Investigating the reproductive migration and spatial ecology of Nassau grouper (*Epinephelus striatus*) on Little Cayman Island using acoustic tags – An Overview

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The Cayman Islands Department of Environment needs to assess the effectiveness of Nassau grouper (*Epinephelus striatus)* spawning aggregation site closures by gaining a better understanding of how local grouper populations use the aggregation sites. During the January 2005 spawning season thirty Nassau grouper were acoustically tagged off the Little Cayman west end aggregation site and during the summer of 2005 an additional twenty Nassau groupers were tagged around Little Cayman. By tagging fish on the aggregation we have been able to determine where fish go after they leave the spawning aggregation. By tagging fish around Little Cayman prior to the 2006 spawning season we will be able to determine the proportion of fish from around the Island that attend the west end spawning aggregation. Also, the frequency of aggregation attendance by individual fishes as a function of demography will be assessed. Initial results show that 60% of the groupers tagged during the January, 2005 aggregation returned to aggregate during the February full moon. Furthermore, these 18 returning fish were amongst the largest of the 30 tagged. Ultimately, this information will allow us to assess the current and future impacts of protections afforded Cayman's spawning aggregations. Moreover, the study will define an aggregation's "sphere of influence" both geographically and demographically and will thus aid in the management of local Nassau grouper populations.

KEY WORDS: Nassau grouper, spawning aggregation, acoustic tag

El departamento de las islas de cayman del ambiente necesita determinar la eficacia del grouper de Nassau (*Epinephelus striatus*) que freza encierros del sitio de la agregación ganando una comprensión mejor de cómo las poblaciones locales del grouper utilizan los sitios de la agregación. Durante la estación de freza de enero 2005 treinta Nassau el grouper acústico fue marcado con etiqueta del pequeño sitio de la agregación del final del oeste del cayman y durante el verano 2005 de veinte Nassau los groupers fueron marcados con etiqueta alrededor de pequeño cayman. Marcando pescados con etiqueta en la agregación hemos podido determinarse adónde van los pescados después de que salgan de la agregación de freza. Marcando pescados con etiqueta alrededor del pequeño cayman antes de las 2006 estaciones de freza podremos determinar la proporción de los pescados alrededor de la isla que atienden a la agregación de freza del final del oeste. También, la frecuencia de la atención de la agregación por los pescados individuales en función de la demografía será determinada. Los resultados iniciales demuestran que el 60% de los groupers marcaron con etiqueta durante la agregación de enero vuelta al agregado durante la Luna Llena de febrero. Además, estos 18 pescados que volvían estaban entre el más grande de los 30 marcados con etiqueta. En última instancia, esta información permitirá que determinemos los impactos actuales y futuros de las agregaciones de freza del cayman producido las protecciones. Por otra parte, el estudio definirá esfera de una agregación la "de la influencia" geográficamente y demográfico y la ayudará así en la gerencia de las poblaciones locales del grouper de Nassau.

PALABRAS CLAVES: Grouper de Nassau, frezando las agregaciones, etiqueta acústica, migración

INTRODUCTION

Nassau grouper (*Epinephelus striatus*) migrate to specific sites during the winter full moons in order to reproduce in mass aggregations (Domeier & Colin 1997, Bolden 2000, Sala et al. 2001). The Nassau grouper is listed as ‘threatened’ by the World Conservation Union (formerly International Union for the Conservation of Nature and Natural Resources; IUCN, 2002). Intense harvesting of spawning aggregations is the primary cause of the precipitous decline in populations throughout the Caribbean (Beets & Hixon 1994, Sadovy & Eklund 1999). In recent years, several Caribbean governments have instituted marine protected areas at known Nassau grouper aggregation sites in response to chronic declines in catch.

Spawning aggregations of reef fishes are of concern to fisheries management because they result in the concentration of individuals from stocks that are otherwise at low densities, and aggregations are disproportionately responsible for the reproductive output of many economically valuable and ecologically important species (Domeier and Colin 1997). Because aggregations are site specific, designating aggregation sites as marine protected areas is likely to be a successful conservation measure. It is important, however, to evaluate the scope of protections afforded stocks through the protection of spawning grounds since such management actions alone may not be sufficient to protect at-risk species.

In 2003 the Cayman Island Marine Conservation Board instituted an 8-year total fishing ban on all known Nassau grouper aggregation sites through the

Restricted Marine Areas (Designation) Regulations legislation. Before these areas were protected, fishers took >90% of all harvested Nassau grouper from aggregations. Six Nassau grouper spawning aggregations have been documented in the Cayman Islands: the east end of Little Cayman, east end Cayman Brac, and east and south west ends of Grand Cayman, and the north east corner of the 12 Mile Bank to the west of Grand Cayman (Tucker et al. 1993) and one recently discovered at the west end of Little Cayman. Four of these aggregations apparently no longer exist and the fifth supports only a few fish. Only the west end site of Little Cayman, maintains annual aggregations of more than 1,000 grouper. In order to assess the effectiveness of the closures the Cayman Islands Department of the Environment (CIDOE) needs answers to the following questions:

1) What proportion of Nassau grouper on the Cayman Islands use the aggregation sites receiving protection?
2) Are there any as yet undiscovered (and thus unprotected) aggregation sites?
3) How often do individual fish participate in aggregations?
4) Where do aggregating individuals come from and where do they go afterward?
5) Does demographic status (sex and size) influence participation in aggregations?

In this paper we present preliminary findings from a study aimed at addressing these questions. We acoustically tagged Nassau grouper both on and off the Little Cayman west end aggregation site, and are subsequently monitoring the movements of the tagged fish over a two year period using an array of passive autonomous hydrophone receivers. By tagging fish on the aggregation we were able to determine where fish go after aggregating. The behavior of fish tagged at sites around Little Cayman prior to the aggregation will provide insight into the proportion of fish from the Island that attend aggregations, and the frequency of aggregation attendance by individual fishes as a function of demography. This information will allow the assessment of current and future impacts of the marine protected areas on Cayman's spawning aggregations; moreover, the study will define an aggregation's "sphere of influence" both geographically and demographically and will thus aid in the management of aggregations and populations generally.

METHODS

Catching

At the start of the January 2005 spawning season (25th – 27th January 2005) we caught 30 mature Nassau grouper (>40 cm TL; Sadovy and Colin 1995) at the west end Little Cayman aggregation site, using hand lines with 12/0 circle hooks, 0.2kg weights and a combination of fresh reef fish and squid as bait. Fish were caught at depths of approximately 30m and brought slowly to the surface to minimize barotrauma. We used circle hooks in order to maximize the likelihood of hooking fish in the corner of mouth. In June and August 2005 we caught 20 mature-sized Nassau grouper around Little Cayman Island using baited Antillean fish traps (Semmens *et al.* in press) and by SCUBA divers using mesh bags. To capture grouper, SCUBA divers chased them into a hole in the reef. In most instances the fish were sedated using 500ml of a 1:500 Quinaldine/seawater solution that was applied to the hole using a squirt bottle. In some cases the fish swam out into a net bag; in other cases the fish was removed by hand and placed in a net bag.

Tagging

Vemco coded transmitter tags were surgically implanted in 50 Nassau grouper using procedures modified from Adams *et al.* (1998). We measured total length (cm) and weight (kg) of all fish intended for tagging, and then placed the fish ventral side up in a'V' shaped cradle, with fresh seawater irrigating their gills and a wet towel covering their head.

We made a 25mm incision in the abdomen just posterior to the pelvic fins and offset from the mid-line and the acoustic tag was inserted into the gut cavity. Prior to surgery we soaked tags and surgical equipment in Betadine solution in an attempt to maintain the best aseptic technique possible under field conditions. Prior to use, tags and equipment were rinsed in sterile water. Surgical sutures (2-0, cutting needle, monofilament sutures) were used to close the wound following tag insertion, and anti-bacterial ointment was applied to the incision in order to minimize the likelihood of infection. Given the perceived high risk of predation during release, we opted not to anesthetize our subjects. During the spawning season we tagged 25 fish with a Vemco v16-4h coded transmitter tag and 5 with a Vemco v16-P depth-sensitive tag with a depth range of 0-204m. The 20 fish caught off the aggregation site were each tagged with a Vemco v16-4h coded transmitter tag. All fish were tagged with an external FLOY streamer tag, with color varying depending on where the fish was caught. The v16-4h tags have a battery life of approximately 900 days and ping (send coded acoustic information) once per 60-182 seconds. Pings are randomized within this time range in order to minimize signal collision when multiple tags are present. Blood samples were collected for hormone analysis in order to determine the sex of the tagged individuals. All animals were bled by caudal puncture into heparinized syringes. Blood was held on ice until the plasma was collected by centrifugation, and the plasma was frozen at -20C initially (~ 3 weeks), then at -80C until laboratory analyses were performed. Existing steroid radioimmunoassays (RIA's) for estradiol-17B (E_2) Testosterone (T) and 11-Ketotestosterone (11KT) were previously validated for use with grouper plasma (Heppell and Sullivan 2000, Heppell and Sullivan unpublished). Duplicate 20 μl aliquots of plasma were ether extracted and dried at 37^0 C under nitrogen gas, resuspended in phosphate buffered saline containing 1% gelatin (PG), and steroid levels were measured by RIA (Feist and Schreck 1996, Heppell and Sullivan 2000). Also, a small fin clip was collected and stored in1% Sarcosyl Urea for future genetic analysis.

All fish were released at depth at the site of their capture either by using a weighted hook recompression line (Bohnsack, 1996; Bartholomew *et al*, in press) or by hand-transporting the fish in a mesh bag to the bottom by a SCUBA diver. The recompression line consisted of an inverted barbless hook, with a 1.4 kg weight on a 1 m line tied to the hook eye, and a hand reel with a monofilament trip line tied to the bend of the hook. The fish was oriented head down, the inverted hook inserted through the top lip, and then gently lowered into the water while free spooling the trip line. The weight was allowed to rapidly carry the fish to a depth of approximately 10 meters at which time the trip line was quickly jerked upward to dislodge the hook from the upper lip. The fish were observed on SCUBA to swim easily to the bottom.

Hydrophone Array

We placed fifteen VEMCO VR2 single channel passive autonomous hydrophone datalogger receivers (VEMCO, 100 Osprey Drive, Shad Bay, Nova Scotia, Canada B3T 2C1) at approximately 2 km increments around Little Cayman prior to the onset of the January 2005 spawning season. The VR2 hydrophones were attached to ¼ inch polypropylene line approximately 8m below the surface using cable ties and moored at the edge of the wall. The line was anchored to a stainless steel pin embedded in the reef and buoyed by subsurface floatation buoys. The VR2 hydrophones have an advertised reception radius of 500-800m, a battery life of approximately 15 months, and can store 300,000 unique tag identifications. If an acoustically tagged fish comes within the reception range the VR2 will log the time, tag ID, and depth if the tag is depth-coded. Hydrophones are retrieved, downloaded, and redeployed every 3 months. Based on range tests, we determined the hydrophones to have a maximum reception radius of 300m in the field.

Mobile Tracking

In order to survey areas around Little Cayman outside of the reception range of the VR2 hydrophones, and in order to survey the islands of Cayman Brac and Grand Cayman, we surveyed near-shore habitat throughout the Cayman Islands using a boat-based hydrophone (Vemco VR100). The boat-based gear was used to search for acoustically tagged fish every 2 months around Little Cayman and every 6 months around Grand Cayman and Cayman Brac. The omni-directional hydrophone is towed 8m behind a boat at 5km/h at approximately 2m below the surface. If an acoustically tagged fish is detected the receiver logs the time, location (using a built-in Global Positioning System), tag ID, and if applicable, depth.

Data Management

Data from the VR2 and VR100 hydrophones are being stored in Microsoft Access and imported into spatially explicit ArcView Geographic Information System (GIS) for analysis. These data will be merged with data from existing CIDOE GIS layers including Little Cayman's shoreline, shelf edge, marine parks and known spawning areas. This, along with aerial photography, will show locations of tagged fish with respect to these features. In order to conduct analyses on the tag data, a Spatial Analyst extension developed by ESRI, and the Animal Movement Analysis extension, developed by the USGS (Hooge and Eichenlaub 2000) is being used. With these packages, density contours, kernel home range estimates, and electivity indices are being established and Monte Carlo site fidelity tests run.

RESULTS

Catching and Tagging

In all, 50 Nassau grouper were acoustically tagged from Little Cayman. The average size these fish was 64 cm (range 44cm - 84cm). (Table 1 & 2). All fish survived tagging and were successfully released. Procedure times range from 2-10 minutes.

January 2005

Fish were caught on hook and line during the January 2005 aggregation season. Because peak spawning occurs 5 nights after the full moon (Whaylen *et al* 2004) we stopped all efforts to catch fish 3 days after the full moon in an effort to minimize any adverse affects on spawning. Immediately following surgery tagged fish typically rested on the bottom. However, usually within 12 hrs tagged individuals acted unaffected. The VR100 mobile gear heard all the tagged fish on the aggregation site up to 7 days after tagging, until the aggregation dispersed.

April and August 2005

We caught 20 Nassau grouper using Antillean fish traps and net bag SCUBA trapping techniques at sites around Little Cayman. After 10 days of trapping with Antillean fish traps in April 2005 we abandoned the method because mature (>50cm TL) Nassau grouper were being attacked by the isopod *Excorallana tricornis tricornis*. Isopods infested approximately half of the Nassau grouper caught with traps; two grouper died in traps presumably due to infestation (Semmens *et al* in press). While we tagged two Nassau grouper moderately infested with *E. tricornis tricornis* most were released. Trapping techniques using SCUBA and mesh bags were very labor and time intensive, resulting in an average of 2 Nassau grouper being acoustically tagged per day.

The Hydrophone Array

We downloaded all VR2 hydrophones in April and August 2005. These preliminary data show that the 30 fish we tagged on the aggregation returned to home reefs that were relatively evenly distributed around the entirety of Little Cayman. Eighteen of these fish returned to the aggregation for a second time in February. These 18 fish were among the largest of the acoustically tagged on the aggregation (Table 2; t test, $p = 0.017$), suggesting that participating in more than one aggregation each year is common.

Mobile Tracking

We have circumnavigated Little Cayman using the VR100 Mobile gear 5 times (April, July, August, September, October 2005) in an effort to detect all tagged fish. While circumnavigating the island we followed a 'zig zag' course up to the reef and across the shelf to the drop off in order to maximize coverage of the shelf edge. We have detected 40 of the 50 acoustically tagged fish with the VR100 mobile gear. The 10 fish not heard include the 2 that were infested by *E. tricornis tricornis* (Semmens *et al* in press), and 8 that were last heard on the VR2 array shortly after tagging (Table 3 and Figure 1).

DISCUSSION

The set-up phase of this project is now complete and data collecting will dominate the rest of the field phase. We anticipate the battery life of the acoustic tags will last for 3 spawning seasons. Despite the relatively poor reception range of the VR2 hydrophones, Little Cayman's short coastal shelf and precipitous shelf drop-off provide a natural 'corridor' that acts to funnel migrating grouper in close proximity to the VR2 hydrophones. As such, with rare exception all tagged fish were heard by each hydrophone they passed on their migration routes. The VR100 has proved invaluable for detecting those acoustically tagged fish residing outside the range of the VR2 hydrophones. According to preliminary VR2 data none of the 10 missing fish disappeared after heading east toward Cayman Brac, and a recent mobile tracking survey around the western end of Cayman Brac did not detect any tags. A more thorough survey of Cayman Brac as well as Grand Cayman is scheduled for 2006.

The extent to which local populations of Nassau grouper use aggregation sites bears directly on the success and effectiveness of protections placed on these sites. If, for instance, virtually all Nassau grouper from Little Cayman aggregate predictably at the west end aggregation site, then enforced fishing prohibitions at the site will be highly effective at limiting over fishing. If on the other hand, only a small portion of the total grouper population attends the aggregations each year, or if much of the local population of grouper attends aggregations at currently unknown locations, then the protections on the aggregation site may be far less effective at reducing fishing impacts than expected. The products of this study will allow the CIDOE to directly assess the efficacy of existing reserves, and will provide guidance for additional protected areas in the event that additional aggregation sites are found.

The recently legislated 8-year ban on fishing Cayman aggregations was enacted with the understanding that any extension to this ban would be contingent on a comprehensive assessment of the status of the Cayman Island's Nassau grouper spawning population. By describing the spatial ecology of Nassau grouper and, more specifically, aggregation site usage as a function of demography, this study will provide a crucial component of this assessment.

It is our experience the popular notions of the fishing community (in this case, abyssal migrations, regular shifting of SPAGS, and as yet undiscovered SPAGS) and the current lack of scientific evidence proving or disproving them, can lead to lack of political support in implementing protective legislation. This research should help to dispel (or prove) such notions. To this end, findings will be presented to fishers on each of the islands in order to disseminate information and elicit feedback from a primary resource user group.

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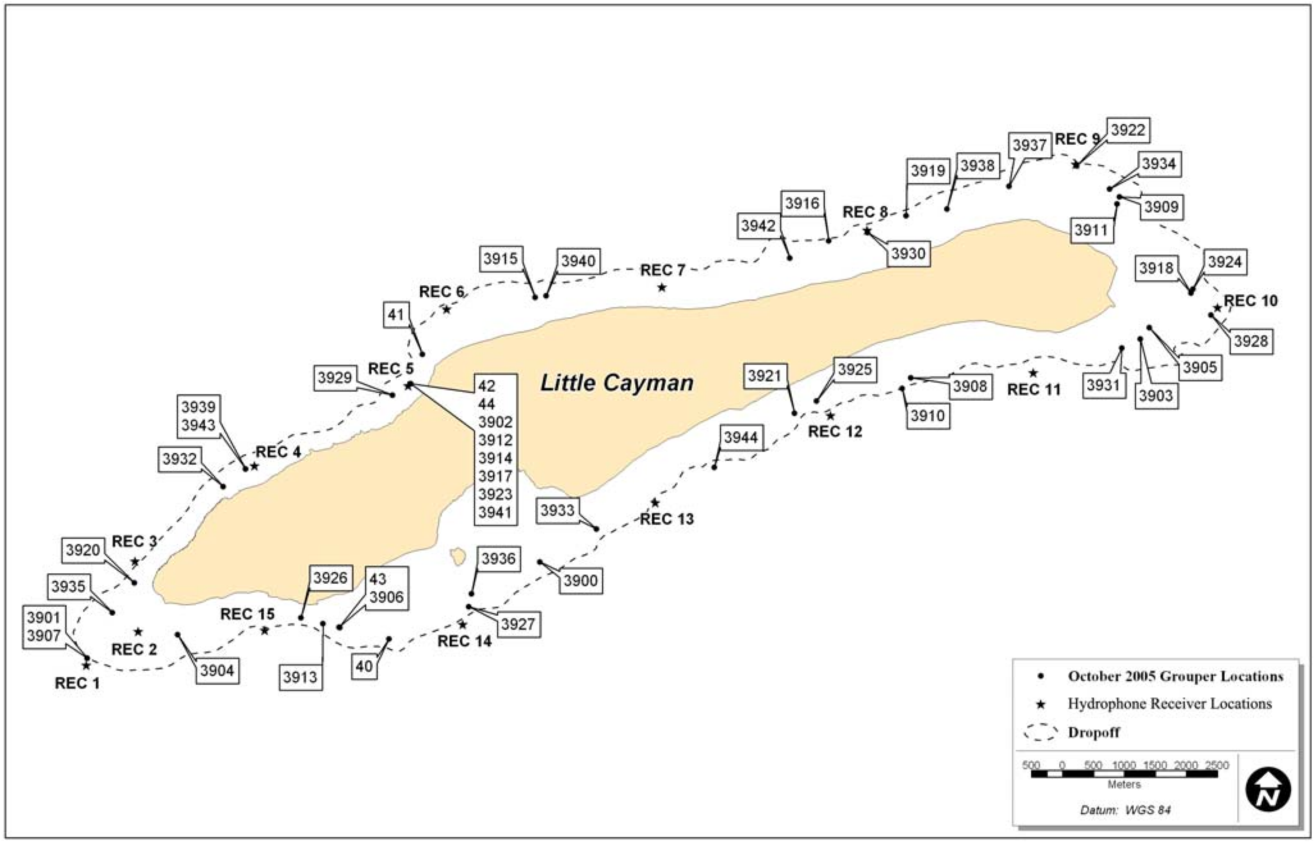
Date tagged	Catch and Release Location	Size cm	Weight kg	Floy tag side tagged	Acoustic tag ID
27-Jan-05	West end aggregation	64	4.95	00026 R	40
27-Jan-05	West end aggregation	70	6.1	00021 R	41
26-Jan-05	West end aggregation	83	12.5	00016 R	42
26-Jan-05	West end aggregation	62	5	00011 R	43
26-Jan-05	West end aggregation	64	4.9	00013 R	44
26-Jan-05	West end aggregation	64.5	4.7	00012 R	3900
27-Jan-05	West end aggregation	65	4.35	00028 R	3901
27-Jan-05	West end aggregation	71	7.15	00025 R	3902
27-Jan-05	West end aggregation	64	4.55	00031 R	3903
3-Aug-05	South west end	66.5	5	yellow01224R	3904
1-Aug-05	South east end	63	5	Green01330R	3905
27-Jan-05	West end aggregation	68	5.45	00034 R	3906
26-Jan-05	West end aggregation	64.5	4.5	00006 R	3907
26-Jan-05	West end aggregation	52	2.2	00017 R	3908
27-Jan-05	West end aggregation	83	12.36	00030 R	3909
27-Jan-05	West end aggregation	72	6.9	00029 R	3910
27-Jan-05	West end aggregation	65	5.35	00024 R	3911
27-Jan-05	West end aggregation	63.5	4.6	00022 R	3912
27-Jan-05	West end aggregation	63	4.32	00019 R	3913
26-Jan-05	West end aggregation	64	4.6	00005 R	3914
27-Jan-05	West end aggregation	63	4.5	00020 R	3915
27-Jan-05	West end aggregation	72	7.4	00023 R	3916
27-Jan-05	West end aggregation	84	11.4	00018 R	3917
25-Jan-05	West end aggregation	77	9.8	00007 ?	3918
25-Jan-05	West end aggregation	56.5	2.65	00009 ?	3919

Date tagged	Catch and Release Location	Size cm	Weight kg	Floy tag side tagged	Acoustic tag ID
26-Jan-05	West end aggregation	67	5.6	00014 R	3920
27-Jan-05	West end aggregation	81	11.75	00035 R	3921
27-Jan-05	West end aggregation	75.5	8.7	00036 R	3922
27-Jan-05	West end aggregation	63	4	00027 R	3923
26-Jan-05	West end aggregation	74.5	8.7	00015 R	3924
10-Apr-05	Rec 12	44.5	3	Red01137R	3925
20-Apr-05	Rec 15	63	4.7	Yellow01218R	3926
18-Apr-05	South – west Owen Island	67.5	6.1	Red01128R	3927
11-Apr-05	Rec 10	61	4.5	Blue01044R	3928
5-Aug-05	Bloody Bay Wall	58.5	4	Orange01419R	3929
12-Apr-05	Rec 7	55	2.75	Green01385R	3930
1-Aug-05	South east end	52	2.5	Blue01039R	3931
3-Aug-05	North west end	57	3.5	Orange01443R	3932
18-Apr-05	South – east Owen Island	52	2.25	Red01120R	3933
2-Aug-05	North east end	54	2.5	Blue01086R	3934
3-Aug-05	West end	74	7.5	yellow01277R	3935
16-Apr-05	South west Owen Island	75	9.5	Red01113R	3936
30-Jul-05	Snipe Point	57.7	4	Green01333R	3937
30-Jul-05	West Snipe Point	63	5.5	Green01340R	3938
10-Apr-05	Rec 11	53	2.4	Red01103R	3939
1-Aug-05	East of Bloody Bay	64	4.5	Green01348R	3940
2-Aug-05	Bloody Bay	59	3.5	Orange01478R	3941
31-Jul-05	Off Mary’s Bay	60	4	Green01337R	3942
27-Jan-05	West end aggregation	64	4.6	00032 R	3943
27-Jan-05	West end aggregation	63.5	4.2	00033 R	3944

Table 1: Acoustically tagged fish data

	n	Average Size cm
Acoustically tagged from January spawning aggregation	30	68.11
Acoustically tagged around Little Cayman	20	59.98
Acoustically tagged fish returned for February spawning aggregation	18	71.22

Table 2: The number and average size of tagged Nassau groupers



Little Cayman
REC 1
REC 2
REC 3
REC 4
REC 5
REC 6
REC 7
REC 8
REC 9
REC 10
REC 11
REC 12
REC 13
REC 14
REC 15
3901
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3927
3926
43
3906
3913
40
October 2005 Grouper Locations
Hydrophone Receiver Locations
Dropoff
500 0 500 1000 1500 2000 2500
Meters
Datum: WGS 84
N

Acoustic tag ID	Date	Location	Hydrophone	When tagged	Size cm
3901	5-Feb-05	REC1	VR2	Jan	65
3907	30-Mar-05	REC1	VR2	Jan	64.5
3914	1-Apr-05	REC5	VR2	Jan	64
3939	11-Apr-05	REC4	VR2	April	53
3930	17-Apr-05	REC8	VR2	April	55
3923	5-May-05	REC5	VR2	Jan	63
3922	4-Jul-05	REC9	VR2	Jan	75.5
3928	6-Aug-05	REC10	VR100	April	61
3902	11-Sep-05	REC5	VR2	Jan	71
3935	12-Sep-05	NW of REC2	VR100	Aug	74
3915	14-Sep-05	E of Jacksons	VR100	Jan	63
3942	14-Sep-05	W Mary's Bay	VR100	July	60
3919	15-Sep-05	NW of Snipe Pt.	VR100	Jan	56.5
3937	15-Sep-05	NE of Snipe Pt.	VR100	July	57.7
3903	10-Oct-05	EE South	VR100	Jan	64
3905	10-Oct-05	EE South	VR100	Aug	63
3909	10-Oct-05	SE of REC9	VR100	Jan	83
3931	10-Oct-05	EE South	VR100	Aug	52
3934	10-Oct-05	SE of REC9	VR100	Aug	54
3938	10-Oct-05	NW of Snipe Pt.	VR100	July	63
41	11-Oct-05	N of REC5	VR100	Jan	70
3911	11-Oct-05	SE of REC9	VR100	Jan	65
3916	11-Oct-05	W of REC8	VR100	Jan	72
3918	11-Oct-05	NW of REC10	VR100	Jan	77
3924	11-Oct-05	NW of REC10	VR100	April	74.5

Acoustic tag ID	Date	Location	Hydrophone	When tagged	Size cm
3929	11-Oct-05	SW of REC5	VR100	Aug	58.5
3932	11-Oct-05	W McCoys	VR100	Aug	57
3940	11-Oct-05	E of Jacksons	VR100	Aug	64
3943	11-Oct-05	REC4	VR100	Jan	64
40	12-Oct-05	W Owen Island	VR100	Jan	64
43	12-Oct-05	W of Flats	VR100	Jan	62
3900	12-Oct-05	E Owen IS	VR100	Jan	64.5
3904	12-Oct-05	E of REC2	VR100	Aug	66.5
3906	12-Oct-05	W of Flats	VR100	Jan	68
3908	12-Oct-05	Charles' Bite	VR100	Jan	52
3910	12-Oct-05	Charles' Bite	VR100	Jan	72
3912	12-Oct-05	REC5	VR2	Jan	63.5
3913	12-Oct-05	W of Flats	VR100	Jan	63
3920	12-Oct-05	SSW of REC3	VR100	Jan	67
3921	12-Oct-05	REC12	VR100	Jan	81
3925	12-Oct-05	REC12	VR100	Jan	44.5
3926	12-Oct-05	E of REC15	VR100	April	63
3927	12-Oct-05	REC14	VR100	April	67.5
3933	12-Oct-05	Off Rocky Pt.	VR100	April	52
3936	12-Oct-05	Off Owen Island	VR100	April	75
3944	12-Oct-05	W of Diggary's	VR100	Jan	63.5
44	13-Oct-05	REC5	VR2	Jan	64
42	14-Oct-05	REC5	VR2	Jan	83
3917	14-Oct-05	REC5	VR2	Jan	84
3941	14-Oct-05	REC5	VR2	Aug	59

Table 2: Where we last heard the fish as of October 2005