



Fig. 2: (left) Monitored activity for a single specimen, with the manual samplign and the automated methods. (right) Cross-correlation of the manual (original) method with itself, and the manual method versus the automated methods.

REFERENCES

[1] J. Aguzzi, C. Costa, P.Menesatti, J.A. García and F. Sardà, "Monochromatic blue light entrains diel activity cycles in the Norway lobster, *Nephrops norvegicus* (L.) as measured by automated video-image analysis," *Scientia Marina*, 2009.
 [2] J. Aguzzi, J.B. Company and P. Abelló, "Locomotor activity of continental slope *Nephrops norvegicus* (Decapoda: Nephropidae)," *Journal of Crustacean Biology*, vol. 24(2), pp. 282-290, 2004.
 [3] R. Reffinetti, *Circadian physiology*, 2nd Ed, Taylor & Francis, Boca Raton, FL.
 [4] J. Aguzzi, D. Sarriá, J.A. García, J. del Rio, F. Sardà and A. Manuel, "A new tracking system for the measurement of diel locomotor rhythms in the Norway lobster, *Nephrops norvegicus* (L.),"

Journal of Neuroscience Methods, vol. 173, pp. 215-224, 2008.
 [5] D. Walther, D.R. Edgington and C. Koch, "Detection and tracking of objects in underwater video," in *IEEE International Conference on Computer Vision and Pattern Recognition (CVPR)*, Washington, D.C., 2004.
 [6] D.E. Cline, D.R. Edgington and J. Mariette, "An Automated Visual Event Detection System for Cabled Observatory Video," in *3rd International Conference on Computer Vision Theory and Applications, Funchal, Madeira Portugal, January 2008*
 [7] U. Fayyad, G. Piatetsky-Shapiro and P. Smyth, "From Data Mining to Knowledge Discovery in Databases," *AI Magazine*, vol. 17, pp. 37-54, 1996.

FISH TELEMETRY AND POSITIONING FROM AN AUTONOMOUS UNDERWATER VEHICLE (AUV)

Grothues, Thomas M. and Joseph A. Dobarro
 Institute of Marine and Coastal Sciences, Rutgers University Marine Field Station, 800 c/o 132 Great Bay Blvd. Tucker-
 ton, NJ 08087 USA 609 296-5260 FAX 609 296-1024
 grothues@marine.rutgers.edu

Abstract - We explored telemetry of transmitter tagged fishes from an autonomous underwater vehicle with a hydrophone/ datalogger processing code-division-multiple-access acoustic signals. Geolocation estimates used synthetic aperture and relative sound strength mapping. Signal reception patterns from tagged Atlantic sturgeon were similar to that of moored reference tags but those from tagged winter flounder were reduced in range due to burying behavior.
 Keywords-AUV; telemetry; sturgeon; flounder; synthetic aperture; habitat mapping

I. INTRODUCTION

Autonomous underwater vehicles (AUVs) are attractive as a complement or alternative to surface vessels for mobile telemetry of marine macrofauna. Robots, in general, excel at deep or tedious missions such as tracking fish in continental shelf waters. AUVs in particular can simultaneously and continuously sample hydrography and benthic sidescan data for habitat delineation at depths relevant to the animals under study. Freedom from a cable allows signal reception and processing at depth, below interfering thermoclines, without line-associated signal attenuation or vehicle pitch. However, AUV users are challenged by a lack of real-time data for en-route decision making and potential conflicts in choos-

ing paths for best sampling of different variables. We explored the signal reception patterns of an AUV telemetering moored reference transmitters and two species of fish to develop bounds of expectation useful for mission planning and data interpretation.

II. METHODS

The Remote Environmental Measuring Units (REMUS-100, Hydroid Inc.) is an autonomous, propeller-driven AUV. The 36 kg (1.6 m length by 0.19 m diameter) vehicle hosts a conductivity/temperature/depth sensor (CTD, Yellow Springs Instruments), a rapid response oxygen optode (Aanderaa Data Instruments), port and starboard sidescan sonar (Marine Sonic Technology, Ltd.) and upward and downward looking acoustic current Doppler profilers (ADCPs, Teledyne RD Instruments) [1].
 REMUS follows a user programmed path. Navigation may apply dead-reckoning, transponder-based trilateration, calibrated by global positioning satellite (GPS) fixes. Ballast is static. Depth and trim is achieved dynamically by control surfaces. REMUS has an endurance of 14 h at 1.5 m/s velocity or approximately 9 h at 2 m/s. It may thus supply a near-synoptic view of mesoscale hydrography [2]. REMUS AUVs are deployed worldwide in various scientific and naval mis-

sions, including under ice.

A hydrophone/processor (WHS_3050, Lotek Wireless, Inc., St. Johns, Canada) was mounted coaxially with the vehicle in place of its nose cone. The package was minimally modified from its intended use as a moored wireless system by removing the battery case and drawing power from the AUV's guest port. Hydrophone and AUV clocks are synchronized before launch. The processor is capable of discerning 80,000 individual coded acoustic (76 kHz) tags using code-division multiple access (CDMA). CDMA is robust against interference from motorized platform noise, echo from ice or reef, or code collision from multiple tags. Therefore, it is not necessary to stagger or vary signal bursts rates within or among tags. Accurate and invariant signal burst timing is a requisite for synthetic aperture geolocation where the transmitter and receiver are not collocated as a transceiver [3, 4]. Signal burst intervals are programmable. Tags may carry and transmit data from optional temperature, pressure, and motion sensors. Detected signals are stored with a time stamp and a value of relative received strength (RSS) and married with location, depth, speed, heading, sound speed, salinity, temperature, depth, flow, oxygen concentration and percent saturation, suspended materials backscatter, and sidescan images in post processing. Nominal power requirements of the WHS represent only 0.5 % of the AUV's 1 kWh battery budget over a 9 hr mission. The channel does not overlap with the operating frequencies of optional long-base-line navigation transducers (20-30 kHz), sidescan (600 kHz), or ADCP (300 and 1200 kHz).

We compiled data on receiver-tag coupling from twelve missions following sinusoidal paths in riverine, estuarine, and coastal ocean environments. Stationary reference tags were deployed as controls in all included missions. Additionally, tagged Atlantic sturgeon (*Acipenser oxyrinchus*) and winter flounder (*Pseudopleuronectes americanus*) were at liberty in the study areas during three and two missions respectively.

III. RESULTS

The AUV-mounted hydrophone detected moored acoustic tags as well as those on fish at liberty. The distance and power with which tags were detected varied with environment and fish behavior. In the Hudson River, the AUV detected tags in excess of 2 km distant. Thus, signals from individual tags were detected during multiple path legs (AUV headings), allowing for creation of synthetic arrays that could calculate position estimates. However, location was determined with greater precision for stationary tags than sturgeon there, because the large fish (~2 m length) could move significant distances during array creation. Winter flounder were detected from smaller distances than reference tags and fewer times per pass. However, power was as high for these tags as for reference tags. This is consistent with flounder being buried, during which sound is occluded to the side by sediment more than overhead. In this situation, the tags were less often detected during at least two adjacent path segments (new headings) and appropriate synthetic arrays could not be constructed for all individuals. RSS mapping was useful for estimating flounder position along a single vector and location estimates from RSS maps always compared favorably with synthetic aperture solutions.

Reference tags were detected at all bearings relative to the AUV's heading.

Bearing had no effect on RSS. However, tags were more frequently detected as the vehicle approached, rather than departed from reference tag locations. Hydrography and bathymetry data was collected during all missions. Sidescan echograms showed seventy nine additional (untagged) Atlantic sturgeon and numerous unidentified fishes, but winter flounder were not imaged [5].

IV. CONCLUSIONS

This demonstrates that an AUV can simultaneously telemeter tagged fish distribution and survey hydrographic and benthic habitat parameters. The use of AUVs to map individual fish movement relative to dynamic habitat features is especially promising for the continental shelf because of the expense and challenges of placing and maintaining instruments there on scales germane to mesoscale questions. The time-invariant coding structure made synthetic aperture possible and proved to be robust to noise and interference that could typify some niche applications for this tool. The success of this simple bolt on makes it worthwhile to explore more complex models, such as integrating of the hydrophone's circuitry with the AUV's. That would lower the system's mass and wetted area, allow different hydrophone orientations, and would facilitate direct communication and a single clock. This, in turn, would allow for reactive navigation (maneuvers cued by data events). Until then, paths must compromise between the detection range of the hydrophone for its transmitting tags, the spatial resolution being sought for fish positions, the suite of possible behaviors exhibited by the tagged fish in response to parameters under study, the resolution of the hydrographic features of interest, and the useful AUV battery life/mission length. Mission parameters must therefore include the size and shape of the search area, the path of the vehicle inside that area, including the spacing and shape of search line, the vehicle speed, and the vertical profile of the path. While these may seem to be a daunting list of requirements, they do not differ from those conducted by a manned surface vessel, and may be conducted in complement to such an operation.

REFERENCES

- [1] Allen, B., R. Stockey, T. Austin, N. Forrester, R. Goldsborough, M. Purcell, and C. von Alt. 1998. *REMUS: A small low cost AUV; system description, field trials and performance results*. Proc. Oceans '97, Halifax, Canada
- [2] ACT Alliance for Coastal Technology 2004. *Mobile sensor platforms: Management applications for AUVs and Gliders in the nearshore environment*. UMCES Technical Report Series TS-453-04-CBL / Ref. No. [UMCES] CBL 04-117
- [3] Niezgodna, G., M. Benfield, M. Sisak, and P. Anson. 2002. *Tracking acoustic transmitters by code division multiple access (CDMA)-based telemetry*. J. Hydrobiol. 483: 275-286
- [4] Nielsen, J. K., G. H. Niezgodna, S. J. Taggart, S. J. Cooke, P. Anson, C. T. Hasler, et al. *In press*. *Mobile positioning of tagged aquatic animals using acoustic telemetry with a synthetic hydrophone array (SYNAPS: Synthetic Aperture Positioning System) in Advances in fish tagging and marking techniques*, American Fisheries Society.
- [5] Grothues, T. M., J. Dobarro, A. Higgs, J. Ladd, G. Niezgodna, D. Miller. *In press*. *Use of a multi-sensored AUV to telemeter tagged Atlantic sturgeon and map their spawning habitat in the Hudson River, USA*. *Proceedings of the 2008 Autonomous Underwater Vehicle (AUV) workshop*. Woods Hole Oceanographic Institute, Woods Hole, Massachusetts

BE A PART OF THE TEAM

watch the video of OBSEA deployment at Martech 2009

