Evaluation of Acoustic-Tagged Juvenile Chinook Salmon and Predatory Fish Movements in the Sacramento – San Joaquin Delta during the 2010 Vernalis Adaptive Management Program

Acoustic-Tagged Chinook Salmon (Photo: Dave Vogel)

Striped Bass (Photo: USFWS)

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Introduction

The spring of 2010 was the fifth year of experiments evaluating the movements of acoustic-tagged juvenile Chinook salmon (*Oncorhynchus tshawytscha*) released in the San Joaquin River during the Vernalis Adaptive Management Program (VAMP). The use of acoustic telemetry had been previously recommended as a useful analytical technique to acquire detailed biological data that was not possible with the more-traditional coded-wire tagging studies historically used for the VAMP program (Vogel 2005). In the fall and winter of 2009-2010, the VAMP Biology Committee formulated a plan for the 2010 fish study similar to 2009 (Vogel 2010a), but expanded in geographic scope, using a network of acoustic receivers[1] deployed in the Delta to detect passage of acoustic-tagged juvenile salmon released in the San Joaquin River and Old River. The 2008 through 2010 studies were expanded from initial pilot acoustic-telemetry studies conducted in 2006 (Vogel 2006a) and 2007 (SJRGA 2008) where fewer acoustic receivers were deployed and fish samples were smaller. It was hypothesized that the study results may estimate fish route "selection" probabilities at critical flow splits (i.e., head of Old River and Turner Cut), fish survival in specific reaches and through the Delta to Chipps/Mallard Islands.

During the 2009 VAMP study, it was estimated that many of the acoustic tags detected by the fixed-station acoustic receivers were actually dead salmon (or the transmitters) inside predatory fish such as striped bass (Vogel 2010a). That conclusion was also corroborated through a separate study of fish behavior at the head of Old River using different analytical techniques (Bowen et al. 2009). This circumstance significantly complicated the ability to accurately estimate true juvenile salmon survival and migration route selection. Estimates of salmon survival using solely presence/absence data could be incorrect from true salmon survival with large error margins causing widespread misunderstanding of study results and negating the potential for scientifically sound decisions. It was therefore recommended that a better understanding of predatory fish behavior in comparison to juvenile salmon behavior was necessary to avoid misinterpretation of telemetry data (Vogel 2010a).

Small numbers of striped bass were also tagged with acoustic transmitters during the 2008 and 2009 VAMP studies to monitor fish movements and behavior concurrent with juvenile salmon monitoring. Results demonstrated that the striped bass were highly mobile during the study period moving large distances throughout the Delta, although some predators also exhibited strong affinity to certain regions (Vogel 2010a, 2010b). Empirical evidence was obtained which confirmed movements and behavior of predatory fish used in the evaluations of predation estimates on salmon smolts. These results also indicated that tag detections by the acoustic receiver array could easily result in incorrect assumptions on acoustic-tagged smolt movements due to similar swim patterns of salmon and predators with flow (e.g., ebb and flood tides). It became evident that, for future studies, collecting data on acoustic-tagged predatory fish movements would be invaluable.

[1] The acoustic telemetry equipment used for the VAMP study was obtained from Hydroacoustic Technology, Inc. (HTI), Seattle, Washington.

To address the major problem with differentiating live acoustic-tagged salmon from dead salmon within the 2010 VAMP acoustic telemetry array, Natural Resource Scientists, Inc. proposed tagging predatory fish with acoustic transmitters for reasons similar to that recommended for an earlier north Delta telemetry study[2] (CALFED 2008). A fundamental question associated with the salmon survival estimates in the Delta is the stationarity of the predator field and, by association, the stationarity of the survival estimates. If the predators are highly mobile or congregate in different regions in the Delta at different times of the year, then the survival estimates will vary depending on the spatial and temporal variability of the predator fields.

Methods

Acoustic Telemetry Array

Fixed-station acoustic receivers were deployed and maintained by the VAMP study team throughout the Delta but not all of those receivers were used for this predatory fish evaluation. The approximate locations of the receivers used in the predator study are shown in Figure 1 with the numbered locations identified in Table 1.

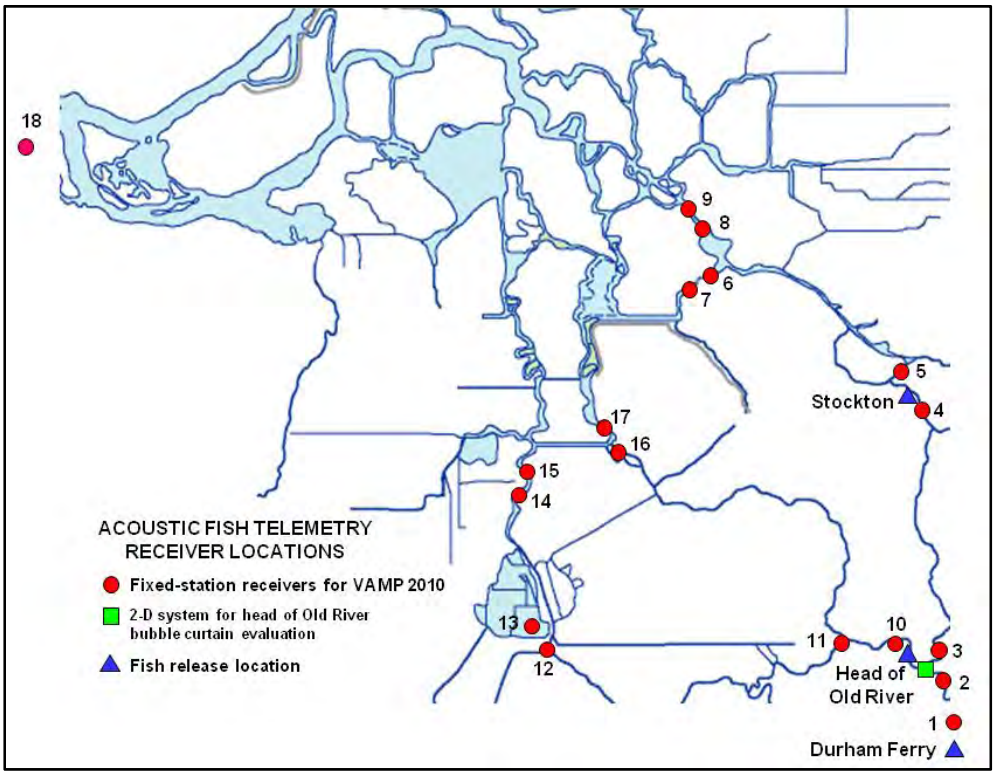

Figure 1. Locations of the fixed-station acoustic receivers and acoustic-tagged salmon release sites during the 2010 study.

[2] A CALFED peer review of a North Delta acoustic-tagged juvenile salmon study recommended increased acoustic tagging of predatory fish because predation is a known major source of salmon mortality and one of the more important covariates in evaluating salmon survival in the Delta.

Table 1. Site number, name and location of acoustic receivers deployed for the 2010 acoustic telemetry fish study (refer to Figure 1). Note: Not all the VAMP receivers are listed.		
Site Number	**Site Name**	**Location**
1	BC	San Joaquin River at Banta Carbona
2	MOS	San Joaquin River downstream of Mossdale
3	SJO(n)	San Joaquin River downstream of the head of Old River
4	WWTP	San Joaquin River in Stockton upstream of the waste water treatment plant
5	Navy Bridge	San Joaquin River in Stockton at Navy Bridge
6	TC(n)	Turner Cut north
7	TC(s)	Turner Cut south
8	C18	San Joaquin River at the Stockton Deep Water Ship Channel marker red 18
9	C16	San Joaquin River at the Stockton Deep Water Ship Channel marker red 16
10	Old(e)	Old River just downstream of the head of Old River flow split
11	MRFS	Old River at the Middle River flow split
12	Tracy	Tracy Fish Facilities trash racks
13	CCFB	Clifton Court Forebay gates just inside (west) of the gates
14	ORNU	Old River south (upstream) of the Highway 4 bridge
15	ORND	Old River north (downstream) of the Highway 4 bridge
16	MRNU	Middle River south (upstream)
17	MRND	Middle River north (downstream)
18	Chipps	Western Delta at Chipps and Mallard Islands

Juvenile Salmon Tagging and Release

Juvenile fall-run Chinook salmon used in the 2010 VAMP acoustic telemetry study were surgically implanted with individually identifiable transmitters programmed prior to insertion. A small incision was made on the ventral side of the fish (under anesthesia) and the sterilized transmitter was inserted into the peritoneal cavity. The incision was closed with several sutures and the fish was allowed to recover from surgery for at least a day prior to release. Details on the fish tagging and release procedures are provided in the 2009 VAMP annual report (SJRGA 2010) available for download at www.sjrg.org. Study fish for the project were obtained from the Department of Fish and Game's (DFG) Merced River Hatchery and the tagging was performed at the federal Tracy Fish Facilities in the south Delta. The fish tagging and subsequent releases were performed by the VAMP study team. Development of the acoustic tag coding scheme for the VAMP study and other concurrent studies was developed by HTI.

Fish releases were made at Durham Ferry on the mainstem San Joaquin River downstream of the Stanislaus River confluence, in upper Old River just downstream of the San Joaquin River flow split, and the lower San Joaquin River near Stockton (Figure 1). Fish were released after the acoustic-tagged salmon had acclimated to local water quality conditions over an approximate 24-hour period.

Predatory Fish Tagging

Striped bass (*Morone saxatilis*), black bass (*Micropterus salmoides*), and white catfish (*Ameiurus catus*) were captured by hook and line angling, externally tagged, and released at the capture site in a variety of locations in the lower San Joaquin River and interior Delta.

Sites included scour holes, near structures, and in front of the trash racks at the federal Tracy Fish Facilities. The acoustic transmitters were similar but larger (13 grams) than the 0.65-gram transmitters implanted in salmon smolts released during the VAMP study. External tag attachment consisted of two plastic-coated stainless steel wires attached to the transmitter, inserted through the musculature under the dorsal fin using hypodermic needles and held in place with two plastic plates crimped on the opposite side of the fish. The predator transmitter batteries lasted for the duration of the one-month study. Each transmitter was individually identifiable and did not overlap with the smolt transmitters. Movements of tagged predatory fish bass were monitored and recorded using the same fixed-station acoustic receiver network (Figure 1).

Data Processing

The acoustic telemetry receivers generate hourly raw acoustic tag data files (.rat files). These files alone do not provide useful data for analyses and, instead, are processed using the vendor's proprietary software program (*MarkTags*®) to view and evaluate collected data. All data were processed manually by visually examining the echograms of electronically recorded tag detections (Ehrenberg and Steig 2003). Although tedious, manual processing is currently advantageous for Delta studies because it minimizes false positive detections and provides greater reliability in the results (Vogel 2010a).

If solely presence/absence receiver data are used during data processing, a common problem arises when a tag is detected by a receiver, but the tagged salmon (or the transmitter) is inside a predator and cannot be differentiated from a live tagged salmon. Perhaps most importantly for the VAMP study, manual processing allows better ability to evaluate fish behavior and fish movements within range of the receiver's hydrophone ("near-field" observations) using the *MarkTags*® graphical page view format [described in Vogel (2010a)]. During manual data processing, we had the exceptional ability to examine subtle movements of acoustic-tagged fish in detection range of all the fixed-station receivers deployed throughout the Delta. Whereas the classical use of detections to determine potential fish survival estimates uses basic tag presence/absence among acoustic receiver arrays, an enormous amount of additional detailed data on acoustic tag movements at each receiver were available from the VAMP array.

Additionally, examination of the spatio-temporal history of each tag detection throughout the telemetry array, medium-field and far-field observations can be made when integrated with flow measurement stations in proximity to the acoustic data loggers. Through detailed analyses, this technique may help to see if tagged salmon have been preyed upon through apparent aberrant fish behavior uncharacteristic of salmon smolts. This circumstance has become increasingly important in the Delta acoustic telemetry studies where small test fish may be subsequently preyed upon and telemetry data can be misinterpreted. A detailed description of data processing methods used for this study is provided by Vogel (2010a) and can be downloaded at: http://www.sjrg.org/technicalreport/2009/2009-VAMP-Tagged-Salmon-Report.pdf.

Results and Discussion

Observations of Acoustic-Tagged Juvenile Salmon Movements

For the 2010 VAMP study, 993 acoustic-tagged juvenile salmon were released in seven separate groups at three locations: Durham Ferry in the lower San Joaquin River, Old River just downstream of the flow split from the San Joaquin River, and the lower San Joaquin River at Stockton (Figure 1). Table 2 provides the numbers of fish released in each group and the date/times of release.

Table 2. Numbers of fish and dates/times of release for the seven groups of acoustic-tagged salmon released at three locations during the 2010 VAMP study.

1	2	3	4	5	6	7
San Joaquin River at Durham Ferry						
N=9 4/27/10 14:02 N=9 4/27/10 14:11 N=9 4/27/10 19:54 N=9 4/27/10 20:01 N=18 4/28/10 02:11 N=9 4/28/10 08:09 N=11 4/28/10 08:12	N=9 4/30/10 14:07 N=9 4/30/10 14:08 N=9 4/30/10 19:58 N=9 4/30/10 19:59 N=9 5/1/10 02:00 N=9 5/1/10 02:01 N=9 5/1/10 07:59 N=9 5/1/10 08:00	N=9 5/4/10 13:55 N=9 5/4/10 14:02 N=9 5/4/10 19:58 N=9 5/4/10 20:04 N=9 5/5/10 01:59 N=9 5/5/10 02:00 N=8 5/5/10 07:59 N=11 5/5/10 08:00	N=9 5/7/10 14:07 N=9 5/7/10 14:08 N=9 5/7/10 20:04 N=9 5/7/10 20:05 N=8 5/8/10 02:02 N=8 5/8/10 02:04 N=9 5/8/10 08:02 N=9 5/8/10 08:03	N=17 5/11/10 14:02 N=17 5/11/10 19:59 N=8 5/12/10 01:58 N=9 5/12/10 01:59 N=8 5/12/10 07:59 N=11 5/12/10 08:01	N=17 5/14/10 14:02 N=9 5/14/10 19:59 N=9 5/14/10 20:00 N=9 5/15/10 02:01 N=9 5/15/10 02:02 N=8 5/15/10 07:59 N=12 5/15/10 08:00	N=9 5/18/10 14:02 N=8 5/18/10 14:03 N=18 5/18/10 20:00 N=8 5/19/10 01:59 N=9 5/19/10 02:00 N=9 5/19/10 07:59 N=9 5/19/10 08:00
Old River at Head of Old River						
N=9 4/28/10 11:03 N=9 4/28/10 17:03 N=9 4/28/10 23:00 N=9 4/29/10 05:05	N=9 5/1/10 13:05 N=9 5/1/10 19:03 N=9 5/2/10 00:59 N=9 5/2/10 07:00	N=9 5/5/10 16:03 N=9 5/5/10 22:07 N=9 5/6/10 04:04 N=9 5/6/10 09:58	N=9 5/8/10 14:34 N=9 5/8/10 20:35 N=9 5/9/10 02:30 N=9 5/9/10 08:30	N=9 5/12/10 10:02 N=9 5/12/10 15:59 N=9 5/12/10 21:59 N=9 5/13/10 03:56	N=9 5/15/10 11:35 N=9 5/15/10 17:33 N=9 5/15/10 23:35 N=8 5/16/10 05:32	N=9 5/19/10 10:28 N=9 5/19/10 16:29 N=8 5/19/10 22:39 N=6 5/20/10 04:34
Lower San Joaquin River at Stockton						
N=9 4/28/10 14:57 N=8 4/28/10 21:02 N=9 4/29/10 03:11 N=9 4/29/10 09:01	N=9 5/1/10 16:30 N=9 5/1/10 22:32 N=9 5/2/10 04:32 N=9 5/2/10 10:42	N=9 5/5/10 19:58 N=8 5/6/10 02:02 N=9 5/6/10 08:01 N=9 5/6/10 14:01	N=9 5/8/10 18:01 N=9 5/9/10 00:02 N=9 5/9/10 06:00 N=9 5/9/10 12:00	N=9 5/12/10 14:00 N=9 5/12/10 19:53 N=8 5/13/10 02:06 N=9 5/13/10 08:04	N=8 5/15/10 15:56 N=9 5/15/10 21:59 N=9 5/16/10 04:15 N=8 5/16/10 10:01	N=9 5/19/10 12:54 N=9 5/19/10 19:01 N=8 5/20/10 01:02 N=5 5/20/10 07:01

During the study, the VAMP study team had difficulty with some of the fixed-station receivers which affected the study results. It was recommended in advance of the study to have a receiver

placed near the Mossdale bridges as was done during the 2009 VAMP study (Vogel 2010a). That site proved to be particularly valuable in 2009 for interpreting fish behavior using near-field observations in known predatory fish habitats and provided excellent coverage across the entire river channel. However, the crew in 2010 was concerned about noise from the bridges and moved the receiver site considerably further downstream. It was also recommended in advance of the study to place redundant receivers just downstream of the head of Old River with placement of the two hydrophones sufficiently far apart to permit medium-field observations of fish movements (Vogel 2010a). Instead, the hydrophones were placed in close proximity which did not provide the opportunity for medium-field observations. The DWR crew maintaining the receiver placed at the Old and Middle River flow split had difficulty keeping the receiver operational and the receiver was not operational for most of the study. In 2009, this Middle River flow split site was particularly valuable for both near- and medium-field observations of fish behavior. Although a receiver was placed inside the fish holding tank at the Tracy Fish Facilities during the 2009 study which provided invaluable data, the VAMP study team decided not to do so in 2010. The receivers placed at Chipps Island were particularly problematic during the early portion of the 2010 study and tag detections were undoubtedly missed.

Upon examination of the data obtained from the VAMP acoustic receivers deployed in 2010, it was apparent, in numerous instances, that we were likely recording and tracking dead acoustic-tagged salmon, or the transmitters, inside predatory fish. This same phenomenon was evident during the 2009 VAMP study (Vogel 2010a). Evidence of this same circumstance, using evaluations of two-dimensional fish movements and different methods, occurred during the study at the head of Old River bubble curtain fish behavioral barrier during 2009 and 2010 (Bowen et al. 2009, Bowen and Bark 2010). For example, of those VAMP tags detected at the fish behavioral barrier, Table 3 provides the numbers of tags believed to be live smolts, dead smolts (or the transmitters) inside predators, or the fate of the fish could not be estimated (unknown category) at the head of Old River for all seven VAMP fish releases at Durham Ferry. Based on these evaluations, predation on the VAMP acoustic-tagged salmon was high (26%). However, it could not be determined where the acoustic-tagged salmon had originally been preyed upon. Interestingly, among those acoustic-tagged salmon believed to have been preyed upon, 15 fish were later detected at the Chipps Island receivers in the western Delta. Those tags would have otherwise been assumed to be live salmon passing acoustic receivers in the telemetry array biasing survival estimates and fish route selection estimates.

Table 3. Acoustic tag detections at the bubble curtain at the head of Old River during 2010. Preliminary data provided by Mark Bowen, USBR.

Durham Ferry Fish Release No.	No. of fish believed to be live salmon	No. of fish believed to have been preyed upon	Status of fish could not be estimated	Total
1	44 (60%)	19 (26%)	10 (14%)	73
2	57 (78%)	13 (18%)	3 (4%)	73
3	47 (69%)	16 (24%)	5 (7%)	68
4	49 (73%)	15 (22%)	3 (4%)	67
5	53 (77%)	13 (19%)	3 (4%)	69
6	39 (55%)	20 (28%)	12 (17%)	71
7	28 (47%)	27 (46%)	4 (7%)	59
Total	317 (66 %)	123 (26%)	40 (8%)	480

Using telemetry data obtained from the Delta-wide telemetry array (Figure 1), the analytical techniques utilizing near-field, medium-field, and far-field observations were elaborate, time-consuming, and painstaking, but yielded a large amount of useful biological information that would have not otherwise been developed. Additionally, knowledge acquired from hundreds of observations made during prior acoustic telemetry studies in the Delta and Sacramento River (e.g., Vogel 2010a, 2008, 2006a, 2006b, 2006c) and radio-tagged salmon studies in the Delta (e.g., Vogel 2004, 2002) were incorporated into the analyses of fish behavior. This combination was ultimately used to estimate if the acoustic tags were in live salmon smolts or acoustic tags inside predators (originating from acoustic-tagged salmon). The following were commonly observed characteristics where it was believed acoustic-tagged salmon had been preyed on by predatory fish.

- Tags moving against the localized flow conditions (e.g., moving upstream against an outgoing tide or opposite direction from the positive river flow (near-field and medium-field observations).
- Tags moving erratically for sustained periods (e.g., hours) in a channel with strong positive flow (near-field observations).
- Tags moving erratically for extended periods (e.g., hours or days) at locations known to harbor large numbers of predatory fish and in locations of unfavorable juvenile salmon habitat (e.g., at the trash racks at the Tracy Fish Facilities and behind the Clifton Court Forebay gates) (near-field observations).
- Long tag transit times between receivers positioned in very close proximity (medium-field observations).
- Tags moving in and out of range of receivers, but remaining in a general location for extended periods (e.g., days near the receivers near the Stockton Waste Water treatment plant and Navy Bridge) (medium-field observations).
- Tags exhibiting movement patterns very similar to those observed from acoustic-tagged predatory fish (e.g., striped bass) (near-field and medium-field observations).
- Tags moving sequentially in the direction of flow, then abruptly changing direction and moving against the flow (medium-field and far-field observations).
- Tags moving over long distances very rapidly or very slowly compared to the majority of other tag detections (far-field observations).

Based on the near-, medium, and far-field observations, the fate of each acoustic-tagged salmon at its last detection location was estimated as either a live salmon smolt or a dead acoustic-tagged salmon (or the transmitter) inside a predatory fish. For each of the seven releases at the three locations, those results are provided in Appendix Tables 1 – 21 and summary tables are provided in Tables 4 - 6. Among the total of 959 tags detected within the telemetry array shown in Figure 1, 332 tags (35%) were estimated to be in live salmon and 627 tags (65%) were estimated to be in predators at the time of last detection.

Table 4. Estimated fate of acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature. Note: of the 504 fish released at Durham Ferry, 12 fish were not detected.

Receiver Site	BC	MOS	SJO(n)	WWTP	Navy Bridge	TC(n)	TC(s)	C18	C16	MRFS	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	15	4	8		22		6	3	22		46			2	12	23	163
Predation	4		9	7	38	1	9	14	58	2	17	52	52	19	17	30	329

Table 5. Estimated fate of acoustic-tagged juvenile salmon released at the head of Old River during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature. Note: of the 247 fish released at the head of Old River, 14 fish were not detected.

Receiver Site	WWTP	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live		39		2	3	10	14	69
Predation	1	20	45	45	19	22	13	164

Table 6. Estimated fate of acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature. Note: of the 242 fish released at Stockton, 8 fish were not detected.

Receiver Site	SJO(n)	WWTP	Navy Bridge	TC(n)	TC(s)	C18	C16	Old(e)	CCFB	ORNU	ORND	MRND	Chipps	Total
Live		1	62		3	5	22						7	100
Predation	1	2	19	2	11	10	60	1	2	1	3	1	21	134

Several noteworthy observations were evident from these results. Consistent with prior VAMP experiments (e.g., Vogel 2010a), an extremely high mortality of juvenile salmon was apparent at the trash racks leading to the Tracy Fish Facilities and behind the Clifton Court Forebay gates. Among the 97 tags last detected at the receiver deployed at the Tracy Fish Facilities trash racks, 100% were believed to be in predators. An extremely high rate of tag defecation occurred at this site as noted by motionless transmitters evident from visual examination of the echograms; the same occurrence was noted during the 2009 study (Vogel 2010a). Of the 102 tags last detected by the receiver placed in Clifton Court Forebay behind the gates, 98% were believed to be in predators. However, it could not be determined where the predation events originally occurred.

The reach of the lower San Joaquin between Navy Bridge and the Deep Water Shipping Channel markers 16 and 18 also appeared to be an area of high predation. Among the total of 335 tags last detected by the three receivers positioned at those sites, 199 tags (59%) were believed to be in predators. An apparent high fish mortality occurrence in this region was also observed during the 2009 VAMP studies (Vogel 2010a). Again, it could not be determined where the predation events originally occurred.

The two receivers positioned in northern Old River just upstream and downstream of the Highway 4 bridge (Figure 1) also appeared to harbor predatory fish. Of the 108 tags last detected in this vicinity, 81 (75%) were believed to be in predators. This assumption was largely based on tags lingering in an unfavorable salmon rearing area for extended periods (e.g., days).

Of the 108 tags last detected at the multiple receivers positioned at Chipps Island, 64 tags (59%) were believed to be in predators. It has previously been assumed that all tag detections at Chipps Island would have originated from live salmon. If the assumption of numerous tags actually inside predators is correct, true salmon survival would be considerably lower. As observed from the predatory fish tagging (discussed below), striped bass are highly mobile throughout the Delta and frequently migrate downstream to Chipps Island.

It is a challenge to differentiate a live acoustic-tagged salmon versus a dead acoustic-tagged salmon inside a predatory fish (e.g., striped bass). In both instances, the acoustic signal gets recorded by the data loggers, but the equipment cannot discriminate between the two scenarios. If a tagged salmon is consumed by a predatory fish, then swims past a data logger, this will bias salmon survival estimates high because, at present, we have no way of knowing that the signal was not transmitting from inside a live salmon. This is a technical concern that Natural Resource Scientists, Inc. has frequently described to the VAMP Biology Committee since conducting the first VAMP acoustic telemetry study in 2006. Given the present limited technological capabilities, recent data suggest that resolving this problem will be complex and difficult to accurately estimate salmon survival and avoid biased estimates (Vogel 2010a).

This problem with predation in interpreting juvenile salmon telemetry results was also observed during radio-tag studies of juvenile salmon in the Delta. Over the course of numerous studies conducted in the north, central, and south Delta, certain “behavior” patterns emerged indicating that some of the radio-tagged salmon (tracked using boat-mounted mobile receivers) were likely inside predators. Some of the indicators of probable predation included: abrupt change (decline)

in radio tag transmission signal strength, signal remaining consistently attenuated, a sudden change in behavior in comparison to prior observations of the same tag or other radio-tagged fish (e.g., moving with strong currents then abruptly moving for extended distances against the current), or a radio tag remaining in the exact same location where a juvenile salmon would not be expected to maintain position for such a long duration (e.g., mid San Joaquin River Deep Water Shipping Channel) (Vogel 2004). However, for an acoustic-tagged salmon eaten by a predator, the signal does not change or attenuate (at least with the present capabilities in data processing) (Vogel 2010a).

These results are obviously not definitive, and misinterpretations of some tag detections were likely, but nonetheless provide compelling evidence of the magnitude of predation on acoustic-tagged salmon. The contrary assumption of all tag detections emanating from live smolts is undoubtedly erroneous. The apparent very low survival is not surprising from the perspective of the estimated very high rate of predation on acoustic-tagged salmon. For example, earlier VAMP studies using coded-wire tagging on large numbers of juvenile salmon showed extremely low recoveries of tagged fish in the western Delta (Table 7), but the reasons for the low survival were unexplained.

Table 7. Recovery information for coded-wire tagged Chinook salmon released during the 2004 VAMP study (SJRGA 2005) (Table from Vogel 2005).

Release Site in the San Joaquin River	Number of Tagged Salmon Released	Number of Tagged Salmon Recovered at Antioch	Number of Tagged Salmon Recovered at Chipps Island
Durham Ferry	23,440	1	0
Durham Ferry	21,714	1	1
Durham Ferry	23,327	0	1
Durham Ferry	23,783	0	1
Mossdale	25,320	1	0
Mossdale	23,586	0	1
Mossdale	24,803	0	2

Observations of Acoustic-Tagged Predatory Fish Movements

Acoustic-tagging of predatory fish was anticipated to provide information on striped bass, black bass, and white catfish movements within the study area and possible affinity of those species to specific locales. During the study, 48 striped bass, 12 large-mouth bass, and one white catfish were tagged with individually identifiable acoustic transmitters and released at the fish capture locations. Instead of having the field crews focus solely on large predators, they were instructed to also include smaller predatory fish, but only those sufficiently large to eat a salmon smolt. The study goal was to tag and release up to 100 predatory fish. A substantial amount of effort was made to capture fish in upstream reaches near Mossdale and the head of Old River but angling in those areas was largely unproductive as compared to areas further downstream. Time spent in the upstream areas where relative predator densities were apparently lower than downstream reaches prevented us from achieving the target of 100 fish. Table 8 provides the information on the tagged predatory fish.

Table 8. Predatory fish tagged with acoustic transmitters during the 2010 VAMP study.			
Fish Species	**Fork Length (mm)**	**Date/Time of Release**	**Location of Release**
Striped Bass	406	4/4/10 1309 hrs.	San Joaquin River 1.7 miles upstream of Highway 4
Striped Bass	533	4/16/10 1530 hrs.	San Joaquin River ½ mile upstream of head of Old River
Largemouth Bass	483	4/24/10 1042 hrs.	Old River at Grant Line Canal
Largemouth Bass	470	4/24/10 1307 hrs.	Southwestern Victoria Canal
Largemouth Bass	457	4/24/10 1345 hrs.	Southwestern Victoria Canal
Largemouth Bass	457	4/24/10 1600 hrs.	Grant Line Canal near S. Tracy Blvd.
Largemouth Bass	368	4/24/10 1700 hrs.	Middle River near Old River flow split
Largemouth Bass	495	4/24/10 1745 hrs.	Old River at Middle River flow split
Largemouth Bass	381	4/24/10 1930 hrs.	Old River 2 miles downstream of head of Old River
Largemouth Bass	394	5/3/10 1241 hrs.	San Joaquin River at Waste Water Treatment Plant
Largemouth Bass	356	5/3/10 1255 hrs.	San Joaquin River at Waste Water Treatment Plant
Largemouth Bass	406	5/3/10 1400 hrs.	San Joaquin River 5 Miles Downstream of Head of Old River
Striped Bass	380	5/5/10 1230 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	480	5/5/10 1230 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	420	5/5/10 1230 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	360	5/5/10 1230 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	520	5/5/10 1230 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	580	5/5/10 1230 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	510	5/5/10 1320 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	430	5/5/10 1320 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	430	5/5/10 1320 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	530	5/5/10 1320 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	430	5/5/10 1320 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	370	5/5/10 1320 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	460	5/5/10 1415 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	450	5/5/10 1415 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	440	5/5/10 1415 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	420	5/5/10 1415 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	380	5/5/10 1415 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	520	5/5/10 1415 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	410	5/5/10 1500 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	390	5/5/10 1500 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	430	5/5/10 1500 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	580	5/5/10 1500 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	370	5/5/10 1500 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	490	5/5/10 1500 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	500	5/5/10 1550 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	470	5/5/10 1550 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	430	5/5/10 1550 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	440	5/5/10 1550 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	420	5/5/10 1550 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	380	5/5/10 1550 hrs.	Upstream of Tracy Fish Facilities trash racks
Largemouth Bass	394	5/8/10 1500 hrs.	San Joaquin River at Waste Water Treatment Plant
Striped Bass	381	5/8/10 1610 hrs.	San Joaquin River at Waste Water Treatment Plant
Striped Bass	394	5/8/10 1720 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	432	5/11/10 1415 hrs.	San Joaquin River upstream of Waste Water Treatment Plant
Striped Bass	508	5/16/10 0855 hrs.	San Joaquin River at head of Old River
Largemouth Bass	368	5/24/10 1150 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	394	5/24/10 1253 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	381	5/24/10 1315 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	419	5/24/10 1350 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	381	5/26/10 1720 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	406	5/26/10 1900 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	356	5/26/10 1820 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	444	5/26/10 1840 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	394	5/26/10 1910 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	427	5/28/10 0700 hrs.	Railroad Bridge in lower San Joaquin River
Striped Bass	483	5/28/10 0951 hrs.	San Joaquin River at Navy Drive Bridge
Striped Bass	432	5/28/10 1200 hrs.	San Joaquin River at Navy Drive Bridge
White Catfish	406	6/1/10 1600 hrs.	San Joaquin River 5 Miles Downstream of Head of Old River
Striped Bass	381	6/2/10 1210 hrs.	San Joaquin River 5 Miles Downstream of Head of Old River

Near-field observational data were obtained for tagged predators within detection range of the VAMP receivers. For example, Figures 2 - 3 show echograms depicting movements of acoustic-tagged striped bass near the Tracy Fish Facilities trash racks and behind the gates inside Clifton Court Forebay, respectively. These movements are similar to acoustic-tagged salmon (or the transmitters) believed to be inside predators at those two locations (e.g., Figures 4 - 5). Details on interpretation of the echograms are provided in Vogel (2010a). Neither site is considered suitable rearing environment for juvenile salmon due to poor physical habitat conditions and very high concentrations of striped bass (Vogel 2010a). However, there were also instances where the predatory fish movements (based on graphical post-processing displays of the echograms) at other sites in the Delta looked similar to movements of salmon smolts passing the receivers.

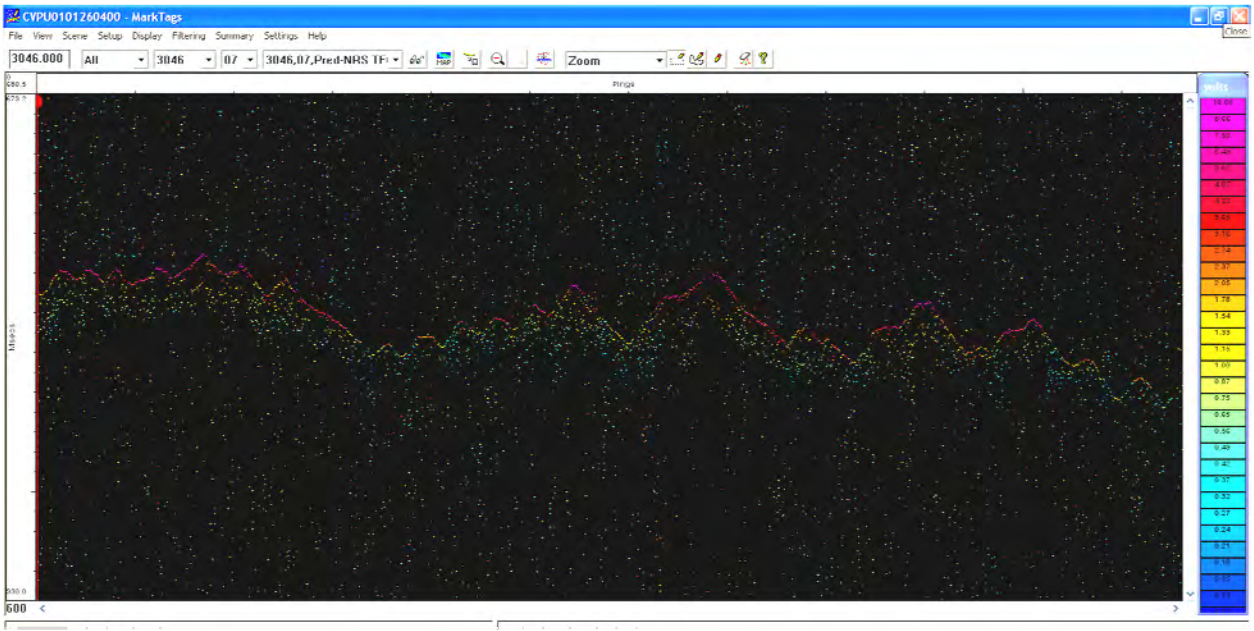

Figure 2. One-hour echogram of an acoustic-tagged striped bass in front of the Tracy Fish Facilities trash racks.

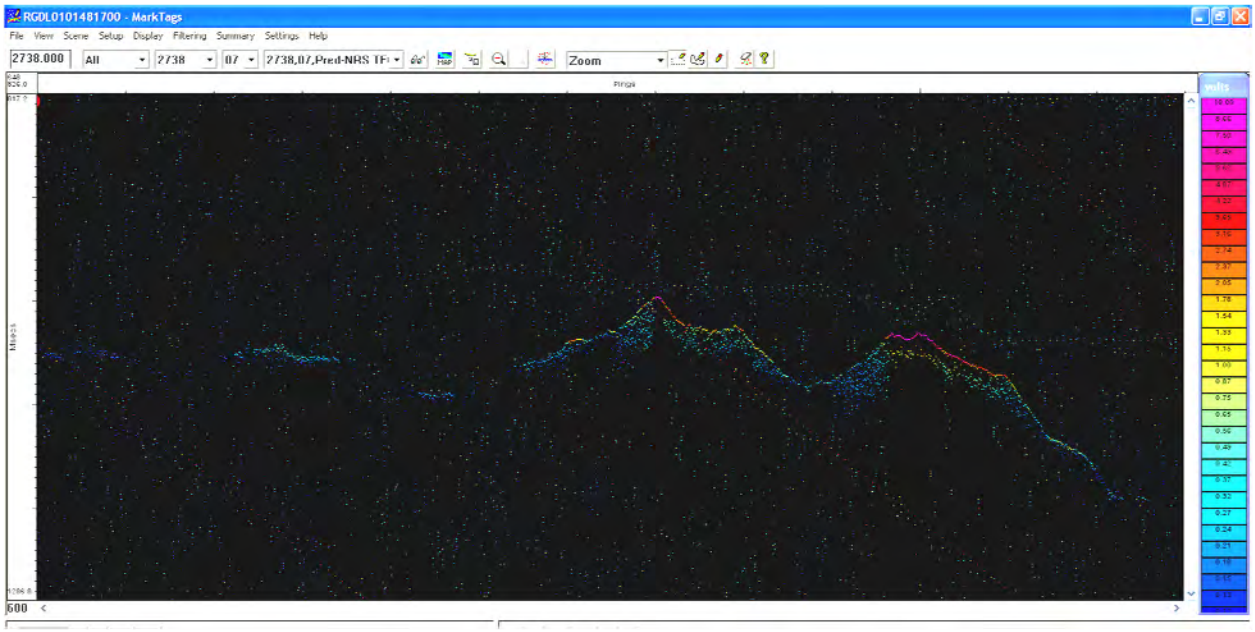

Figure 3. One-hour echogram of an acoustic-tagged striped bass behind the Clifton Court Forebay gates.

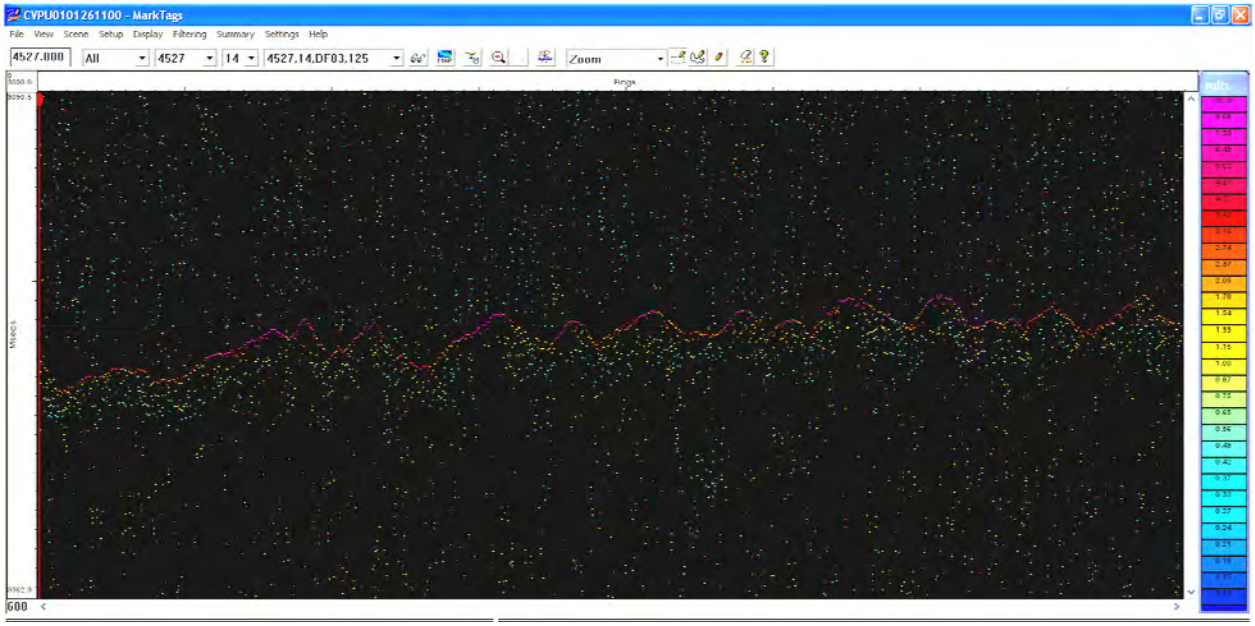

Figure 4. One-hour echogram of an acoustic-tagged salmon (or the transmitter) believed to be inside a predatory fish in front of the Tracy Fish Facilities trash racks.

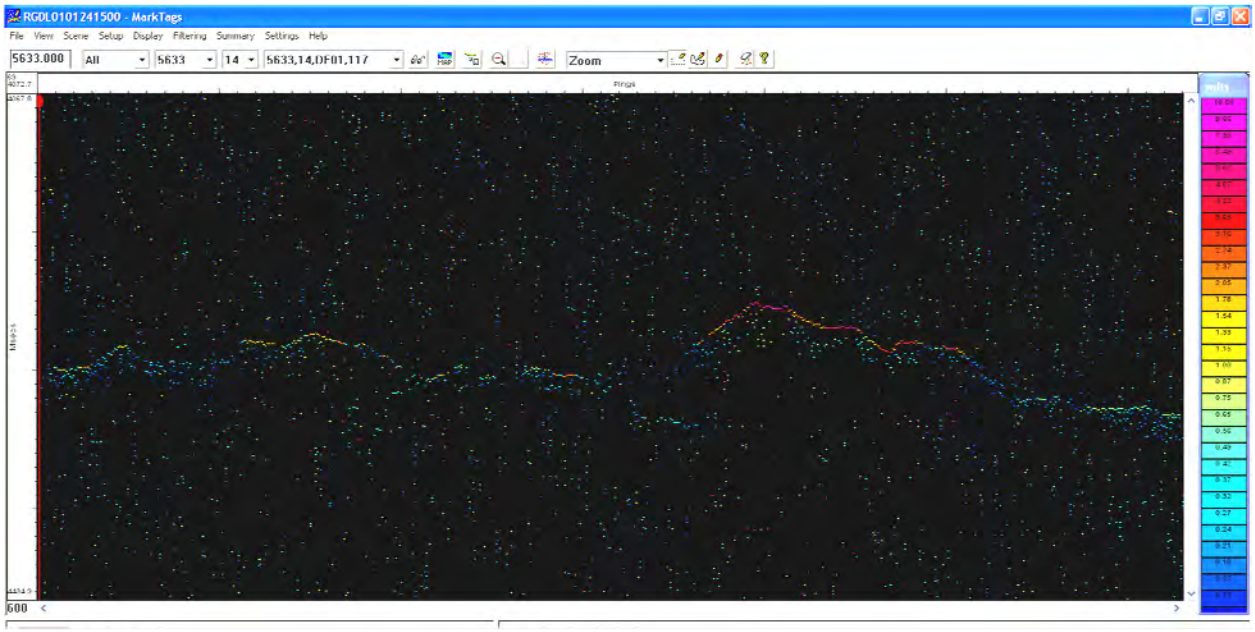

Figure 5. One-hour echogram of an acoustic-tagged salmon (or the transmitter) believed to be inside a predatory fish behind the Clifton Court Forebay gates.

Additionally, we noted an occurrence where two acoustic-tagged salmon had been eaten by one predatory fish. The echograms of the two salmon tags recorded behind the Clifton Court Forebay gates were nearly identical for extended periods (Figures 6 – 7). This phenomenon is not easy to detect but has been observed elsewhere (Vogel 2010a).

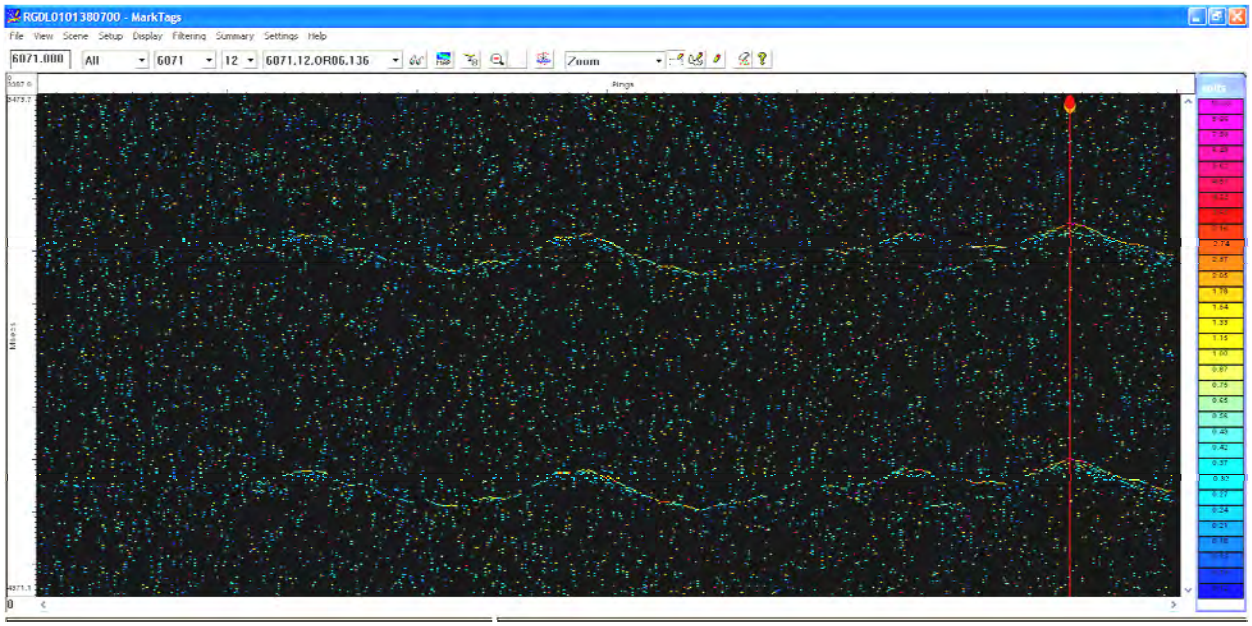

Figure 6. One-hour echogram of acoustic-tagged salmon no. 6071 (or the transmitter) believed to be inside a predatory fish behind the Clifton Court Forebay gates.

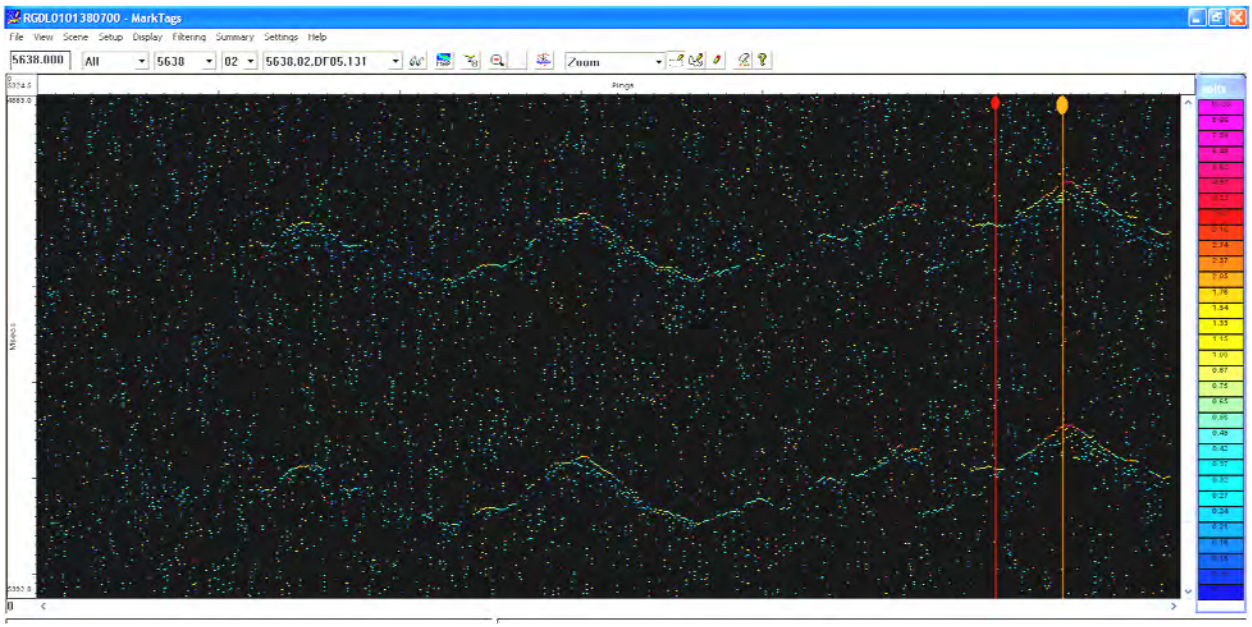

Figure 7. One-hour echogram of acoustic-tagged salmon no. 5638 (or the transmitter) believed to be inside a predatory fish behind the Clifton Court Forebay gates.

The far-field observations of predatory fish movements were particularly interesting. Appendix Figures 1 - 46 show the movements of acoustic-tagged predators within the telemetry array (Figure 1) during the 2010 VAMP study. Several noteworthy observations can be made from these results.

Among the 30 striped bass tagged and released in the south Delta at the Tracy Fish Facilities, 13 bass were documented to have migrated downstream and west to Chipps Island (Appendix Figures 1 - 13. The migration route for most of those fish was northerly through Old River, although several fish migrated past the receivers placed in Middle River. Interestingly, some of the tagged striped bass were detected multiple times at Chipps Island over days, similar to some of the tagged smolts (or the transmitters) believed to be inside predators. Four of the 30 striped bass moved to various locations in the south Delta and were last detected by the receiver inside Clifton Court Forebay (Appendix Figures 14 - 17). This latter behavior was also noted during predatory fish tagging conducted during the 2009 VAMP study (Vogel 2010b). Four of the 30 bass moved north and were last detected by the receivers in northern Old River near the Highway 4 bridge (Appendix Figures 18 - 21) an area where high numbers of tagged salmon assumed to have been preyed upon were last detected. Two of the 30 bass moved east to the head of Old River, then upstream to Mossdale (Appendix Figures 22 - 23). One of the striped bass moved east to the head of Old River, then downstream to Stockton and down the San Joaquin Deep Water Ship Channel past the receivers placed at the channel markers 18 and 16 (Appendix Figure 24). Six of the 30 bass were not detected. However, several anglers reported catching tagged striped bass in the south Delta near the Tracy Fish Facilities but did not report the tag numbers.

Striped bass tagged in the San Joaquin River also exhibited highly migratory behavior. Seven of the striped bass tagged in the San Joaquin River were documented to have migrated westerly to Chipps Island (Appendix Figures 25 – 31). Two of those fish initially migrated upstream as far

as Banta Carbona prior to downstream movement to Chipps Island (Appendix Figures 30 – 31). Seven striped bass tagged in the San Joaquin River were last detected among the receivers placed in the lower San Joaquin near Stockton (Appendix Figures 32 – 38). One striped bass tagged at Stockton moved downstream to the Stockton Deep Water Ship channel marker 18 then moved back upstream into Turner Cut (Appendix Figure 39). One striped bass tagged at Stockton moved upstream and entered the head of Old River (Appendix Figure 40).

Although 12 largemouth bass were tagged, only five fish were detected within the acoustic telemetry array. This circumstance is likely attributable to largemouth bass exhibiting more residency than migratory behavior as compared to striped bass. Four of those bass were tagged in the lower San Joaquin River and were last detected at the receivers near Stockton (Appendix Figures 41 – 44). One bass tagged near the head of Old River was last detected at the receiver placed just downstream of the head of Old River (Appendix Figure 45).

Only one white catfish was tagged during the study. After tagging and release in the San Joaquin River downstream of the head of Old River, the catfish migrated downstream and was last detected lingering in the lower river near Stockton (Appendix Figure 46).

Some limited observations using a DIDSON^{TM} sonar camera were made at a variety of locations in the San Joaquin River during the study. Unlike the study conducted in 2009, high numbers of predatory fish at the Mossdale bridges were not evident. The only site where high numbers of predators were observed was on a channel bend adjacent to a pump station approximately 5 miles downstream of the head of Old River. Numerous small striped bass were observed at that location: http://www.youtube.com/watch?v=GUME4O0Kfmk Species identification was determined by extensive angling at the site.

Conclusions

It appears that we were frequently tracking dead salmon (or the transmitters) inside predatory fish during the 2010 VAMP study, not live salmon; this was also apparent during the 2009 VAMP study. There is a complex problem with differentiating between live acoustic-tagged salmon and predatory fish that had eaten acoustic-tagged salmon making it very difficult to accurately estimate overall salmon survival, salmon survival by reach, and fish route selection at key flow splits, all of which were key objectives of the VAMP study. This will be a challenging problem to solve using acoustic tags on juvenile salmon in Delta studies but must be addressed. These 2010 study results, as well as the 2009 study results (Vogel 2010a) strongly indicate significant problems with the ability to accurately quantify salmon smolt survival rates through the Delta. Sole reliance on assumed passage of salmon past the VAMP receivers using simple presence/absence of acoustic tag transmissions could have resulted in incorrect conclusions on assumed fish survival and fish route selections. It also indicates that these issues must be adequately addressed before management decisions are made based on Delta juvenile salmon acoustic telemetry studies using solely presence/absence detection data.

Acoustic telemetry technology continues to be demonstrated as a powerful analytical tool to study juvenile salmon movements in the Delta, but only if it is appropriately implemented and the results are properly analyzed and understood. Information developed from the 2009 and

2010 VAMP studies indicates that if we attempt to accurately estimate salmon survival in the Delta using acoustic telemetry, a new approach should be used by perhaps seeking changes in the technology to determine predation. Data on striped bass movements collected during this study amply demonstrate that the predatory fish are highly migratory throughout the Delta, moving large distances including a high percentage of striped bass emigrating westerly (downstream) to Chipps Island which compromises the prior assumption of stationarity of predators and potential effects on juvenile salmon survival estimates. DWR plans to conduct a study of striped bass gut evacuation rates at various meal sizes and temperatures to further refine telemetry results (K. Clark, DWR, pers. comm.). A technological advancement in acoustic transmitters should be actively pursued to provide empirical evidence of when an acoustic-tagged salmon is eaten by a predator. Until this critically important issue is resolved, it is recommended that acoustic telemetry studies on juvenile salmon to estimate fish survival over long Delta reaches be postponed until the problem can be reliably resolved.

Acknowledgements

Many individuals within local, state, and federal agencies and private organizations made this project successful and are thanked for their contributions. Appreciation is extended to the California Department of Water Resources for funding this research study and to the San Joaquin River Group Authority for managing the project. Thanks are also due to: Dennis Westcot for serving as the contract project manager; the numerous individuals from FWS, DFG, FishBio, and Hanson Environmental for tagging and releasing the salmon; the FWS, DFG, DWR, and USBR crews for battery swaps and data downloads of VAMP receivers; Mark Bowen for providing data from his evaluations at the head of Old River; Pat Brandes for coordinating the VAMP Biology Committee meetings, and many other individuals too numerous to name here. HTI staff continued to provide very helpful assistance to our staff on use of their hardware and software, acoustic telemetry field procedures, and data analytical techniques. Trevor Kennedy and the Fishery Foundation of California provided me with very capable assistance during the field portion of the predator study. Thanks are also due to Kevin Clark (DWR), Dennis Westcot (SJRGA), and DWR staff from the South Delta Branch for reviewing and providing helpful comments on an earlier draft of this report. Denisa Vogel deserves special credit for processing many of the acoustic telemetry data files, data compilation and summarization, developing report graphics, report editing, and performing administrative duties for the project.

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Appendix Table 1. Estimated fate of 74 acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry (DF01) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	BC	MOS	WWTP	Navy Bridge	TC(s)	C18	C16	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	4	2		4	1	1	2	1				4	1	20
Predation	1		3	5	2	3	11	2	7	11	1	5	2	53

Appendix Table 2. Estimated fate of 36 acoustic-tagged juvenile salmon released at the head of Old River (OR01) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live				1	1	1	3
Predation	1	4	6	3	8		22

Appendix Table 3. Estimated fate of 35 acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton (STK01) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	SJO(n)	WWTP	Navy Bridge	TC(n)	TC(s)	C18	C16	Chipps	Total
Live		1	5			1	6	7	100
Predation	1	1	2	1	3	1	9	21	135

Appendix Table 4. Estimated fate of 74 acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry (DF02) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Navy Bridge	TC(s)	C16	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	3		5	6				5		19
Predation	3	1	17	1	10	9	2	7	2	52

Appendix Table 5. Estimated fate of 36 acoustic-tagged juvenile salmon released at the head of Old River (OR02) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	WWTP	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	1	5				4	3	13
Predation		1	6	9	1	2	3	22

Appendix Table 6. Estimated fate of 36 acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton (STK02) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Navy Bridge	C18	C16	ORND	MRND	Chipps	Total
Live	10		4			1	15
Predation	2	3	13	1	1		20

Appendix Table 7. Estimated fate of 73 acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry (DF03) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	BC	SJO(n)	WWTP	Navy Bridge	TC(s)	C18	C16	MRFS	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	3	1		4		1	3		12						24
Predation	1	1	1	5	1	2	5	1	2	9	11	3	2	4	48

Appendix Table 8. Estimated fate of 36 acoustic-tagged juvenile salmon released at the head of Old River (OR03) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	5		2	1	2	1	11
Predation		7	9	2	5	2	25

Appendix Table 9. Estimated fate of 35 acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton (STK03) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Navy Bridge	TC(n)	C18	C16	CCFB	ORNU	Chipps	Total
Live	10			2				12
Predation	4	1	1	8	1	1	5	21

Appendix Table 10. Estimated fate of 70 acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry (DF04) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	BC	SJO(n)	WWTP	Navy Bridge	TC(s)	C18	C16	MRFS	Old(e)	Tracy	CCFB	ORNU	Chipps	Total
Live	3	3		5	3	1	5		12				3	35
Predation		1	1	2	2	3	6	1	1	2	8	4	4	35

Appendix Table 11. Estimated fate of 36 acoustic-tagged juvenile salmon released at the head of Old River (OR04) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	11			1	1	4	17
Predation	1	7	4	2	2	3	19

Appendix Table 12. Estimated fate of 36 acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton (STK04) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Navy Bridge	TC(s)	C18	C16	Old(e)	ORND	Chipps	Total
Live	10		2	1			1	14
Predation	2	3		8	1	1	5	20

Appendix Table 13. Estimated fate of 70 acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry (DF05) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	BC	SJO(n)	Navy Bridge	TC(n)	TC(s)	C18	C16	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	1	2	2		2		4	6			1	2	7	27
Predation			3	1	2	5	6		8	7	2	1	7	42

Appendix Table 14. Estimated fate of 36 acoustic-tagged juvenile salmon released at the head of Old River (OR05) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	7				1	2	10
Predation	3	5	8	6	1	1	24

Appendix Table 15. Estimated fate of 36 acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton (STK04) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Navy Bridge	TC(s)	C18	C16	Chipps	Total
Live	5	1	1	5	1	13
Predation	2	2	4	9	5	22

Appendix Table 16. Estimated fate of 73 acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry (DF06) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	BC	SJO(n)	WWTP	Navy Bridge	TC(s)	C18	C16	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	1	2		2							1	1	7	14
Predation		2	1	15	1	1	5	9	9	5	5	1	5	59

Appendix Table 17. Estimated fate of 35 acoustic-tagged juvenile salmon released at the head of Old River (OR06) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Old(e)	Tracy	CCFB	ORNU	ORND	Total
Live					1	1
Predation	14	5	9	3	3	34

Appendix Table 18. Estimated fate of 34 acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton (STK06) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	WWTP	Navy Bridge	TC(s)	C18	C16	Chipps	Total
Live		15			1	2	18
Predation	1	5	2	1	4	1	14

Appendix Table 19. Estimated fate of 70 acoustic-tagged juvenile salmon released in the San Joaquin River at Durham Ferry (DF07) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

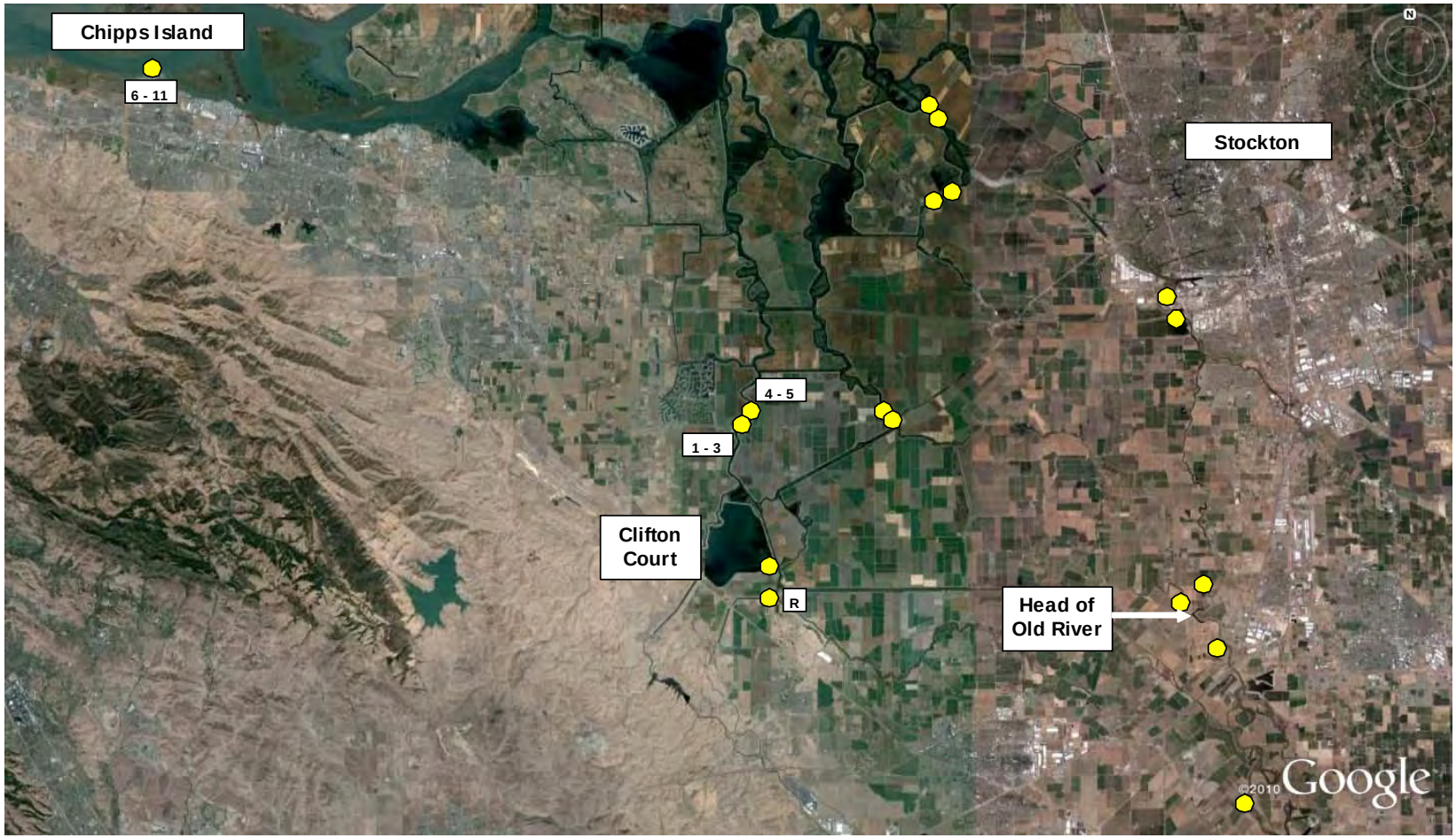
Receiver Site	BC	MOS	SJO(n)	WWTP	Navy Bridge	C16	Old(e)	Tracy	CCFB	ORNU	ORND	Chipps	Total
Live	3	2			2	3	9					5	24
Predation	2		5	1	5	8	2	7	1	2	1	6	40

Appendix Table 20. Estimated fate of 32 acoustic-tagged juvenile salmon released at the head of Old River (OR07) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

Receiver Site	Old(e)	Tracy	ORNU	ORND	Chipps	Total
Live	11				3	14
Predation		11	2	1	4	18

Appendix Table 21. Estimated fate of 31 acoustic-tagged juvenile salmon released in the lower San Joaquin at Stockton (STK07) during the 2010 VAMP experiments. Estimated fate is at the last recorded detection within the acoustic-telemetry array shown in Figure 1. Refer to Table 1 for Receiver Site nomenclature.

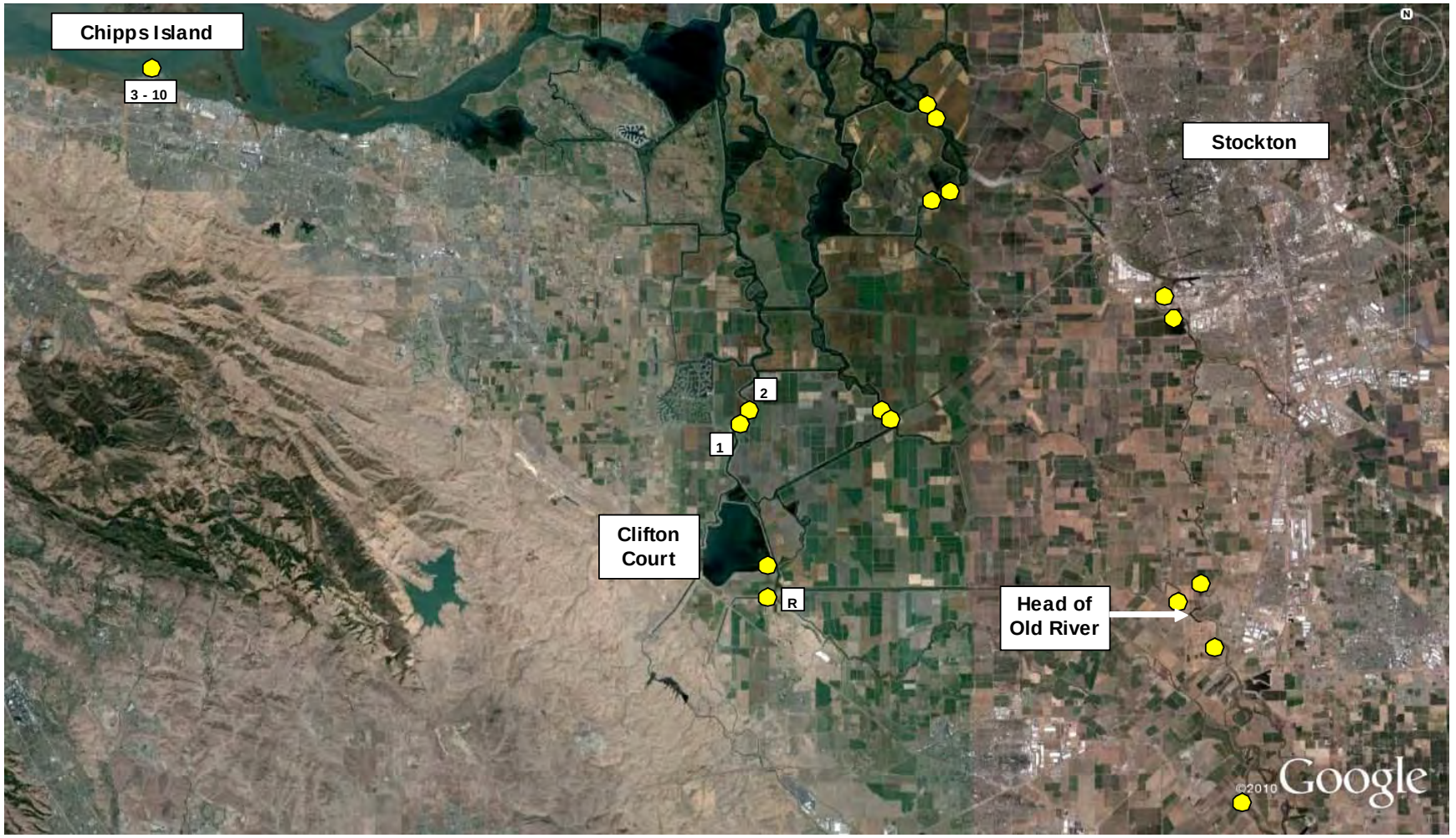
Receiver Site	Navy Bridge	TC(s)	C18	C16	CCFB)	ORND	Chipps	Total
Live	7	2	1	3			2	15
Predation	2	1		9	1	1	1	15



Striped Bass 3046.07. Released at 15:50 on 5/5/10

1) 5/25/10 @ 07:06 - 5/25/10 @ 09:26
2) 5/26/10 @ 05:13
3) 5/27/10 @ 00:11
4) 5/27/10 @ 00:50
5) 5/27/10 @ 03:46 - 5/27/10 @ 04:05
6) 5/28/10 @ 08:14
6) 6/3/10 @ 21:23
7) 6/6/10 @ 01:48
8) 6/7/10 @ 09:58
9) 6/8/10 @ 08:08
10) 6/10/10 @ 03:40

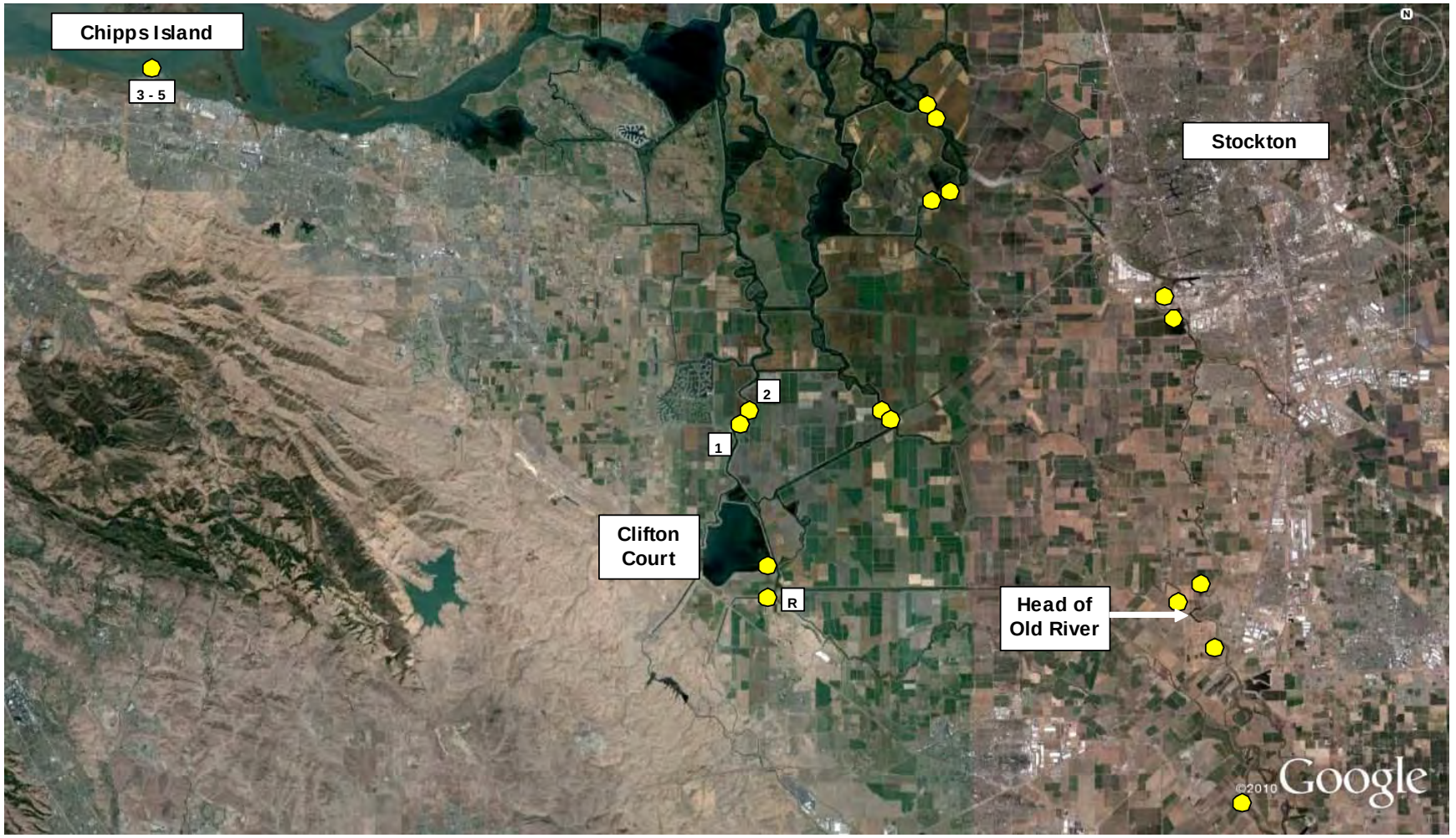
Appendix Figure 1. Movements of acoustic-tagged striped bass No. 3046.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 3032.07. Released at 14:15 on 5/5/10

1) 5/6/10 @ 12:28
2) 5/6/10 @ 12:48 - 5/6/10 @ 13:11
3) 5/9/10 @ 17:55
4) 5/21/10 @ 22:45
5) 5/22/10 @ 00:01
6) 6/5/10 @ 09:40
7) 6/6/10 @ 03:07
8) 6/9/10 @ 15:01
9) 6/11/10 @ 05:39
10) 6/14/10 @ 03:04

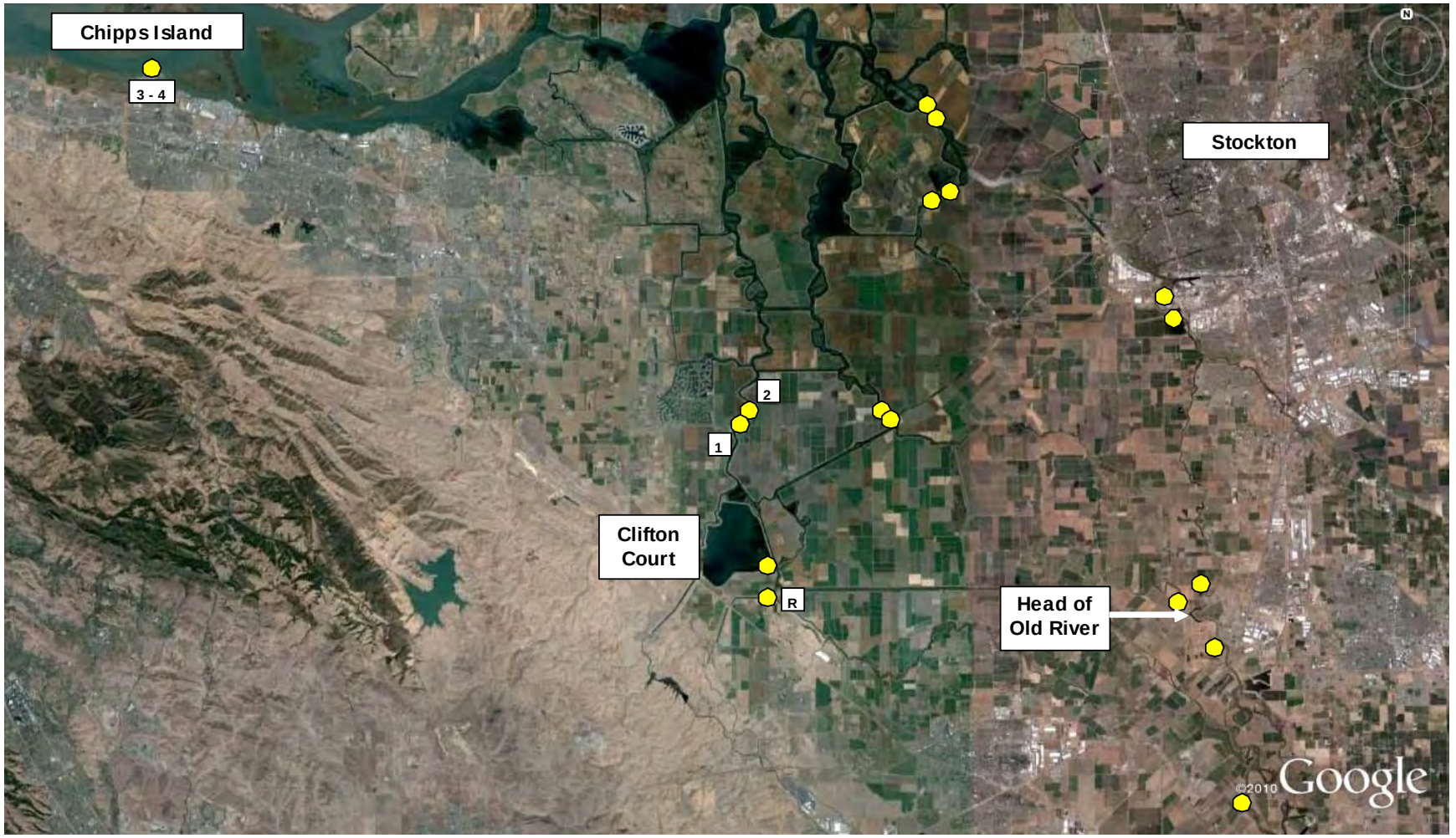
Appendix Figure 2. Movements of acoustic-tagged striped bass No. 3032.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2962.07. Released at 14:15 on 5/5/10

1) 5/6/10 @ 19:27
2) 5/6/10 @ 19:49 - 5/6/10 @ 22:50
3) 5/23/10 @ 13:53
4) 6/11/10 @ 00:08
5) 6/11/10 @ 04:38

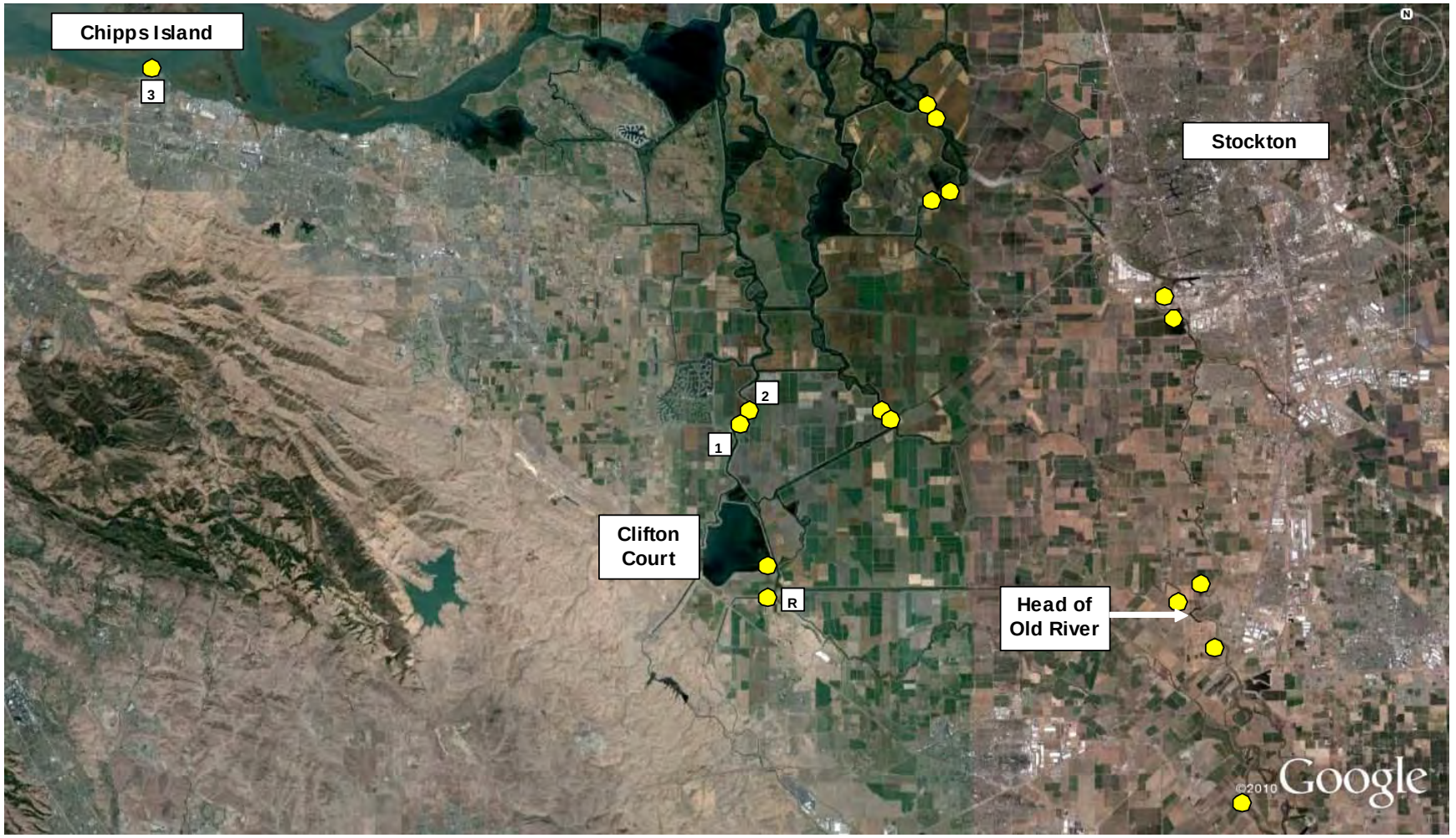
Appendix Figure 3. Movements of acoustic-tagged striped bass No. 2962.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2934.07. Released at 15:50 on 5/5/10

1) 5/7/10 @ 03:27
2) 5/7/10 @ 03:50 - 5/7/10 @ 04:08
3) 6/1/10 @ 06:49
4) 6/3/10 @ 03:12

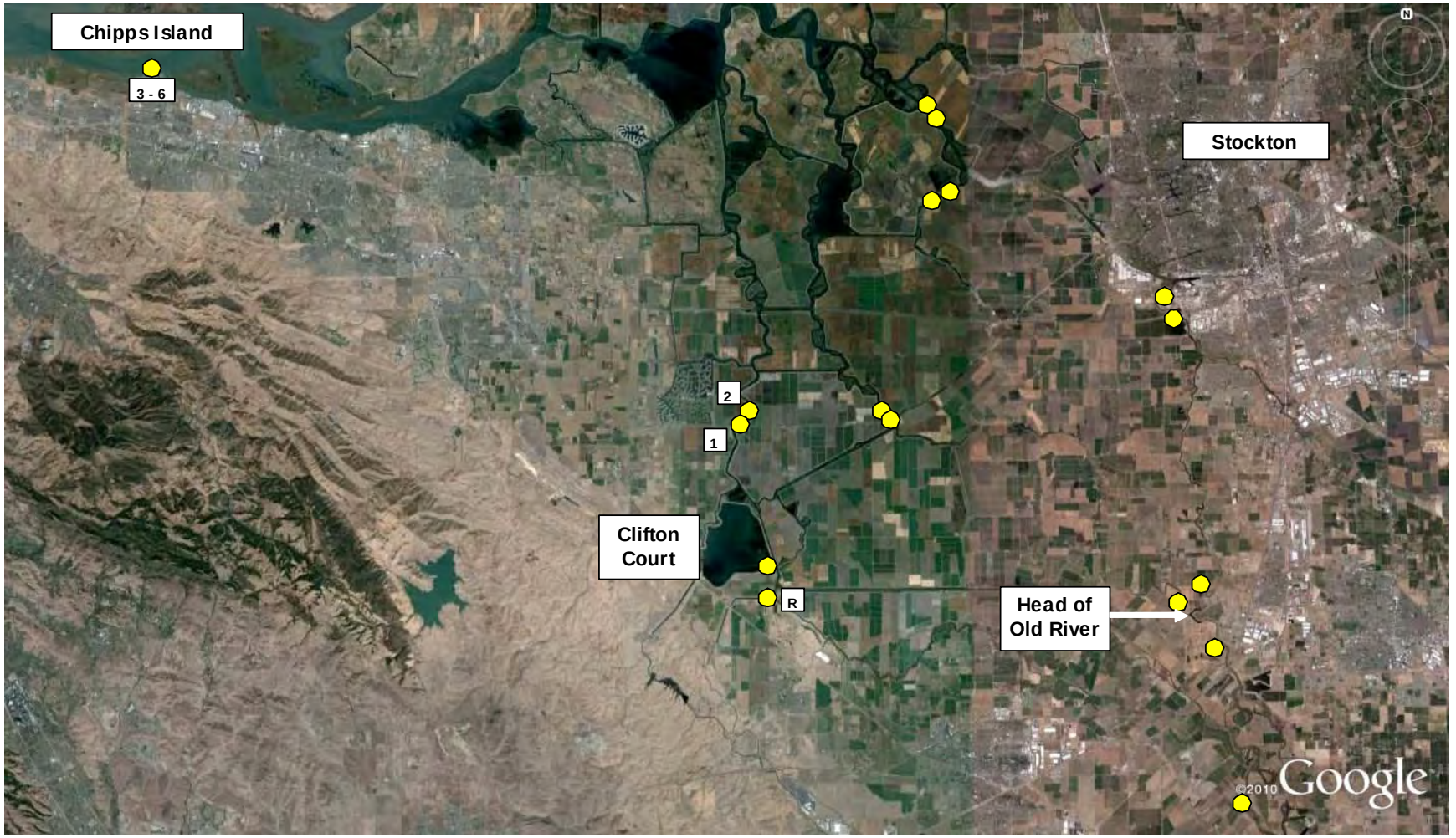
Appendix Figure 4. Movements of acoustic-tagged striped bass No. 2934.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2906.07. Released at 13:20 on 5/5/10

1) 5/5/10 @ 18:29
2) 5/5/10 @ 18:44
3) 5/22/10 @ 12:18

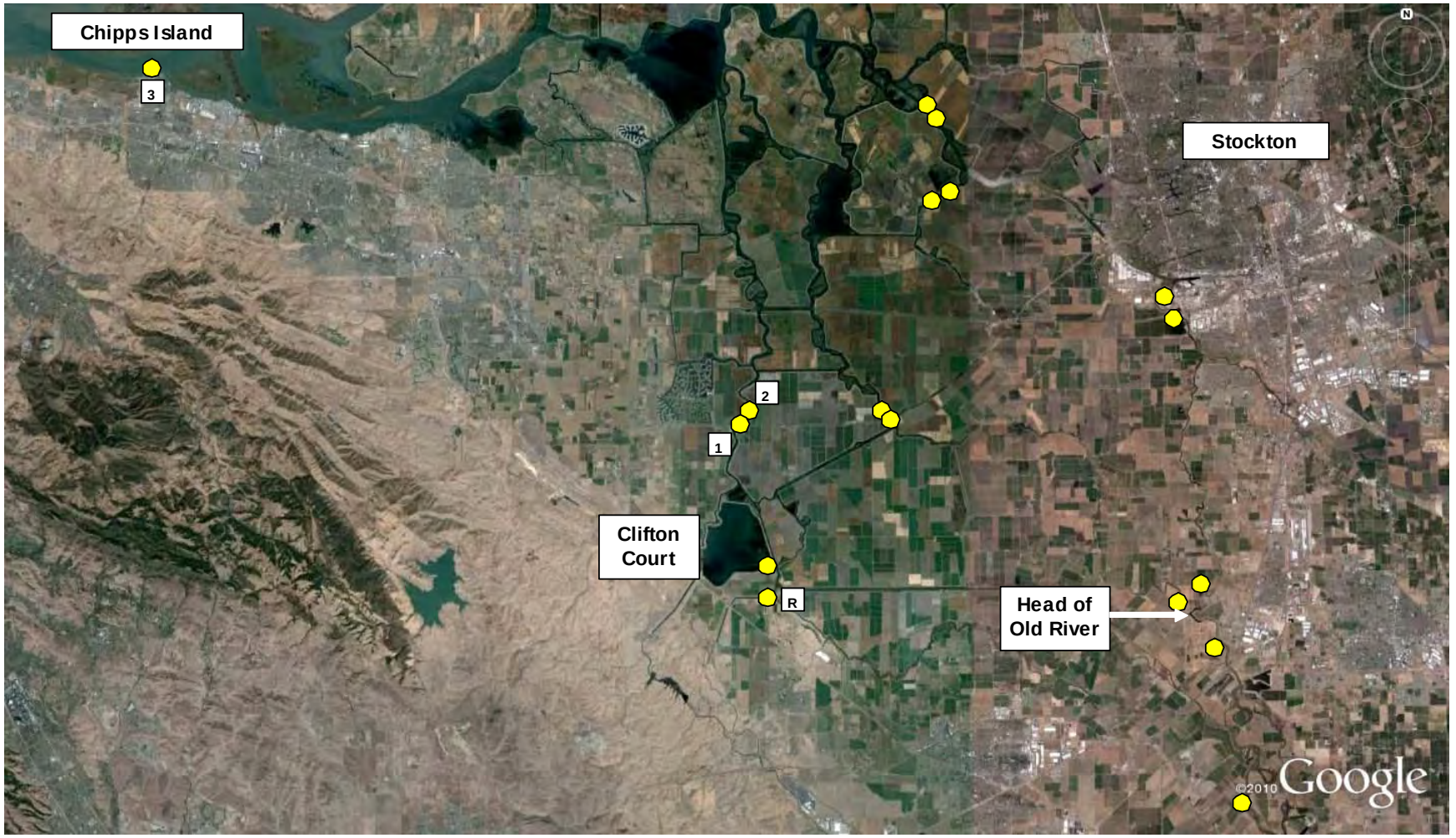
Appendix Figure 5. Movements of acoustic-tagged striped bass No. 2906.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2878.07. Released at 13:20 on 5/5/10

1) 5/23/10 @ 06:49 - 5/23/10 @ 07:49
2) 5/23/10 @ 07:58
3) 6/4/10 @ 23:28
4) 6/5/10 @ 22:36
5) 6/6/10 @ 00:37
6) 6/13/10 @ 03:00 - 6/13/10 @ 04:06

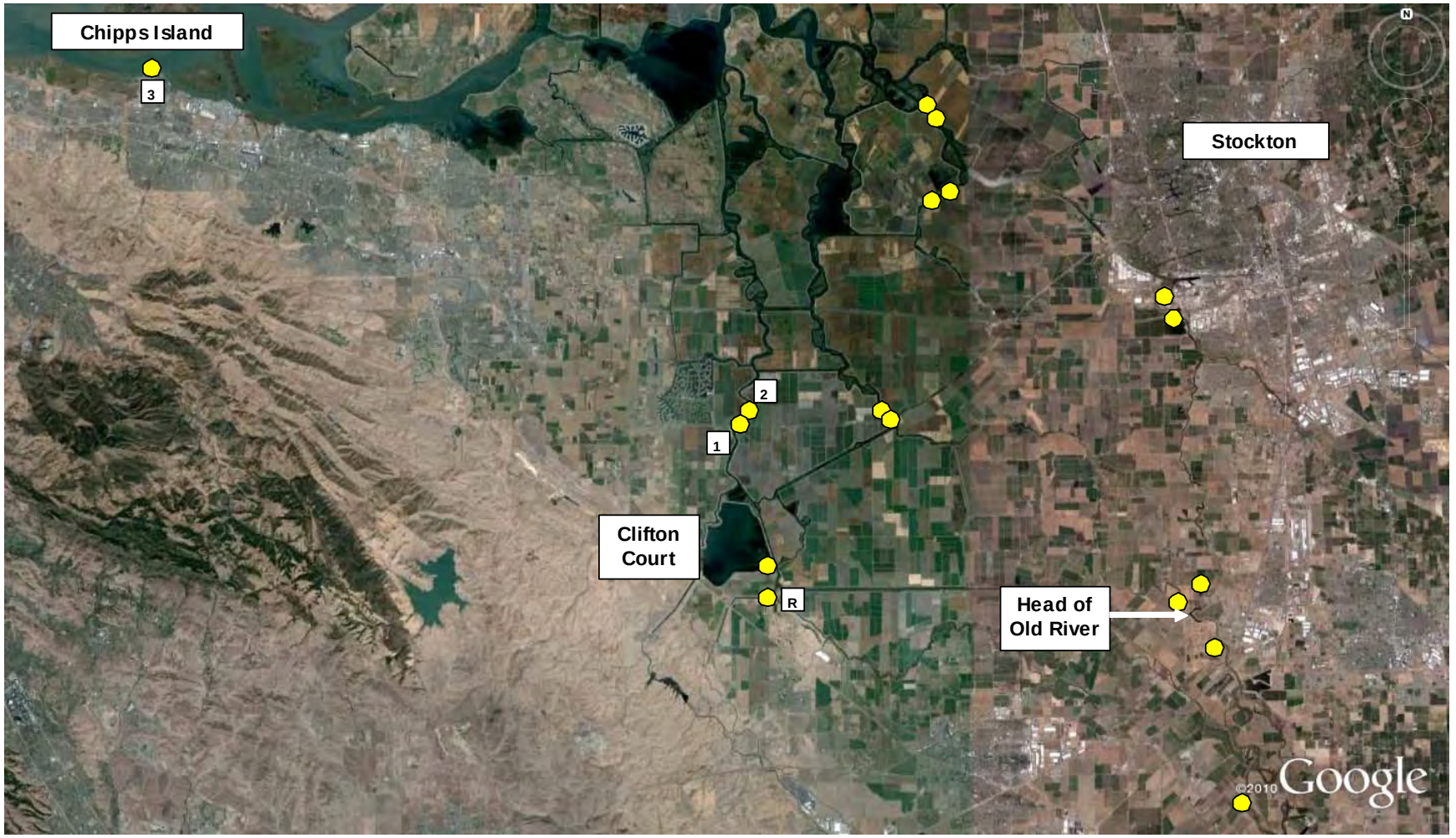
Appendix Figure 6. Movements of acoustic-tagged striped bass No. 2878.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2808.07. Released at 15:50 on 5/5/10

1) 5/6/10 @ 21:10
2) 5/6/10 @ 22:52 - 5/7/10 @ 00:04
3) 5/31/10 @ 12:35

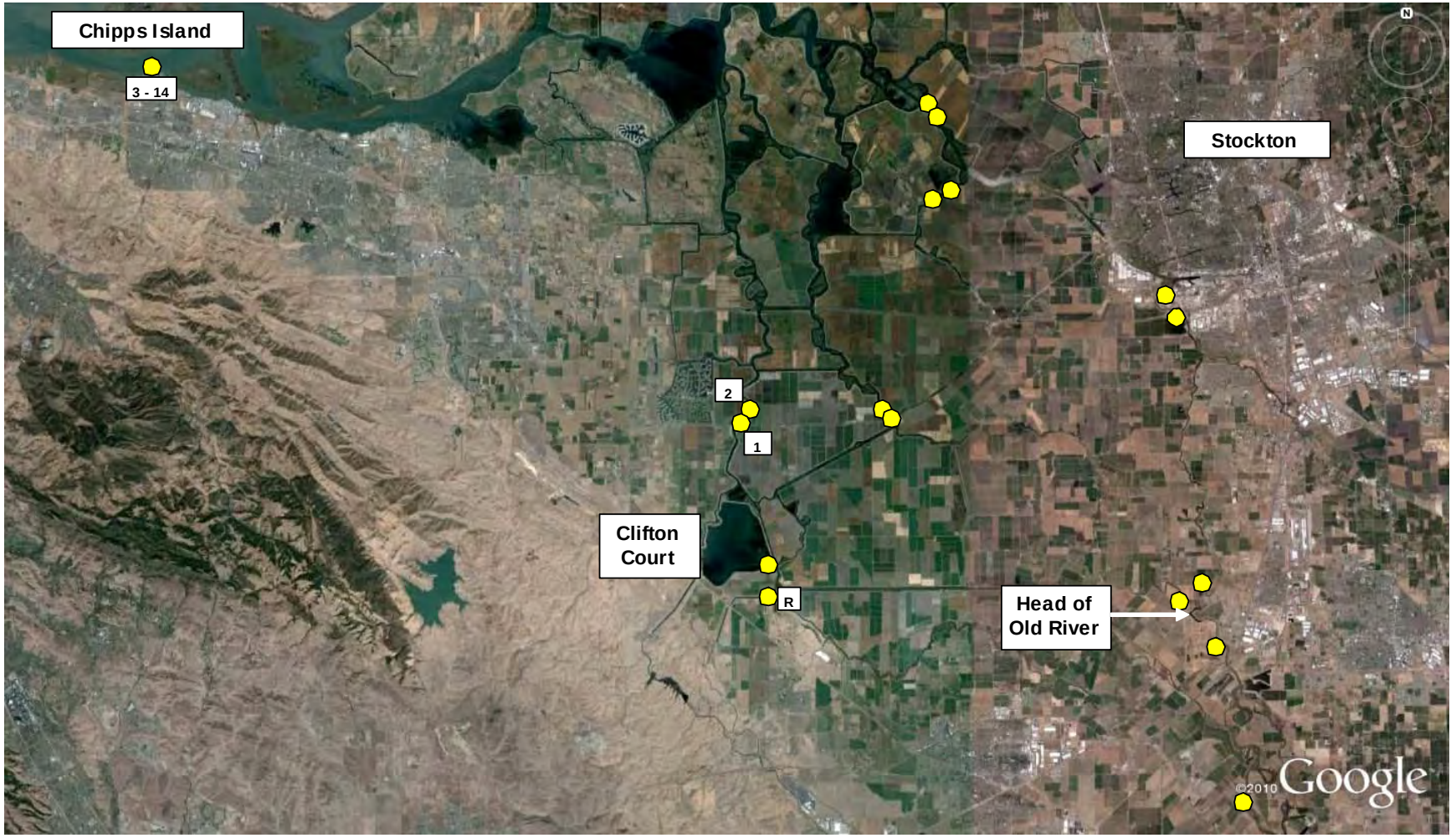
Appendix Figure 7. Movements of acoustic-tagged striped bass No. 2808.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2752.07. Released at 12:30 on 5/5/10

1) 5/30/10 @ 09:22
2) 5/30/10 @ 09:53
3) 6/5/10 @ 08:33

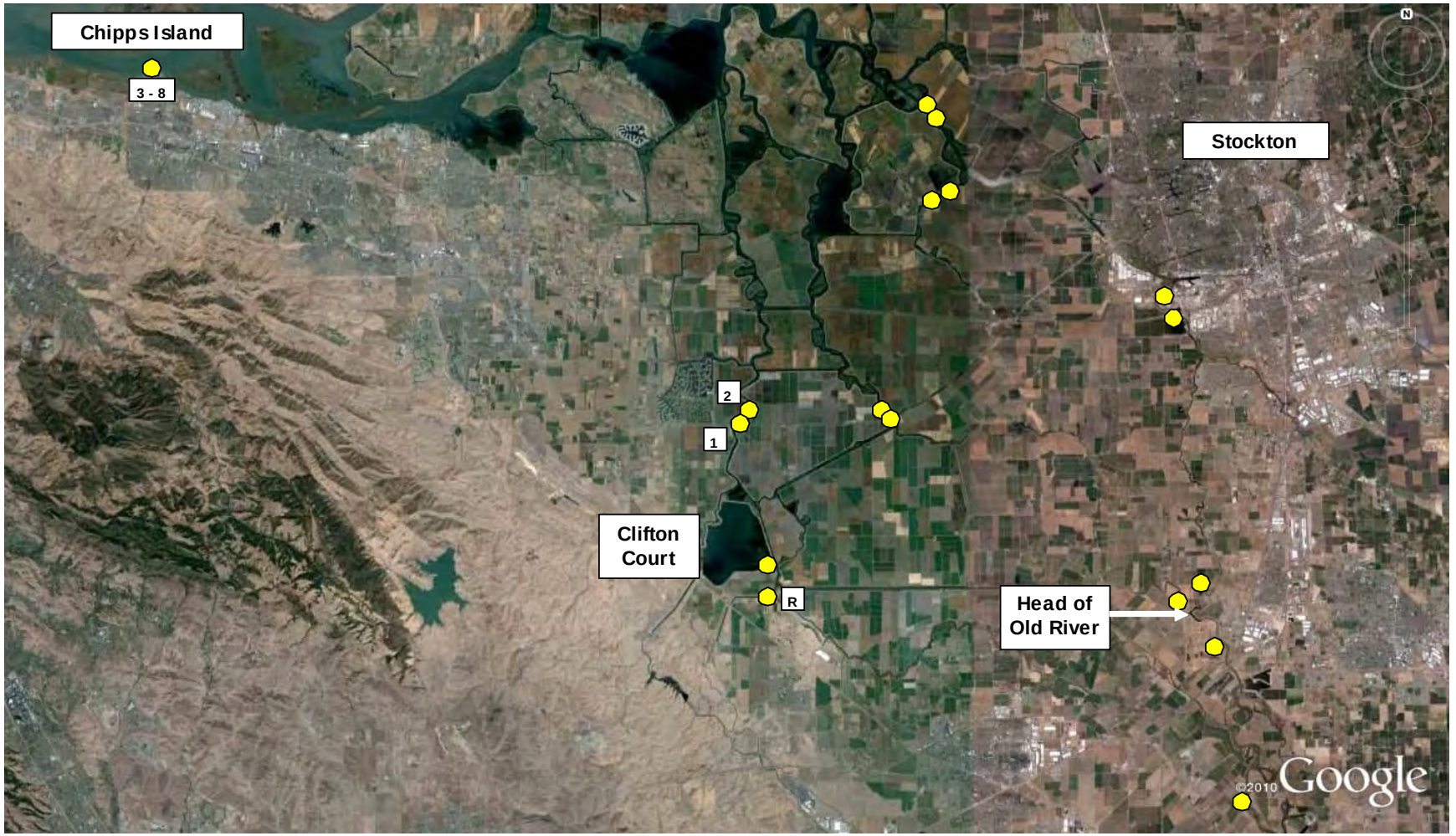
Appendix Figure 8. Movements of acoustic-tagged striped bass No. 2752.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2710.07. Released at 15:00 on 5/5/10

1) 5/6/10 @ 17:19
2) 5/6/10 @ 17:30
3) 5/9/10 @ 09:31 - 5/9/10 @ 13:36
4) 5/28/10 @ 02:05
5) 5/28/10 @ 04:13
6) 6/10/10 @ 23:02
7) 6/10/10 @ 05:31
8) 6/11/10 @ 17:27
9) 6/11/10 @ 23:16
10) 6/12/10 @ 06:36
11) 6/12/10 @ 17:14
12) 6/12/10 @ 19:04
13) 6/12/10 @ 23:43
14) 6/13/10 @ 08:03

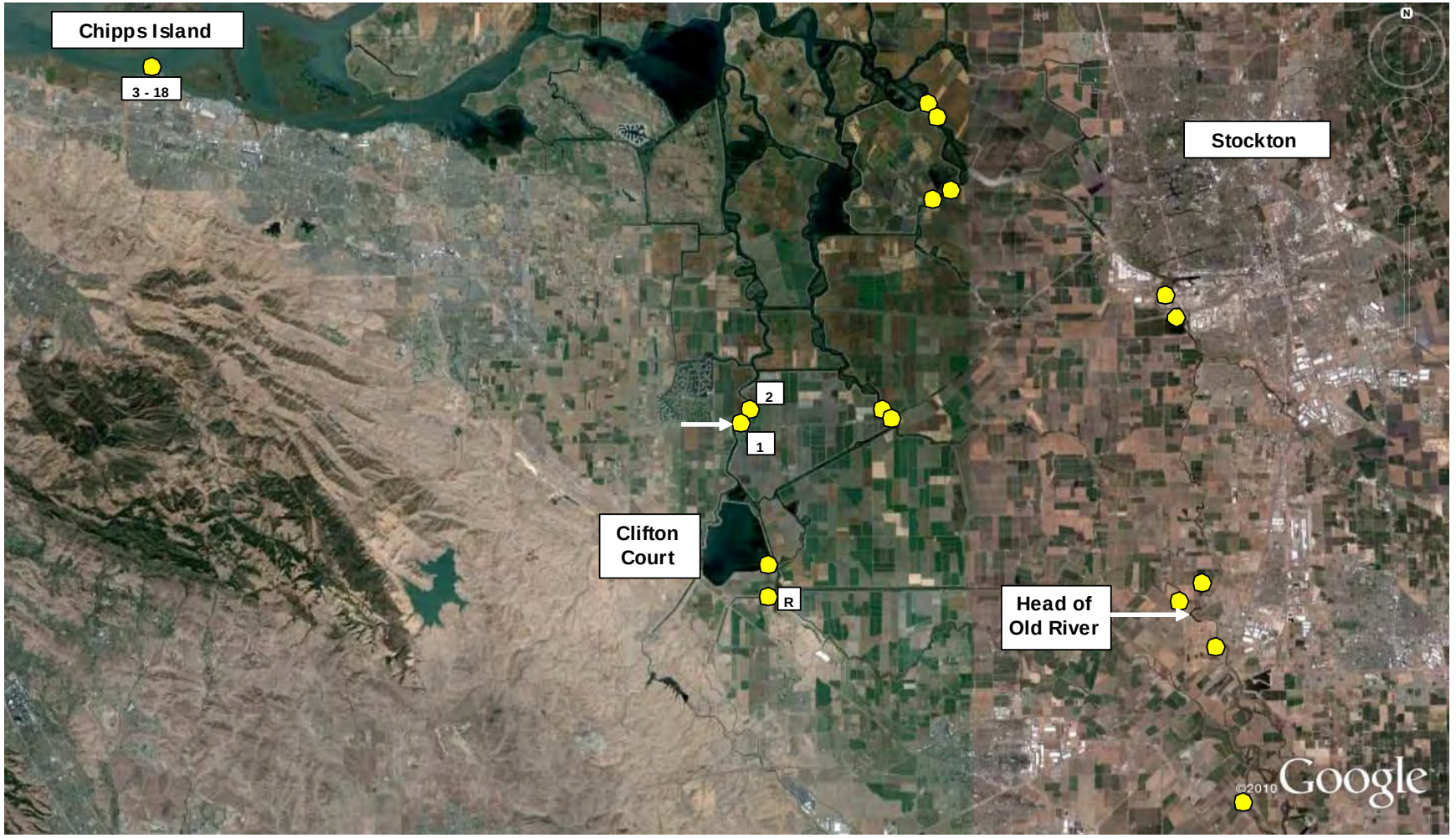
Appendix Figure 9. Movements of acoustic-tagged striped bass No. 2710.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2682.07. Released at 15:00 on 5/5/10

1) 5/21/10 @ 17:26
2) 5/21/10 @ 18:02
3) 5/23/10 @ 06:57
4) 6/9/10 @ 21:54
5) 6/10/10 @ 16:47
6) 6/10/10 @ 23:39
7) 6/11/10 @ 04:59
8) 6/14/10 @ 02:18

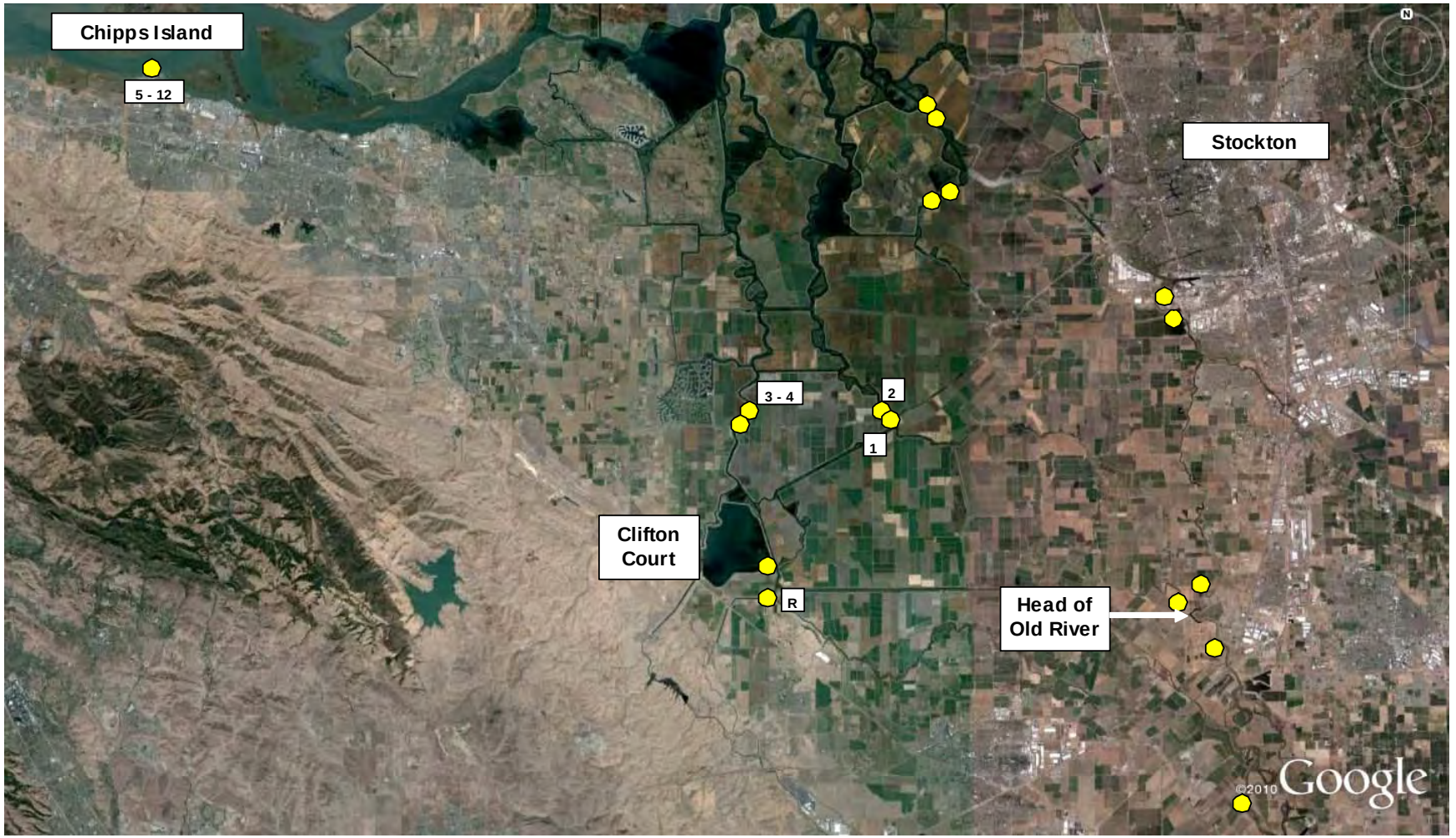
Appendix Figure 10. Movements of acoustic-tagged striped bass No. 2682.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2920.07. Released at 14:15 on 5/5/10

1) 5/8/10 @ 05:59
2) 5/8/10 @ 06:25
3) 5/12/10 @ 04:08
4) 5/16/10 @ 01:49
5) 5/16/10 @ 19:39 - 5/16/10 @ 20:39
6) 5/17/10 @ 02:34
7) 5/17/10 @ 17:15
8) 5/20/10 @ 06:51
9) 5/20/10 @ 09:47
10) 5/21/10 @ 07:39
11) 5/22/10 @ 23:24
12) 5/23/10 @ 02:02
13) 5/26/10 @ 00:03
14) 5/26/10 @ 04:53
15) 5/27/10 @ 06:36
16) 5/28/10 @ 04:27
17) 6/7/10 @ 21:24
18) 6/10/10 @ 09:17

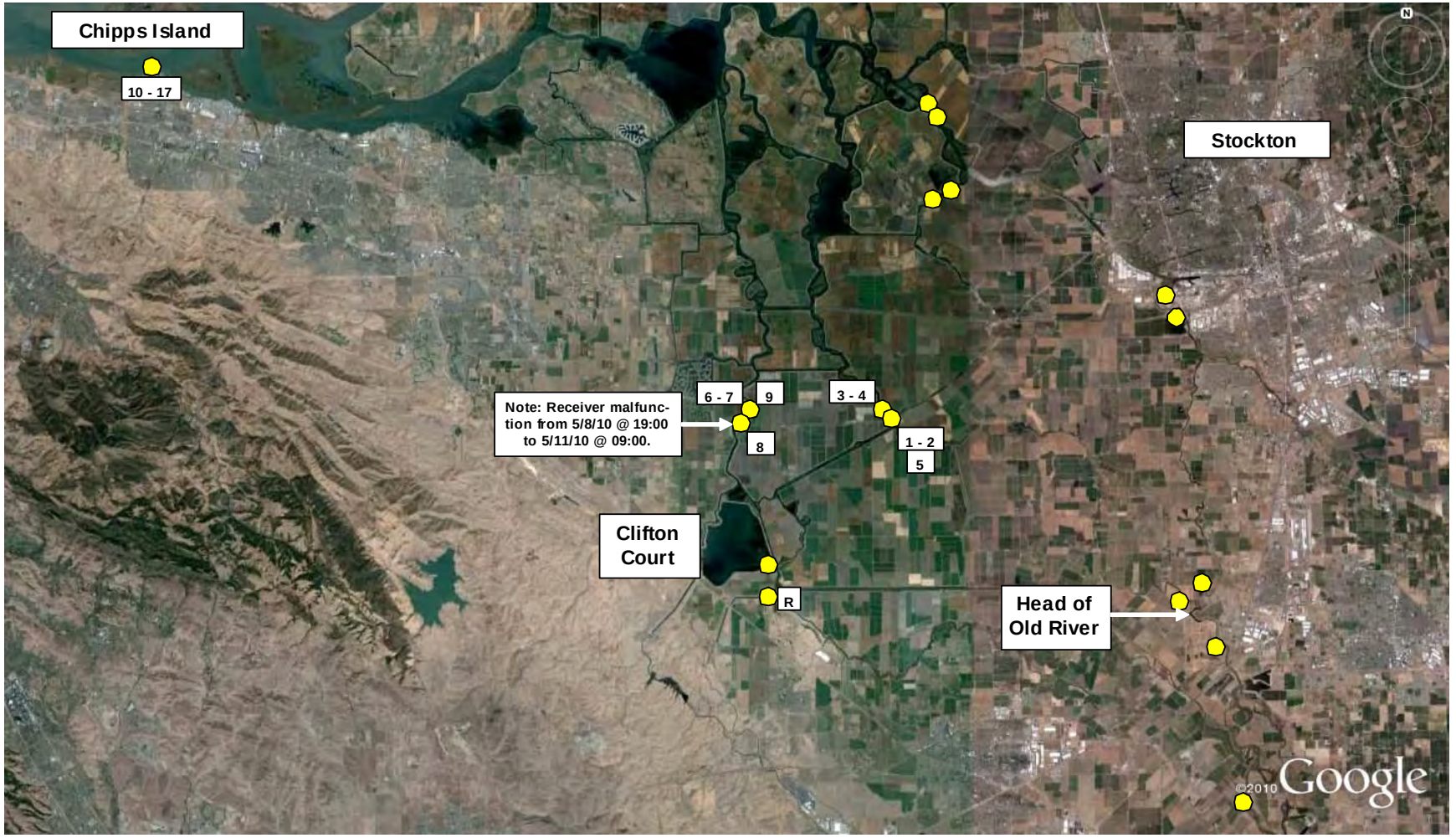
Appendix Figure 11. Movements of acoustic-tagged striped bass No. 2920.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2668.07. Released at 15:50 on 5/5/10

1) 5/6/10 @ 18:49	5) 5/12/10 @ 19:19	9) 6/11/10 @ 03:41
2) 5/6/10 @ 18:57	6) 5/12/10 @ 23:08	10) 6/12/10 @ 08:51
3) 5/8/10 @ 18:27	7) 5/13/10 @ 04:14	11) 6/13/10 @ 00:49
4) 5/10/10 @ 19:21	8) 6/11/10 @ 01:25	12) 6/13/10 @ 06:09

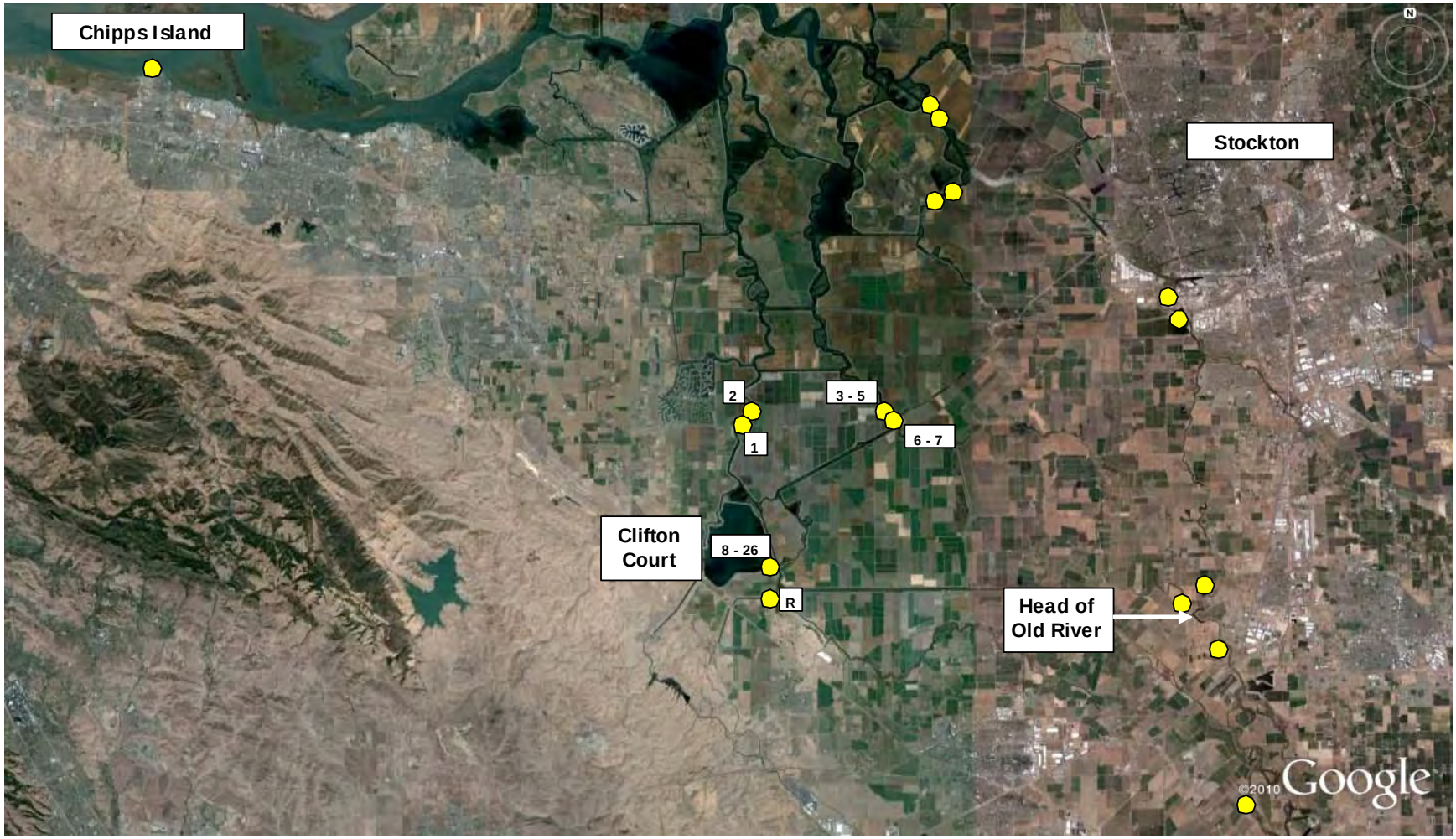
Appendix Figure 12. Movements of acoustic-tagged striped bass No. 2668.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2780.07. Released at 13:20 on 5/5/10

1) 5/8/10 @ 14:20
2) 5/8/10 @ 17:24
3) 5/8/10 @ 17:39
4) 5/9/10 @ 11:38
5) 5/9/10 @ 11:45
6) 5/9/10 @ 17:26
7) 5/10/10 @ 16:23
8) 5/22/10 @ 13:39
9) 5/22/10 @ 13:58
10) 5/31/10 @ 12:18 - 5/31/10 @ 14:21
11) 6/6/10 @ 06:04
12) 6/8/10 @ 12:42
13) 6/8/10 @ 15:57
14) 6/8/10 @ 22:38
15) 6/10/10 @ 20:48 - 6/10/10 @ 22:33
16) 6/11/10 @ 05:30
17) 6/13/10 @ 14:54

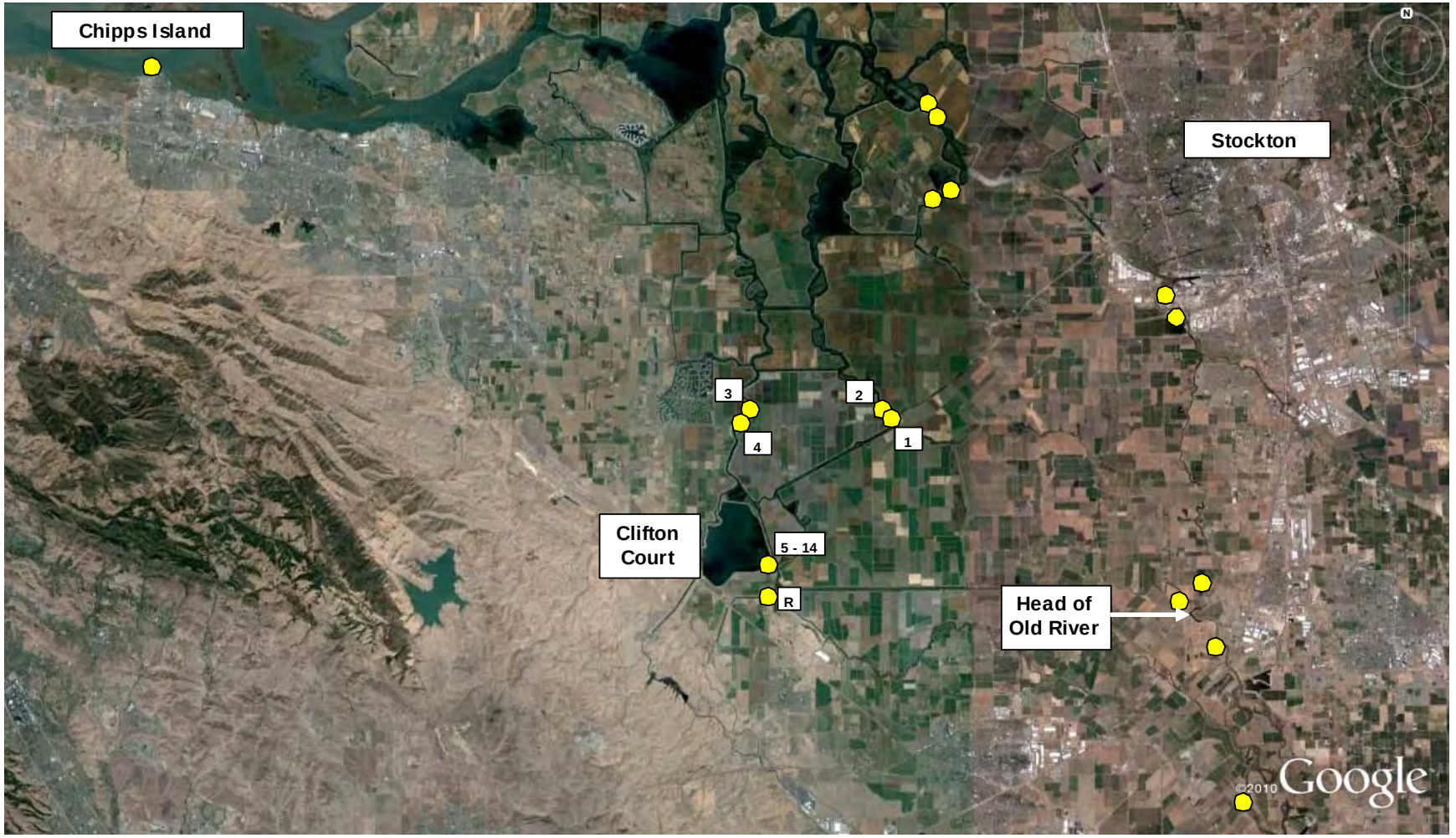
Appendix Figure 13. Movements of acoustic-tagged striped bass No. 2780.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2738.07. Released at 14:15 on 5/5/10

1) 5/17/10 @ 04:19
2) 5/17/10 @ 04:54
3) 5/19/10 @ 20:37 - 5/19/10 @ 21:45
4) 5/22/10 @ 10:11
5) 5/25/10 @ 13:24
6) 5/25/10 @ 13:33 - 5/25/10 @ 22:36
7) 5/26/10 @ 03:54 - 5/26/10 @ 08:09
8) 5/26/10 @ 18:52 - 5/26/10 @ 23:03
9) 5/27/10 @ 02:57 - 5/27/10 @ 13:14
10) 5/27/10 @ 16:39 - 5/2810 @ 05:07
11) 5/28/10 @ 09:15 - 5/29/10 @ 04:20
12) 5/29/10 @ 08:37 - 6/1/10 @ 06:13
13) 6/1/10 @ 22:20 - 6/2/10 @ 10:36
14) 6/2/10 @ 15:54 - 6/3/10 @ 17:04
15) 6/4/10 @ 02:28 - 6/4/10 @ 18:45
16) 6/5/10 @ 01:48 - 6/5/10 @ 19:08
17) 6/6/10 @ 02:37 - 6/6/10 @ 04:01
18) 6/6/10 @ 04:38 - 6/7/10 @ 14:16
19) 6/7/10 @ 21:03 - 6/8/10 @ 02:10
20) 6/9/10 @ 08:51 - 6/9/10 @ 14:24
21) 6/9/10 @ 20:35
22) 6/10/10 @ 02:04 - 6/10/10 @ 04:11
23) 6/10/10 @ 10:53 - 6/10/10 @ 15:28
24) 6/10/10 @ 17:35
25) 6/10/10 @ 20:33 - 6/11/10 @ 02:04
26) 6/13/10 @ 21:40 - 6/14/10 @ 18:37

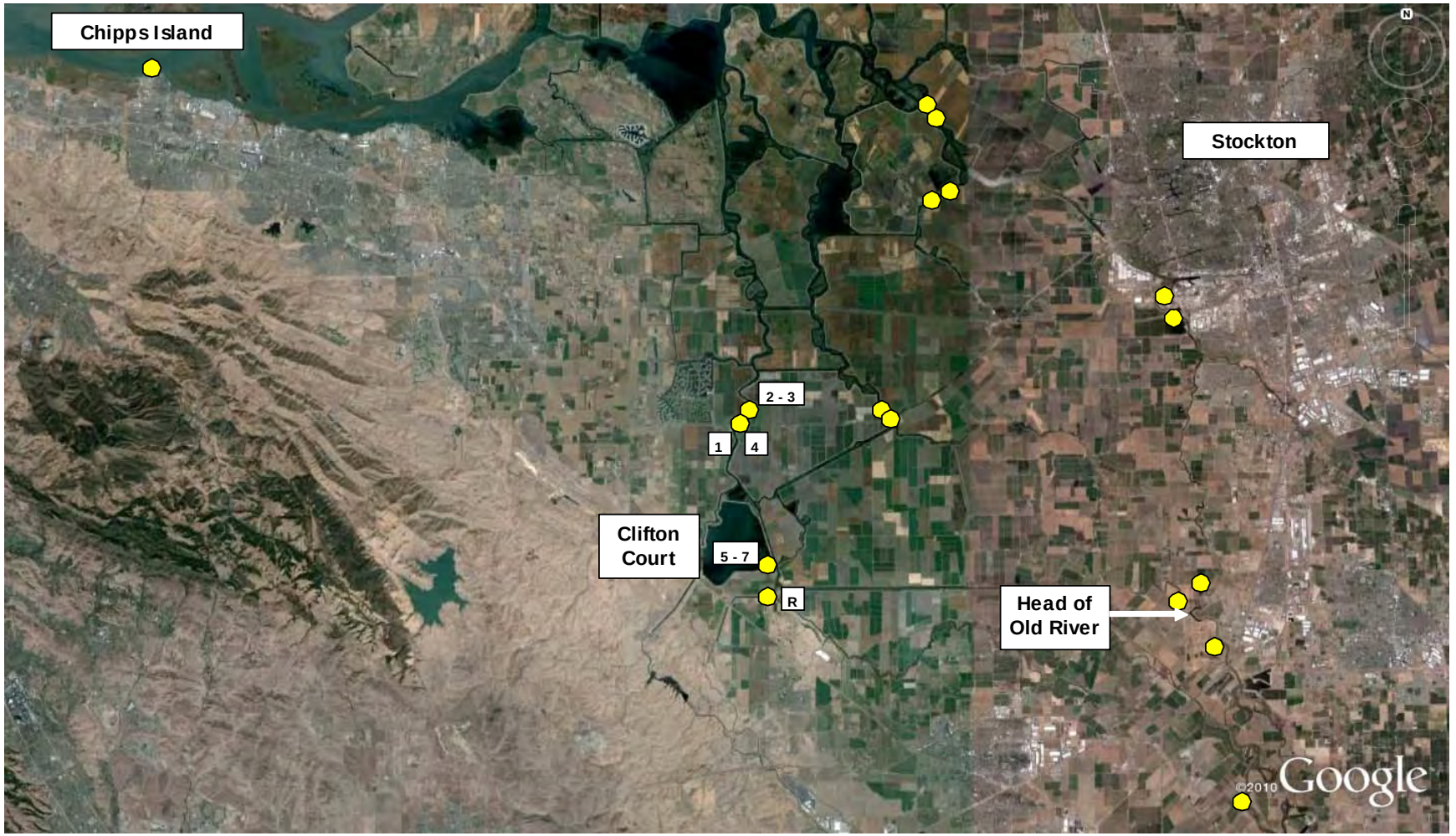
Appendix Figure 14. Movements of acoustic-tagged striped bass No. 2738.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2696.07. Released at 15:00 on 5/5/10

1) 5/8/10 @ 23:32
2) 5/9/10 @ 00:09
3) 5/28/10 @ 13:23 - 5/28/10 @ 14:04
4) 5/28/10 @ 14:35
5) 6/11/10 @ 01:17
6) 6/11/10 @ 03:51
7) 6/12/10 @ 01:20 - 6/12/10 08:06
8) 6/12/10 @ 13:10
9) 6/12/10 @ 18:39 - 6/12/10 @ 21:04
10) 6/13/10 @ 04:27
11) 6/13/10 @ 08:01
12) 6/13/10 @ 15:50 - 6/13/10 @ 23:40
13) 6/14/10 @ 17:24 - 6/15/10 @ 00:45
14) 6/15/10 @ 06:21

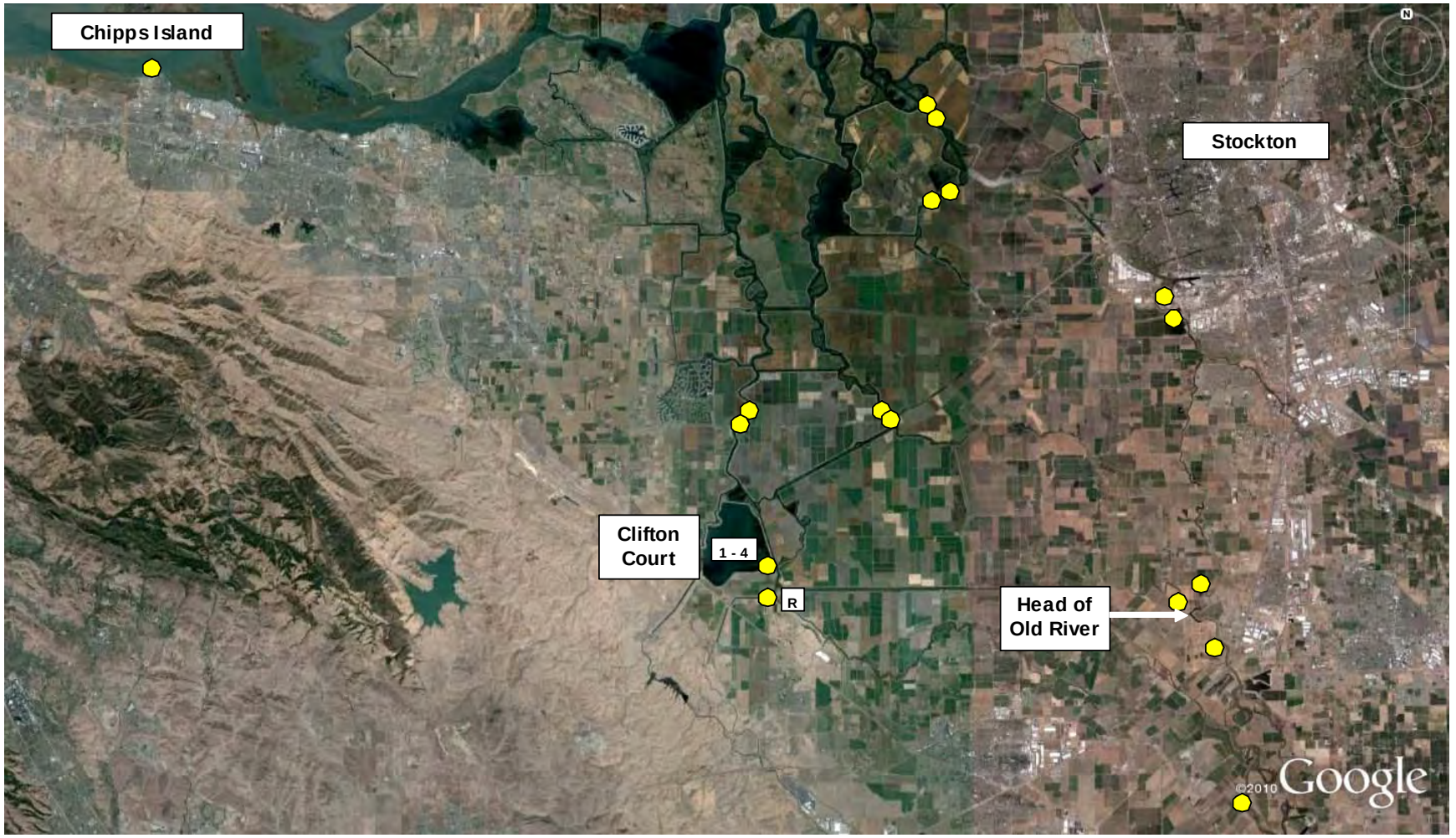
Appendix Figure 15. Movements of acoustic-tagged striped bass No. 2696.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2794.07. Released at 12:30 on 5/5/10

1) 5/22/10 @ 13:31
2) 5/22/10 @ 13:50
3) 6/5/10 @ 13:14
4) 6/5/10 @ 13:45
5) 6/5/10 @ 22:48 - 6/8/10 @ 18:04
6) 6/10/10 @ 00:55 - 6/15/10 @ 00:18
7) 6/15/10 @ 06:20

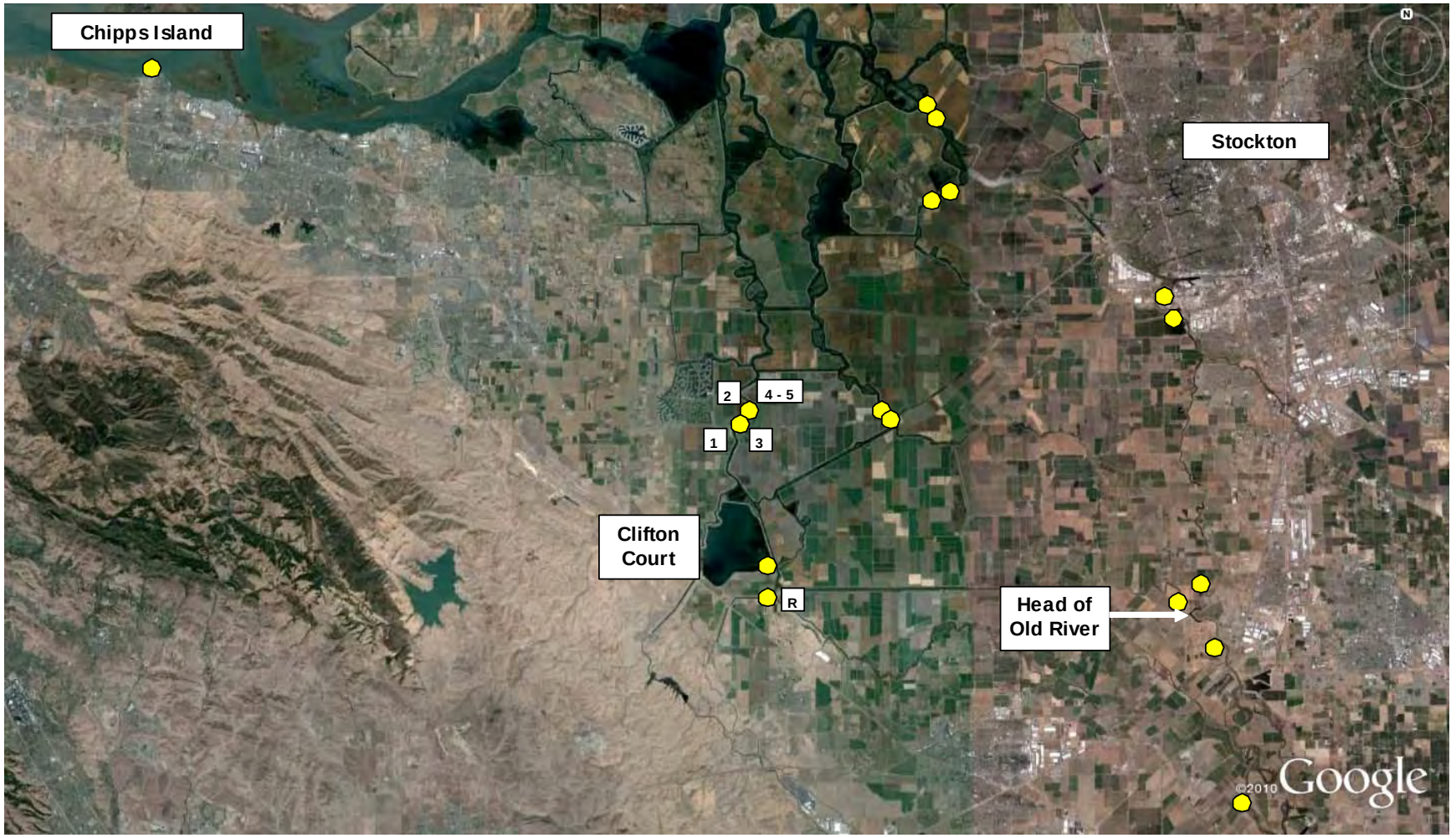
Appendix Figure 16. Movements of acoustic-tagged striped bass No. 2794.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2836.07. Released at 15:00 on 5/5/10

1) 5/7/10 @ 12:55 - 5/7/10 @ 15:01
2) 5/7/10 @ 18:48 - 5/7/10 @ 19:12
3) 5/10/10 @ 11:25
3) 5/11/10 @ 01:48 - 5/11/10 @ 02:04
4) 5/11/10 @ 04:54

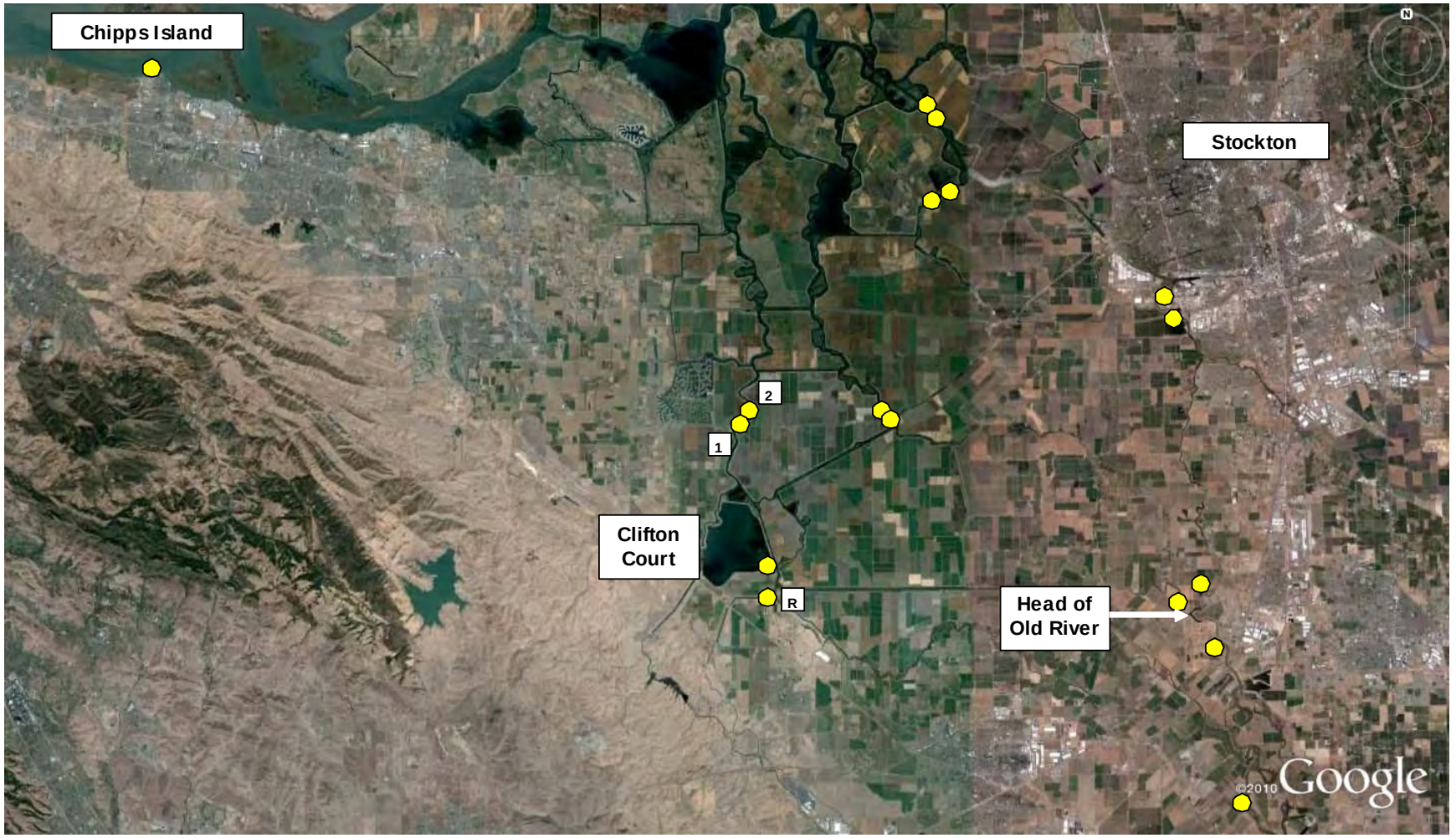
Appendix Figure 17. Movements of acoustic-tagged striped bass No. 2836.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2640.07. Released at 15:50 on 5/5/10

1) 5/24/10 @ 18:18
2) 5/24/10 @ 18:32
3) 5/24/10 @ 19:23
4) 5/24/10 @ 19:39
5) 6/9/10 @ 19:39

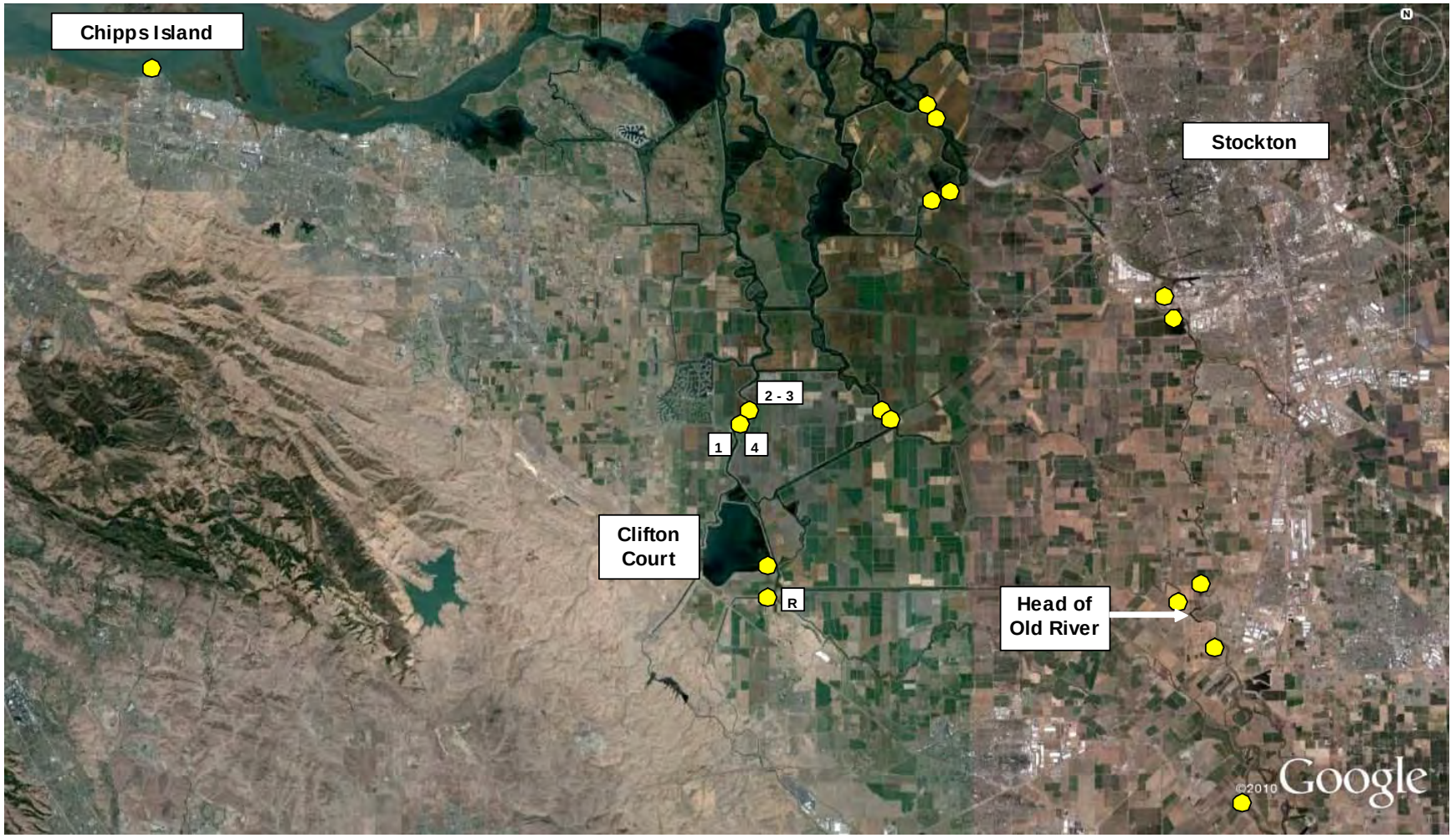
Appendix Figure 18. Movements of acoustic-tagged striped bass No. 2640.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2766.07. Released at 12:30 on 5/5/10

1) 5/6/10 @ 16:32
2) 5/6/10 @ 16:45

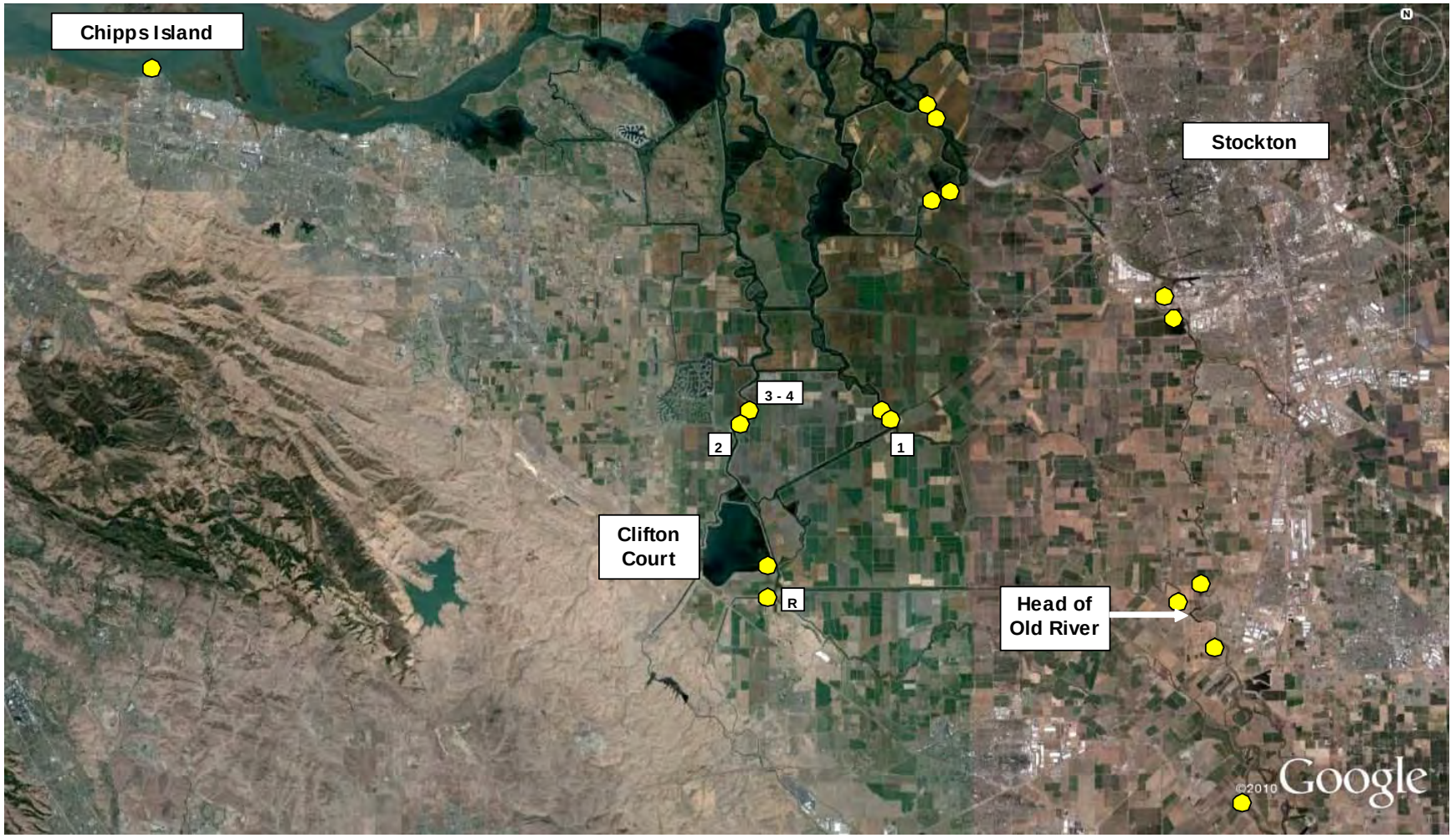
Appendix Figure 19. Movements of acoustic-tagged striped bass No. 2766.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2822.07. Released at 12:30 on 5/5/10

1) 5/31/10 @ 00:54
2) 5/31/10 @ 01:22
3) 5/31/10 @ 01:50 - 5/31/10 @ 03:08
4) 5/31/10 @ 03:06

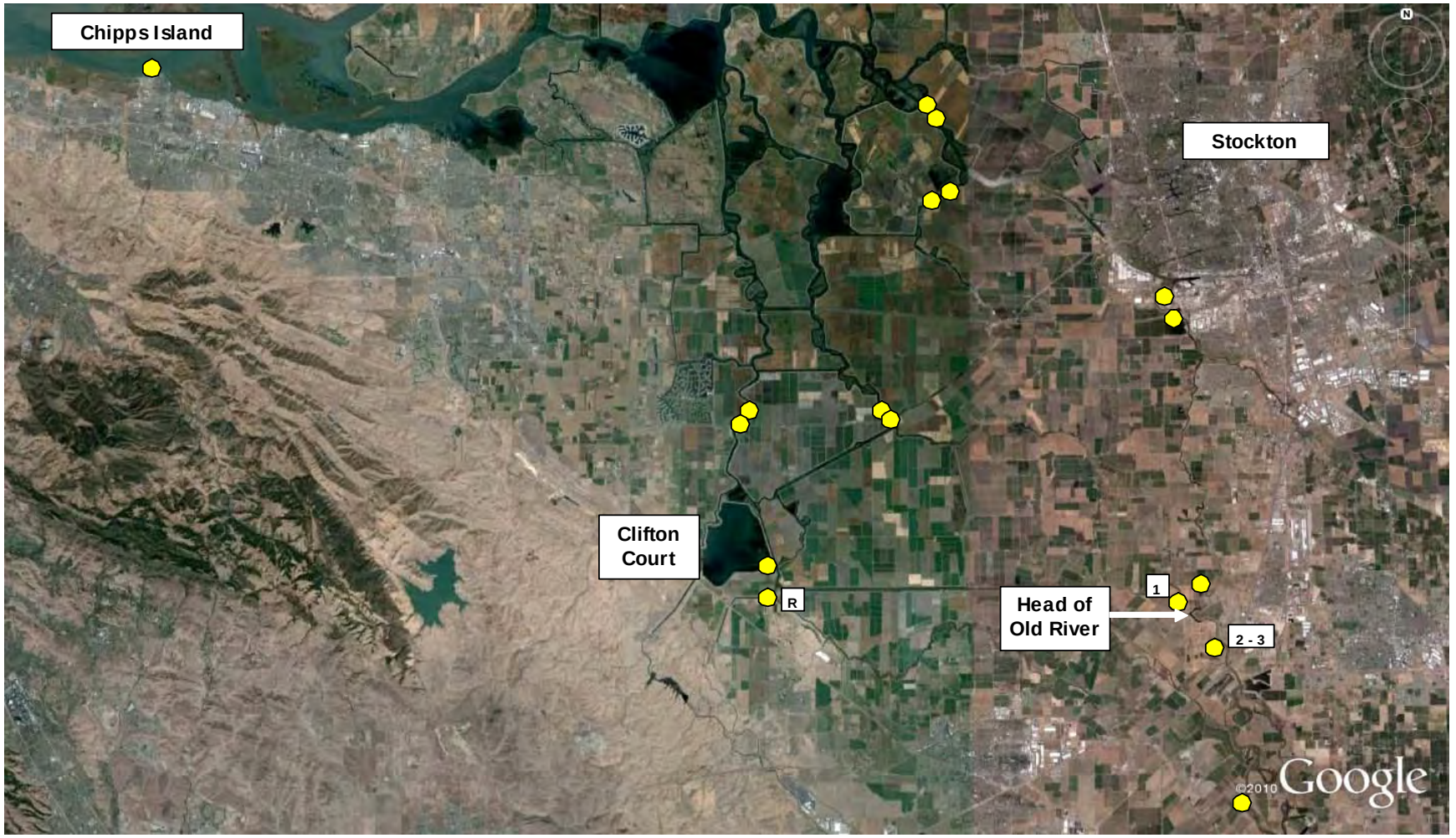
Appendix Figure 20. Movements of acoustic-tagged striped bass No. 2822.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2724.07. Released at 15:00 on 5/5/10

1) 5/27/10 @ 07:21 - 5/27/10 @ 08:01
2) 5/30/10 @ 06:32
3) 5/30/10 @ 06:53
4) 6/6/10 @ 22:02

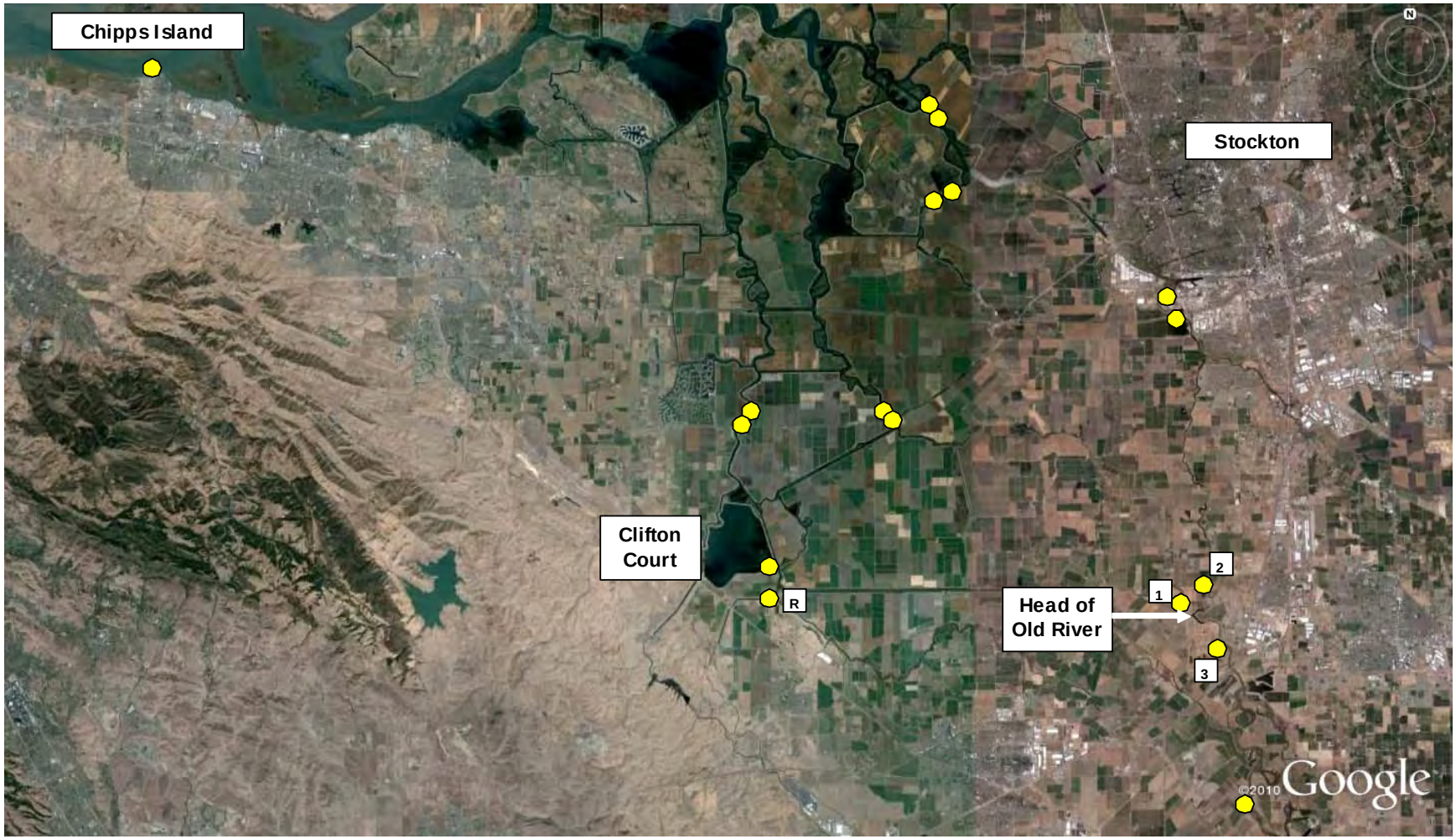
Appendix Figure 21. Movements of acoustic-tagged striped bass No. 2724.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2850.07. Released at 14:15 on 5/5/10

1) 5/31/10 @ 01:33
2) 6/1/10 @ 09:53 - 6/1/10 @ 10:26
3) 6/11/10 @ 16:18

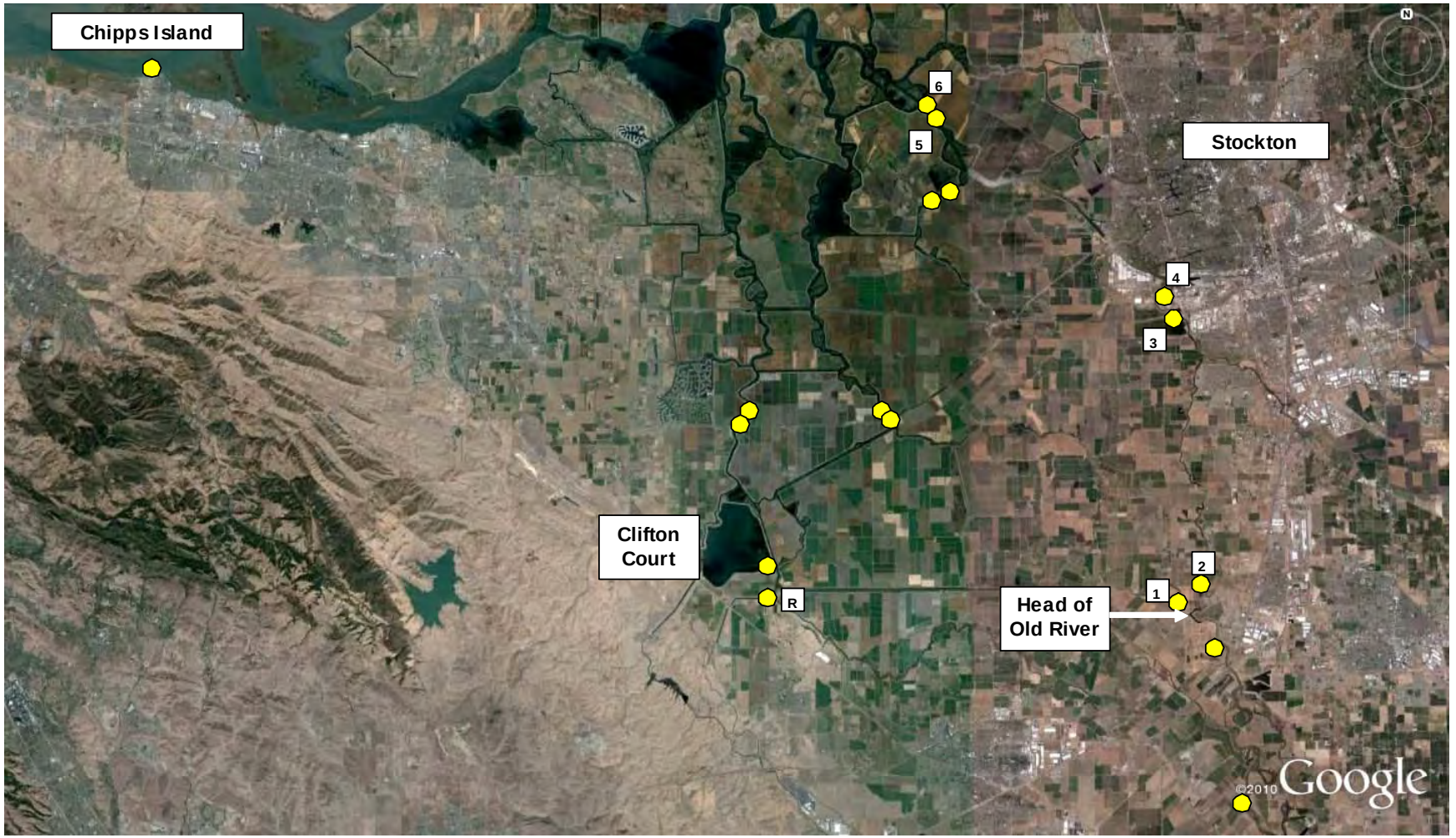
Appendix Figure 22. Movements of acoustic-tagged striped bass No. 2850.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2976.07. Released at 13:20 on 5/5/10

1) 5/22/10 @ 10:38
2) 5/22/10 @ 15:44
3) 5/24/10 @ 08:14

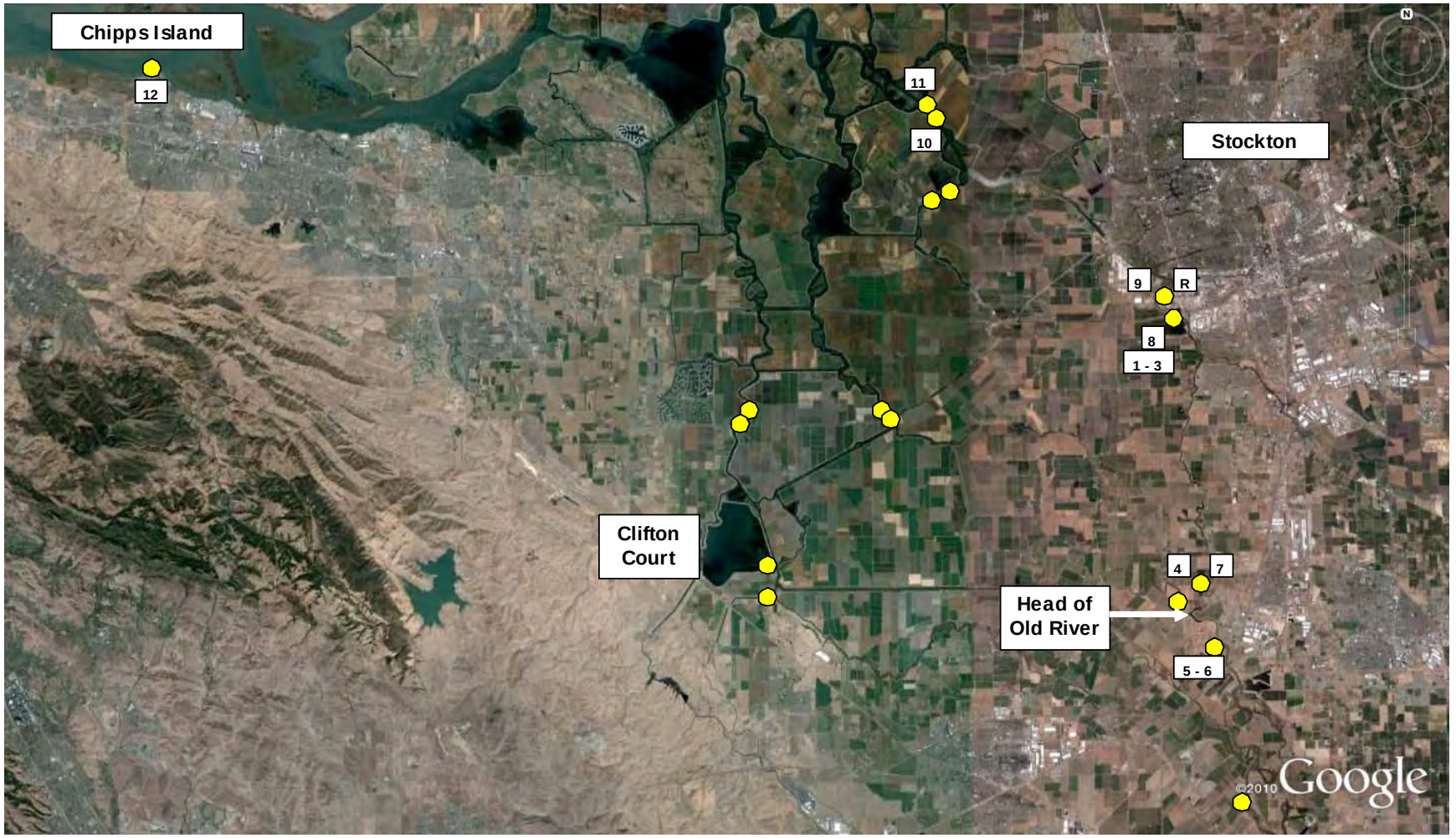
Appendix Figure 23. Movements of acoustic-tagged striped bass No. 2976.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2948.07. Released at 15:00 on 5/5/10

1) 6/10/10 @ 15:37
2) 6/10/10 @ 22:15
3) 6/11/10 @ 13:05
4) 6/11/10 @ 17:06 - 6/11/10 @ 19:07
5) 6/12/10 @ 13:58
6) 6/12/10 @ 14:21

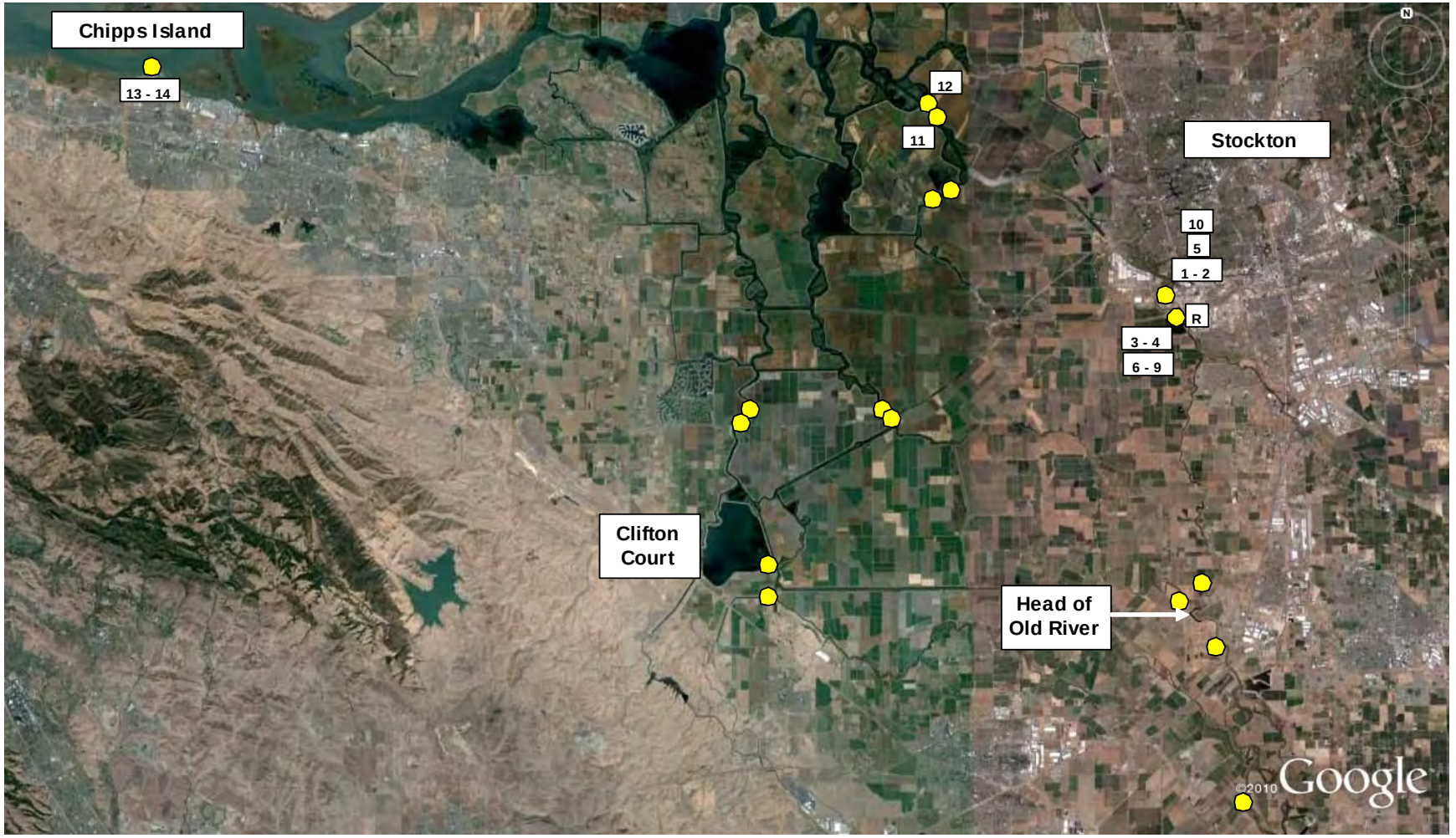
Appendix Figure 24. Movements of acoustic-tagged striped bass No. 2948.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2570.07. Released at 17:20 on 5/8/10

1) 5/20/10 @ 12:48	5) 5/26/10 @ 08:26	9) 6/4/10 @ 09:47
2) 5/20/10 @ 14:16	6) 6/2/10 @ 23:14	10) 6/7/10 @ 08:37
3) 5/21/10 @ 06:30	7) 6/3/10 @ 04:18	11) 6/7/10 @ 09:13
4) 5/25/10 @ 04:20	8) 6/3/10 @ 16:13	12) 6/9/10 @ 04:25

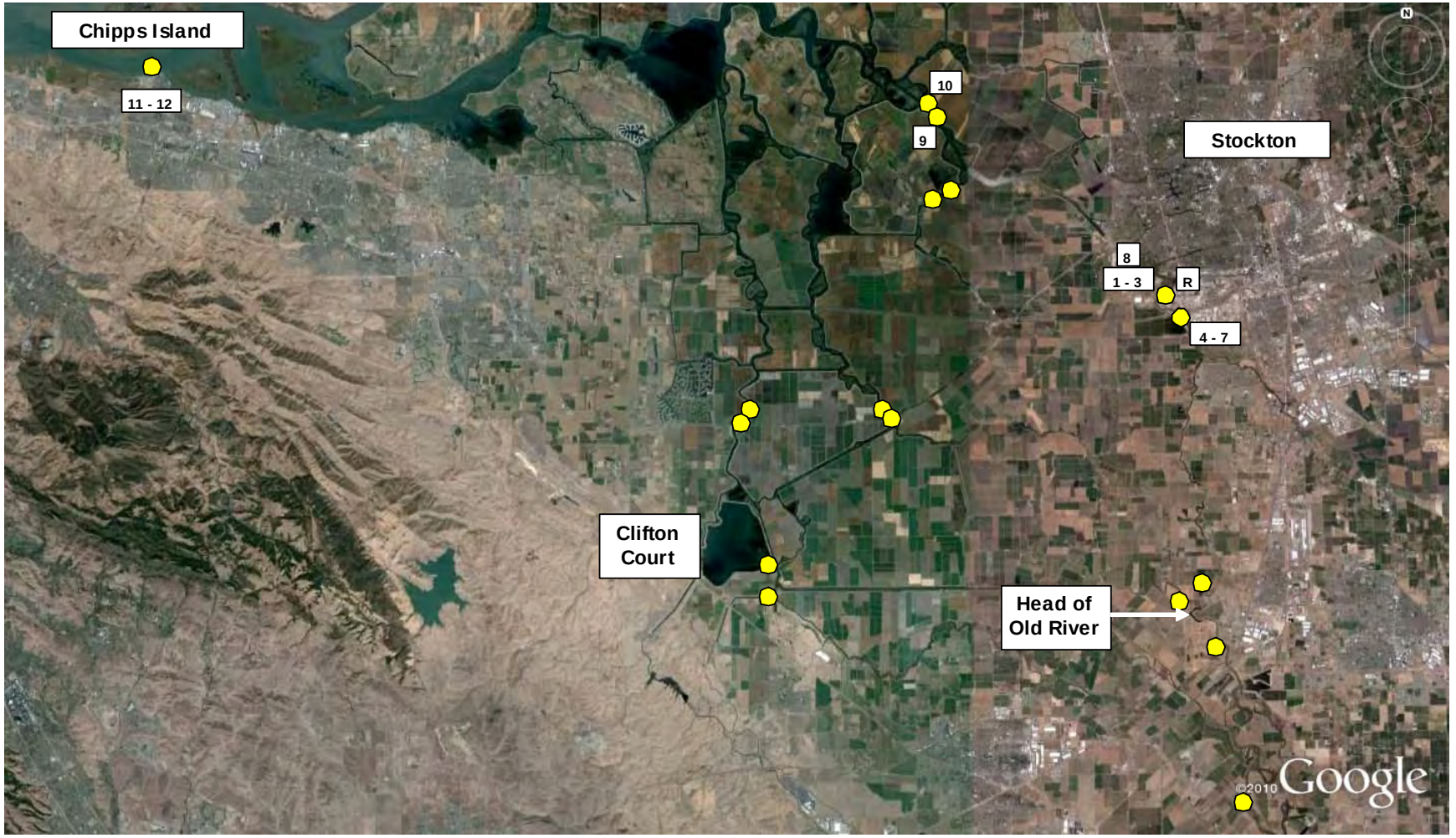
Appendix Figure 25. Movements of acoustic-tagged striped bass No. 2570.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2542.07. Released at 16:10 on 5/8/10

1) 5/9/10 @ 21:17
2) 5/11/10 @17:37
3) 5/12/10 @ 15:25
4) 5/12/10 @ 18:53 - 5/12/10 @ 19:08
5) 5/13/10 @ 22:40 - 5/14/01 @ 02:01
6) 5/14/10 @ 18:41
7) 5/14/10 @ 21:49
8) 5/18/10 @ 07:59
9) 5/19/10 @ 18:29
10) 5/20/10 @ 06:19
11) 5/22/10 @ 06:40
12) 5/22/10 @ 07:14
13) 5/29/10 @ 08:58
14) 6/10/10 @ 23:05

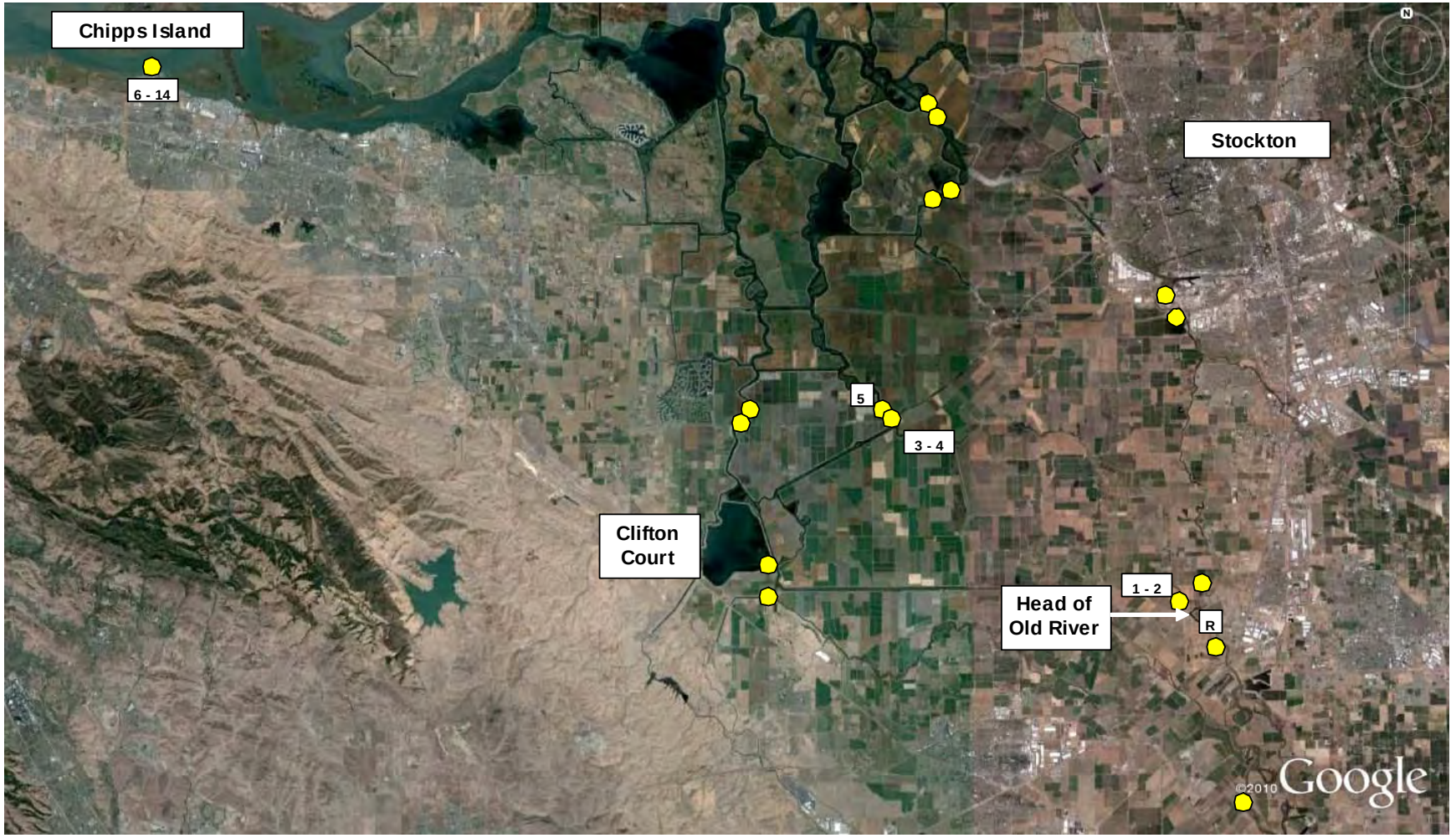
Appendix Figure 26. Movements of acoustic-tagged striped bass No. 2542.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2416.07. Released at 18:20 on 5/26/10

1) 5/26/10 @ 18:54
2) 5/26/10 @ 20:30
3) 5/29/10 @ 07:00
4) 5/30/10 @ 03:46
5) 6/4/10 @ 21:45
6) 6/8/10 @ 01:24
7) 6/8/10 @ 05:21
8) 6/8/10 @ 09:11
9) 6/9/10 @ 10:02
10) 6/9/10 @ 10:23
11) 6/11/10 @ 20:20 - 6/11/10 @ 23:40
12) 6/12/10 @ 01:43 - 6/12/10 @ 04:32

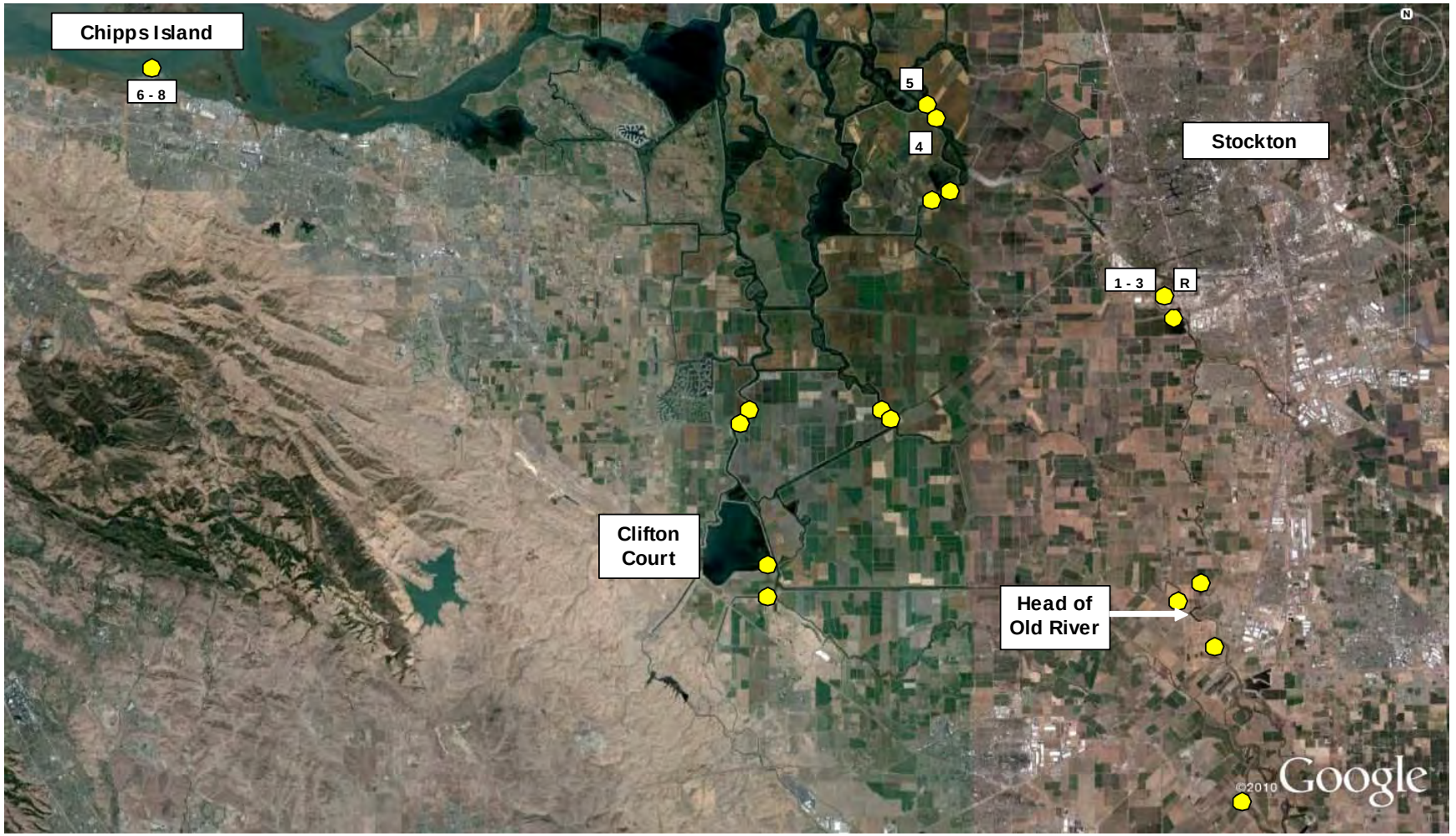
Appendix Figure 27. Movements of acoustic-tagged striped bass No. 2416.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2150.07. Released at 15:30 on 4/16/10

1) 5/7/10 @ 06:43
2) 5/7/10 @ 08:54
3) 5/16/10 @ 06:18
4) 5/16/10 @ 09:42
5) 5/16/10 @ 09:55
6) 5/21/10 @ 14:47
7) 5/31/10 @ 02:34
8) 5/31/10 @ 09:12
9) 6/1/10 @ 03:31
10) 6/1/10 @ 09:51
11) 6/2/10 @ 04:06
12) 6/2/10 @ 12:09
13) 6/3/10 @ 17:28
14) 6/8/10 @ 06:54

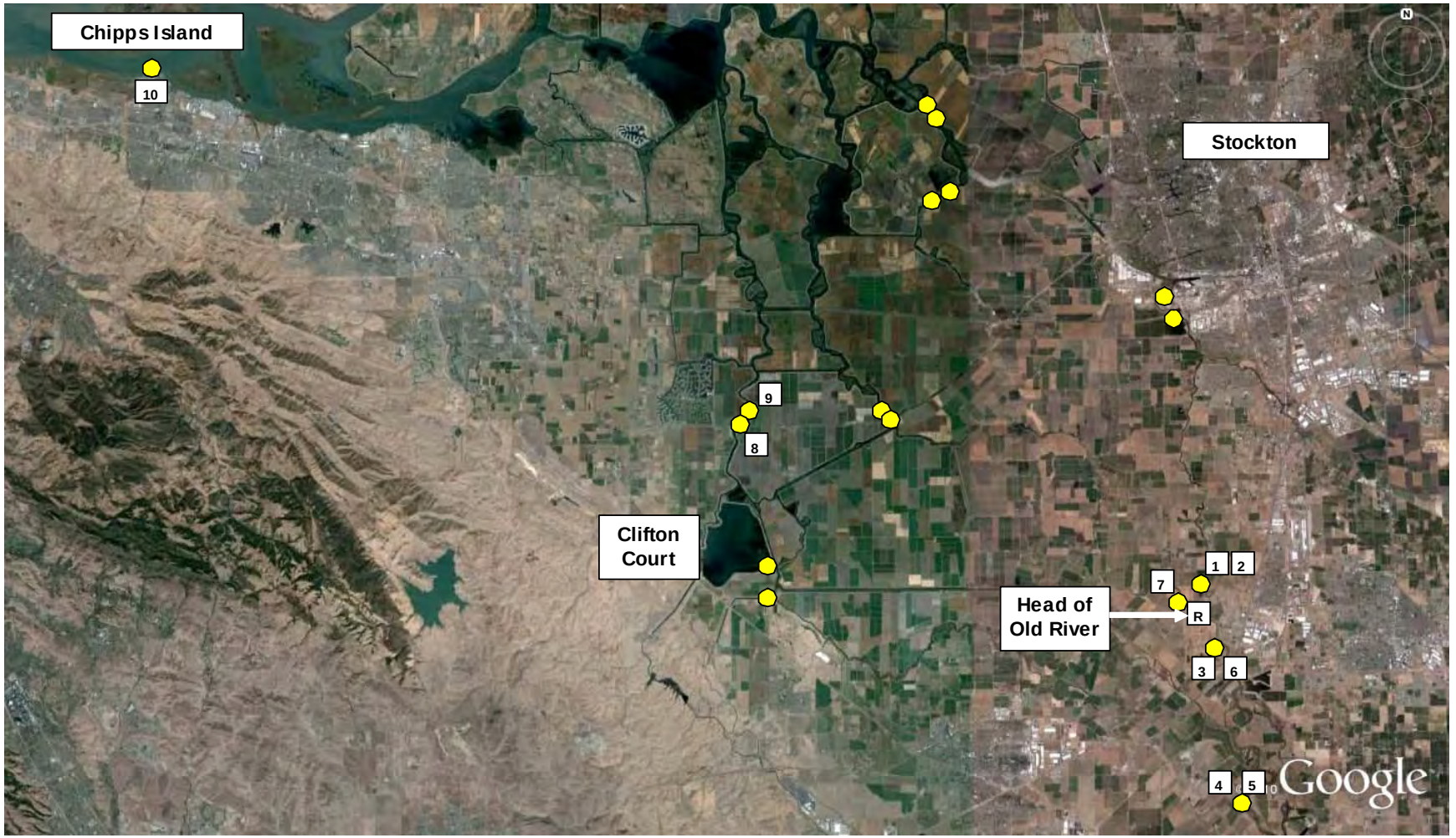
Appendix Figure 28. Movements of acoustic-tagged striped bass No. 2150.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2584.07. Released at 12:53 on 5/24/10

1) 5/24/10 @ 13:10
2) 5/27/10 @ 05:58 - 5/27/10 @ 06:24
3) 5/27/10 @ 15:39 - 5/27/10 @ 19:31
4) 5/30/10 @ 12:31
5) 5/30/10 @ 12:57
6) 6/1/10 @ 13:29
7) 6/10/10 @ 01:08 - 6/10/10 @ 02:45
8) 6/14/10 @ 01:25

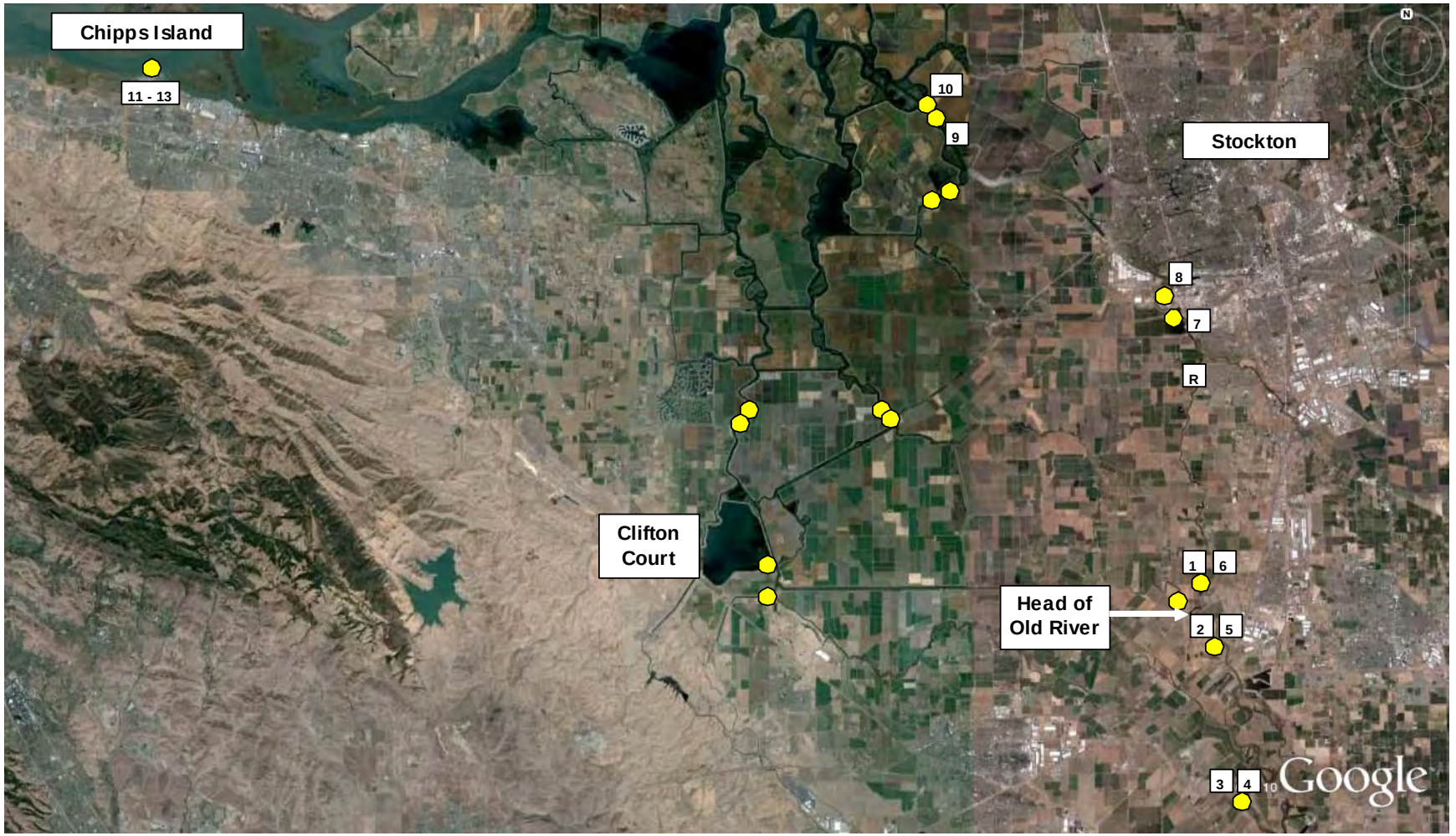
Appendix Figure 29. Movements of acoustic-tagged striped bass No. 2584.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2472.07. Released at 08:55 on 5/16/10

1) 5/16/10 @ 21:06
2) 5/17/10 @ 02:42
3) 5/17/10 @ 09:48
4) 5/18/10 @ 02:02
5) 5/18/10 @ 11:19
6) 5/18/10 @ 15:13
7) 5/18/10 @ 19:55
8) 5/19/10 @ 16:05
9) 5/19/10 @ 16:15
10) 5/21/10 @ 03:36

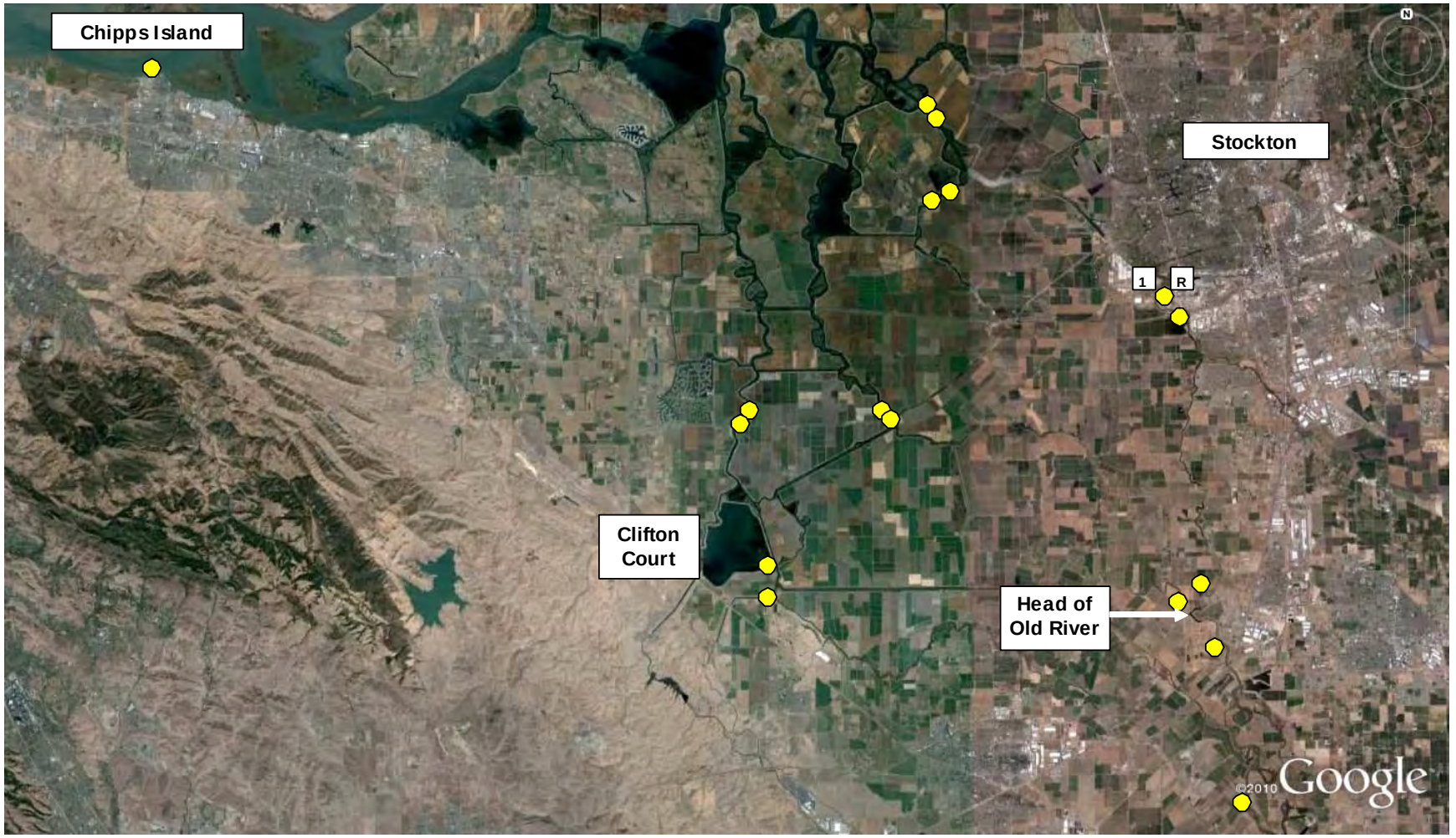
Appendix Figure 30. Movements of acoustic-tagged striped bass No. 2472.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2024.07. Released at 13:09 on 4/4/10

1) 4/28/10 @ 01:21
2) 4/28/10 @ 09:08
3) 5/1/10 @ 11:47 - 5/2/10 @ 06:12
4) 5/7/10 @ 14:57
5) 5/7/10 @ 17:54
6) 5/7/10 @ 20:16
7) 5/8/10 @ 03:46
8) 5/8/10 @ 05:07
9) 5/10/10 @ 22:08
10) 5/10/10 @ 22:34
11) 5/12/10 @ 05:01
12) 5/26/10 @ 00:26
13) 5/26/10 @ 03:44

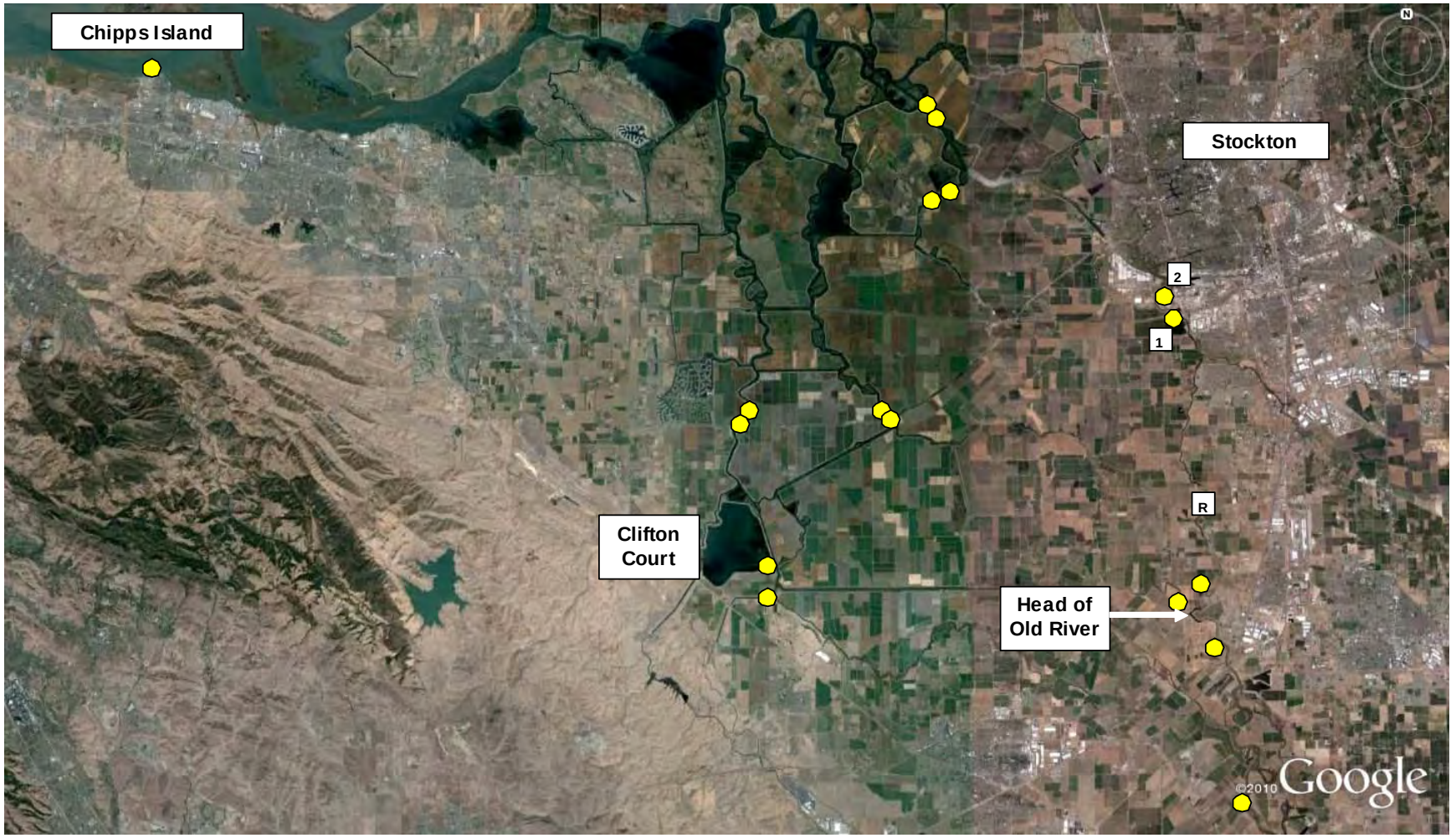
Appendix Figure 31. Movements of acoustic-tagged striped bass No. 2024.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2612.07. Released at 19:10 on 5/26/10

1) 5/26/10 @ 19:30 - 5/26/10 @ 20:16

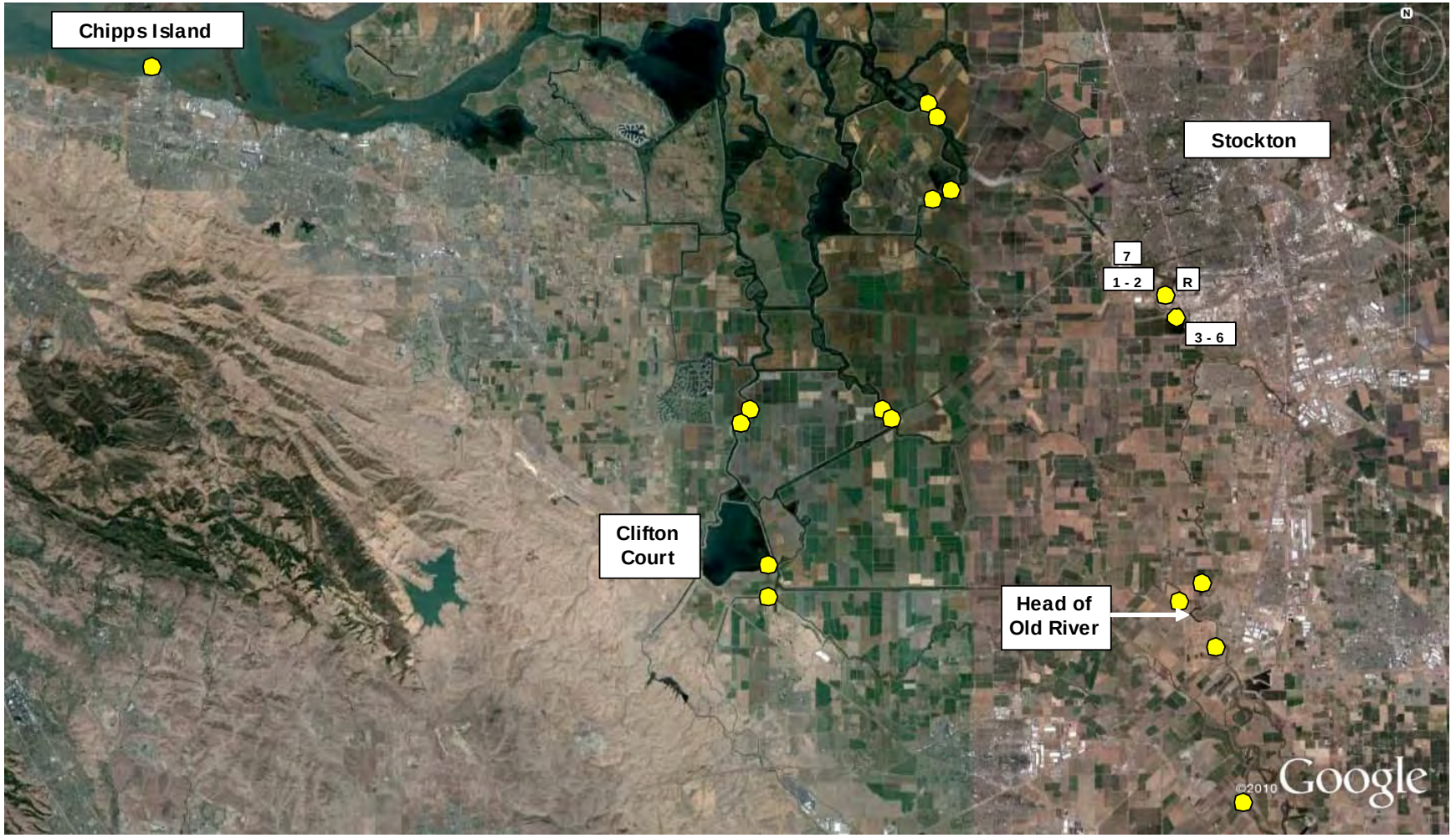
Appendix Figure 32. Movements of acoustic-tagged striped bass No. 2612.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 3214.07. Released at 12:10 on 6/2/10

1) 6/3/10 @ 11:44
2) 6/4/10 @ 03:40

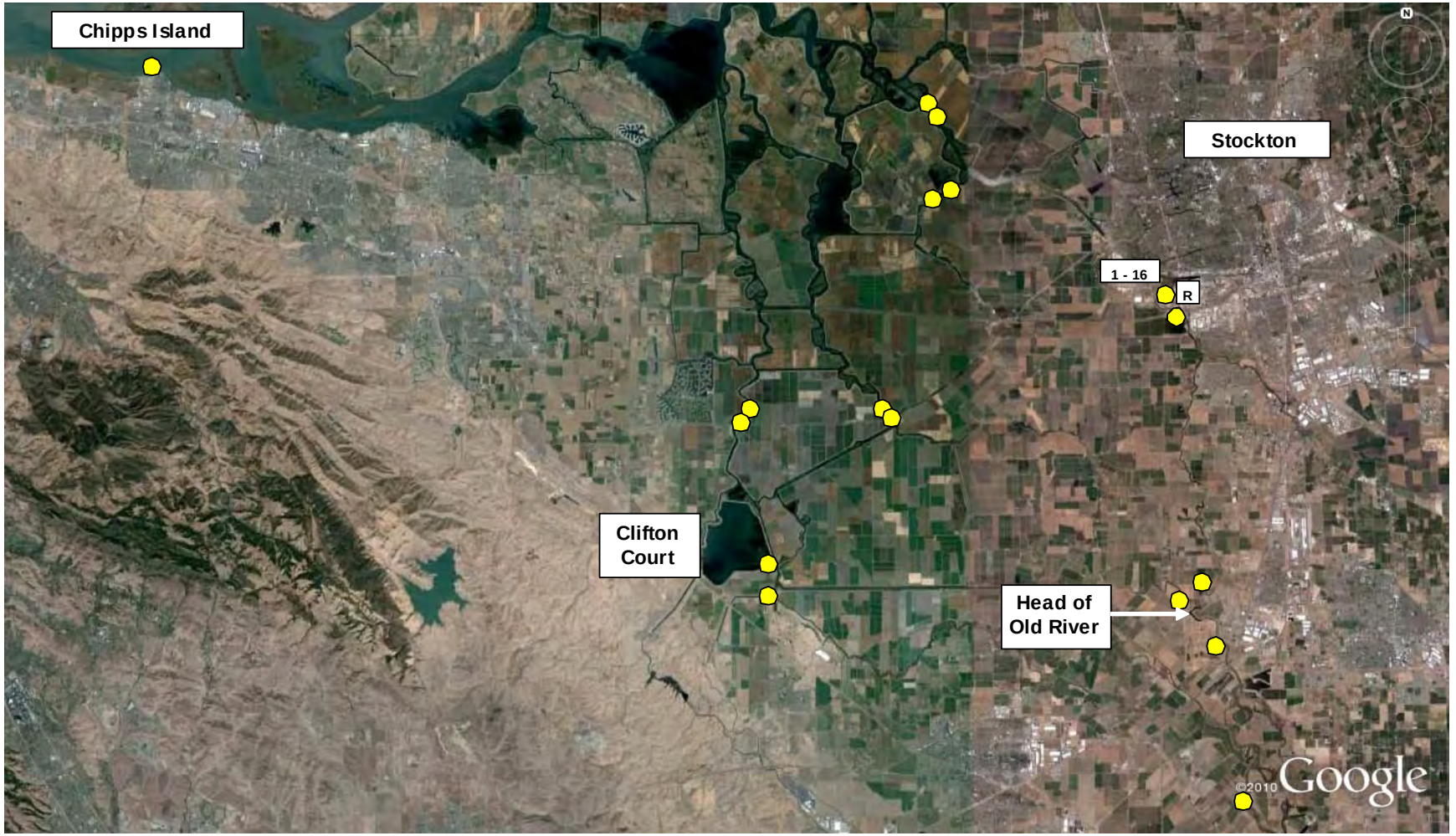
Appendix Figure 33. Movements of acoustic-tagged striped bass No. 3214.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2430.07. Released at 17:20 on 5/26/10

1) 5/26/10 @ 18:35
2) 5/27/10 @ 19:00
3) 5/28/10 @ 06:05
4) 5/28/10 @ 07:49
5) 5/28/10 @ 17:48
6) 5/29/10 @ 08:29
7) 5/29/10 @ 10:46

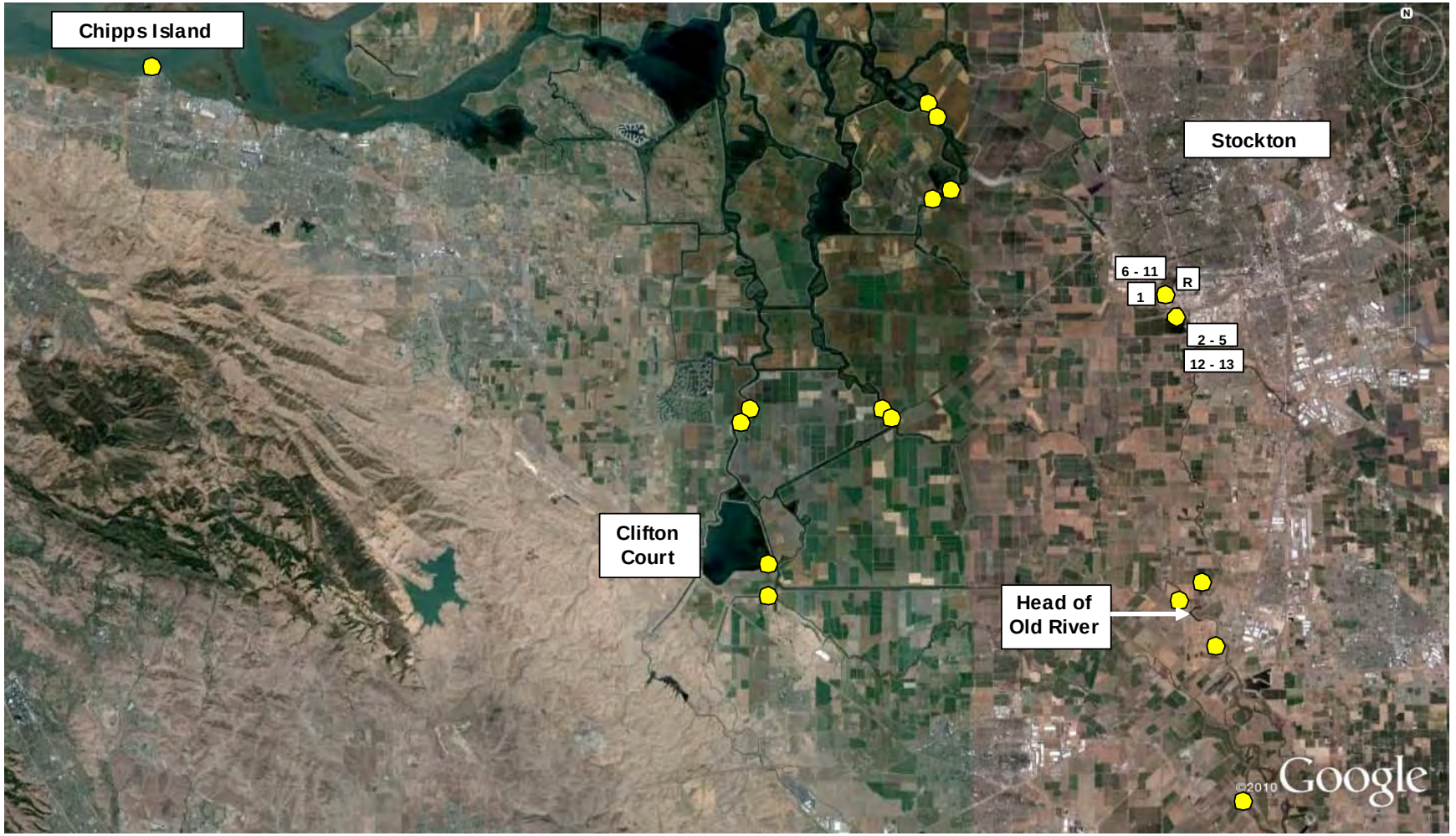
Appendix Figure 34. Movements of acoustic-tagged striped bass No. 2430.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2444.07. Released at 09:51 on 5/28/10

1) 6/2/10 @ 00:18
2) 6/2/10 @ 21:58 - 6/2/10 @ 23:12
3) 6/3/10 @ 02:00
4) 6/4/10 @ 05:00 - 6/4/10 @ 02:22
5) 6/5/10 @ 01:11 - 6/5/10 @ 02:11
6) 6/5/10 @ 21:26
7) 6/6/10 @ 00:12
8) 6/6/10 @ 01:33 - 6/6/10 @ 02:27
9) 6/6/10 @ 21:48 - 6/7/10 @ 03:11
10) 6/7/10 @ 22:41 - 6/8/10 @ 04:15
11) 6/10/10 @ 02:57
12) 6/10/10 @ 19:50
13) 6/11/10 @ 00:26 - 6/11/10 @ 05:01
14) 6/11/10 @ 16:21 - 6/11/10 @ 19:05
15) 6/12/10 @ 00:48 - 6/12/10 @ 01:18
16) 6/12/10 @18:42 - 6/12/10 @ 21:10

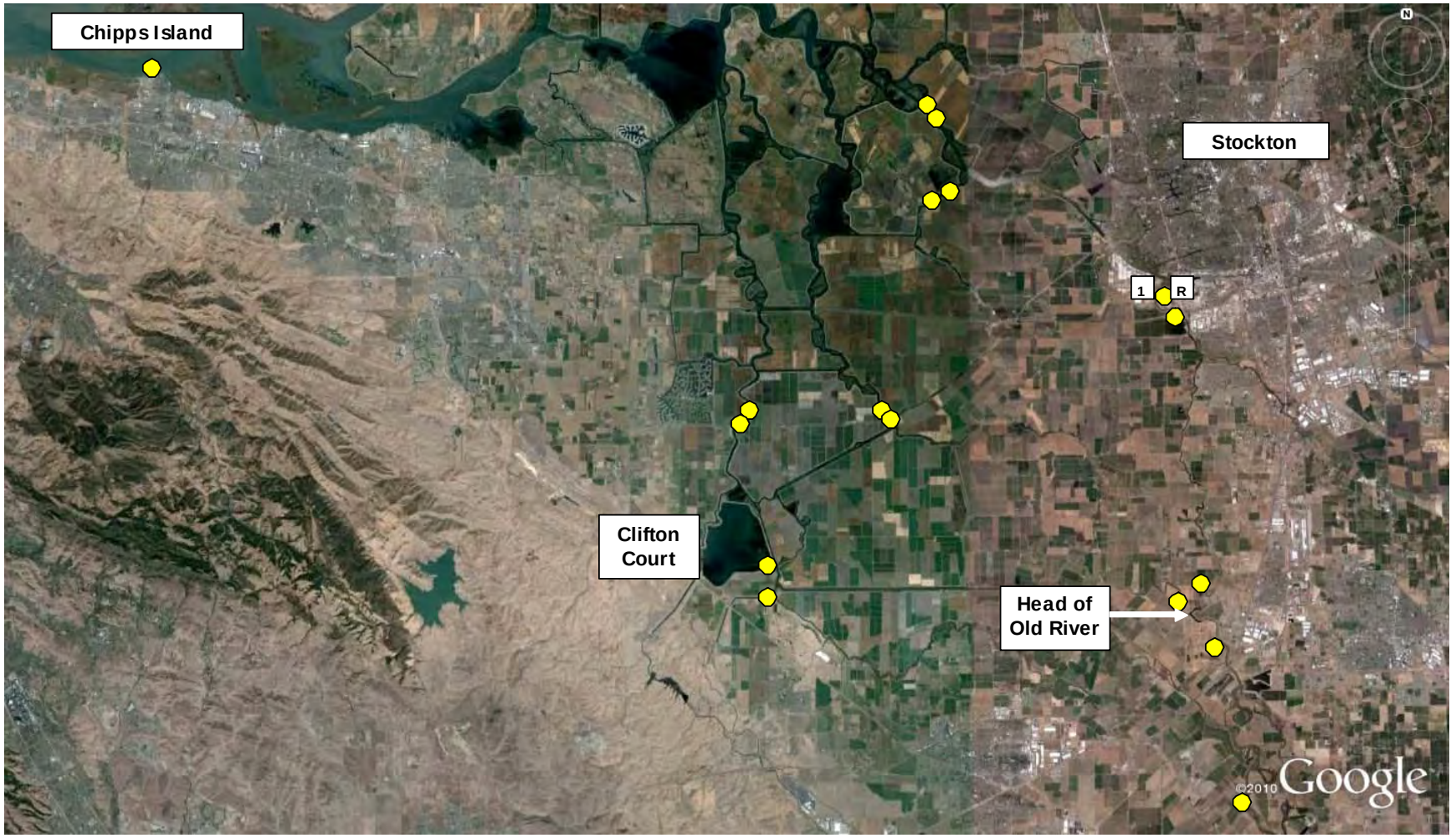
Appendix Figure 35. Movements of acoustic-tagged striped bass No. 2444.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2458.07. Released at 13:15 on 5/24/10

1) 5/26/10 @ 04:45
2) 5/26/10 @ 10:28
3) 5/26/10 @ 22:11
4) 5/27/10 @ 06:08
5) 5/29/10 @ 09:21
6) 5/29/10 @ 12:56
7) 6/10/10 @ 05:36
8) 6/10/10 @ 21:47
9) 6/10/10 @ 23:57 - 6/11/10 @ 00:15
10) 6/11/10 @ 06:54
11) 6/12/10 @ 02:29 -06/12/10 @ 03:27
12) 6/13/10 @ 02:30
13) 6/13/10 @ 12:31 - 6/13/10 @ 13:45

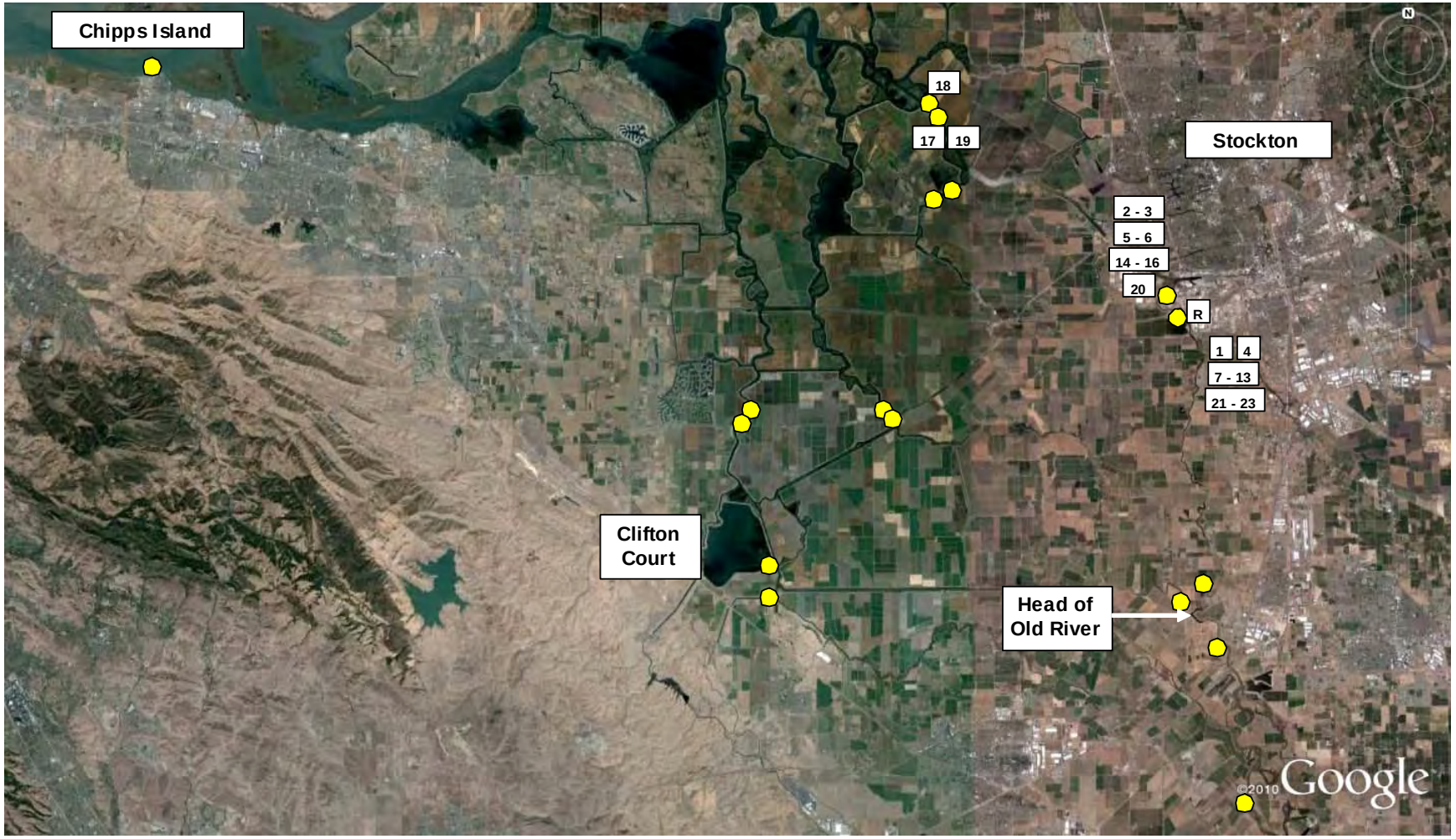
Appendix Figure 36. Movements of acoustic-tagged striped bass No. 2458.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2500.07. Released at 13:50 on 5/24/10

1) 5/24/10 @ 13:54

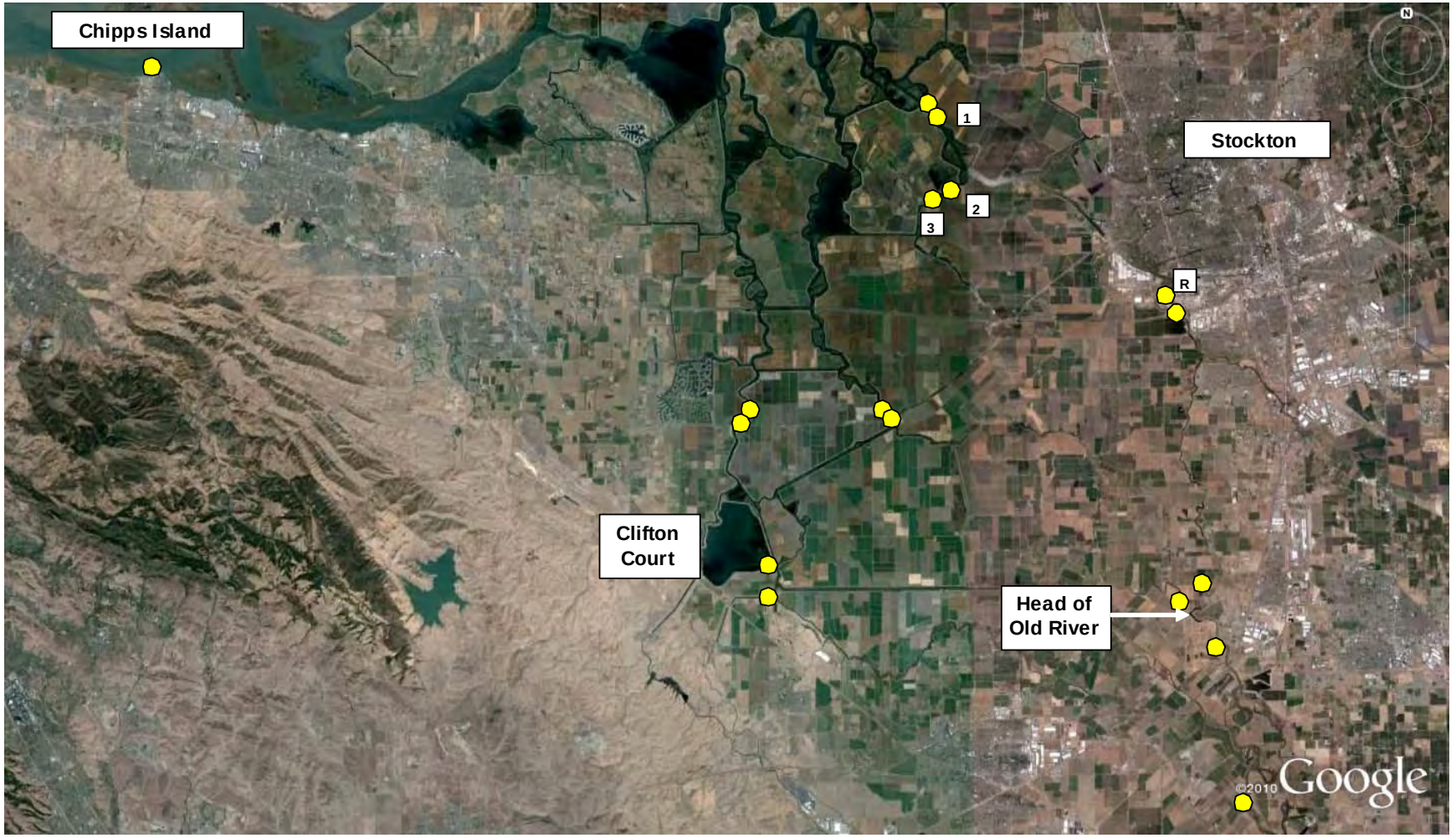
Appendix Figure 37. Movements of acoustic-tagged striped bass No. 2500.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2402.07. Released at 14:15 on 5/11/10

1) 5/11/10 @ 14:23
2) 5/11/10 @ 23:13
3) 5/13/10 @ 11:17
4) 5/14/10 @ 07:17
5) 5/14/10 @ 20:59
6) 5/20/10 @ 12:01
7) 5/28/10 @ 07:07
8) 5/29/10 @ 06:37
9) 5/31/10 @ 07:33 - 5/31/10 @ 08:35
10) 6/1/10 @ 06:47 - 6/1/10 @ 07:50
11) 6/3/10 @ 07:34
12) 6/4/10 @ 12:48
13) 6/4/10 @ 19:09
14) 6/5/10 @ 12:12
15) 6/7/10 @ 19:58
16) 6/9/10 @ 04:22
17) 6/10/10 @ 13:45 - 6/10/10 @ 14:20
18) 6/10/10 @ 15:20
19) 6/10/10 @ 15:58
20) 6/12/10 @ 16:53
21) 6/13/10 @ 05:12
22) 6/13/10 @ 07:05
23) 6/14/10 @ 00:01

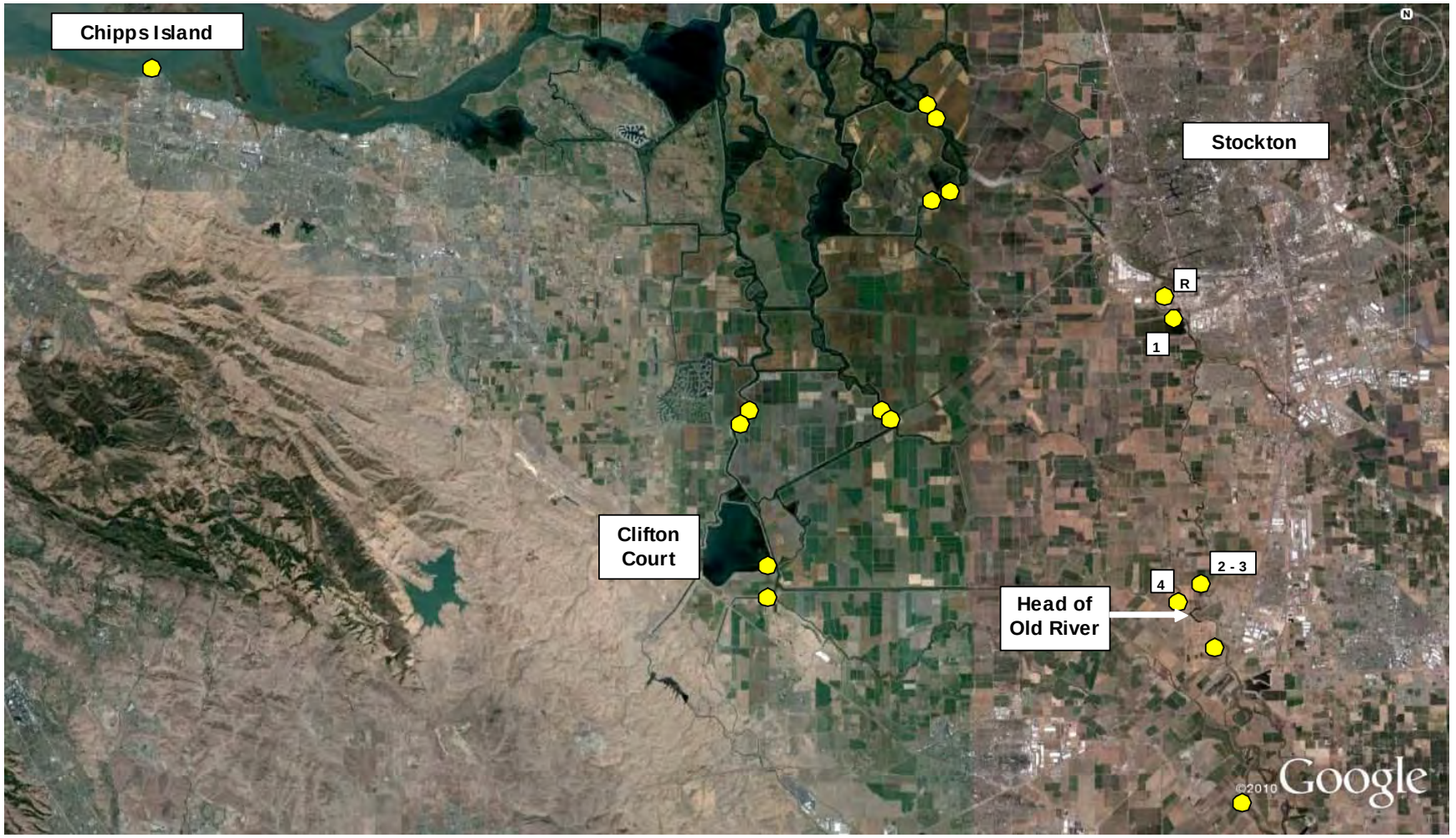
Appendix Figure 38. Movements of acoustic-tagged striped bass No. 2402.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2528.07. Released at 12:00 on 5/28/10

1) 6/8/10 @ 11:36 - 6/8/10 @ 12:07
2) 6/9/10 @ 08:53
3) 6/9/10 @ 09:18

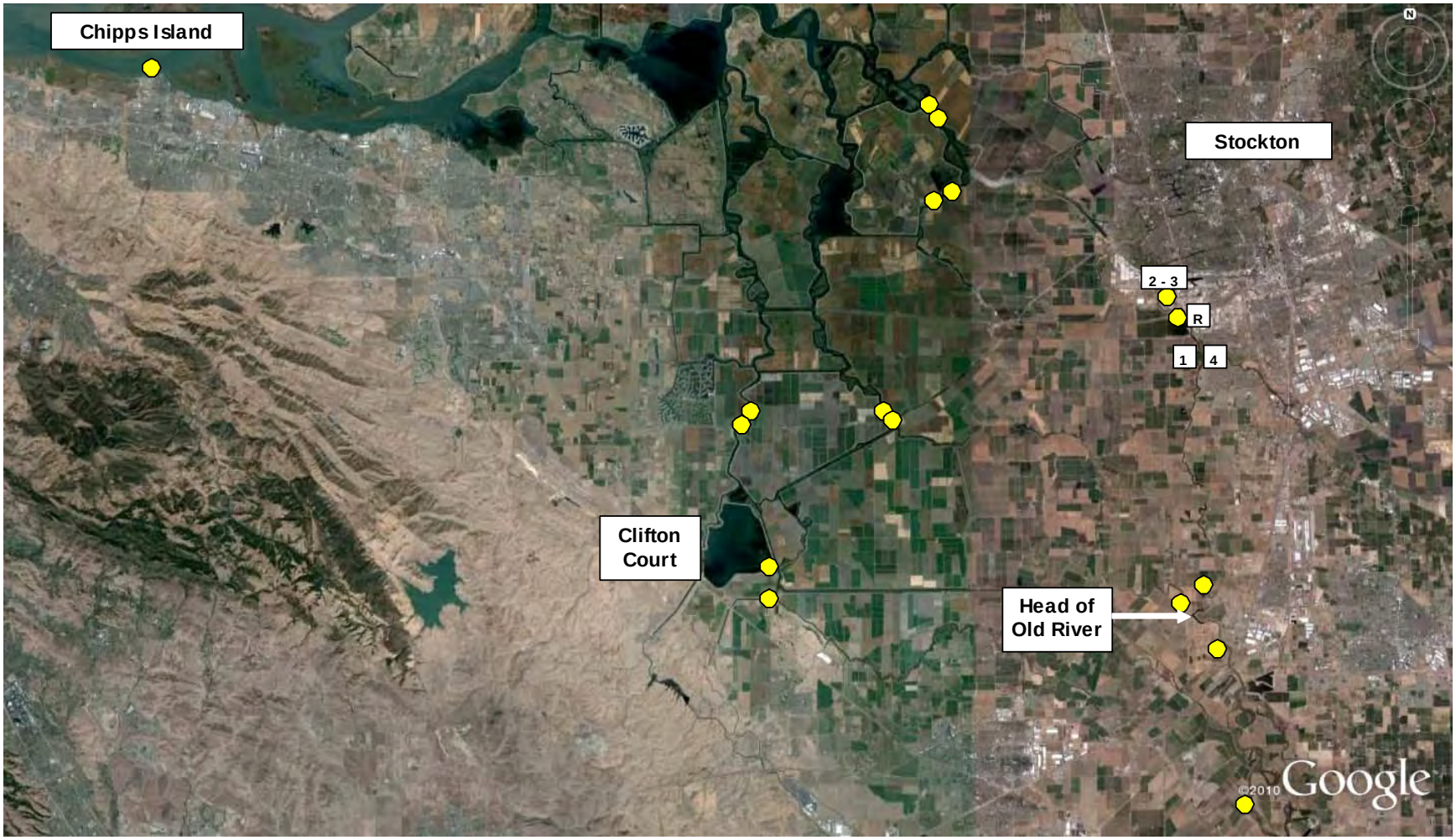
Appendix Figure 39. Movements of acoustic-tagged striped bass No. 2528.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Striped Bass 2626.07. Released at 18:40 on 5/26/10

1) 5/31/10 @ 13:55
2) 6/2/10 @ 14:59 - 6/3/10 @ 02:01
3) 6/10/10 @ 20:50 - 6/10/10 @ 23:02
4) 6/11/10 @ 05:03

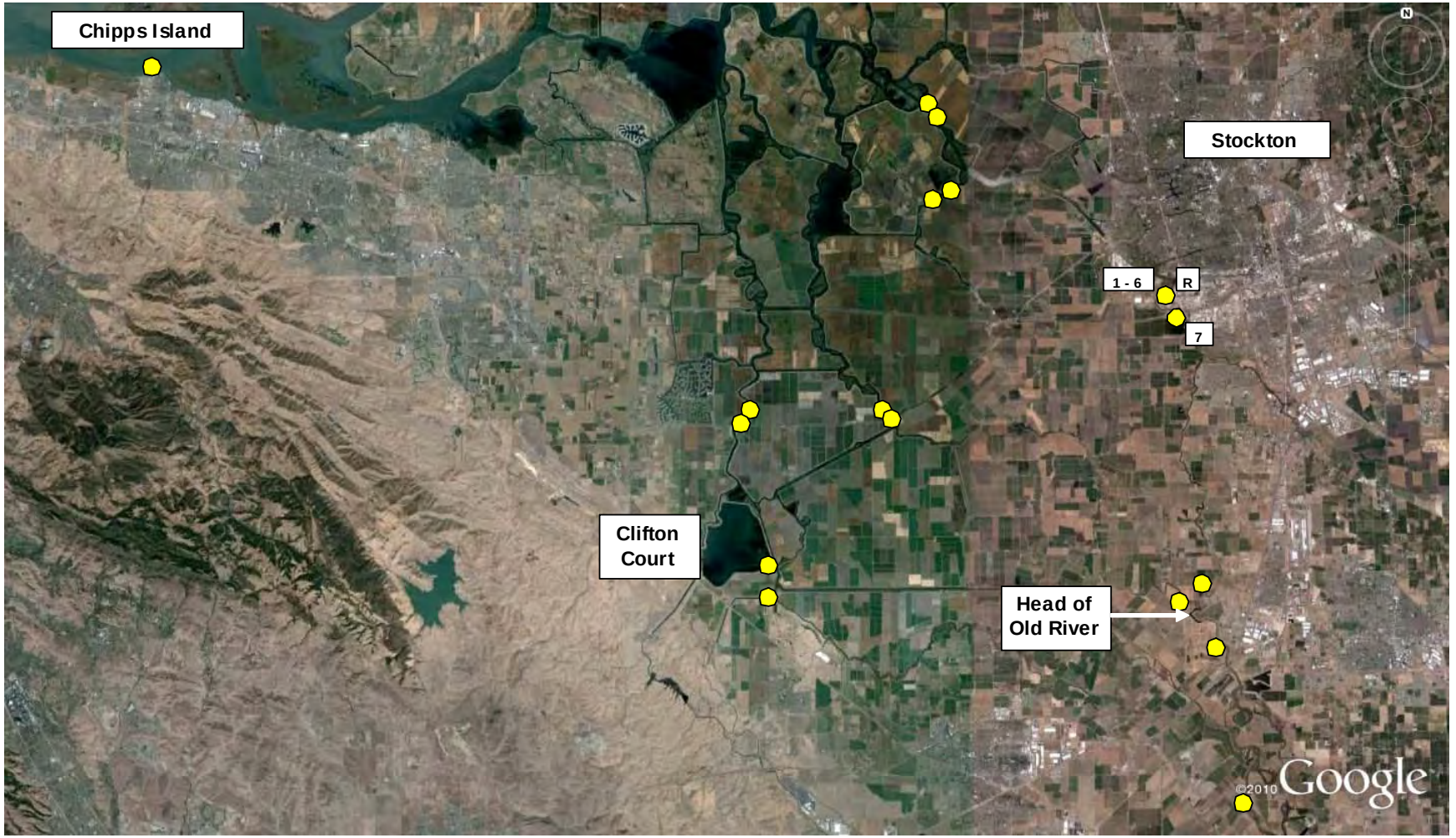
Appendix Figure 40. Movements of acoustic-tagged striped bass No. 2626.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Largemouth Bass 2010.07. Released at 12:55 on 5/3/10

1) 5/11/10 @ 17:14
2) 5/17/10 @ 18:05
3) 6/12/10 @ 14:27
4) 6/12/10 @ 19:54 - 6/12/10 @ 20:01

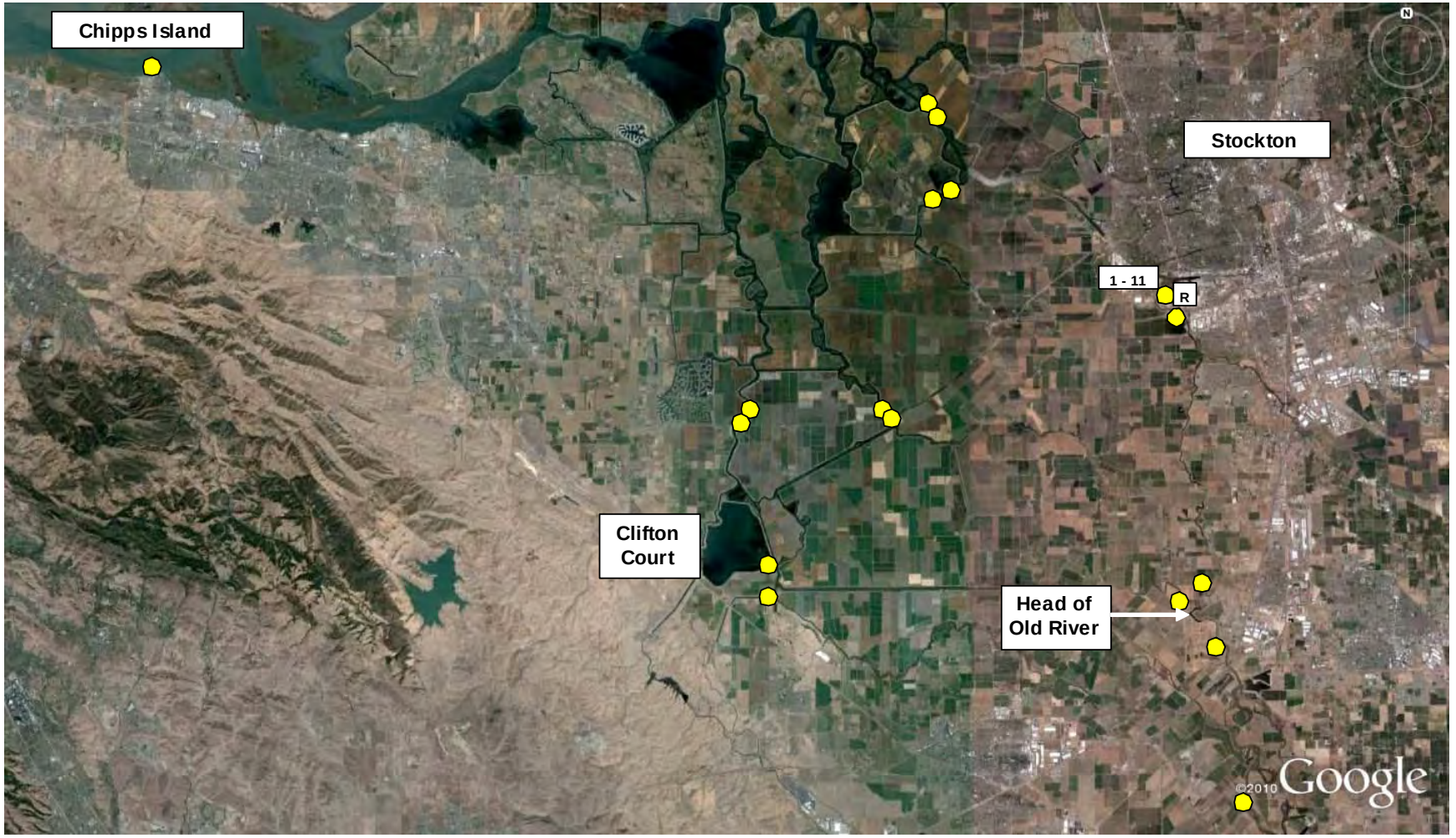
Appendix Figure 41. Movements of acoustic-tagged largemouth bass No. 2010.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Largemouth Bass 2514.07. Released at 15:00 on 5/8/10

1) 5/15/10 @ 20:39
2) 5/15/10 @ 22:34
3) 5/16/10 @ 03:27 - 5/16/10 @ 04:33
4) 5/16/10 @ 06:31 - 5/16/10 @ 08:42
5) 5/16/10 @ 12:08
6) 5/17/10 @ 08:15
7) 6/7/10 @ 17:30

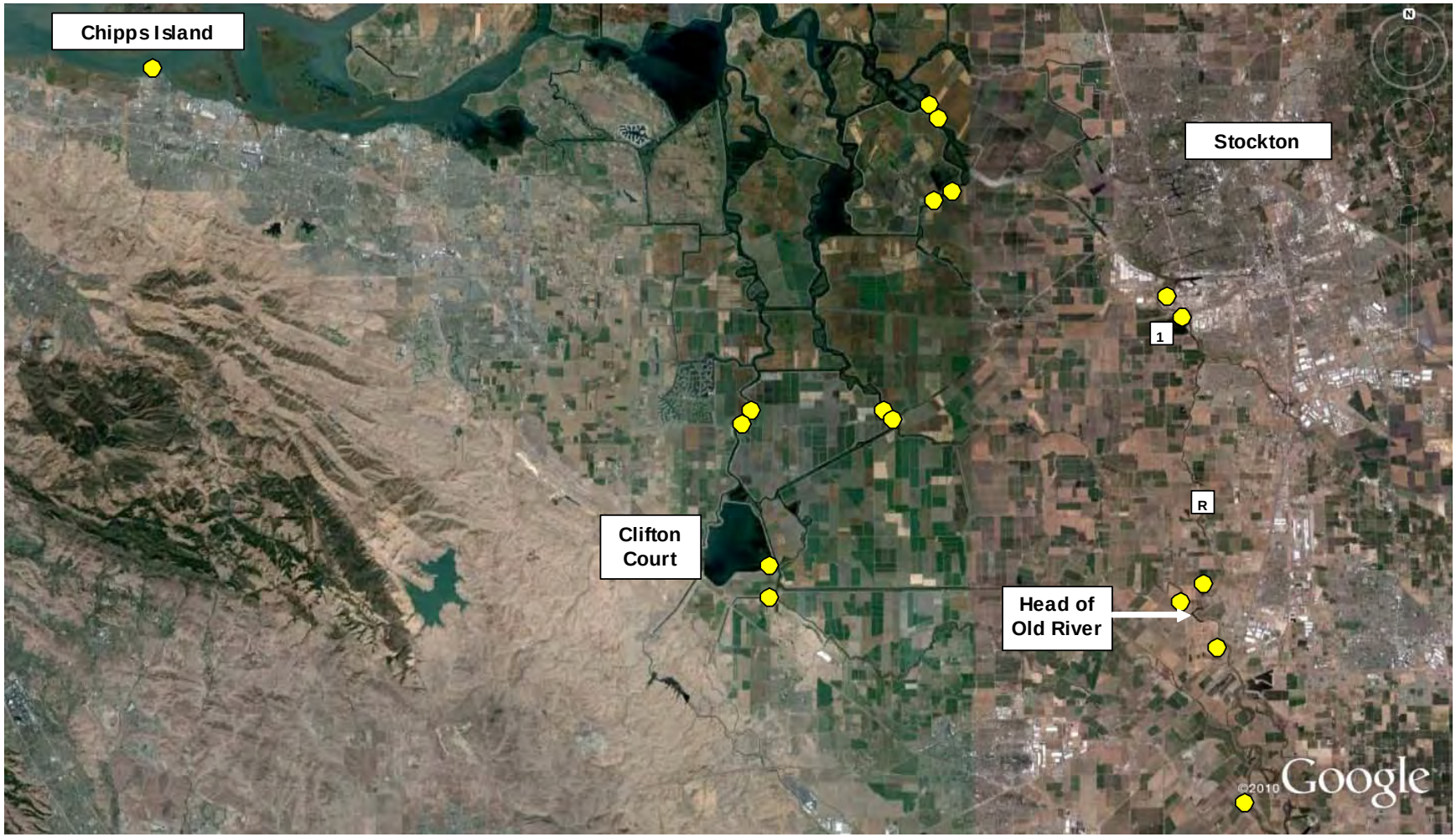
Appendix Figure 42. Movements of acoustic-tagged largemouth bass No. 2514.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Largemouth Bass 2388.07. Released at 11:50 on 5/24/10

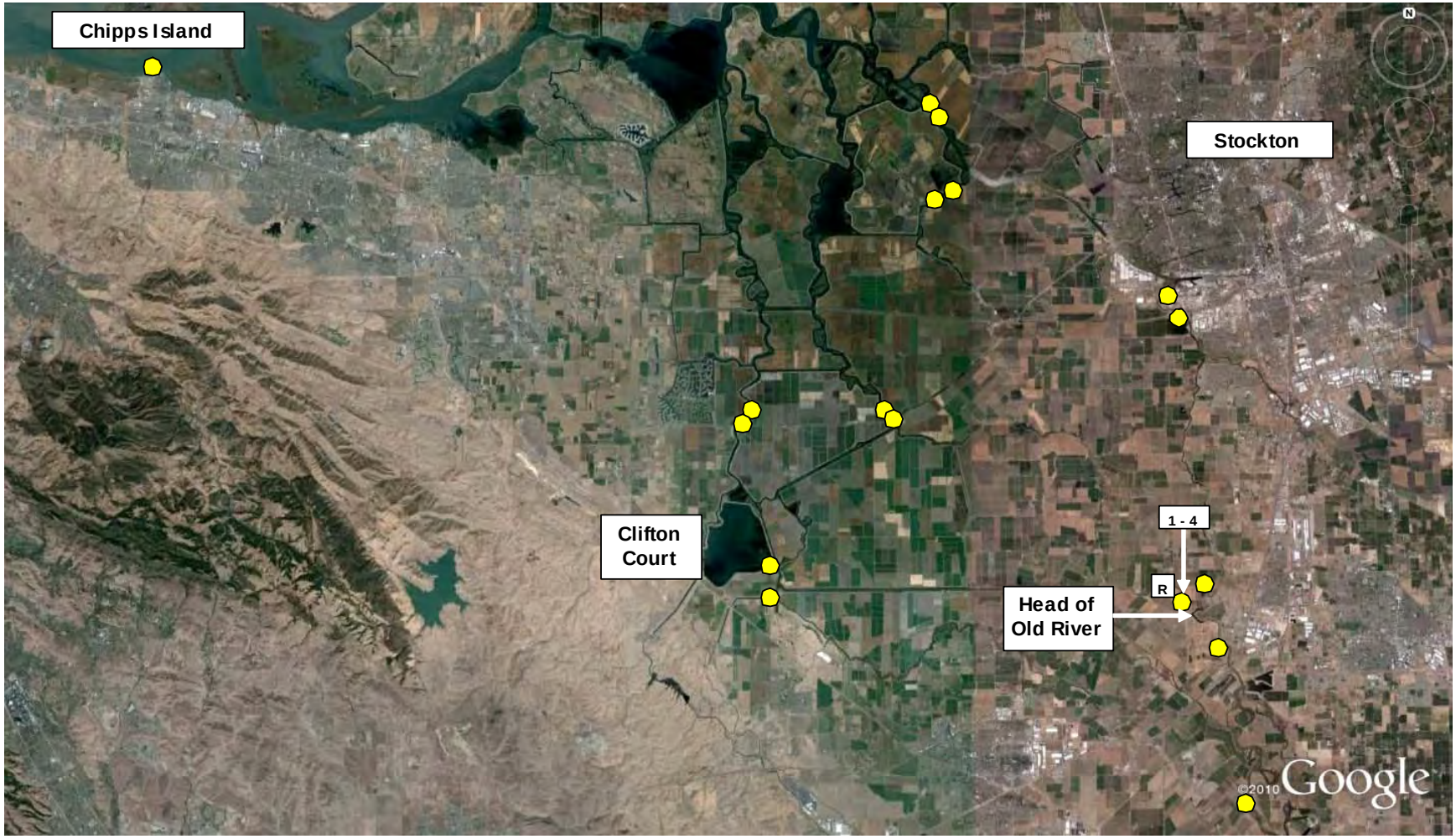
1) 5/24/10 @ 13:35 - 5/24/10 @ 19:06
2) 5/25/10 @ 07:39 - 5/25/10 @ 09:09
3) 5/26/10 @ 05:31 - 5/26/10 @ 09:22
4) 5/26/10 @ 22:27
5) 5/27/10 @ 05:54
6) 5/27/10 @ 14:51 - 5/27/10 @ 15:03
7) 5/28/10 @ 07:49 - 5/28/10 @ 10:36
8) 5/30/10 @ 06:52 - 5/30/10 @ 08:09
9) 5/31/10 @ 10:35 - 5/31/10 @ 13:23
10) 6/1/10 @ 11:44 - 6/1/10 @ 14:30
11) 6/2/10 @ 10:00

Appendix Figure 43. Movements of acoustic-tagged largemouth bass No. 2388.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Largemouth Bass 2038.07. Released at 14:00 on 5/3/10
1) 5/14/10 @ 13:26

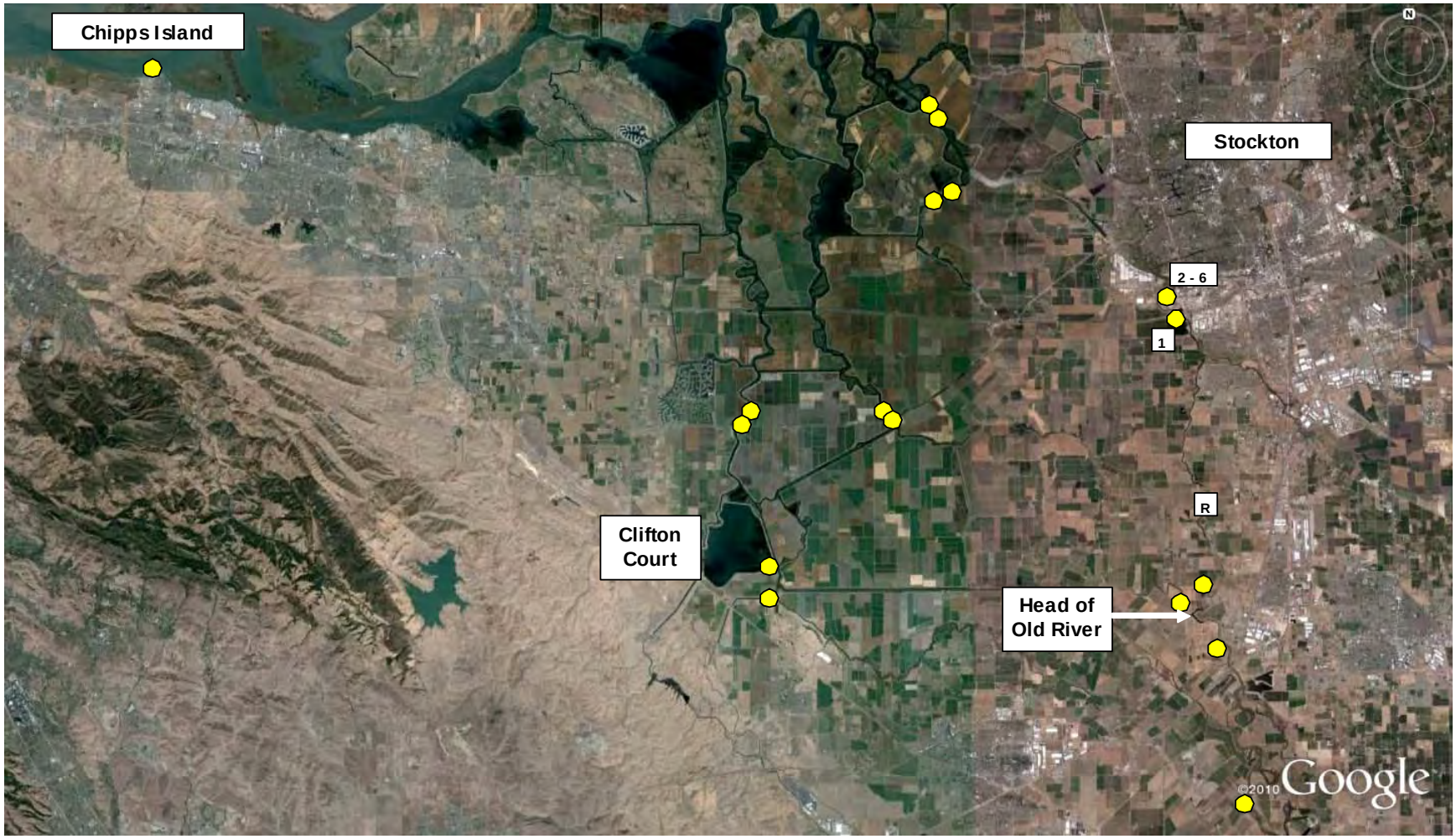
Appendix Figure 44. Movements of acoustic-tagged largemouth bass No. 2038.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



Largemouth Bass 2192.07. Released at 19:30 on 4/24/10

1) 5/31/10 @ 07:57
2) 5/31/10 @ 12:33
3) 5/31/10 @ 18:40 - 6/1/10 @ 07:33
4) 6/6/10 @ 09:04

Appendix Figure 45. Movements of acoustic-tagged largemouth bass No. 2192.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.



White Catfish 3326.07. Released at 16:00 on 6/1/10

1) 6/3/10 @ 00:43
2) 6/3/10 @ 03:13
3) 6/3/10 @ 05:58
4) 6/5/10 @ 23:15
5) 6/11/10 @ 05:19
6) 6/11/10 @ 08:07

Appendix Figure 46. Movements of acoustic-tagged white catfish No. 3326.07 in the Delta during the 2010 VAMP study. R=Release site. Fixed-station acoustic receiver locations depicted by yellow dots.