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Determining Marine Migration Patterns and Behavior of Gulf Sturgeon in the Gulf of Mexico off Eglin Air Force Base, Florida

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Abstract

The Eglin Natural Resources Section (NRS) received funding from the Department of Defense (DoD) Legacy Resource Management Program to conduct a multi-year study to determine migration patterns and behavior of the federally protected Gulf sturgeon (*Acipenser oxyrinchus desotoi*) within critical habitat areas of Eglin's Gulf Test and Training Range (EGTTR) in the Gulf of Mexico. This report is a compilation of data and information covering three years of monitoring and significantly expands on knowledge of the spatial and temporal distribution of Gulf sturgeon. Prior to this project it was not known where Gulf sturgeon traveled during the winter months in the Gulf of Mexico. The results of this study provide an abundance of data and analyses that can be utilized for Endangered Species Act (ESA) Section 7 consultations, National Environmental Policy Act (NEPA), and a multitude of other environmental management applications. These findings are not only applicable to Eglin Air Force Base (AFB), but may also benefit other DoD installations around the Gulf Coast such as Tyndall AFB, Naval Air Station Pensacola, Naval Station Pascagoula, and Keesler AFB. Over the course of three years, 120 adult Gulf sturgeon were tagged with acoustic transmitters from four different river systems in the area surrounding Eglin AFB. Their movements were tracked by Vemco VR2W receivers placed in strategic locations in the marine, estuarine, and riverine areas surrounding Eglin's properties, including the Gulf of Mexico, Santa Rosa Sound, Pensacola Bay, and Yellow, Blackwater, and Escambia Rivers. This configuration allowed data collection in critical habitat areas heavily utilized for military testing and training activities. These receivers were able to detect Gulf sturgeon tagged by Eglin in 2008, 2009, and 2010 and sturgeon tagged by other researchers utilizing the same acoustic technology. Gulf sturgeon typically occur within 1,000 meters of the shoreline in the Gulf of Mexico. Our data also indicates that sturgeon activity in critical habitat areas of the EGTTR begins in November, peaks in December and January, and lasts through April. These results will allow more accurate assessment of potential impacts to Gulf sturgeon from military activities in the EGTTR and development of effective mitigation measures. This report also identifies movement patterns of Gulf sturgeon from different river systems, overwintering locations in the Gulf of Mexico, level of river fidelity of the sample, and performance evaluation of the acoustic technology in a harsh marine environment.

Introduction

The Gulf sturgeon, *Acipenser oxyrinchus desotoi*, is an anadromous fish occurring in riverine, estuarine, and nearshore marine environments of coastal states along the Gulf of Mexico (Figure 1). Gulf sturgeon have bony plates called scutes instead of scales, and an extended snout. Adults range in length from 4 to 8 feet (ft) (1 to 2.5 meters [m]). The species' freshwater range encompasses seven river systems from Lake Pontchartrain in Louisiana to the Suwannee River in Florida. Adult Gulf sturgeon occur in fresh water during warm months when spawning occurs, and migrate into estuarine and marine environments in the fall to forage and overwinter (NOAA OPR 2011). Most subadult and adult Gulf sturgeon generally do not feed in the riverine habitats. Instead, feeding occurs on the bottom sediments of marine and estuarine habitats during fall and winter. Prey items consist primarily of macroinvertebrates such as brachiopods, mollusks, worms, and crustaceans (NOAA OPR 2011). Some individuals have been documented in estuarine waters such as bays and sounds for at least a portion of the fall and winter months, although the extent of this habitat use is not well studied. Juveniles may remain in the rivers for the first two to three years (NOAA, 2011).

There are increasing conservation concerns for all species of sturgeon due to a variety of reasons, including their size, high value of meat and eggs, delayed age of maturity (10 years old for the Gulf sturgeon), and long life span (Gross et al., 2002). The Gulf sturgeon was listed as a threatened species in 1991 under the federal Endangered Species Act of 1973 (ESA). Under the same Act, critical habitat for the species was designated in 2003. Critical habitat is defined as specific areas that are considered essential to the conservation of a listed species due to the presence of primary constituent elements, and that may require special management considerations or protection. Gulf sturgeon critical habitat consists of seven geographic areas (units) of riverine habitat and seven units of estuarine and marine habitat, for a total of 14 units (Figure 2). Critical habitat of the river units extends to the river mouths and up to the ordinary high water line. Estuarine habitat consists of several lakes, bays, and sounds. Gulf of Mexico critical habitat extends from the shoreline out to 1 nautical mile (NM) (1,852 meters [m]) offshore.

Under Section 7 of the ESA, all federal agencies are required to insure that actions authorized, funded, or carried out by the agency are not likely to jeopardize the continued existence of an endangered or threatened species or result in the destruction or adverse

modification of critical habitat. As a federal agency, the Department of Defense (DoD) complies with these requirements by conducting Section 7 consultations with the National Marine Fisheries Service (NMFS) and/or the U.S. Fish and Wildlife Service (USFWS) when testing, training, or construction activities have the potential to impact Gulf sturgeon or adversely modify critical habitat. Eglin Air Force Base (AFB) schedules military activities (including Air Force, Army, Navy, and Marine Corps testing and training missions) within several areas that could result in impacts to Gulf sturgeon, including potential impacts to designated critical habitat. These areas include the Eglin Gulf Test and Training Range (EGTTR) in the Gulf of Mexico, Santa Rosa Sound, Choctawhatchee Bay, and the Yellow and Shoal Rivers. Therefore, Eglin AFB expects that consultations with the Services will continue to be required in the future due to potential impacts to Gulf sturgeon and critical habitat.

The timing and frequency of movements among different habitats of sturgeon is generally poorly understood because external marking programs have resulted in only a handful of recaptures (Adams et al., 2002). Although information on Gulf sturgeon distribution and behavior in riverine habitats is lacking to some degree, occurrence patterns are understood well enough to reasonably evaluate the effects of human activities on the species. Conversely, little has historically been known of the occurrence, spatial distribution, and movement patterns of Gulf sturgeon in the marine environment of the Gulf of Mexico, resulting in a scarcity of scientific data available for use during Section 7 consultations. However, recent significant insights into the migratory habits of marine fishes have been gained from electronic tagging. Long-lived acoustic tags, which may be detected by hydrophones, offer the potential to estimate and monitor behavior and movements of Gulf sturgeon and other large fish. In addition, the long life (three to five years) of these tags offer the additional prospect of generating information on demographic rates, such as reproductive periodicity and survival (Erickson and Webb, 2007). Such measurements are needed to assess the importance of large-scale movements of Gulf sturgeon, particularly because they are a threatened species. The relatively new field of acoustic telemetry may provide a greater understanding of the migratory behavior of Gulf sturgeon.

In response to the lack of information, Eglin AFB conducted a pilot research project in 2008 utilizing acoustic telemetry technology to determine the presence or absence, location, and timing of movement of Gulf sturgeon in Gulf of Mexico critical habitat near Eglin. The project included cooperative efforts of the Air Force, USFWS, U.S. Geological Survey (USGS), and

Florida Fish and Wildlife Conservation Commission (FWC). Based on the results of the 2008 Pilot Study, Eglin AFB expanded the scope of the study in 2009 and received funding from the DoD's Legacy Resource Management Program (Number 09-428 and 10-428) to continue the study for two more years. The results of this effort are included in this report.

Study Area

Eglin AFB consists of approximately 724 square miles of land ranges across three counties in the northwest Florida panhandle: Okaloosa, Santa Rosa, and Walton. Eglin's property also includes a 17-mile stretch of land on Santa Rosa Island (SRI), 0.5-mile wide barrier island located in the southern portion of Eglin AFB in Okaloosa and Santa Rosa counties. It is separated from mainland northwest Florida on the north by Choctawhatchee Bay and Santa Rosa Sound and bordered to the south by the Gulf of Mexico. In addition, Eglin AFB contains over 124,000 square miles of over-water air space in the Gulf of Mexico, collectively referred to as the EGTTTR. As pertains to Eglin AFB, Choctawhatchee Bay, Santa Rosa Sound, Yellow River, Shoal River, Blackwater Bay, East Bay, and the Gulf of Mexico out to 1 NM (1,852 m) offshore of SRI and Cape San Blas have been designated as Gulf sturgeon critical habitat. The EGTTTR is divided into several air space units, or warning areas. The only warning areas that contain Gulf sturgeon critical habitat are Warning Area (W)-155 and W-151. This report will mainly focus on Gulf sturgeon movements in the nearshore waters of the Gulf of Mexico off the coast of SRI within W-151 of the EGTTTR because a much higher percentage of military actions scheduled by Eglin occur in W-151 than in W-155. Some conclusions will be made concerning the eastern and western extent of Gulf sturgeon winter migration in areas outside of the EGTTTR based on a separate telemetry array also deployed in the nearshore waters of the Gulf of Mexico. It will also identify movement patterns of Gulf sturgeon in water bodies within and around Eglin AFB including the Santa Rosa Sound, Pensacola Bay, Yellow River, Blackwater River, and Escambia River.

Methods

Acoustic tagging

Adult Gulf sturgeon from four different rivers near Eglin AFB were tagged with Vemco V16 coded acoustic transmitters. Each acoustic transmitter, or tag, was surgically implanted into

the abdominal cavity and was set to emit a 69 kilohertz transmission once every 30 to 90 seconds (with a nominal time of 60 seconds). The Vemco V16 tags are about three inches long and have a battery life of around three to five years, depending on the transmission delay (Figure 3). Adult Gulf sturgeon weighing at least 50 pounds (23 kilograms [kg]) were targeted for tagging because these individuals are most likely to overwinter in the Gulf (Figures 4 – 6). All fish captures and tagging occurred in the rivers between September and October, before the fall out-migration from the rivers began. From 2008 to 2010, 40 adult Gulf sturgeon were tagged each year. In 2008, as part of the Pilot Study, tagging efforts were focused in the Choctawhatchee River. However, with other on-going Gulf sturgeon tagging projects occurring in this area already, in 2009 and 2010 tagging efforts were shifted to the Yellow River, Blackwater River, and Escambia River. All tagging activities were conducted and/or supervised by a USFWS biologist with over 30 years of experience in tagging Gulf sturgeon utilizing the proper and established protocols. In addition, all personnel who participated in tagging attended a two-day tagging workshop sponsored by the USFWS.

Receiver arrays

To track the sturgeon's movements, Vemco VR2W data-logging hydrophones, or receivers, were placed in various locations to detect the transmissions emitted from tagged individuals. Each tag emits a uniquely coded ultrasonic acoustic pulse that can be detected and distinguished by the VR2W receiver, so that individual fish can be tracked. The receivers decode, record, and store these acoustic pulses, along with other data such as date and time of detection. Receivers deployed in an estuarine or riverine environment were attached to concrete cinder blocks with rope and plastic zip ties. The blocks were then secured to a dock, piling, or other permanent structure in the water body, and sunk to the bottom with the attached receivers. VR2Ws deployed in the Gulf of Mexico required an anchor/buoy assembly to secure the receiver in open Gulf waters. The buoy/anchor system consisted of a 14-inch diameter buoy attached to galvanized steel ¼ inch cable wire that connects to a 130-pound anchor block. The receivers were attached to an aluminum bar located just beneath the buoy with bolts and zip ties and then wrapped with netting to help protect the receiver from marine growth (Figure 7).

For the 2008 Pilot Study, 13 VR2W receivers were placed in various locations in the Choctawhatchee Bay, Gulf of Mexico and Santa Rosa Sound (Figure 8). The receivers in the

Gulf were placed in three separate locations with three receivers at each location. The receivers in each array were configured to align perpendicular to the shoreline and spaced out at 500, 1,000, and 1,500 m from shore. It was thought that the receivers could detect transmissions emitted within a 500-m radius; therefore this configuration would allow coverage from the shoreline to 2,000 m from the shore, thereby encompassing the entire seaward range of critical habitat (1 NM [1,852 m]). Two receiver arrays were placed in critical habitat areas offshore of SRI, while one array was placed east of the Destin Pass. Three receivers were placed in the Santa Rosa Sound and one receiver was placed near the Intercoastal Waterway in Choctawhatchee Bay. This arrangement allowed Eglin to determine sturgeon movements in estuarine areas before they entered the Gulf, where they traveled once they entered the Gulf, and whether or not they remained in the area throughout the winter. The receivers were deployed from October 2008 to April 2009.

For 2009-2010 and 2010-2011 data collection periods, stainless steel cable was substituted for the galvanized steel to prevent corrosion due to submersion in the marine environment for an extended period of time. Additionally, the receivers were wrapped with copper foil to protect them from marine growth such as barnacles (Figure 9). Since the scope of the study was slightly expanded with the DoD Legacy funding, additional receivers were purchased and the receiver array was reconfigured based on preliminary results from the 2008 Pilot Study and to cover a wider area of the Gulf of Mexico. VR2Ws were placed in similar locations in the Gulf of Mexico as in the 2008 Pilot Study: in the nearshore waters east of the East Pass, south of Eglin's Test Site A-3, and south of Test Site A-15 on SRI. However, based on the results from the Pilot Study only two receivers per array were deployed. The outer receiver location (1,500 m from shore) was omitted because of the low sturgeon occurrence documented at that distance from the shore. Receivers in the Gulf of Mexico were placed in nearshore areas along Eglin's SRI property, east and west of the Pensacola Pass, and near Perdido Key, Alabama. They were also deployed near the mouths of the Yellow, Blackwater, and Escambia Rivers, as well as the Pensacola Bay and Santa Rosa Sound. The receivers were therefore set up to detect sturgeon movement in riverine, estuarine, and marine environments from Destin, Florida to Perdido Key, Alabama (Figures 10 and 11). This configuration allowed data collection in areas heavily utilized by the DoD for testing and training activities. Due to the battery life of the tags, the 2009-2010 and 2010-2011 array configurations were able to detect all

Gulf sturgeon tagged by Eglin from 2008 through 2010, as well as sturgeon tagged by other researchers utilizing the same acoustic technology including a 2005 study of Gulf sturgeon in the Escambia River and an on-going study of Gulf sturgeon residency patterns in the Choctawhatchee Bay. It is important to note that these studies are separate efforts and are not connected to this study. However, since the researchers also used Vemco tags, our receiver array was able to detect these individuals. Detection data from these tags are included in the analysis only as observations of the amount of Gulf sturgeon activity within our study area. Tag IDs were confirmed with the other researchers; however, this report does not include any results from these other studies.

In 2010, a separate telemetry array was deployed in the Gulf of Mexico by the USFWS, which consisted of 135 VR2W receivers that stretched from Lake Pontchartrain, Louisiana to Cedar Key, Florida. The locations of the receivers in this extensive array were provided to us as well as any detection data from Gulf sturgeon tagged as part of our study. Figure 12 shows a map of receivers from this array where Eglin-tagged sturgeon were detected. In addition, some Gulf sturgeon tagged for our study were detected by an array in the Choctawhatchee Bay. While exact locations of those receivers are not included in this report, general conclusions of our tagged Gulf sturgeon entering the Choctawhatchee Bay can be drawn from the data provided to us.

Test pinger/VR2W detection range study

The marine environment provides a more turbulent setting for conducting acoustic telemetry studies when compared to calmer estuarine or riverine environments. The sea state of the Gulf changes on a daily and, at times, hourly basis usually dependent on weather and wind speed. High levels of boat traffic and regular changes in tide also contribute to a wide range of changes in the study area which may interfere with the receiver's ability to detect transmissions. Variable transmission rates, moving fish, and unpredictable weather in a harsh marine environment were identified as potential issues that may impact a receiver's detection rate, (i.e., the receiver's success in detecting or receiving transmissions from nearby tags). To determine the percentage of actual detections received over time through various weather conditions, a separate Vemco V16 acoustic transmitter was used as a dedicated sentinel tag (test pinger) and was placed in the Gulf of Mexico 500 m from one receiver (receiver 3) and 350 m from another (receiver 4). The test pinger (transmitting once every 15 minutes) was placed at the bottom of the

Gulf to simulate a stationary fish emitting a continuous and regular transmission to be detected by the nearby VR2Ws (Figure 13). Once deployed, both receivers began receiving transmissions from the test pinger. This study was conducted during the 2009-2010 and 2010-2011 data collection periods.

Results

Acoustic tagging

Table 1 is a list of all Gulf sturgeon tagged between 2008 and 2010. Forty sturgeon from the Choctawhatchee River were tagged in 2008. Fork length (FL) ranged from 138-196 centimeters (cm) and weight ranged from 21-64 kg. Total length (TL) and sex of the sturgeon were not recorded. Of these, 26 were detected by the 2008-2009 array deployed between October 2008 and April 2009, 14 were detected by the 2009-2010 array deployed between October 2009 and April 2010, and 8 were detected by the 2010-2011 array deployed between October 2010 and May 2011.

In 2009, 40 total sturgeon were tagged from the Yellow River, Blackwater River, and Escambia River. Twelve were from the Yellow River, including two females. FL ranged from 123-189 cm and weight ranged from 14-54 kg. All 12 were detected by the 2009-2010 array and 11 were detected by the 2010-2011 array. Twenty-five sturgeon were tagged in the Blackwater River, including 14 females. FL ranged from 132-188 cm and weight ranged from 14-63 kg. Of these, 24 were detected by the 2009-2010 and 2010-2011 arrays. One tagged individual was not detected on either array. Finally, three sturgeon were tagged in the Escambia River in 2009, including two documented females. FL ranged from 160-179 cm and weight ranged from 36-54 kg. All three sturgeon from the Escambia River were detected in the 2009-2010 and 2010-2011 arrays.

In 2010, 40 more sturgeon were tagged from the Yellow, Blackwater, and Escambia Rivers. Fourteen were from the Yellow River with FLs ranging from 128-187 cm and weight ranging from 16-47 kg. All of these tagged individuals were detected in the 2010-2011 array. Eleven sturgeon were tagged from the Blackwater River in 2010, three of which were females. FL ranged from 116-188 cm and weight ranged from 14-56 kg. One of these tagged sturgeon was not detected in the 2010-2011 array. Lastly, 15 sturgeon were tagged in the Escambia River with FLs ranging from 127-191 cm and weight ranging from 16-62 kg. Two of these individuals

were detected within a day after being implanted with a tag, but no more detections were received from them. All other sturgeon tagged in the Escambia River were detected on the 2010-2011 array.

Table 2 summarizes the tagging results and shows the detection success for each year. As Table 2 shows, detection success of tagged sturgeon in the Choctawhatchee River was much lower than that for the Yellow, Blackwater, and Escambia Rivers. Only 65 percent (26 of 40) of the tagged individuals were detected during the 2008 Pilot Study, whereas 96 to 100 percent of sturgeon tagged in the Yellow, Blackwater, and Escambia Rivers were detected during the 2009-2011 data collection period. One reason for this could have been the smaller number of receivers used for the Pilot Study and the limited area monitored during this effort. However, the following two years showed even lower detection rates (35 and 20 percent) although more VR2Ws were deployed in an expanded array design, providing a wider area of coverage. Some of the undetected individuals may have stayed in areas of the Choctawhatchee Bay that were not monitored and others may have entered the Gulf undetected. As the study progressed over the next two years, it is also likely that tag battery life may have been a factor for some Choctawhatchee River-tagged sturgeon going undetected. Since sturgeon tagged in the Yellow, Blackwater, and Escambia Rivers showed a higher detection success, detection data and the resulting conclusions made about sturgeon from these rivers are likely more accurate since a higher percentage of tagged individuals were represented in the data analysis.

Receiver arrays

Table 3 lists the GPS coordinates of receiver deployment locations. The maps in Figures 8, 10, and 11 only show the general locations of each receiver. As both the table and the figures depict, each year the array was modified to accommodate either the expanding scope of the study that occurred in 2009 or to account for lost receivers. Twenty-one VR2Ws were utilized for the 2009-2010 data collection period; however, several unforeseen events and issues such as tropical storms and public interference arose which led to either the loss or relocation of VR2Ws within the array. Detections from the remaining 18 VR2Ws in the 2009-2010 array set-up are included in the analysis. For the 2010-2011 data collection period, the 18 remaining VR2Ws were re-deployed in the same locations as in the 2009-2010 data collection period, where possible. A few locations were omitted because fewer receivers were available but the same general areas were

monitored for consistency between the two years of monitoring and data collection. During the 2010-2011 data collection period, one more VR2W went missing, likely due to inclement weather in the Gulf of Mexico, therefore detections from the 17 remaining receivers in the 2010-2011 array are included in the analysis.

Detections

Of the 40 sturgeon tagged in 2008, 26 were detected either by the 2008-2009 array or by hand-held hydrophone tracking conducted by the USFWS. Sturgeon were found to move through the Santa Rosa Sound, and both east and west in the Gulf after passing through the Destin Pass. No receivers were deployed near the Pensacola Pass therefore it is unknown whether sturgeon from this tagging effort moved into or out of the Gulf through the Pensacola Pass. The most inshore receivers (deployed approximately 500 m from the shoreline) recorded the majority of detections (approximately 82 percent), suggesting that these individuals remained close to the shore while in the Gulf of Mexico. The middle receivers (deployed approximately 1,000 m from the shoreline) recorded 18 percent of the detections, while the receivers located furthest from shore (approximately 1,500 m from the shoreline) recorded less than one percent. Of the three receivers deployed 1,500 m from shore, one VR2W recorded only four detections from a single tagged sturgeon, compared to approximately 4,000 detections received on the VR2Ws deployed closer to the shoreline. In addition, few sturgeon detections were documented from mid-December through the early March, suggesting that the sturgeon moved away from this area near Eglin's SRI property during this time. The last Gulf sturgeon detection documented in the Gulf of Mexico occurred on 3/13/2009, suggesting the spring migration back to the Choctawhatchee River had begun at this time.

The 2009-2010 array collected 161,569 detections from 86 tagged sturgeon between late September 2009 to mid-May 2010. Figure 14 shows the total number of detections received compared to the total number of sturgeon detected by each receiver for the 2009-2010 data collection period. Of the 40 sturgeon tagged in 2009, 39 were detected by this expanded array design. Furthermore, 14 of the 40 sturgeon tagged in 2008 were also detected during the 2009-2010 data collection. Thirty of the sturgeon were tagged in the Choctawhatchee River by other researchers studying Gulf sturgeon habitat use and patterns of residency in the Choctawhatchee Bay and three sturgeon were tagged in 2005 in the Escambia River.

Gulf of Mexico receiver distances from the shore (estimated in ArcGIS), water depth, and total detections received in the 2009-2010 array and the 2010-2011 array are listed in Table 4. Receivers that are designated as inshore receivers are those deployed between 200 m and 500 m from the shore which included receiver numbers 1, 3, 5, 19, and 21. Water depths ranged from 5 m to 7 m (15 ft to 24 ft). Receivers designated as offshore receivers are ones deployed between 600 m and 1,300 m from the shore which included receiver numbers 2, 4, 6, 8, and 20. Water depths ranged from 5 m to 17 m (15 ft to 56 ft). Similar to the 2008 Pilot Study, the majority of detections (73 percent) were recorded on the inshore receivers in the Gulf when compared to offshore receivers (27 percent).

The 2010-2011 array collected 422,340 detections from 126 tagged sturgeon between early October 2010 to late May 2011. Figure 15 shows the total number of detections received compared to the total number of sturgeon detected by each receiver for the 2010-2011 data collection period. Of the 40 sturgeon tagged in 2010, 39 were detected by the 2010-2011 array design. In addition, 38 of the 40 sturgeon tagged in 2009, and nine of the 40 sturgeon tagged in 2008 were also detected by this year's array. Forty of the sturgeon tagged between 2009 and 2010 in the Choctawhatchee River as part of the Gulf sturgeon habitat use and residency study in the Choctawhatchee Bay were also detected on the 2010-2011 array.

The distribution of detections between inshore and offshore receivers was different this year compared to the previous two years' findings (Figure 16). Only 18 percent of the total detections were received on inshore VR2Ws which included receiver numbers 1, 3, 5, 7, and 16. Meanwhile, 82 percent of the total detections were received on the offshore portion of the array, which included receiver numbers 2, 4, 6, 8, and 17. Detections on offshore receiver 2 alone, located approximately 1,250 m from the shore in water depth of 17 m, accounted for 60 percent of the total detections for all Gulf receivers in the 2010-2011 array. The amount of sturgeon activity at this location (east of the East Pass) is substantially higher than what was documented the previous year with only 882 detections received in 2009-2010. Even with the greater number of tagged sturgeon available to be detected in 2010-2011, there seemed to be a shift in habitat preference based on the amount of detections received on receivers 3 and 4 in 2009-2010 (77,475 total detections) compared to 2010-2011 (17,858 total detections).

Overall movement patterns

Gulf sturgeon migration into and out of the Gulf of Mexico has been estimated to occur in November and April, respectively. Within our study area, Gulf sturgeon may enter the Gulf either through the Pensacola Pass or the East Pass and from there will head either east or west. The placement of VR2Ws in the Gulf has allowed us to capture movement patterns and distribution of Gulf sturgeon during the winter months. Figures 17 and 18 show how detections were distributed across our study area from October 2009 through May 2010 and October 2010 through May 2011, respectively. The number of detections is shown as ranges and color coded on each map as described in Table 5 and includes all tagged sturgeon. As both figures indicate, the fall outmigration from the rivers to the Gulf had apparently already begun by October. This is suggested by the detections on the Pensacola Bay and Santa Rosa Sound receivers in October for both years. By November, most if not all sturgeon have left the rivers and the first detections in the Gulf have been documented on the VR2Ws deployed near the Pensacola Pass and East Pass. Activity in the Pensacola Bay and Santa Rosa Sound has also increased during this time as the remaining tagged sturgeon are completing their fall outmigration. Gulf sturgeon activity peaked in the Gulf of Mexico during December and January for both years, especially around the East Pass. Detections remain high in February in this part of the study area, while areas near Eglin's property on SRI have a lower level of activity. In 2010-2011, detections were being recorded in the Santa Rosa Sound throughout the entire winter, suggesting that some of the tagged sturgeon did not enter the Gulf at all. This could support the possibility of year-round sturgeon occurrence in the Santa Rosa Sound, which has not been fully investigated. In March, detections around the Pensacola Pass increased, marking the beginning of the spring spawning migration from the Gulf back to the rivers. The first detections in the Yellow River for the spring were also captured in March for both years.

Figure 19 shows similar detection maps as Figures 17 and 18, however this depicts activity only from Eglin-tagged sturgeon that were detected on the USFWS array from October 2010 to May 2011. Based on the results from this array of VR2Ws it appears that the western extent of Gulf sturgeon winter migration ends in the nearshore waters of the Mississippi Gulf Coast. The western portion of the USFWS array documented a much higher level of sturgeon activity than any other area in this region of the Gulf of Mexico (Figure 20). Since the majority of the sturgeon tagged by Eglin were from either the Yellow, Blackwater, or Escambia Rivers, it

seems that once sturgeon from these rivers enter the Gulf of Mexico in the winter, they will typically head west and inhabit the inshore waters off the Alabama and Mississippi Gulf coasts. Figure 21 shows how detections are distributed temporally throughout the winter within different regions of the Gulf of Mexico based on receiver deployment locations. While some sturgeon activity is documented throughout the winter in the nearshore waters off Eglin's property on SRI, it does not appear to be the most desirable location for sturgeon to overwinter when compared to other parts of the Gulf of Mexico.

Gulf sturgeon movements by river system

Detections alone do not tell the complete story of sturgeon migration patterns and movements in the Gulf of Mexico during the winter. The number of sturgeon detected and river source of each tagged individual may be indicative of certain movement behaviors while they are overwintering in the Gulf. Figures 22 and 23 show the total number of sturgeon detected at each receiver in the Eglin 2009-2010 and 2010-2011 arrays, respectively. The numbers of sturgeon detected are separated by river origin, where sturgeon tagged in the Yellow, Blackwater, and Escambia Rivers are grouped together and sturgeon tagged in the Choctawhatchee River are categorized separately. The sturgeon tagged in the Yellow, Blackwater, and Escambia Rivers are grouped in the same category because the individuals that overwinter in the Gulf use similar fall outmigration routes; they all exit the rivers, travel through the Pensacola Bay and Santa Rosa Sound, then enter the Gulf of Mexico through the Pensacola Pass. Sturgeon tagged in the Choctawhatchee River that overwinter in the Gulf travel through the Choctawhatchee Bay and Santa Rosa Sound, and then enter the Gulf of Mexico through the East Pass. These fish include those tagged by Eglin in 2008 and sturgeon tagged for the study on residency and habitat use in the Choctawhatchee Bay. Both years show similar results; most of the activity within the nearshore waters off Eglin's property is from sturgeon tagged in the Choctawhatchee River. Furthermore, this confirms that most sturgeon tagged in the Yellow, Blackwater, and Escambia Rivers indeed entered the Gulf through the Pensacola Pass and proceeded to head west for the winter.

Figure 24 shows the number of sturgeon from the Yellow, Blackwater, and Escambia Rivers that were detected on both the Eglin and USFWS 2010-2011 Gulf of Mexico arrays. As mentioned before, once these sturgeon entered the Gulf, most of them headed west, which is

depicted by the higher number of sturgeon detected on the western portion of the USFWS array. While a few sturgeon from the Yellow and Escambia Rivers were detected on the eastern portion of the USFWS array, no Blackwater River-tagged sturgeon were documented in this area of the Gulf. The following subsections will examine the movements of sturgeon tagged from different river systems more closely.

Yellow River

Twelve sturgeon were tagged in the Yellow River during the fall of 2009; therefore, two years of detection data have been collected on these individuals on Eglin's 2009-2010 and 2010-2011 arrays. During the 2009-2010 data collection period, three of the twelve tagged individuals (tag IDs 61026, 61027, and 61036) were not detected on any Gulf of Mexico receivers. No detections on any receiver were documented from mid-December to early March for 61026, early October to late March for 61027, and mid-November to mid-March for 61036. While it is possible that these individuals may have entered the Gulf un-detected, their actual overwintering location is not known. These individuals were on the smaller side of the size spectrum of the sample, with FLs of 123.19 cm, 129.54 cm, and 147.32 cm and weights of 14.17 kg, 18.6 kg, and 24.27 kg. Of the remaining nine that did enter the Gulf, only two of them were detected on receivers in the nearshore waters off Eglin's property on SRI. The others were detected near the Pensacola Pass and from the lack of detections anywhere else, likely headed west outside the study area. The first detections on Gulf of Mexico receivers occurred between 11/11/2009 and 12/20/2009 and the last detections occurred between 2/14/2010 and 4/12/2010. All but one sturgeon returned to the Yellow River in the spring. Tag ID 61016 was last detected in the Santa Rosa Sound on 3/19/2010, which may indicate that this individual re-entered the rivers after the data collection period was completed. Another sturgeon was detected in the Blackwater River on 5/8/2010 before returning to the Yellow River nearly a week later on 5/14/2010.

For the 2010-2011 data collection period, an additional 14 sturgeon were tagged in the Yellow River during the fall of 2010. A total of 26 Gulf sturgeon from the Yellow River were tracked on the 2010-2011 array. One tag ID (61025) was not detected on any receiver during the 2010-2011 data collection period. The last detection received from this individual occurred on 3/28/2010 on the VR2W deployed in the Yellow River. If a mortality occurred, it is not likely to have been a result of complications from surgery while implanting the tag because it went

through an entire winter and spring migration cycle. Of the remaining tagged sturgeon, five individuals were not detected on any Gulf of Mexico receivers. Two of them were IDs 61027 and 61036, which were also not detected in the Gulf of Mexico the previous year. Both of these individuals were detected in the Santa Rosa Sound and Pensacola Bay in January, February and March, showing that they did not overwinter in the Gulf. Another was tag ID 61016 (FL = 159.39 cm; weight = 28.8 kg when tagged in 2009) which was detected in the Gulf the previous year, but was not recorded on any receiver between 11/22/2010 and 3/20/2011. Due to a lack of any detections during this time no conclusions can be drawn about the overwintering location for this individual. Tag IDs 46440 (FL = 139 cm; weight = 21.7 kg) and 46445 (FL = 145 cm; weight = 23.2 kg) were also not detected in the Gulf. These individuals were among the smaller portion of the sample and appeared to overwinter in the Santa Rosa Sound and Pensacola Bay instead of entering the Gulf. This is evidenced by detections from both IDs on the VR2Ws deployed in the Sound and Bay in December, January, February, and March.

The remaining 20 sturgeon tagged in the Yellow River entered the Gulf of Mexico during the winter of 2010-2011. The first detections in the Gulf occurred between 11/9/2010 and 12/15/2010. All of these sturgeon entered the Gulf through the Pensacola Pass. Eleven of them continued west and were detected on the western portion of the USFWS array. Tag ID 61020 was detected the furthest west on a USFWS receiver deployed in the nearshore Gulf waters off Fort Morgan, Alabama, just south of Mobile Bay (approximately 66 km west of the Pensacola Pass). This sturgeon was the largest individual tagged in the Yellow River in 2009 with a FL of 189.23 cm and weighed 53.52 kg when tagged. The westernmost extent of the winter migration of other Yellow River-tagged sturgeon detected on this array was to Gulf Shores, Alabama (approximately 45 km west of Pensacola Pass). Three Yellow River-tagged sturgeon headed east instead of west, and were detected on receivers within Eglin's Gulf of Mexico array, near the East Pass, and two of the three were detected on the eastern portion of the USFWS array. Tag ID 46457 (FL = 132 cm; weight = 16.9 kg) was detected out by St. Joseph Peninsula, Florida (approximately 124 km southeast of the East Pass) and tag ID 46428 (FL = 187 cm; weight = 47 kg) was detected near Dog Island, Florida (approximately 236 km southeast of the East Pass). Tag ID 46428, which was detected the furthest distance from the Yellow River, was the largest sturgeon tagged in this river in 2010.

The last detections in the Gulf occurred between 3/2/2011 and 4/7/2011. Of the 25 Yellow River-tagged sturgeon that were detected on the 2010-2011 array, eight did not return to the Yellow River. Of those eight, one was first detected in the Blackwater River on 4/13/2011 before it returned to the Yellow River five days later; four returned to the Blackwater River between 4/14/2011 and 5/17/2011 and were not detected in the Yellow River at all; and three were last detected in the Gulf between 3/19/2011 and 3/24/2011 but were not detected again. The remaining 17 sturgeon that did return to the Yellow River in the spring entered the river between 3/14/2011 and 4/11/2011.

Blackwater River

Twenty-five Gulf sturgeon from the Blackwater River were tagged in the fall of 2009. During the 2009-2010 data collection period, one individual was not detected after tagging. Three of the remaining 24 Blackwater River-tagged sturgeon were not detected on Gulf of Mexico receivers in the 2009-2010 receiver array (tag IDs 61007, 61028 and 61045). Tag ID 61007 was among the smaller of the sample with a FL of 141.61 cm and weighed 22.23 kg. Tag IDs 61028 and 61045 were larger female sturgeon with FLs of 187.96 cm and 175.26 cm and weighed 60.21 kg and 42.64 kg, respectively. Each of these individuals were not detected between November and early March on any VR2W in the 2009-2010 array, therefore no conclusions can be made as to where they overwintered during that time. Four of the Blackwater River-tagged sturgeon that entered the Gulf were detected on receivers deployed in the nearshore waters off of Eglin's properties on SRI and three of those were detected on receivers near the East Pass. The remaining 17 were detected near the Pensacola Pass only and presumably headed west from there to overwinter. The first detections in the Gulf were received between 10/28/2009 and 12/14/2009 and the last detections were received between 3/1/2010 and 4/16/2010. The majority of the Blackwater River-tagged sturgeon actually returned to the Yellow River in the spring instead of going directly to the Blackwater. These individuals entered the river between 3/12/2010 and 4/23/2010. Four Blackwater River-tagged sturgeon entered the Yellow River between 3/8/2010 and 4/16/2010 before returning to the Blackwater River between 5/5/2010 and 5/16/2010. Only four of the 24 Blackwater River-tagged sturgeon returned directly to the Blackwater River in the spring, between 4/13/2010 and 5/17/2010. One sturgeon first returned to the Blackwater River in April, but was later detected in the Yellow River in May.

Two sturgeon (tag IDs 61006 and 61042) entered the Escambia River between 4/3/2010 and 4/5/2010, one sturgeon (tag ID 61007) was last detected in Pensacola Bay on 3/12/2010 and one (tag ID 61014) was last detected in the Gulf by the East Pass on 3/26/2010.

For the 2010-2011 data collection period, an additional 11 Gulf sturgeon were tagged in the Blackwater River during the fall of 2010. One of these individuals (tag ID 46436) was not detected, which suggests that it died shortly after being tagged. Tag ID 61011 was not detected on any of the receivers on the 2010-2011 array either, which may confirm that this individual died shortly after being tagged in 2009. As a result, 34 sturgeon from the Blackwater River were tracked during the 2010-2011 data collection period. Eleven of the sturgeon tagged in 2009 were detected in the Yellow River at some point during the summer after the 2009-2010 data collection was complete. Tag ID 61014, last detected near the East Pass at the end of the 2009-2010 data collection period, was later detected in the Choctawhatchee Bay, which suggests that it spent the summer in the Choctawhatchee River instead of returning to the Blackwater River.

Of the 34 Blackwater River-tagged sturgeon, five were not detected on Gulf receivers during the winter. Tag ID 61007 once again did not appear to enter the Gulf, similar to the previous year. For both years, there are no detections from this ID from November through mid-March on any receivers within the array. Therefore the exact location of the overwintering habitat for this individual is unknown. Tag IDs 61032 and 46430 showed similar behavior in that there were no detections for these IDs between 12/2/2010 – 4/5/2011 and 11/10/2010 – 4/15/2011, respectively. While tag ID 61032 was one of the smaller sturgeon tagged in 2009 (FL = 132.08 cm; weight = 20.18 kg), it was documented on Gulf VR2Ws deployed near the Pensacola Pass and Eglin's property on SRI in 2009-2010. Therefore the lack of detections during the 2010-2011 data collection period may not conclusively prove that it did not enter the Gulf during the winter. Tag ID 46430 also belonged to a smaller sturgeon (FL = 116 cm; weight = 14.1 kg), but due to the absence of detections from November to April, no conclusions can be made as to where it overwintered in 2010-2011. The other two tag IDs not detected in the Gulf (61043 and 46425) were documented on the Santa Rosa Sound and Pensacola Bay receivers at various times during December and January which supports the conclusion that they did not overwinter in the Gulf. Tag ID 61043 was tagged in 2009 with a FL of 124.46 cm and weighed 14.17 kg, however tag ID 46425 was a larger sturgeon with a FL of 174 cm and weighed 43.65 kg.

The remaining 29 Blackwater River-tagged sturgeon entered the Gulf between 10/27/2010 and 12/21/2010. All but one entered the Gulf through the Pensacola Pass and either remained in that area for the winter or headed west. Tag ID 61014, which was detected in the Choctawhatchee Bay on 11/10/2010, entered the Gulf through the East Pass and headed west to overwinter in the nearshore waters by Eglin's SRI property and the Pensacola Pass. Twenty-one Blackwater River tag IDs were documented on VR2Ws from the western portion of the USFWS array. Tag ID 61034 was detected the furthest west of all Eglin-tagged sturgeon on a USFWS receiver deployed in the Gulf south of Biloxi, Mississippi (approximately 144 km west of the Pensacola Pass). This sturgeon was a large female tagged in 2009 with a FL of 186.69 cm and weighed 57.83 kg. Other Blackwater River-tagged sturgeon were detected on USFWS receivers deployed in Gulf areas south of Pascagoula, Mississippi (approximately 120 km west of the Pensacola Pass) and around Dauphin Island, Alabama (approximately 100 km west of the Pensacola Pass). No Blackwater River-tagged sturgeon were recorded on the eastern portion of the USFWS array.

The last detections on Gulf receivers occurred between 2/16/2011 and 4/18/2011. Of the 34 Blackwater River-tagged sturgeon detected on the 2010-2011 array, 11 were not documented to re-enter the rivers at the end of the data collection season. Six were last detected in the Pensacola Bay, four were last detected in the Santa Rosa Sound, and one was last detected in the Gulf near Eglin's property. It is likely that the ten sturgeon that remained in the Bay and Sound re-entered the rivers at a later time, after the receivers had been collected. The one sturgeon that was last detected in the Gulf was tag ID 61014, so it presumably returned to the Choctawhatchee Bay where it was detected in the fall of 2010. The remaining 23 sturgeon entered the rivers between 3/21/2011 and 5/15/2011. Only five Blackwater River-tagged sturgeon returned to the Blackwater River between 4/11/2011 and 5/15/2011. One sturgeon entered the Blackwater River on 4/20/2011 and was later detected in the Yellow River on 5/2/2011. Seven sturgeon were first detected in the Yellow River between 3/8/2011 and 4/5/2011 before returning to the Blackwater River between 5/4/2011 – 5/27/2011. The remaining ten sturgeon returned to the Yellow River between 3/22/2011 and 4/12/2011.

Escambia River

Only three Gulf sturgeon were tagged in the Escambia River in the fall of 2009 and all three were detected on Gulf receivers during the 2009-2010 data collection period. The first detections in the Gulf occurred between 11/7/2009 and 12/31/2009. Tag IDs 61008 and 61033 were documented on Gulf receivers in the nearshore waters off Eglin's property on SRI as well as near the East Pass. Tag ID 61008 belonged to a large female with a FL of 177.8 cm and weighed 53.75 kg when tagged. Tag ID 61033 belonged to a medium-sized sturgeon with a FL of 160.02 cm and weighed 36.06 kg. The last detections in the Gulf for these IDs occurred on 4/1/2010 and 4/12/2010. Both of these individuals returned to the Escambia River in the spring between 4/5/2010 and 4/12/2010. The other Escambia River-tagged sturgeon (tag ID 61015) was only documented near the Pensacola Pass and likely headed west for the winter. This ID belonged to a medium-sized female with a FL of 160.02 cm and weighed 37.65 kg when tagged. She was last detected in the Gulf on 3/30/2010. Later that spring this individual did not return to the Escambia River, but instead was detected in the Blackwater River on 4/20/2010.

In the fall of 2010, 15 additional Gulf sturgeon were tagged in the Escambia River for the 2010-2011 data collection period. Two of these individuals (tag IDs 46422 and 46444) were detected briefly after being tagged but were not detected again on any receiver in the 2010-2011 array, suggesting that they did not survive the tagging procedure. The remaining 16 Escambia River-tagged sturgeon (including those tagged in 2009) were documented to enter the Gulf between 11/8/2010 and 12/22/2010. Tag IDs 61008 and 61033 were the only individuals that traveled east once they entered the Gulf, similar to the previous year. These sturgeon were detected on receivers near Eglin's property, the East Pass, and even on the eastern portion of the USFWS array. Both were documented on receivers deployed in the Gulf on the west coast of St. Joseph Peninsula, Florida, but ID 61008 traveled slightly farther (approximately 135 km southeast from the East Pass) than ID 61033 (approximately 125 km southeast from the East Pass). In addition, tag ID 61008 traveled west when it first entered the Gulf and was recorded on a USFWS receiver deployed near Orange Beach, Alabama (approximately 28 km west of the Pensacola Pass) in mid-November before heading east in December. Eleven other Escambia River-tagged sturgeon were also detected on the western portion of the USFWS array. Tag ID 46452 traveled the farthest west and was detected on a USFWS receiver deployed in the Gulf south of Fort Morgan, Alabama (approximately 66 km west of the Pensacola Pass). This

sturgeon was the one of largest sturgeon tagged in the entire sample with a FL of 191 cm and weighed 62.05 kg. Other Escambia River tag IDs were documented on receivers near Gulf Shores, Alabama (approximately 45 km west of Pensacola Pass) and Orange Beach, Alabama (approximately 28 km west of the Pensacola Pass).

The last detections in the Gulf occurred between 2/16/2011 and 4/1/2011. None of these sturgeon were documented to return to the Escambia River in the spring and only six were detected on other River receivers. Four were found to enter the Blackwater River between 4/13/2011 and 5/13/2011. Two entered the Yellow River between 3/31/2011 and 3/23/2011, but one of them was later detected in the Blackwater River on 5/27/2011. Eight of the Escambia River-tagged sturgeon were last detected on Gulf receivers and two were last detected in the Santa Rosa Sound so it is likely that these individuals had not completed their spring spawning migration when the VR2Ws were collected at the end of the data collection period. Furthermore, given that the VR2W was deployed in a location farther north along the Escambia River instead of at the mouth, no definitive conclusions can be made as to whether they returned to the Escambia River in the spring or not.

Choctawhatchee River

Of the 40 Gulf sturgeon tagged in the Choctawhatchee River in 2008, only 13 were detected on the 2009-2010 array. Tag ID 51891 was the only individual among the 13 not detected on any Gulf receivers, but was detected in the Santa Rosa Sound in December and March. With a FL of 175 cm and weight of 42.3 kg when tagged in 2008, this large sturgeon likely overwintered in the Santa Rosa Sound in 2009-2010. The remaining 12 Choctawhatchee River-tagged sturgeon entered the Gulf through the East Pass between 11/11/2009 and 12/19/2009. All but one were detected on receivers near Eglin's property and six were detected near the Pensacola Pass. The last detections in the Gulf occurred between 3/9/2010 and 5/9/2010. Since no VR2Ws associated with this study were deployed in the Choctawhatchee Bay or Choctawhatchee River and none of these individuals were detected on the other River receivers, it is presumed that they all eventually returned to the Choctawhatchee River later that spring.

Similar movement patterns were observed during the 2010-2011 data collection period, however only eight Choctawhatchee River-tagged sturgeon were detected on the 2010-2011 array. The first detections in the Gulf occurred between 11/16/2010 and 12/20/2010 as these

sturgeon entered the Gulf through the East Pass. Seven of them were detected on receivers deployed in the nearshore waters off Eglin's SRI property and six were detected by the Pensacola Pass. Tag IDs 51884, 51920, and 51922 were detected on both the eastern and western portion of the USFWS array. Tag ID 51884 belonged to a large sturgeon (FL = 174 cm; weight = 48.6 kg when tagged in 2008) that traveled the farthest west of all Choctawhatchee River-tagged sturgeon. This individual was detected on a USFWS receiver south of Gulf Shores, Alabama (approximately 45 km west of Pensacola Pass) throughout the month of December and was later detected on a USFWS receiver just south of Cape San Blas, Florida (approximately 149 km southeast from the East Pass) during mid-March. Tag ID 51920 (FL = 168 cm; weight = 41.2 kg when tagged in 2008) showed sporadic movements throughout the 2010-2011 winter. After spending some time near Eglin's property in the Gulf in early December, it re-entered the Choctawhatchee Bay for a few days and then re-entered the Gulf and headed east from there. It was later detected on a receiver just off the west coast of St. Joseph Peninsula (approximately 135 km southeast from the East Pass) in early March when it made its way back west and was detected on a USFWS receiver about five km west of the Pensacola Pass about two weeks later, traveling approximately 217 km during that time period. Tag ID 51922 (FL = 191 cm; weight = 51.1 kg when tagged in 2008) also showed sporadic movements throughout the Gulf. Upon entering the Gulf in November, it originally headed east and was detected on a USFWS receiver south of Blue Mountain Beach, Florida (approximately 29 km southeast from the East Pass) but then turned around and headed west and showed up on a USFWS receiver five km west of the Pensacola Pass nearly three weeks later. Afterwards, this sturgeon turned around again and traveled the farthest east of all Choctawhatchee River-tagged sturgeon, hitting receivers deployed all along the Florida Gulf coast where it reached its final destination in mid-January at a USFWS receiver deployed just south of St. Vincent Island, Florida (approximately 172 km from the East Pass). Two other Choctawhatchee River-tagged sturgeon were detected on the eastern portion of the USFWS array, traveling as far as the west coast of St. Joseph Peninsula, Florida (approximately 135 km southeast from the East Pass). The remaining two Choctawhatchee River-tagged sturgeon stayed in the nearshore waters of Eglin's SRI property and near Pensacola Pass.

The last detections in the Gulf were recorded between 2/1/2011 and 4/10/2011. One sturgeon was detected on the Choctawhatchee Bay array in late February and another sturgeon

was detected in the Yellow River where it remained from late March to early May. All the other Choctawhatchee River-tagged sturgeon were last detected in the Gulf where presumably they began their spring spawning migration sometime after the VR2Ws were collected at the end of the data collection period.

River fidelity

Blackwater River-tagged sturgeon showed the lowest level of river fidelity when compared to sturgeon tagged from other rivers. In the 2009-2010 data collection period, 64 percent (16 out of 25) of sturgeon tagged in the Blackwater River were detected in the Yellow River at some point in the spring. Thirteen of those individuals were detected in the Blackwater River at the beginning of the 2010 fall outmigration. For the 2010-2011 data collection period, half of the Blackwater River-tagged sturgeon were detected in the Yellow River during the spring of 2011. Ten Blackwater River sturgeon were last detected in either the Pensacola Bay or Santa Rosa Sound, suggesting that they had not completed their spring spawning migration; therefore it is not known which river they entered to spend the summer months. Yellow River-tagged sturgeon, on the other hand, showed a much higher level of river fidelity. Eighty-three percent (10 out of 12) of those tagged in 2009 returned directly to the Yellow River. Only one individual was detected in the Blackwater River before returning to the Yellow. During the 2010-2011 data collection period 65 percent (17 out of 26) of Yellow River-tagged sturgeon returned directly to the Yellow River. Only five were detected in the Blackwater River during the spring of 2011. Thirty-three percent (6 out of 18) of Escambia River-tagged sturgeon were also documented to enter either the Yellow or Blackwater Rivers during the spring of 2011. The rest of those individuals were last detected either in the Gulf of Mexico, Santa Rosa Sound, or Pensacola Bay at the end of the 2010-2011 data collection period, so it is not known which river they entered to spend the summer. In total, 50 percent of sturgeon tagged in 2009 (20 of 40) and 36 percent of sturgeon tagged in 2010 (29 of 80) from the Yellow, Blackwater, and Escambia Rivers were detected in rivers where they were not originally tagged. This documented level of river-swapping combined with similar movement patterns observed during the winter, may support the theory that sturgeon from the Yellow, Blackwater, and Escambia Rivers could be considered as one population unit.

Test pinger analysis

Upon downloading the data from the VR2Ws, the test pinger ID was separated out from the rest of the detection data. Test pinger detection data captured on receivers 3 and 4 were then compiled and analyzed. The corresponding average daily wind speed was collected and compared to the number of detections received per day on each receiver. The test pinger detection data in the 2009 – 2010 study were averaged with the test pinger detection data in the 2010 – 2011 study. Based on the comparison, a negative correlation was found such that low numbers of detections were typically received during time periods of high winds and high numbers of detections were usually received during time periods of low winds (Figure 25). As indicated in the figure, the maximum possible detections were received on days with very low wind averages. Conversely, days with low detection reception correlated with high daily wind speed averages.

To focus in on this correlation, the specific detection rate associated with a given wind speed was calculated for the data set. To calculate detection rates for a given day, the total detections received per day on both receivers were tallied and averaged. The detection rate was determined by dividing the average number of detections received by the maximum possible detections. Daily average wind speed was also collected. Table 6 shows this information sorted by wind speed averages.

Figure 26 shows the relationship between detection rates and daily average wind speed where average detection rates (in percentages) were plotted over wind speed (in miles per hour) for the data collected between 2009-2010 and 2010-2011; a trend line was fitted to this curve to estimate average detection rates for a given wind speed. Figure 26 shows that weather conditions causing wind speeds greater than 15 miles per hour (mph) (which can produce waves in the Gulf higher than 3 feet) can lower a receiver's detection rate to 35 percent or less. A fairly high (70 percent or more) detection rate was found for winds that were less than 6 mph. Wind speeds of nine mph or more resulted in greater variability of detection rate around the trend line, with detection rates between approximately 35 and 71 percent. The reason for this level of variation is not known; however changes in wind direction (i.e., northerly vs. southerly or leeward vs. windward) affects the sea state differently, which can create different levels of interference in the water column that prevents the VR2Ws from detecting transmissions. Differing locations and scales of thermoclines would also affect the transmission over long time periods of data

collection. The average wind speed over the entire course of the test pinger investigation was approximately 7.2 mph. Therefore, according to the results of this investigation, an estimated 68 percent of all transmissions emitted from the V16 tags would be detected by VR2Ws deployed in this part of the Gulf.

Comparing the data downloaded from receiver 4 (350 m distance from test pinger) and receiver 3 (500 m distance from test pinger), revealed that receiver 3 contained far fewer detections than receiver 4. Hourly wind data was collected and compared with the hourly detections received on each receiver to determine what the weather conditions were during the time periods of missing detections. The results indicate that a VR2W's ability to detect transmissions is likely less at a 500 m distance than at a 350 m distance, especially when wind speeds exceed 15 mph (Figure 27). Therefore 350 m would be a more accurate detection range in an environment such as that of the Gulf of Mexico. This is evidenced by receiver 4 detecting transmissions that were missed on receiver 3 under the same weather conditions. This point is further illustrated in Figure 28, which shows a graph comparing average detection success of receiver 4 (350 m distance) to the average detection success of receiver 3 (500 m distance) over a given daily average wind speed. Receiver 4 consistently demonstrates a higher rate of detection success over all wind speeds when compared to receiver 3.

Discussion

Before 2008, Gulf sturgeon temporal and spatial activity in the Gulf of Mexico during the winter was relatively unknown to science. Unsatisfied with the amount of knowledge of this species in the marine environment when dealing with the complexities of permitting with the NMFS, personnel at Eglin AFB and colleagues set out to answer these questions. The amount of information gained from this study, including similar efforts from other researchers between 2008 and 2011, has expanded the knowledge of Gulf sturgeon overwintering activity significantly. All federal agencies must consult on testing, training, or construction activities that have the potential to impact Gulf sturgeon or adversely modify their critical habitat. DoD actions that require Section 7 consultation and/or NEPA analysis will greatly benefit from the results in this report. Prior to this study, assumptions about spatial and temporal distribution erred on the conservative side and simply assumed equal presence of the species during the winter months in all of the critical habitat area in the EGTRR. Due to the lack of knowledge that

could either confirm or disprove those assumptions, permitting has been delayed. However, known Gulf sturgeon population estimates for each river system, such as that for the Choctawhatchee River (approximately 3,314 sturgeon) (Parauka, 2011), can be correlated with the data collected from tagged sturgeon detected in the Gulf, to determine probable comparative density estimates of sturgeon in a given area during a given month of the year. As a result, a military mission or construction project could estimate the number of Gulf sturgeon potentially impacted by these activities with greater precision. Also, a mission or project can either relocate to an area devoid of sturgeon presence or change the timing of the event to coincide with zero or low sturgeon presence. For Eglin AFB missions, this study shows that the majority of all sturgeon activity in the Gulf offshore of SRI occurred within 1,000 meters of the shoreline, in water depths of 13.7 m (45 ft) or less. In other words, the sturgeon are only utilizing about half (0.54 NM) of the seaward extent of their critical habitat area in the Gulf of Mexico in the nearshore waters off Eglin AFB. The area east of the East Pass demonstrated different habitat utilization patterns from the previous years' results, with approximately 60 percent of detections in the Gulf occurring at receiver 2, deployed 1,250 m from the shore. However, focusing only on areas directly offshore of Eglin AFB property on SRI, federal actions that can be relocated outside of 1,000 m from the Eglin property shoreline will have a very low probability of impacting Gulf sturgeon. Also, by utilizing the data in this report, missions could be scheduled during times of the year that would eliminate any potential impact to the Gulf sturgeon.

The detection results from this study undoubtedly have many implications, not only for federal/military actions, but also for the overall conservation efforts for the species. It is therefore imperative to know how reliable these results are and how well the equipment and technology used to gather the data performs long term in an unstable environment. The test pinger investigation and long term range testing illustrates how a receiver performs in the marine environment of the Gulf of Mexico. The VR2Ws deployed in the Gulf of Mexico array were arranged such that an acoustic fence would be created that would cover the maximum area possible and still detect all tagged sturgeon traveling between each receiver. The distance between inshore and offshore receivers was estimated based on the receiver's presumed detection range such that there would not be any gaps between the receivers where sturgeon could potentially swim through the fence undetected. Based on the results of our test pinger study, to create an acoustic fence of VR2Ws in the Gulf that accurately captures sturgeon

movements in a given area, it appears a distance up to 700 m between each VR2W would be adequate to ensure maximum detection of transmissions from the tags while providing the widest coverage of area, even during weather conditions that yield high wind speeds. This distance is based on the higher level of performance of the receiver located 350 m away from the test pinger when compared to the receiver deployed 500 m away. Furthermore, we were able to estimate that over the course of the two-year Legacy project, on average only 68 percent of actual transmissions emitted from tagged sturgeon were detected on the VR2Ws. Taking into account that 100 percent detection success is highly unlikely in the Gulf, the results provided in this paper may actually underestimate the true amount of sturgeon activity in the Gulf. This may also explain a lack of detections from certain tag IDs for extended time periods. Continued monitoring in different locations over several more years may be able to confirm overwintering locations of sturgeon not detected on this array.

This test pinger analysis and range testing study can also be used to estimate the location of tagged sturgeon that have been detected. For example, for the sturgeon that were detected on receivers deployed the farthest offshore in the array, in this case out to 1,300 m (0.70 NM), given that the detection success of these receivers is greater at a 350 m distance, offshore distribution of sturgeon in this part of the Gulf can be estimated to range between 950 m (0.51 NM) and 1,650 m (0.89 NM) from the shore. However, this study has also shown that the Gulf waters near Eglin AFB may not be the most desirable location in the Gulf for sturgeon to overwinter. Areas west of Eglin, specifically off the Alabama and Mississippi Gulf coasts, demonstrated higher levels of activity from sturgeon tagged by Eglin AFB personnel. Similar inshore/offshore occurrence patterns and VR2W range testing would need to be conducted in those areas of the Gulf as well. Increased levels of shipping traffic and locations near busy ports may provide additional signal interference that would also impact the receiver's ability to detect a transmission from a nearby tag. Similar range testing in these areas of the Gulf could yield different results based on variable ambient underwater noise levels throughout the Gulf of Mexico.

Recommendations

Activities that involve disturbing the bottom of the Gulf, such as dredging or underwater detonations, may affect Gulf sturgeon and their critical habitat. To avoid impacts and lengthy consultations, these activities should be conducted either during the summer months in the Gulf

of Mexico when sturgeon are spawning in the rivers or outside 1 NM from the shore. When these measures are not possible, planners should investigate the possibility of using the eastern areas of the Gulf where sturgeon activity is relatively low in the winter.

Continued tagging and monitoring of Gulf sturgeon in the Gulf of Mexico would provide opportunities to better understand marine habitat utilization and possibly calculate density estimates for different areas of the Gulf. Providing take estimates of Gulf sturgeon will improve a proponent's ability to determine a more precise level of impact from an activity and perhaps reduce consultation timelines.

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Tables

Table 1. Gulf sturgeon tagged between 2008 and 2010

Tag ID	Date Tagged	Location Tagged	Fork length (cm)	Weight (kg)
51883	Tag implanted. No other information available.			
51884	9/9/2008	Choctawhatchee River	174	48.6
51885	10/13/2008	Choctawhatchee River	191	56.8
51886	9/15/2008	Choctawhatchee River	180	42.4
51887	10/26/2008	Choctawhatchee River	152	27.7
51888	10/13/2008	Choctawhatchee River	150	26.4
51889	10/25/2008	Choctawhatchee River	146	22.5
51890	10/12/2008	Choctawhatchee River	183	54
51891	10/26/2008	Choctawhatchee River	175	42.3
51892	10/11/2008	Choctawhatchee River	180	47.7
51893	9/15/2008	Choctawhatchee River	147	23.3
51894	9/15/2008	Choctawhatchee River	142	27.25
51895	8/14/2008	Choctawhatchee River	149	24.1
51896	8/12/2008	Choctawhatchee River	169	40.75
51897	8/14/2008	Choctawhatchee River	138	22.6
51898	8/14/2008	Choctawhatchee River	138	24.5
51899	8/14/2008	Choctawhatchee River	165	37.35
51900	8/14/2008	Choctawhatchee River	179	48.5
51901	8/14/2008	Choctawhatchee River	189	54
51902	8/14/2008	Choctawhatchee River	196	55.35
51903	9/9/2008	Choctawhatchee River	172	46.7
51904	9/9/2008	Choctawhatchee River	183	21
51905	9/9/2008	Choctawhatchee River	152	24
51906	9/9/2008	Choctawhatchee River	146	24.3
51907	8/12/2008	Choctawhatchee River	142	24.4
51908	8/12/2008	Choctawhatchee River	175	46.7
51909	8/12/2008	Choctawhatchee River	177	38.8
51910	8/12/2008	Choctawhatchee River	163	63.9
51911	8/5/2008	Choctawhatchee River	183	58.6
51912	7/31/2008	Choctawhatchee River	156	29.5
51913	8/5/2008	Choctawhatchee River	170	44.8
51914	8/5/2008	Choctawhatchee River	160	31.3
51915	8/8/2008	Choctawhatchee River	189	58.5
51916	8/12/2008	Choctawhatchee River	182	59.4
51917	8/8/2008	Choctawhatchee River	172	46.7
51918	8/8/2008	Choctawhatchee River	156	27.75
51919	7/31/2008	Choctawhatchee River	180	49.5
51920	7/31/2008	Choctawhatchee River	168	41.2
51921	7/31/2008	Choctawhatchee River	155	28.8
51922	7/31/2008	Choctawhatchee River	191	51.1

Tag ID	Date Tagged	Location Tagged	Fork length (cm)	Weight (kg)
61006	10/2/2009	Blackwater River	153.67	25.06
61007	9/30/2009	Blackwater River	141.61	22.23
61008*	9/30/2009	Escambia River	177.8	53.75
61009	9/30/2009	Blackwater River	150.5	26.31
61010*	10/2/2009	Blackwater River	185.42	62.59
61011*	9/30/2009	Blackwater River	161.29	38.44
61012	10/2/2009	Blackwater River	154.94	29.03
61013	10/2/2009	Blackwater River	172.72	44.23
61014	10/2/2009	Blackwater River	140.97	23.25
61015*	9/30/2009	Escambia River	160.02	37.65
61016*	9/18/2009	Yellow River	159.39	28.8
61017	9/11/2009	Yellow River	142.24	23.59
61018*	9/21/2009	Blackwater River	177.8	45.13
61019	9/18/2009	Yellow River	127	18.6
61020*	9/18/2009	Yellow River	189.23	53.52
61021	9/18/2009	Yellow River	171.45	42.64
61022	9/18/2009	Yellow River	147.32	23.81
61023	9/18/2009	Yellow River	145.42	20.64
61024	9/11/2009	Yellow River	148.59	28.58
61025	9/11/2009	Yellow River	139.7	21.55
61026	9/11/2009	Yellow River	129.54	18.6
61027	9/11/2009	Yellow River	147.32	24.27
61028*	9/21/2009	Blackwater River	187.96	60.21
61029*	9/21/2009	Blackwater River	175.26	49.67
61030	9/21/2009	Blackwater River	140.97	24.27
61031	9/21/2009	Blackwater River	171.45	47.63
61032	10/2/2009	Blackwater River	132.08	20.18
61033	9/30/2009	Escambia River	160.02	36.06
61034*	9/22/2009	Blackwater River	186.69	57.83
61035*	9/22/2009	Blackwater River	166.37	31.86
61036	9/29/2009	Yellow River	123.19	14.17
61037	9/21/2009	Blackwater River	136.53	23.81
61038*	9/21/2009	Blackwater River	182.88	49.9
61039*	9/21/2009	Blackwater River	175.26	52.59
61040*	9/21/2009	Blackwater River	163.83	38.67
61041	10/2/2009	Blackwater River	146.05	23.81
61042*	10/2/2009	Blackwater River	180.34	57.61
61043	10/2/2009	Blackwater River	124.46	14.17
61044*	10/2/2009	Blackwater River	164.473	38.1
61045*	10/2/2009	Blackwater River	175.26	42.64
46418	9/30/2010	Yellow River	143	23.65
46419	9/10/2010	Blackwater River	137	21.25
46420*	9/10/2010	Blackwater River	152	-

Tag ID	Date Tagged	Location Tagged	Fork length (cm)	Weight (kg)
46421	9/10/2010	Blackwater River	165	45
46422	9/14/2010	Escambia River	150	25.1
46423*	9/10/2010	Blackwater River	188	56
46424	9/14/2010	Escambia River	170	36.2
46425*	9/10/2010	Blackwater River	174	44
46426	9/14/2010	Escambia River	142	16.1
46427	9/10/2010	Blackwater River	147	22.8
46428	9/1/2010	Yellow River	187	46.86
46429	8/31/3010	Escambia River	135	20.3
46430	9/2/2010	Blackwater River	116	14.1
46431	8/31/2010	Escambia River	137	22
46432	9/2/2010	Blackwater River	140	24.7
46433	9/1/2010	Yellow River	128	15.65
46434	9/2/2010	Blackwater River	163	33.1
46435	9/1/2010	Yellow River	174	43.65
46436	9/2/2010	Blackwater River	127	16.4
46437	9/1/2010	Yellow River	137	20.55
46438	9/2/2010	Blackwater River	133	18.9
46439	9/1/2010	Yellow River	135	18.85
46440	10/1/2010	Yellow River	139	21.7
46441	10/1/2010	Yellow River	133	17.4
46442	9/30/210	Yellow River	130	16
46443	9/28/2010	Yellow River	155	35.85
46444	9/14/2010	Escambia River	162	31.5
46445	9/30/2010	Yellow River	145	23.2
46446	9/9/2010	Escambia River	127	?
46447	9/9/2010	Escambia River	145	25.9
46448	9/9/2010	Escambia River	135	20.4
46449	9/9/2010	Escambia River	145	26.5
46450	9/9/2010	Escambia River	132	18.4
46451	9/9/2010	Escambia River	150	22.9
46452	9/9/2010	Escambia River	191	62.05
46453	9/9/2010	Escambia River	160	31.1
46454	9/8/2010	Yellow River	151	28.45
46455	9/9/2010	Escambia River	140	20.2
46456	9/8/2010	Yellow River	178	44
46457	9/8/2010	Yellow River	132	16.9

* Gulf sturgeon identified as a female by U.S. Fish and Wildlife biologist

Table 2. Summary of tagging results and detection success

RIVER SOURCE	YEAR TAGGED	# TAGGED	# DETECTED	% SUCCESS
2008-2009 Pilot Study				
Choctawhatchee River	2008	40	26	65%
2008-2009 TOTAL		40	26	65%
2009-2010 Legacy Study				
Choctawhatchee River	2008	40	14	35%
Yellow River	2009	12	12	100%
Blackwater River	2009	25	24	96%
Escambia River	2009	3	3	100%
2009-2010 TOTAL		80	53	66%
2010-2011 Legacy Study				
Choctawhatchee River	2008	40	8	20%
Yellow River	2009	12	11	92%
	2010	14	14	100%
	Total	26	25	96%
	Blackwater River	2009	25	24
2010		11	10	91%
Total		36	34	94%
Escambia River	2009	3	3	100%
	2010	15	13	87%
	Total	18	16	89%
2010-2011 TOTAL		120	83	69%

Table 3. Receiver IDs and deployment locations

Receiver ID	2009-2010			2010-2011		
	Receiver Location	Latitude	Longitude	Receiver Location	Latitude	Longitude
1	GOM East Pass Inshore	N30° 22.7'	W086° 29.5'	GOM East Pass Inshore	N30° 22.7'	W086° 29.5'
2	GOM East Pass Offshore	N30° 22.3'	W086° 29.6'	GOM East Pass Offshore	N30° 22.3'	W086° 29.5'
3	GOM A-3 Inshore	N30° 23.1'	W086° 32.8'	GOM A-3 Inshore	N30° 23.1'	W086° 32.8'
4	GOM A-3 Offshore	N30° 22.6'	W086° 32.8'	GOM A-3 Offshore	N30° 22.6'	W086° 32.8'
5	GOM A-11 Inshore	N30° 23.5'	W086° 42.8'	GOM A-11 Inshore	N30° 23.5'	W086° 42.8'
6	GOM A-11 Offshore	N30° 23.3'	W086° 42.8'	GOM A-11 Offshore	N30° 23.3'	W086° 42.8'
7	GOM A-18 Inshore	N30° 22.8'	W086° 50.7'	GOM A-18 Inshore	N30° 22.8'	W086° 50.7'
8	GOM A-18 Offshore	N30° 22.5'	W086° 50.7'	GOM A-18 Offshore	N30° 22.5'	W086° 50.7'
9	SRS Brooks Bridge	N30° 23.9'	W086° 36.1'			
10	SRS A-10	N30° 24.1'	W086° 42.0'	SRS Brooks Bridge	N30° 23.9'	W086° 36.1'
11	SRS A-15	N30° 23.5'	W086° 48.5'	SRS EPA Lab	N30° 20.2'	W087° 09.4'
12	Yellow River	N30° 33.5'	W086° 58.9'	Yellow River	N30° 33.5'	W086° 58.9'
13	Blackwater River	N30° 37.5'	W087° 02.1'	Blackwater River	N30° 37.5'	W087° 02.1'
14	Escambia River	N30° 40.2'	W087° 16.0'	Escambia River	N30° 40.2'	W087° 16.0'
15	SRS EPA Lab ¹	N30° 20.2'	W087° 09.4'	Pensacola Bay South	N30° 22.4'	W087° 10.7'
16	Pensacola Bay North	N30° 24.9'	W087° 11.5'	GOM E Pensacola Pass	N30° 18.9'	W087° 17.2'
17	Pensacola Bay South	N30° 22.4'	W087° 10.7'	GOM W Pensacola Pass	N30° 18.6'	W087° 20.4'
18	SRS Bob Sikes Bridge	N30° 21.0'	W087° 10.5'	GOM Perdido Key, AL	N30° 16.0'	W087° 34.5'
19	GOM E Pensacola Pass	N30° 18.9'	W087° 17.2'			
20	GOM W Pensacola Pass	N30° 18.6'	W087° 20.4'			
21	GOM Perdido Key, AL	N30° 15.7'	W087° 34.8'			

GOM = Gulf of Mexico; SRS = Santa Rosa Sound; E = East; W = West; AL = Alabama

¹Receiver 15 was originally located in a southern portion of the Escambia River but was relocated to the EPA Lab in Gulf Breeze in the Santa Rosa Sound

Table 4. GOM receiver distances from the shore

Receiver ID	Receiver Location	Distance from shore (m)	Water depth (m)	Total detections from 2009-2010	Total detections from 2010-2011
1	GOM East Pass Inshore	450	7	8,456	40,366
2	GOM East Pass Offshore	1,250	17	882	191,787
3	GOM A-3 Inshore	450	7	54,740	12,742
4	GOM A-3 Offshore	1,300	9	22,735	4,116
5	GOM A-11 Inshore	200	5	3,091	1,676
6	GOM A-11 Offshore	600	11	318	24,818
7	GOM A-18 Inshore	250	5	0 ²	1,101
8	GOM A-18 Offshore	800	14	426	5,625
19 (16) ¹	GOM E Pensacola Pass	350	5	17,427	1,461
20 (17) ¹	GOM W Pensacola Pass	600	5	7,120	32,638
21 (18) ¹	GOM Perdido Key, AL	500	7	3,449 ³	0 ²

GOM = Gulf of Mexico

¹Receiver IDs in parentheses are for 2010-2011 array;

²Indicates that these receivers went missing before any data downloads could occur;

³Receiver went missing in the middle of the data collection period. Last data download occurred on 2/18/2010, before final collection of all other receivers in May 2010.

Table 5. Detection ranges as depicted on maps in Figures 17 - 19

Circle Color	Corresponding Number of Detections
White	1 to 100
Purple	101 to 500
Blue	501 to 1,000
Green	1,001 to 5,000
Yellow	5,001 to 10,000
Orange	10,001 to 20,000
Red	Over 20,000

Table 6. Detection rates and average wind speed over two years

Daily Average Wind Speed (mph)	2009-2010 Average Detections Received	% Detection Success (2009-2010)	2010-2011 Average Detections Received	% Detection Success (2010-2011)	Total Average Detections (2 yrs)	Total % Detection Success (2 yrs)
1	90	94%	86	89%	88	92%
2	85	88%	83	86%	84	87%
3	80	84%	74	77%	77	80%
4	76	79%	77	80%	76	79%
5	75	79%	75	78%	75	78%
6	76	79%	64	67%	70	73%
7	69	72%	65	68%	67	70%
8	70	73%	56	59%	63	66%
9	78	81%	58	61%	68	71%
10	51	53%	57	60%	54	56%
11	43	44%	53	55%	48	50%
12	69	71%	29	30%	49	51%
13	44	46%	49	51%	47	48%
14	55	57%	33	34%	44	46%
15	43	45%	0	0%	22	22%

Figures



Figure 1. Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

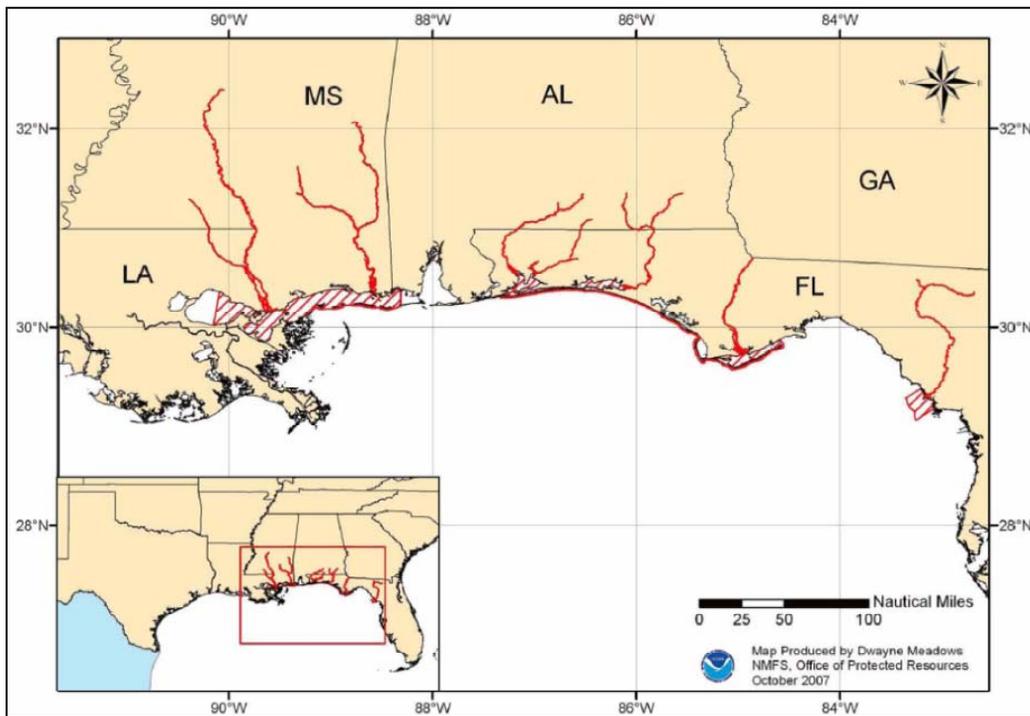


Figure 2. Gulf Sturgeon Critical Habitat (NMFS, 2010)



Figure 3. Vemco V16 tag



Figure 4. Making the incision for the tag



Figure 5. Inserting the tag into the abdominal cavity



Figure 6. Suturing the incision



Figure 7. Receiver/buoy assembly

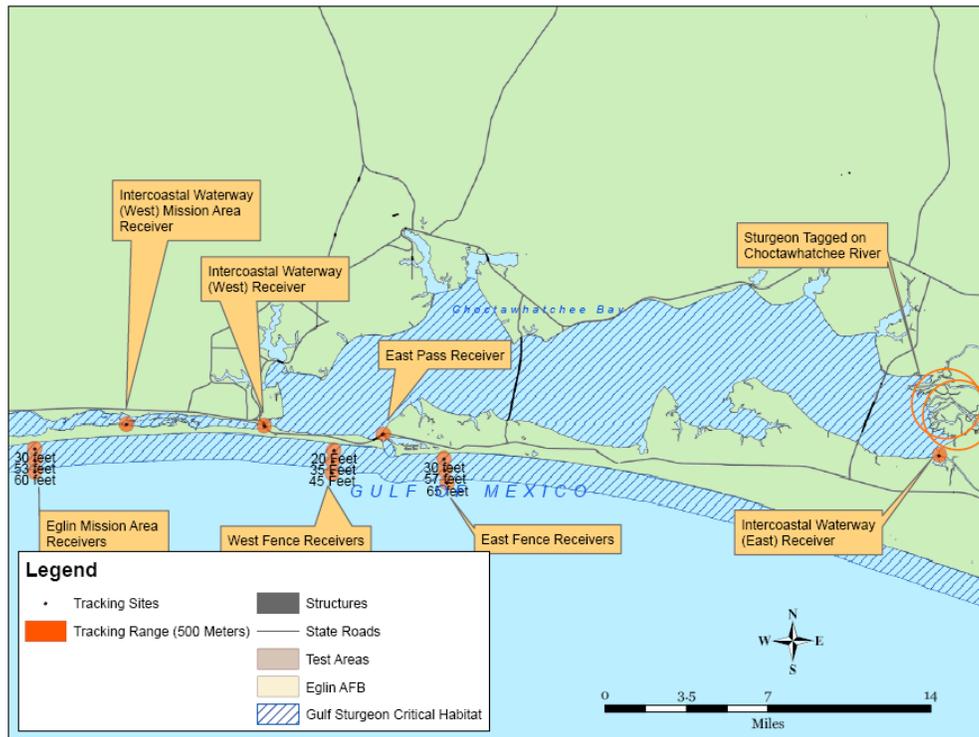


Figure 8. Receiver locations for the 2008 Pilot Study



Figure 9. Updated receiver/buoy assembly

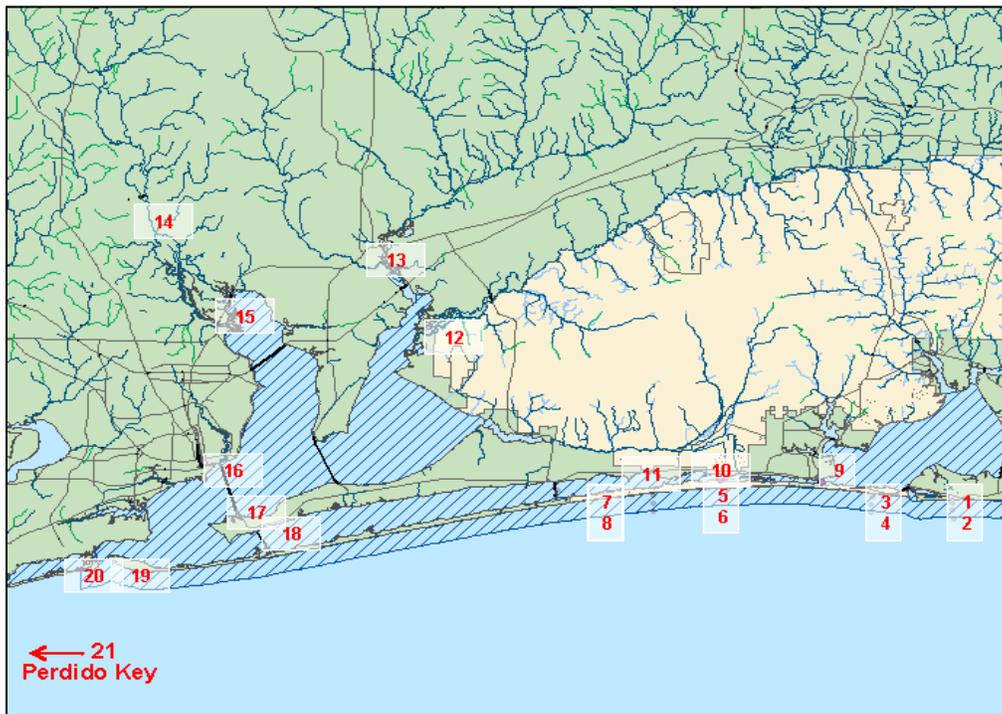


Figure 10. Receiver locations for 2009-2010 data collection



Figure 11. Receiver locations for 2010-2011 data collection



Figure 12. USFWS Gulf of Mexico receiver array

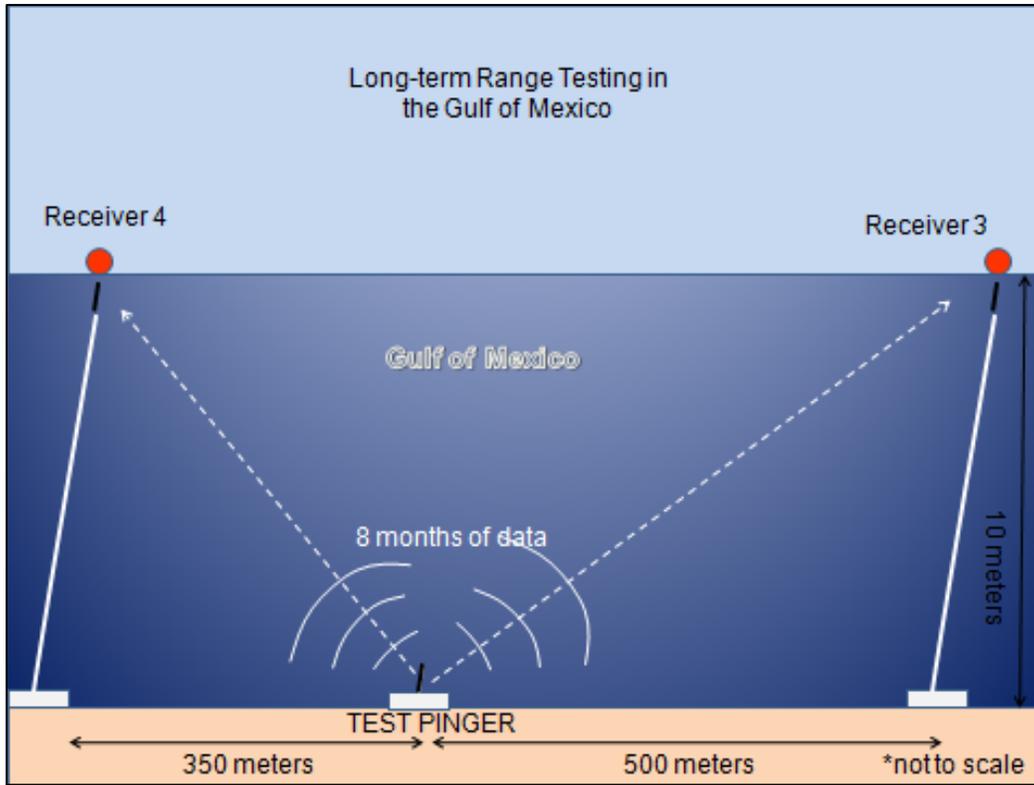


Figure 13. Diagram of test pinger placement between inshore (3) and offshore (4) receivers

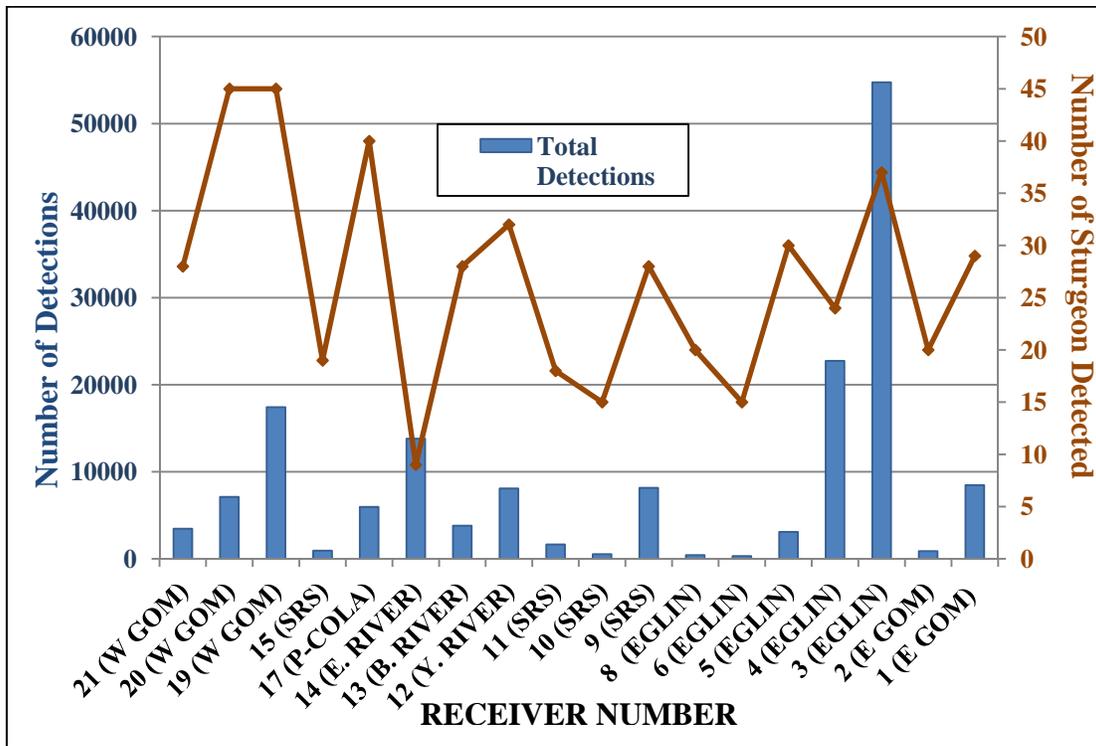


Figure 14. Total detections vs. total number of sturgeon detected on 2009-2010 array

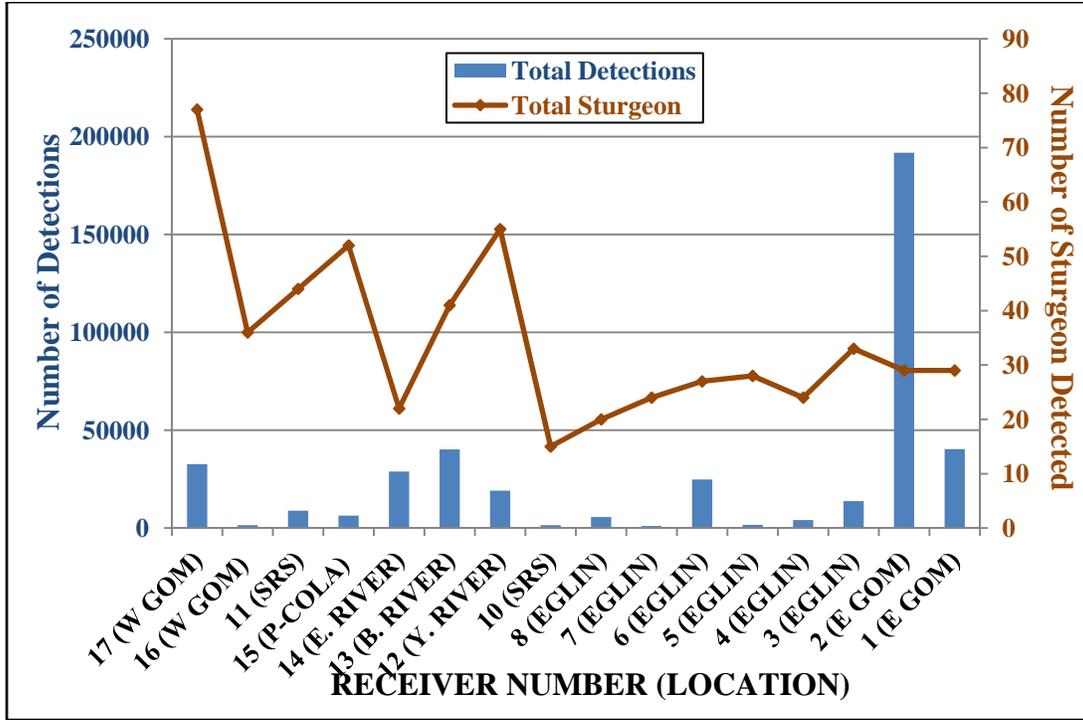


Figure 15. Total detections vs. total number of sturgeon detected on 2010-2011 array

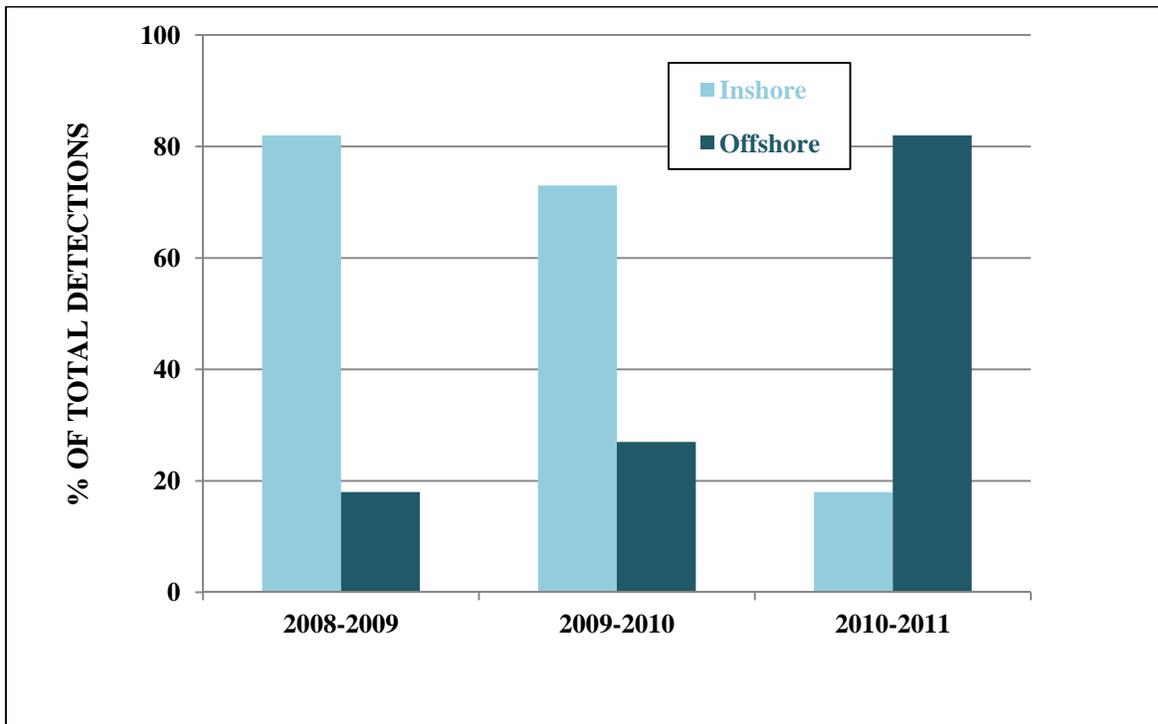


Figure 16. Comparison of % inshore detections vs. % offshore detections

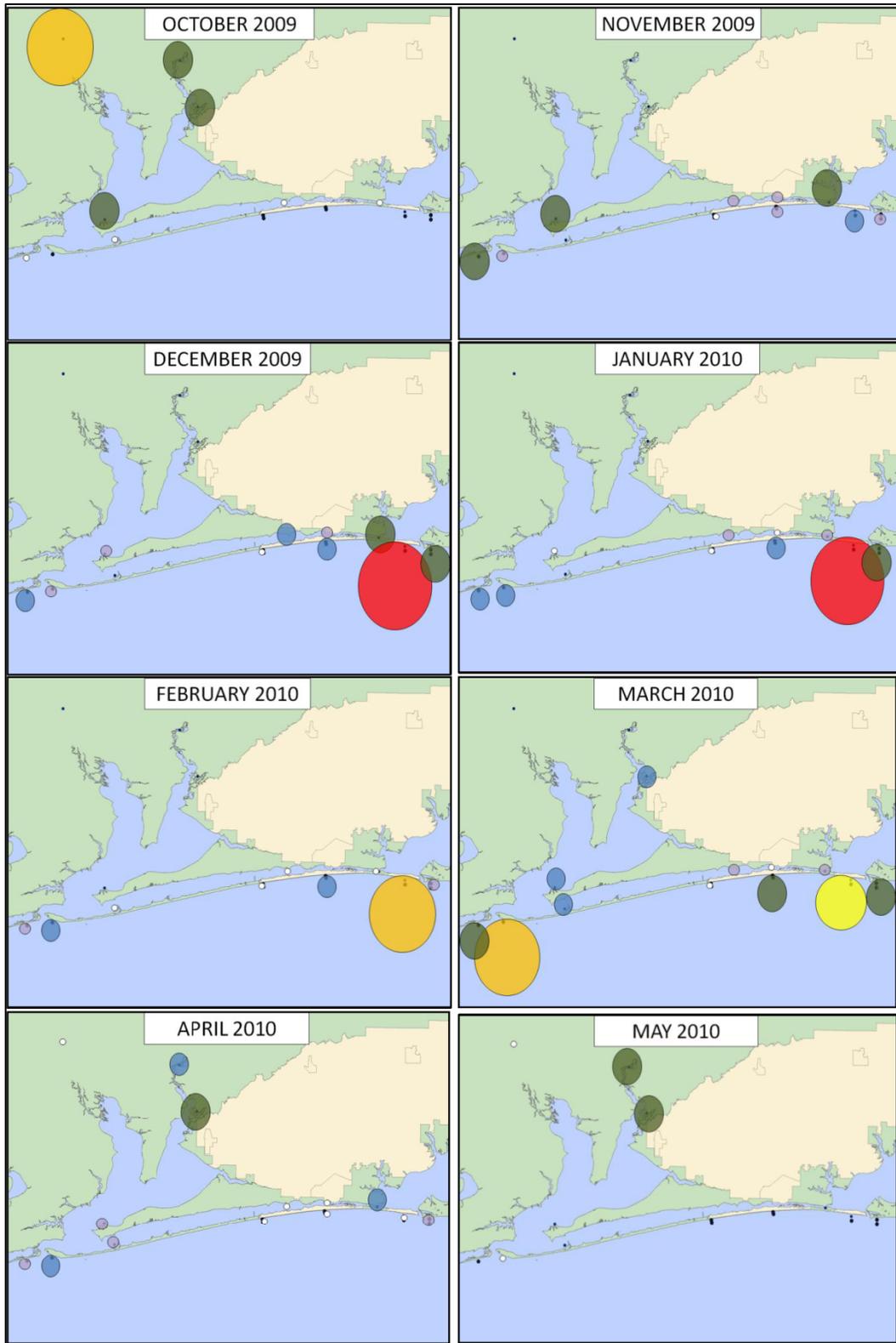


Figure 17. 2009-2010 Detection Maps of all tagged sturgeon on Eglin array
 Note that the size of circles do not depict actual range of sturgeon movements in the Gulf, only magnitude of sturgeon activity (detections) in that particular area.

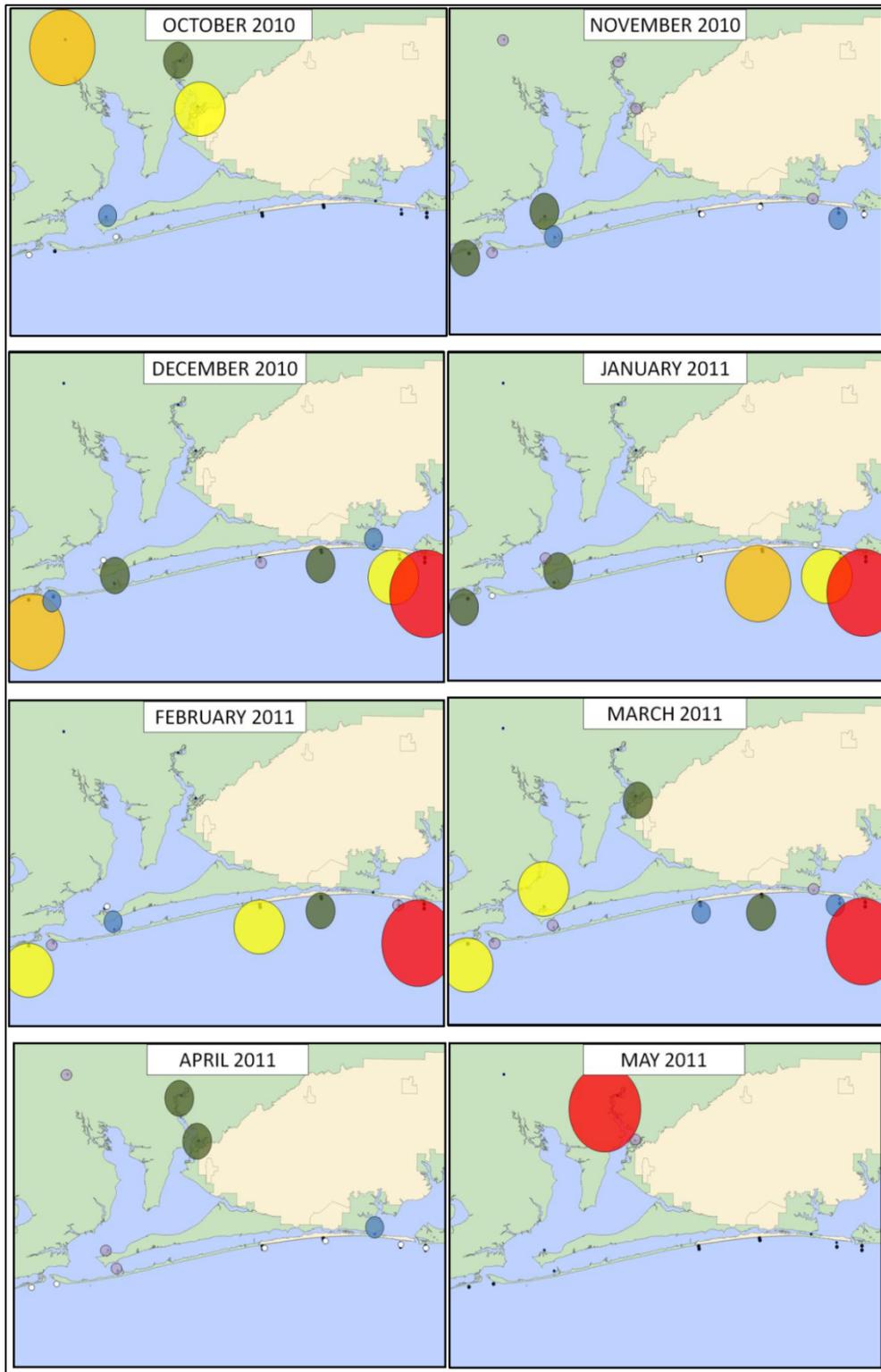


Figure 18. 2010-2011 Detection Maps of all tagged sturgeon on Eglin array
 Note that the size of circles do not depict actual range of sturgeon movements in the Gulf, only magnitude of sturgeon activity (detections) in that particular area.

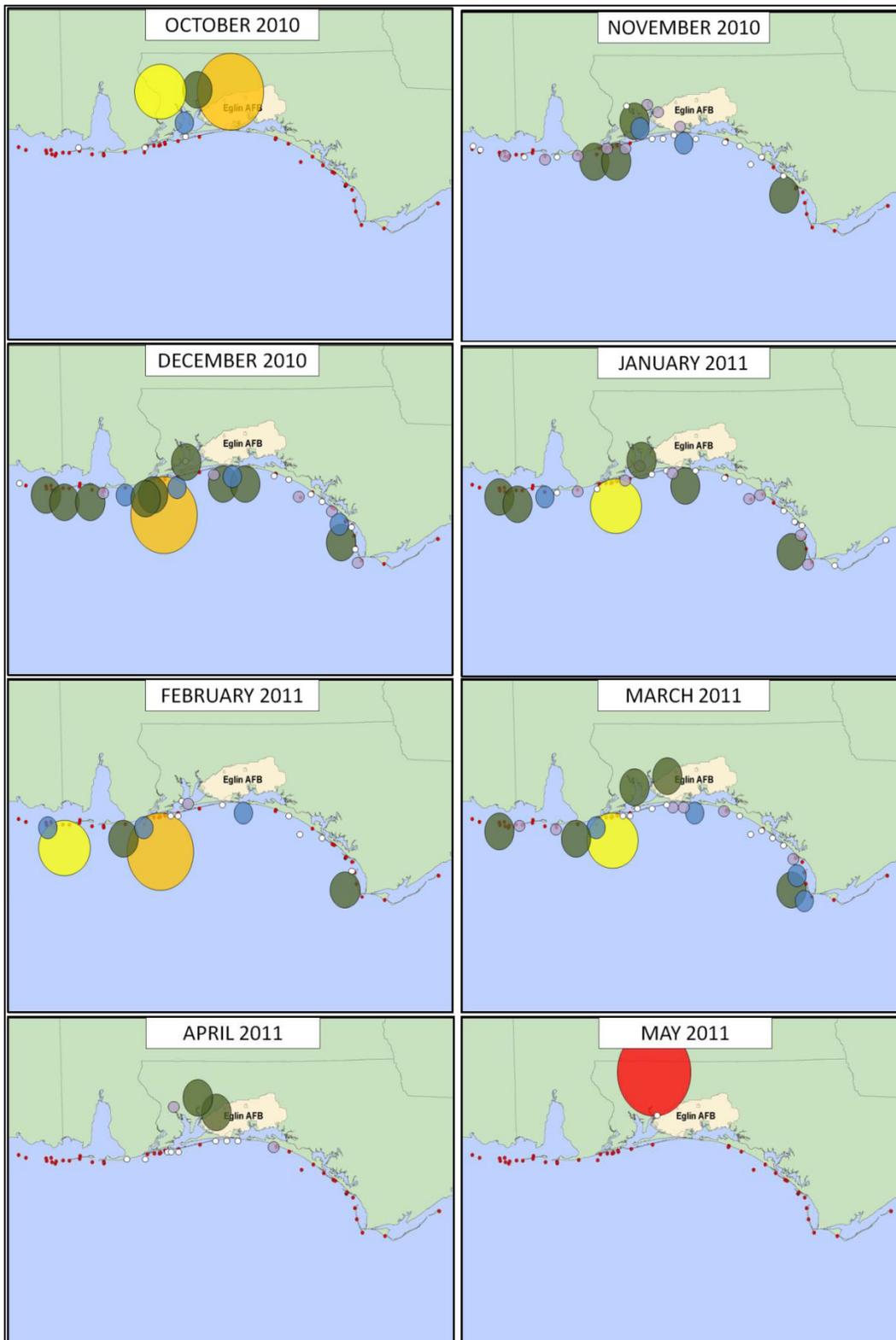


Figure 19. 2010-2011 Detection Maps of Eglin-tagged sturgeon on USFWS array
 Note that the size of circles do not depict actual range of sturgeon movements in the Gulf, only magnitude of sturgeon activity (detections) in that particular area.

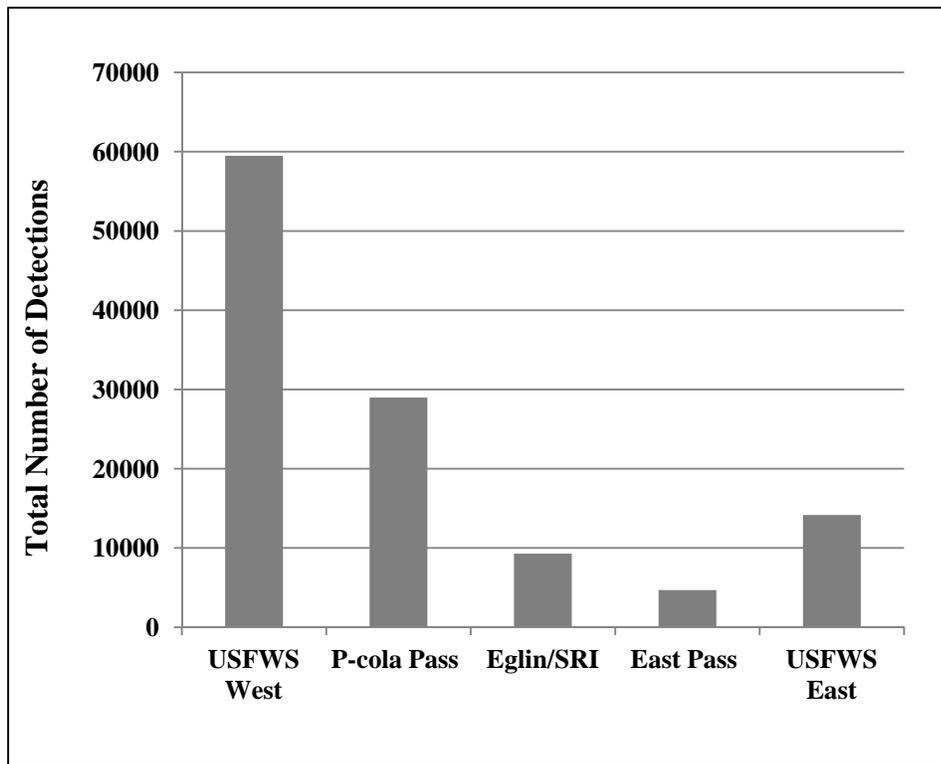


Figure 20. Total number of detections received by Eglin-tagged sturgeon on VR2Ws deployed in various regions of the Gulf of Mexico

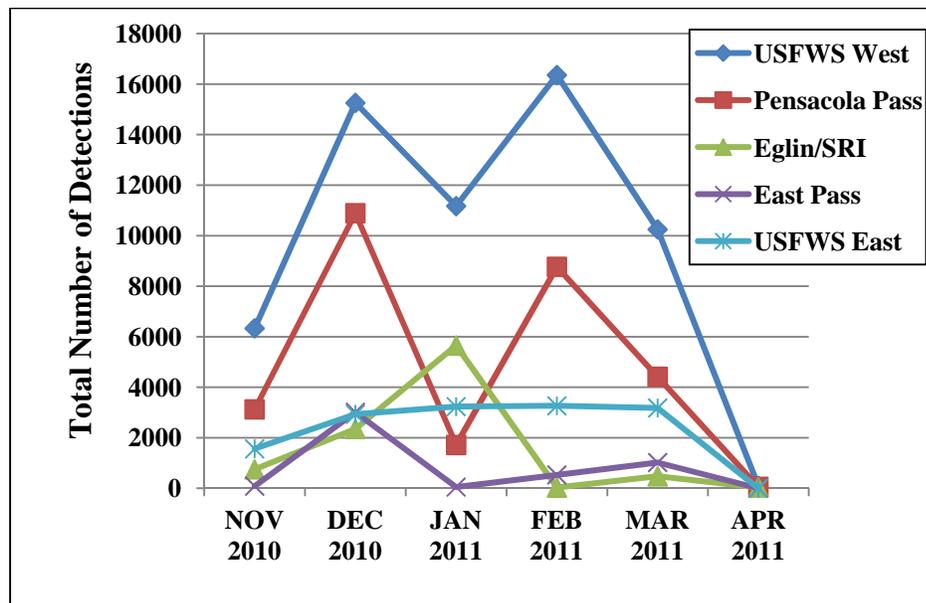


Figure 21. Detections of Eglin-tagged sturgeon on VR2Ws deployed in various regions in the Gulf of Mexico over the winter

Note: USFWS West includes receivers deployed from Pensacola, Florida to Biloxi, Mississippi. USFWS East includes receivers deployed from Destin to Dog Island, Florida

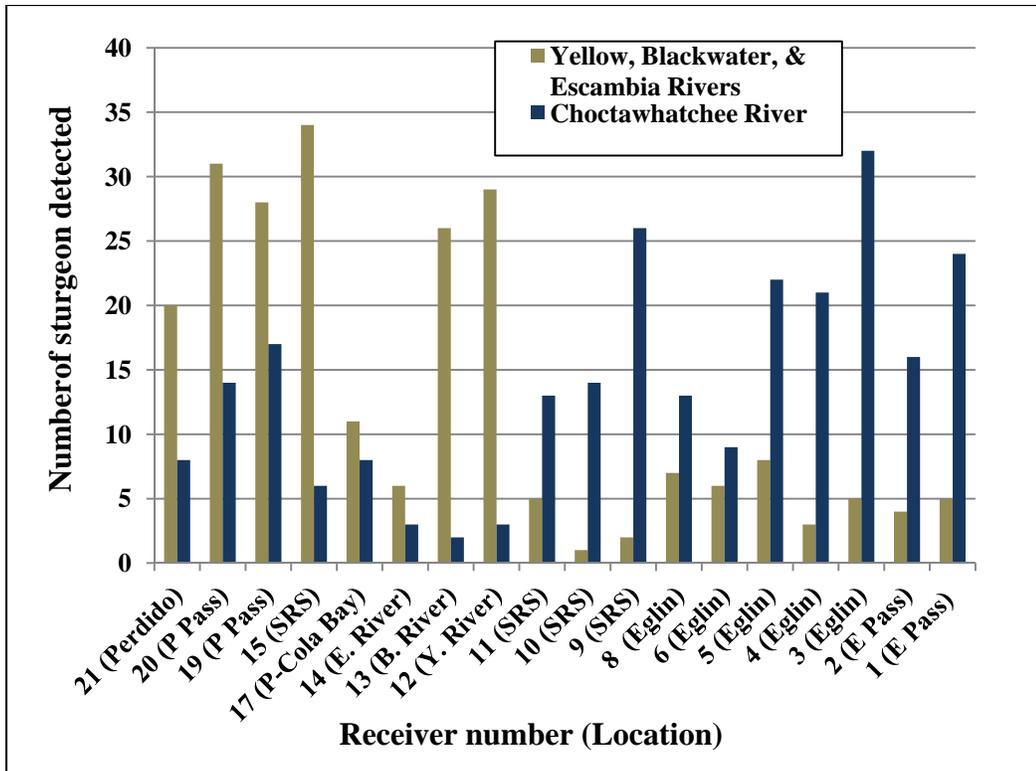


Figure 22. Number of sturgeon detected on each receiver on Eglin's 2009-2010 array
 Note: Choctawhatchee River data includes individuals tagged as part of the study on residency and habitat use of Gulf sturgeon in the Choctawhatchee Bay

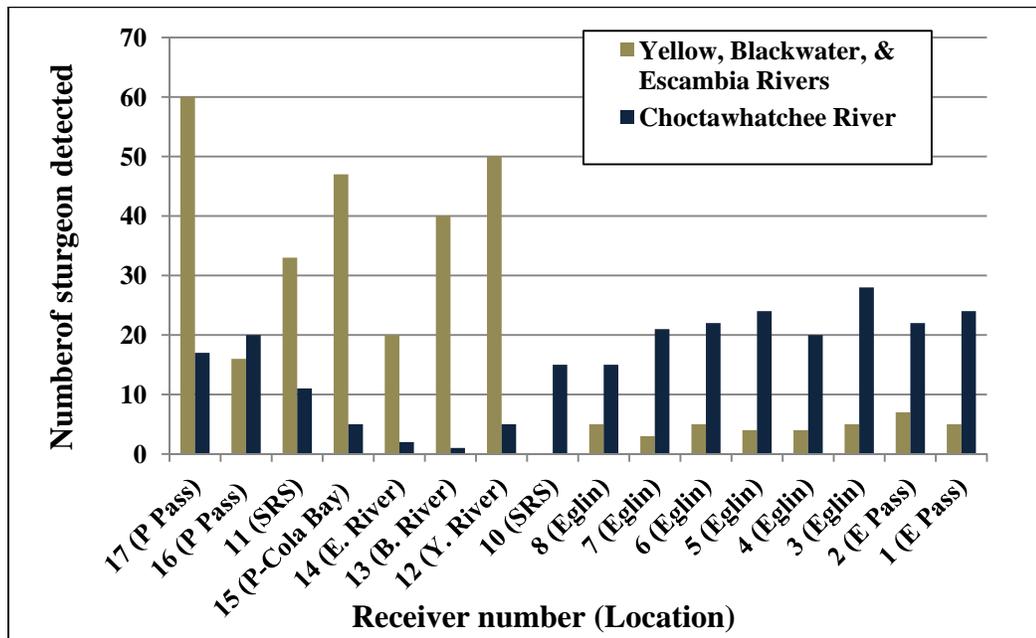


Figure 23. Number of sturgeon detected on each receiver on Eglin's 2010-2011 array
 Note: Choctawhatchee River data includes individuals tagged as part of the study on residency and habitat use of Gulf sturgeon in the Choctawhatchee Bay

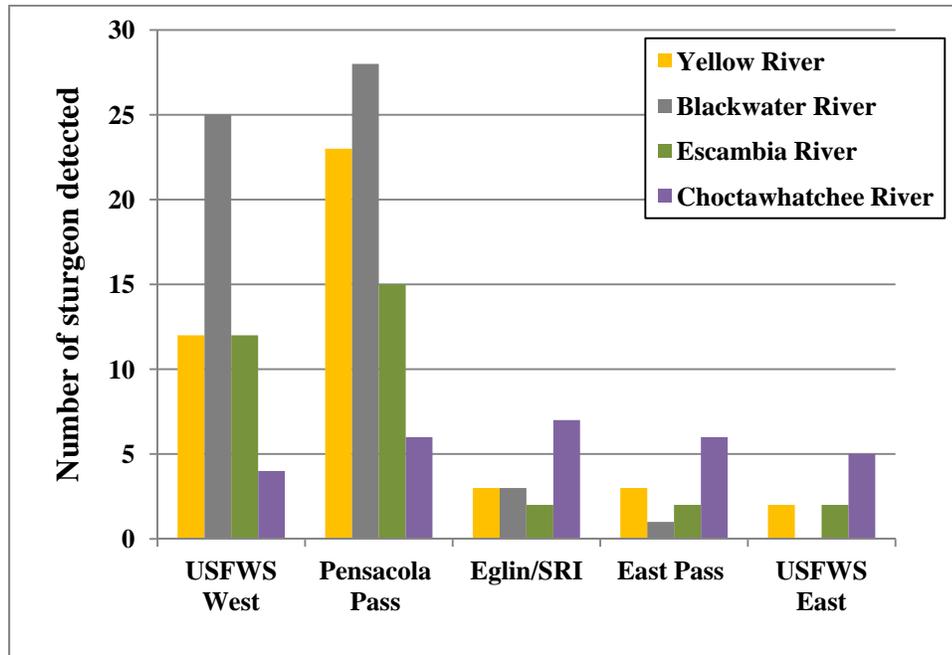


Figure 24. Eglin-tagged sturgeon detected on Eglin and USFWS 2010-2011 arrays in the Gulf of Mexico

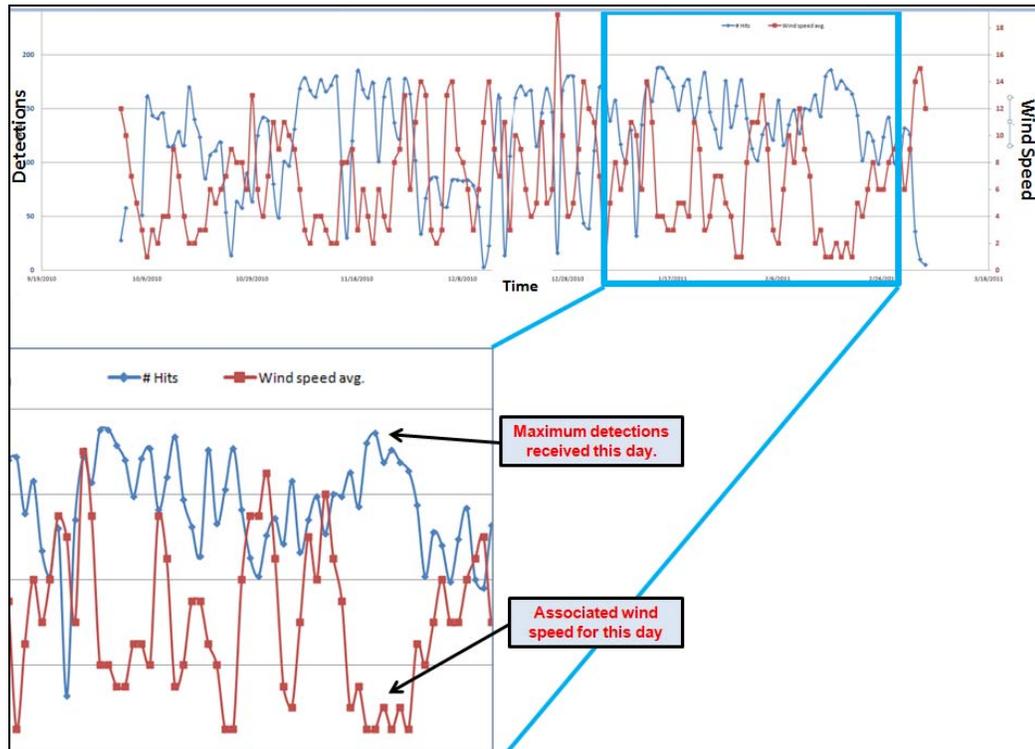


Figure 25. Negative correlation between wind speed and detections received

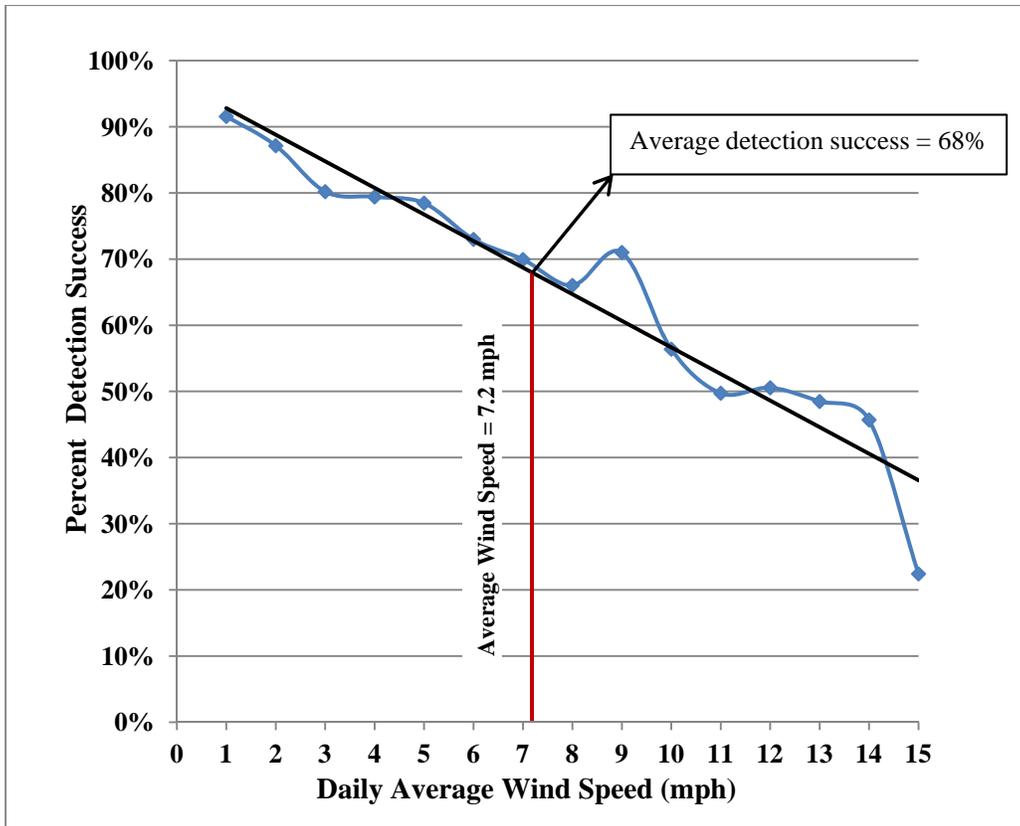


Figure 26. Percentage of detections received vs. average wind speed

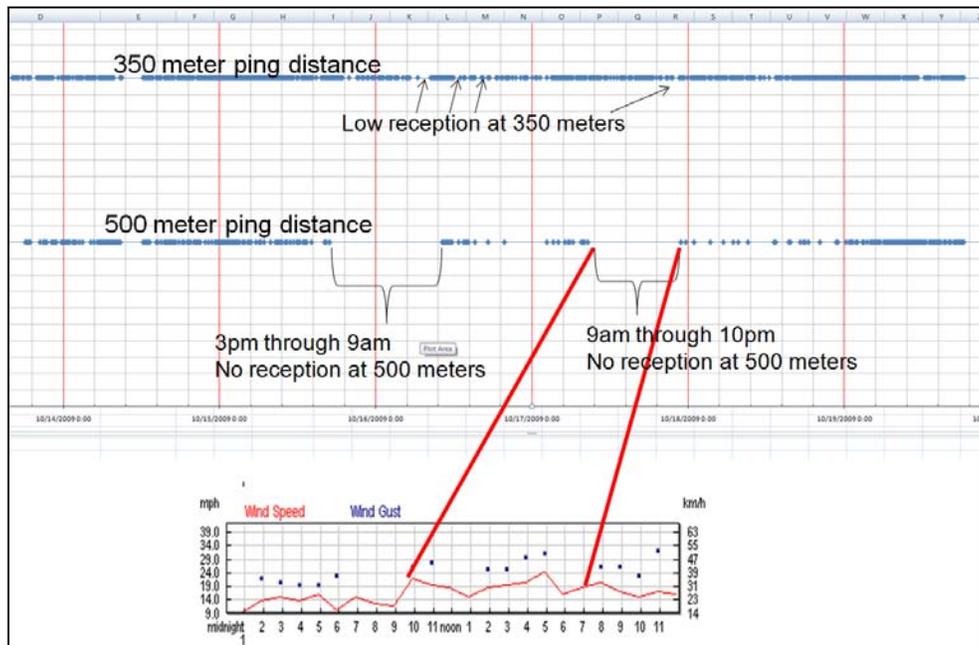


Figure 27. Detections received during test pinger study on receivers 3 (500 m ping distance) and 4 (350 m ping distance) during 2009-2010

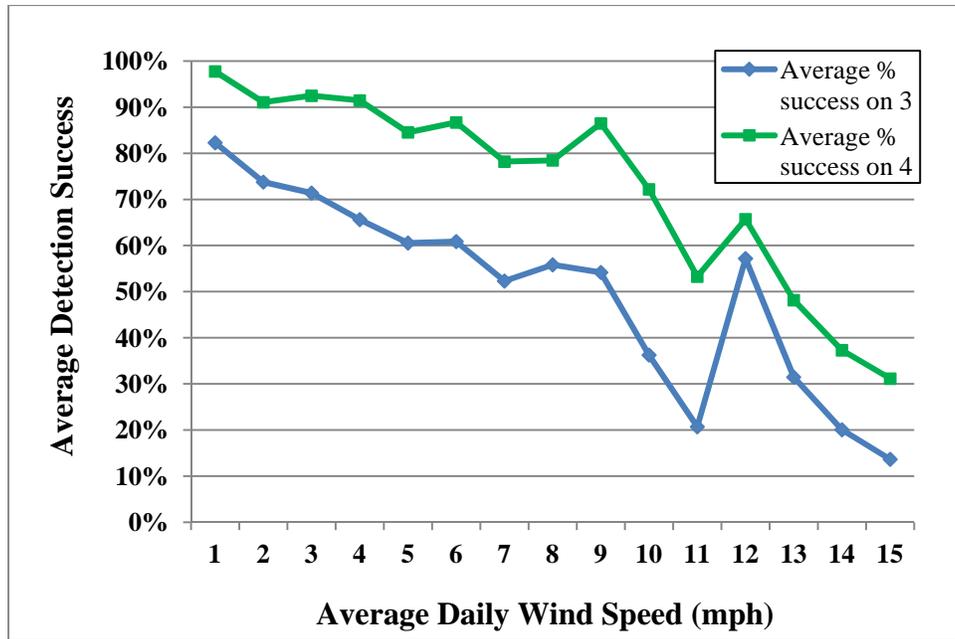


Figure 28. Average detection success on receiver 3 vs. receiver 4 over given average daily wind speeds