



DATE: 30 April 2010

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**Progress report: "Identifying critical habitat for endangered species in San Diego Bay",  
SDSU and NOAA**

The goal of this project is to characterize the movements of East Pacific green turtles in San Diego Bay using a combination of active and passive acoustic telemetry. This is a Port-supported collaborative research effort between NOAA and SDSU. Using NOAA and Port-sponsored equipment, researchers at SDSU are leading the efforts to track turtles and monitor the Bay for turtle activity.

Presence and temperature data will be used to calculate home range size, map movement patterns, and assess thermal conditions across use areas. Variability in home range among individuals will be examined based on size, sex, season, and association with high-risk areas where density of human activities are highest. Temperature and location data will also be collected to determine variability in habitat usage based on temperature, time of day, and season. Knowledge of green sea turtle habitat usage in San Diego Bay will identify what degree of overlap they may have with high activity areas in the bay, such as shipping channels, commercial docks, marinas, and Naval testing and training grounds. Emergent behavioral patterns will

inform local conservation strategies for reducing anthropogenically-induced mortalities and indirect negative impacts on turtles in San Diego Bay.

The activities described herein focus specifically on activities from Jan 1, 2010 to March 31, 2010. It also includes work conducted by NOAA in 2009 and by SDSU researchers in Fall 2009 as both are directly related to current research.

This report covers 4 main areas of research activity

1. **Turtle capture and telemetry deployment**
2. **Equipment testing**
3. **Passive tracking**
4. **Active tracking**
5. **Summary of tracking activities (1/10/10 – 3/31/10)**
6. **Upcoming objectives**
7. **Executive summary**

The data included in this report should be cited as “Eguchi, Seminoff, Madrak, McDonald, and Lewison, unpublished data.”

## 1. Turtle capture and telemetry deployment

NOAA scientists lead the turtle capture and telemetry deployment efforts necessary for this project. A total of 27 acoustic tags (CHP-87L; Sonotronics, Tucson, AZ) were active during the 2009-2010 season (Table 1), although some may have been detached from the turtles. To allow identification of individual turtles, acoustic tags are designed to transmit tag-specific high frequency pulses. Each acoustic tag was affixed to the carapace using fiberglass tape and resin (Figure 1).

Table 1. Summary of ultrasonic transmitter deployments on green turtles during the 2008-2009 and 2009-2010 capture seasons. Two turtles that were tagged in the 2007-2008 season and were detected during this report period also were included. Juv in the last column indicates juveniles, for which sex could not be determined externally.

ID	Capture date	Freq.	Pulse width	Mass (kg)	SCL (cm)	Sex
13583	2/15/2008	36	1050	59	72.8	Juv
33147	2/27/2008	39	890	17	48.3	Juv
2008-2009						
33145	12/2/2008	35	950	36	62.9	Juv
7220	12/18/2008	37	1110	152	105.5	Female
33151	12/18/2008	38	1230	30	60.1	Juv
33152	12/18/2008	35	910	27	59.6	Juv
11761	12/18/2008	40	1030	134	99.2	Female
2272	01/22/2009	37	1150	143	99.5	Male
4546	01/8/2009	40	1050	130	95.1	Female

8367	02/26/2009	40	1150	107	94.8	Female
33153	02/26/2009	38	1210	188	108.0	Female
3004	03/25/2009	37	950	143	101.0	Female
2009-2010						
1990	11/5/2009	36	930	121	100.4	Female
33145	11/17/2009	38	950	50	70.0	Juv
88129	12/3/2009	36	870	146	98.0	Male
88329	12/16/2009	37	1230	35	65.3	Juv
13585	12/3/2009	38	890	147	102.5	Female
3004	12/3/2009	36	1130	153	101.0	Female
3005	12/3/2009	36	1210	89	86.9	Male
8356	12/16/2009	39	1250	130	97.2	Male
88416	01/5/2010	37	890	81	87.0	Female
13690	02/3/2010	37	1050	62	80.9	Juv
88466	02/3/2010	38	1070	18	54.9	Juv
1989	02/18/2010	40	1090	130	101.1	Male
33149	02/3/2010	40	1250	48	71.1	Juv
4546	02/3/2010	39	1070	130	95.2	Female
11761	03/3/2010	39	1190	133	100.8	Female
8370	03/3/2010	36	1150	132	101.8	Female
4546	04/15/2010	40	1190	-	94.7	Female

Four turtles (33145, 11761, 4546, and 3004) were caught in the consecutive capture seasons. New acoustic tags were deployed on these turtles when they were recaptured.



Figure 1. Acoustic tags attached to the carapace of adult and juvenile green turtles in San Diego Bay.

## **2. Equipment testing**

Although the SURs were deployed during 2009, a formal test of the equipment had not been conducted. Prior to initiation of focused tracking, SDSU students MacDonald and Madrak conducted a controlled bench experiment to assess performance of SURs in the field,. Ideally, a SUR detects and records a tag anytime the tag is within its range. However, because field conditions are never ideal, performance of SUR for detecting tags needs to be evaluated for understanding and interpreting field records.

### **SUR bench test**

The first stage in evaluating SUR tag detection rates was to test a single tag and a single SUR in a bench test. The tag and SUR were aligned approximately 6 inches apart on the lab bench (per recommendation from Sonotronics technical support). The SUR was programmed to detect the single frequency at which the tag was transmitting, there was no scan delay, and the ping/response was turned off – all to simplify the process and eliminate unnecessary time in the scan cycle. Prior to data collection, SURsoft (communication software for SUR) was set to “debug on” mode thus allowing us to visualize detections (hits) and non-detections (misses) in real-time. When there is a hit during a scan, the software displays an “!” and when there is a miss, the software displays an “A.” The test was conducted for 5 minutes.

The tag that was used in the bench test operated at a frequency of 38 kHz and had a acoustic pulse pattern of 4-4-6-7 (to the unaided ear, this sounds like a series of click and pauses). Visually, the test resulted in a repeating pattern of 4 “!” followed by 1 “A” - !!!A!!!!A!!!!A!!!!A!!!!A.... The results thus showed an 80% detection rate. Further inquiry with Sonotronics technical support revealed that each individual tag has a short delay between pulse cycles, such that the pulse *cycles* (in this case 4-4-6-7) and then delays (no acoustic information transmitted) for 1 second or greater. The actual tag used in this bench test had an inter-cycle delay of approximately 3 seconds. Given this new information, the bench test was repeated and each scan cycle was timed to determine how long before either an “!” or an “A” appeared.

The results demonstrated that scans with hits (indicated by “!”) took about 7-8 seconds and that scans with misses (indicated by “A”) took about 3 seconds – exactly equal to the inter-cycle delay period. This means that the misses were as a result of the SUR scanning for a tag during the time that the tag was between pulse cycles (the inter-cycle delay). Thus, we now know there is a likelihood that misses will occur (false negatives) for a given tag and that this will be dependent on (and can be calculated by) the inter-cycle delay for each individual tag.

### **SUR scan time**

The SURs are set to scan for tags of each programmed frequency for 2 seconds, according to the operations manual. In actuality (according to personal communication with Sonotronics technical support), the scan time per frequency can range from 3-5 seconds depending on the frequency and whether a tag is detected. Based on the bench test, the scan time can actually be 7-8 seconds per frequency.

### **SUR scan delay (time between scans)**

The rest time between scans, or the scan delay, can be manipulated via SURsoft to save battery life. The SURs for the San Diego Bay project scan for a wide range of frequencies and thus the total scan cycle is around 2 minutes in length. Eliminating this scan delay will save 3 seconds from the total cycling time. Although this seems like an insignificant delay, removing a

scan delay will shorten the total scan cycle and thus increase likelihood of detection of tagged turtles. The impact on battery life should be inconsequential.

### **Field trial methods**

Performance of SURs in the field was determined by the number of actual, recorded detections compared to the potential number of detections in a five-minute interval. Three sites within south San Diego Bay (SF3, SF1, and Jacuzzi Ramp) were selected for initial tests of detection during high tide. Detection rates are known to decrease as a function of increased distance between the SUR and acoustic transmitter. Consequently, several distances between SUR and transmitter were tested for detection at each site: 5m, 25m, 50m, 100m, and 200m.

Two SURs, attached to 8 x 8 in. cinder blocks, were deployed at each test site and GPS coordinates for that site were recorded. One SUR was encased in a protective PVC sleeve, while the other SUR was left unprotected, in order to examine what effects, if any, a protective casing might have on the performance of an SUR. The ability to place protective casings on SURs in future deployments would be beneficial for protecting the devices from potential boat propeller strikes at low tide and any other debris that might strike an SUR in the water column. The boat and crew anchored the vessel at the approximate distance from the SUR and recorded GPS coordinates for that distance. An acoustic transmitter was then lowered approximately 1.5 m into the water for a period of five minutes. This process was repeated for each of the desired distances. Due to the fact that distances were only approximate in the field tests, actual distance was later calculated using the GPS coordinates recorded for each site. Also, at each site, an additional test was conducted to test the potential effect of boat engine noise on the SUR's detection of a nearby transmitter. This was accomplished by lowering the acoustic transmitter into the water for five minutes at a distance of 5m from the SUR and running the boat engine during this period.

### **Results**

#### *Percent Detection*

Overall percent detection was high at site SF3, low at site SF1, and intermediate at site Jacuzzi Ramp (Figure 7). Although specific causal relationships cannot be established, it is possible that the depths may affected the detection. Studies on passive acoustic telemetry arrays have indicated increased detection rates and ranges as a function of increased depth. SF3 is approximately 30% deeper than site SF1, while the Jacuzzi Ramp has a variable bathymetry and thus a range of depths between those of SF1 and SF3. Other variables that are known to affect performance of SURs include water temperature, thermoclines, turbidity, bathymetry, ambient noise, and bottom substrate.

Furthermore, relative detection rates were highest between 25-50 m, and percent detection for all sites followed a similar decreasing trend as distance from the SUR increased. Percent detection at site SF3 was notably high, detecting between 85-95% of possible detections between 25-60 m. It continued to detect the tag (~40%) up to the greatest tested distance of 130 m. Detection at site Jacuzzi Ramp was low (~30%) within 5 m, higher between 25-50 m (~75-90%), and ~70% at 100 m, which was the greatest distance tested. Detection at site SF1 was lower than other test sites: ~5% at 5 m, ~35% at 25 m and 50 m, ~20% at 100 m, and ~15% at 200 m. Low detection rates were found within 5 m of the SUR.

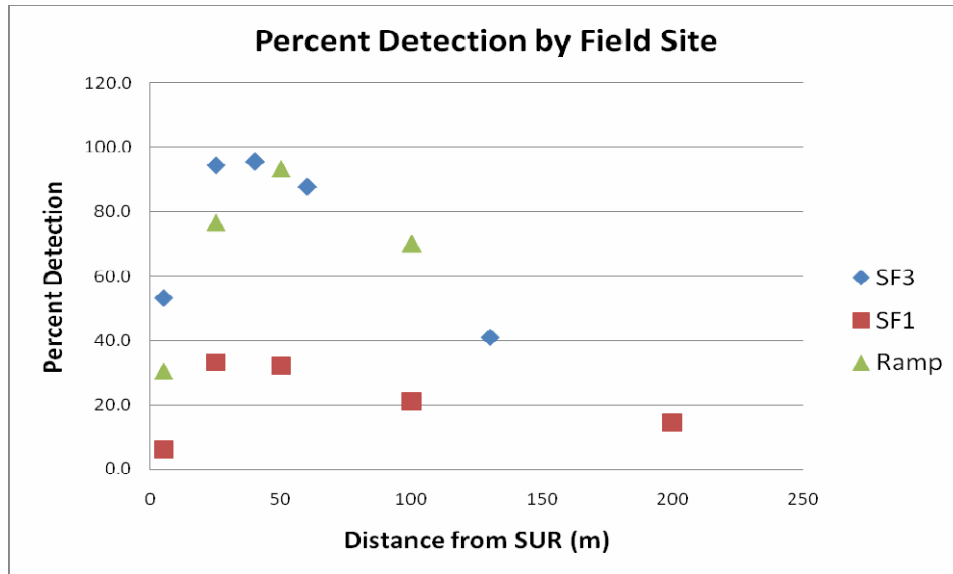


Figure 7. Percent detection as a function of distance from SUR and field sites

*Effects of protective sleeve*

SURs in protective sleeve appeared to perform as good as those that are not encased (Figures 8, 9, and 10). This finding is encouraging, because the protective casing will protect SURs from incidental boat propeller strikes, collisions with marine debris, and other unforeseen physical events that might damage or destroy an SUR.

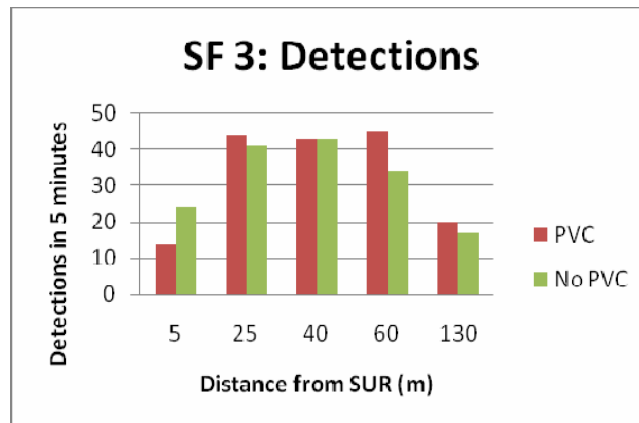


Figure 8. Effects of protective PVC casing around SUR on tag detections as measured by the number of detection per 5 minute interval at SF3.

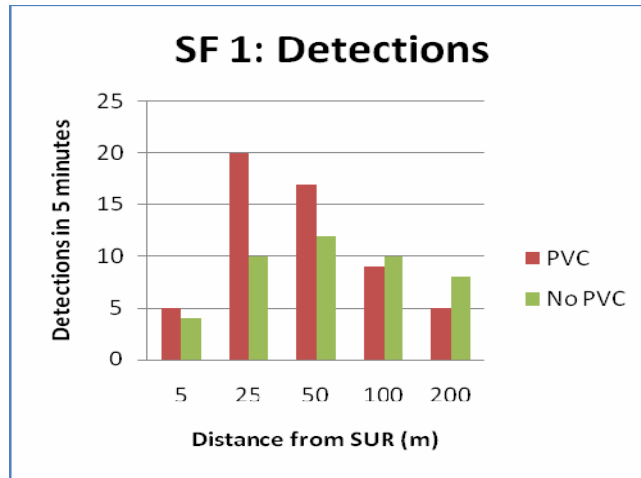


Figure 9. Effects of protective PVC casing around SUR on tag detections as measured by the number of detection per 5 minute interval at SF1.

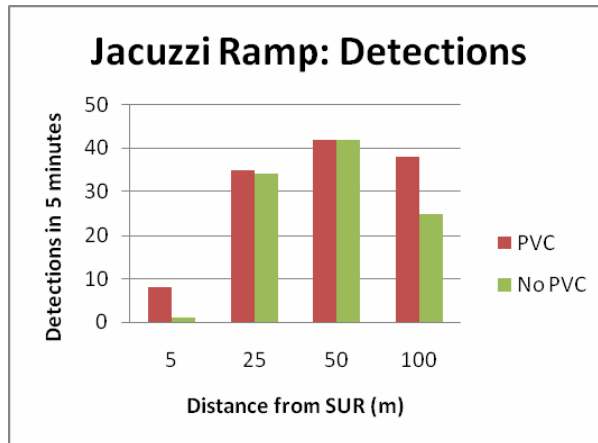


Figure 10. Effects of protective PVC casing around SUR on tag detections as measured by the number of detection per 5 minute interval at Ramp

### *Effects of engine noise*

The operation of a boat engine within 5m of both an SUR and an acoustic transmitter did not result in a decreased number of detections by the SUR. This was the case for both SURs with a protective sleeve and those without (Figures 11 and 12). Although previous studies have suggested that noise from boat engines can destructively interfere with transmissions from acoustic transmitters, observed data did not support this.

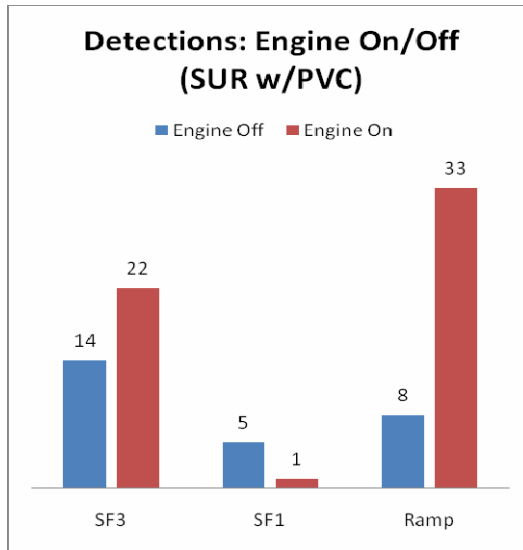


Figure 11. Effects of engine noise on acoustic tag detections by SUR. An SUR and acoustic tag were placed at 5 m from the boat engine. Numbers indicate the number of detections by the SUR per 5 min.

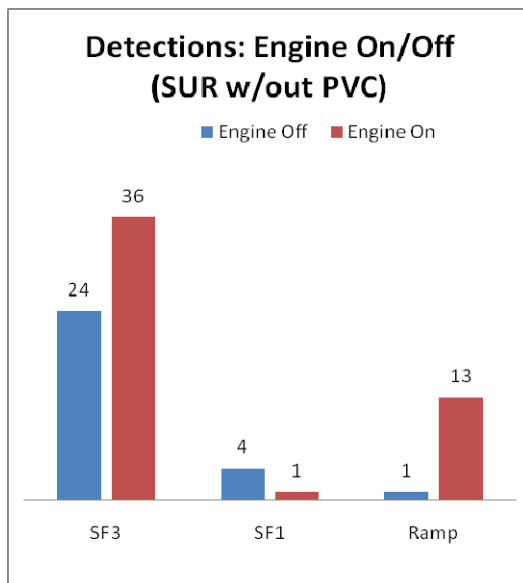


Figure 12. Effects of engine noise on acoustic tag detections by SUR. An SUR and acoustic tag were placed at 5 m from the boat engine. Numbers indicate the number of detections by the SUR per 5 min.

### 3. Passive tracking: Deployment of SUR stations

Turtles are tracked passively using Sonotronics SUR-1 submersible ultrasonic receivers. The submersible ultrasonic receivers (SURs) are programmed to scan for a range of frequencies. Presence of acoustic tags is recorded into the SUR memory when a tag is within detectable range. We plan to deploy between 15-18 fixed SUR sites in South Bay based on areas of interest, including foraging areas (i.e. seagrass beds) and high-risk areas (boating channels & docks). Hobo U22 Water Temp Pro v2 temperature data loggers are deployed at each of the SUR sites. SURs are checked for proper functioning and battery life once every 6-8 weeks and data are downloaded at that time. These data will help to determine when and where turtles occur over time, particularly with regard to diel patterns of presence/absence at sites.



Figure 2. Submersible ultrasonic receiver (SUR; Sonotronics, Tucson, AZ).

SURs have been deployed throughout the south portion of San Diego Bay (Figure 3). Not all stations shown in Figure 3 were deployed at the same time (Figure 4). For "Sweetwater" and "Elbow" stations, the same names were used for two proximate locations. SUR deployment records are summarized in Table 2. The locations of SURs were determined by the distribution of eelgrass in the south bay, turtle sightings in the past, and management requirements.

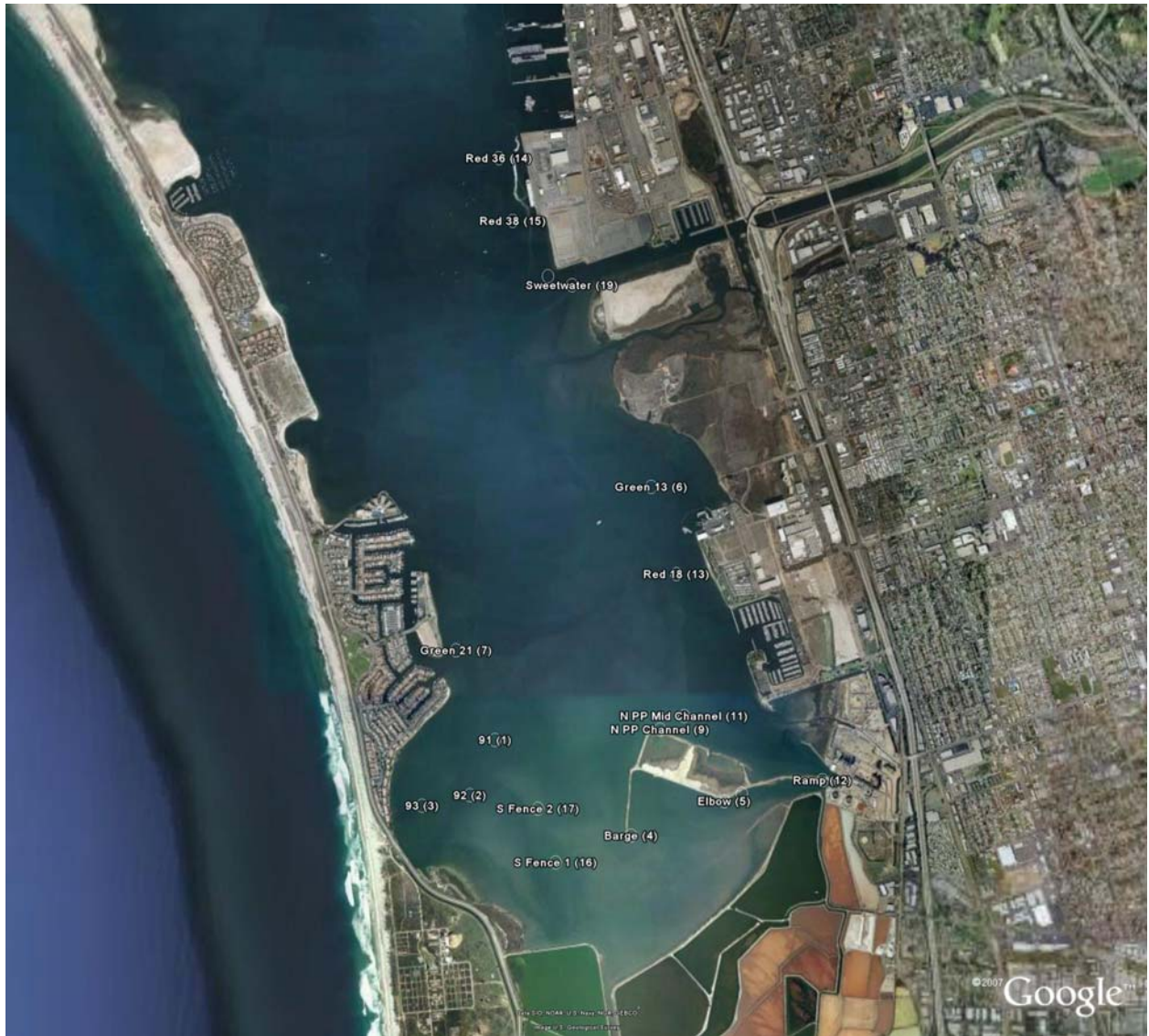


Figure 3. SUR locations in San Diego Bay during the 2009 study period. The numbers on location labels correspond to those in Figure 4.

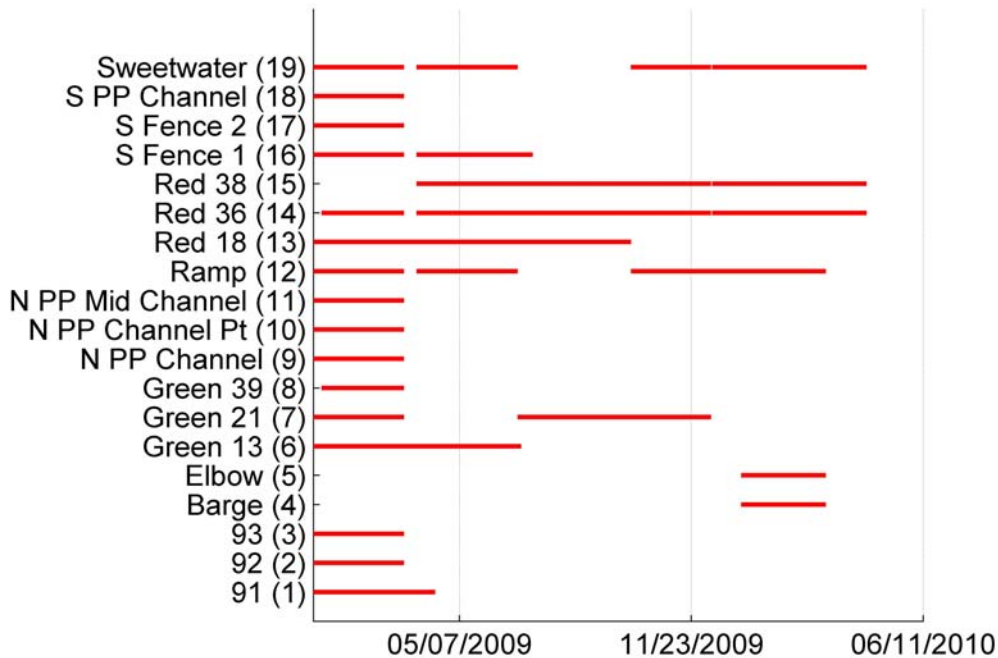
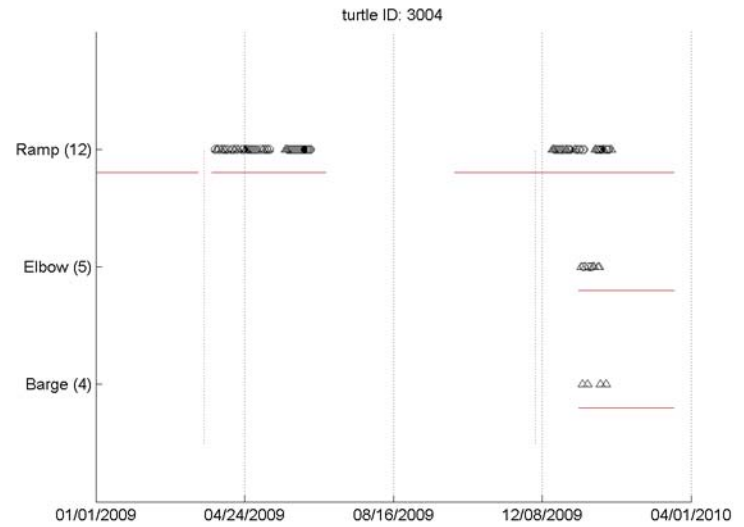
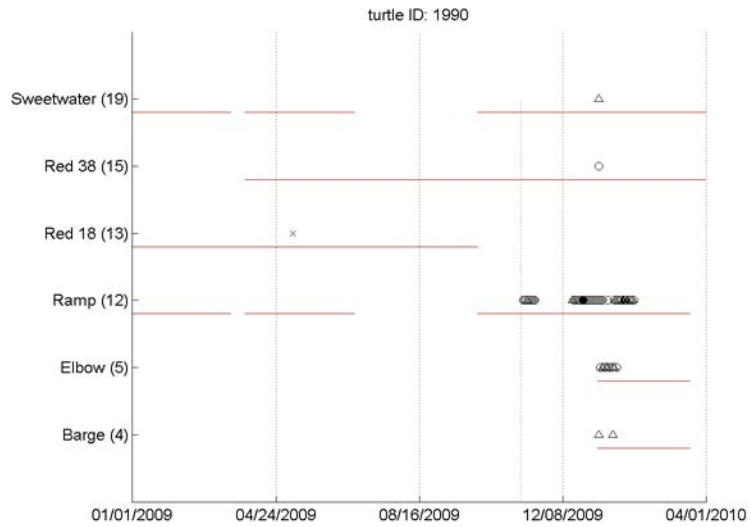
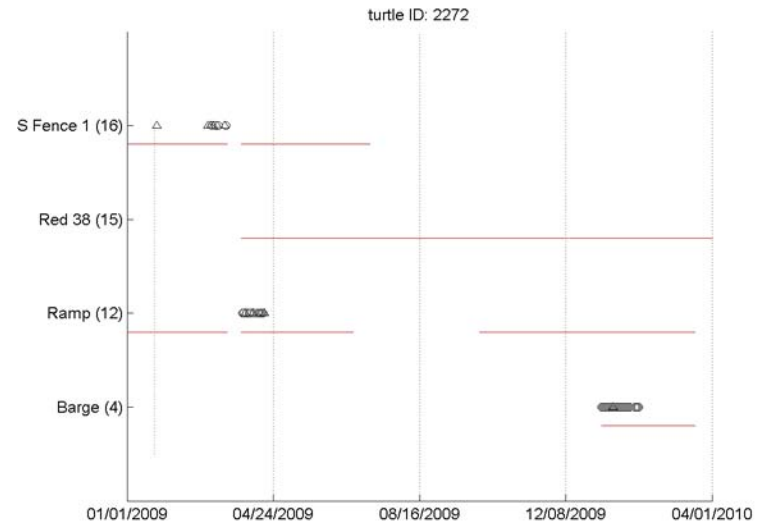
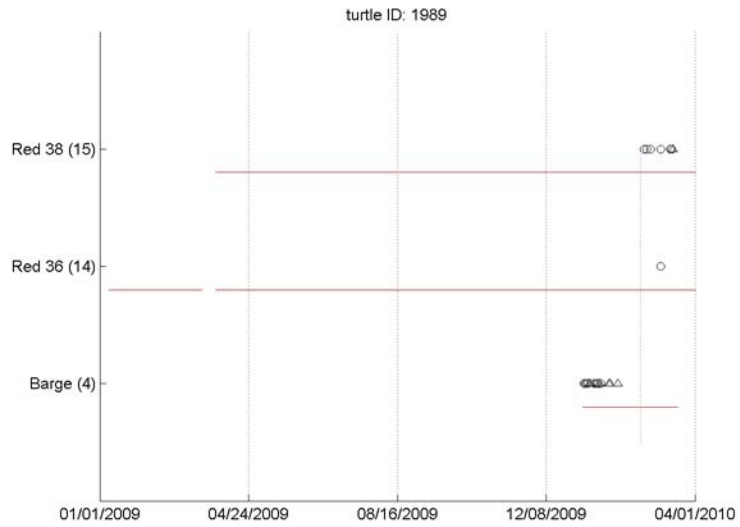
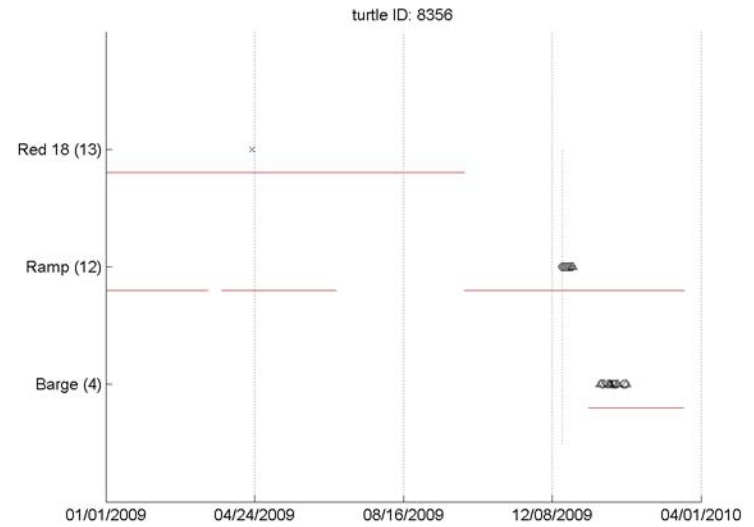
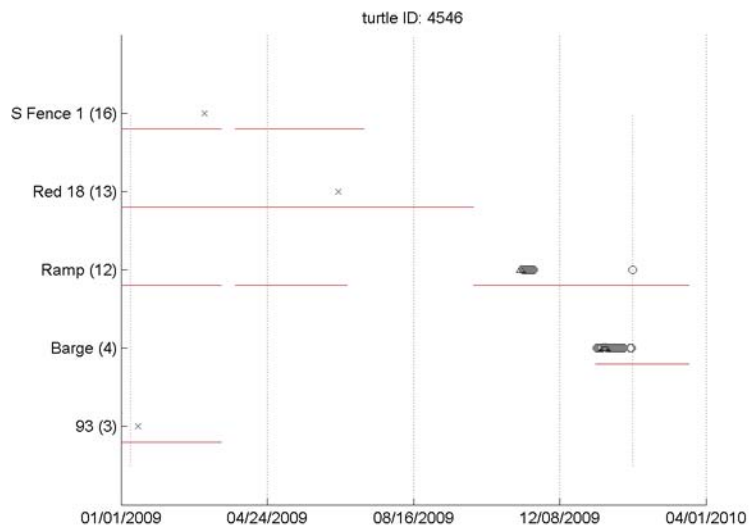
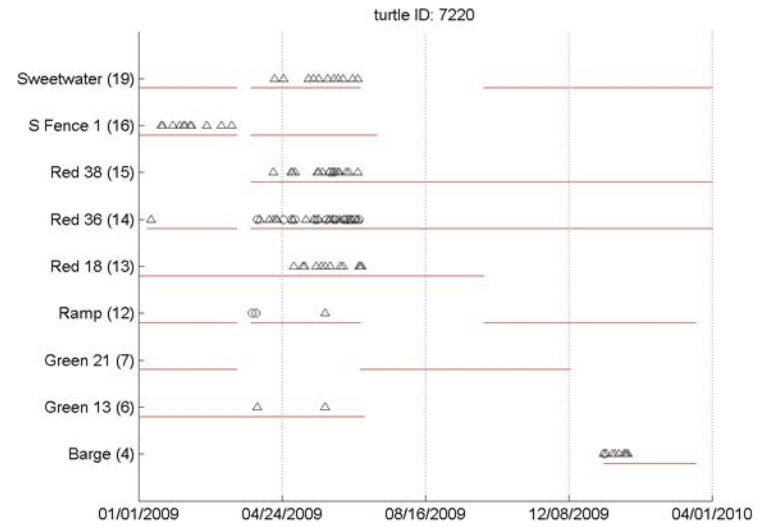
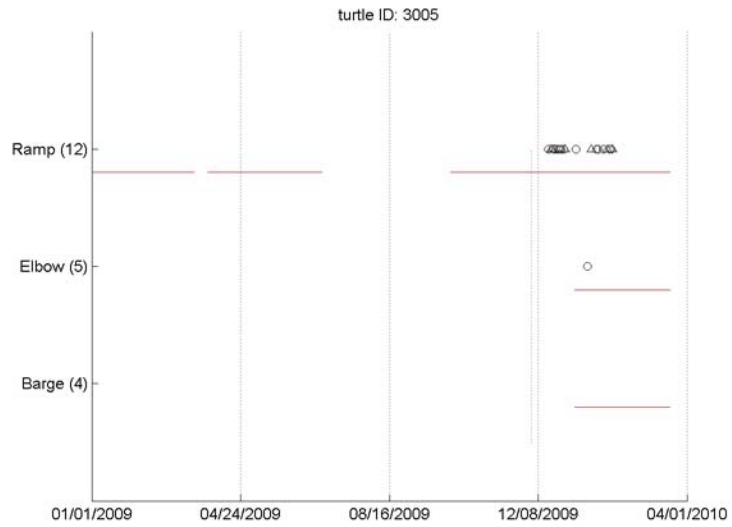
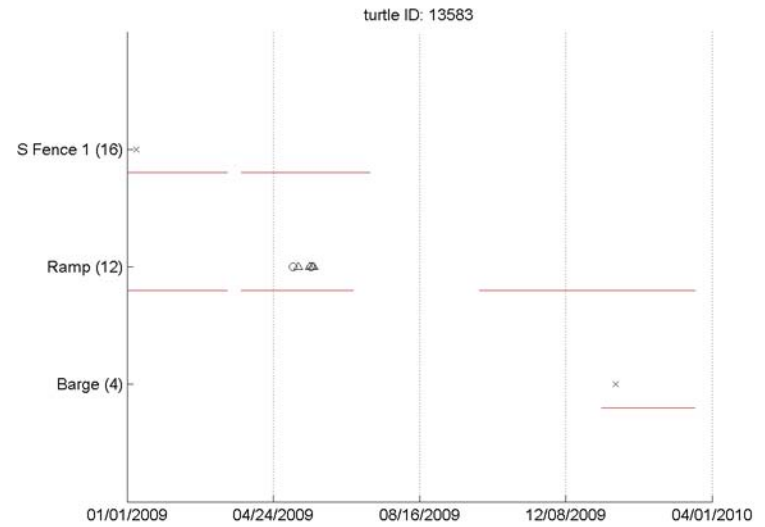
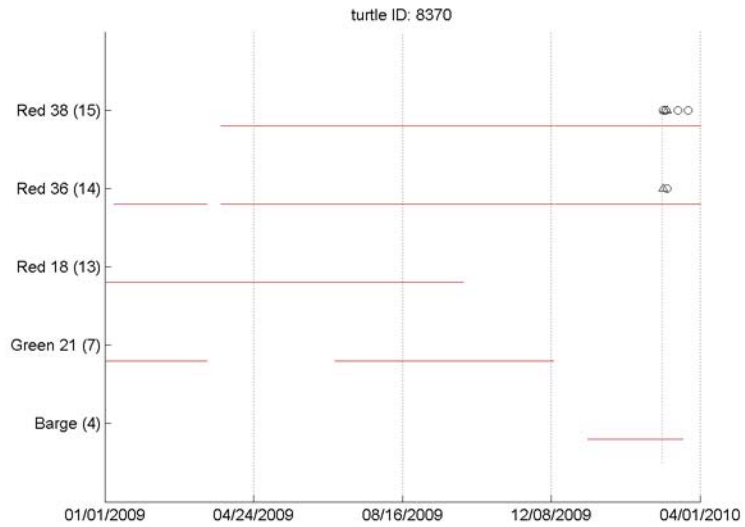
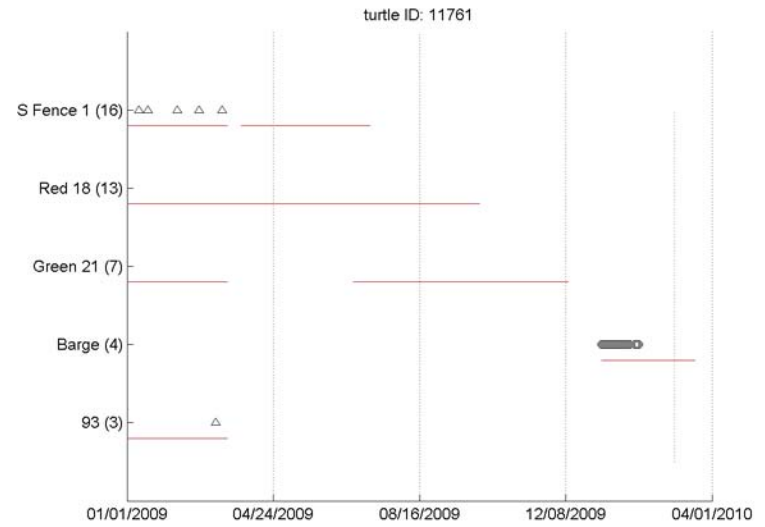
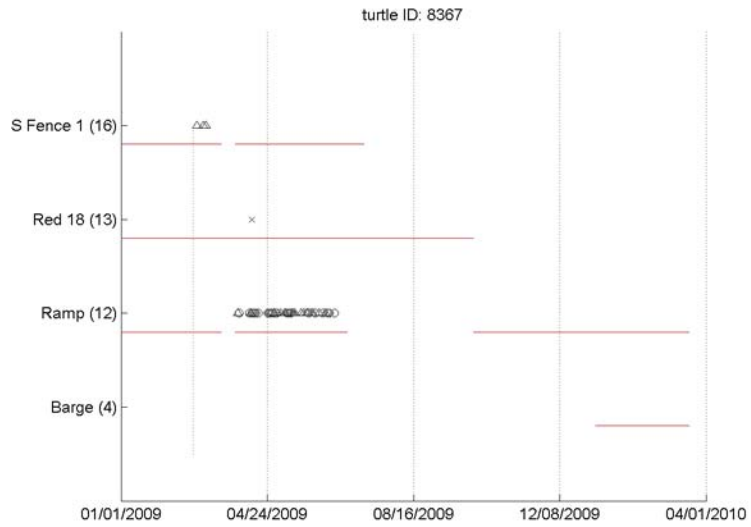


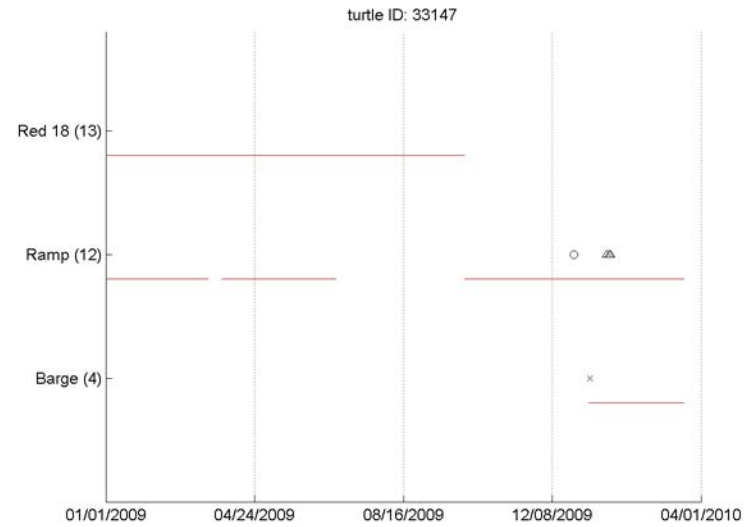
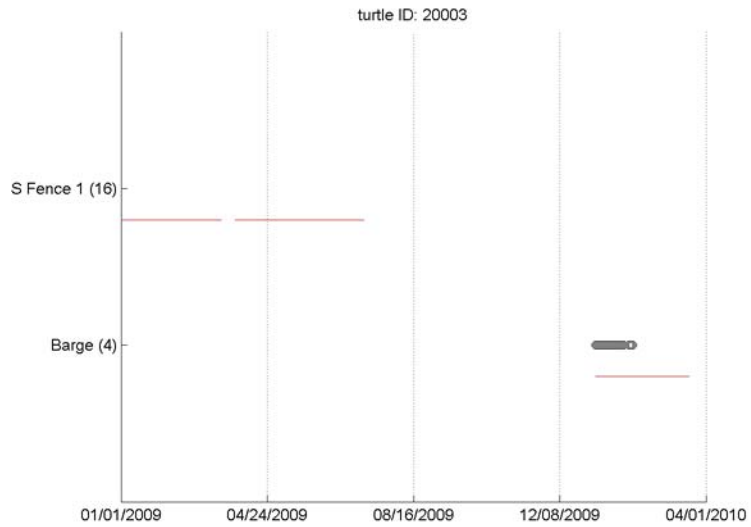
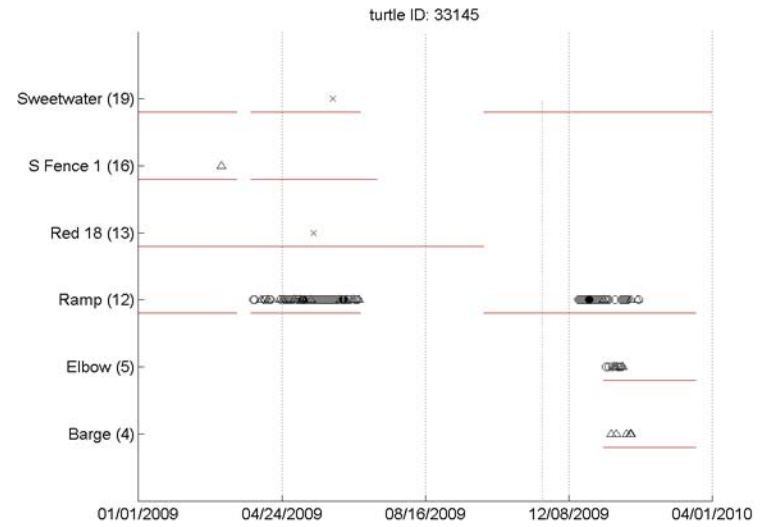
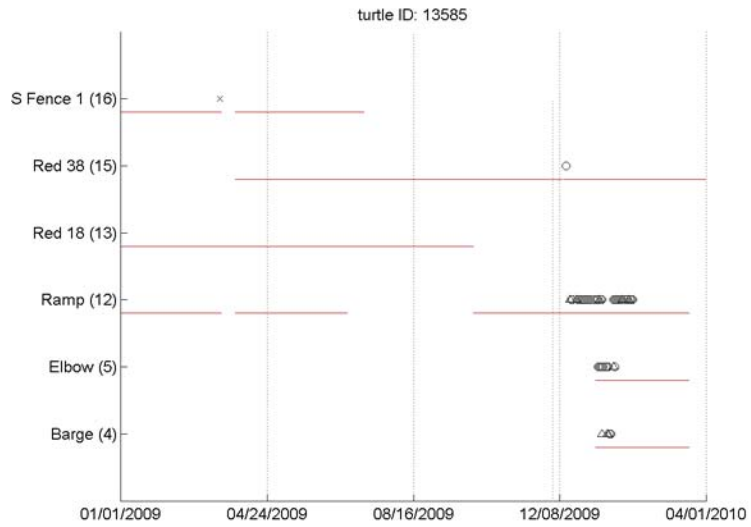
Figure 4. SUR deployment records. Horizontal bars indicate time spans in which SURs were deployed at these locations. The horizontal axis starts at January 1, 2009.

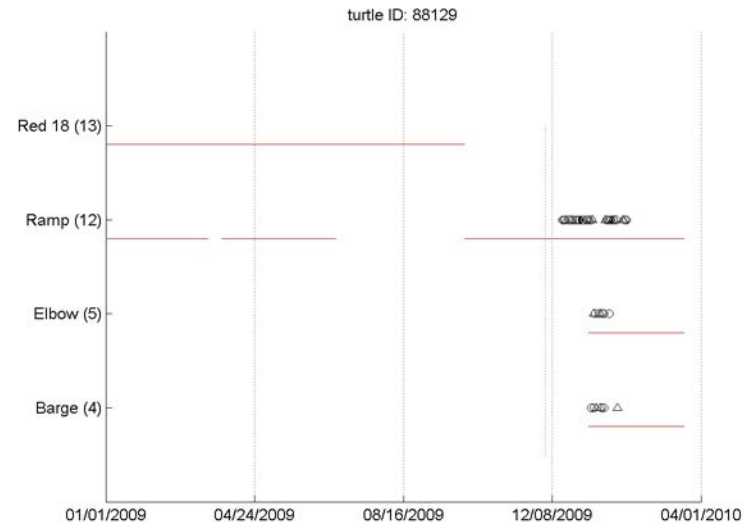
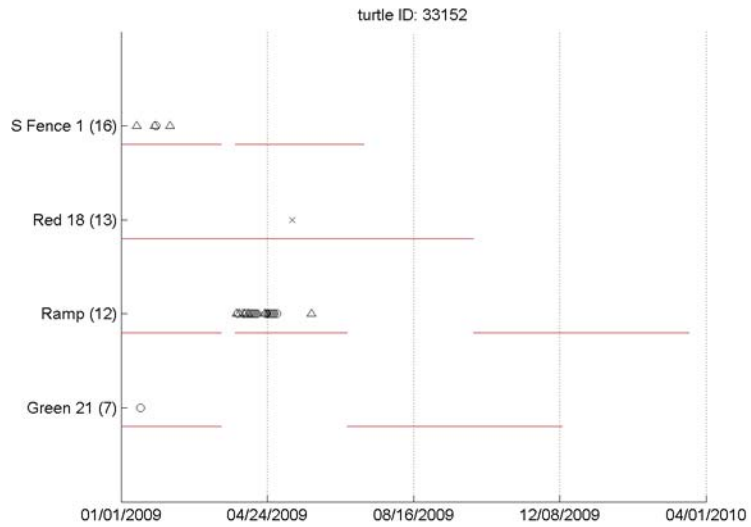
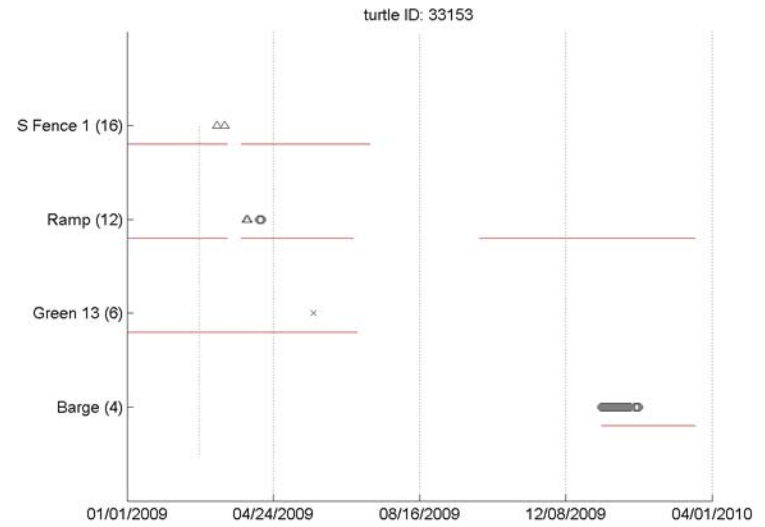
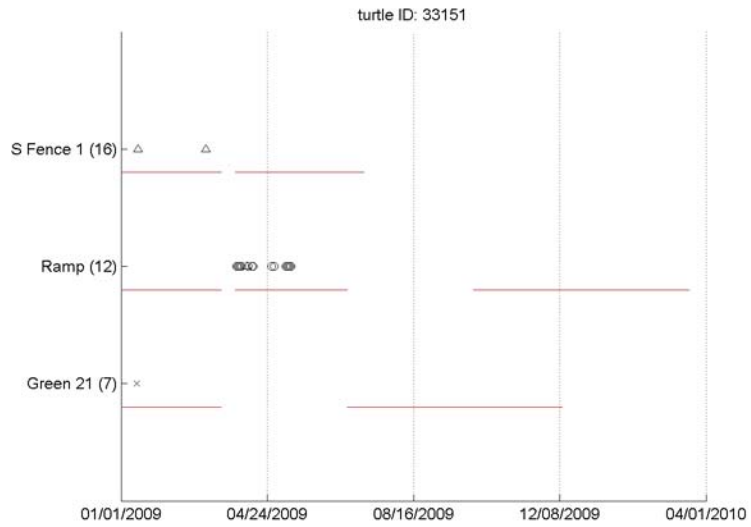
Downloaded data from each SUR were processed using SURsoftDPC (Sonotronics, Tucson, AZ), which extracted date and time of detections of all tags. Habitat use of tagged turtles was determined by compiling detections of each turtle by SURs. Useful data were retrieved for 23 turtles (Figures 5). Detections of tagged turtles by SURs throughout the south bay indicated that some turtles have affinities to certain locations (Figures 5). For example, turtle 33145 was found often at the effluent channel (Ramp and Elbow), but not found far from the effluent channel. For another example, turtle 88416 was found near the Sweetwater river outlet (Red 36, Red 38, and Sweetwater), as well as in the effluent channel (Elbow). Turtle 7220 was found at various locations. Non-detections of tagged turtles indicated that there are unmonitored areas in the bay that are used by these turtles. Seven tags were eventually found consistently at Barge and stayed in the vicinity (2272, 11761, 4546, 8356, 7220, 20003, 33153). This and the field observations indicated that the turtles are "cleaning" their carapace at the barge thereby removing the tags.











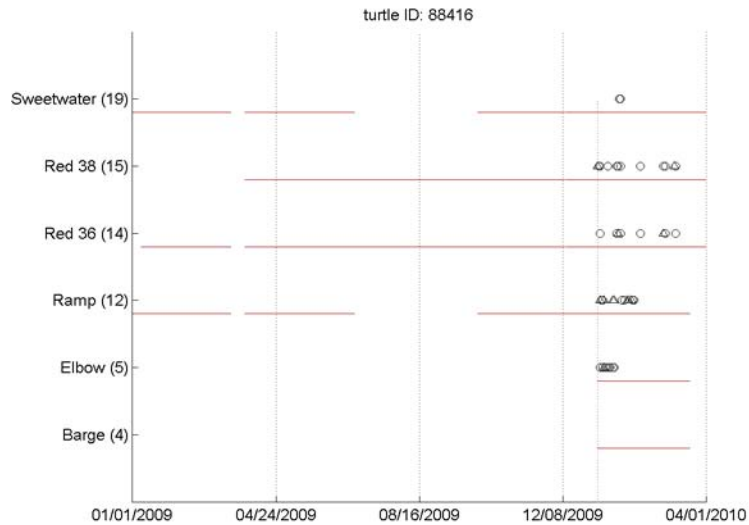
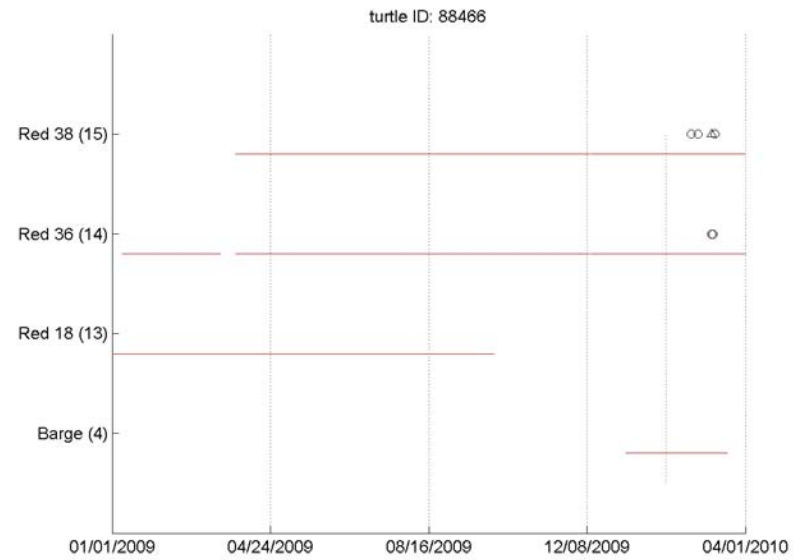
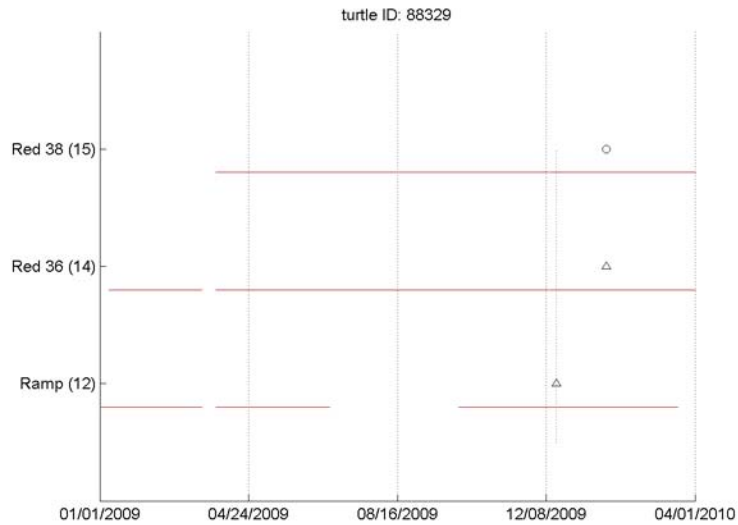


Figure 5. Detections of acoustic tags deployed on green turtles in San Diego bay. The horizontal axis is date and the vertical axis indicates SUR locations. Location names are listed in Table 1 and Figure 1. Each plot is for a particular turtle, where the identification of a turtle is shown on the top of each figure. Red horizontal lines indicate the time spans for which a SUR was deployed at a particular location. Vertical dotted lines indicate the time of acoustic deployments and replacements. A circle indicates the turtle was detected > 5 times per day, a triangle indicates >1 and < 6, and an x indicates one detection per day. Red lines with no detections indicate the turtle was detected at those locations before 1 January 2009.

#### 4. Active tracking: Bay-wide monitoring and individual follows

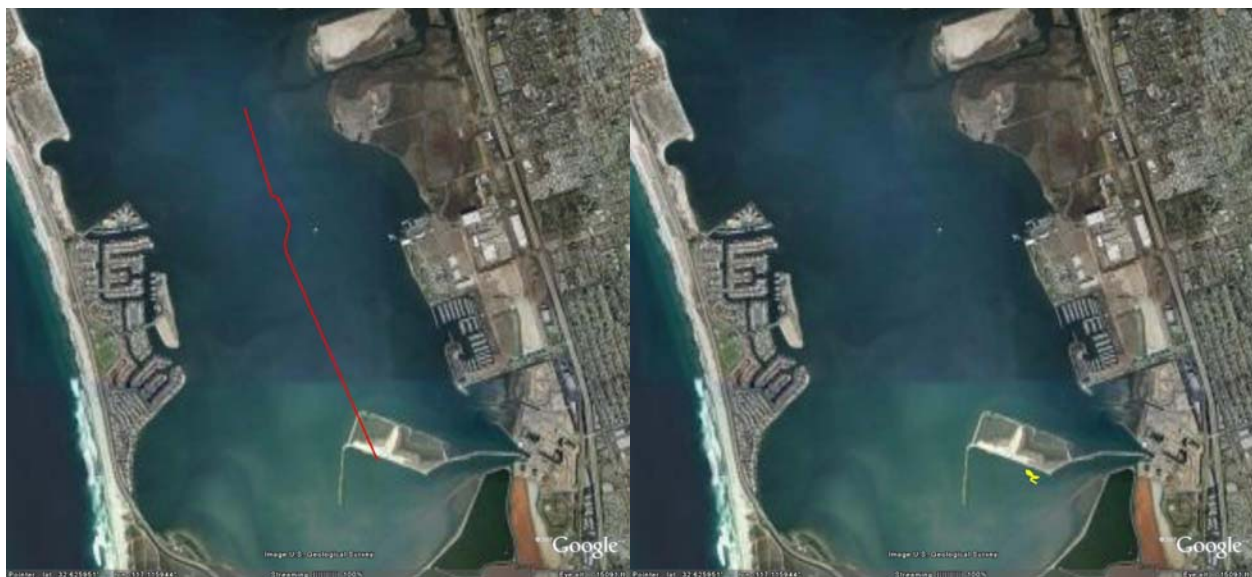
Tagged turtles are actively tracked in the water using Sonotronics DH-4 directional and omnidirectional hydrophones and a Sonotronics USR-96 ultrasonic receiver.

##### *Bay-wide monitoring*

To systematically monitor the entire Bay for turtle activity, we have established a "grid" of intersecting transect lines spaced at 500m x 500m intervals, creating a comprehensive series of listening stations across the entirety of San Diego Bay. Each location on the grid is visited weekly to determine presence/absence of tagged turtles. Regular visitation to all locations accounts for spatiotemporal sampling biases common to traditional telemetry studies. When a turtle's transmitter is detected, the research vessel tracks and locates the exact position of the detected individual. A turtle is considered to be in close proximity when the transmitter can be heard uniformly through a 360-degree rotation of the hydrophone at the receiver's lowest gain setting. A GPS coordinate is recorded using a handheld Garmin GPS unit (accuracy 3-5 m); water temperature at the location is recorded at a depth of 1m. Once a turtle's location has been determined, the research vessel continues to the next listening station.

##### *Individual follows*

Manual tracking of tagged green turtles first commenced on 11/13/2009 and was conducted by NOAA employees. As of 12/11/2009, approximately 14 hours of manual tracking had been logged in south San Diego Bay. Five of the six turtles captured by NOAA-NMFS in the Fall of 2009 have been re-sighted, and all re-sightings have taken place south of Sweetwater Inlet. Excluding one turtle re-sighting that took place just south of Sweetwater Inlet of one turtle, Bonita (ID# 1190), all other re-sightings occurred within 1 km of the effluent outfall area of the South Bay Power Plant.



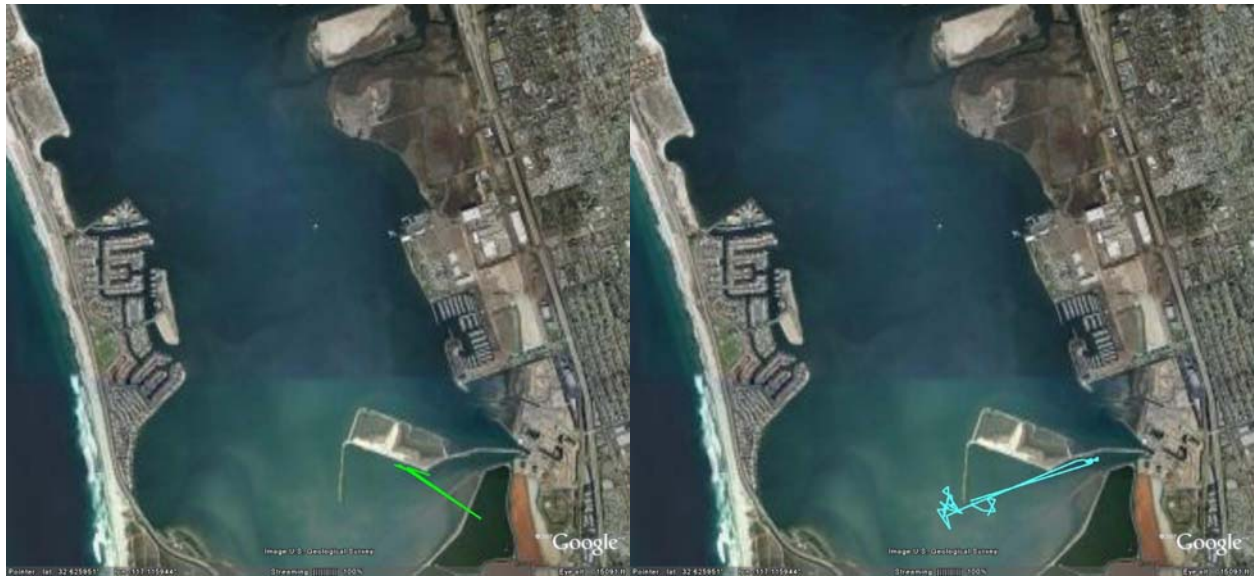


Figure 6. Movements of four turtles that were manually tracked on 11/13/2009, 11/20/2009, and 12/11/2009. Turtle identifications are, in clockwise from upper left, 1190 (14:00 to 15:45 on 11/13/2009 and one location (09:57) on 12/11/2009), 3005 (08:41 to 10:09 on 12/11/2009), 33145 (12:42 to 13:45 on 12/11/2009), and 13585 (10:13 to 14:55 on 12/11/2009).

**Starting Jan 1, 2010**, SDSU students Madrak and MacDonald assumed all tracking responsibilities. Once monthly, they conduct 24-hour tracking periods of tagged individuals to collect high-resolution diurnal and nocturnal movement data for specific individuals. Once a tagged turtle is detected, rotating research teams continuously monitor the same individual at a distance of approximately 50m for 24-hours. GPS coordinates and water temperature are recorded at 10 minute intervals throughout the tracking period to provide high resolution data. We will attempt to collect 24-hour tracking periods for all tagged individuals, but transmitter failure (i.e. wear and tear, battery failure) may prevent data collection on some individuals.

## 5. Summary of tracking work conducted to date (Jan 1, 2010 – Mar 31, 2010)

### January

- Total Field Days: 9
- Capture Days: 2
- Active tracking: 6 days; 34 hours on-water
- Passive tracking: SURs station maintenance

### February

- Total Field Days: 12
- Capture Days: 2
- Active tracking: 8 days; 43 hours on-water (not counting 24-hour track)
- Passive tracking: SURs station maintenance
- 24-Hour tracking: 1 track on 2/25-2/26, 2010 of Turtle 88329 (37 kHz, 5-7-8-7)

### March

- Total Field Days: 13

- Capture Days: 2
- Active tracking: 8 days; 42 hours on-water (not including 24-hour track)
- Passive tracking: SURs station maintenance
- 24-Hour tracking: 1 track on 3/24-3/25, 2010 of Turtle 33145 (38 kHz, 6-7-8)
- Research presented at SDSU Graduate Research Symposium on 3/5/2010

## **6. Upcoming Objectives**

### Active Tracking

- 24-hour individual follows
  - Once per month; twice when personnel and equipment (boats, vehicles, etc.) are available
- Bay-wide monitoring
  - 3 tracking days (approximately 8 hours per day) per week
  - Entire coordinate grid of San Diego Bay covered each week with 1 day spent at each of the 3 regional sections of San Diego Bay (south, central, north)

### Passive Tracking

- Currently 7 SURs deployed
- Up to an additional 10 SURs will be deployed by June 2010 (pending available funding)

### Data Analysis

- Preliminary analysis of spatial and thermal data based on collection from 2009 – 2010 field seasons.

## **7. Executive Summary**

- We have made excellent progress in the project thusfar. We have a robust protocol, based on a thorough exploration of equipment limitations through our equipment tests.
- Our bench and field tests of SURs indicated 1) SUR performance, even under ideal conditions (bench test), is tag-specific, 2) performance of SUR in the field is variable from site to site, but follows a clear trend of higher detection rate within 25-100 m, followed by a sharp decrease in detection from 100-200 m, 3) detection rates are likely influenced by a suite of factors, including depth, bathymetry, water temperature, turbidity, amount of sediment in the water column, ambient noise, substrate type, etc., and that these factors must be considered when designing future deployment of SUR arrays, 4) despite decreases in detection rate, tags were detected beyond 100 m at all test sites and up to 200m in the case of site SF, 5) using ABS sleeves to protect SURs does not hinder the performance of SURs, and 6) Boat engine noise, even in close proximity to SURs and sonic transmitters, did not result in a decreased number of detections. All future sites at which SURs will be deployed should still be tested at high and low tides to determine approximate minimums and maximums for percent detection and the overall spatial range of detection.

- We have established a robust Bay-wide monitoring regime that is providing critical information on turtle habitat use throughout the Bay. This will be conducted every week to assess turtle activity and changes in those patterns.
- We will continue to conduct focal animal follows to obtain high-resolution habitat use issues. We anticipate more frequent individual follows in the months to come.