Virginia Recreational Fishing Development Fund
Final Report

Project Title: Use of pop-up satellite archival tags (PSATs) to determine the fate, movements, and habitat utilization of red drum released from Virginia's recreational fishery

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Award Number: RF 09-06

Funding Total: Direct $93,569; Match $33,802

Award Period: 1 January 2009 to 31 December 2009, no cost extension to 31 March 2010

Executive Summary:

To follow the fate, movements, and habitat utilization of adult red drum, fifteen small pop-up satellite archival tags (PSATs) with release times of 1 month (30 days), 3 months, and 6 months (five tags per treatment), were deployed on large individuals caught in the spring recreational fishery at the mouth of Chesapeake Bay. Fourteen of 15 tags reported, and archived depth data indicated that all fourteen individuals survived throughout their respective tagging periods. The five red drum tagged for one month had limited net displacements of 1.45 – 25.1 nautical miles (nmi) and remained within Chesapeake Bay. Five tags (four three-month tags and one six-month tag) popped up in mid-late August after approximately three months at liberty. One one of these tags popped up in Chesapeake Bay near the mouth of the York River, while the other four surfaced in waters 20 - 30 nmi off the coast of Virginia and North Carolina. The four tags that were attached to red drum for six months popped up in late November within a few miles of the North Carolina coast, one south of Cape Lookout and three off Ocracoke Island, resulting in net displacements of 122 to 158 nautical miles.

For the first month following release, the red drum remained in relatively shallow waters; the majority of time spent at depths of 5 m or less. During this time temperatures were relatively stable, increasing over the 30 days from 18 - 24°C as the Bay waters warmed. For the month of July, temperatures remained relatively stable, and in August, much greater variations were observed as many of the fish moved into deeper waters and made excursions from the surface to depths as great as 50 m. During this time the average depth occupied by the fish also increased.

These changes likely corresponded to movements of fish from the Bay to offshore locations. In early September the fish remained in deeper waters but experienced less temperature fluctuations, although mean temperatures slightly decreased due to seasonal cooling. It is likely that these fish returned to the Bay or the sounds of North Carolina during this period this time. Temperature fluctuations increased again at the end of October, and remained high until the last tags popped off near the end of November.

The results of this study indicate a very high post-release survival of large red drum taken in the Virginia recreational fishery and suggest that the low recovery rates of adult red drum with conventional tags previously reported are likely the result of tag shedding and not mortality. The PSAT data indicate that red drum are capable of undertaking large movements within a season, and many adults appear to leave Chesapeake Bay earlier in the year than previously thought, moving into offshore coastal waters during the month of August. The tagging data also demonstrate a high connectivity between the Virginia and North Carolina red drum recreational fisheries.

INTRODUCTION

The Virginia portion of Chesapeake Bay supports a large recreational fishery for red drum (*Sciaenops ocellatus*) that has an important economic impact for the state (Kirkley and Kerstetter 1998). Many of the red drum captured by recreational gear are released because they either fall short of the regulatory slot limit minimum size (18") or exceed the slot maximum size (26"). Estimated annual catches (including releases) within Virginia waters ranged from 33,592 to 851,034 individuals between 2000 and 2007 (NMFS Marine Fisheries Statistics).

Despite the importance of red drum to marine recreational anglers in Virginia and other states along the U.S. Atlantic and Gulf of Mexico coasts, surprisingly little is known regarding the fate, movements, and habitat utilization of this species. Much of what we know about the fate and movements of red drum has come from studies employing conventional tags In Virginia, from 1995 through 2007, the number of adult red drum tagged has ranged from 37 to 1,091, with the largest numbers of tagged fish occurring over the past six years (Lucy and Gillingham 20008). Surprisingly, tag returns have been very low, with a maximum of 3.3% for fish tagged in 2003. Analysis of tag recapture data indicates the majority of recaptures of adult red drum tagged in Virginia waters occurs in Virginia waters, even after substantial times at liberty. Of the 37 recaptures noted since 1996, 31 (82%) have come from Virginia waters (Lucy and Gillingham 2008). The remaining six tag recoveries occurred in North Carolina, four during the summer and two during the winter. The connectivity of the Virginia and North Carolina fishery is also supported by Virginia recaptures of adult red drum tagged in North Carolina. Of 4,544 adult red drum tagged in North Carolina waters and subsequently recaptured, 13 were reported from Chesapeake Bay (Burdick et al. 2007).

Burdick et al. (2007) noted a decrease in the reporting rate of tagged red drum with increasing body size; juveniles had a tag reporting rate of 18%, subadults had a 13% return rate, and adults had a reporting rate of only 2%. The reporting rate of 2% for adult red drum tagged in North Carolina is similar to the values reported for adults tagged in Virginia (ranging from 0 – 3.3% between 1995 and 2007; Lucy and Gillingham 2008). The low rate of return for adults could reflect a high post-release mortality, or a high rate of tag shedding. Tag shedding may be influenced by the type of tag anchor. For example, increasing use of stainless steel dart anchors (as opposed to plastic or T-bar anchors) over the past few years in the Virginia Tagging Program correlates with increasing tag recapture rates (J. Lucy, Virginia Institute of Marine Science, personal communication).

There is a clear need to differentiate between tag shedding and post-release mortality of red drum released from the recreational fishery. Pop-up satellite archival tags present an excellent means to do so. Developments in satellite archival tags have greatly improved scientific understanding of the behavior, movements and post-release survival of marine vertebrates – animals from which it is not practical to physically recover tags to obtain data (Arnold and Dewar, 2001; Graves et. al., 2002; Holland, 2003). PSATs take physical and positional measurements while attached to study animals, independently detach at predetermined times, float to the surface, and transmit data to orbiting satellites of the Argos system (Graves et al., 2002). Data are then transmitted from satellites to a ground station and to the individual researcher. Using high resolution PSATs, it is easy to determine the fate of tagged animals and the data reveal exciting insights into short term depth and temperature utilization as well as horizontal movements.

Until recently, most PSAT deployments have been on large pelagic marine vertebrates such as billfishes, tunas, sharks, and sea turtles, owing to the size and mass of the tags (~ 65g). However, miniaturization of tag subcomponents has led to the development of a new generation of PSATs that are 33% smaller, extending the potential use of these tags to smaller species. In a recent study Graves et al. (2009) deployed ten of the smaller PSATs (Microwave Telemetry X-Tags), to large striped bass caught on live eels in the winter recreational fishery near the mouth of Chesapeake Bay, demonstrating that the technology was well-suited for studying the fate and habitat utilization of large coastal species. Eight of the ten tags deployed transmitted usable data after releasing from the striped bass after 30 days, with data recoveries of 80 – 90% of the archived data for tags that remained at sea for the 30 day transmission period. Three tags washed ashore during the 30 day transmission period, and as expected, data transmission rates were reduced for two of these tags, but two were physically recovered allowing access to 100% of the archived data. Analysis of the depth date indicated that all eight fish lived, including two that were hooked deeply with J hooks. Net movements (from point of release to the first transmission location of the popped up tag) were under 100 miles for all fish, and three of the fish tagged outside of Chesapeake Bay entered the Bay, presumably on their annual spawning migration. The success of the new, smaller PSATs with striped bass suggests that they are well suited to follow the fate of adult red drum released from the Virginia recreational fishery. In addition, the tags can provide valuable information on movements and habitat utilization of this important recreational species.

To improve our understanding of the fate, movements, and habitat utilization of adult red drum released from the Virginia recreational fishery, we deployed 15 small PSATs, programmed to pop-up after one, three or six months.

MATERIALS AND METHODS

Adult red drum were caught between May 21st and 25th 2009 near Fishermen's Island at the tip of Virginia's eastern shore. As is typical for the fishery, we used live blue crab (*Callinectes sapidus*) baits rigged with standard "J" hooks (Gamakatsu Octopus #02418, size 8/0, Gamakatsu USA, Tacoma, WA) in conjunction with 30 lb class sportfishing tackle with three to four foot leaders of 80lb test line. Fish were fought in a manner consistent with typical recreational fishing practice, and were netted before being brought into the boat. Once in the boat and prior to tagging, fish were measured, the hook location was noted and, when practical, the hook was removed. We tagged the first 15 adult red drum available to us.

The Microwave Telemetry, Inc. (Columbia, MD) X-Tag was used in this study (Figure 1). The tag is slightly buoyant, and weighs 40 grams in air. The body of the tag contains a lithium composite battery, a microprocessor, a pressure sensor, a temperature gauge, and a transmitter, all housed within a black resin-filled carbon fiber tube that can withstand pressure equivalent to a depth of 2500 m. Flotation is provided by a spherical resin bulb embedded with buoyant glass beads. This tag model is programmed to record and archive a continuous series of temperature, light, and pressure (depth) measurements at two minute intervals, and has the capacity to transmit 15,000 data messages to the Argo satellites. Tags were programmed by the manufacturer to disengage after 30 days (5 tags), three months (5 tags) and six months (5 tags).

PSATs were attached to red drum by an assembly composed of 16 cm of 400-pound test Momoi® brand (Momoi Fishing Co., Ako City, Japan) monofilament fishing line attached to a large hydroscopic, surgical grade nylon intramuscular tag anchor according to the method of Graves et al. (2002). Anchors were implanted with 5-cm stainless steel applicators attached to a 0.3-m tagging pole and were inserted approximately 5 cm deep into an area about 6 cm posterior to the origin of the dorsal fin and 5 cm ventral to the base of the dorsal fin (Figure 1). In this region, the nylon anchor has an opportunity to pass through and potentially interlock with pterygiophores supporting the dorsal fin well above the coelomic cavity containing visceral organs (Graves et al., 2002). A conventional tag with a stainless steel anchor was also implanted posterior to the PSAT on the opposite side of the fish. The entire process (measurement, hook removal, and tagging) required less than three minutes after which time the fish was returned to the water and released.

At a preprogrammed time (or four days after remaining at a constant depth), the PSATs released from the fish, floated to the surface, and began transmission to satellites of the ARGOS System. Net displacement was calculated as a minimum straight line distance traveled between coordinates of initial tagging and coordinates of the first reliable satellite transmission using Argos location codes 1, 2, or 3 (Horodysky et al., 2007).

RESULTS

Fifteen PSATs were deployed on large (43 – 50.5 inch) red drum caught between 21 and 25 May 2009. Fight times ranged between 2 and 18 min, with a mean of 10.2 min (Table 4). Most fish were hooked in the corner of the jaw. Only two fish were hooked deeply, and we were able to extract the hook from one of these fish while the other was released with the hook still lodged in the esophagus. Two fish exhibited minor bleeding, one from the location of the hook, the other from the area where the tag dart was inserted.

We received data from 14 of 15 tags. No information was received from tag attached to fish #7. Two tags released prematurely. The tag on fish #6, a three month tag, was scheduled to release on August 24th but released on August 16th, eight days early. The tag floated at the surface for four days before the constant depth program began transmission. The tag on fish # 2, a six month tag, popped up approximately three and a half months prematurely. This tag prematurely released on August 10th and floated at the surface before it began transmission of archived data on August 21st. Seven tags were physically recovered, allowing retrieval of 100% of their archived data. For the remaining seven tags, data recovery rates varied from 4%, the tag on fish #1 for which we only received transmissions for less than one day, to 80% (Table 1). Excluding the tags that were physically recovered and the tag from fish #2, the mean data recovery for transmitting tags was 66.3%.

Survival and Movement

One month (30 day) tags. The five PSATs programmed for release after 1 month (30 days) all popped up on 24 June and began transmitting data to satellites of the Argos system. Net displacements for the tags ranged from 1.45 – 25.1 nautical miles (Figure 2). Tags 12, 14 & 15 began transmitting in the vicinity of Fishermen's Island, fish 13 had moved across the Bay mouth towards Cape Henry when its tag released, and the fish 11, which had the greatest 30 day displacement, had moved northward along the bayside of the eastern shore about 25 nmi. These five tags were capable of transmitting data for about 30 days after release. However, reception of transmissions can decrease when the tags are in a horizontal position (beached), and will cease if the is antenna becomes fouled with algae. Four of the tags beached within a week or so of surfacing and transmission quality decreased, or in the case of one tag, ceased. The tag from fish 13, which popped up off Cape Henry, was transported southward by currents for a few weeks and recovered by a beachcomber off the Outer Banks of North Carolina. With help from the tag manufacturer and the use of a radio receiver tuned to the tag's transmission frequencies, we were able to locate tags 11, 12, and 15 that had washed up along the eastern shore of Chesapeake Bay and continued to transmit. We ceased to receive transmissions from tag 14 which appeared to wash ashore near Sunset Beach on the eastern shore of Chesapeake Bay, two and a half days after it popped up. Data recovery from this tag via ARGOS satellites was only 22%; however, the tag was subsequently found on the Outer Banks of North Carolina by a beachcomber and was returned to us, allowing full data recovery. Consequently, all five tags deployed for 30 days were recovered, allowing 100% data recovery. Analyses of the depth data indicate that all five red drum survived for the 30 day tagging period.

Three month tags. Two of the five tags programmed to release after three months popped up as programmed on August 23rd and 24th (Figure 3). The tag from fish 8 popped up in Chesapeake Bay in the vicinity of York Spit and was recovered after it beached near the VEPCO power station on the York River. The tag from fish 6 popped up about 30 nautical miles off the coast of North Carolina, resulting in a net displacement of 103 nautical miles. The tag from fish 10 released seven days prematurely on August 16th and floated at the surface for four days before the constant depth release mechanism activated transmission. At the time of the first transmission the tag was also off the coast of North Carolina with a net displacement of 63 nautical miles. The tag attached to fish 9 first reported on August 30th. At the time this tag first reported, it was well offshore, about 335 nautical miles from the point of release. Review of the archived data received from this tag indicates that the PSAT released on August 24th as programmed. However, after releasing the tag floated at the surface for seven days before the first transmission was received. During the seven days the tag was at the surface prior to transmission it apparently became entrained in the Gulf Stream and was transported far to the northeast and offshore.

We received no transmissions from the tag from fish 7 that was programmed to release after three months. However, the tag attached to fish 2 that was programmed to release after six months began transmitting on August 21st, approximately three months early. At this time the tag began transmission, it was about 55 nautical miles offshore from where the fish was released (Figure 3). Review of data from this fish indicated that this tag had released prematurely and floated at the surface for four days before the constant depth feature activated transmission of archived data; consequently, the site of first transmission is not reflective of the fish's location when the tag first surfaced. The tag from this fish was recovered after it beached on Bodie Island on the Outer Banks of North Carolina. The tags from red drum 6, 9 and 10 each transmitted data for about thirty days. In sum, two of the five tags that reported after 3 months were recovered, allowing retrieval of 100% of the data. Analyses of the depth data indicated that all five red drum survived for three months following release.

Six month tags. The four remaining tags programmed to release after six months popped up on November 22nd or November 23rd in the nearshore coastal waters of North Carolina (Figure 4). One tag started reporting south of Cape Lookout, and three off Ocracoke Island, yielding net displacements of 122 to 158 nautical miles (Figure 4). The tag that surfaced south of Cape Lookout only reported for one day. The transmitted data indicated that this tag had ample battery strength to continue reporting for several weeks, so it is possible that the floating tag may have been predated upon by a large animal or physically damaged by a motorized vessel. Only 4% of the archived data were received from this tag during its brief transmission period, but there was sufficient information to ascertain that the fish had survived for six months following release. Data recovery from the other six month tags ranged from 42% to 87%, and depth time series indicate that these three fish survived as well. None of the six month tags were recovered.

Habitat Utilization

Late May – late June. For the first two weeks following release adult red drum exhibited two slightly different patterns of habitat utilization. About half of the tagged fish remained near the surface, without diving into waters greater than five meters in depth (Figure 5), while the others moved into slightly deeper waters. During the first two weeks the surface-associated individuals experienced significant fluctuations in temperature, suggesting that the animals were in shallow waters that responded to tidal induced temperature changes and/or daily heating and cooling of shallow waters. Sometime during the second week following release, most of these shallow-associated red drum demonstrated a shift in depth utilization patterns, moving into slightly deeper waters, characteristic of the habitat utilized by the other group of red drum fish for the entire 30 days. Most fish maintained an average depth of approximately five meters, but made dives to depths of 20 meters or more, as well as some movements to the surface. Despite these vertical excursions, the temperature variations for most fish were reduced relative to those encountered by the shallows-associated fish during the earlier part of the month. Over the course of the month as Bay temperatures warmed, the average daily temperature for most red drum increased from approximately 16°C to 24°C.*Late June – late August*. The nine fish that carried tags through the second and third months of this study exhibited fairly similar depth and temperature profiles through the middle of July, spending most of their time at depths of approximately 5 meters but making excursions to the surface or to depths of 15 meters. During this time temperature fluctuations were minor, and fish experienced a mean temperature of about 25°C. Beginning around the middle of July, the behavior of all red drum changed markedly. This included an increase in the magnitude of daily temperature variations, and a gradual increase in average depth as well as the depth of the deepest dives for most individuals (Figure 6). This behavior was ongoing when the tags for four fished popped up in waters 20 – 30 miles off the Virginia and North Carolina coast in mid-late August. A slightly different behavior was noted for the one red drum (fish #8) whose tag popped up after 3 months in the vicinity of York Spit, at the mouth of the York River, Chesapeake Bay. This fish moved into deeper waters in mid-July, but did not exhibit the large daily temperature fluctuations characteristic of the fish whose tags released offshore. On 8 August, this fish moved up in the water column or into shallow waters, decreasing the average depth from approximately 15 meters to 5 meters, a behavior that it maintained for approximately two weeks at which time the tag released. From our data it is not possible to determine whether the deeper habitat utilization exhibited by this fish occurred outside of Chesapeake Bay, or whether the red drum moved into deeper waters within the Bay.

Late August – late November. The four red drum that maintained tags for six months exhibited similar patterns of habitat utilization. The pattern of deep dives and considerable temperature fluctuations observed at the end of the three months continued through the month of August (Figure 7). In early September the temperature fluctuations of all fish subsided dramatically although the pressure data indicate that these red drum were continuing to make vertical excursions. The majority of time was spent at depths of 10 – 20 m, although dives to 25 or 30 m were common, as well as ascents into the upper 5 m. During this time, the daily variation in temperature was very slight, although there was a gradual decrease in temperature from 22°C to 18°C. Beginning at the end of October or early November, all four fish exhibited a significant increase in daily temperature variation, and for one fish, the temperature coincided with a movement into deeper waters.

DISCUSSION

Tag performance. The results of this study indicate that the new generation of smaller PSATs is well suited for investigation of red drum post-release survival, movements, and habitat utilization. Overall, 14 of 15 tags (93%) transmitted data, a value slightly higher than that reported for striped bass in which eight of ten (80%) transmitted data. Data recovery rates from tags varied greatly. For those tags that remained at sea for the entire 30 day transmission period, reporting rates were generally 70 – 80%. The amount of data received was reduced for tags that beached during the transmission period, with greater recovery rates for tags that remained in the water for longer periods. During the early phase of the transmission period, data recovery rates are approximately 8% per day (Graves et al. 2009). The loss in data transmission recovery for beached tags was offset by the opportunity to physically recover the tags. In this study, all seven tags that came ashore were eventually recovered, allowing retrieval of 100% of the archived data. The use of a directional radio antenna and receiver greatly improved our ability to recover beached tags.

We received transmissions for one of the six month tags for less than a single day and then we failed to receive further transmissions. The transmitted data indicated that this tag had a strong battery and should have been able to transmit for several weeks. We can only surmise that this tag may have been predated upon by a large marine organism (shark), damaged by a motorized vessel, or trapped under floating debris. While only 4% of the archived data were recovered from this tag, that included more than 600 data points over the course of the six month tag deployment, which were more that sufficient evidence to infer survival.

Two tags released prematurely, one on August 16th, about a week before scheduled pop-up and the other on August 10th, about three and a half months before it was scheduled to pop-up. Both prematurely released tags popped up within a week of each other in August, coinciding with the apparent movement of red drum from the Bay into offshore waters, movements that may be associated with spawning (see below). It is possible that the premature releases resulted from fish-tag interactions. Such interactions could also result in the damage to a tag, resulting in a non-reporting PSAT.

Post-release mortality. Review of the depth profiles clearly indicate that all fourteen red drum for which we received data survived. Previous conventional tagging studies of adult red drum have reported very low recovery rates, typically on the order of 2% (Burdick et al. 2007; Lucy and Gillingham 2008). Such low rates of recovery, especially in light of higher recovery rates for smaller red drum, are consistent with high post-release mortality for adult red drum. However, the results of this study indicate that post-release mortality for adult red drum is very low. Consequently, the low recapture/reporting rates of conventionally tagged large red drum may be the result of high rates of tag shedding, and/or anglers may not see and report many tags on large red drum as the animals cannot be retained.

One tag used in this study failed to report, and it is not possible to determine whether the failure resulted from mechanical damage to the tag (tag predation), a mechanical or software problem with the device, or scavenging or predation of the fish (and tag) by a larger animal (shark). Because the tag was programmed to release after 96 hours at constant depth, one would have expected transmissions from a fish that died and remained on the bottom. However, scavenging or predation of a fish and PSAT has been reported for pelagic fishes (Kerstetter et al. 2004) and cannot be excluded as a reason for non-reporting.

Habitat utilization and movements. The pop-up locations of the tags demonstrated little movement over the first month following release. During that period, red drum spent most of their time at depths around five meters and experienced moderate levels of temperature variation on a daily basis. The pop-up locations of those tags attached to red drum for three months indicated that most of the fish had moved out of Chesapeake Bay. In late July, an increase in temperature variation was noted in all of the red drum except for the one individual that remained in the Bay. Coincident with the increase in daily temperature variation was a movement of fish into deeper waters, with some dives approaching 50 m. These data suggest that red drum left Chesapeake Bay for deeper coastal waters. The increased diving behavior and daily temperature variations were ongoing as the three month tags popped up. Similar behaviors were noted at the same time for the four fish that carried tags for six months. These behaviors persisted until early September at which time daily temperature variations became greatly reduced although the red drum continued to exhibit large vertical excursions. A general decrease in temperature was noted in these fish through late October, when temperature variations increased until the tags popped off in late November in coastal waters of North Carolina.

Our interpretation of the habitat information, coupled with our knowledge of tag pop-up locations suggests that the majority of large red drum leave Chesapeake Bay during late July, moving into deeper offshore waters. Morphological and histological studies demonstrate that red drumspawn in August and September in the estuarine and coastal waters of North Carolina (Ross et al. 1995): however, larval surveys of Chesapeake Bay have not demonstrated high numbers of young red drum larvae, suggesting on limited spawning within the Bay (John Olney, personal communication). Thus, it is likely that the movements of large red drum into waters offshore of Virginia and North Carolina may have been associated with spawning. While our light level data are not sufficient to allow accurate or precise positions based on geolocation, it would appear the large red drum moved into inshore waters in early September, as evidenced by the marked decrease in daily temperature fluctuations despite considerable vertical movements, suggesting a well mixed water column. Possible locations include the Chesapeake Bay and the sounds of North Carolina. Red drum remained in these waters and presumably moved into coastal waters, at the end of October, where they remained until the final set of tags popped up in late November.

The results of this study have demonstrated high post-release survival for red drum taken in the Virginia recreational fishery. In addition, new insights into the movement of red drum through the course of the summer have been noted, as well and a high connectivity between the Virginia and North Carolina red drum fisheries. Future research should be directed to understand the reasons underlying the summer movements of red drum outside of Chesapeake Bay, as well as to better characterize movements in the early fall as fish move back into coastal waters.

References

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Table 1. Fish and satellite tag information, including intended tag duration, date of release, fight time, hook location, presence/absence of bleeding, total length, net displacement, and percent data recovered. Premature release (PR), delayed first transmission (DFT), and tag recovery (TR) are noted under Other.

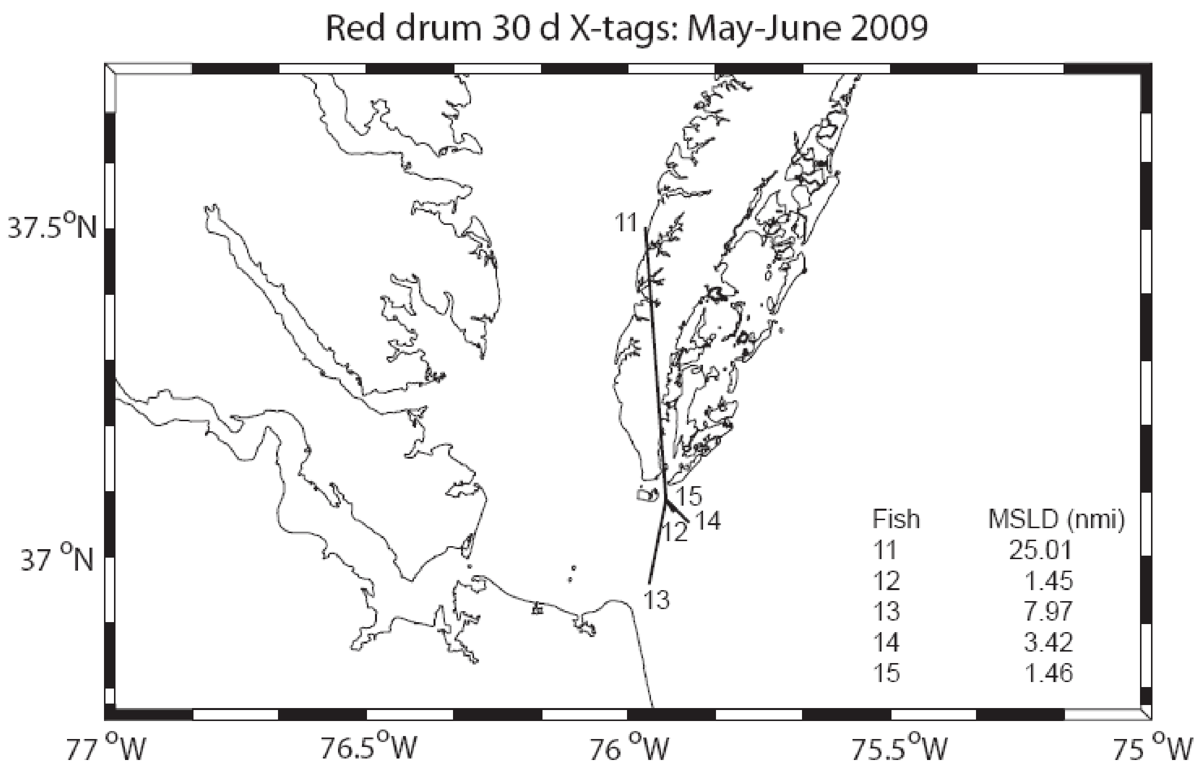
Fish	Tag Duration	Date	Fight Time	Hook Location	Bleeding	Total Length	Net Disp.	Data Recovery	Other
1	180 day	21 May	12 min	Corner of jaw	No	48"	158.2	4%	
2	180 day	21 May	10 min	Roof of mouth	No	50"	62.1*	100%	PR,TR
3	180 day	21 May	11 min	Gullet - removed	No	49"	131.3	56%	
4	180 day	23 May	6 min	Deep - left in	No	43"	127.9	62%	
5	180 day	23 May	13 min	Bottom lip	No	50"	122.0	42%	
6	90 day	23 May	15 min	Corner of jaw	No	50"	63.1*	87%	PR
7	90 day	23 May	15 min	Deep - left in	Some/hook	44"			
8	90 day	23 May	10 min	Top of mouth	No	48"	30.5	100%	TR
9	90 day	23 May	13 min	Corner of jaw	Some/tag	49"	335.3*	71%	DFT
10	90 day	23-May	18 min	Corner of jaw	No	49"	102.8	80%	
11	30 day	25 May	3 min	Corner of jaw	No	44"	25.0	100%	TR
12	30 day	25 May	13 min	Tongue	No	42"	1.5	100%	TR
13	30 day	25 May	2 min	External/head	No	42"	8.0	100%	TR
14	30 day	25 May	2 min	Lower Jaw	No	44.5"	3.4	100%	TR
15	30 day	25 May	10 min	Corner of jaw	No	50.5"	1.5	100%	TR

Figure Legends

1. A large red drum with a Microwave X-Tag attached.
2. Net displacement (minimum straight line distance) for the red drum #1 – 5 tagged with 30 day tags.
3. Net displacement (minimum straight line distance) for red drum #6, 8, 9 and 10, all tagged with three month tags, and red drum #2, tagged with a six month tag that popped off prematurely after three months. Note that tags #2, 6, and 9 floated at the surface for 4 – 7 days before the first transmission was received.
4. Net displacement (minimum straight ine distance for red drum #1, 3, 4, and 5, all tagged with six month tags.
5. Temperature and depth plot for red drum #13, tagged for 30 days.
6. Temperature and depth plot for red drum #10, tagged for three months.
7. Temperature and depth plot for red drum #3, tagged for six months.

Figure 1.

Figure 2.



Red drum 30 d X-tags: May-June 2009
37.5°N
37 °N
77 °W
76.5°W
76 °W
75.5°W
75 °W
11
12
13
14
15
Fish
MSLD (nmi)
11 25.01
12 1.45
13 7.97
14 3.42
15 1.46

Figure 3.

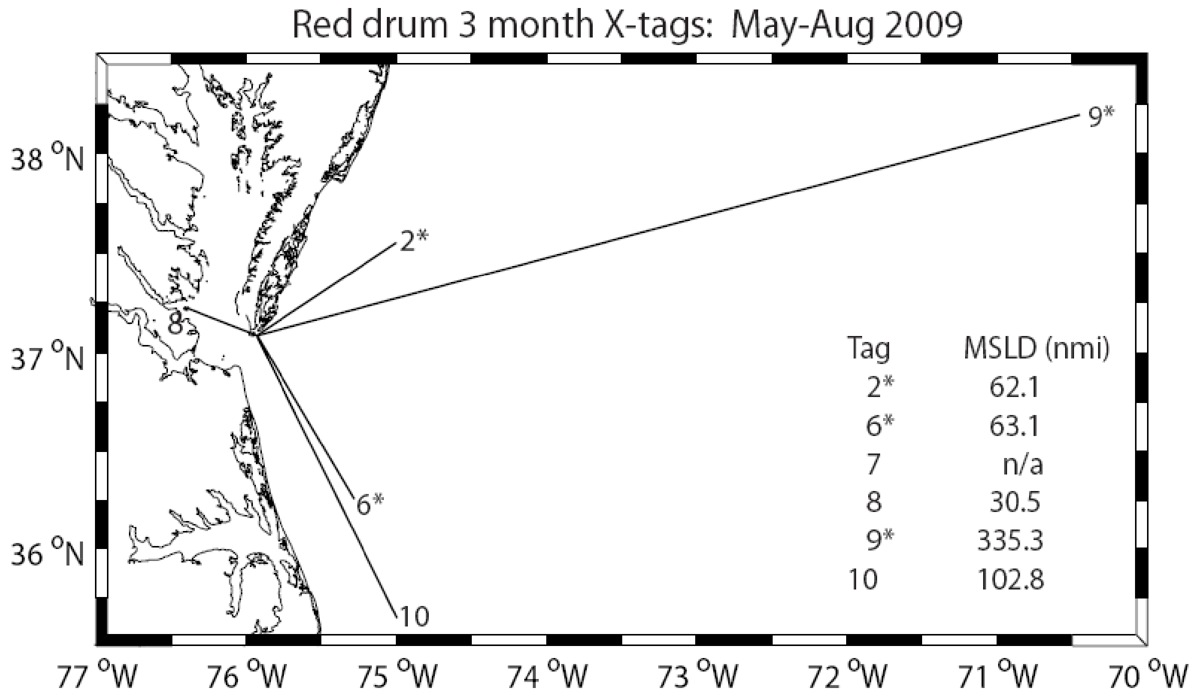

Red drum 3 month X-tags: May-Aug 2009
38 °N
37 °N
36 °N
77 °W
76 °W
75 °W
74 °W
73 °W
72 °W
71 °W
70 °W
2*
6*
8
9*
10
Tag MSLD (nmi)
2* 62.1
6* 63.1
7 n/a
8 30.5
9* 335.3
10 102.8

Figure 4.

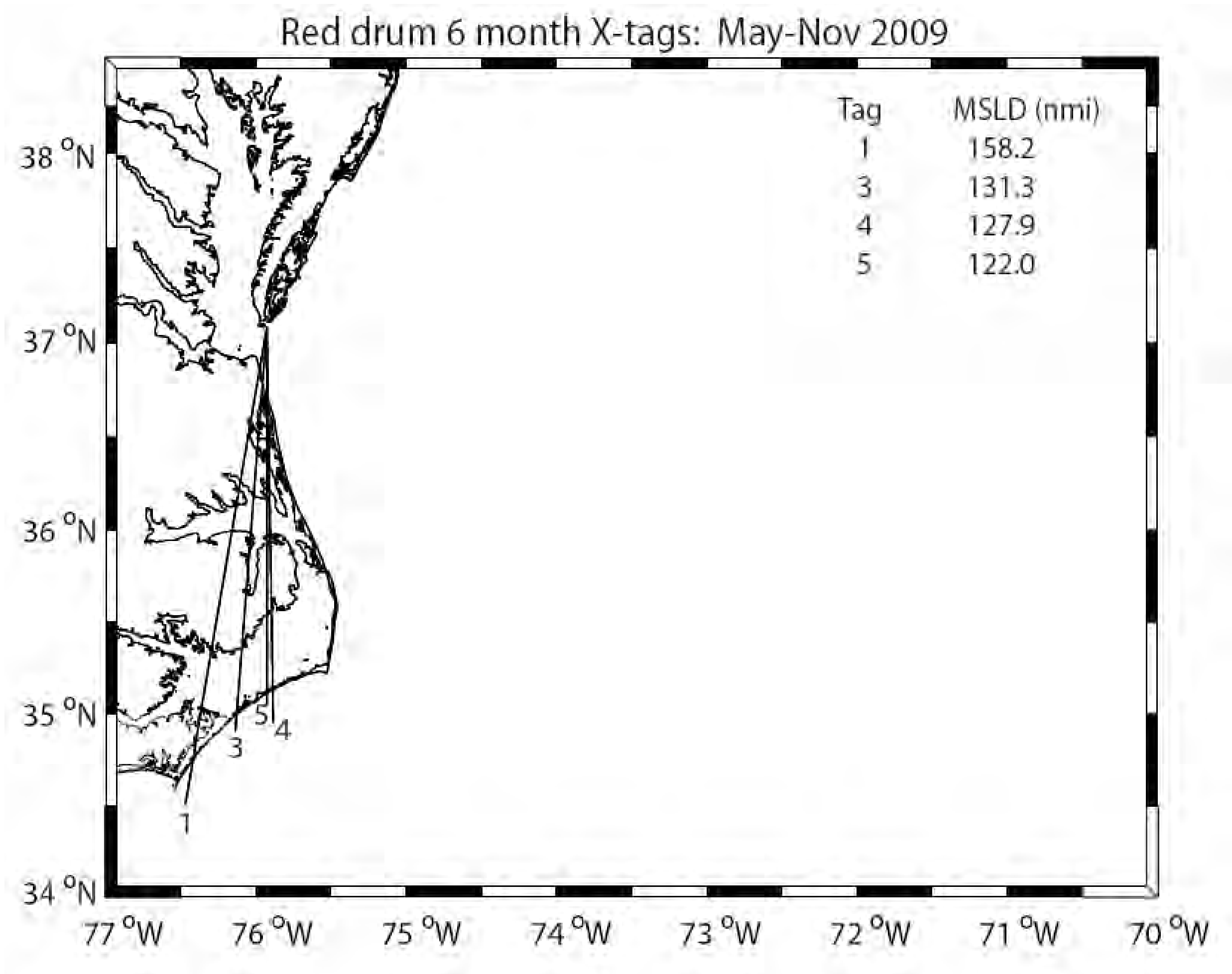
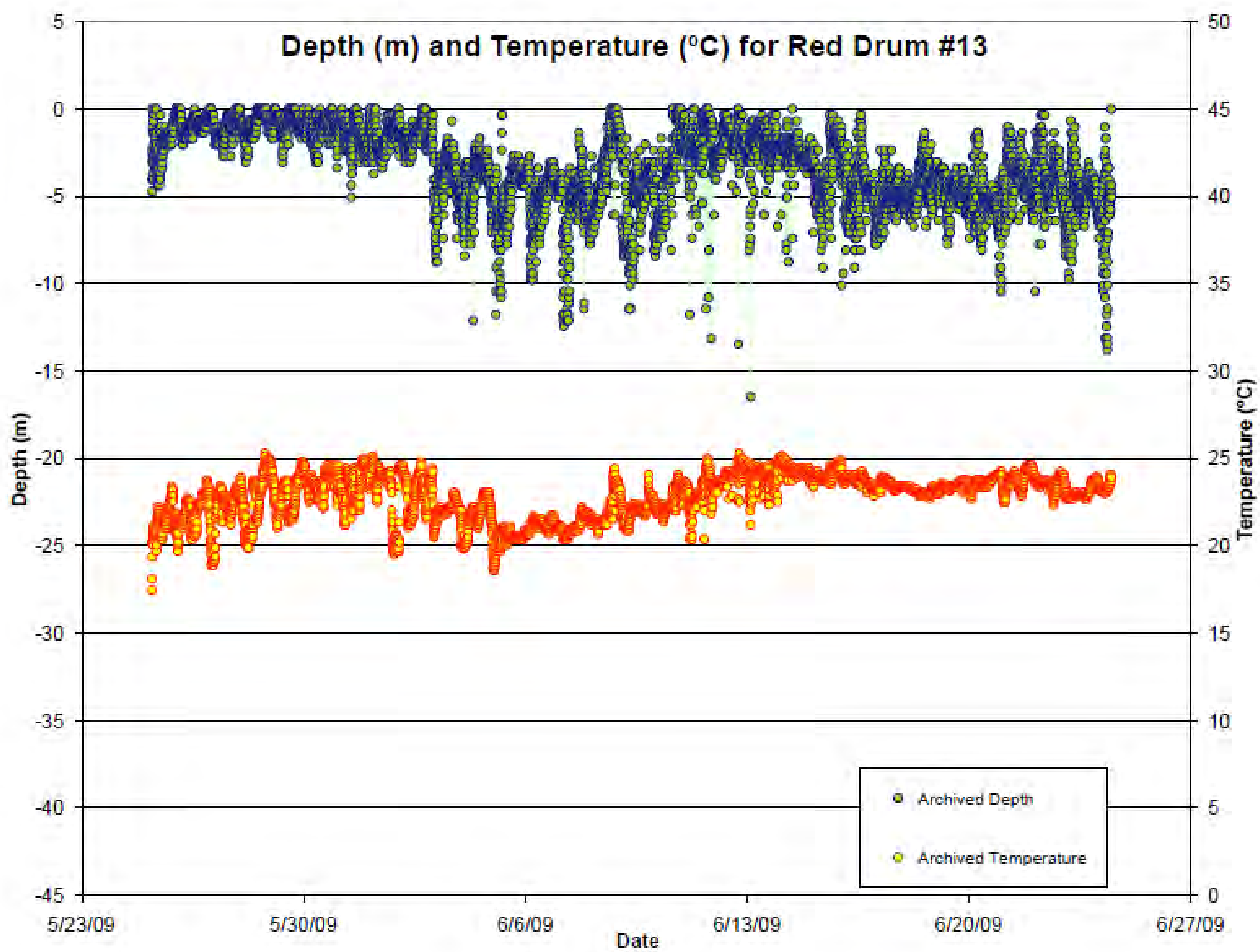
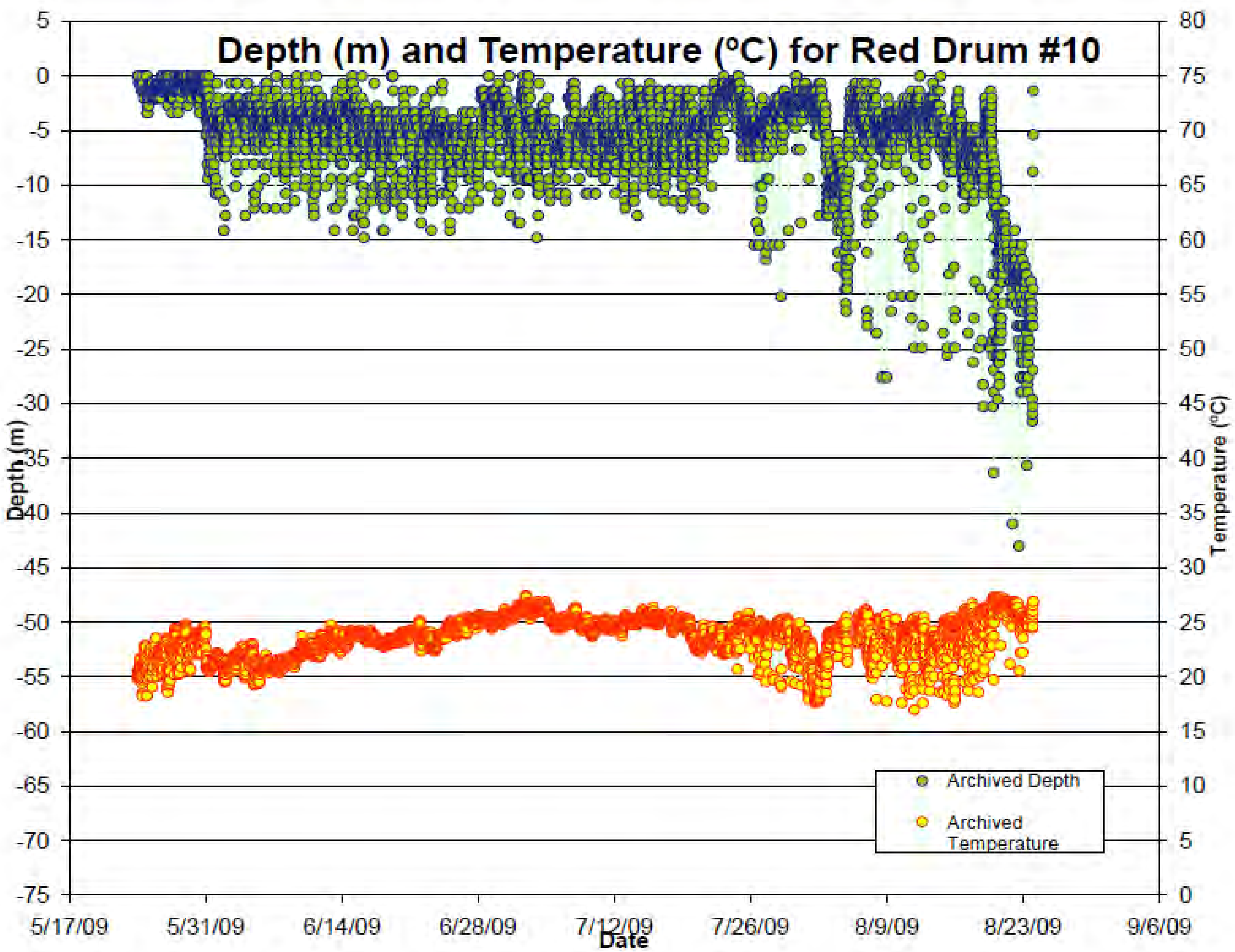

Red drum 6 month X-tags: May-Nov 2009
Tag
MSLD (nmi)
1
158.2
3
131.3
4
127.9
5
122.0
38 °N
37 °N
36 °N
35 °N
34 °N
77 °W
76 °W
75 °W
74 °W
73 °W
72 °W
71 °W
70 °W
1
3
5
4

Figure 5.



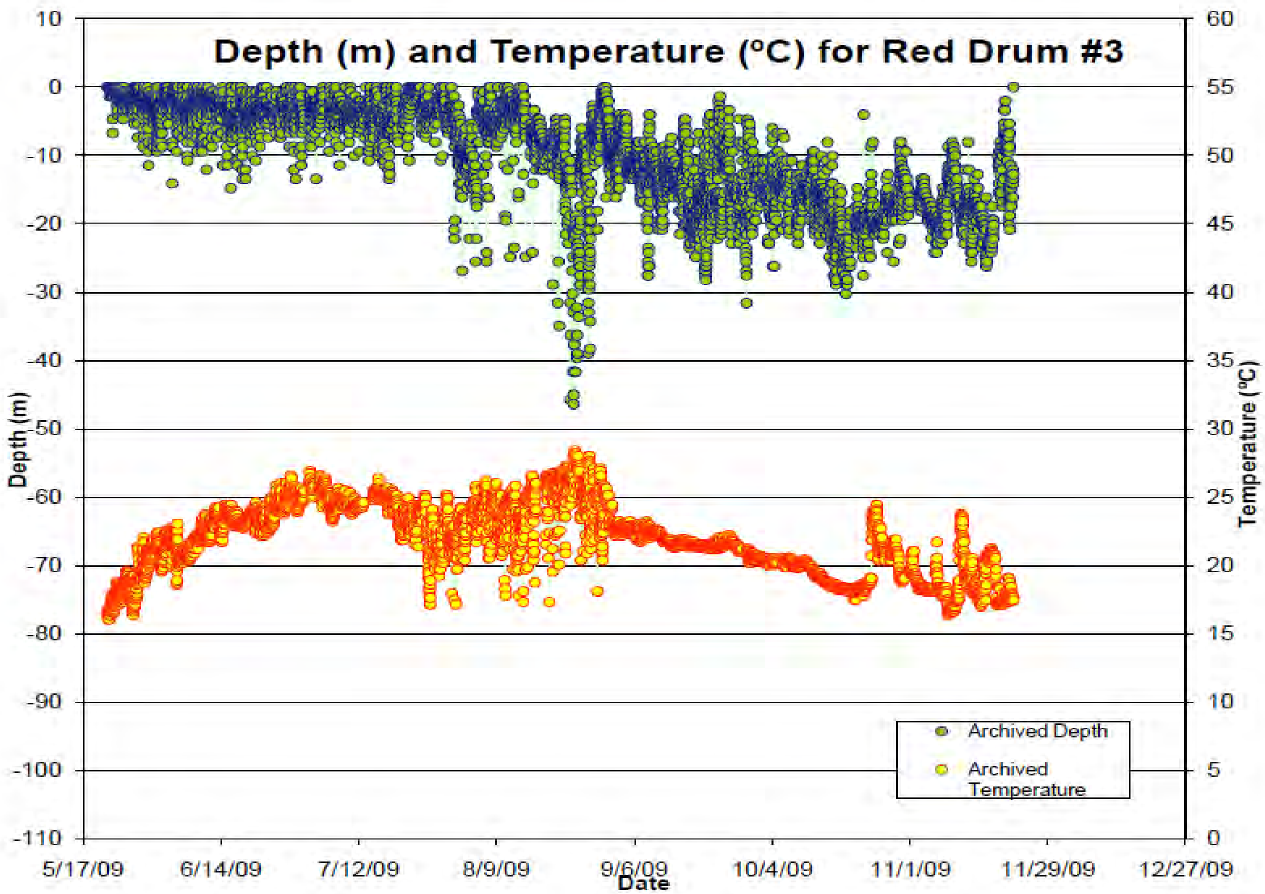
Depth (m) and Temperature (°C) for Red Drum #13
Depth (m)
Temperature (°C)
Date
5/23/09
5/30/09
6/6/09
6/13/09
6/20/09
6/27/09
Archived Depth
Archived Temperature

Figure 6.



Depth (m) and Temperature (ºC) for Red Drum #10
Depth (m)
Temperature (ºC)
Date
5/17/09
5/31/09
6/14/09
6/28/09
7/12/09
7/26/09
8/9/09
8/23/09
9/6/09
Archived Depth
Archived Temperature

Figure 7.



Depth (m) and Temperature (°C) for Red Drum #3
Depth (m)
Temperature (°C)
Date
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
60
55
50
45
40
35
30
25
20
15
10
5
0
5/17/09
6/14/09
7/12/09
8/9/09
9/6/09
10/4/09
11/1/09
11/29/09
12/27/09
Archived Depth
Archived Temperature