The following supplements accompany the article

Parrotfish movement patterns vary with spatiotemporal scale

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Marine Ecology Progress Series 577: 149–164 (2017)

Supplement 1: Acoustic tagging methods

We captured fish using large wall nets, then transferred them to soft mesh bags. Once a fish was secured in a bag, one diver would slowly ascend with the fish to the boat while a second diver would ascend and fill a large holding tank with ~150 L of seawater. We transferred the fish to the holding tank and begin pumping fresh seawater with a hand pump for the remainder of the holding time. We then drove offsite several hundred meters in order to minimize the attraction of predators due to spillage of water from the holding tank. We recorded the capture location coordinates, fish total length, standard length, and color phase, tag types, serial numbers, and frequencies, and any physical markings or features on the fish that would aid in future visual identification. One person held the fish in position for surgery with a chamois cloth with head and gills submerged and just a small amount of the underside exposed for surgery. We then used sterile forceps to remove two scales on the underside of the fish, just off of the midline between the pelvic fins and the anus. We used a sterile scalpel blade to make a small incision through the skin just large enough to insert the transmitters. We inserted a continuous (Vemco, V9, 21 mm long x 9 mm diam., 4.7 g in air, 2.9 g in water, battery life 69 d, power output 145 dB) and/or coded (Vemco, V9-2L, 29 mm long x 9 mm diam., 4.7 g in air, 2.9 g in water, nominal delay 120 sec, battery life 484 d, power output 145 dB, 69 kHz) transmitter (both in most cases) into the peritoneal cavity of the fish and performed two discontinuous surgical sutures to close the incision. We then returned to the capture site, and checked to ensure that there were no sharks in the area before we released the fish down into a crevice in the reef. Five frequencies are available in the V9 continuous active tracking tags (63, 75, 78, 81, 84 kHz) but there is potential for the 63 and 75 kHz tags to interfere with the 69 kHz coded tags transmitting to the VR2W receivers, so we did not use these frequencies within our receiver array. Thus, we were limited to three frequencies per site at a given time. Tag life for the continuous tags was approximately 69 days. We allowed at least four d for recovery from tagging before commencing tracking.

Supplement 2: Range Testing

Methods

To range test the VR2W acoustic array we moored a Vemco V9 69 kHz coded test tag at 15, 30, 45, and 60 m from a moored VR2Ws at one m from the bottom. We then estimated the percent of expected detections for each distance position, calculated from the number of detections at that position and the transmission rate of the tag tested in the lab.

To range test the active acoustic tracking equipment at each tracking site we used a Vemco V9 continuous tag, 75 kHz, connected to a weighted float-line marked with a surface buoy. We ranged tested at each location at two tag heights: 1m off of the bottom (to mimic a tag inside of fish feeding on the benthos) and 3m off of the bottom (to mimic a tag inside of a fish swimming in the water column). For each test, we moored the tag and took a GPS recording of its position then drove the boat to a position out of detection range. Then we slowly drove the boat in a straight line toward the marker buoy with the directional hydrophone pointed at the buoy until reaching it. We drove 4 transects (from each cardinal direction) for each location and each tag height. Using the Point Distance tool in the Analysis toolbox in ArcGis we calculated the distance of each recorded detection to plot against signal strength.

Results

Consistent with the literature reporting typical detection ranges in highly complex coral reef environments (Welsh et al. 2012), our VR2W detection ranges were quite small. Detection rate dropped precipitously between 15 and 45 m. At 15 m distance the Rubblepile and Western Terrace receivers recorded 82% and 98% of expected detections respectively. By 45 m the detection rates had dropped to 1% and 6% respectively and at 60 m to 0% and 1% respectively (Figure S1A). We did not test the Deep Terrace receivers but we hypothesize that the detection ranges in that location are slightly larger because the receivers are moored in deeper water and our observations indicate that the fish were engaging in behaviors that likely make them more detectable while offshore (e.g. swimming in the water column as opposed to benthic foraging). However, with the small, low power transmitters that we used it is likely that detection ranges were consistently <100 m in the complex and noisy reef environment.

Testing of the VR100 to estimate potential error in active tracking locations showed that the hydrophone was within just a few meters of the tag when the detection decibels read greater than 95 dB while at a gain of 0 (our target lower threshold for recording a detection), even when the tag was fixed in the water column, three meters from the bottom (Figure S1B, C). This indicates that our positional error was relatively low (less than a few meters) when tracking fish in their shallow, highly complex diurnal foraging grounds. We also performed additional procedures to try to minimize our positional error including frequent visual confirmations of the position of the tagged fish, and slowly driving over the point of the highest signal until the signal dropped off indicating where exactly the fish was passed over.

LITERATURE CITED

Welsh, J. Q., Fox, R. J., Webber, D. M., & Bellwood, D. R. (2012). Performance of remote acoustic receivers within a coral reef habitat: implications for array design. Coral reefs, 31:693-702. doi:10.1007/s00338-012-0892-1

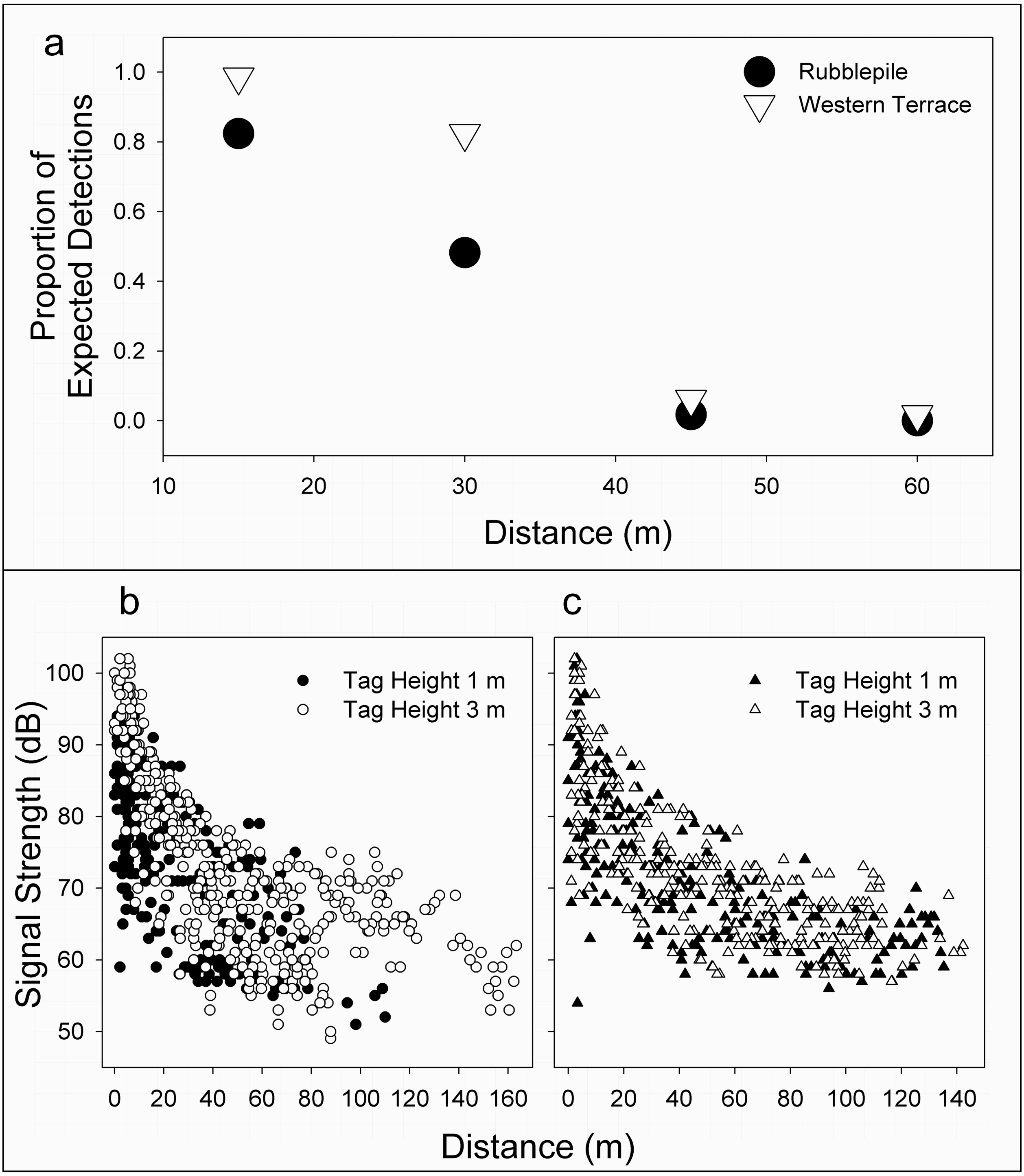


Fig. S1: Range testing results for a) the VR2Ws at both sites, b) VR100 at the Rubblepile and c) Western Terrace. Plots indicate the distance between the tag and the receiver and the percent of expected detections (a) or signal strength (b, c).

Supplement 3: Tracking methods

We tracked fish at the same sites where we conducted the passive monitoring observations (n=4 fish per site). We tracked fish from a flat-bottom 4.8 m outboard motor Carolina Skiff outfitted with a hydrophone bracket mount. We tracked fish using a Vemco VR100 acoustic receiver that logged the location coordinates, time, frequency, signal strength, gain, and detection interval for each signal detected belonging to the preset frequencies. Approximately every ten minutes the tracker drove the boat slowly in the direction of the signal until the highest possible signal was detected and the detection strength was high from all directions. When the highest signal was achieved the tracker or an additional data recorder logged the time, coordinates, signal strength, compass heading, and depth. We generally only recorded a location when we could achieve at least 95 dB of signal strength to ensure that we were positioned in close proximity to the tagged fish. We made frequent visual confirmations (sometimes with a snorkeler and sometimes it was possible to see the fish from the boat without entering the water) that the fish was under the boat when signal strength was high, in addition to extensive range testing (see Supplement 1 for range testing methods and results). We also observed fish behavior when the boat was maneuvering overhead and did not perceive behavior that indicated that the fish were reacting to or avoiding the boat.

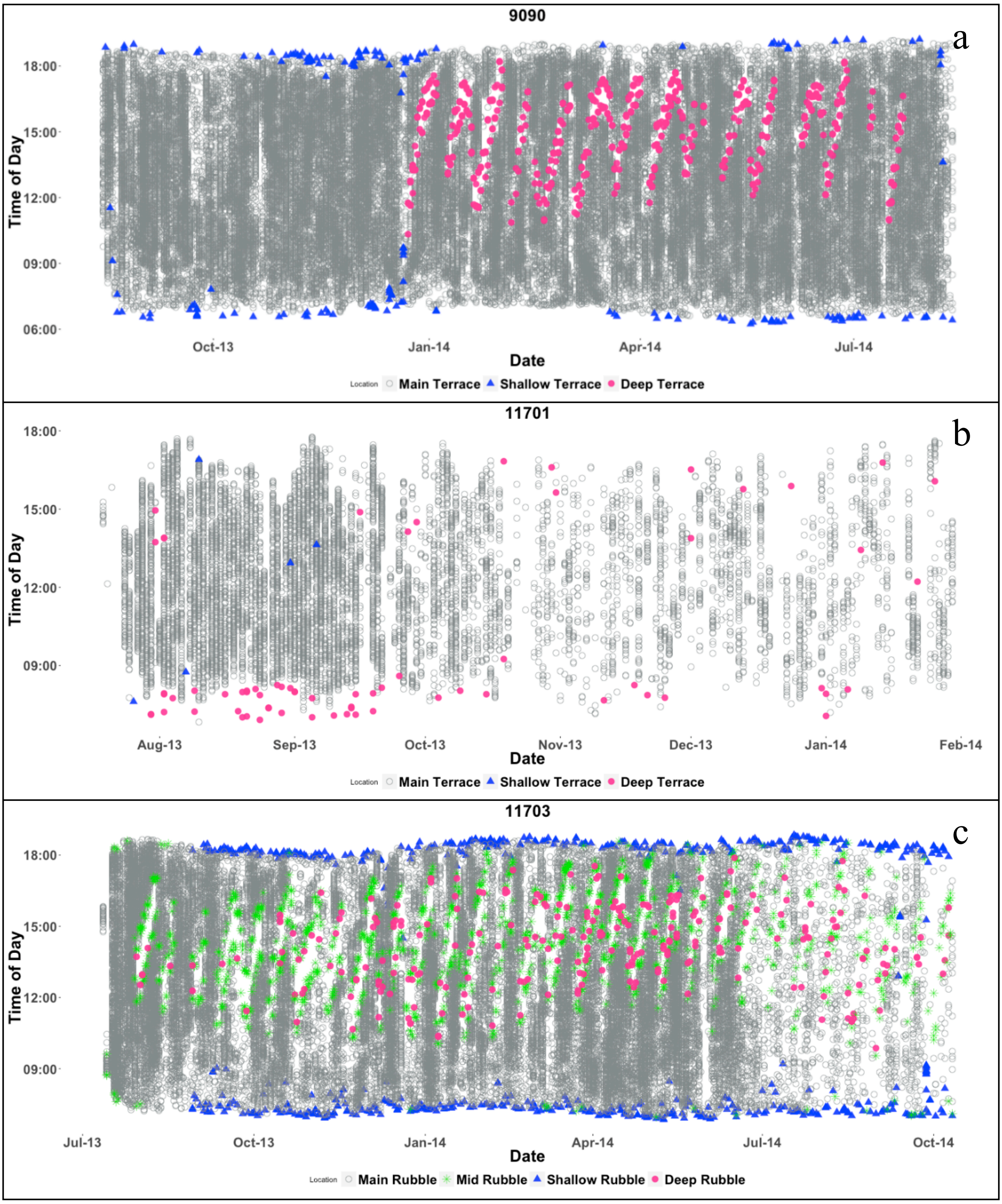
Supplement 4: Discussion of premature transmitter loss

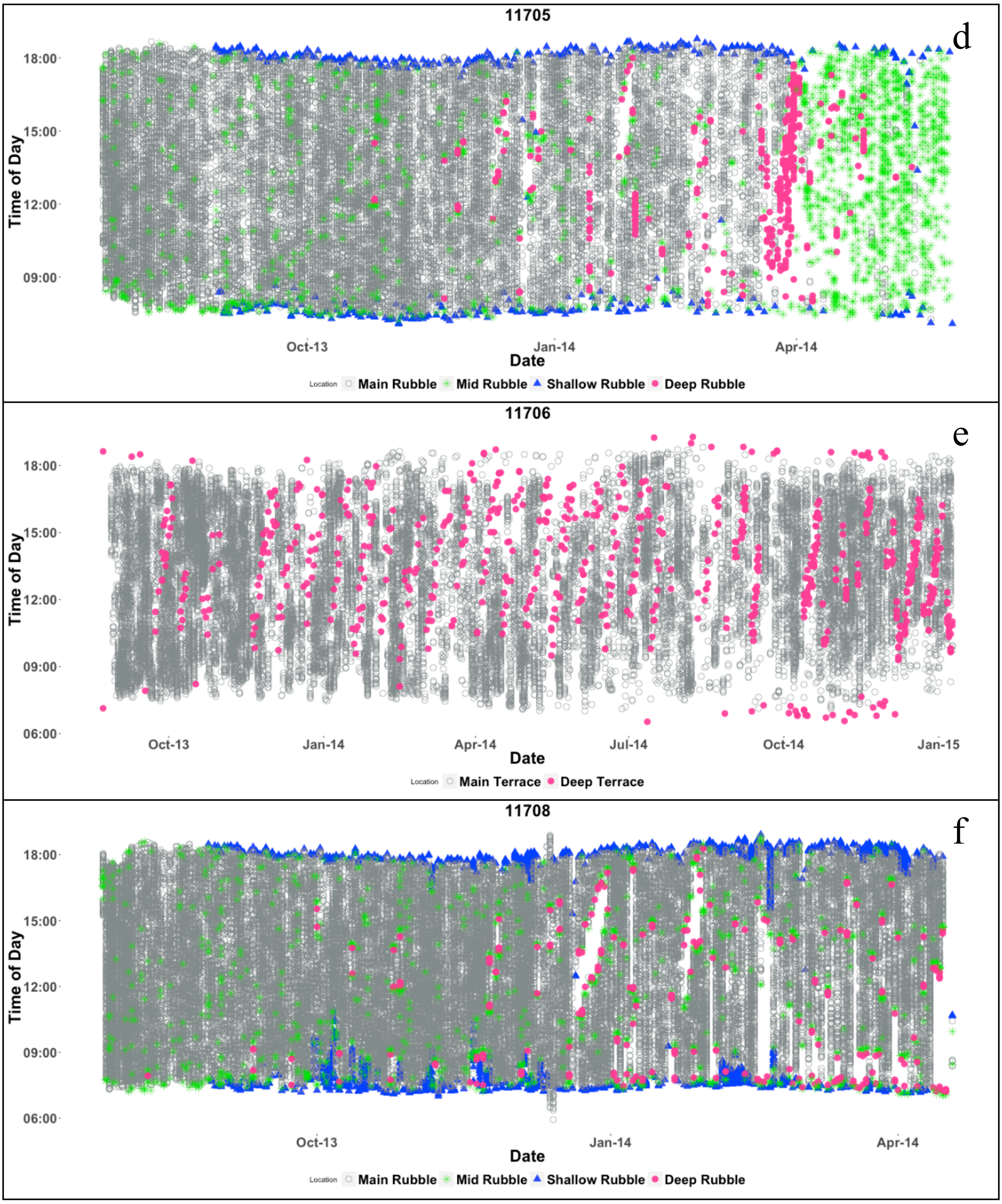
Three scenarios that could have caused tags to stop being detected before the time expected from their estimated transmitter battery life include premature failure/ejection of the transmitter, emigration of the fish from the receiver array, or a mortality event. Transmitter failure is extremely uncommon (C. Lowe, personal observation) and Vemco reports malfunctioning transmitter return rates at less than 1% (Khan et al. 2016). Transmitter ejection is a possibility but we have not seen any reports of ejection from a live fish and our observations of fish several weeks post-tagging showed that tagging scars had all healed and appeared normal. Emigration from the receiver array is a potential explanation for the disappearance of a transmitter, and we did observe home range shifts for some individuals. However, each fish was detected on multiple receivers related to various activities within their home range so the spatial shift would have occurred for all activities in order for the fish to cease getting detected entirely. Therefore, mortality of the tagged fish is the most likely cause of tag disappearance. Because these disappearances happened at least a few months after tagging and we observed all fish to resume normal feeding and social activities after tagging, it is unlikely that tagging induced mortality was occurring. In a large bodied species like *C. microrhinos*, it is likely that predation-induced mortality would be lower than for smaller species, but Palmyra is a predator-heavy system and it is possible that some predation may have occurred.

LITERATURE CITED

Khan, J. A., Welsh, J. Q., & Bellwood, D. R. (2016). Using passive acoustic telemetry to infer mortality events in adult herbivorous coral reef fishes. Coral Reefs, 35:411-420. doi:10.1007/s00338-015-1387-7

Supplement 5: Detection plots and GAMM results for all tagged fish

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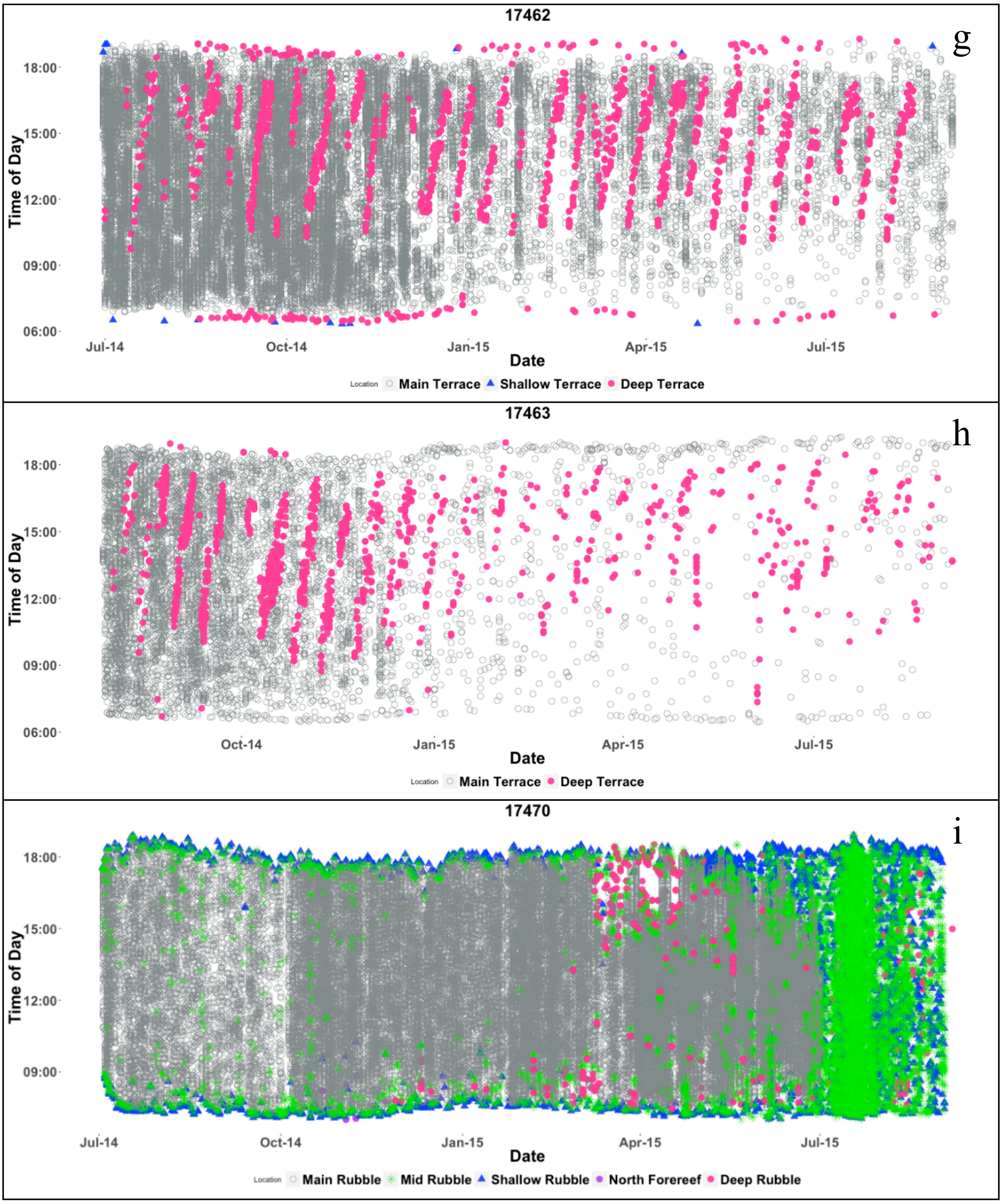

Fig. S2: Raw VR2W detection data from each tagged fish. Each point is a detection logged at that specific date and time on a particular receiver. Colors correspond with the locations of receivers from the maps on Figure 2

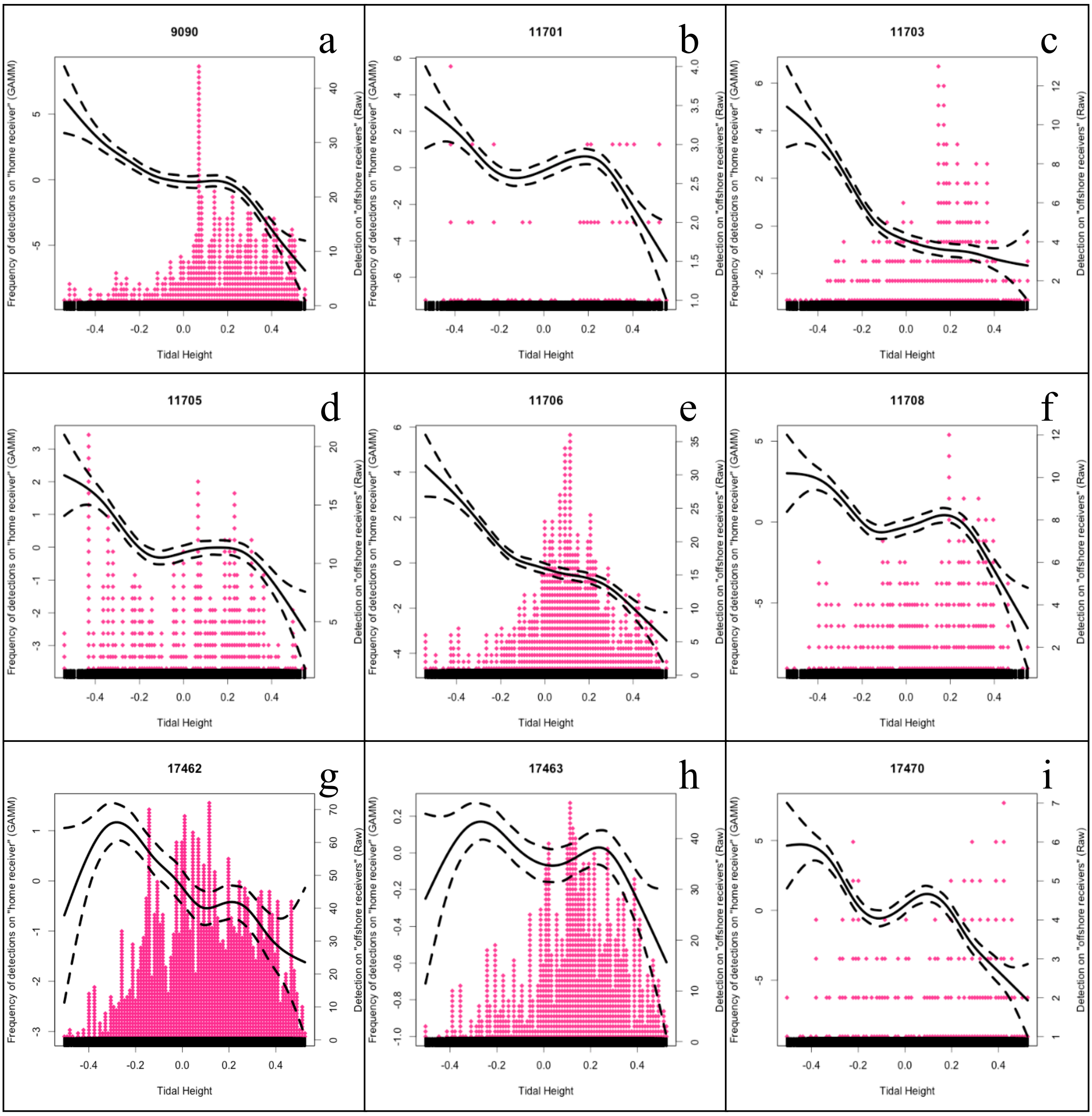

Fig. S3: GAMM results for individual fish. X-axis shows tidal height measured in meters. The left axis and smoothed spline show frequency of detection at home receivers with tidal height. Right axis and raw data overlaid in pink show frequency of detection at offshore receivers. P-values for tidal height GAMM smooth terms and t-test comparing tidal height at offshore detections and null tidal height distributions respectively are as follows: a: < 0.001, < 0.001; b: < 0.001, < 0.001; c: < 0.001, < 0.001; d: < 0.001, 0.0087; e: < 0.001, < 0.001; f: < 0.001, < 0.001; g: < 0.001, < 0.001; h: < 0.001, < 0.001; i: < 0.001, < 0.001. Letters correspond to the letters from the previous figure.

Supplement 6: Aggregations of *Chlorurus microrhinos* on the North Forereef