

Automated Detection and Classification of Beaked Whale Buzzes using Bottom-mounted Hydrophones





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Range (m):567







### > Overview of Buzz Classification within M3R

- > Buzzes in the context of foraging dive
- > Challenges of buzz detection by widely spaced hyds
- Some recent results
- > What's next ...

## Classification of Odontocetes by M3R





#### M3R: Marine Mammal Monitoring on Navy Ranges

Real-time *Detection*, *Localization* and *Classification* on Navy's 3 major undersea ranges -- AUTEC (Bahamas), SCORE (California), PMRF (Kauaii, Hawaii) <sup>3</sup>



## **Classification within M3R**



- >> The Class-Specific Support Vector Machine (CS-SVM)
  - -- Each SVM differentiates between class and ambient noise
  - -- Total of 8 classes have been developed for *odontocete clicks*
  - -- Classes, training sets, thresholds now range specific
  - >> Currently running 4 Classes at AUTEC & PMRF
    - -- Blainville's beaked whale (*Md*), Cuvier's beaked whale (*Zc*), Sperm whale (*Pm*), generic dolphin (*DF*)

#### >> And 3 Classes at SCORE

- -- Cuvier's (*Zc*), Sperm whale (*Pm*), generic dolphin (*DF*)
- >> Using times between successive zero-crossings about peak and inter-click interval (ICI) as features
- >> Classifying *each click* as detected (then post processing)
- >> Separate CS-SVM for buzzes!





## *Md*, *Zc*, *Pm* & others emit nearly continuous streams of clicks during foraging dives



--> Vocal periods during dives last several 10s of minutes

--> Inter-click interval (ICI) species dependent (~0.32 s, ~0.5 s, 0.7+s)

--> Md, Zc appear to sweep head in scanning motion

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Foraging Click Trains & Buzzes



#### *Md*, *Zc*, *Pm* & others emit bouts of very rapid clicking just prior to prey capture attempt $\rightarrow$ Called *Buzz* (for *Md* and *Zc*)







## >> Structure of buzz click is different from forage click >> Buzz ICI is <u>much</u> faster (and often accelerates)









#### Some ground rules ...

- -- Buzzes have significantly lower SL than foraging clicks
- -- Buzzes like foraging clicks appear to be highly directional >> Ensonify 1 hyd at a time, *if we're lucky!*
- -- <u>Must</u> lower detection thresholds to see them
- -- Buzzes only occur in the context of a foraging dive

### Our approach ...

- -- Buzz Classifier is its own class
- -- Buzz Classifier runs alone in its own process
- -- Buzz Classifier is launched by multi-class CS-SVM only when *Md* or *Zc* forage train detected >> 80% of clicks in last 20 seconds are *Md* or *Zc*
- -- Buzz Classifier process dies automatically after 30 min >> 30 minutes is approximate vocal period of dive



## Examples of In-Situ Performance of CS-SVM Classifier







## Examples of In-Situ Performance of CS-SVM Classifier



CS-SVM Results: spc-20140708-075245-5&6-H64 -- Day 189 17:45:54 to 19:12:54Z



AUTEC Jul 2014



## Examples of In-Situ Performance of CS-SVM Classifier



CS-SVM Results: spc-20140708-075245-10-H4 -- Day 189 21:30:10 to 22:19:36Z Dolphin 00 Sa Class Number Pm Gq Gm Md Buzz Automatically detected Zc buzz Zc Md buzz Md 1030 1025 1026 1027 1028 1029 1031 1032 1033 1034 Time (sec)

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## What Do We REALLY Want from an Automated Classifier?



Is it necessary to detect/classify *every* click? >> Often only really care about presence/absence

Want to reliably detect dive events (density estimation cues) -- including start and stop times

Want to detect buzz events (PCoD cues?)

-- does not require detecting *every* click

#### This requires **<u>Post-Processing</u>** of classifier outputs

- -- heuristic rules for i.d. of foraging trains, buzzes
- -- association of detections across multiple sensors







Day: 267 01:00:00Z JessILIR-267-cs-svm-tf0-0005-mod-buzz-clkTrains.mat -- Hyds 4 1 3 5 7 2 6



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## **Post-processing of CS-SVM Outputs**



Day: 267 01:00:00Z JessILIR-267-cs-svm-tf0-0005-mod-buzz-clkTrains.mat -- Hyds 4 1 3 5 7 2 6





## Buzz Detection at AUTEC



- >> Ran CS-SVM (with updated thresholds) on dive from 23 Sep 2008
  >> 37 buzzes automatically recognized by post processing, manual review of time series identified 39 buzzes
- >> Trying to correlate buzz times with animal motion from high precision tracks [Baggenstoss, 2014] form same dive (3 vocal animals present)

\*Plot courtesy of Jess Shaffer & Paul Baggenstoss and the GROUPAM Project. (See Tiago Marques' presentation for the details!)



X-Y (color is depth)



## **Buzz Detection at AUTEC**



# >> Reviewed CS-SVM archives over 48 hours 8-10 July 2014 >> Post-processed associating detections across 7 hyd arrays >> 71 dives with buzzes detections with avg 3.6 buzzes/dive (high 13)

	Α	В	С	D	E	F	G	Н	1
1	Day	Dive #	Num. Buzzes	Start Hr (Z)	Hyds	Dive Strt (sec)	Dive Stop (sec)	Buzz Start (sec)	Buzz Stop (sec)
2	189			14:00	2,1,4,5,7,3,6	1721	4900		
3					2	3554	4855	4823.797	4824.024
4		1	11		4	1721	3268	1955.155	1955.476
5								2078.403	2078.638
6								2755.517	2755.866
7								2810.741	2812.472
8								2992.968	2993.069
9		2	9			3405	4900	4533.255	4535.187
10								4762.743	4764.843
11					5	1747	2812	2783.206	2783.484
12						3084	4874	4205.137	4207.414
13					7	1756	3572	2161.006	2161.093
14								2301.444	2301.626
15								2742.232	2743.258
16								3012.012	3012.818
17								3476.456	3476.696
18								3616.531	3616.942
19								3692.543	3692.572
20								4411.813	4413.643
21								4588.935	4589.042
22					3	1376	3260	2114.727	2115.06
23									
24	189	3	1	15:00	18,15,17,19,5,22	4211	5959		
25					18			4710.249	4710.656
26									
27	189	4	1	15:00	27,9,12,22,28,11,26	4522	6028		
28					27			5513.026	5513.429
29									







#### Borrow methods from Density Estimation [Marques, 2010] to estimate the **"Abundance of Buzzes"**

$$D = \frac{n_c(1-c)}{K\pi w^2 PTr}$$

where D = density,

 $n_c$  = number of detected cues (buzzes) per time T,

r = cue production rate,

K = number of replicate sensors used,

c =portion of false positives,

P = probability of detection que produced with in distance w

(*w* is the distance beyond which cues are assumed not detected)

#### Still need to fully estimate P, c

Could use r from DTAGs, lit.







#### >> Buzzes are direct evidence of prey capture attempts (i.e. feeding)

- >> M3R CS-SVM classifier can automatically detect buzz clicks in acoustic data received on bottom mounted hydrophones
- >> Unlike foraging clicks, detection of buzz clicks within range hydrophone field not gauranteed,  $P_{det} < 1.0$ 
  - -- Buzz clicks have SL ~15-20 dB lower than foraging clicks
- >> Automatically detected 255 buzzes during 71 dives across AUTEC range over 48 hrs period (pessimistic forage threshold)
  - -- This is Small Fraction of the buzzes produced!
  - -- We are detecting buzzes at SCORE, too
- >> Plan to review M3R archives to count buzzes & develop detection statistics

-- Ground truth against DTAG data also use high precision track data

>> Use DE methods to extrapolate "abundance of buzzes" produced from fraction of buzzes detected







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