EVALUATION OF LARGE-SCALE MOVEMENT PATTERNS OF SPOTTED SEATROUT (*CYNOSCION NEBULOSUS*) USING ACOUSTIC TELEMETRY

Prepared by

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April 2011

A Thesis Submitted
In Partial Fulfillment of
The Requirements for the Degree of

MASTER OF SCIENCE

The Graduate Committee
Biology Program
Department of Life Sciences
Texas A&M University-Corpus Christi

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Format: *Transactions of the American Fisheries Society*

ABSTRACT

Recreational saltwater fishing is a multi-billion dollar industry in Texas, with spotted seatrout (*Cynoscion nebulosus*) being the most sought after game fish in Texas' near-shore waters. Recently, spotted seatrout population and spawning stock biomass declines prompted regionalized management strategies within Texas waters. Effective fishery management requires an understanding of movement patterns of managed species; although little is known about migratory patterns and residency times. Spotted seatrout are presumed to be estuarine resident with limited movement outside of natal estuaries. Anecdotal information suggests that spotted seatrout migrate from near-shore waters into bays to spawn and that these migratory fish may sustain populations of spotted seatrout within the Laguna Madre system. To further explore spotted seatrout movement patterns both laboratory tagging trials and acoustic tracking technology was employed to investigate movement patterns on a large-scale. A preliminary laboratory study was performed to determine the most effective surgery technique and suture material when implanting acoustic transmitters. Six treatment groups were used to investigate two incision locations (midline and off-midline) and three suture materials (braided, monofilament, and staples). Based on survival, tag retention, and healing scores, these results showed that the size of the fish as opposed to incision location or suture material had the most influence on tagging success. Following surgical trials, a total of 81 spotted seatrout greater than 400 mm TL were captured via hook and line between 8 December 2009 and 20 October 2010 and implanted with acoustic tags: 31 within bay waters, 30 fish from surf zones, and 20 live-release tournament fish. Movements were monitored with an array of 24 stationary receivers strategically placed between Port Aransas and Port Mansfield inlets. We found an overall minimal survival rate of 70% between angler recaptures and receiver detections. Many long distance travels were recorded and movement patterns varied greatly. Seventy-five percent of fish tagged in surf waters were detected on our receivers in tidal inlets, and two fish from the Upper Laguna Madre were detected leaving the Laguna into CC Bay. These data suggest Gulf-bay and inter-bay mixing of spotted seatrout populations. The high percentage of angler recaptures validates previous studies that determined catch-and-release practices are viable to help maintain healthy fish stocks. These data will be useful for fisheries managers to evaluate regionalized management tactics to further improve management of spotted seatrout in Texas.

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ACKNOWLEDGEMENTS

I would like to thank the Coastal Conservation Association-Texas, the Rotary Club of Corpus Christi (Harvey Weil Sportsman Conservationist Award), Texas Chapter of the American Fisheries Society Student Scholarship, the Hans and Patricia Suter Endowment, Harte Research Institute for Gulf of Mexico Studies, and Texas A&M University – Corpus Christi for funding this research. I thank my mentor and advisor, Dr. Gregory W. Stunz for providing me with the tools and guidance to succeed in the Biology program. I would also like to thank my committee members Drs. Rebekah J. Thomas, Matthew W. Johnson (TAMU-CC), and Robert R. Vega (TPWD), for their support and mentorship throughout not only my thesis project, but my entire graduate journey. I also greatly appreciate the countless student workers, volunteers, and members of the Fisheries and Ocean Health Lab at TAMU-CC for their field and laboratory assistance. Particularly, I would like to thank Megan Reese Robillard for her outstanding assistance throughout all aspects of this project. Judd Curtis, Jason Williams, Rachel Brewton, and Ruben Palacios also contributed many hours assisting with field activities. Catching this many fish was difficult and would not been possible without expert help. Many thanks go to Capts. Billy Sandifer, David Rowsey, Jay Watkins, and Mike McBride for their expert guide services. Jay Gardner of CCA-Texas Corpus Christi Chapter was instrumental in recruiting volunteer fishermen as well as volunteering many hours himself. A big thank you goes to Todd Neahr of TPWD for assisting in numerous field expeditions. Also, Thomas Petroleum-Speedy Stop stores Baffin Bash and Roger Viar Baffin Bay Rodeo live-release tournaments, as well as the staff of Bluffs Landing Marina was a major help and essential in allowing me to surgically tag tournament caught spotted seatrout. I would also like to thank the countless number of volunteer anglers who helped to capture fish for this tagging study. Without guidance and encouraging words from past mentors Dr. James Biggs, Jim Whittington, and Ron Taylor, I would not have begun this endeavor. My parents, Roger and Heide, have provided continued support throughout my college career; thank you for believing in me. Finally, I would like to thank the many friends I have found along the way for their patience and inspiration. I would not have been able to do it without all of you.

INTRODUCTION

The spotted seatrout (*Cynoscion nebulosus*) is an estuarine-dependent sciaenid and one of the most important recreational fisheries in the Gulf of Mexico (Kostecki 1984, Pattillo et al. 1997, Bortone 2003). Spotted seatrout occur from Massachusetts to the Bay of Campeche, Mexico, but are most abundant in the Gulf of Mexico from Florida to Texas (Kostecki 1984, Pattillo et al. 1997, Blanchet et al. 2001). Juveniles and adults are found in vegetated, non-vegetated, or structured estuarine habitats, in the surf zones of barrier islands, and near drilling platforms located close to shore (Pattillo et al. 1997). This species is an important economic resource in Texas as it is one of the most targeted recreational fishes in the southeastern United States (Blanchet et al. 2001, Anderson and Ditton 2004, Stunz and McKee 2006). In 2006, the Texas spotted seatrout recreational fishery had an economic impact valued at over two billion dollars (NOAA 2008). The spotted seatrout fishery in Texas has been regulated since 1987 through minimum size and bag limits (Hegen et al. 1984).

Current Texas regulations require that spotted seatrout must be a minimum of 381 mm and maximum of 635 mm total length (TL) for harvest; however, anglers are permitted to harvest one trophy sized (>635 mm TL; 25 inches) spotted seatrout per day with overall bag limits of ten fish per day in all regions except the lower Laguna Madre (LLM). Declines in the number of “trophy-sized” trout prompted the addition of the maximum size limit to facilitate an increase in the number of larger fish. Historically, the LLM has been regarded as one of the most productive ecosystems for the size and quantity of spotted seatrout. During the past 30 years, Texas Parks and Wildlife Department (TPWD) fisheries independent data has shown a decreasing trend in population and spawning stock biomass within LLM, while all other bay systems in Texas have shown increases (McKinney 2007). This decline prompted TPWD to implement a regionalized management plan which decreased bag limits to 5 fish per day in the LLM system. Management of spotted seatrout in Texas has traditionally assumed minimum migration of the stock based on limited passive tagging data.

Understanding movement patterns of managed fishes is important because it can provide a spatial and temporal scale at which a species should be managed, define potential environmental and biological drivers, provide the basis for implementing ecosystem based fisheries management principles, and identify source/sink populations (Pulliam 1988, Metcalfe and Arnold 1997, Beck et al. 2001). Connectivity, the exchange of individuals among geographically separated groups, determines colonization patterns of new habitats, resiliency of populations to harvest, and aids in the design of marine protected areas (MPAs) (Thorrold et al. 2001). Knowledge of fish movements is also important to evaluate the effectiveness of regionalized management of species (Starr et al. 2000).

Previous tagging studies on spotted seatrout movement have reported highly variable patterns. Most studies have concluded that this species rarely migrates from natal estuaries or adjoining near-shore areas, but some have shown instances of long migrations from point of release (Kostecki 1984, Baker and Matlock 1993). Texas Parks and Wildlife Department maintained a passive fish tagging program from 1975 – 1990, and 88% of spotted seatrout tagged in the upper Laguna Madre (ULM) were reportedly recaptured within the ULM, 11% were recaptured in another bay, and 1% were recaptured from Gulf of Mexico waters (Bowling 1991). Genetic analysis has indicated that there may be several overlapping subpopulations of spotted seatrout inhabiting the Texas coast with sufficient population mixing between adjacent estuaries to prevent genetic divergence (Gold et al. 2003, Anderson and Karel 2010). Anecdotally, fisherman claims suggest large adult spotted seatrout found in near-shore surf zones migrate into bays during spring and may populate critical spawning stocks of spotted seatrout in the Laguna Madre. Movement cues are unknown, but hypothesized to be driven by environmental change, spawning activity, and feeding (Kostecki 1984). Spotted seatrout are believed to adapt to temperature changes by moving between shallow water and deeper channels, or occasionally offshore (Pattillo et al. 1997). Historical reports indicate that large spotted seatrout move from the Gulf of Mexico to estuarine waters to feed during spring months (Pearson 1928). Inshore movements are thought to be related to temperature fluctuations and spawning activity (Kostecki 1984).

One of the most effective ways to identify movement patterns of fishes is through the use of acoustic tracking technology. Passive acoustic ultrasonic telemetry employs an array of stationary receivers to detect signals from fish affixed with uniquely coded transmitters. In addition to movement patterns, this method can identify habitat use and residency times at multiple scales based on the array design. Moreover, acoustic telemetry is more reliable than fisheries-dependent sources because data collection does not rely solely on angler tag returns. For a successful acoustic telemetry study it is imperative to ensure that the test subjects survive tagging, retain transmitters throughout the study, and that fish health and behavior is not compromised (Bridger and Booth 2003, Cooke and Wagner 2004, Wagner and Cooke 2005, Brown et al. 2010). Transmitters may be attached externally, inserted intra-gastrically, or surgically implanted into the peritoneal cavity (Bridger and Booth 2003). External attachment requires a short handling time (Bridger and Booth 2003) and has been regarded as less invasive than other techniques (Mulcahy 2003); however, this method was found to increase risk of fish entanglement and transmitter loss (Bridger and Booth 2003, Mulcahy 2003) and alter spotted seatrout behavior and health (Bradshaw 2006). Intra-gastric insertion minimizes handling time but tags are often regurgitated or passed through the digestive tract and may impede feeding, swimming, or cause death (Adams et al. 1998, Jepsen et al. 2002, Bridger and Booth 2003, Hall et al. 2009). Surgical implantation involves a ventral incision, tag insertion, and closure (Harms 2005, Wagner and Cooke 2005). Surgical procedures increase handling time, infection risk, physiological stressors (Jepsen et al. 2001, Bridger and Booth 2003, Hall et al. 2009) and may influence behavior and movement (Wagner and Cooke 2005). However, surgical implantation decreases drag and transmitter loss (Bridger and Booth 2003, Harms 2005) and is considered more appropriate for long-term tracking studies (Adams et al. 1998, Zeller 1999, Starr et al. 2000, Jepsen et al. 2002). In general, long-term effects of surgical implantation on survival, growth, behavior, and physiology of fish are minimal (Bridger and Booth 2003). Hall et al. (2009) reported that mortality in Chinook salmon (*Oncorhynchus tshawytscha*) that underwent surgical procedures with or without tag implantation was due to surgery alone. For implanted fish, reduction of surgical time may be the most important factor in post-surgical survival (Petering and Johnson 1991). Additionally, since tagging is often conducted in the field, surgical techniques must be simple and efficient to ensure stressors are kept to a minimum (Jepsen et al. 2002).

Surgical techniques are species specific, suggesting a need to develop optimal surgical procedures in a controlled setting prior to conducting experiments in the field (Moore et al. 1990, Bridger and Booth 2003, Wagner and Cooke 2005, Fabrizio and Pessutti 2007). Predatory fish, like spotted seatrout, generally have a large body cavity and more flexible body wall (Jepsen et al. 2002), making the spotted seatrout an ideal candidate for surgical implantation. Successful surgical tag implantation in spotted seatrout has been reported (S. K. Lowerre-Barbieri, Florida Fish and Wildlife Conservation Commission, personal communication); however, a direct investigation of effective surgical techniques to implant transmitters in spotted seatrout has not been published in primary literature. Typical incision placement is between the pelvic girdle and anus on the ventral midline (linea alba) or lateral to the midline (Wagner and Stevens 2000) but can vary by species and age (Bridger and Booth 2003). For example, Wagner and Stevens (2000) found no difference in the amount of inflammation between midline and off-midline incision locations in rainbow trout (*Oncorhynchus mykiss*). However, unlike the rainbow trout, male spotted seatrout, as most sciaenids, have well-developed sonic muscles running laterally along the ventral wall of the peritoneal cavity. Damaging these muscles may influence the reproductive capabilities of male spotted seatrout and/or impact healing and survival of surgically implanted spotted seatrout (S. K. Lowerre-Barbieri, Florida Fish and Wildlife Conservation Commission, personal communication).

Opinions regarding the most appropriate surgical materials and methods vary among researchers and species. Suture material is often a personal preference; however, suture selection should consider the tissue reactivity and healing time (Harms and Lewbart 2000). It is important to ensure the suture will remain long enough to allow the incision to heal. The most commonly used incision closure materials include braided and monofilament suture, though some researchers prefer surgical staples. Braided suture has the benefit of relative ease of tying and adequate strength (Jepsen et al. 2002) but has wicking properties that provide a potential transport pathway for bacteria to enter the peritoneal cavity (Wildgoose 2000, Harms 2005), potentially increasing risk of infection and death. In addition, braided suture has been documented to irritate skin surrounding needle punctures (Wagner et al. 2000, Jepsen et al. 2002) and to provide a surface for algal attachment potentially creating extra drag and promoting grazing activity by other fishes (Thoreau and Baras 1997, Jepsen et al. 2002). Monofilament suture with swaged-on needles minimizes tissue damage and prevents bacterial ingress through capillary effect of braided materials (Wildgoose 2000, Harms 2005). Thoreau and Baras (1997) reported that incisions closed with polyamide monofilament heal faster than braided silk or plain catgut suture in blue tilapia (*Oreochromis aureus*). Suture that is designed to be rapidly absorbed in mammalian tissue may exhibit long-term retention in fish (Harms and Lewbart 2000); therefore, monofilament suture may be more appropriate than braided suture to minimize bacterial intrusion (Harms 2005). Use of staples can dramatically decrease handling time and cause less local infection, potentially reducing mortality in species that are easily stressed (Mulford 1984, Swanberg et al. 1999) such as spotted seatrout. However, fish skin can be unfavorable for consistent staple placement, resulting in increased mortality and transmitter loss (Harms and Lewbart 2000, Mulcahy 2003, Harms 2005).

The overall goal of this study was to assess movement patterns and migratory pathways of spotted seatrout among south Texas bays and coastal waters. To date, no 'real-time' tracking studies have investigated potential migrations of spotted seatrout along the south Texas coast. These data will elucidate migratory patterns and allow fishery managers to make more informed decisions regarding management of spotted seatrout populations. Specifically, this study addressed three aspects of acoustically tagging and tracking spotted seatrout: (1) determine the most effective surgical techniques to ensure both survival of spotted seatrout and retention of peritoneally implanted acoustic transmitters; (2) document movement patterns within the LLM and connectivity between the LLM and adjacent bay systems, and through passes that connect the LLM or adjacent bays with the Gulf of Mexico; and (3) provide additional data on catch-and-release angling as a viable management practice.

OBJECTIVES:

1) Evaluate effective surgical procedures including placement of incision and suture material for acoustic transmitter implantation in spotted seatrout.

$H_{O,1}$**:** Surgical transponder implantation procedure has no effect on post-surgical survival, incision healing, or transmitter retention of spotted seatrout.

$H_{A,1}$**:** Incision placement and suture material will affect post-surgical mortality, healing, and transmitter retention of spotted seatrout.

2) Surgically tag spotted seatrout and track their landscape-scale movement patterns among south Texas bays and coastal waters.

$H_{O,2}$**:** Spotted seatrout populations do not mix between near-shore and inshore waters.

***$H_{A,2}$*:** Spotted seatrout exhibit a wide range of migration patterns including among bay systems and from near-shore to inshore waters of Baffin Bay via tidal inlets.

3) Assess mortality rates of recreational and tournament-caught spotted seatrout implanted with acoustic transmitters.

***$H_{O,3}$*:** There is no additional effect on catch-and-release mortality when implanting fish with acoustic receivers.

***$H_{A,3}$*:** Spotted seatrout will have decreased survival rates after undergoing surgical procedures to implant acoustic transmitters.

MATERIALS AND METHODS

Study Site

This study focused on the Northwestern Gulf of Mexico in the South Texas Coastal Bend (Fig. 1). Specifically, the tracking array was located from Aransas Pass to Port Mansfield (East Cut), Texas. An acoustic gateway was deployed in each inlet (Aransas Inlet, Mansfield Inlet, and Packery Channel) with the most bay coverage in Upper Laguna Madre. The Laguna Madre (LM) is a hypersaline estuary (2160 km^2) located along the southwest Texas coastline. It is approximately 185 km in length and has a varying width of 3 to 12 km (Tunnell and Judd 2002). The estuary is divided into two regions, the upper LM and lower LM by a land-bridge extending from Padre Island to the mainland. The regions are connected by a narrow man made channel, the Land-Cut, built in the 1940's to facilitate marine transportation through the Gulf Intracoastal Waterway (GIWW). The average depth of the LM is 1.2 m with deeper areas associated with the

GIWW ship channel. The LM has a semi-arid climate and is one of the largest hypersaline lagoons in the world due to limited freshwater inflow, low rainfall, and high evaporation rates. Freshwater is primarily received through highly variable annual precipitation averaging approximately 69 cm per year with the most rain occurring

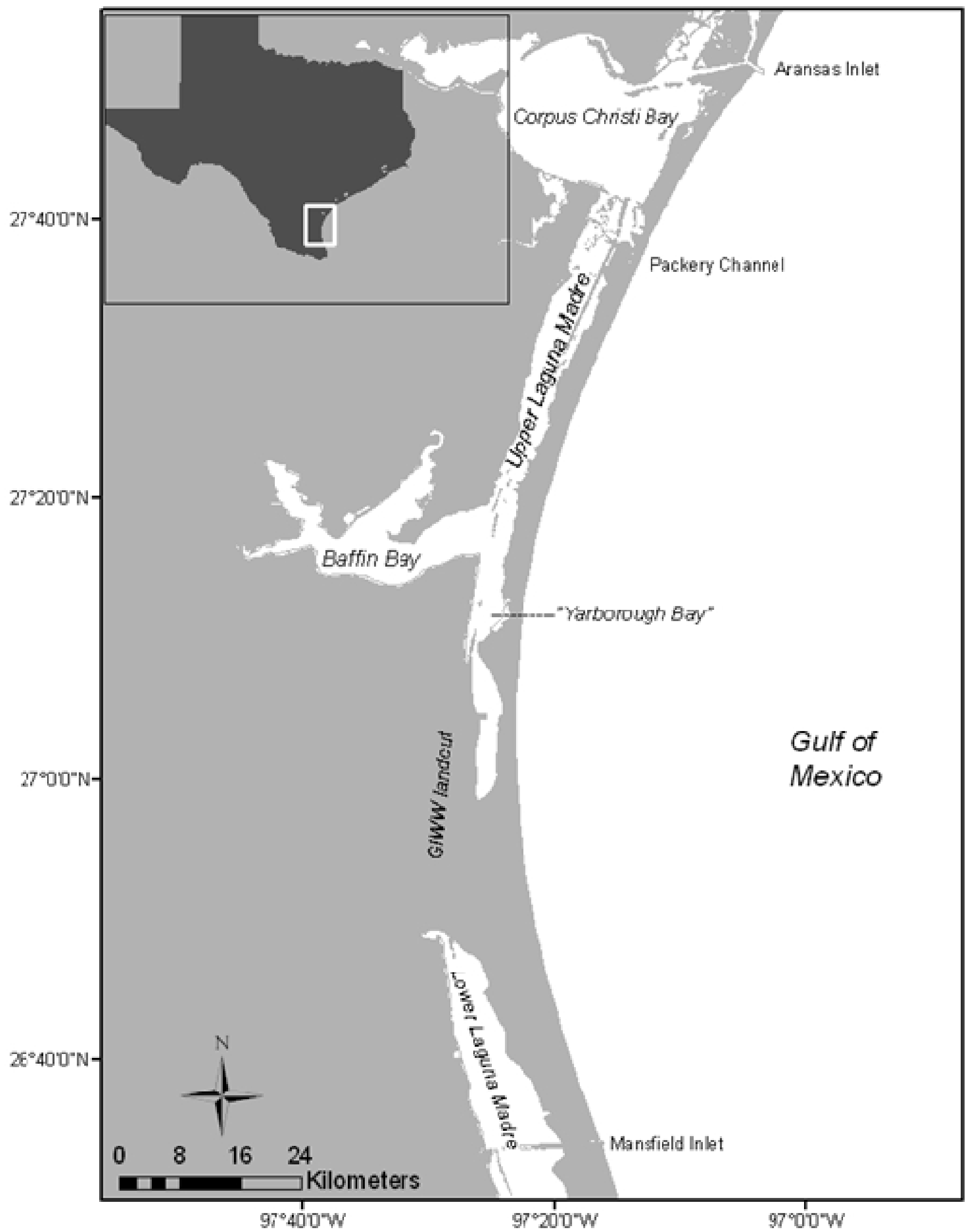

Figure 1. Map of study area along the Northwestern Gulf of Mexico in the South Texas Coastal Bend.

in May-June and August-October. Estuarine habitat types in the LM system include: seagrass meadows (predominantly *Halodule wrightii*), non-vegetated bottom, oyster reefs (*Crassostrea virginica*), relic serpulid worm reefs, and remnant rocky shorelines (McKee 2008). Sixty-one percent of the submerged habitat is seagrass which serves as a food source and nursery refuge for many estuarine species.

Surgical Implantation Experiment

Seventy spotted seatrout were collected via hook and line from varying locations within Corpus Christi Bay, Aransas Bay and the Upper Laguna Madre. Spotted seatrout greater than 350 mm total length (TL) were targeted to follow tag/bodymass guidelines which recommend tag weight should not exceed 2% of body weight (Winter 1992, Jepsen et al. 2002, Bradshaw 2006). Collected fish were held in 416-L oxygenated holding tanks and transported to the TPWD, CCA/AEP Marine Development Center (TPWD-MDC), Corpus Christi, Texas. Spotted seatrout were held in 12,000-L circular fiberglass tanks (3.7 m x 1.5 m) at TPWD-MDC and fed a mixture of dead shrimp and squid to satiation three times weekly. Fish were acclimated for a minimum of one week before any experimental procedures were conducted; they were monitored for mortality from the catch and transport process, and prompted to resume feeding activity. Spotted seatrout were surgically implanted with inactive “dummy” transmitters to evaluate surgical procedures. Dummy transmitters were identical replicates of the Vemco (A division of AMIRIX Systems Inc., Halifax, Nova Scotia, Canada) V13 transmitters (36 mm length x 13 mm diameter, 6 g weight in water, 11g weight in air) that were used for subsequent movement studies.

Six treatment groups (nine fish in each treatment for a total of 54 fish) were used to investigate two incision locations (midline and off-midline) and three suture materials (braided, monofilament, and staples). Control procedures (two fish in each treatment for a total of 12 fish) included each of the six surgical treatments without dummy tag implantation (Table 1). Four additional fish served as tank controls; two fish were held in the cradle for three minutes without surgery, and two fish were transferred directly to the recovery tank. Food was withheld from fish 24 h prior to surgery to minimize regurgitation and defecation during surgical procedures (Summerfelt and Smith 1990, Wildgoose 2000).

Table 1. Number of fish in each treatment group, listed by incision location and suture material, for laboratory surgical trials. Four additional fish were used as tank controls, two were held in the cradle for 3 min without undergoing surgery and two underwent a direct transfer between tanks without any holding time or surgical procedures. Surgery fish were implanted with an acoustic dummy tag. Surgical controls underwent the surgical process of incision and closure without placement of an internal tag. Vicryl = polyglactin braided suture, PDS = polydioxanone monofilament suture, Staples = surgical skin staples.

Treatment	Midline n=33			Off-midline n=33		
	Vicryl	PDS	Staples	Vicryl	PDS	Staples
Surgery	9	9	9	9	9	9
Surgical control	2	2	2	2	2	2
Totals	11	11	11	11	11	11

Surgical procedures were alternated randomly between treatment groups to decrease any effect of surgeon experience (Wagner and Cooke 2005). Surgical treatments were performed on fish indiscriminately captured from the holding tank and randomly assigned to a treatment. Fish were placed dorso-ventrally in a surgical cradle designed to allow the head and gills to remain submerged. A 2.5 cm incision (#10 scalpel blade) was made posterior to the pelvic fin insertion either directly on the midline or approximately 1.5 cm lateral to the midline depending on the treatment for transmitter insertion. Transmitters were disinfected in a 12.9% solution of benzalkonium chloride and rinsed in sterile water before insertion into the peritoneal cavity (Mulcahy 2003). A uniquely numbered anchor tag (Floy Tag & Mfg. Inc., Seattle, Washington, USA) was placed at the posterior end of the incision for individual fish identification. Incisions were closed with a single suture secured with a surgeons knot when using absorbable braided suture material (Vicryl, 4-0 PS-2 cutting, Ethicon, Inc., Somerville, New Jersey) or absorbable mono-filament suture material (PDS II, 4-0 PS-2 cutting, Ethicon, Inc., Somerville, New Jersey), or 3 surgical staples (Appose ULC 35, Tyco healthcare UK Ltd., Gosport, United Kingdom). The holding tank was checked daily for the first week post surgery to monitor for mortality, transmitter loss, and anchor tag loss. During weeks two through four, fish were checked three times weekly at scheduled feedings. Fish were fed dead shrimp, cut squid, and mackerel to satiation three times per week. Dead fish were removed and evaluated immediately upon discovery. After 31 d, fish were euthanized with a lethal dose of tricaine methanesulfonate (MS-222), evaluated, and assigned incision healing scores adapted from Wagner and Stevens (2000) (Table 2). Suture material was evaluated on the basis of presence/absence of inflammation (reddened or raised tissue) at each suture entry/exit site with a minimum score of 0 indicating no inflammation and a maximum score of 2 indicating both sites were inflamed.

Table 2. Rating scale of macroscopic appearance and healing of incisions. Inflammation is defined as red raised skin around the incision and suture sites. Adapted from Wagner (1999).

Score	Scoring criteria
0	Incision completely closed, no inflammation present
1	Incision closed, some inflammation present
2	Incision held in proximity, but not completely closed. Little to moderate inflammation.
3	Incision held in proximity, but not closed. Moderate inflammation.
4	Incision partially open, moderate to high inflammation.
5	More than 50% of incision open. Moderate to high inflammation.
6	Completely open wound. High inflammation.

Acoustic Telemetry Tracking

An array of 24 VR2W acoustic receivers was deployed during the fall of 2009 to monitor individual fish movements throughout the study area. Receivers were attached to navigational markers and other fixed posts with a system of cable ties and a rope leash. A stainless eye screw was secured in the wood piling and a 1.5 m rope leash was tied through the eye screw and receiver to act as a safety. A minimum of four cable ties (122 cm long; 79 kg strength) were used to secure receivers to the piling. Receivers were placed at a depth approximately 1.5 m below the low water mark to ensure equipment remained submerged during any low tide events.

Acoustic receivers were placed strategically in areas of "bottlenecks" near the inlets and throughout the GIWW (Figure 2). Receiver locations were identified based on a 1,000 m radius detection range; however, this range can vary with environmental conditions. Range testing was performed at nine receiver locations representative of the varying environmental conditions where all receivers were deployed: high energy, shallow water and inlet. High energy areas were areas of deep (>1.5 m), open water

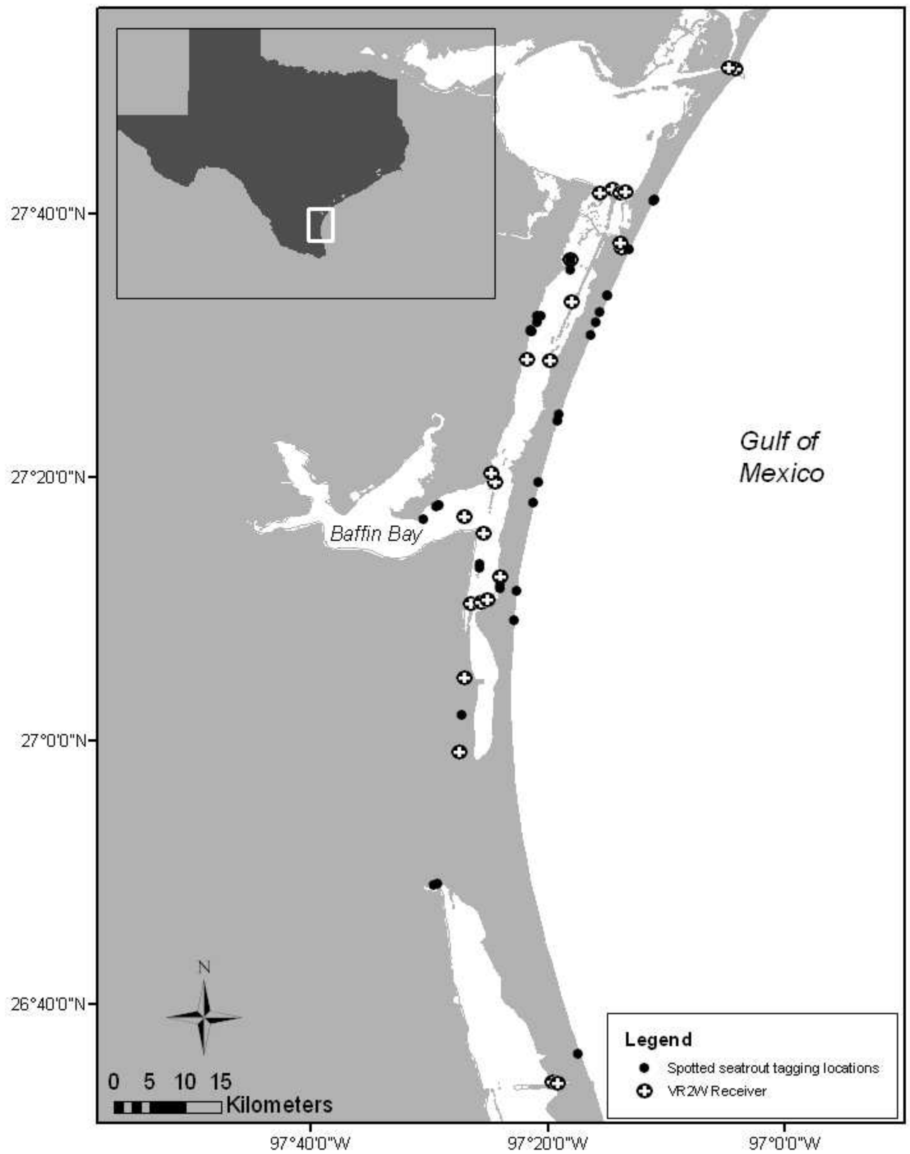

Figure 2. Map of VR2W receiver and spotted seatrout tag-and-release locations. Cross hatched circles are receiver locations and solid dots are fish tagging locations.

highly affected by wind and wave energy. Shallow areas were characterized by shallow water (<1.5 m) typically with vast amounts of submerged aquatic vegetation. Inlet areas had increased boat traffic and tidal movement. A test transmitter with a constant transmission interval of 15 s was deployed at distances of 100 m, 250 m, 500 m, and

1,000 m in at least three directions from the receiver to determine the number of signals received during the given timeframe. Additional tests were completed at a distance of 50 m on receivers with low detections to ensure signal acquisition. Testing at a distance of 50 m only occurred at shallow and high energy receiver locations. The test transmitter was held at approximately 1 m depth for 5 min at each location. The number of detections at each distance was averaged among receivers with similar environmental conditions. Conditions that may influence tag detections (e.g., wave energy, current, etc.) are highly variable throughout the study system. Thus, I only used simple probabilities to calculate the chances of detecting the signal from a tag at each distance.

For spotted seatrout tracking, acoustic receivers were checked every 4-6 months to download data, remove any bio-fouling, and ensure that receivers were in proper working condition. Data was downloaded using a Panasonic Toughbook CF-30 and Vemco's VUE 1.6.5 software. Data recorded by receivers included the unique acoustic identification number, date, and time that each individual fish was present within the signal detection radius.

To determine fish movements and connectivity, spotted seatrout greater than 400 mm TL from LLM, ULM, and near-shore surf zones were captured by hook-and-line, tagged, and released during 8 December 2009 and 20 October 2010. Captured fish were held in a 114-L cooler filled with oxygenated seawater. Spotted seatrout were surgically implanted with Vemco V13 (36mm length X 13mm diameter, 6g weight in water, 11g weight in air) coded transmitters in the field and released after a brief (approximately 5 min) post surgical observation period. Transmitters were coded to emit an identifying pulse series for each fish, operated on a 69.0 kHz frequency with randomly spaced intervals of 50 s to 130 s, and had an estimated battery life of 890 d. Random signal transmissions are designed to prevent signal blockage when more than one study animal is within detection range of an acoustic receiver. Field implantations followed the same procedures as those described for surgical trials above. All incisions were made lateral to the mid-line and closed with two sutures using braided suture material (Vicryl, 4-0 PS-2 cutting, Ethicon, Inc., Somerville, New Jersey). The addition of another closing suture added minimal time to the surgical process and provided assurance that incisions would remain closed if a suture failed. All fish were externally marked for identification with a uniquely numbered dart tag (PDS plastic tipped, Hallprint Pty Ltd, Victor Harbor, South Australia, Australia) inserted at the base of the first dorsal fin. Fish were released into the area from which they were captured.

Fish captured during live-release tournaments came from unknown locations and may have been transported tens to hundreds of km to a central weigh station. Fish may have been from any waters in which it was reasonable to travel within the tournament time guidelines. However, tournament rules restrict fishing activity to inshore waters only; anglers may not fish outside the inlet jetties. To determine movements and survival of tournament displaced fish, a total of 20 spotted seatrout were tagged and released from two different live-release tournaments in January (n = 10) and February (n = 10) of 2010. Following tournament weigh-in activities, spotted seatrout were placed in an oxygenated holding tank at the tournament facility to recover from capture, holding and transport, and weigh-in activities. Implant procedures were the same as the field tagging procedures described above. Following transmitter implantation, fish were transported in

114-L coolers to a single release location in the ULM where one of the tracking receivers was deployed (ULM Pita Island).

Data Analysis

Surgical Implantation Experiment Analysis

To determine what surgical factors influence survival, I used a one-way Analysis of Variance (ANOVA) with incision location (midline or off-midline) and sex (i.e. male midline incision) as the independent variable and percent survival as the dependent variable. Significant ANOVA results were further analyzed using Holm-Sidak pairwise multiple comparison procedures. An ANOVA was also used to assess differences in survival and tag retention among incision location and suture treatment groups. Survival tests included all fish that underwent surgical procedures, and tag retention tests excluded all mortalities and surgical control fish. Student's t-test was used to evaluate incision healing and suture healing scores. A statistical significance levels at $\alpha=0.05$ was used for all tests.

Acoustic Telemetry Analysis

All movement data was imported into ArcMap (ArcView, ESRI, Redmond, CA, USA) to map animal migration. Due to the potential for surgical stress to alter behavior, data collected within 24 hours post surgery was eliminated from movement analyses (Bridger and Booth 2003). Movement data was analyzed with Animal Movements Analyst Extension (AMAE) for ArcMap. The AMAE calculates total straight-line distances traveled between receiver locations and allows formation of minimum convex polygons (MCP) to estimate the minimum area used by each individual. Days at liberty (DAL), the number of days the fish was tracked, was calculated by subtracting the last known detection date from the initial tagging date. The last known detection date was the last day a fish was detected within the array or recaptured by an angler. Distance traveled per day was calculated by dividing the total distance traveled by the number of days at large. The MCP provides a reasonable assumption of the general area in which you may find an individual fish that was detected on more than one receiver (Hooge et al. 2000, Lowe et al. 2003). Mean distance traveled per day was compared among bay, surf and tournament-tagged spotted seatrout using one-way ANOVA (α=0.05). Mean areas were compared between bay and tournament spotted seatrout using Student's *t*-test.

RESULTS

Surgical Trials

Generally, there was high survival of spotted seatrout during the surgical implantation experiment. Survival was 100% for non-surgical controls, 75% for surgical controls, and

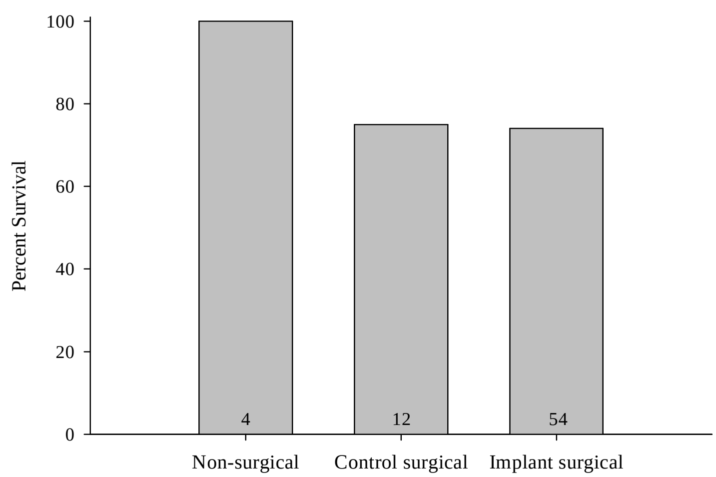

Figure 3. Percent survival for surgical trial fish. Non surgical fish were transferred to the tank only, surgical control fish had surgery without tag implantation, and surgical implant fish received an internal dummy tag. Numbers at the bottom of the bars indicate sample size (n) for each group.

74% for surgically implanted fish (Fig. 3). Male fish with an off-midline incision had significantly lower survival (p=0.002, $F_{3,62}$ = 5.456) (33.3%) than females, regardless of the incision location (midline=84%, off-midline=87.5%). There was no significant difference in survival for male fish with a midline incision (50%) compared to male fish with off-midline incision (Fig. 4). Due to low sample size after accounting for fish mortality and removing control fish from the analysis (female n = 37, male n = 3), I was unable to reliably determine differences in tag retention or incision healing between sexes.

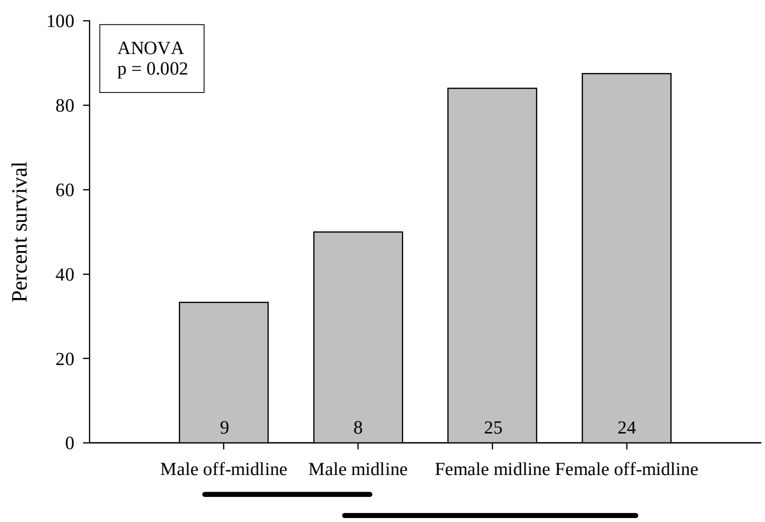

Figure 4. Comparison of survival rates between sexes with midline and off-midline incision locations. Numbers at the bottom of the bars indicate sample size (n) for each group.

I also determined the effect of suture material and incision placement on survival of spotted seatrout. Surgical staples were problematic due to poor staple adhesion (i.e., incision closure), low tag retention (62% overall), and high suture inflammation (midline mean = 0.67, SE = 0.37; off-midline mean = 1.0, SE = 0.54); therefore staples were eliminated as a viable closure material for spotted seatrout and were not used as a treatment group in the remaining analyses. Additionally, sex was excluded as a variable due low sample size because very few males (n = 17) were captured. There was no

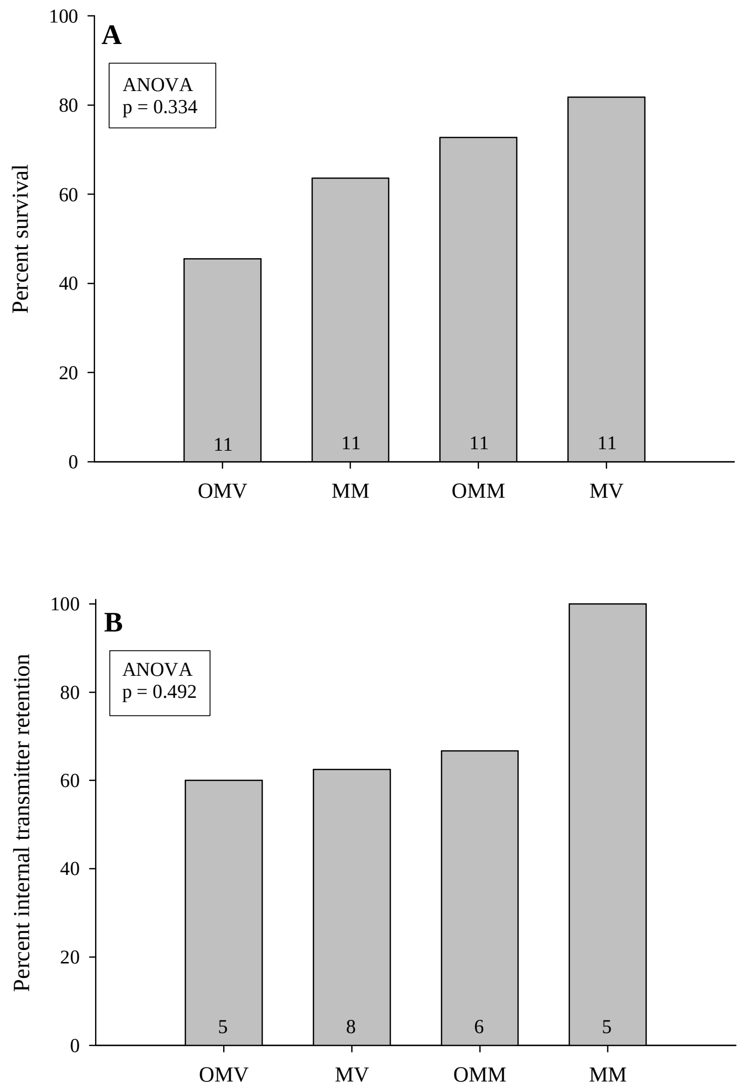

Figure 5. (A) Percent survival among treatment groups. (B) Percent internal transmitter retention among treatment groups with non survivors excluded. MM = midline incision with monofilament closure material; MV = midline incision with vicryl (braided) closure material; OMM = off-midline incision with monofilament closure material; OMV = off-midline incision with vicryl (braided) closure material. Numbers at the bottom of the bars indicate sample size (n) for each group.

significant difference in survival ($p = 0.334$, $F_{3,40} = 1.167$, $1 - \beta = 0.077$) or tag retention ($p = 0.492$, $F_{3,20} = 0.832$, $1 - \beta = 0.049$) among combined incision placement and suture material treatment groups (Fig. 5). However, survival was lowest in the off-midline vicryl (46%) followed by midline monofilament (64%), off-midline monofilament (73%), and midline vicryl (82%). Transmitter retention was also lowest in the off-midline vicryl (60%), but different from survival, midline vicryl (63%) had lower transmitter retention than midline monofilament (100%), and off-midline monofilament had transmitter retention of 67%.

Incision healing was assessed by combining treatments according to incision location. There was no significant difference ($p = 0.980$, $t = 0.0257$, $df = 47$, $1 - \beta = 0.05$) in mean incision healing between midline and off-midline incision placement (Fig. 6). Mean incision score for an off-midline incision location was ($0.75 \pm$ SE 0.30) and

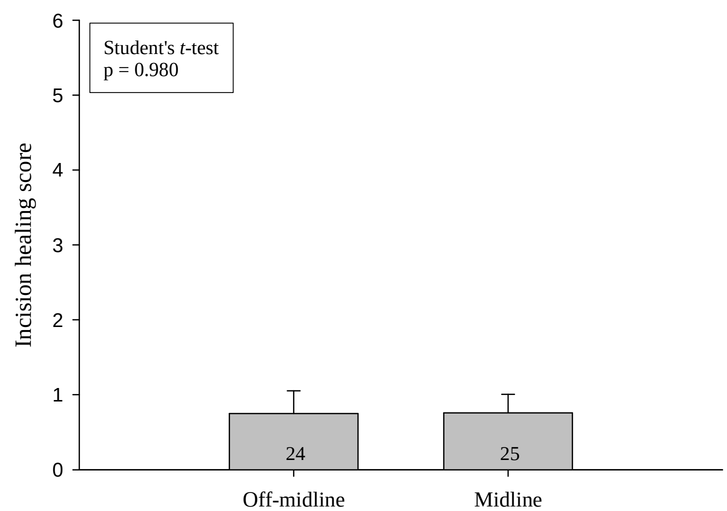

Figure 6. Comparison of healing between off-midline and midline incision locations. Numbers at the bottom of the bars indicate sample size (n) for each group.

midline incision was (0.76 ± SE 0.25). Suture induced irritation was evaluated by combining treatments according to suture material. Student's *t*-test showed no significant difference ($p = 0.130$, $t = -1.560$, $df = 27$, $1 - \beta = 0.198$) in suture induced irritation between braided Vicryl and monofilament suture materials (Fig. 7). Vicryl suture material had a mean suture inflammation score of 1.2 and monofilament suture material had a mean score of 1.8.

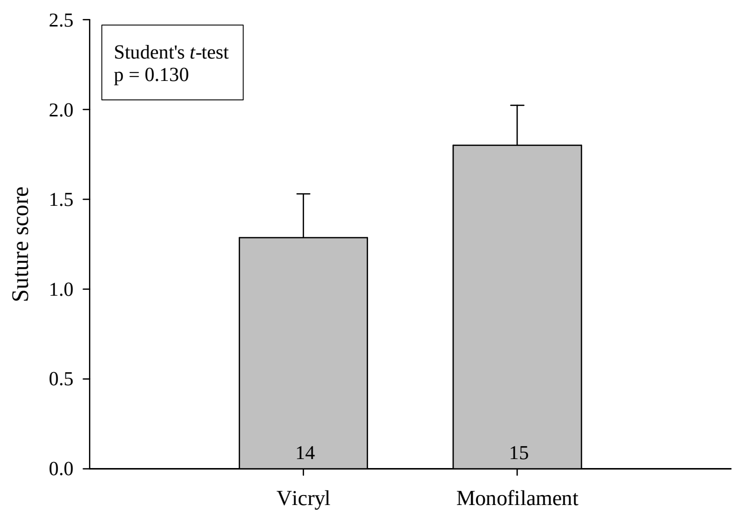

Figure 7. Comparison of suture induced inflammation between monofilament and vicryl (braided) suture material. Numbers at the bottom of the bars indicate sample size (n) for each group.

External anchor tags used to identify individual fish were also problematic. Many were expelled along with transmitter losses; therefore, some fish were identified by total length, incision location, and suture type. Anchor tags in the current study were placed at the posterior end of a 25 mm incision. In this study there was a 24.3% loss of the external anchor tags. Of those fish that did retain the external tags 73.4% were inflamed at the exit point or the anchor had prevented the incision from healing completely.

While not the main goal of this study, I noticed a general trend of decreased survival and tag retention as the tag to body mass ratio increased. However, linear regression indicated that there is not a significant difference in survival ($R^2 = 0.30$, $p = 0.452$, $1 - \beta = 0.089$) or tag retention ($R^2 = 0.414$, $p = 0.168$, $1 - \beta = 0.262$) with increasing tag to bodymass ratio (Fig. 8). In smaller fish (<16” TL), transmitters were clearly visible putting pressure on the body wall.

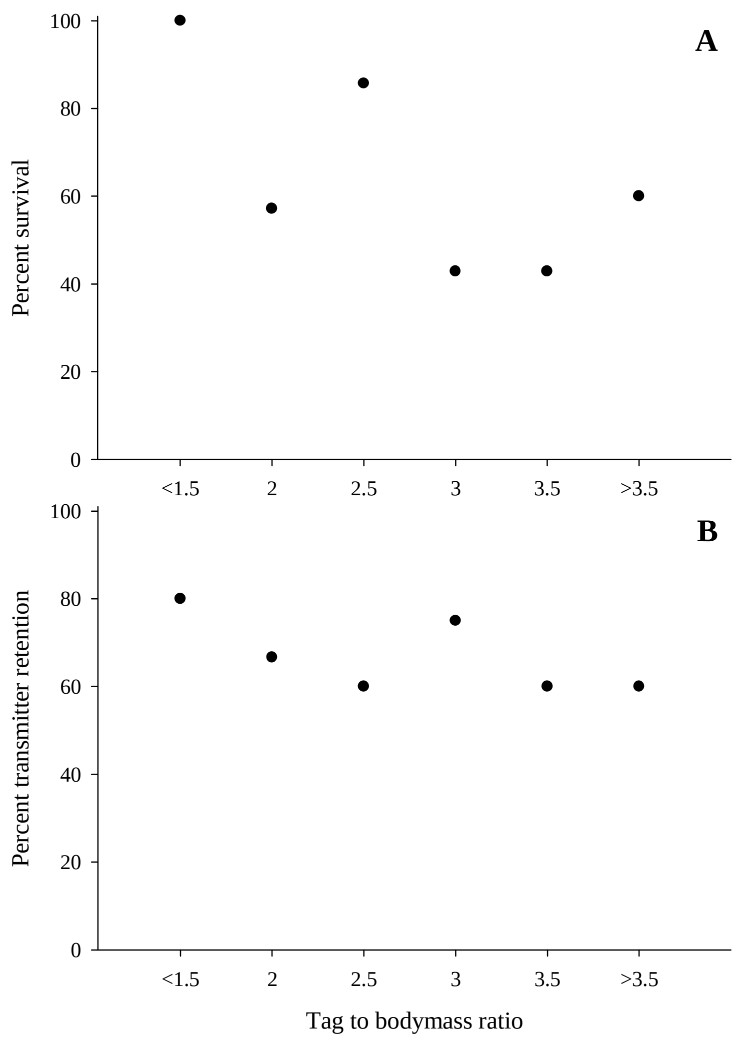

Figure 8. Linear regression of percent survival (A) and percent transmitter retention (B) with increasing tag to body mass ratio.

Range Testing

Detection ranges were lower than anticipated at all distances, regardless of location. Range testing was completed in one day; therefore, detection ranges may vary considerably with changes in environmental conditions. Mean simple probabilities of signal detection were calculated for four test distances (100 m, 250 m, 500 m, and 1000 m) (Table 3). Initial tests were planned to test a minimum distance of 100 m; however,

Table 3. Mean probability of signal detection among receivers in locations representative of the varying environmental conditions where all array receivers are placed. A dash (-) indicates a distance that was not tested.

Environmental Conditions	Distance from Reciever (m)				
	50	100	250	500	1000
High Energy	-	0.60	0.16	0.00	0.00
Inlet	0.51	0.24	0.09	0.22	0.00
Shallow	0.37	0.20	0.00	0.00	0.00

low detections at inlet and shallow water sites prompted 50 m signal detection tests at these locations. Receivers in high energy areas had the highest detection probability (60%) at 100m then decreased sharply as distance increased (Fig 9). Inlet and shallow water receivers had very low detection probabilities at 100 m, with the highest detection probabilities of 51% and 37%, respectively, at 50 m. Similar to the high energy locations, the signal detection was fair at very close range, but declined with increasing distance.

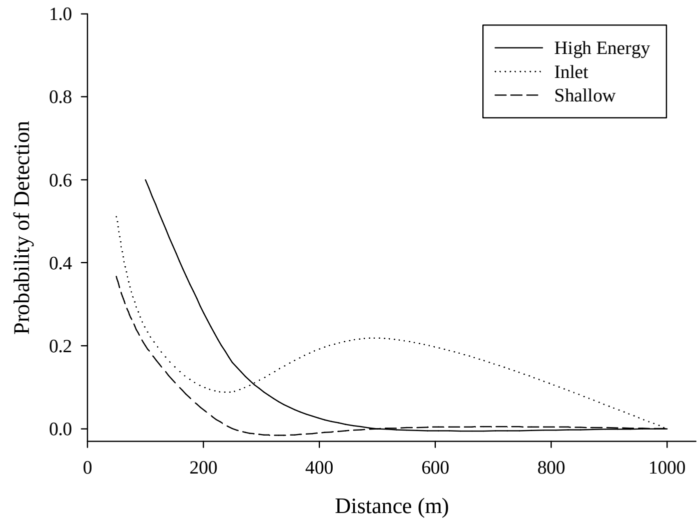

Figure 9. Probability of tag detection at increasing distances from receivers. High Energy = areas of deep (>1.5 m), open water highly affected by wind and wave energy; Inlet = areas of increased tidal movement and boat traffic; Shallow = areas where water depth is less than 1.5 m and typically had vast amounts of submerged aquatic vegetation.

Acoustic Telemetry

A total of 81 spotted seatrout were captured and implanted with acoustic tags for long term tracking (Table 4). Five fish from the LLM and 26 fish from the ULM were captured and tagged between December 2009 and September 2010 (Fig. 2). Thirty fish were collected, tagged, and released from varying locations along the seaward side of barrier islands (surf) between Port Aransas and Port Mansfield between December 2009 and October 2010. Days at liberty varied considerably among individual fish with a range of 1 to 272 d. Distance traveled included individual movements between detection and/or recaptures locations and ranged from 0.4 to 96.9 km. Individual daily distances ranged from 0 to 12.8 km. Mean minimum area was calculated when possible and ranged from 2.9 to 140.1 km^2. Mean area per day ranged from 0 to 7.8 km^2.

Table 4. Summary data of 81 spotted seatrout tracked using acoustic telemetry at the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University - Corpus Christi, Corpus Christi, Texas. Tag ID = unique fish identifier. TL = total length of the fish, tail compressed. Zone represents the general area of capture and tagging: I = inshore; S = surf; T = tournament. Recapture date indicates that a fish was caught and reported by an angler, * indicates a fish that was reported as released after recapture. Last detection date is the last date the fish was detected within the acoustic array. Days at large is the number of days the fish was tracked. Distance traveled is the shortest distance the fish traveled assuming the fish traveled in a straight line between points. Distance per day is the approximate distance traveled in the course of one day. Area is the minimum area of fish travel. Area per day is the approximate area utilized by each fish per day.

Tag ID	TL (mm)	Sex	Zone	Tagging date	Recapture date	Last detection date	Days at large	Distance traveled (km)	Distance per day (km)	Area (km^2)	Area per day (km^2)
51129	420	U	I	12/8/2009	6/19/2010	4/22/2010	193	77.4	0.4	8.8	0.0
51128	475	U	I	12/8/2009	-	3/10/2010	92	5.4	0.1	-	-
51127	524	U	I	12/8/2009	-	5/2/2010	145	36.7	0.3	12.5	0.1
51130	660	U	I	12/14/2009	-	9/12/2010	272	21.1	0.1	-	-
51132	447	U	I	12/14/2009	-	-	-	-	-	-	-
51131	471	U	I	12/14/2009	-	-	-	-	-	-	-
51133	538	U	I	12/14/2009	-	-	-	-	-	-	-
51134	517	U	S	12/20/2009	-	-	-	-	-	-	-
51136	586	U	T	1/30/2010	-	4/6/2010	66	112.6	1.7	127.1	1.9
51138	590	U	T	1/30/2010	-	2/17/2010	18	55.8	3.1	140.1	7.8
51135	617	U	T	1/30/2010	-	3/31/2010	60	32	0.5	-	-
51143	630	U	T	1/30/2010	-	5/18/2010	108	102.9	1.0	37.9	0.4
51142	655	U	T	1/30/2010	-	4/15/2010	75	60.4	0.8	72.6	1.0
51140	685	U	T	1/30/2010	-	2/3/2010	4	0.005	0.0	-	-
51144	725	U	T	1/30/2010	-	2/23/2010	24	32.9	1.4	-	-
51139	664	U	T	1/30/2010	-	-	-	-	-	-	-
51137	675	U	T	1/30/2010	-	-	-	-	-	-	-
51141	720	U	T	1/30/2010	-	-	-	-	-	-	-
51147	473	U	I	2/17/2010	4/27/2010*, 5/8/2010*	-	69	0.4	0.0	-	-
51146	497	U	I	2/17/2010	4/23/2010	-	65	2.8	0.0	-	-
51148	596	U	T	2/27/2010	-	9/4/2010	189	79.9	0.4	20.5	0.1
51149	610	U	T	2/27/2010	7/16/2010	6/7/2010	139	37.1	0.3	2.9	0.0
51153	659	U	T	2/27/2010	-	4/6/2010	38	32	0.8	41.1	1.1
51152	660	U	T	2/27/2010	-	3/31/2010	32	32	1.0	-	-
51155	670	U	T	2/27/2010	-	7/7/2010	130	86.8	0.7	41.9	0.3
51156	582	M	T	2/27/2010	6/23/2010	-	116	1.1	0.0	-	-
51158	595	U	T	2/27/2010	-	-	-	-	-	-	-
51154	656	U	T	2/27/2010	-	-	-	-	-	-	-
51151	672	U	T	2/27/2010	-	-	-	-	-	-	-
51150	688	U	T	2/27/2010	-	-	-	-	-	-	-
51162	406	U	I	3/5/2010	-	10/2/2010	211	32.9	0.2	47	0.2
51163	405	U	I	3/5/2010	-	-	-	-	-	-	-
51165	443	U	I	3/10/2010	-	9/26/2010	200	11.5	0.1	5.3	0.0
51157	469	U	I	3/10/2010	-	5/13/2010	64	26.5	0.4	15.1	0.2
51164	473	U	I	3/10/2010	-	5/6/2010	57	12.1	0.2	5.9	0.1
51166	488	U	I	3/10/2010	-	6/30/2010	112	4.3	0.0	-	-
51160	492	U	I	3/10/2010	-	4/16/2010	37	40.9	1.1	38.1	1.0
51159	515	U	I	3/10/2010	-	8/16/2010	159	36.9	0.2	2.9	0.0
51161	430	U	I	3/10/2010	-	-	-	-	-	-	-

Table 4 continued

Tag ID	TL (mm)	Sex	Zone	Tagging date	Recapture date	Last detection date	Days at large	Distance traveled (km)	Distance per day (km)	Area (km^2)	Area per day (km^2)
51170	440	U	I	3/11/2010	-	8/30/2010	172	9.2	0.1	-	-
51167	463	U	I	3/11/2010	6/7/2010	5/2/2010	88	28.9	0.3	-	-
51168	597	U	I	3/11/2010	-	-	-	-	-	-	-
51169	600	U	I	3/11/2010	-	-	-	-	-	-	-
51171	441	U	I	3/17/2010	4/10/2010	-	24	14.8	0.6	-	-
51172	520	U	I	3/17/2010	-	4/8/2010	22	3.9	0.2	-	-
51173	568	U	I	3/17/2010	-	-	-	-	-	-	-
51175	480	U	I	3/27/2010	-	8/9/2010	135	77.4	0.6	-	-
51174	630	F	I	3/27/2010	-	3/28/2010	1	5.1	5.1	-	-
51176	510	U	I	4/1/2010	-	-	-	-	-	-	-
51177	511	U	I	4/7/2010	-	9/26/2010	172	53.4	0.3	5.3	0.0
51178	508	F	I	4/7/2010	-	9/17/2010	163	70.1	0.4	14.6	0.1
51179	442	M	S	4/21/2010	-	4/27/2010	6	9.4	1.6	-	-
51180	444	F	S	4/21/2010	5/6/2010	-	15	20.3	1.4	-	-
51182	415	U	S	5/28/2010	-	6/23/2010	26	9.5	0.4	-	-
51186	417	U	S	5/28/2010	-	6/5/2010	8	23.9	3.0	-	-
51183	438	U	S	5/28/2010	-	8/27/2010	91	9.5	0.1	-	-
51187	401	M	S	5/28/2010	-	6/2/2010	5	9.4	1.9	-	-
51184	421	F	S	5/28/2010	-	6/6/2010	9	9.5	1.1	-	-
51185	423	F	S	5/28/2010	-	6/2/2010	5	23.9	4.8	-	-
51181	500	F	S	5/28/2010	-	6/6/2010	9	9.5	1.1	-	-
51189	417	F	S	6/22/2010	-	7/10/2010	18	1.1	0.1	-	-
51190	486	F	S	6/23/2010	-	6/24/2010	1	1.1	1.1	-	-
51192	416	F	S	8/1/2010	-	8/5/2010	4	12.2	3.1	-	-
51191	473	M	S	8/1/2010	-	-	-	-	-	-	-
51194	424	U	S	8/11/2010	-	9/1/2010	21	28.7	1.4	-	-
51193	427	M	S	8/11/2010	-	8/19/2010	8	26	3.3	-	-
51199	408	F	S	8/11/2010	-	8/19/2010	8	96.9	12.1	-	-
51195	413	F	S	8/11/2010	-	8/25/2010	14	30.3	2.2	-	-
51200	423	F	S	8/11/2010	-	8/16/2010	5	64	12.8	-	-
51198	461	F	S	8/11/2010	-	8/16/2010	5	36.1	7.2	-	-
51203	499	F	S	8/11/2010	-	8/15/2010	4	55.4	13.9	-	-
51197	541	F	S	8/11/2010	-	10/3/2010	53	36.1	0.7	-	-
51204	422	U	S	8/11/2010	-	-	-	-	-	-	-
51205	435	F	S	8/17/2010	-	8/27/2010	10	15.9	1.6	-	-
51129b	434	M	S	8/17/2010	-	-	-	-	-	-	-
51206	436	F	S	8/17/2010	-	-	-	-	-	-	-
51171b	476	F	S	8/18/2010	-	-	-	-	-	-	-
51146b	587	F	S	8/24/2010	-	-	-	-	-	-	-
51149b	590	F	I	9/13/2010	-	-	-	-	-	-	-
51156b	465	M	S	10/20/2010	10/31/2010*	-	11	10.9	1.0	-	-
51167b	565	U	S	10/20/2010	-	-	-	-	-	-	-

Size differences among the different groups of spotted seatrout tagged were calculated for comparison among groups. The overall mean size of all tagged fish was 519 mm TL (SE = 10.3; range = 401 – 725 mm TL), and there was a significant difference ($p < 0.001$, $F_{2,78} = 78.92$) in TL (mm) among surf, bay, and tournament-tagged spotted seatrout (Fig. 10) . Tournament fish were the largest fish tagged with a mean size

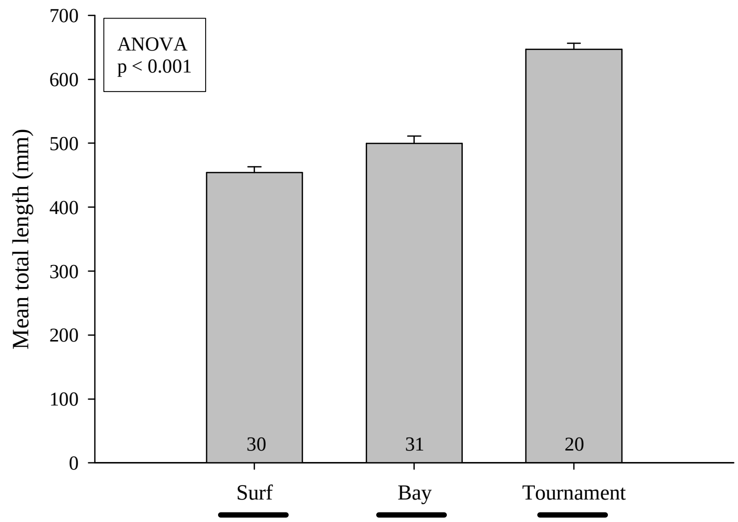

Figure 10. Mean total length (mm) of surf, bay, and tournament-tagged spotted seatrout. Numbers at the bottom of the bars indicate sample size (n) for each group.

of 647 mm TL (SE = 9.8; range = 582-725 mm TL). Spotted seatrout tagged from bay waters were the next largest with a mean size of 499 mm TL (SE = 11.6; range = 405 – 660 mm TL), and surf captured fish were the smallest with a mean size of 454 mm TL (SE = 8.8; range = 401-587 mm TL). Differences in size between sexes was assessed using Student's t-test which indicated there was no significant difference in size between sexes ($p = 0.501$, $t = 0.688$, $df = 16$, $1 - \beta = 0.050$). Mean total length for males was 434 mm (± SE 13.4) and for females was 449 mm (± SE 11.1). However, sex was only recorded when it was confidently identifiable, for this reason our numbers are limited (n = 4 males, n = 14 females) and only data from surf-tagged spotted seatrout were utilized for comparisons of sex differences.

Overall percent survival of all groups of spotted seatrout tagged was high with a combined overall survival was 72%. Tournament spotted seatrout had the lowest survival at 65%, followed by bay-tagged spotted seatrout (68%), and surf-tagged spotted seatrout had the highest survival at 73% (Fig 11). Fish were considered to have survived if they were detected within the acoustic array or recaptured by an angler.

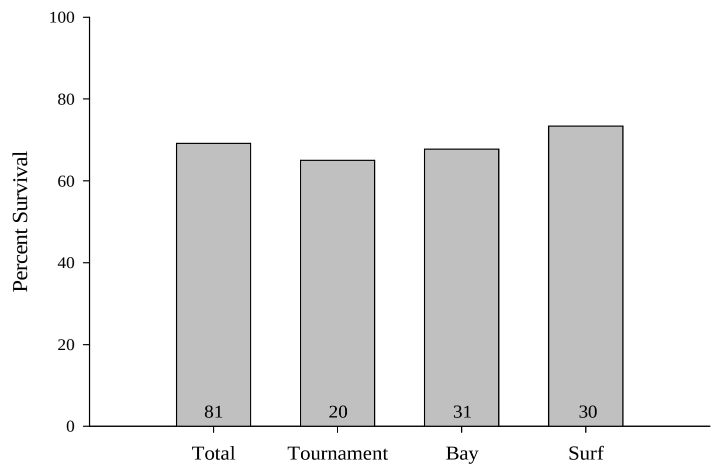

Figure 11. Percent survival among tournament, bay and surf-tagged spotted seatrout. Numbers at the bottom of the bars indicate sample size (n) for each group.

Generally, individual spotted seatrout movements did not indicate any predictable patterns. Some fish showed extensive movements while other fish showed site fidelity. All detected surf fish exhibited movement toward inlets. Tournament-tagged fish showed extensive movements throughout the LM system, but some fish were never detected on more than one receiver. I presume these fish did not leave the general area and indicate strong site fidelity. Bay-tagged fish showed similar patterns to tournament-tagged fish, some moved great distance while others traveled very little. Individual fish movements are mapped in the Appendix.

Seventy percent of surf-tagged spotted seatrout were detected (n=20) or recaptured (n=1) in an inlet within days to weeks after tagging. Seventy-six percent of the detected or recaptured fish were detected within Packery Channel. Only 3 fish (51185, 51186, and 51200) (13.6%) were detected in Aransas Inlet and 1 fish (51180) (5%) was recaptured approximately 1 km southeast of Aransas Inlet at the Horace Caldwell Pier. One (5%) surf-tagged spotted seatrout (51199) was detected in Mansfield Inlet. None of the surf-tagged spotted seatrout were detected on any of the inshore bay receivers.

Sixty-nine percent of bay-tagged spotted seatrout were detected moving throughout the ULM. Three fish that were tagged and released in the ULM north of Baffin Bay were never detected outside of the general area (51128, 51167, and 51170), and 3 fish traveled south to or into Baffin Bay and back (51127, 51129, and 51162). Four fish (51163, 51168, 51169, and 51176) tagged in the same region were never detected or reported as recaptured and are assumed to have perished. Of the 4 fish that were tagged in Baffin Bay proper, three (51146, 51147, and 51172) were never detected outside of the bay. One fish was reported recaptured and harvested (51171) south of Baffin Bay. Eight of the nine fish tagged in “Yarborough Bay” were detected on receivers. Six fish (75%) of the eight traveled between Yarborough and Baffin Bay (51157, 51164, 51165, 51166, 51177, and 51178), and 1 fish (12.5%) was detected only in the Yarborough area (51159). Spotted seatrout #51160 (12.5%) was detected in Baffin Bay, returned to Yarborough for several months, then traveled south through the GIWW Land-Cut and has not been detected again. Two fish were tagged in the GIWW Land-Cut: 1 (51174) traveled south and was detected on the “Land-Cut south” receiver and never detected again, and the other (51175) traveled extensively throughout the Land-Cut and into the extreme southern portion of the ULM. Five fish were tagged in the northern portion of the LLM and only one fish (#51130) was detected on the “Land-Cut south” receiver, nine months after it was tagged. None of the other LLM tagged fish were detected on any receivers or reported as recaptured. Fish that have not been detected or recaptured are considered to be mortalities until survival is confirmed. None of the bay-tagged spotted seatrout were detected on any inlet receivers.

Two of 13 (15%) tournament-tagged spotted seatrout (51140 and 51156) were only detected within the northern portion of the ULM. Seven (54%) traveled at least to Baffin Bay, two (15%) spotted seatrout (51138 and 51142) were detected in Yarborough Bay, and one (51136) (7%) traveled into the GIWW Land-Cut. Two fish (#51143 and #51155) were detected traveling out of ULM into Corpus Christi Bay. Fish 51155 traveled south as far as Baffin Bay before returning north along the west shoreline of the ULM and exiting into Corpus Christi Bay, then returning to Pita Island 2 months later. Similar to the bay-tagged fish, none of the tournament-tagged spotted seatrout were detected on inlet gateway receivers.

There were large differences in the distance traveled per day among groups. Surf spotted seatrout moved a much greater distance per day (mean = 3.4 ± 0.90 SE km/day) than either bay (mean = 0.5 ± 0.24 SE km/day) or tournament (mean = 0.9 ± 0.23 SE km/day) tagged spotted seatrout (Fig 12). Some pathways were modified slightly to exclude land layers before distances were calculated. These distances per day are the minimum they could have traveled because distance calculations assumed straight line movements between acoustic receivers.

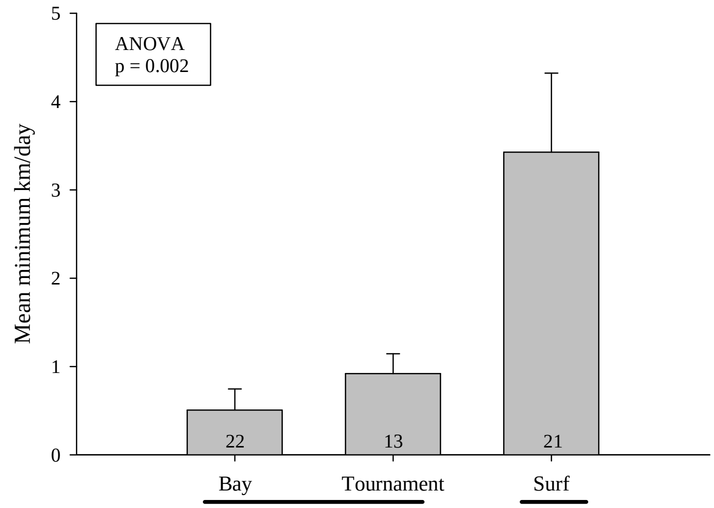

Figure 12. Mean distance traveled per day (km) of surf, bay, and tournament spotted seatrout. Numbers at the bottom of the bars indicate sample size (n) for each group.

Additionally, no significant difference was detected in distance traveled between males and females (log (x+1) transformed, $p = 0.492$, $t = -0.704$, $df = 16$, $1 - \beta = 0.050$) (Fig. 13).

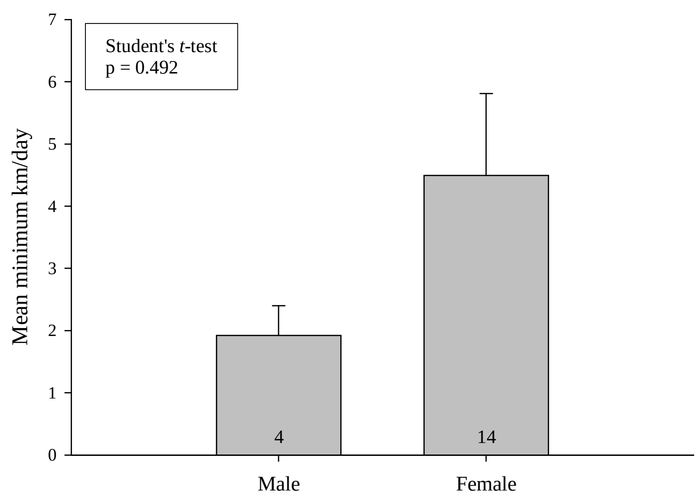

Figure 13. Comparison of mean minimum distance traveled per day between male and female spotted seatrout. Numbers at the bottom of the bars indicate sample size (n) for each group.

Mean minimum area used by each group of fish was calculated to investigate differences in area used by tournament versus bay-tagged spotted seatrout. Only fish detected on a minimum of two receivers (initial tagging location plus two additional detection locations) could be used to calculate. Due to this restriction all surf-tagged spotted seatrout were excluded from this analysis because none were detected at more than one receiver location. Because surf-tagged spotted seatrout were excluded from this analysis, it was not possible to determine differences in mean area used between sexes. There was a significant difference ($p = 0.014$, $t = 2.745$, $df = 16$) in total area used between bay and tournament-tagged spotted seatrout (Fig. 14). Mean area used by tournament fish was approximately four times higher (60.5 km^2 ± SE 17.5) than mean area used by bay spotted seatrout (15.6 km^2 ± SE 4.7). When necessary, mean area polygons were modified by hand to follow shorelines and exclude land layers.

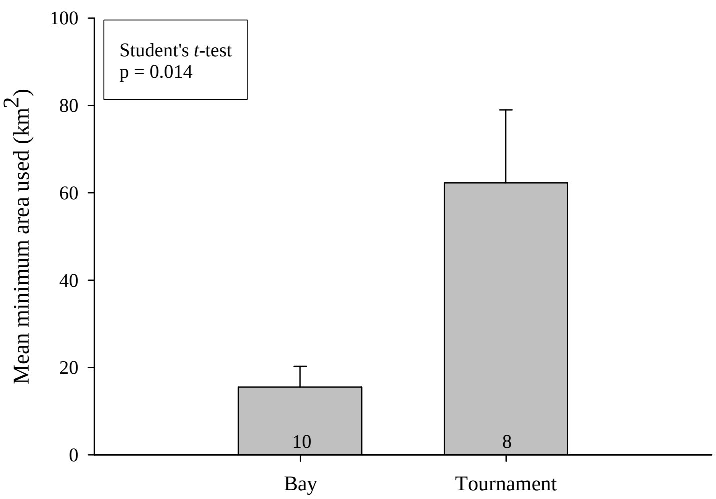

Figure 14. Mean minimum area used (km^2) by bay and tournament-tagged spotted seatrout. Numbers at the bottom of the bars indicate sample size (n) for each group.

DISCUSSION

This study was designed to evaluate surgical techniques to determine the best method to implant acoustic transmitters in spotted seatrout and then use that knowledge to track large-scale movements of surgically implanted fish in their natural environment. I determined that it is feasible to implant spotted seatrout with acoustic transmitters and maintain high survival and tag retention. Overall, through the use of acoustic telemetry I documented movements of individual fish and found that some spotted seatrout show site fidelity while some move extensively throughout south Texas bays and surf zones and are able to travel great distances in a relatively short amount of time. These movements include inter-bay exchange and movement from Gulf of Mexico into tidal inlets.

Surgical Tagging Techniques

Generally, spotted seatrout had high survival for both control (non-implant) surgery and implant surgery treatment groups. Survival rates were nearly the same between control and implant treatment groups suggesting that the surgery process is the main cause of mortality. These findings are similar to Hall et al. (2009), who also suggested that surgery alone is the primary source of mortality. Male fish with the off-midline incision location had the lowest survival suggesting that cutting through the sonic muscles of male spotted seatrout may be detrimental to healing and survival, however; in this study few males of appropriate size were captured and tagged; therefore, results should be interpreted cautiously. Ideally, this study would have included an equal number of male and female fish in the study including large male trout, but there is not a reliable way to determine the sex of spotted seatrout without examining the gonads. To better assess the impact of incision location for male fish, future experiments should ensure adequate numbers of both sexes.

There was high survival and transmitter retention among most of the surgical treatment groups suggesting that all methods were equally viable. Staples were eliminated from consideration and analysis due to the difficulty in attaining secure incision closure. Surgical staples easily pulled through the skin and many fish lost transmitters. Neither survival nor tag retention were affected by incision placement or suture material. Although some techniques/locations were easiest and most efficient to tag, there was no statistical difference among treatments in terms of survival, tag retention, or suture healing score. Inflammation scores were not statistically different between midline and off-midline incision locations suggesting that incision location has little effect on healing. Vicryl suture material did not cause additional irritation from suture retention compared to monofilament. Others have found higher irritation with Vicryl (Wagner and Cooke 2005). Results suggest the use of Vicryl because of the ease of use, while still providing adequate closure. Cooke et al. (2003) found no inflammation differences between braided silk and monofilament suture, but did report better incision healing and ease of use with braided silk suture material. There was not one treatment that showed distinct differences in survival and transmitter retention; thus, my recommendation is for researchers to use the surgical method of preference. Harms and Lewbart (2000) also suggest that surgeons use the materials of choice. For future telemetry studies I suggest off-midline incision placement to reduce tag induced pressure on the incision, and Vicryl suture material for its ease of use and decreased irritation at the incision site.

Aside from surgical techniques, there were other factors that appeared to greatly influence fish survival and transmitter retention. Perhaps these observed differences were not statistically detected due to small samples sizes. Nonetheless, smaller fish were observed to have less room in the peritoneal cavity and thinner body walls which placed more pressure on incision sites. This back-pressure may have prevented proper incision healing, caused further internal damage, and decreased survival and tag retention among treatments. Results suggest that the tag to bodymass ratio be no more than 2.5% for spotted seatrout. Similarly, implantation experiments on other species have recommended that tag to bodymass ratio be less than 2% (Jepsen et al. 2005). Additionally, anchor tags located in the incision induced irritation and may have contributed to fish mortality, loss of transmitters, and poor healing. Initially, these anchor tags were thought to be the best choice for external identification to avoid additional puncture wounds. Vogelbein and Overstreet (1987) assessed tissue responses as a result of anchor tag insertion and reported favorable findings for anchor tag retention in spotted seatrout with minimal complications due to inflammation or infection; however, placement incisions were only 8-10 mm long and did not include insertion of a transmitter. Incisions in this study were approximately 25 mm long and in several cases the anchor of the tag was protruding out the incision, apparently hindering the healing process. Therefore, future external tagging methods were modified to use a Hallprint dart tag placed just lateral of the first dorsal fin to decrease interference with incision healing and improve transmitter retention. Finally, because trial fish were held and fed for numerous days before the experiment, most fish were well recovered and capture and restraint for the tagging process proved difficult and most likely stressful for the fish.

This stress may have increased mortality because they became highly aggravated while trying to avoid capture and often collided with tank walls and some fish had fresh wounds at the time of surgery. Additionally, these fish were captured and transported in nets to the surgical station, which increased potential damage to their protective slime layers. Finally, I do not recommend the use of anesthetic. Currently there is not any anesthetic that is FDA approved for use on food fish without an extensive holding period. Spotted seatrout are often targeted by anglers with the intention of harvest and consumption. All fish tagged in future studies will be within the legal harvest regulations and fish need to be tagged and released immediately to minimize behavioral alterations. Therefore, we were unable to use anesthesia prior to surgical implantation. Additionally, anesthesia can take several minutes to be metabolized through the system once post surgical recovery has begun. Fish released into the natural environment must be able to maintain swimming ability and awareness in order to avoid potential predators.

Overall, despite some limitations, surgical implantation of acoustic transmitters was successful. This experiment was useful to gain insight on the best surgical methodology for future tracking studies and a crucial precursor to the acoustic telemetry study. These data help to ensure confidence in our surgical survival, tag retention, and techniques for field trials. Having these data are essential, because in the field acoustic transmitters are not recoverable if an implanted fish succumbs or expels the transmitter the fate of that fish is unknown.

Range Testing

This project was planned to cover large-scale movements of fishes and designed with signal range expectancy of 1 km radius, but range testing clearly showed reduced detection ranges compared to manufacturer suggestion. However, I did detect 72% of my fish and many on multiple occasions. A short detection range may have prevented signal detection from individual fish at some receiver locations. Therefore, it is important to know what the probability of detection was for receivers in different environmental conditions. Range testing was limited and I was unable to complete extensive tests though all weather conditions. Environmental changes may cause detection ranges to vary. It is unknown the extent that tidal levels, wind speeds, currents, and boat traffic effect signal detection. Low detection ranges in shallow water may result from submerged aquatic vegetation inhibition of signal transmission and wind driven turbulence. High energy areas had the best signal detection despite any environmental influences, although still half the distance of manufacturer specifications of 1 km radius. The better detection at the high energy locations could be due to the lack of signal obstructions in the deeper water column. Inlet receiver ranges were expected to be the lowest due to vessel traffic and increased turbulence due to tidal and wind driven currents. Obviously, it is unknown how many detections may have been missed due to low detection ranges or during times of increased turbulence and/or noise distortion. Despite the low detection range, over 8,000 detections were documented within the array.

Implications for Catch-and-release Mortality

Acoustic tracking data has shown promising catch-and-release survival of spotted seatrout. Percent survival was calculated for spotted seatrout that underwent typical hook and line catch procedures and those that came from live-release fishing tournaments. These were calculated separately due to the increased handling that is endured by tournament-captured fish. Size and bag limit management and live-release tournament strategies are often criticized due to variability in catch-and-release mortality studies.

Previous studies have indicated that post capture mortality of spotted seatrout greatly varies with ranges from 0-70% (Hegen et al. 1984, Matlock et al. 1993, Murphy et al. 1995, Duffy 2002, Stunz and McKee 2006). These studies have examined mortality as a result of fish size (Duffy 2002, Stunz and McKee 2006), bait and hook type (Matlock et al. 1993, Duffy 2002, Stunz and McKee 2006), season (Hegen et al. 1984), and gear type (Murphy et al. 1995). The majority of the studies held fish for no more than 3 d because previous studies have indicated that the majority of post-capture deaths occur in this time period. Recent research on post capture survival of spotted seatrout in Texas found 11.1% mortality overall (Stunz and McKee 2006), this mortality was influenced most by angler skill level and subsequent hooking location. Surgical trials indicated that 25% mortality could be expected from surgery alone, and current fish survival from this study is near 75%. Percent survival is likely to increase over the future study duration as more fish are detected. For example, it is common to hear from fish after many months with no detection. Moreover, these fish were captured, went through surgery, and then released; therefore, it is conceivable that survivorship will be even higher when released under typical, much less evasive, catch-and-release practices. These survival results provide additional evidence that catch-and-release practices are viable strategies to maintain spotted seatrout stocks.

Tournament-captured spotted seatrout are often close to the upper harvest limits (635 mm) or trophy size and endure increased handling stresses compared to recreational catch-and-release fish. Additional stressors include holding and transport in live wells, and handling throughout weigh in and release processes. Live-release tournament formats that encourage anglers to keep their fish alive throughout the tournament for later release have gained popularity in response to concerns over increased harvest and sustainability of fish stocks. James et al. (2007) found tournament-related mortality was higher than "normal" catch-and-release but still low at 14.1%, with highest mortality rates in warmer months. Additionally, Stunz and McKee (2006) found no relationship between survival and size, indicating that the larger fish have similar probability of post-capture survival as smaller fish. Tournament-tagged spotted seatrout from this study had the lowest known survival. However, the survival rate was only 10% lower than what could be expected from surgery alone. High percent survival of tournament spotted seatrout in this study supports the live-release tournament format as a viable method of returning competition fish to the environment because these fish were subjected not only to tournament handling stress but also transmitter implantation surgery.

Additionally, angler recaptures represented 14% of the tagged fish. A typical tag-and-recapture study can expect a 2-3% recapture rate, with 6% considered excellent returns. One fish 51156b was recaptured 11 days after surgical implantation at a location nearly 11 km from the original tagging site which indicates that surgically tagged fish are capable of extensive movement and normal feeding behavior shortly after surgical implantation. The reason for increased angler returns in this study is unknown, but may be an indication of decreasing populations or increasing fishing pressure.

Fish Movement and Connectivity

Acoustic tracking is quickly becoming one of the most effective ways to document real time movement of marine animals, and has proved to be successful at tracking movement patterns of spotted seatrout at the landscape level. I was able to determine movement patterns and residency times and identify pathways of connectivity between spotted seatrout populations by relocating 72% of tagged fish. Movement patterns were variable and often unpredictable, but several consistent patterns did emerge. A subset of fish moved greatly, while some remained near release locations. I observed no movement of bay-tagged fish out of the tidal inlets. However, all fish that were tagged in the surf made relatively long migrations and were detected on inlet receivers. These results have important implications for understanding the ecology and life history of this species because connectivity between subpopulations has potential to influence population structure, population size, and can alter genetic structure. Knowledge of migratory pathways, subpopulations mixing, and home range of this species will be important for fishery managers to determine appropriate strategies for managing this valuable sportfish.

Individual tracking data is summarized in the Appendix for each individual fish, but there are a few fish discussed here to show example movement patterns. For example, over a period of 92 days, spotted seatrout 51128 was detected on two occasions at a single receiver, only 5.4 km from its tagging location. Similarly, spotted seatrout

51166 moved a total detectable distance of 4.3 km over 112 days. This fish was detected on 12 intermittent days during the tracking duration thus far. These fish had the potential to travel more extensively throughout the ULM but may have escaped detection range during this time. However, for the purpose of this study, if fish were not detected exiting a system, it was assumed that these fish did not leave the general tagging location. Conversely, spotted seatrout 51136 traveled a minimum of 112.6 km over 66 days and traveled into the Land-Cut then returned to the ULM. This fish was detected on 6 array receivers; however it was not detected on 3 receivers it is presumed to have passed near throughout its migration. Overall, surf-tagged spotted seatrout traveled the greatest mean distances per day, nearly four times further than mean daily distances recorded for bay and tournament-tagged fish. Rapid movements of these fish may be facilitated by long-shore currents. However, one tournament-tagged fish (51143) traveled approximately 15 km in a 12 hour period. It is unclear why a tournament fish would exhibit such large-scale movement patterns. These fish are captured often hundreds of km from the release point. Previous passive tag studies (James et al. 2007) recovered fish from the exact location of original capture after being release over 20 km away. One hypothesis is that these fish could be "lost" or exhibiting some type of homing behavior. While more research is necessary to elucidate movement patterns, these data clearly show that spotted seatrout are able to travel substantial distances in a relatively short period of time including inter-bay and Gulf of Mexico to Bay exchange.

Bay-tagged spotted seatrout had highly variable movements; some were repeatedly detected in the same location (35%), while some displayed extensive movements throughout the tracking system (65%), with several crossing between bay systems (16%). Interestingly, none of the bay-tagged fish were detected on inlet receivers suggesting that bay fish do not travel into Gulf of Mexico waters. Tournament-tagged spotted seatrout showed similar trends; 15% did not leave the ULM, 15% traveled north into Corpus Christi Bay, and 77% traveled south as far as the Land-Cut. One of these fish (51155) was detected moving to the north end of Baffin Bay as well as into Corpus Christi Bay. Similar to bay-tagged fish, none of these fish were detected on inlet receivers. The movements of bay and tournament-tagged spotted seatrout suggest a potential pathway for intra-bay mixing among populations. Movements of tournament-tagged spotted seatrout suggest that live-release tournaments may provide a pathway to alter sub-population genetics over time. Tournament displacement and resulting mixing may be important because one fish can release large numbers of eggs during a single spawning season, resulting in a genetic alteration of a population with only a few fish mixing. Documentation of inter-bay movement is useful because TPWD’s current stocking efforts are separated by region to minimize any anthropogenic genetic effects. Additionally, this provides more information to fishery managers when considering future management strategies. Mean minimum home range (km^2) was statistically different between bay and tournament-tagged spotted seatrout, with tournament-tagged fish covering nearly 4 times more area. It is unknown if this is a result of a longer tracking period or an indication that these fish are seeking out their natal estuary after tournament displacement.

All recovered surf-tagged spotted seatrout were detected within inlets or recaptured in or very near an inlet. The majority of the fish were found in Packery Channel which was closed prior to 2005 when it was dredged and permanently reopened.

It is unclear why there was increased use of this inlet because some fish moved south and others north to reach this inlet. Fish may have moved into inlets for feeding, refuge, or spawning. Additionally, surf-fish were tagged over a period of 10 months; however, all recovered fish moved into inlets within days to weeks of tagging, regardless of the season. This use of tidal inlets is an indication of the importance of inlets to spotted seatrout in Texas, and may be useful to agencies responsible for maintaining tidal inlets. These data suggest potential Gulf to bay mixing of spotted seatrout populations, which may contribute to the understanding of population overlaps between bays that have been noted in prior genetic studies (Gold et al. 2003, Anderson and Karel 2010). None of the surf-tagged fish were detected by any bay (inshore) receivers; therefore, the distance fish travel into bay systems is unknown at this time. However, once a fish has entered an inlet it would need to travel a minimum of 8-10 km from Packery Inlet, 25 km from Aransas Inlet, and 54 km from Mansfield Inlet to be detected on any bay receivers. It is anecdotally believed that spotted seatrout move from Gulf of Mexico waters into bays in the spring to spawn. I did not have fish tagged in the surf during spring due to difficulties catching appropriately sized spotted seatrout from surf zones during the winter and early spring of 2010. Thus, the spring 2010 migration may have been missed and will be assessed during spring-summer 2011. Beyond the scope of this study, the transmitter life is approximately 3 years, and I am is currently monitoring and assessing these movement patterns. Certainly, if surf-tagged fish make a seasonal spawning migration through inlets into bay systems, this study should identify those movements throughout continuing data collection. In retrospect, additional receivers placed in the bays closer to the inlets may have clarified bay use by surf-tagged spotted seatrout, and this should be the focus of future studies.

Tournament-tagged fish traveled the greatest overall distances and covered the most area. However, tournament spotted seatrout were tagged early in the year, had the greatest amount of time to travel, and had the greatest mean size. This may point to size-specific movement patterns. However, surf-tagged fish had the smallest mean size but the greatest mean minimum distance traveled (km)/day. Larger fish may have the capacity for more extensive movement, but even the smaller fish in this study moved long distances. It is unknown if there is a difference in migratory behaviors between larger and smaller fish. More extensive tracking needs to be done before examining the effect of size on spotted seatrout movement patterns.

I found no difference in size or sex-specific movement patterns; there were no differences in size or distance traveled per day between male and female fish. Fish survival was of utmost priority in this study; therefore, to minimize handling, sex was not recorded in fish unless it was easily and confidently identifiable. As a result, sex was determined for a limited number of fish, and the surf tagged spotted seatrout were the only group with enough identified genders to compare. Low sample numbers likely reduced power of this analysis indicating that these results should be interpreted with caution. Further investigation into migratory differences between sexes is warranted.

Individual movements of spotted seatrout are largely unpredictable and variable. Fish may use similar home ranges yet move throughout the areas at varying times. For example: two bay-tagged spotted seatrout 51164 and 51165 were similar size and tagged on the same day and general location. These fish were detected on the same receivers traveling the same pathway, but their travels were 3 months apart. Additionally, two surf-tagged fish (51199 and 51200) of similar size, both females, and tagged at the same date and location, traveled in opposite directions and were detected in tidal inlets. Data collection will continue throughout the duration of the tag life (approximately 2 additional years). With additional tracking time future data may further elucidate movement patterns as well as increase survival statistics. New fish are detected with every data collection event and it is anticipated that our knowledge base for spotted seatrout movement will continue to increase over the remaining lifespan of the tags.

The variability of these movements indicates the need to identify the influence of biotic and abiotic environmental factors on fish movement. Fish may move for a variety of biotic reasons such as to seek out food sources or suitable spawning habitats. Fish move in response to changes in environmental parameters such as fluctuations in salinity or temperature. Increases or decreases in salinity may encourage fish to move to more suitable conditions. For example: spotted seatrout # 51130 was tagged in the LLM in December of 2009 and went undetected for nearly 9 months. This fish was detected moving north into the Land-Cut approximately one month after two tropical systems passed over South Texas and flooded the Rio Grande Valley. In response to flooding from these storm events, divergence canals were opened and drained large amounts of freshwater into the LLM. The salinity decreased to zero in many areas, and may have prompted this fish to seek more saline waters. Similarly, dramatic changes in temperature may influence fish movements. Decreases in water temperature are thought to drive fish to find deeper waters with more stable temperatures. While no movements of this sort have been detected to date, a freeze event occurred in South Texas during the early part of February 2011, and future data collection may provide evidence that movements of this nature do occur.

Conclusions, Management Implications, and Future Studies

This study has generated information that will be useful for fishery researchers and managers alike. I have demonstrated a successful method to surgically implant spotted seatrout with acoustic transmitters. High detection and recapture rates of wild caught fish also indicate that spotted seatrout can survive surgical transmitter implantation as well as retain the transmitter on a long term basis, both are critical for a successful telemetry study. Additionally, this study has shown that catch-and-release practices can be an effective way to manage and maintain healthy spotted seatrout stocks. Findings from this study suggest spotted seatrout can have wide and large-scale movement patterns among bays, and Gulf-Bay exchange, but some have relatively small home ranges. Spotted seatrout travel between neighboring bay systems much more than previous passive tagging and recapture studies indicated. Prior studies relied solely on catch reporting from recreational anglers and had few recaptures reported from outside the bay where fish were originally tagged. Prior to this study, fish movement data of this extent or this refined level has never been documented in Gulf of Mexico waters. This study has documented long-distance movements of spotted seatrout complete with date and times of detections which was impossible to record until this advanced acoustic technology became available to allow individual fish tracking. These data provide concrete evidence that spotted seatrout are capable of moving great distances over short periods of time.

Management Implications

Spotted seatrout movement patterns are vital knowledge for managing this valuable sport-fishery. Recent findings by TPWD fisheries independent monitoring indicate declines in spotted seatrout populations among middle coast bays which prompted managers to consider extending the 5 fish bag limit coast-wide. This study is the first of its kind to be completed in Texas waters and has provided real time movement data. This data will be useful for resource managers especially when considering future management strategies because it has provided concrete evidence of fish movements. The extensive movements these fish made contradict prior tag-and-release studies which determined fish rarely leave natal estuaries. For example, one fish (51129) tagged December 2009 and recaptured 6 months later approximately 2.5 km away from the original tag-and-release location. Previous tag-and-recapture studies would have determined that this fish did not move from its original tagging location. However, acoustic tracking data shows that this fish traveled approximately 77 km throughout the ULM before recapture and harvest. Data suggesting that spotted seatrout show potential for inter-bay movement could be useful to fisheries managers when considering the adoption of additional regionalized management agendas. These results will have important implications to understanding the ecology and life history of this species because connectivity between subpopulations has potential to influence population structure, population size, and can alter genetic structure. Knowledge of migratory pathways, subpopulation mixing, and home range of this popular gamefish will be important for fishery managers to determine appropriate strategies for managing this valuable sportfish.

Future Acoustic Studies

This was the first attempt at acoustically tracking spotted-seatrout along the Texas coast. As with most studies, future work could greatly improve on my abilities to track these fish. First would be the addition of more acoustic receivers, particularly near the tidal inlets. Fish that were tagged in the near-shore surf zones have little chance of detection unless they enter one of the acoustically monitored inlets. It would be beneficial to place receivers in the near-shore surf zones; however, wave energy is likely to impede signal detection and requires a sturdy anchoring technique built to withstand extreme wind and wave energy. The addition of inshore (bay) receivers placed in closer proximity to inlet passes may provide additional data on inlet usage for both surf and bay/tournament-tagged spotted seatrout. Future studies should expand the array into neighboring bays to identify use of Aransas, Corpus Christi, and the LLM. Second, increase sample size by tagging fish from expanded coverage regions, to continue to track fish on a larger scale and see if spotted seatrout in different bay systems have varied movement patterns. Future tagging should ensure an adequate number of male and female fish across all size ranges. Additional receivers provide the opportunity to document more data; however, equipment expenses add up quickly when considering additional receivers and transmitters. Also, maintenance of the array can become cumbersome and expensive. Data should be downloaded quarterly to maintain receiver integrity, and battery life requires receivers to be pulled and replaced on a minimum of every 15 months. However, benefits of expanding the current array outweigh any drawbacks because the array could be used by multiple collaborative studies to monitor multiple species and cooperative agreements can be formed to cover maintenance and share tag data.

These data collection are ongoing and fish tracking will continue throughout the duration of the transmitter life. Additional tracking duration may identify seasonal movements that have not occurred at the time of this writing, as well as increased catch-and-release surgical survival. This study has demonstrated great success acoustically tracking spotted seatrout and recorded the most detailed movement paths of these fish with in Texas waters to date. This technology could be useful to identify movements of almost any recreationally or commercially important species and through the use of acoustic telemetry scientists are able to broaden the knowledge base of user groups and fishery managers alike.

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APPENDIX

Appendix: Individual spotted seatrout movements

The following list describes the series of maps of individual spotted seatrout movements throughout south Texas coastal waters (pages X-X).

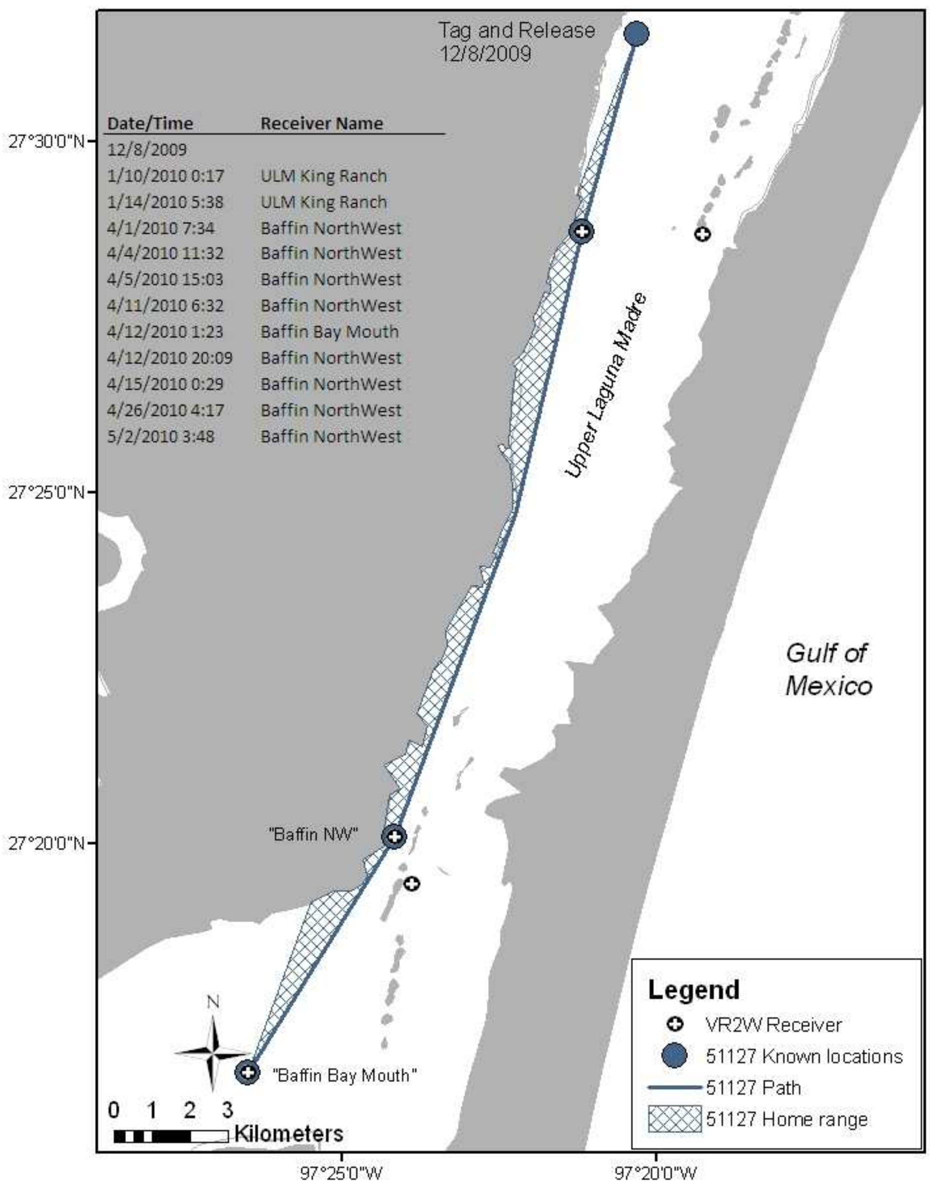
- “Spotted seatrout number” is the unique identifying acoustic tag number.
- “Total length” is the maximum total length (mm) of the fish at the time of tag-and-release.
- “Tag-and-release date” is the date that the fish was captured (or relinquished from anglers following tournament weigh-in), implanted with an acoustic tag, and released. Tag-and-release locations are different for each fish and are noted on each map.
- “Recapture location and date,” where applicable, were obtained from angler descriptions and are best estimates of the actual location. All other locations were recorded using a global positioning system.
- “Days at liberty” is the number of days between initial tagging date and either last detection within the acoustic array or date of recapture/harvest. Individuals that were recaptured by anglers are also noted when applicable.
- “Total minimum distance traveled” represents the minimum distance an individual could travel assuming straight line movements between locations. This distance calculation includes each migration between detection locations. All maps include known fish locations and travel pathways.
- “Minimum home range” represents the minimum area an individual traversed. Alterations to pathways and areas were made when straight line distances

intersected land masses, as a result, pathways and areas may not share the same boundaries. Home ranges are included only when more than two known locations were recorded.

- Within each map is a chronological table listing the date and time a fish was detected at each location. In many cases a fish had multiple detections on each receiver per day; therefore, all detections following the first detection per location were eliminated for map clarity. This table should provide the reader means to follow directionality and speed of travel. Unlabeled receivers did not detect the fish but are included to provide an indication of array coverage and potential detection sites near the fish's range.

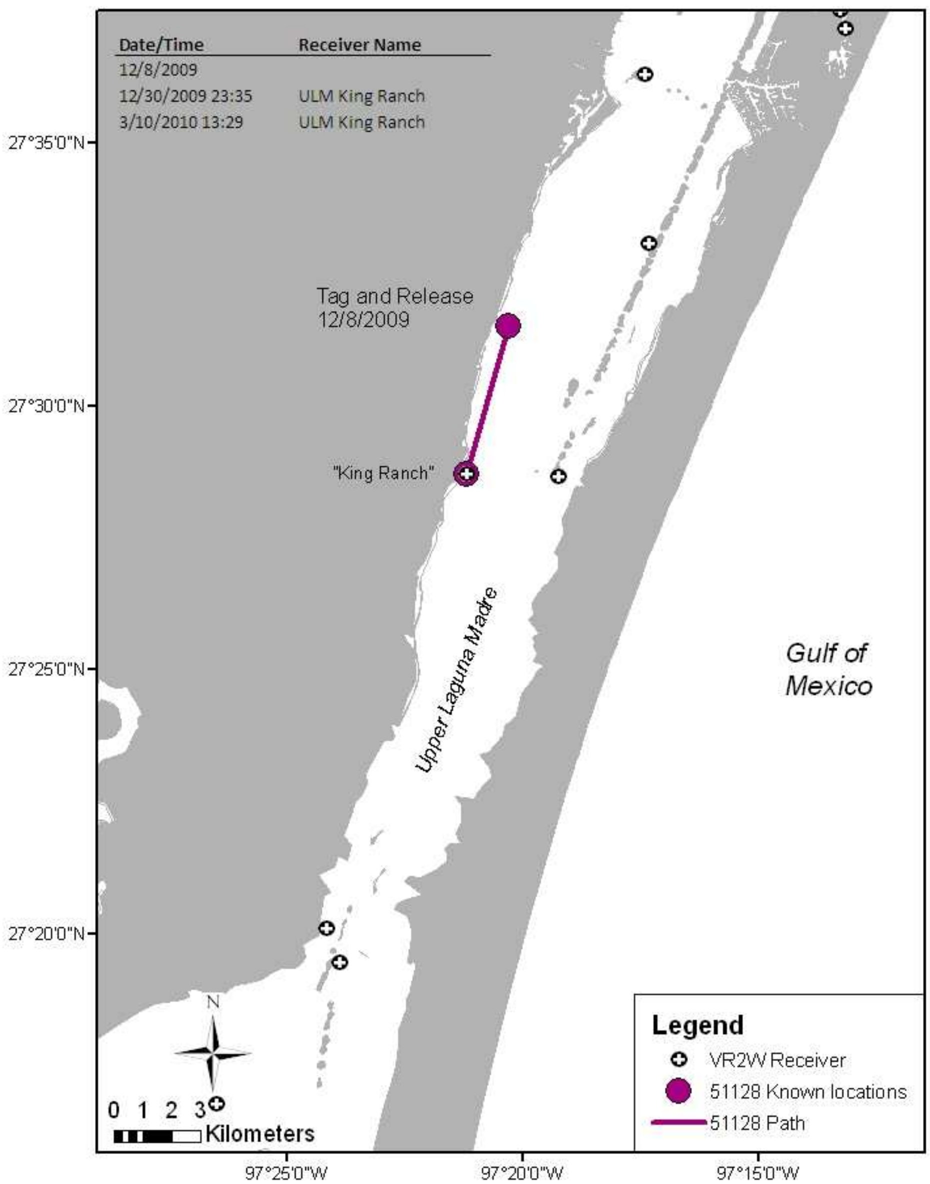
Spotted seatrout #51127

Total length: 524 mm
Tag-and-release date: 12/8/2009
Days at Liberty: 145
Total minimum distance traveled: 36.7 km
Minimum home range: 12.5 km^2



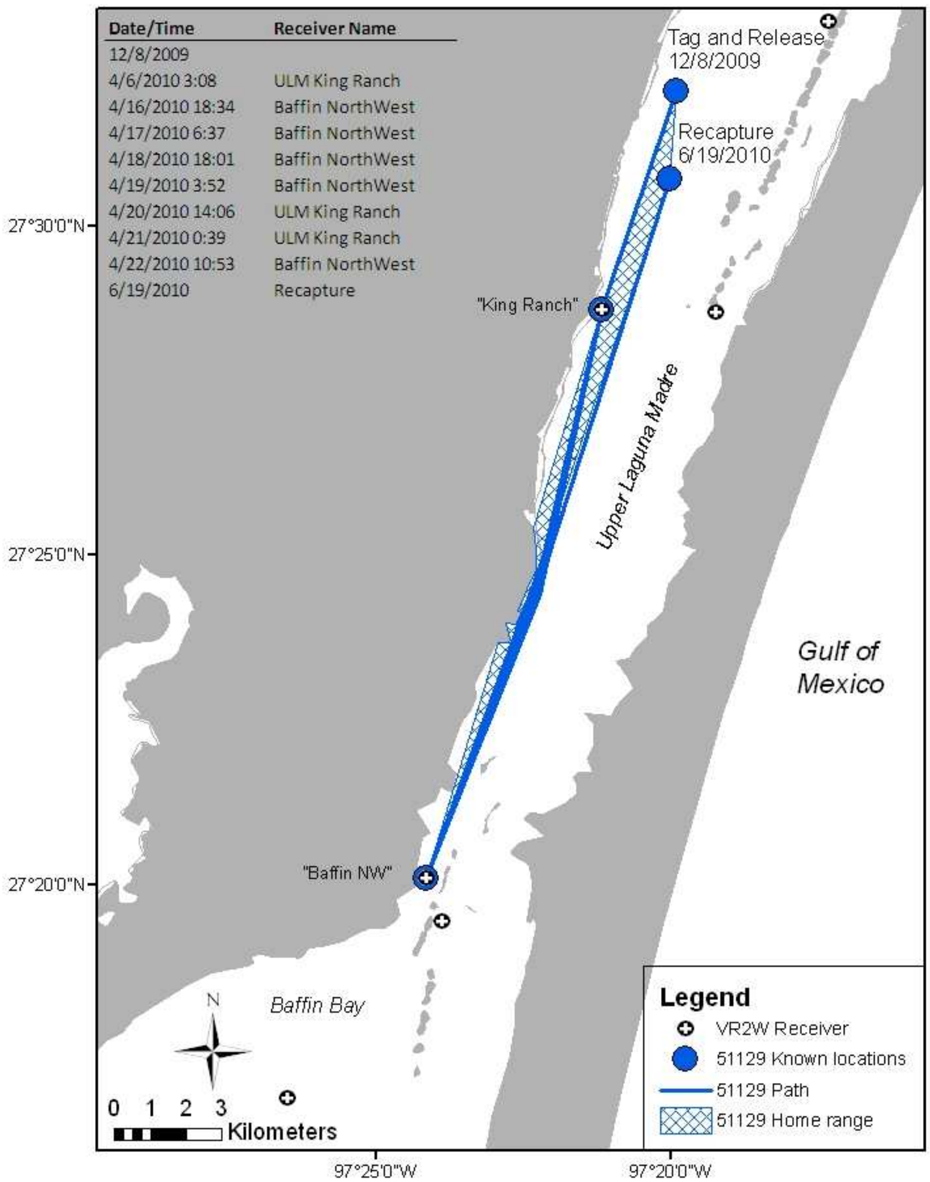
Spotted seatrout #51128

Total length: 475 mm
Tag-and-release date: 12/8/2009
Days at Liberty: 92
Total minimum distance traveled: 5.4 km
Minimum home range: NA



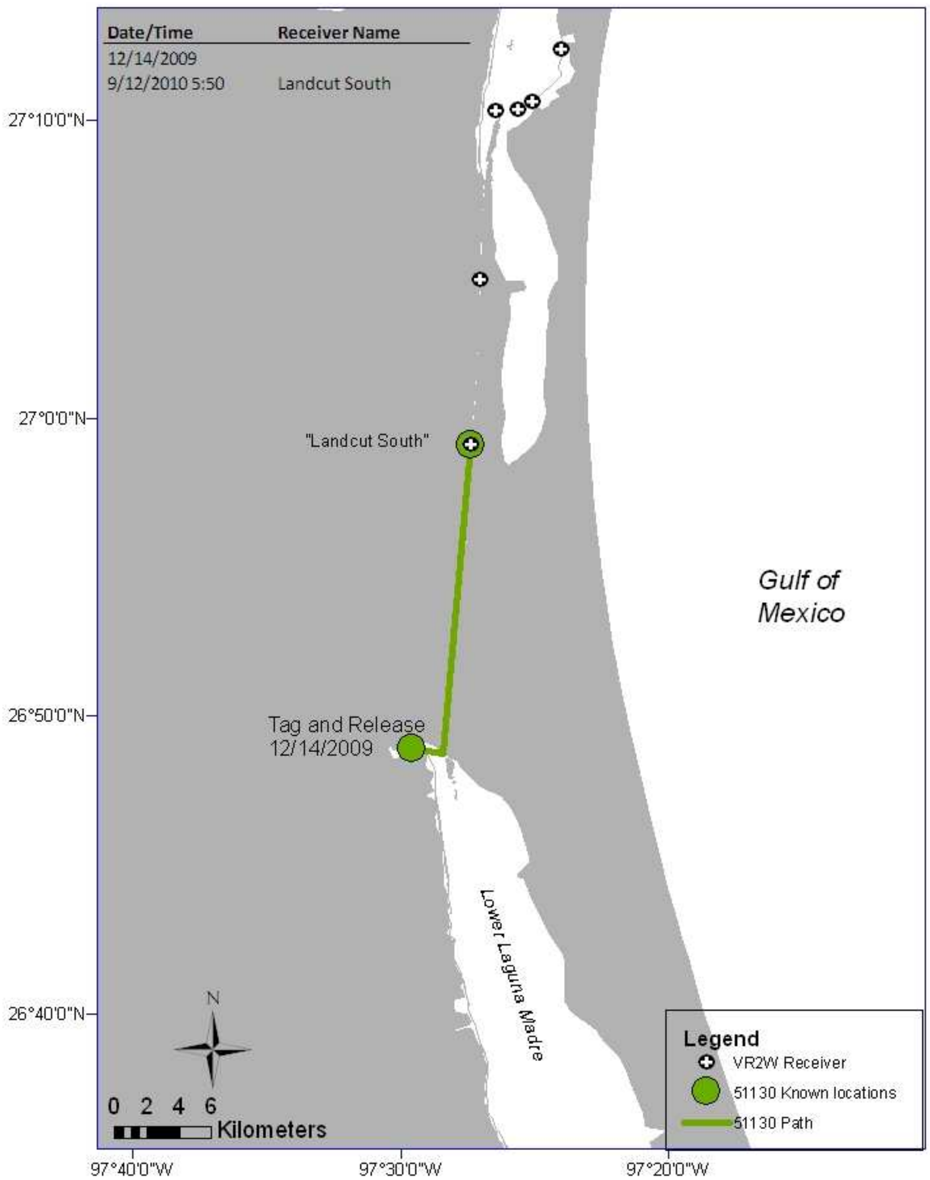
Spotted seatrout #51129

Total length: 420 mm
Tag-and-release date: 12/8/2009
Days at Liberty: 193
Total minimum distance traveled: 77.4 km
Minimum home range: 8.8 km^2



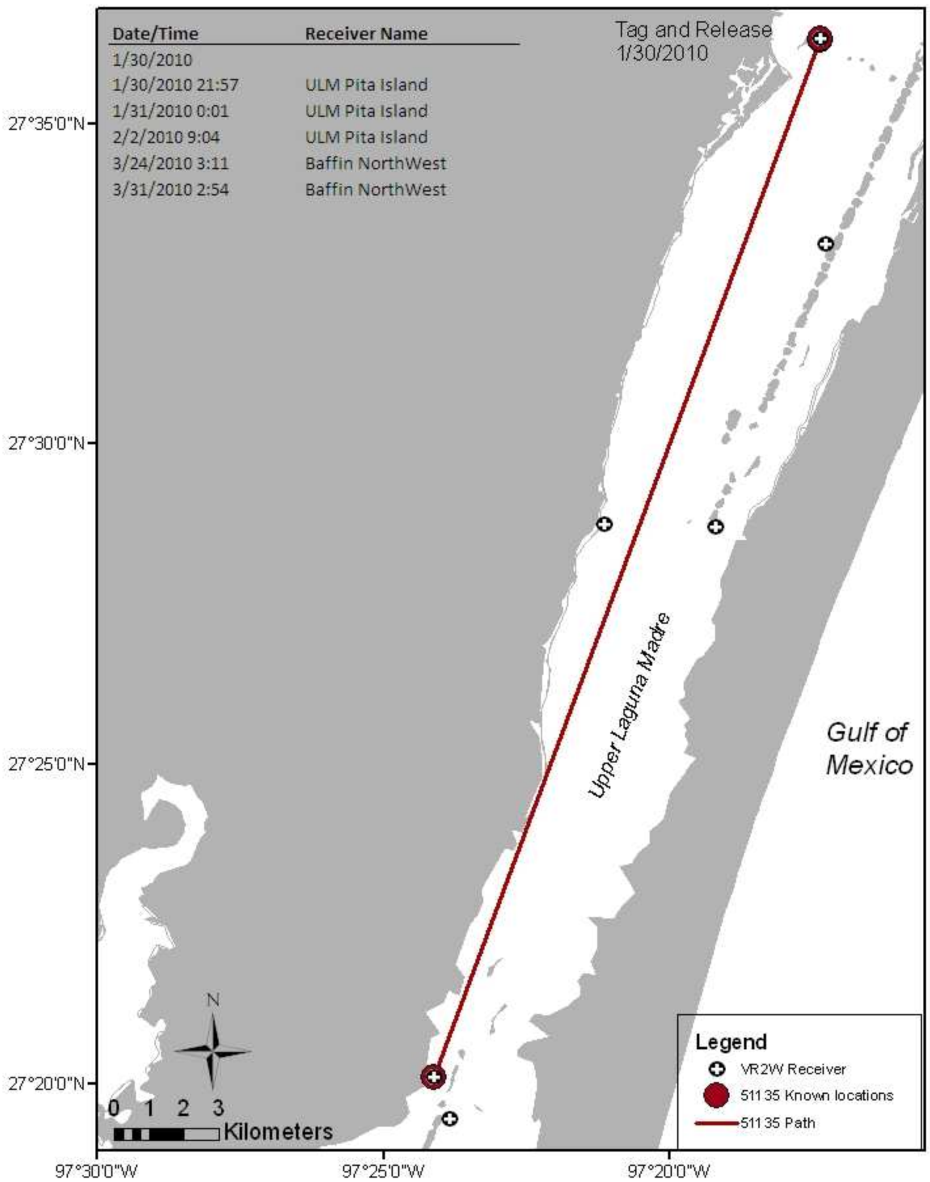
Spotted seatrout #51130

Total length: 660 mm
Tag-and-release date: 12/14/2009
Days at Liberty: 272
Total minimum distance traveled: 21.1 km
Minimum home range: NA



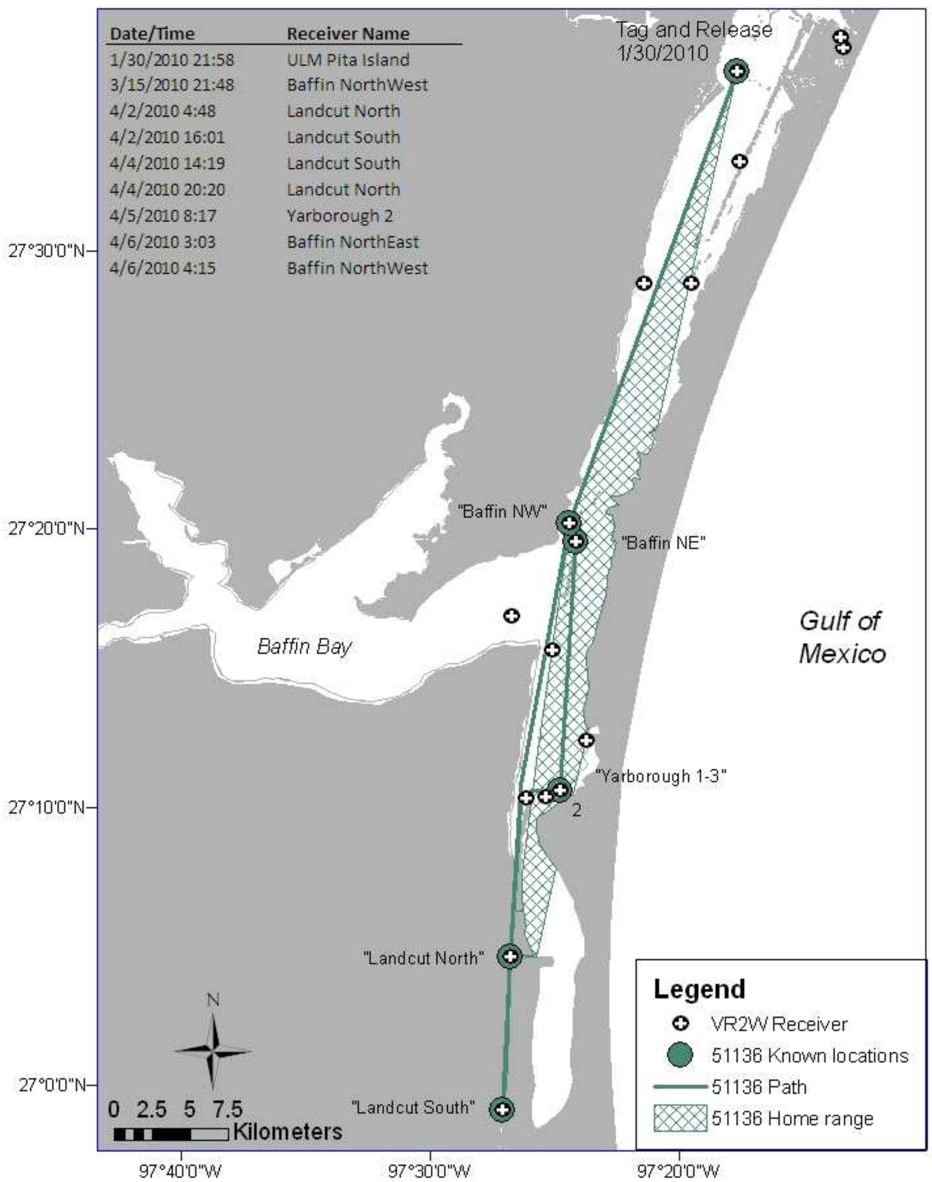
Spotted seatrout #51135

Total length: 617 mm
Tag-and-release date: 1/30/2010 Baffin Bash Tournament
Days at Liberty: 60
Total minimum distance traveled: 32.0 km
Minimum home range: NA



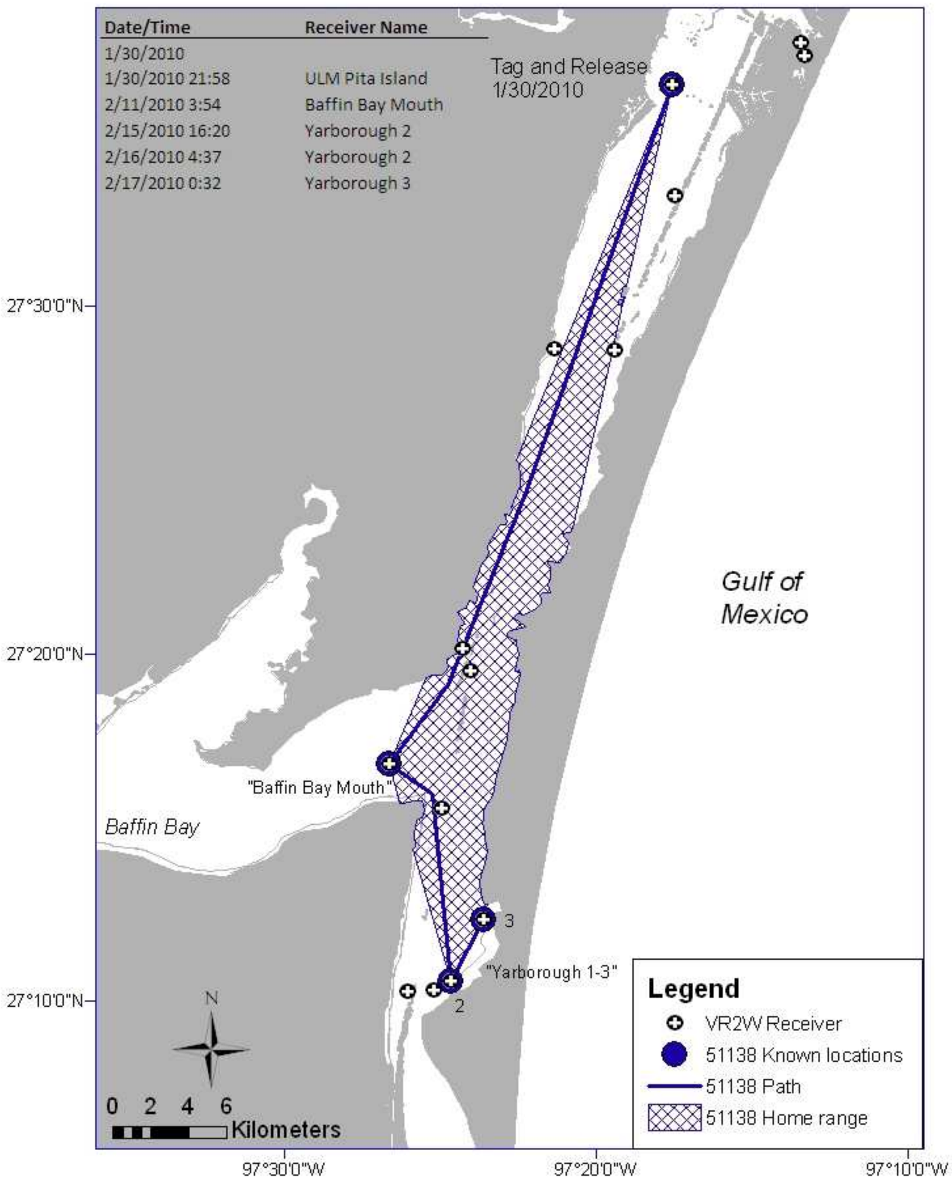
Spotted seatrout #51136

Total length: 586 mm
Tag-and-release date: 1/30/2010 Baffin Bash Tournament
Days at Liberty: 66
Total minimum distance traveled: 112.6 km
Minimum home range: 127.1 km^2



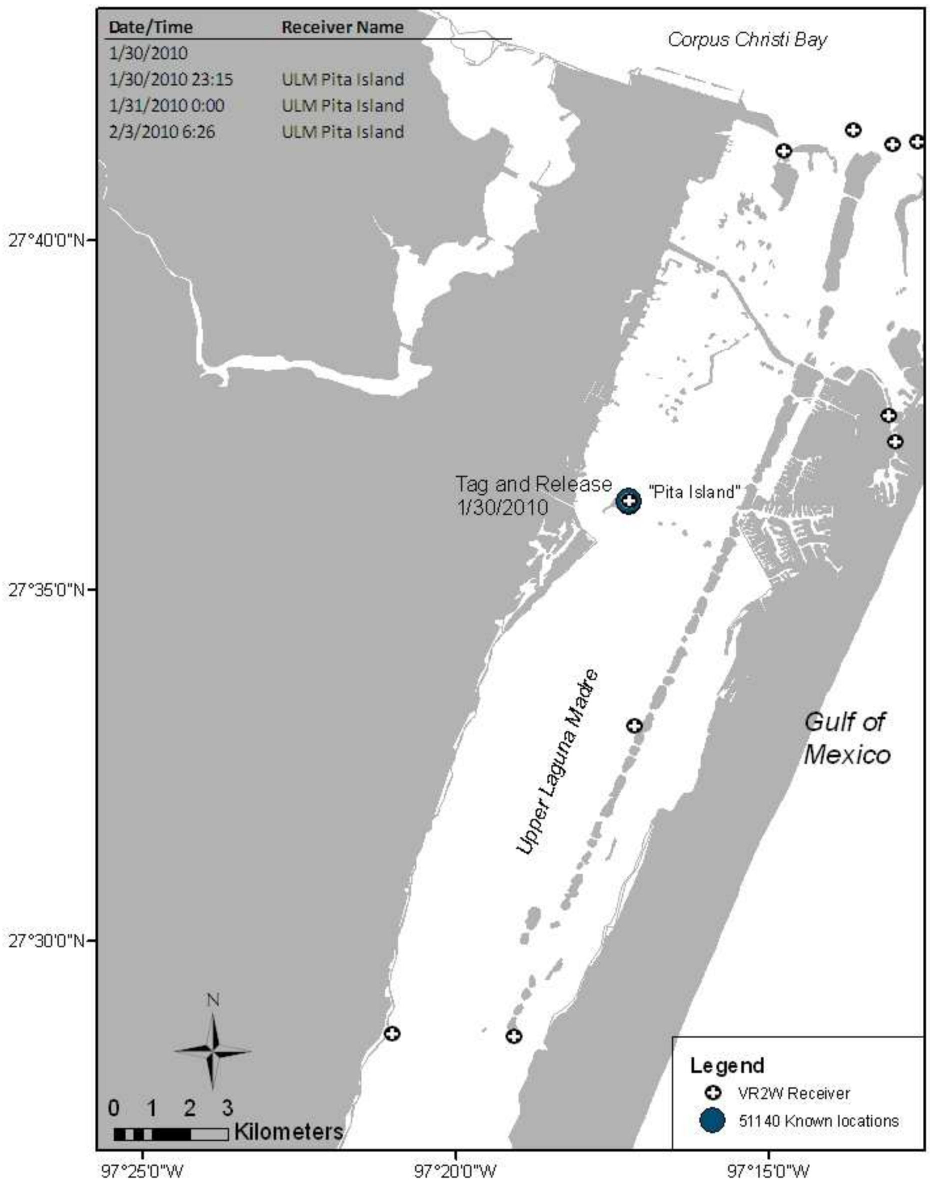
Spotted seatrout #51138

Total length: 590 mm
Tag-and-release date: 1/30/2010 Baffin Bash Tournament
Days at Liberty: 18
Total minimum distance traveled: 55.8 km
Minimum home range: 140.1 km^2



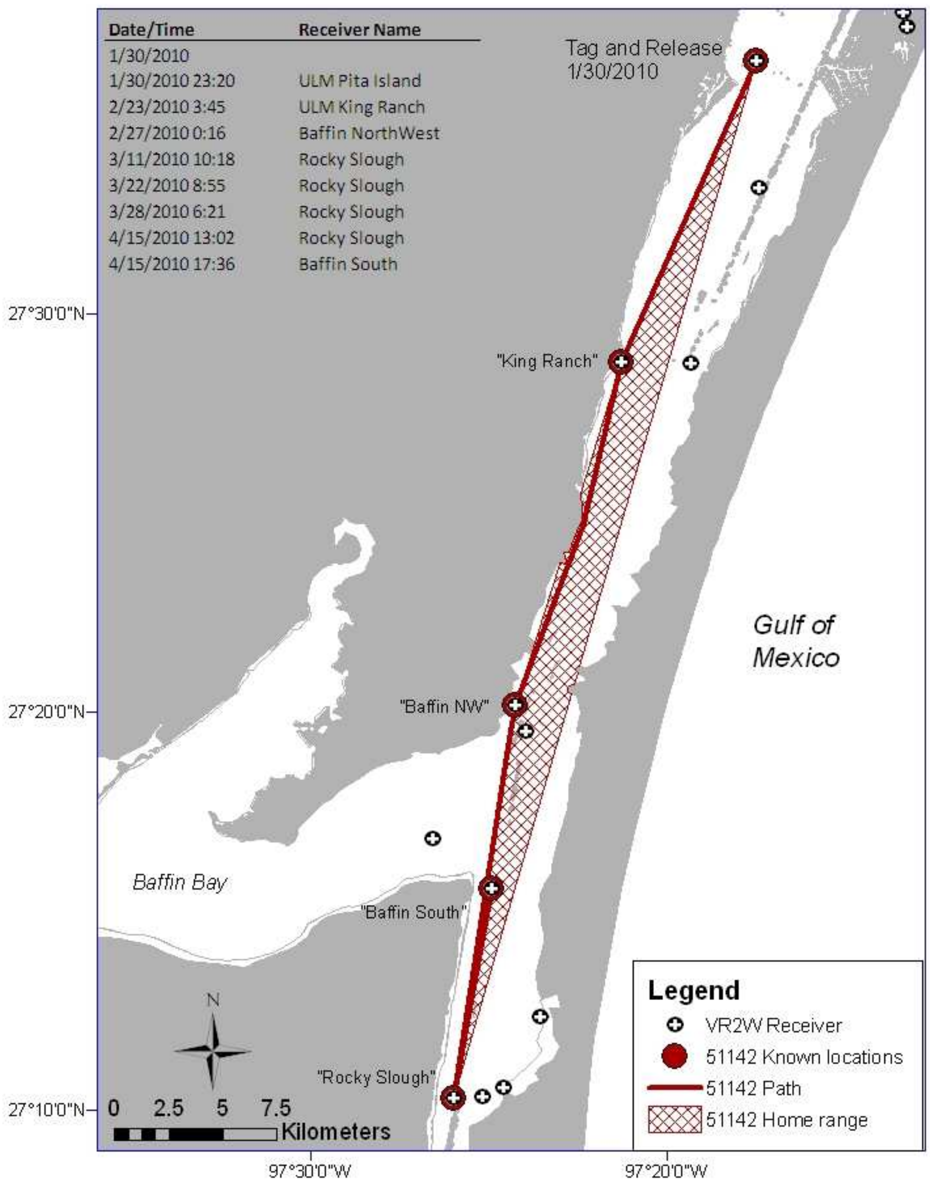
Spotted seatrout #51140

Total length: 685 mm
Tag-and-release date: 1/30/2010 Baffin Bash Tournament
Days at Liberty: 4
Total minimum distance traveled: 0.005 km
Minimum home range: NA



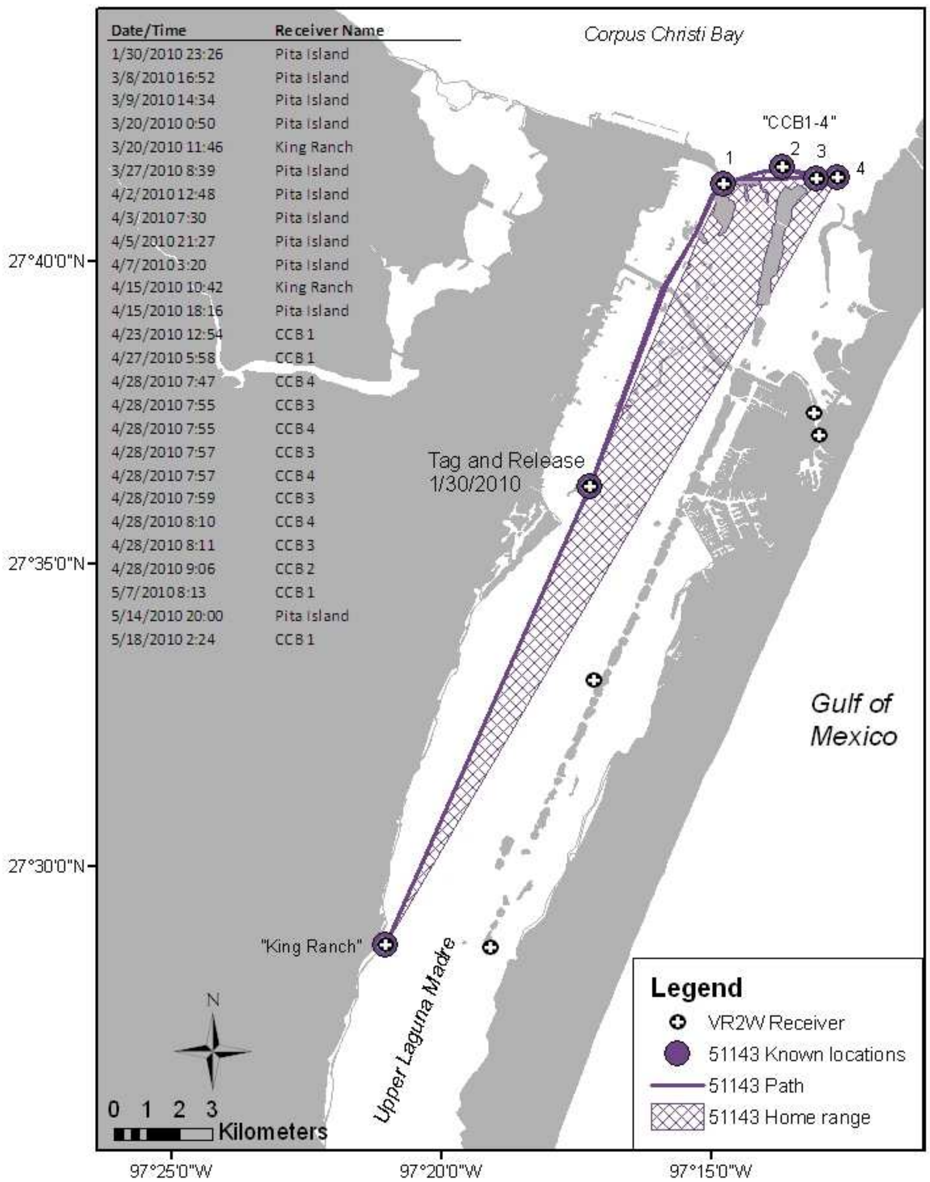
Spotted seatrout #51142

Total length: 655 mm
Tag-and-release date: 1/30/2010 Baffin Bash Tournament
Days at Liberty: 75
Total minimum distance traveled: 60.4 km
Minimum home range: 72.6 km^2



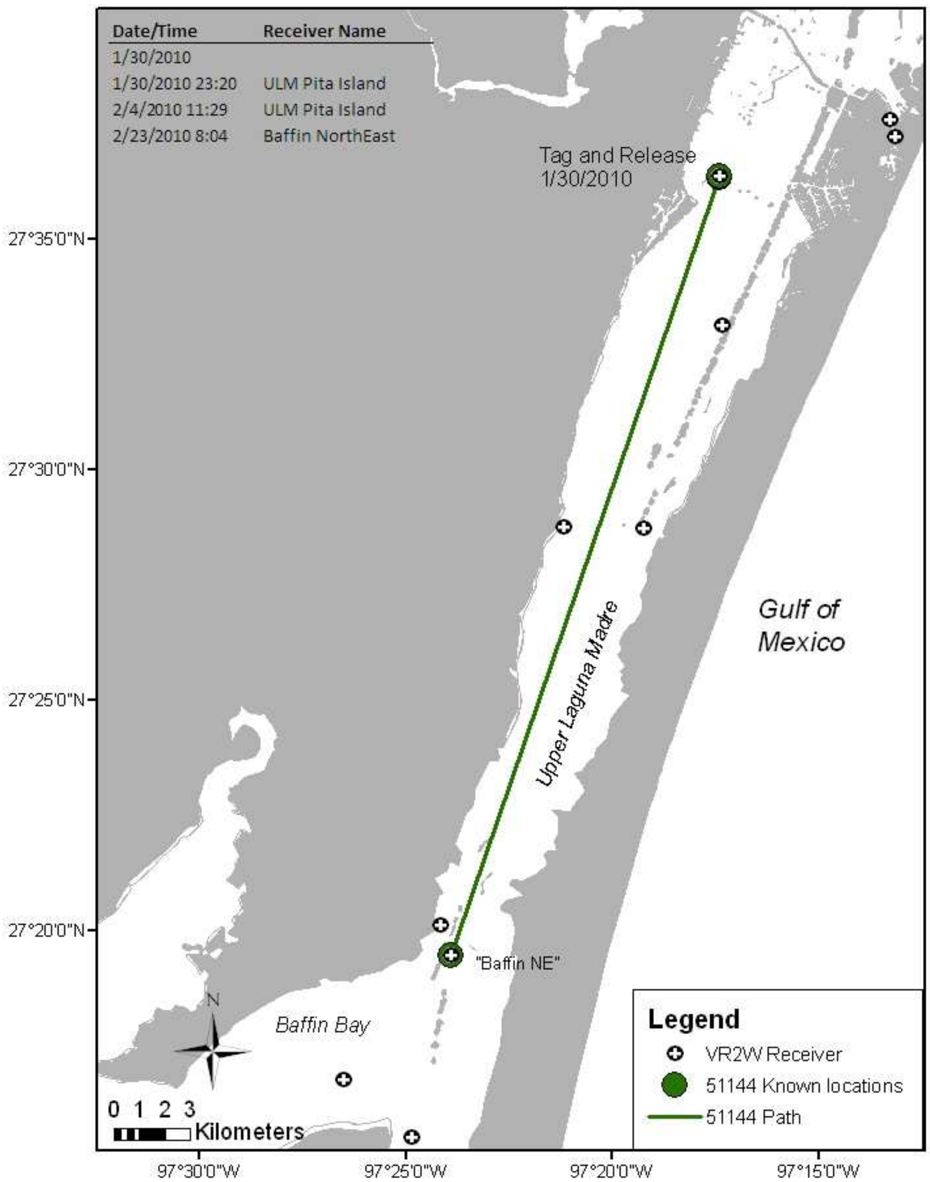
Spotted seatrout #51143

Total length: 630 mm
Tag-and-release date: 1/30/2010 Baffin Bash Tournament
Days at Liberty: 108
Total minimum distance traveled: 102.9 km
Minimum home range: 37.9 km^2



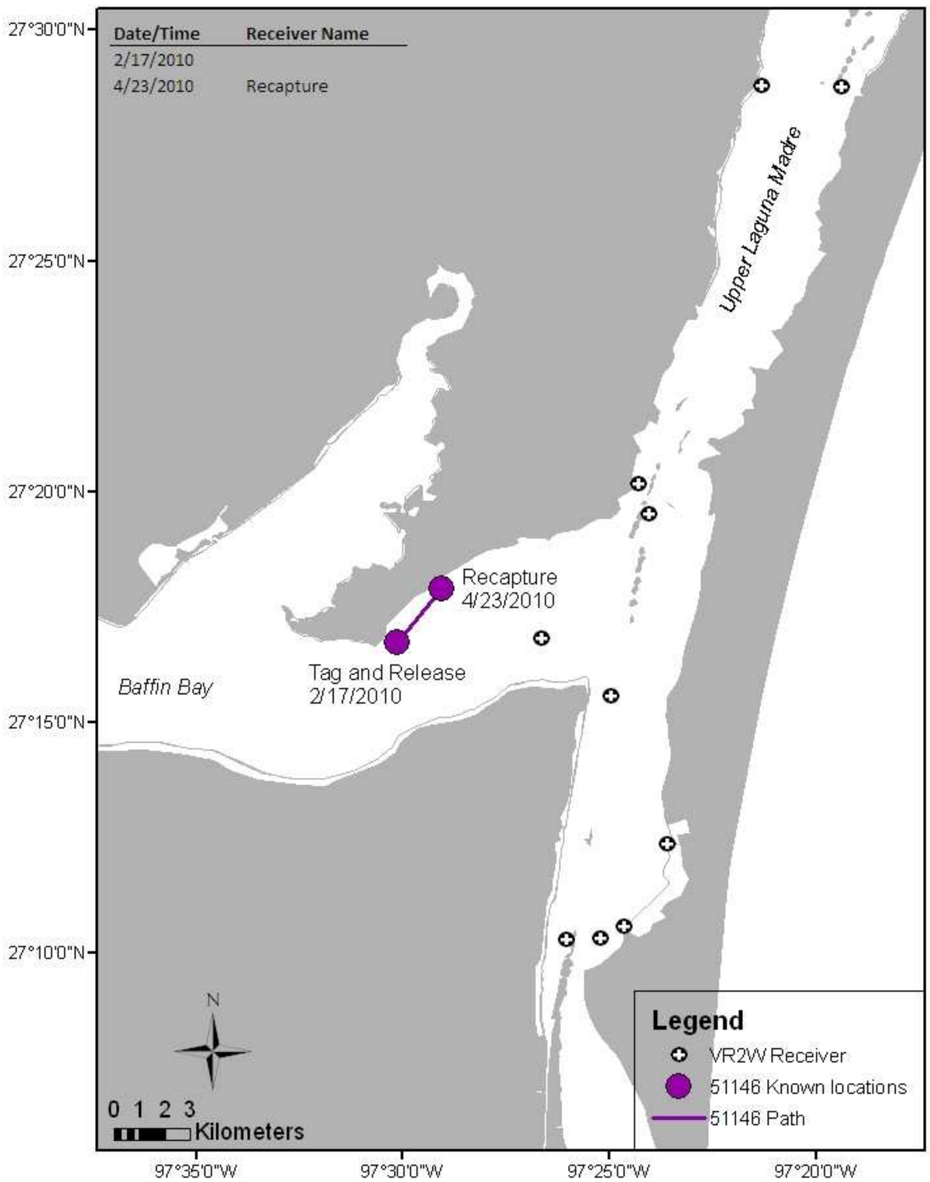
Spotted seatrout #51144

Total length: 725 mm
Tag-and-release date: 1/30/2010 Baffin Bash Tournament
Days at Liberty: 24
Total minimum distance traveled: 32.9 km
Minimum home range: NA



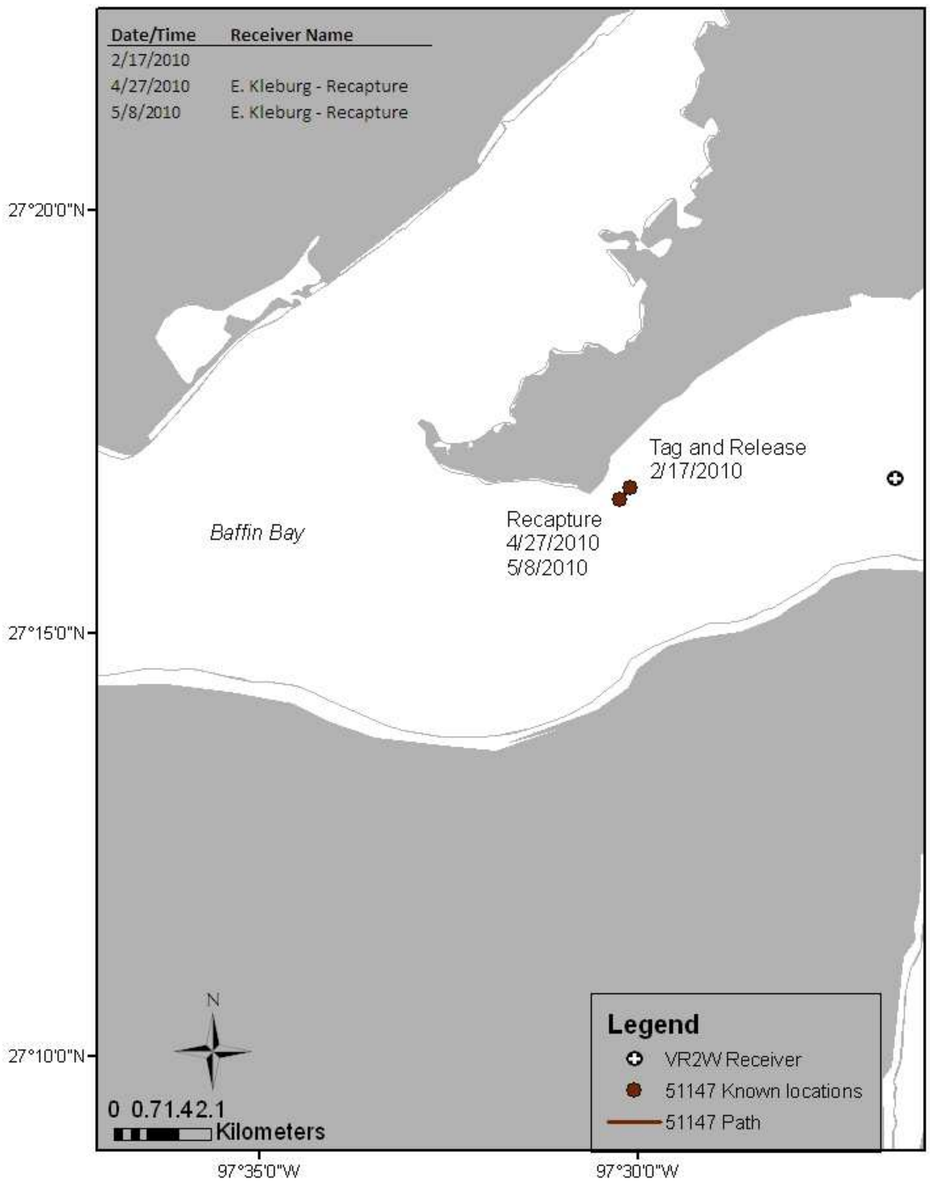
Spotted seatrout #51146

Total length: 497 mm
Tag-and-release date: 2/17/2010
Days at Liberty: 65
Total minimum distance traveled: 2.8 km
Minimum home range: NA



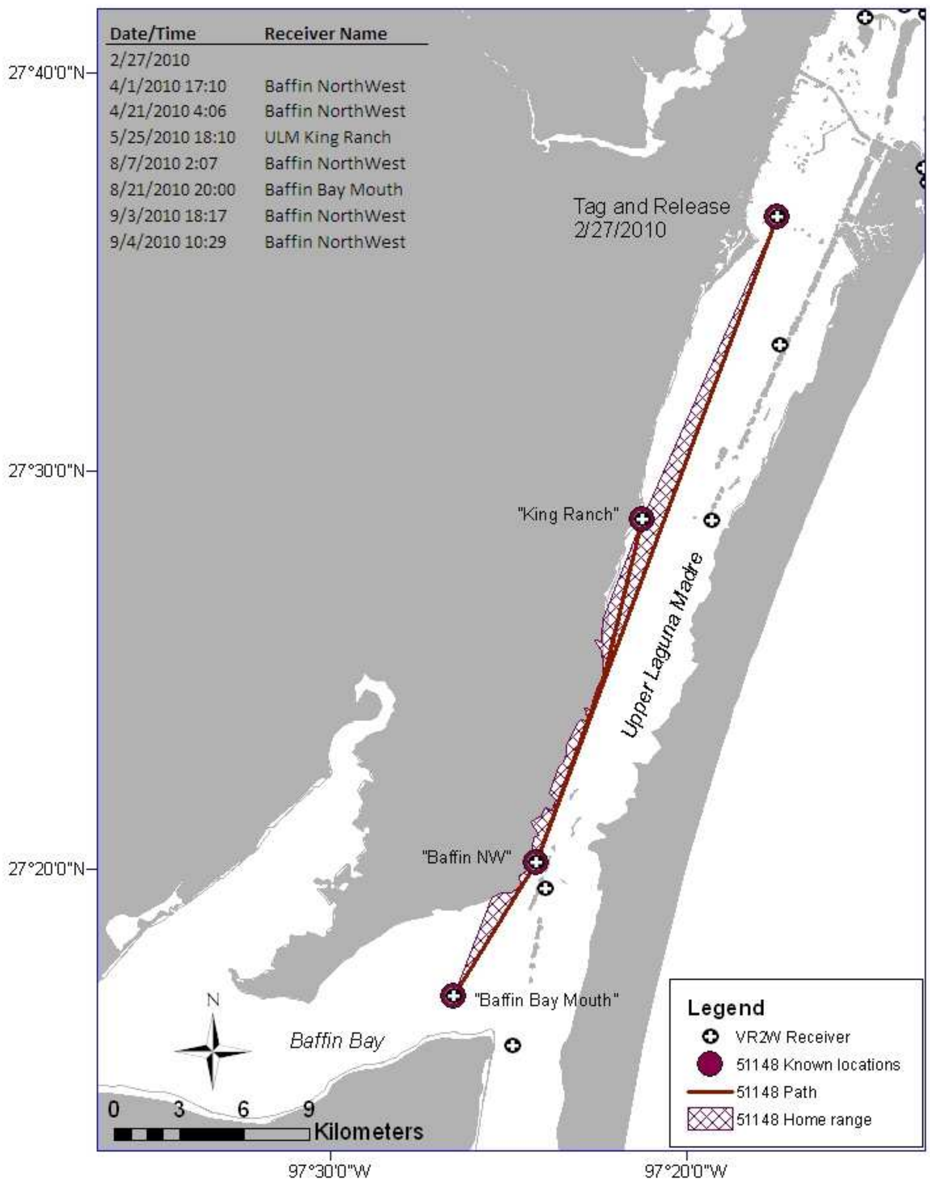
Spotted seatrout #51147

Total length: 473 mm
Tag-and-release date: 2/17/2010
Days at Liberty: 69
Total minimum distance traveled: 0.4 km
Minimum home range: NA



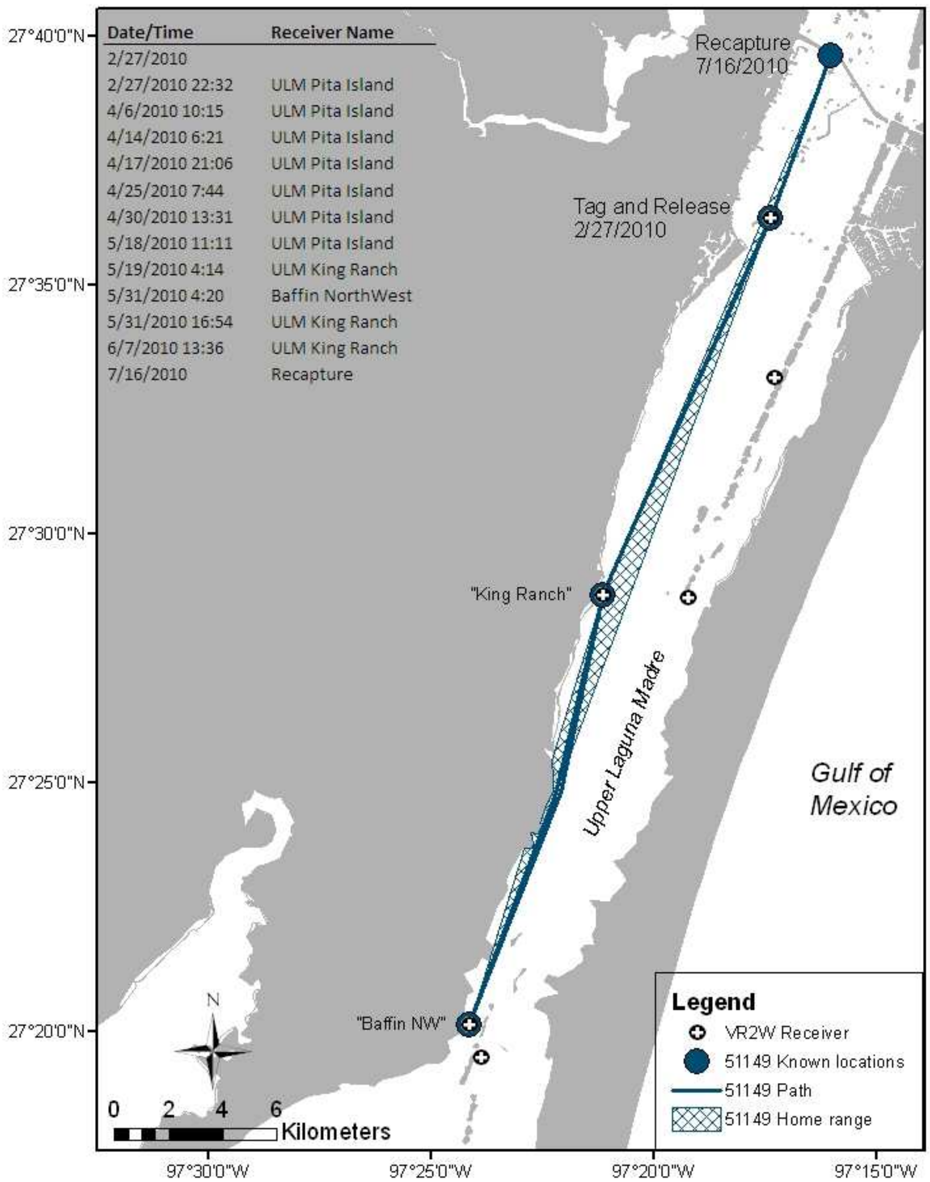
Spotted seatrout #51148

Total length: 596 mm
Tag-and-release date: 2/27/2010 Baffin Bay Rodeo Tournament
Days at Liberty: 189
Total minimum distance traveled: 79.9 km
Minimum home range: 20.5 km^2



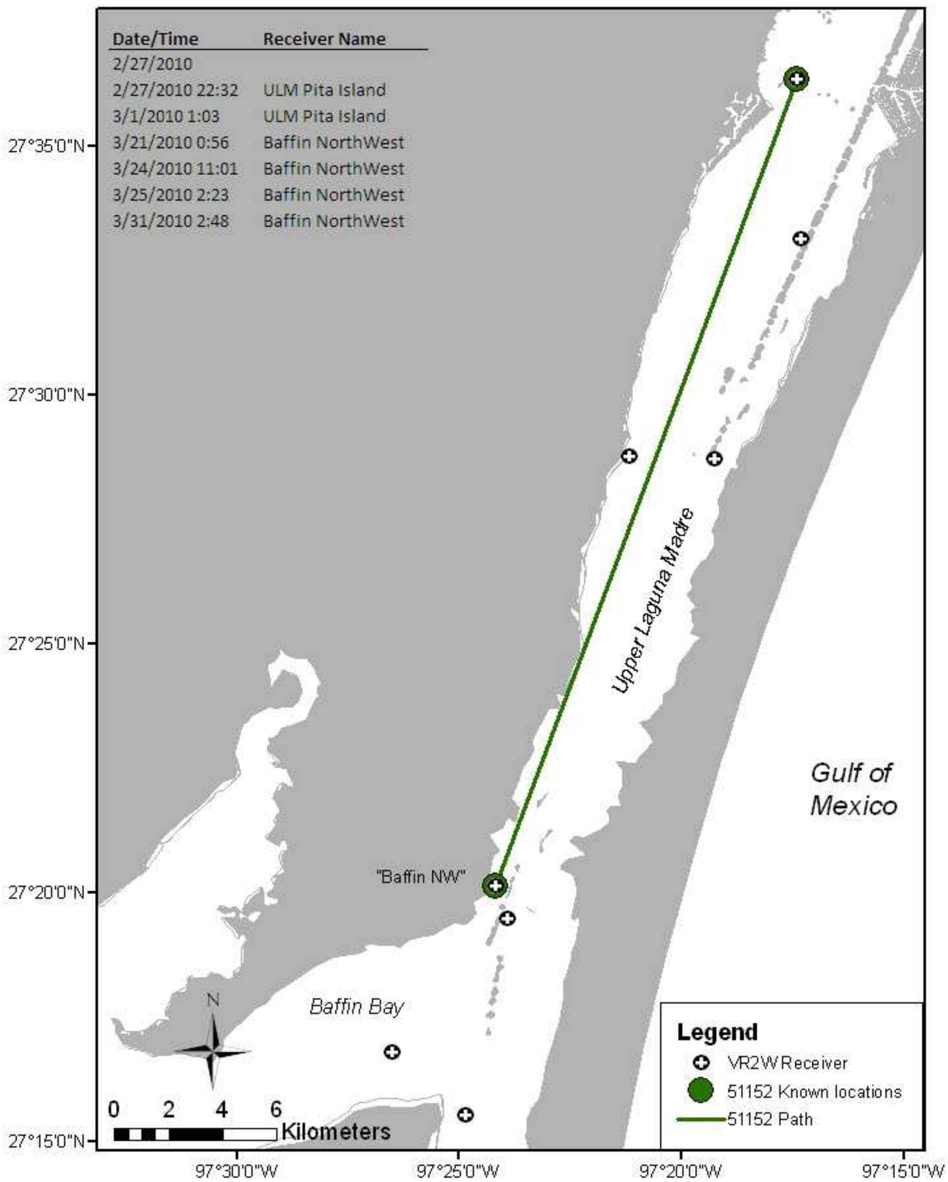
Spotted seatrout #51149

Total length: 610 mm
Tag-and-release date: 2/27/2010 Baffin Bay Rodeo Tournament
Days at Liberty: 139
Total minimum distance traveled: 70.5 km
Minimum home range: 17.2 km^2



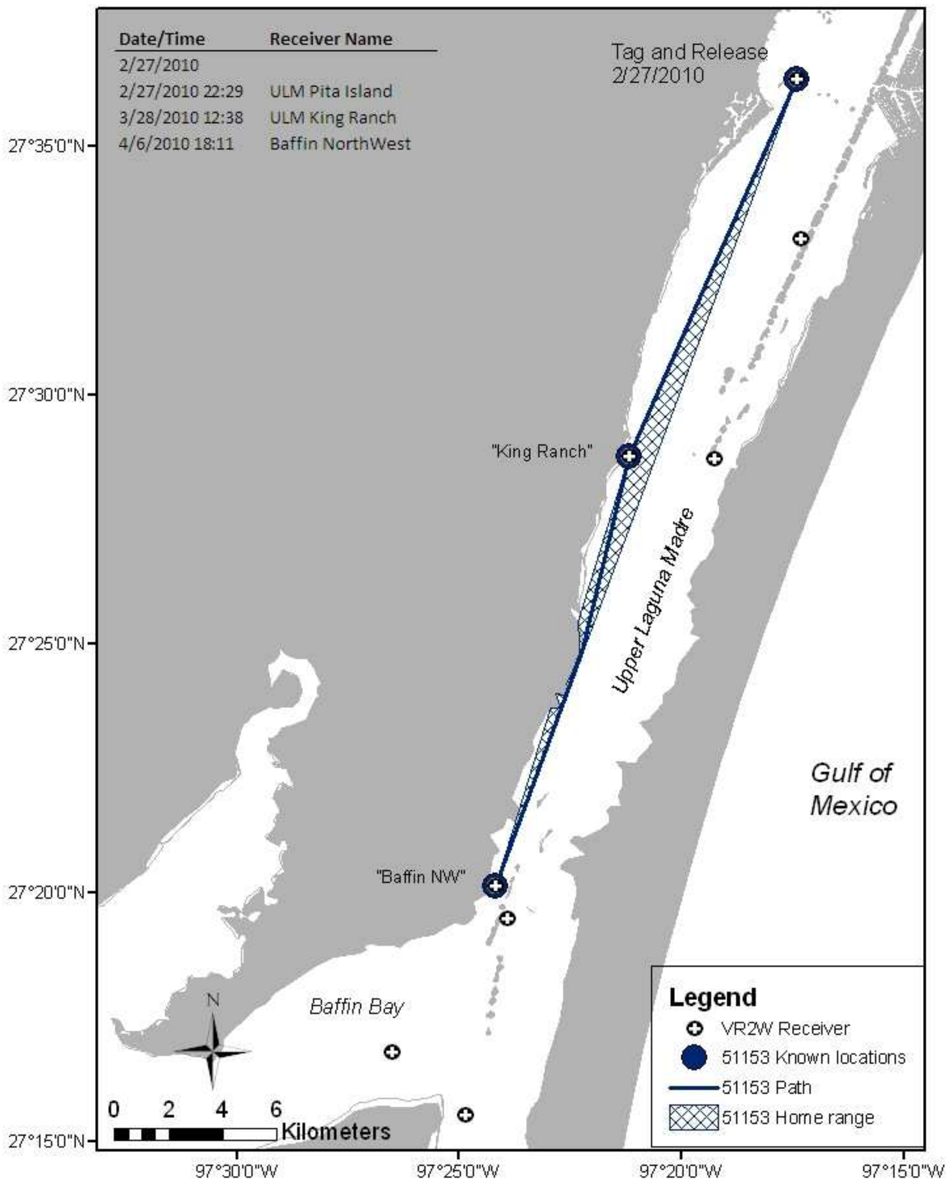
Spotted seatrout #51152

Total length: 660 mm
Tag-and-release date: 2/27/2010 Baffin Bay Rodeo Tournament
Days at Liberty: 32
Total minimum distance traveled: 32.0 km
Minimum home range: NA



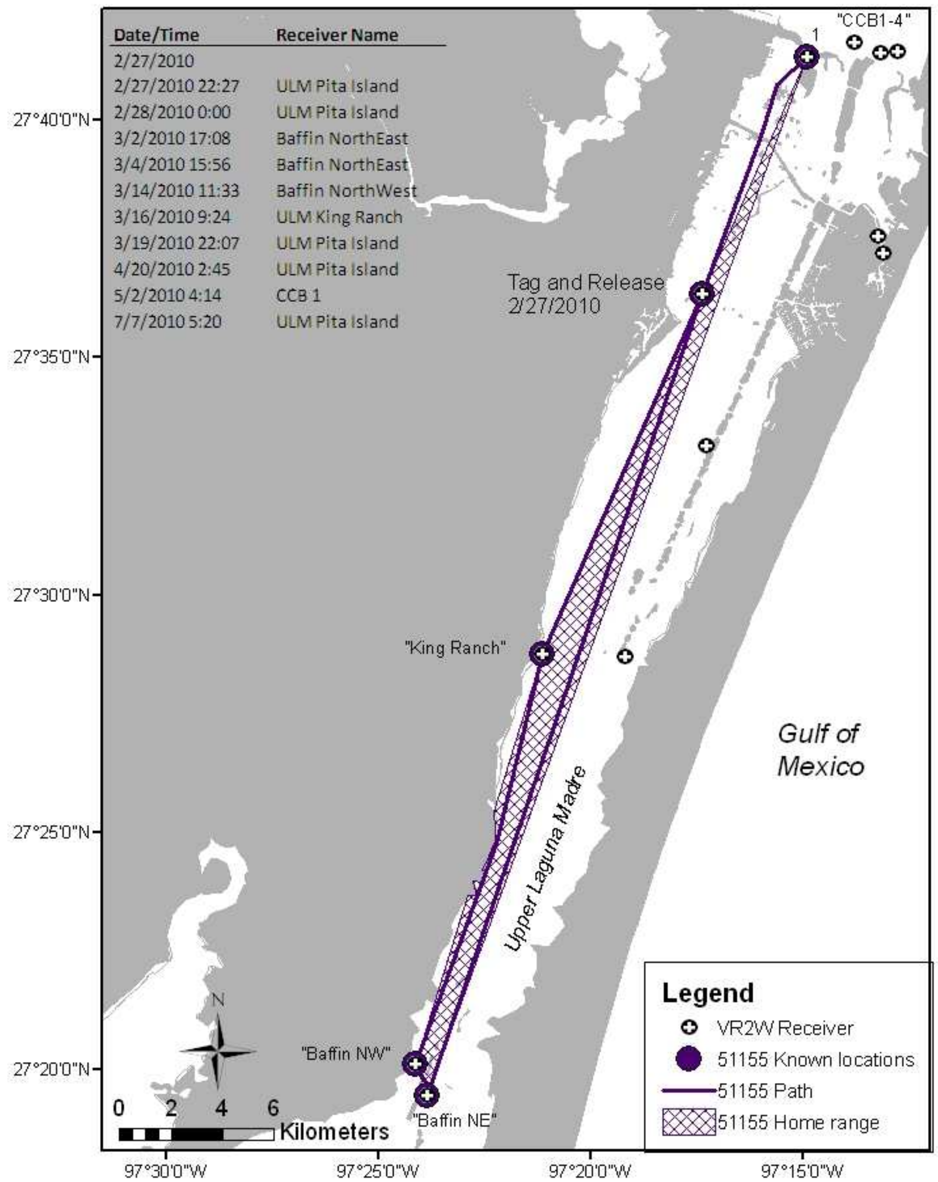
Spotted seatrout #51153

Total length: 659 mm
Tag-and-release date: 2/27/2010 Baffin Bay Rodeo Tournament
Days at Liberty: 38
Total minimum distance traveled: 32.0 km
Minimum home range: 41.1 km^2



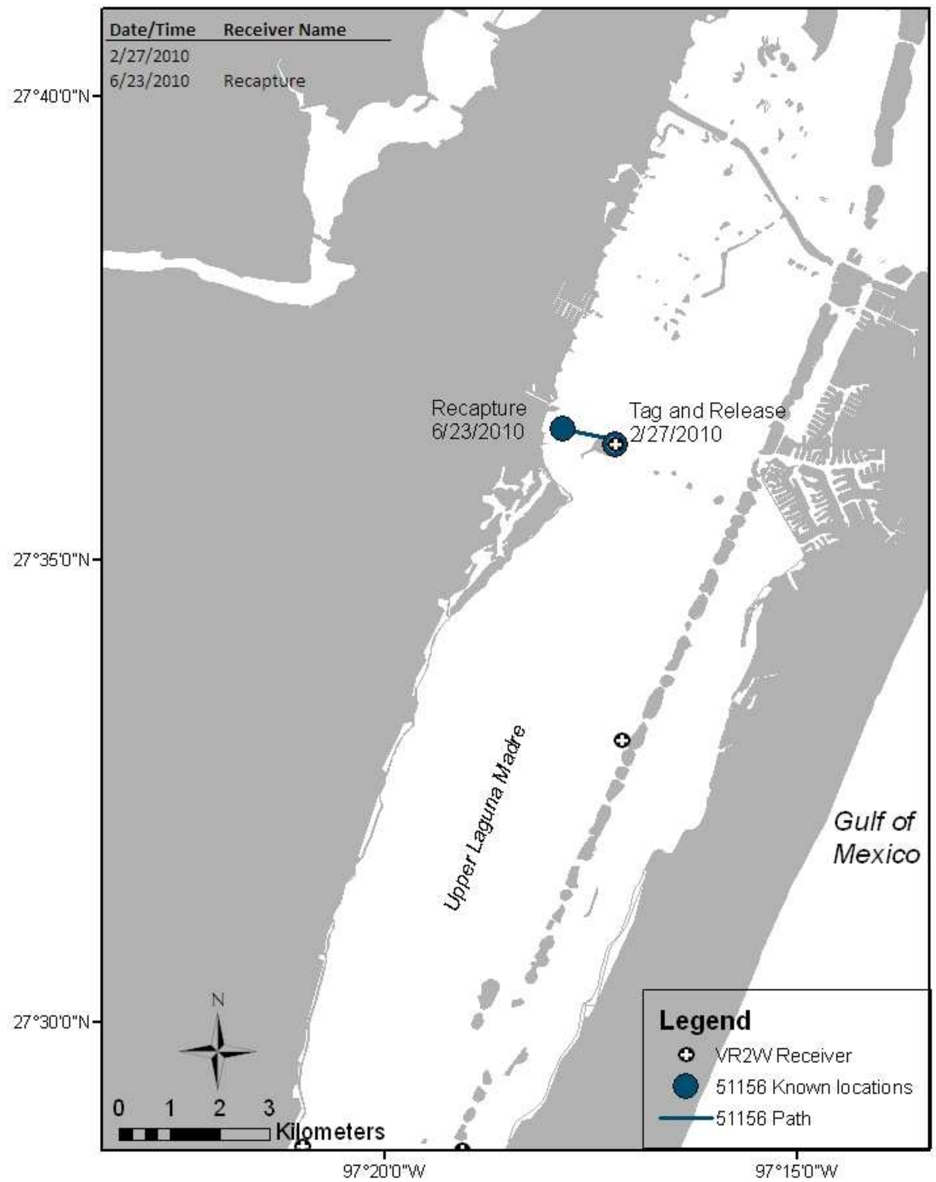
Spotted seatrout #51155

Total length: 670 mm
Tag-and-release date: 2/27/2010 Baffin Bay Rodeo Tournament
Days at Liberty: 130
Total minimum distance traveled: 86.8 km
Minimum home range: 41.9 km^2



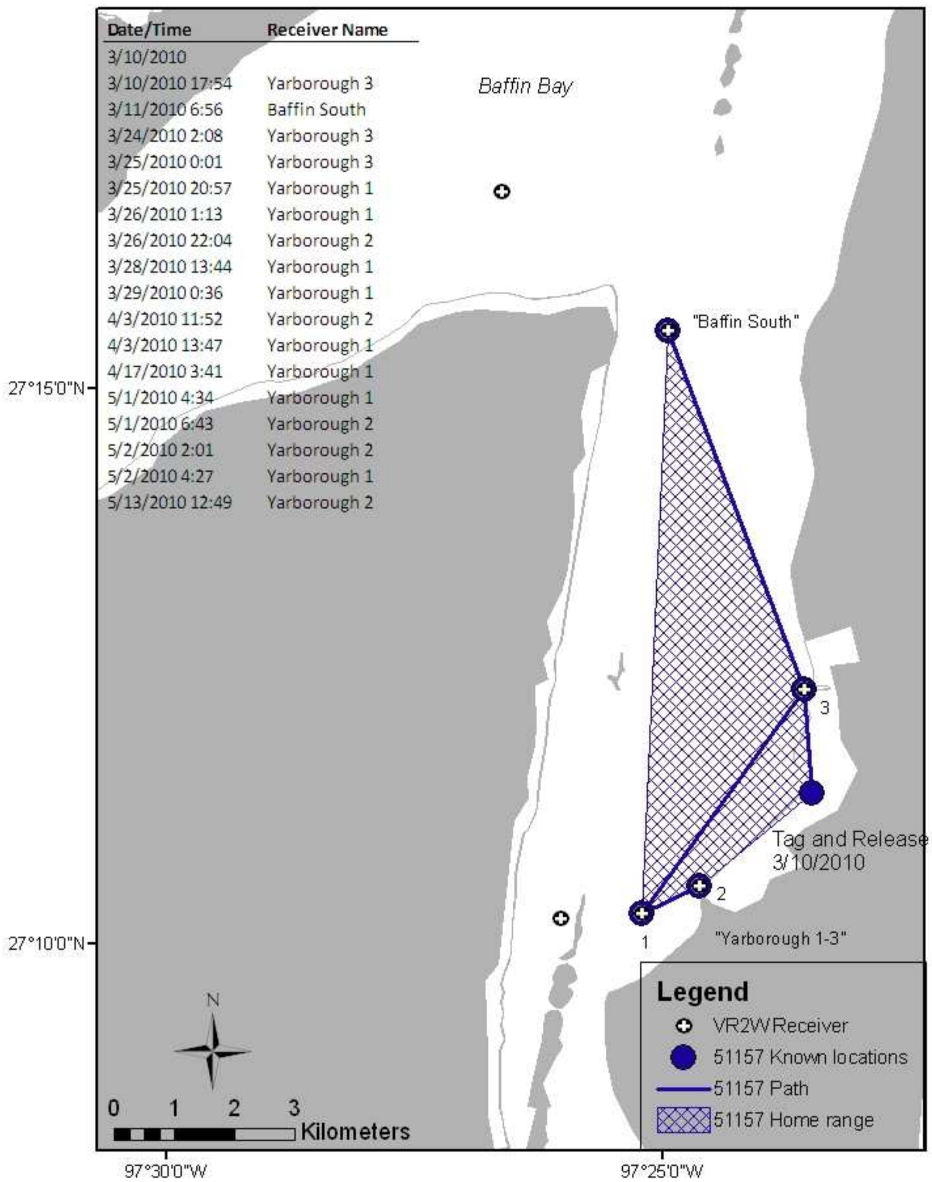
Spotted seatrout #51156

Total length: 582 mm
Tag-and-release date: 2/27/2010 Baffin Bay Rodeo Tournament
Days at Liberty: 116
Total minimum distance traveled: 1.1 km
Minimum home range: NA



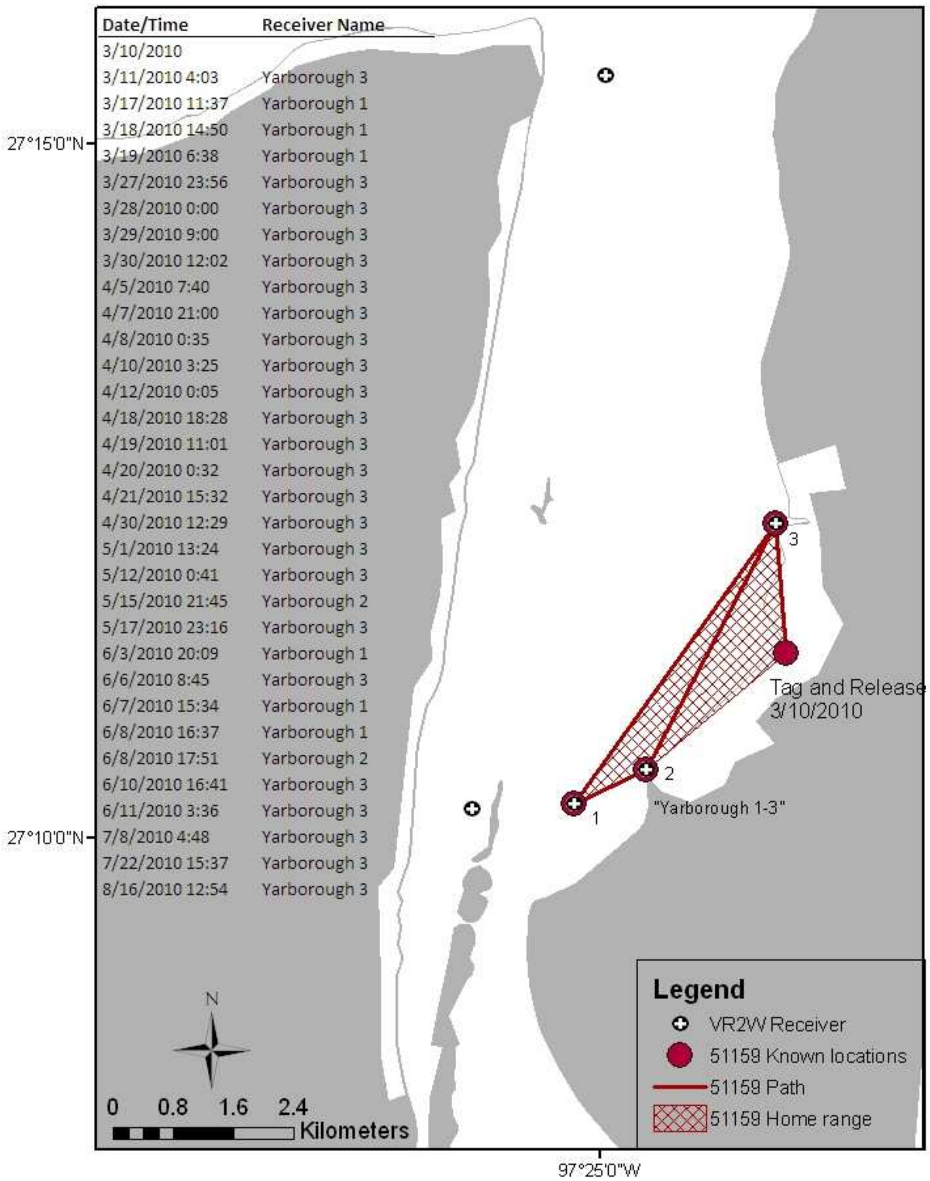
Spotted seatrout #51157

Total length: 469 mm
Tag-and-release date: 3/10/2010
Days at Liberty: 64
Total minimum distance traveled: 26.5 km
Minimum home range: 15.1 km^2



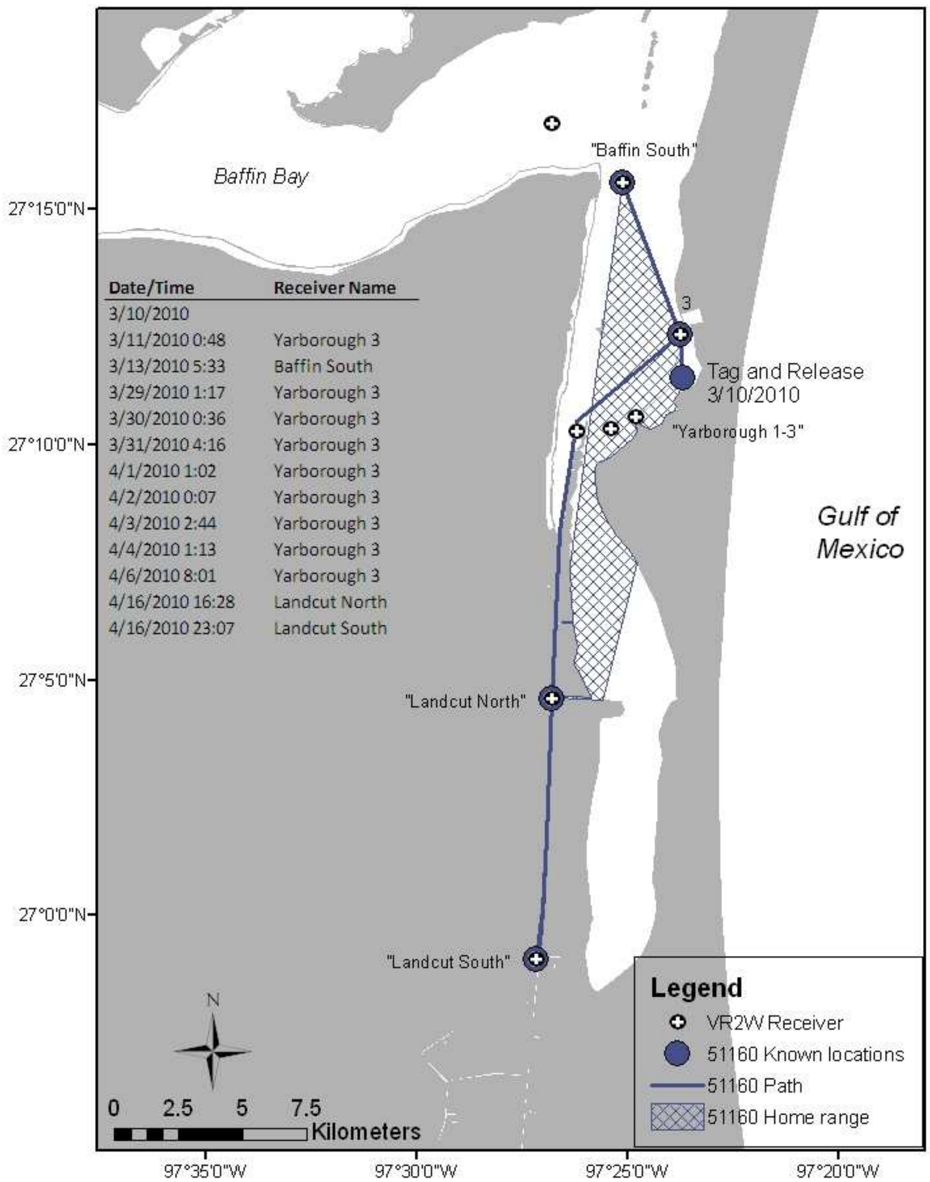
Spotted seatrout #51159

Total length: 515 mm
Tag-and-release date: 3/10/2010
Days at Liberty: 159
Total minimum distance traveled: 36.9 km
Minimum home range: 2.9 km^2



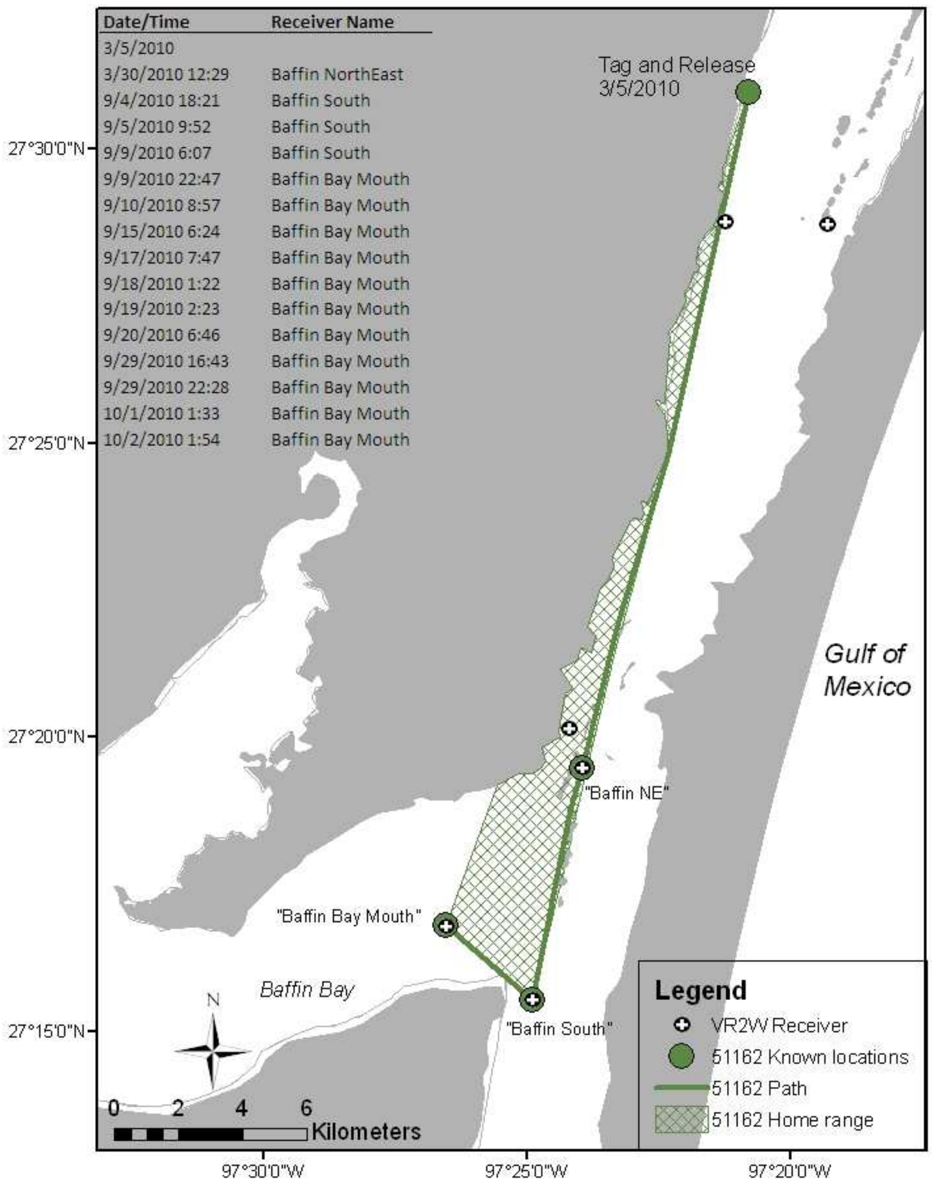
Spotted seatrout #51160

Total length: 492 mm
Tag-and-release date: 3/10/2010
Days at Liberty: 37
Total minimum distance traveled: 40.9 km
Minimum home range: 38.1 km^2



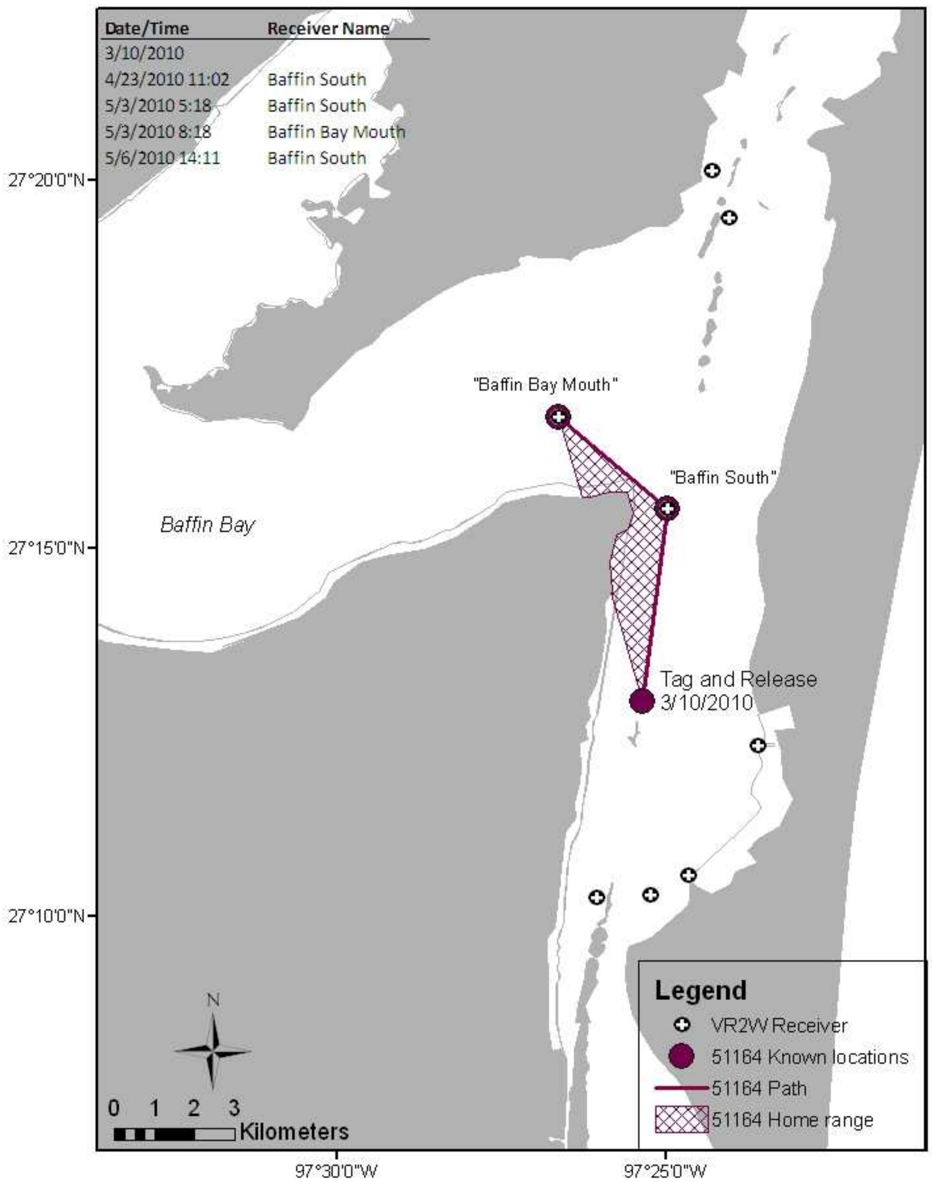
Spotted seatrout #51162

Total length: 406 mm
Tag-and-release date: 3/5/2010
Days at Liberty: 211
Total minimum distance traveled: 32.9 km
Minimum home range: 47.0 km^2



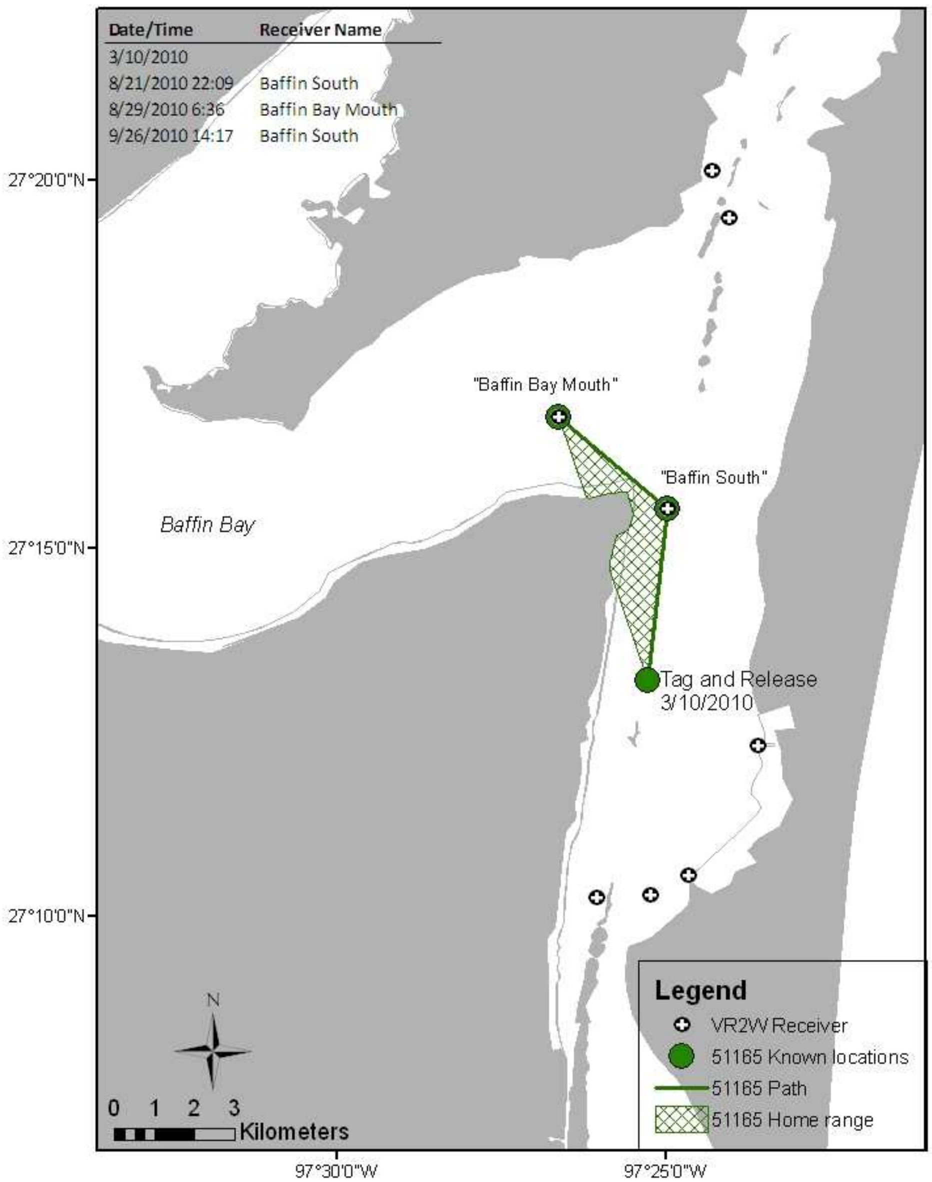
Spotted seatrout #51164

Total length: 473 mm
Tag-and-release date: 3/10/2010
Days at Liberty: 57
Total minimum distance traveled: 12.1 km
Minimum home range: 5.9 km^2



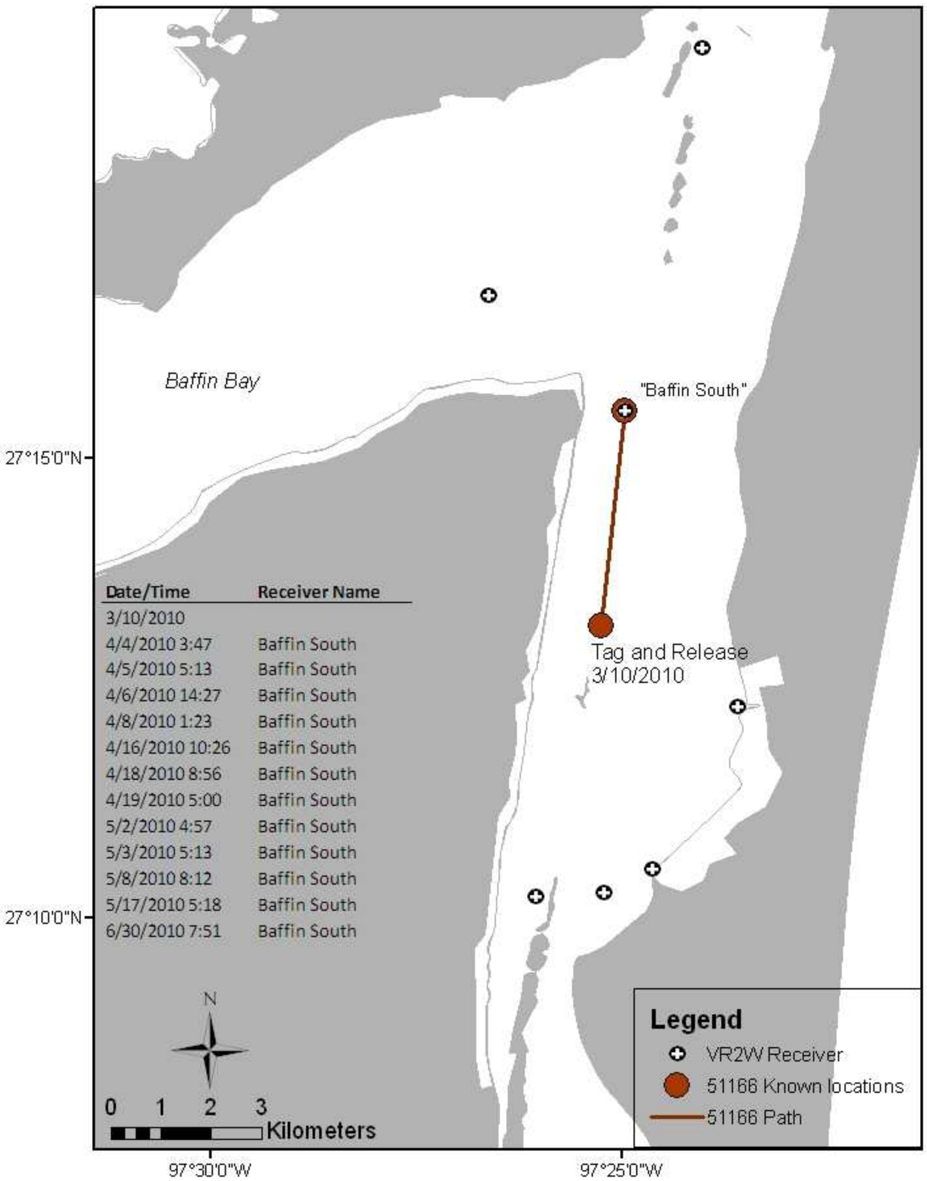
Spotted seatrout #51165

Total length: 443 mm
Tag-and-release date: 3/10/2010
Days at Liberty: 200
Total minimum distance traveled: 11.5 km
Minimum home range: 5.3 km^2



Spotted seatrout #51166

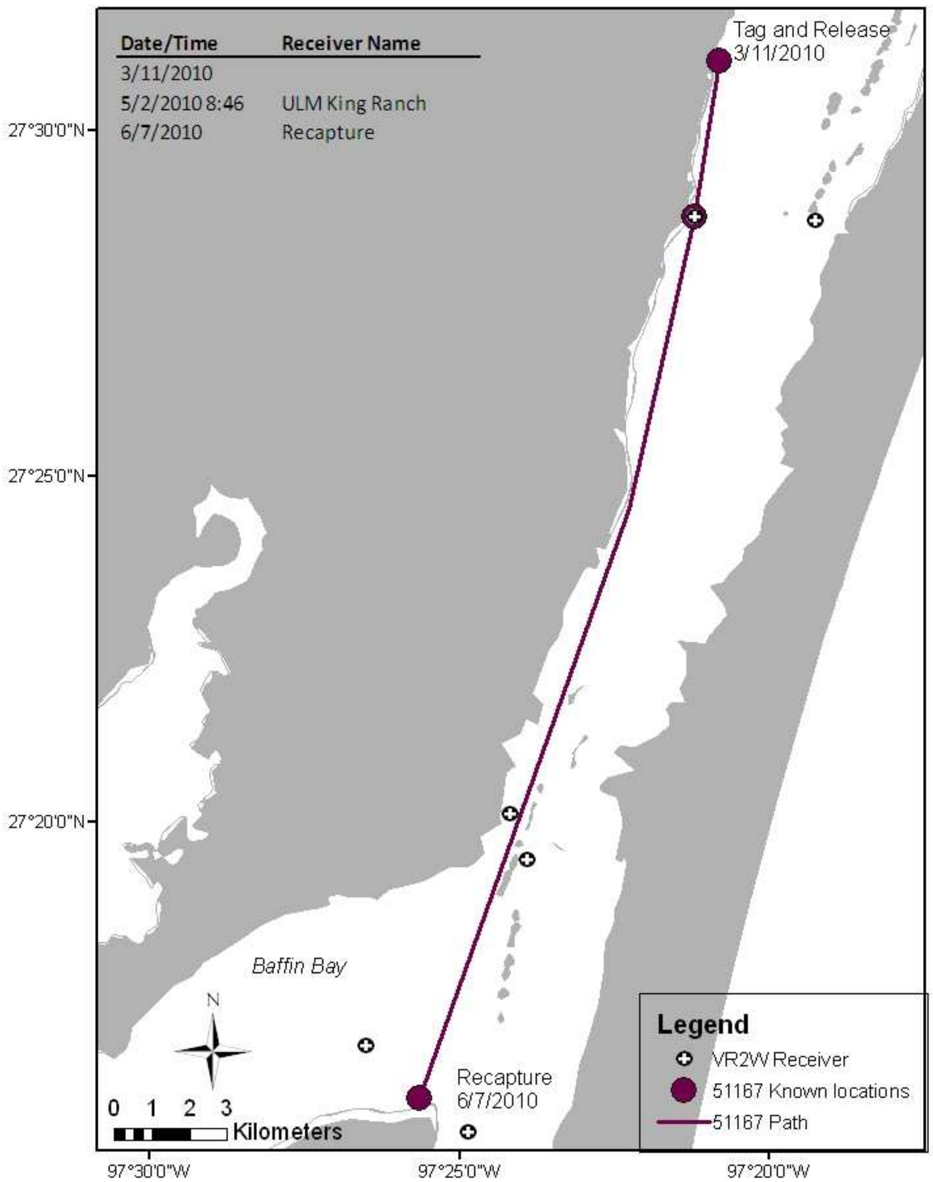
Total length: 488 mm
Tag-and-release date: 3/10/2010
Days at Liberty: 112
Total minimum distance traveled: 4.3 km
Minimum home range: NA



Date/Time	Receiver Name
3/10/2010	
4/4/2010 3:47	Baffin South
4/5/2010 5:13	Baffin South
4/6/2010 14:27	Baffin South
4/8/2010 1:23	Baffin South
4/16/2010 10:26	Baffin South
4/18/2010 8:56	Baffin South
4/19/2010 5:00	Baffin South
5/2/2010 4:57	Baffin South
5/3/2010 5:13	Baffin South
5/8/2010 8:12	Baffin South
5/17/2010 5:18	Baffin South
6/30/2010 7:51	Baffin South

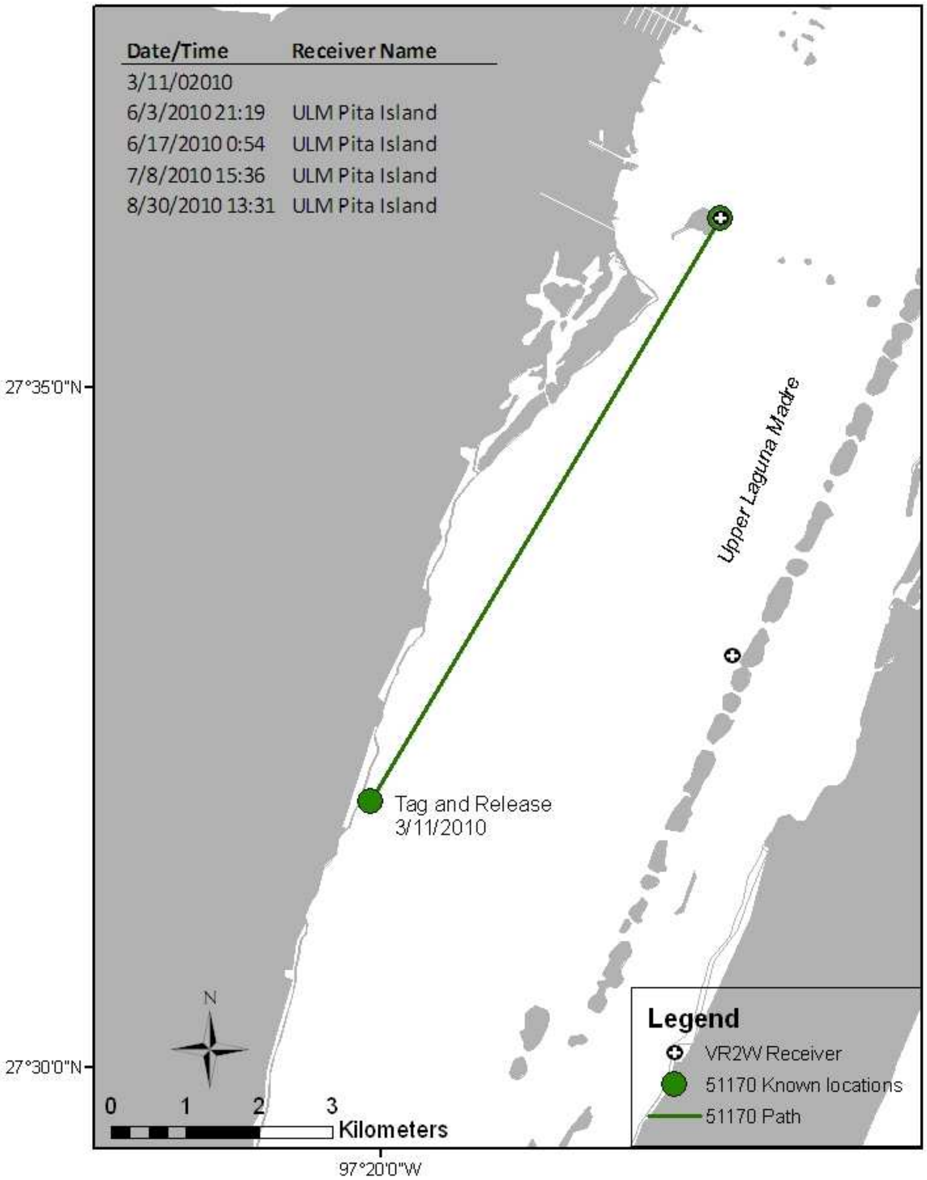
Spotted seatrout #51167

Total length: 463 mm
Tag-and-release date: 3/11/2010
Days at Liberty: 88
Total minimum distance traveled: 28.9 km
Minimum home range: NA



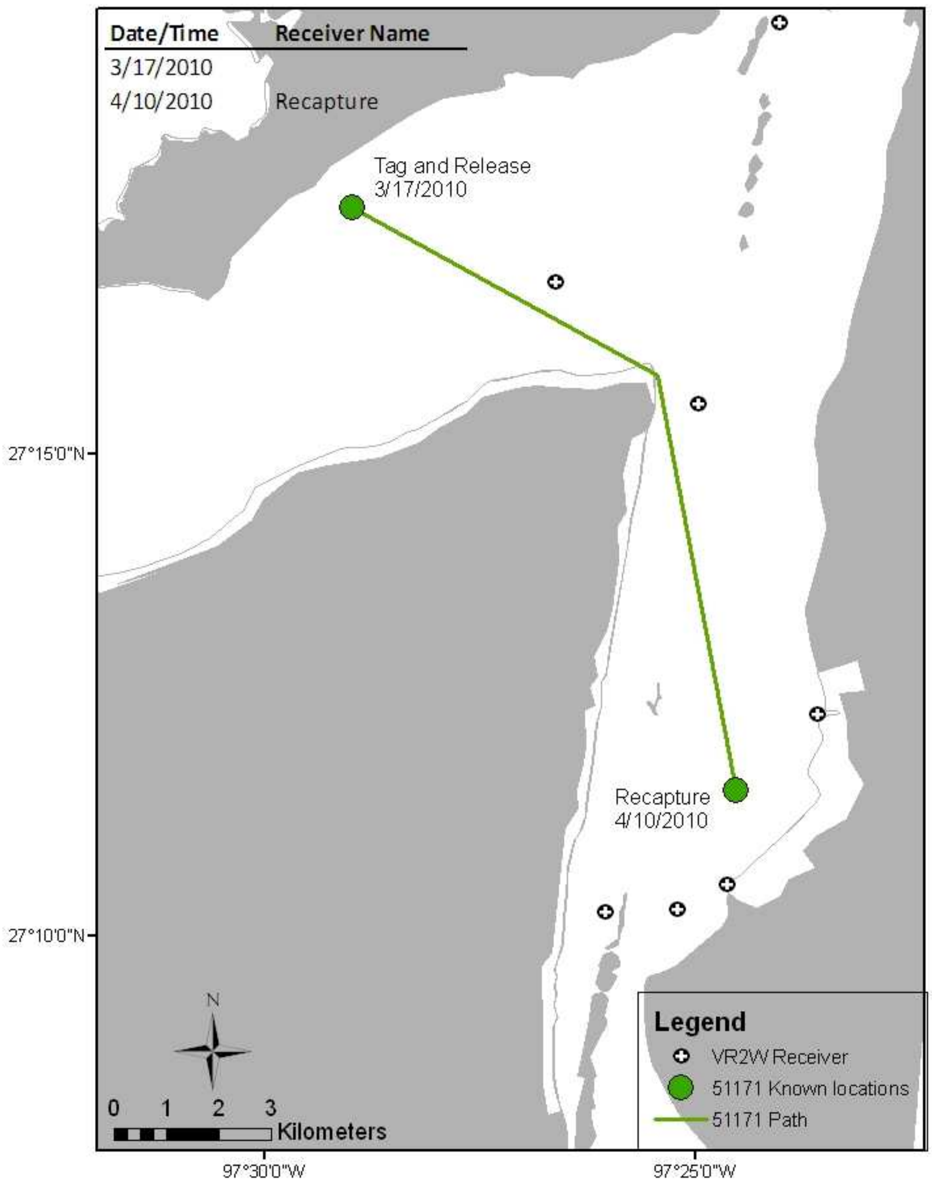
Spotted seatrout #51170

Total length: 440 mm
Tag-and-release date: 3/11/2010
Days at Liberty: 172
Total minimum distance traveled: 9.2 km
Minimum home range: NA



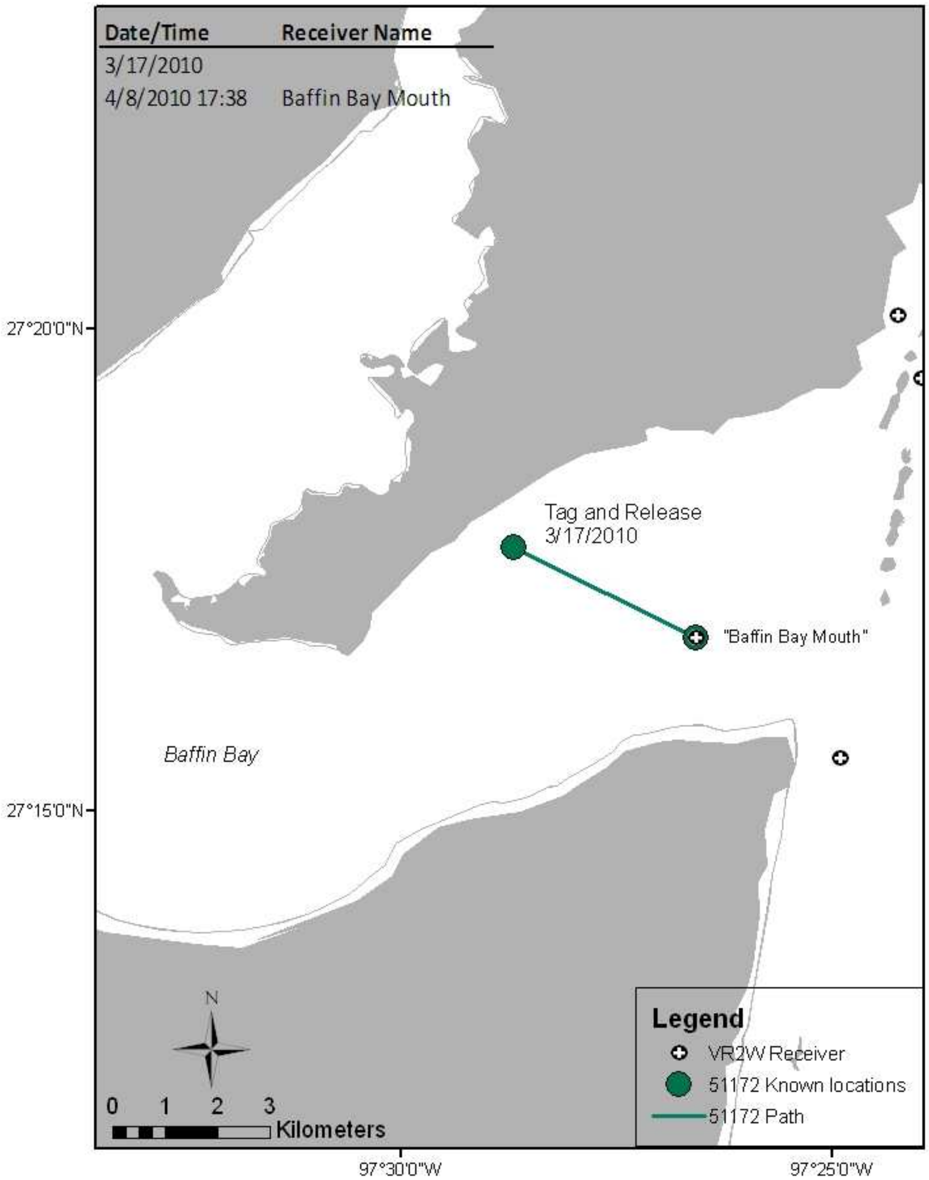
Spotted seatrout #51171

Total length: 441 mm
Tag-and-release date: 3/17/2010
Days at Liberty: 24
Total minimum distance traveled: 14.8 km
Minimum home range: NA



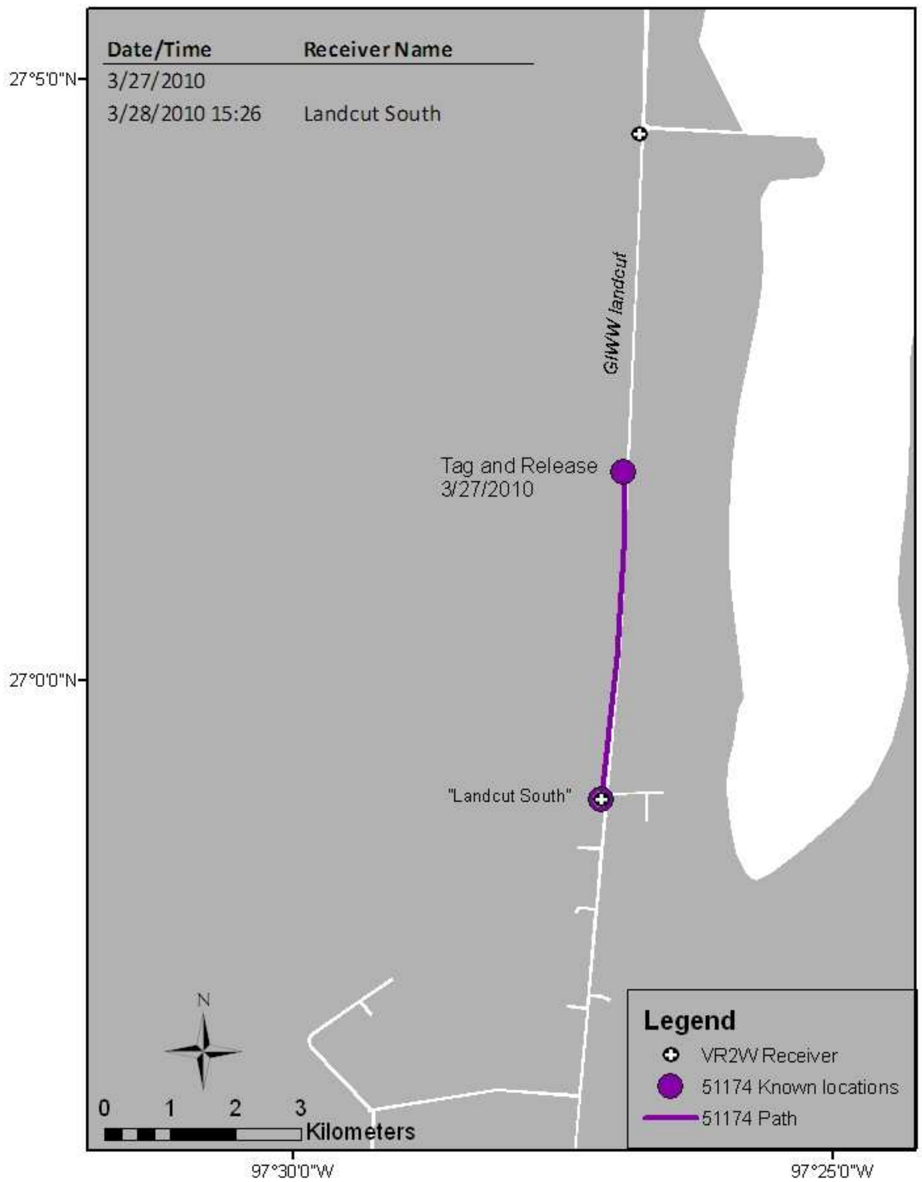
Spotted seatrout #51172

Total length: 520 mm
Tag-and-release date: 3/17/2010
Days at Liberty: 22
Total minimum distance traveled: 3.9 km
Minimum home range: NA



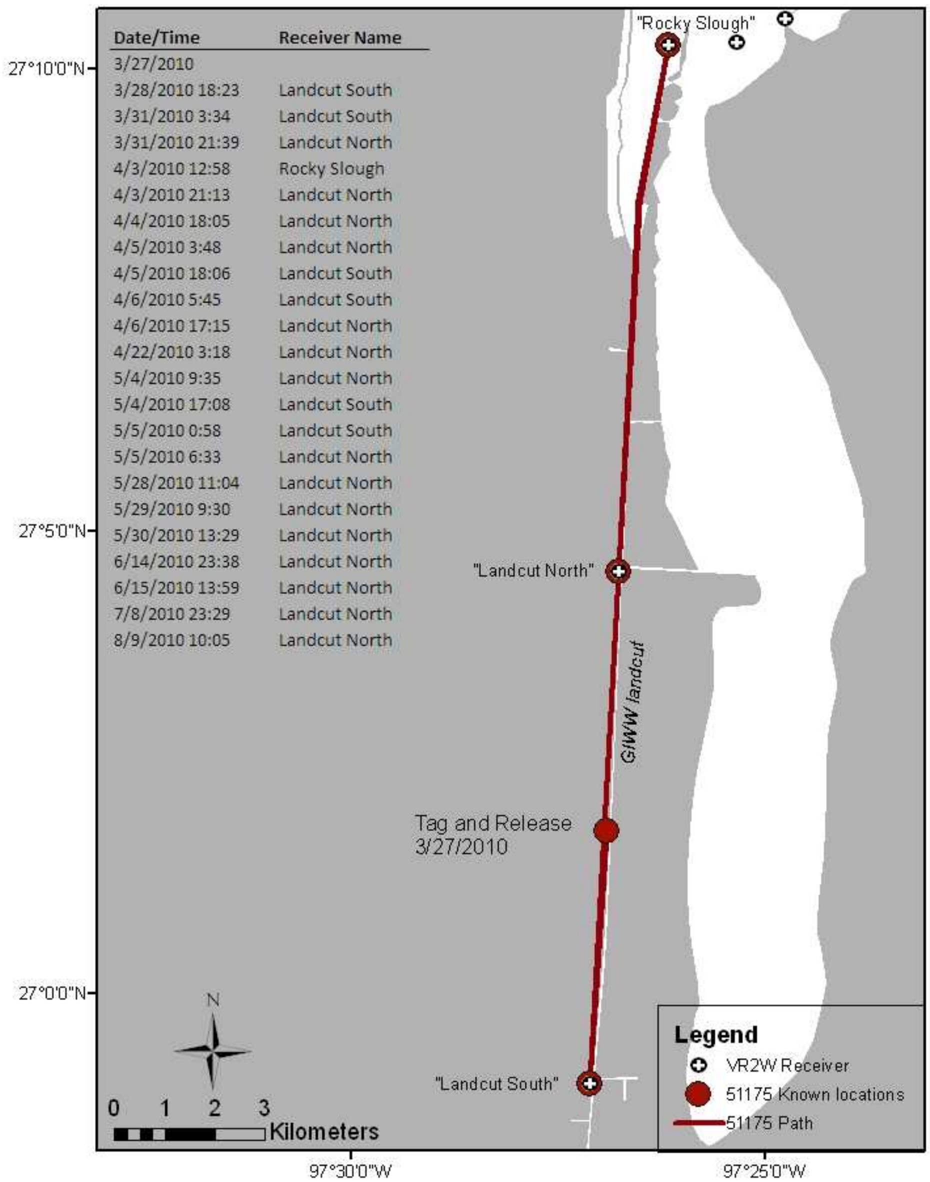
Spotted seatrout #51174

Total length: 630 mm
Tag-and-release date: 3/27/2010
Days at Liberty: 1
Total minimum distance traveled: 5.1 km
Minimum home range: NA



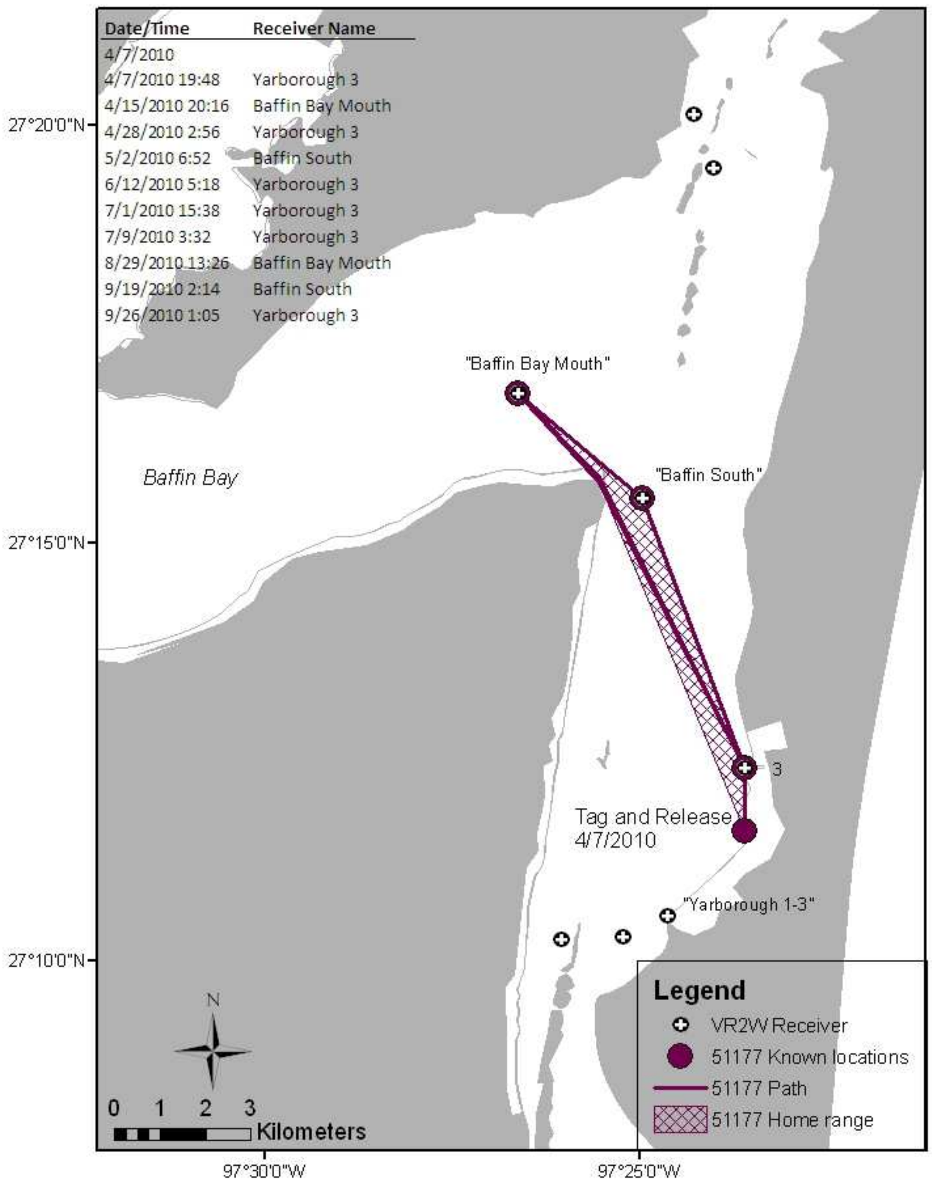
Spotted seatrout #51175

Total length: 480 mm
Tag-and-release date: 3/27/2010
Days at Liberty: 135
Total minimum distance traveled: 77.4 km
Minimum home range: NA



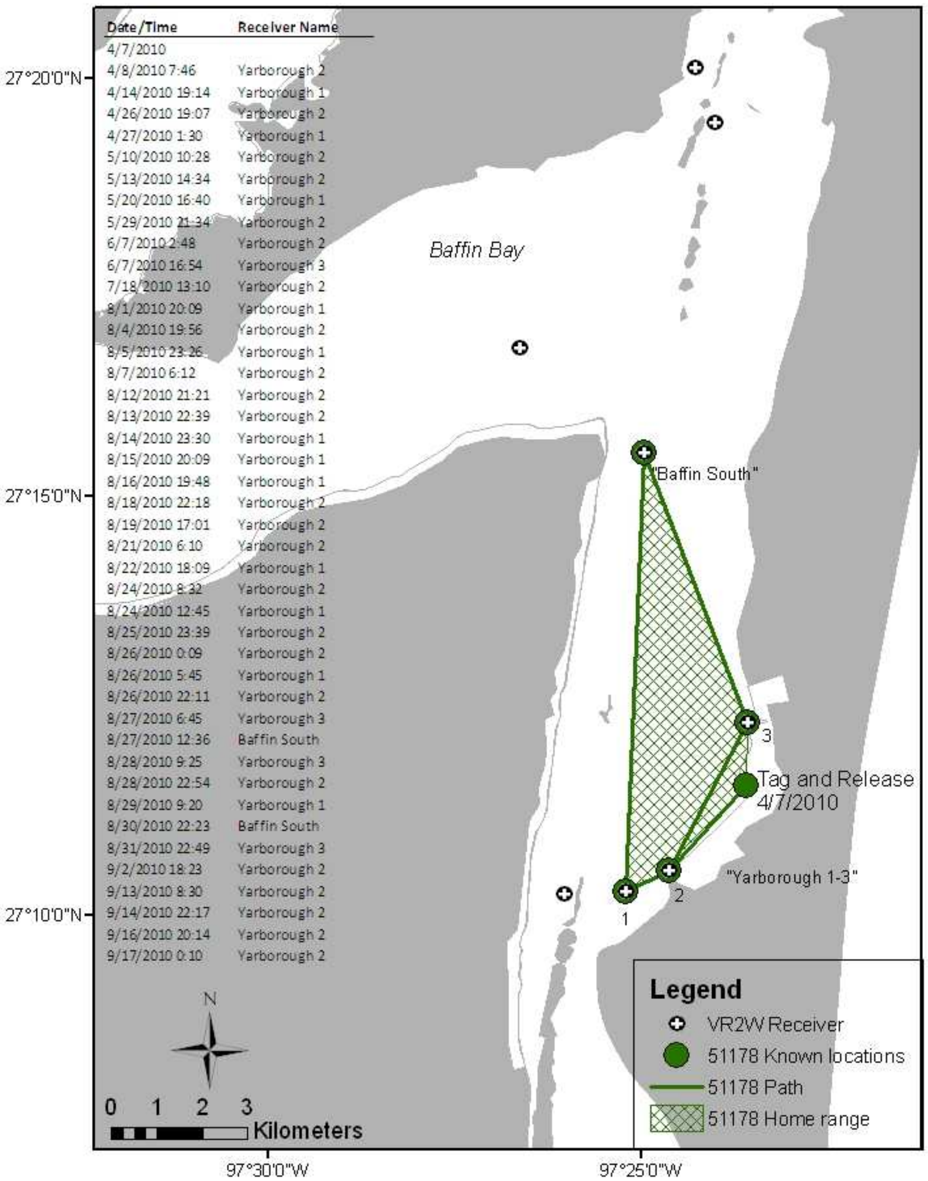
Spotted seatrout #51177

Total length: 511 mm
Tag-and-release date: 4/7/2010
Days at Liberty: 172
Total minimum distance traveled: 53.4 km
Minimum home range: 5.3 km^2



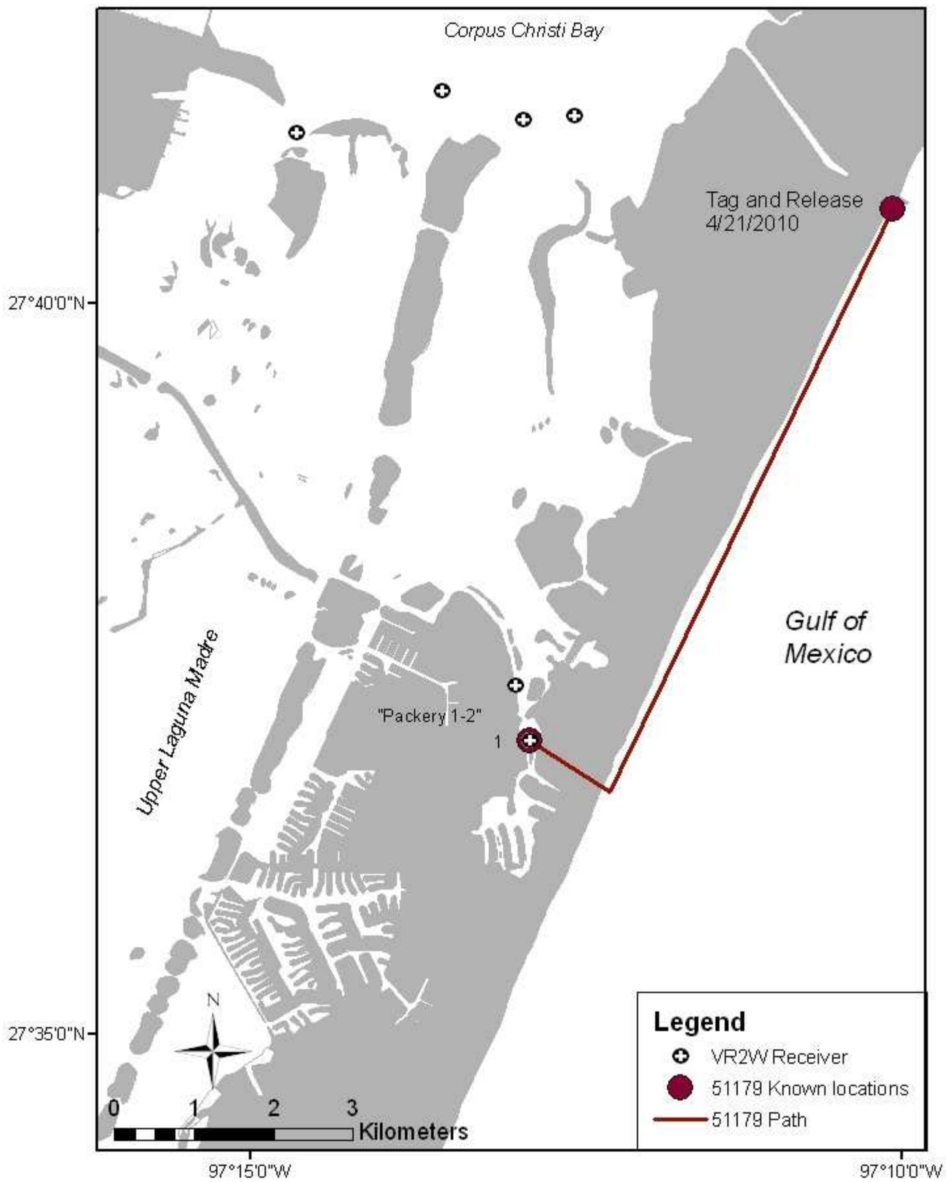
Spotted seatrout #51178

Total length: 508 mm
Tag-and-release date: 4/7/2010
Days at Liberty: 163
Total minimum distance traveled: 70.1 km
Minimum home range: 14.6 km^2



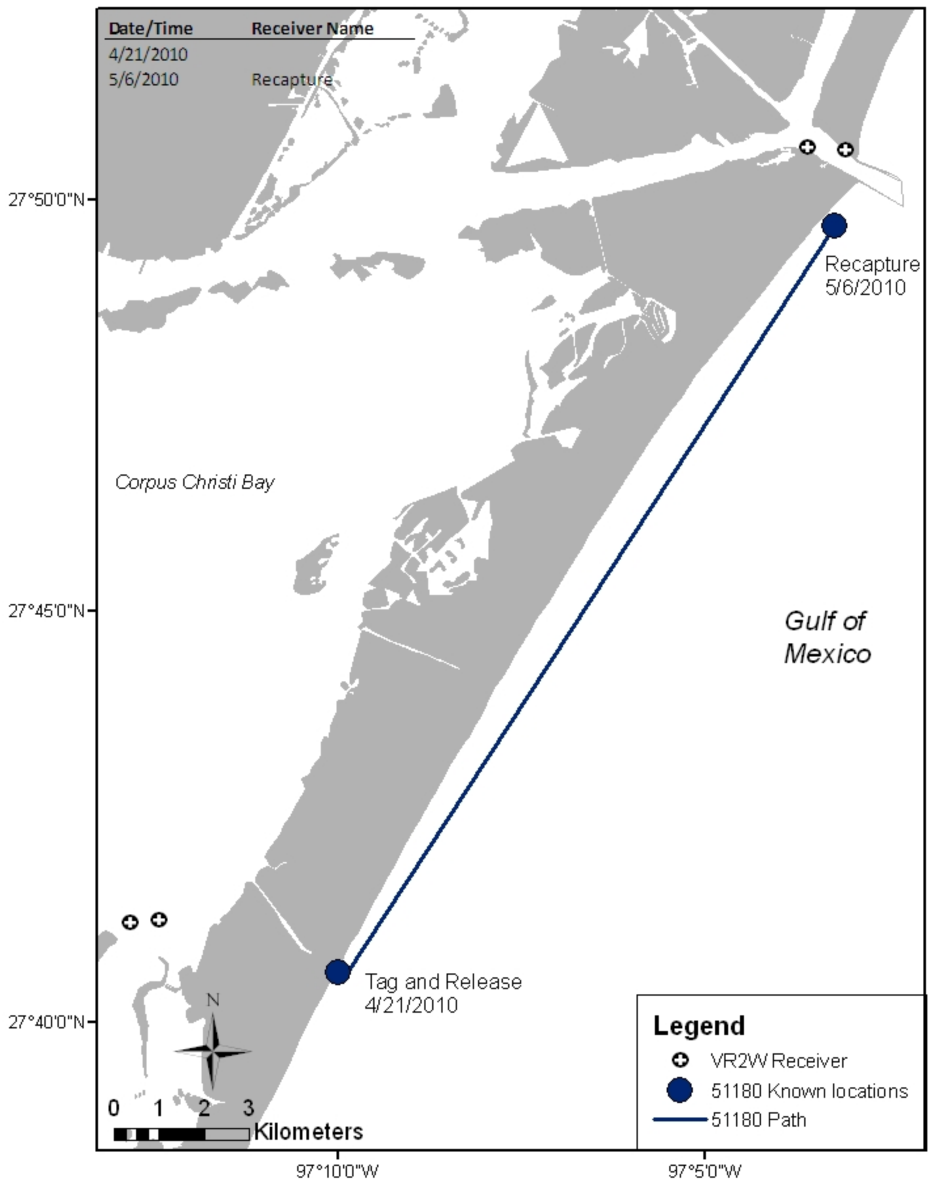
Spotted seatrout #51179

Total length: 442 mm
Tag-and-release date: 4/21/2010
Days at Liberty: 6
Total minimum distance traveled: 9.4 km
Minimum home range: NA



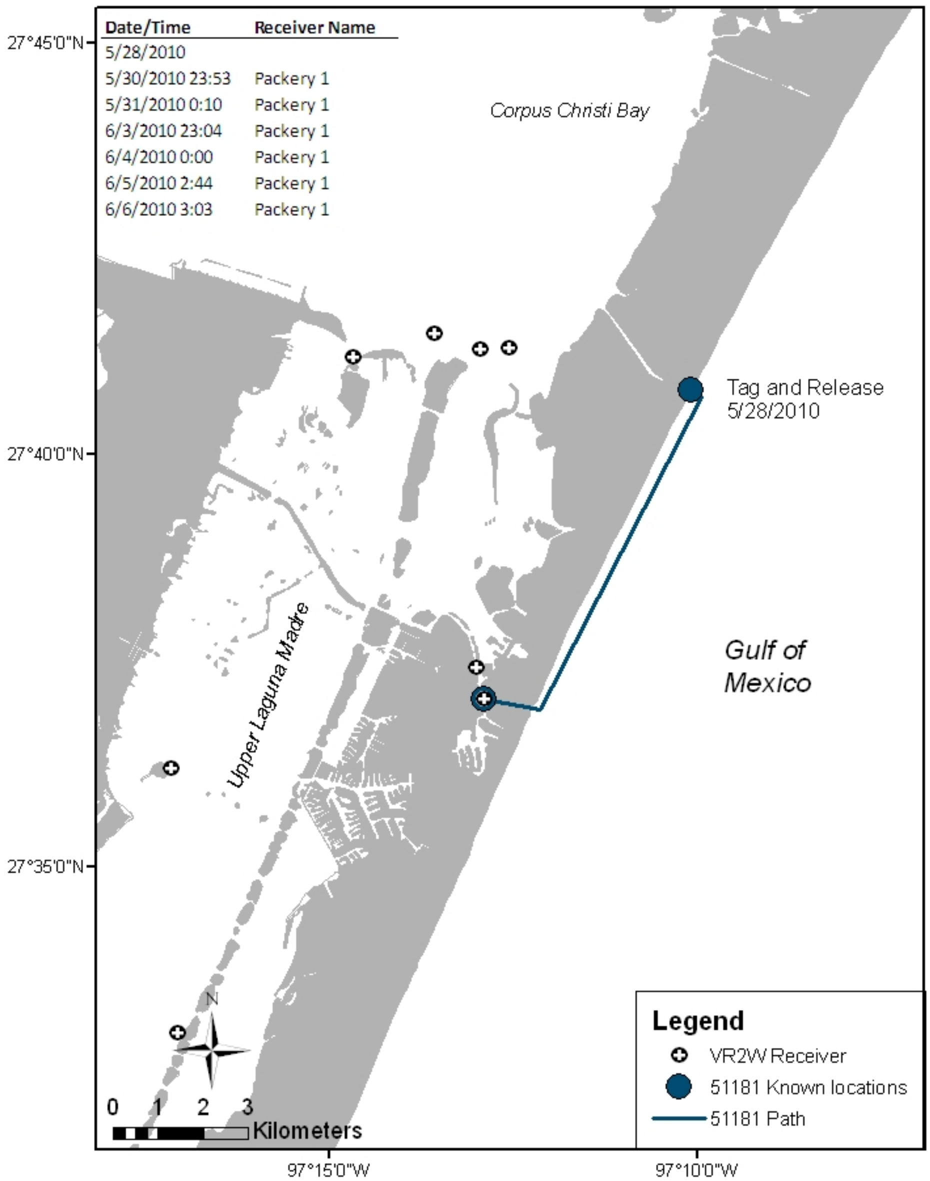
Spotted seatrout #51180

Total length: 444 mm
Tag-and-release date: 4/21/2010
Days at Liberty: 15
Total minimum distance traveled: 20.3 km
Minimum home range: NA



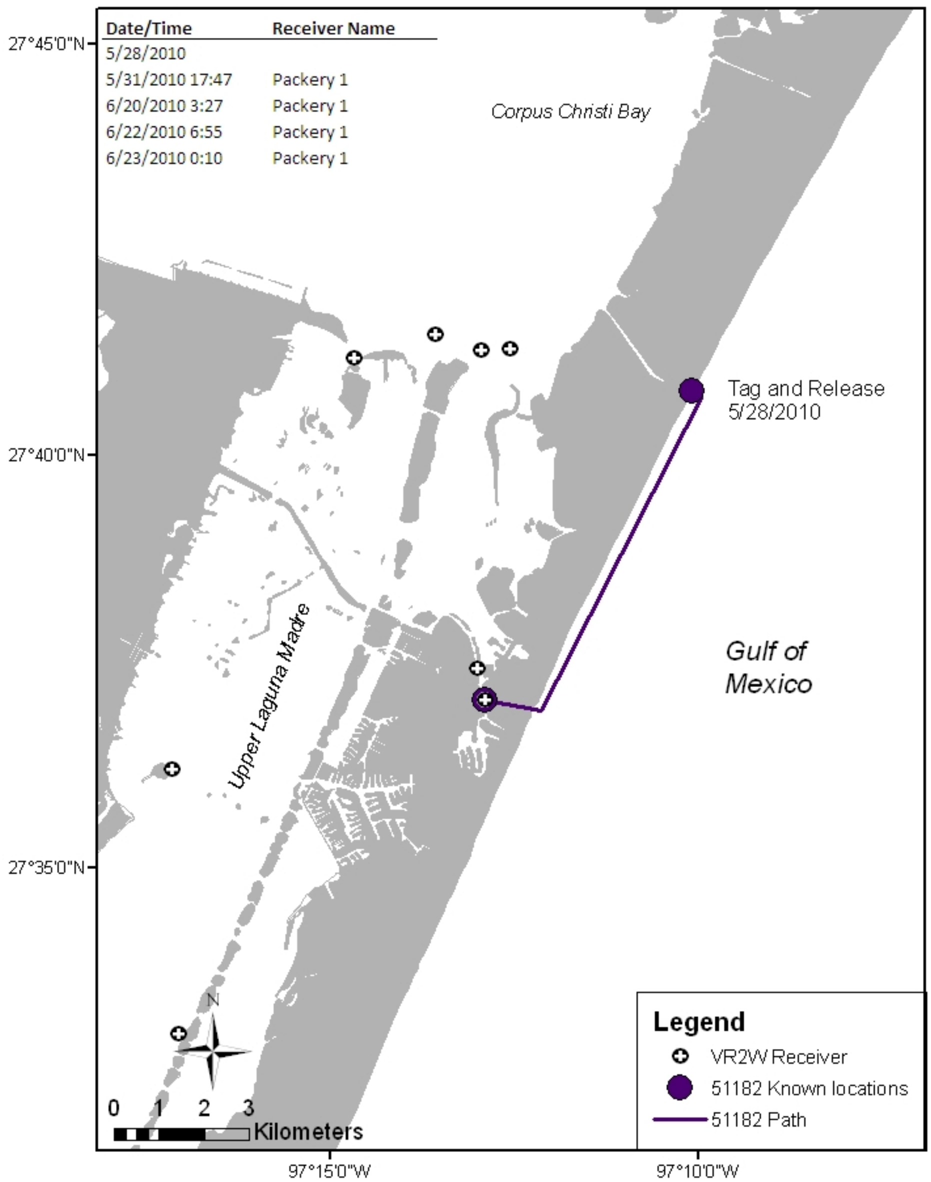
Spotted seatrout #51181

Total length: 500 mm
Tag-and-release date: 5/28/2010
Days at Liberty: 9
Total minimum distance traveled: 9.5 km
Minimum home range: NA



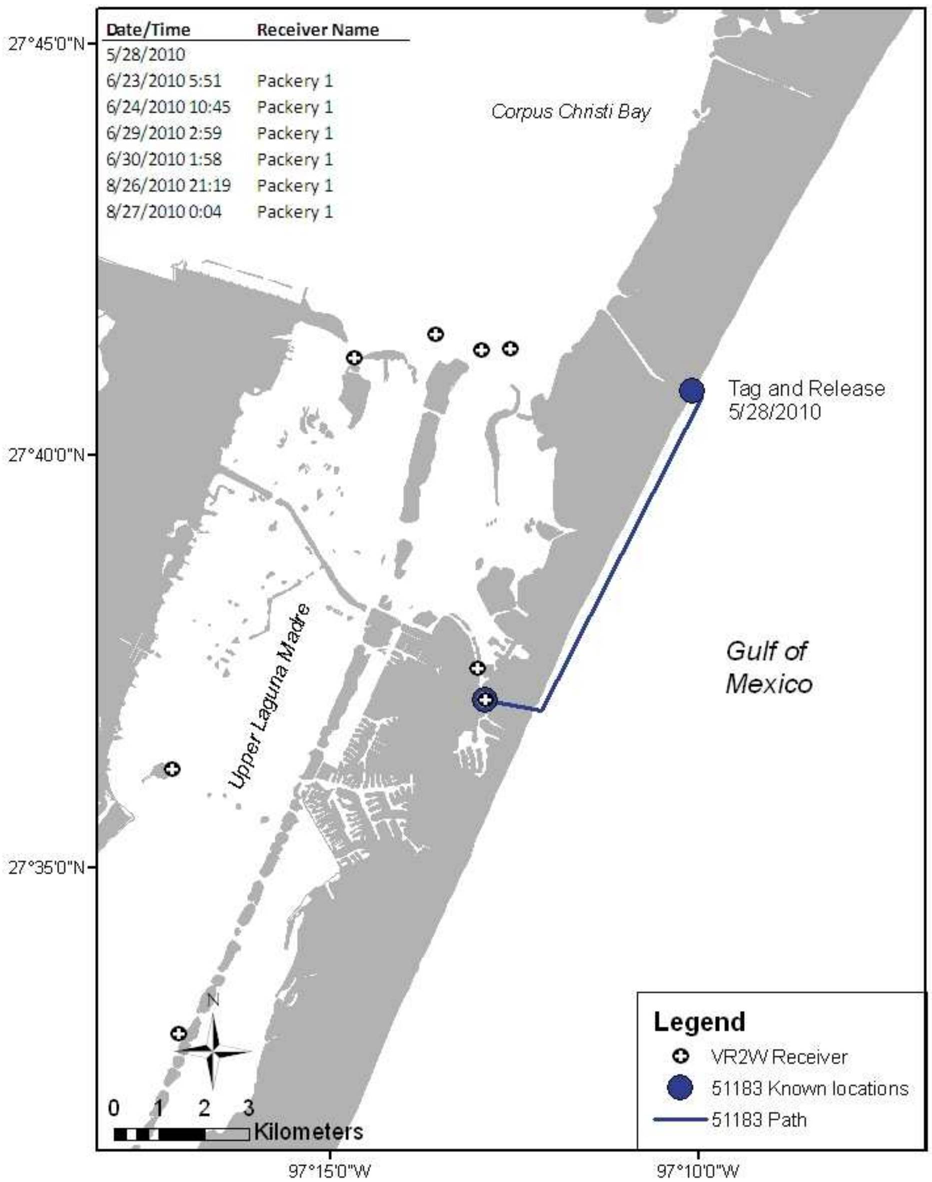
Spotted seatrout #51182

Total length: 415 mm
Tag-and-release date: 5/28/2010
Days at Liberty: 26
Total minimum distance traveled: 9.5 km
Minimum home range: NA



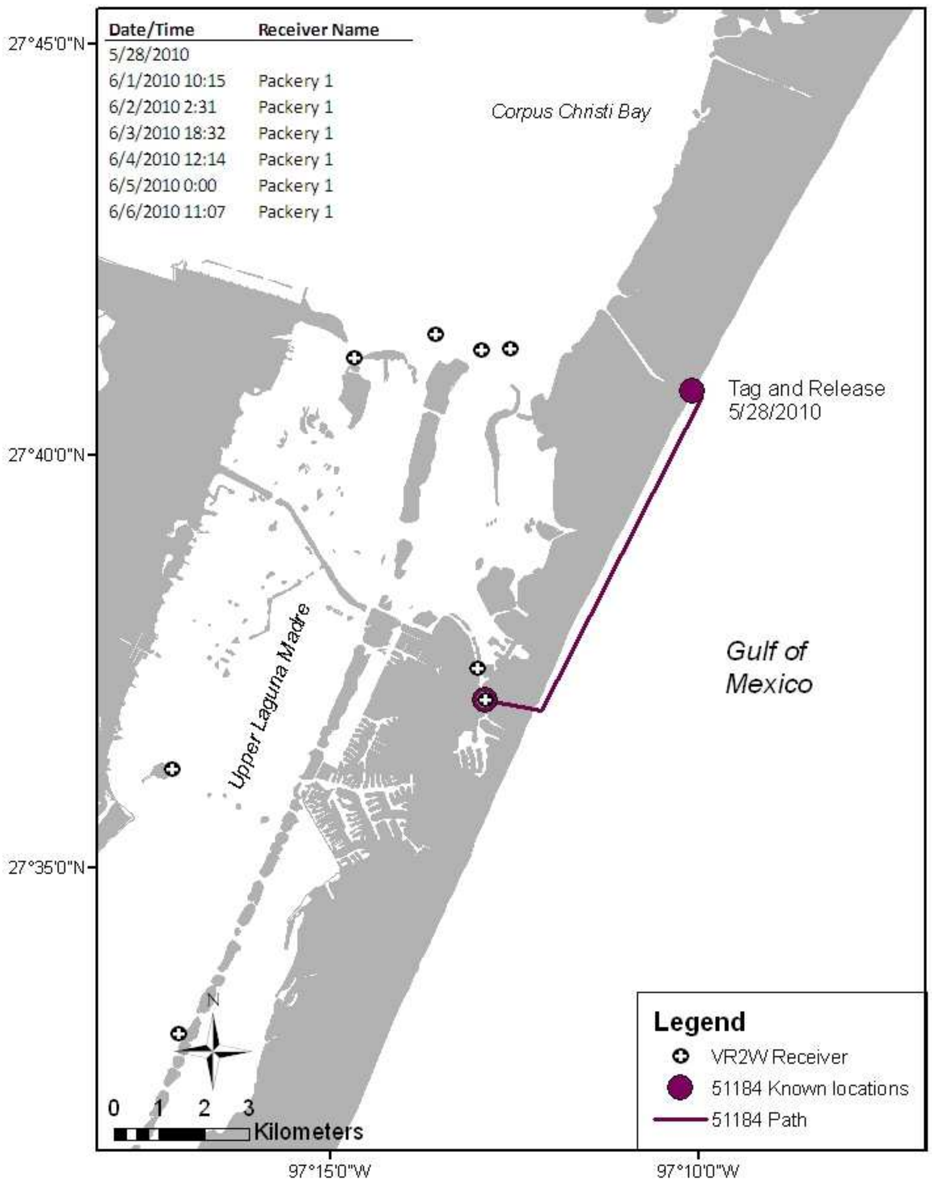
Spotted seatrout #51183

Total length: 438 mm
Tag-and-release date: 5/28/2010
Days at Liberty: 91
Total minimum distance traveled: 9.5 km
Minimum home range: NA



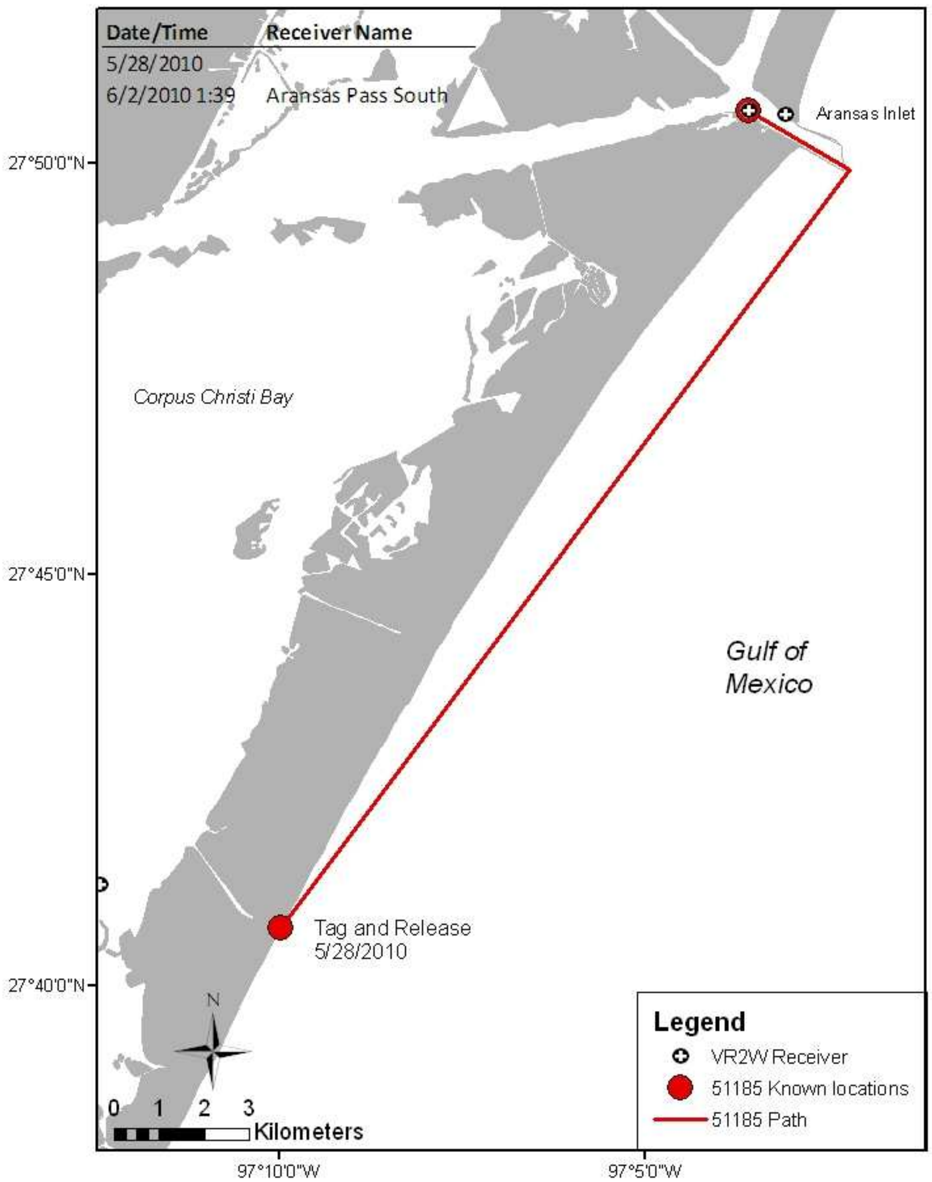
Spotted seatrout #51184

Total length: 421 mm
Tag-and-release date: 5/28/2010
Days at Liberty: 9
Total minimum distance traveled: 9.5 km
Minimum home range: NA



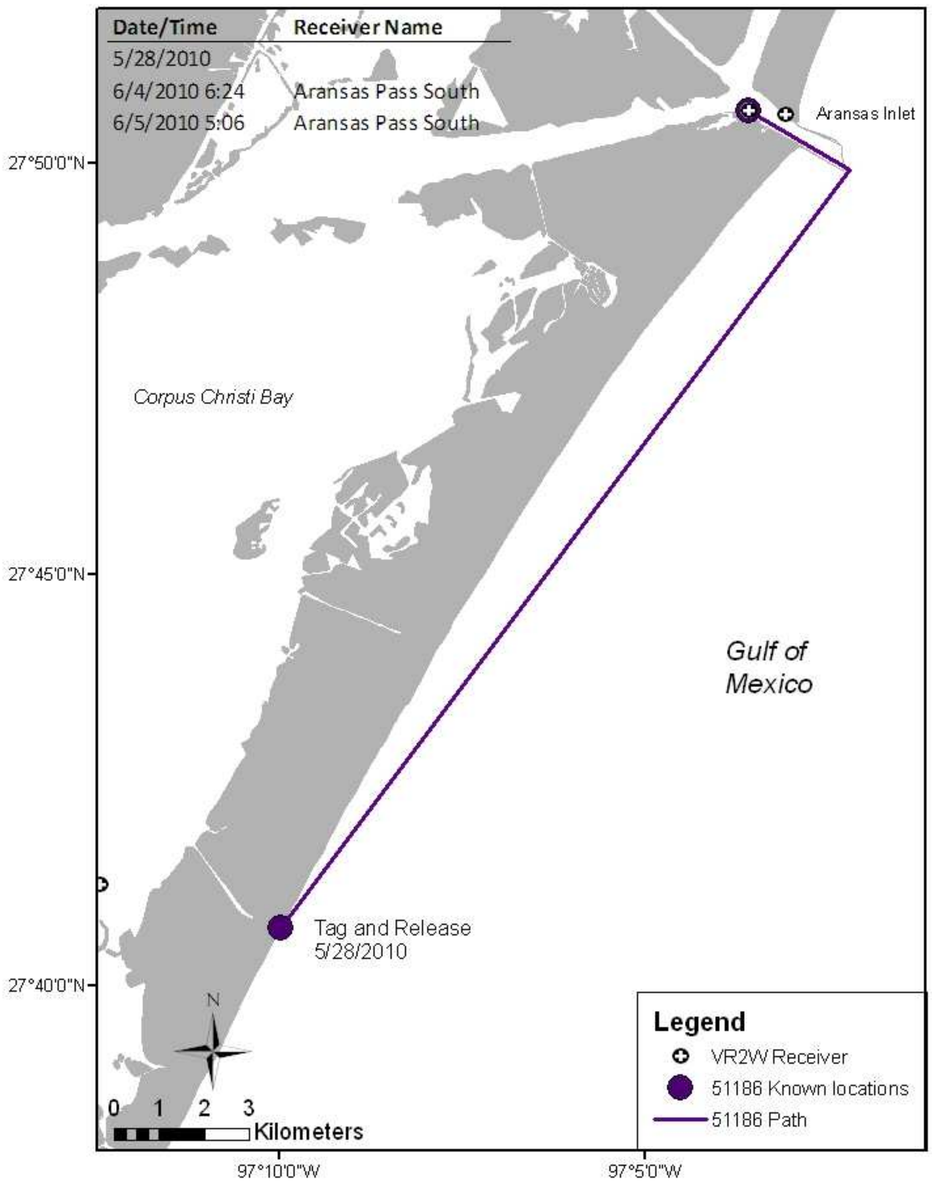
Spotted seatrout #51185

Total length: 423 mm
Tag-and-release date: 5/28/2010
Days at Liberty: 5
Total minimum distance traveled: 23.9 km
Minimum home range: NA



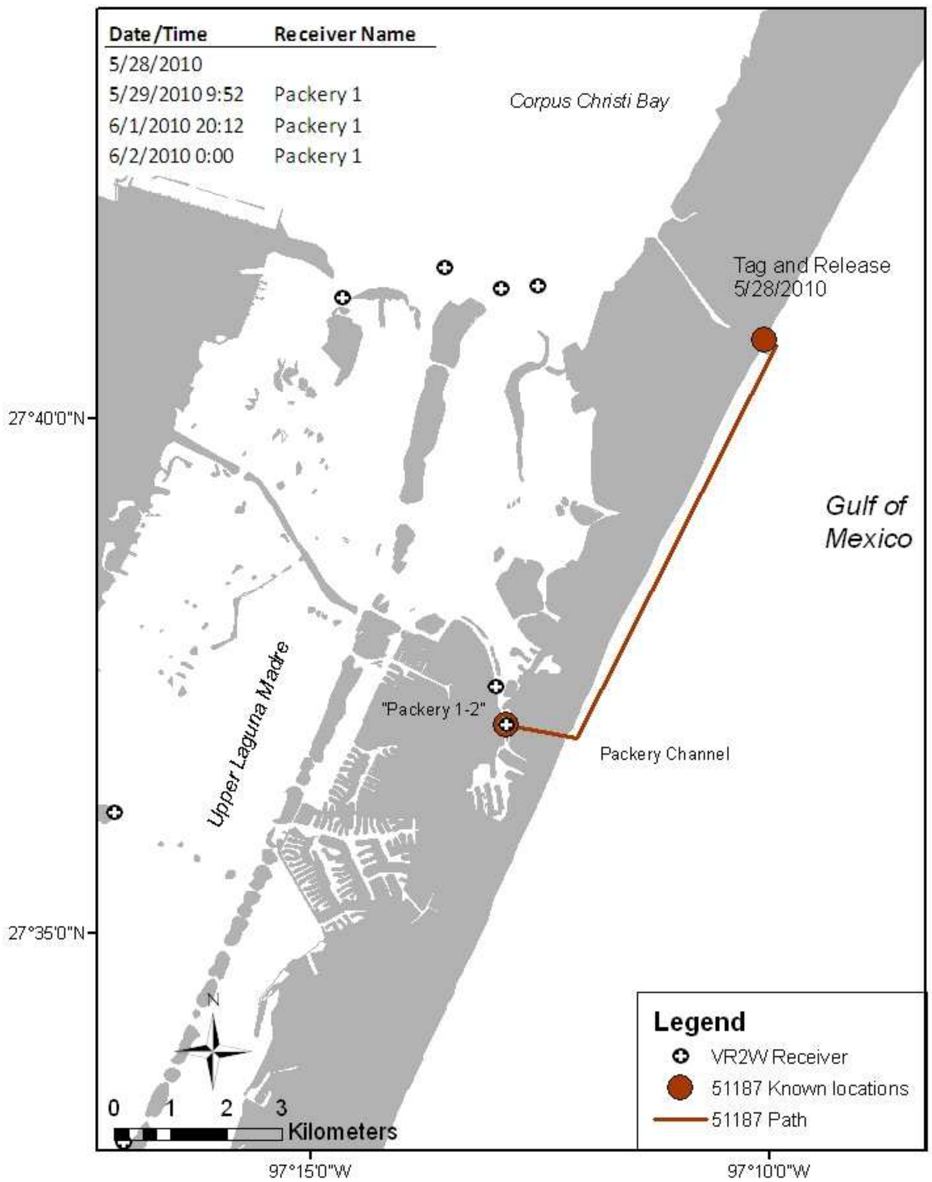
Spotted seatrout #51186

Total length: 417 mm
Tag-and-release date: 5/28/2010
Days at Liberty: 8
Total minimum distance traveled: 23.9 km
Minimum home range: NA



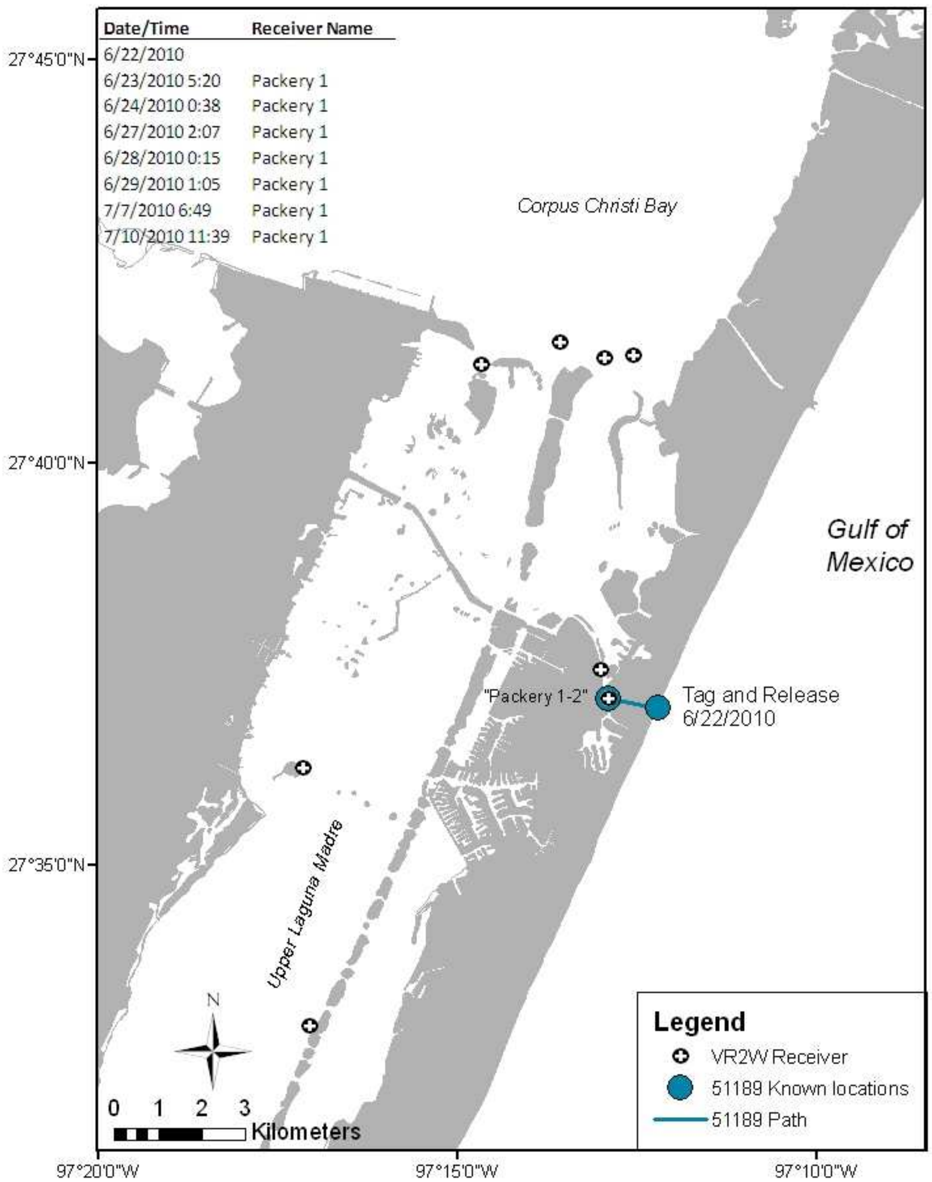
Spotted seatrout #51187

Total length: 401 mm
Tag-and-release date: 5/28/2010
Days at Liberty: 5
Total minimum distance traveled: 9.4 km
Minimum home range: NA



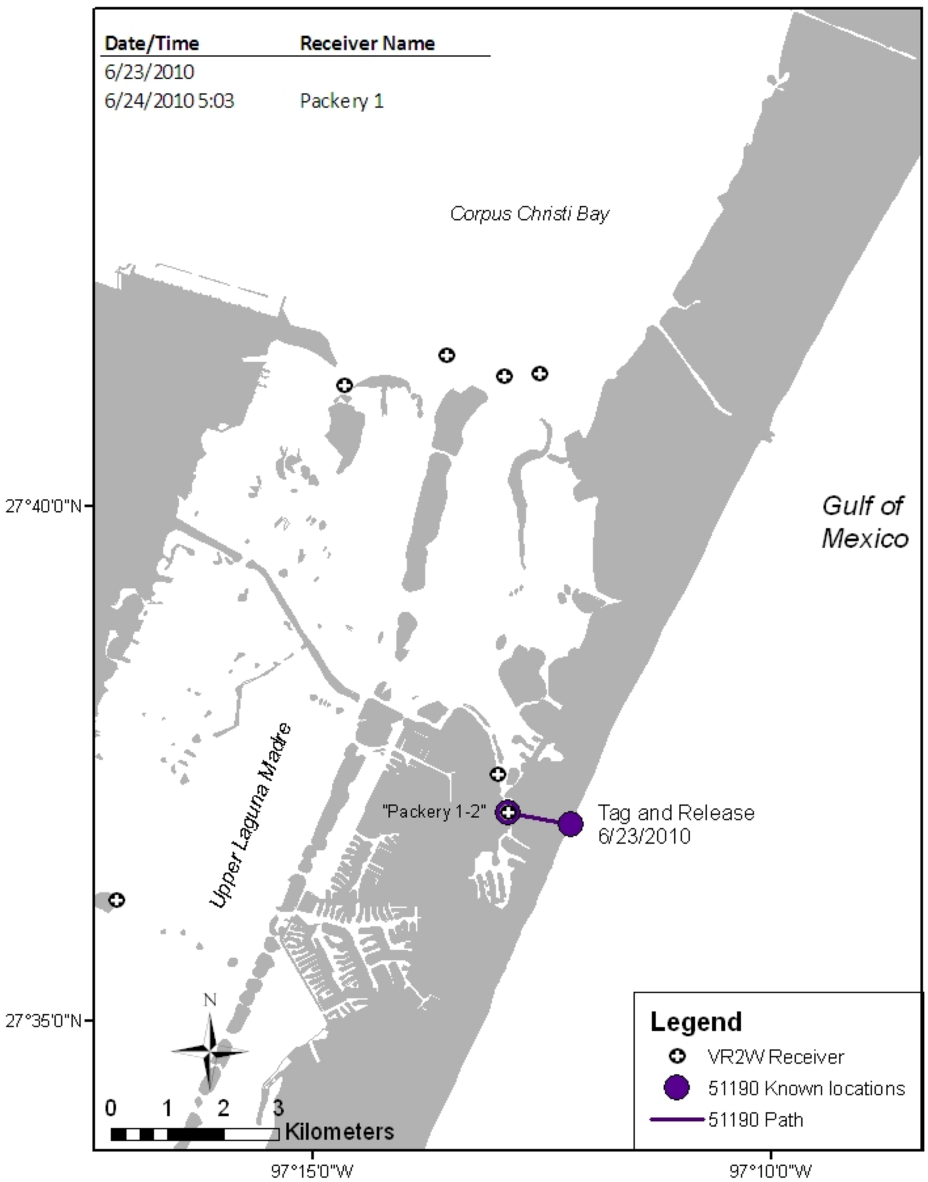
Spotted seatrout #51189

Total length: 417 mm
Tag-and-release date: 6/22/2010
Days at Liberty: 18
Total minimum distance traveled: 1.1 km
Minimum home range: NA



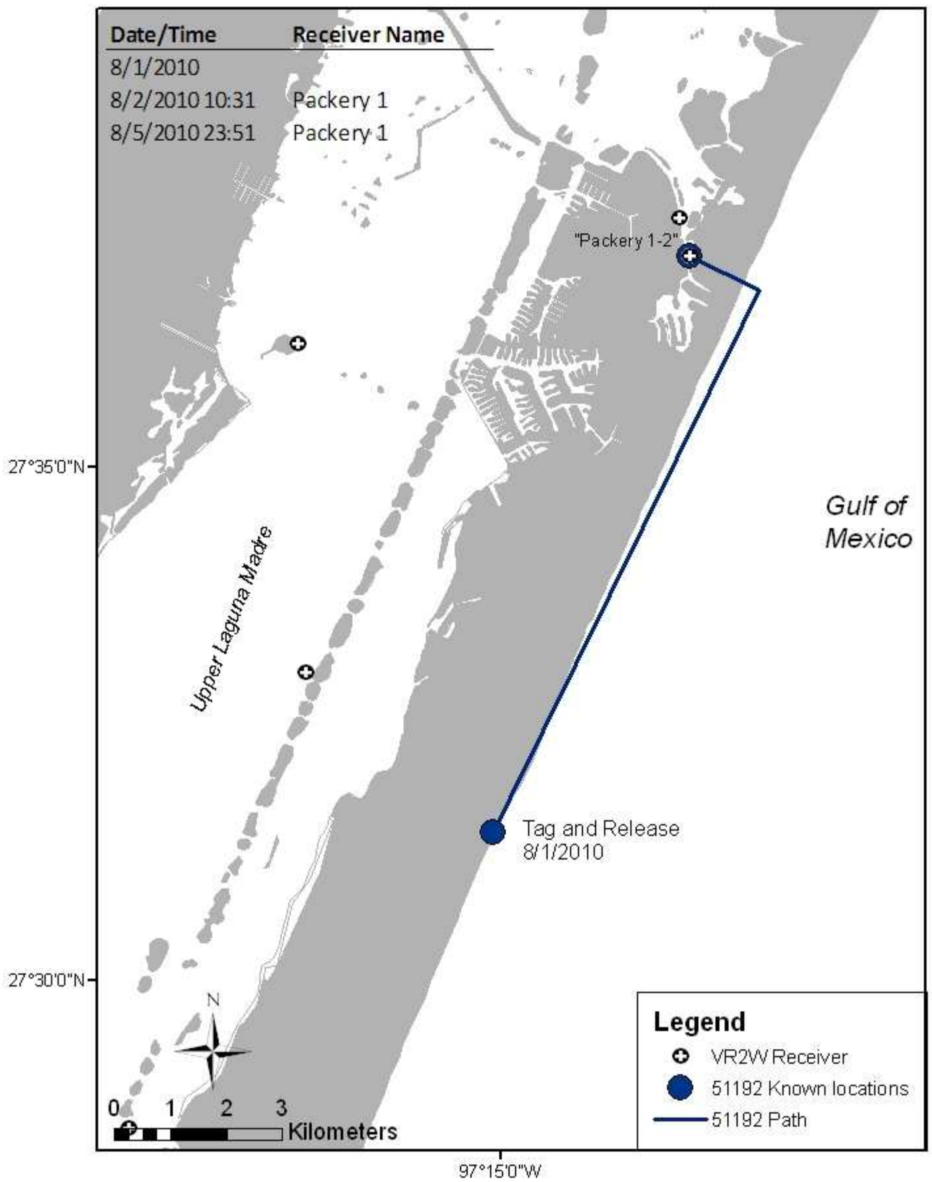
Spotted seatrout #51190

Total length: 486 mm
Tag-and-release date: 6/23/2010
Days at Liberty: 1
Total minimum distance traveled: 1.1 km
Minimum home range: NA



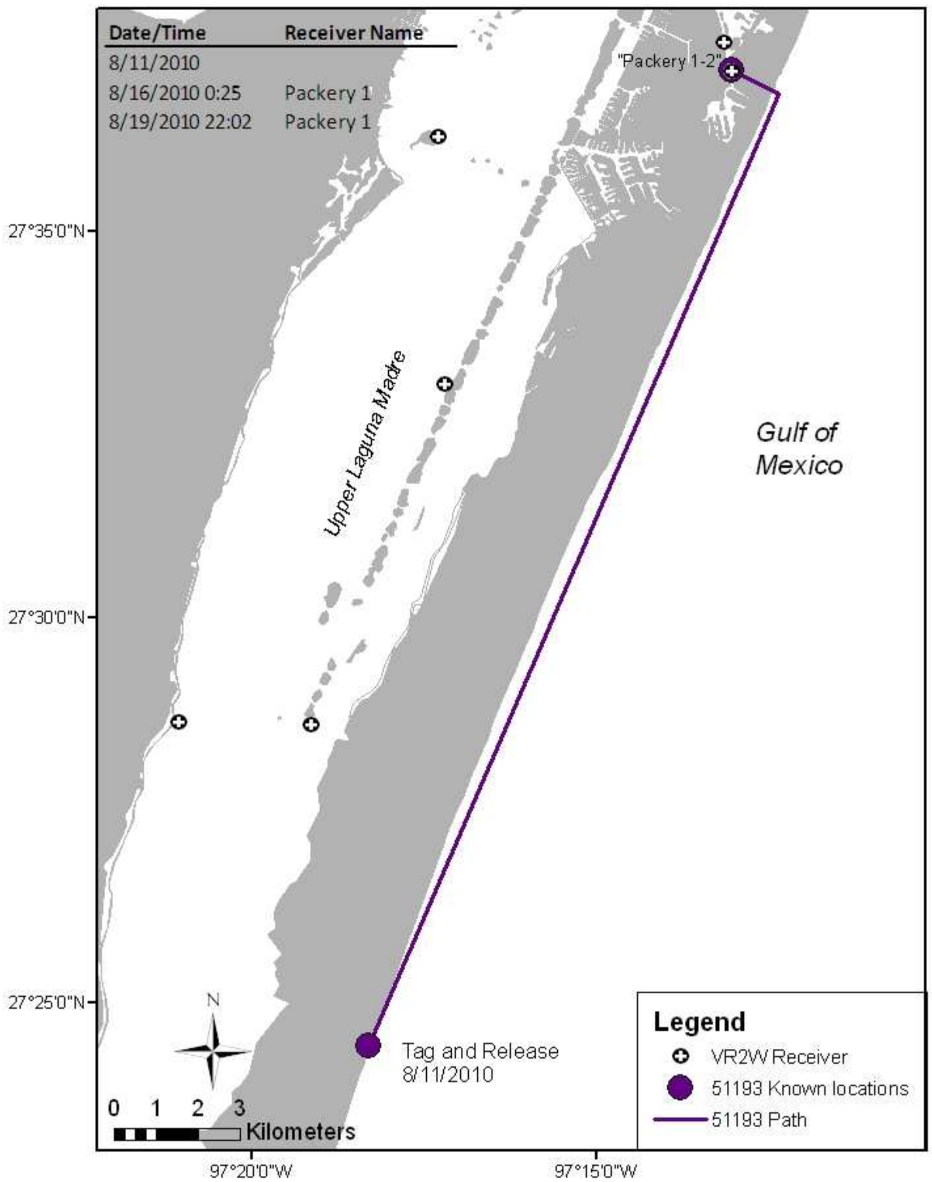
Spotted seatrout #51192

Total length: 416 mm
Tag-and-release date: 8/1/2010
Days at Liberty: 4
Total minimum distance traveled: 12.2 km
Minimum home range: NA



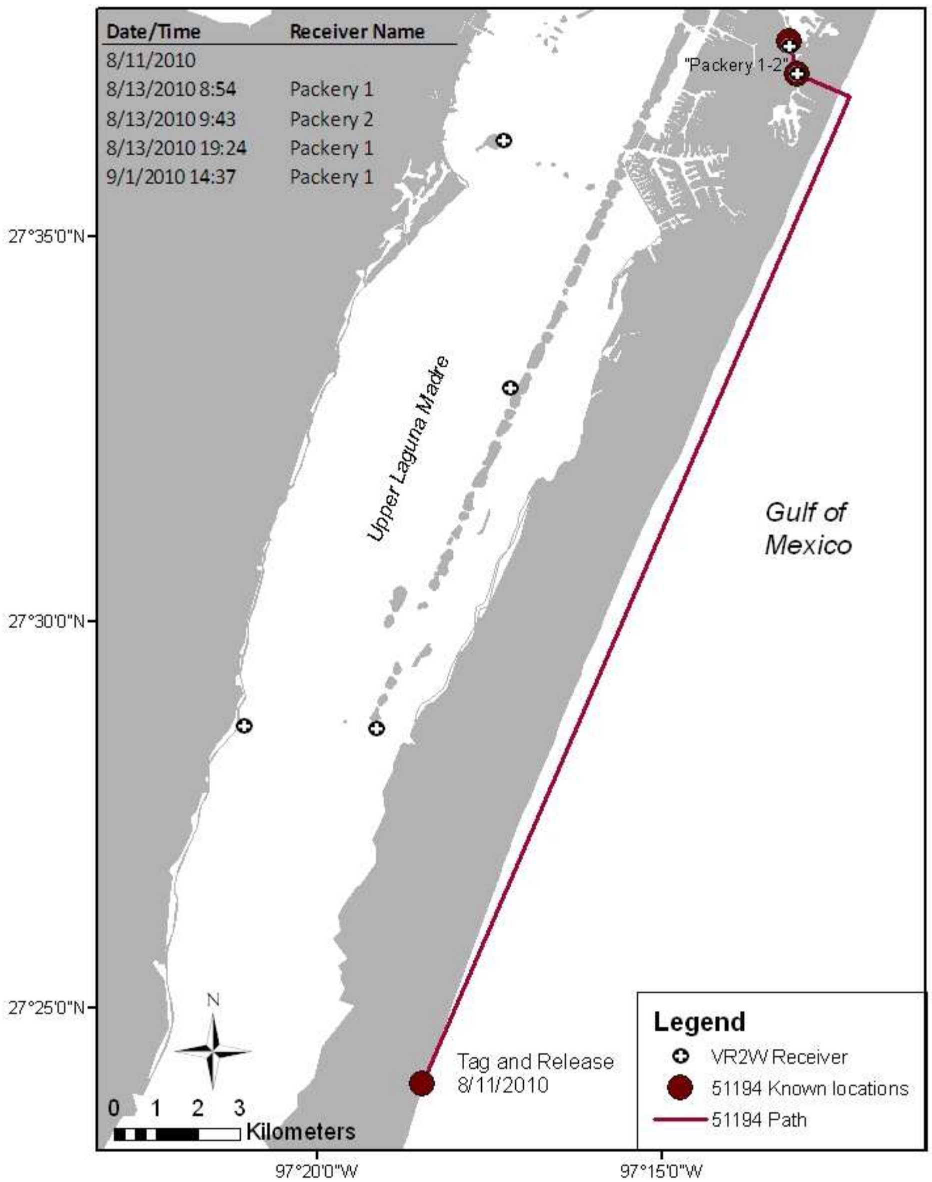
Spotted seatrout #51193

Total length: 427 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 8
Total minimum distance traveled: 26.0 km
Minimum home range: NA



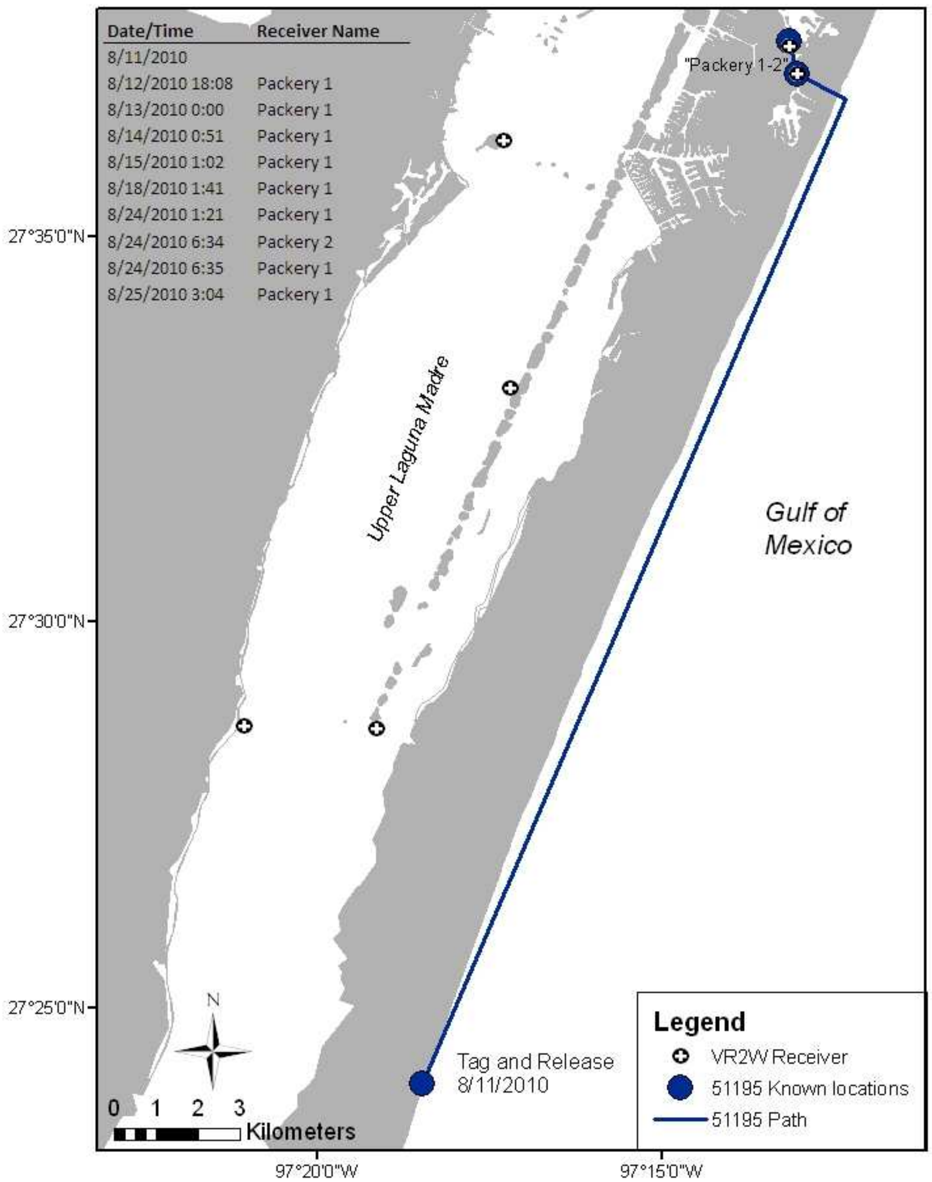
Spotted seatrout #51194

Total length: 424 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 21
Total minimum distance traveled: 28.7 km
Minimum home range: NA



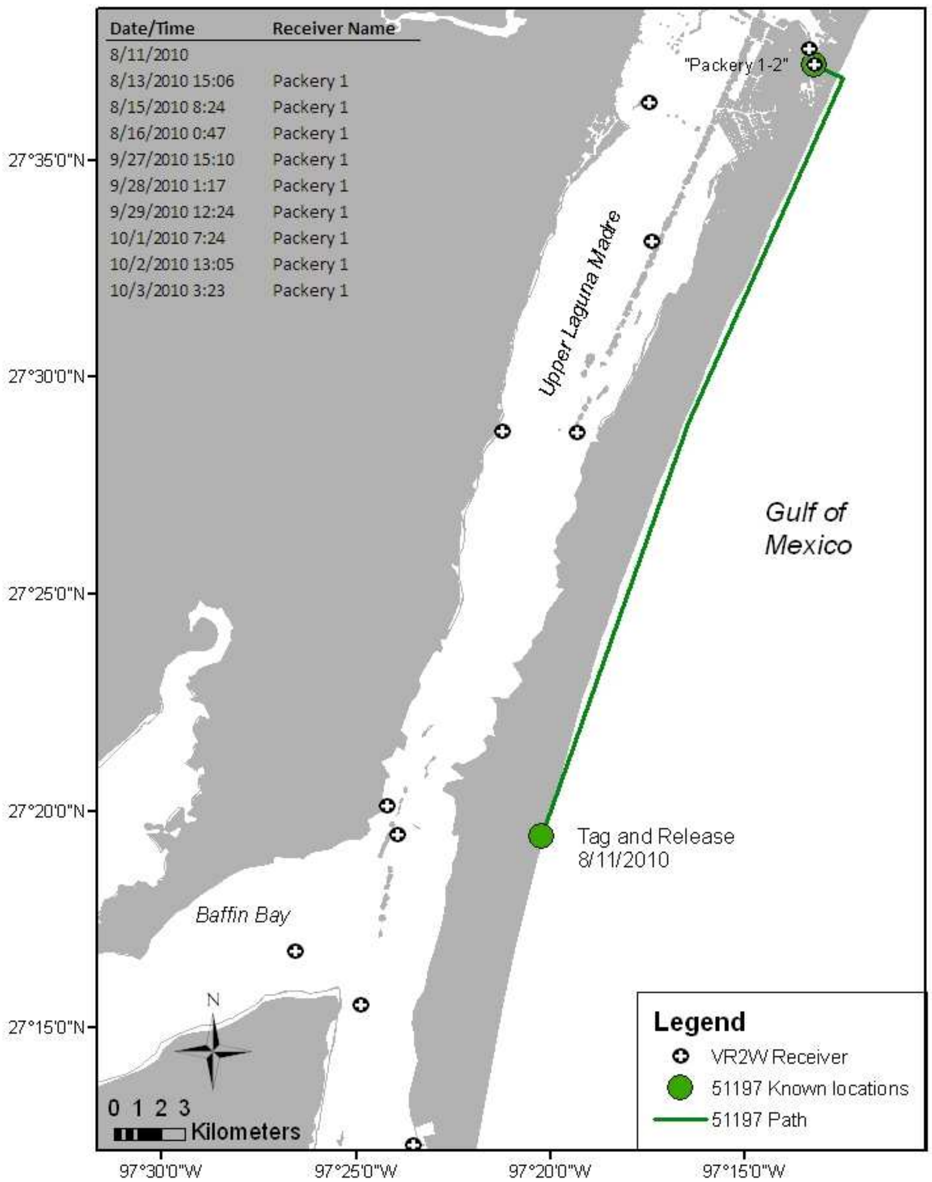
Spotted seatrout #51195

Total length: 413 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 14
Total minimum distance traveled: 30.3 km
Minimum home range: NA



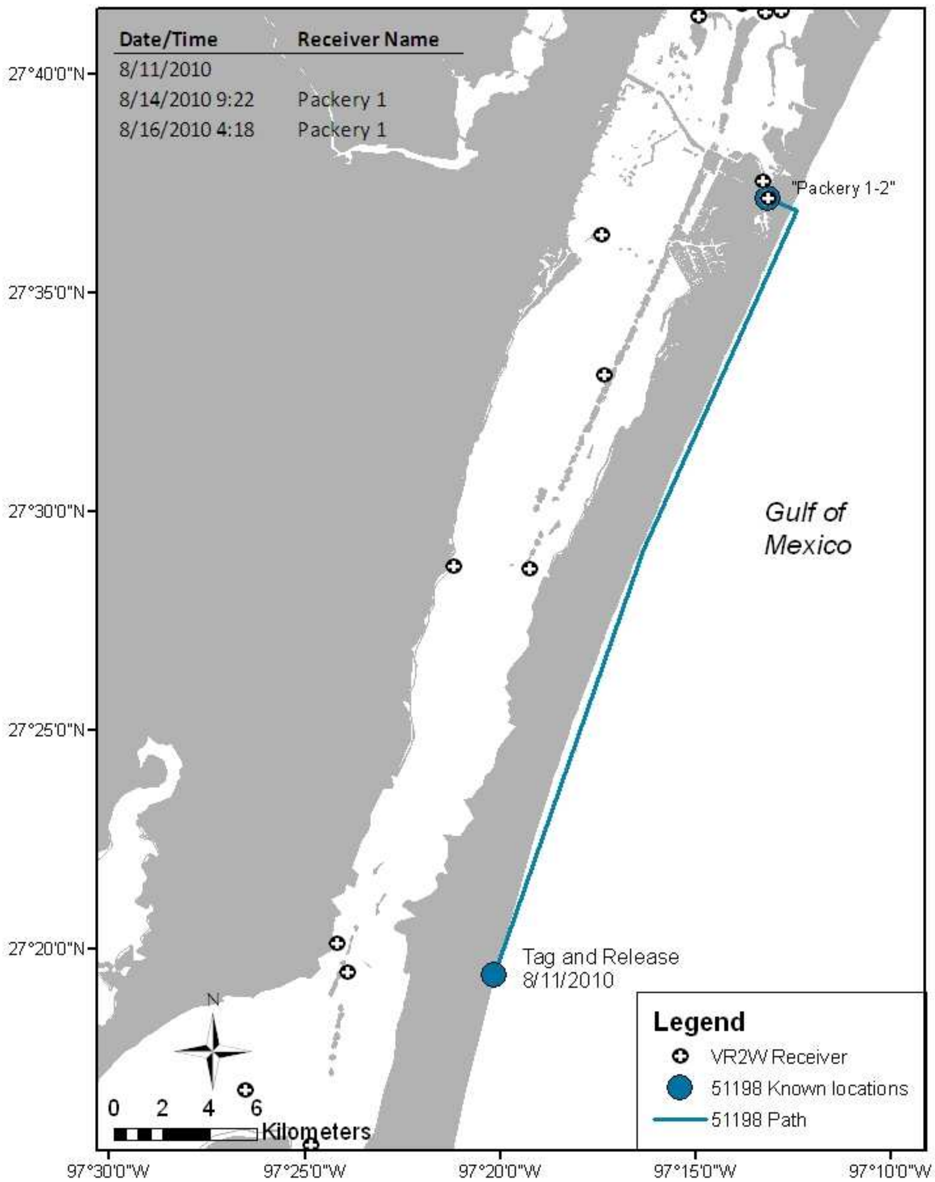
Spotted seatrout #51197

Total length: 541 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 53
Total minimum distance traveled: 36.1 km
Minimum home range: NA



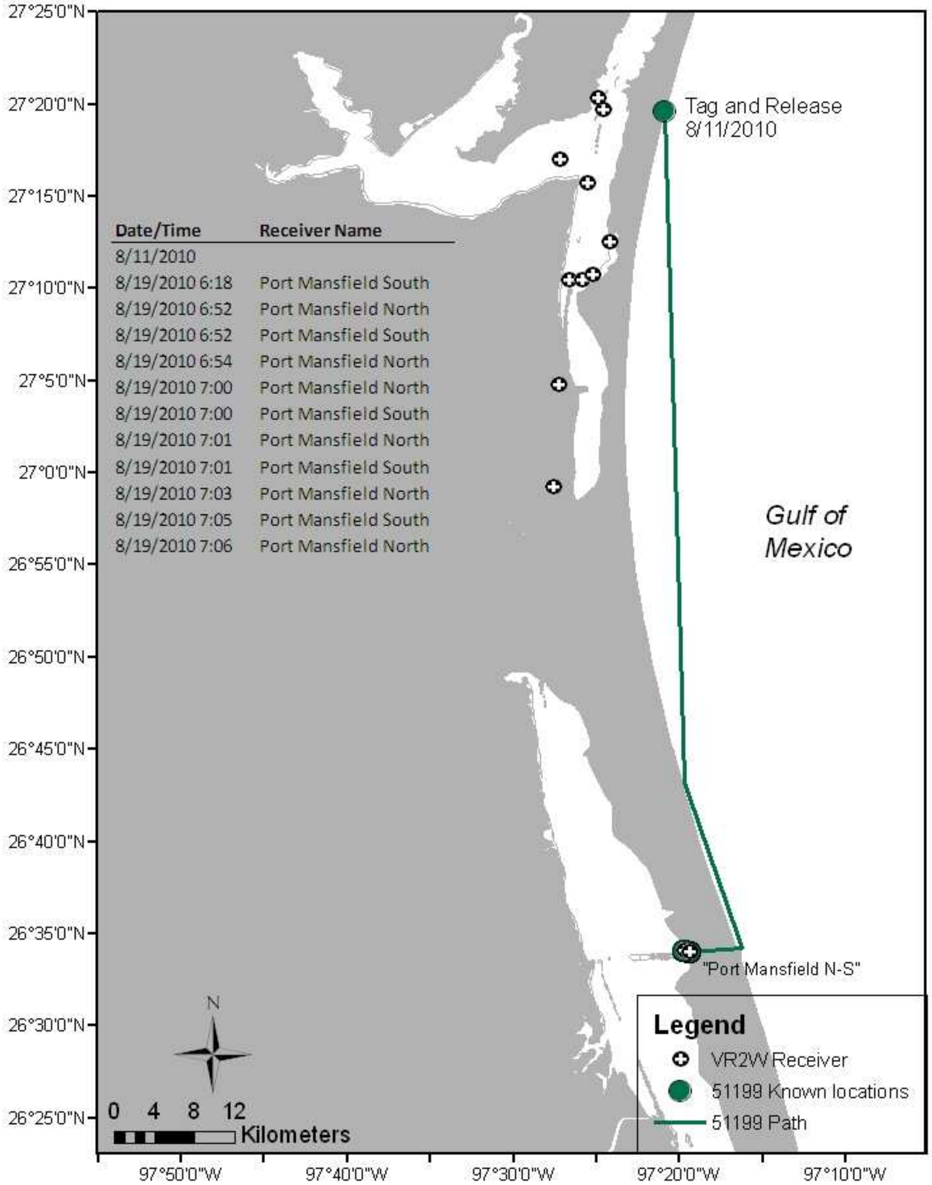
Spotted seatrout #51198

Total length: 461 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 5
Total minimum distance traveled: 36.1 km
Minimum home range: NA



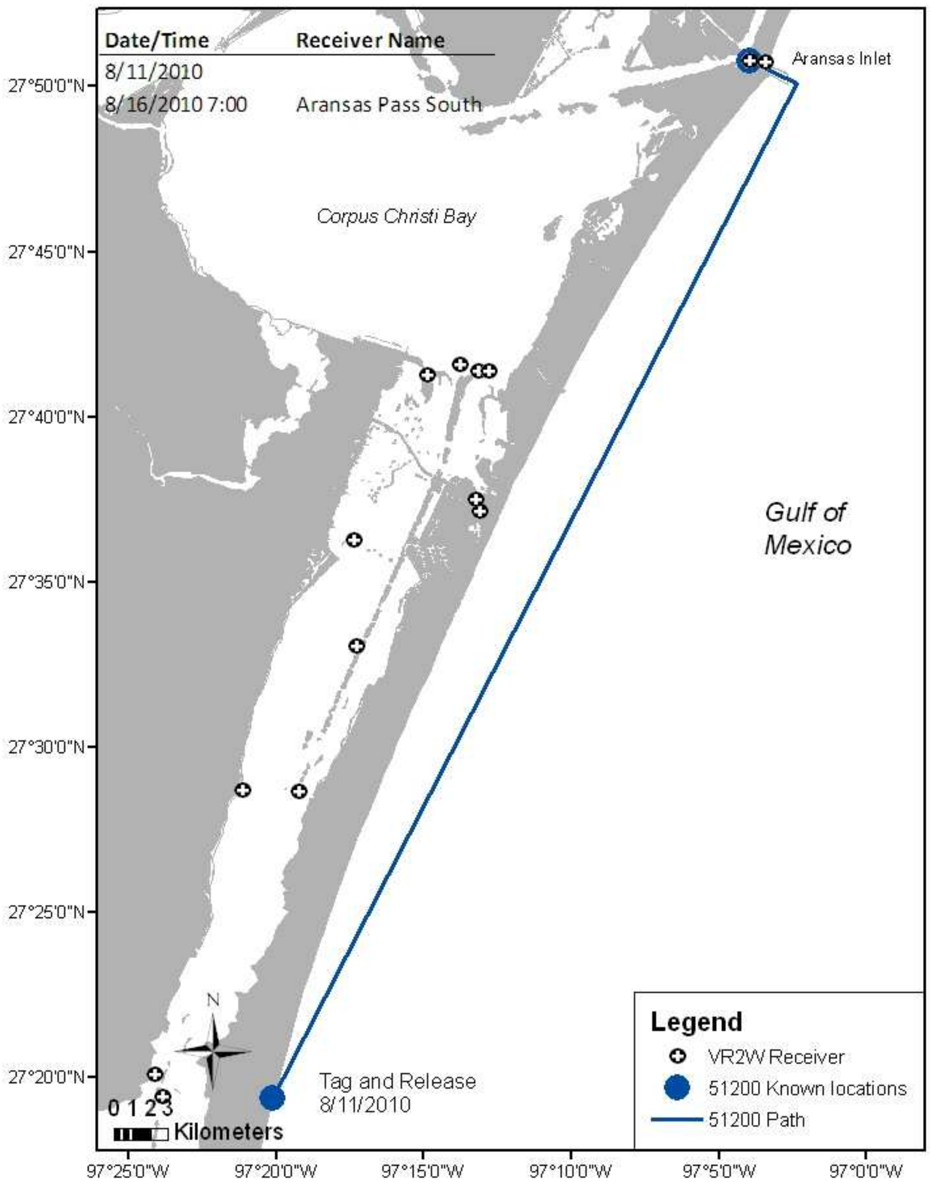
Spotted seatrout #51199

Total length: 408 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 8
Total minimum distance traveled: 96.9 km
Minimum home range: NA



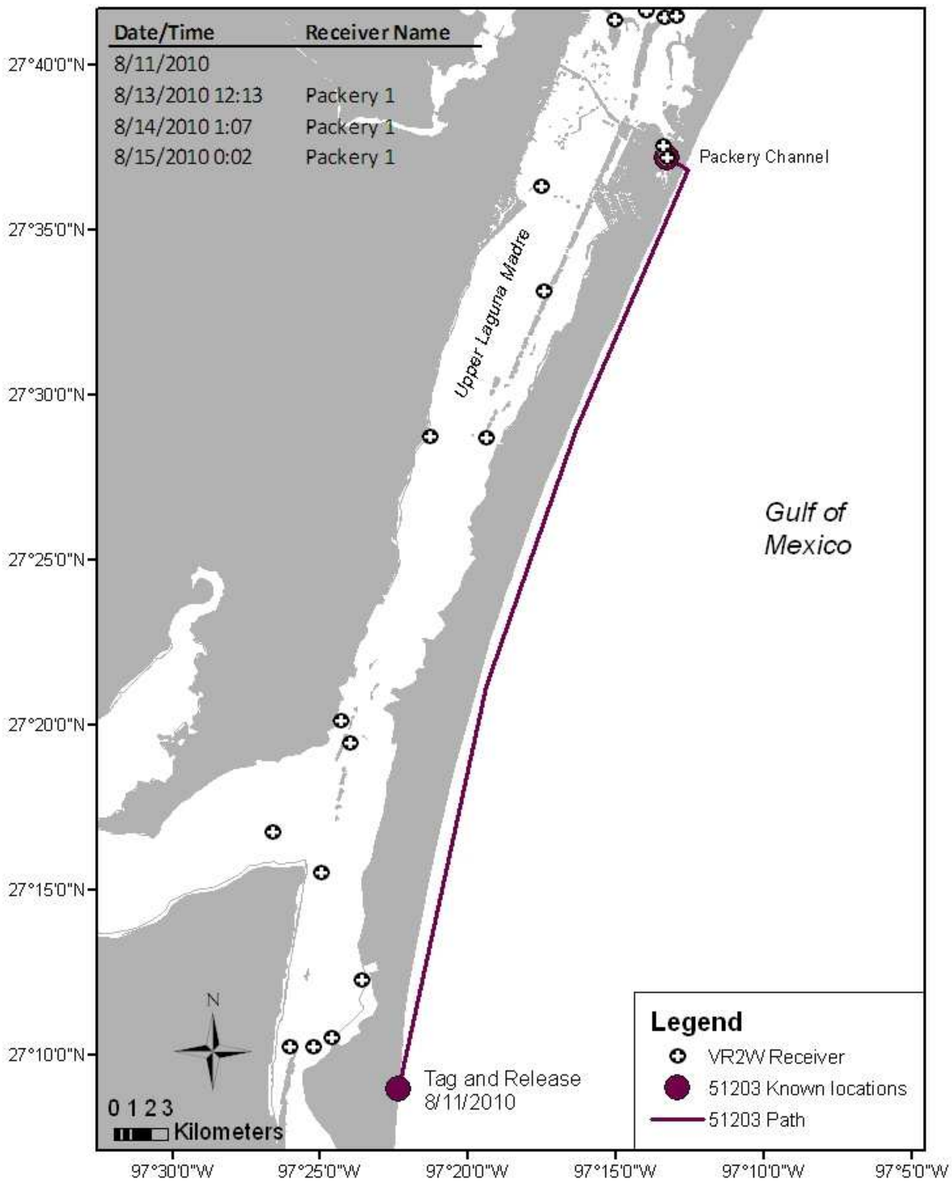
Spotted seatrout #51200

Total length: 423 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 5
Total minimum distance traveled: 64.0 km
Minimum home range: NA



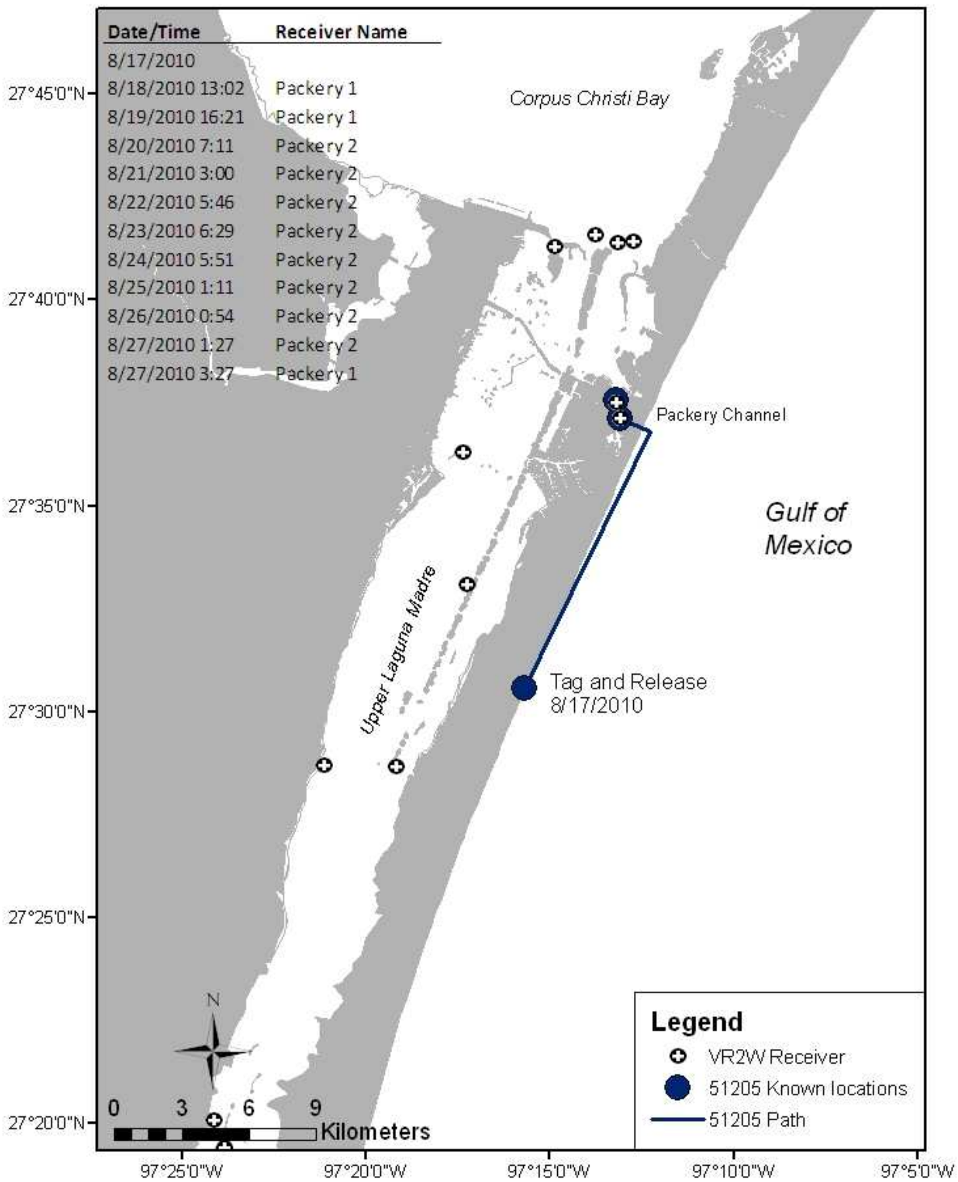
Spotted seatrout #51203

Total length: 499 mm
Tag-and-release date: 8/11/2010
Days at Liberty: 4
Total minimum distance traveled: 55.4 km
Minimum home range: NA



Spotted seatrout #51205

Total length: 435 mm
Tag-and-release date: 8/17/2010
Days at Liberty: 10
Total minimum distance traveled: 15.9 km
Minimum home range: NA



Spotted seatrout #51156b

Total length: 465 mm
Tag-and-release date: 10/20/2010
Days at Liberty: 11
Total minimum distance traveled: 10.9 km
Minimum home range: NA