A hydrodynamic acoustic recording tag for small cetaceans and first results from a pantropical spotted dolphin

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WHY CARE ABOUT HYDRODYNAMICS?

Attachment stability	Hydrodynamic tags should enjoy reduced tag migration.
Attachment duration	Hydrodynamic tags should enjoy longer attachment life.
Effect on subject	Hydrodynamic tags should mitigate subject discomfort.
Accelerometry	Hydrodynamic tags should be less susceptible to wobble that could contaminate accelerometer records.
Acoustic Recording	Acoustic recordings by hydrodynamic tags should suffer less flow noise, improving signal-to-noise at low frequencies.

WHAT MAKES A TAG HYDRODYNAMIC?

- **LOW PROFILE**
- **TEARDROP SHAPE**
- **SELF-ALIGNMENT WITH FLOW** (or minimal increase in drag with off-axis flow)

These are not especially hydrodynamic tags:

This tag has a medium profile (6.6 cm / 2.6 in), and being long (36 cm / 14.1 in) and unlikely to self-align with the flow it will suffer an increase in drag and flow noise when located off-axis to the flow as pictured here.

Acousonde 3A acoustic recording tag on short-finned pilot whale, Kona, Hawaii, May 2011. *Photo by R. Baird.*

This tag has a high profile, and its box shape is as far from a teardrop as one can get. Shown with a northern elephant seal (*Burgess et al.*, 1998)

Compact Acoustic Probe acoustic recording tag on northern elephant seal, Año Nuevo, California, May 1995. *Photo by W. Burgess.*

ABSTRACT

Thorough mechanical reconfiguration of the Acousonde, an acoustic and kinematic recording tag, has enabled its application to small cetaceans. Reconfiguration emphasized hydrodynamics and size reduction by unifying electronics, flotation and suction cups in an integrated low-profile design. Development culminated in the Acousonde 3B, a streamlined package with 22.4 cm body length and weighing under 360 g fully assembled. The Acousonde 3B adds a few capabilities beyond those of the cylindrical Acousonde 3A introduced in 2009, such as light sensing and a retrieval strobe. The two designs' electronics remain otherwise nearly identical, with both a low-power and, optionally, a high-frequency hydrophone; 3D accelerometer; 3D compass; tag temperature; and depth. The first deployment of the Acousonde 3B took place on 11 May 2011 on a pantropical spotted dolphin (*Stenella attenuata*) off the west coast of the Island of Hawai`i, with recovery two days later. The depth record indicates the tag's suction cups remained attached for 12 hours, 18 minutes. The tag gathered acoustic data from its high-frequency hydrophone at a 116 kHz sample rate until its primary storage card filled, yielding an 8 hour 22 minute sound record in addition to 50 minutes pre-deployment. Auxiliary data consisted of dive depth and tag temperature sampled at 10 Hz, and 3D tilt and 3D compass sampled at 20 Hz, gathered continuously until the tag was manually stopped after recovery. The acoustic data show abundant whistles and clicks, some possibly emitted by the subject based on relative strength and/or regular echo signatures, as well as noise from fishing activity taking place amidst the subject's group. *[Work supported by ONR]*

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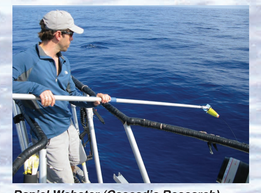
FIRST DEPLOYMENT



Daniel Webster (Cascadia Research) prepares to apply the Acousonde 3B. *Photo by W. Burgess.*

The first deployment of the Acousonde 3B took place 11 May 2011 off Kona, Hawaii.

The tag's suction cups were placed onto the side of a bowriding animal with direct pressure via a deployment pole.

The first successful attachment lasted 12 h 18 m according to the dive record.

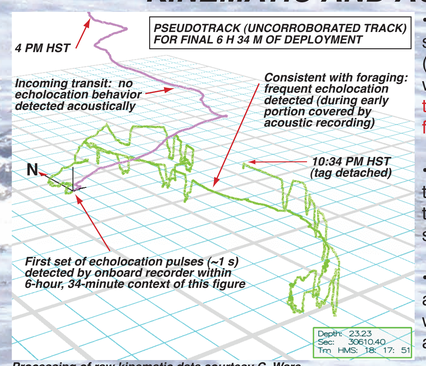
Attachment (10:16:10 HST). *Photo by J. Aschettino.*

84 s after attachment. *The tag has self-aligned with the flow direction. Photo by J. Aschettino.*

6 m 10 s after attachment. *Photo by R. Baird.*

3 h 21 m after attachment (13:37:40 HST). *No tag migration is evident. Photo by A. Douglas.*

KINEMATIC AND ACOUSTIC DATA



Processing of raw kinematic data courtesy C. Ware.

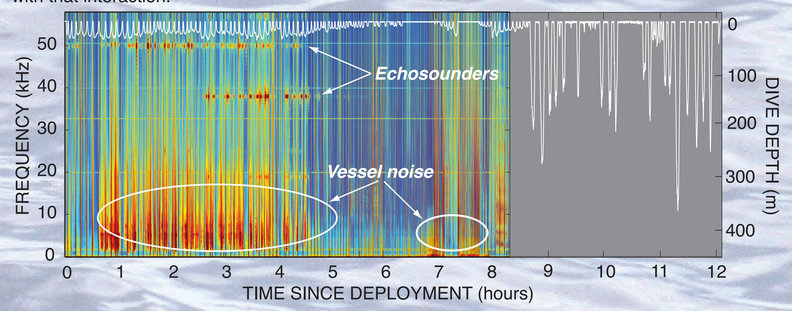
• 3D compass, 3D tilt, and pressure sensors sufficed to reconstruct a pseudotrack (uncorroborated track) using *TrackPlot* software (*Ware et al.*, 2006). (Dr. Colin Ware, the designer of TrackPlot, speaks at this conference Tuesday morning 29 November.)

•The 3D crosshairs indicate position at the time of the first strong echolocation pulse trains recorded onboard during the period shown, 8 hours into the deployment.

•The beginning of echolocation coincides with a qualitative shift in kinematic behavior from what appears to be transiting (purple) to what appears to be foraging (green).

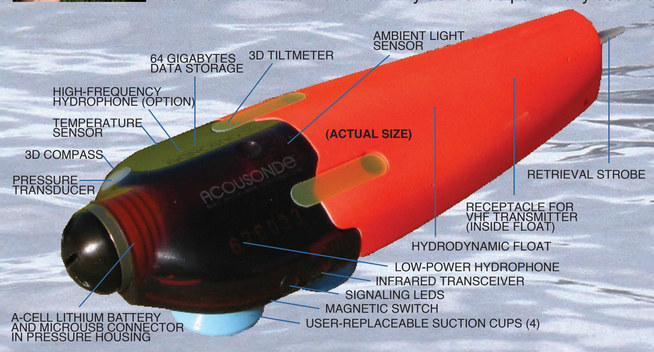
• Acoustic data sampled at 116 kHz sample rate, with high-pass "pre-whitening" filter at 10 kHz.
• Acoustic storage filled 8.3 hours into the deployment (kinematic data acquisition continued).
• Signals strong between 2 and 20 kHz correspond to nearby vessel activity.
• Narrowband signals at ~50 and ~38 kHz consistent with depth echosounder activity.

The subject belonged to a group that experienced protracted interaction with multiple small fishing vessels during our time of visual contact. Dominance of vessel-related noise is consistent with that interaction.



THE ACOUSONDE™ 3B: A HYDRODYNAMIC ACOUSTIC RECORDING TAG

The Acousonde™ 3B is a self-contained underwater acoustic recorder comprising one or, optionally, two hydrophones, sensors for attitude, orientation, depth and temperature, a digital recorder, and a field-replaceable battery. Attached to an animal subject, the Acousonde measures the subject's sound environment and vocalization activity as well as potentially associated behavior.



LENGTH: 22.4 cm (8.8 in) *not including strobe or VHF transmitter* WEIGHT IN AIR: 360 g (12.7 oz) *with battery and VHF transmitter*

SPECIFICATIONS, ACOUSONDE 3B UNDERWATER ACOUSTIC RECORDER

Maximum operating depth (fixed build option)	500 m (-500m suffix) / 1000 m (-1km) / 2000 m (-2km) / 3000 m (-3km)
Maximum continuous acoustic sampling rate	232 kHz
Anti-alias filter, low-power channel	8-pole elliptic, adjustable (automatic) up to 9.2 kHz maximum
Anti-alias filter, high-frequency channel	6-pole linear phase, fixed
3-dB anti-alias cutoff	9.2 kHz (low-power channel max.), 42 kHz (high-frequency channel)
22-dB anti-alias cutoff	11.1 kHz (low-power channel max.), 100 kHz (high-frequency channel)
3-dB high-pass cutoff	22 Hz (low-power channel), 10 kHz (high-frequency channel)
Unamplified hydrophone sensitivity, re 1 V/µPa	-201 dB (low-power channel) & -204 dB (high-frequency channel)
Saturation at 0-dB gain, re 1 µPa zero-peak	187 dB (low-power channel) & 172 dB (high-frequency channel)
Acoustic gains, selectable at deployment	0 or +20 dB
Acoustic sampling resolution	16 bits
Auxiliary sampling rate	Deployment-time choices ranging from 40 Hz to once every 5 s
Auxiliary sampling resolution	16 bits (except 10 bits for tilt)
Auxiliary sampling channels	Depth (pressure), internal temperature, 3D tilt, 3D compass, ambient light level
Total storage capacity (primary & spare)	64 gigabytes (*battery should support at least 8 gigabytes acquisition*)
Life at 2 kHz acoustic sampling rate	23 days (*assuming minimum expected battery longevity*)
Maximum measured data download rate	490 kilobytes/s, via MicroUSB connector

Firmware support for some specifications, performance and/or functionality may be pending; see current release notes. Data subject to change without notice.

HOME PAGE http://www.acousonde.com
E-MAIL info@acousonde.com

The Acousonde™ is made by Acoustimetrics, a brand of Greeneridge Sciences, Inc.

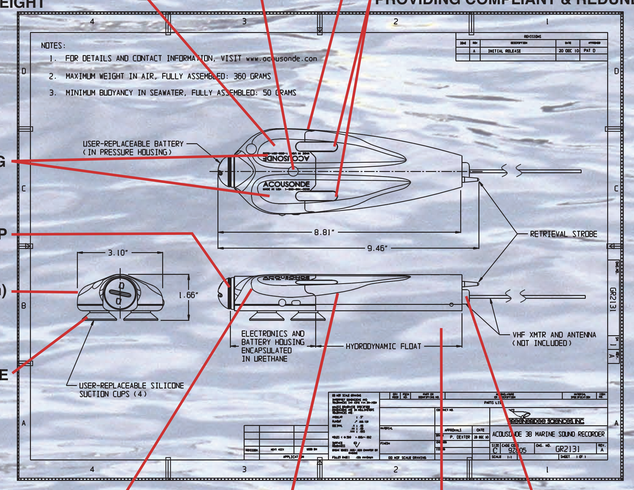
ACOUSONDE™ 3B KEY MECHANICAL DESIGN ELEMENTS

LOCATING "DIVOT" FOR ALIGNING DEPLOYMENT GRIP OVER TAG'S STRONGEST MECHANICAL REGION

INSTRUMENT PACKAGE AND FLOAT DESIGNED TOGETHER FOR COMBINED HYDRODYNAMIC SHAPE

COMPRESSED COMPONENT PLACEMENT MINIMIZES SIZE AND WEIGHT

TWO URETHANE POSTS ON INSTRUMENT PACKAGE SECURE BRITTLE FLOAT MATERIAL, PROVIDING COMPLIANT & REDUNDANT ATTACHMENT



HYDROPHONES PLACED FAR FORWARD TO MINIMIZE FLOW NOISE FROM VORTEX SHEDDING

HYDRODYNAMIC BATTERY CAP

LOW PROFILE (1.66 in / 4.2 cm)

CUSTOM SUCTION CUPS AND CUP MOUNT FLANGES MINIMIZE PROFILE AND STANDOFF DISTANCE

WEIGHT OF BATTERY HOUSING LOCATED OPPOSITE FROM FLOAT TO MAXIMIZE RIGHTING MOMENT WHEN DETACHED FROM THE SUBJECT

FLOAT MATES WITH OFF-THE-SHELF VHF TRANSMITTER

FLOAT MAXIMIZES DISTANCE BETWEEN VHF XMTR AND SENSITIVE ELECTRONCS TO REDUCE POTENTIAL FOR RADIO-FREQUENCY INTERFERENCE

CANTILEVERED FLOAT ENCOURAGES SELF-ALIGNMENT WITH FLOW

CONCLUSIONS

- An acoustic recording tag has been especially designed for hydrodynamics.
- On its first successful deployment the tag held well to a small cetacean, remaining attached for 12 h 18 m.
- Kinematic sensors yielded data that appeared to export well to kinematic analysis software (*TrackPlot*).
- Acoustic levels above and below 10 kHz were balanced; the prewhitening filter on the HF channel is OK.

REFERENCES

Burgess, W.C., P.L. Tyack, B.J. Le Boeuf, and D.P. Costa. 1998. A programmable acoustic recording tag and first results from free-ranging northern elephant seals. Deep- Sea Res. Part II 45, *1327–1351.*

Ware, C., R. Arsenault, M. Plumlee, and D. Wiley. 2006. Visualizing the underwater behavior of humpback whales, IEEE Computer Graphics and Applications 26(4), *14– 18.*

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