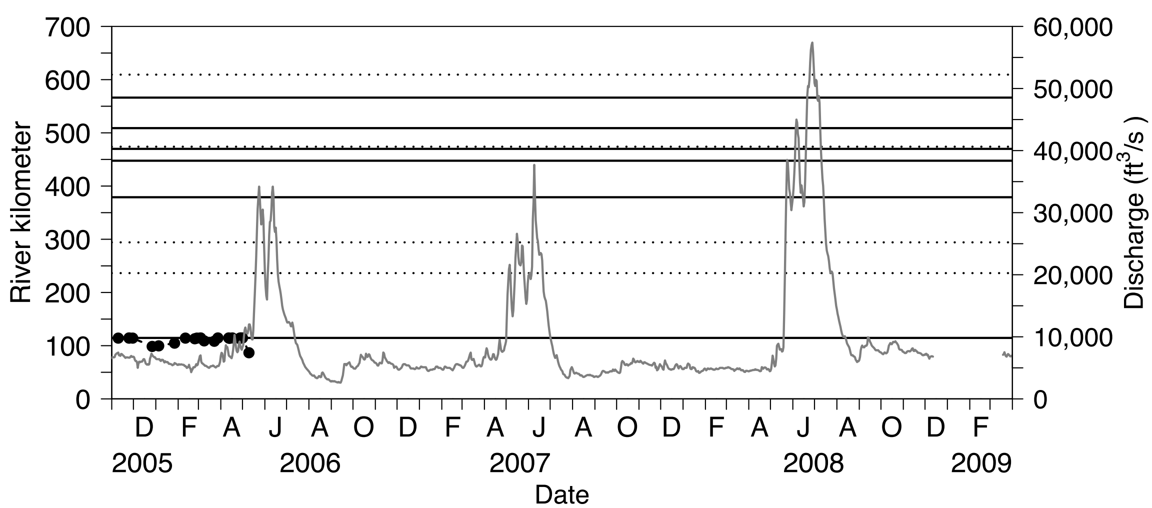

Figure 117. Movements of BURB #77 (frequency = 600, code = 35, N = 23)

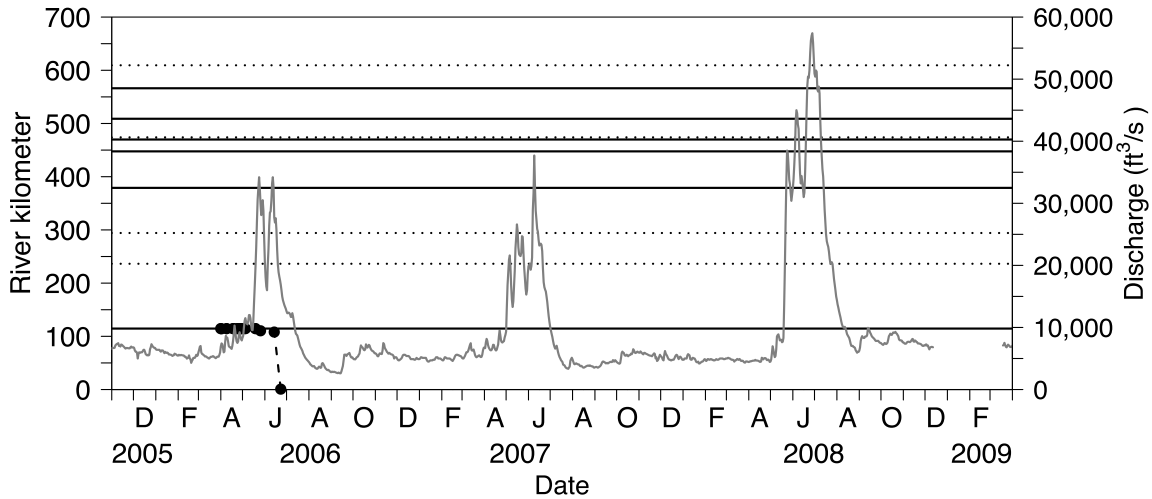

Figure 118. Movements of BURB #78 (frequency = 600, code = 36, N = 23)

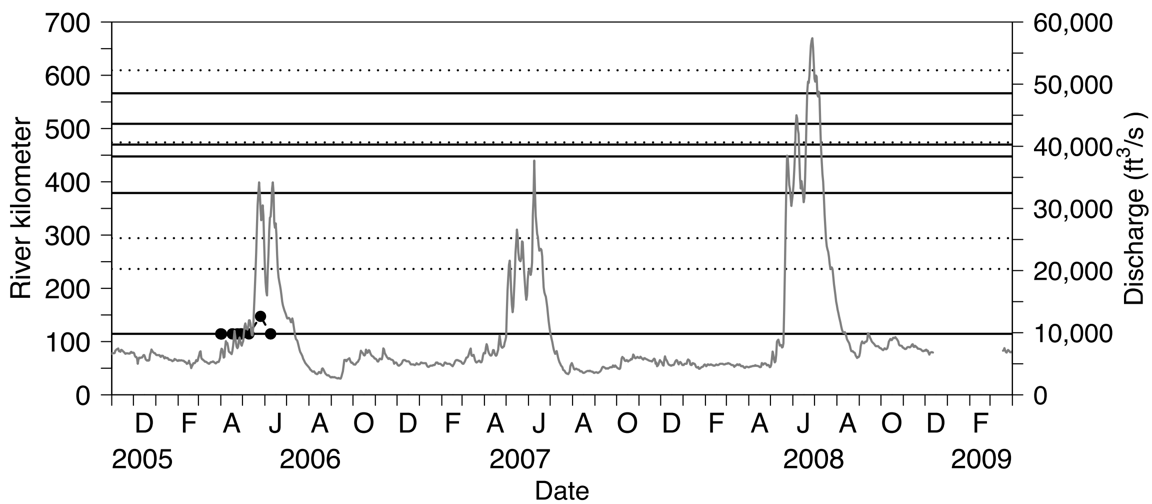

Figure 119. Movements of BURB #79 (frequency = 600, code = 37, N = 16)

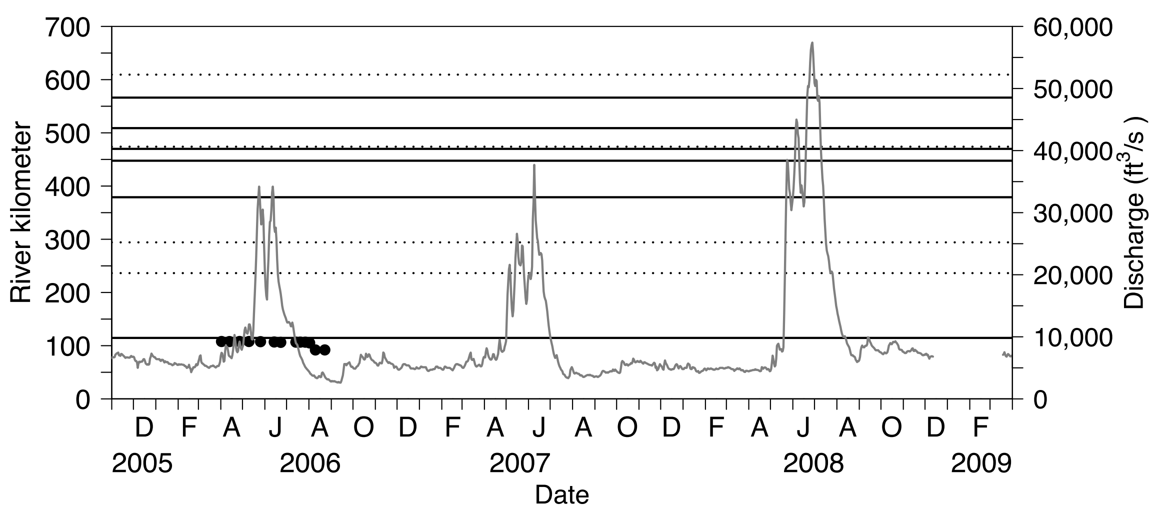

Figure 120. Movements of BURB #80 (frequency = 600, code = 38, N = 13)

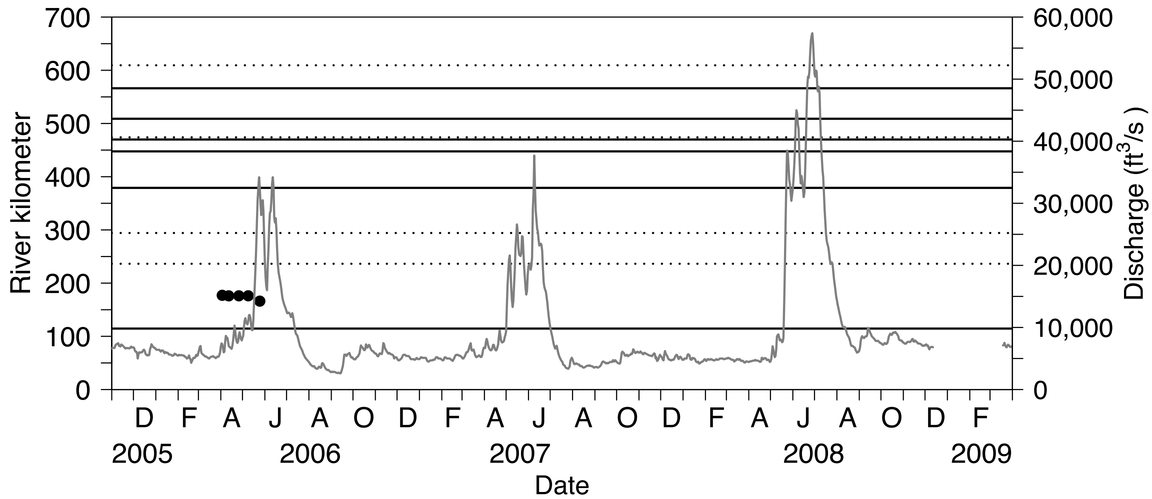

Figure 121. Movements of BURB #81 (frequency = 600, code = 39, N = 5)

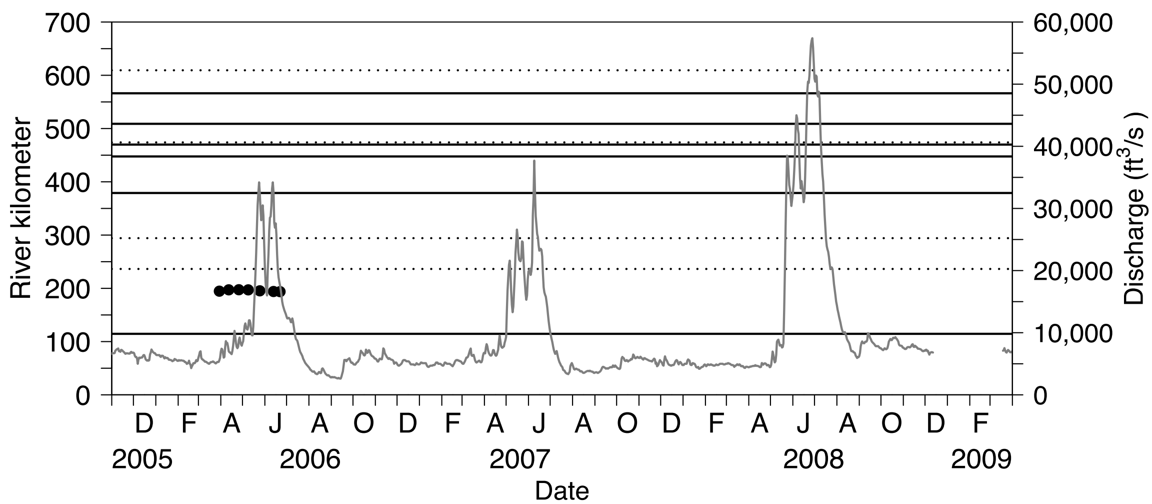

Figure 122. Movements of BURB #82 (frequency = 600, code = 40, N = 7)

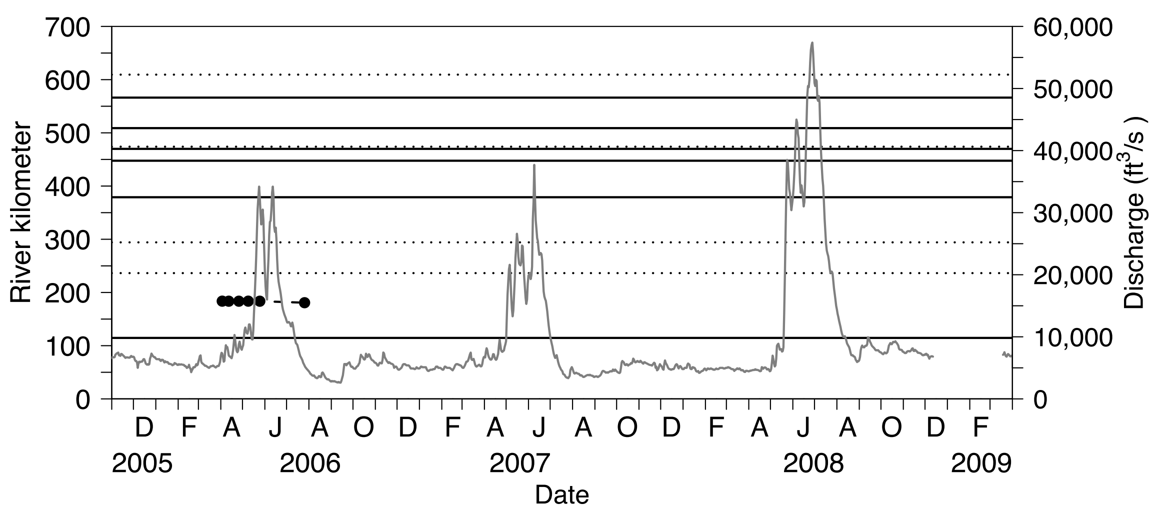

Figure 123. Movements of BURB #83 (frequency = 600, code = 41, N = 6)

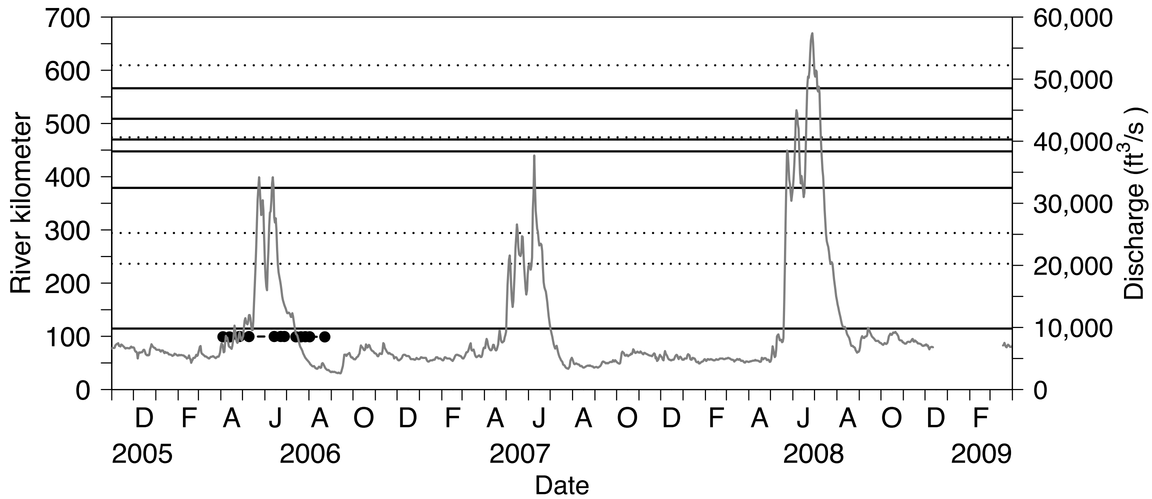

Figure 124. Movements of BURB #84 (frequency = 600, code = 42, N = 12)

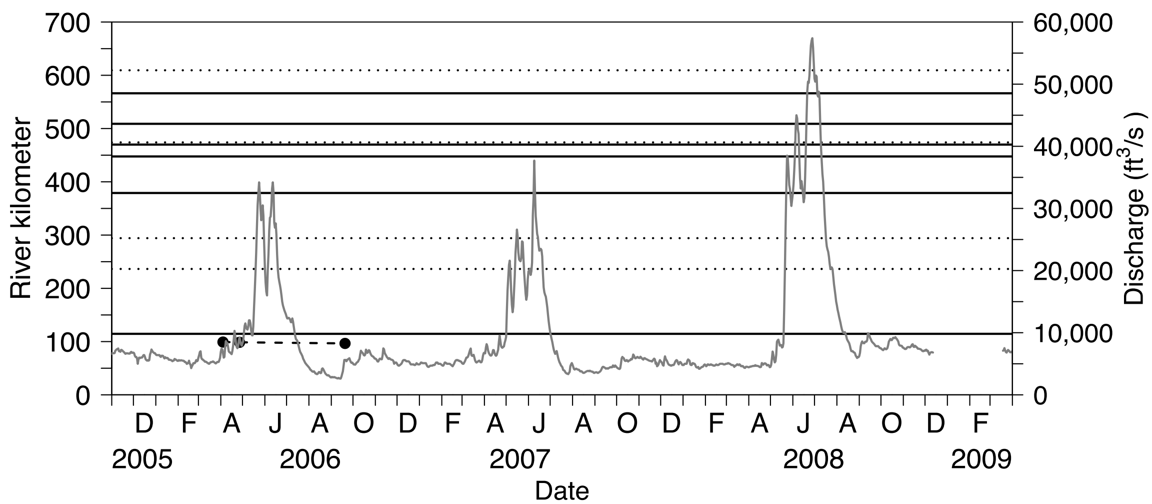

Figure 125. Movements of BURB #85 (frequency = 600, code = 43, N = 3)

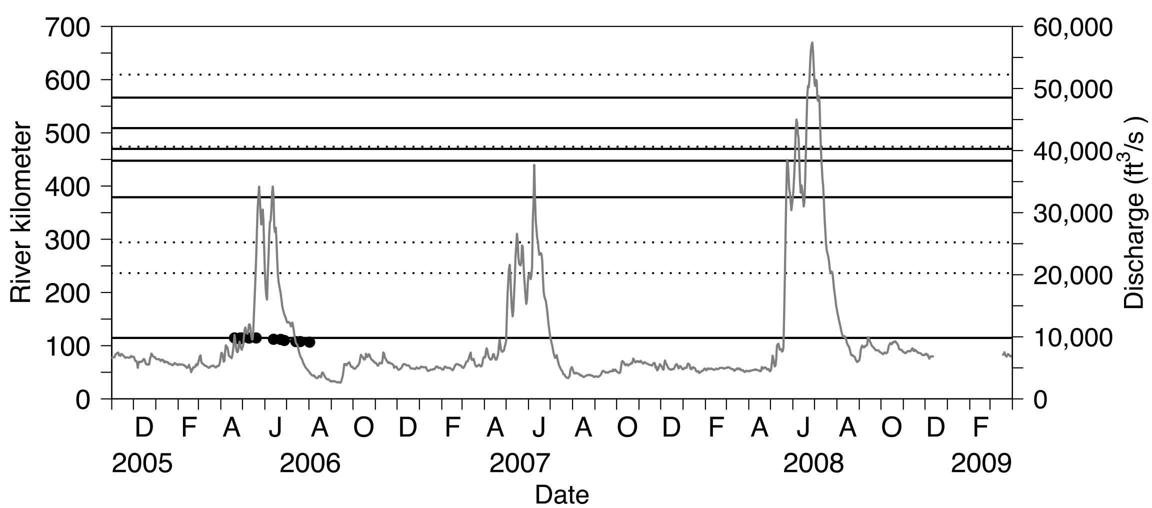

Figure 126. Movements of BURB #86 (frequency = 600, code = 44, N = 12)

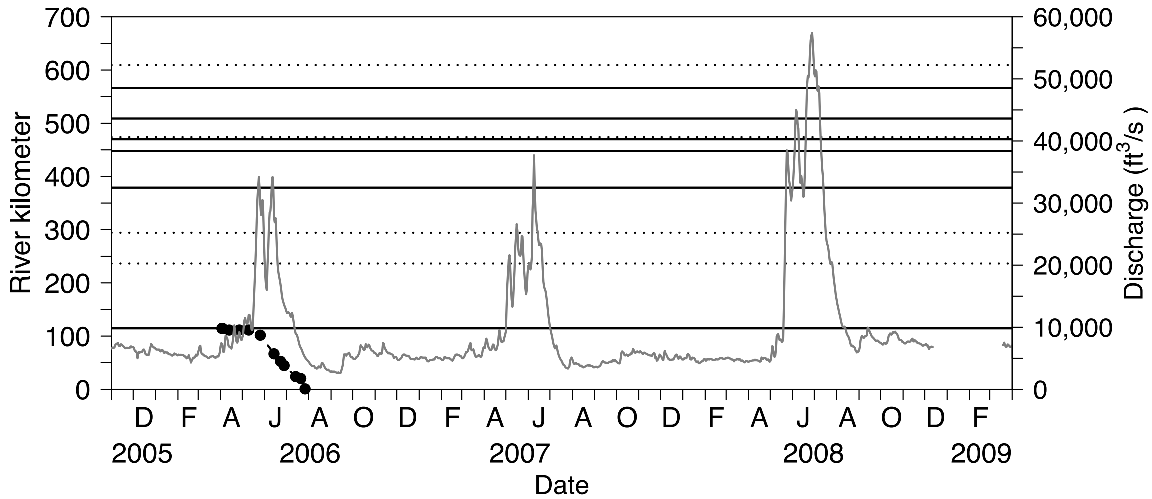

Figure 127. Movements of BURB #87 (frequency = 600, code = 45, N = 13)

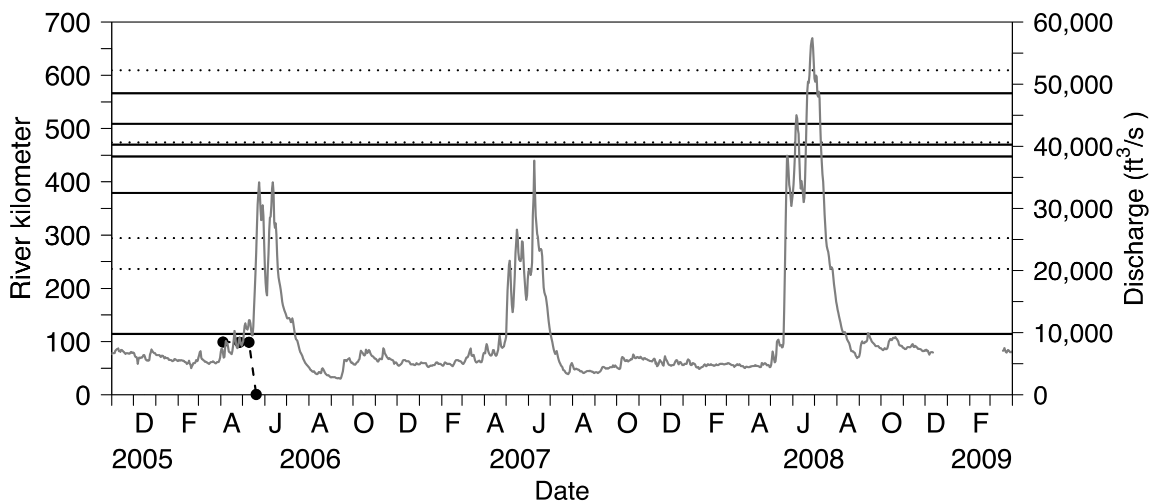

Figure 128. Movements of BURB #88 (frequency = 600, code = 46, N = 4)

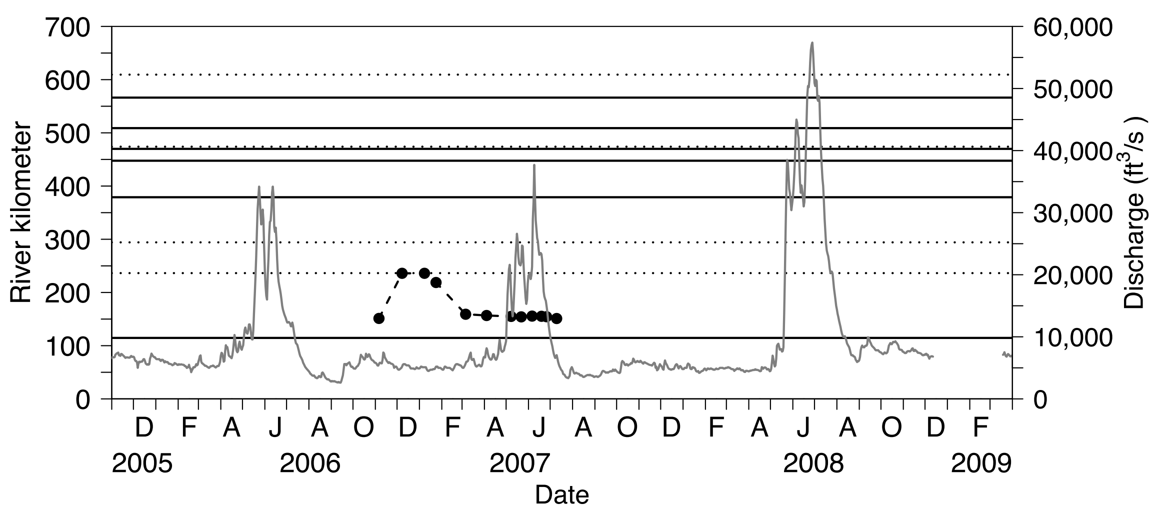

Figure 129. Movements of BURB #89 (frequency = 600, code = 47, N = 12)

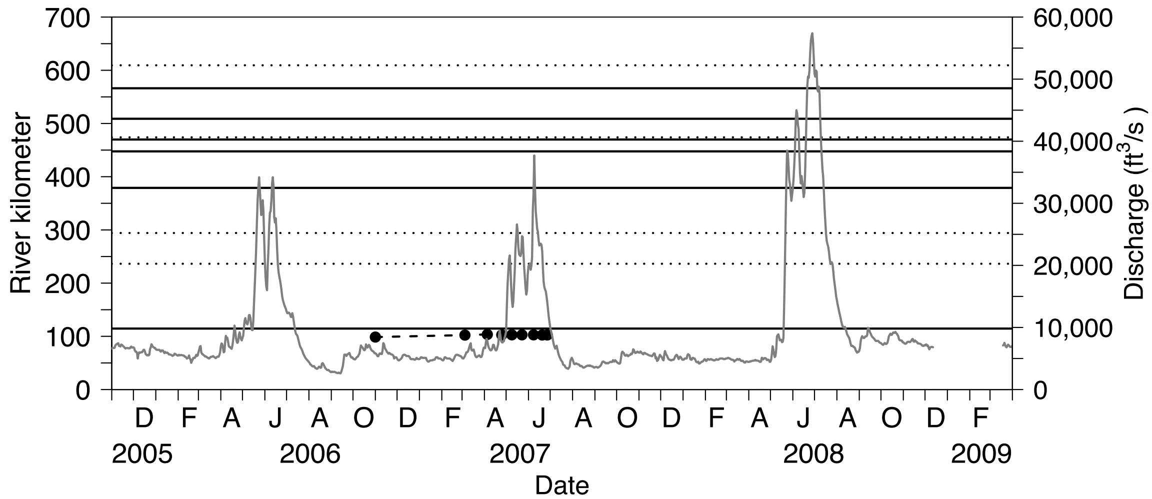

Figure 130. Movements of BURB #90 (frequency = 600, code = 48, N = 9)

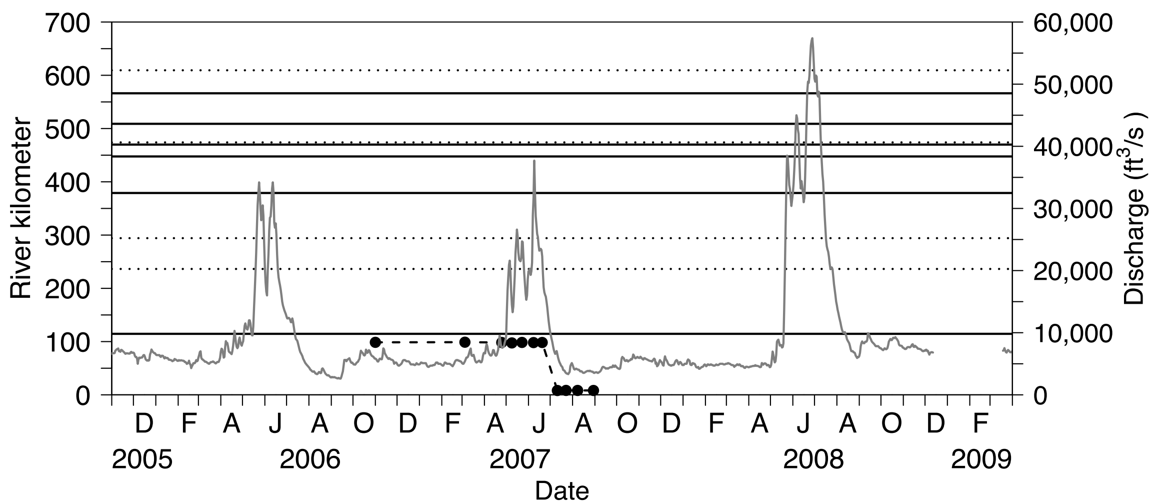

Figure 131. Movements of BURB #91 (frequency = 600, code = 49, N = 11)

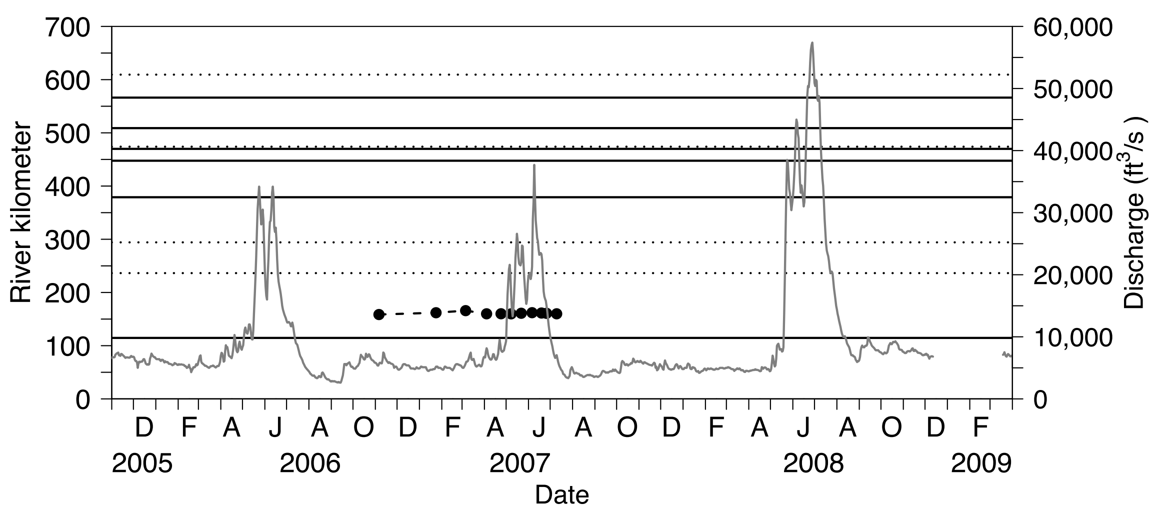

Figure 132. Movements of BURB #92 (frequency = 600, code = 50, N = 11)

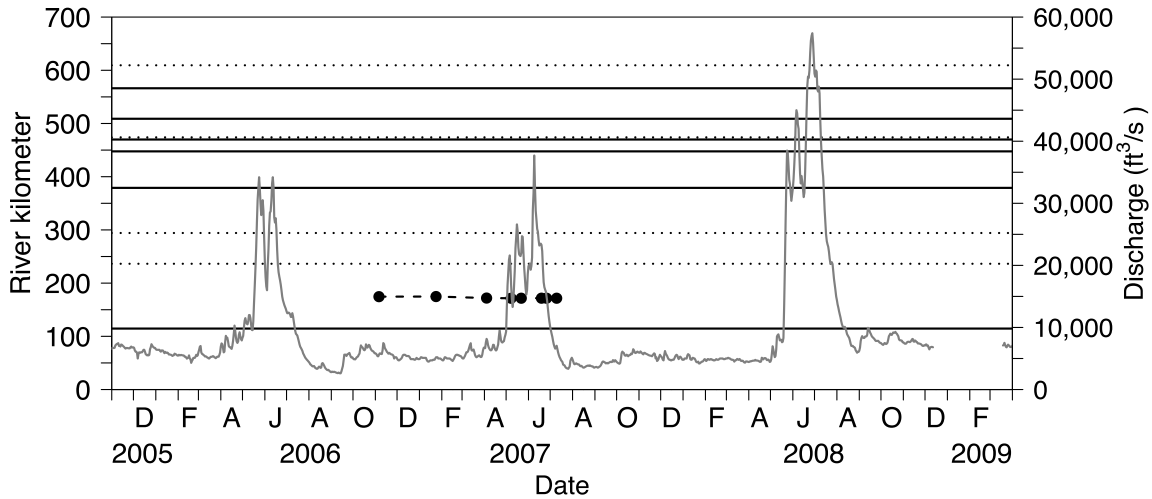

Figure 133. Movements of BURB #93 (frequency = 600, code = 51, N = 8)

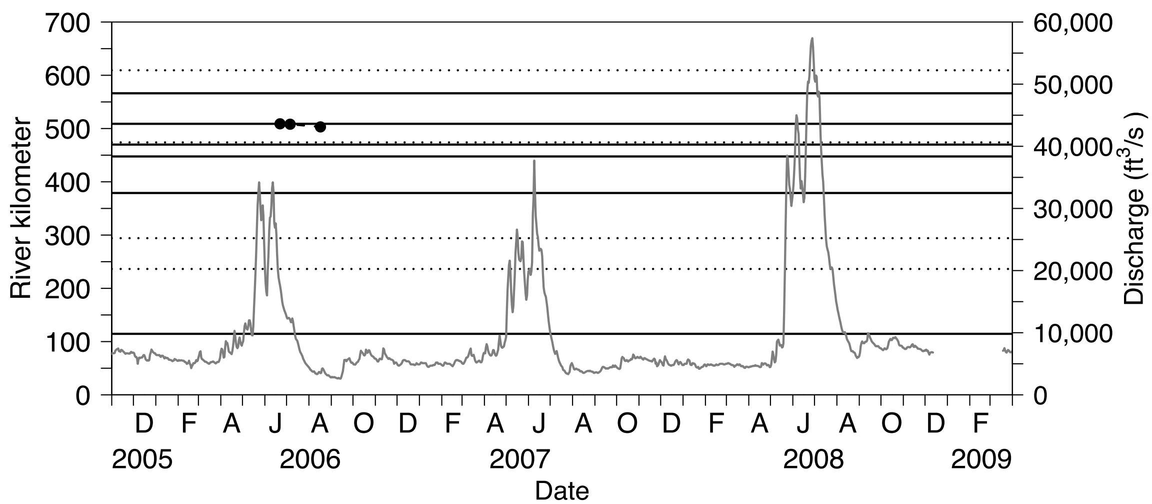

Figure 134. Movements of BURB #94 (frequency = 600, code = 74, N = 3)

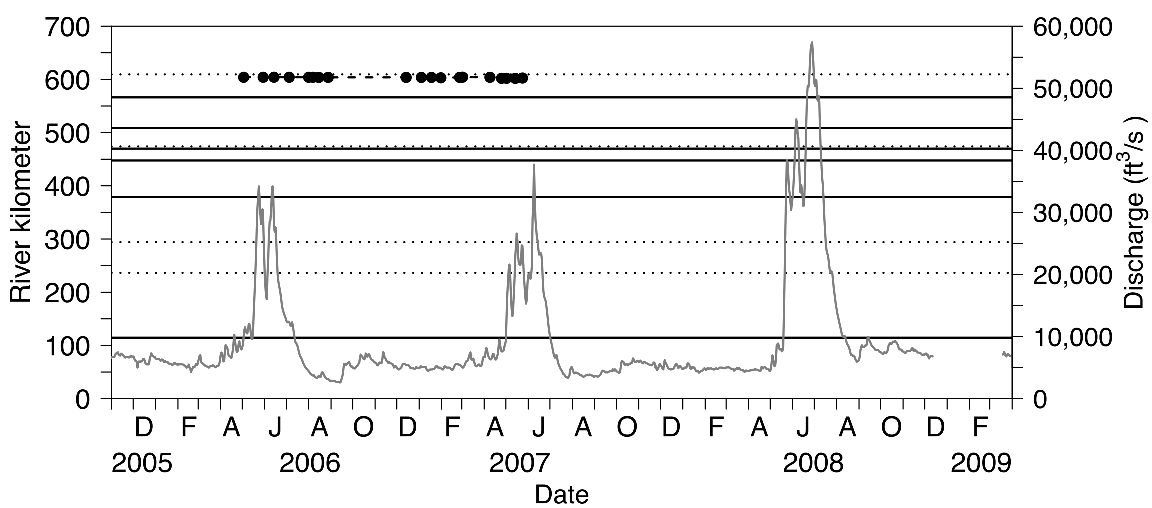

Figure 135. Movements of BURB #95 (frequency = 600, code = 75, N = 19)

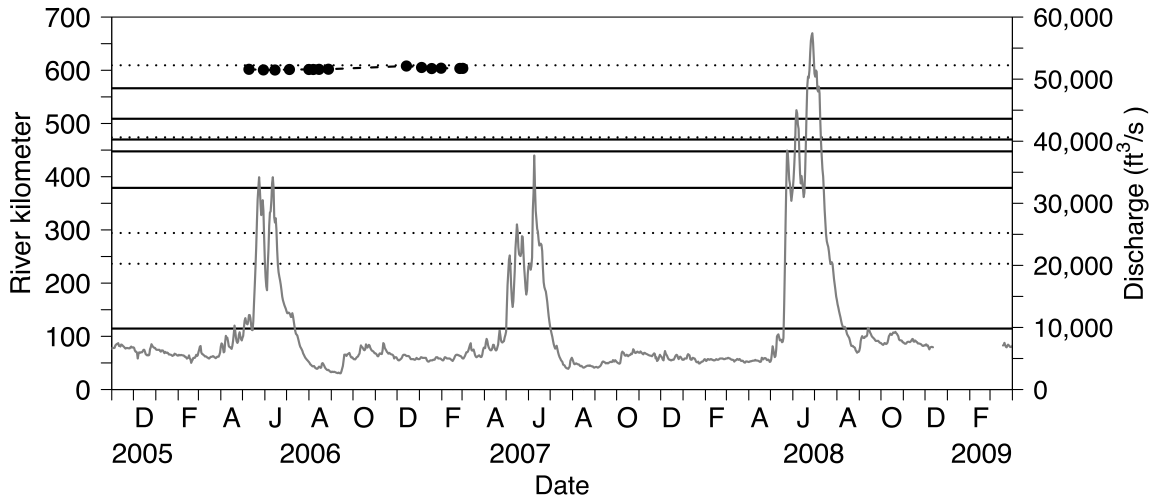

Figure 136. Movements of BURB #96 (frequency = 600, code = 76, N = 14)

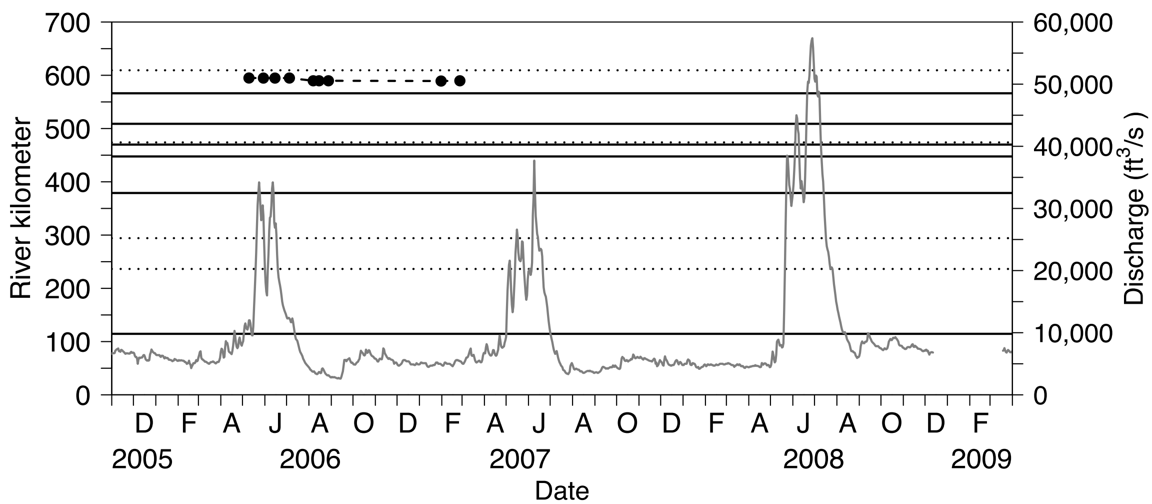

Figure 137. Movements of BURB #97 (frequency = 600, code = 77, N = 9)

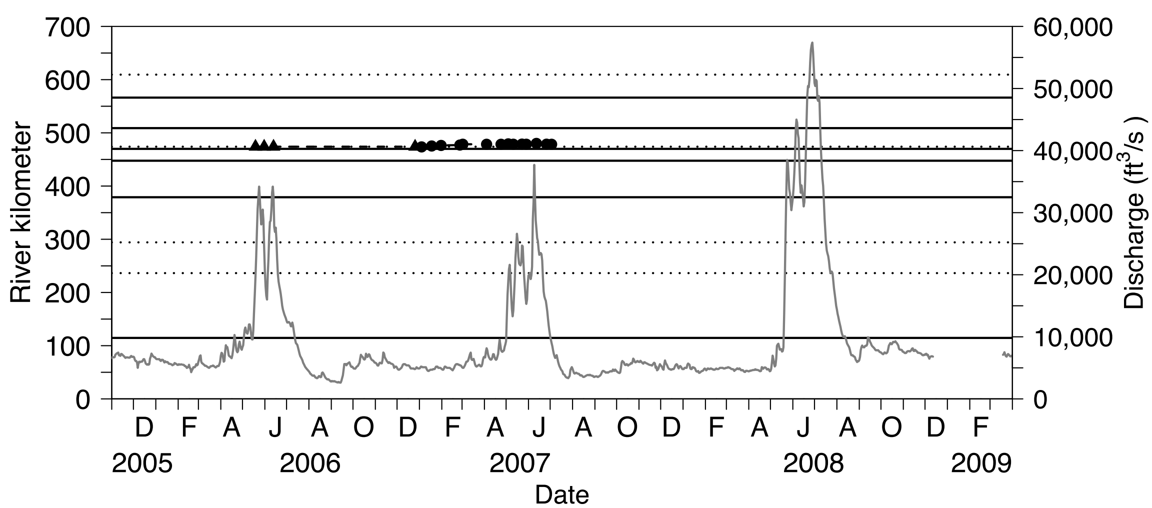

Figure 138. Movements of BURB #98 (frequency = 600, code = 78, N = 18)

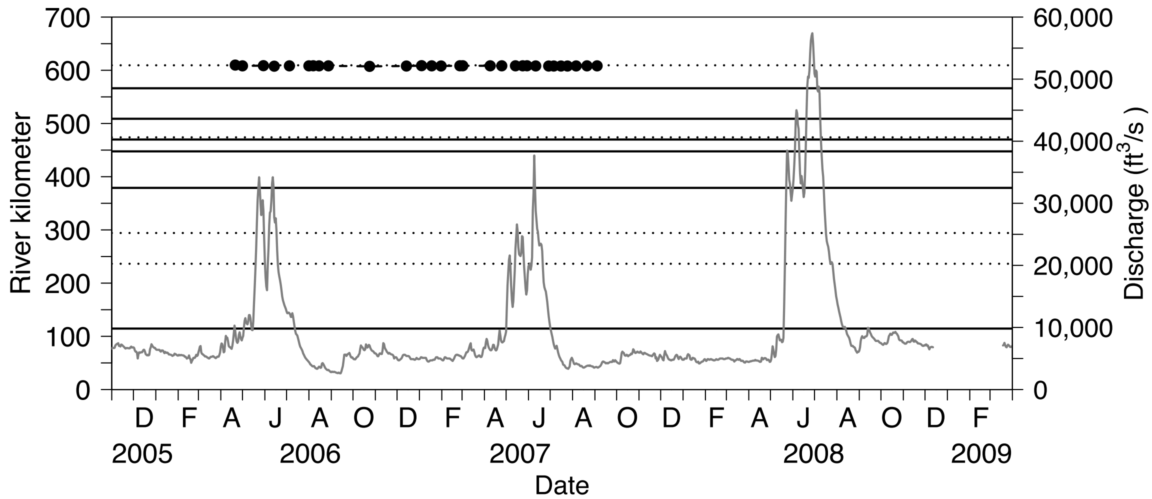

Figure 139. Movements of BURB #99 (frequency = 600, code = 79, N = 29)

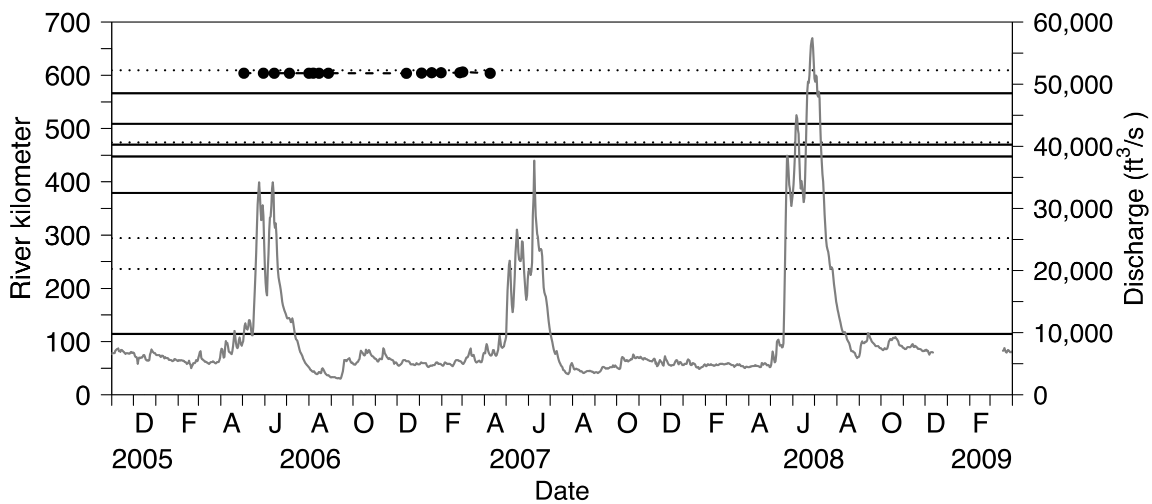

Figure 140. Movements of BURB #100 (frequency = 600, code = 80, N = 15)

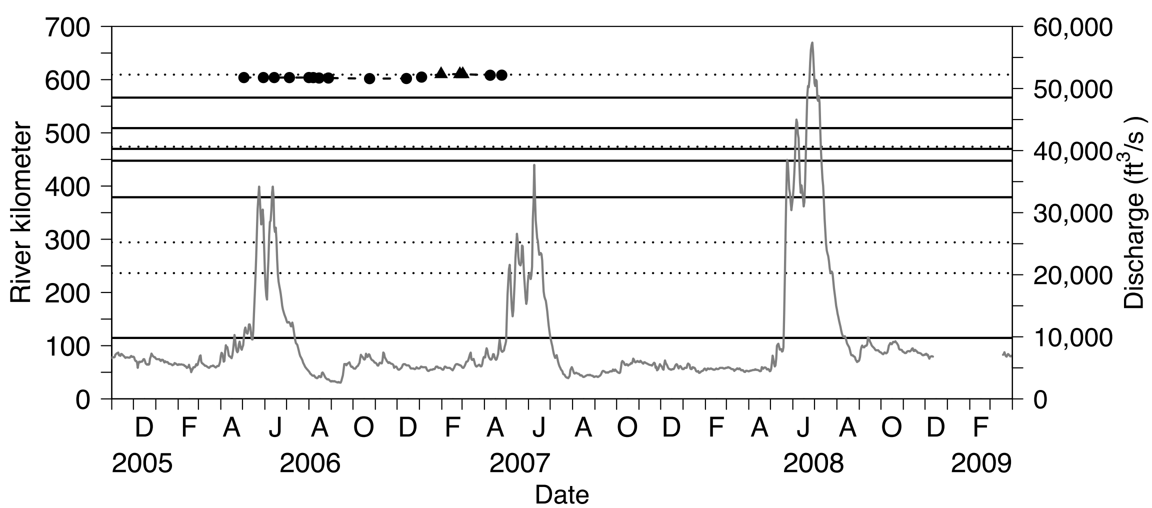

Figure 141. Movements of BURB #101 (frequency = 600, code = 81, N = 16)

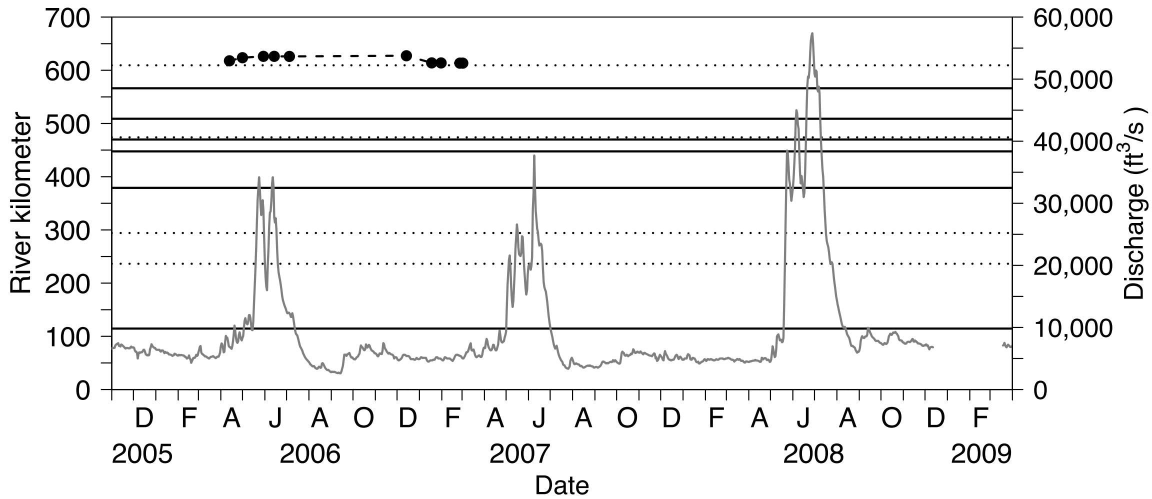

Figure 142. Movements of BURB #102 (frequency = 600, code = 82, N = 10)

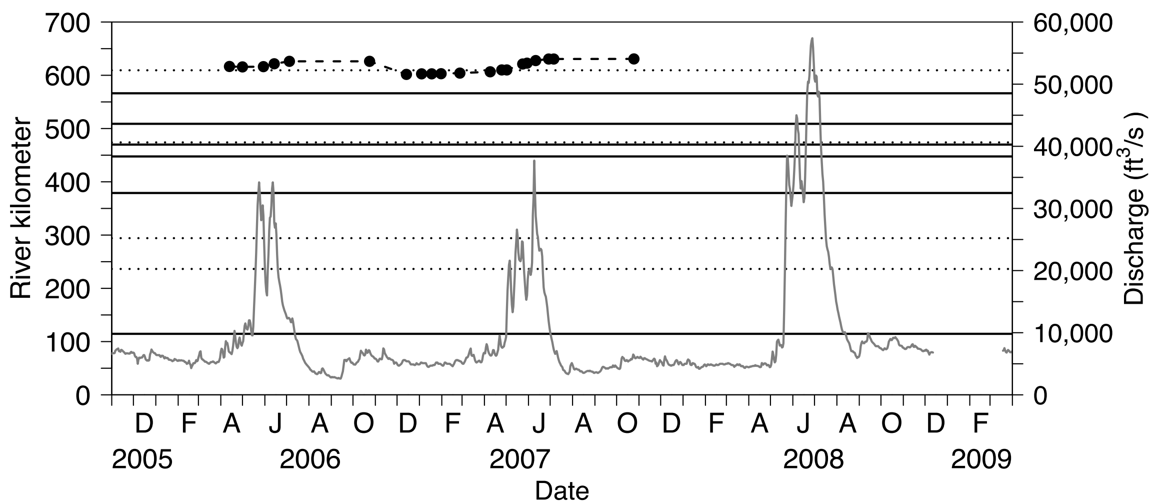

Figure 143. Movements of BURB #103 (frequency = 600, code = 83, N = 20)

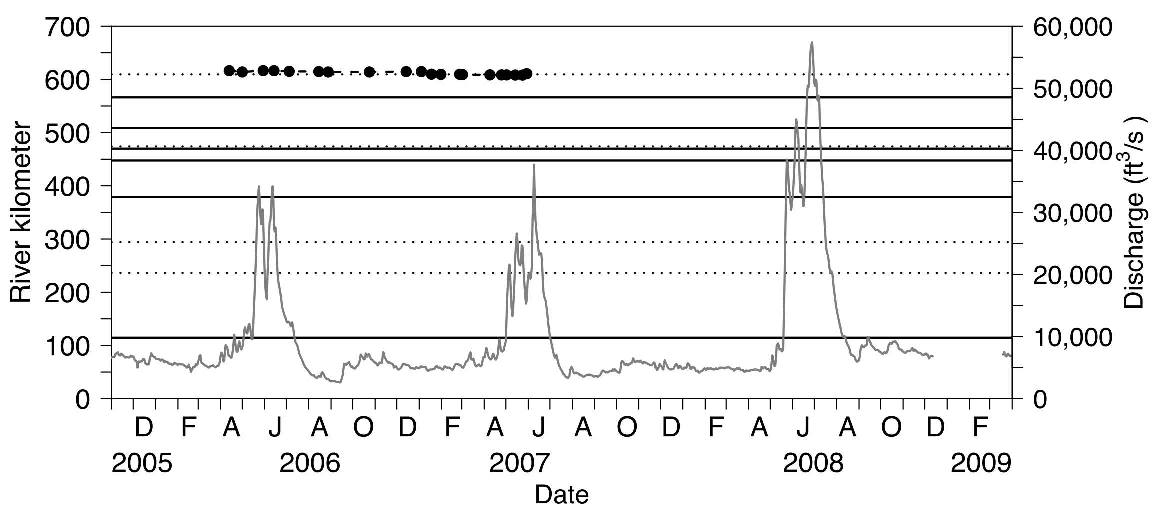

Figure 144. Movements of BURB #104 (frequency = 600, code = 84, N = 20)

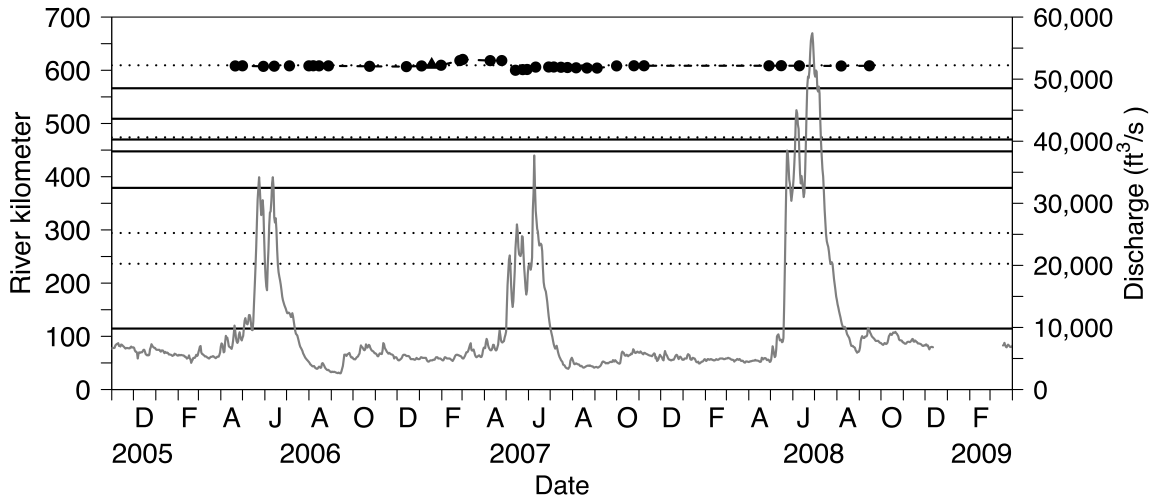

Figure 145. Movements of BURB #105 (frequency = 600, code = 85, N = 37)

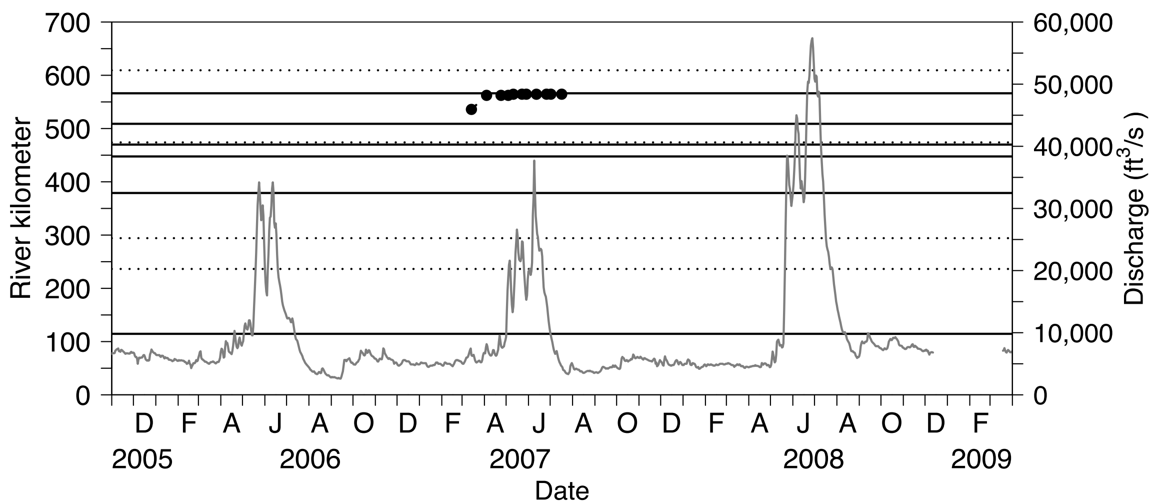

Figure 146. Movements of BURB #106 (frequency = 600, code = 86, N = 11)

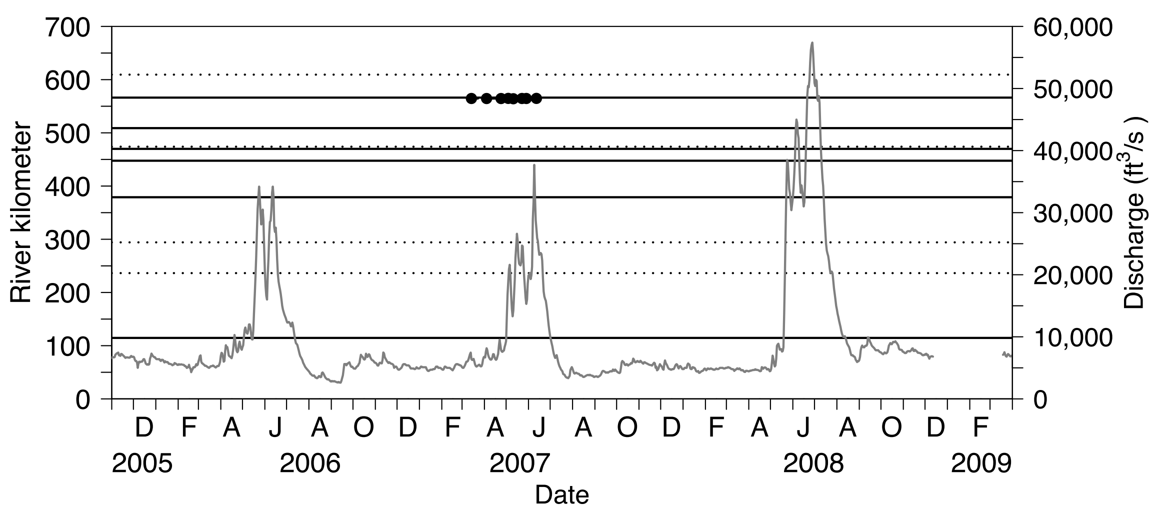

Figure 147. Movements of BURB #107 (frequency = 600, code = 87, N = 8)

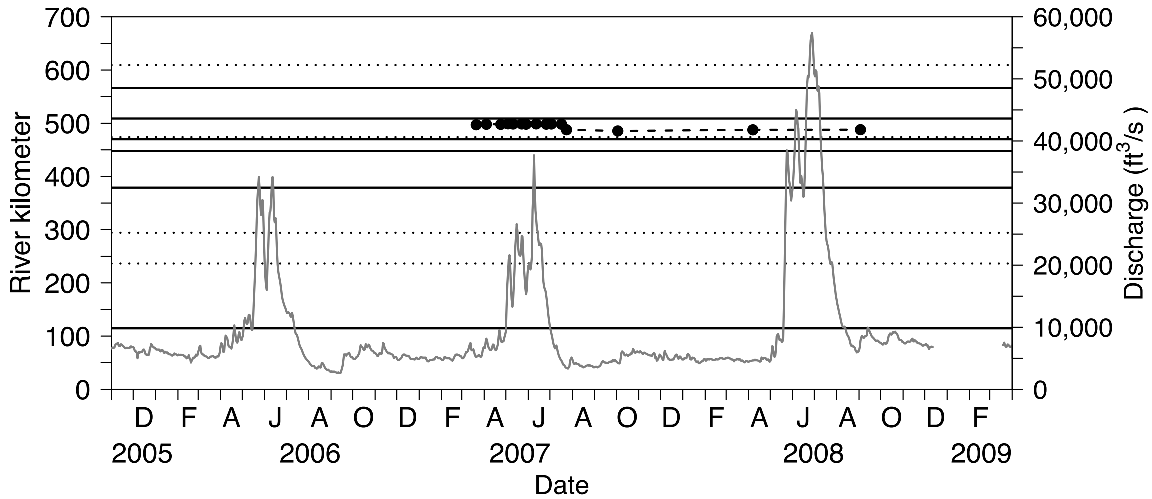

Figure 148. Movements of BURB #108 (frequency = 600, code = 89, N = 15)

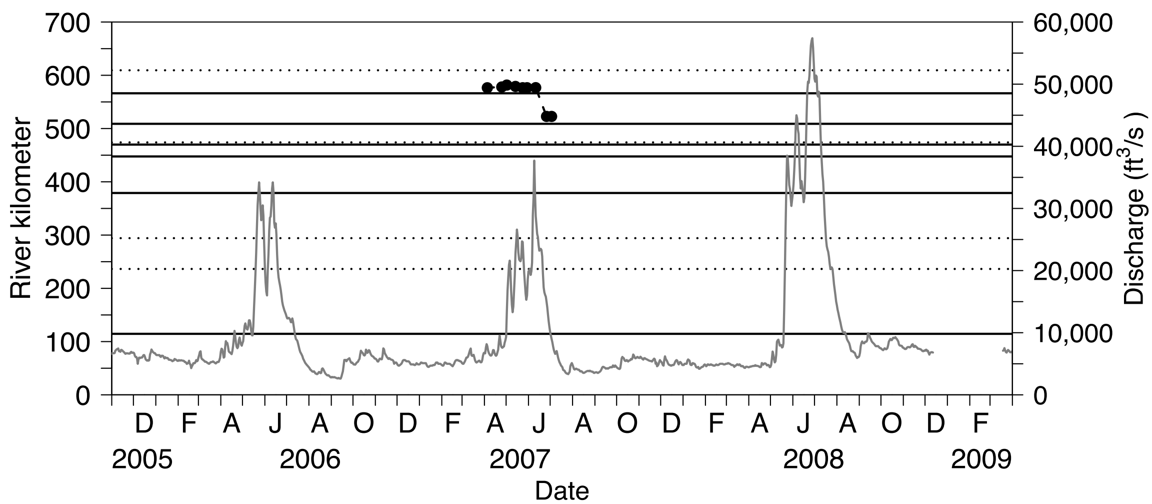

Figure 149. Movements of BURB #109 (frequency = 600, code = 90, N = 9)

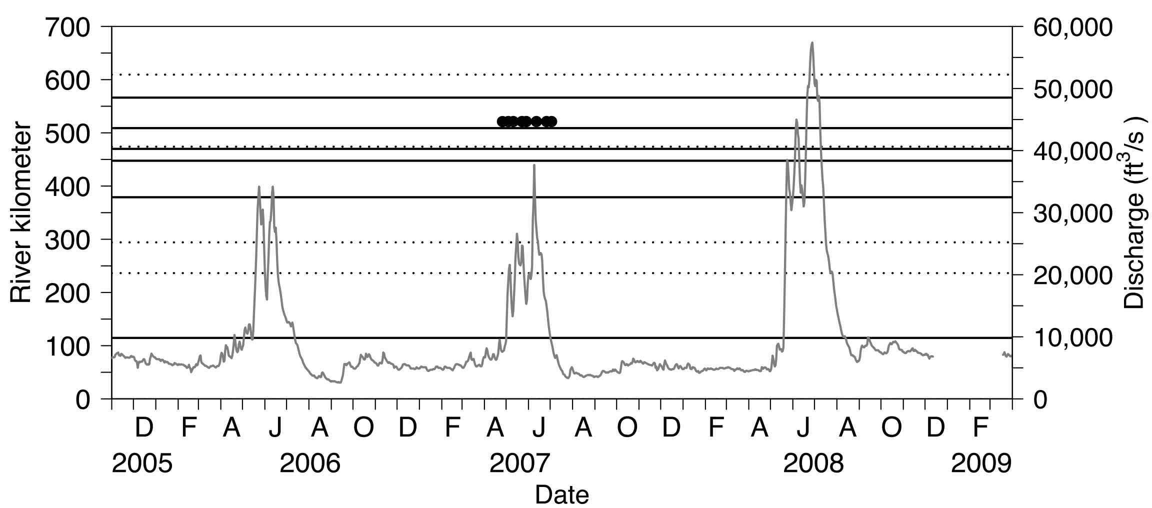

Figure 150. Movements of BURB #110 (frequency = 600, code = 93, N = 8)

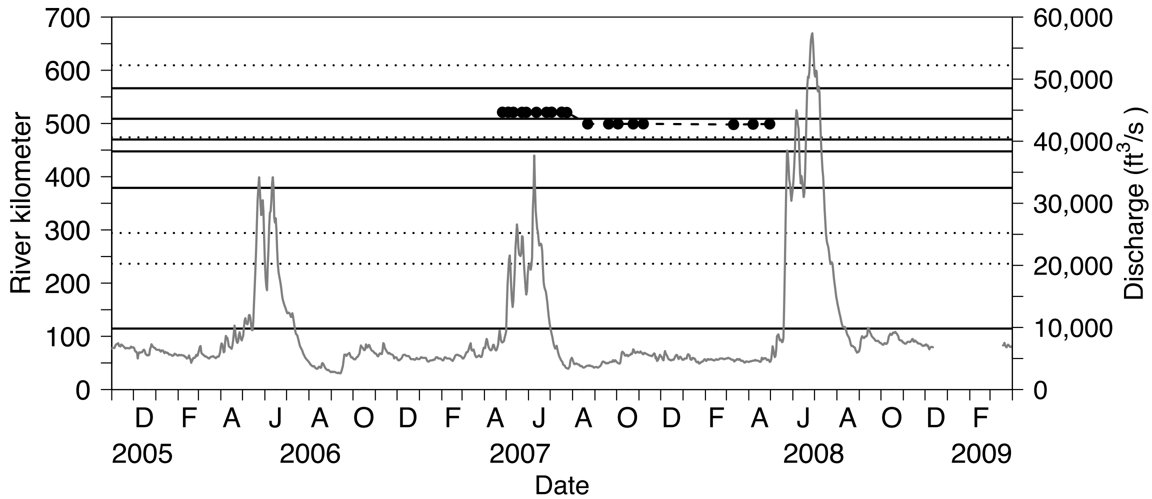

Figure 151. Movements of BURB #111 (frequency = 600, code = 94, N = 18)

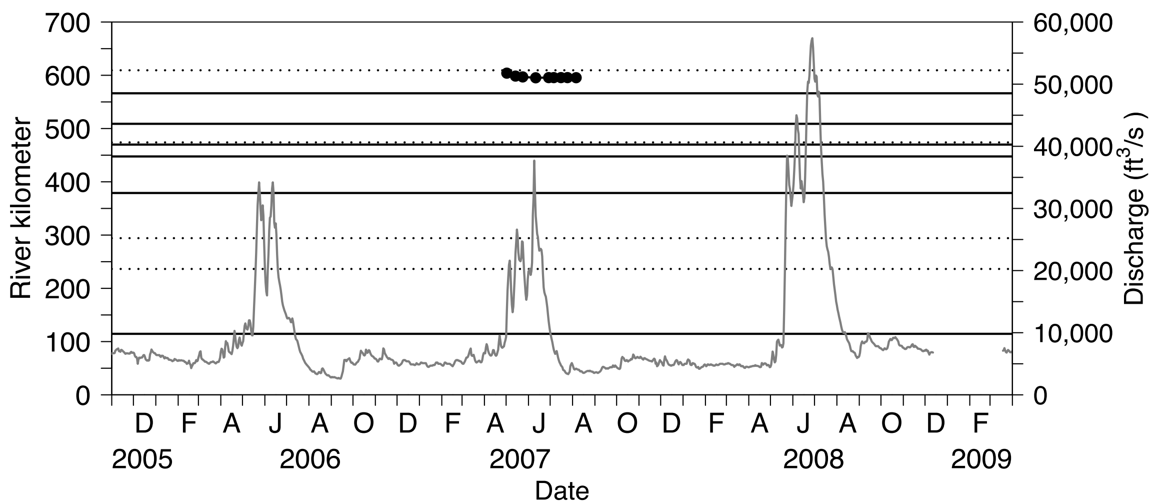

Figure 152. Movements of BURB #112 (frequency = 600, code = 95, N = 9)

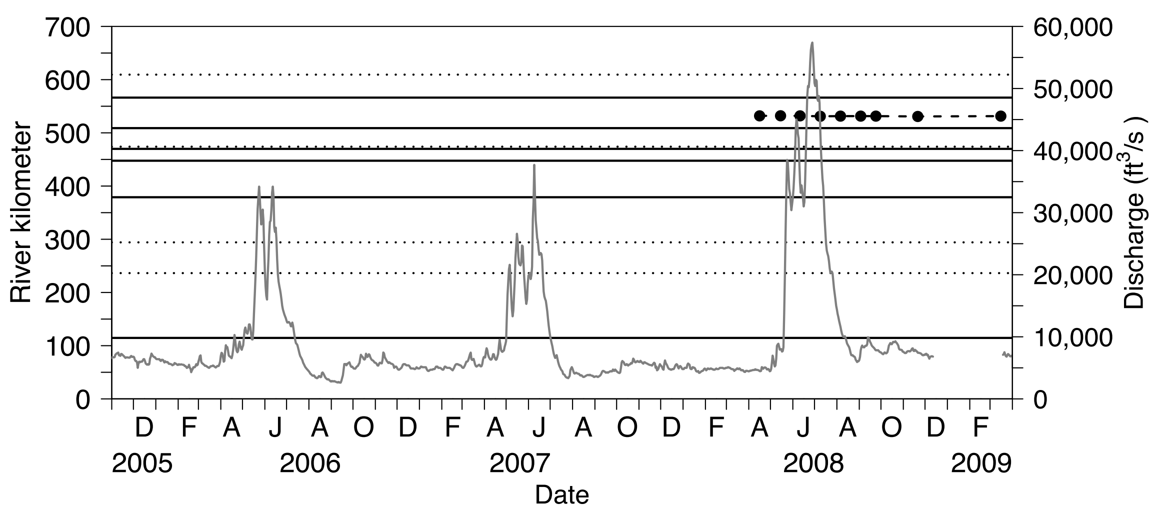

Figure 153. Movements of BURB #113 (frequency = 600, code = 108, N = 9)

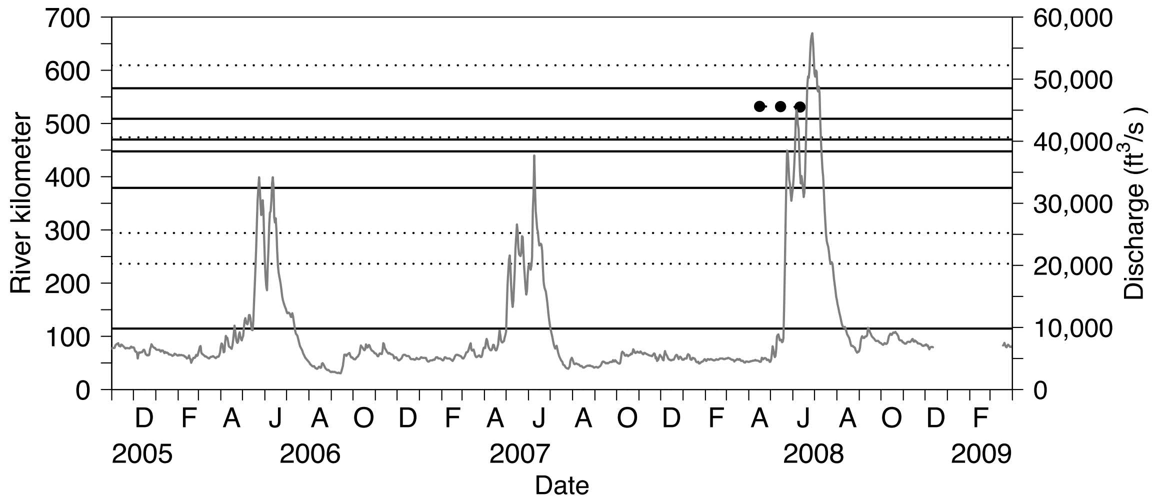

Figure 154. Movements of BURB #114 (frequency = 600, code = 110, N = 3)

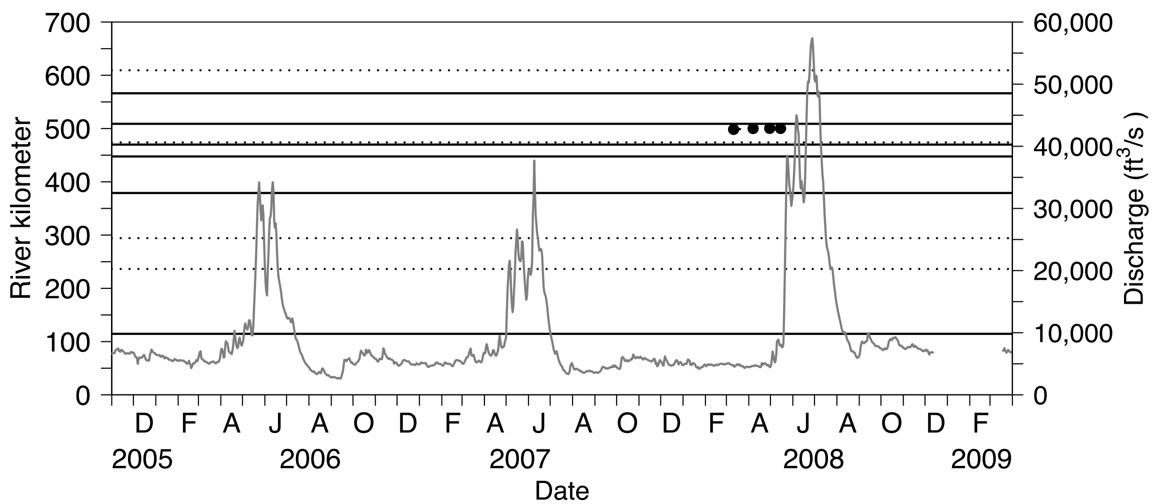

Figure 155. Movements of BURB #115 (frequency = 600, code = 111, N = 4)

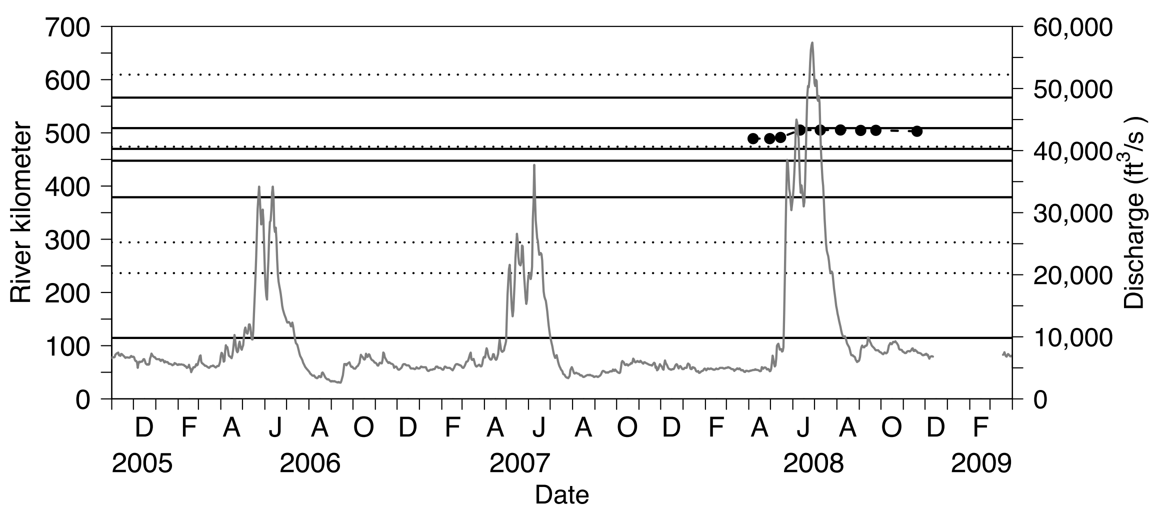

Figure 156. Movements of BURB #116 (frequency = 600, code = 112, N = 9)

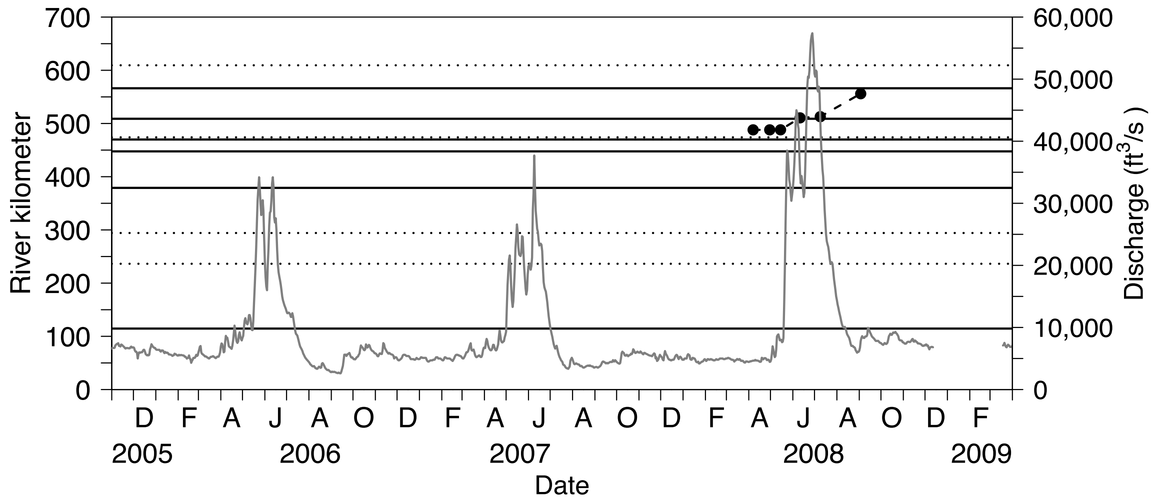

Figure 157. Movements of BURB #117 (frequency = 600, code = 113, N = 6)

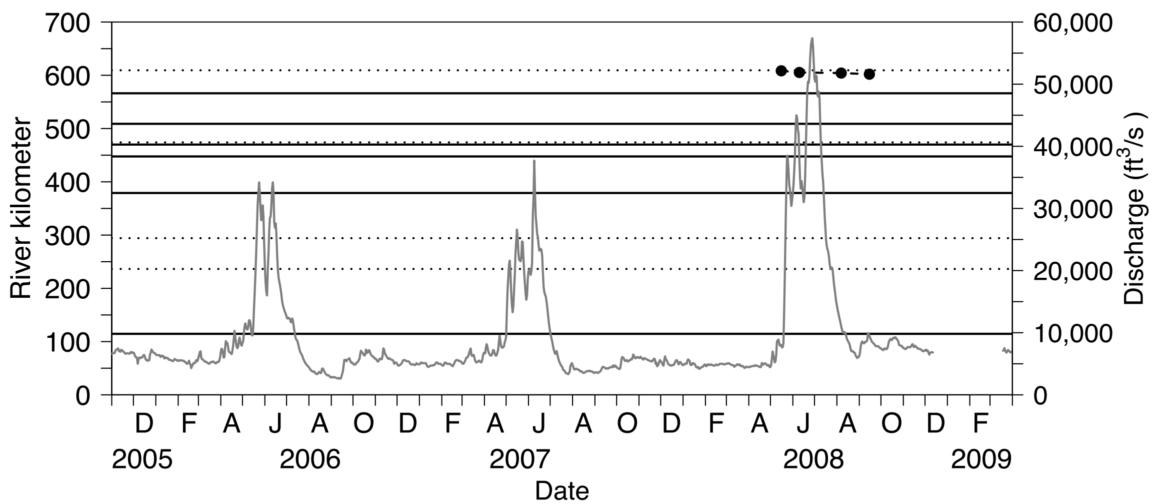

Figure 158. Movements of BURB #118 (frequency = 600, code = 114, N = 4)

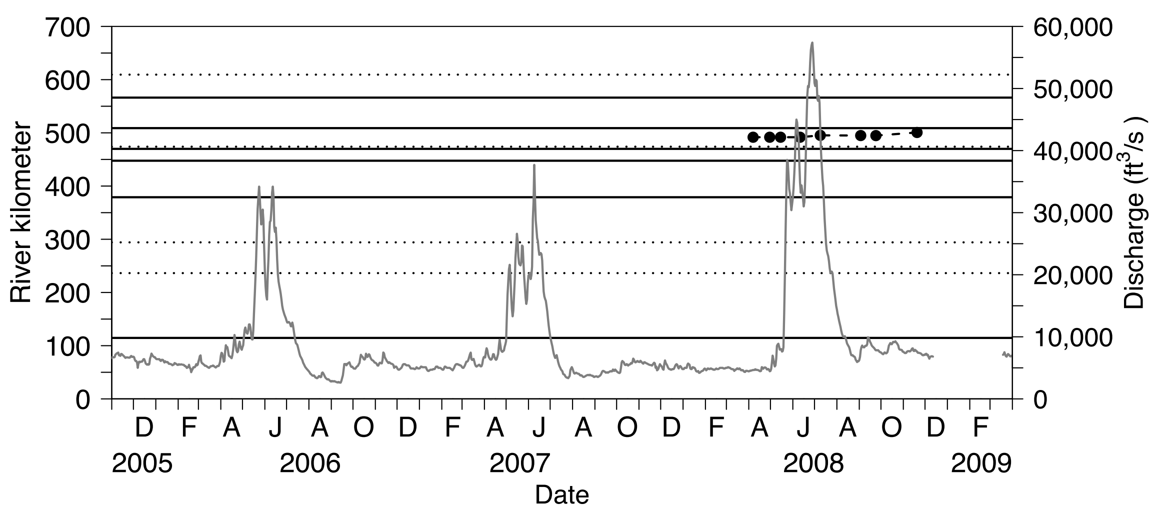

Figure 159. Movements of BURB #119 (frequency = 600, code = 115, N = 8)

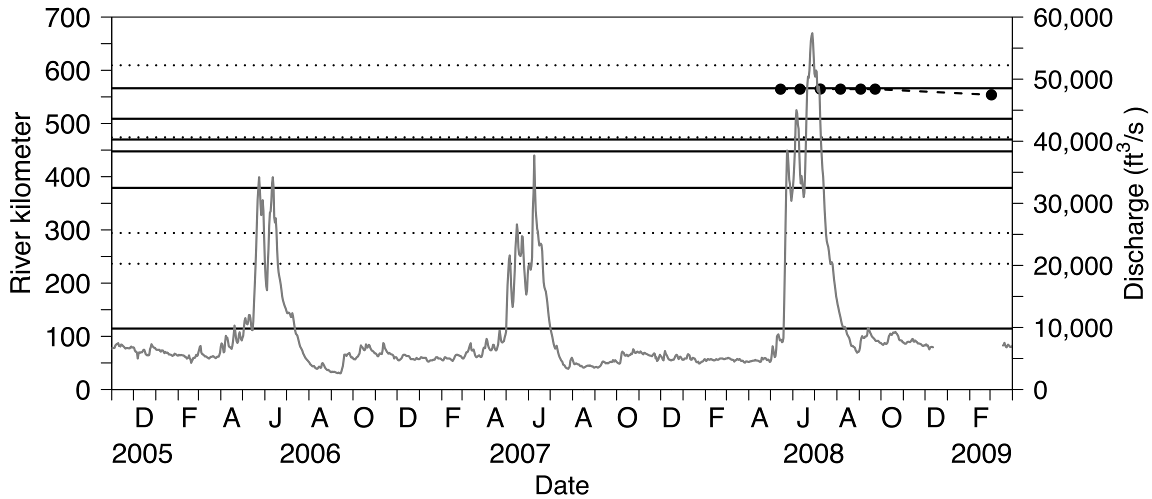

Figure 160. Movements of BURB #120 (frequency = 600, code = 117, N = 7)

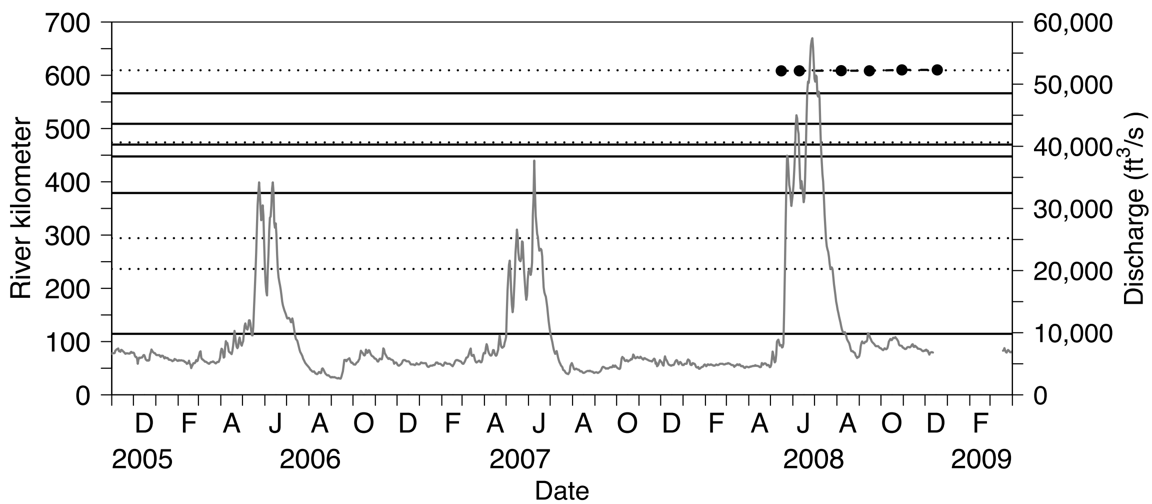

Figure 161. Movements of BURB #121 (frequency = 600, code = 120, N = 6)

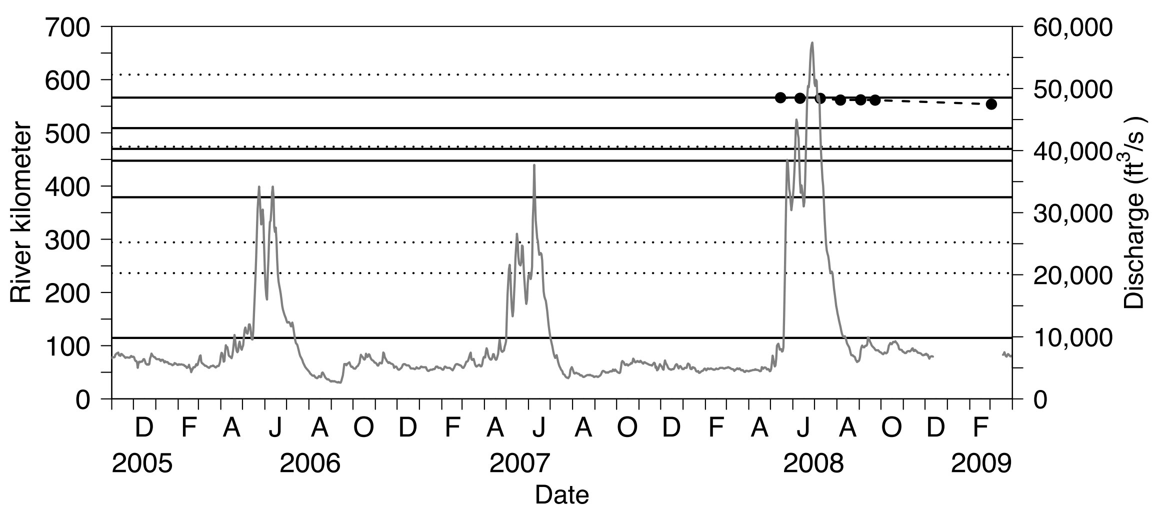

Figure 162. Movements of BURB #122 (frequency = 600, code = 122, N = 7)

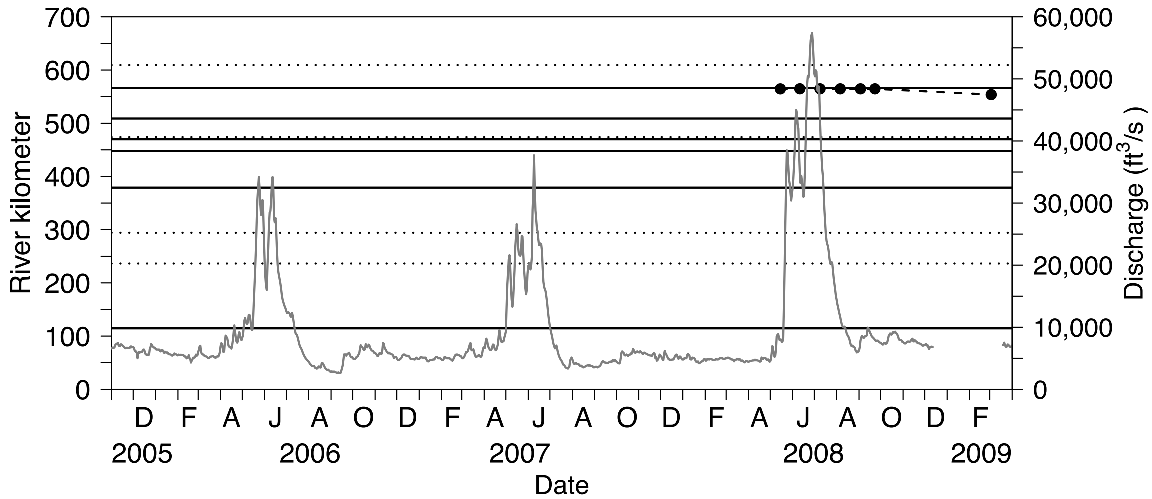

Figure 163. Movements of BURB #123 (frequency = 600, code = 123, N = 7)

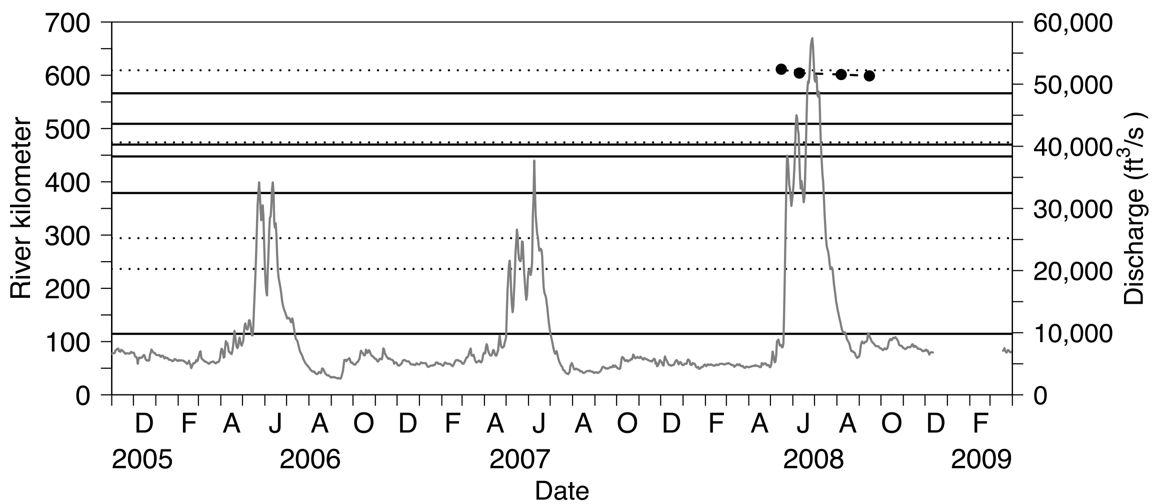

Figure 164. Movements of BURB #124 (frequency = 600, code = 124, N = 4)

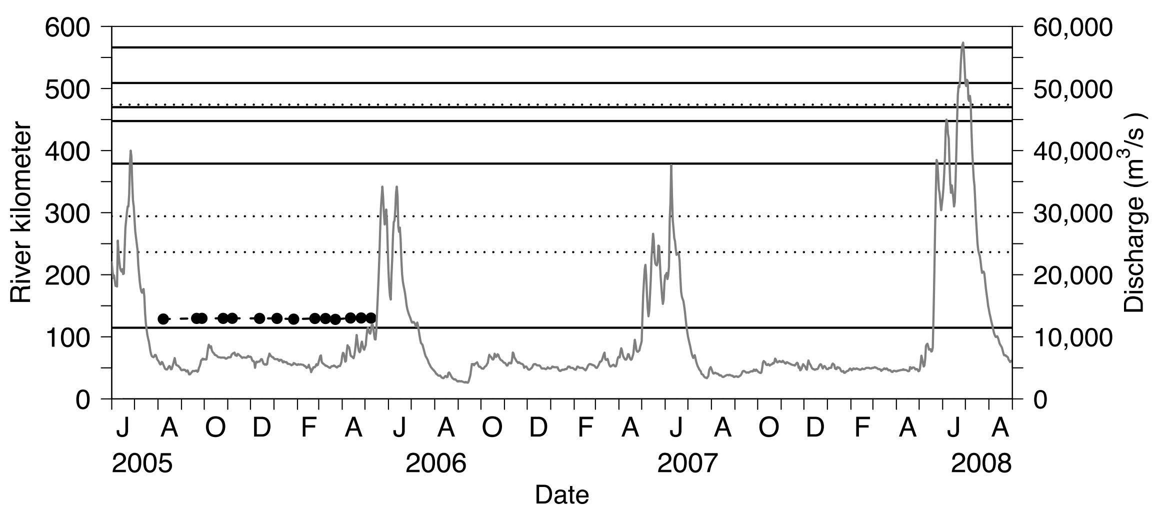

Figure 165. Movements of CHCA #1 (frequency = 420, code = 13a, N = 14)

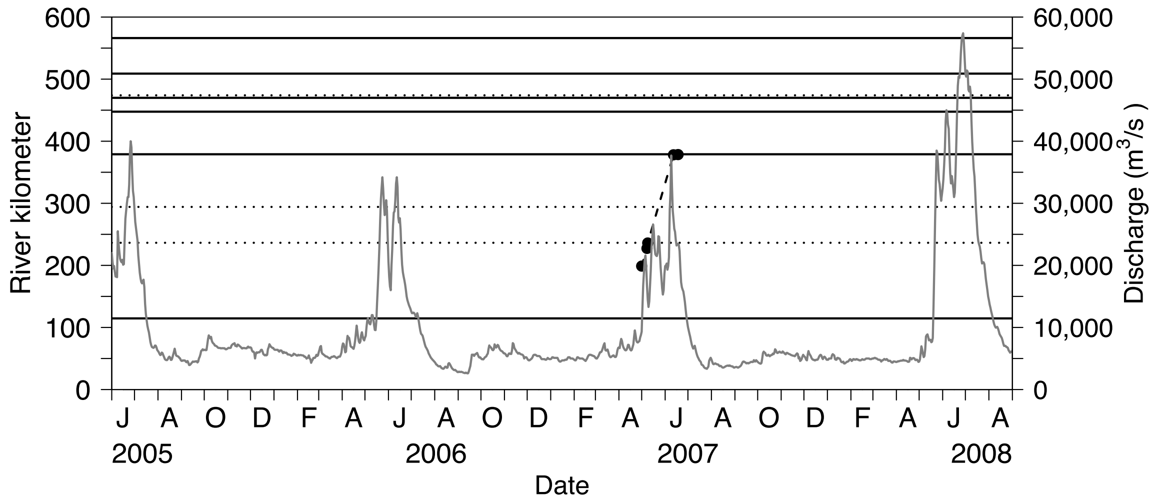

Figure 166. Movements of CHCA #2 (frequency = 420, code = 13b, N = 5)

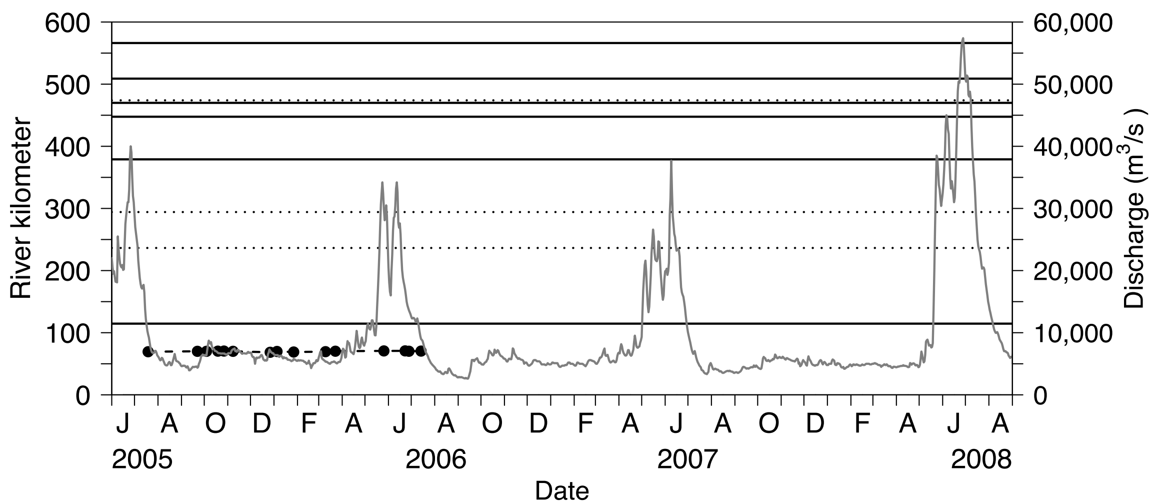

Figure 167. Movements of CHCA #3 (frequency = 420, code = 60a, N = 15)

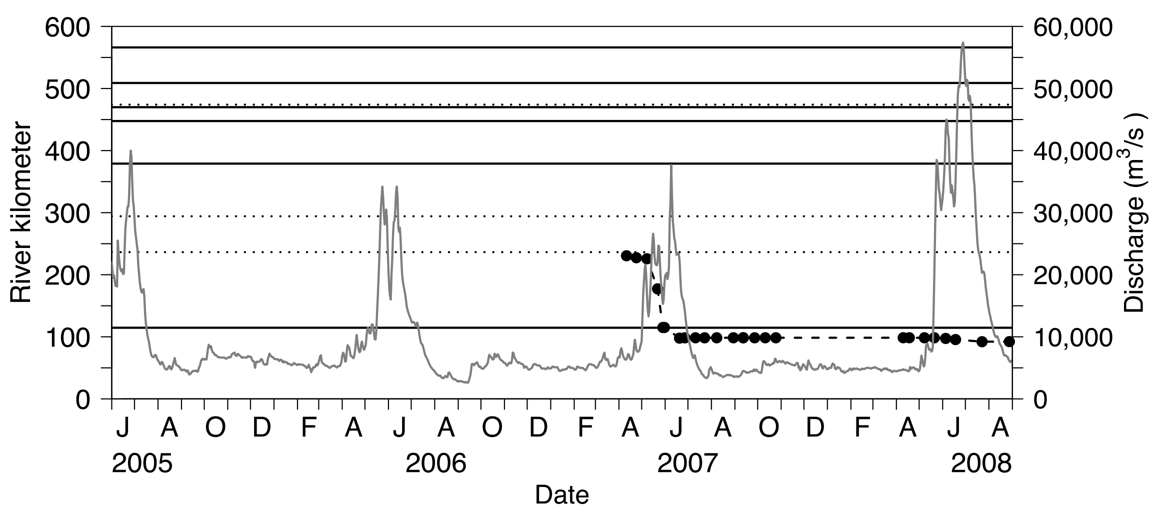

Figure 168. Movements of CHCA #4 (frequency = 420, code = 60b, N = 25)

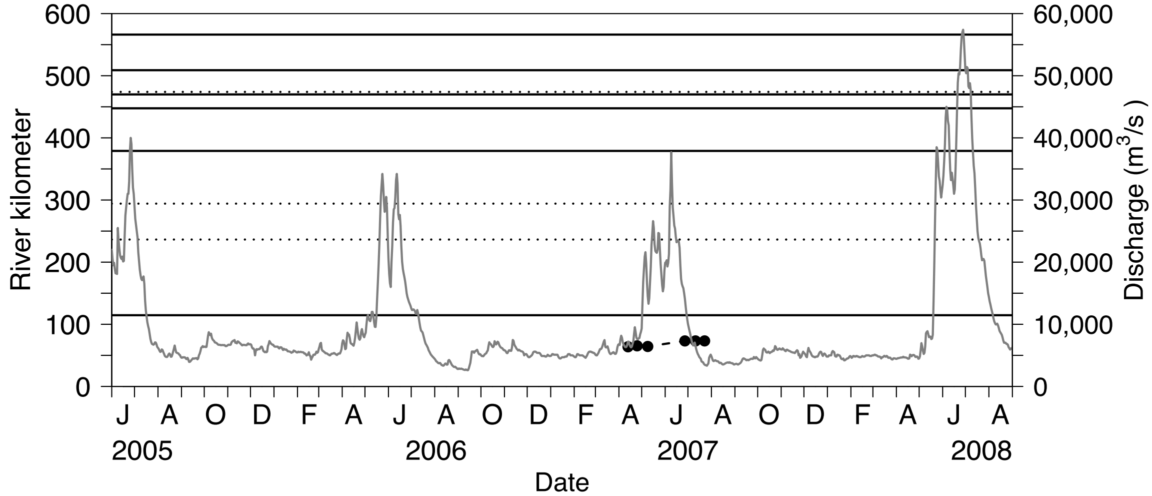

Figure 169. Movements of CHCA #5 (frequency = 420, code = 66b, N = 6)

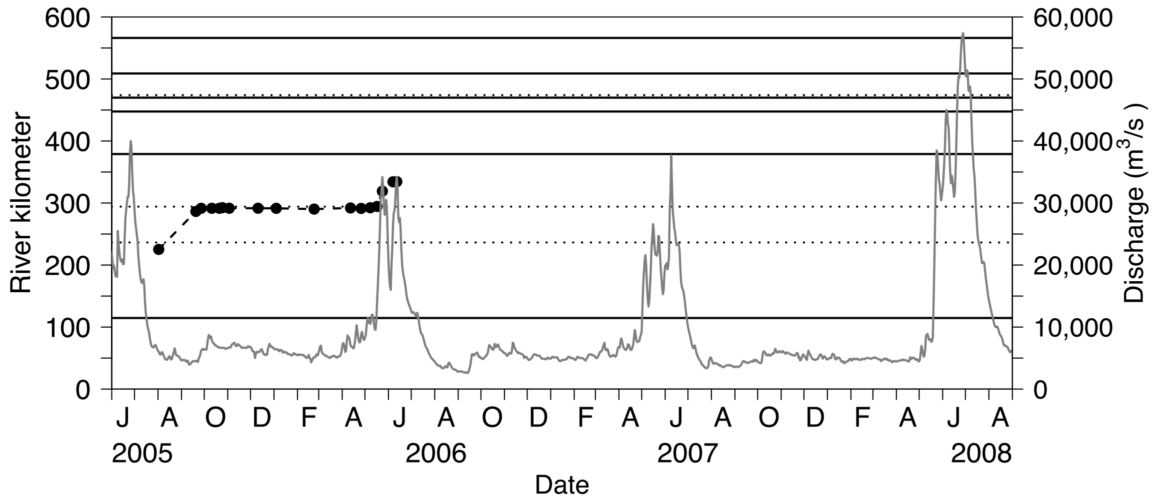

Figure 170. Movements of CHCA #6 (frequency = 420, code = 71a, N = 17)

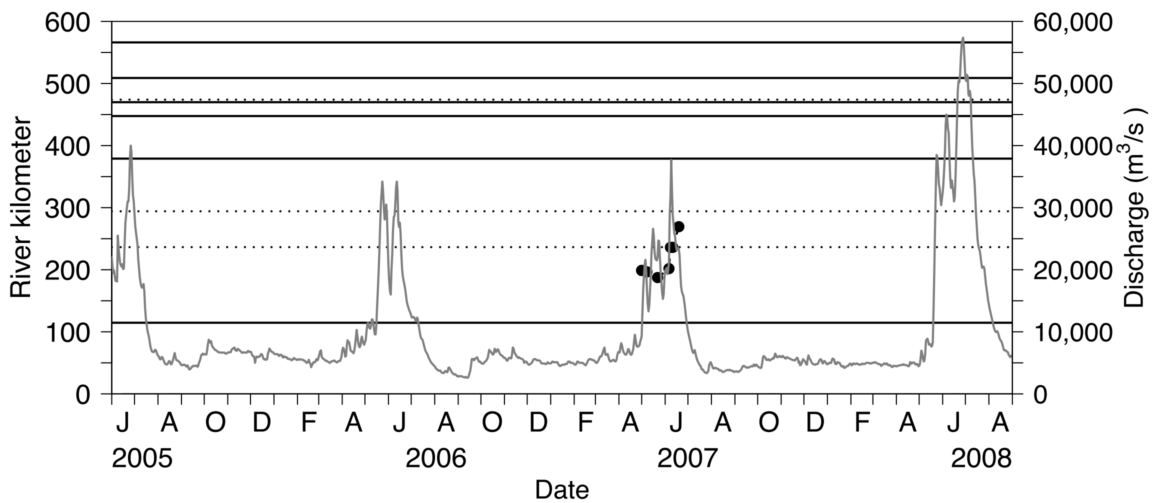

Figure 171. Movements of CHCA #7 (frequency = 420, code = 71b, N = 8)

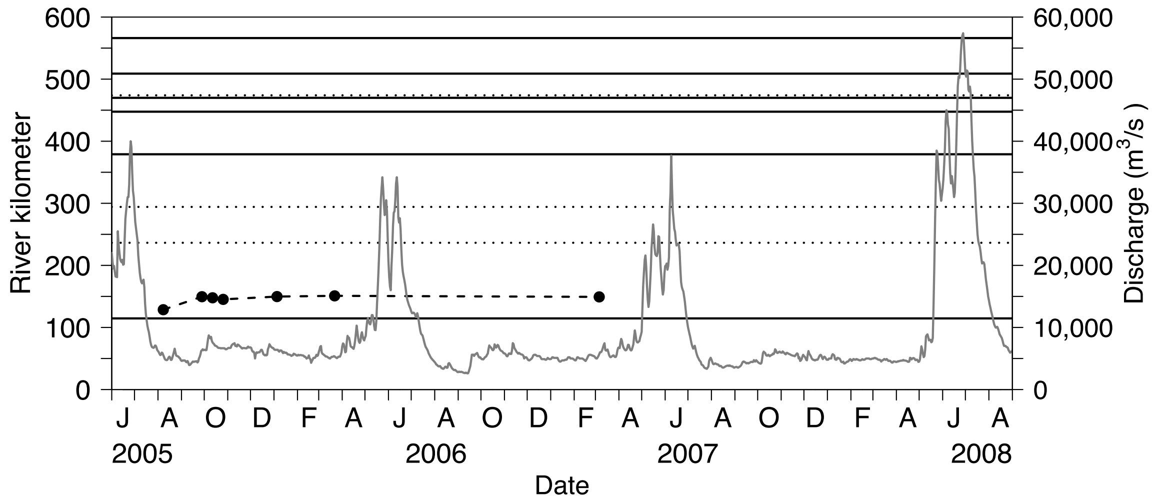

Figure 172. Movements of CHCA #8 (frequency = 420, code = 14, N = 7)

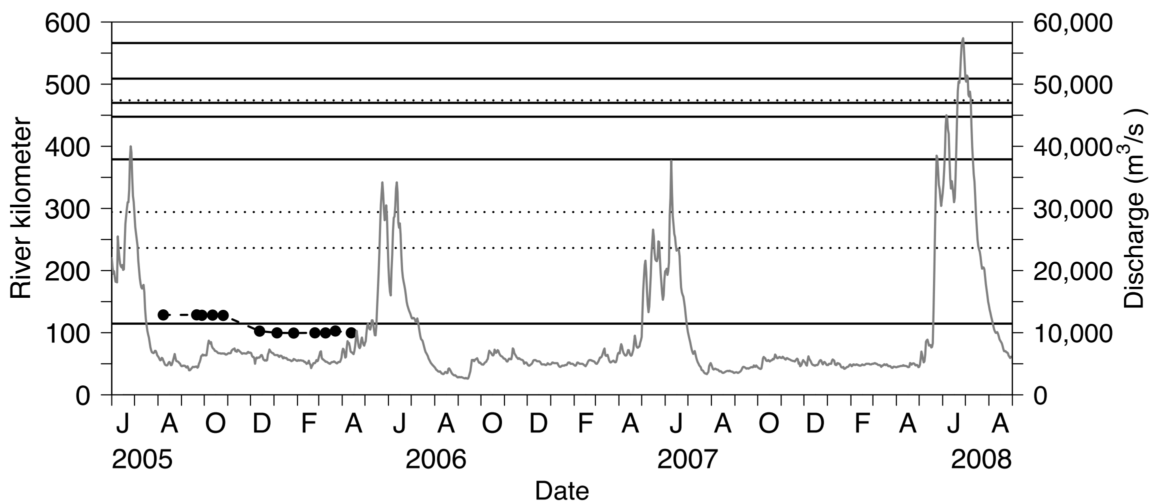

Figure 173. Movements of CHCA #9 (frequency = 420, code = 17, N = 12)

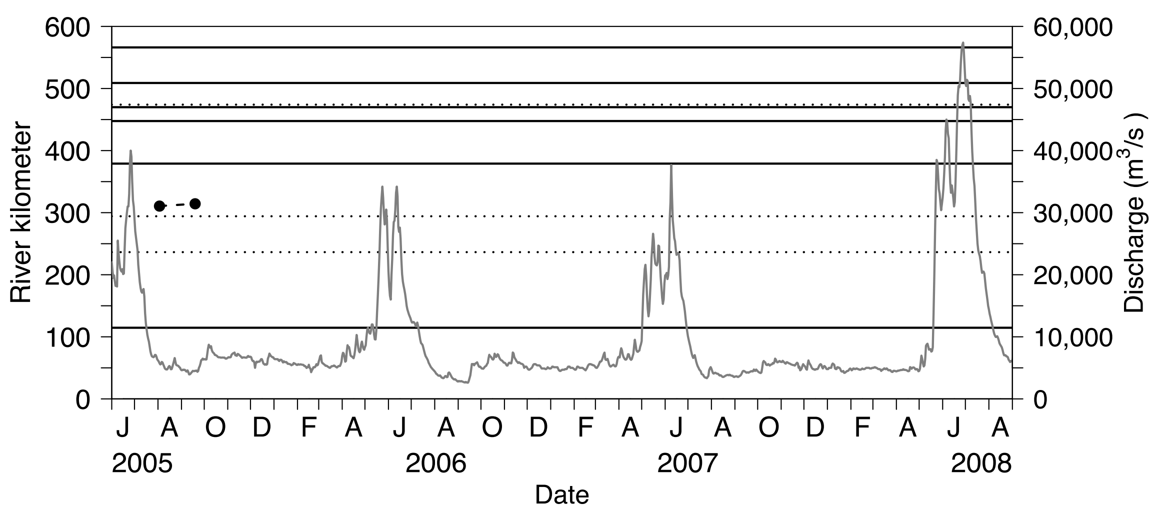

Figure 174. Movements of CHCA #10 (frequency = 420, code = 26, N = 2)

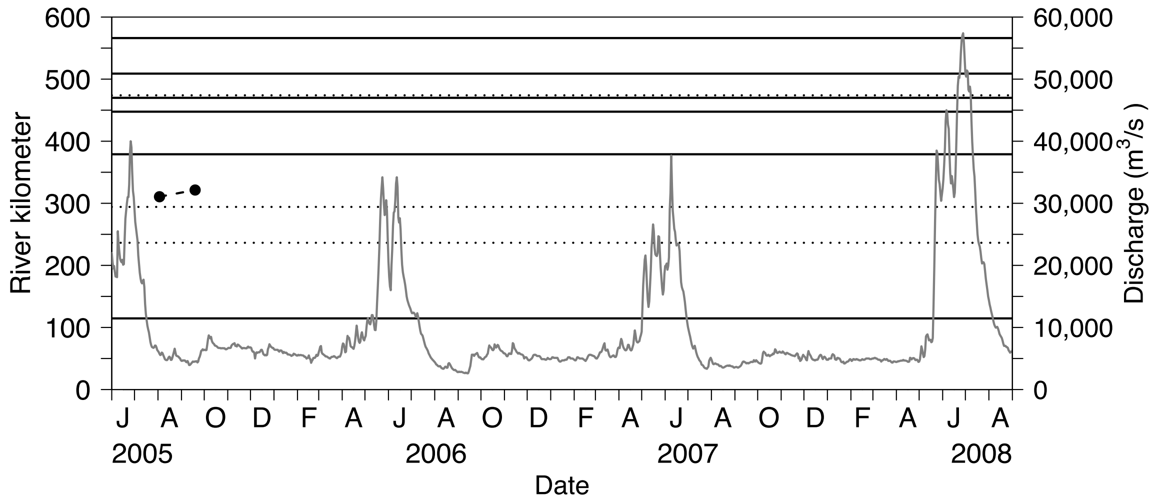

Figure 175. Movements of CHCA #11 (frequency = 420, code = 28, N = 2)

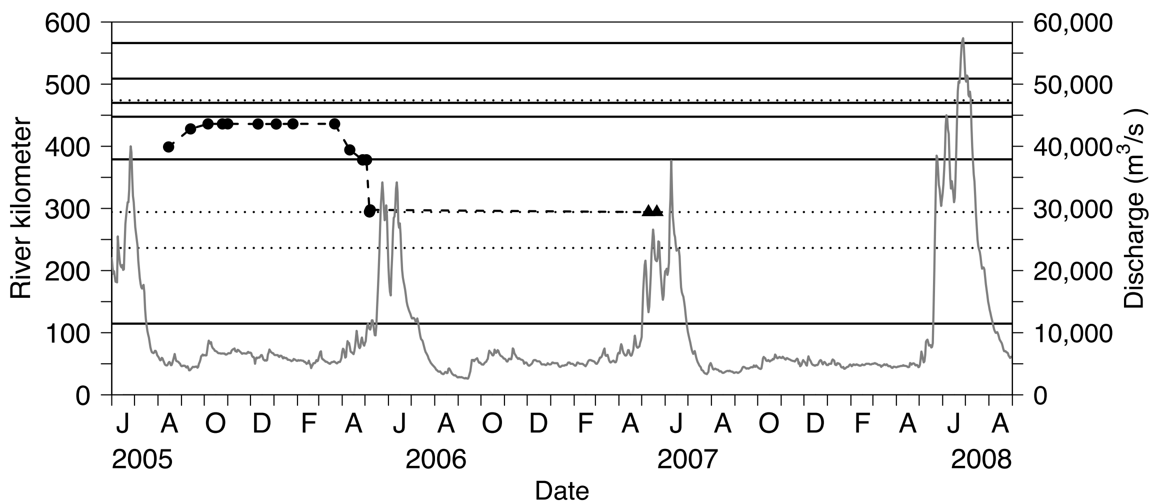

Figure 176. Movements of CHCA #12 (frequency = 420, code = 34, N = 20)

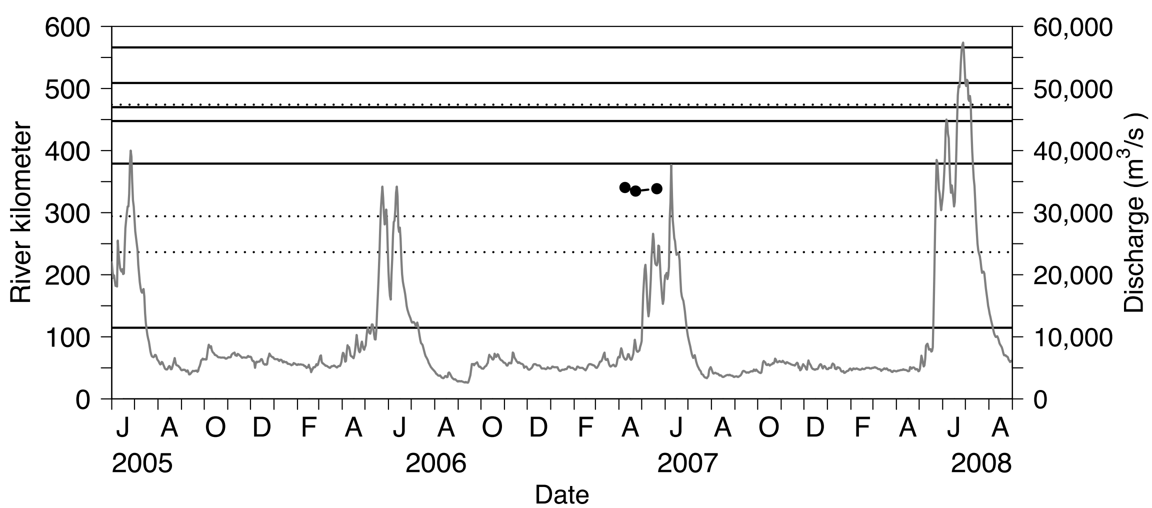

Figure 177. Movements of CHCA #13 (frequency = 420, code = 35, N = 3)

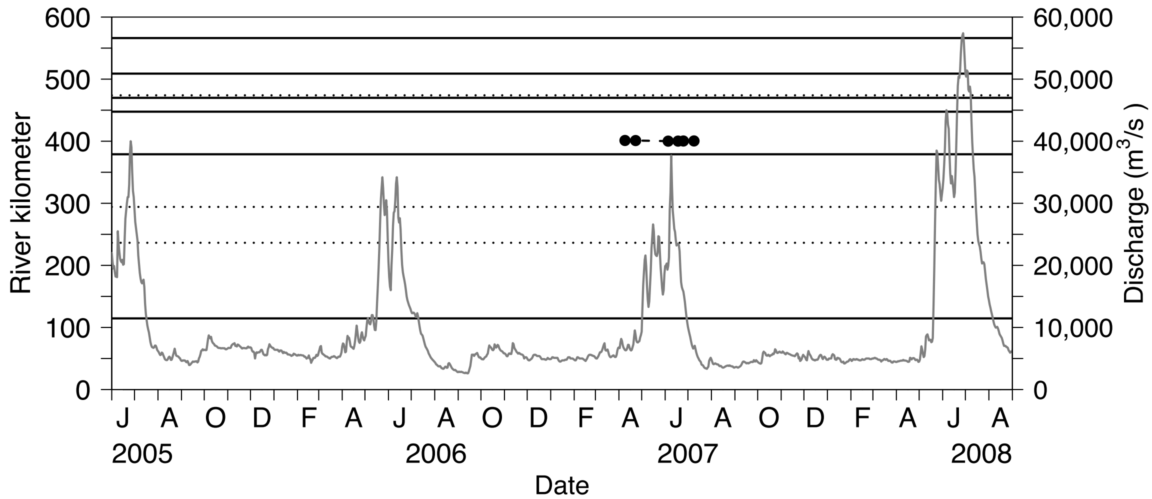

Figure 178. Movements of CHCA #14 (frequency = 420, code = 36, N = 6)

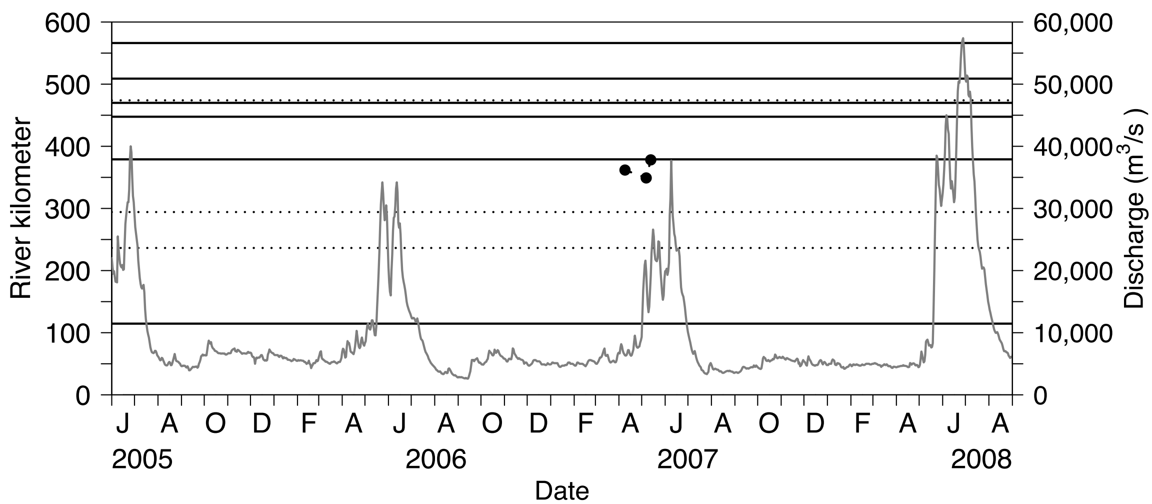

Figure 179. Movements of CHCA #15 (frequency = 420, code = 37, N = 3)

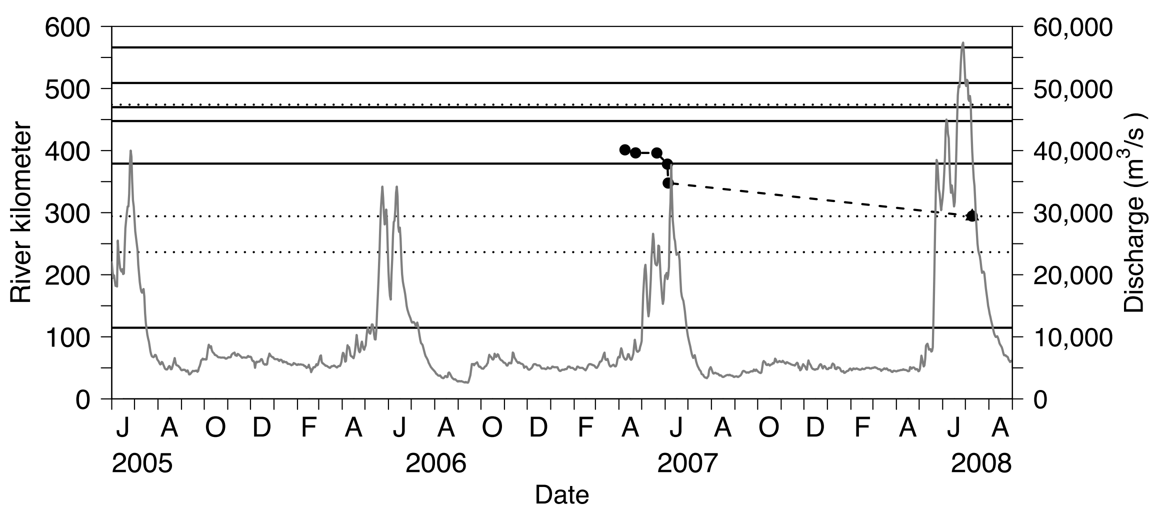

Figure 180. Movements of CHCA #16 (frequency = 420, code = 39, N = 8)

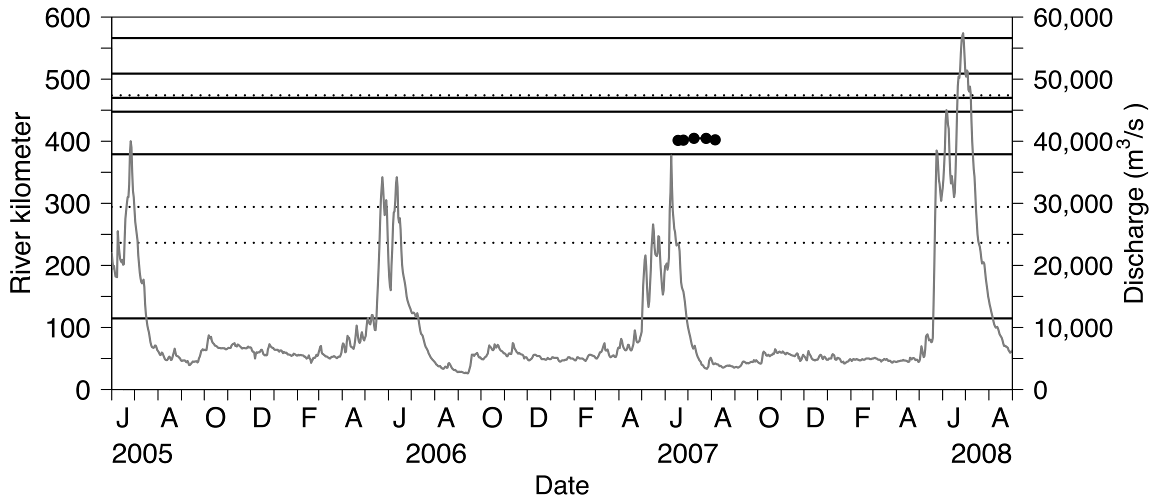

Figure 181. Movements of CHCA #17 (frequency = 420, code = 40, N = 5)

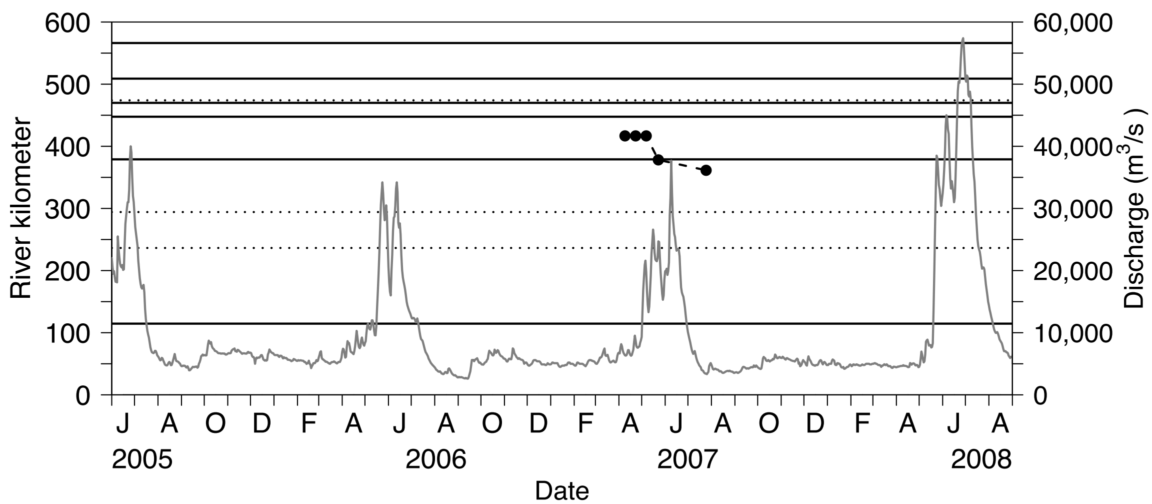

Figure 182. Movements of CHCA #18 (frequency = 420, code = 41, N = 5)

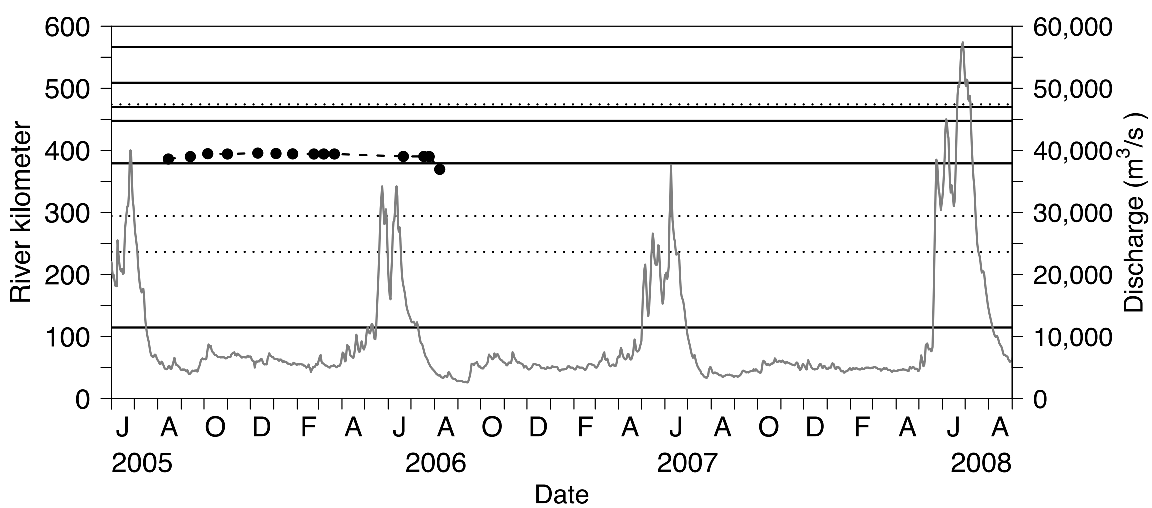

Figure 183. Movements of CHCA #19 (frequency = 420, code = 42, N = 14)

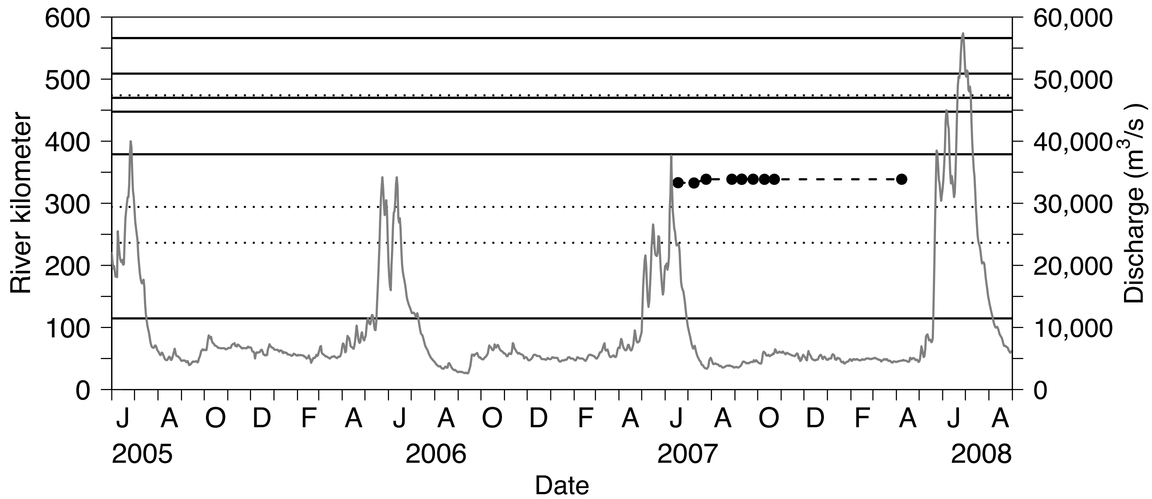

Figure 184. Movements of CHCA #20 (frequency = 420, code = 45, N = 10)

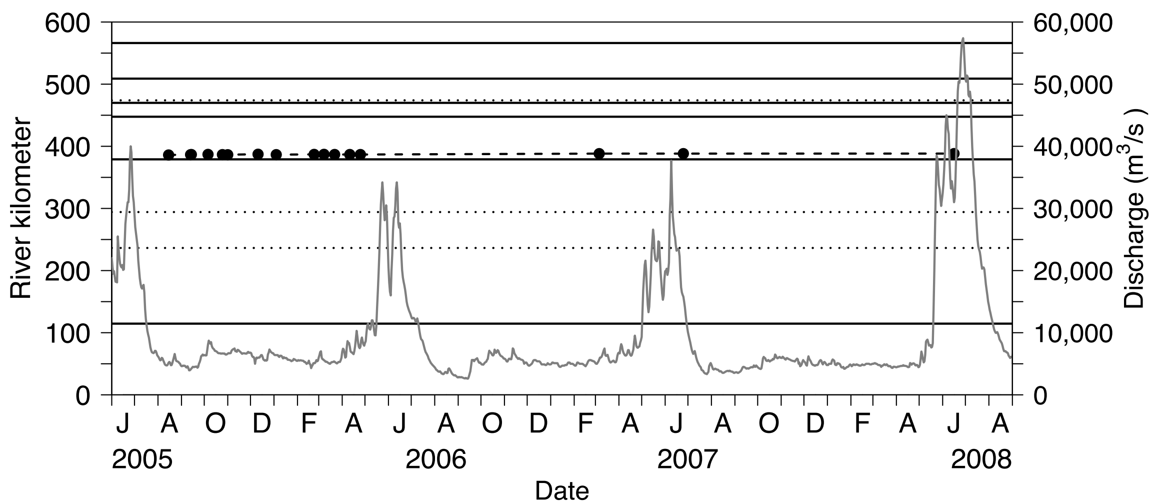

Figure 185. Movements of CHCA #21 (frequency = 420, code = 46, N = 16)

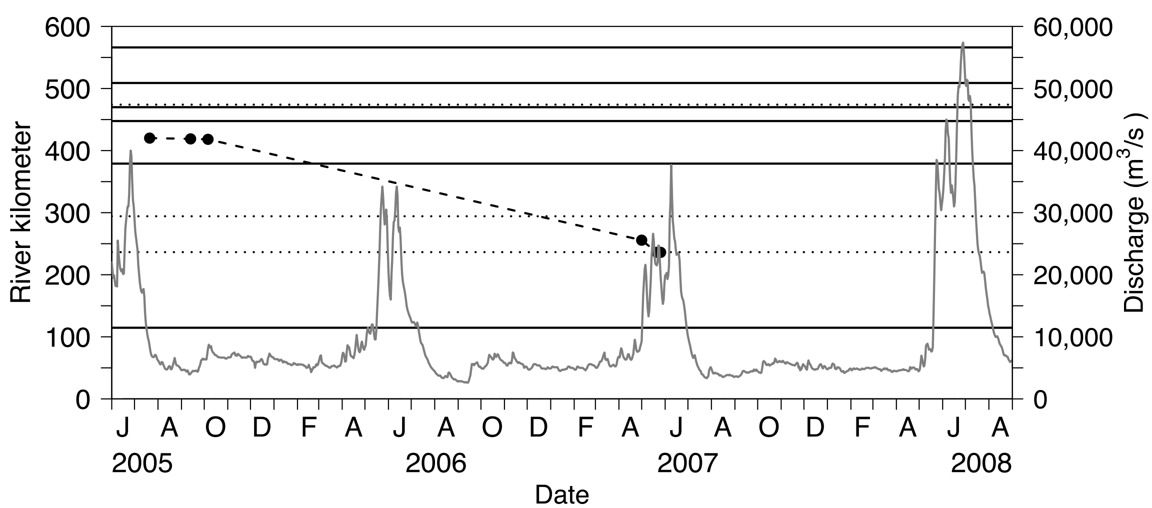

Figure 186. Movements of CHCA #22 (frequency = 420, code = 55, N = 6)

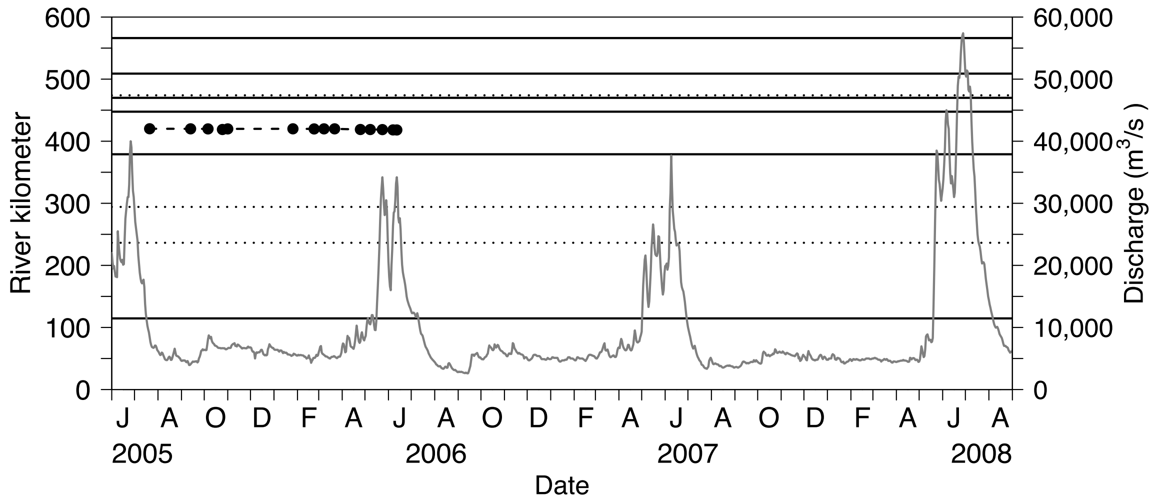

Figure 187. Movements of CHCA #23 (frequency = 420, code = 56, N = 14)

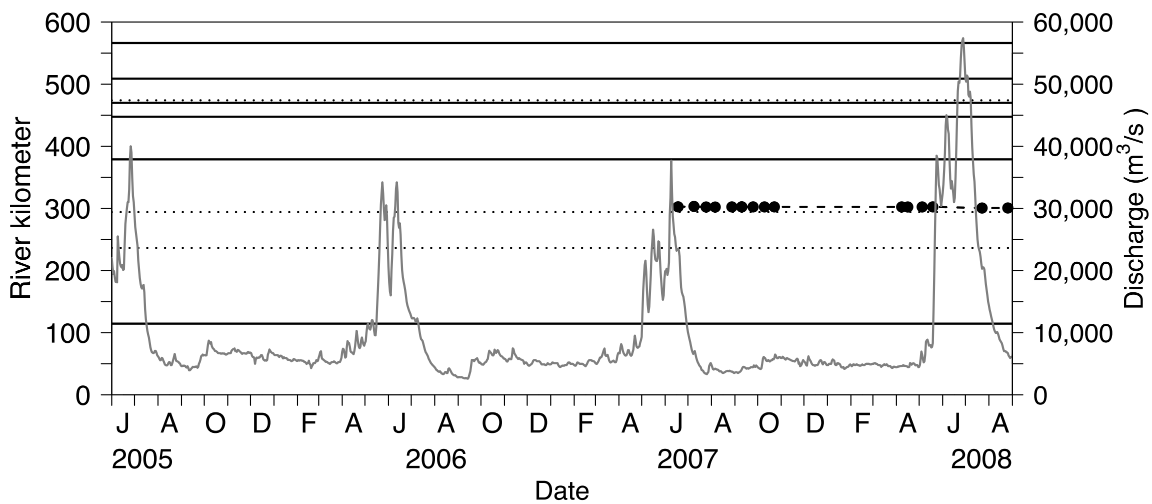

Figure 188. Movements of CHCA #24 (frequency = 420, code = 57, N = 16)

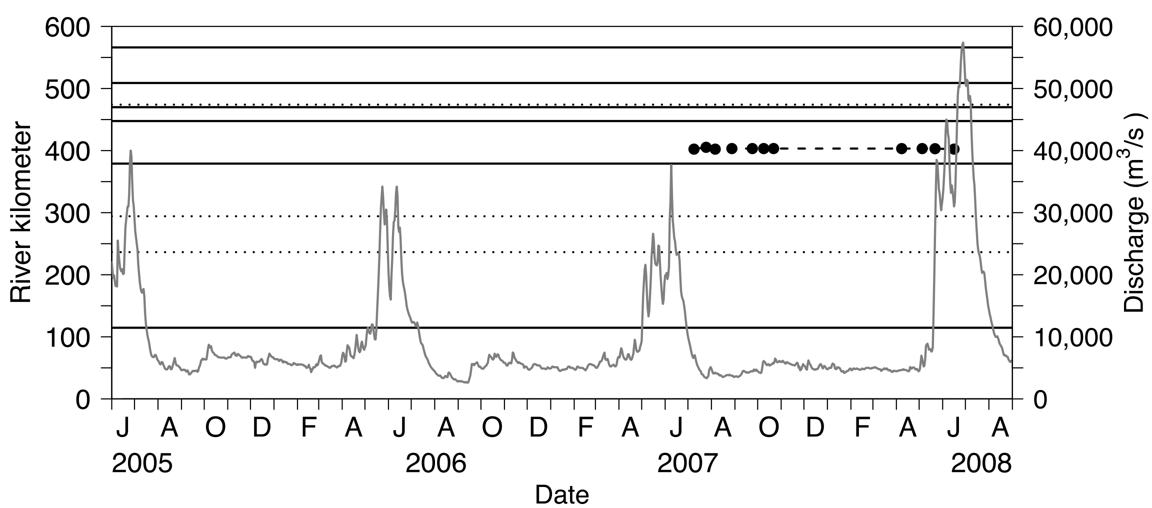

Figure 189. Movements of CHCA #25 (frequency = 420, code = 61, N = 11)

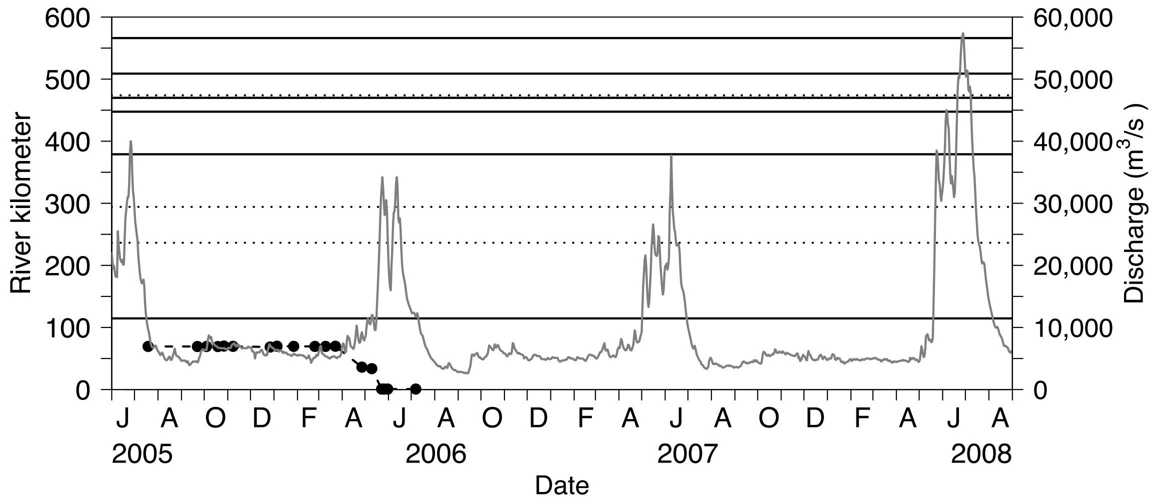

Figure 190. Movements of CHCA #26 (frequency = 420, code = 62, N = 18)

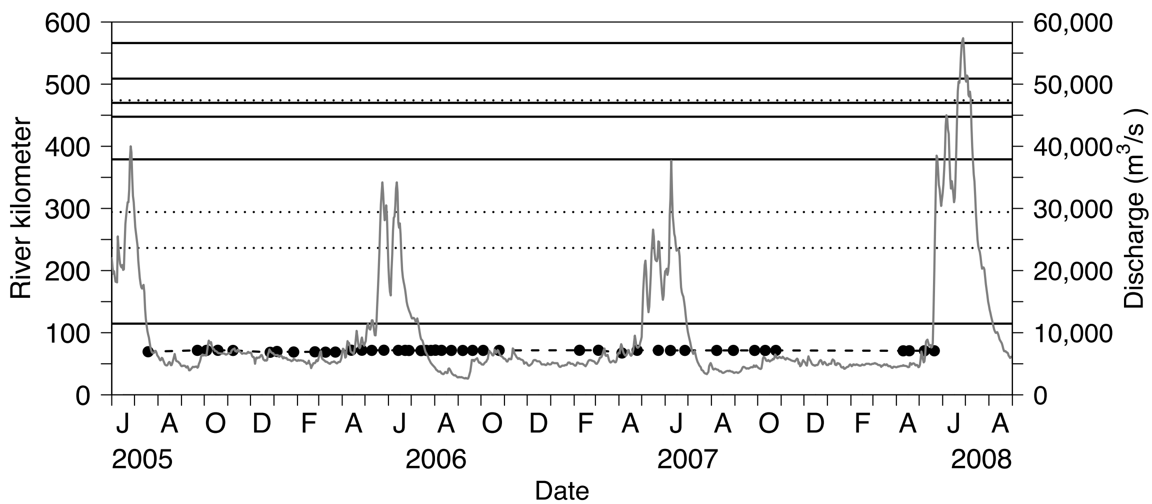

Figure 191. Movements of CHCA #27 (frequency = 420, code = 64, N = 45)

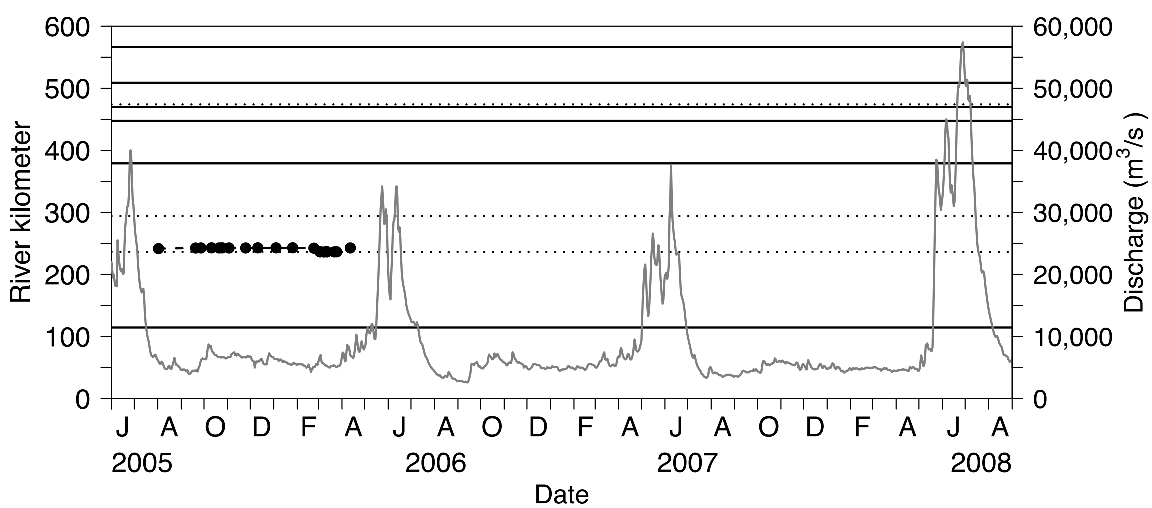

Figure 192. Movements of CHCA #28 (frequency = 420, code = 66, N = 21)

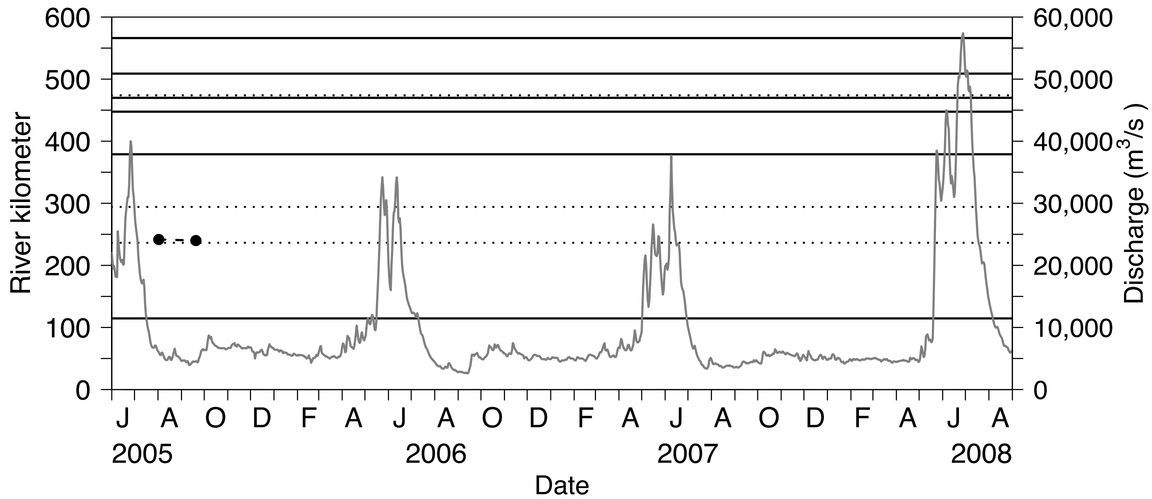

Figure 193. Movements of CHCA #29 (frequency = 420, code = 70, N = 2)

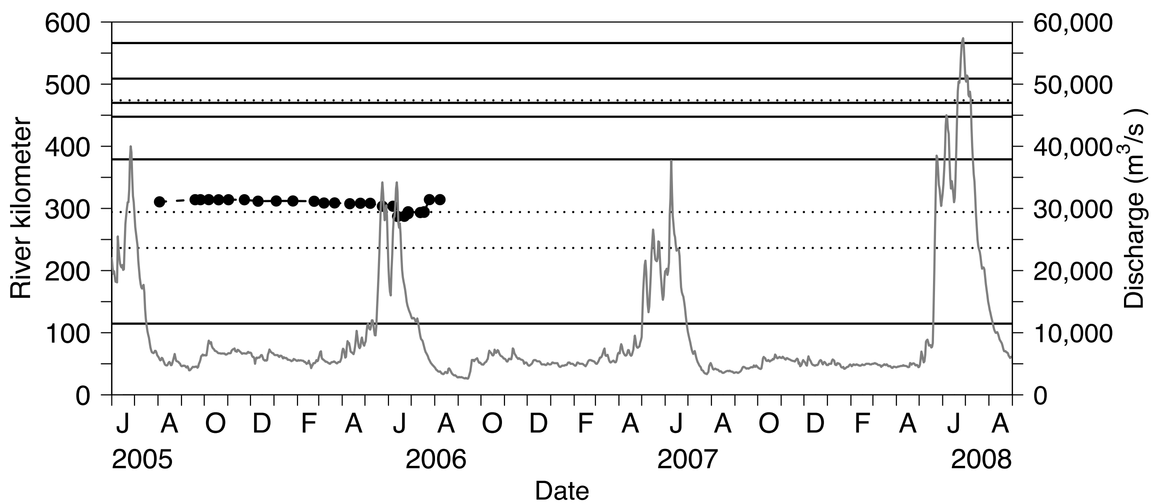

Figure 194. Movements of CHCA #30 (frequency = 420, code = 73, N = 29)

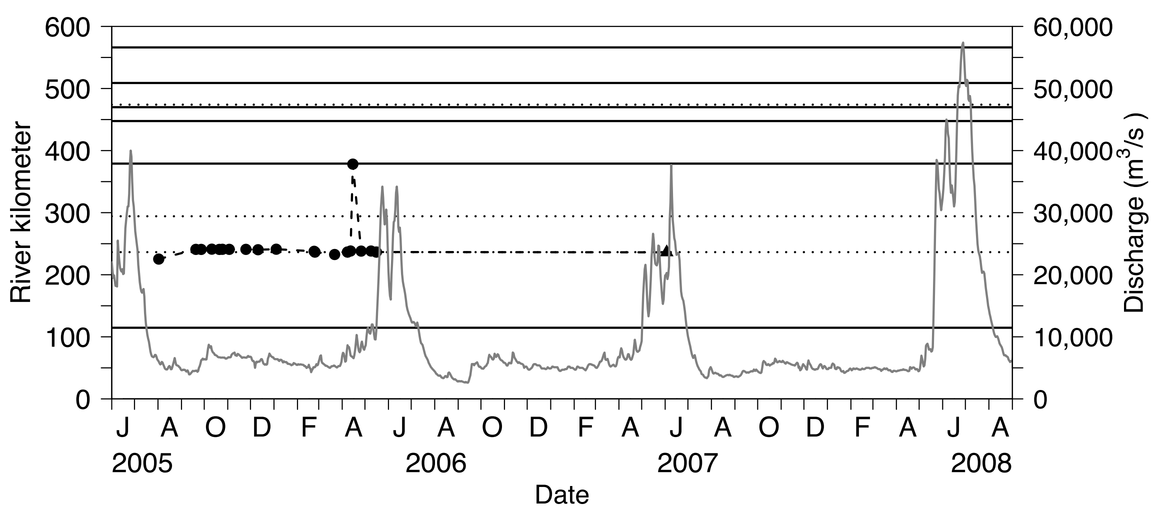

Figure 195. Movements of CHCA #31 (frequency = 420, code = 78, N = 23)

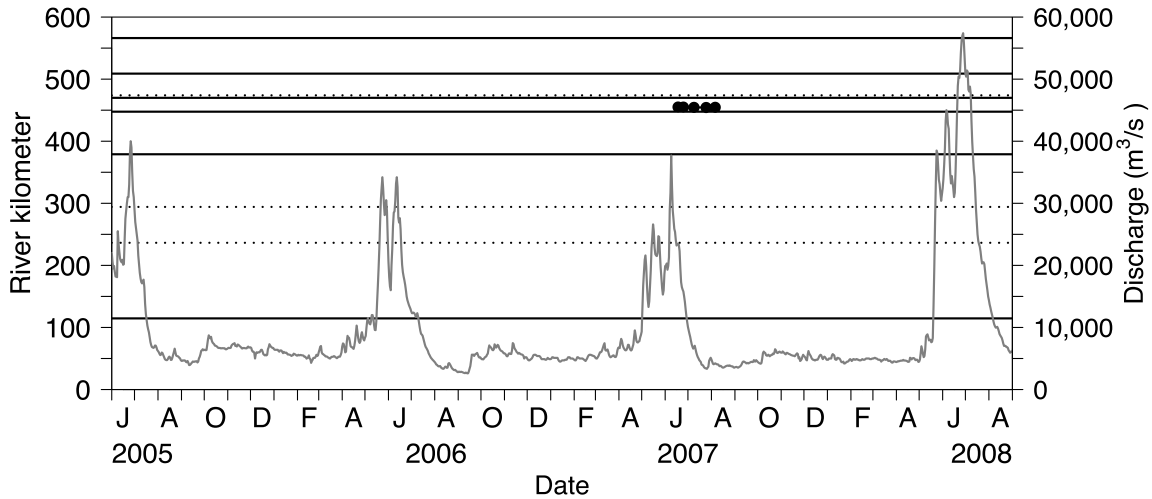

Figure 196. Movements of CHCA #32 (frequency = 420, code = 17b, N = 5)

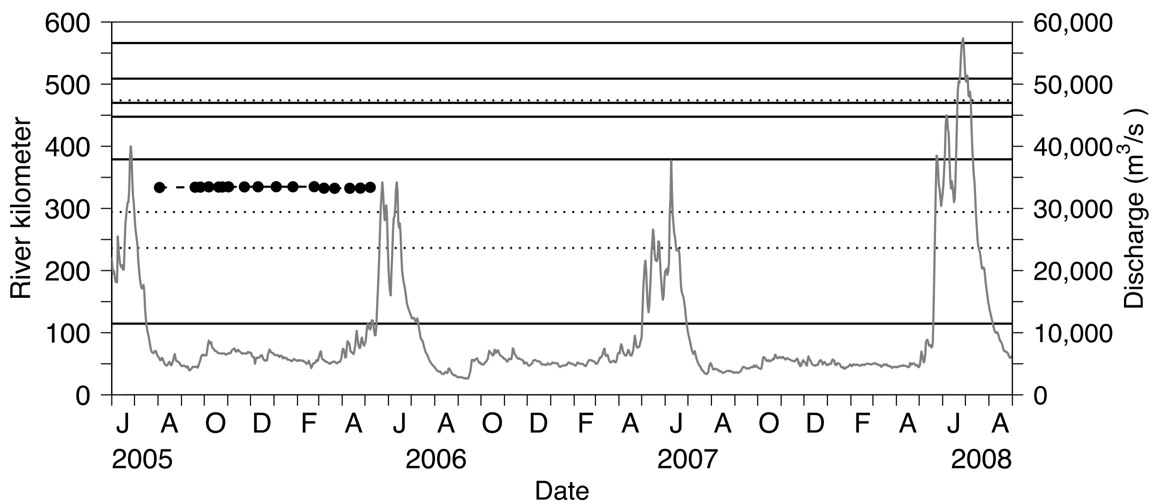

Figure 197. Movements of CHCA #33 (frequency = 420, code = 23a, N = 17)

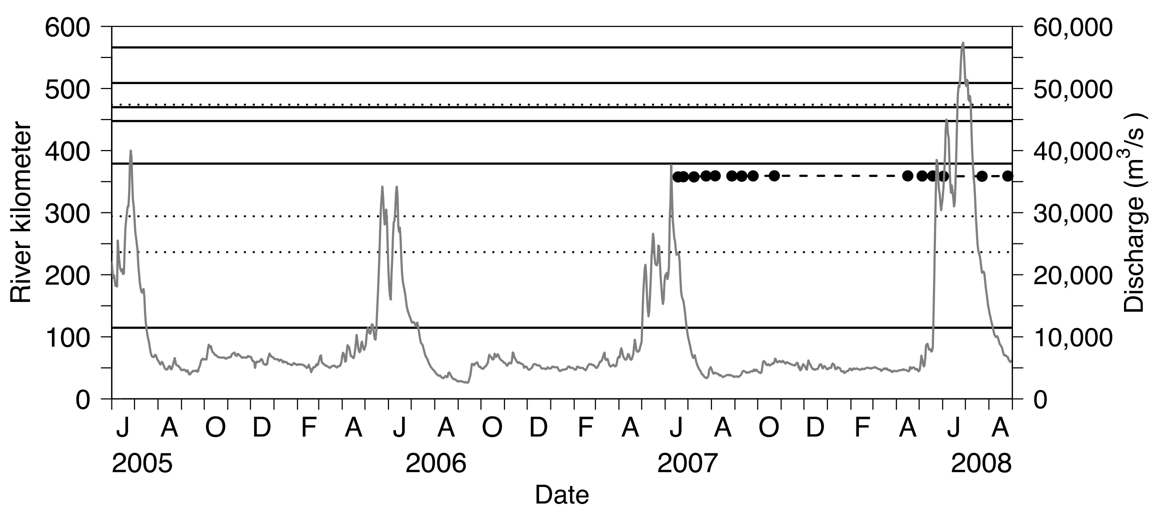

Figure 198. Movements of CHCA #34 (frequency = 420, code = 23b, N = 16)

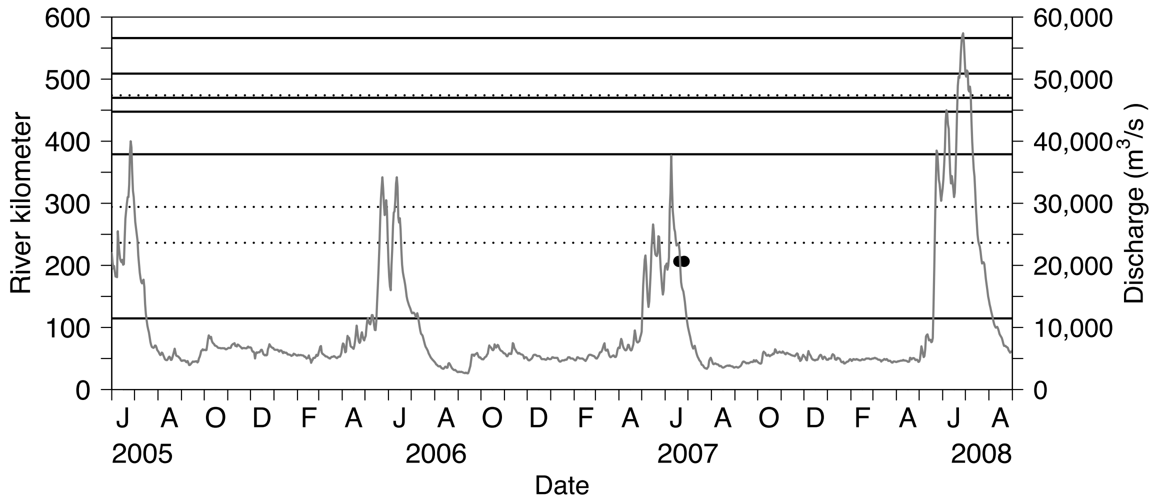

Figure 199. Movements of CHCA #35 (frequency = 420, code = 26b, N = 2)

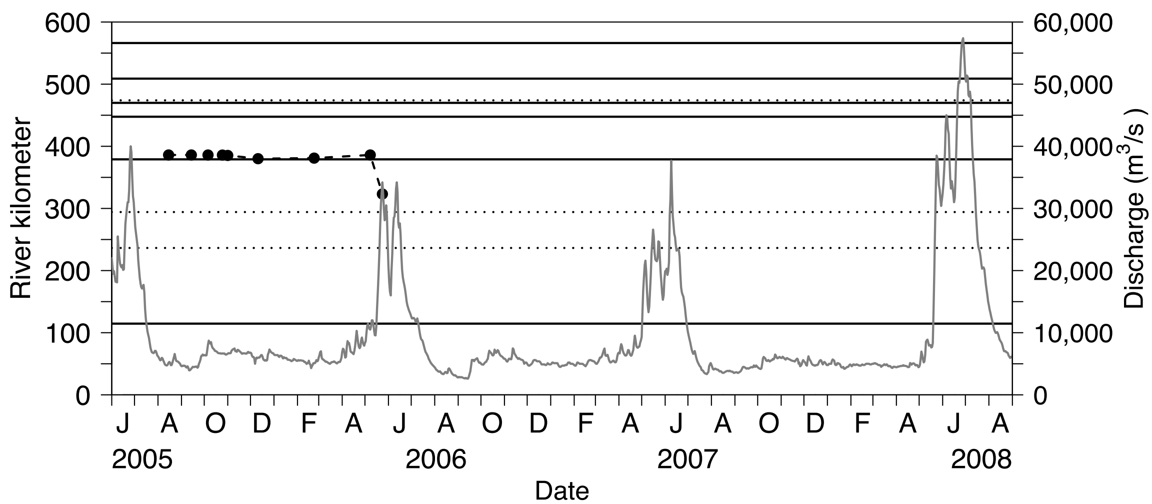

Figure 200. Movements of CHCA #36 (frequency = 420, code = 43a, N = 9)

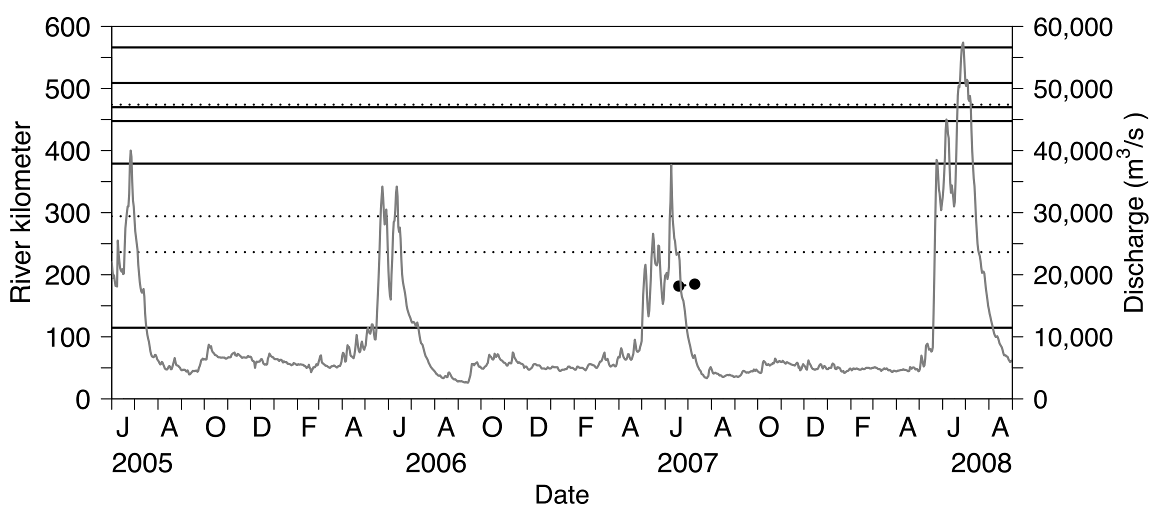

Figure 201. Movements of CHCA #37 (frequency = 420, code = 43b, N = 2)

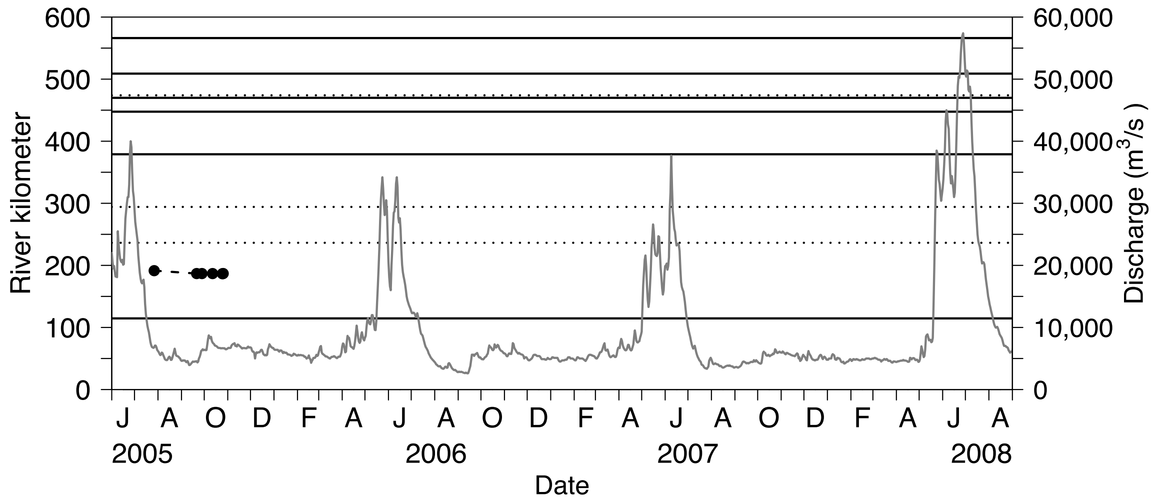

Figure 202. Movements of CHCA #38 (frequency = 420, code = 51a, N = 6)

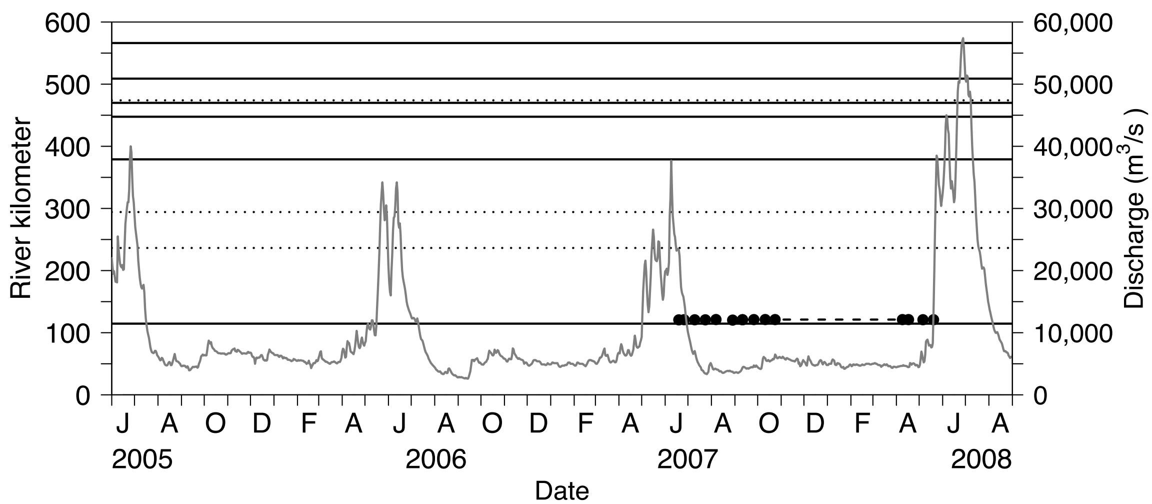

Figure 203. Movements of CHCA #39 (frequency = 420, code = 51b, N = 15)

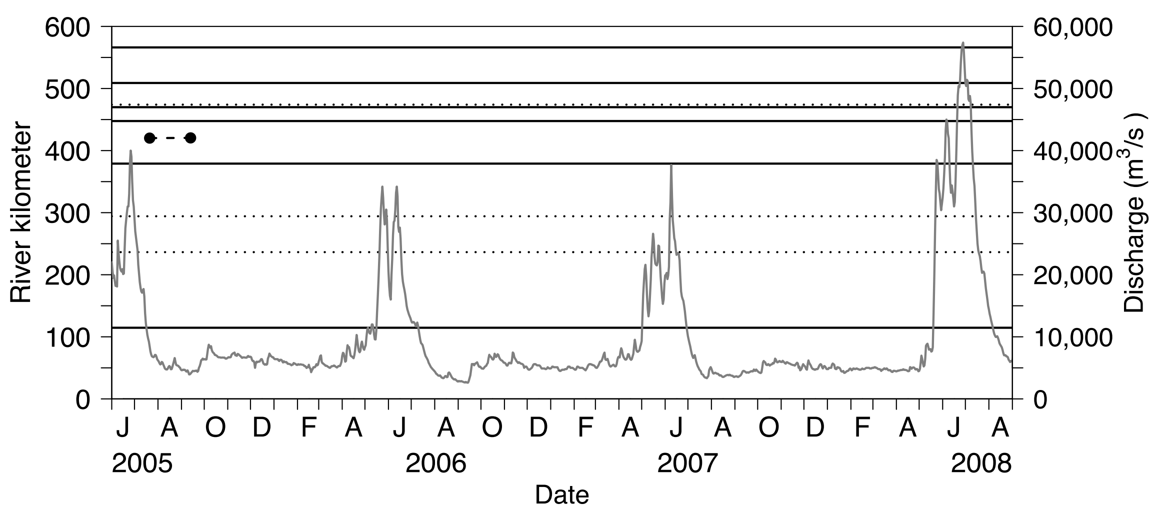

Figure 204. Movements of CHCA #40 (frequency = 420, code = 52a, N = 2)

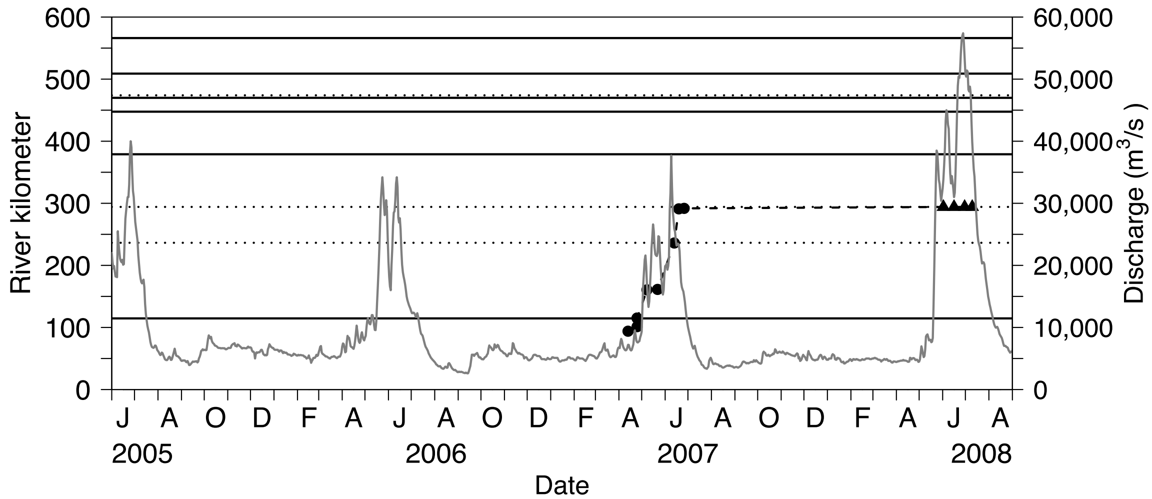

Figure 205. Movements of CHCA #41 (frequency = 420, code = 52b, N = 13)

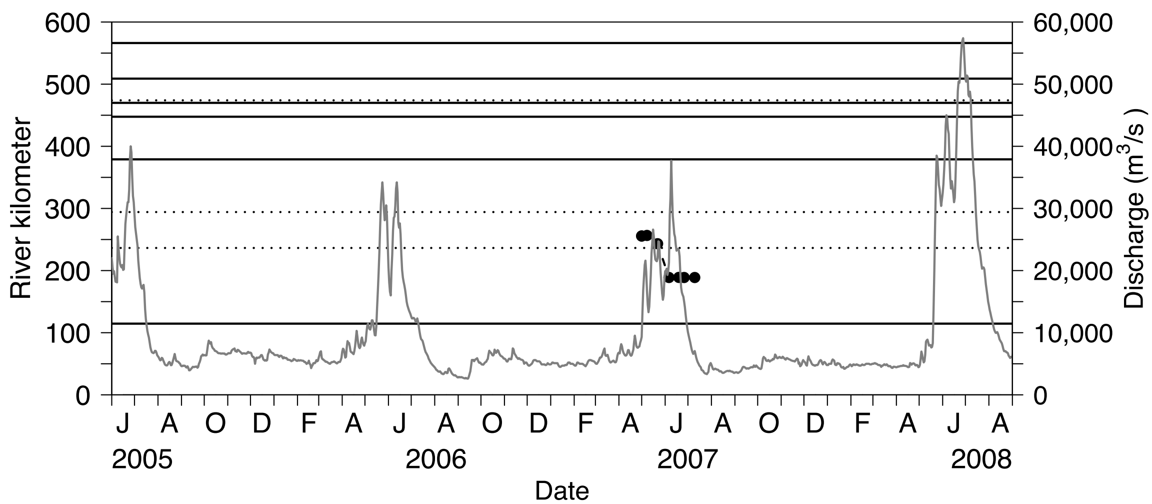

Figure 206. Movements of CHCA #42 (frequency = 420, code = 55b, N = 8)

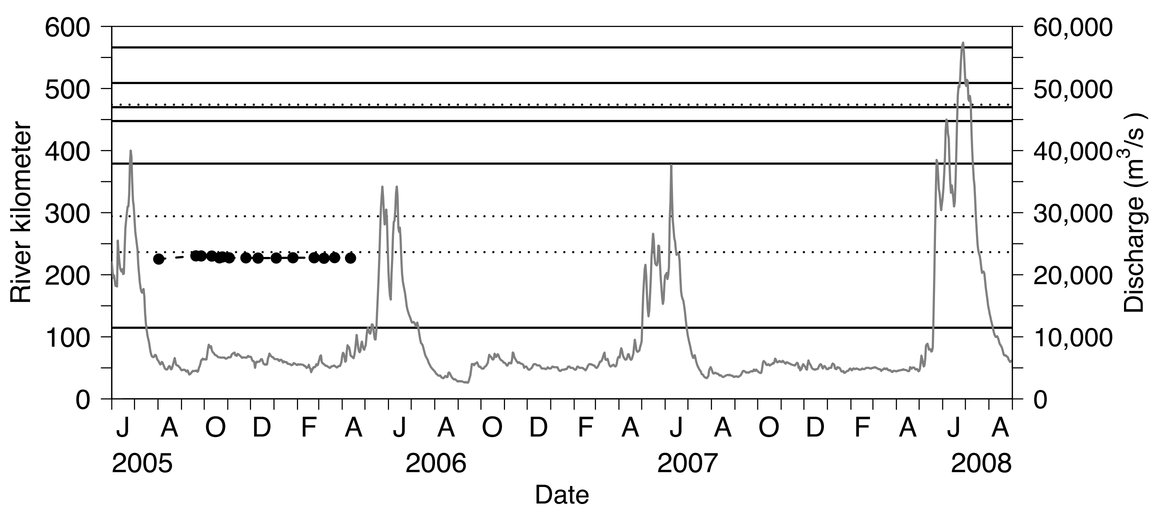

Figure 207. Movements of CHCA #43 (frequency = 420, code = 76a, N = 15)

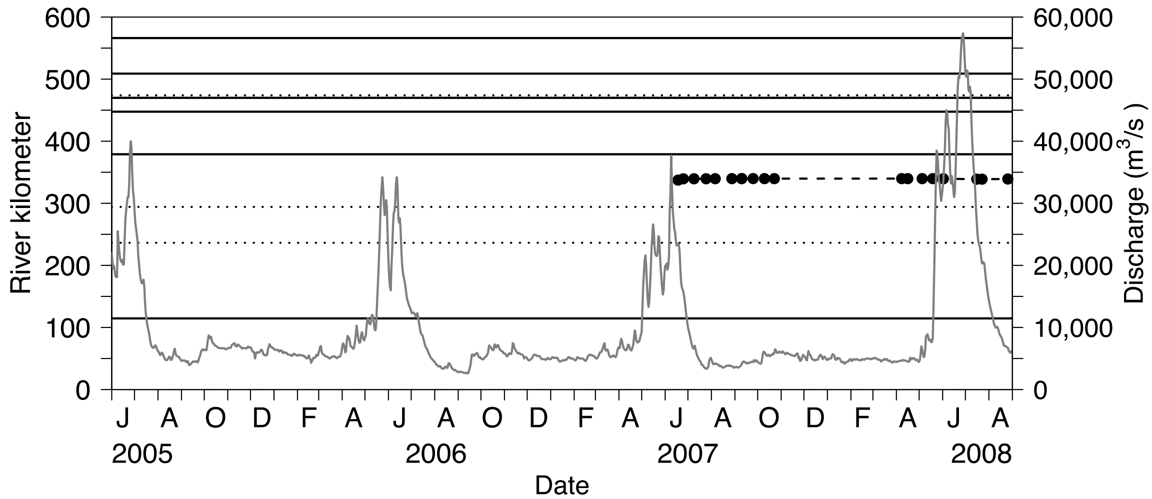

Figure 208. Movements of CHCA #44 (frequency = 420, code = 76b, N = 19)

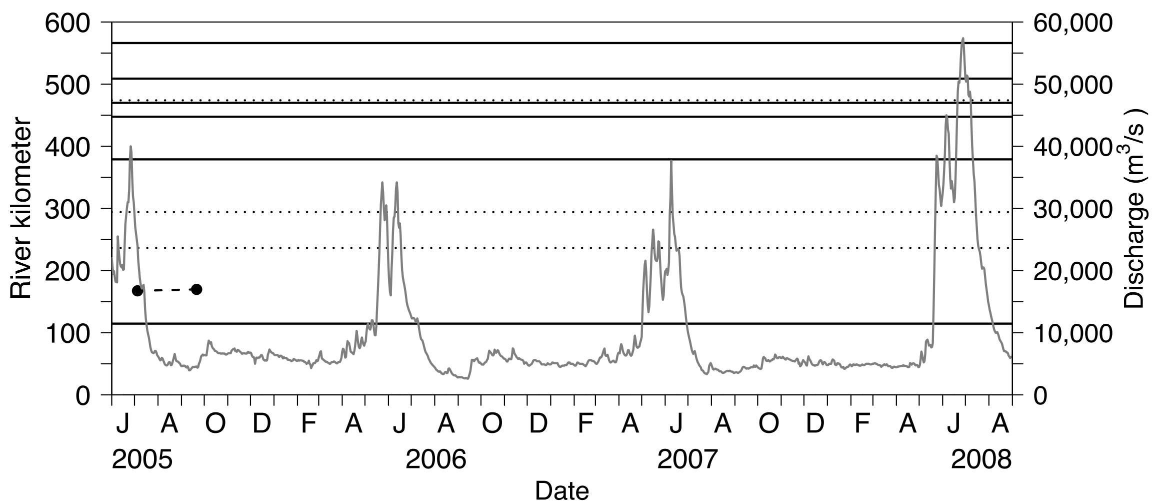

Figure 209. Movements of CHCA #45 (frequency = 480, code = 11, N = 2)

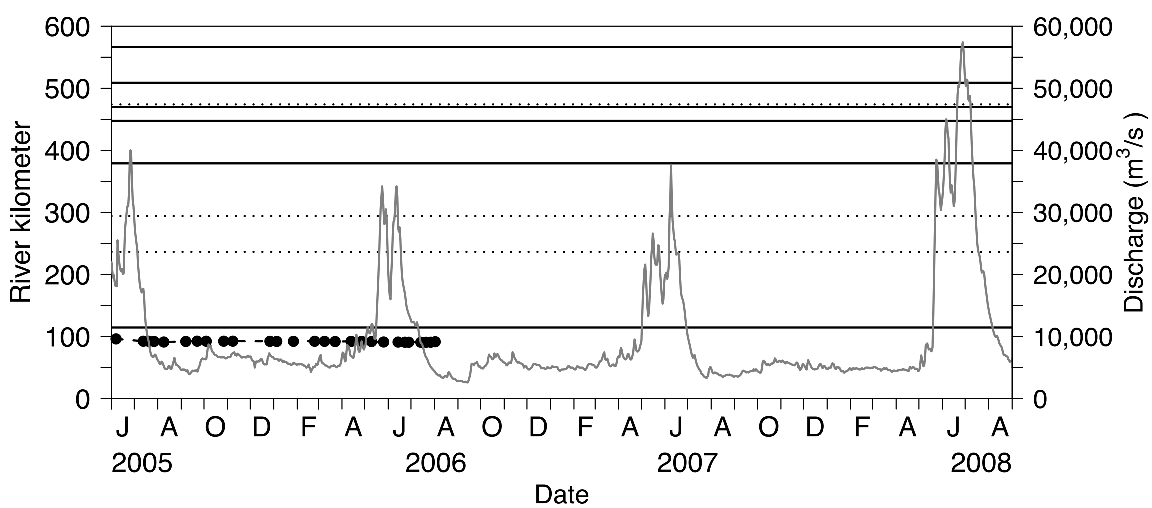

Figure 210. Movements of CHCA #46 (frequency = 480, code = 58a, N = 27)

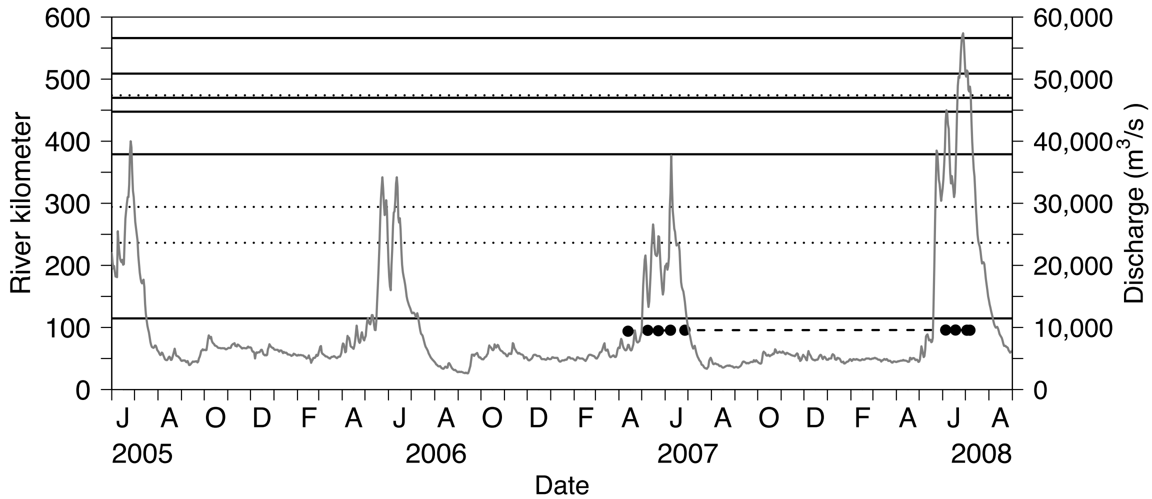

Figure 211. Movements of CHCA #47 (frequency = 480, code = 58b, N = 9)

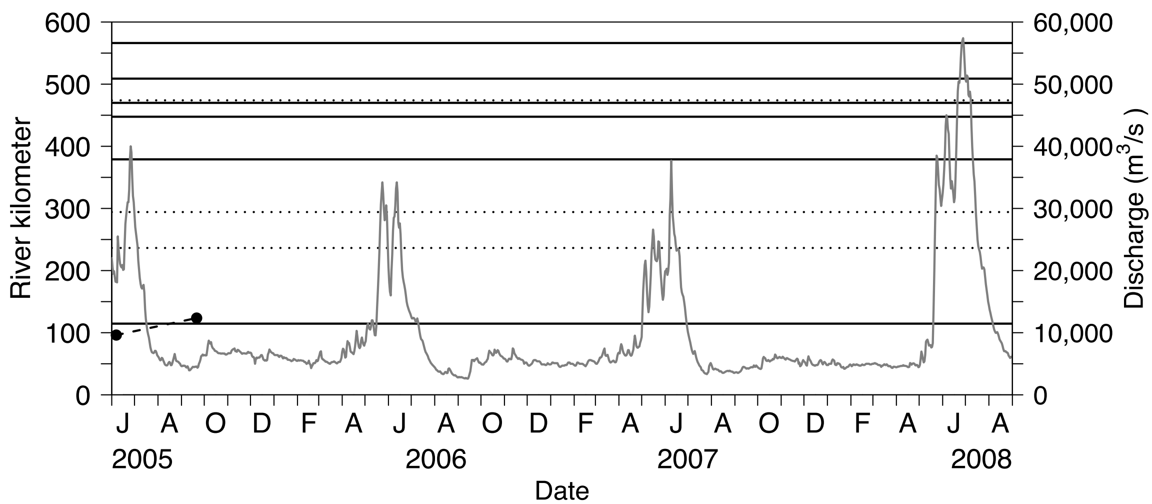

Figure 212. Movements of CHCA #48 (frequency = 480, code = 59a, N = 2)

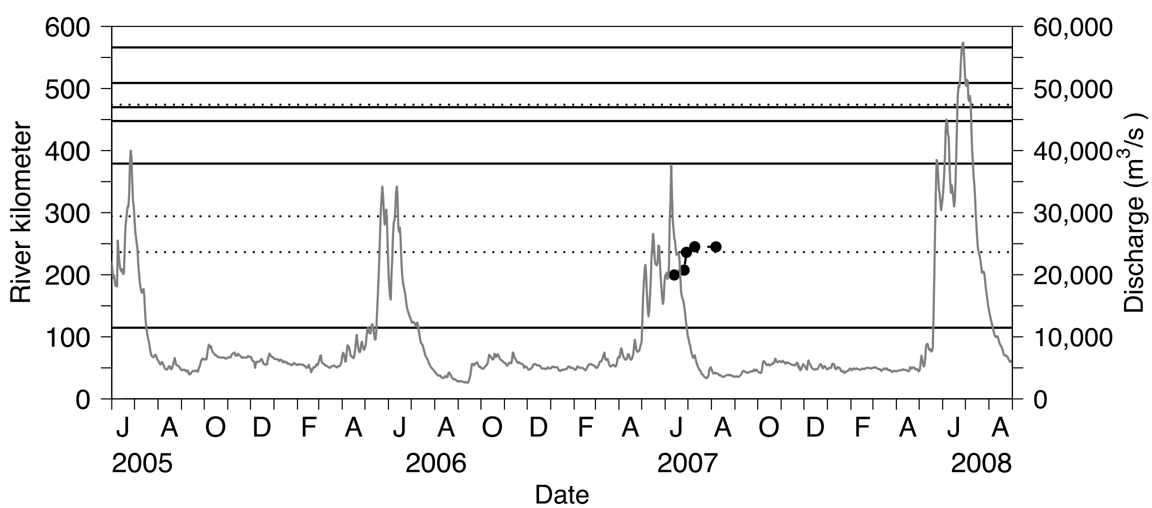

Figure 213. Movements of CHCA #49 (frequency = 480, code = 59b, N = 5)

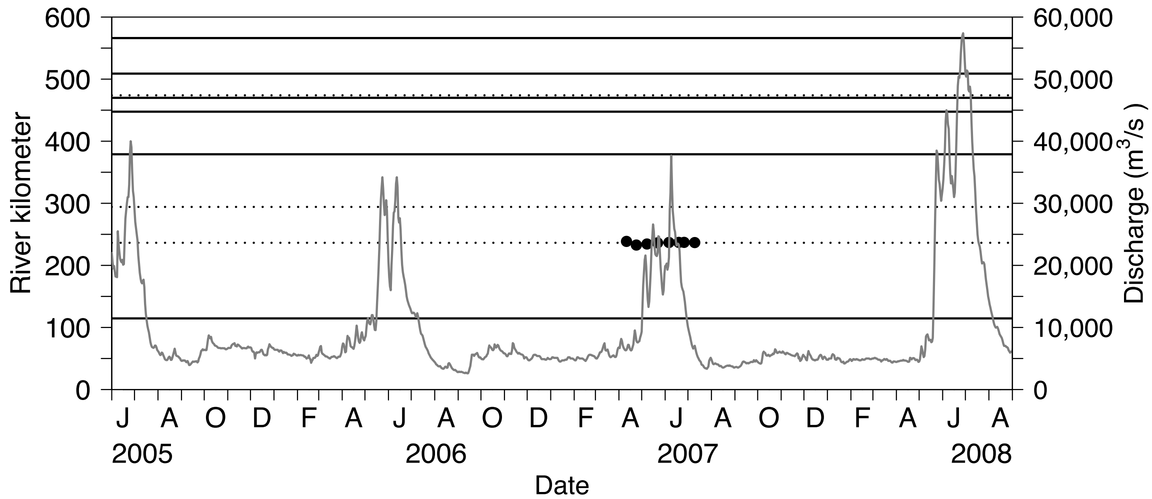

Figure 214. Movements of CHCA #50 (frequency = 480, code = 69b, N = 8)

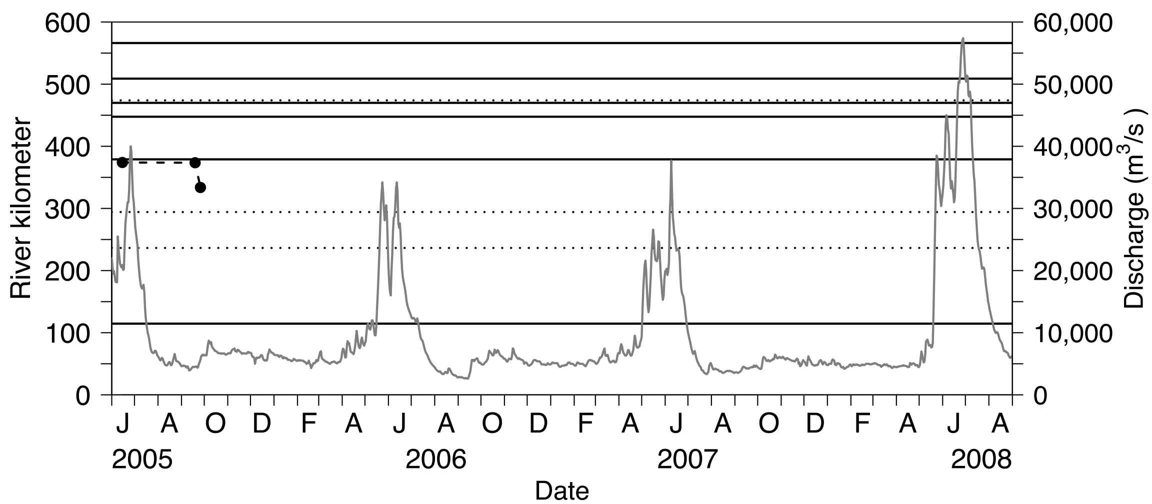

Figure 215. Movements of CHCA #51 (frequency = 480, code = 71a, N = 3)

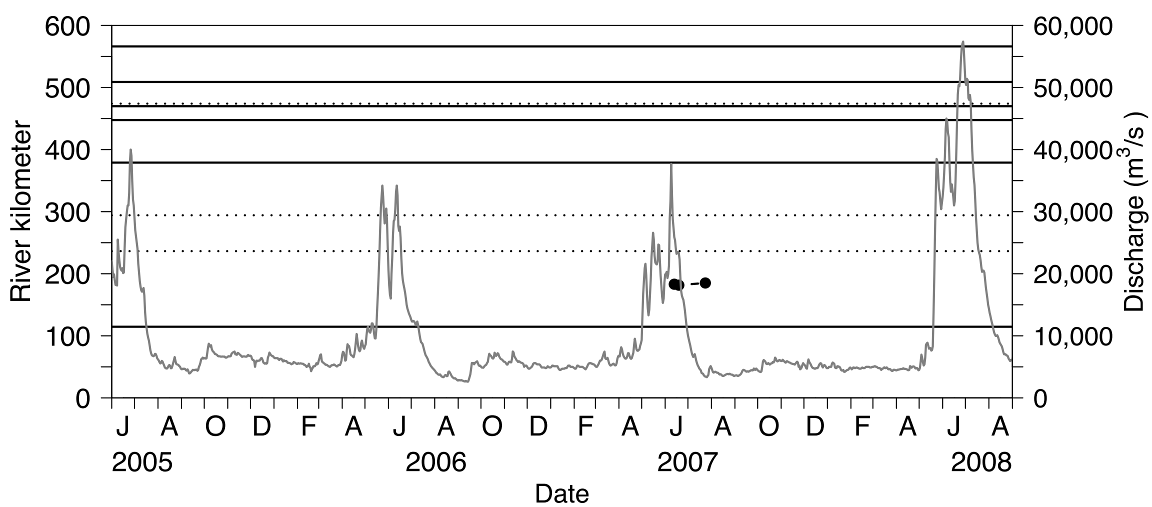

Figure 216. Movements of CHCA #52 (frequency = 480, code = 71b, N = 3)

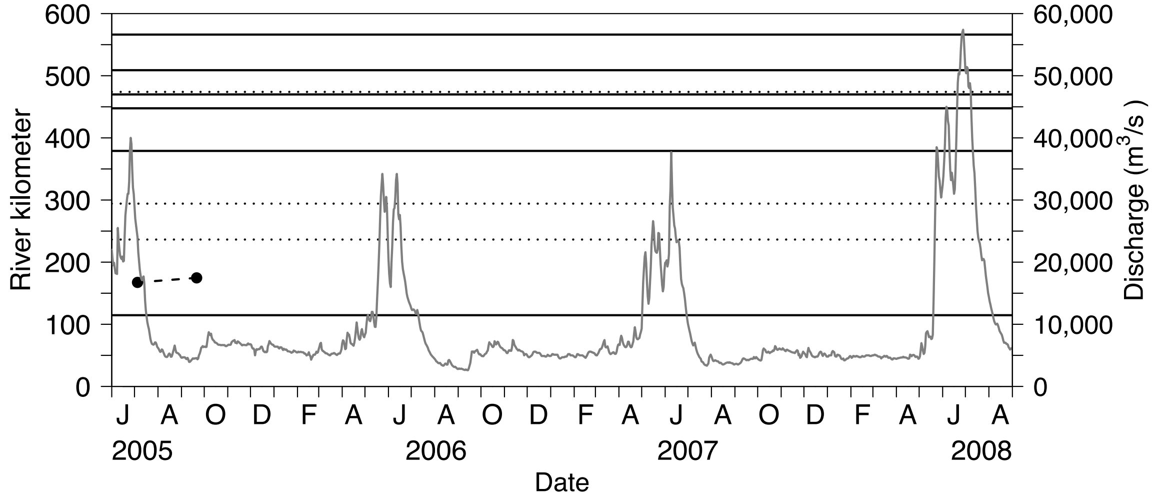

Figure 217. Movements of CHCA #53 (frequency = 480, code = 12, N = 2)

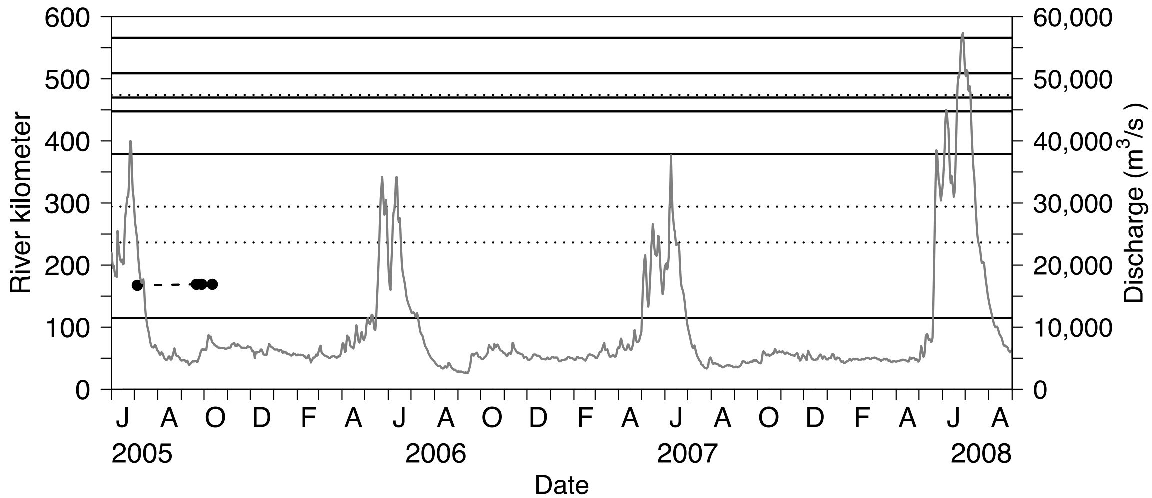

Figure 218. Movements of CHCA #54 (frequency = 480, code = 13, N = 4)

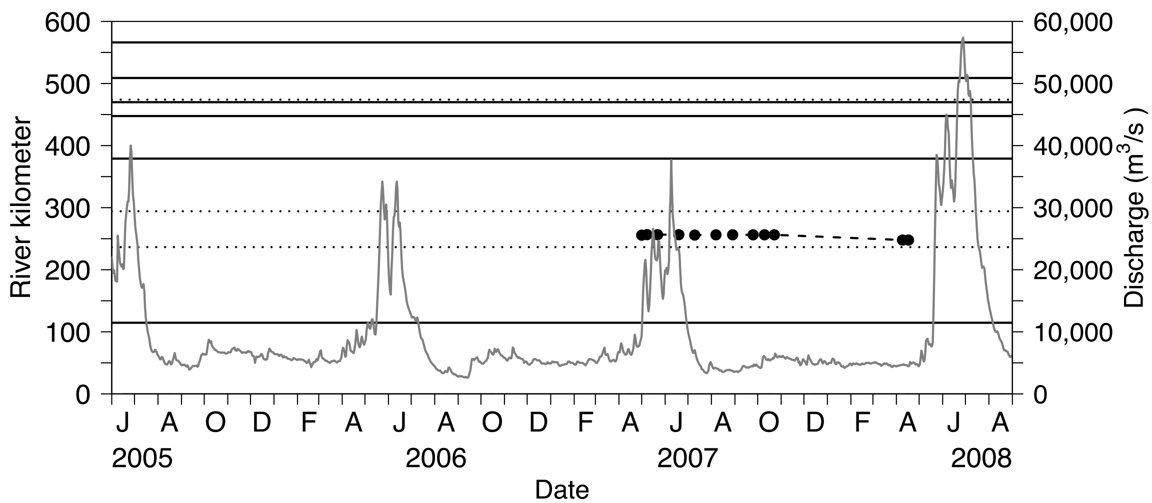

Figure 219. Movements of CHCA #55 (frequency = 480, code = 14, N = 12)

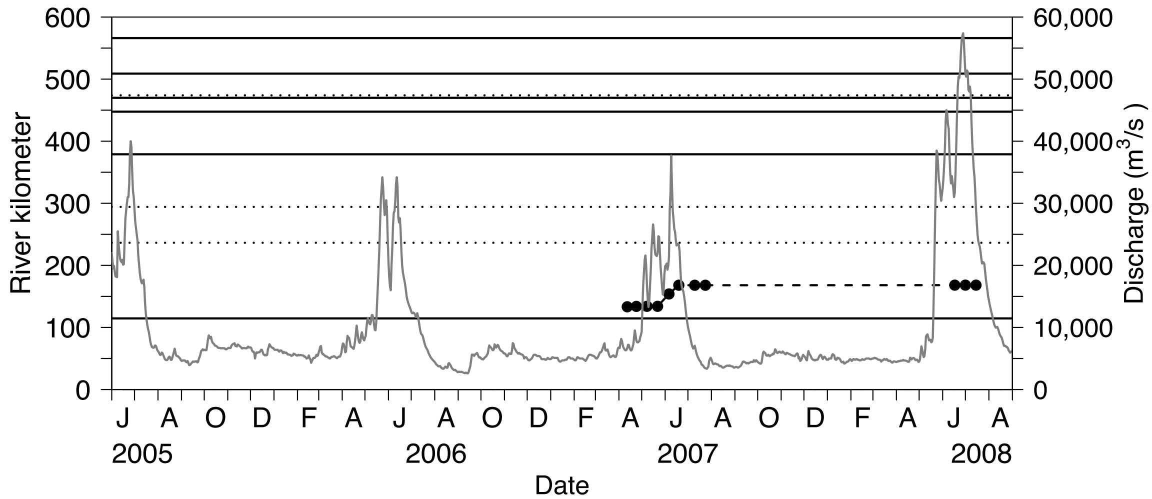

Figure 220. Movements of CHCA #56 (frequency = 480, code = 27, N = 11)

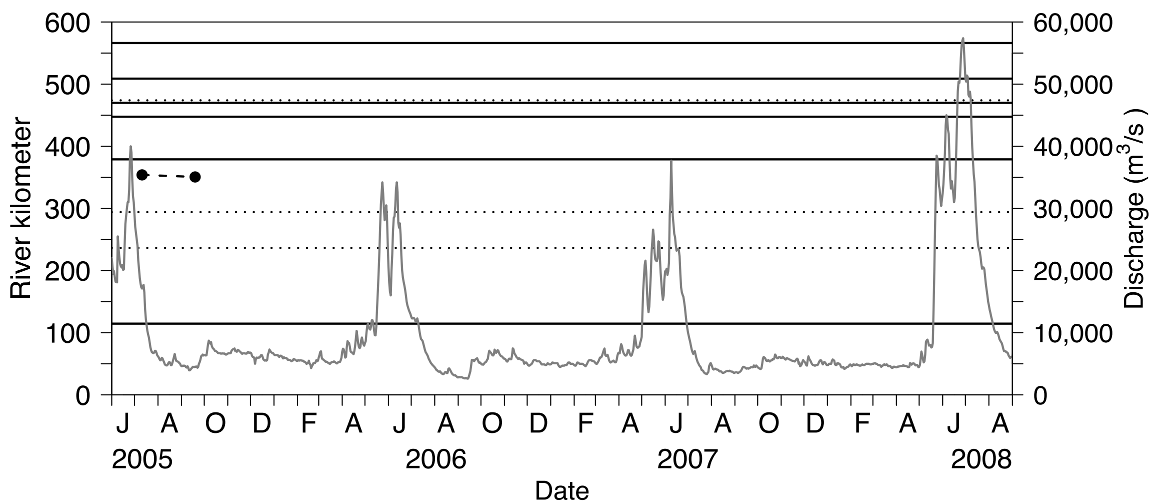

Figure 221. Movements of CHCA #57 (frequency = 480, code = 31, N = 2)

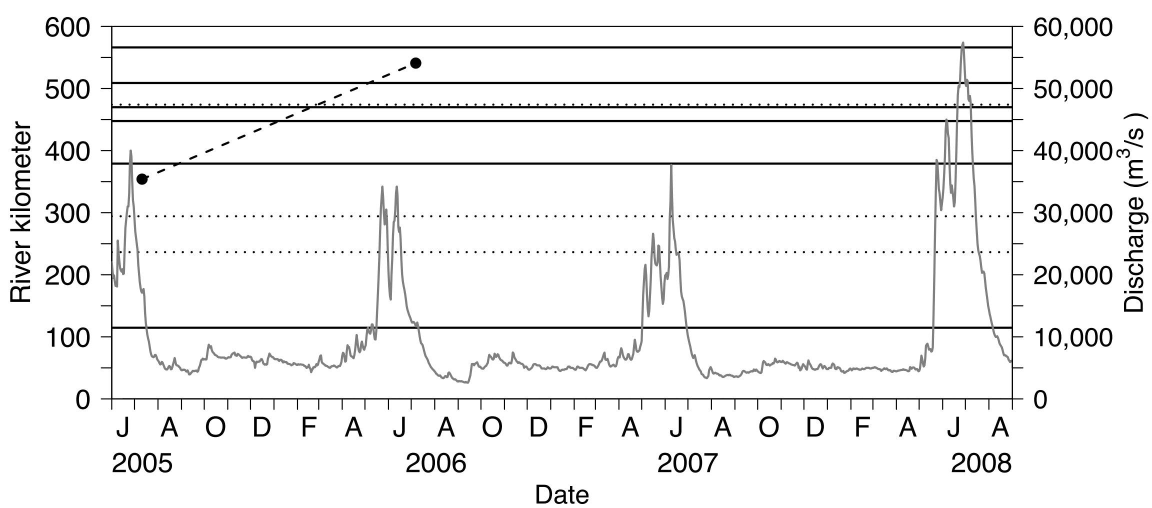

Figure 222. Movements of CHCA #58 (frequency = 480, code = 38, N = 2)

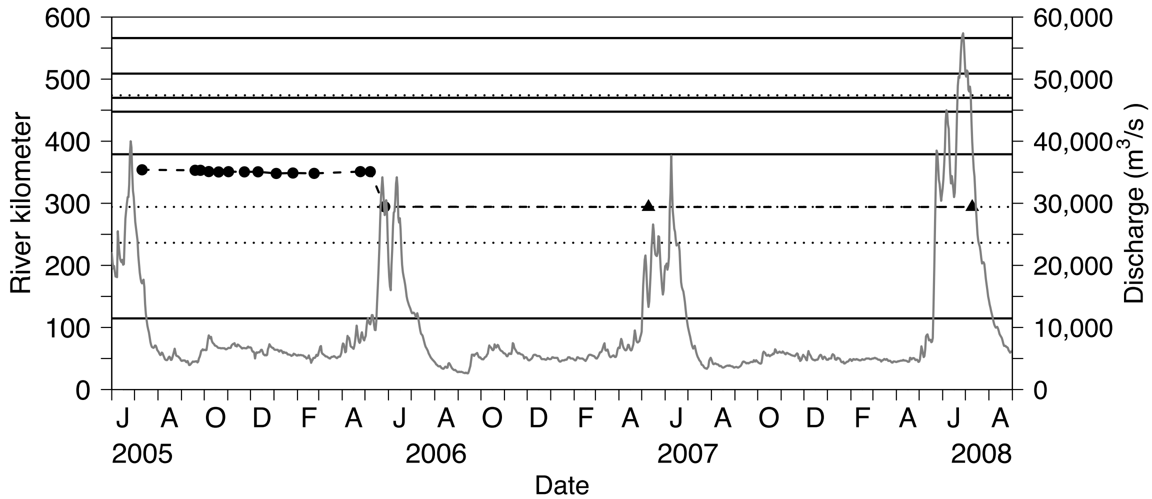

Figure 223. Movements of CHCA #59 (frequency = 480, code = 40, N = 17)

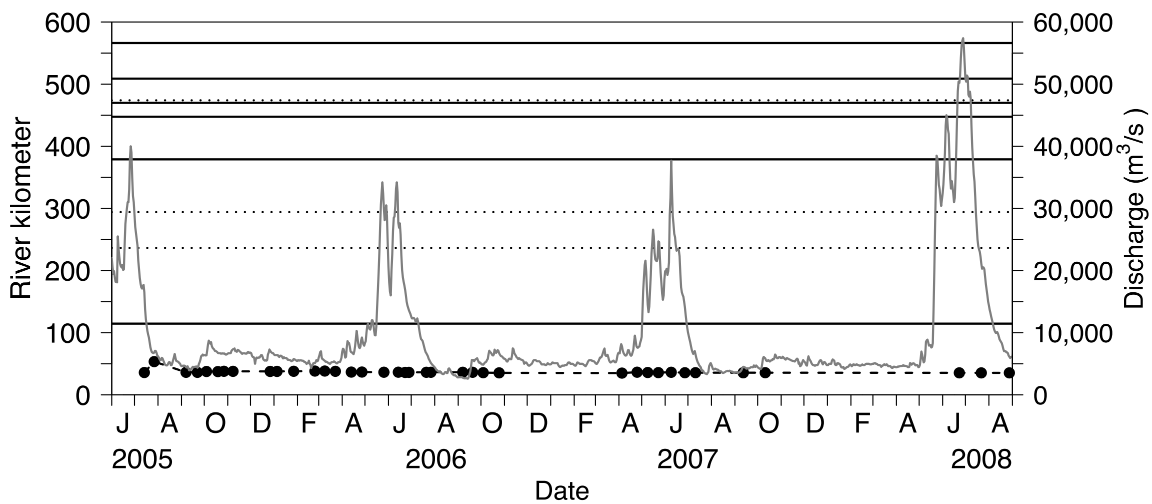

Figure 224. Movements of CHCA #60 (frequency = 480, code = 42, N = 39)

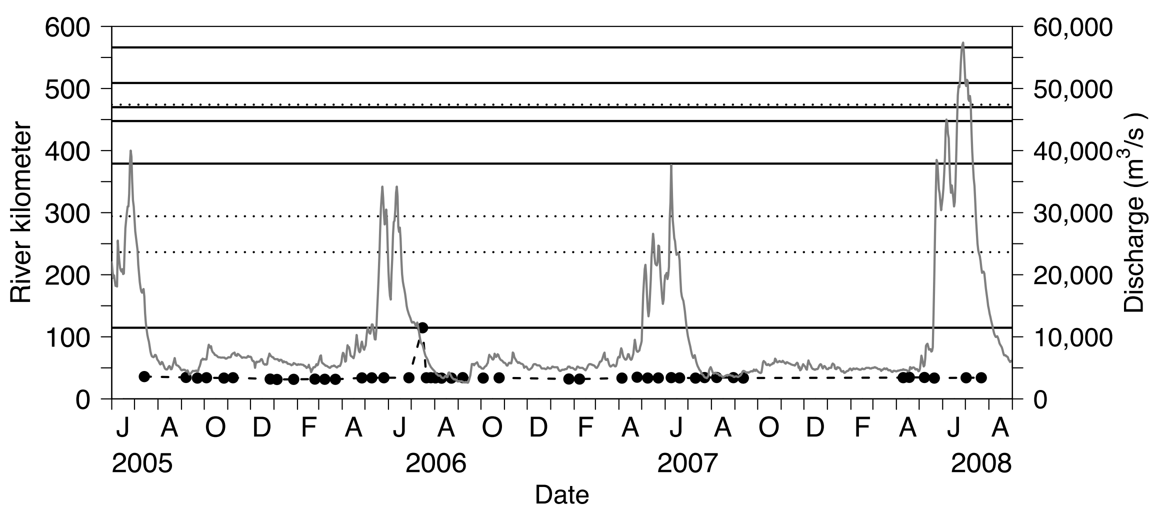

Figure 225. Movements of CHCA #61 (frequency = 480, code = 43, N = 46)

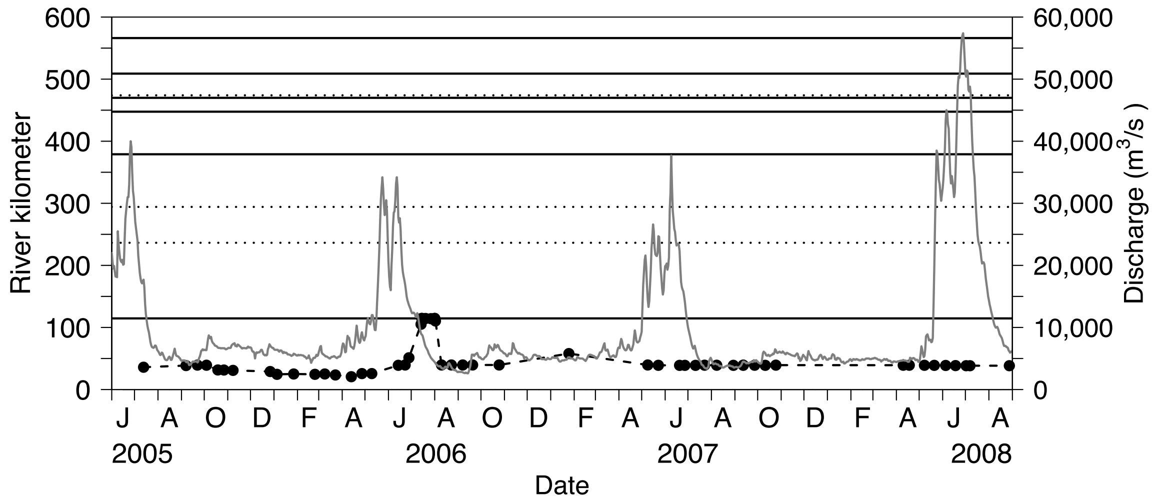

Figure 226. Movements of CHCA #62 (frequency = 480, code = 45, N = 55)

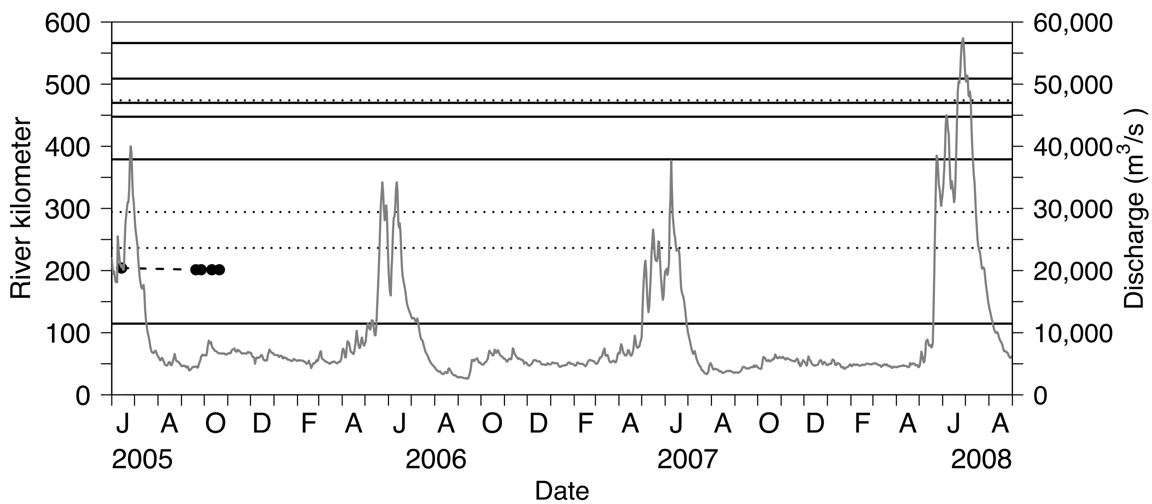

Figure 227. Movements of CHCA #63 (frequency = 480, code = 48, N = 5)

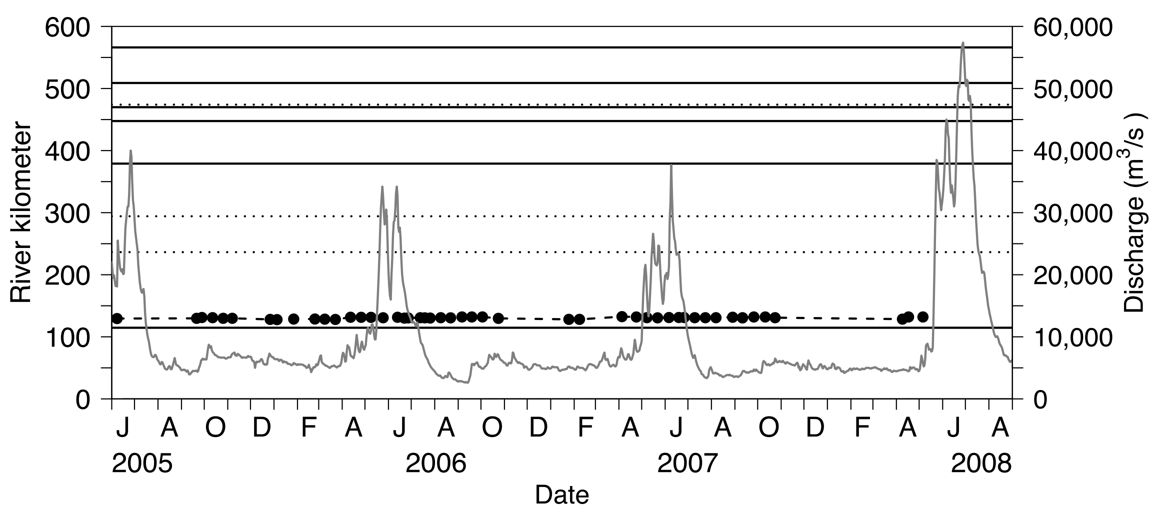

Figure 228. Movements of CHCA #64 (frequency = 480, code = 54, N = 49)

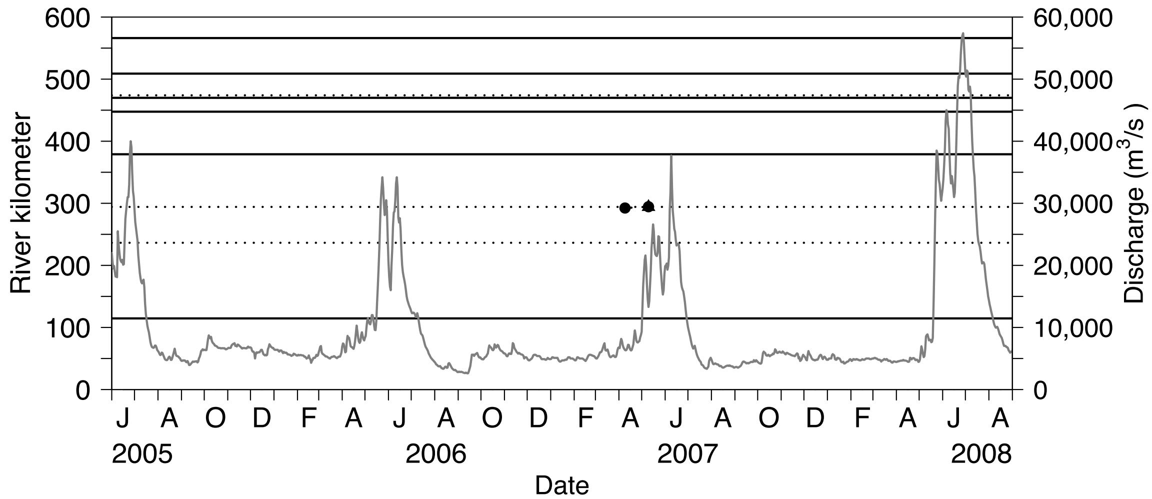

Figure 229. Movements of CHCA #65 (frequency = 480, code = 61, N = 3)

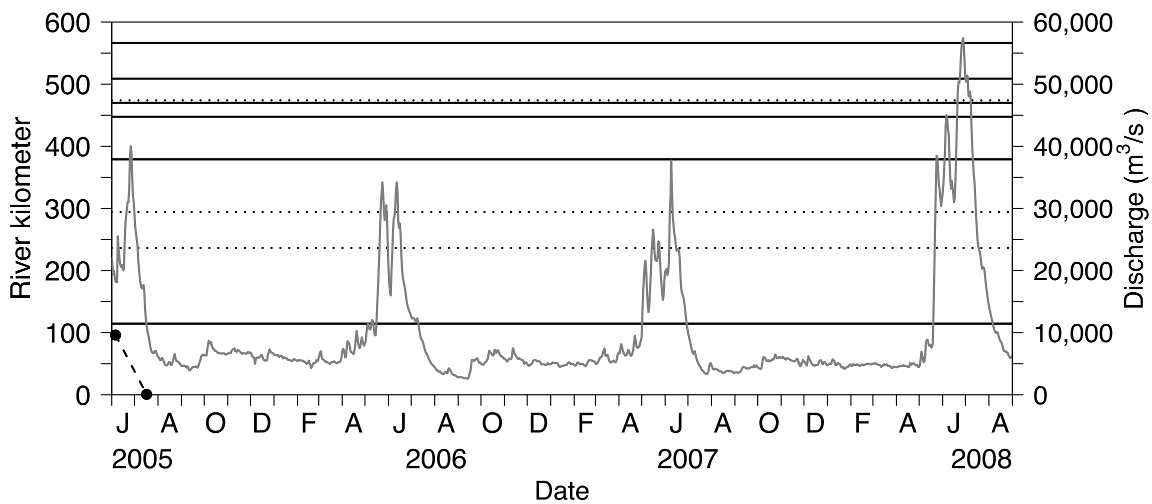

Figure 230. Movements of CHCA #66 (frequency = 480, code = 63, N = 2)

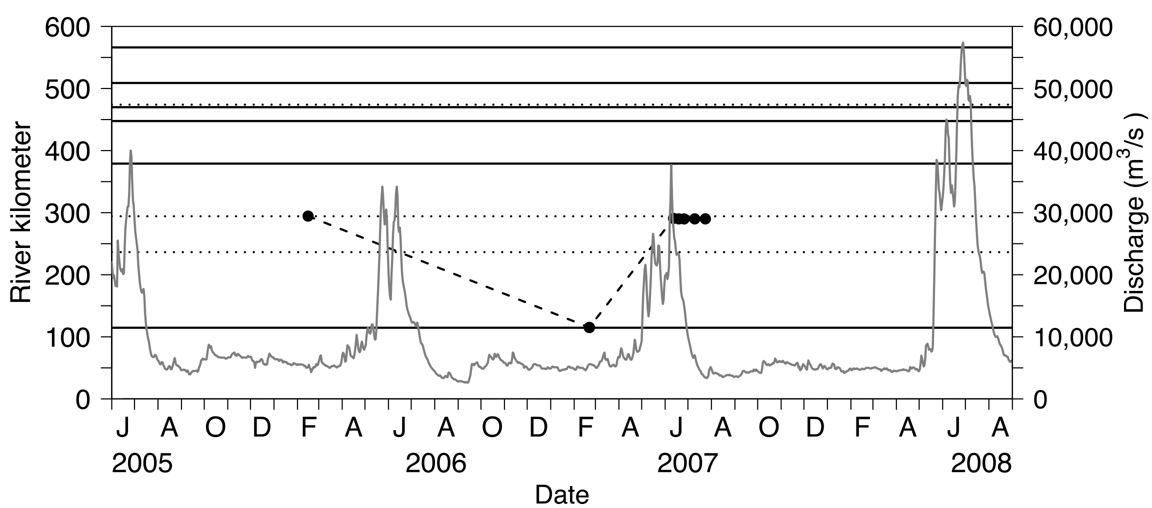

Figure 231. Movements of CHCA #67 (frequency = 480, code = 64, N = 8)

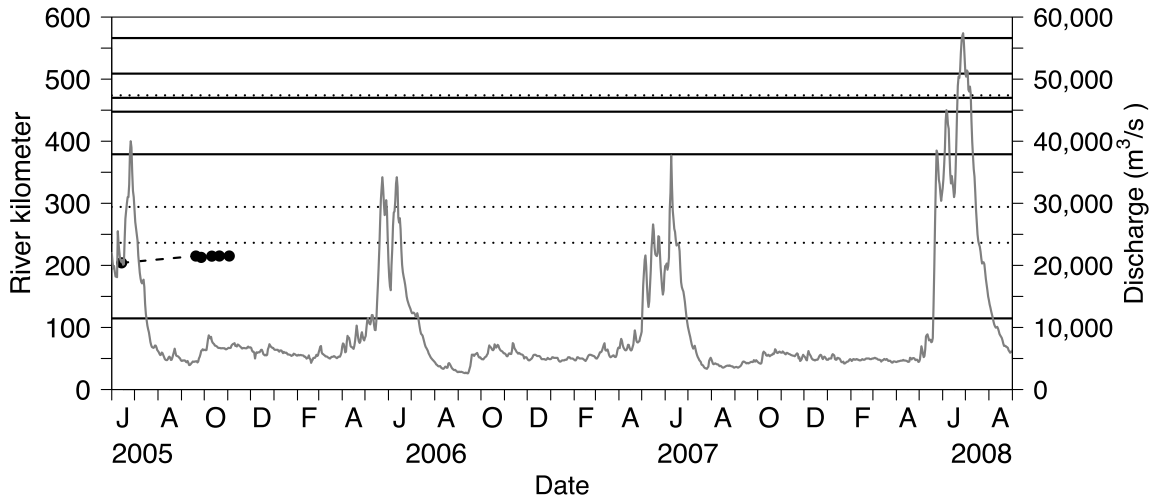

Figure 232. Movements of CHCA #68 (frequency = 480, code = 65, N = 6)

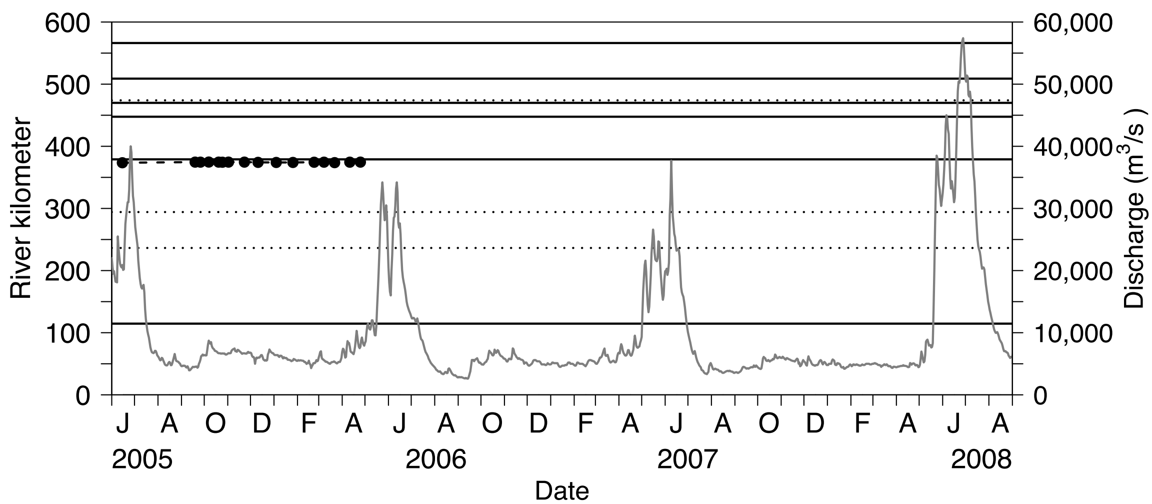

Figure 233. Movements of CHCA #69 (frequency = 480, code = 68, N = 16)

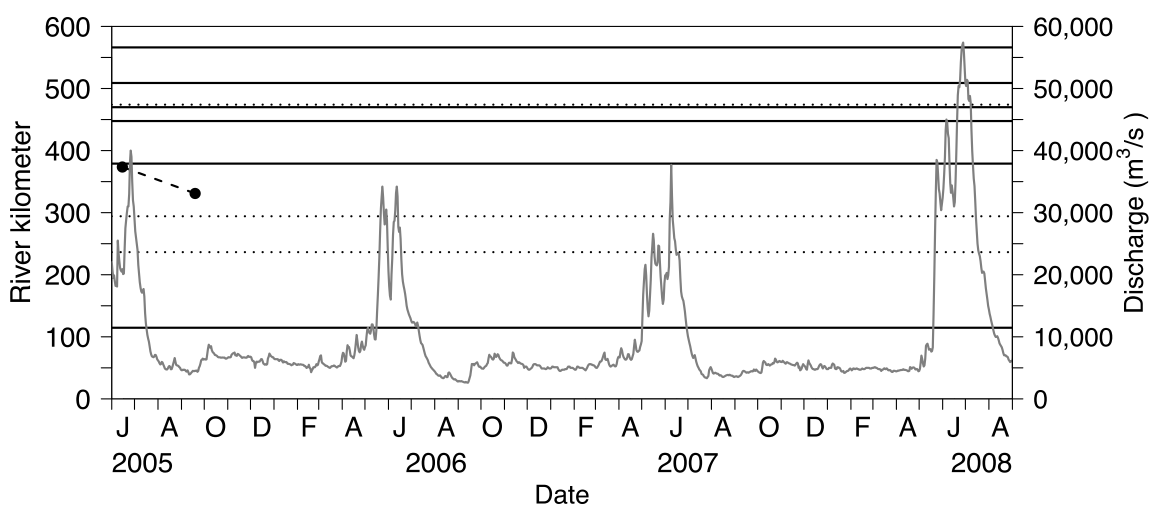

Figure 234. Movements of CHCA #70 (frequency = 480, code = 69, N = 2)

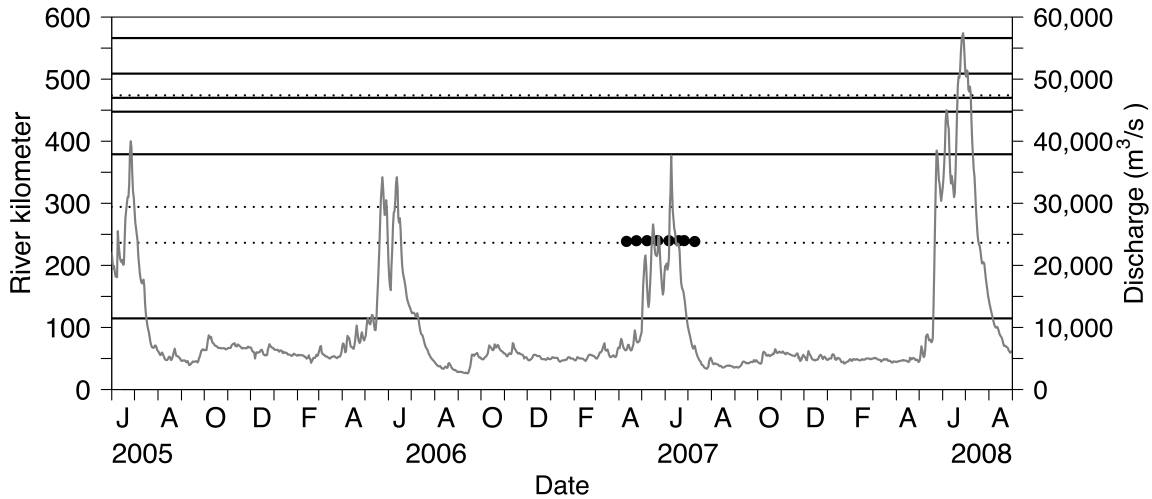

Figure 235. Movements of CHCA #71 (frequency = 480, code = 72, N = 8)

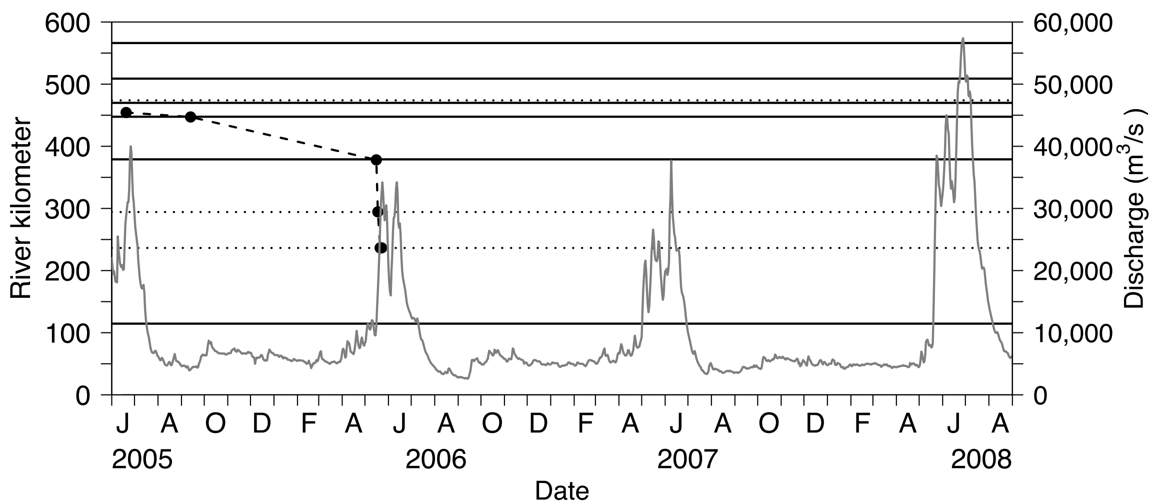

Figure 236. Movements of CHCA #72 (frequency = 480, code = 73, N = 6)

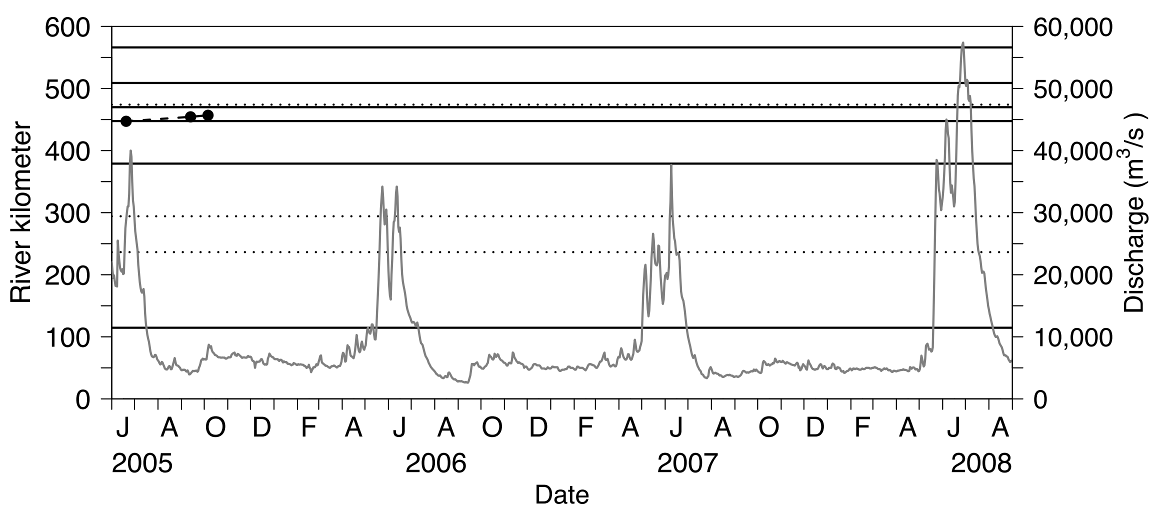

Figure 237. Movements of CHCA #73 (frequency = 480, code = 74, N = 3)

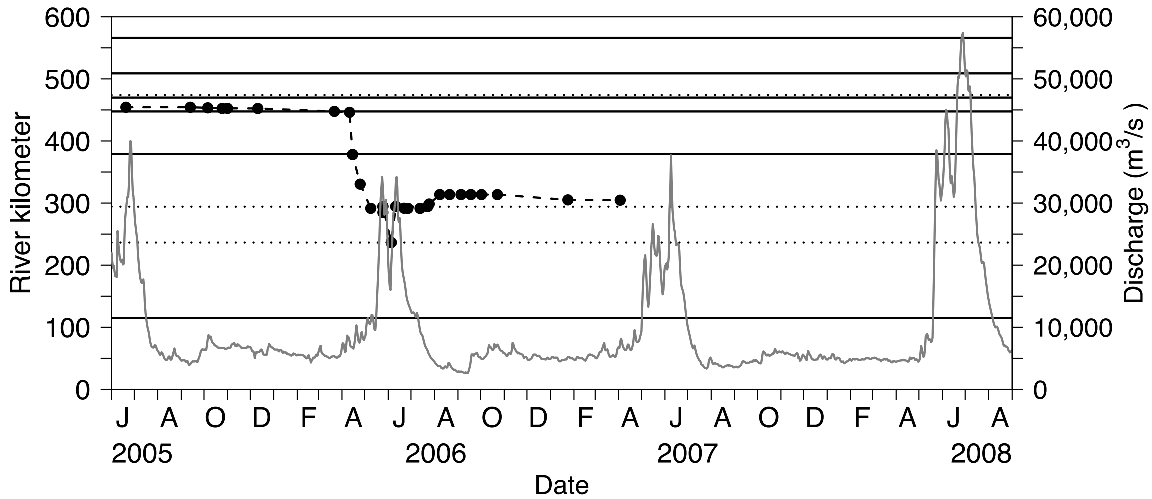

Figure 238. Movements of CHCA #74 (frequency = 480, code = 77, N = 33)

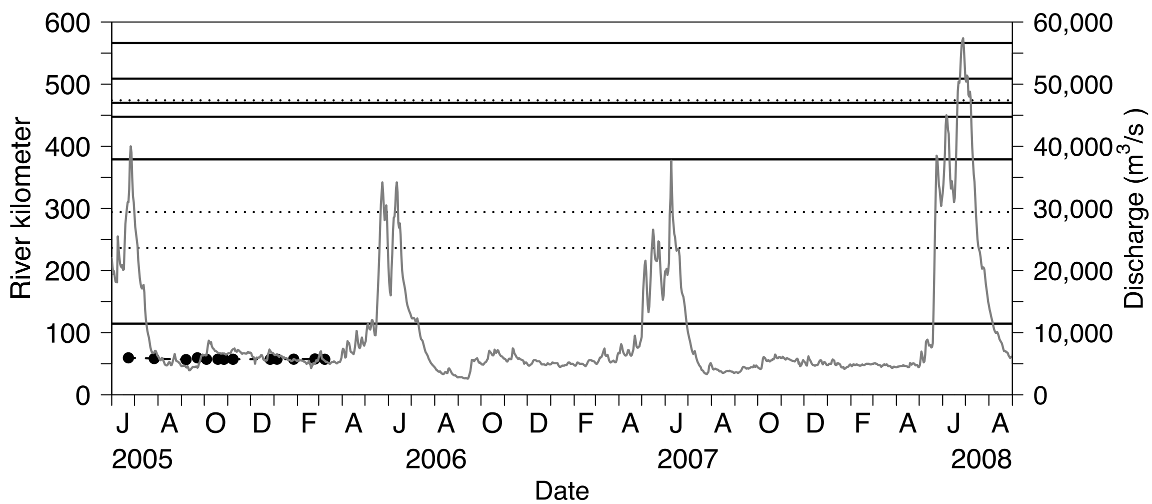

Figure 239. Movements of CHCA #75 (frequency = 480, code = 78, N = 13)

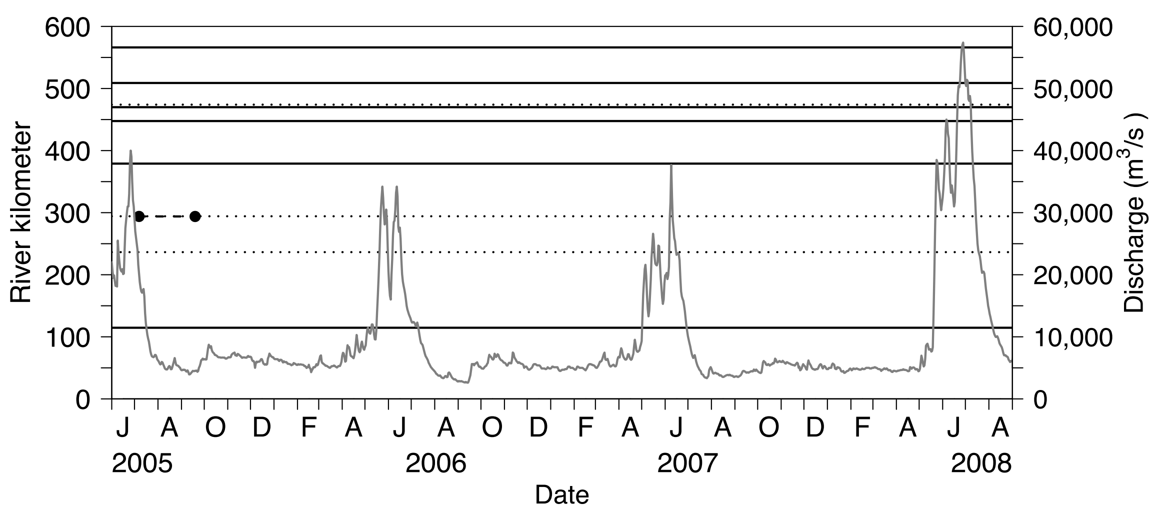

Figure 240. Movements of CHCA #76 (frequency = 480, code = 22a, N = 2)

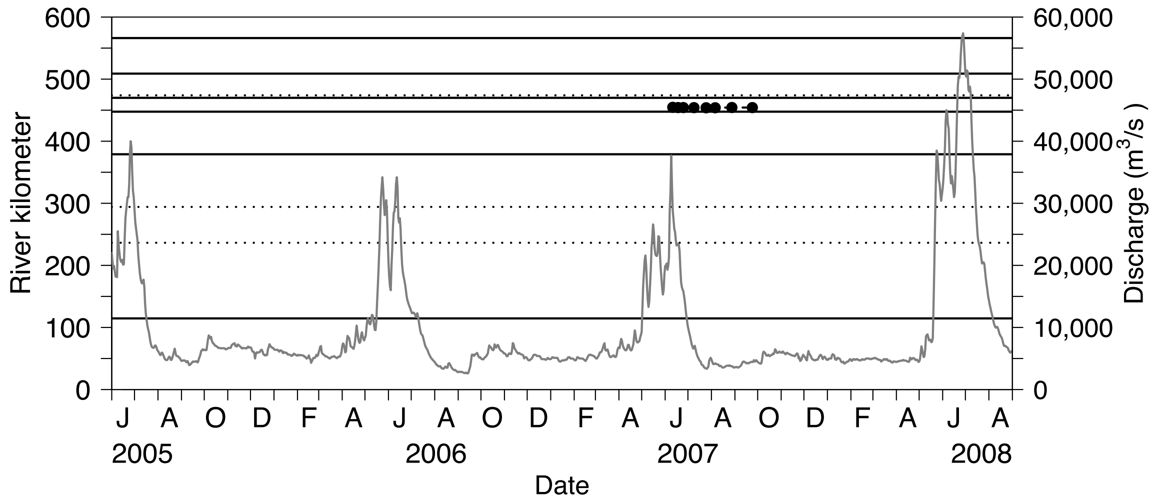

Figure 241. Movements of CHCA #77 (frequency = 480, code = 22b, N = 8)

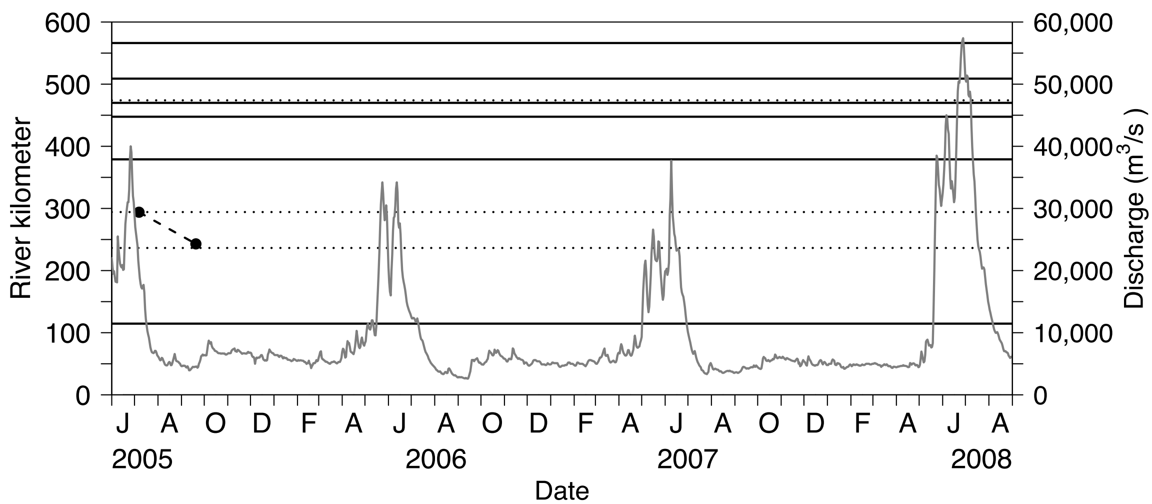

Figure 242. Movements of CHCA #78 (frequency = 480, code = 24a, N = 2)

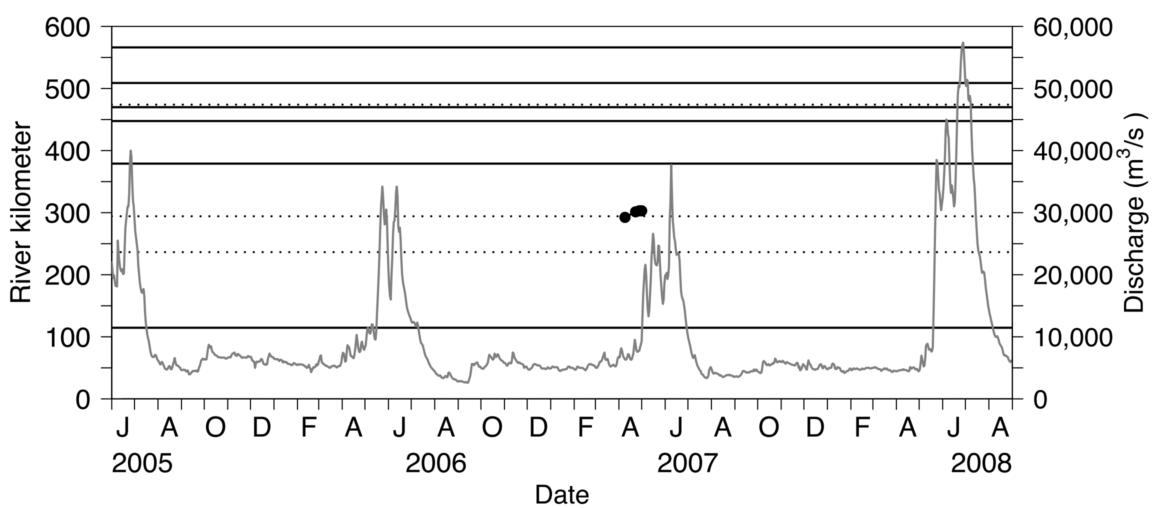

Figure 243. Movements of CHCA #79 (frequency = 480, code = 24b, N = 4)

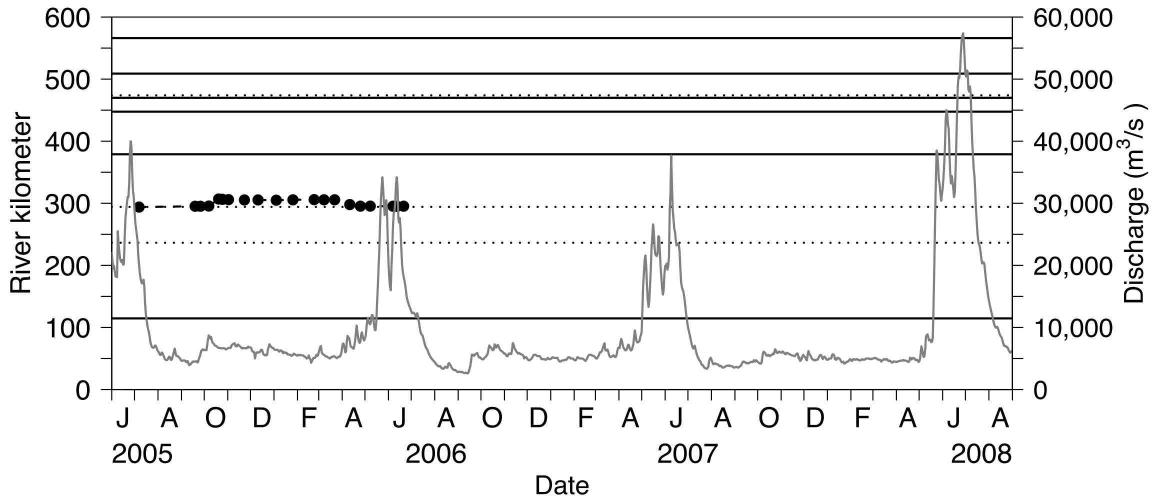

Figure 244. Movements of CHCA #80 (frequency = 480, code = 26a, N = 20)

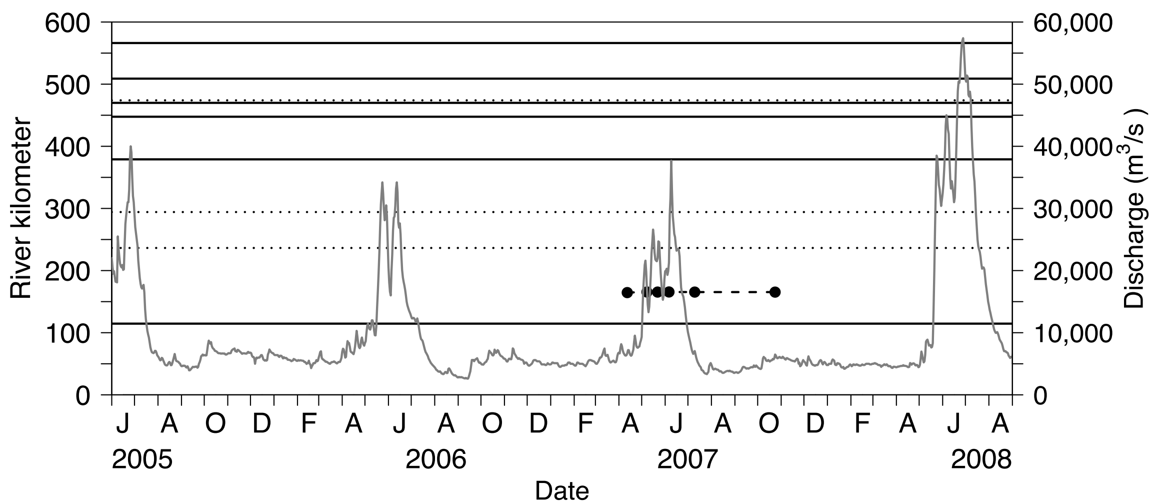

Figure 245. Movements of CHCA #81 (frequency = 480, code = 26b, N = 6)

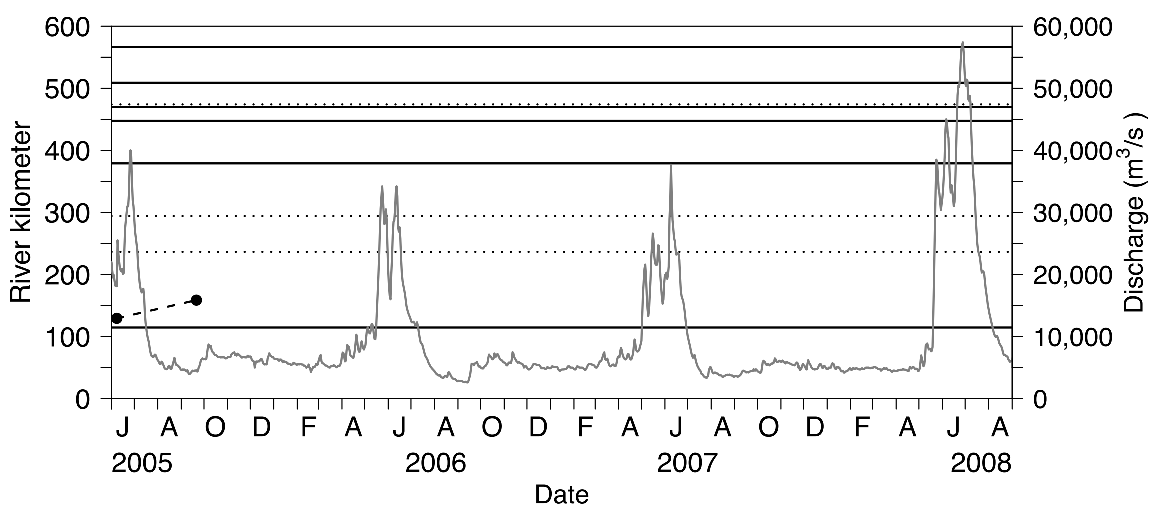

Figure 246. Movements of CHCA #82 (frequency = 480, code = 55a, N = 2)

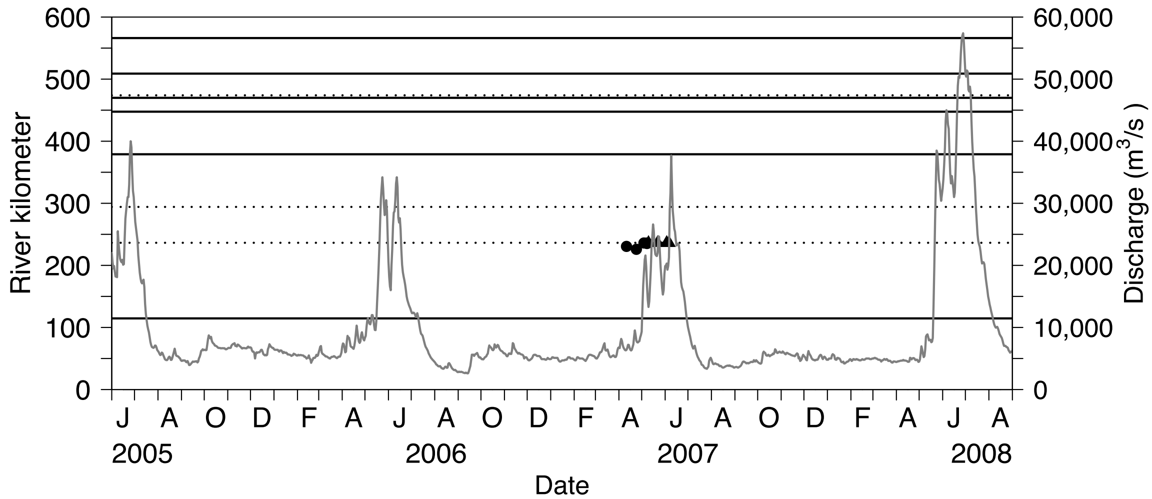

Figure 247. Movements of CHCA #83 (frequency = 480, code = 55b, N = 9)

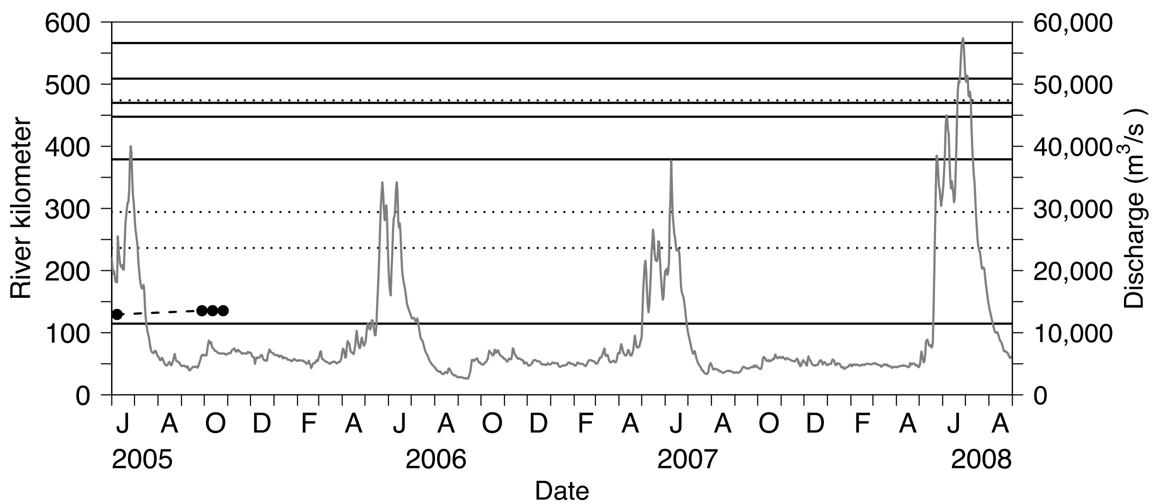

Figure 248. Movements of CHCA #84 (frequency = 480, code = 56a, N = 4)

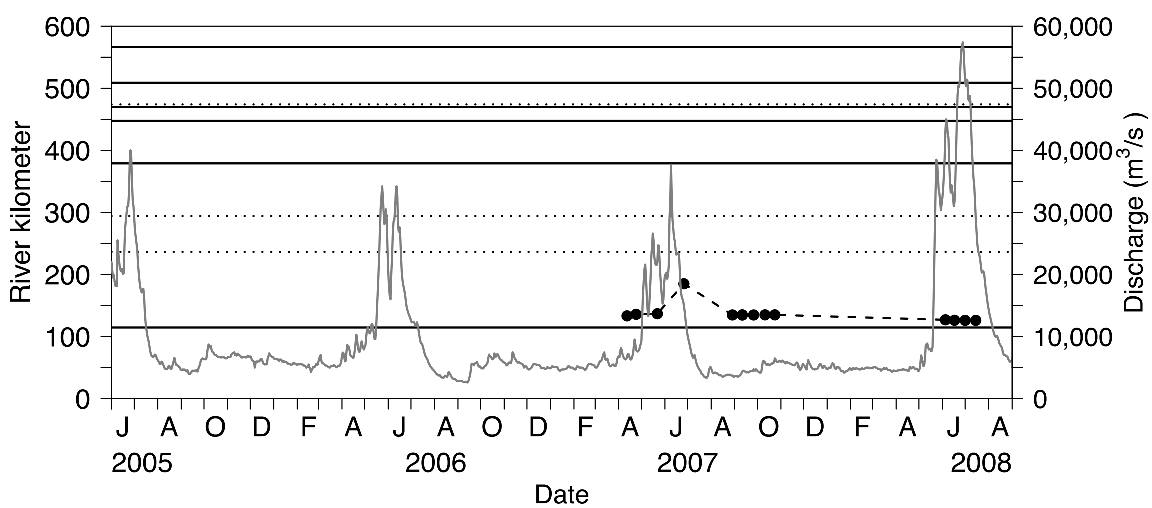

Figure 249. Movements of CHCA #85 (frequency = 480, code = 56b, N = 14)

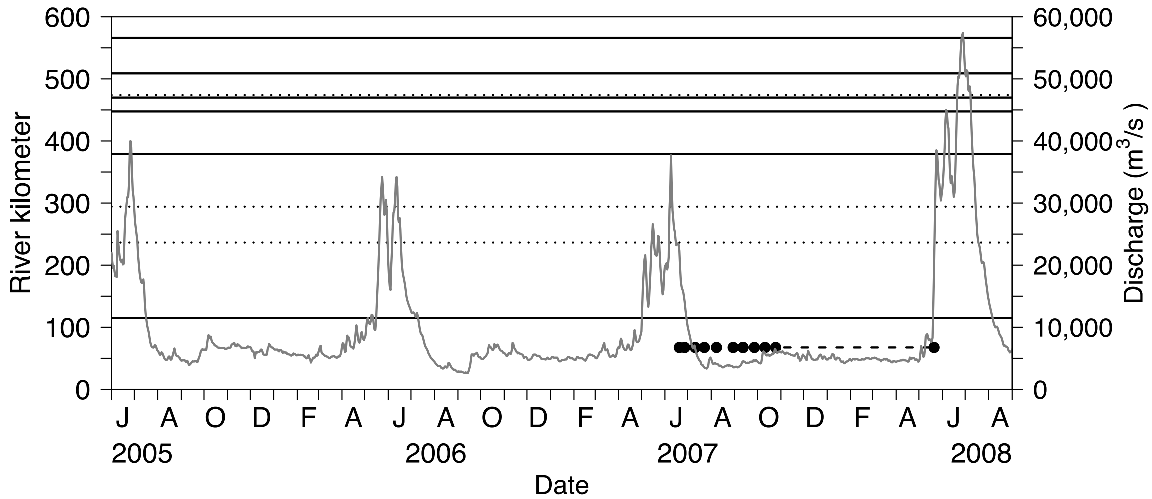

Figure 250. Movements of CHCA #86 (frequency = 600, code = 11, N = 12)

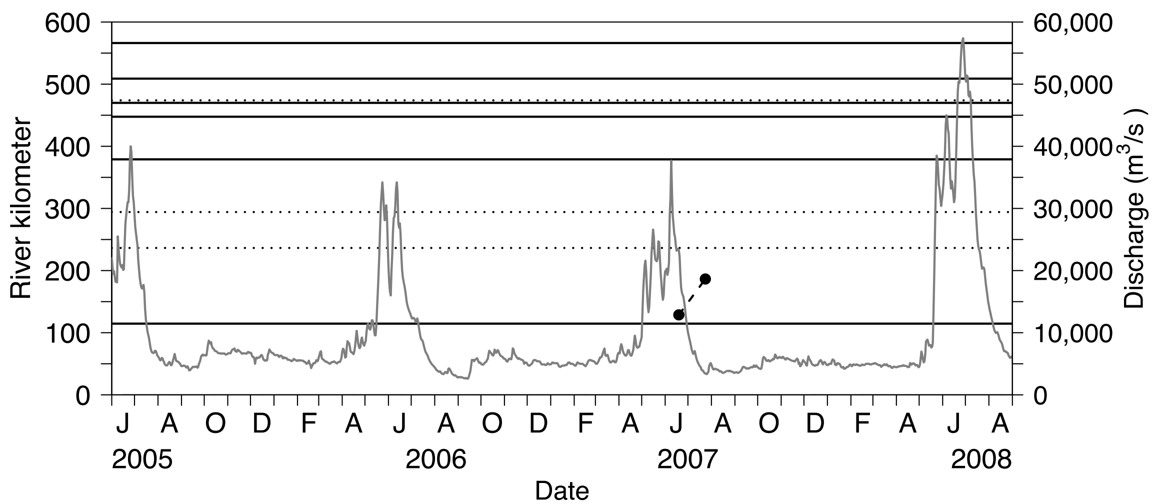

Figure 251. Movements of CHCA #87 (frequency = 600, code = 12, N = 2)

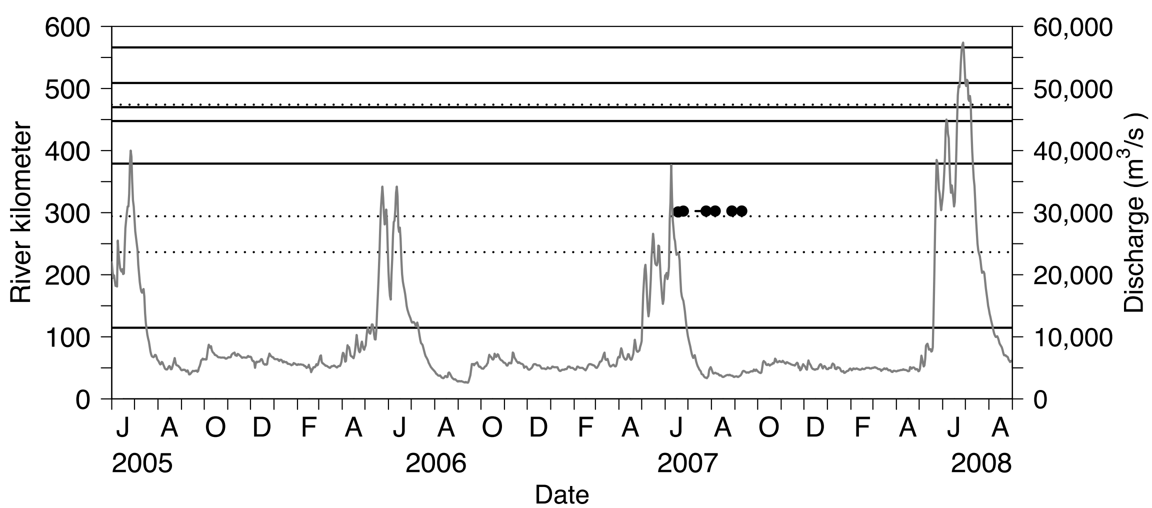

Figure 252. Movements of CHCA #88 (frequency = 600, code = 13, N = 6)

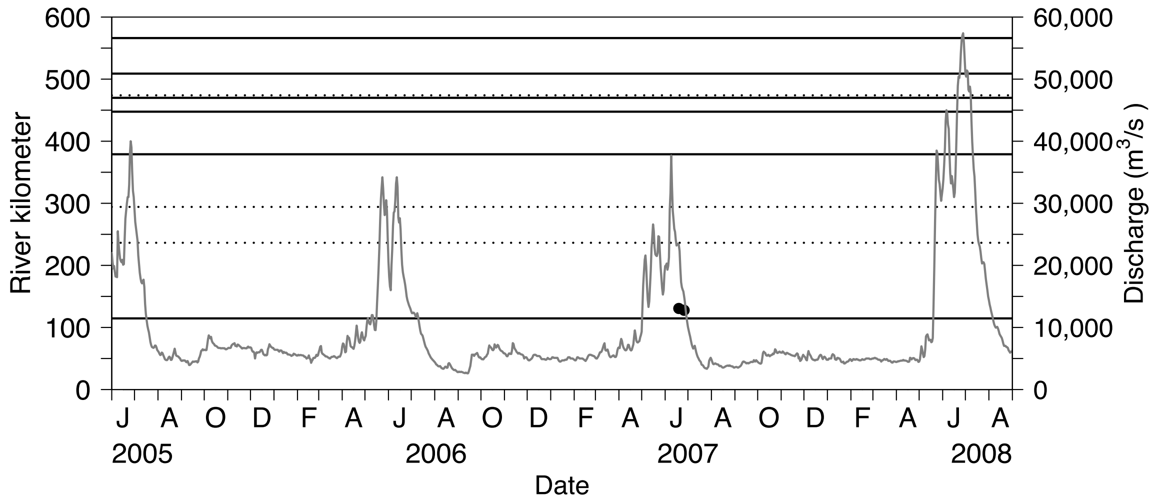

Figure 253. Movements of CHCA #89 (frequency = 600, code = 15, N = 2)

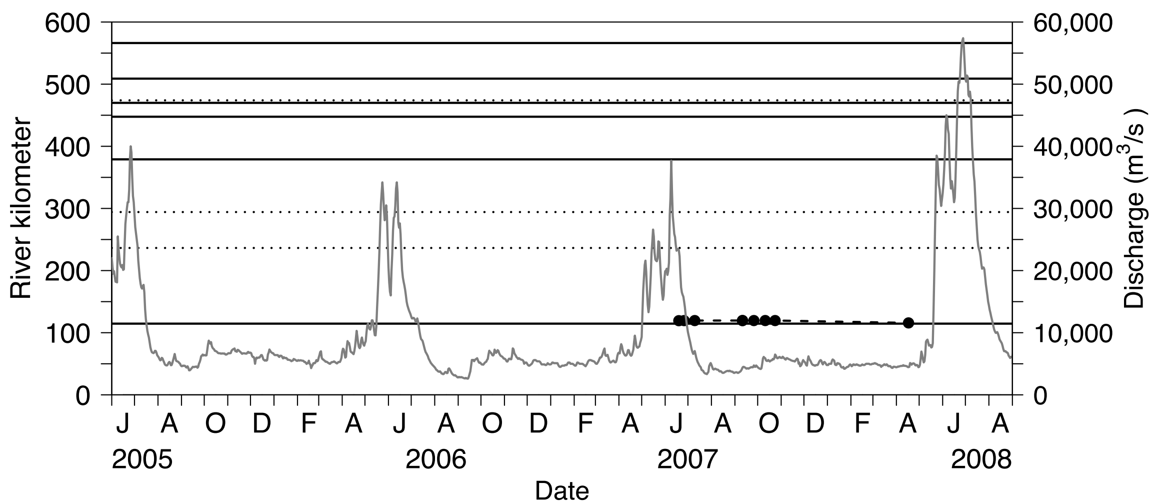

Figure 254. Movements of CHCA #90 (frequency = 600, code = 16, N = 9)

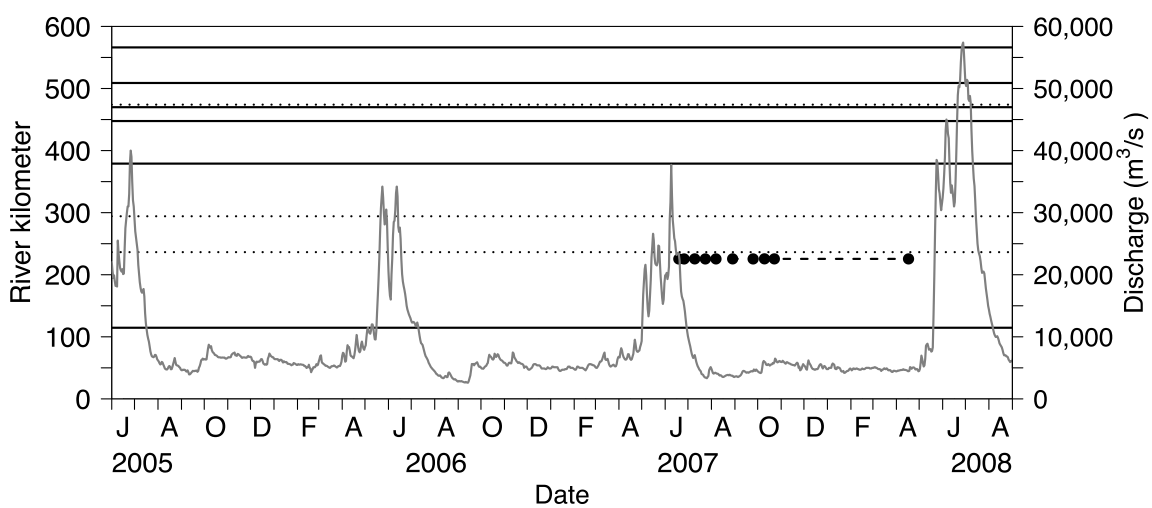

Figure 255. Movements of CHCA #91 (frequency = 600, code = 18, N = 10)

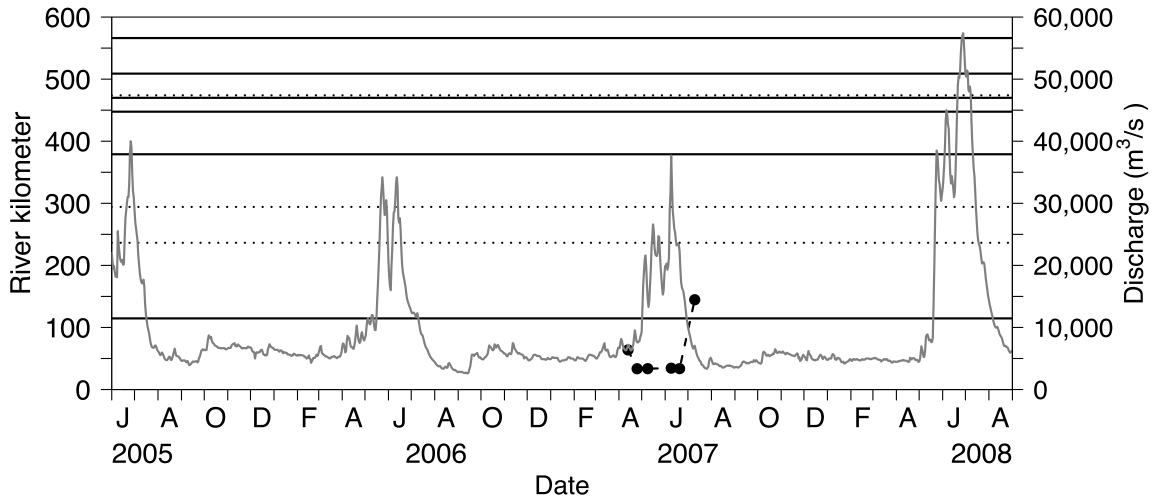

Figure 256. Movements of CHCA #92 (frequency = 600, code = 19, N = 6)

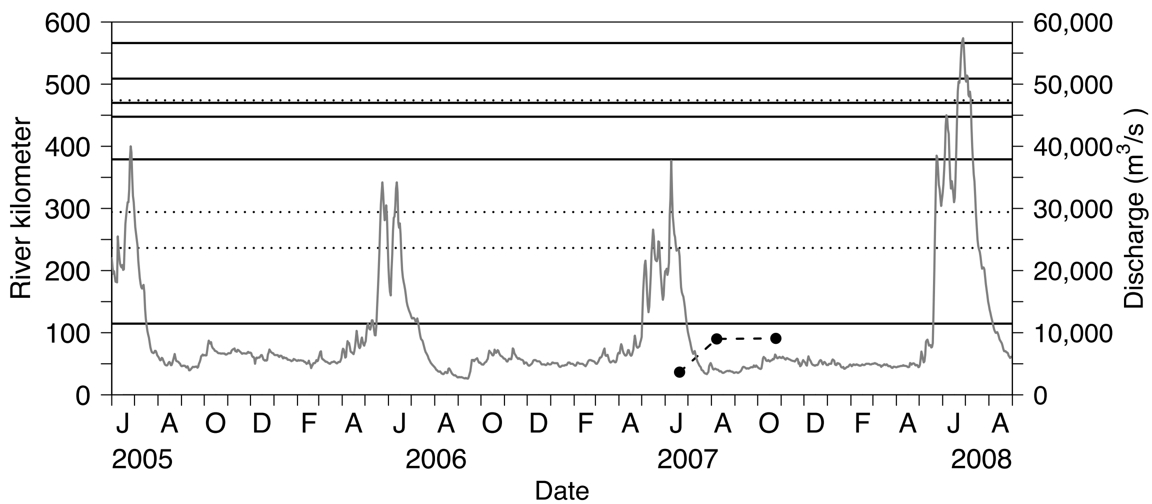

Figure 257. Movements of CHCA #93 (frequency = 600, code = 26, N = 3)

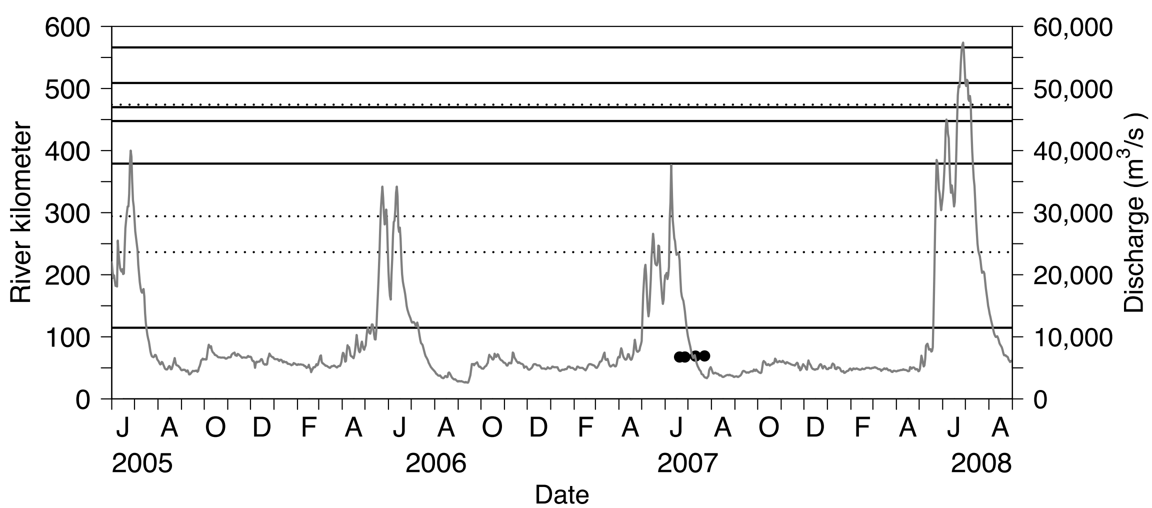

Figure 258. Movements of CHCA #94 (frequency = 600, code = 27, N = 4)

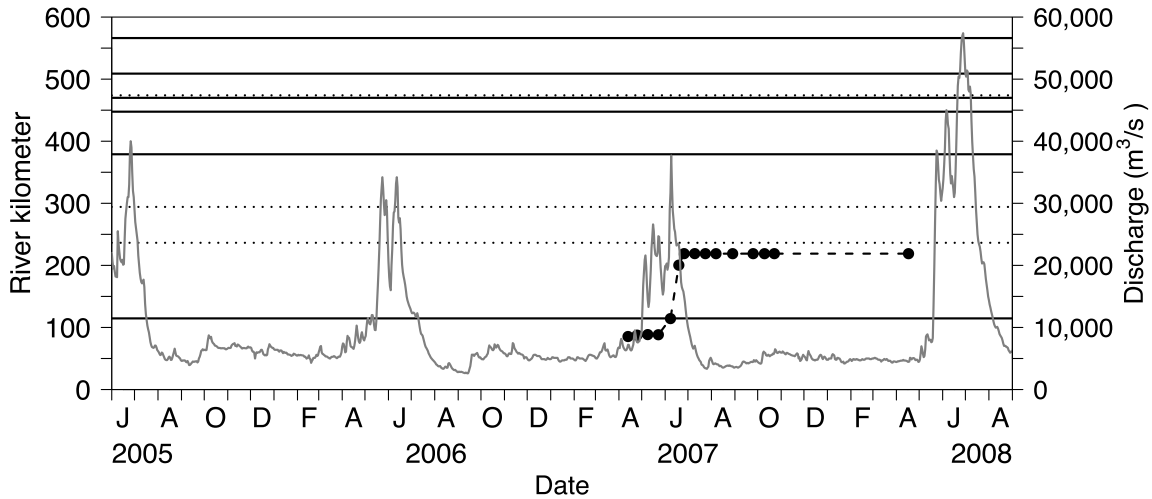

Figure 259. Movements of CHCA #95 (frequency = 600, code = 34, N = 15)

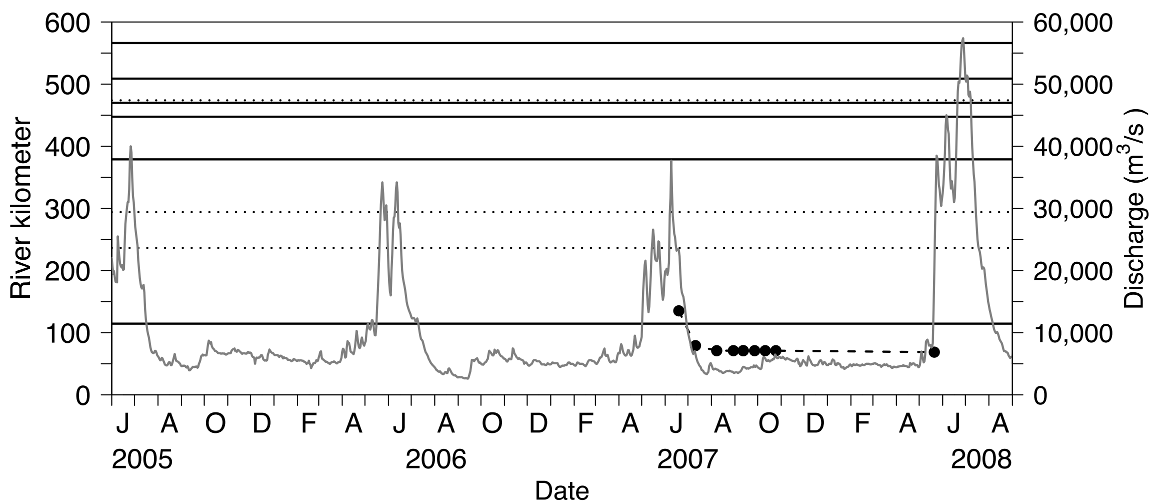

Figure 260. Movements of CHCA #96 (frequency = 600, code = 39, N = 10)

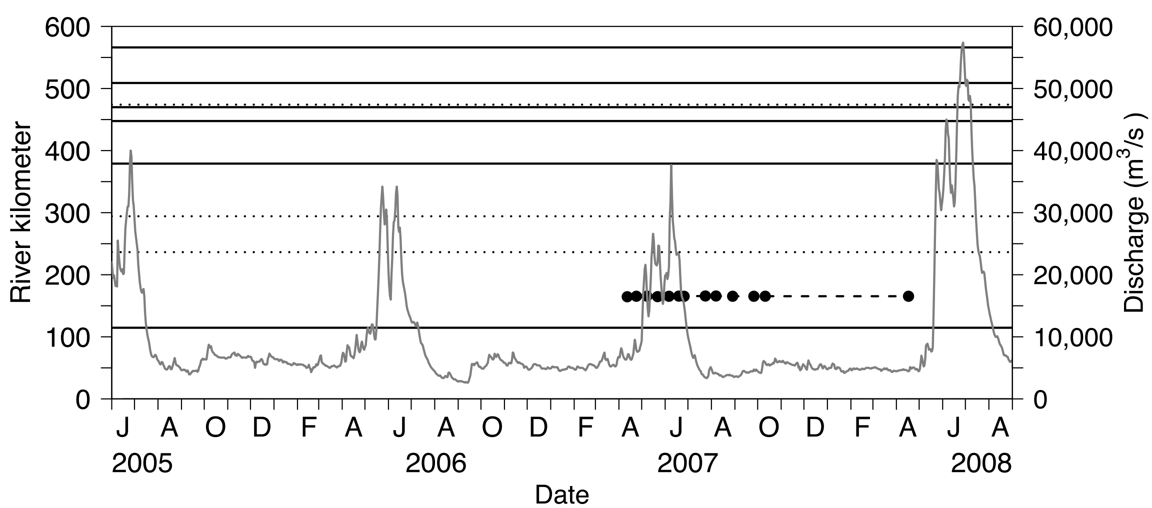

Figure 261. Movements of CHCA #97 (frequency = 600, code = 52, N = 13)

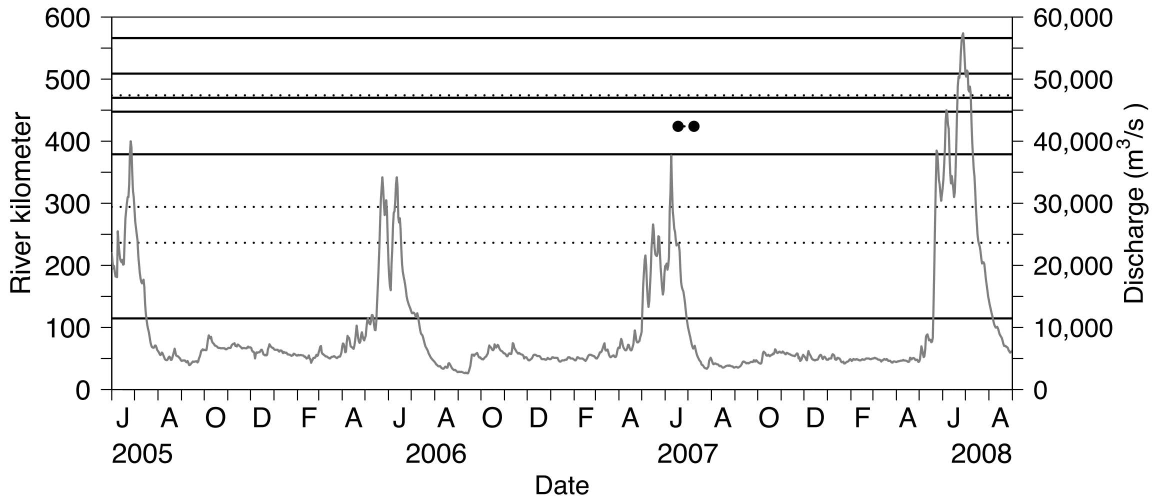

Figure 262. Movements of CHCA #98 (frequency = 600, code = 53, N = 2)

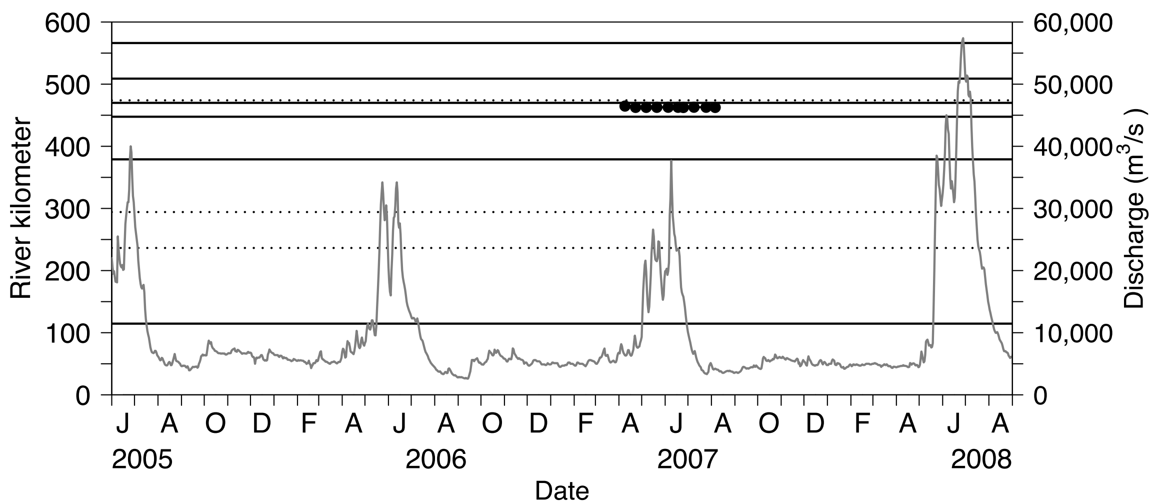

Figure 263. Movements of CHCA #99 (frequency = 600, code = 54, N = 10)

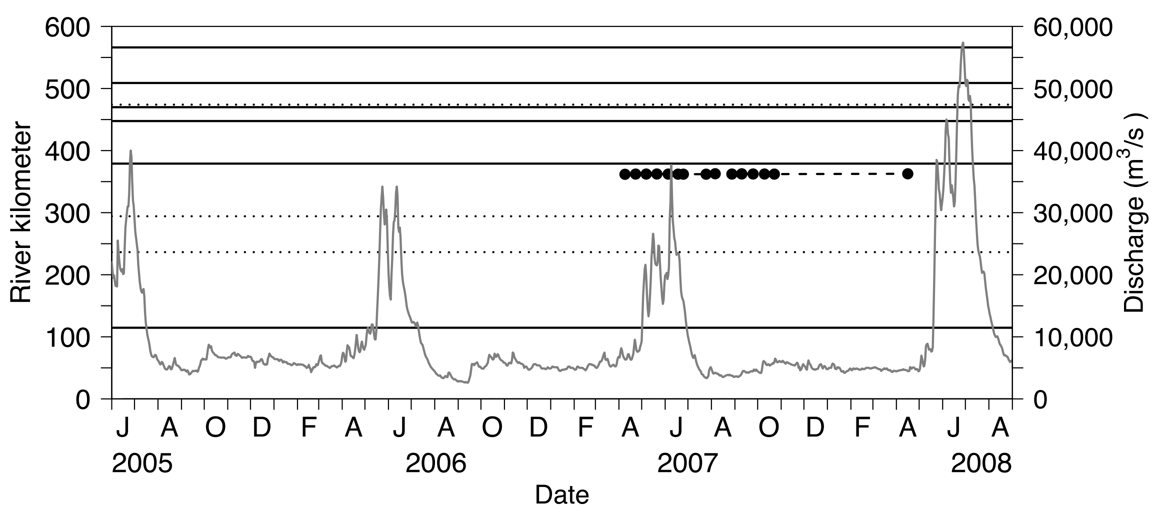

Figure 264. Movements of CHCA #100 (frequency = 600, code = 55, N = 16)

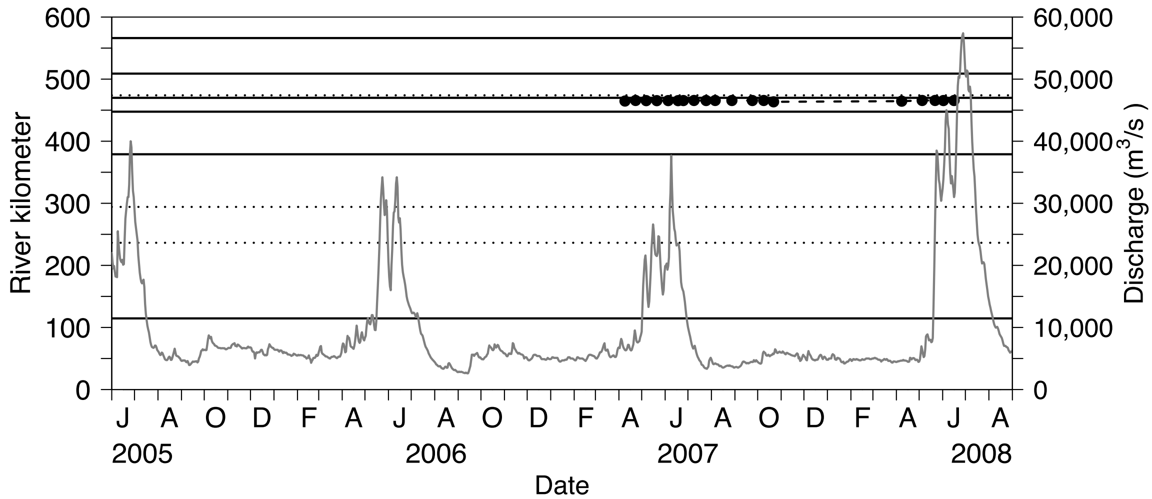

Figure 265. Movements of CHCA #101 (frequency = 600, code = 56, N = 19)

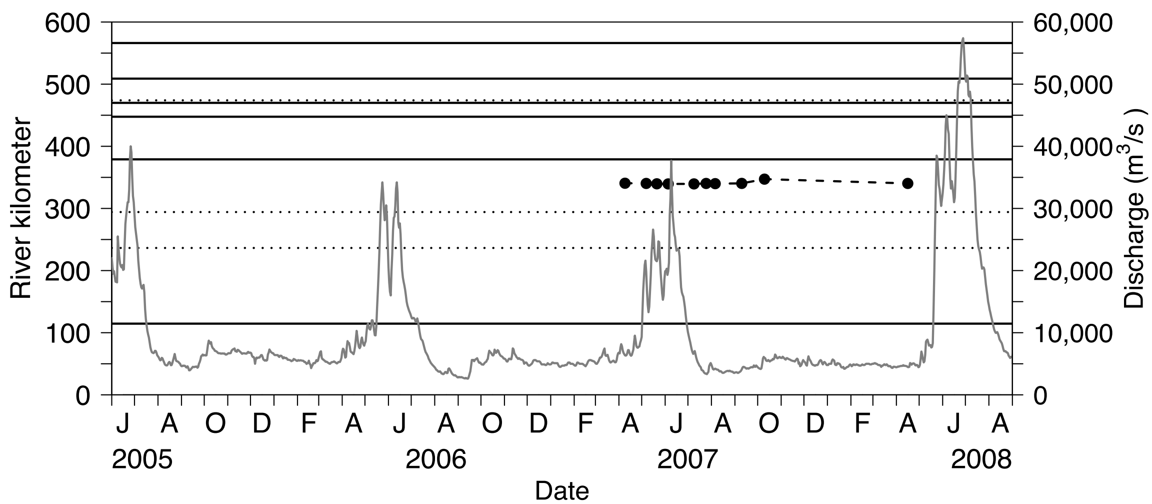

Figure 266. Movements of CHCA #102 (frequency = 600, code = 57, N = 10)

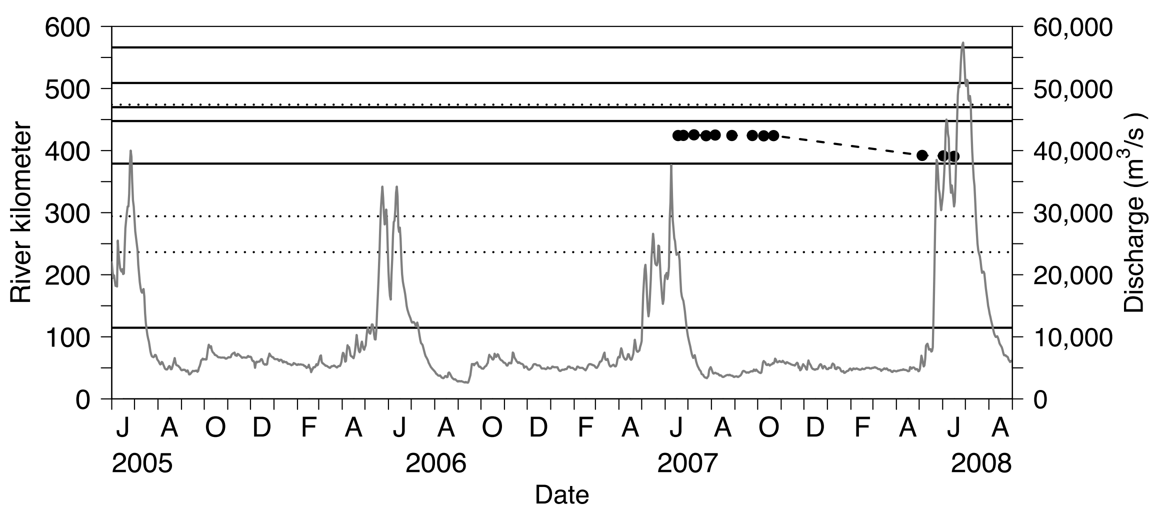

Figure 267. Movements of CHCA #103 (frequency = 600, code = 58, N = 12)

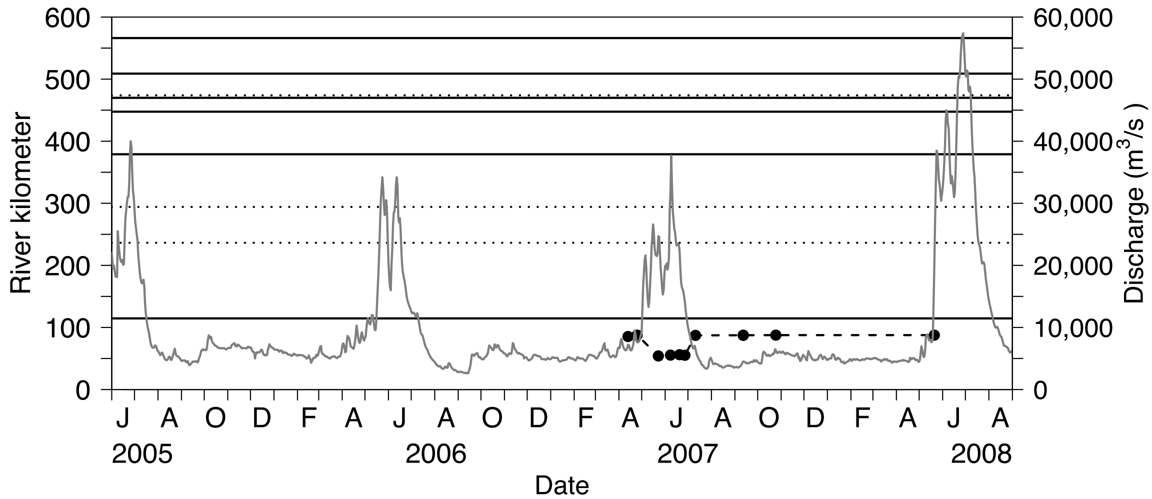

Figure 268. Movements of CHCA #104 (frequency = 600, code = 59, N = 11)

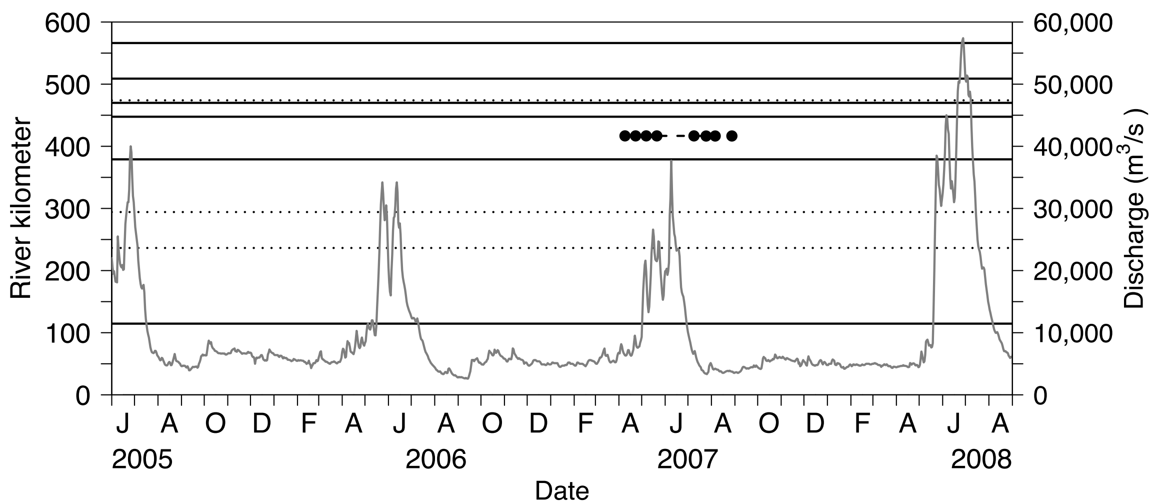

Figure 269. Movements of CHCA #105 (frequency = 600, code = 60, N = 8)

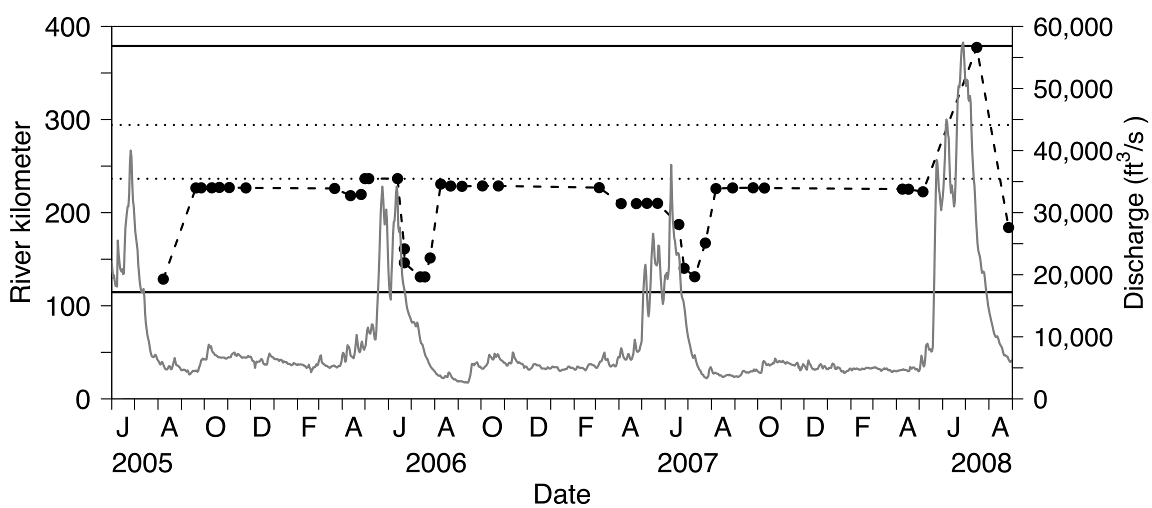

Figure 270. Movements of SHST #1 (frequency = 420, code = 11, N = 41)

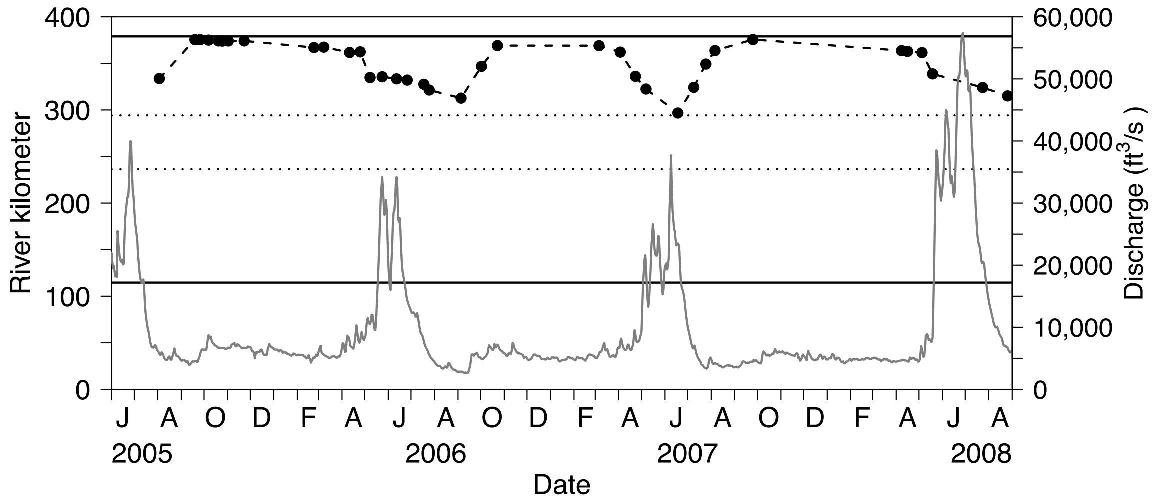

Figure 271. Movements of SHST #2 (frequency = 420, code = 21, N = 36)

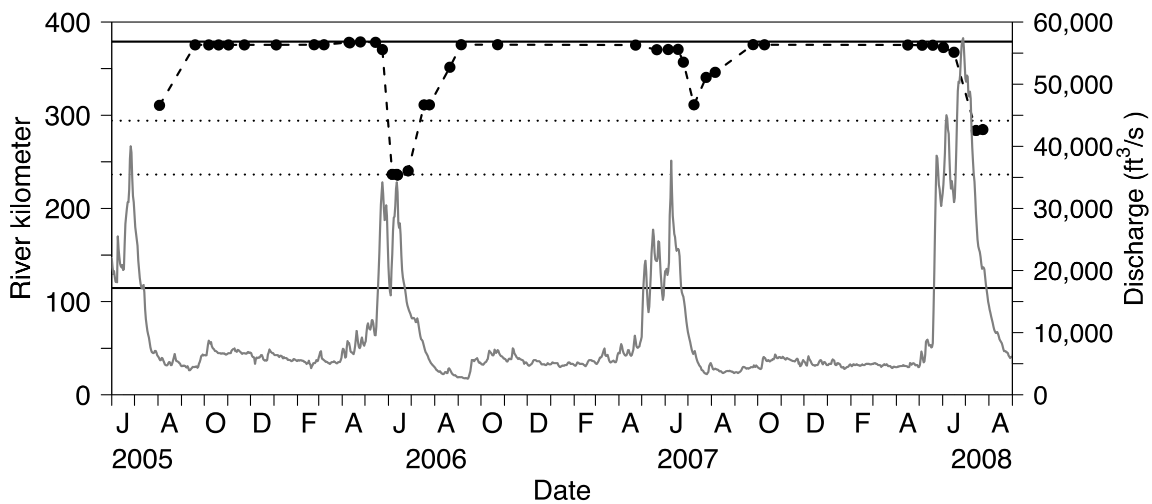

Figure 272. Movements of SHST #3 (frequency = 420, code = 27, N = 40)

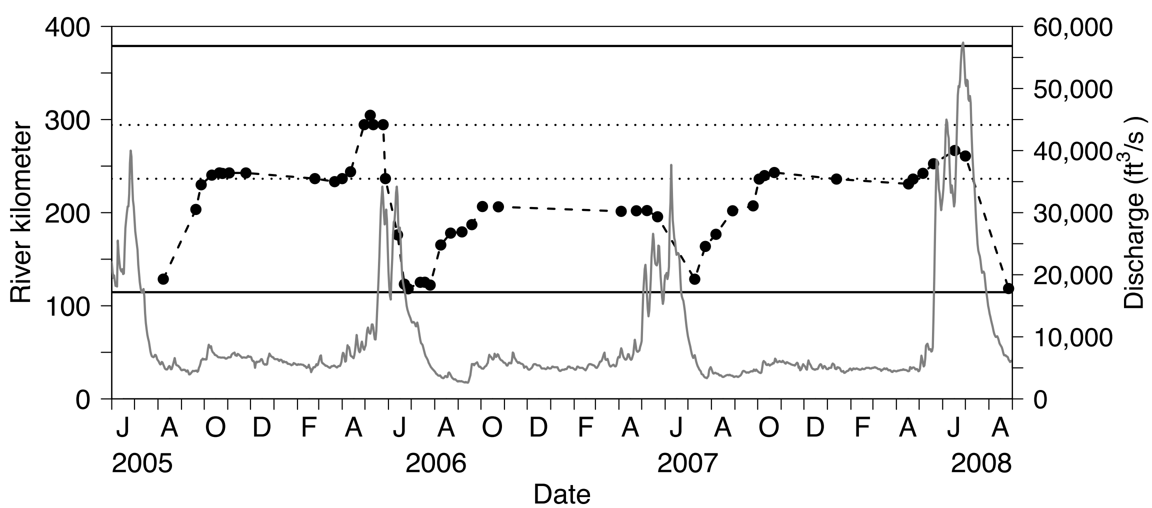

Figure 273. Movements of SHST #4 (frequency = 420, code = 30, N = 49)

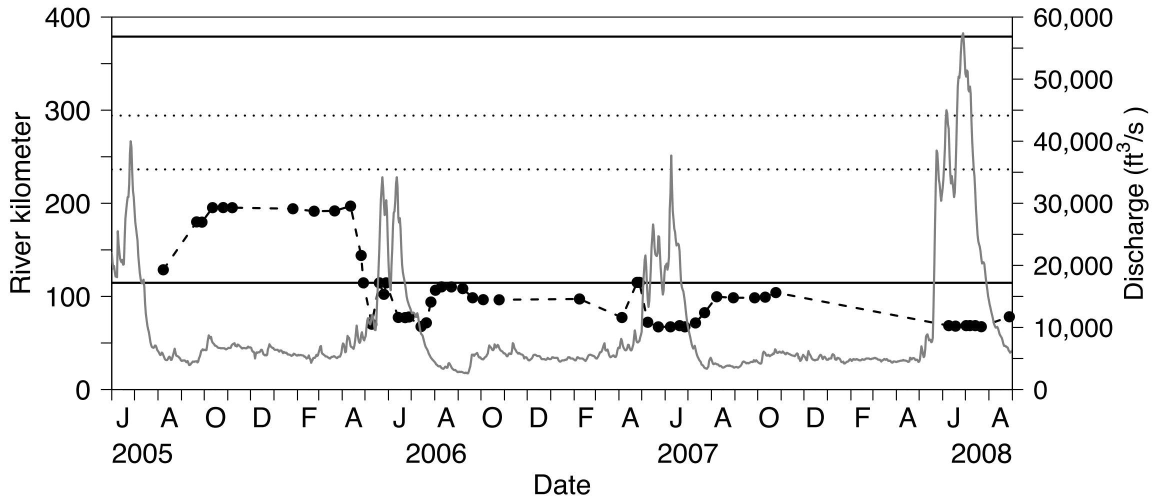

Figure 274. Movements of SHST #5 (frequency = 420, code = 31, N = 52)

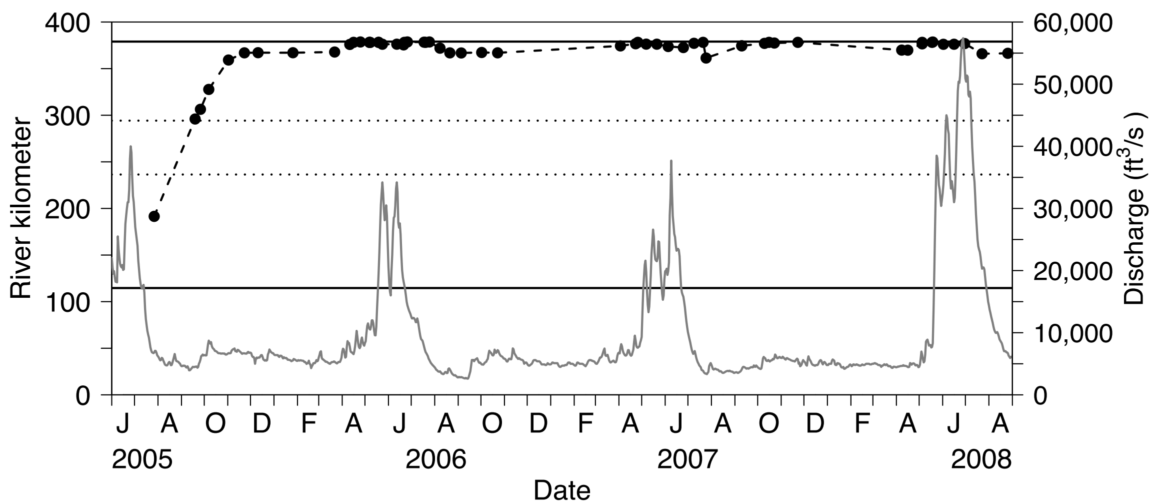

Figure 275. Movements of SHST #6 (frequency = 420, code = 47, N = 57)

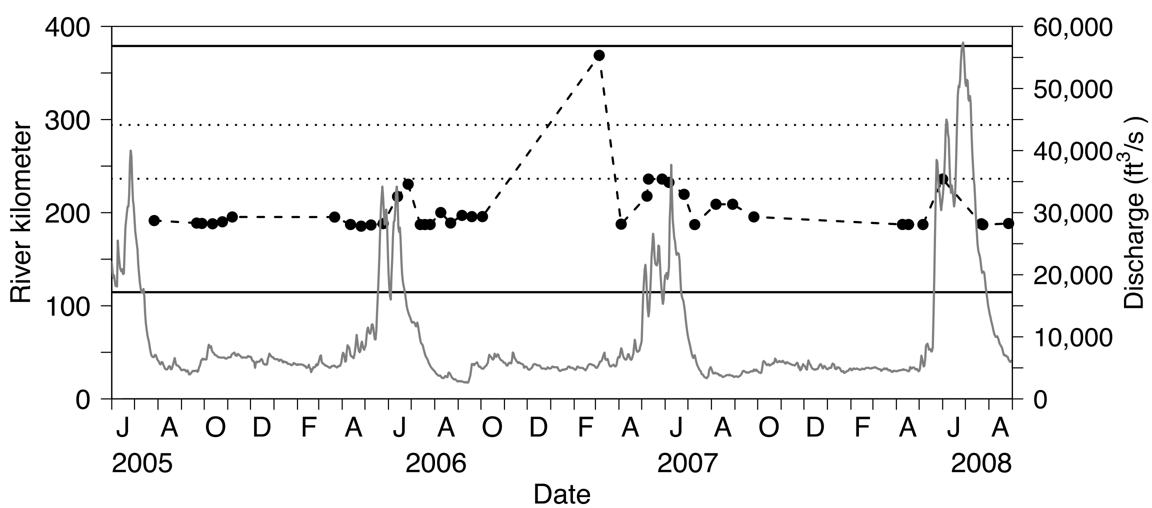

Figure 276. Movements of SHST #7 (frequency = 420, code = 48, N = 39)

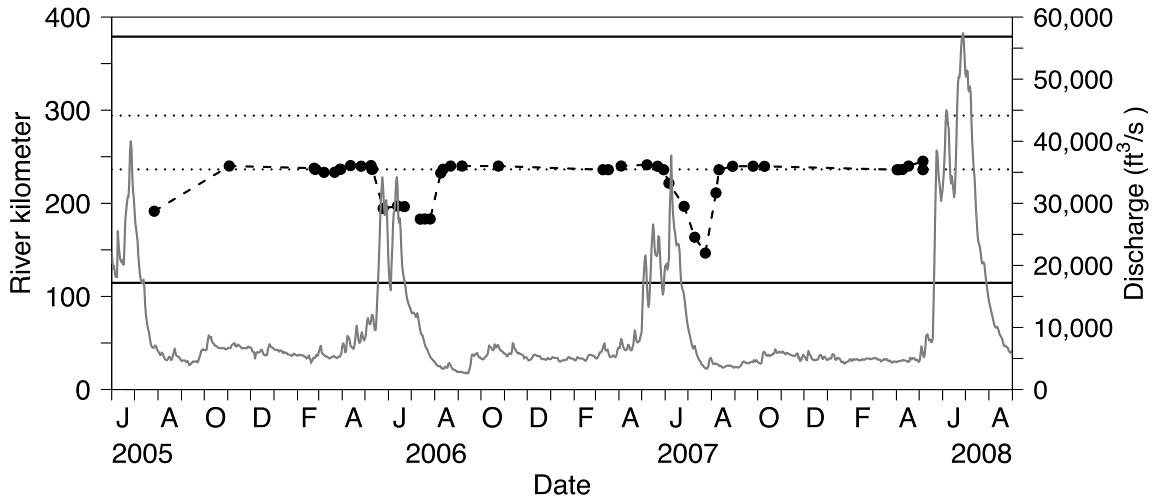

Figure 277. Movements of SHST #8 (frequency = 420, code = 50, N = 46)

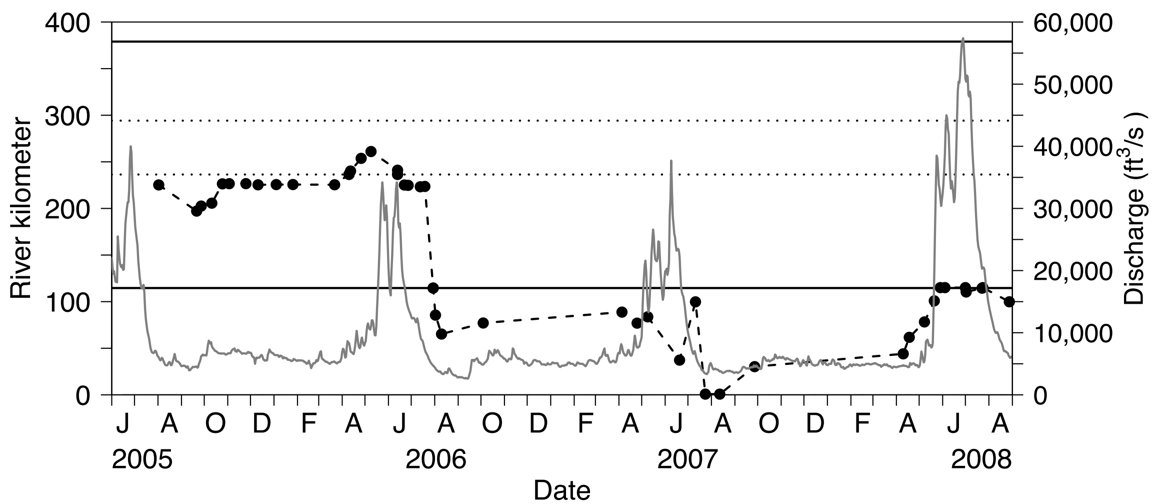

Figure 278. Movements of SHST #9 (frequency = 420, code = 53, N = 47)

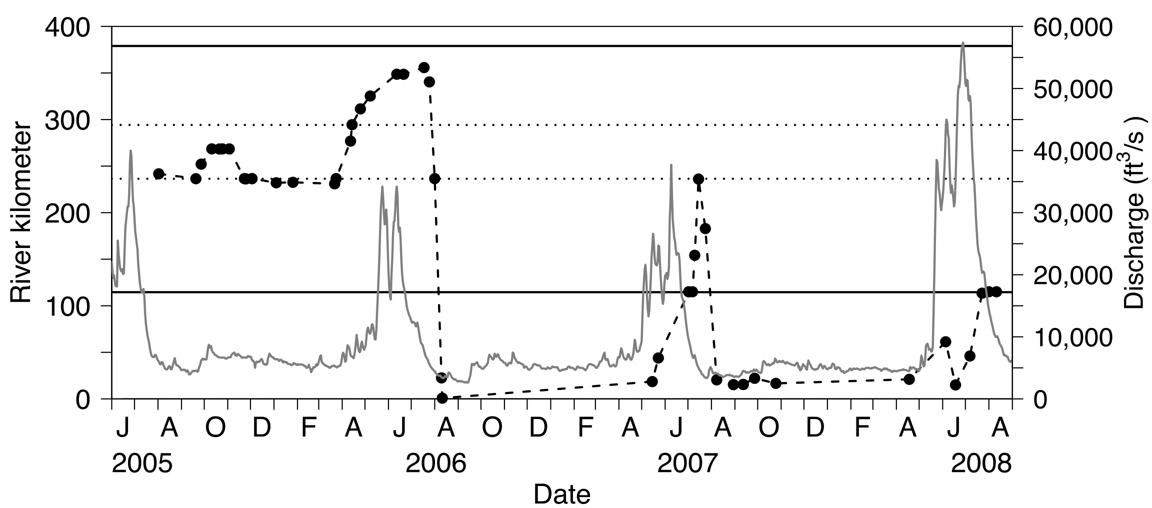

Figure 279. Movements of SHST #10 (frequency = 420, code = 54, N = 46)

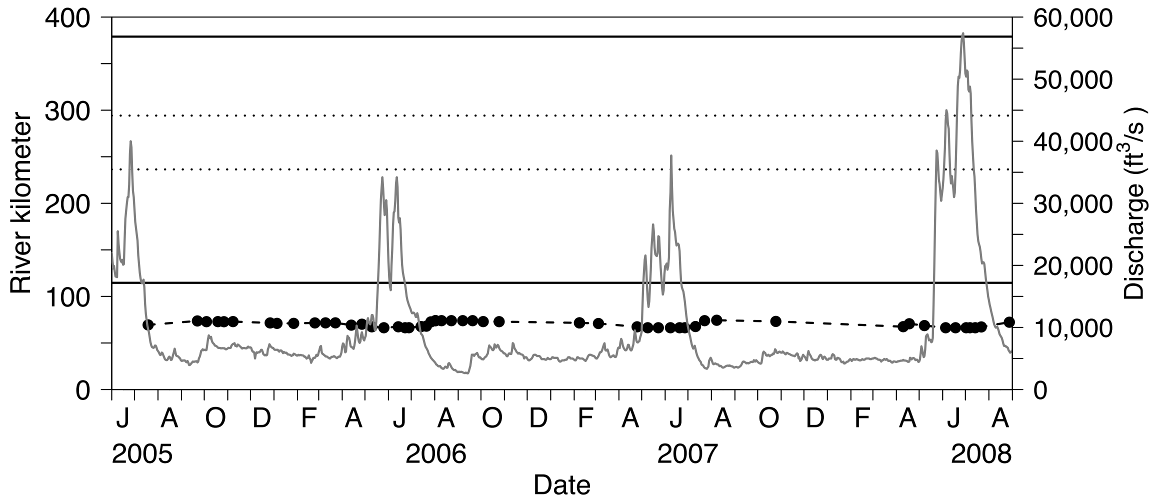

Figure 280. Movements of SHST #11 (frequency = 420, code = 59, N = 53)

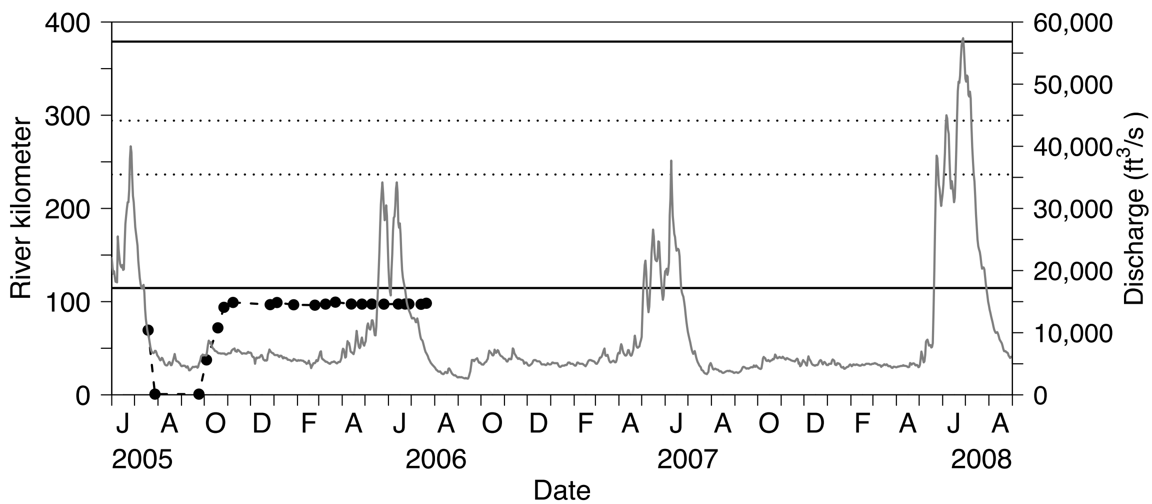

Figure 281. Movements of SHST #12 (frequency = 420, code = 61, N = 22)

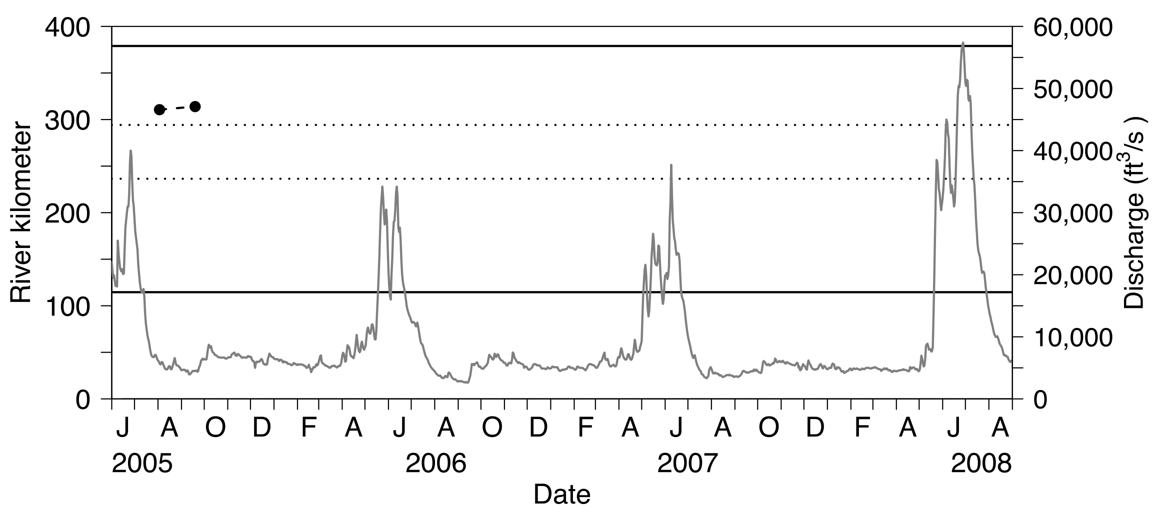

Figure 282. Movements of SHST #13 (frequency = 420, code = 67, N = 2)

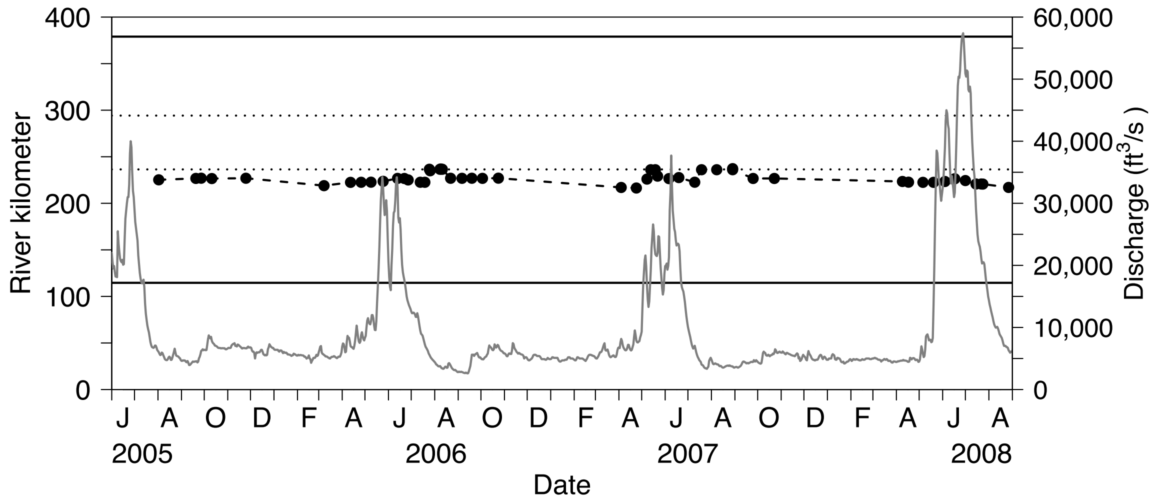

Figure 283. Movements of SHST #14 (frequency = 420, code = 79, N = 51)

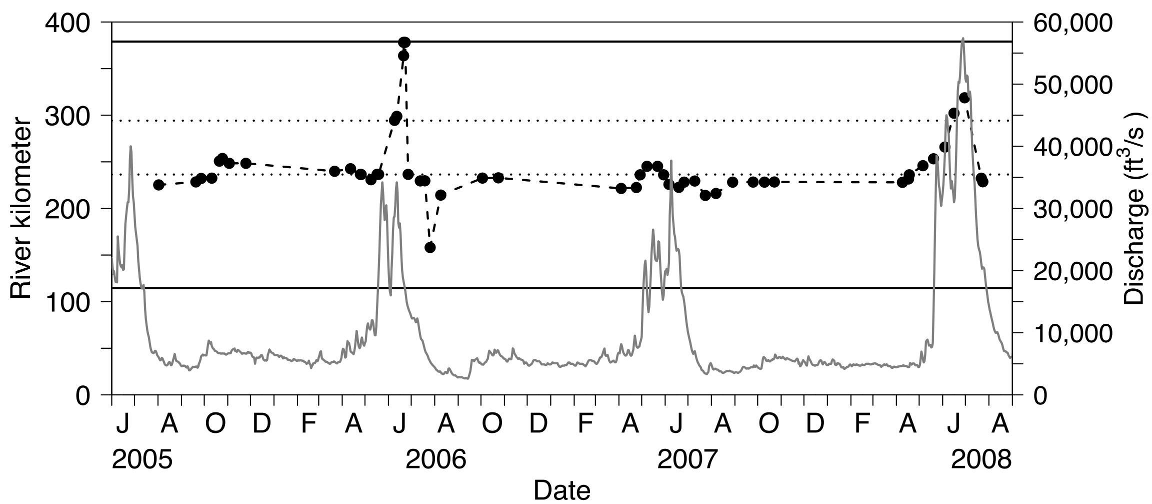

Figure 284. Movements of SHST #15 (frequency = 420, code = 80, N = 53)

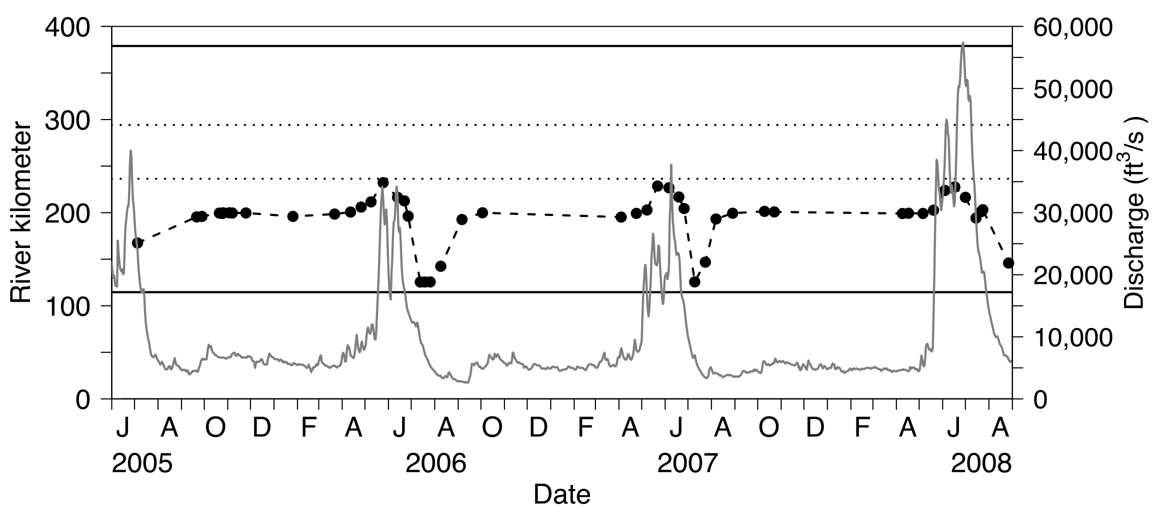

Figure 285. Movements of SHST #16 (frequency = 480, code = 16, N = 48)

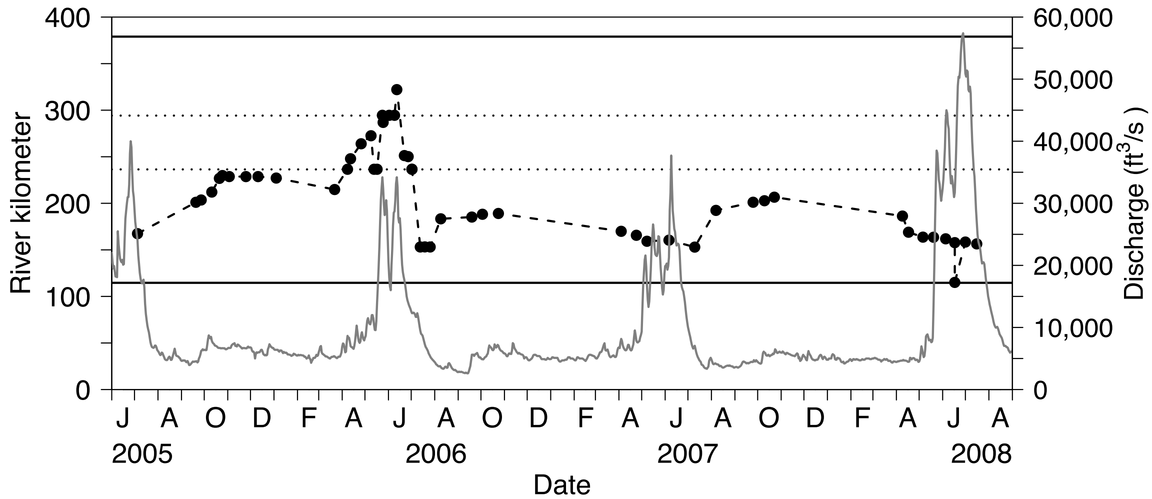

Figure 286. Movements of SHST #17 (frequency = 480, code = 17, N = 51)

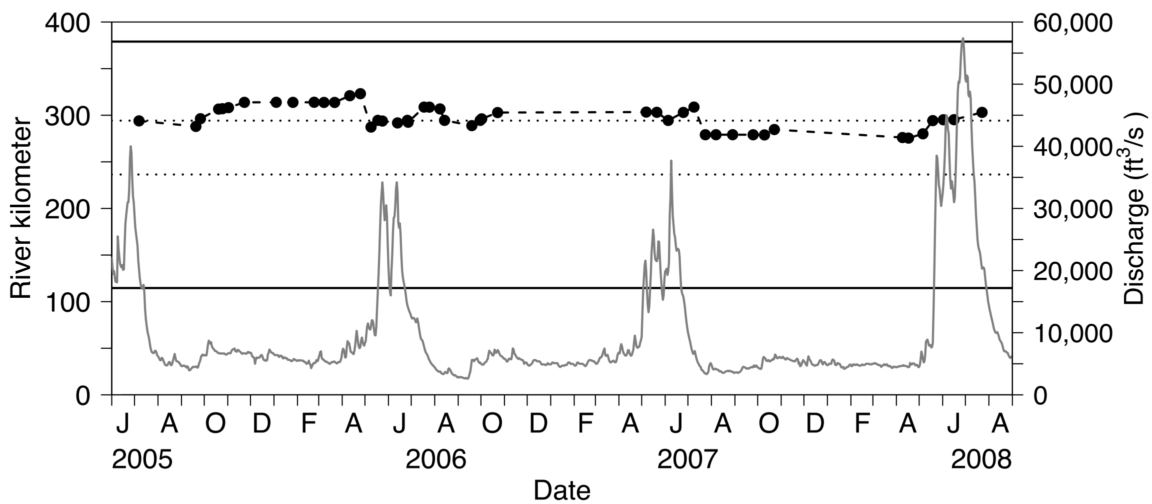

Figure 287. Movements of SHST #18 (frequency = 480, code = 20, N = 46)

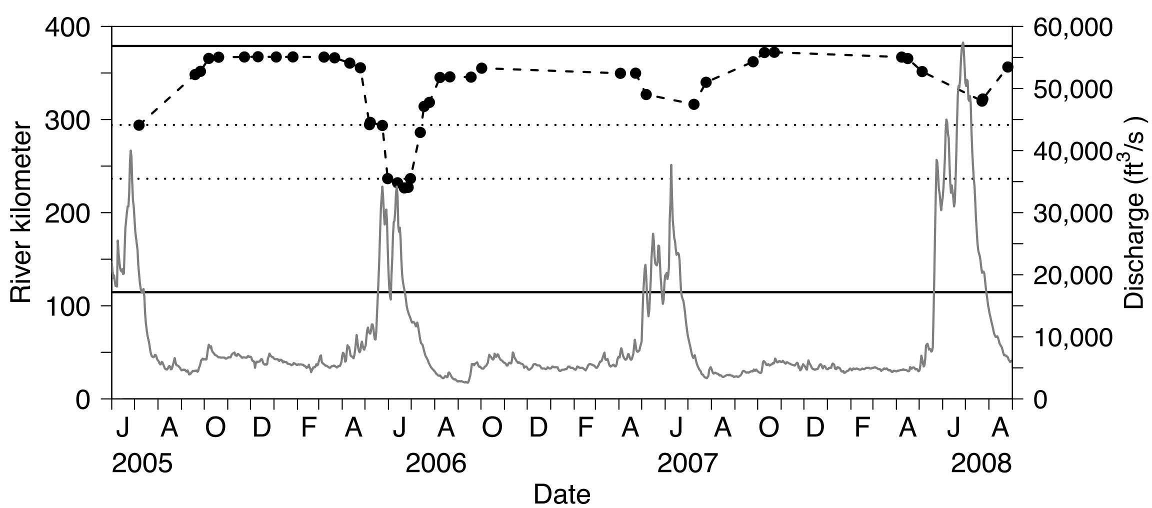

Figure 288. Movements of SHST #19 (frequency = 480, code = 21, N = 42)

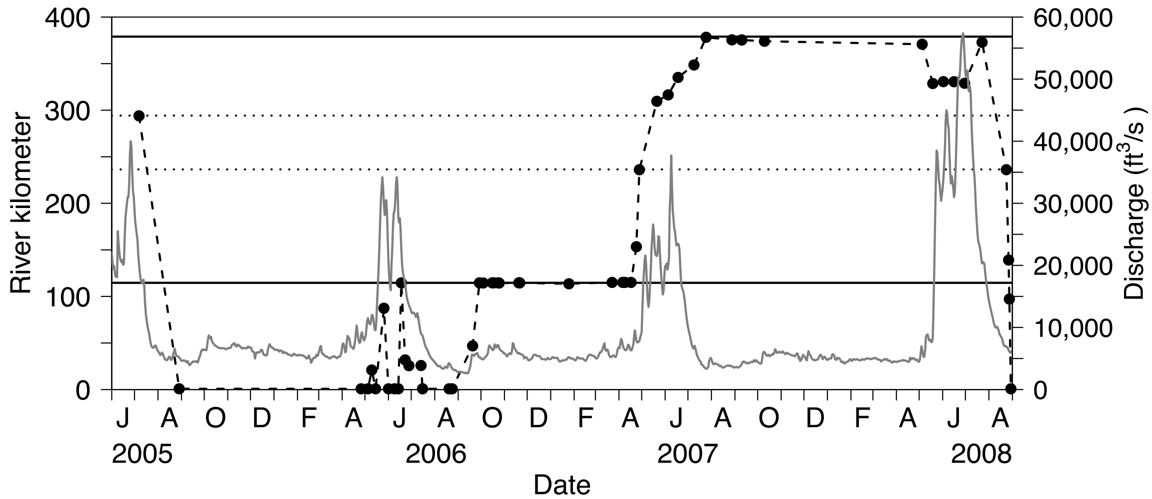

Figure 289. Movements of SHST #20 (frequency = 480, code = 25, N = 53)

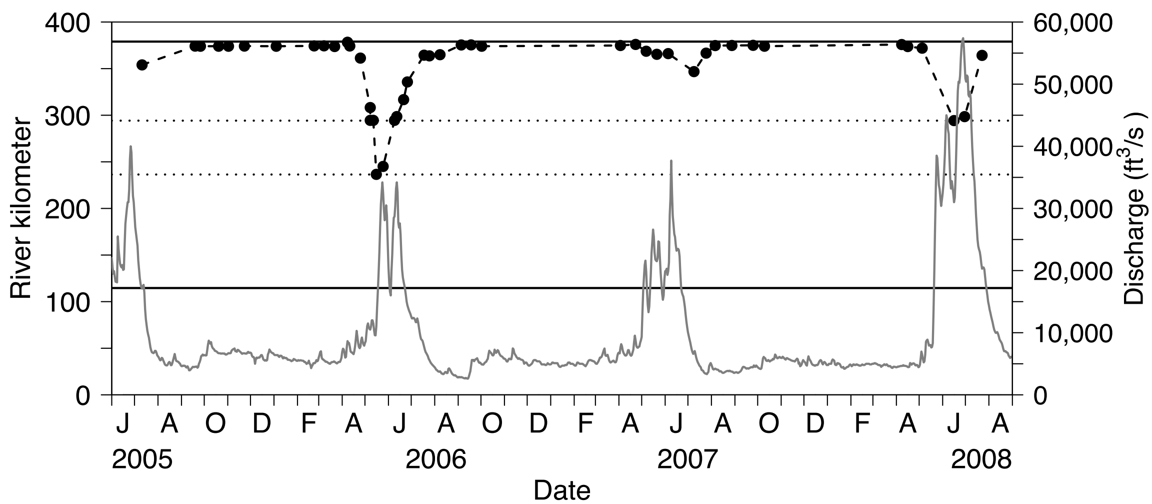

Figure 290. Movements of SHST #21 (frequency = 480, code = 29, N = 46)

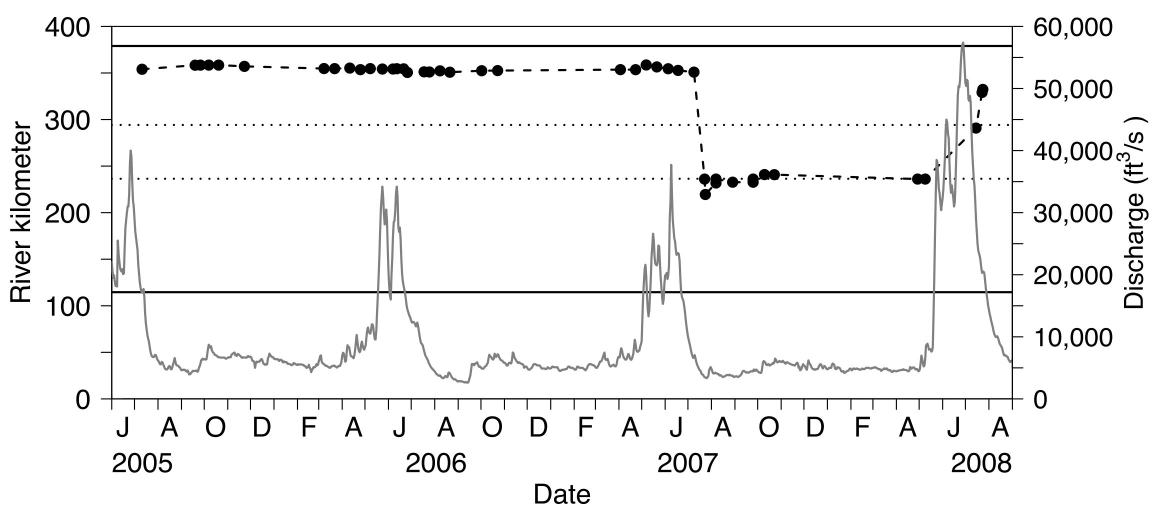

Figure 291. Movements of SHST #22 (frequency = 480, code = 33, N = 43)

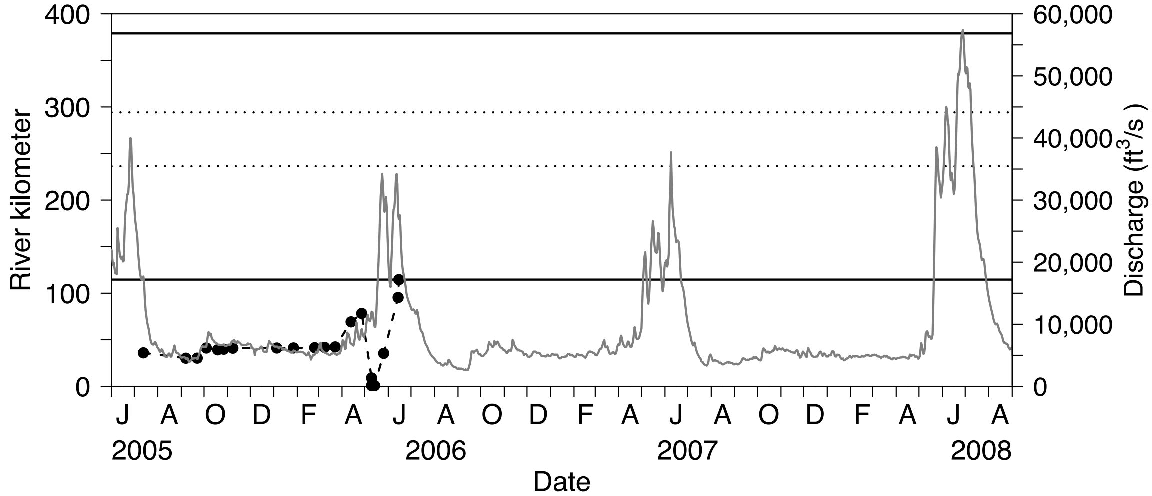

Figure 292. Movements of SHST #23 (frequency = 480, code = 37, N = 20)

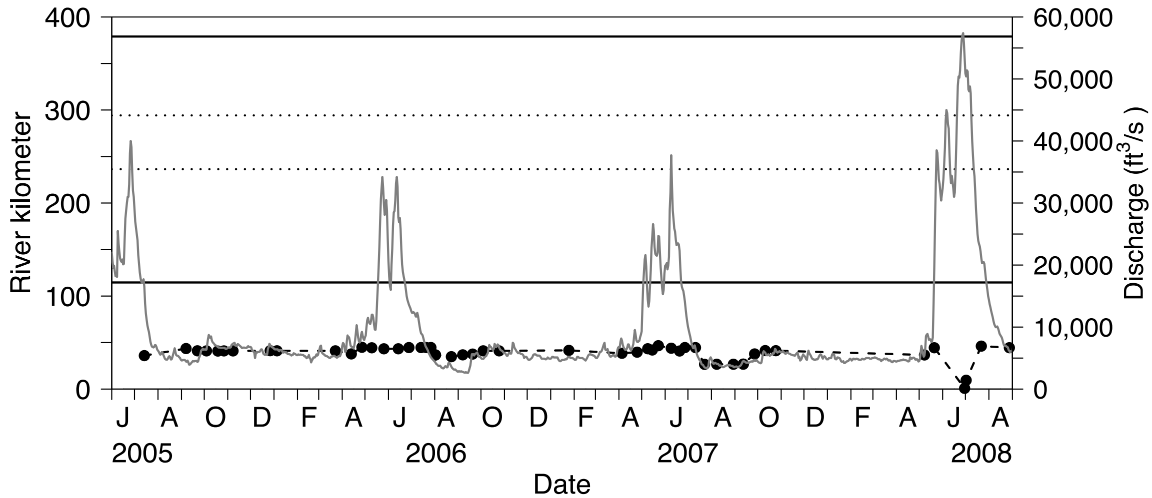

Figure 293. Movements of SHST #24 (frequency = 480, code = 39, N = 50)

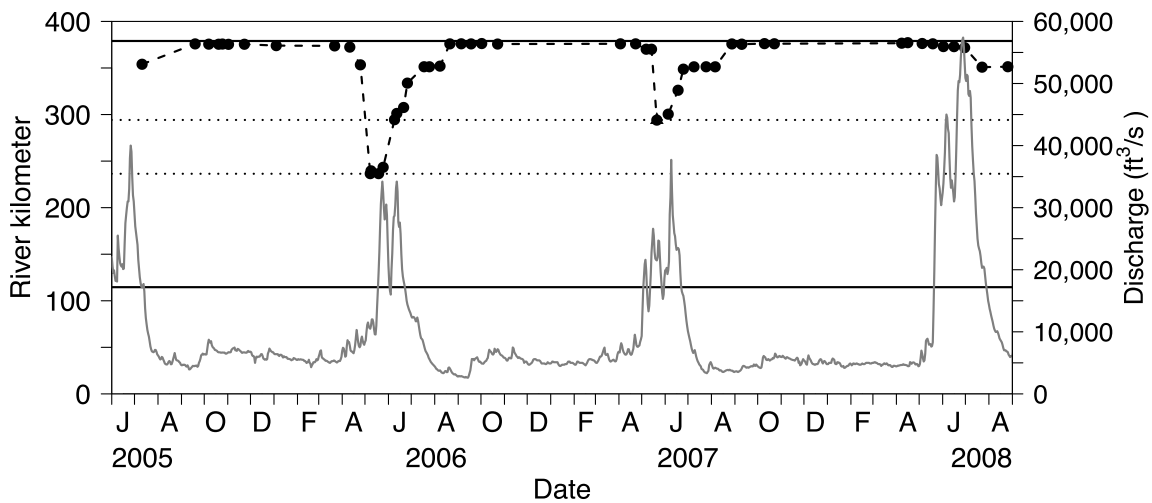

Figure 294. Movements of SHST #25 (frequency = 480, code = 41, N = 53)

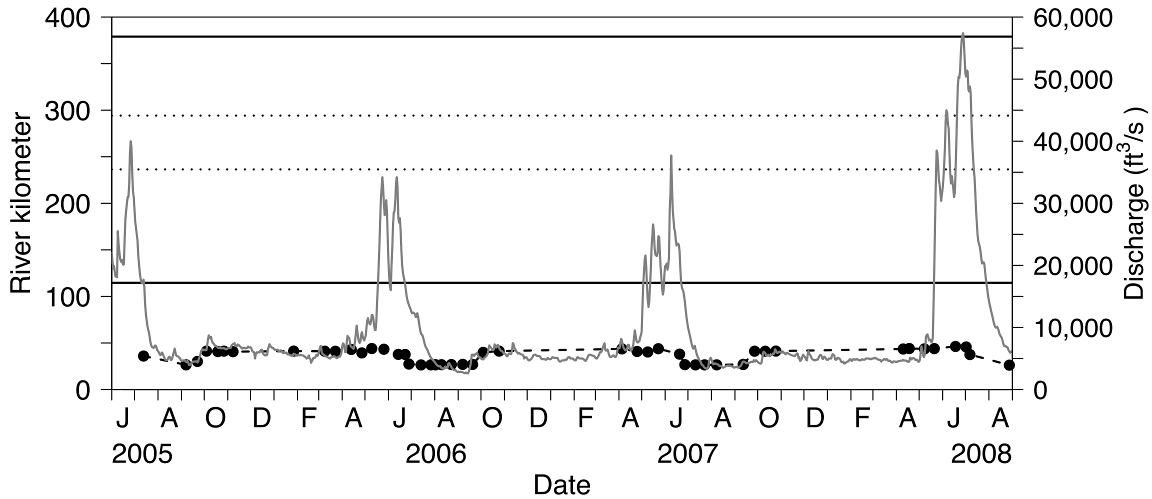

Figure 295. Movements of SHST #26 (frequency = 480, code = 44, N = 49)

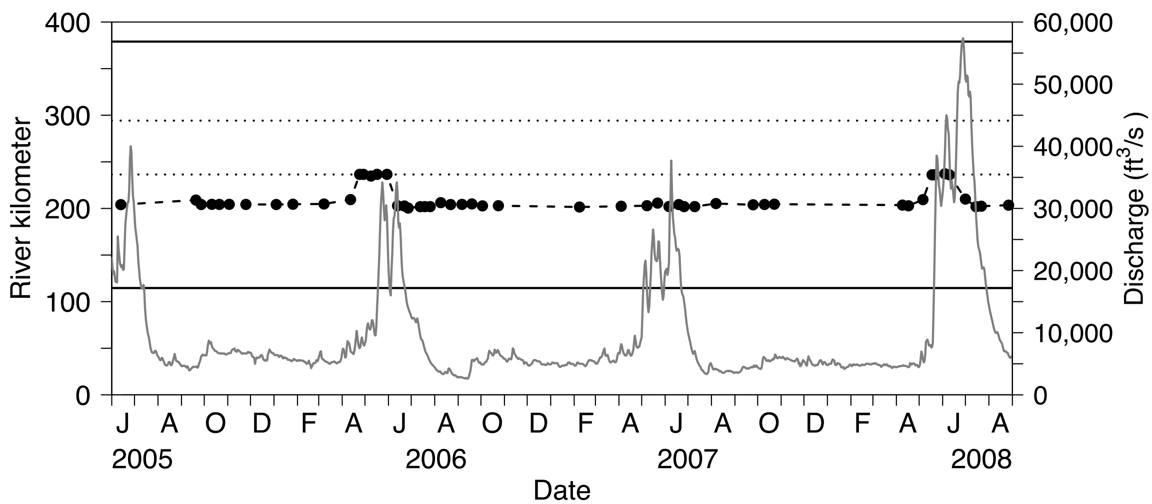

Figure 296. Movements of SHST #27 (frequency = 480, code = 50, N = 51)

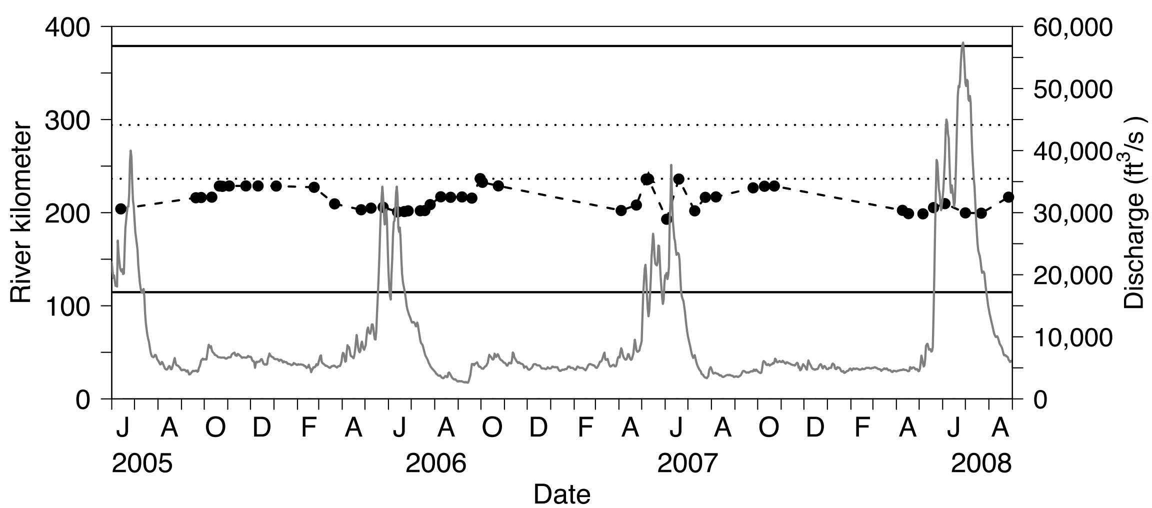

Figure 297. Movements of SHST #28 (frequency = 480, code = 51, N = 50)

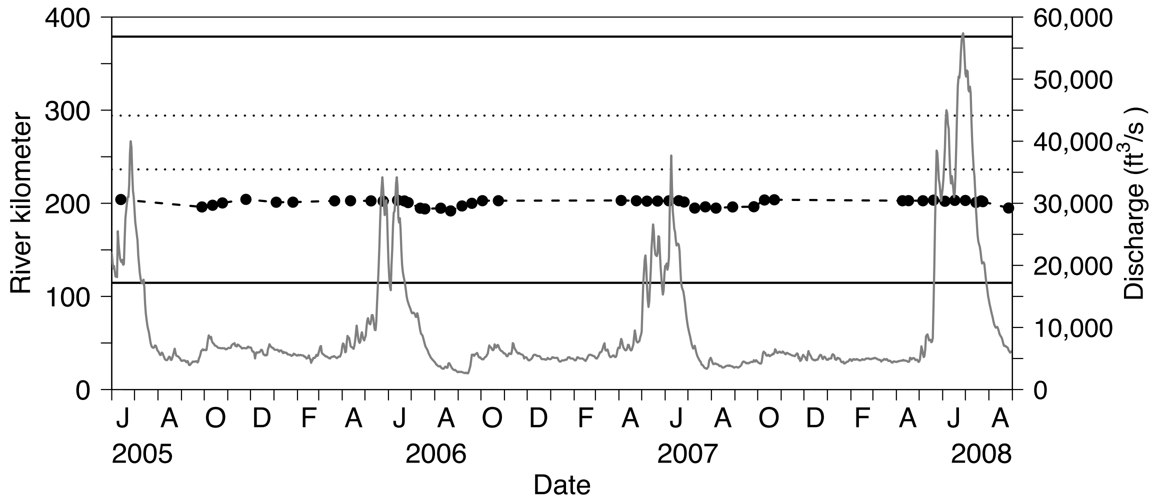

Figure 298. Movements of SHST #29 (frequency = 480, code = 52, N = 47)

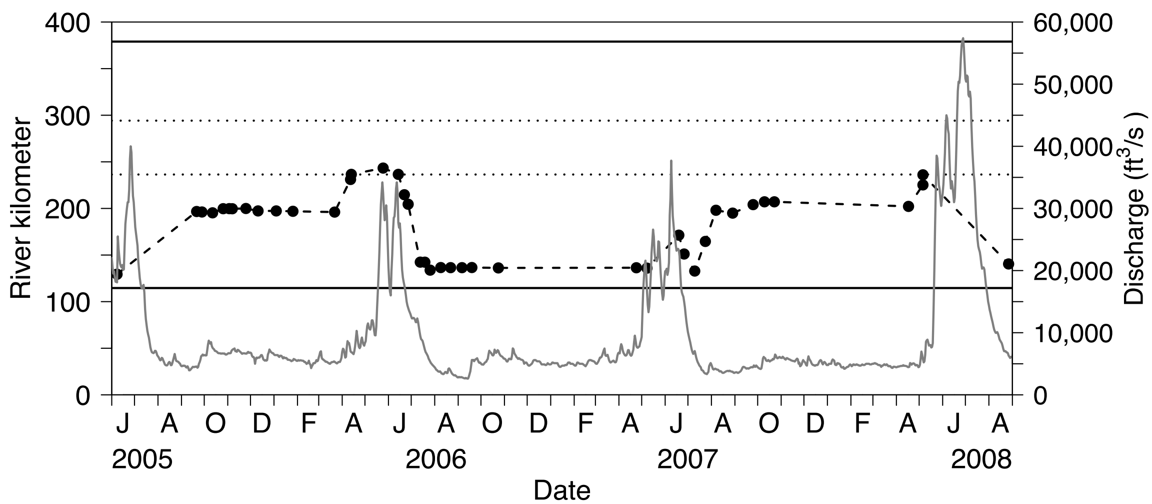

Figure 299. Movements of SHST #30 (frequency = 480, code = 53, N = 41)

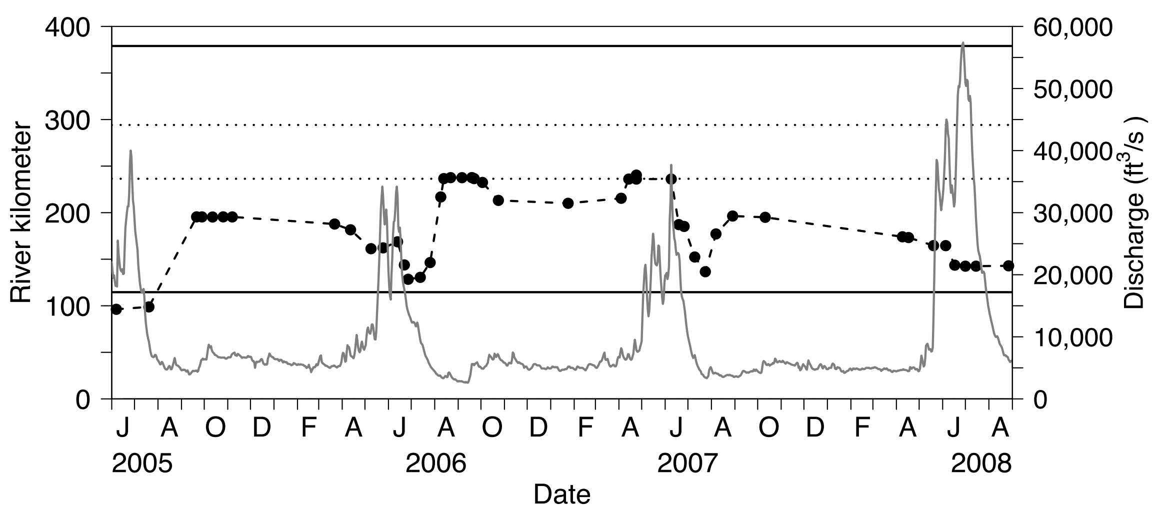

Figure 300. Movements of SHST #31 (frequency = 480, code = 57, N = 45)

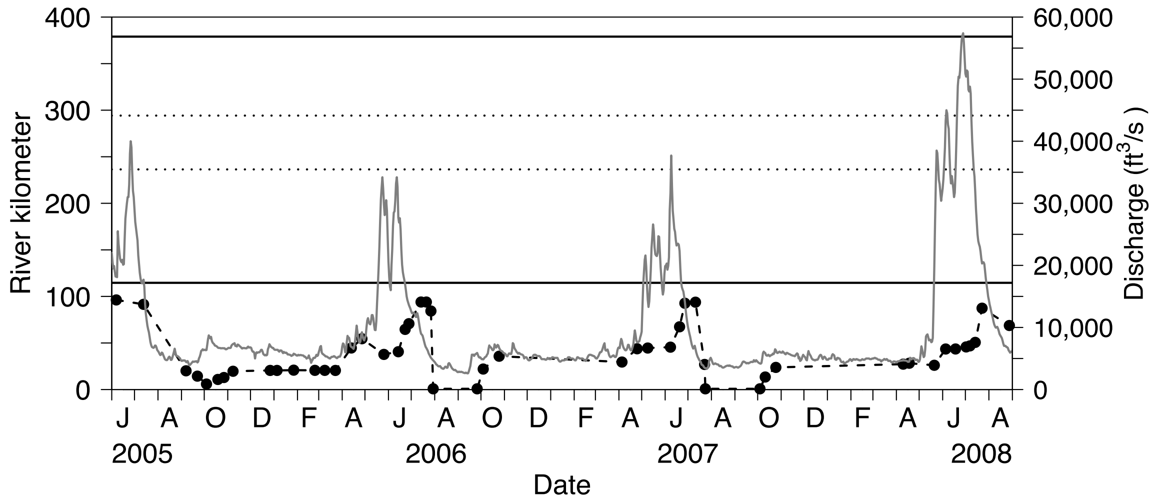

Figure 301. Movements of SHST #32 (frequency = 480, code = 60, N = 49)

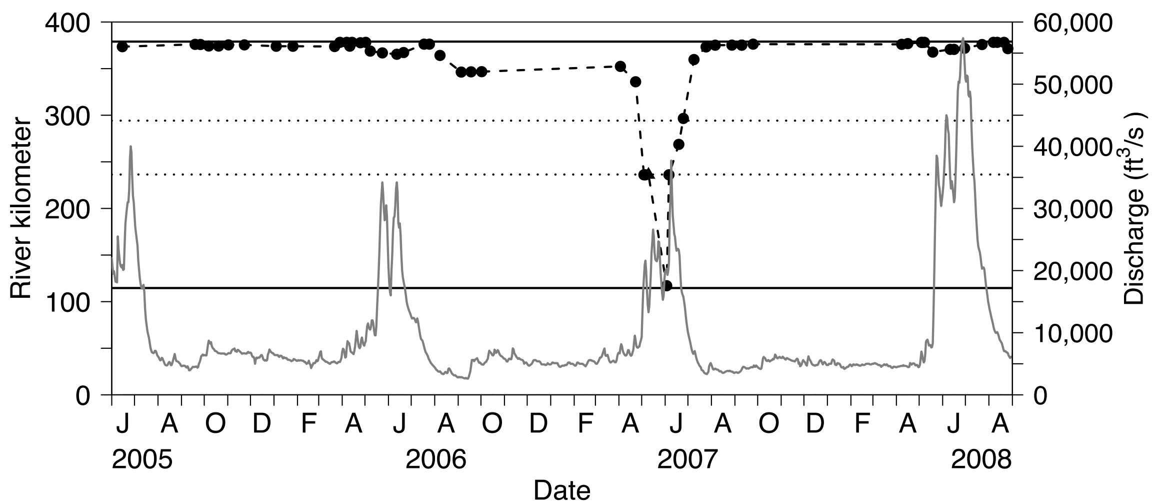

Figure 302. Movements of SHST #33 (frequency = 480, code = 66, N = 56)

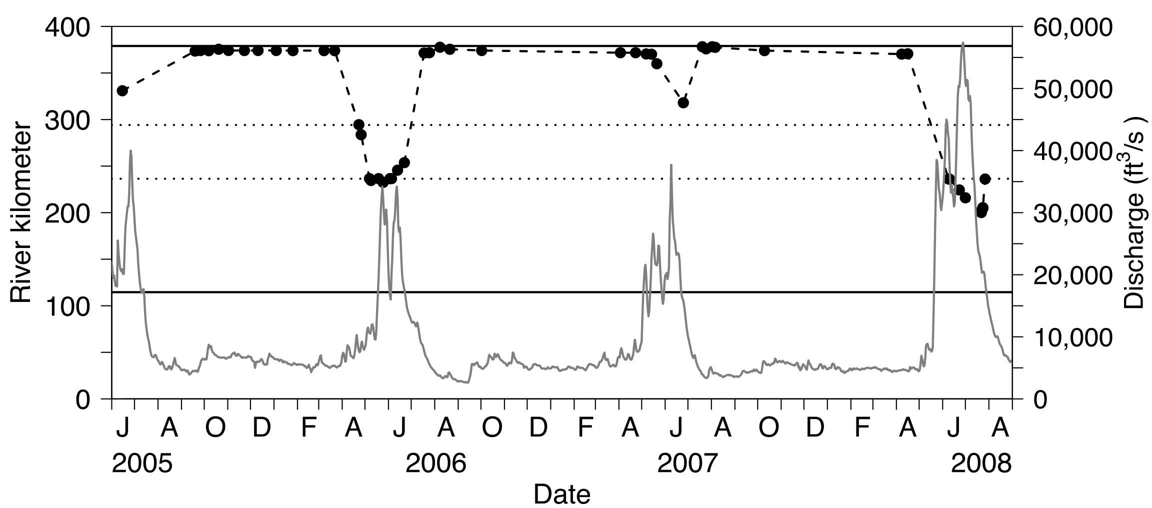

Figure 303. Movements of SHST #34 (frequency = 480, code = 70, N = 48)

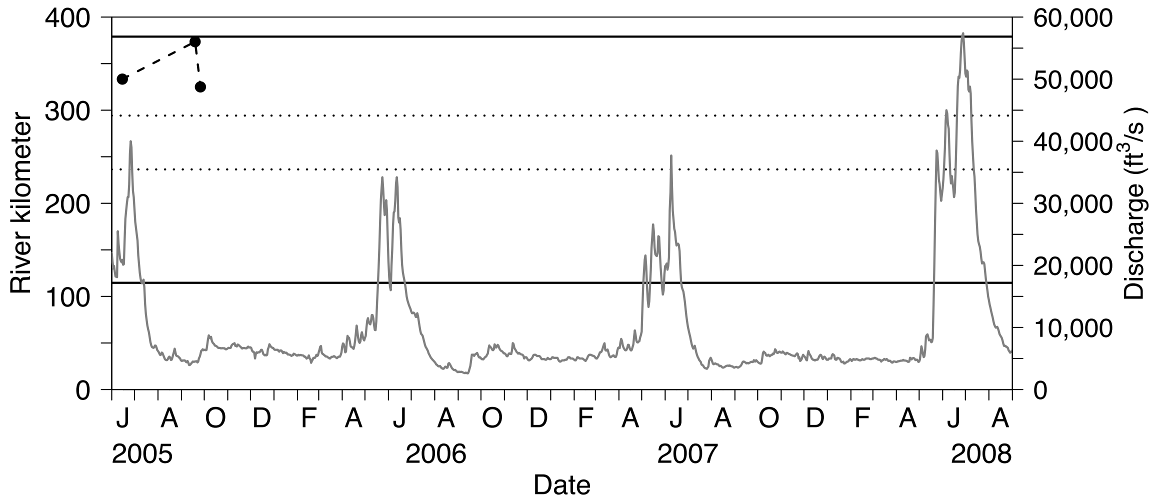

Figure 304. Movements of SHST #35 (frequency = 480, code = 72, N = 3)

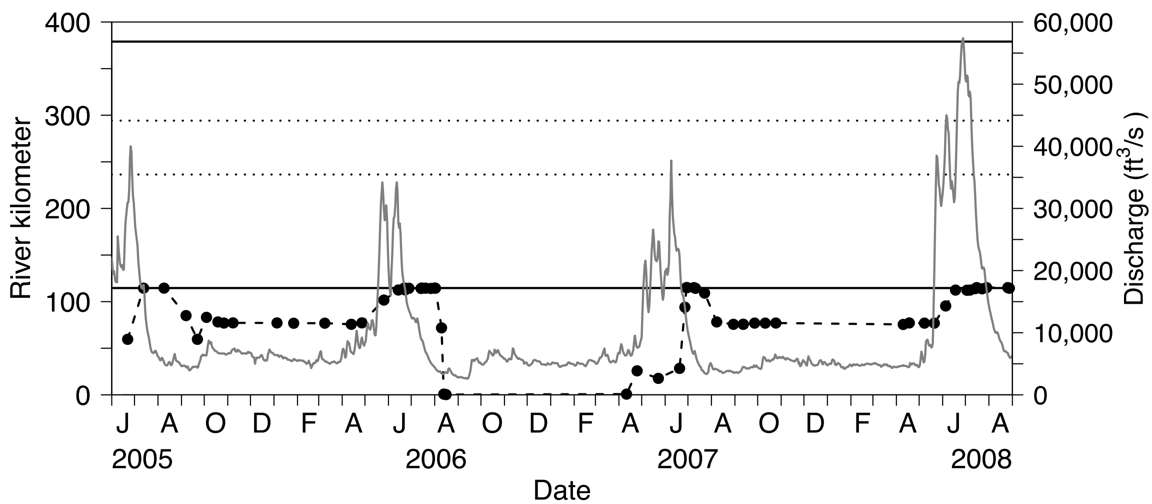

Figure 305. Movements of SHST #36 (frequency = 480, code = 76, N = 59)

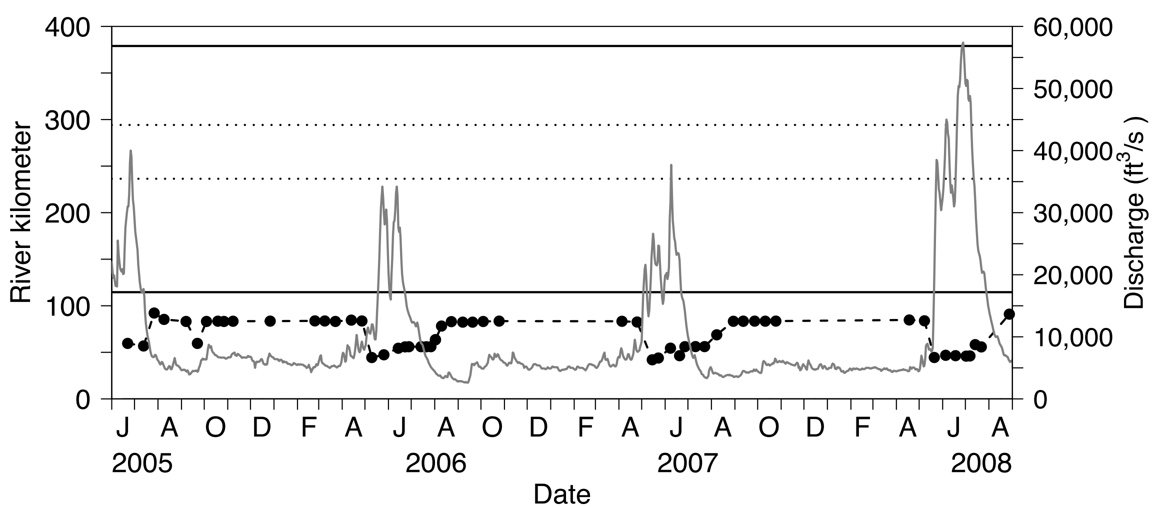

Figure 306. Movements of SHST #37 (frequency = 480, code = 80, N = 58)

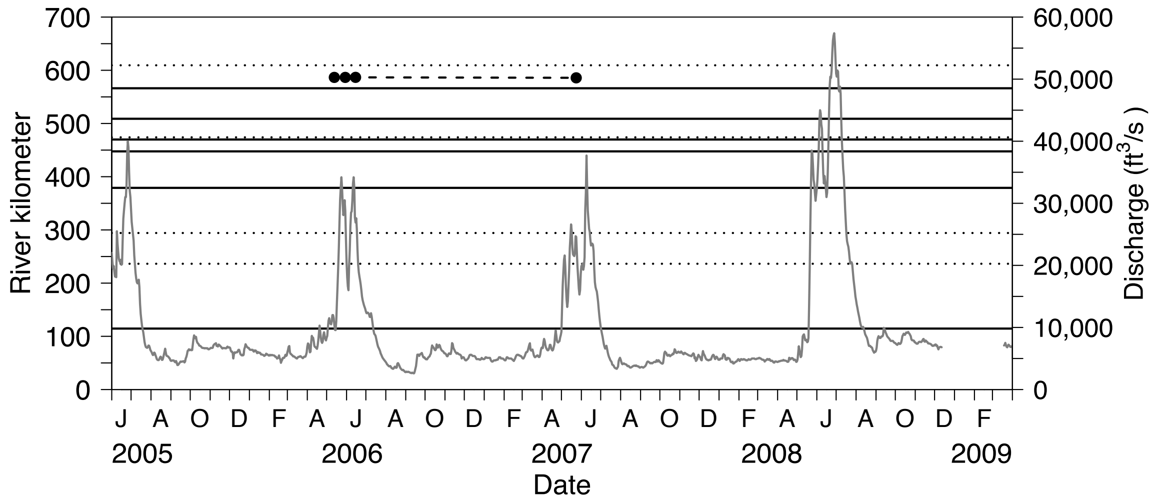

Figure 307. Movements of SPSO #1 (frequency = 480, code = 102, N = 4)

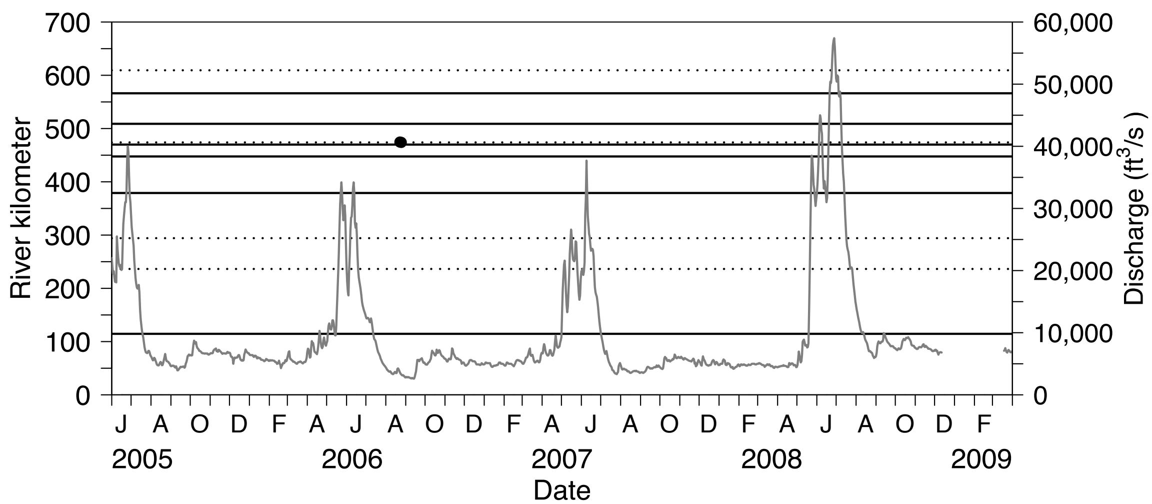

Figure 308. Movements of SPSO #2 (frequency = 480, code = 106, N = 2)

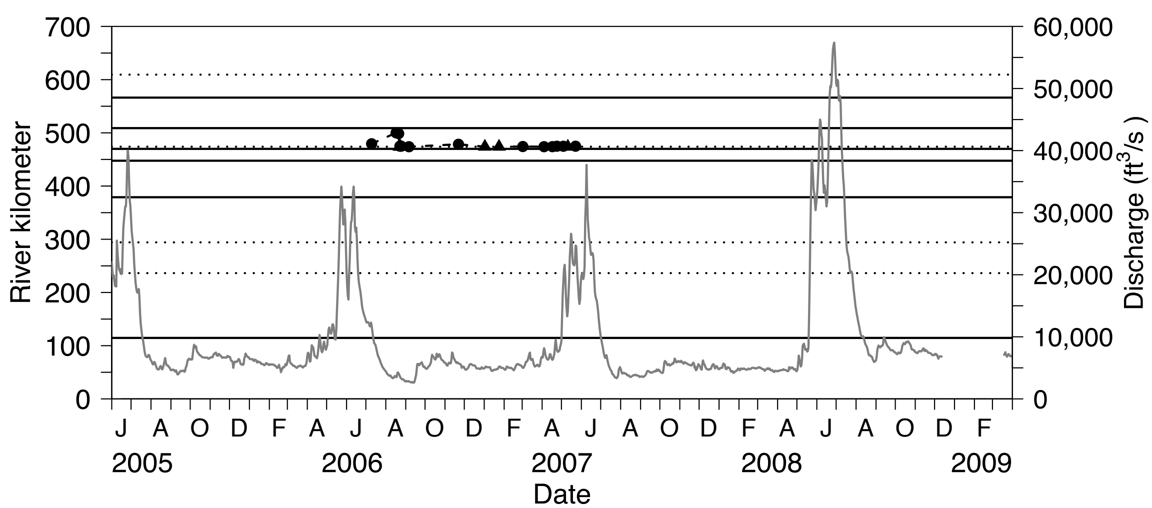

Figure 309. Movements of SPSO #3 (frequency = 480, code = 107, N = 18)

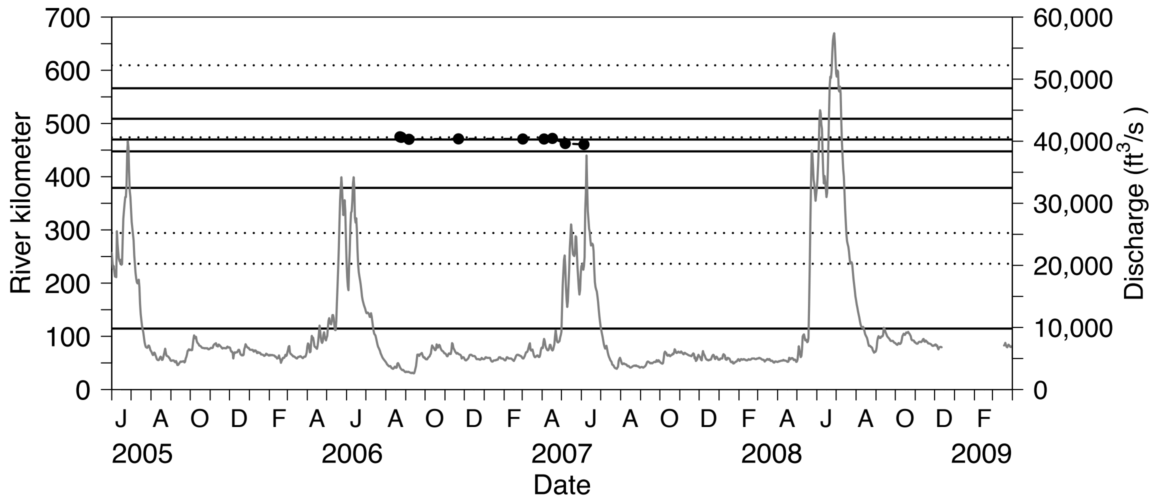

Figure 310. Movements of SPSO #4 (frequency = 480, code = 108, N = 9)

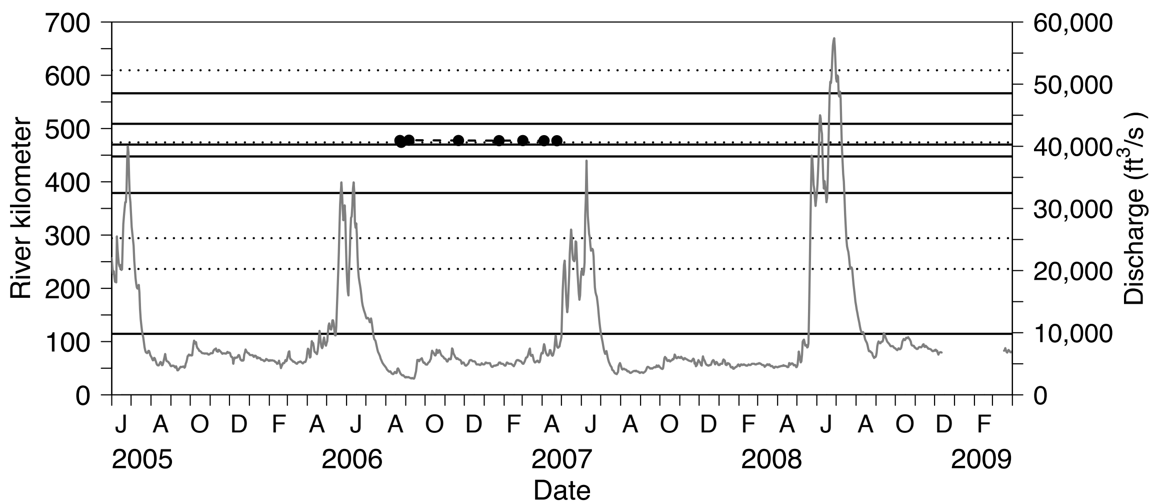

Figure 311. Movements of SPSO #5 (frequency = 480, code = 109, N = 8)

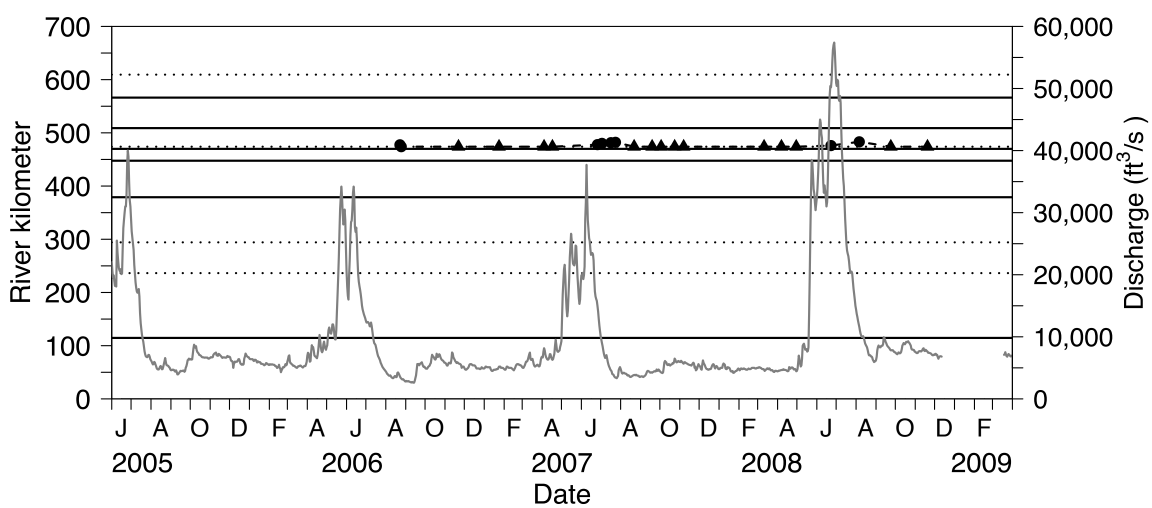

Figure 312. Movements of SPSO #6 (frequency = 480, code = 110, N = 22)

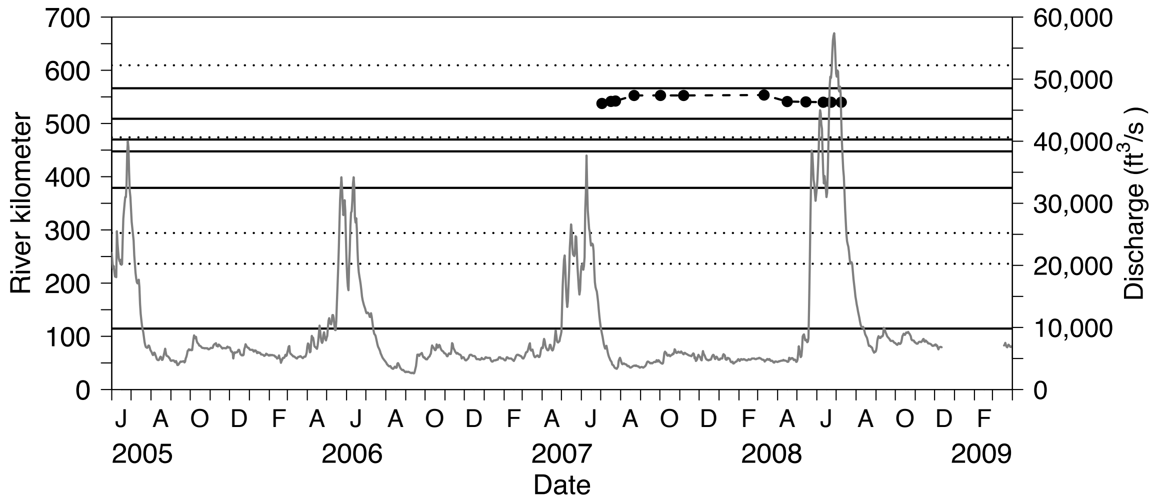

Figure 313. Movements of SPSO #7 (frequency = 480, code = 111, N = 12)

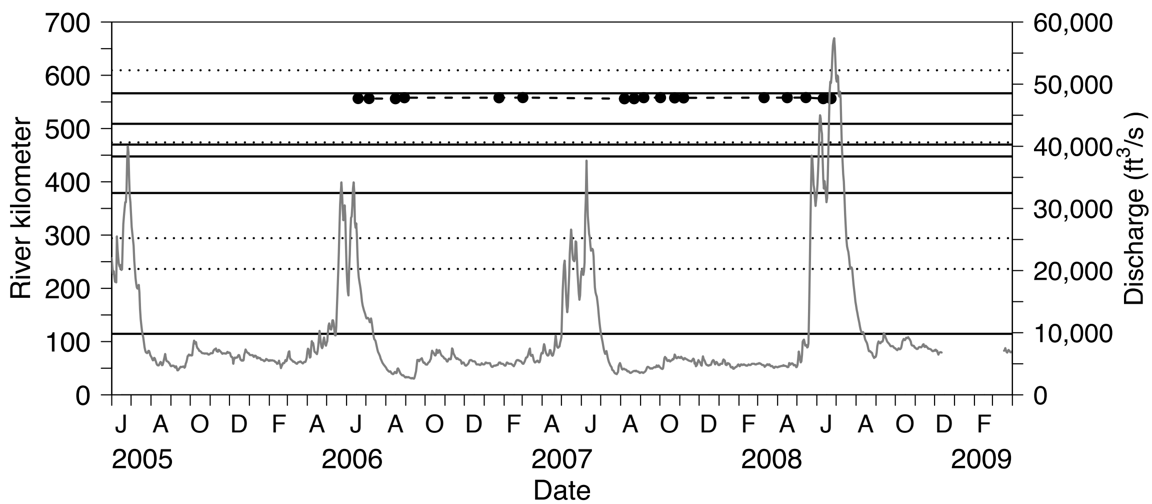

Figure 314. Movements of SPSO #8 (frequency = 480, code = 113, N = 17)

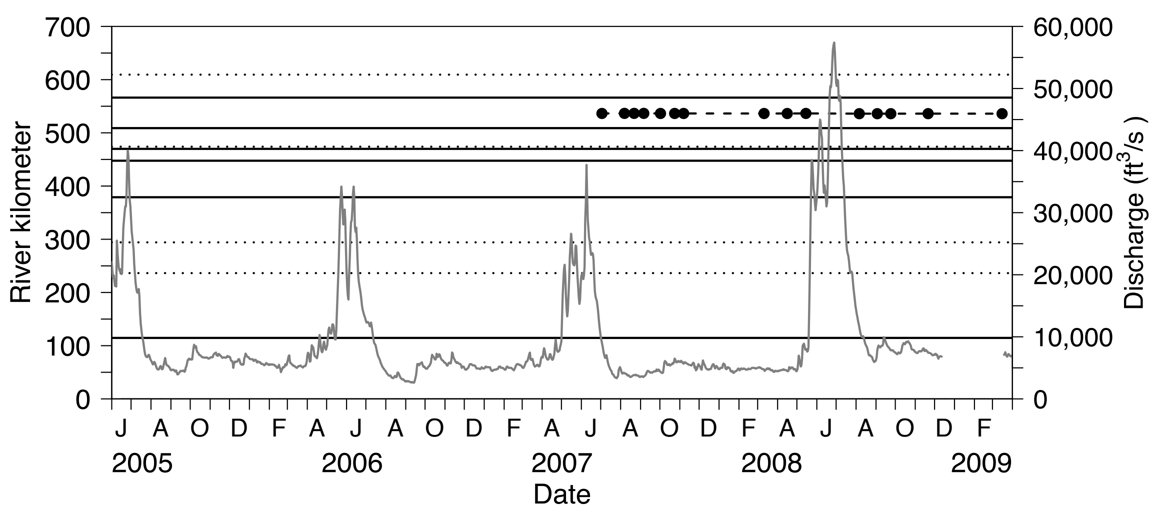

Figure 315. Movements of SPSO #9 (frequency = 480, code = 116, N = 15)

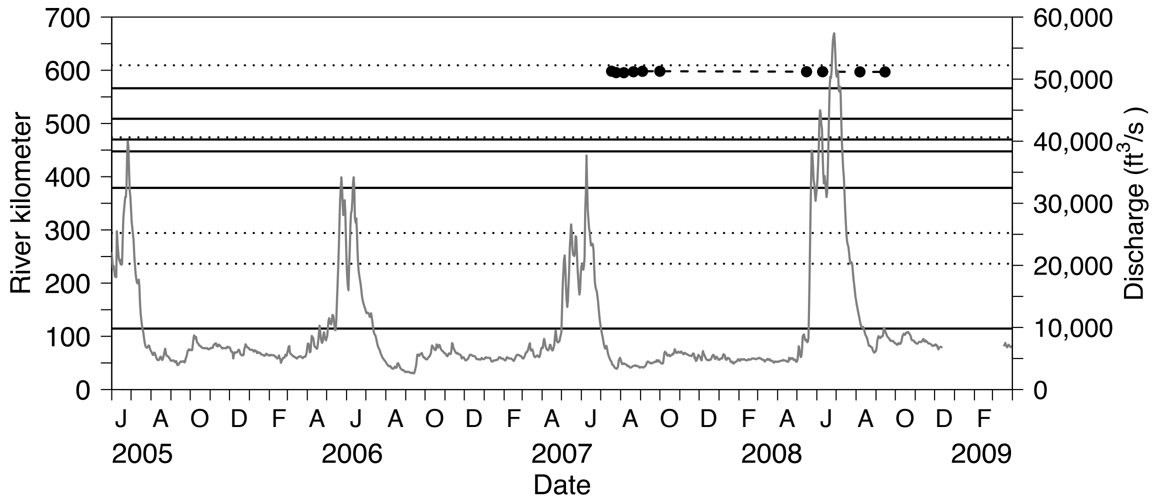

Figure 316. Movements of SPSO #10 (frequency = 480, code = 117, N = 10)

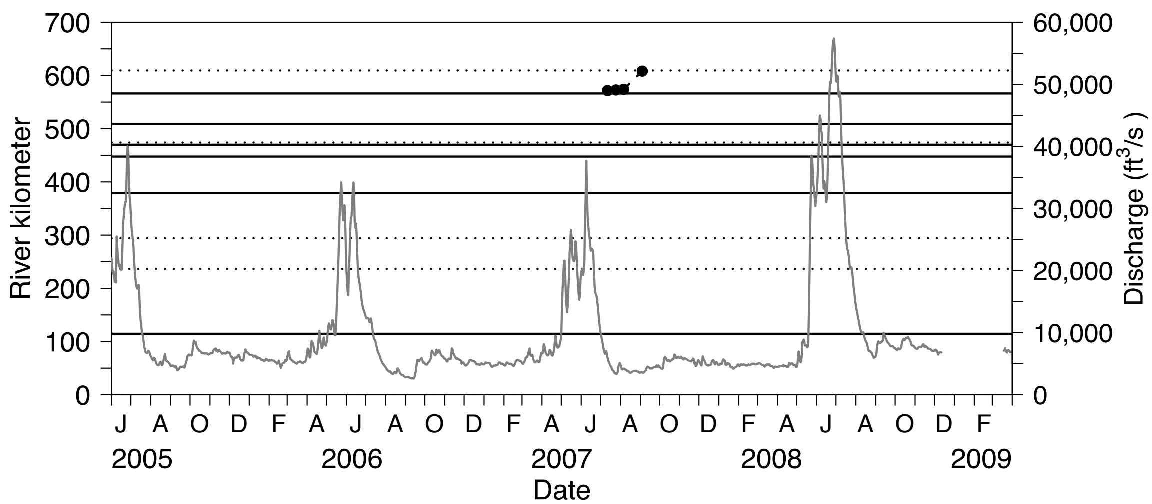

Figure 317. Movements of SPSO #11 (frequency = 480, code = 118, N = 4)

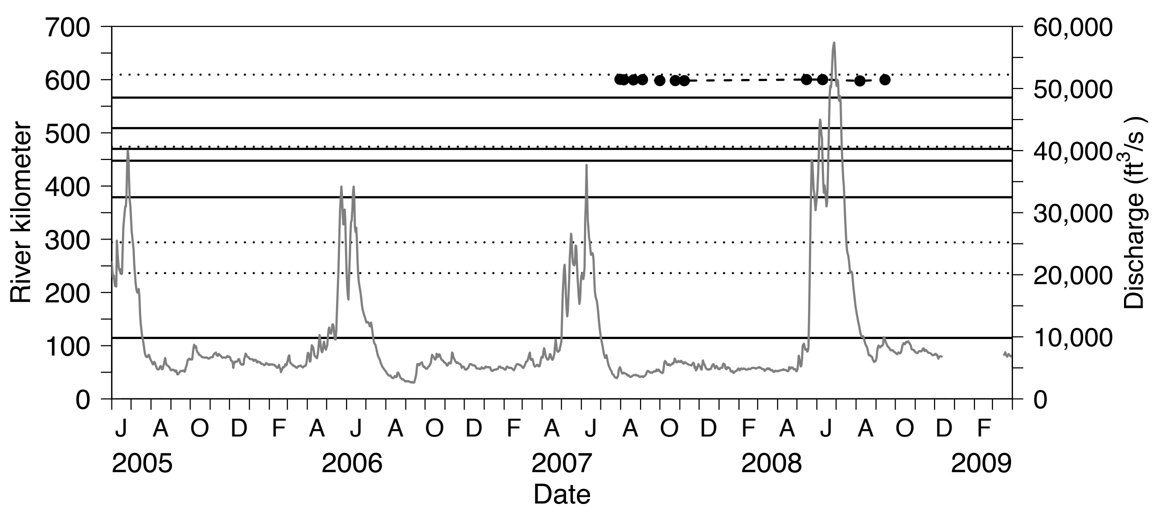

Figure 318. Movements of SPSO #12 (frequency = 480, code = 119, N = 11)

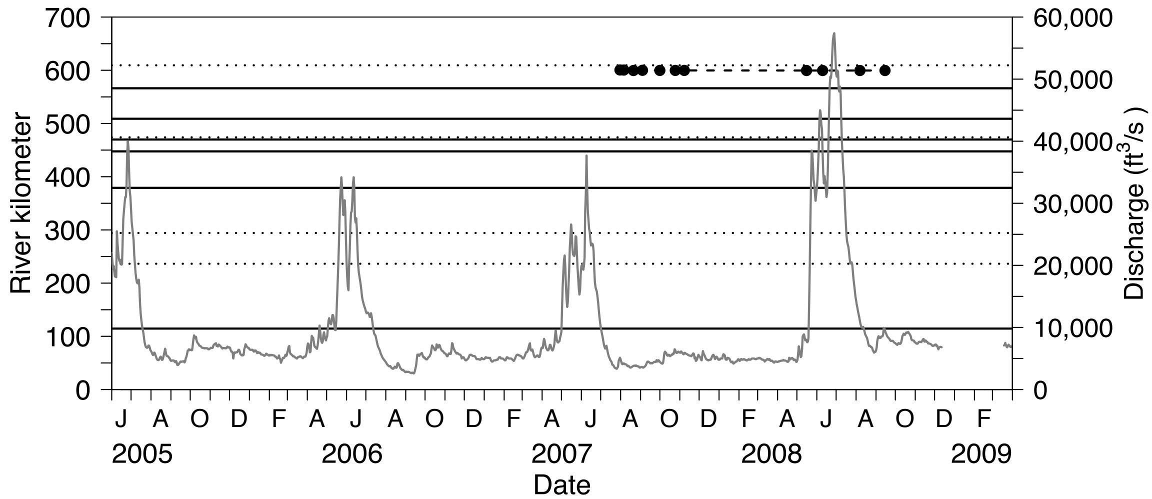

Figure 319. Movements of SPSO #13 (frequency = 480, code = 120, N = 11)

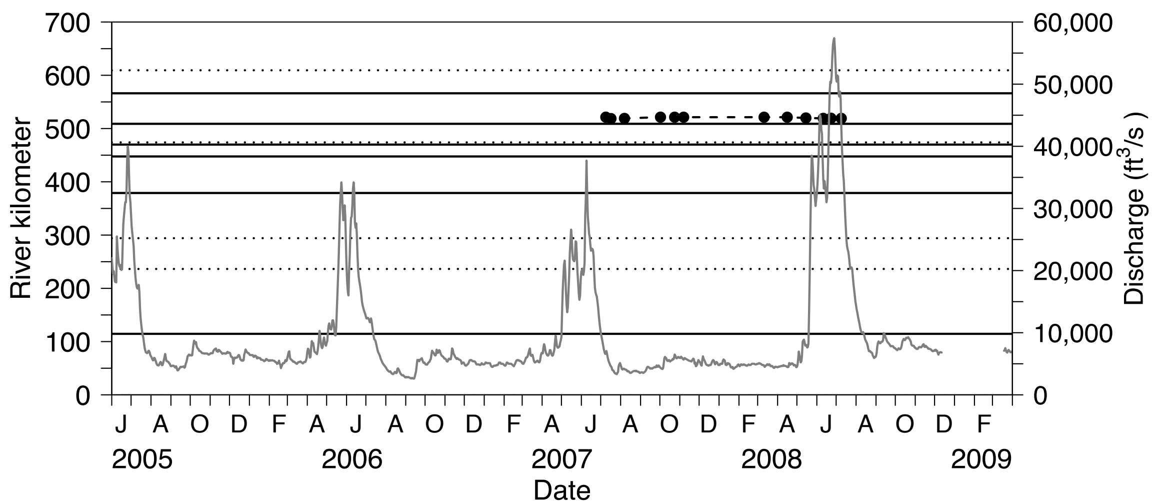

Figure 320. Movements of SPSO #14 (frequency = 480, code = 121, N = 12)

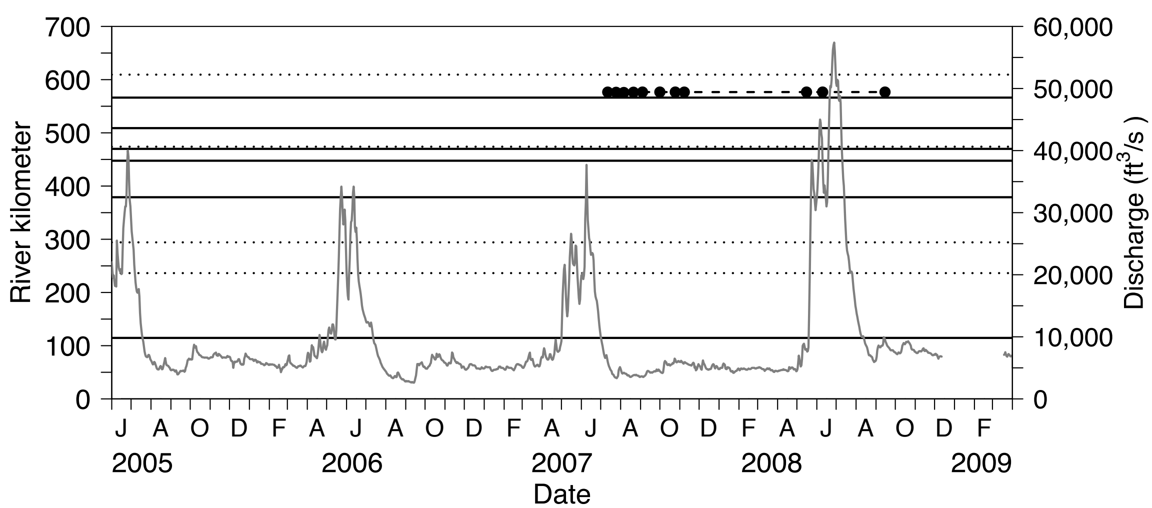

Figure 321. Movements of SPSO #15 (frequency = 480, code = 122, N = 11)

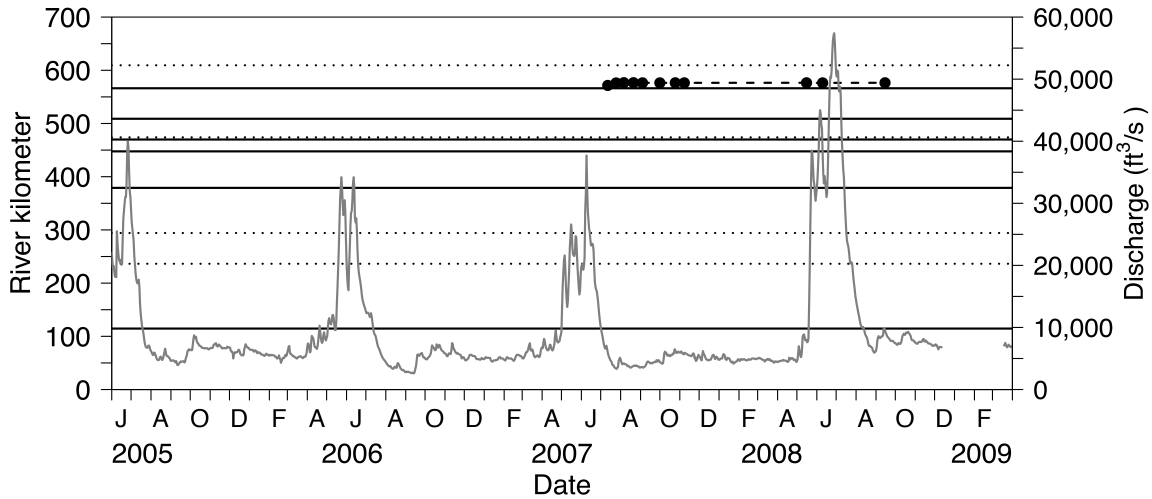

Figure 322. Movements of SPSO #16 (frequency = 480, code = 123, N = 11)

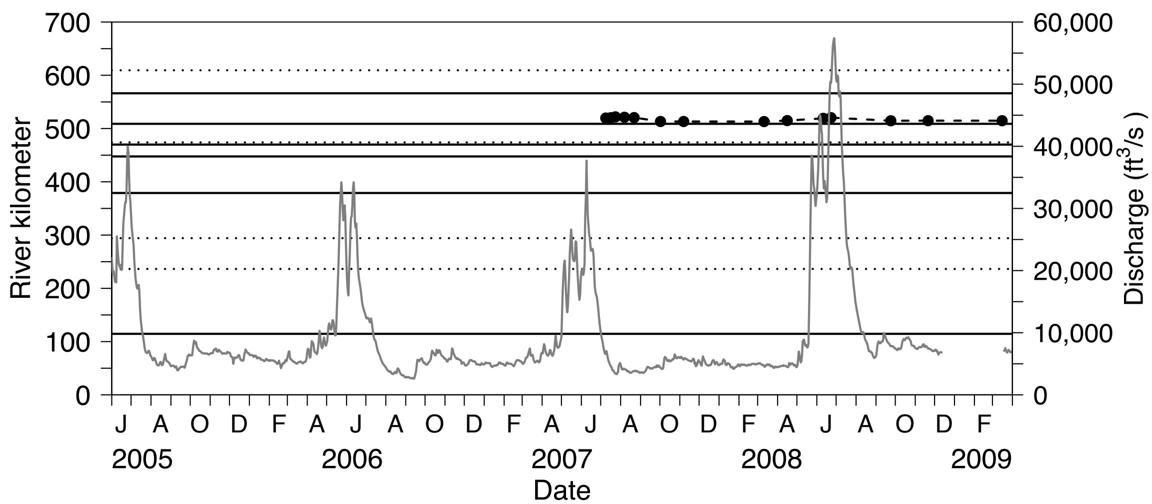

Figure 323. Movements of SPSO #17 (frequency = 480, code = 124, N = 14)

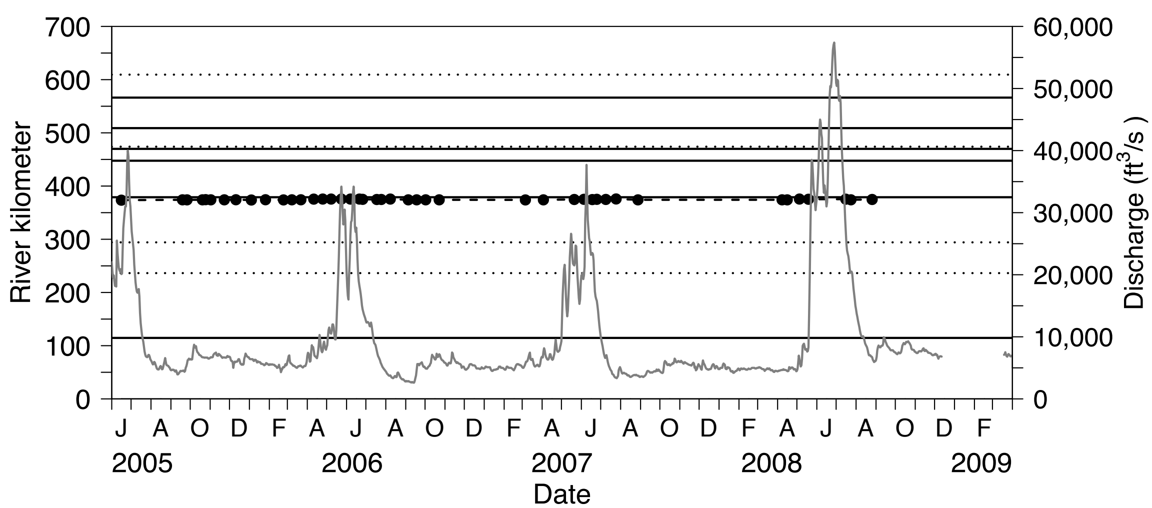

Figure 324. Movements of SPSO #18 (frequency = 420, code = 81, N = 43)

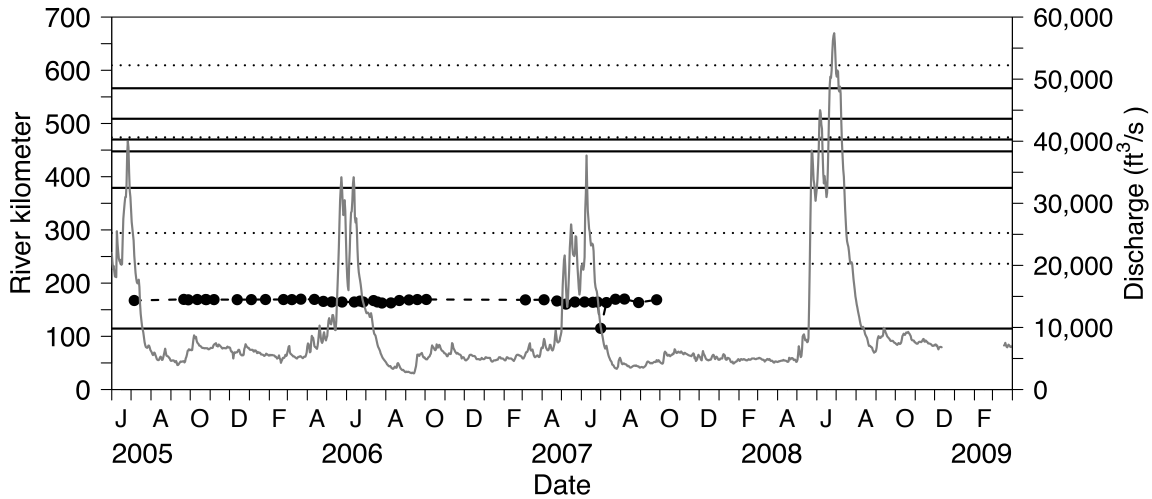

Figure 325. Movements of SPSO #19 (frequency = 420, code = 82, N = 42)

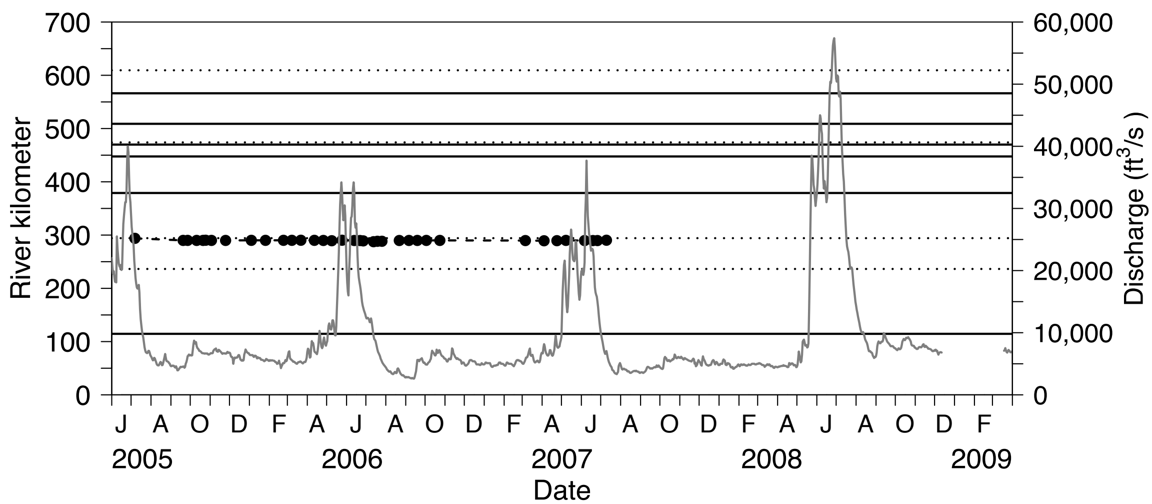

Figure 326. Movements of SPSO #20 (frequency = 420, code = 83, N = 36)

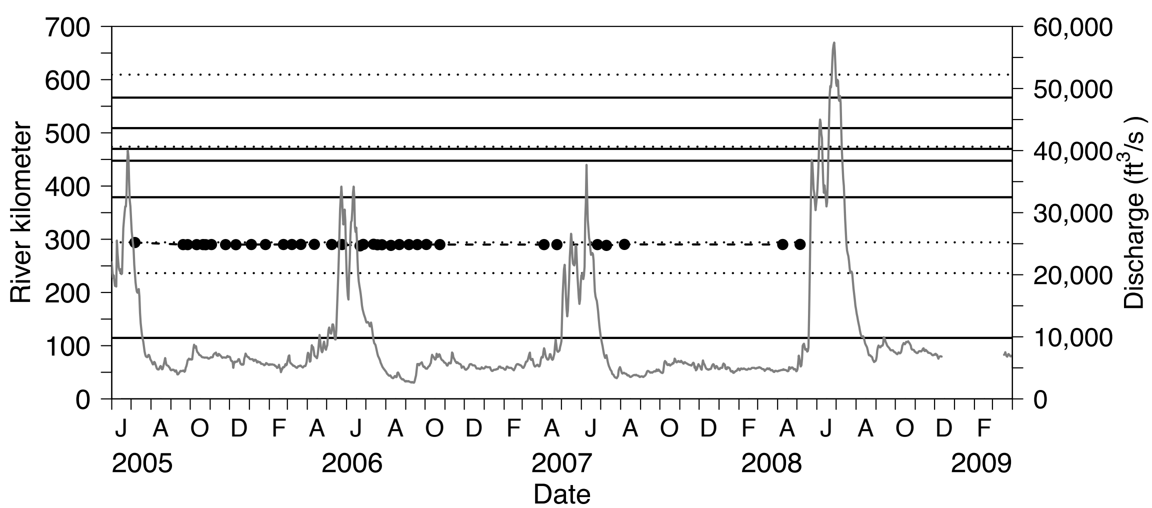

Figure 327. Movements of SPSO #21 (frequency = 420, code = 84, N = 35)

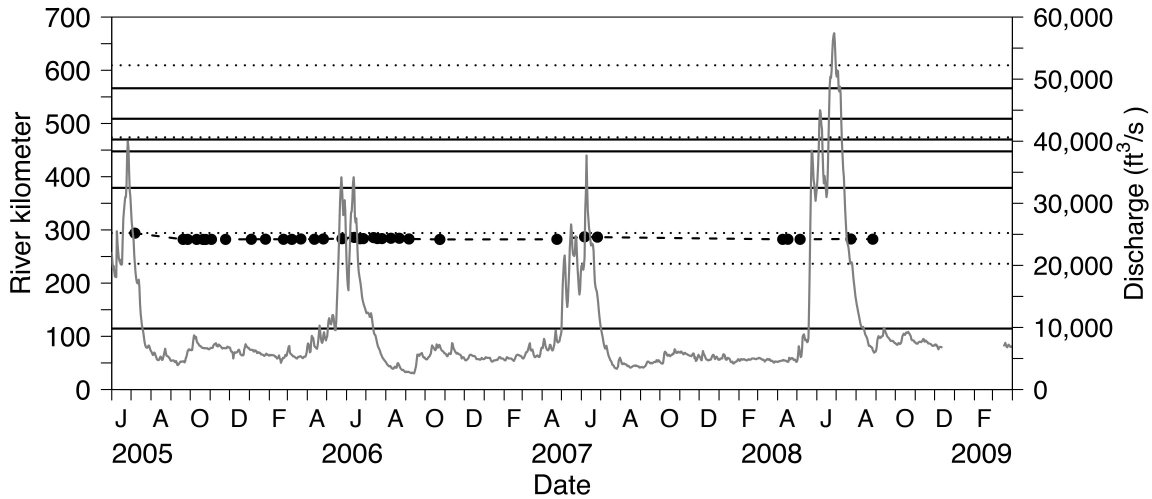

Figure 328. Movements of SPSO #22 (frequency = 420, code = 85, N = 34)

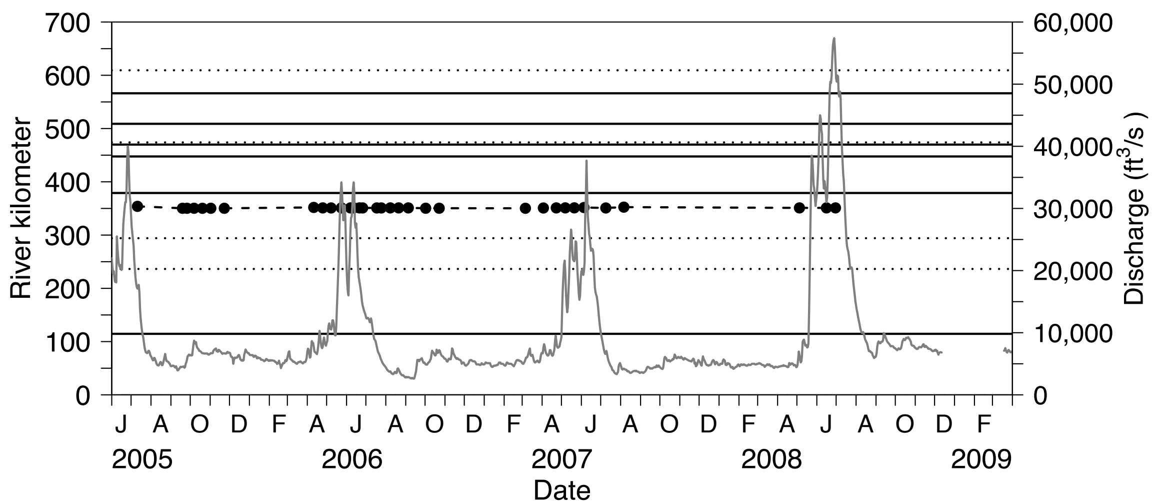

Figure 329. Movements of SPSO #23 (frequency = 420, code = 87, N = 33)

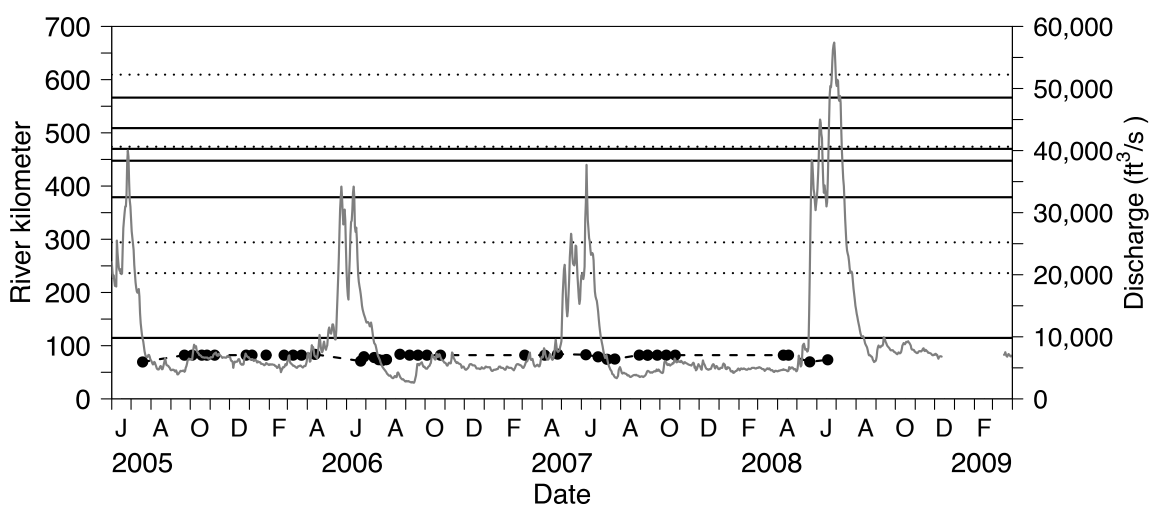

Figure 330. Movements of SPSO #24 (frequency = 420, code = 88, N = 42)

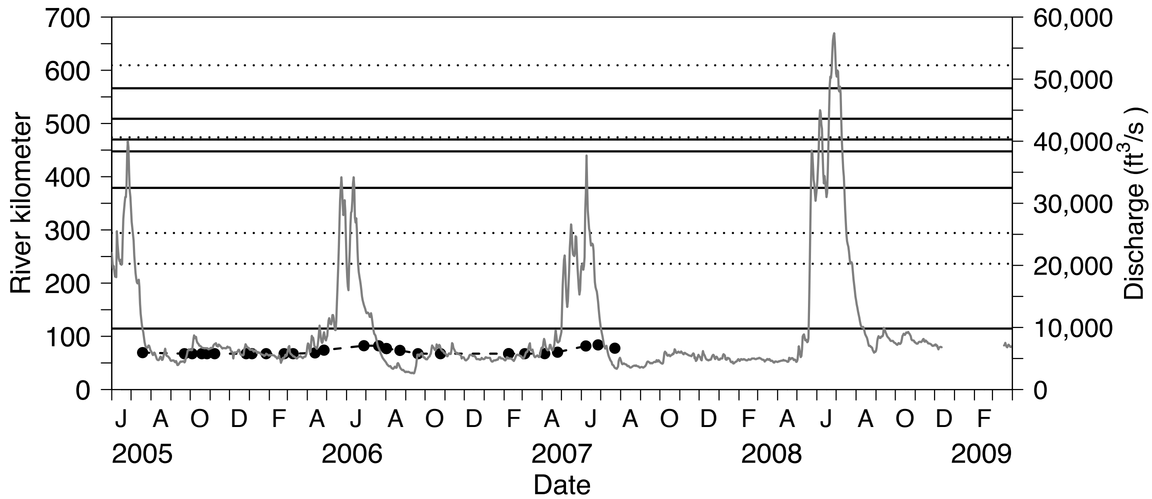

Figure 331. Movements of SPSO #25 (frequency = 420, code = 89, N = 28)

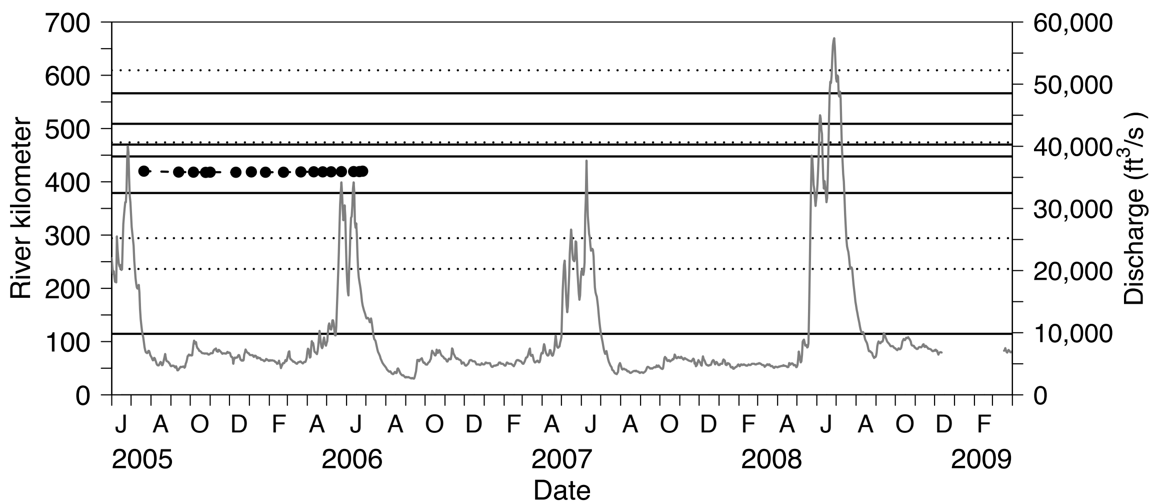

Figure 332. Movements of SPSO #26 (frequency = 420, code = 91, N = 17)

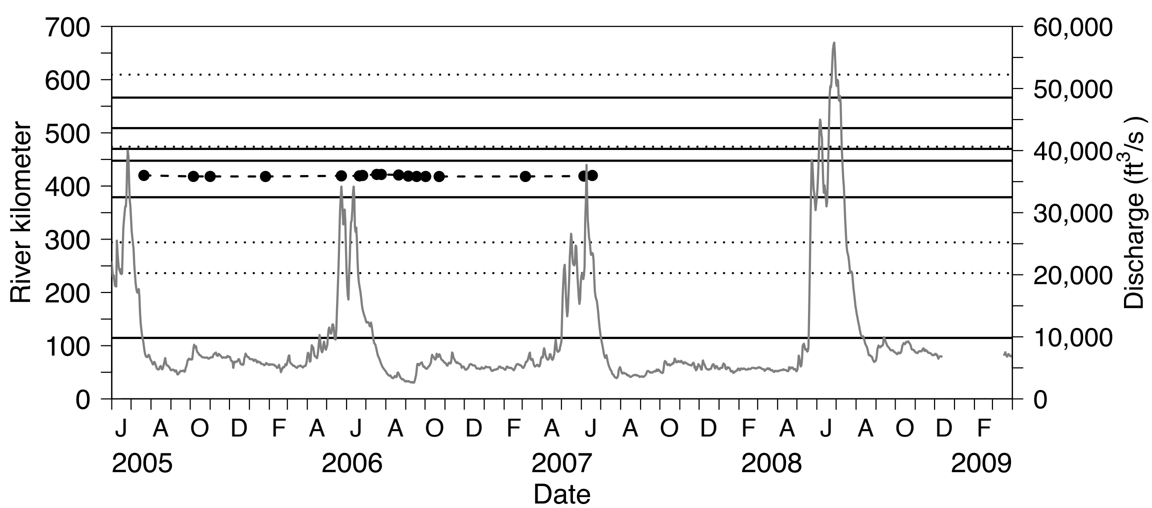

Figure 333. Movements of SPSO #27 (frequency = 420, code = 92, N = 17)

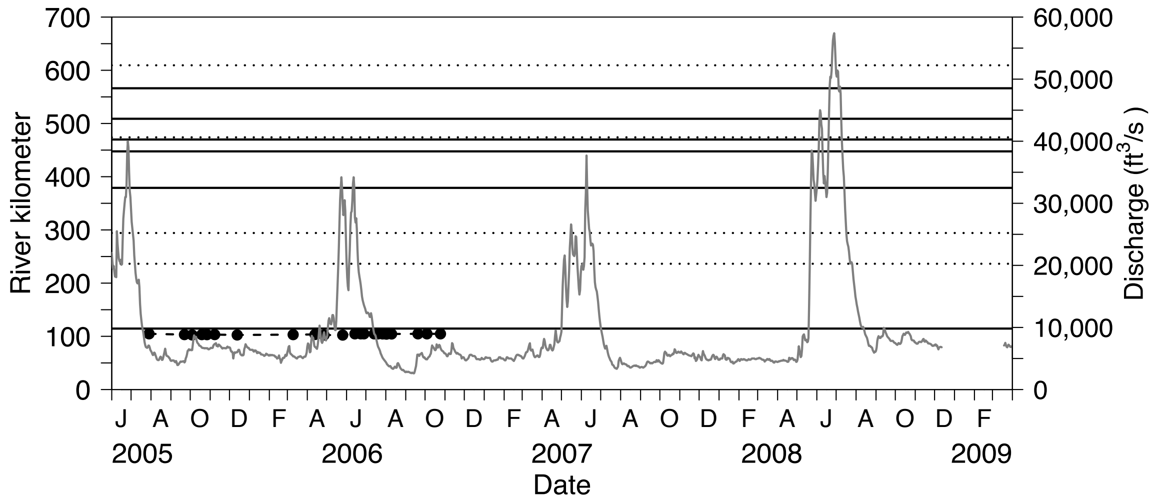

Figure 334. Movements of SPSO #28 (frequency = 420, code = 93, N = 22)

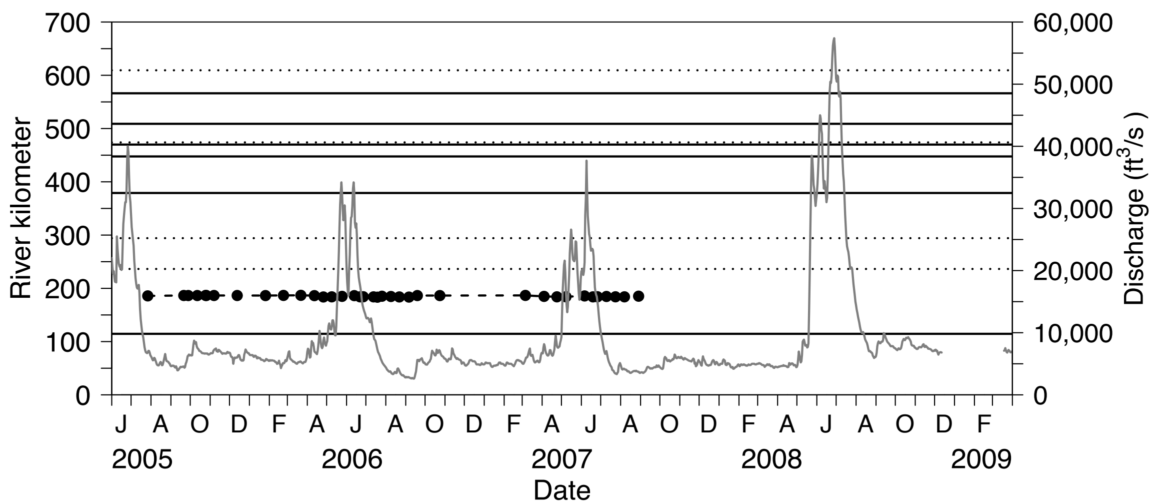

Figure 335. Movements of SPSO #29 (frequency = 420, code = 94, N = 37)

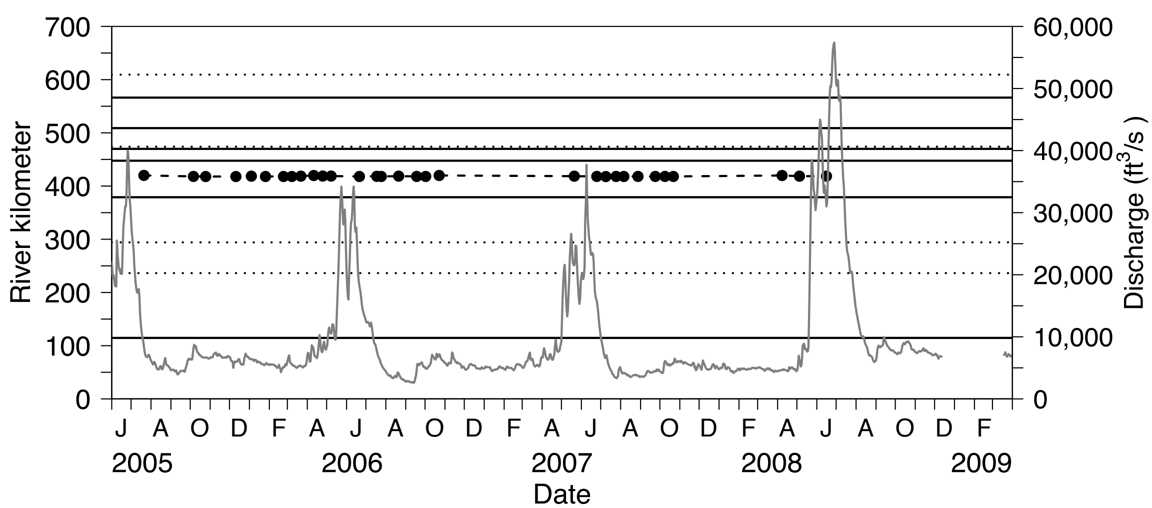

Figure 336. Movements of SPSO #30 (frequency = 420, code = 95, N = 31)

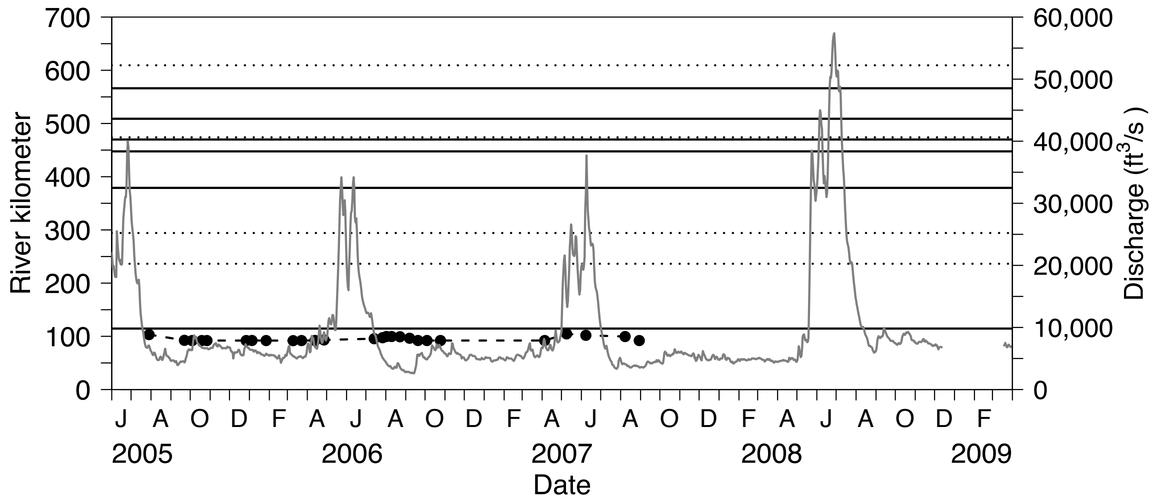

Figure 337. Movements of SPSO #31 (frequency = 420, code = 96, N = 26)

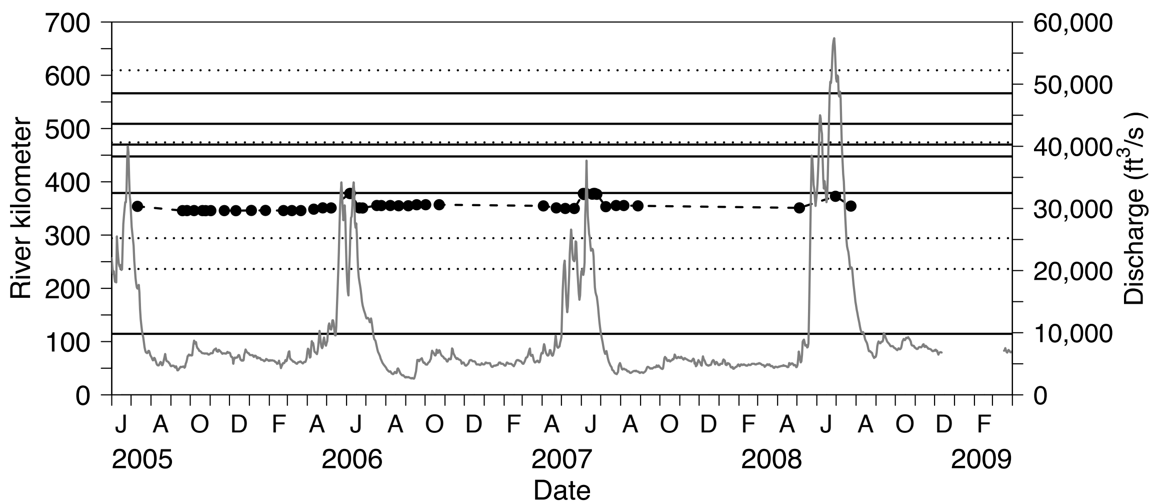

Figure 338. Movements of SPSO #32 (frequency = 420, code = 97, N = 47)

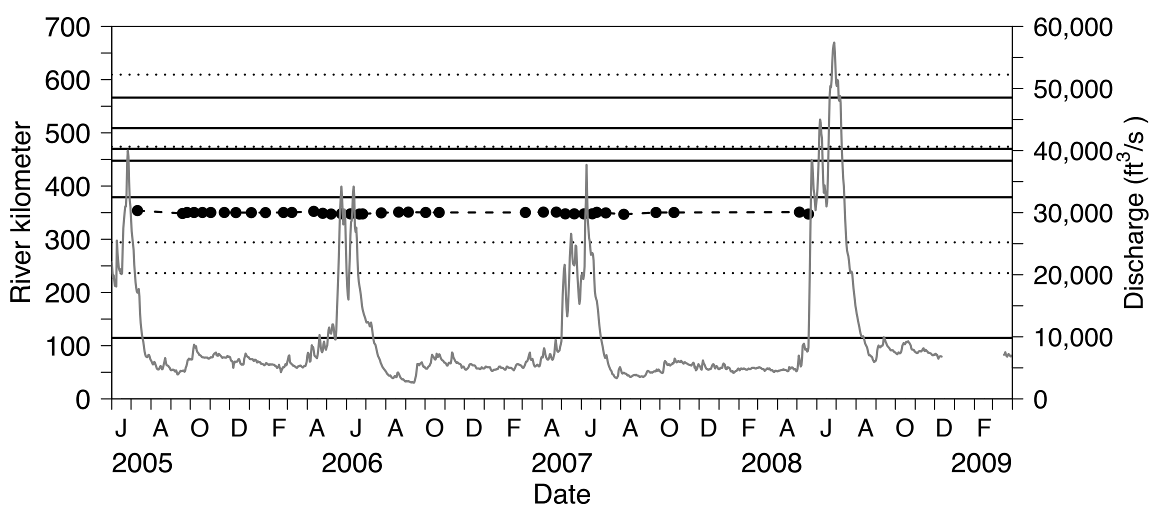

Figure 339. Movements of SPSO #33 (frequency = 420, code = 98, N = 38)

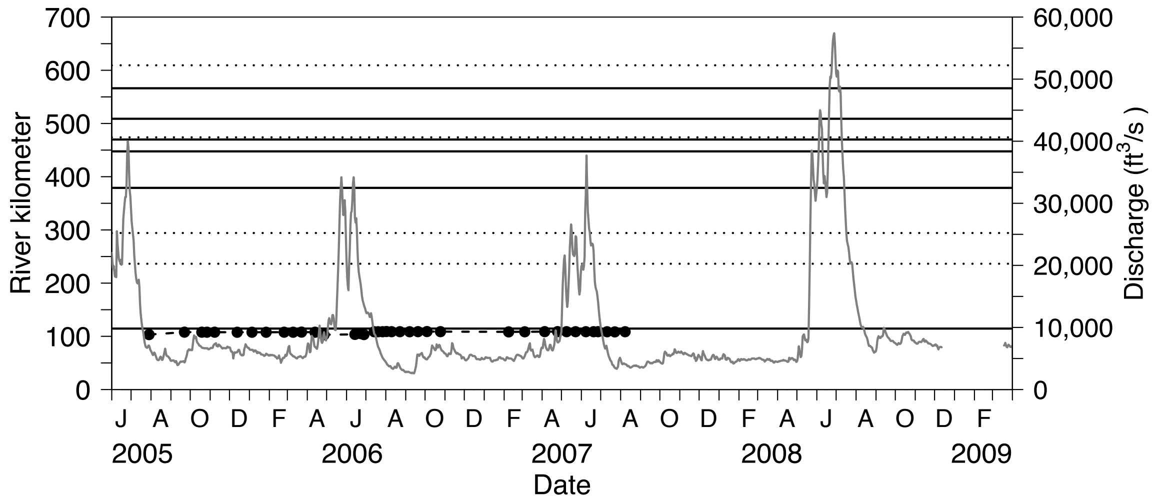

Figure 340. Movements of SPSO #34 (frequency = 420, code = 99, N = 38)

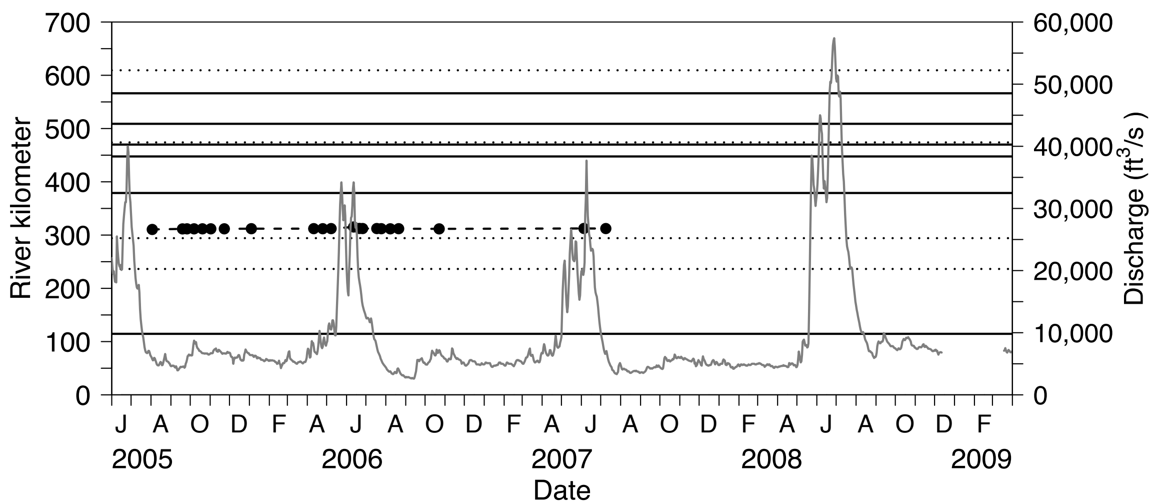

Figure 341. Movements of SPSO #35 (frequency = 420, code = 100, N = 21)

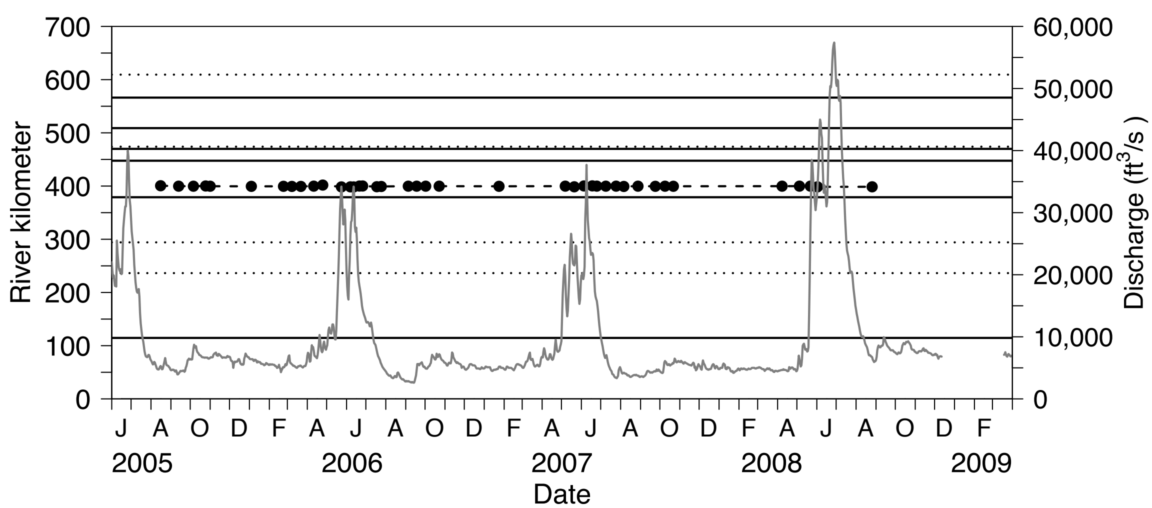

Figure 342. Movements of SPSO #36 (frequency = 480, code = 81, N = 40)

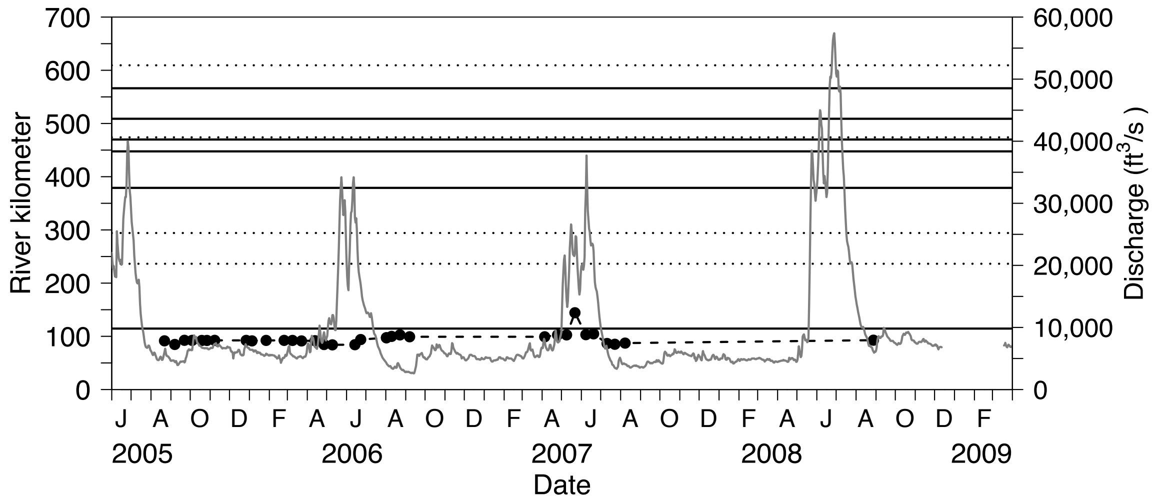

Figure 343. Movements of SPSO #37 (frequency = 480, code = 82, N = 33)

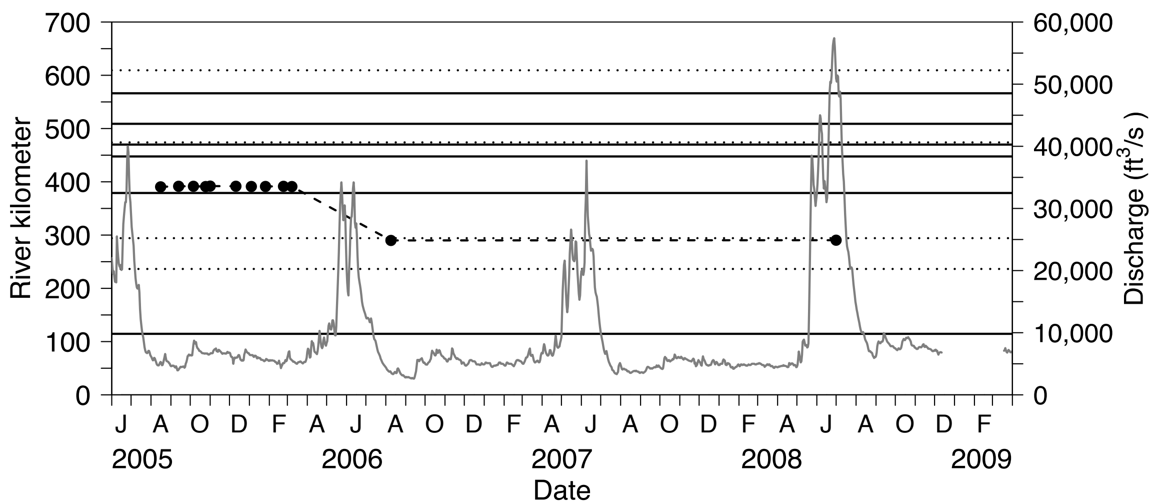

Figure 344. Movements of SPSO #38 (frequency = 480, code = 83, N = 12)

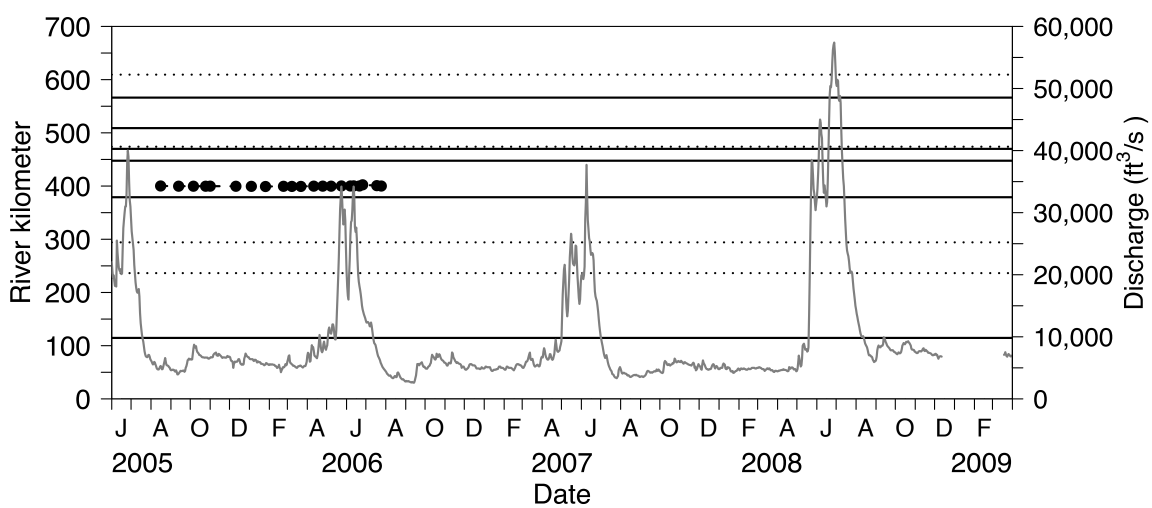

Figure 345. Movements of SPSO #39 (frequency = 480, code = 84, N = 21)

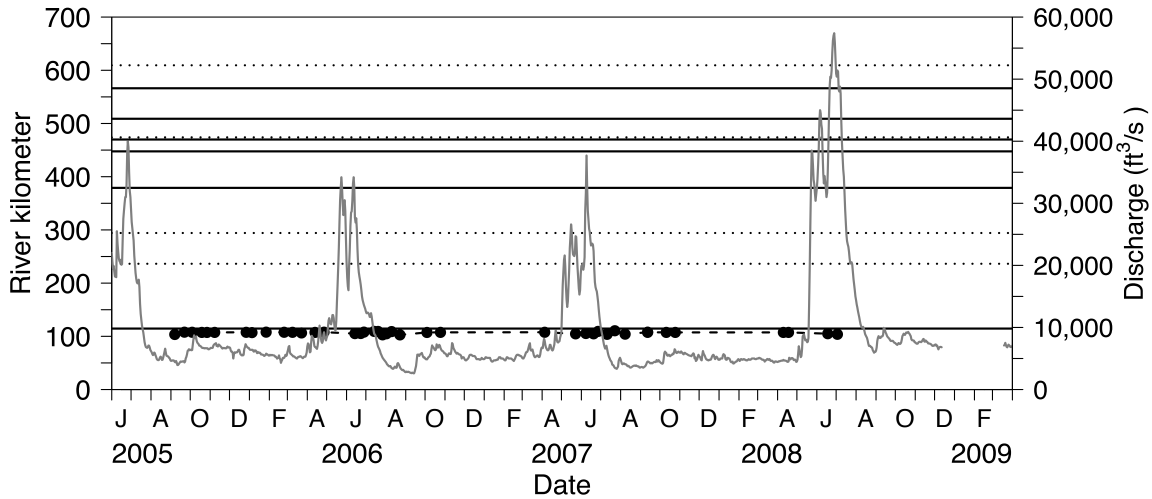

Figure 346. Movements of SPSO #40 (frequency = 480, code = 85, N = 41)

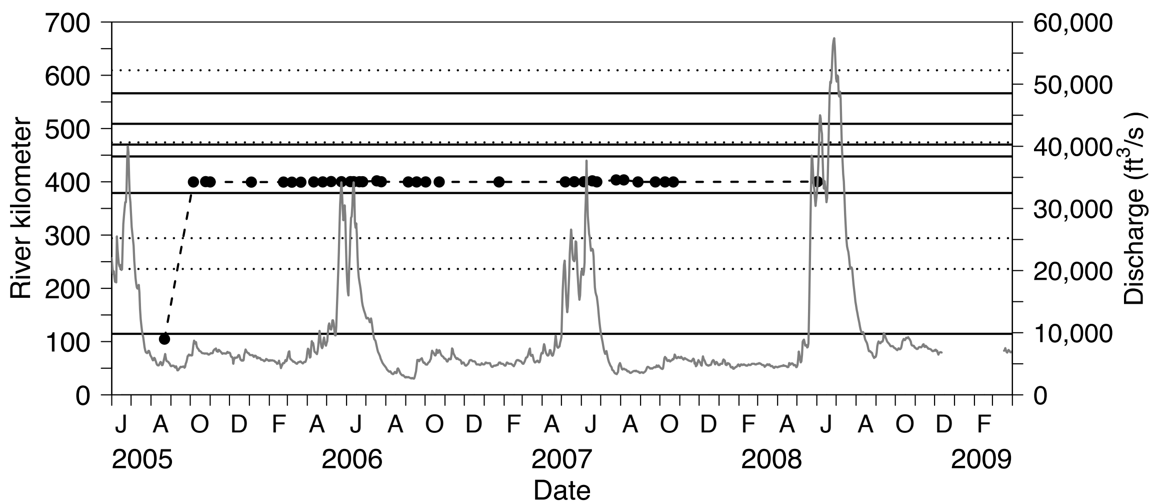

Figure 347. Movements of SPSO #41 (frequency = 480, code = 86, N = 35)

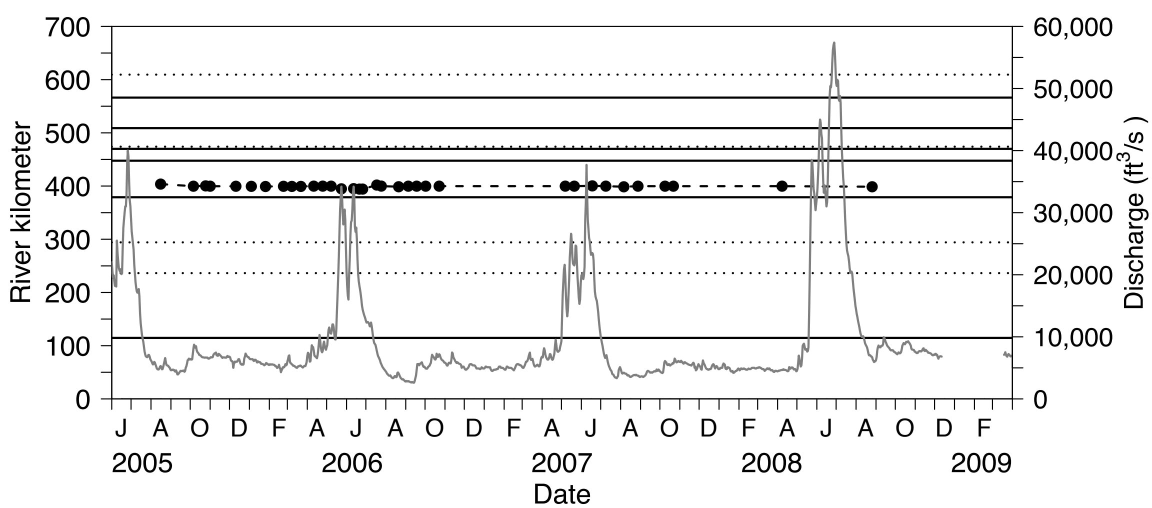

Figure 348. Movements of SPSO #42 (frequency = 480, code = 87, N = 34)

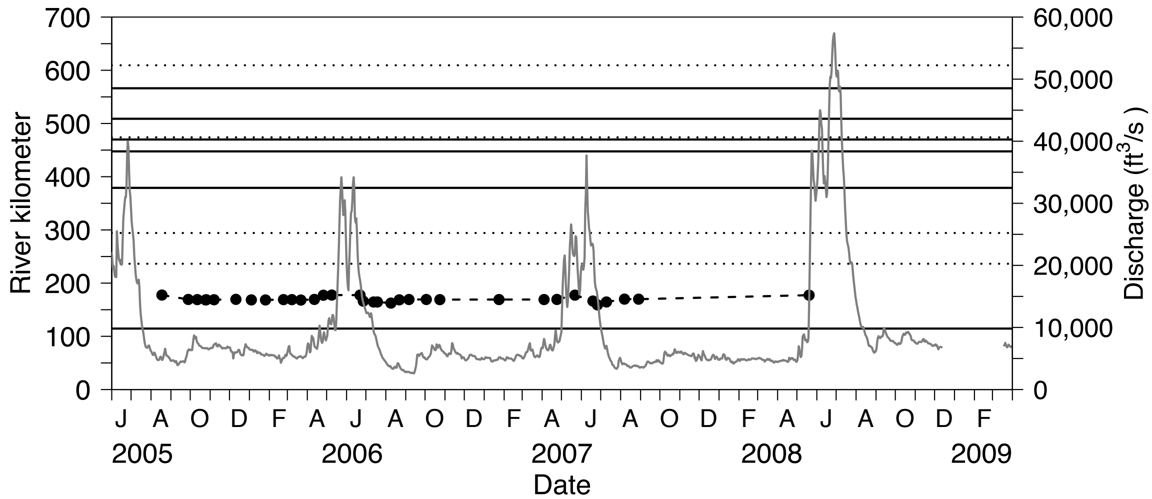

Figure 349. Movements of SPSO #43 (frequency = 480, code = 88, N = 34)

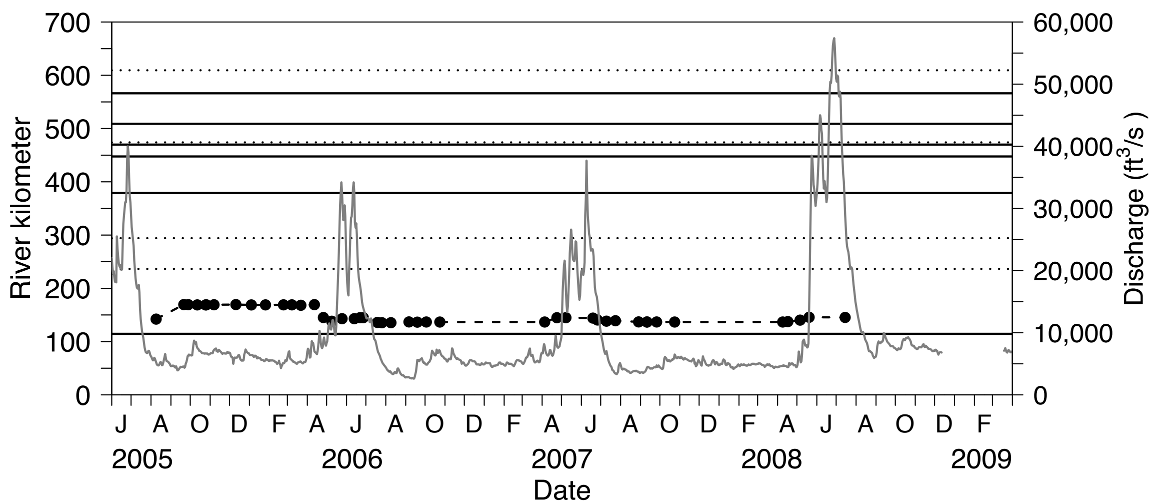

Figure 350. Movements of SPSO #44 (frequency = 480, code = 89, N = 44)

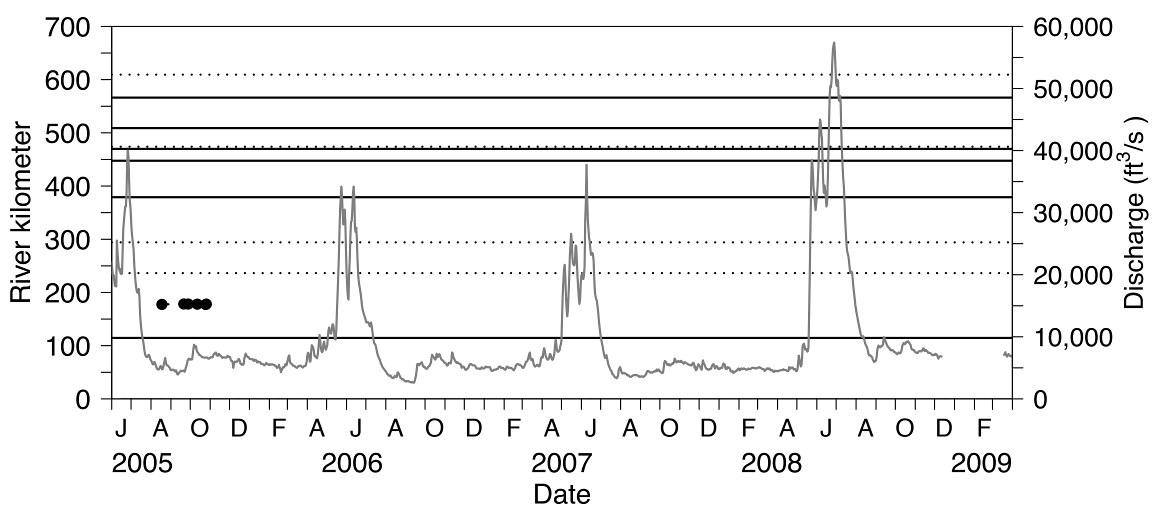

Figure 351. Movements of SPSO #45 (frequency = 480, code = 90, N = 6)

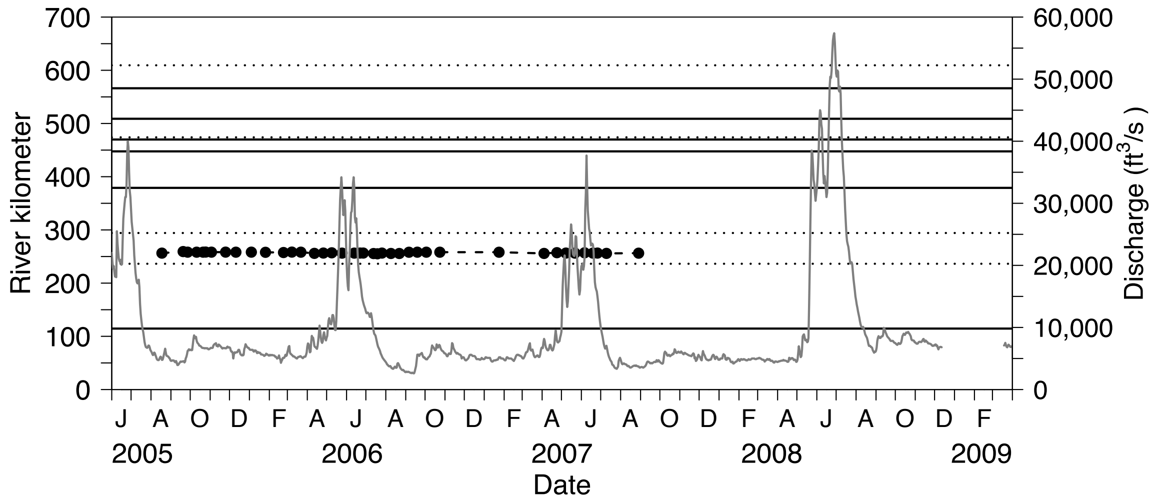

Figure 352. Movements of SPSO #46 (frequency = 480, code = 91, N = 40)

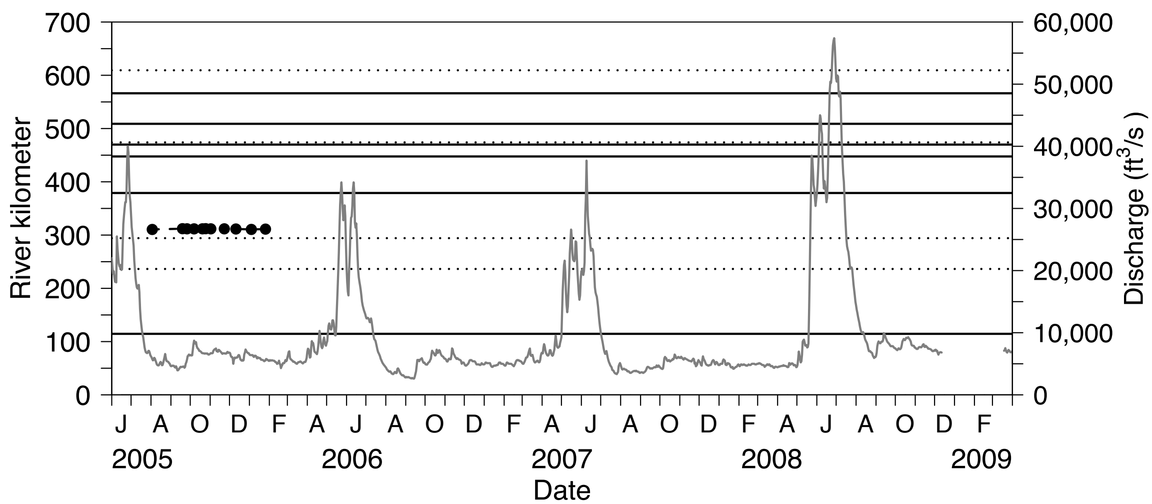

Figure 353. Movements of SPSO #47 (frequency = 480, code = 92, N = 11)

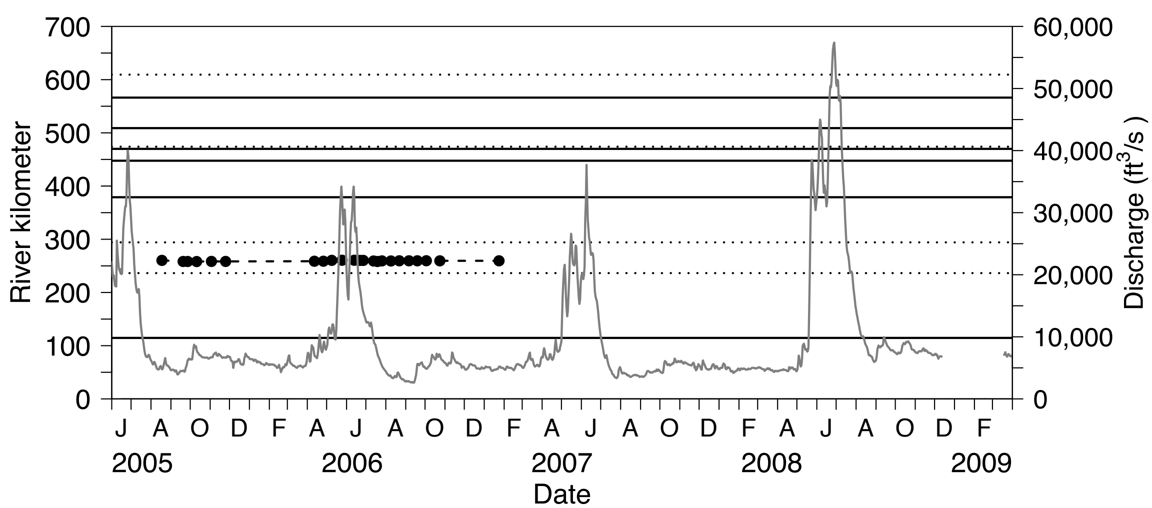

Figure 354. Movements of SPSO #48 (frequency = 480, code = 93, N = 23)

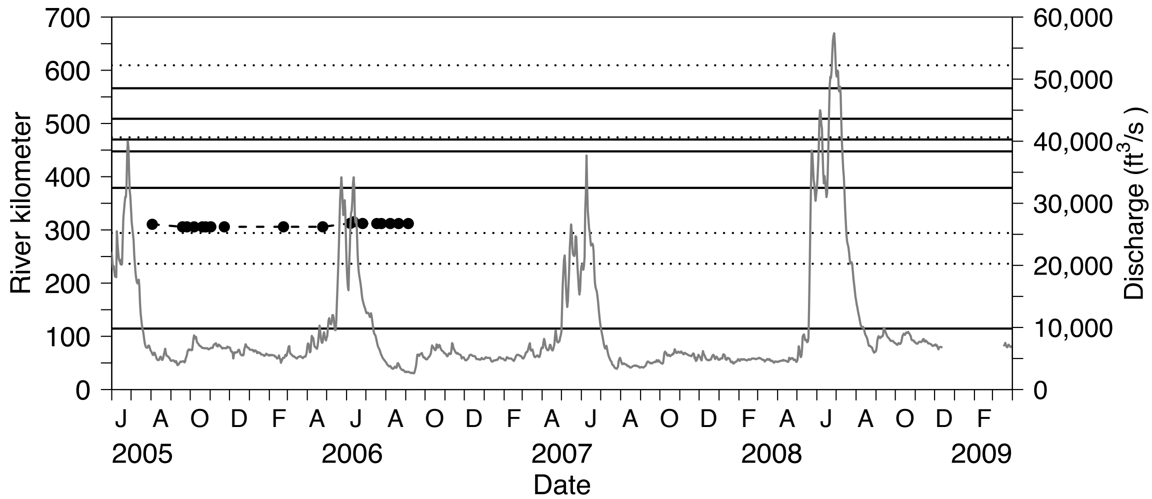

Figure 355. Movements of SPSO #49 (frequency = 480, code = 94, N = 18)

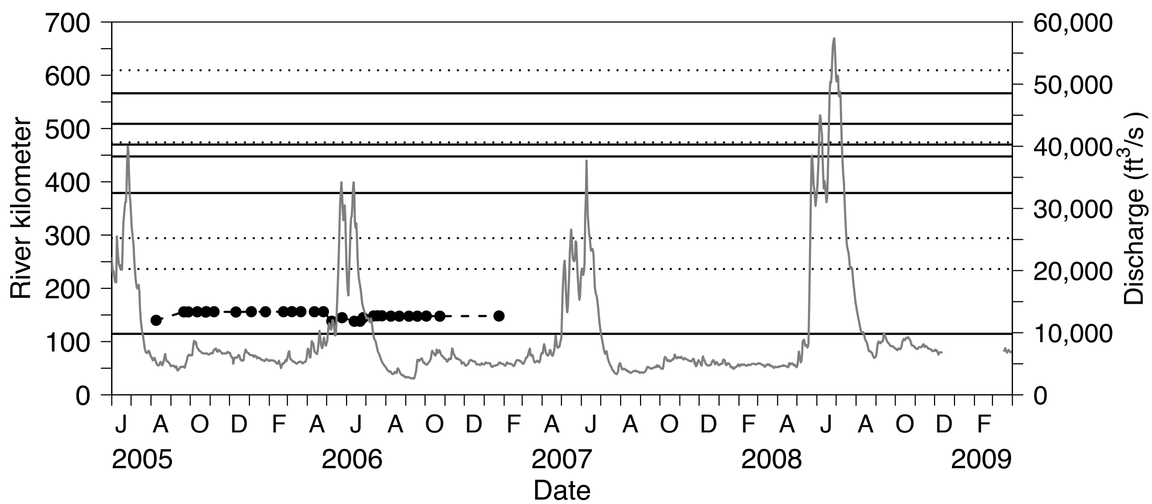

Figure 356. Movements of SPSO #50 (frequency = 480, code = 95, N = 30)

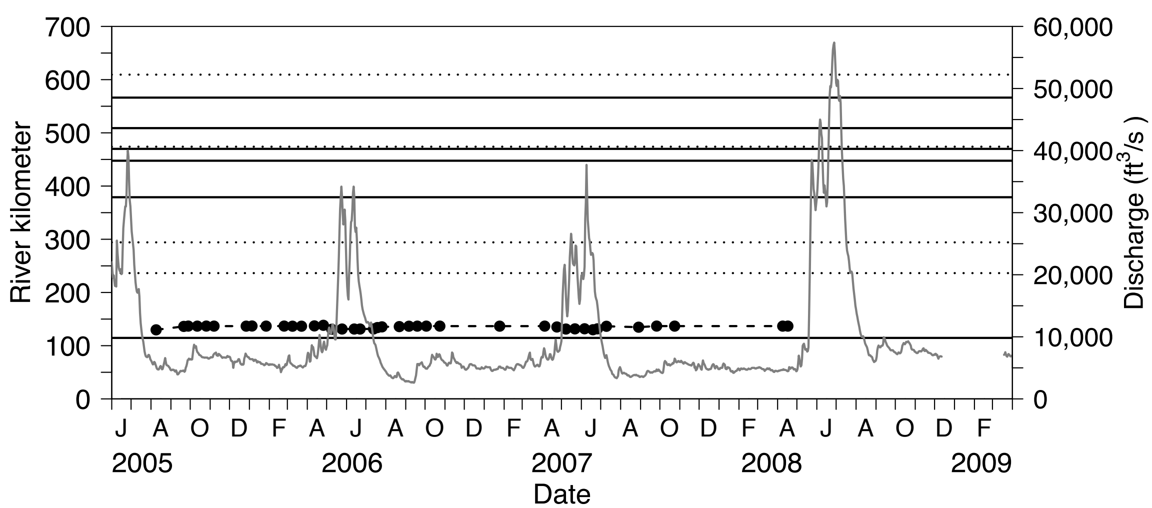

Figure 357. Movements of SPSO #51 (frequency = 480, code = 96, N = 40)

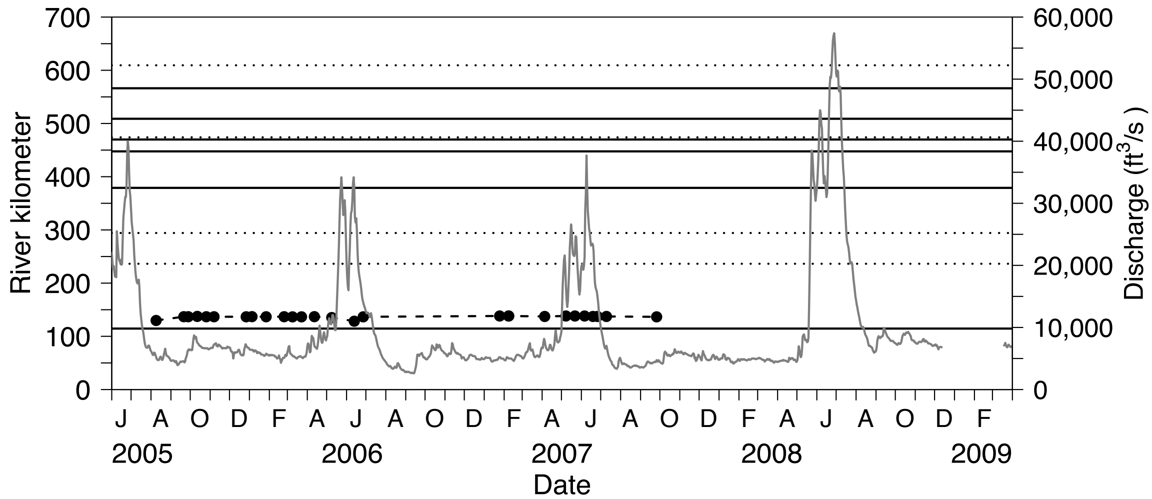

Figure 358. Movements of SPSO #52 (frequency = 480, code = 97, N = 27)

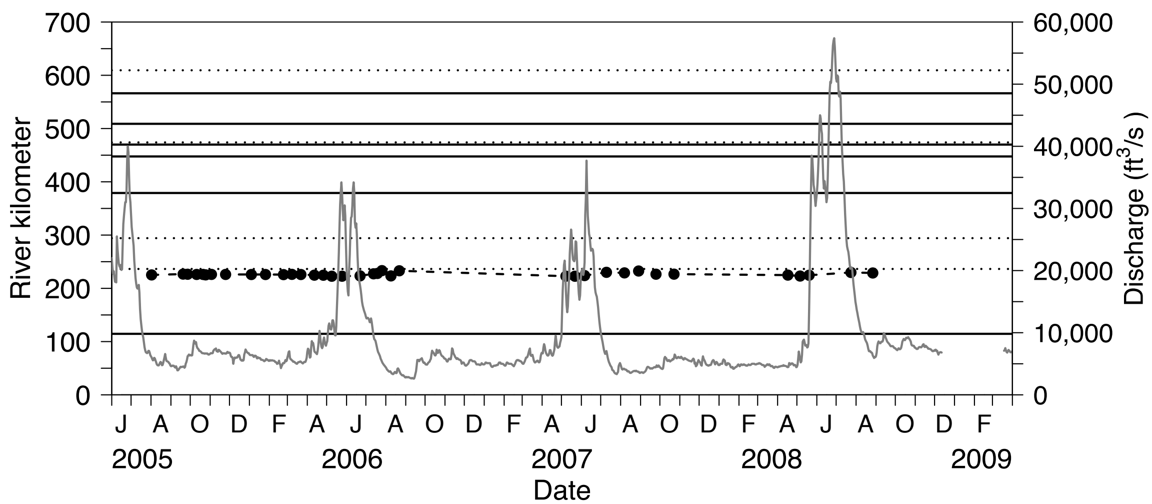

Figure 359. Movements of SPSO #53 (frequency = 480, code = 98, N = 36)

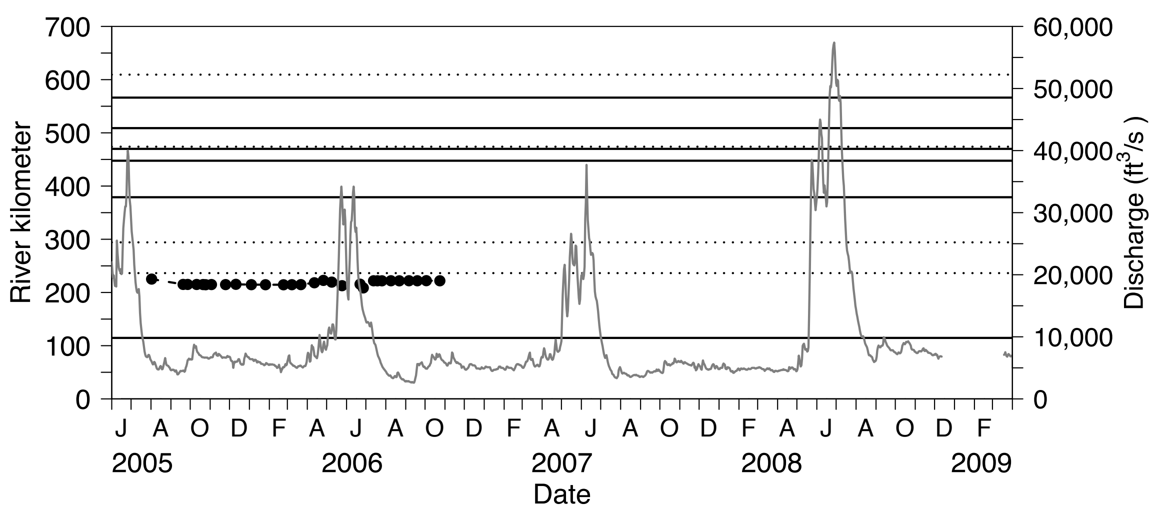

Figure 360. Movements of SPSO #54 (frequency = 480, code = 99, N = 29)