FINAL TECHNICAL REPORT

Klamath Hydroelectric Project
(FERC Project No. 2082)

Description of Migratory Behavior of Juvenile Salmon Smolts Through California Reservoirs Using Radio-Telemetry Techniques in the Klamath Basin

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1.1 Description and Purpose

PacifiCorp initiated this study to explore the feasibility of reintroducing anadromous salmonids (*Oncorhynchus sp.*) to areas within the Klamath Hydroelectric Project (Project). The development and execution of this study was part of the Federal Energy Regulatory Commission (FERC) relicensing process for the Project which includes environmental studies that assist in determining measures that may be necessary to further protect and enhance resources in the Project area. One of the issues facing anadromous salmon is whether juvenile salmonids will successfully migrate through Project reservoirs.

The purpose of this study is to observe the response of juvenile anadromous fish as they migrate through the Project's two lowermost reservoirs. The Aquatics Working Group (AWG) is engaged in a variety of activities to assess the efficacy of reintroducing anadromous salmonids upstream of Iron Gate dam. An integral part of that assessment is the habitat modeling analysis that requires input describing smolt migratory dynamics and migration success past PacifiCorp hydroelectric developments. A subcommittee is exploring options for providing fish passage at those dams. However, at this time the migratory behavior and characteristics as well as the migration success of juvenile migrants through the hydroelectric system are unknown. A major concern is the ability of smolts to efficiently navigate through each Project reservoir. Also, both the Ecosystem Diagnosis and Treatment (EDT) model analyses and the design of smolt bypass/collection systems require migratory information in order to properly conduct these tasks. Therefore, the purpose of this study is to provide that foundation information for two anadromous species, coho (*O. kisutch*) and fall Chinook salmon (*O. tshawytscha*).

1.2 Study Objectives

The objective of this study is to describe the migratory behavior of radio-tagged juvenile coho and fall Chinook within PacifiCorp's Copco and Iron Gate reservoirs. The migratory behavior of radio-tagged juveniles within each reservoir will be described by migration success, documenting travel times, migration rates, and arrival distribution at the dam. In addition mobile surveys will help document the dispersal and general movement patterns of fish through each reservoir.

1.3 Relicensing Relevance and Use in Decision Making

The Klamath Hydroelectric Project (FERC No. 2082) is owned and operated by PacifiCorp under a license issued in 1956 by the Federal Energy Regulatory Commission. The existing FERC license for the Project expires on March 1, 2006. As part of relicensing the Project, environmental studies are conducted to describe existing conditions and to assist in determining measures that may be necessary to further protect and enhance resources associated with the Project.

The focus of this study is on the spring migratory phases (outmigration) of juvenile Chinook and coho salmon. As discussed herein, hatchery fish were used to evaluate migration behavior under conditions that are typical with water management strategies and dam operations currently in place. Some of these aspects may be considered limitations. However, at this juncture hatchery fish are the predominant stocks that must function under prevailing contemporary water management scenarios. Observations from this study may provide the basic information to determine whether the downstream migrant life stages can effectively navigate the reservoirs. Certainly, not all necessary information may be gathered from this evaluation. However, by using this year's results the AWG will have site-specific information to include in the fish passage models. Juvenile salmonid behavior and success through the JC Boyle and Keno reservoirs in the Oregon portion of the Klamath River and Upper Klamath Lake proper have not been evaluated in this study.

1.4 Study Area

1.4.1 Environmental Setting

The Klamath River basin is located in northern California and south-central Oregon and has a drainage area of about 12,100 mi^2. The Klamath River watershed begins in the headwaters of the Wood, Williamson and Sprague rivers of Oregon and flows from the outlet of Upper Klamath Lake about 255 river miles southwest to the Pacific Ocean (Figure 1). Annual runoff measured at the mouth is about 13 X 10^6 acre-feet. The upper watershed above Iron Gate dam comprises about 38% of the total watershed but only contributes about 12% of the annual runoff (National Research Council 2004). Runoff in the lower basin is dominated by the Scott, Salmon, Shasta and Trinity rivers that drain the coast range, Trinity Alps, and the Marble, Salmon and Russian mountains. Unlike most basins, the Klamath River watershed has its greatest relief and topographic complexity in the lower basin rather than its headwaters. The Klamath basin has several major lakes in the upper basin including Upper Klamath Lake, Lower Klamath Lake, Tule Lake, Clear Lake and Gerber Reservoir (National Research Council 2004).

Figure 1. Map of Klamath River basin showing major rivers and lakes within the watershed (From NRC 2004).

1.4.2 Project Descriptions

There are six main-stem dams on the Klamath River. In order going upstream the developments are; Iron Gate, Copco No. 2, Copco No. 1, J.C. Boyle, Keno and Link River dams. The geographic scope of this study was the Klamath River upstream of Iron Gate dam to the head of Copco reservoir (Figure 2). The following development descriptions were summarized from details contained in PacifiCorp (2002 and 2003) and FishPro (2000) on Iron Gate, Copco No. 1 and Copco No. 2 facilities.

Iron Gate dam is located at RM 190.1 on the Klamath River and is the most downstream hydroelectric facility on the Klamath River. The Iron Gate facility is used for power generation, storage and reregulation of Klamath River flows. The rock-fill earthen dam was completed in 1962 and is 173 feet high. Presently, there are no fish passage facilities at this dam. The original construction of the facility included the Iron Gate fish hatchery and a fish ladder at the base of the dam that serves as an adult collection and holding facility for hatchery broodstock.

The powerhouse is located on the left bank at the base of the dam and contains a single vertical Francis unit capable of providing 18 megawatts at a flow of 1550 cfs. The unit has a hydraulic capacity of 1,735 cfs. The power house has an intake tower that draws water from the reservoir at a depth of about 35 ft (2293 ft msl) below normal full pool (2,328 ft msl). The intake is equipped with a trash rack 17.5 ft by 45.0 ft with 4 in bar spacing. A second tower serves as an emergency water release during high flow events and can pass about 5,000 cfs. Iron Gate dam is equipped with a side spillway channel on the right bank that is 727 feet long and runs perpendicular to the dam. The spill crest elevation is 2,328 ft msl. The reservoir formed by Iron Gate dam is about 6.8 miles long and has a surface area of 944 acres with a total storage capacity of 58,794 acre-feet. Normal pool elevation in Iron Gate reservoir ranges from 2,324 ft msl to 2,328 ft msl.

Construction of Copco No. 2 facility was completed in 1925 and consists of a dam located at RM 198.3 and about a mile long system of tunnels, pipes and steel penstocks that divert water to the powerhouse located at RM 196.9. The main purpose of the development is to generate power, and it typically operates as a load-following facility. Presently, there are no fish passage facilities at the dam. The dam has a total length of 278 feet with a concrete structure that supports the powerhouse intake, bypass flume, and spillway near the left bank and an earthen wing located on the right bank. The spillway is comprised of five Tainter gates that can release water into the bypass section of the Klamath River. Located between the powerhouse intake and spillway is a flume that directs approximately 10 cfs to maintain water flow in the bypass section of the river. The powerhouse intake is located on the left bank of the dam and is equipped with an angled trash rack about 50 feet wide and 32 feet high. Water is conveyed from this point approximately one mile to the powerhouse. The powerhouse consists of two vertical-shaft Francis units rated at 27 megawatts at 2,535 cfs. Copco No. 2 reservoir extends 0.3 miles upstream to the base of Copco No. 1 dam. Normal full pool elevation is 2,483 ft-msl with a maximum depth of 28 feet at the intake structure. The reservoir has a surface area of 40 acres and a storage capacity of 73.5 acre-feet.

Construction of Copco No. 1 dam was completed in 1918 and is located at RM 198.6 on the Klamath River. The main function of the facility is power generation, and like Copco No. 2, it typically operates as a load-following plant. There are no fish passage facilities at the dam. Copco No. 1 dam is a concrete gravity arch dam. The dam's spillway is located on the left bank and has 13 spillbays each equipped with a 14 ft wide Tainter gate. The intake structure is located on the right bank with four intakes for unit 1 and two intakes for unit 2. Each pair of intake pipes for unit 1 join together forming two 10-foot diameter penstocks. Unit 2 intakes join to form a single 14-foot diameter penstock. The controlling invert elevation of the operable power conduits is at an elevation of 2,575 msl. The depth of the intakes ranges from 26 to 31 feet below the normal pool elevation. The powerhouse is equipped with two double runner horizontal Francis turbine units that have a total nameplate rating of 20 megawatts at 2,360 cfs. The reservoir created by the dam is about 4.5 miles long and has surface area of 1,000-acres and a total storage capacity of 45,390 acre-feet. The reservoir pool elevation ranges 6 feet and typically varies from 2,601 to 2,607.5 ft. msl.

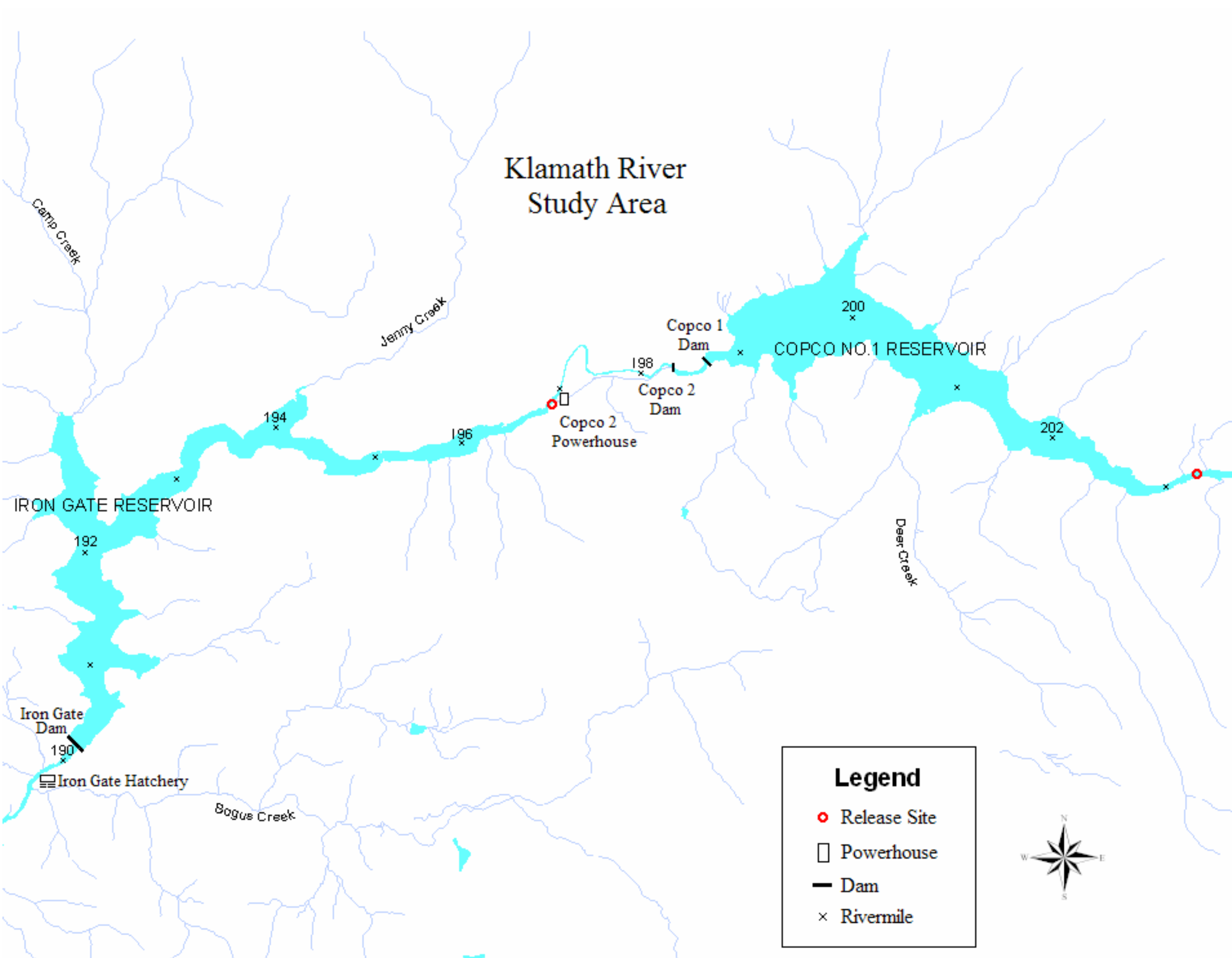


Figure 2. Klamath River study area displaying the location of hydroelectric facilities, Iron Gate fish hatchery and release sites.

1.5 Methods

1.5.1 Site Reconnaissance and Noise Evaluation

Previous to the 2003 trout movement study (Miller et al. 2003), researchers monitored ambient background electrical noise that is inherent at most Project facilities. The data was used to select appropriate channel/code combinations for use in the study that did not coincide with ambient background noise at each Project development or interfere with other ongoing telemetry studies. This work helped minimize the potential risk of reducing the detection efficiency for telemetry systems, and expedite data analysis.

Field reconnaissance facilitated the design and deployment of telemetry systems at dams, and locating tagging and release sites prior to initiating the study. The following sections detail the telemetry design, fish handling and other methods used during this study.

1.5.2 Telemetry System Design

The telemetry systems used in this study were designed to detect radio-tagged smolts that entered the forebay and downstream from the tailrace of each facility. The fixed station telemetry systems deployed in the forebay of each dam was usually a combination of aerial and underwater antennas. The aerial and underwater antennas were setup to provide a detection zone within each forebay that would extend upstream approximately 380 ft. from the dam for fish near the surface and about 20 ft. from the dam for fish at a depth of 45 ft. The detection zone for underwater antennas used in this study typically extend about 15-20 ft. from the location of the antenna. The aerial systems deployed downstream from the tailrace of each development were set up to provide detection across the entire channel.

All aerial antennas deployed at fixed station sites were 3-element Yagi antennas suspended from 10 ft. masts. Similarly, all underwater antennas used in this study were bared coaxial cable suspended in the water with weighted ropes. Each system was balanced so that for each antenna, signal strength at the receiver was equal to that at the antenna. This was accomplished by amplification or attenuation of each antenna as necessary. After installation, all telemetry systems were tested and adjusted for each location (i.e., aerial antenna angles, adjustments for noise, etc.).

Researchers used Lotek's DSP/SRX receivers to monitor underwater arrays and SRX units to monitor aerial arrays. The primary purpose of the aerial antenna arrays was to assess the migration success of fish released at the head of each reservoir. However, in the event that fish traveled at depths beyond the detection of the aerial antennas, underwater antennas could also be used to establish the presence of tagged fish in the forebay. Underwater antenna arrays are also useful in describing fish behavior close to the dam. Later, in this report we compare the number of fish detected by the aerial, underwater, and mobile surveys to confirm our application of the telemetry data for analysis. Below is a description of the telemetry systems used at Copco No. 1, Copco No. 2 and Iron Gate.

Copco No. 1-A combination of aerial and underwater antennas was used to monitor radio-tagged smolts in the forebay of Copco No. 1 dam. Three aerial antennas were deployed across the face of the dam. One antenna was located at the north end of the dam, between the intakes for Units 1 and 2 and covered the forebay from the center to the right-bank. The second antenna was placed in front of spillgate 4 near the center of the dam and was orientated to cover the middle of the forebay. The last antenna was located in front of spillgate 13 and covered the forebay from the center to the left-bank. All three antennas were combined into a single antenna at the receiver. To identify the location of fish close to the dam, nine underwater antennas were installed across the upstream face of the dam. These antennas were combined in three sets at the receiver to describe fish close to Unit 1 intakes, Unit 2 intakes, or near the spillway. For Unit 1, two antennas were installed at the center between each pair of the four intakes. At Unit 2, one underwater antenna was installed in the front of each of the three intakes. In the spillway, five antennas were deployed at a depth of 3.5-ft. in front of spill gates 1,3,6,9 and 12. These antennas were then combined back at the receiver as one functional antenna. Thus, there were two antennas combined for Unit 1, three antennas combined for Unit 2, and five antennas combined for the spillway. These three antennas arrays were monitored by a single SRX/DSP unit. The underwater antennas at both intakes were set at a depth of 3.5-ft.

Copco No. 2-The telemetry system at Copco No. 2 dam was installed to monitor the passage of radio-tagged fish at Copco No. 1 dam. The aerial antennas deployed at this dam detected fish as they moved downstream from the tailrace of Copco No. 1 dam. Two aerial antennas were deployed on either side of the dam at spillgate 1 and spillgate 5. The aerial antennas were aimed toward the center and upstream to cover the center and left and right banks. The two aerial antennas were then combined at the receiver and functioned as one large antenna to monitor downstream fish movement.

Iron Gate-A combination of aerial and underwater antennas were deployed at this development to monitor the forebay, spillway and powerhouse intake. Four aerial antennas were deployed across the dam to monitor the forebay. One antenna was installed on the powerhouse intake tower to monitor the left-bank, two were placed near the center of the dam on top of the overhead lights, and one was placed on the emergency water release tower located near the spillway to monitor the right-bank. These four antennas were combined at the receiver and functioned as one large antenna. Two antennas were placed about mid-way down the spillway channel with one facing upstream and the other downstream. These two antennas were combined to monitor the passage of fish through the spillway channel. A series of six underwater antennas were deployed in front of the powerhouse intake. Two antennas were placed in the center in the front of the intake and secured to the log boom. Two additional antennas were placed on the right side and two on the left side of the intake for a total of four antennas. The two antennas placed at each location were set at a depth of 5 ft. and 20 ft. All six underwater antennas were monitored separately to provide both vertical and horizontal detections across the powerhouse intake. Two aerial antennas were setup at Iron Gate fish hatchery to monitor fish movement past Iron Gate dam. These two antennas were aimed slightly upstream and downstream to create a large detection area across the Klamath River. The antennas were combined and functioned as a single antenna.

1.5.3 Radio-tag Selection

The radio transmitters used in this study were pulse-coded Nano-tag transmitters developed by Lotek Engineering of Newmarket, Ontario, Canada. The transmitters, model NTC-3-1, are available on 21 unique frequencies (channels), with a total of 212 unique codes on each of the 21 frequencies within a given frequency range (i.e., 148 MHz). The transmitters were 6.3 mm in diameter and 14.5 mm in length, and weighed 0.85 grams in air. The transmitters were equipped with a 7.3-in. stainless steel external antenna, sheathed in a clear plastic material to protect the antenna.

The tag was selected because at 0.85 grams, the tag would not exceed 5% of the fish weight for fish used in this study. Based on information provided by the California Department of Fish and Game (CDFG), a fall Chinook of this size from the hatchery would be about 110 mm FL and weigh at least 16 grams. Therefore, the minimum size tagging limit was set at 110 mm FL. The tag was also ideal because it could be configured with a 7.0 second transmission rate (1 pulse every 7.0 seconds) that resulted in a typical operational life of 32.0 days.

1.5.4 Fish Handling

Juvenile hatchery coho and fall Chinook salmon from the Iron Gate fish hatchery were selected as the test fish in this study. Juvenile coho at Iron Gate fish hatchery are raised for a year and released in March and April as age-1+ migrants. The fall Chinook smolts used in this study are typically released as small age-0 fish in the spring or as larger fish in the fall of the same year. To accommodate this study, the growth of the fall Chinook was accelerated to attain fish of an appropriate size for tagging. Other considerations for the use of these test fish included screening for infectious hematopoietic necrosis (IHN) on the female Chinook salmon that subsequently produced the smolts to be used for this study. Tagged fish were released over a three week period in early April for coho and a three week period in mid-May for fall Chinook.

Surgical Procedures-Fish were surgically implanted with transmitters following procedures outlined in Summerfelt and Smith (1990). Chinook and coho were tagged in three separated release groups for each release location. Surgery was conducted in three steps: (1) pre-operative MS-222 bath, (2) surgical implantation of the radio-transmitter, and (3) freshwater recovery. Initially, test animals were narcotized in a pre-operative solution of MS-222 at 80 mg/L until fish lose equilibrium. During surgery the MS-222 concentration was reduced to 60 mg/L to maintain anesthesia. Fish were rejected from tagging if they displayed external injuries, extensive scale loss, or did not meet the minimum size criteria (>110mm FL).

During surgery, the fish were placed on a V-shaped Plexiglas cradle that is integrated into a rectangular catchment tray. A hose fed through one end of the surgical cradle supplied anesthetic water to the fish during surgery. Fish were placed into the cradle and swabbed with Betadine at the incision site, and sprayed with a diluted solution of Pro-polyaqua (synthetic fish mucous). Fish were implanted with a radio-tag through a 1.0-cm incision between the pectoral and pelvic fins slightly off the mid-ventral line. A cannula placed through the incision site was used to pierce the body wall and provide an exit site for the radio-tag antenna. The radio-tag antenna was then inserted into the cannula and the antenna was pulled through the exit site. The tag is then inserted into the body cavity and the incision is closed with 2-3 sutures. The procedure is finished with a second application of Betadine over the sutures and a spray of Pro-polyaqua. Scalpel and cannula were then immersed in isopropyl alcohol for 2–4 minutes following tag implantation of each fish.

Fish Holding- Prior to tagging, test fish were raised and held on site at the Iron Gate fish hatchery. A sufficient number of juvenile coho were held outdoor in a rectangular fiberglass trough that measured 16 ft. x 45 in. x 24 inches. Juvenile Chinook were held in a round tank that had a diameter of 48 inches and a height of 28 inches. This tank was supplied with a mixture of fresh and recirculated water to maintain temperatures that would accelerate the growth these fish. As with the rest of Iron Gate fish hatchery, water is supplied from the Klamath River via the intake tower in Iron Gate reservoir. Fall Chinook growth was also enhanced by selection of the first spawning production lots, density reduction during development, and increased feeding regime. Before tagging, Chinook and coho were taken off feed for at least one day. Their feed schedule resumed after each release group was tagged.

Once fish were radio-tagged they were held for 48-hrs before release in 2 in. x 18 in. PVC live tubes with holes drilled in the cap ends and slits cut into the sides. These live tubes were designed to provide maximum water flow/exchange. Each tube was numbered and held a single fish. These tubes were not used for the last two release groups of Chinook. Researchers felt that the tube diameter and construction was not appropriate for the smaller Chinook, which could turnaround within the tube. During the first and second releases for Chinook, a total of six fish were rejected because of scale loss concentrated around the caudal peduncle. The size and construction of the PVC live tubes may have caused this scale loss. Based on these observations researchers decided to use a thin walled clear plastic tube 1.5 in. x 14 in. with knotless net mesh cap ends secured with rubber bands. These live tubes were used for the final Chinook releases in Copco and Iron Gate reservoirs. Use of the clear plastic tubing allowed single fish to be inspected within the tube for quality control. The tubes were placed in wire mesh baskets and held indoors at the Iron Gate fish hatchery in a 16 ft. x 22 in. x 12 in. elevated fiberglass hatchery trough. Water depth was set at 10 in. and the rate of water exchange in the trough was held at 20-gallons per minute. Plywood covers were placed over the trough to reduce stress.

Transport and Release- Prior to transport and release, radio tags were checked with a SRX receiver to verify that all tags were operational. After the tags were checked, fish were transferred to a 150 gallon transport tank supplied with compressed air during transport. To reduce potential stress, water temperatures in the holding tank were adjusted over the period of about 1-hr to within 2-3 degrees Celsius of the release site temperature. A forklift was then used to place the holding tank onto the transport vehicle. Water temperatures and transport times were recorded. Fish were then transported to a predetermined transfer location.

Near the release sites, tagged fish were transferred from the holding tank to a 17-gallon insulated container placed on a powerboat or drift boat. Water temperatures in the container were adjusted to the holding tank temperature and the reservoir temperature. Fish were then transported to their release site. At the release site the boat anchor was deployed, a GPS waypoint was assigned, and a release time was recorded. Three to four test fish were placed in a five-gallon bucket half-full of water. Once in the bucket, fish were visually inspected for any external abnormalities, excessive scale loss, loss of equilibrium or mortality. Rejected fish were not released and the tags were removed and deactivated. Fish that passed the quality control inspection were released into the test area. All fish were released between the hours of 1300-1500 to provide a consistent release time.

A total of 240 fish were released into Copco and Iron Gate reservoirs. Coho (120 fish) were released at the beginning of April and Chinook (120 fish) were released in mid-May. There were three release groups for each species at each release site. About 20 fish made up each release group. The release groups were liberated every 7-days. In Copco reservoir, fish were released about 0.5 miles upstream from the upper reservoir bridge. In Iron Gate reservoir, the fish were released approximately 200-300 yards downstream from Copco No. 2 powerhouse.

1.5.5 Mobile Tracking

From April to mid-June, mobile surveys (boat and ground) were used to assess the movement of radio-tagged fish in the reservoirs. Typically, both Copco and Iron Gate reservoirs were surveyed twice each week on alternate days. In areas where boat access was limited a follow up ground survey was conducted to complete the survey.

Mobile surveys were conducted in a powerboat that had two 6 element Yagi antennas mounted to 10 ft. masts installed on both sides of the boat. The antennas were pointed at an angle of 45 degrees from the sides of the boat to provide maximum detection coverage. Both antennas were combined and monitored by a single SRX 400 radio telemetry receiver. Ground surveys were conducted using a hand-held 3-element Yagi antenna and the SRX receiver. Typically, during each survey the perimeter of the reservoirs was surveyed followed by two “passes” near the center effectively dividing the reservoirs into fifths, thus providing maximum surface area coverage.

Detection of tagged fish occurred as the boat slowly moved around and through the reservoir. Once a signal was acquired the boat was pointed in the direction of the strongest signal and the individual fish was tracked to the location of greatest signal strength. At this location, a GPS waypoint was assigned, along with the date, time, tag channel and code, and receiver power strength. Field data was entered into computer spreadsheets and GPS data was downloaded at least once per week. Researchers used GIS to plot all fish positions into 3-zones within Iron Gate and Copco reservoirs.

In Copco Reservoir, Zone I extended from the release site down reservoir to where the reservoir begins to widen at Parks Canyon Creek (Figure 3). Zone II encompassed from Parks Canyon Creek to the point of land on the south shore extending into the reservoir across from Beaver Creek. Zone III extended from that point of land to Copco No. 1 dam and generally outlines the widest part of the reservoir. In Iron Gate reservoir, Zone I was from the tailrace of Copco No. 2 powerhouse to the embayment at Jenny Creek and is the narrowest part of the reservoir (Figure 3). Zone II extended from the embayment at Jenny Creek to just after Camp Creek cove. This area is also fairly narrow but contains the largest coves in Iron Gate Reservoir. Zone III extends from the cove at Camp Creek to Iron Gate dam and is typically wider than either Zone I or II.

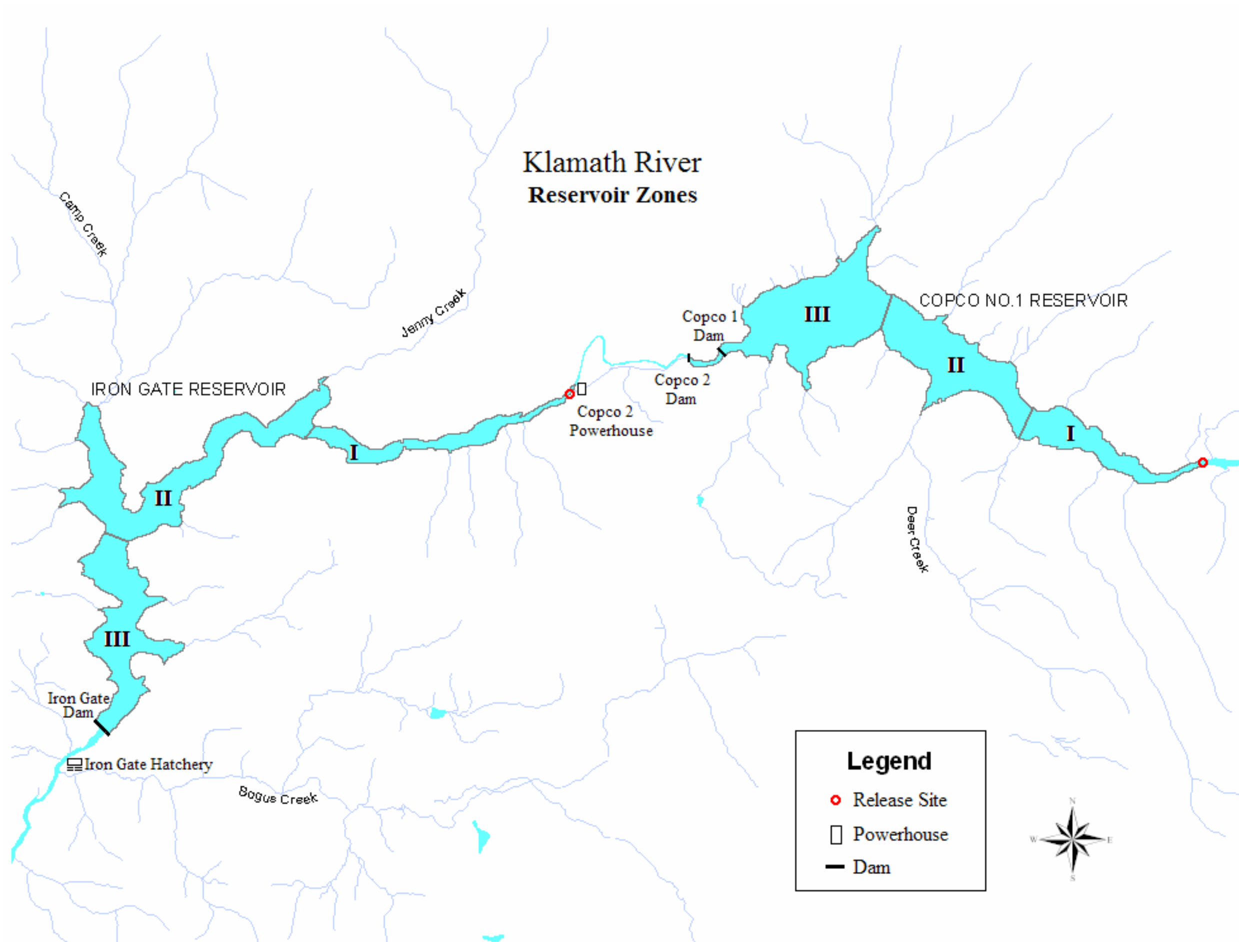


Figure 3. Reservoir zones used to delineate general areas of detections in Iron Gate and Copco reservoirs.

1.5.6 Temperature, Discharge and Pool Elevation

Reservoir temperatures (C°) along with powerhouse discharge (cfs) and pool elevation (msl) were collected to describe reservoir conditions during the study period. There were two temperature stations located within the study area. The temperature loggers were placed in the forebay of Copco and Iron Gate reservoirs at 10-meter depth increment to monitor temperatures in each reservoir. Each temperature logger recorded at hourly intervals. Researchers used the mean, minimum and maximum daily temperatures to display temperature trends throughout the study period.

Discharge and pool elevation at the developments was recorded each hour and plotted over the course of the study period. Pool elevation was recorded in the forebay of Iron Gate and Copco No. 1 dams each hour and summarized by mean daily pool elevations for the study period. Discharge at Iron Gate dam was taken from USGS records at gage station No. 11516530 on the Klamath River and includes discharge from Iron Gate dam, the Iron Gate fish hatchery and Bogus Creek. Discharge at Copco No. 1 dam was taken from the PacifiCorp's KWH database (spill+turbine flows). Mean hourly discharge at both developments was used to characterize flow conditions.

1.5.7 Data Retrieval and Management

During the study period (March-June), each receiver and telemetry system was inspected at least twice a week. In addition, all telemetry systems were tested throughout the study period to ensure proper operation. On a weekly basis, and more frequently if necessary, researchers downloaded all telemetry receivers. These data, along with tagging data, and mobile surveys were archived for analysis.

Three types of files were combined (fixed station receivers, boat surveys, and release information) into a relational database to assess migration behavior. The first file contained tagging and release information for each of the fish. That file has specific information on each fish such as; fork length, channel, code, date and time of release, release location, and species. The second file contained all mobile tracking information, which includes location, and date and time of detection recorded by the GPS receiver in each reservoir. The third file contained information from fixed station receivers located at the forebay and tailrace of each development. This file recorded the channel, code, time, date, signal strength and antenna for each fish detected at a project. The combination of these files into the database helped form complete "detection histories" over the course of the study period for each fish. A complete detection history for each fish allows the data to be analyzed to assess travel time, migration rate, arrival distribution, and minimum arrival success to the forebay of each dam.

Before data analysis began, criteria were developed to distinguish valid detections from ambient background noise. The criteria helped to eliminate invalid detections (noise) recorded on fixed station receivers. The following criteria were used to eliminate invalid detections at all fixed station receivers; 1) no fish can be detected before the date and time of release, 2) a valid detection must have at least two hits (records) within 0.5 hrs., and (3) valid detections cannot occur out of sequence (i.e., detection on the tailrace system cannot be valid if the fish is detected in the reservoir at a later date).

1.5.8 Migration Behavior

Migration Success-The minimum reservoir migration success for radio-tagged smolts was assessed for each reservoir. This estimate is based on unique channel code detections by the telemetry systems at the Copco and Iron Gate facilities. Minimum success is simply the proportion of released fish that are detected in the forebay of each dam. The minimum success estimate cannot account for tag loss, tag failure, delayed mortality from tag and release procedures, or detection efficiencies less than 100 percent. Moreover, the minimum success estimate cannot account for live fish that did not migrate completely through the reservoir or for slow migrants that exceed the operational life span of the tag. For these reasons, repeated mobile surveys are an important aspect of minimum success and help describe the migration behavior of fish as they move through reservoir.

Travel Time-Travel time in 1-day increments was calculated for each fish from the time of release to first detection in the forebay. Here, researchers use travel times as a means of comparison for tagged fish migrating through the same reservoir. Travel times and migration rates could only be calculated for successful migrants.

Migration Rate- Another important behavioral component of fish migration is the pace of movement or rate of progress made by salmonid smolts. Migration rate in miles per day was calculated for each successful migrant at Copco No. 1 and Iron Gate dams. Migration rate is calculated as the distance fish traveled, in this case from the release site to forebay, divided by the travel time. A line was plotted mid-channel through the each reservoir to estimate travel distance for each fish from the release sites to the respective forebay. The travel distance estimated was 6.3 miles for Iron Gate Reservoir and 4.8 miles for Copco reservoir. Migration rates offer a means of comparing fish movement in reservoirs of different lengths and possibly hydro-operation management.

Arrival Distribution-The arrival distribution for tagged fish that migrated to Copco No. 1 and Iron Gate dams was compiled within 1-day intervals. The arrival distribution displays the number and cumulative percent of fish arriving at each dam for both Chinook and coho. Arrival distribution is simply another way to display the length of time and pattern displayed for successful migrant fish.

Fish Passage-Fish passage at the Copco and Iron Gate developments was assessed by reviewing the detection histories of fish detected at each dam. Fixed station receivers were sequentially numbered from upstream to downstream within the study area. In order for fish passage to be confirmed at the dam there must be a series of valid detections from upstream areas (forebay) to downstream areas (tailrace) in a chronological sequence. For fish in Copco reservoir the sequence would occur on either the forebay aerial or underwater antennas to detections downstream in the tailrace at the aerial system deployed at Copco No. 2 dam. From there the detection sequence would include Copco No. 2 powerhouse, Iron Gate aerial and underwater antennas or spillway, and lastly the tailrace receiver setup up at Iron Gate fish hatchery. Mobile surveys were also used to help confirm passage at each development.

Detections at the Dams- To describe the movement of radio-tagged fish near each dam the underwater antenna systems were used to help document where fish were detected at each dam and provide some indication of how long they stayed in a particular area. Underwater antennas at Copco No. 1 dam were deployed near the intakes for Units 1 and 2 and the spillway to describe the horizontal distribution across the face of the dam. At Iron Gate, underwater antennas were deployed at two depths (5 ft. and 20 ft.) in front of the intake tower along the north and south sides and in the middle to describe horizontal and vertical distribution. To evaluate horizontal distribution at Iron Gate, researchers combined the surface (5-ft) and deep (20-ft) antennas for each location (north, south, middle). For vertical distribution, the north, south and middle antennas were combined for the surface and compared to those detections at the deep antennas for each of the locations. Three indices were used to describe the behavior of the radio-tagged fish that were detected by the underwater antenna systems at Copco No. l and Iron Gate dams.

First, researchers looked at the antenna array where fish were initially detected as they approached the dam or the intake structure. This index defined the location where fish first encountered an area of interest for downstream passage during their migration through the reservoir. Second, researchers compiled the number of repeat detections at each location when radio-tagged fish approached on subsequent visits. Here, researchers separated repeat detections by a minimum of one hour from other previous detections. This index helped explain behavior as fish made repeat attempts to migrate downstream. Finally, the total number of detections recorded at each location was used to evaluate where fish spend most of their time.

1.6 Results

1.6.1 Fish Handling

The coho used in this study were generally larger than the Chinook but displayed a greater range in size. Coho varied in size from 118-197mm FL for fish released in Copco reservoir and from 111-193mm FL for fish released in Iron Gate reservoir. For Chinook the size ranged from 112 to 133mm FL for fish released in Copco and from 112 to 134 mm FL for fish released in Iron Gate reservoir. The mean size for both species was fairly consistent across their respective release groups and release sites (Table 1).

The holding and tagging temperatures at Iron Gate fish hatchery for coho ranged from 7.5-10°C from the first to last release groups. Temperature at the release sites for coho ranged from 12-13°C. For Chinook the tagging and holding temperatures varied from 12-14°C for all release groups. Temperature at the release sites for Chinook ranged from 14-18 °C. For the last release groups of Chinook in Iron Gate and Copco reservoirs the fish were acclimated 2 °C over a period of 2-hrs before the fish were transported. Transport from the hatchery to each release site remained fairly consistent throughout the study period at about 0.5 hr (range: 23-39 minutes). None of the fish tagged in this study died during the 48-hr holding period or after they were transported to the release sites. However, when researchers inspected some of the radio-tagged Chinook (Copco release 1 and Iron Gate release 2) prior to their release they found six fish that had scale loss on either side of the caudal peduncle. These fish were not released and the total number of tagged fish needed was made up in subsequent releases (Table 1).

Table 1. The number and size (FL-mm) of coho and Chinook for each release group liberated in Iron Gate and Copco reservoirs, 2004.

			Release Groups			
Reservoir	**Fish**	**Metrics**	**1**	**2**	**3**	**Total**
Coho	Copco	Number of fish	20	20	20	60
		Minimum	118	116	127	116
		Maximum	175	153	197	197
		Mean	137	134	146	139
	Iron Gate	Number of fish	20	20	20	60
		Minimum	111	122	129	111
		Maximum	172	156	193	193
		Mean	137	132	142	137
Chinook	Copco	Number of fish	17	22	21	60
		Minimum	112	113	116	112
		Maximum	127	128	133	133
		Mean	119	120	124	121

	Iron Gate	Number of fish	20	17	23	60
		Minimum	112	112	113	112
		Maximum	126	134	128	134
		Mean	119	119	120	119

1.6.2 Temperature, Discharge and Pool Elevation

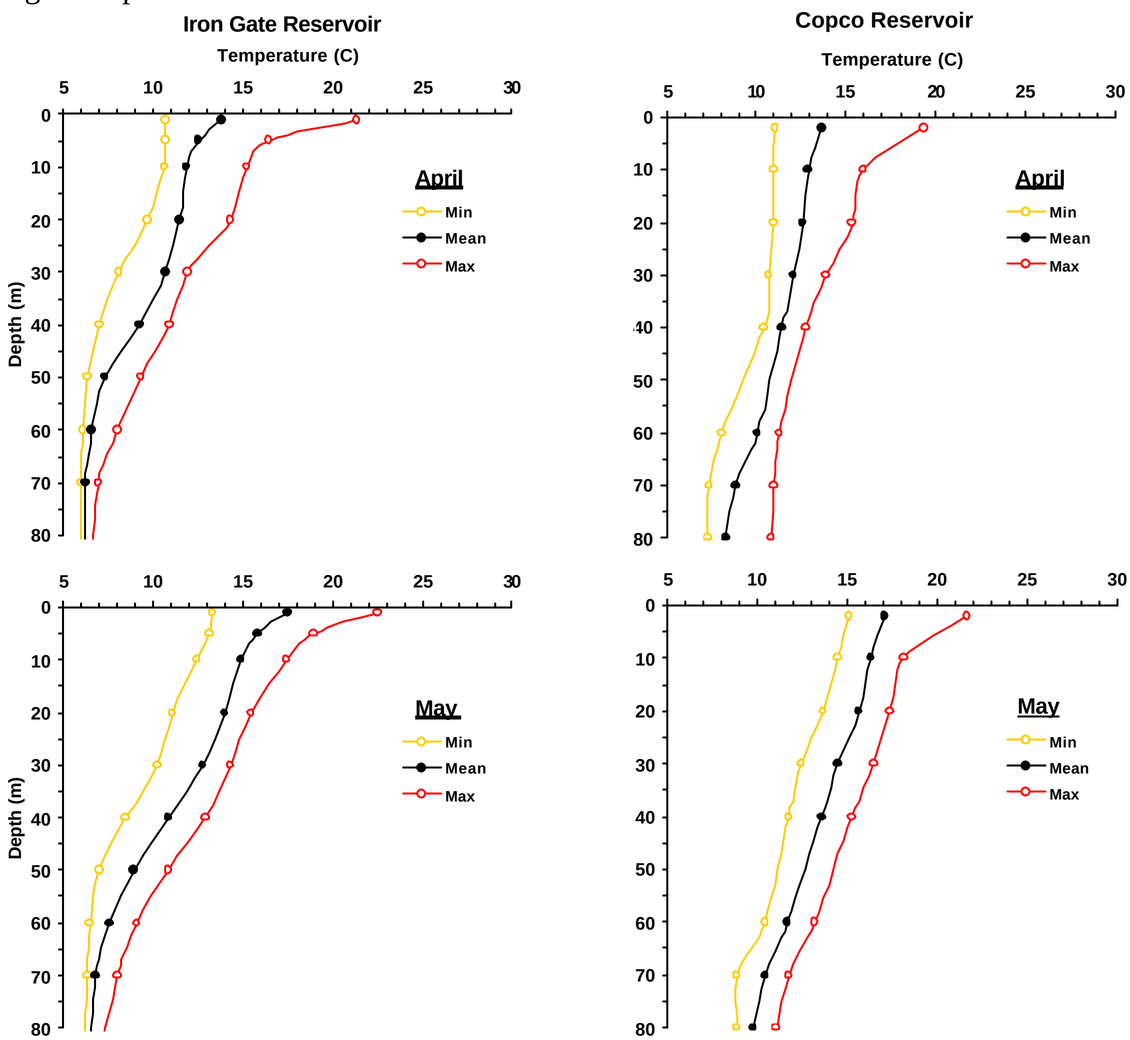
Temperature-Reservoir temperatures recorded at 10 meter depth increments in the forebay of Iron Gate and Copco reservoirs were used to characterize the thermal conditions that Chinook and coho migrated through during the study period. The study period was separated into a migration period for coho (1 April-16 May) and one for Chinook (12 May-30 June), based on typical Iron Gate fish hatchery release periods for these species. The migration periods extend from the first liberation of fish extending 32-days after the last release group to account for the life of the radio tags.

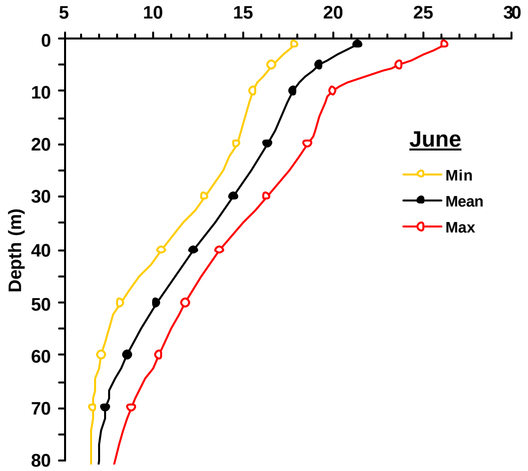
To describe reservoir temperature at different depths during the study period, researchers profiled minimum, mean, and maximum temperatures during each month of the study (Figure 4). To evaluate migration conditions, the minimum, maximum, and mean temperatures were calculated during each migration period for a given reservoir to a depth of 20 meters (Table 2). Researchers then expressed the range and the mean of the daily temperature fluctuations within each reservoir and migration period at those depths (Table 2). Finally, we display the minimum, mean and maximum daily temperature observed for the entire study period to a depth of 20 meters along with temperatures ranges that are considerable optimal for growth and smoltification in Chinook and coho (Figure 5).

The temperature profiles for Iron Gate and Copco reservoirs show that the mean surface temperature increased about 3-4°C per month (Figure 4). From the profiles the mean temperatures during most of the study period appear to be fairly suitable for Chinook and coho at depths greater than 20 meters. Therefore, the remainder of the analysis will address reservoir temperatures at depths less than 20 meters. The temperatures at those depths are also more representative of the thermal conditions encountered by fish detected during the course of this study.

Coho Migration Period-During the coho migration period mean temperatures in the upper water column (1-20 meters) ranged from 12.2 to 14.9 °C in Iron Gate reservoir (Figure 5; Table 2). The temperature range observed during the migration period in Iron Gate varied from10.7 to 22.3 °C at a depth of 1-meter. The temperature range decreased at 10-meters (10.6-17.1 °C) and 20-meters (9.6-15.4 °C). The daily temperature fluctuation in Iron Gate ranged from 0.1 to 6.9 °C but on average ranged from 0.9 to 3.1 °C (Table 2). In Copco reservoir during the coho migration period the mean temperatures ranged from 13.5 to 14.7 °C (Figure 5; Table 2). The temperature range at 1-meter varied from 11.0 to 19.4 °C. At a depth of 10 and 20-meters the range was 11.0 to 17.4 °C and 11.0 to 16.8 °C, respectively. The daily temperature fluctuation in Copco reservoir ranged from 0.0 to 4.4 °C but typically averaged from 0.9 to 2.3 °C.

Chinook Migration Period-In Iron Gate reservoir, during the Chinook migration period, mean temperatures ranged from 15.6 to 20.0 °C (Figure 5; Table 2). Temperatures in Iron Gate during the migration period varied from 14.9 to 26.3 °C at the surface and decreased to 14.6 to 20.0 °C at 10-meters and 13.7 to 18.6 °C at 20-meters. Mean daily temperature fluctuation in Iron Gate varied from 0.9 to 2.8 °C at different depths. Daily temperature fluctuation ranged from 0.3 to 5.3 °C. In Copco reservoir, temperatures ranged from 14.6 to 24.9 °C with mean daily temperatures that varied from 17.3 to 19.0 °C (Figure 5; Table 2). Daily temperature fluctuations in Copco reservoir ranged from 0.2 to 4.5 °C but on average ranged from 1.0 to 2.4 °C during the migration period.





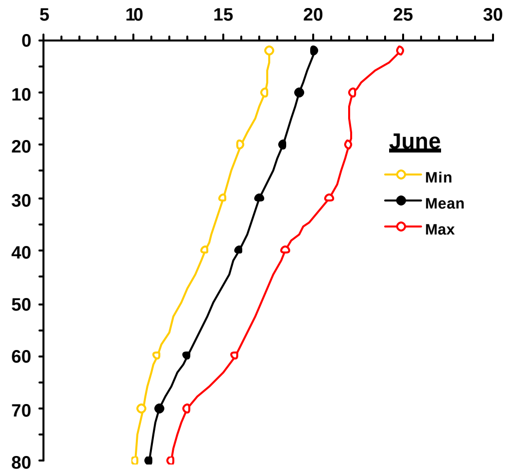


Figure 4. Minimum, maximum and mean monthly temperature profiles for Iron Gate and Copco reservoirs from April through June, 2004.

Table 2. Minimum, maximum and mean daily fluctuation and migration period temperatures calculated for Iron Gate and Copco reservoirs at the surface (1-2 meters), 10 meters and 20 meters.

Fish	Study Period	Reservoir	Depth (m)	Reservoir Temperatures (°C)					
				Migration Period			Daily Fluctuation		
				Min	Mean	Max	Min	Mean	Max
Coho	1 April – 16 May	Iron Gate	1	10.7	14.9	22.3	0.5	3.1	6.9
			10	10.6	12.7	17.1	0.1	1.0	3.3
			20	9.6	12.2	15.4	0.2	0.9	2.6
		Copco	2	11.0	14.7	19.4	0.2	2.3	4.4
			10	11.0	14.0	17.4	0.2	0.9	3.4
			20	11.0	13.5	16.8	0.0	1.0	2.7
Chinook	12 May – 30 June	Iron Gate	1	14.9	20.0	26.3	0.6	2.8	5.3
			10	14.6	16.8	20.0	0.3	1.1	2.8
			20	13.7	15.6	18.6	0.3	0.9	2.5
		Copco	2	15.1	19.0	24.9	0.6	2.4	4.5
			10	15.1	18.1	22.2	0.2	1.0	2.1
			20	14.6	17.3	22.0	0.2	1.3	2.6

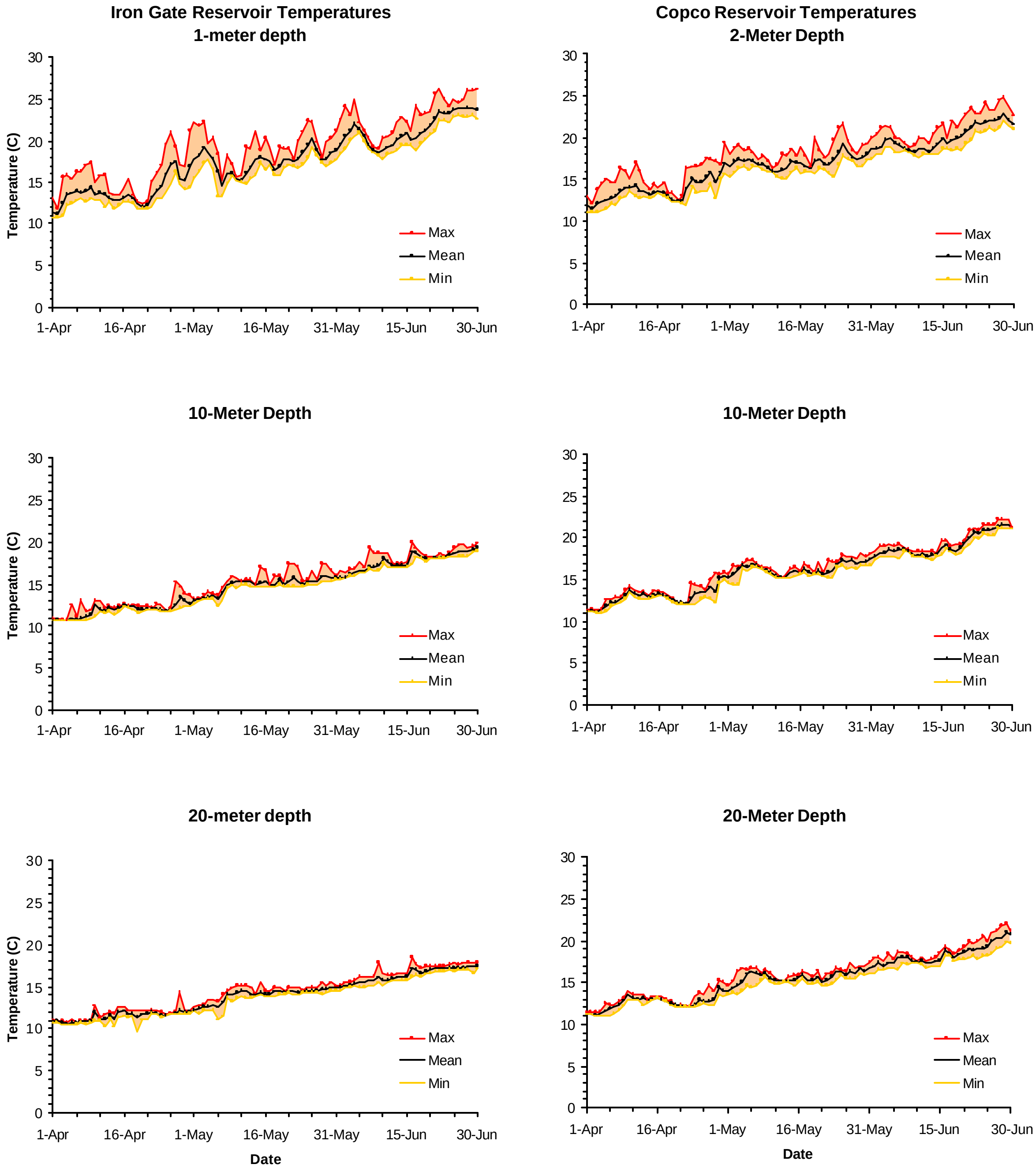


Figure 5. Minimum, maximum and mean daily temperatures recorded for Iron Gate and Copco reservoirs at the surface (1-2 meters), 10 meters and 20 meters during study period. The red shaded portion of the graph represents the temperatures above the upper incipient lethal temperature for Chinook and coho (McCullough et al. 2001). The orange shaded area represents temperatures that have been associated with impaired smoltification indices and predator avoidance in Chinook (Marine and Cech 2004). The yellow shaded portion is centered on 15 °C and represents optimal temperatures for growth and smoltification of Chinook and coho (McCullough et al. 2001; Marine and Cech 2004).

Discharge-During the coho migration study period (April to mid-May) the mean hourly discharge (cfs), as measured from downstream of Iron Gate dam, decreased in series of steps from about 2,100 cfs in the beginning of April to 1,250 cfs in mid-May (Figure 6). At Copco No. 1 dam during that period the mean hourly discharge at the beginning of April was held fairly constant around 1,650 for the first nine days. Thereafter, until the second week of May, hourly discharge fluctuated between 0 and 2,650 cfs with off generation periods lasting about 3 to 8 hrs. During the juvenile Chinook migration study period (mid-May to end of June) discharge at Iron Gate decreased gradually in a series of steps from 1,250 cfs in mid-May to about 800 cfs near the end of June (Figure 6). Hourly discharge at Copco No. 1 dam during the same period was defined at the beginning with several days where the discharge fluctuated between 0 and 1,300 cfs with 3 to 6 hrs periods of no generation. Discharge at Copco No. 1 dam during the rest of the study period generally fluctuated between 0 and 2,650 cfs with off generation periods lasting from about 7 to 17 hrs.

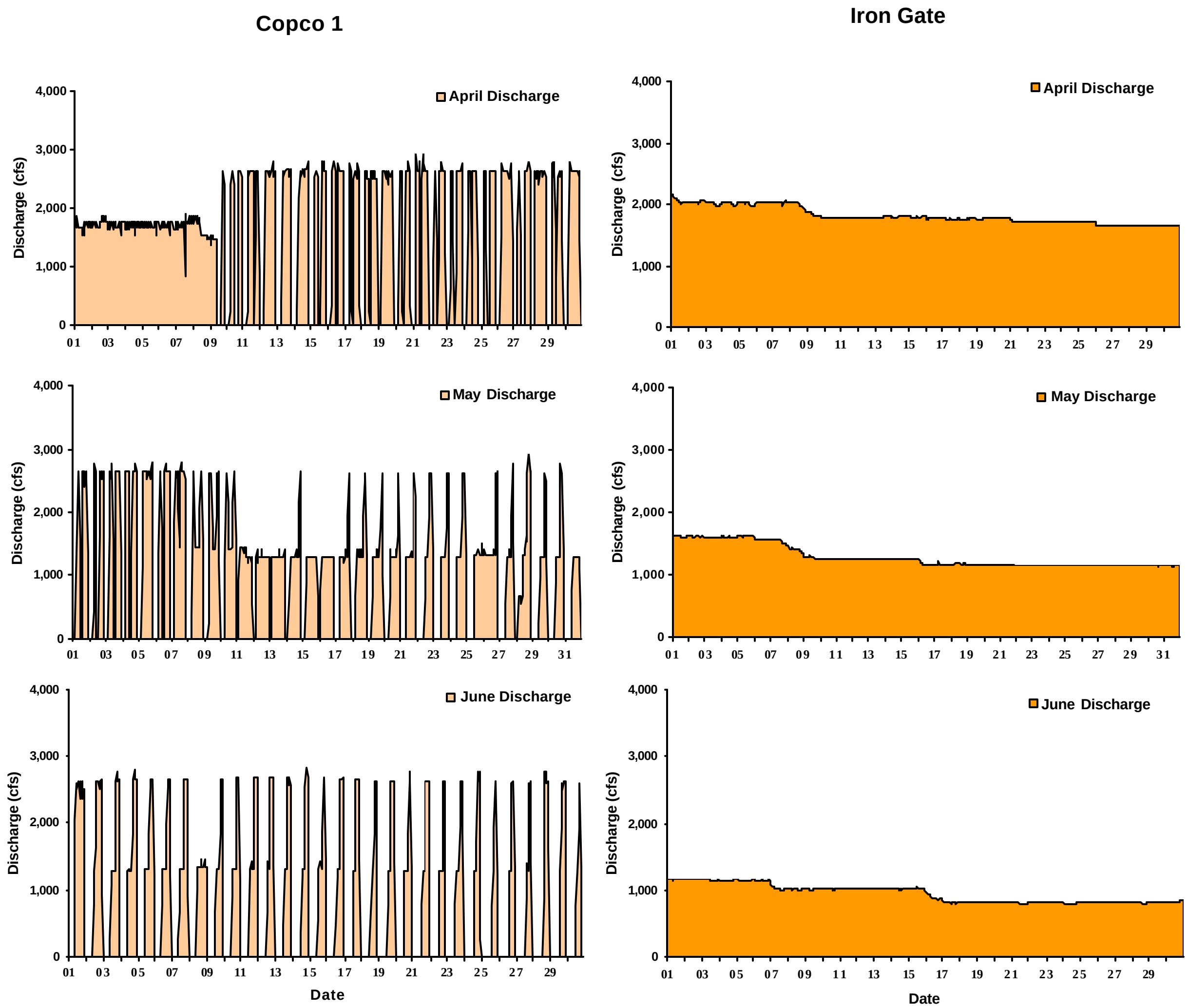
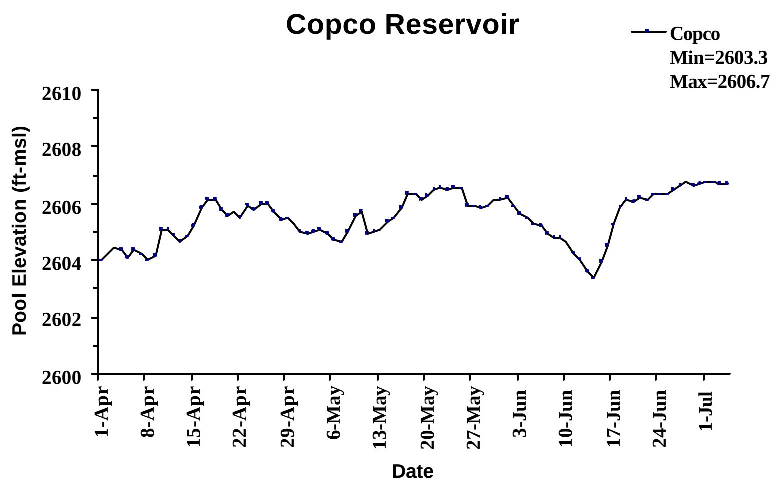


Figure 6. Mean hourly discharge (cfs) for Iron Gate and Copco No. 1 dams on the Klamath River from April-June, 2004.

Pool Elevation-Mean daily pool elevations in Copco reservoir during the coho study period (April to mid-May) generally increased and only varied about two feet from 2604 ft-msl to 2606 ft-msl (Figure 7). From mid-May to mid-June the pool elevation decreased from 2606 ft-msl to 2603 ft-msl and then returned back to 2606 ft-msl by the last week of June. In Iron Gate during the coho study period, mean daily pool elevation dipped from a high of 2328 ft-msl at the beginning of April down to 2325 ft-msl at the end of April and beginning of May. From mid-May to the end of June pool elevations were fairly cyclic from 2326-2327ft-msl.



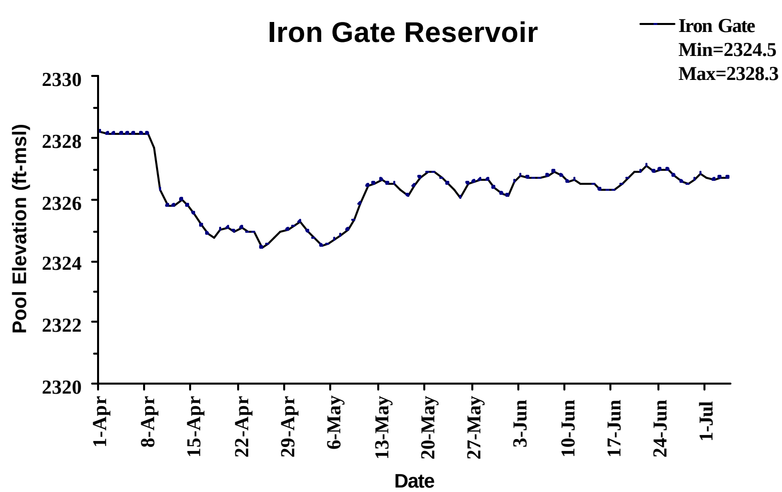


Figure 7. Mean daily pool elevations (ft-msl) recorded for Copco and Iron Gate reservoir from April-June, 2004.

1.6.3 Detection Rates

In order to confirm the application of the telemetry data for analysis of migration success and behavior, researchers compared detections by fixed station receivers and mobile tracking surveys. First, the number of fish detected by aerial systems was compared to the number of fish detected by the underwater systems at each dam. This evaluation helped determine if some tagged fish were migrating at depths greater than could be detected by the aerial system when they were near the dam. If fish were too deep for aerial detection when they were near the dam then the combination of the aerial and underwater system could be used to estimate migration success and behavior. The next comparison was the number of fish detected by the aerial systems to the number of fish detected during mobile surveys in Zone 3 of each reservoir. Zone 3 for each reservoir was near the forebay of each dam. In this comparison, researchers are evaluating if some fish migrated through most of the reservoir but did not approach close enough to the dam to be detected by the telemetry systems or potentially remained undetected when they were near the dam. This evaluation is important because if there are numerous fish that appear to be successful migrants through most of the reservoir and are never detected at the dam it could indicate that detection by the fixed telemetry system was less than 100 percent. The estimate for migration success might then be too low. The last comparison is the number of fish released in each reservoir to the number of unique detections during all mobile surveys within each reservoir. This comparison serves as a way to evaluate the ability of mobile surveys to detect tagged fish in each reservoir. These types of comparisons help to assess which telemetry system or combination is best used for determining migration success and behavior and may also reveal patterns of detection for both coho and Chinook migrants.

Aerial vs. Underwater-In the first comparison it was found that the aerial telemetry system detected all the fish that were detected by the underwater systems. Only 88 percent of the coho (22/25) and 84 percent of the Chinook (32/39) detected on the aerial system at Copco No. 1 dam were also detected by the underwater system (Table 3). At Iron Gate the underwater system detected 55 percent of the Chinook (6/11) and 64 percent of the coho (32/39) detected by the aerial system. This indicates that the large detection zones created by of the aerial systems alone were sufficient to monitor Chinook and coho close to the dam to estimate migration success.

Aerial vs. Zone 3-In this comparison researchers evaluated if there were fish that appear to be migrating toward the dam but were never detected by the fixed telemetry systems at the dams. The number of fish detected by aerial systems was similar to the number of fish detected in Zone 3 of each reservoir (Table 3). Mobile surveys in Zone 3 detected 52 to 68 percent of the coho and 45 to 64 percent of the Chinook detected by aerial systems at Copco 1 and Iron Gate dams, respectively (Table 3). However, there were three fish (2 coho and 1 Chinook) that were detected in Zone 3 of Iron Gate during mobile surveys that were not detected by the aerial system at the dam. There were also three fish (2 coho and 1 Chinook) detected in Zone 3 of Copco reservoir that were not detected by the aerial system at the dam. These numbers are expressed in parenthesis in the table provided (Table 3). This indicates that a very low percentage of coho (3 percent) and Chinook (1 percent) released into each reservoir had moved through most of their respective reservoirs and either did not approach close enough to the dam to be detected by the telemetry systems or were missed by the telemetry systems at each dam.

Released vs. All Zones-In the final comparison the number of fish released in each reservoir was compared to the number of unique detections during all mobile surveys within each reservoir. Mobile surveys during the study period detected more coho than Chinook and the detection rates were higher in Iron Gate reservoir than they were in Copco reservoir. Mobile surveys detected 70 to 97 percent of all the fish released during the study (Table 3). For coho, mobile surveys detected 50 of 60 fish (83 percent) released in Copco and 58 of 60 fish (97 percent) released in Iron Gate reservoir. The number of Chinook detected was 42 of 60 fish (70 percent) in Copco and 55 of 60 (92 percent) in Iron Gate reservoir.

From the comparisons above, migration success, travel time, migration rates and arrival distribution are best developed using the aerial systems located at each dam. The underwater telemetry systems did not detect all the fish that approached the dam. Mobile surveys in Zone 3 for both reservoirs did not indicate that there were numerous fish that may have been missed by the aerial systems at both dams. Lastly, the relatively high percent (>70%) of tagged fish detected during mobile surveys over the entire study period suggests that most fish were located at depths less than 45 ft. and that mobile surveys are appropriate for developing general patterns to show differences in migration behavior.

Table 3. Comparison of the number of Chinook and coho detected by different telemetry systems used to monitor the movements of the radio-tagged fish released in Iron Gate and Copco reservoirs. The numbers in parenthesis for Zone 3 mobile survey detections represent fish that were not detected by the aerial systems at either dam.

		Release		Forebay		Reservoir		Comparison (percent)		
Fish	**Reservoir**	**Group**	**Number**	**Aerial**	**Underwater**	**Zone 3**	**All Zones**	**Aerial vs. Underwater**	**Aerial vs. Zone 3**	**Released vs. All Zones**
Coho	Copco	1	20	8	7	4	18	88	50	90
		2	20	7	6	3	15	86	43	75
		3	20	10	9	6 (2)	17	100	60	85
		Total	**60**	**25**	**22**	**13 (2)**	**50**	**88**	**52**	**83**
	Iron Gate	1	20	7	5	4	20	71	57	100
		2	20	5	3	2 (1)	20	60	40	100
		3	20	10	6	9 (1)	18	60	90	90
		Total	**60**	**22**	**14**	**15 (2)**	**58**	**64**	**68**	**97**
Chinook	Copco	1	17	3	3	2 (1)	12	100	67	71
		2	22	15	13	7	16	87	47	73
		3	21	21	16	8	14	76	38	67
		Total	**60**	**39**	**32**	**17 (1)**	**42**	**84**	**45**	**70**
	Iron Gate	1	20	4	3	4	17	75	100	85
		2	17	0	0	0	16	0	0	94
		3	23	7	3	3 (1)	22	43	43	96
		Total	**60**	**11**	**6**	**7 (1)**	**55**	**55**	**64**	**92**

1.6.4 Migration Success

The purpose of estimating migration success in this study was to assess if coho and Chinook smolts would migrate through lower Project reservoirs on the Klamath River under typical water management strategies and dam operations. Migration success is simply the proportion of fish released at the head of the reservoir that migrate to and are detected in the forebay of each project. As noted previously, the migration success observed during this study should be considered a minimum. The estimate cannot account for tag loss, tag failure, or delayed mortality from tag and release procedures or detection efficiencies less than 100 percent. Moreover, the minimum success estimate cannot account for live fish that did not migrate completely through the reservoir or for slow migrants that exceed the operational life span of the tag.

In general the migration success observed during this study showed that coho and Chinook had a higher migration success rate in Copco reservoir than in Iron Gate reservoir. The trend in migration success for juvenile coho release groups in both reservoirs was much more consistent than for Chinook. The migration success for coho ranged from 37 to 42 percent for all release groups combined (Table 4). The percentage of coho that migrated successfully from different release groups varied from 35 to 50 percent for Copco and 25 to 50 percent in Iron Gate (Table 4). For juvenile Chinook, migration success varied from 18 to 65 percent for all release groups in Iron Gate and Copco reservoirs. The percentage of Chinook that migrated successfully from different release groups within Copco reservoir varied from 18 to 100 percent and from 0 to 30 percent in Iron Gate (Table 4).

The relatively poor migration success displayed for Chinook release group 1 (18 percent) in comparison to 2 (68 percent) and 3 (100 percent) in Copco reservoir may be related to Project operations. Three days after the fish from group 1 were released peak discharge at Copco No. 1 powerhouse was reduced from 2,600 to 1,300 cfs. The low number of successful migrants also occurred in Iron Gate release group 1. However, when the number of successful migrants increased in release group 2 for Copco there was not a corresponding increase for release group 2 in Iron Gate. Mobile surveys show that the detection rate in the Iron Gate reservoir was high (94%) for this release group but the fish did not move more than two miles away from the release site. There was also no substantial decrease in the flow at Iron Gate that would explain the poor migration success in release group 2.

Table 4. Release location and date for three groups of radio-tagged coho released into Copco and Iron Gate reservoirs. The number and percent of coho from each release group that migrated successfully through each reservoir and were detected at the dams.

Fish	Release			Number Released	Detections	
	Location	Date	Group		Dam	Percent
Coho	Copco	1-April	1	20	8	40
		8-April	2	20	7	35
		15-April	3	20	10	50
		Total		**60**	**25**	**41.6**
	Iron Gate	3-April	1	20	7	35
		9-April	2	20	5	25
		16-April	3	20	10	50
		Total		**60**	**22**	**36.7**
Chinook	Copco	12-May	1	17	3	17.6
		19-May	2	22	14	68.2
		26-May	3	21	21	100.0
		Total		**60**	**39**	**65.0**
	Iron Gate	13-May	1	20	4	20.0
		20-May	2	17	0	0.0
		27-May	3	23	7	30.4
		Total		**60**	**11**	**18.3**

1.6.5 Migration Behavior

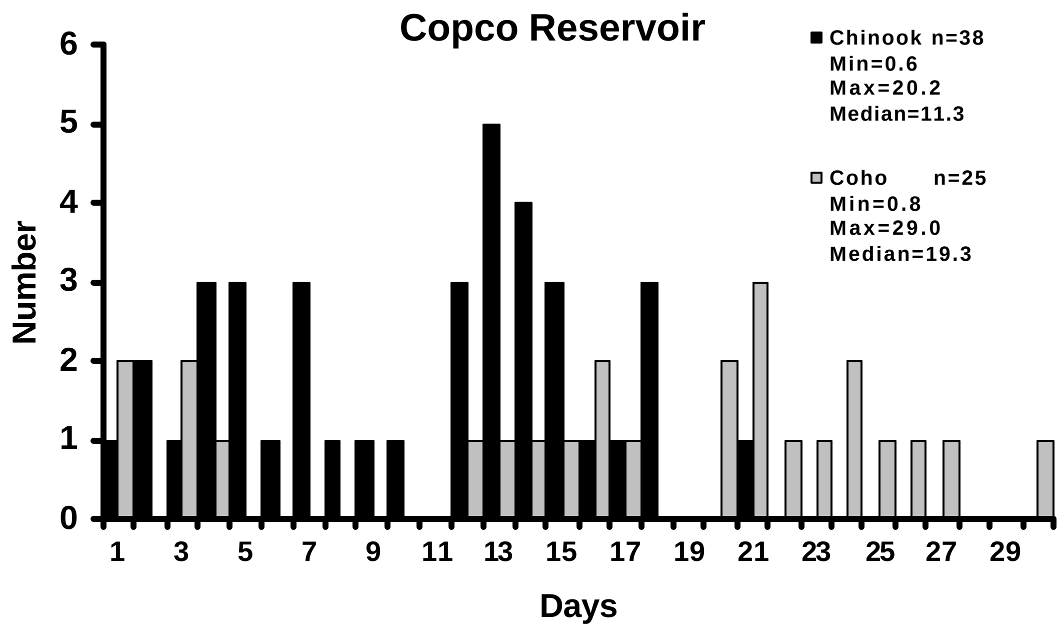
Travel Times-To describe one aspect of the migration behavior of radio-tagged fish through California's Klamath River reservoirs, travel times were calculated for each fish from the point of release to the forebay, using the first detection by the aerial system as the metric to indicate arrival. For this analysis, travel times were used as a means of comparison for tagged fish migrating through the same reservoir and migration rates were used to make comparison between reservoirs. The distinction here is that travel time is dependent on reservoir length as well as Project operations and migration rate should be independent of reservoir length but not Project operations. The median travel times were used to describe the central tendency rather than the mean which may be more sensitive to rather large or small individual migration times.

The median travel times for tagged fish revealed that Chinook arrived at both dams in less time than coho and travel time for both Chinook and coho through Iron Gate reservoir was typically several days longer than for Copco reservoir. The median travel time for radio-tagged coho released into Copco reservoir was 19-days and ranged from 0.8 to 29-days (Figure 8; Table 5).

For Chinook released in Copco reservoir the median travel time was 11-days and varied from 0.5 to 20-days. In Iron Gate, the median travel time for coho was 21-days and varied from 4 to 39-days. The travel time for juvenile Chinook in Iron Gate reservoir ranged from 3 to 26-days with a median travel time of 13-days (Figure 8; Table 5). In both reservoirs there were a few fish that arrived within the first two weeks after they were released. Interestingly, Chinook generally required less time to migrate through each reservoir even though the discharge (migration cue) at Iron Gate and Copco in April for coho was higher than it was for Chinook in May.

Table 5. Travel times (days) for Chinook and coho released in Iron Gate and Copco reservoirs that were detected by the fixed telemetry systems at each dam.

Reservoir	Fish	Metrics	Travel Time (days)
Copco	Chinook	Number of fish = 38	
		Minimum	0.6
		Maximum	20.2
		Median	11.3
	Coho	Number of fish = 25	
		Minimum	0.8
		Maximum	29.0
		Median	19.3
Iron Gate	Chinook	Number of fish = 11	
		Minimum	2.6
		Maximum	25.6
		Median	12.9
	Coho	Number of fish = 22	
		Minimum	3.7
		Maximum	38.6
		Median	20.7



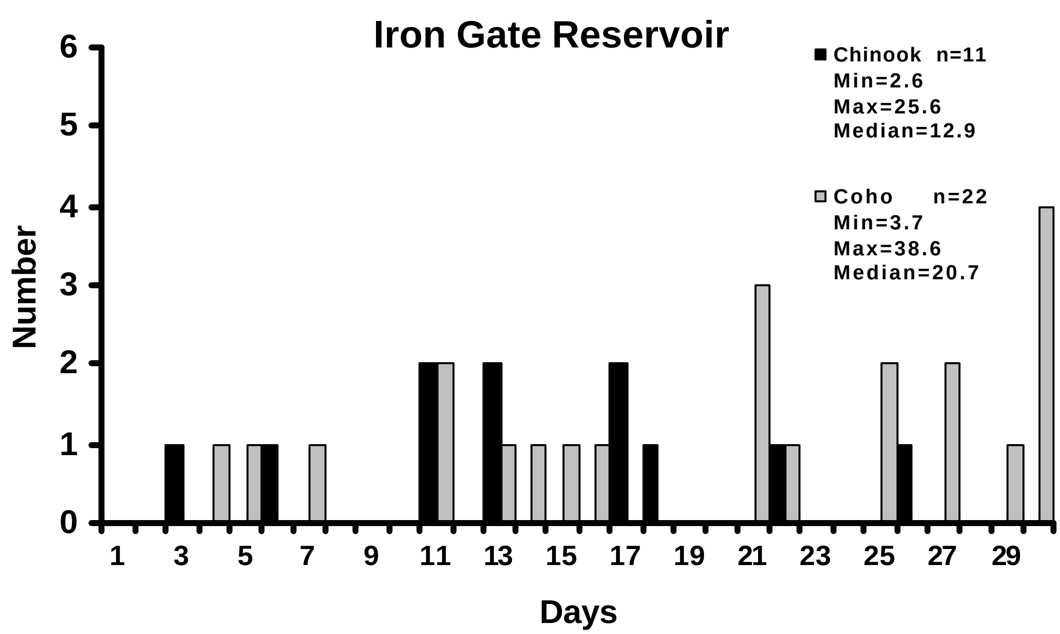


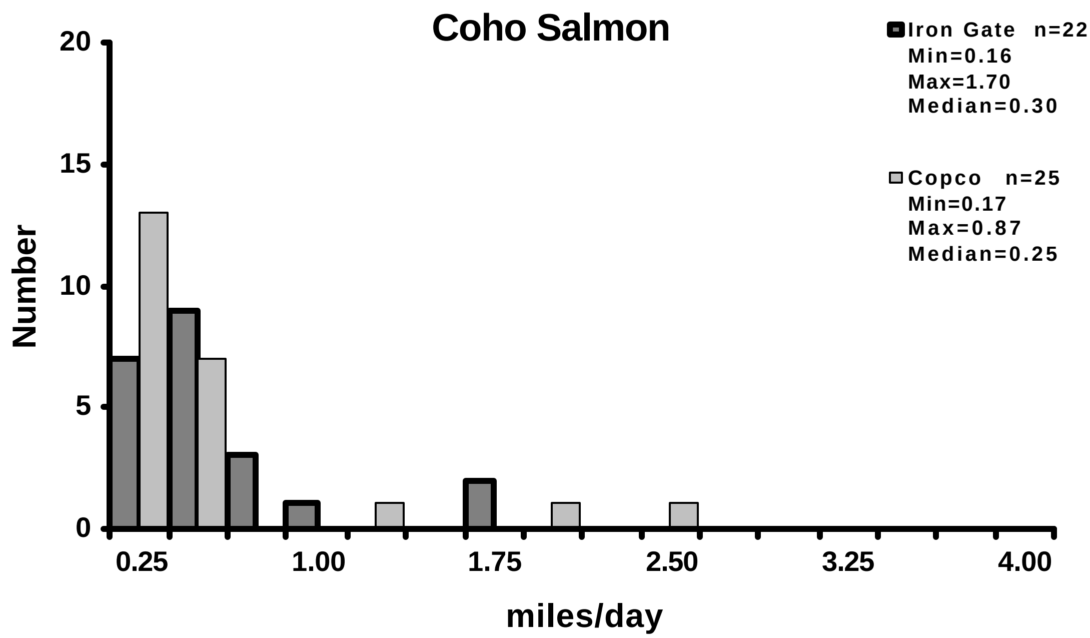
Figure 8. Travel times for juvenile Chinook and coho salmon released at the head of Copco and Iron Gate reservoirs to first detection at each dam. The number of fish displayed in each plot is represented by the letter "n". The travel time for one coho (38.6-days) in the Iron Gate reservoir plot was not displayed to preserve the scale for the x-axis in both plots.

Migration Rate-Another important component of migration behavior is the pace or rate of progress for migrant fish through Copco and Iron Gate reservoirs. Migration rates (mile/days) were calculated for each fish from point of release to arrival at each development. Migration rate is useful in describing the behavior of Chinook and coho in reservoirs of different lengths and shapes such as Iron Gate reservoir at 6.3 miles and Copco reservoir at 4.8 miles.

The migration rates observed during this study for Chinook were higher than coho and both species tended to move faster through Iron Gate reservoir than they did in Copco. However, some fish released in Copco reservoir displayed the fastest migration rates. The median migration rate for radio-tagged coho released into Copco reservoir was about 0.25-miles/day and ranged from 0.17 to 6.0-miles/day (Figure 9; Table 6). For Chinook released in Copco reservoir the median migration rate was 0.42-miles/day and varied from 0.24 to 7.5-miles/day. In Iron Gate, the median migration rate for coho was 0.30-miles/day and varied from 0.16 to 1.7-miles/day. The migration rate for juvenile Chinook in Iron Gate reservoir ranged from 0.25 to 2.4-miles/day with a median travel time of 0.49-miles/day (Figure 9; Table 6).

Table 6. Migration rates (miles/day) for Chinook and coho released in Iron Gate and Copco reservoirs that were detected in the forebay of each project.

Fish	Reservoir	Metrics	Migration Rate (miles/day)
Coho	Copco	Number of fish	25
		Minimum	0.17
		Maximum	6.00
		Median	0.25
	Iron Gate	Number of fish	22
		Minimum	0.16
		Maximum	1.70
		Median	0.30
Chinook	Copco	Number of fish	38
		Minimum	0.24
		Maximum	7.49
		Median	0.42
	Iron Gate	Number of fish	11
		Minimum	0.25
		Maximum	2.39
		Median	0.49



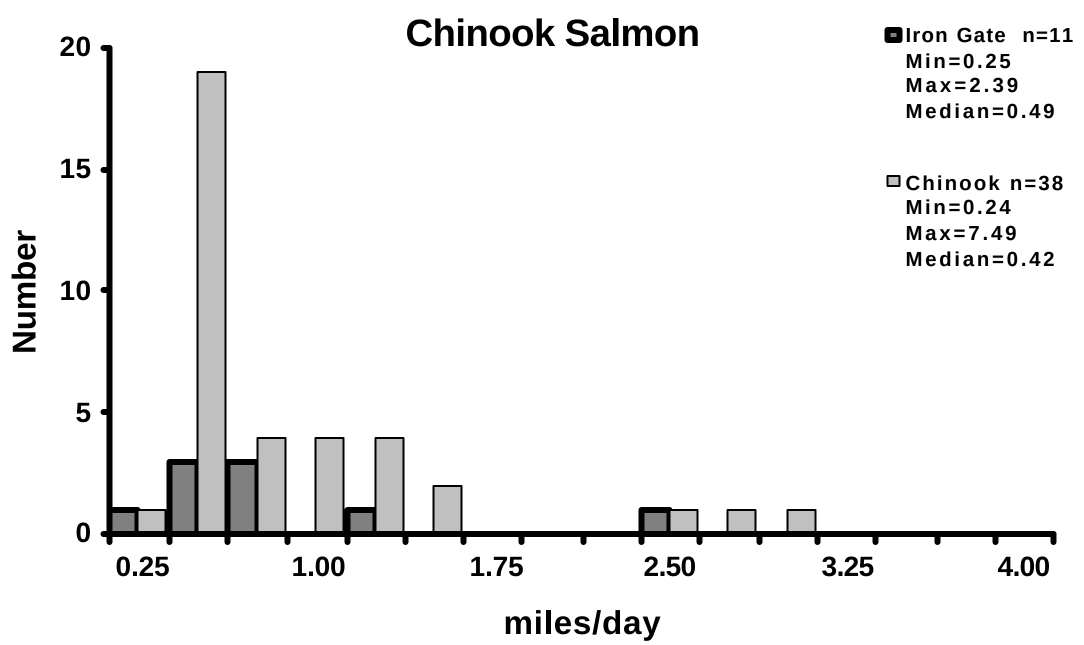


Figure 9. Migration rates (miles/day) for juvenile Chinook and coho salmon released at the head of Copco and Iron Gate reservoirs to first detection at each dam. The number of fish displayed in each plot is represented by the letter "n". The migration rate for one coho (7.49 miles/day) in the Iron Gate reservoir plot was not displayed to preserve the scale of the x-axis for both plots.

Arrival Distribution-Arrival distribution for tagged fish that migrated to Copco No. 1 and Iron Gate dams was compiled within 1.0-day intervals for each project. The arrival distribution displays the number and cumulative percent of fish arriving at each development for both Chinook and coho. The arrival distribution is just another way to display the length of time required for juvenile salmon to migrate through the reservoir under normal Project operations.

The arrival distribution for Chinook showed that most fish (90%) in Copco and Iron Gate arrived at the dams 18 to 25-days after they were released, respectively (Figure 10). Nearly half of the juvenile Chinook were detected in the first two weeks at both projects. There were no Chinook detected at the dams 21 to 26-days after release. Ninety percent of the coho arrived at Copco No. 1 and Iron Gate dams 25 to 30-days with almost half of the fish detected three weeks after they were released.

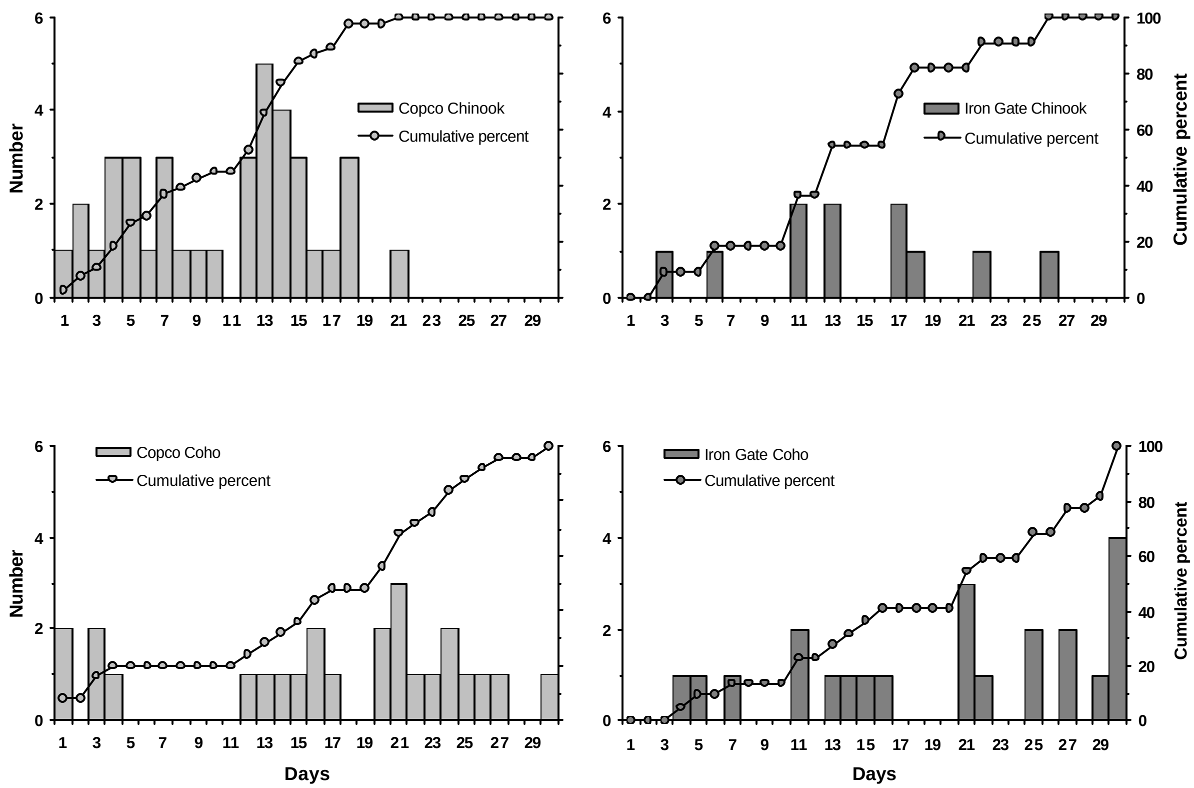


Figure 10. Arrival distribution in number and cumulative percent for Chinook (top) and coho (bottom) that migrated to Copco No. 1 and Iron Gate dams.

Fish Passage-To assess fish passage at each dam, underwater antennas were deployed near the intakes and aerial antennas downstream from the powerhouse of Copco No. 1 and Iron Gate dams. In addition, mobile surveys helped confirm the passage of fish when they were detected downstream from both projects. The telemetry system setup downstream from the tailrace of Copco No. 2 powerhouse could also help confirm passage of fish released upstream in Copco reservoir. Thus, fish released in Copco reservoir could be monitored through Copco No. 1, Copco No. 2 and Iron Gate developments. However, fish released into Iron Gate reservoir were only monitored to the tailrace of that project.

During the study several fish were captured by avian predators and transported within the study area encountering fixed station receivers. Therefore, researchers assumed that only those fish that had migrated through a reservoir and were detected in the forebay would qualify for fish passage. In addition the detections of a particular fish by different telemetry receivers must be in a sequence (upstream to downstream) that indicates downstream passage. Finally, during this study there was no spill at Copco No. 1 or Copco No. 2 dams and no fish were detected on the aerial antennas that monitored the spillway at Iron Gate dam. Consequently, all fish passage during this study occurred at the powerhouse of Copco No. 1 and Iron Gate dams. Fish passage at Copco No. 2 could occur either through the powerhouse intake or bypass flume.

In general, Chinook showed a greater propensity to find available passage routes downstream and it appeared that both Chinook and coho were more likely to pass Copco No. 1 dam than Iron Gate dam (Table 7). The fish released into Copco reservoir that migrated to Copco No. 1 dam showed a fairly high passage rate often through multiple dams. The percentage of fish that passed Copco No. 1 dam for Chinook was 87 percent (33 of 38) and 68 percent for coho (17 of 25) (Table 7). Fish passage remained fairly high with 82 percent (27 of 33) of the Chinook and about 76 percent of the coho (13 of 17) passing Copco No. 2 dam. Thereafter, migration through Iron Gate reservoir and passage at Iron Gate dam decreased substantially (Table 7). There were six fish that passed Iron Gate dam. Only two of those fish were released into Iron Gate reservoir. None of the coho and only two of the Chinook released in Iron Gate passed through the development (Table 7).

Table 7. The number of Chinook and coho salmon that were released in the reservoirs and detected at Copco and Iron Gate dams that passed downstre am of Copco No. 1, Copco No. 2, and Iron Gate dams.

Fish	Release			Number Released	Fish Passage				
					Copco 1		Copco 2	Iron Gate	
	Location	Date	Group		Forebay	Tailrace	Tailrace	Forebay	Tailrace
Copco	Coho	1-April	1	20	8	7	5	4	1
		8-April	2	20	7	3	2	1	1
		15-April	3	20	10	7	6	2	0
		Total		**60**	**25**	**17**	**13**	**7**	**2**
	Chinook	12-May	1	17	3	3	2	2	0
		19-May	2	22	15	14	13	7	1
		26-May	3	21	21	16	12	4	1
		Total		**60**	**38**	**33**	**27**	**13**	**2**
Iron Gate	Coho	3-April	1	20				7	0
		9-April	2	20				5	0
		16-April	3	20				10	0
		Total		**60**				**22**	**0**
	Chinook	13-May	1	20				4	1
		20-May	2	17				0	0
		27-May	3	23				7	1
		Total		**60**				**11**	**2**

Detections at the Dam- An important part of describing the migration behavior is the movement pattern displayed near the dam. Often fish display definite vertical or horizontal patterns as they encounter a dam. The patterns displayed may be particularly important when considering bypass or downstream migrant collection systems. One way to describe such patterns near the dam is to document where fish encountered a particular area and some measure of how long they stayed.

Researchers used three indices to describe behavior of the radio-tagged fish that were detected by the underwater antenna systems at Copco No.1 and Iron Gate dams. First, they looked at the antenna array where fish were initially detected as they approached the dam or the intake structure. This index defined the location where fish first encountered the dam face, or intake during their downstream migration. Second, they compiled the number of repeat detections at each location when radio-tagged fish approached on subsequent visits. Here, they separated repeat detections by a minimum of one hour from other previous detections. This index helped explain behavior as fish made repeat attempts to migrate downstream. Finally, the total number of detections recorded at each location was used to evaluate where fish tended to reside..

Copco No. 1 dam- At Copco No. 1 dam, underwater antennas were deployed near the intakes for Units 1 and 2 and at the spillway to describe the movement near the dam. Here, researchers used first, repeat and total detections to determine horizontal distribution across the face of the dam (Table 8).

There was a definite horizontal detection pattern displayed at Copco No. 1 dam for coho. There were 22 coho detected by the underwater system at the dam that contributed to 20,222 detections. All the coho (22/22) detected by the underwater system were eventually detected at the intakes. The majority (16/22) of the coho were first detected in front of the Unit 2 intakes (Table 8). When fish left and returned there was nearly an equal split on repeat visits for Unit 1 (11-detections) and Unit 2 (14-detections). There was only one fish that was first detected at the spillway with three repeat detections that occurred along the spillway. The concentration of fish movement near the intakes is shown by the total number of detections in front of the Unit 2 intakes (10,939-detections) followed by Unit 1 intakes (7,764-detections) and along the spillway (1,519-detections). The uneven distribution along the face of the dam for each of the indices suggests that coho traveled in a fairly direct path to the powerhouse intakes and spent most of their time there.

For Chinook, there was a fairly even distribution of fish detected across the face of the dam for first and repeat detection (Table 8). However, as a measure of the time spent at each location, Chinook appeared to spend more time near the intakes than along the spillway. There were 32 Chinook detected by the underwater system at Copco dam that added to the total number of detections (11,512-detections). Almost all Chinook (28/32) were eventually detected near the intakes. For Chinook there were more first (14/32) and repeat detections (16/39) along the spillway than either of the intakes (Table 8). However, the total number of detections within a particular area definitely showed that most Chinook spent more time in front of the Unit 2 (5,932-detections) and Unit 1 (3,698-detections) intakes than along the spillway (1,882-detections.

Table 8. The number of first, repeat, and total detections recorded at the intakes for Units 1 and 2 and along the spillway for coho and Chinook at Copco No. 1 dam.

Fish	Location	First Detections	Repeat Detections	Total Detections
Coho	Unit 1 Intakes	5	11	7,764
	Unit 2 Intakes	16	14	10,939
	Spillway	1	3	1,519
	Total	**22**	**28**	**20,222**
Chinook	Unit 1 Intakes	9	11	5,932
	Unit 2 Intakes	9	12	3,698
	Spillway	14	16	1,882
	Total	**32**	**39**	**11,512**

Iron Gate Dam- At Iron Gate six underwater antennas were deployed in front of the intake structure. Two were placed on the north side, two in the middle and two on the south side. At each location the antennas were set at two depths (5 ft. and 20 ft.), thus, researchers could combine different antennas to assess both horizontal and vertical distribution near the intake. To evaluate horizontal distribution at Iron Gate, detections at the top and bottom antennas were combined for each location (north, middle, and south). Likewise, the north, south and middle antennas arrays were combined for the top and compared to those detections at the bottom for each of the locations to describe vertical distribution.

The pattern of detections at the intake structure of the dam showed that coho were most often detected near the surface along the north side and in the middle (Table 9). There were 14 coho detected at the intake contributing to 19,574-detections. Most (11/14) radio-tagged coho were first detected at the surface typically on the north side and in the middle. When fish returned to the intake, the number of repeat detections clearly showed that nearly all visits (48-detections) were at the surface on the north side and in the middle (Table 9). This pattern remained consistent with total detections, which showed that coho appeared to remain near the surface (16,863-detections) along the north side (9,301-detections) and in the middle (4,698-detections).

The limited number of Chinook detected at the intake provides less information to assess. However, Chinook were usually detected deeper on the north and south sides. There were 7 fish detected at the intake that contributed to 1,919-detections. Almost all Chinook (6/7) were first detected on the deeper antennas and all were detected on the north side (Table 9). On repeat visits, more Chinook were detected on the deep antennas (12-detections) than on the shallow antenna array (6-detections). The number of repeat visits indicated that some fish shifted their approach to the south side (7-detections) but most were recorded on the north side (11-detections). The total number of detections indicates that fish spent more time on the south side (1,498-detections) near the deep antenna (1,476-detections).

Table 9. Number of first, repeat and total detections recorded for radio-tagged juvenile coho and Chinook salmon by the underwater antenna system at Iron Gate Dam.

Fish	Depth	First Detection				Repeat Detections				Total Detections			
		North	Middle	South	Total	North	Middle	South	Total	North	Middle	South	Total
Coho	Surface	6	4	1	11	24	19	5	48	9,301	4,698	2,864	16,863
	Deep	1	0	2	3	0	1	0	1	852	1,734	127	2,711
	Total	**7**	**4**	**1**	**14**	**24**	**20**	**5**	**49**	**10,153**	**6,432**	**2,991**	**19,574**
Chinook	Surface	1	0	0	1	5	0	1	6	116	17	22	155
	Deep	6	0	0	6	6	0	6	12	223	65	1,476	1,764
	Total	**7**	**0**	**0**	**7**	**11**	**0**	**7**	**18**	**339**	**82**	**1,498**	**1,919**

1.6.6 Movement Patterns

The description of migration behavior through each reservoir was separated into two migration outcomes. The distinction is between successful and unsuccessful migration to Copco No. 1 and Iron Gate dams. Successful migrants were fish that had moved through the reservoir and were detected by the fixed telemetry system at either dam. Unsuccessful fish were not detected by the fixed telemetry systems at either dam. This fundamental separation will reveal the most useful information on data collected from mobile surveys. To facilitate the assessment of migration behavior, three zones were created within each reservoir to describe dispersal of fish once they were released. The plots for coho and Chinook are displayed in the appendix of this report and represent the cumulative detections observed during mobile surveys over the entire study period.

Copco Coho-Mobile surveys detected 83 percent (50/60) of the coho released into Copco reservoir and obtained 310 detections for these fish (Table 10). Over 70 percent (224/310) of the detections for coho in Copco reservoir occurred in Zone 1 (Table 10). This suggests that coho released in Copco reservoir were reluctant to leave the release site area, contributing to multiple detections near the release site and in Zone I (Table 10). However, successful coho migrants eventually moved down reservoir, but their migration was slow, with some fish detected on five separate mobile survey dates (21-days) in Zones I and or II before moving toward the dam. After successful coho migrants left Zone II they were most often detected along the north shore in Zone III (Appendix 1-4). No fish were detected in the center of the reservoir in Zone III. More than half of the successful coho migrants were later detected downstream in Iron Gate reservoir (Appendix 1-4). Unsuccessful coho migrants rarely made it out of Zone I (Appendix 5-8). Two coho, both from release group 3, were the only unsuccessful migrant fish to reach Zone III (Appendix 8). An additional five fish were detected in Zone II from all release groups combined. However, three of these fish that left Zone 1 were later detected in the same location on successive survey dates.

Iron Gate Coho-In Iron Gate reservoir mobile surveys detected 97 percent (58/60) of the coho released and recorded 408 detections for these fish. Similar to Copco reservoir, over 70 percent (315/408) of the coho in Iron Gate were detected in Zone I (Table 10). The migration behavior of coho in Iron Gate reservoir showed that most fish did not move quickly from the release site. The movement of successful coho migrants appeared to progress more quickly once the fish moved away from the release area. However, upon reaching Zone III eleven coho moved back upstream some as far as Zone I. There was no distinct north or south shoreline migration pattern through the reservoir because successful coho migrants were detected almost everywhere (shorelines, mid-reservoir, and coves) (Appendix 9-12). Unsuccessful coho migrants in Iron Gate spent most of their time in Zone I (Appendix 13-16). Several of the fish that migrated downstream within Zone I moved back up again. There were only two unsuccessful coho migrants that were detected in Zone III (Table 10). These two fish returned to Zone II for the remainder of the study. Five additional fish moved from Zone 1 into Zone II. One fish returned to Zone 1 and the rest remained in Zone II. There were seven coho released in Iron Gate reservoir that were detected upstream in Copco reservoir (Appendix 14-16). These fish were transported by avian predators such as great blue herons (*Ardea herodias*) and American white pelicans (*Pelecanus occidentalis*).

Table 10. The number of radio-tagged juvenile coho observed during mobile surveys in each zone of Copco and Iron Gate reservoirs versus the frequency of detections recorded in each zone. For example there were 65 detections recorded for the 19 successful migrant fish observed in Zone I of Copco reservoir during all mobile surveys.

		Coho					
		Copco			Iron Gate		
		Migration			Migration		
Reservoir Zones	Number	Successful	Unsuccessful	Total	Successful	Unsuccessful	Total
Zone I	Detections	65	159	224	88	227	315
	Fish	19	26	45	17	33	50
Zone II	Detections	28	16	44	41	26	67
	Fish	11	5	16	17	7	24
Zone III	Detections	27	13	40	24	2	26
	Fish	13	2	15	15	2	17
Total	Detections	120	188	310	153	255	408
	Fish	22	28	50	22	36	58

Copco Chinook- Mobile surveys detected 70 percent (42/60) of the Chinook released into Copco reservoir and obtained 152 detections for these fish (Table 11). In comparison to coho, Chinook detections in Copco were more evenly distributed throughout the reservoir. The successful Chinook migrants in Copco reservoir appeared to travel in a fairly direct path to the forebay of the dam (Appendix 17-20). That is, there were few successful migrants detected in the coves or inlets of Copco reservoir. Chinook that reached Zone II tended to use the north shore of the reservoir but then moved through the middle of the reservoir in Zone III to reach the forebay. Successful Chinook migrants were detected only a few times in the reservoir and passed through Copco reservoir faster than coho migrants. Often times successful Chinook migrants were only detected once in the reservoir. Indeed several Chinook in release group 3 were not even detected until they passed Copco No. 1 dam and moved into Iron Gate reservoir (Appendix 20). All the Chinook released in group 3 were successful and most detections for this group occurred in Zone III. Successful Chinook migrants appeared to move through the reservoir faster and at greater depths than other fish making them more difficult to detect. Unsuccessful Chinook migrants, fish that did not reach the forebay of the project, tended to reside along the North shoreline of Copco reservoir or near the release site (Appendix 21-24). These Chinook migrants typically remained in Zones I and II and had numerous detections in the same area. Researchers often observed herons and pelicans in these areas. There was only one unsuccessful Chinook migrant that was detected in Zone III (Appendix 22). The dispersal pattern for unsuccessful migrants is best observed in release group 1 and release group 2. None of the unsuccessful migrants in release group 2 were detected outside of Zone I except detections in Iron Gate reservoir from avian predation.

Iron Gate Chinook- In Iron Gate reservoir mobile surveys detected 92 percent (55/60) of the Chinook released and recorded 302 detections for these fish (Table 11). Similar to Chinook migrants in Copco reservoir, successful Chinook migrants in Iron Gate typically were not detected in coves or inlets and most detections occurred in Zones II and III. These migrants also did not appear to spend much time near the release site (Appendix 25-28). Most of the detections for successful migrants were in the middle of the reservoir. The successful Chinook appeared to migrate directly toward the dam and spent more time in Zones II and III of the reservoir. The successful migrants in Iron Gate reservoir showed that only two or three fish were even detected in Zone I. This pattern is best observed in release groups 1 and 3. Some Chinook that reached Zones II or III moved back upstream either from Zone III to Zone II or within Zone II. Most unsuccessful Chinook migrants remained in Zone I and Zone II with only one fish detected in Zone III (Appendix 29-32). There were only five unsuccessful Chinook that reached Zone II. The majority of unsuccessful migrants were detected in Zone I within approximately 2 miles of the release site. This pattern is best observed in release groups 1 and 2 for Chinook.

Table 11. The number of radio-tagged Chinook observed during mobile surveys in each zone of Copco and Iron Gate reservoirs versus the frequency of detections recorded in each zone. For example there were 29 detections recorded for the 15 successful migrant fish observed in Zone I of Copco reservoir during all mobile surveys.

Reservoir Zones	Number	Chinook					
		Copco			Iron Gate		
		Migration			Migration		
		Successful	Unsuccessful	Total	Successful	Unsuccessful	Total
Zone I	Detection	29	60	89	4	252	256
	Fish	15	8	23	3	41	44
Zone II	Detection	11	19	30	14	21	35
	Fish	10	5	15	6	5	11
Zone III	Detection	24	9	33	10	1	11
	Fish	17	1	18	7	1	8
Total	Detection	64	88	152	28	274	302
	Fish	29	13	42	10	45	55

1.7 Discussion

The purpose of this study was to provide information on the migration success and behavior of coho and Chinook in Iron Gate and Copco reservoirs. The principal question was whether or not juvenile Chinook and coho smolts can efficiently negotiate these reservoirs under typical water management and dam operations. Providing this type of information is fundamental to reintroduction efforts in the lower Klamath River Project area. In this study hatchery fish were used to evaluate migration behavior under current conditions because they are the predominant stocks that must function if reintroduction efforts are to proceed.

The migration success for hatchery coho and Chinook was relatively low but some fish clearly demonstrated an ability to migrate through each reservoir. The migration success for coho and Chinook was consistently higher in Copco reservoir than it was in Iron Gate reservoir. Migration success for coho was fairly consistent between reservoirs at 37 percent in Iron Gate and 42 percent in Copco reservoir. However, for Chinook migration success was more variable at 18 percent in Iron Gate and 65 percent in Copco reservoir. Overall Iron Gate reservoir appears to present more difficulties to successful migration of Chinook than does Copco reservoir.

There were Chinook and coho that demonstrated the ability to navigate project reservoirs within approximately two to three weeks. In general, the median travel times observed during this study indicate that Chinook required less time to negotiate reservoirs than coho. The median travel time for Chinook from release site to the dam was about 11-days for Copco reservoir (4.8-miles long) and 13-days for Iron Gate reservoir (6.3-miles long). Coho required about 8 more days than Chinook to migrate through Copco (19-days) and Iron Gate (21-days) reservoirs. The rate of movement for Chinook and coho was higher in Iron Gate reservoir than it was in Copco reservoir. For Chinook, the median migration rate through Copco reservoir was 0.42-miles/days compared to 0.49-miles/day through Iron Gate reservoir. The median migration rate for coho was 0.25-miles/day through Copco and 0.30-miles/day through Iron Gate. Chinook moved through the reservoirs faster than coho even though the prevailing flow through the reservoirs should have provided a better migration cue for coho than Chinook.

From mobile surveys in both reservoirs, researchers noted that many of the tagged fish did not readily move down reservoir toward the dams, instead many were detected multiple times at the head of the reservoir or near the release site. Prolonged residence in the upper reservoir may have indicated mortality especially if these areas were focal points for predators. Fish that did not successfully migrate to the dams were usually last detected in the upper portions of the reservoirs where numerous predatory birds were observed. Indeed, several fish were consumed by birds. Mobile surveys confirmed that at least 15 fish were preyed upon during the study period. During the study coho were preyed upon by great blue herons because several of the tags (12 of 120) from releases in Copco and Iron Gate were tracked near a rookery located just upstream from Copco No. 1 dam. This represents about 10 percent of the total number of coho released during this study. There were also five Chinook that were preyed upon by American white pelicans. This represents about 4 percent of the total number of Chinook released during the study (5 of 120). These numbers should be viewed as a conservative estimate of the avian predation because it is likely that other fish were probably consumed and either transported out of the area or the birds could have discharged the tags back into the reservoir before the fate of the fish could be identified.

Although predation by fish is difficult to confirm, it is likely that predatory fish such as rainbow trout (*Oncorhynchus mykiss*) and large mouth bass (*Micropterus salmoides*) were concentrated in the upper portions of the reservoir where it is more shallow and confined. Unsuccessful migrant Chinook and coho were usually last observed in these areas of both reservoirs. Fish could also have resided in these areas but were not considered to represent the migratory behavior of Chinook and coho smolts. In past studies at other Pacific Northwest hydroelectric project reservoirs, Chinook and coho moved away from the release site within several hours after being liberated and tended to disperse throughout the reservoir with time (Miller et al. 2001, 2002).

The migration success observed during this study may have been affected by reservoir temperatures. In particular, the low detection rate of Chinook at Iron Gate Dam may be associated with reservoir temperatures coupled with intense predation. In contrast, migration success rates were similar for both reservoirs for coho migrating in early-spring when water temperatures were cooler. The surface temperatures observed during this study in both reservoirs appeared to be favorable for the coho migration period (April-mid May). The mean migration period temperatures ranged from 12.2 to 14.9°C near the surface (<20 meters) in Iron Gate reservoir and ranged from 13.5 to 14.7°C in Copco reservoir. However, some mean daily temperatures in late April and beginning of May at the surface (1-2 meters) exceeded 15°C in Iron Gate and Copco reservoirs. The temperatures reported for optimal growth and smoltification of coho is about 15°C (McCullough et al. 2001).

The mean reservoir surface temperatures at depths less than 20 meters were adequate for Chinook growth but may have been too high for migrant smolts. The mean migration period temperatures at the surface (< 20 meters) ranged from 15.6 to 20.0 °C. The temperatures reported for optimal Chinook growth vary from 15 to 20°C but for smoltification range from 12 to 17°C (McCullough et al. 2001). Some research has indicated that smoltification indices and predator avoidance may be impaired with increasing temperatures above 17 °C (Marine and Cech (2004). In both reservoirs, mean daily temperatures generally did not exceed 17°C until the end of May and beginning of June at depths less than 20 meters. However, some of the maximum daily temperatures recorded at the surface (1-meter) in late June for Iron Gate reservoir were above or near the upper incipient lethal temperature (25°C) reported for Chinook (McCullough et al. 2001). Clearly, reservoir temperatures were more suitable at depth (10 and 20-meters) for migrant fish in late May and June. However, low dissolved oxygen levels have been recorded (NRC 2004) at depth in Iron Gate and Copco reservoirs in July. It does not appear that low DO levels are present in June, although differences in DO concentrations are noted at depth and may influence the migration depth selected by fish. As surface water temperatures increase and dissolved oxygen levels decrease at depth, successful smolt migrations could become impaired through Iron Gate reservoir and possibly Copco reservoir in June.

Fish arriving at the dams were more often detected near the intakes at Copco No. 1 dam than at the intake at Iron Gate dam. This was demonstrated by the detection of fish at the underwater antennas near the intakes and by the number of fish passing each dam. The underwater antennas located near the intakes at Copco No. 1 dam detected 22 of 25 (88 percent) coho that migrated to the dam. For Chinook the antennas near the intakes detected 28 of 39 (72 percent) fish that migrated to the dam. At Iron Gate, the underwater antennas near the intake detected 14 of 22 (64 percent) coho and 6 of 11 (55 percent) Chinook that migrated to the dam. At Copco No. 1, detections on the underwater systems near the intakes showed that both coho and Chinook spent the majority of there time there compared to the spillway. At Iron Gate, when coho were near the intake they tended to stay near the surface while Chinook were most often detected deeper in the water column.

At Copco No. 1 dam there were 63-fish (25 coho and 38 Chinook) that arrived at the dam and 50-fish (17 coho and 33 Chinook) that eventually passed. At Iron Gate dam there was a total of 53-fish (27 coho and 24 Chinook) that arrived at the dam from releases in both Copco and Iron Gate reservoirs. Only 6-fish (2 coho and 4 Chinook) passed Iron Gate dam. The lower detection rates, fish passage and apparent depth selection observed near the intake at Iron Gate for both Chinook and coho indicate that special considerations may be needed if collection/bypass systems are employed near the intake. However, at Copco No. 1 dam Chinook and coho passed the dam at fairly high rates and appeared to concentrate near the intakes, which indicates that they may be susceptible to a collection/bypass system at that location.

1.8 Literature Cited

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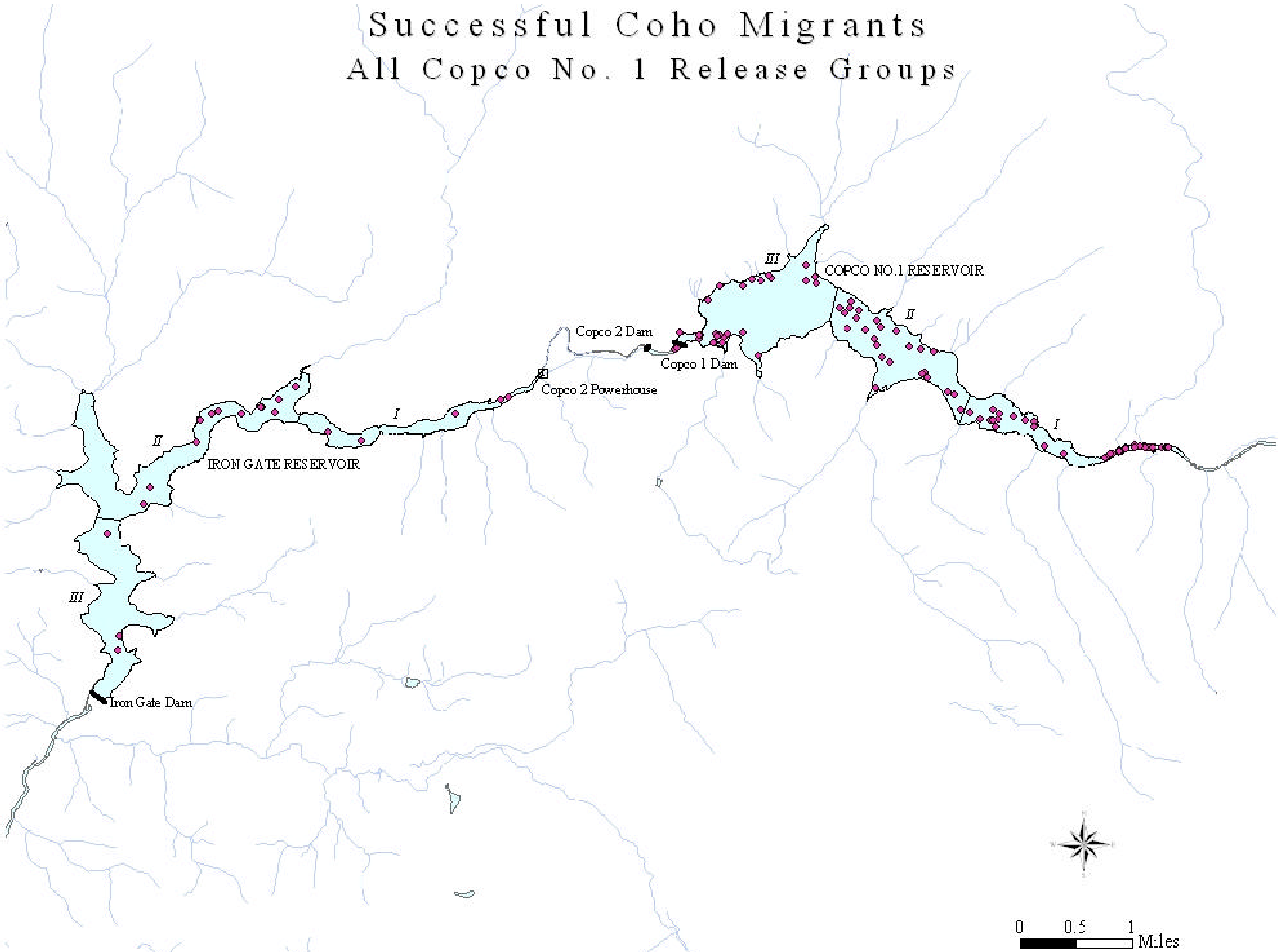
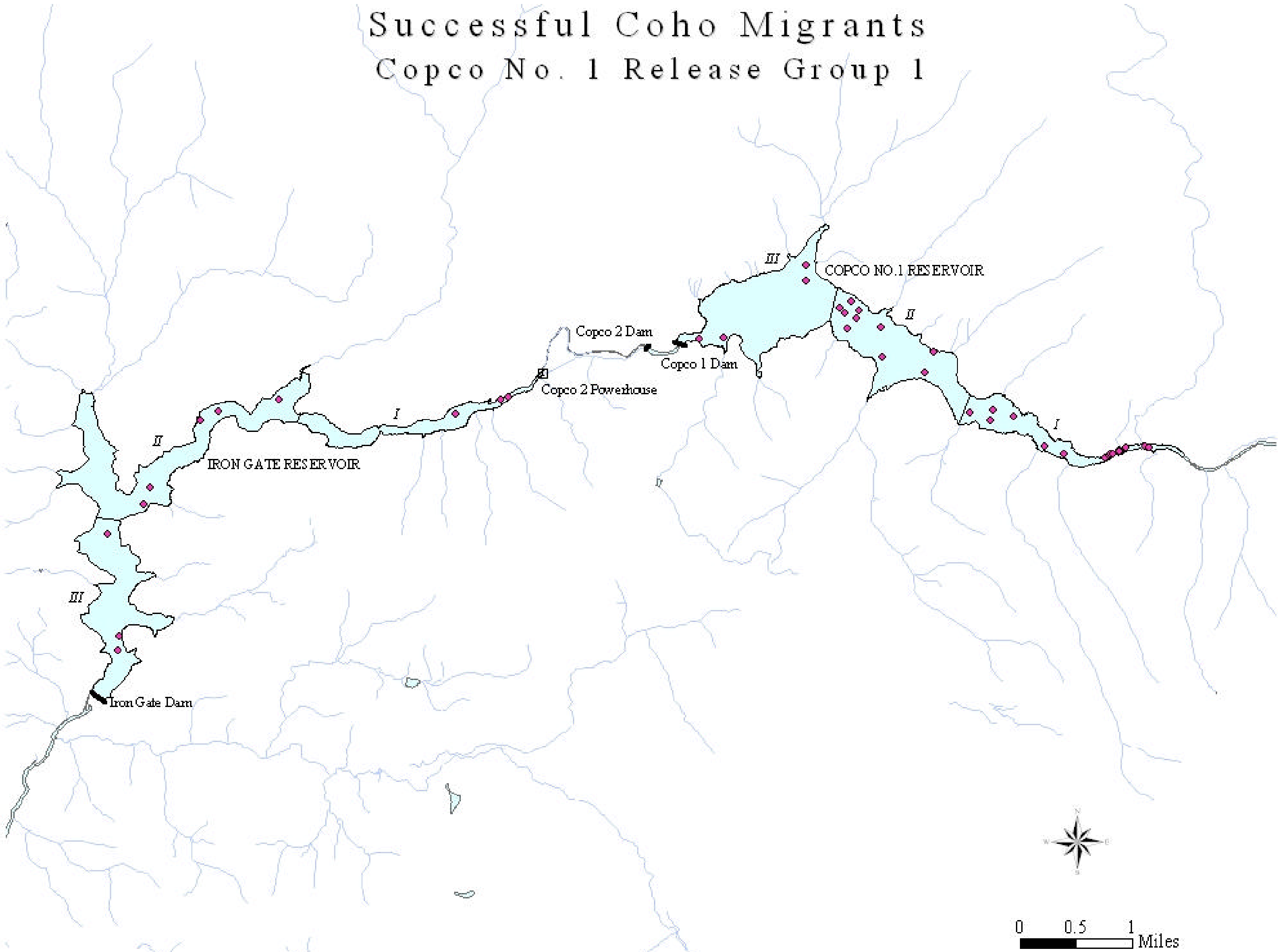
1.9 Appendices

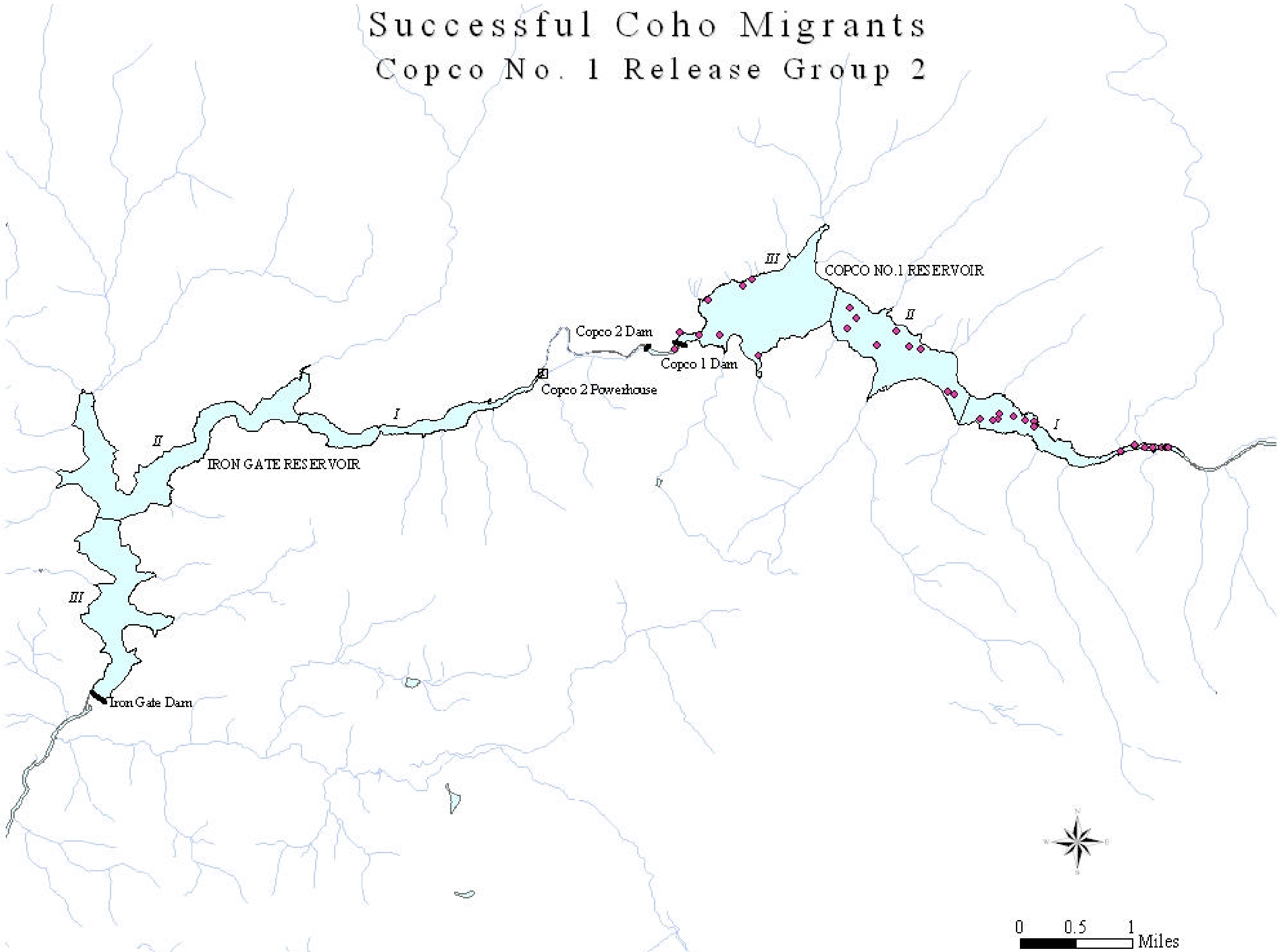
The following appendices display the cumulative detections during mobile surveys for successful and unsuccessful migrant coho and Chinook in Copco 1 and Iron Gate reservoirs. For example, in the first series of four maps there is one map that displays the cumulative positions plotted for all successful coho migrants released within Copco 1 reservoir followed by three more maps that display the successful coho migrants from each of the three release groups. This series is then repeated with four maps for all unsuccessful coho migrants and for each release group within Copco 1 reservoir. The series is then finished with a similar plots for coho released in Iron Gate reservoir and then for Chinook in both reservoirs. Thus, there are a total of 32 plots for the cumulative detections during all mobile survey for the entire study period for Chinook and coho in Copco and Iron Gate reservoirs.



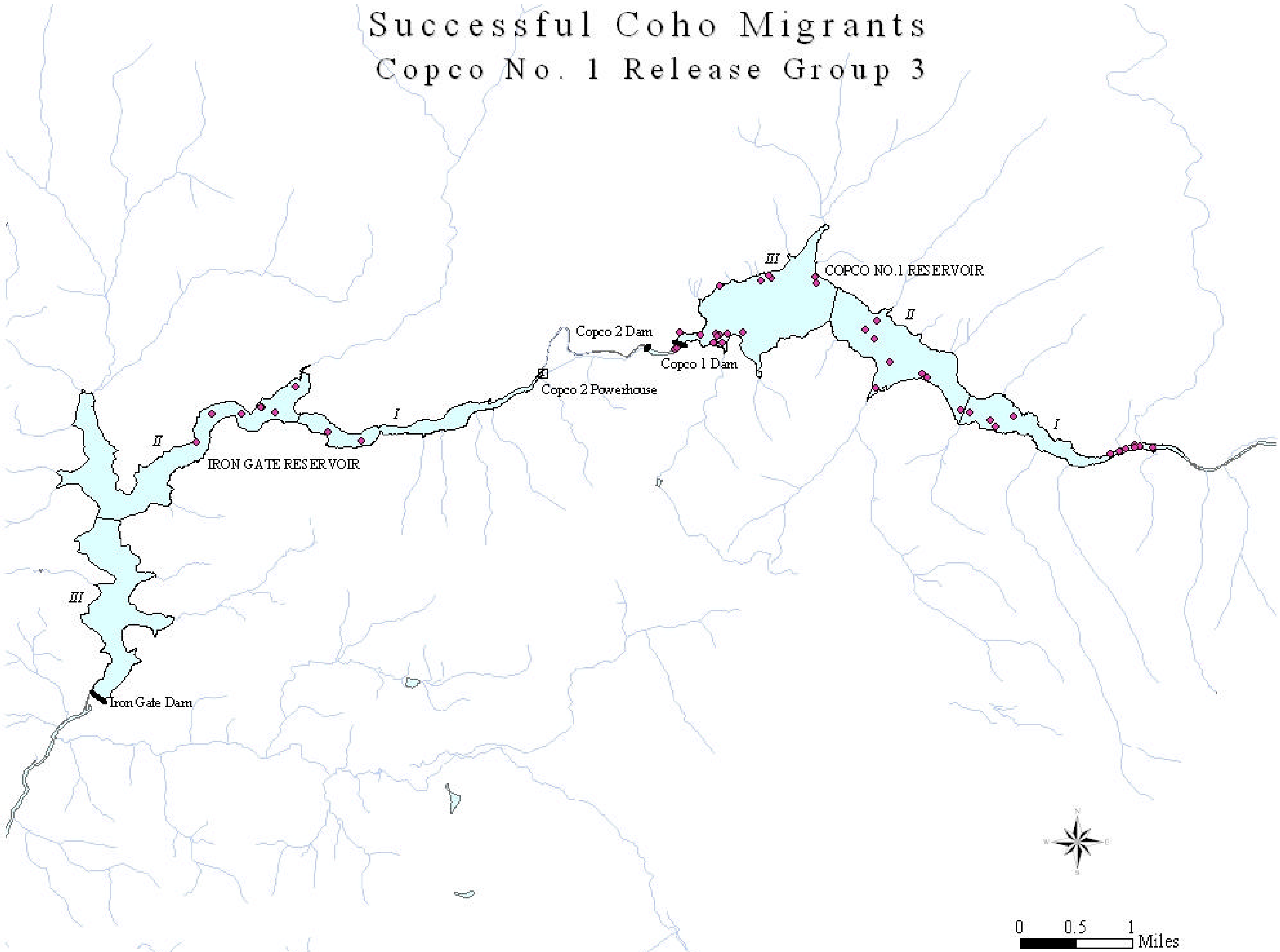
Appendix 1. Cumulative detections observed during mobile surveys over the entire study period for all successful coho migrants released in Copco reservoir. Fish detected in Iron Gate indicate the cumulative detections for fish that had passed Copco No. 1 and Copco No. 2 dams.



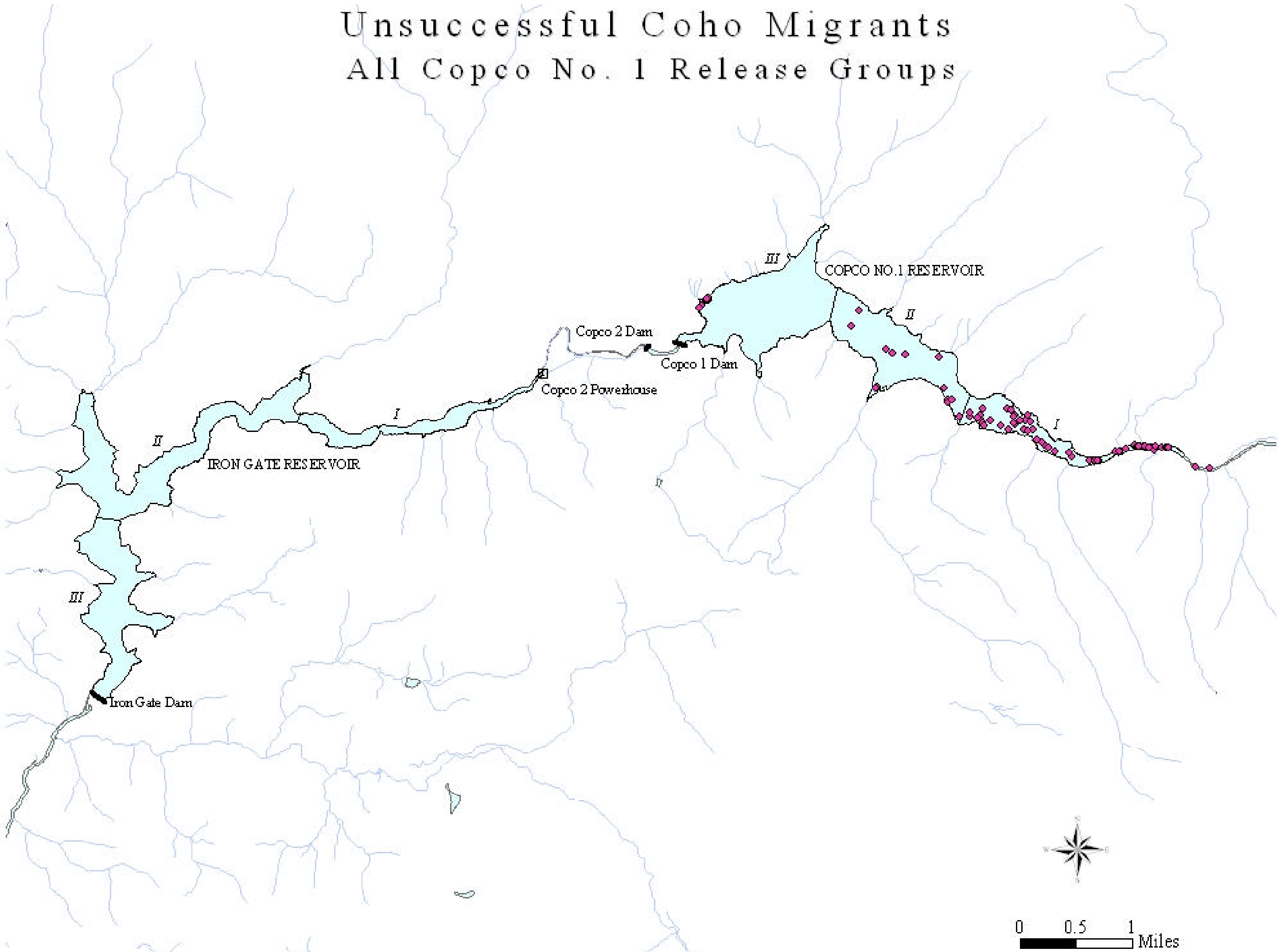
Appendix 2. Cumulative detections observed during mobile surveys over the entire study period for successful coho migrants from release group 1 in Copco reservoir. Fish detected in Iron Gate indicate the cumulative detections for fish that had passed Copco No. 1 and Copco No. 2 dams.



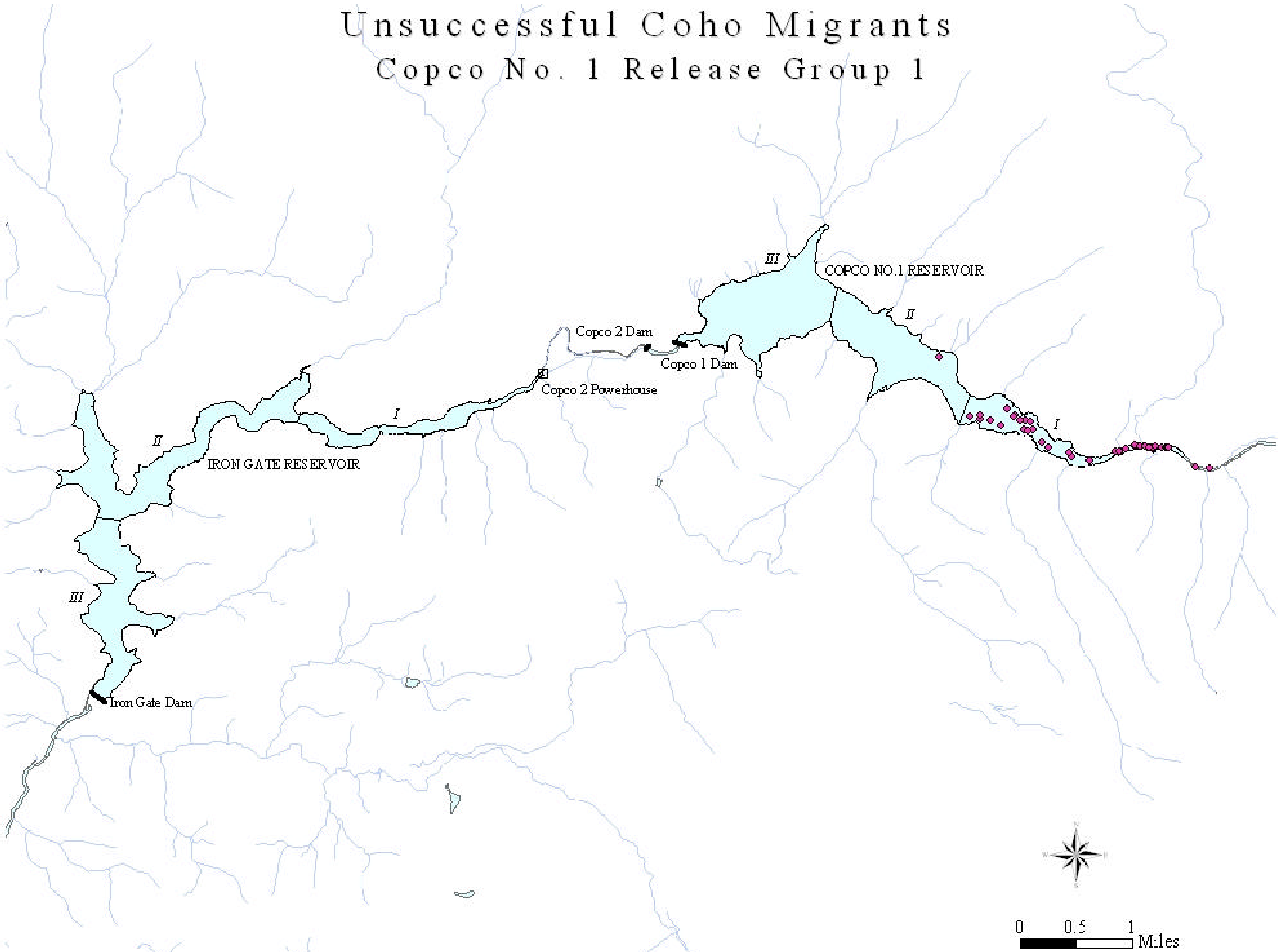
Appendix 3. Cumulative detections observed during mobile surveys over the entire study period for successful coho migrants from release group 2 in Copco reservoir.



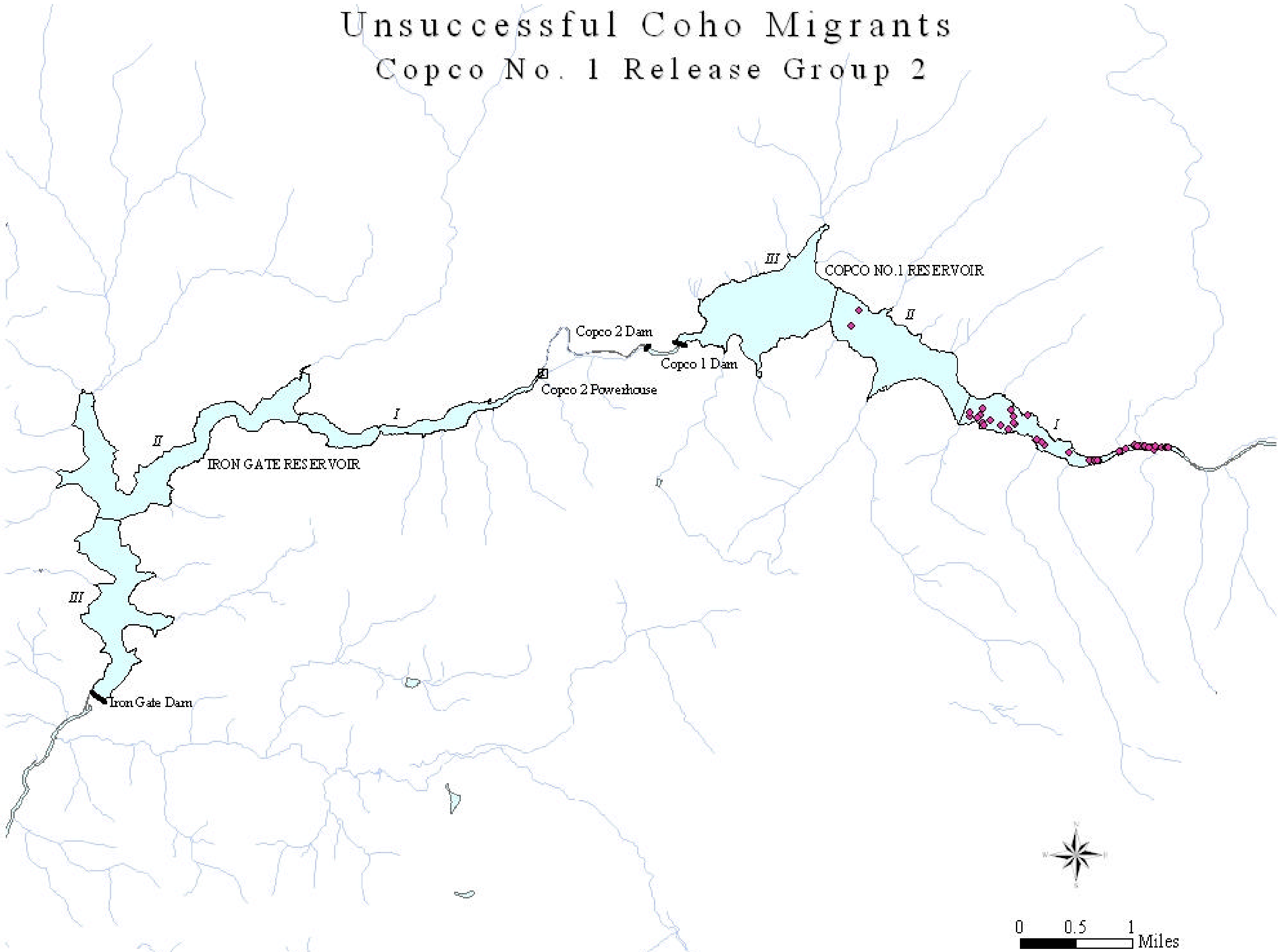
Appendix 4. Cumulative detections observed during mobile surveys over the entire study period for successful coho migrants from release group 3 in Copco reservoir. Fish detected in Iron Gate indicate the cumulative detections for fish that had passed Copco No. 1 and Copco No. 2 dams.



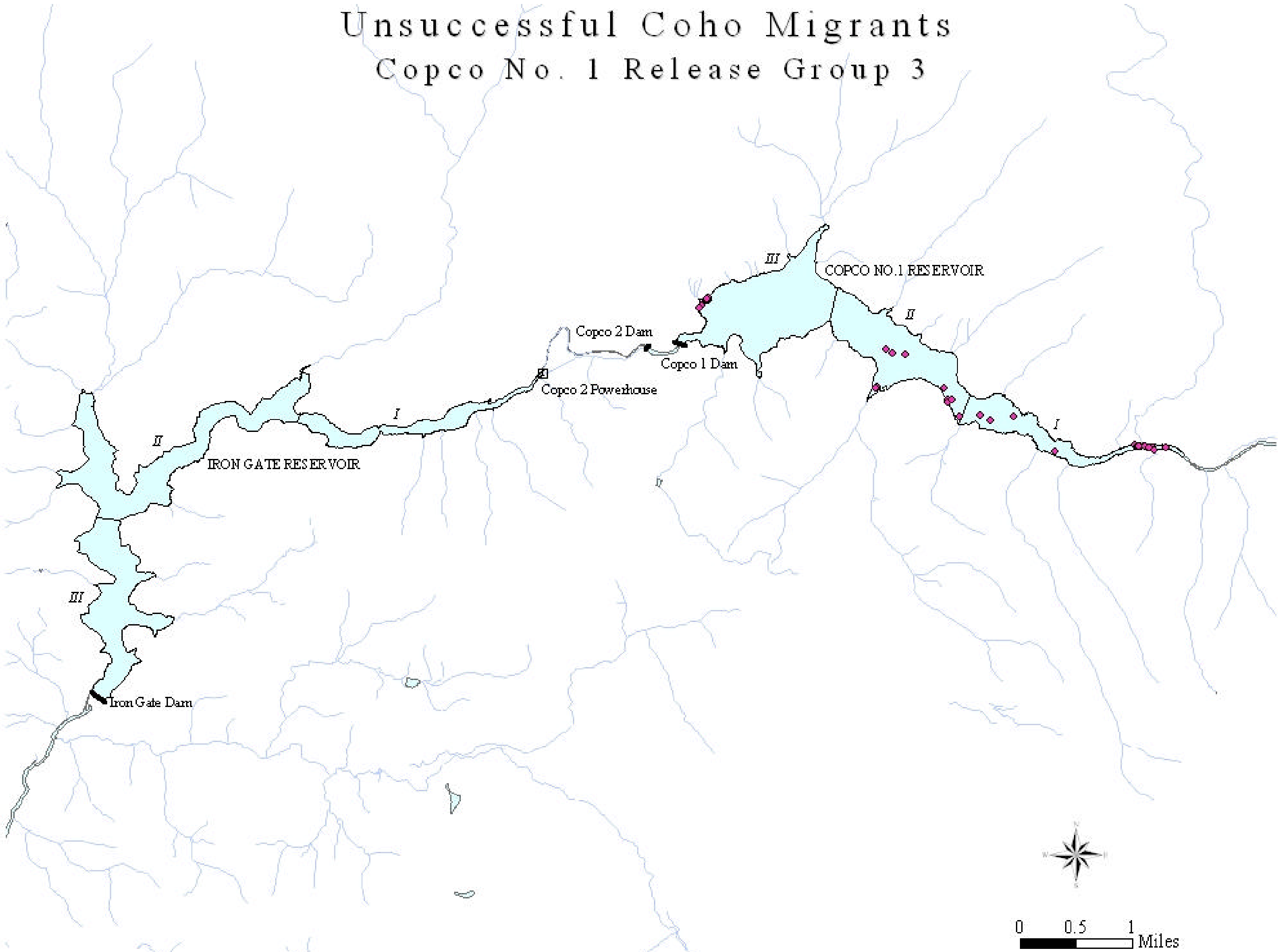
Appendix 5. Cumulative detections observed during mobile surveys over the entire study period for all unsuccessful coho migrants released in Copco reservoir.



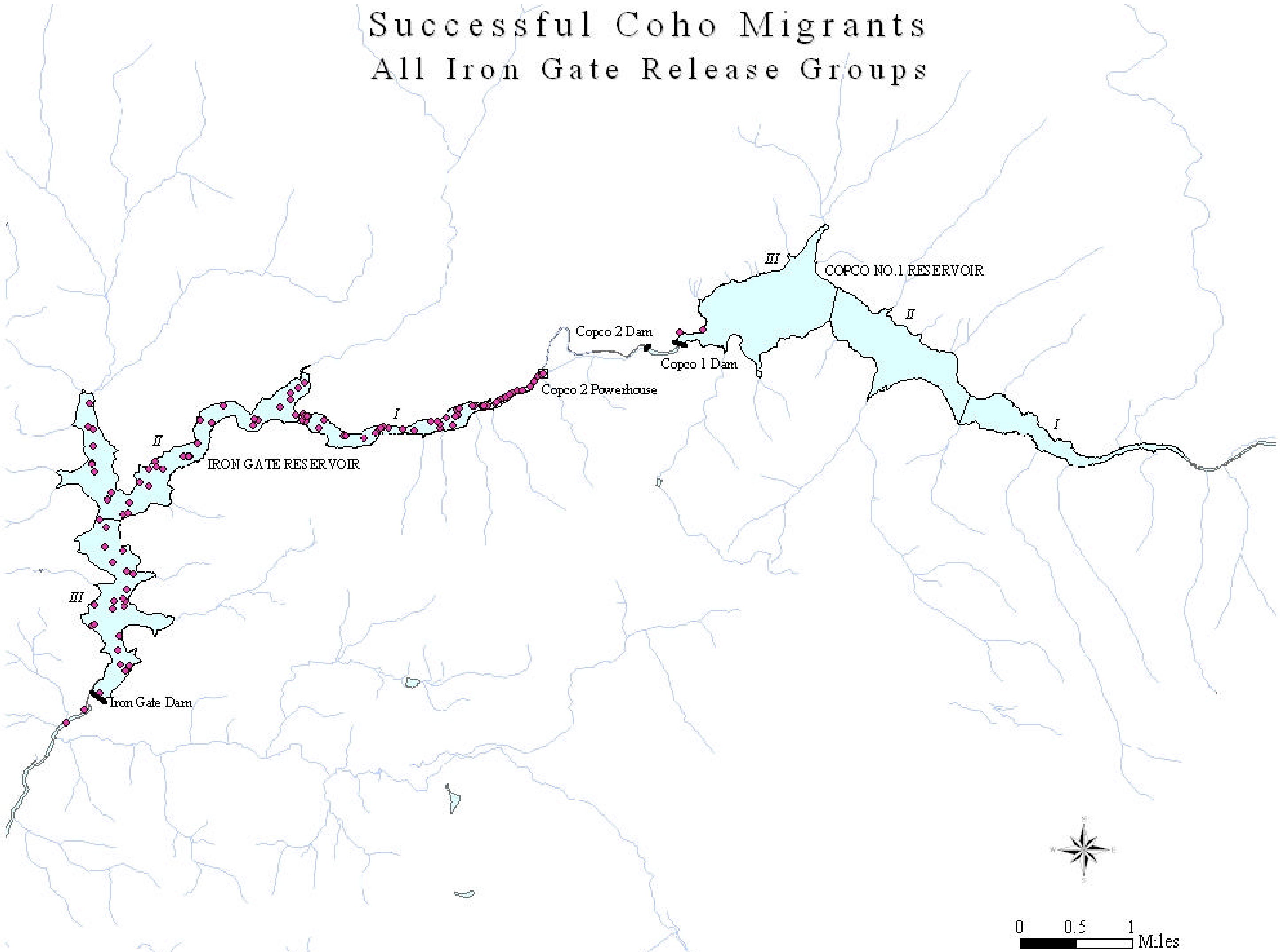
Appendix 6. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful coho migrants from release group 1 in Copco reservoir.



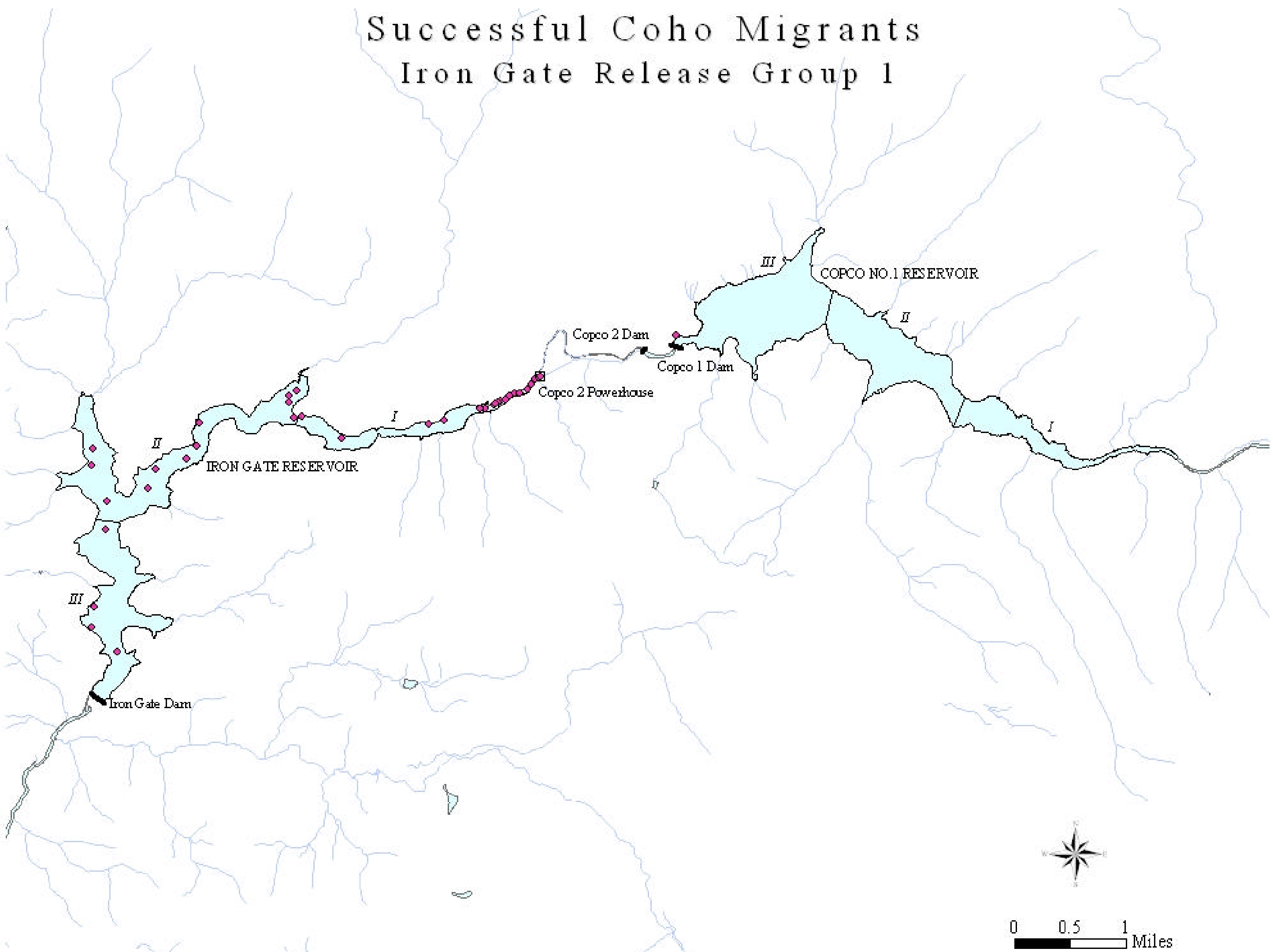
Appendix 7. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful coho migrants from release group 2 in Copco reservoir.



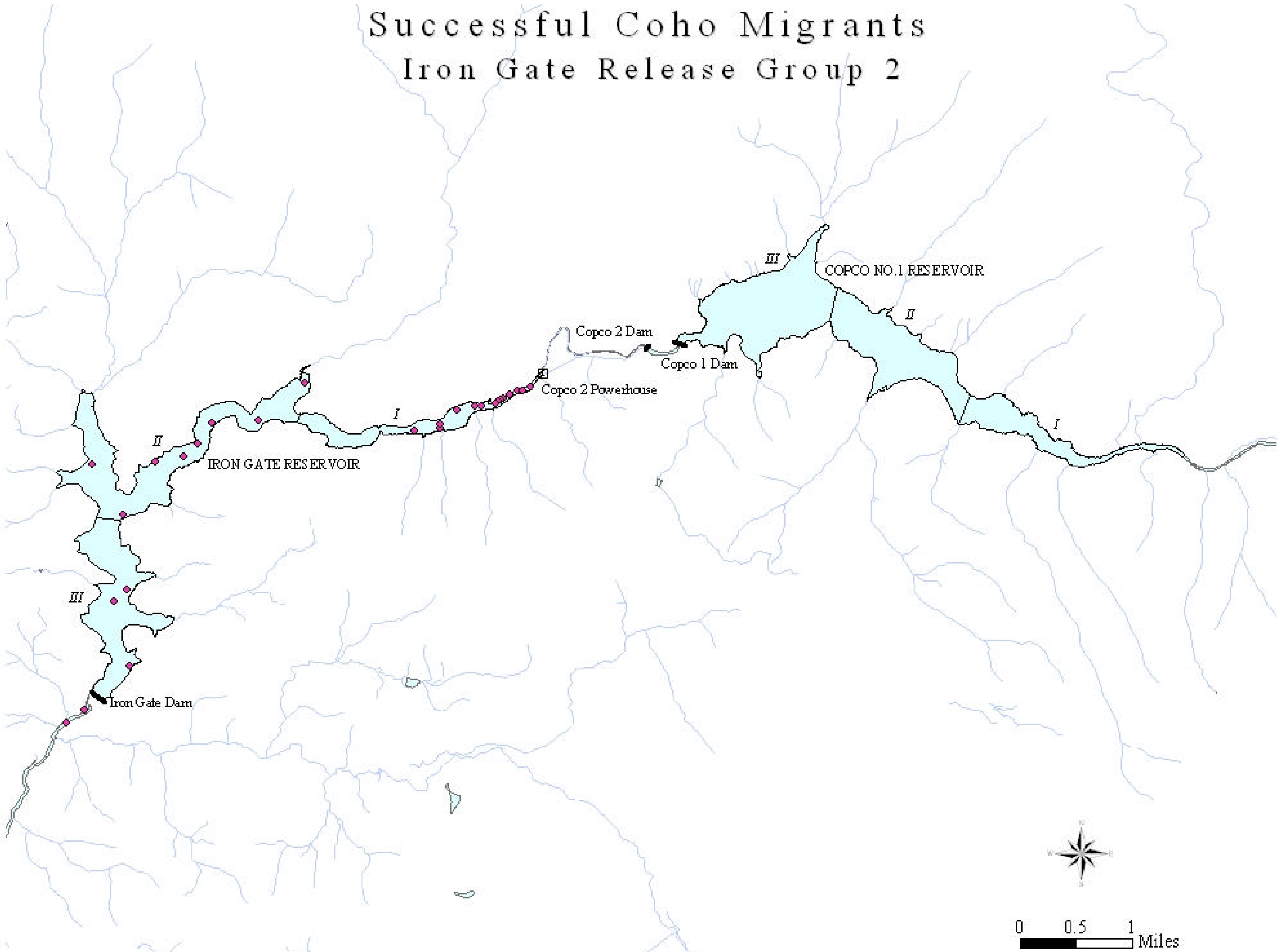
Appendix 8. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful coho migrants from release group 3 in Copco reservoir



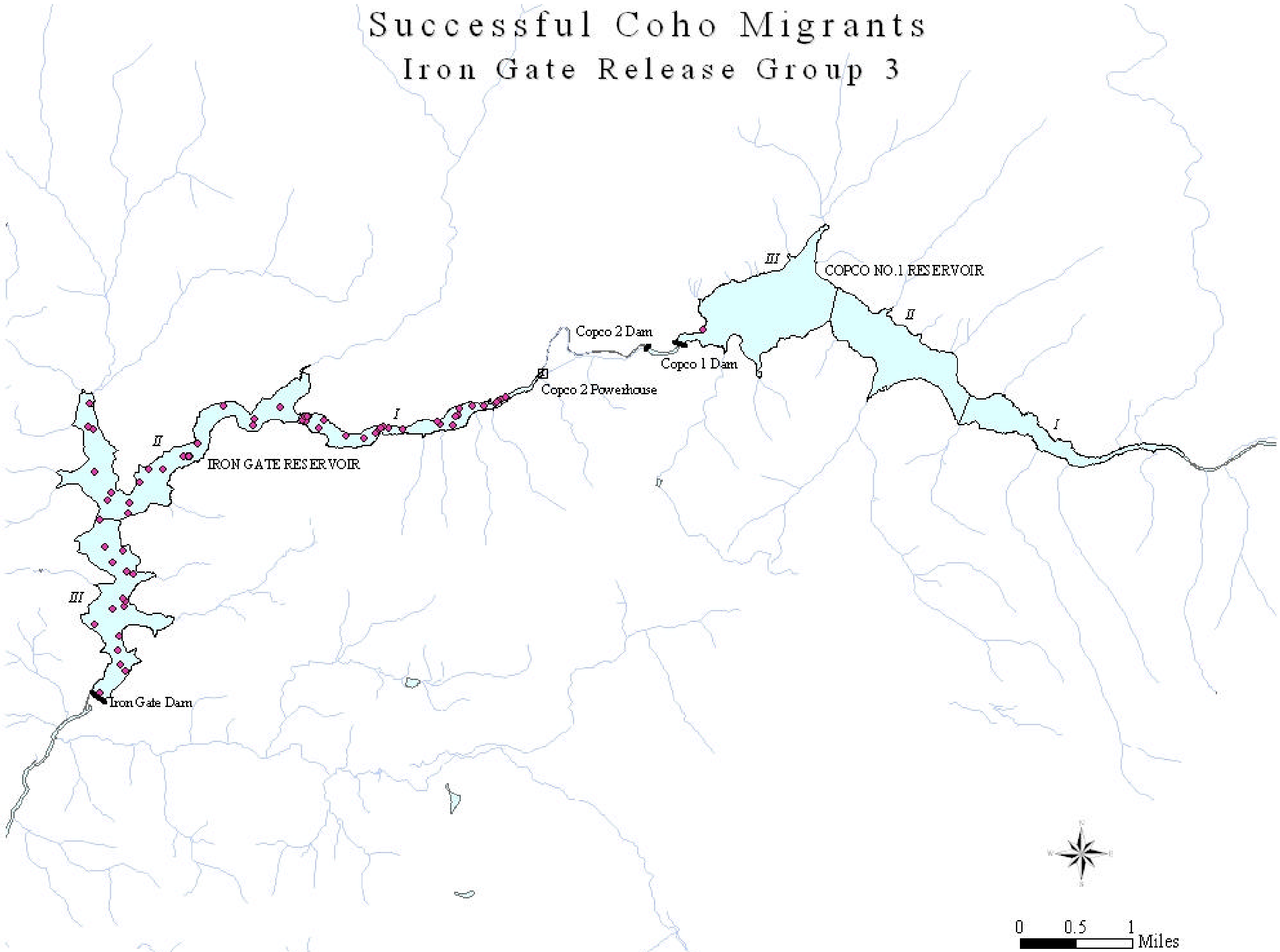
Appendix 9. Cumulative detections observed during mobile surveys over the entire study period for all successful coho migrants released in Iron Gate reservoir. The two positions plotted downstream from Iron Gate dam indicate two coho that had passed the dam. The two position plotted along the shoreline of Copco reservoir indicate two fish that had been transported by avian predators after they had made a successful migration to Iron Gate dam.



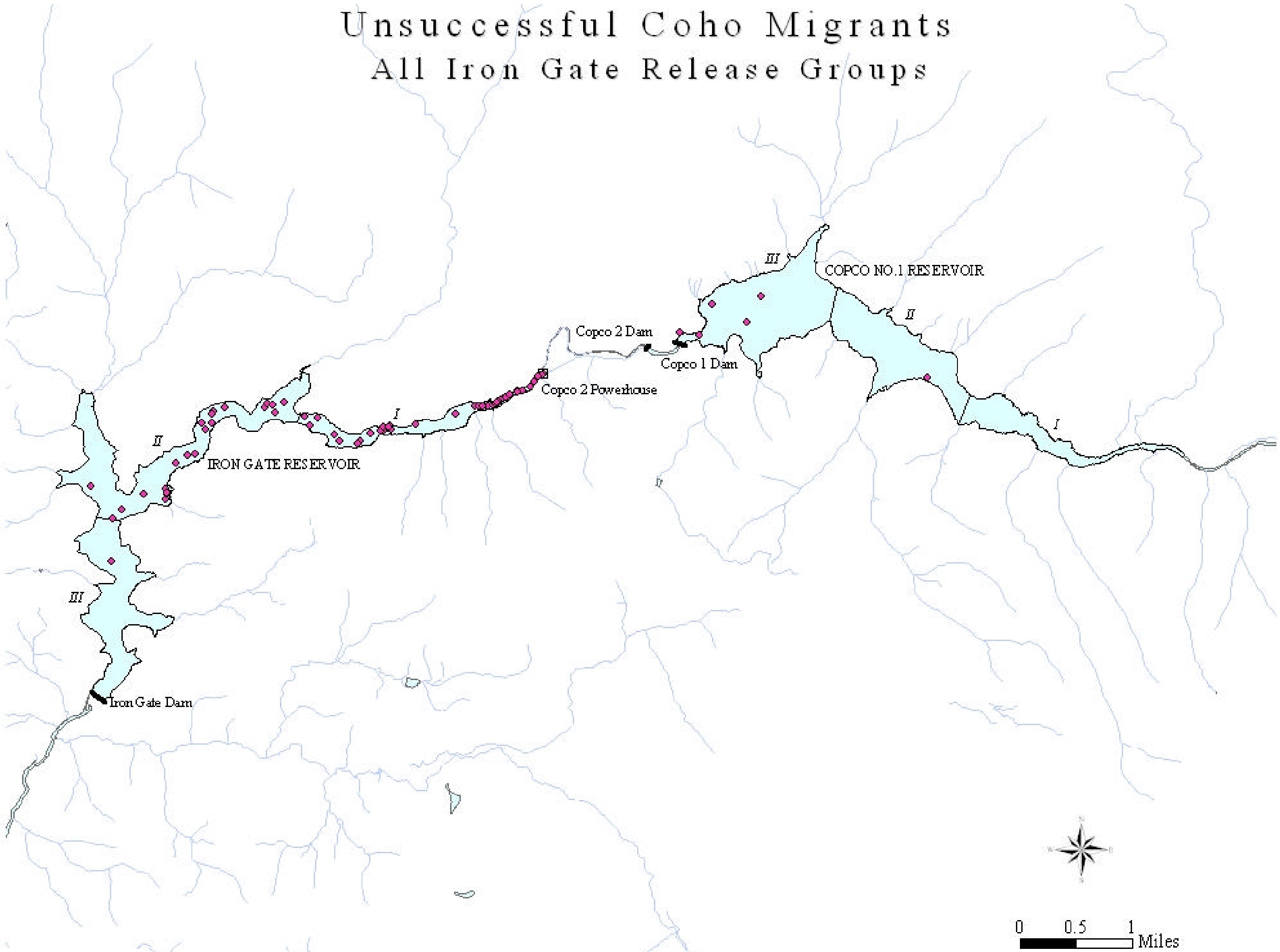
Appendix 10. Cumulative detections observed during mobile surveys over the entire study period for successful coho migrants from release group 1 in Iron Gate reservoir. The one position plotted along the shoreline of Copco reservoir indicates a fish that had been transported by an avian predator after it had made a successful migration to Iron Gate dam.



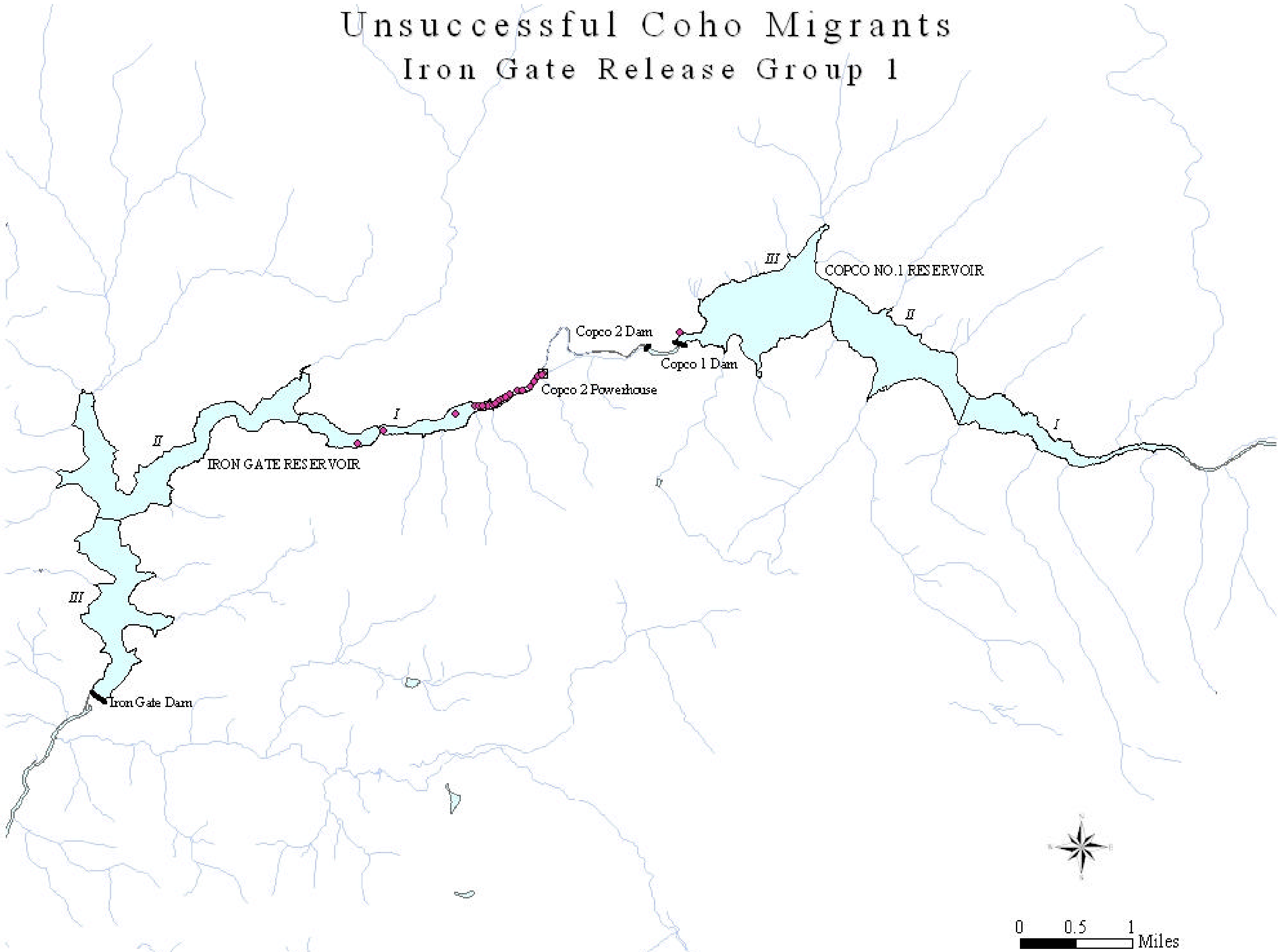
Appendix 11. Cumulative detections observed during mobile surveys over the entire study period for successful coho migrants from release group 2 in Iron Gate reservoir. The two positions plotted downstream from Iron Gate dam indicate two coho that had passed the dam.



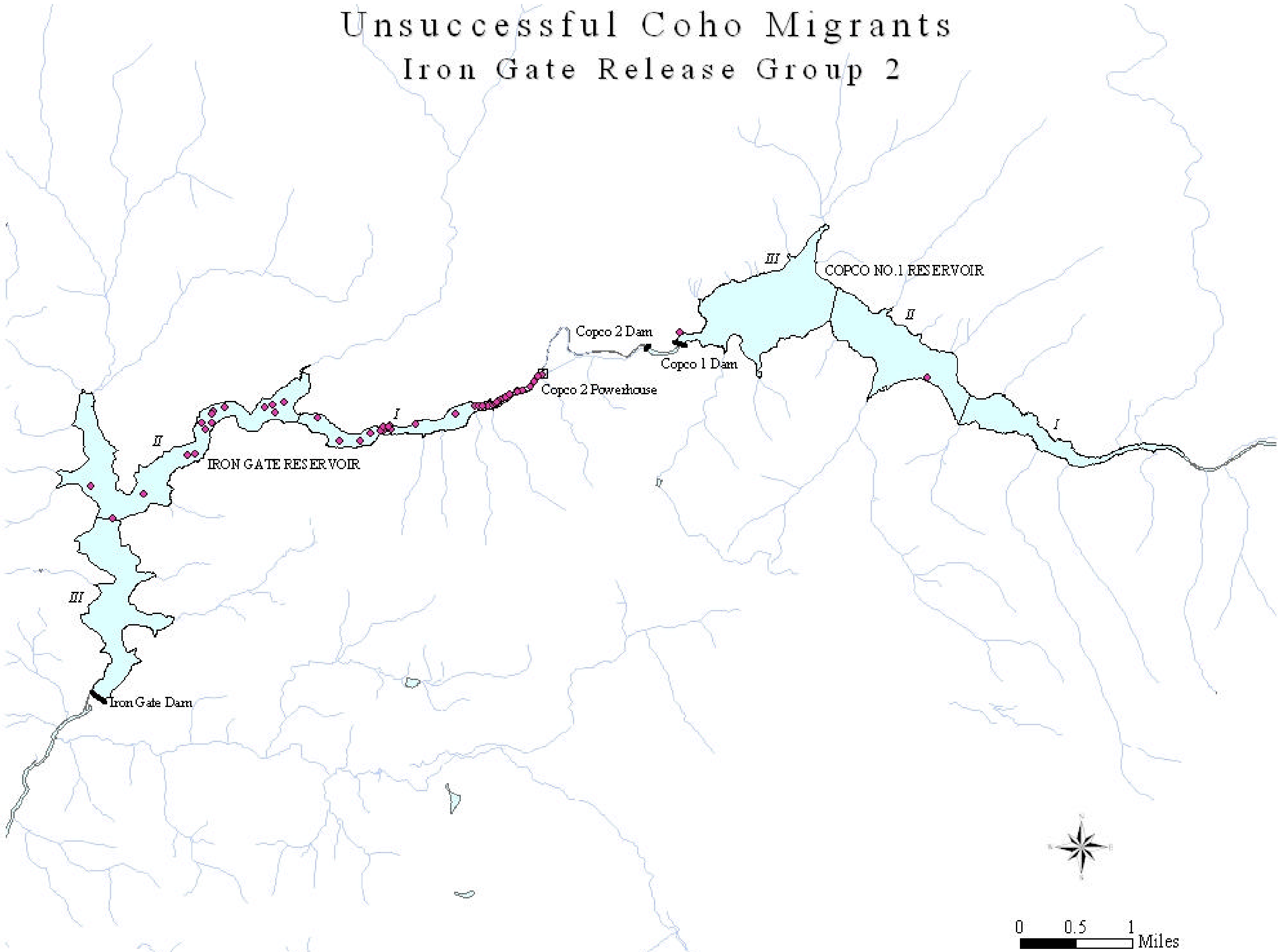
Appendix 12. Cumulative detections observed during mobile surveys over the entire study period for successful coho migrants from release group 3 in Iron Gate reservoir. The one position plotted along the shoreline of Copco reservoir indicates a fish that had been transported by an avian predator after it had made a successful migration to Iron Gate dam.



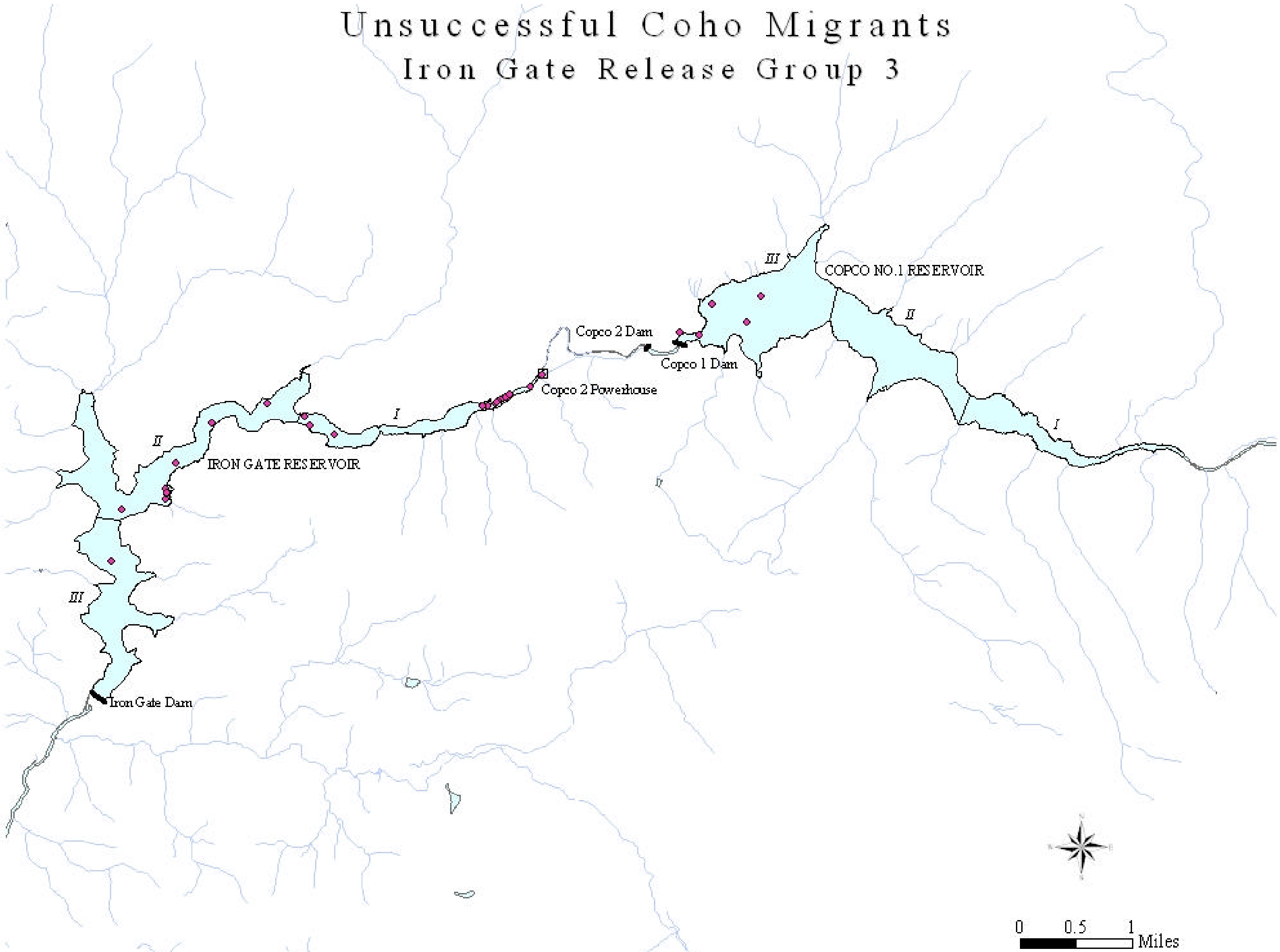
Appendix 13. Cumulative detections observed during mobile surveys over the entire study period for all unsuccessful coho migrants released in Iron Gate reservoir. The six positions plotted along the shoreline of Copco reservoir indicate eight fish that had been transported upstream by avian predators.



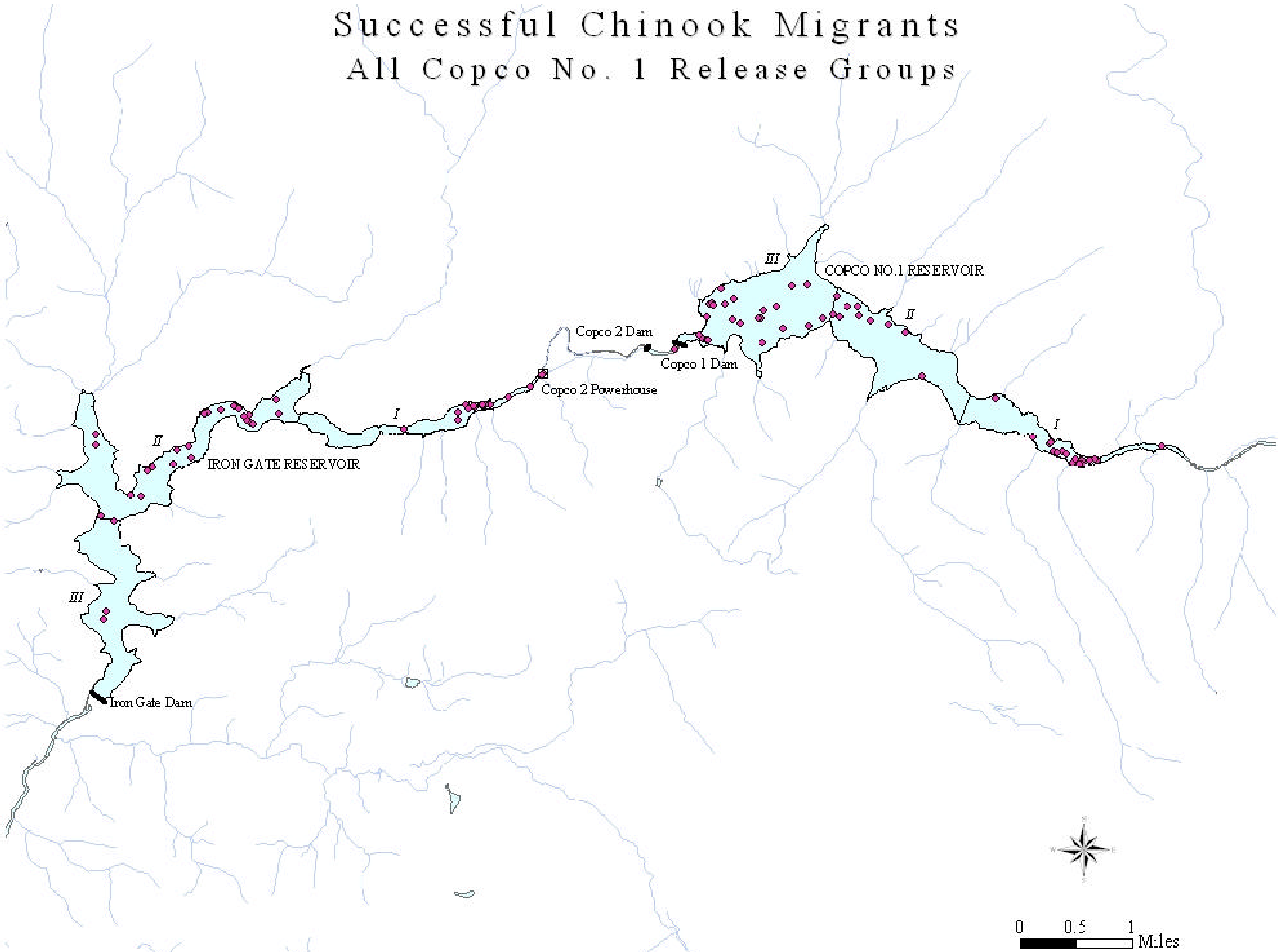
Appendix 14. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful coho migrants from release group 1 in Iron Gate reservoir. The single position plotted along the shoreline of Copco reservoir indicates one fish that had been transported upstream by an avian predator.



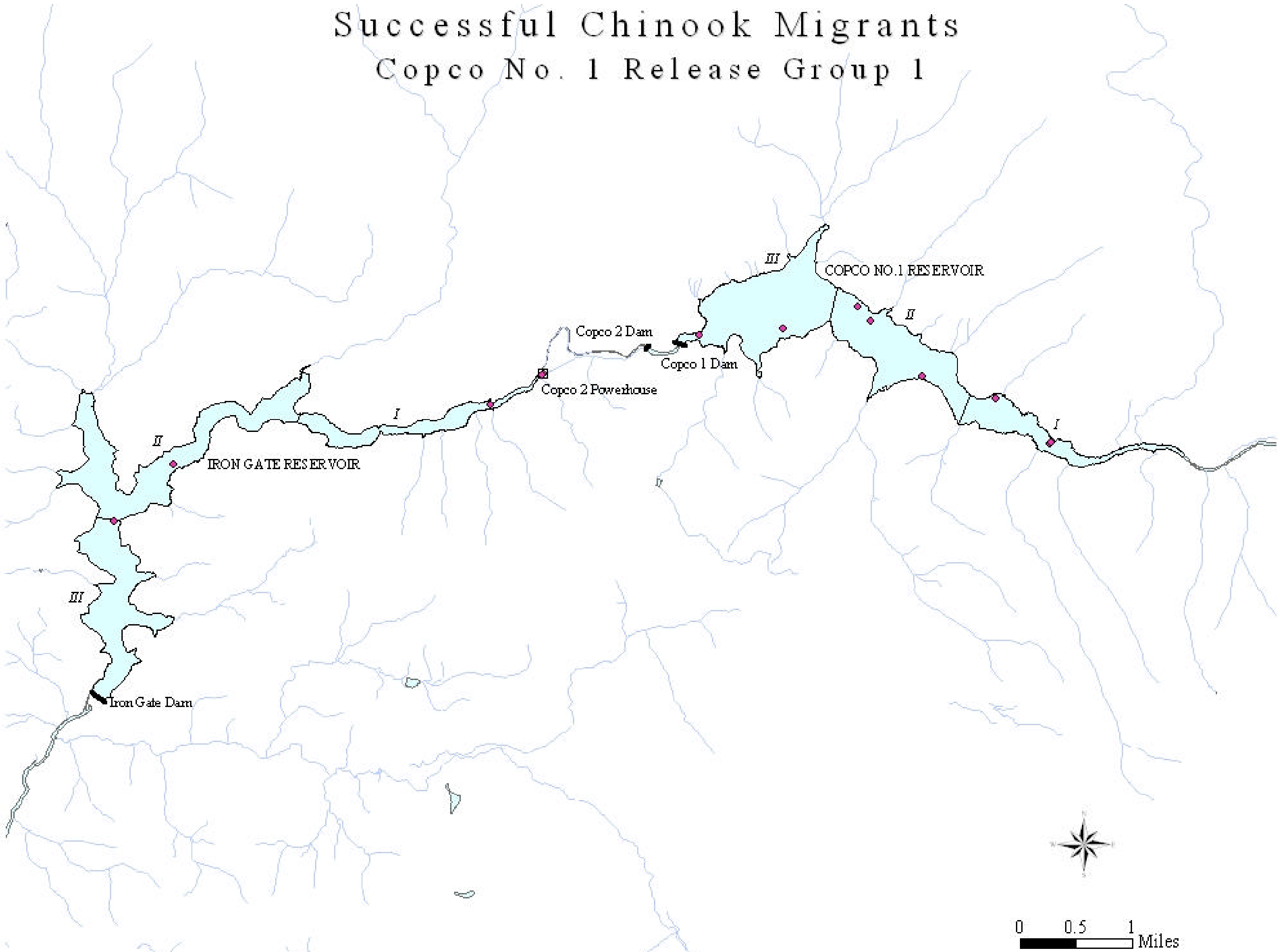
Appendix 15. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful coho migrants from release group 2 in Iron Gate reservoir. The two positions plotted along the shoreline of Copco reservoir indicates two fish that had been transported upstream by avian predators.



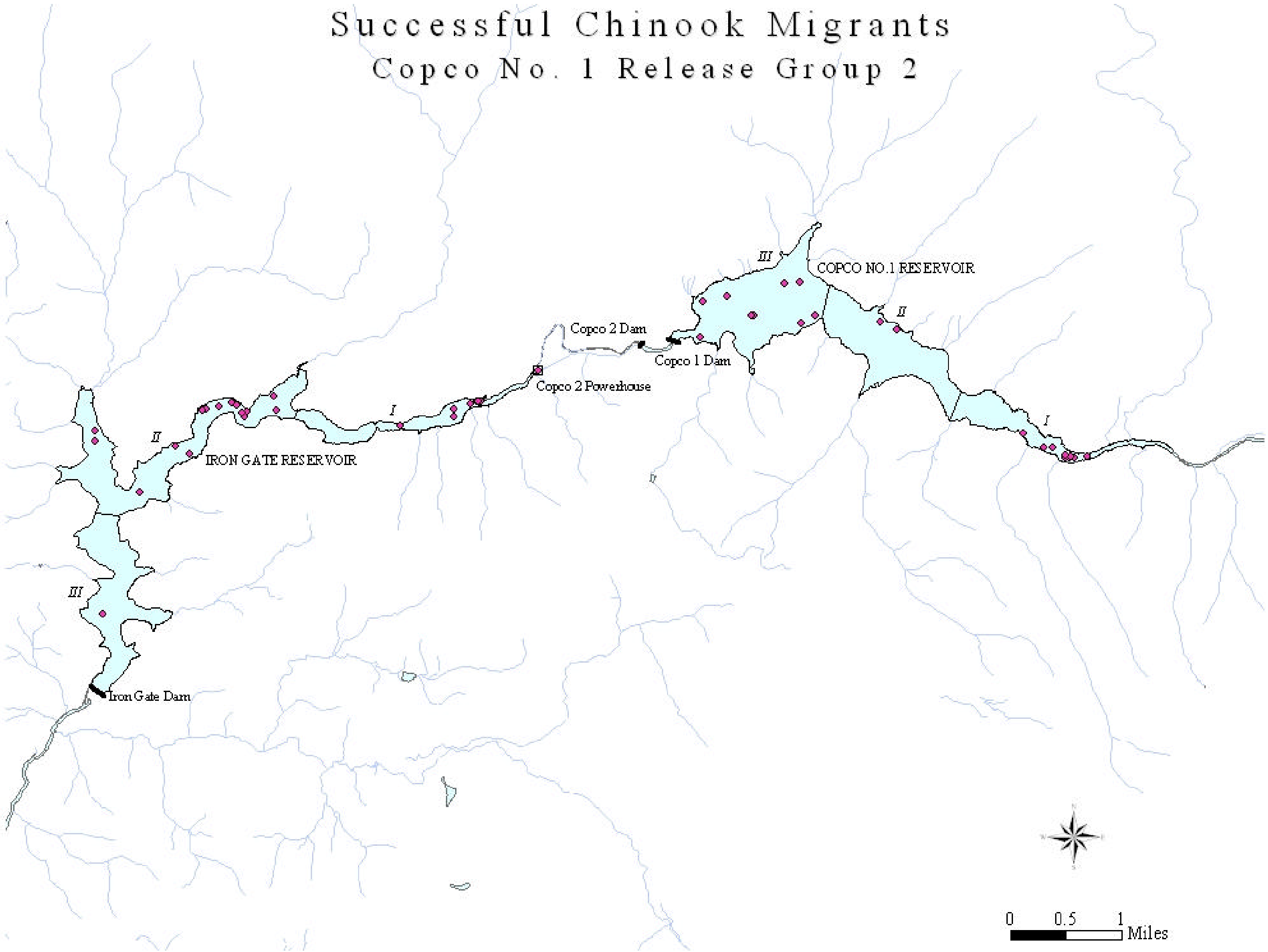
Appendix 16. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful coho migrants from release group 3 in Iron Gate reservoir. The five positions plotted along the shoreline of Copco reservoir indicates five fish that had been transported upstream by avian predators.



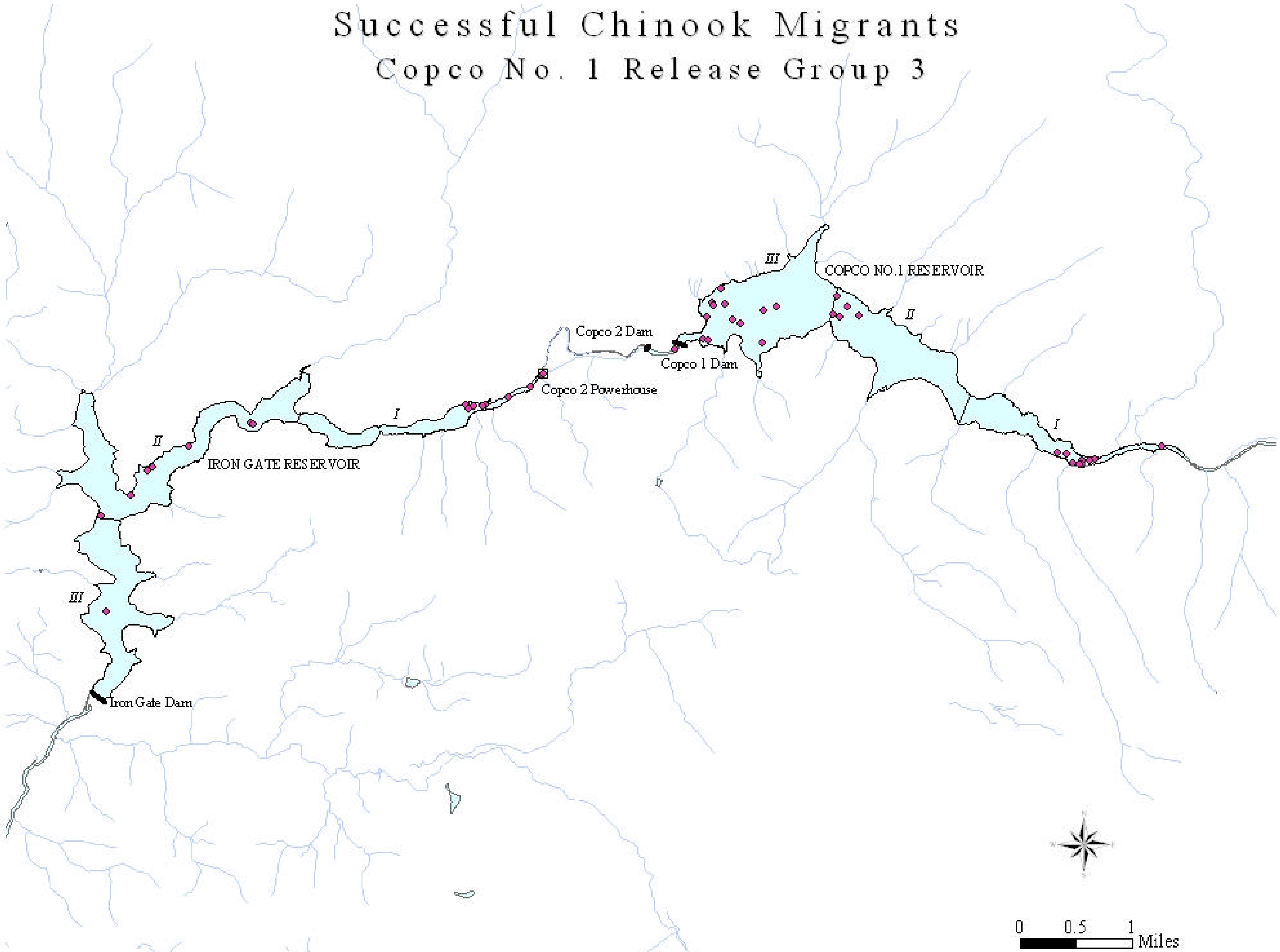
Appendix 17. Cumulative detections observed during mobile surveys over the entire study period for all successful Chinook migrants released in Copco reservoir. Fish detected in Iron Gate indicate the cumulative detections for fish that had passed Copco No. 1 and Copco No. 2 projects.



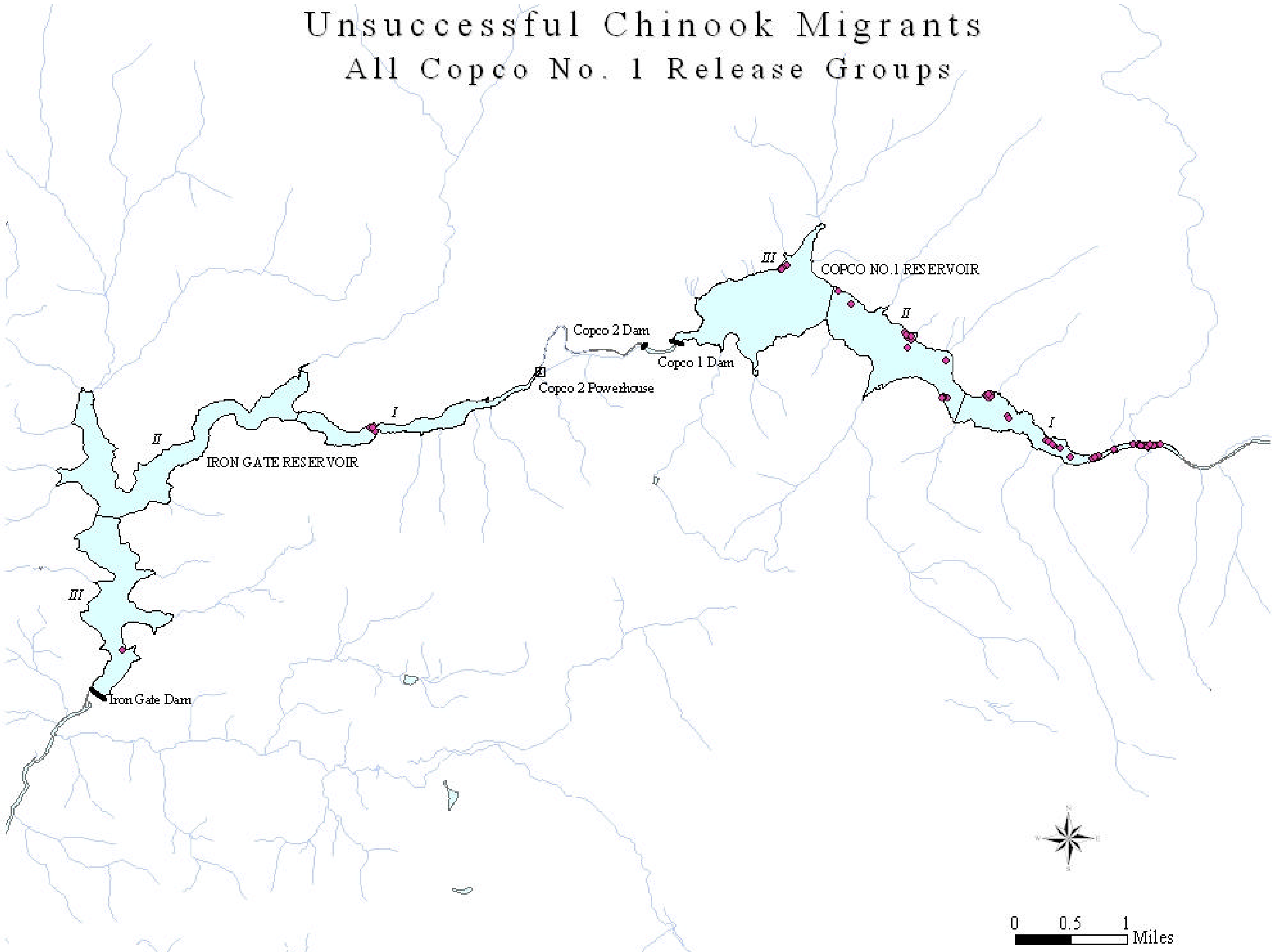
Appendix 18. Cumulative detections observed during mobile surveys over the entire study period for successful Chinook migrants from release group 1 in Copco reservoir. Fish detected in Iron Gate indicate the cumulative detections for fish that had passed Copco No. 1 and Copco No. 2 projects.



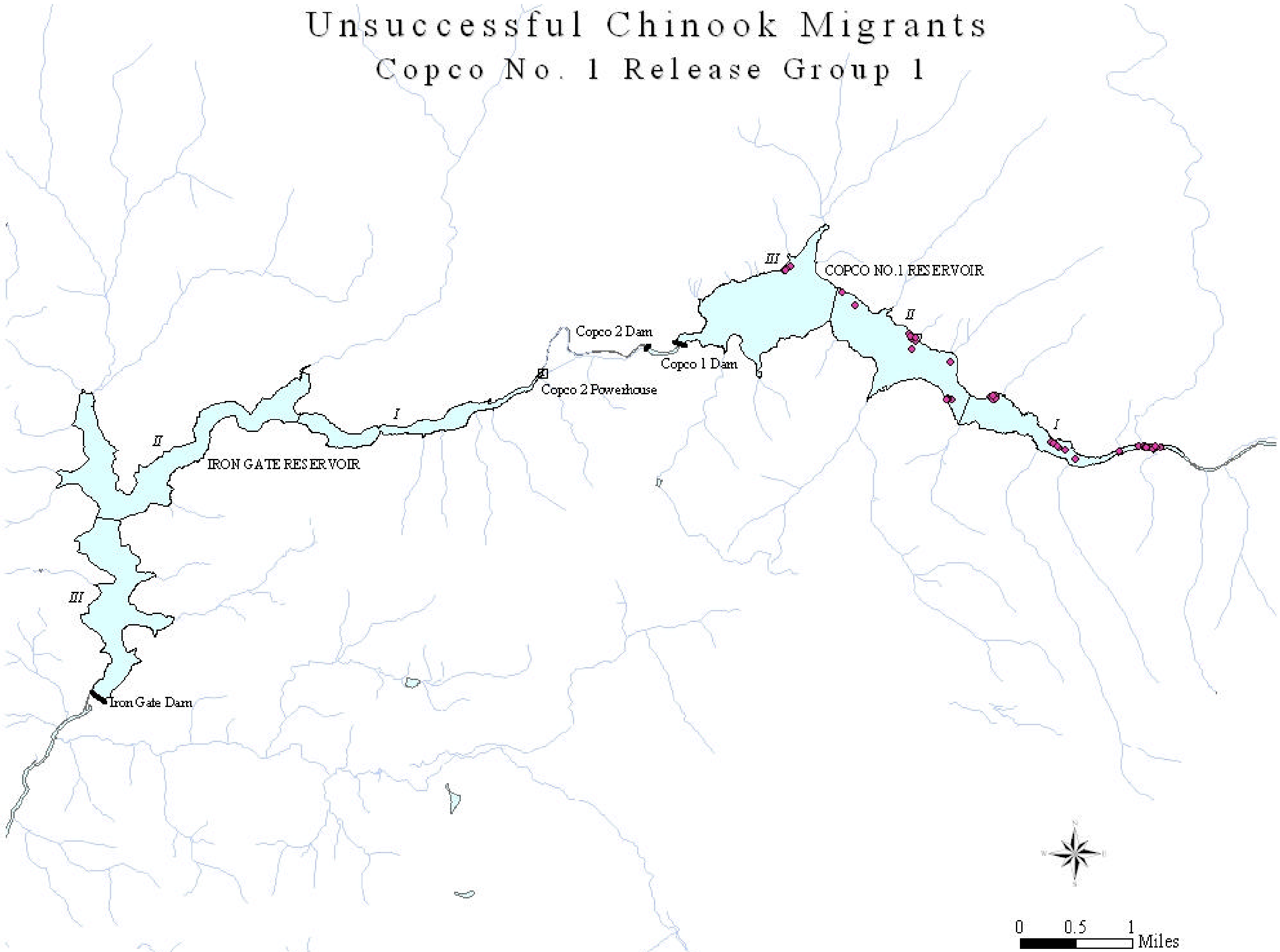
Appendix 19. Cumulative detections observed during mobile surveys over the entire study period for successful Chinook migrants from release group 2 in Copco reservoir. Fish detected in Iron Gate indicate the cumulative detections for fish that had passed Copco No. 1 and Copco No. 2 projects.



Appendix 20. Cumulative detections observed during mobile surveys over the entire study period for successful Chinook migrants from release group 3 in Copco reservoir. Fish detected in Iron Gate indicate the cumulative detections for fish that had passed Copco No. 1 and Copco No. 2 projects.



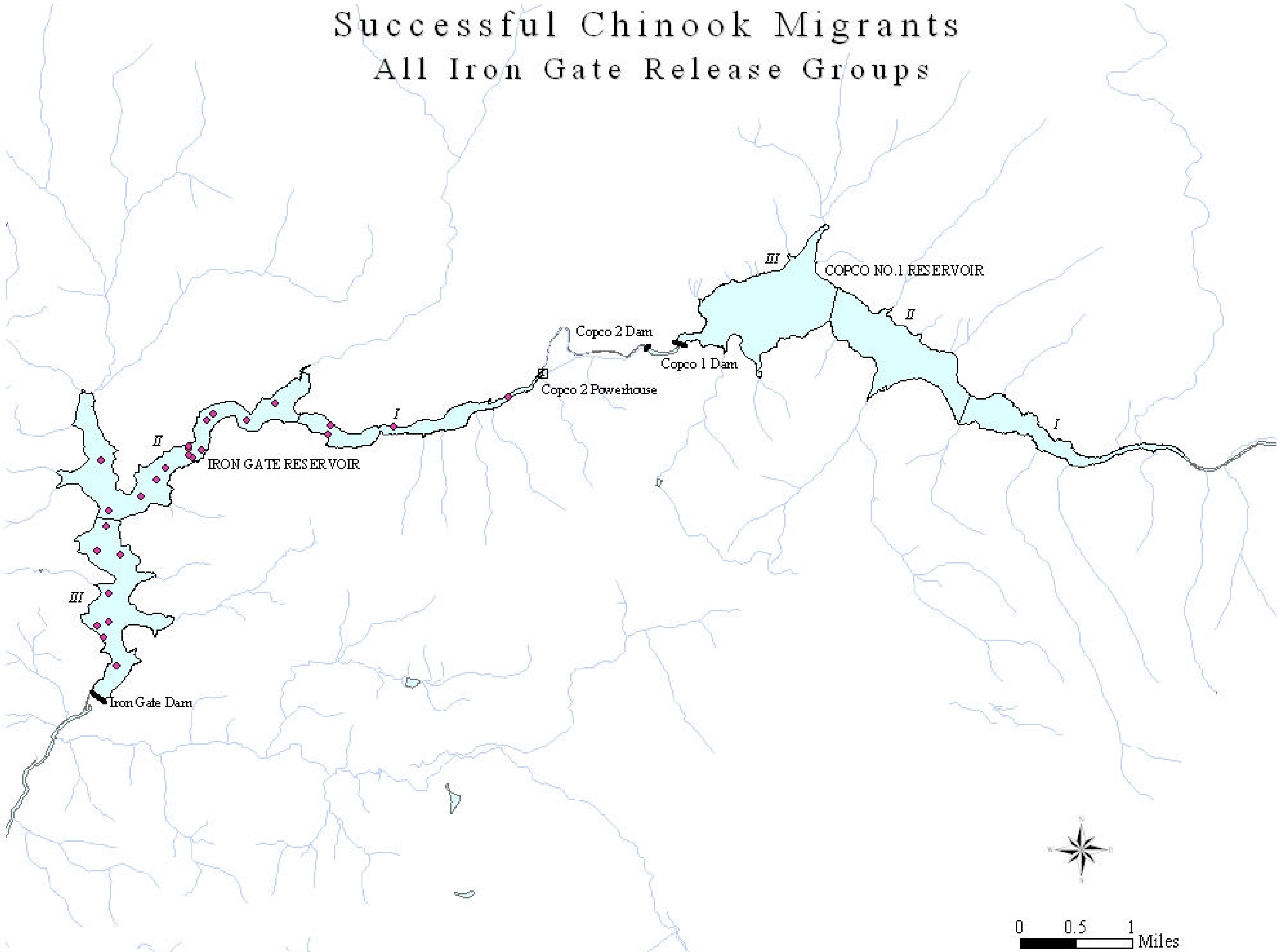
Appendix 21. Cumulative detections observed during mobile surveys over the entire study period for all unsuccessful Chinook migrants released in Copco reservoir. The three positions plotted in Zone 1 of Iron Gate reservoir indicate three fish that had been transported downstream by avian predators.



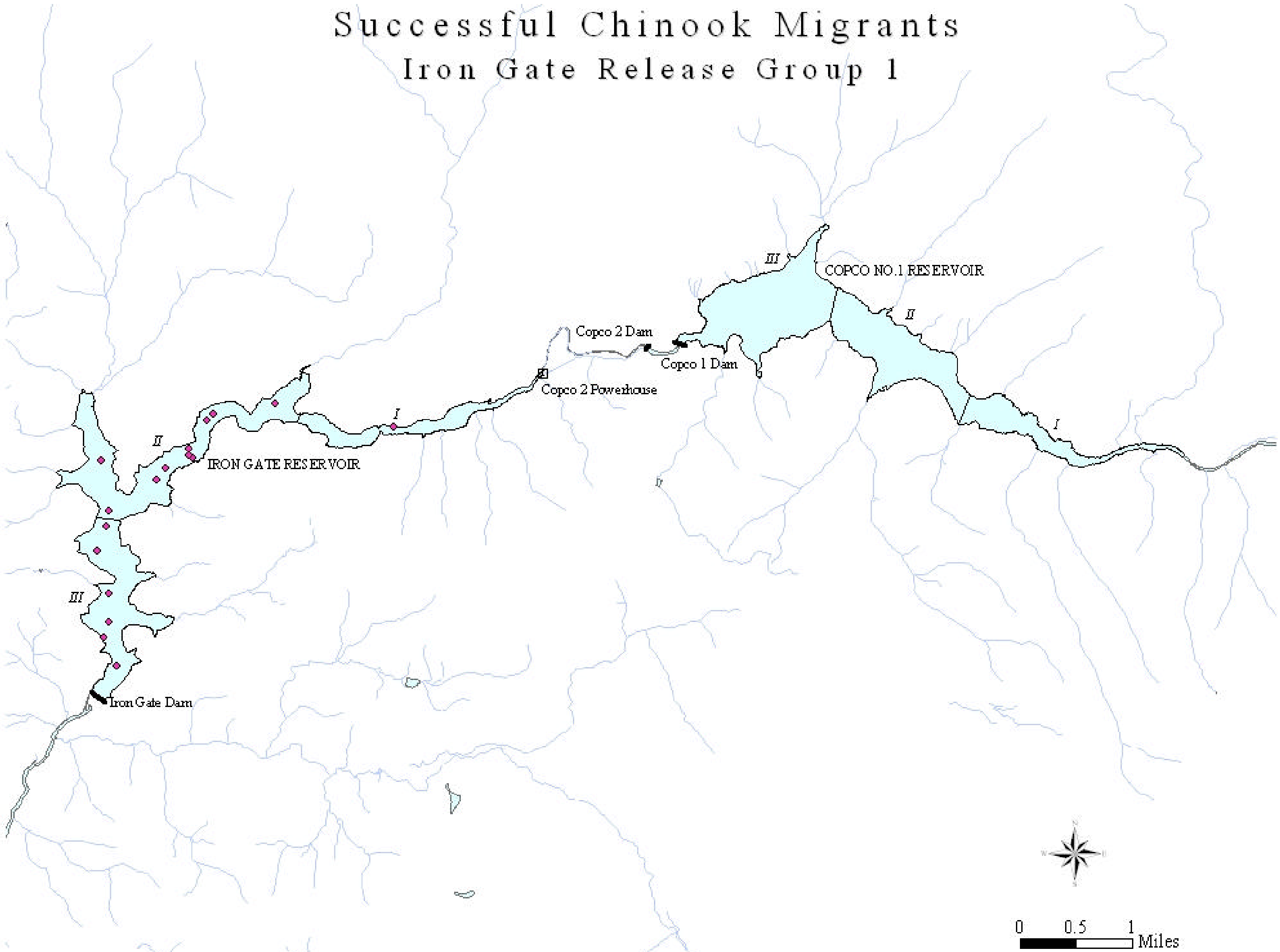
Appendix 22. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful Chinook migrants from release group 1 in Copco reservoir.

Appendix 23. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful Chinook migrants from release group 2 in Copco reservoir. The three positions plotted in Zone 1 and 3 of Iron Gate reservoir indicate three fish that had been transported downstream by avian predators

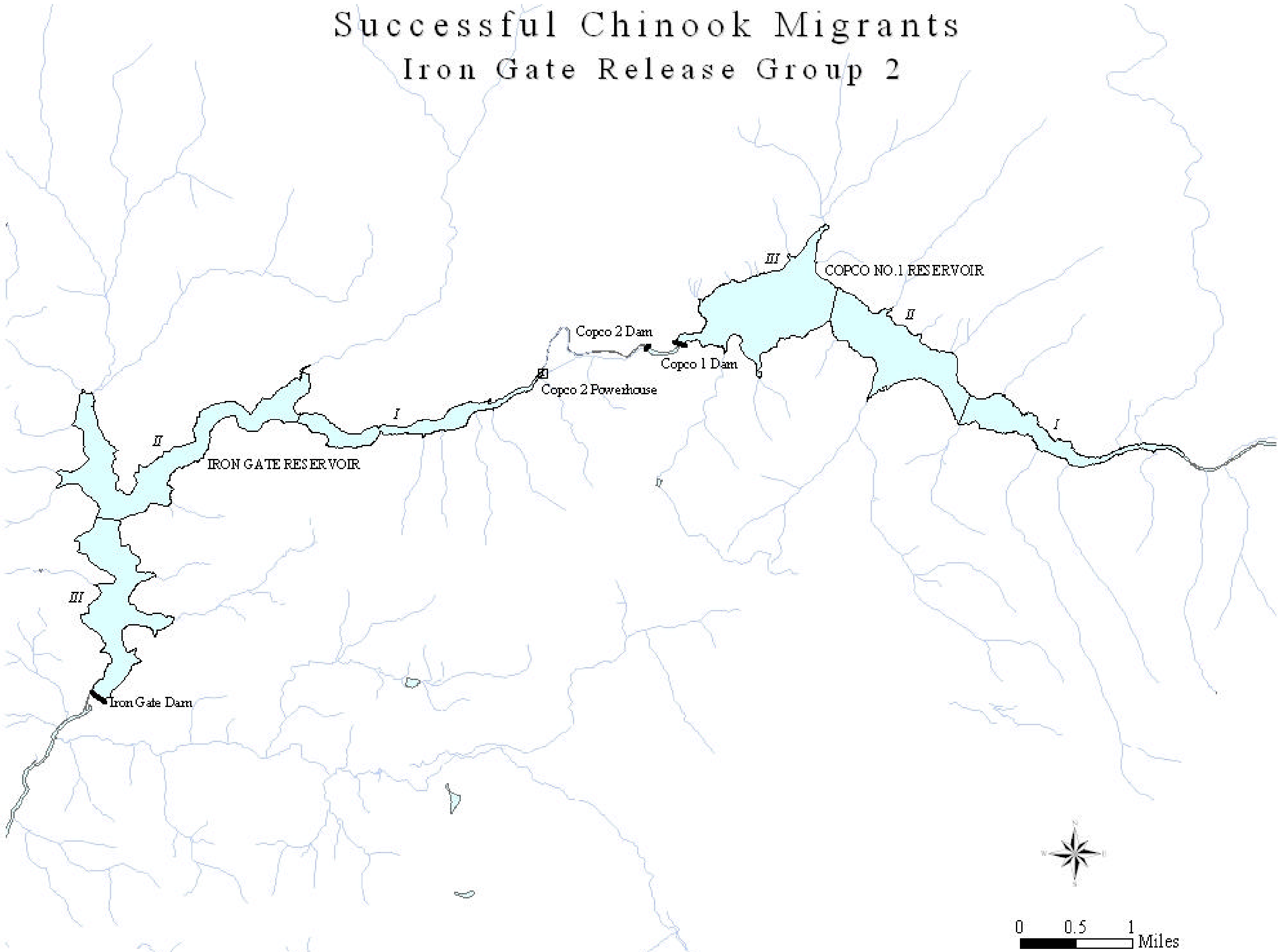
Appendix 24. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful Chinook migrants from release group 3 in Copco reservoir. There were no Chinook in release group three that were unsuccessful migrants.



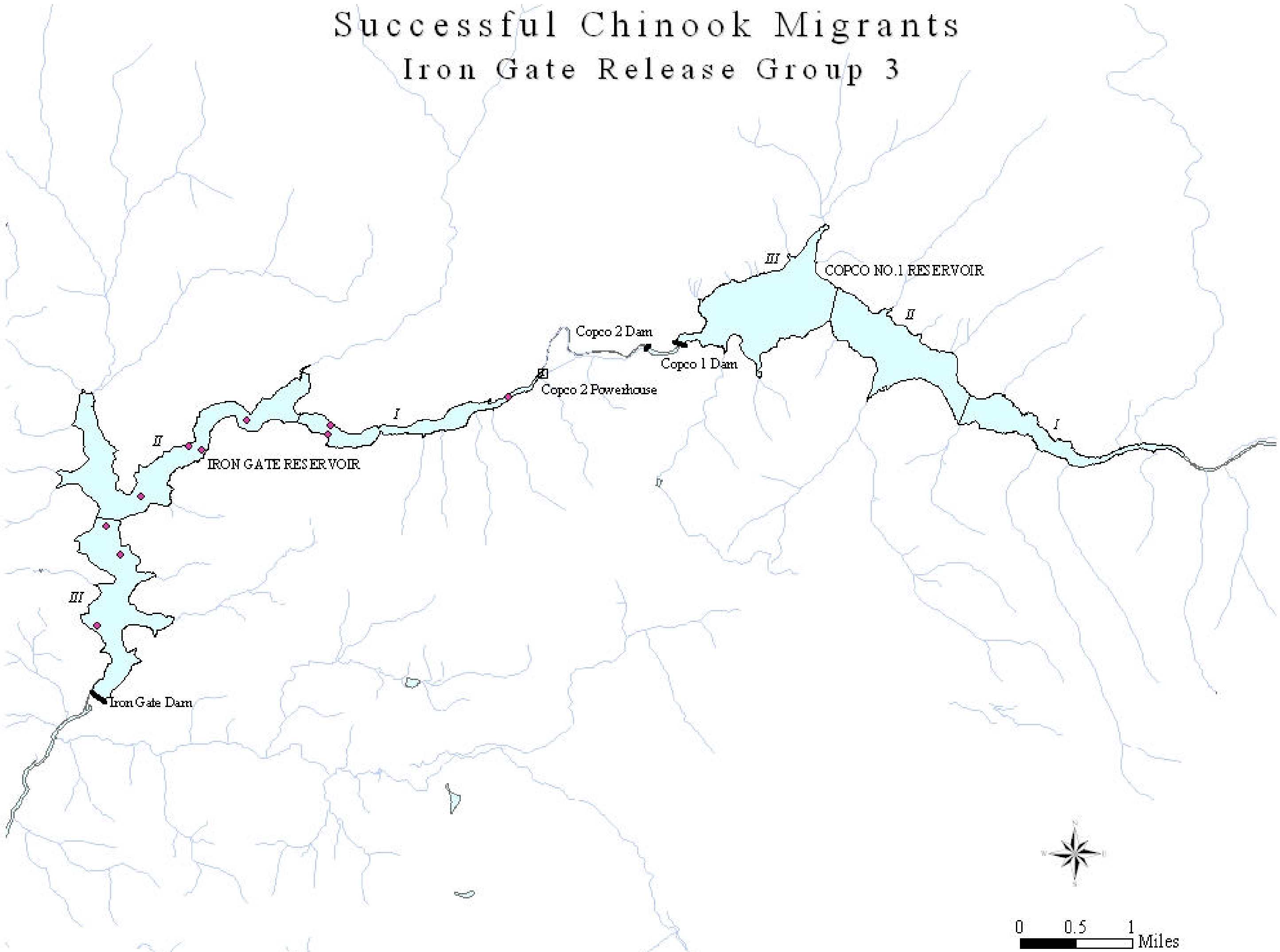
Appendix 25. Cumulative detections observed during mobile surveys over the entire study period for all successful Chinook migrants released in Iron Gate reservoir.



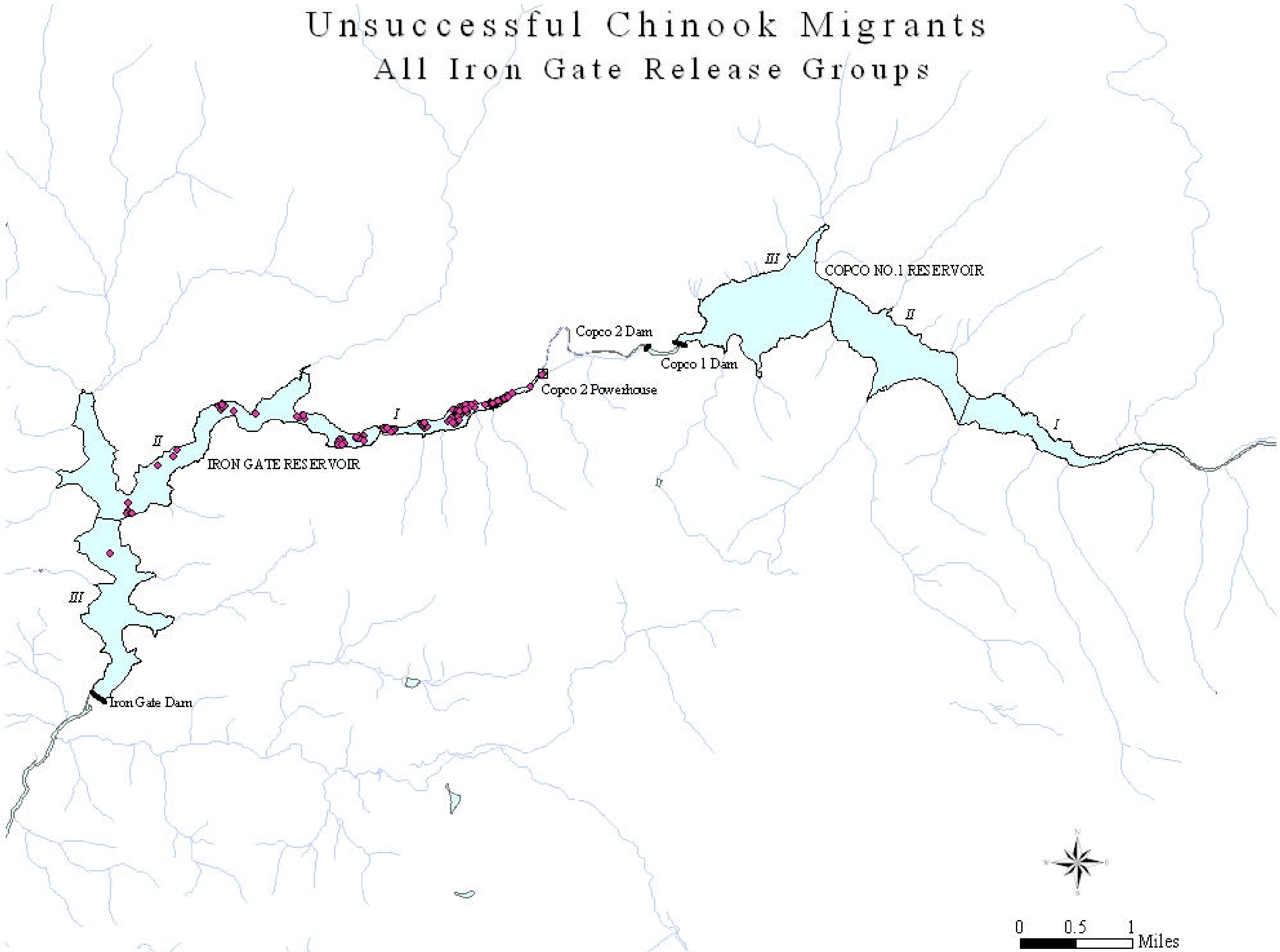
Appendix 26. Cumulative detections observed during mobile surveys over the entire study period for successful Chinook migrants from release group 1 in Iron Gate reservoir.



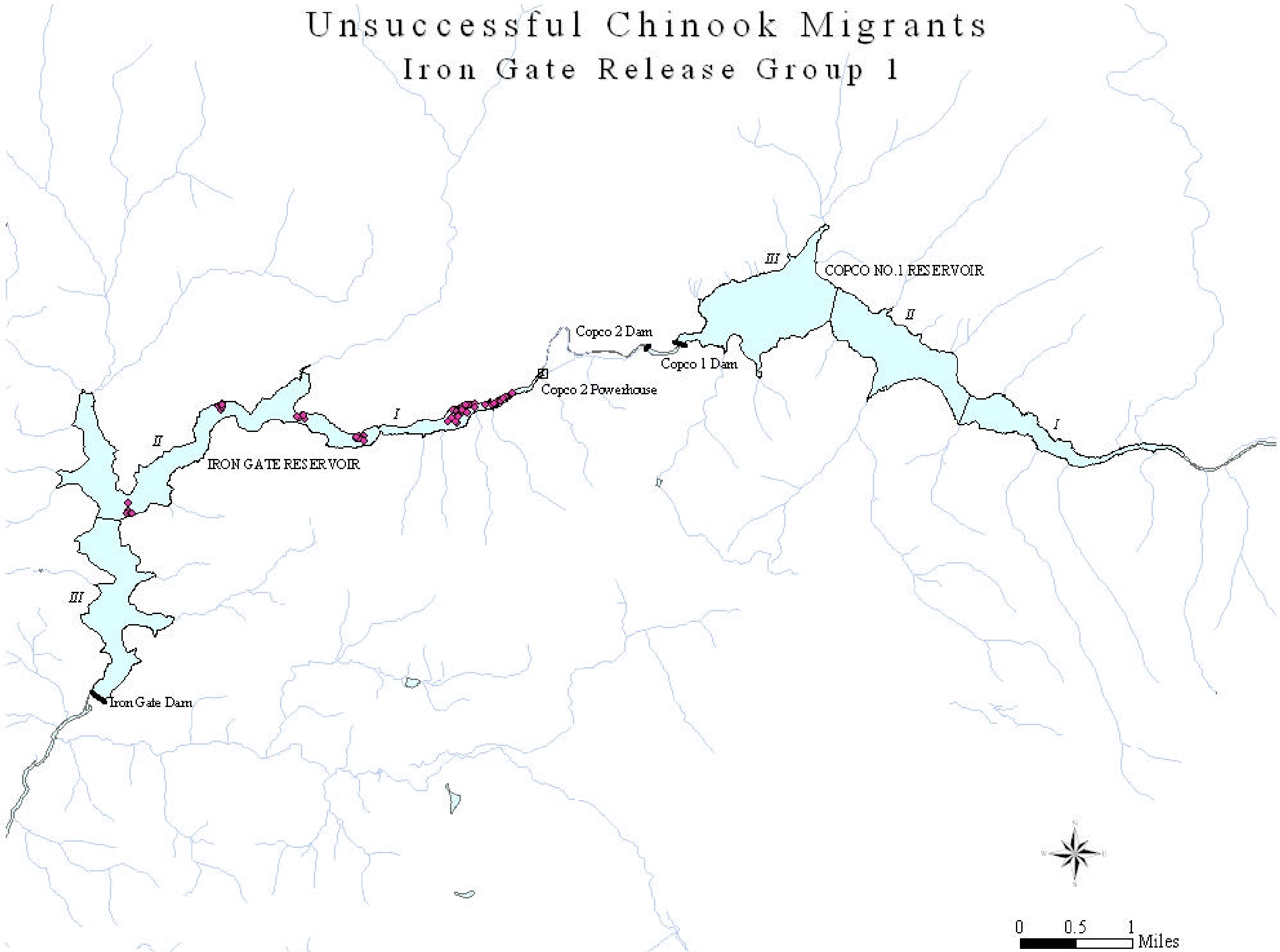
Appendix 27. Cumulative detections observed during mobile surveys over the entire study period for successful Chinook migrants from release group 2 in Iron Gate reservoir. There were no successful Chinook migrants from release group 2 in Iron Gate reservoir.



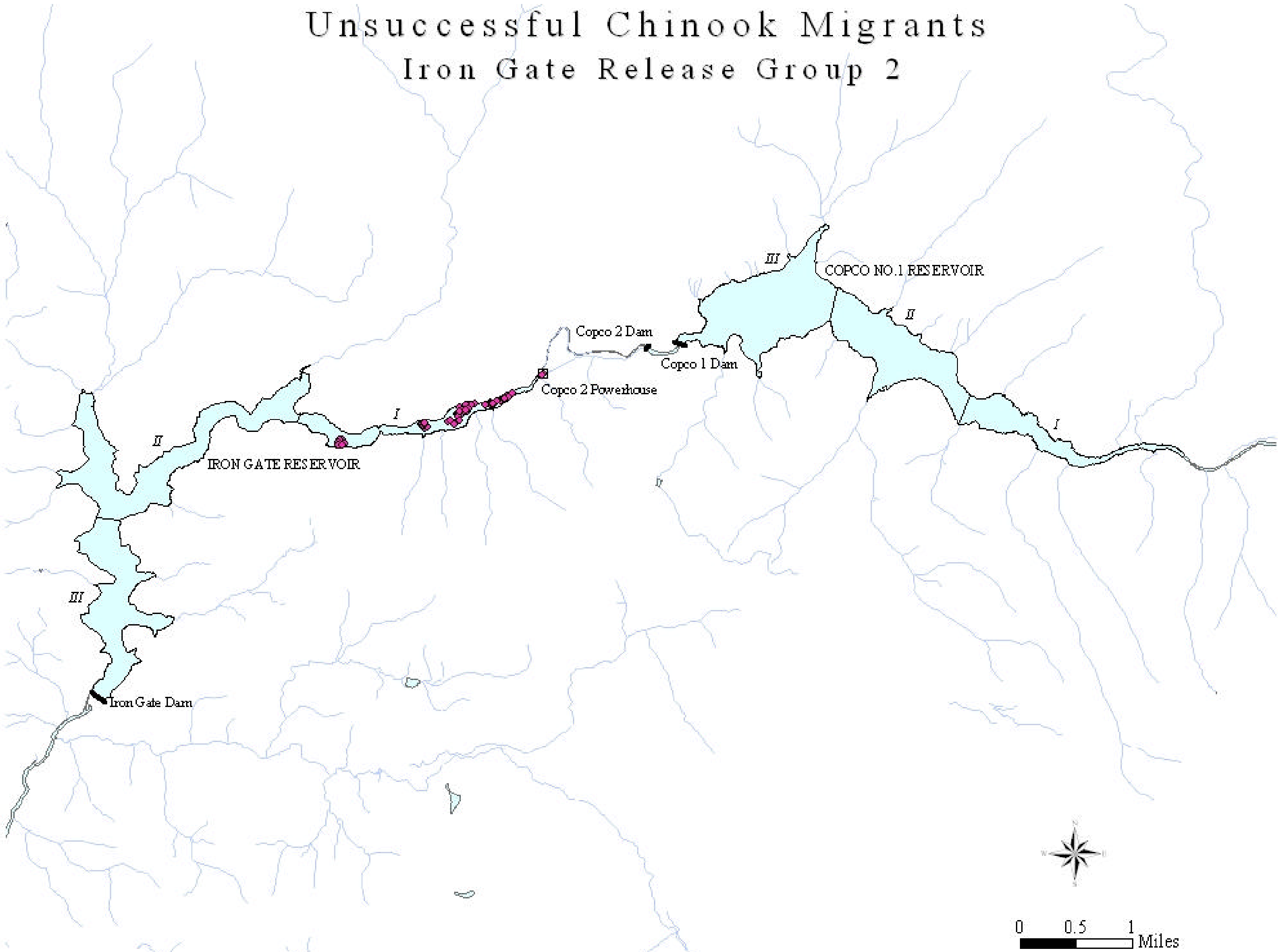
Appendix 28. Cumulative detections observed during mobile surveys over the entire study period for successful Chinook migrants from release group 3 in Iron Gate reservoir.



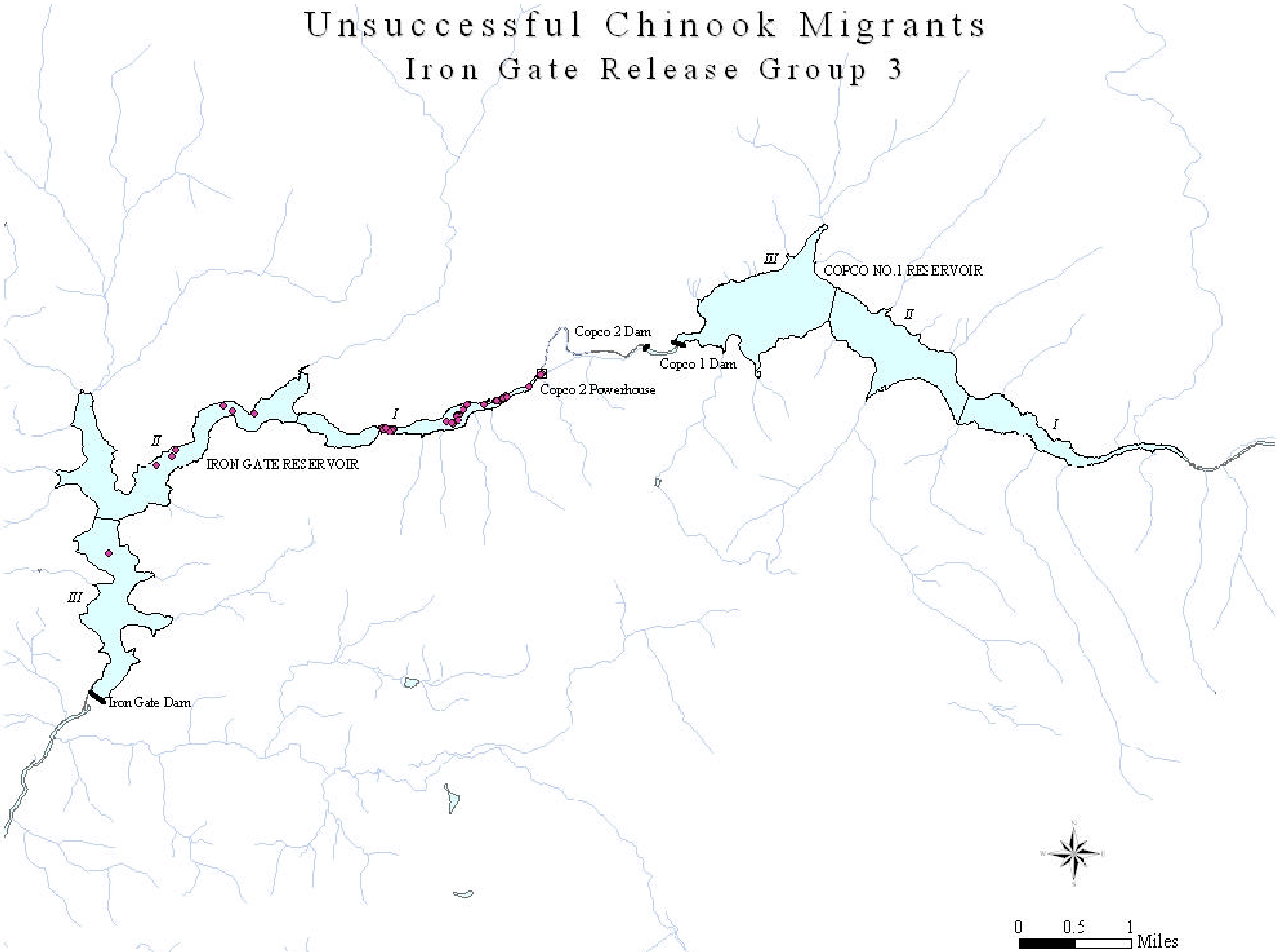
Appendix 29. Cumulative detections observed during mobile surveys over the entire study period for all unsuccessful Chinook migrants released in Iron Gate reservoir.



Appendix 30. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful Chinook migrants from release group 1 in Iron Gate reservoir.



Appendix 31. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful Chinook migrants from release group 2 in Iron Gate reservoir.



Appendix 32. Cumulative detections observed during mobile surveys over the entire study period for unsuccessful Chinook migrants from release group 3 in Iron Gate reservoir.