Enhanced feature extraction using the Morlet transform on 1 MHz recordings reveals the complex nature of Amazon River dolphin (*Inia geoffrensis*) clicks

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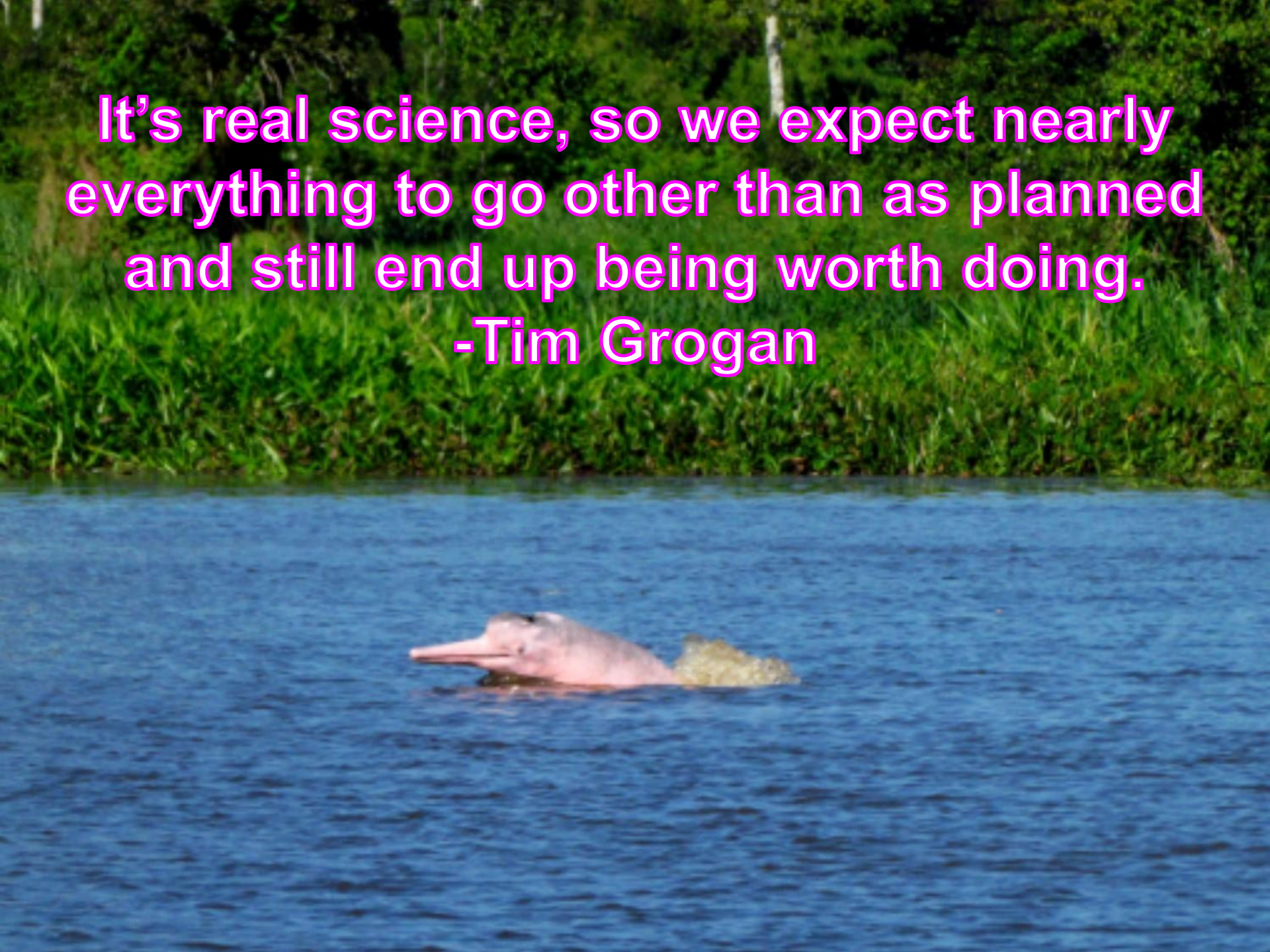
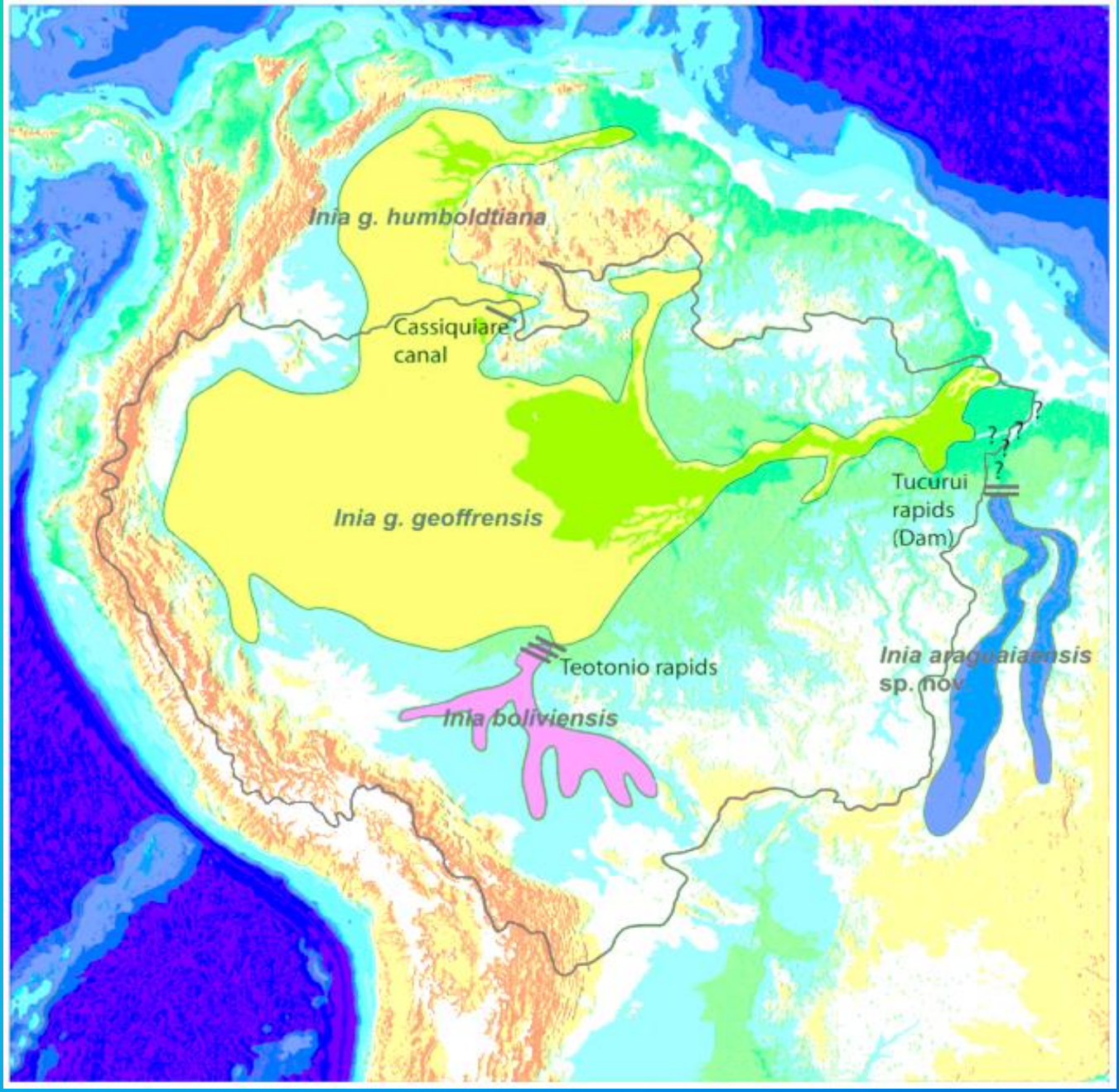
Signal Analyst (Ret.)


It’s real science, so we expect nearly everything to go other than as planned and still end up being worth doing.
-Tim Grogan


Well…
that’s what happened to us


Amazon River dolphin (a.k.a. boto)
(*Inia geoffrensis*)



From: https://en.wikipedia.org/wiki/Amazon_river_dolphin

Piracatinga catfish
exported to Colombia
~1650 dolphins killed / yr. in one area in Brazil

From: Iriarte & Marmontel, 2013


Transecto Lineal
150 m
Transecto en Banda
150 m

But, even in this study 23% (141/611) of *Inia* sightings and 5% (7/133) of *Sotalia* sightings were missed

From: Gomez-Salazar et al, 2012

291 line & 890 strip transects
2,704 linear kilometers

***Inia geoffrensis*: 778**
***Inia boliviensis*: 1,323**
***Inia sp*. 2101**

From: Gomez-Salazar et al, 2012


IUCN lists *Inia* sp. as data deficient
...lacks protection provided by endangered species status


NO FUMAR
PELIGRO COMBUSTIBLE


60

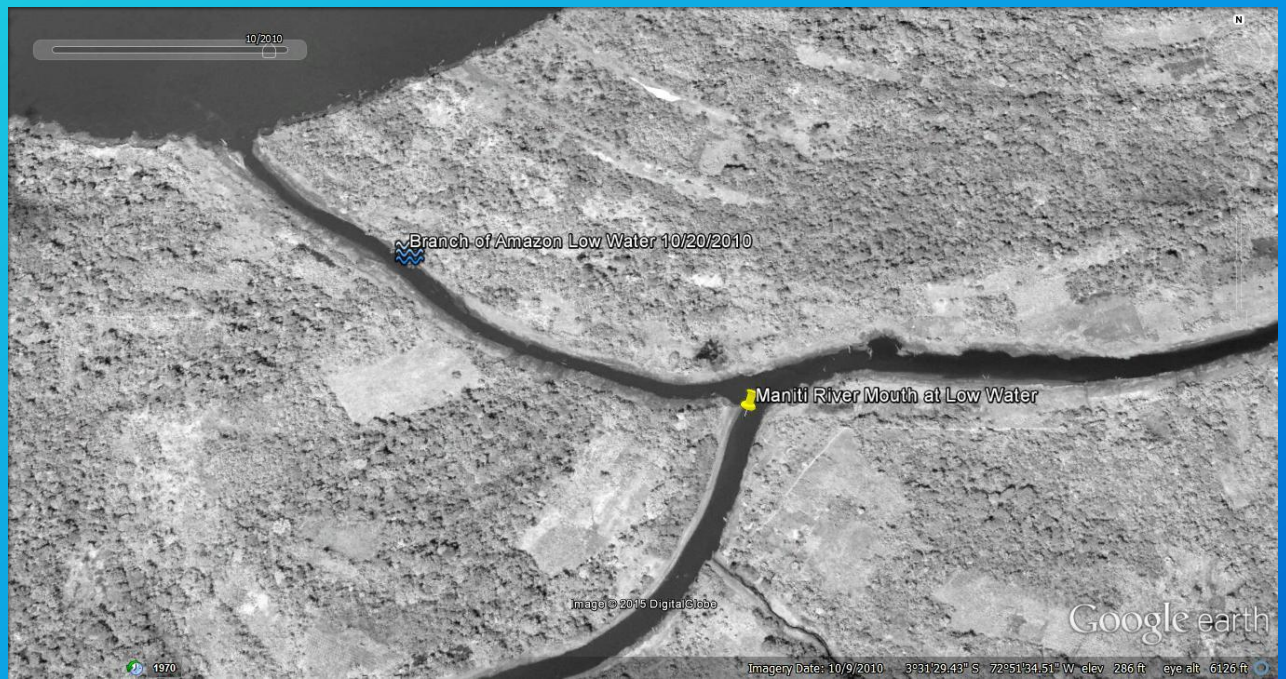

EXPLORAMA
INN
CEIBA TOPS
TOYOTA


AZON QUEEN
051 ME

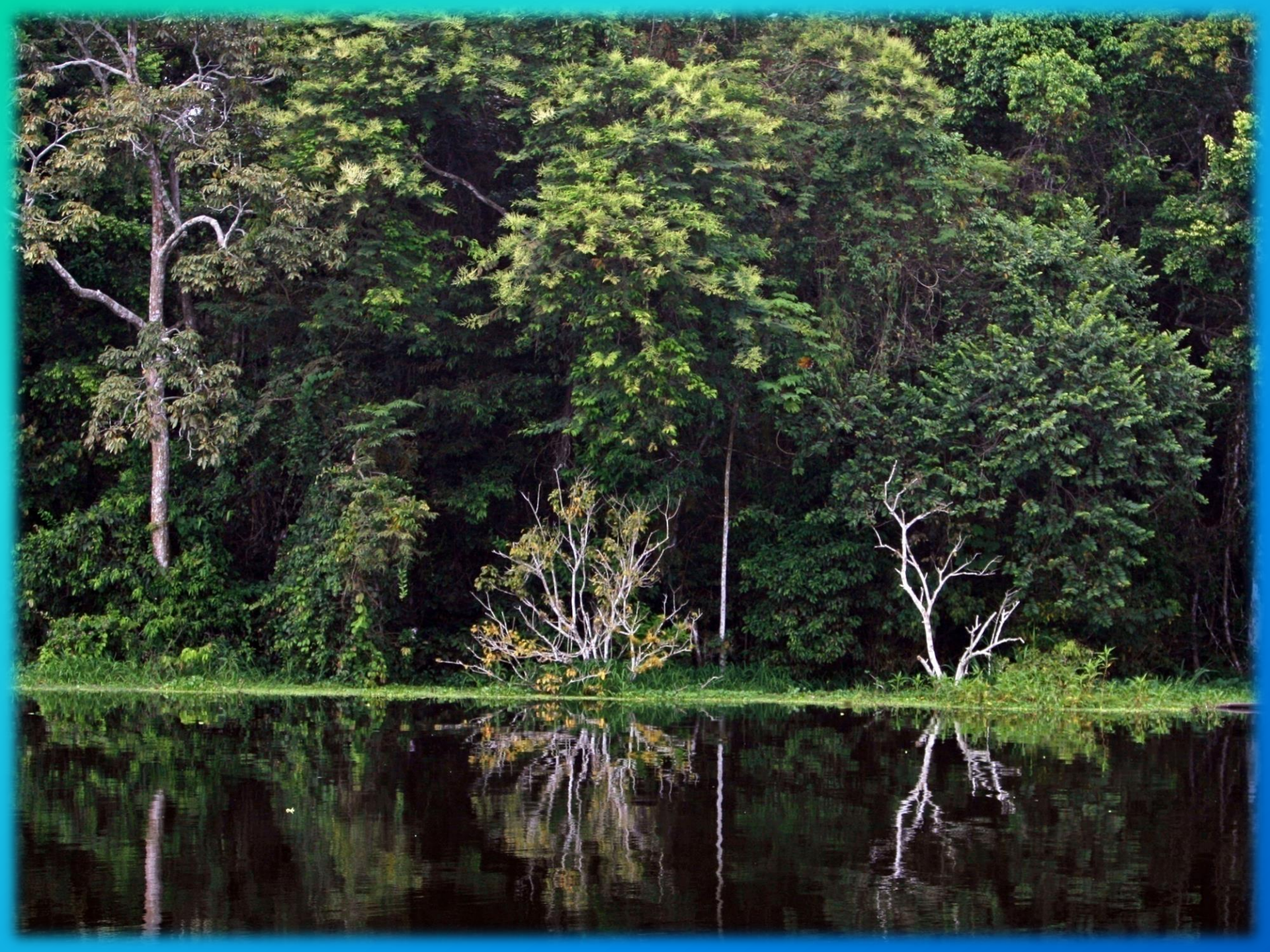

Amazon
Inia Recording Area
Mouth of Maniti River at highwater
Image © 2015 CNES / Astrium
Google earth
03 31.764'S 72 51.539'w

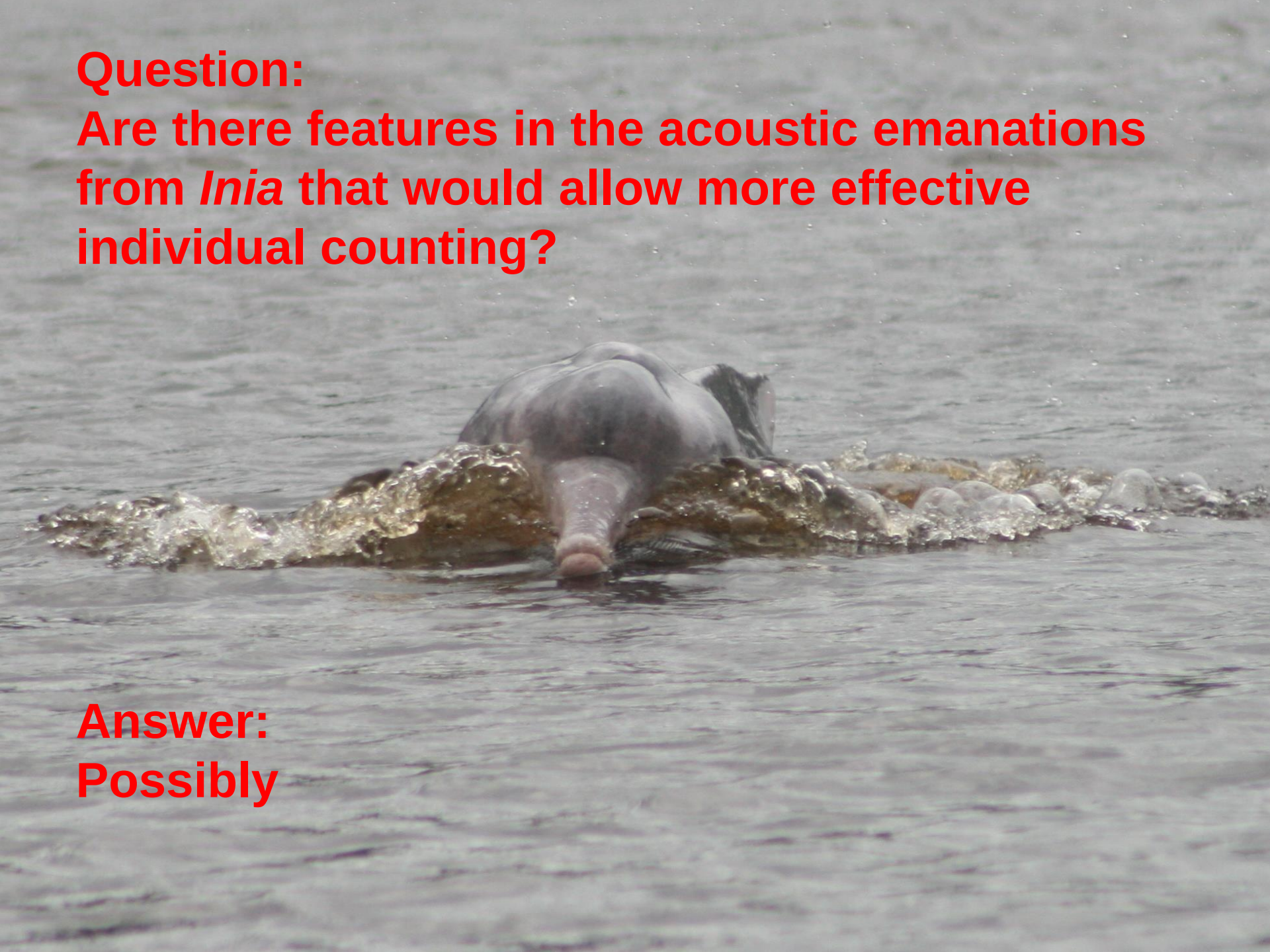

10/2010
Branch of Amazon Low Water 10/20/2010
Maniti River Mouth at Low Water
Image © 2015 DigitalGlobe
Google earth
1970
Imagery Date: 10/9/2010 3°31'29.43" S 72°51'34.51" W elev 286 ft eye alt 6126 ft


Amazon
Inia Recording Area
Mouth of Maniti River at highwater
Image © 2015 CNES / Astrium
03 31.764'S 72 51.539'w
Google earth


10/2010
Branch of Amazon Low Water 10/20/2010
Maniti River Mouth at Low Water
Image © 2015 DigitalGlobe
Google earth
1970
Imagery Date: 10/9/2010 3°31'29.43" S 72°51'34.51" W elev 286 ft eye alt 6126 ft

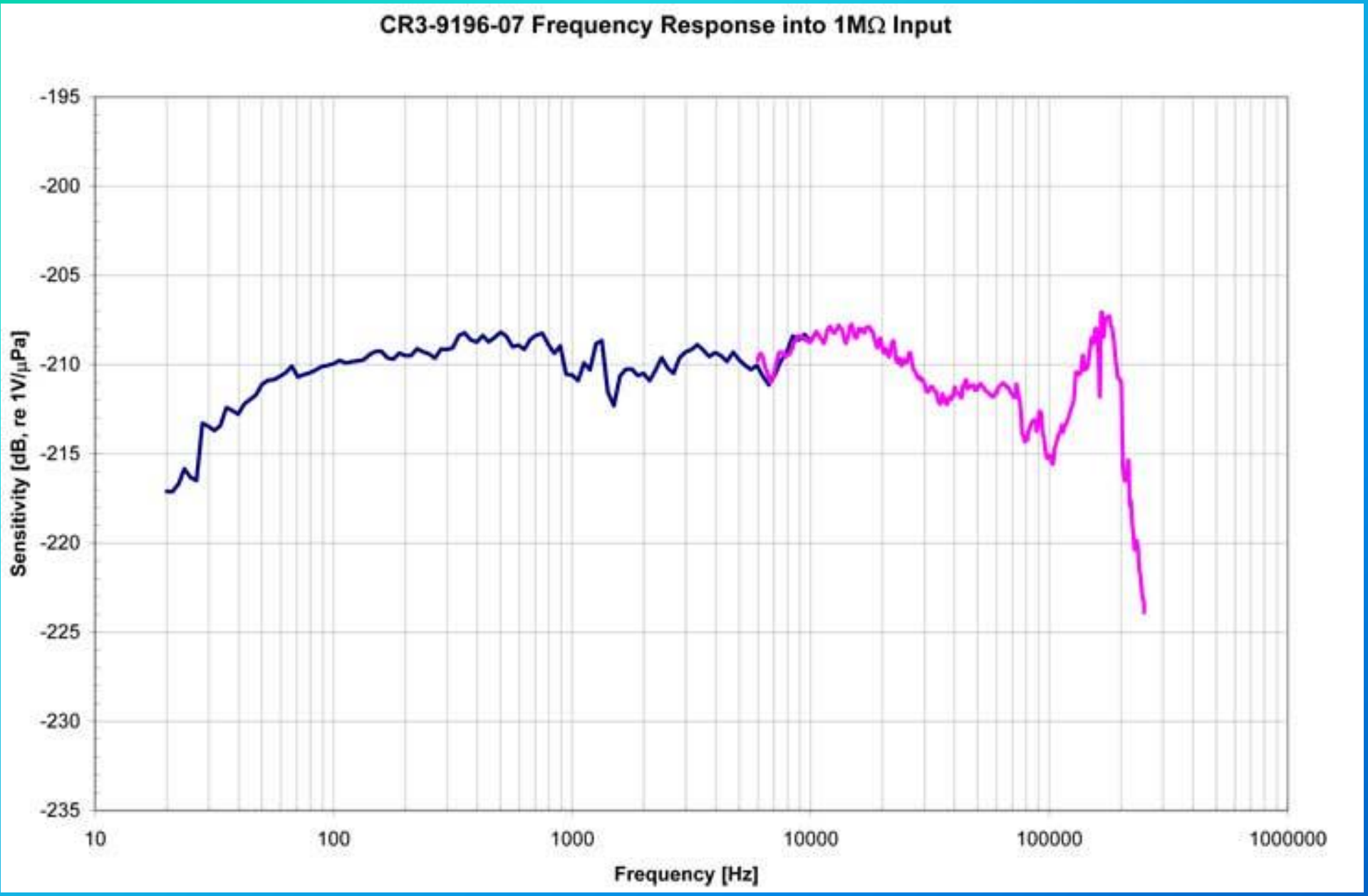

Tahuyao River level dropped 2 Meters in 24 hours, 2007



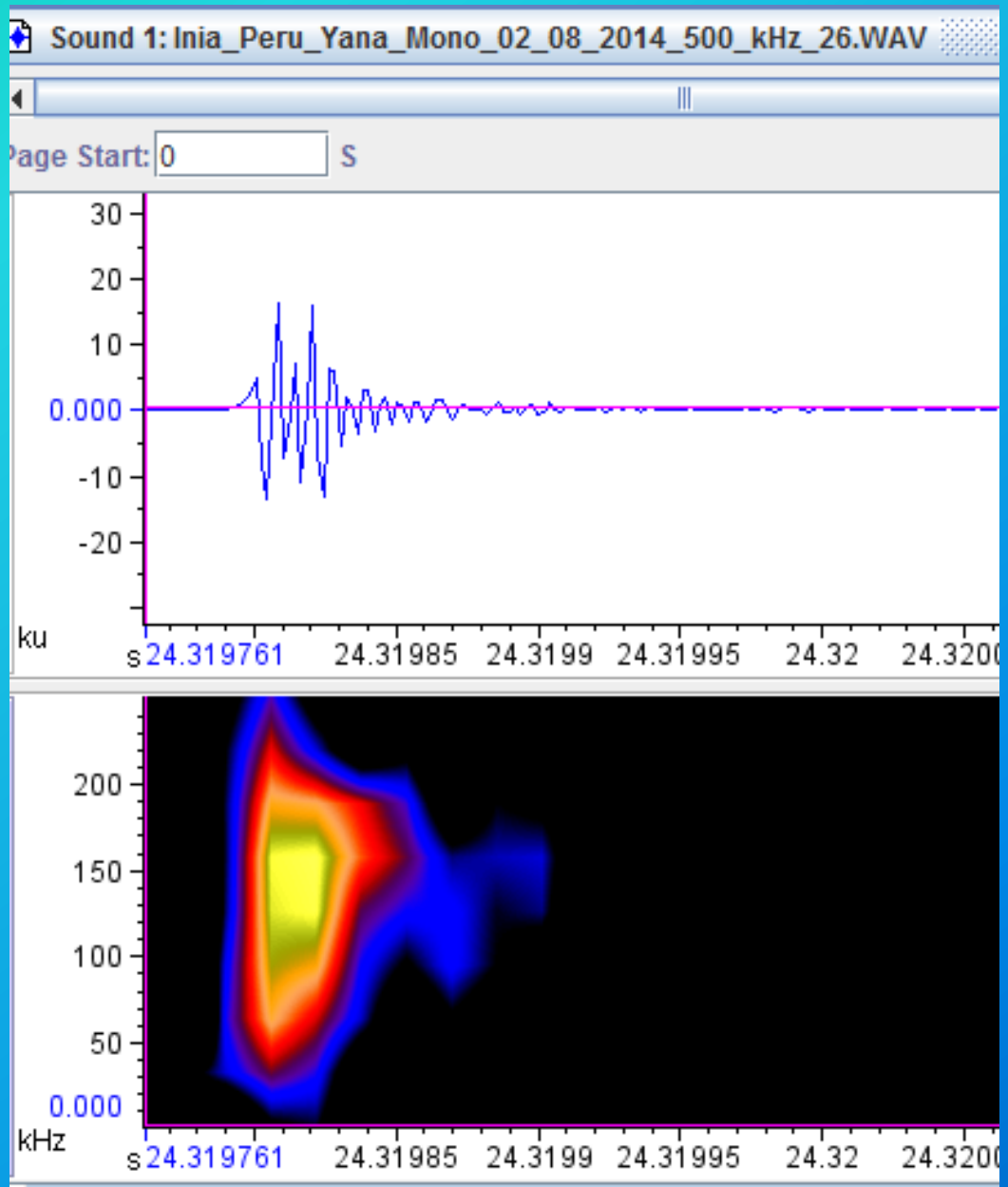

Question:
Are there features in the acoustic emanations from *Inia* that would allow more effective individual counting?
Answer:
Possibly

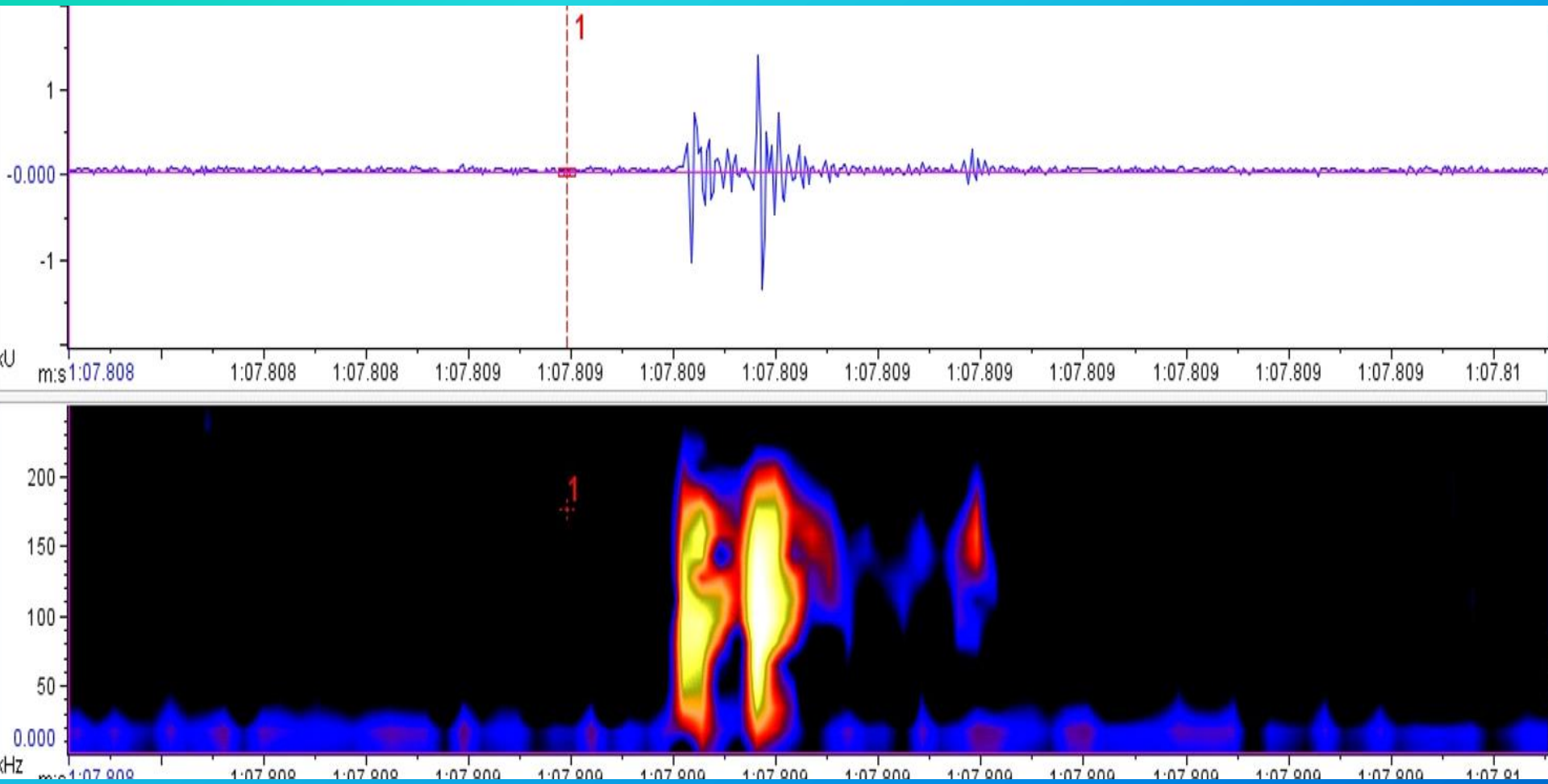
CETACEAN RESEARCH TECHNOLOGY
SINCE 1994

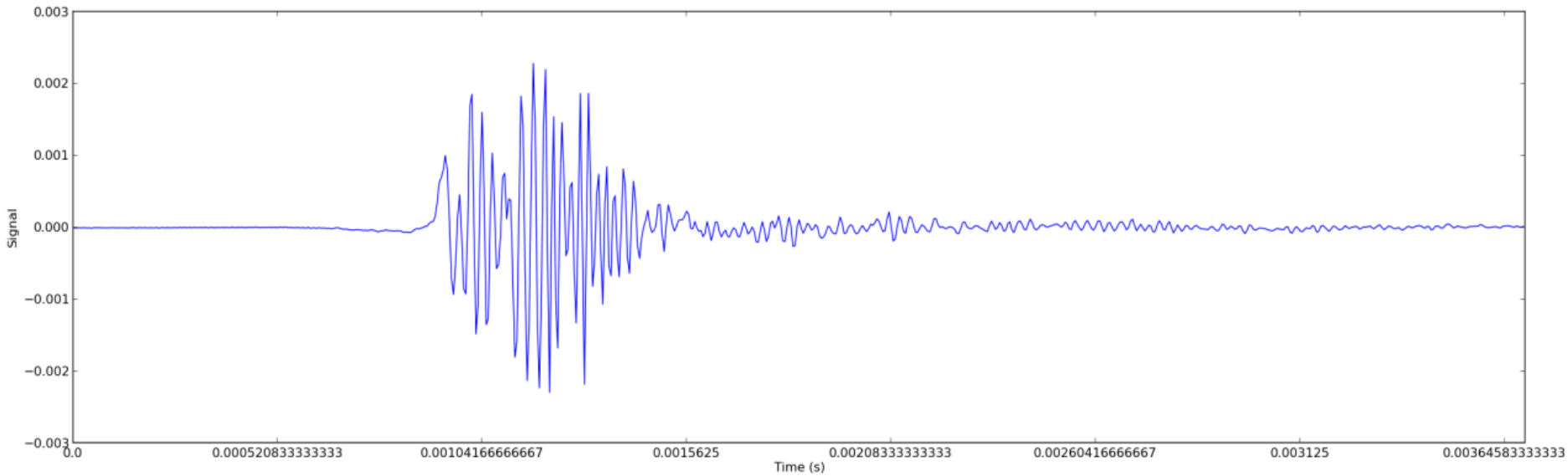
www.cetaceanresearch.com


CR3-9196-07 Frequency Response into 1MΩ Input
-195
-200
-205
-210
-215
-220
-225
-230
-235
Sensitivity [dB, re 1V/μPa]
10
100
1000
10000
100000
1000000
Frequency [Hz]

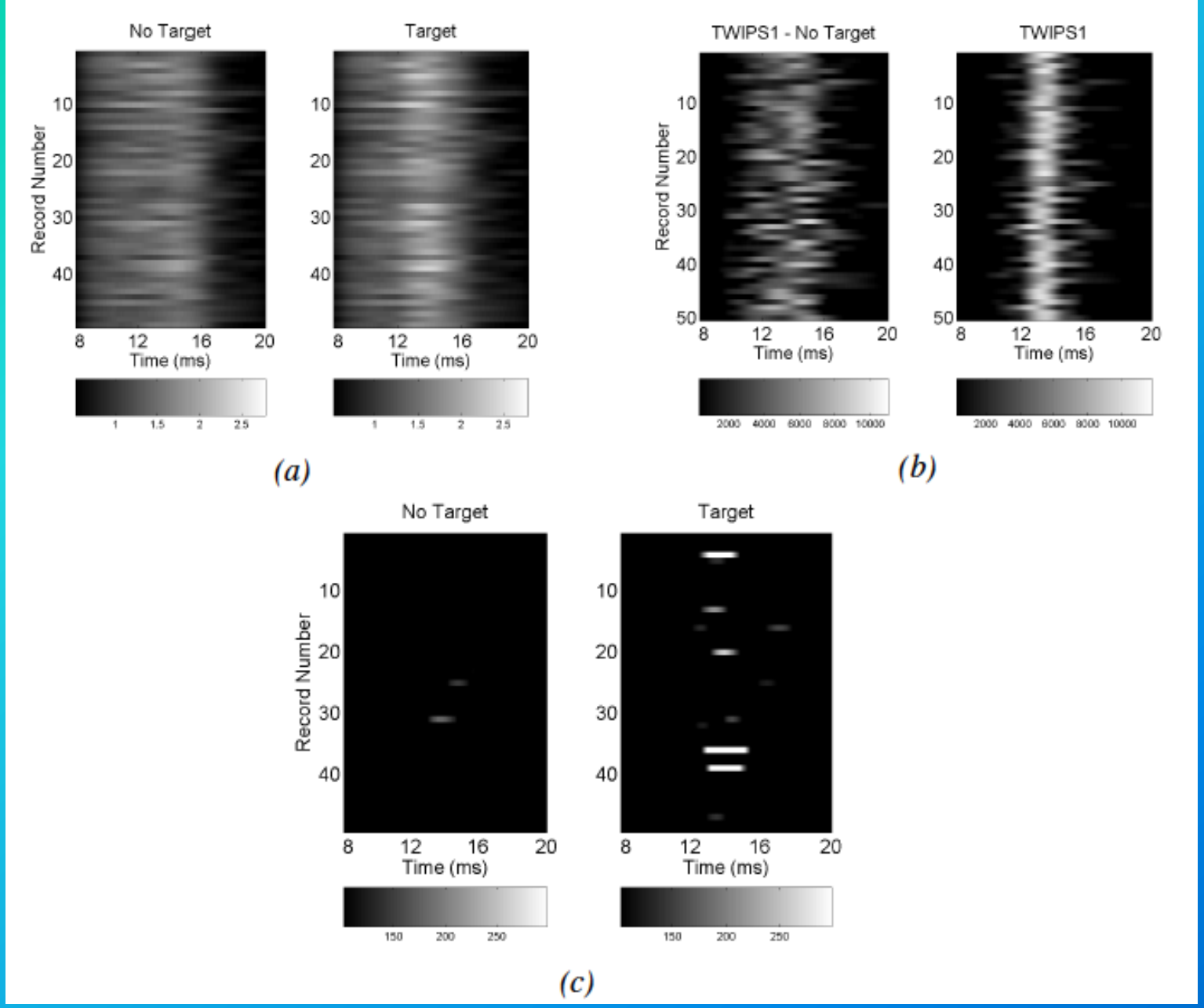
Ceiling effect at 250 kHz



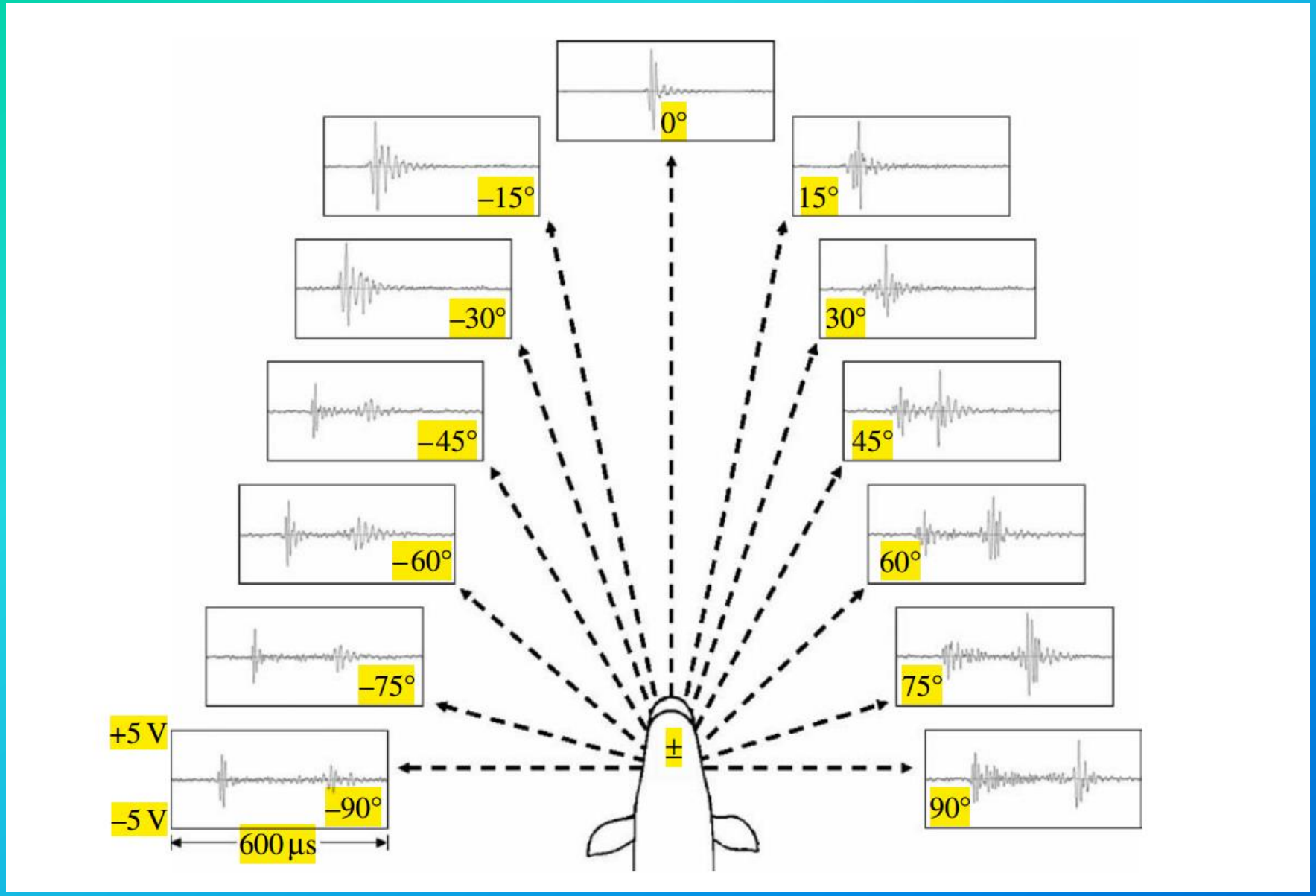

1
1
-0.000
-1
kU
m:s 1:07.808
1:07.808
1:07.808
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.81
1
200
150
100
50
0.000
kHz



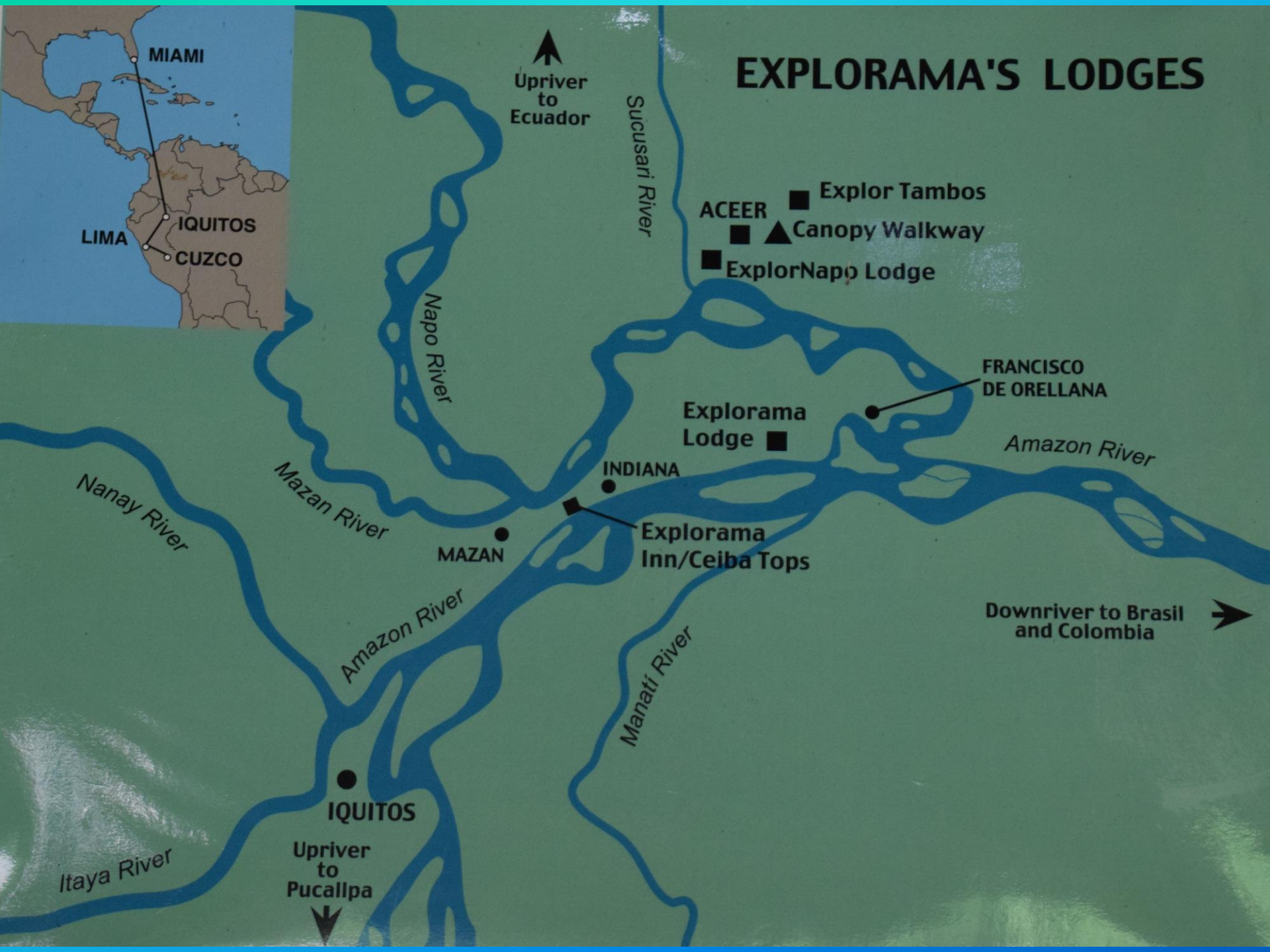
From: Glotin et al., 2014



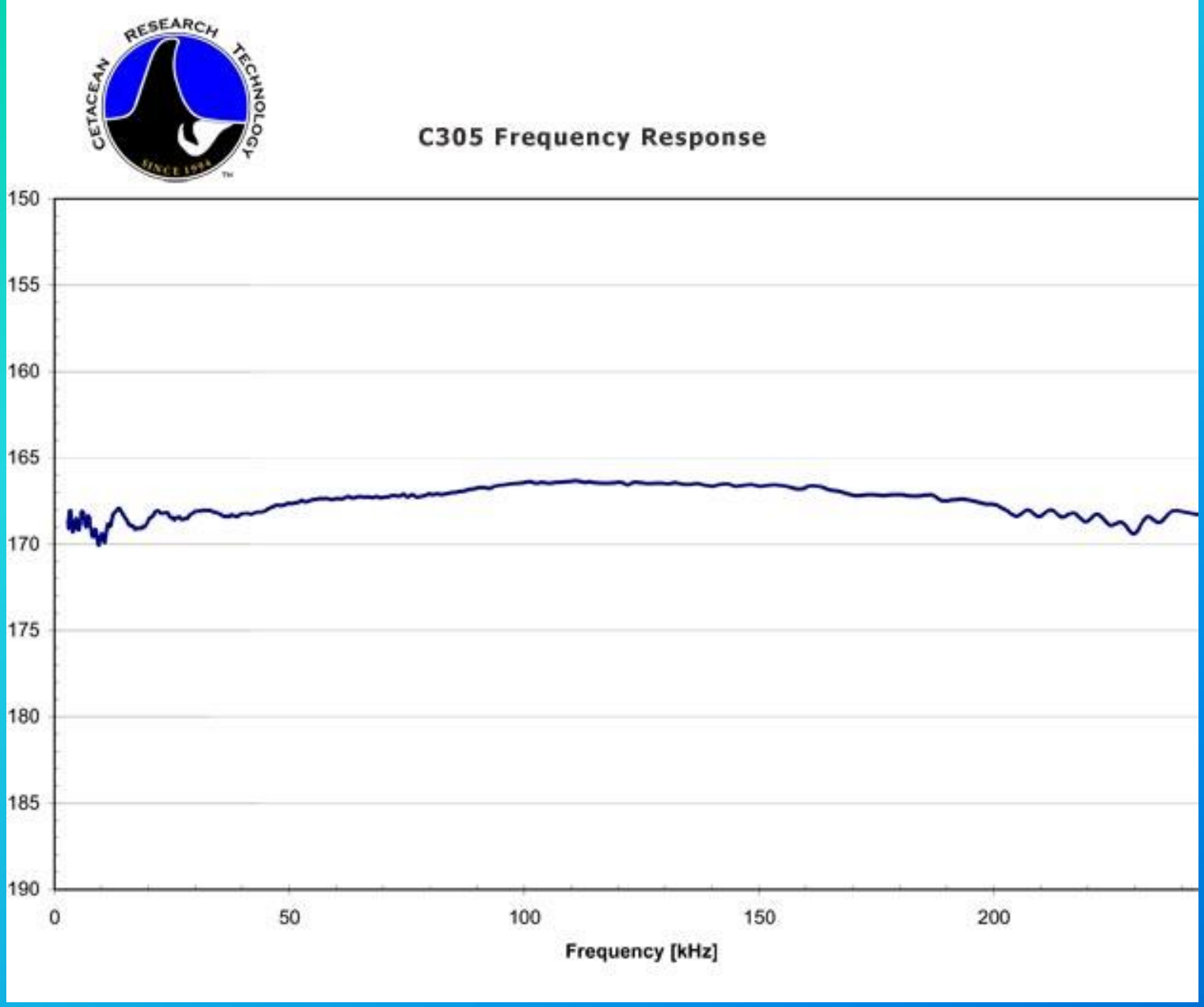
From: Leighton et al., 2005



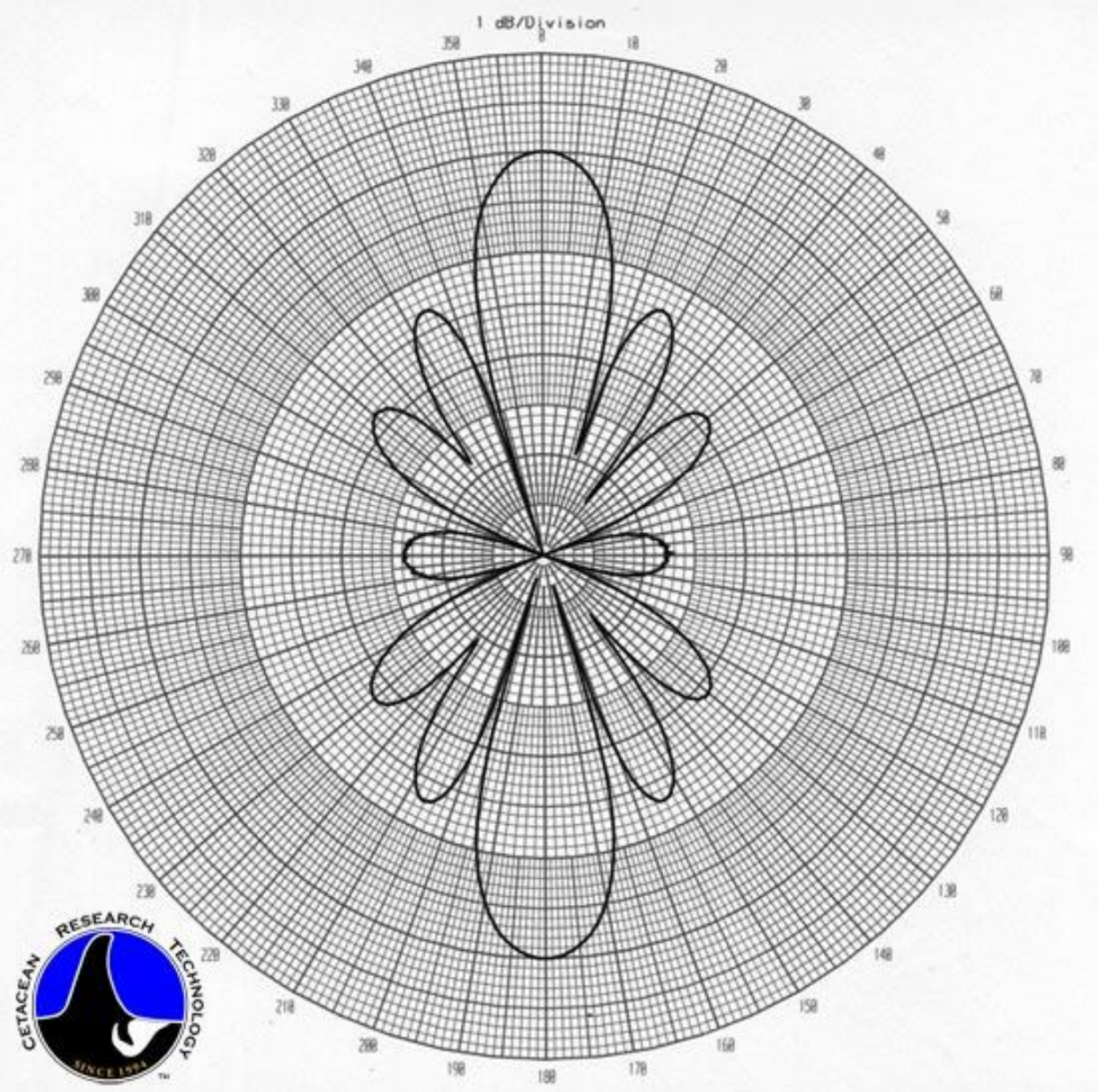
From: Lammers & Castellote, 2009


EXPLORAMA'S LODGES
MIAMI
IQUITOS
LIMA
CUZCO
Upriver to Ecuador
Sucusari River
Napo River
Explor Tambos
ACEER
Canopy Walkway
ExplorNapo Lodge
FRANCISCO DE ORELLANA
Explorama Lodge
Amazon River
INDIANA
Nanay River
Mazan River
MAZAN
Explorama Inn/Ceiba Tops
Amazon River
Downriver to Brasil and Colombia
Manati River
IQUITOS
Itaya River
Upriver to Pucallpa

C305 Hydrophone

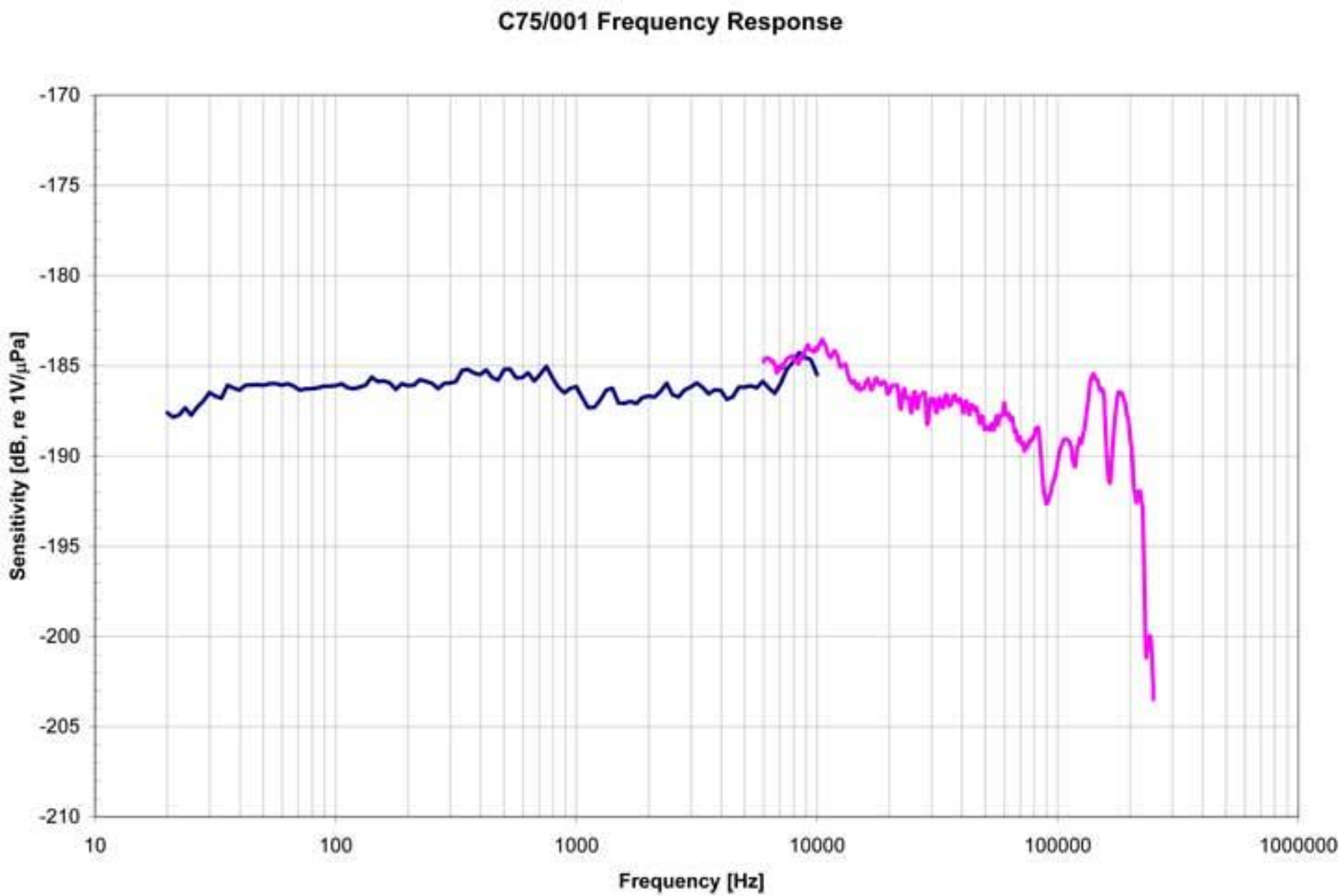


C305 Hydrophone Sensitivity

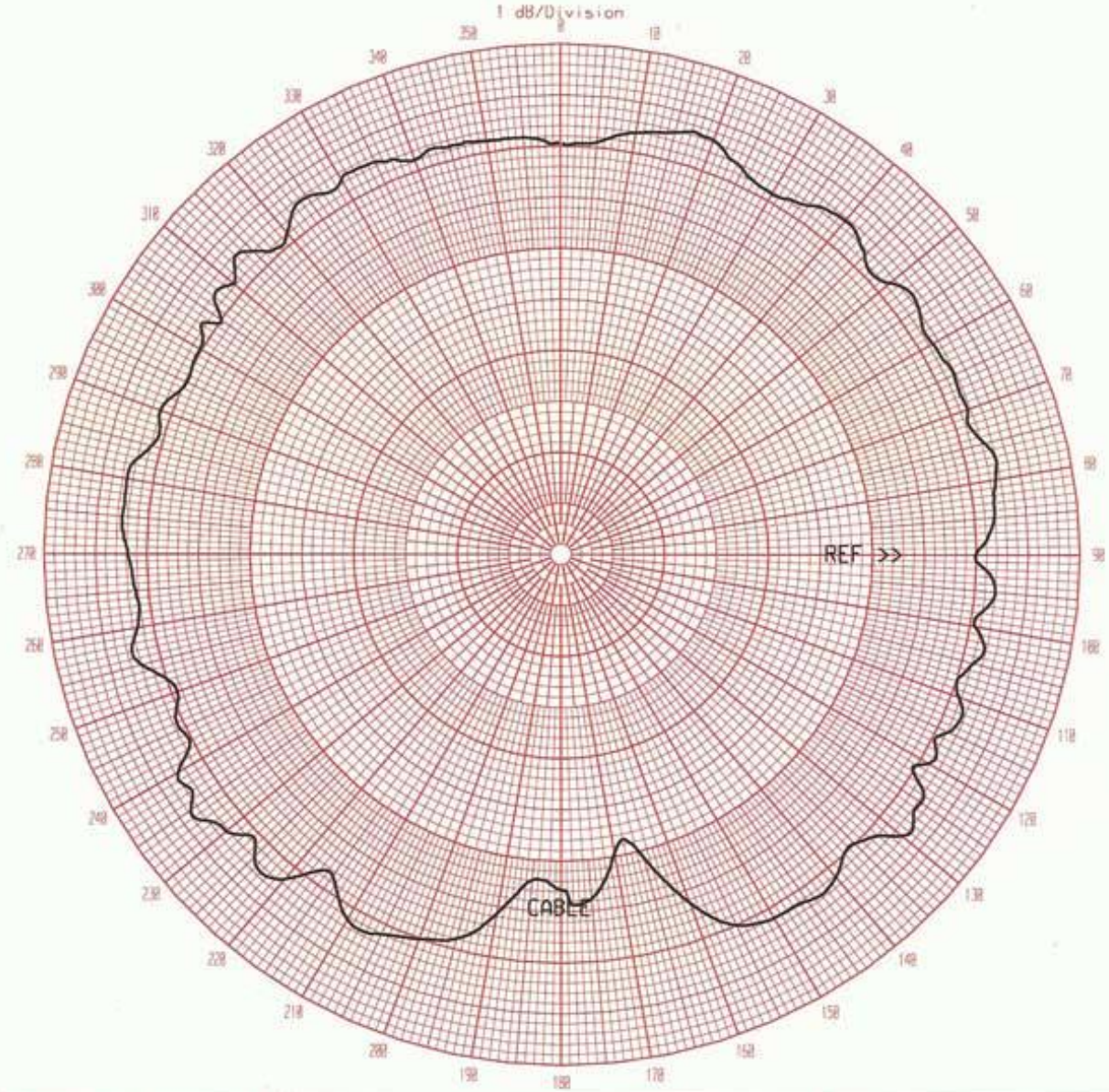


C305 Hydrophone Beam Pattern
200kHz horizontal receive pattern
showing receiving directivity response

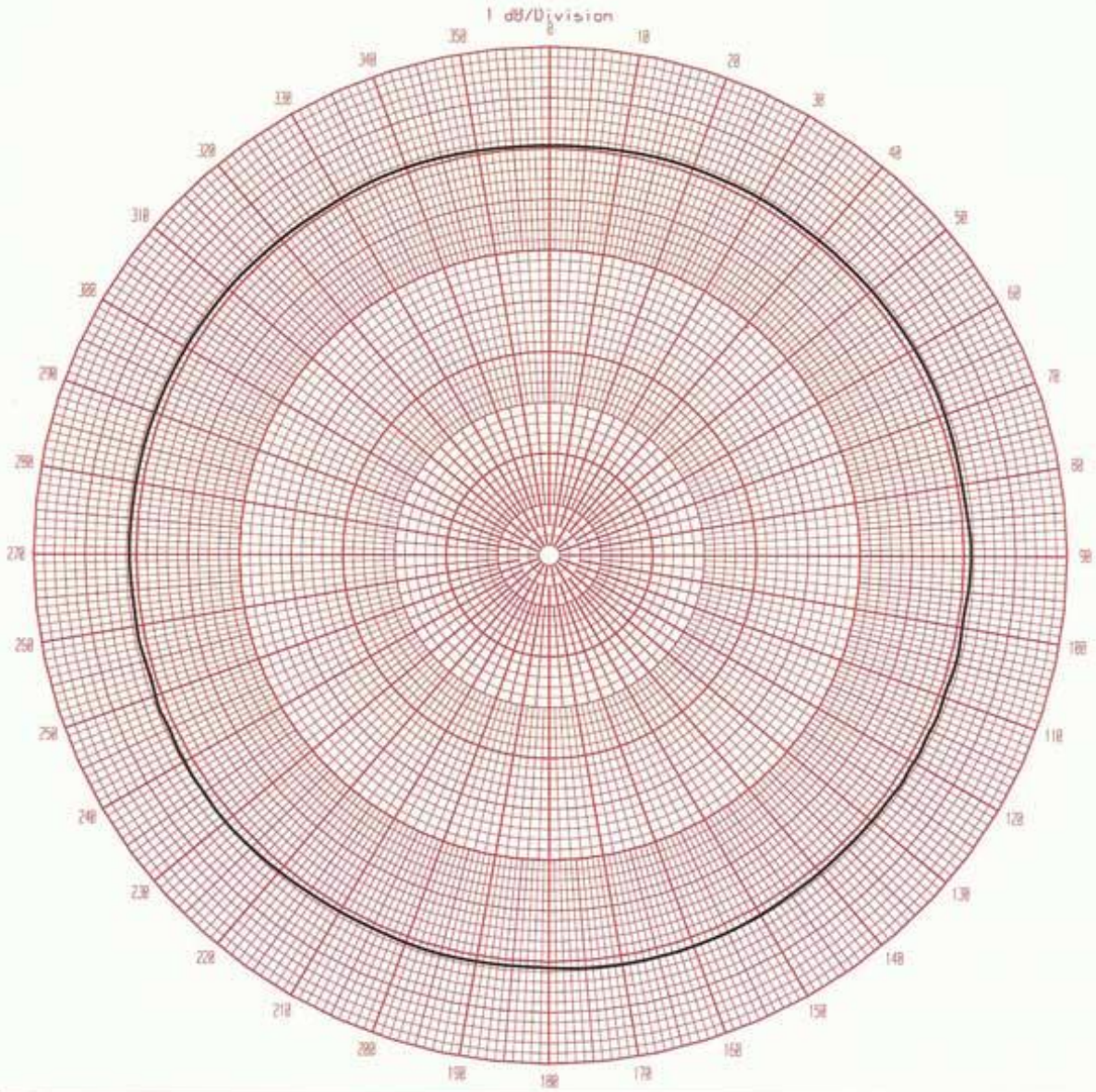
C75



C75 Hydrophone Sensitivity

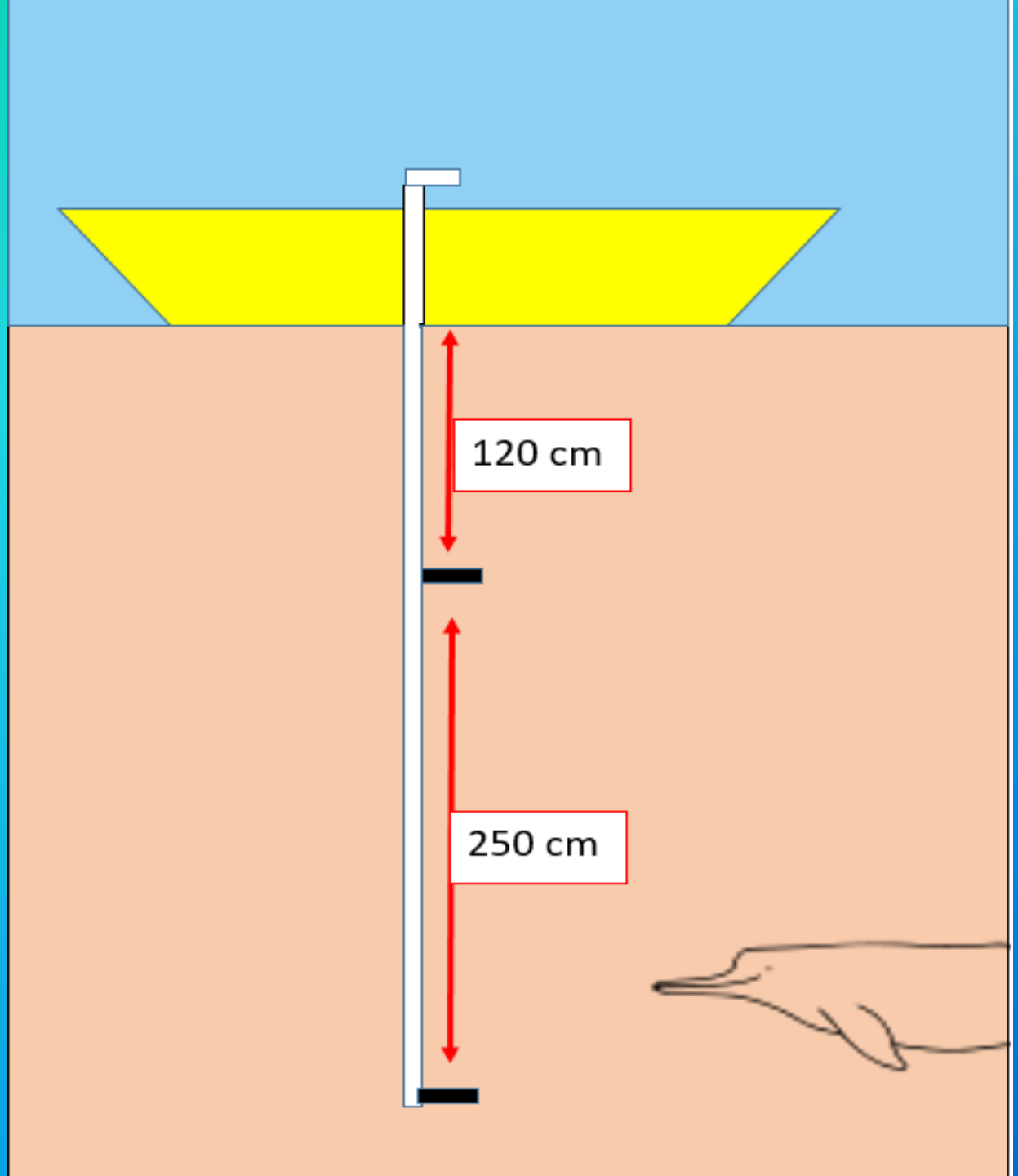


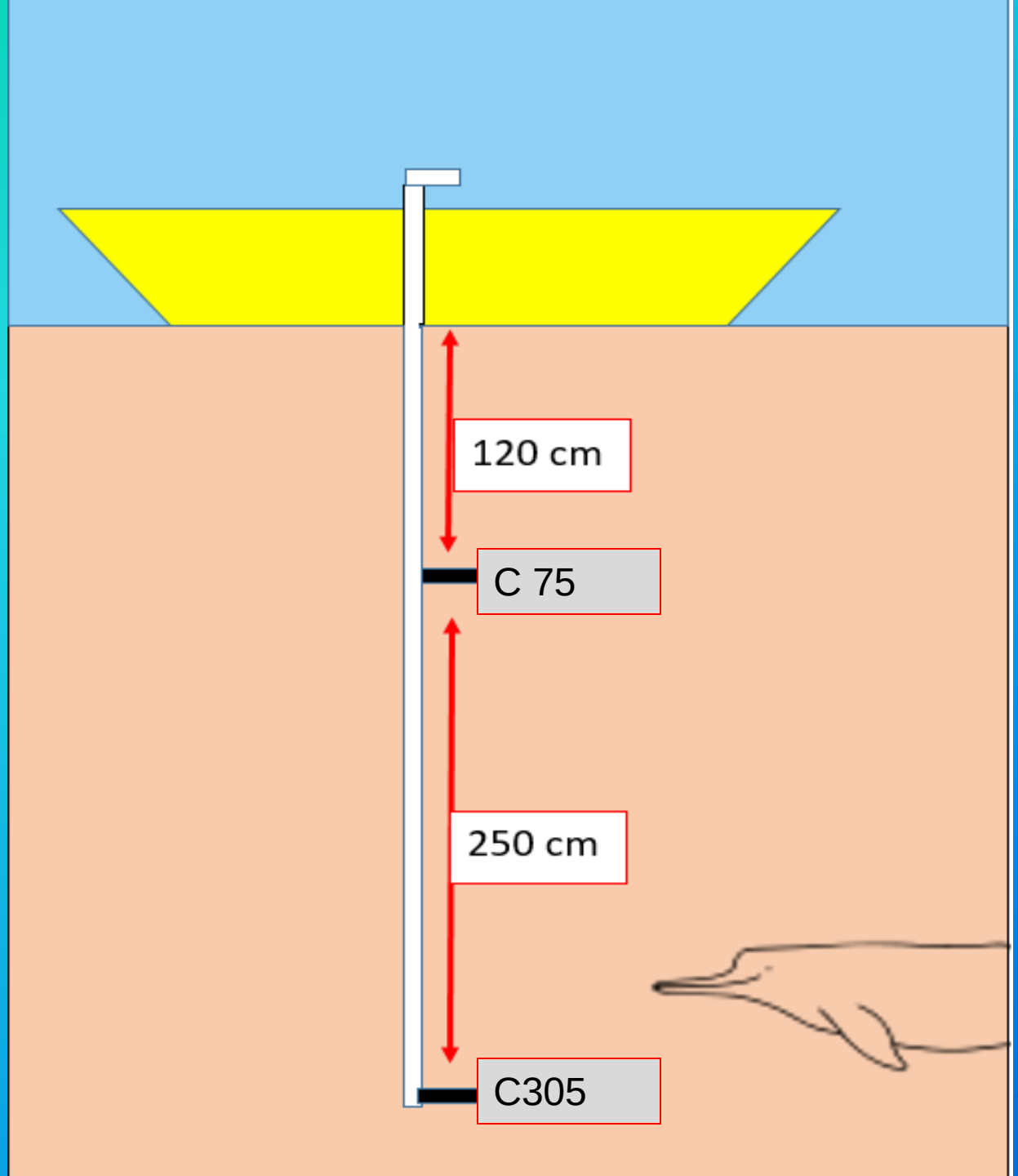
Water Temp 11.7 C Frequency 50 kHz Spacing 3.16 M Depth 3.81 M Plane XZ Console 1	RECEIVING DIRECTIVITY RESPONSE CR3 SER.# 9196-07	Acoustic Test Facility NUWC Keyport Time 13:52:53 Date 22 Apr 2010 Technician MF

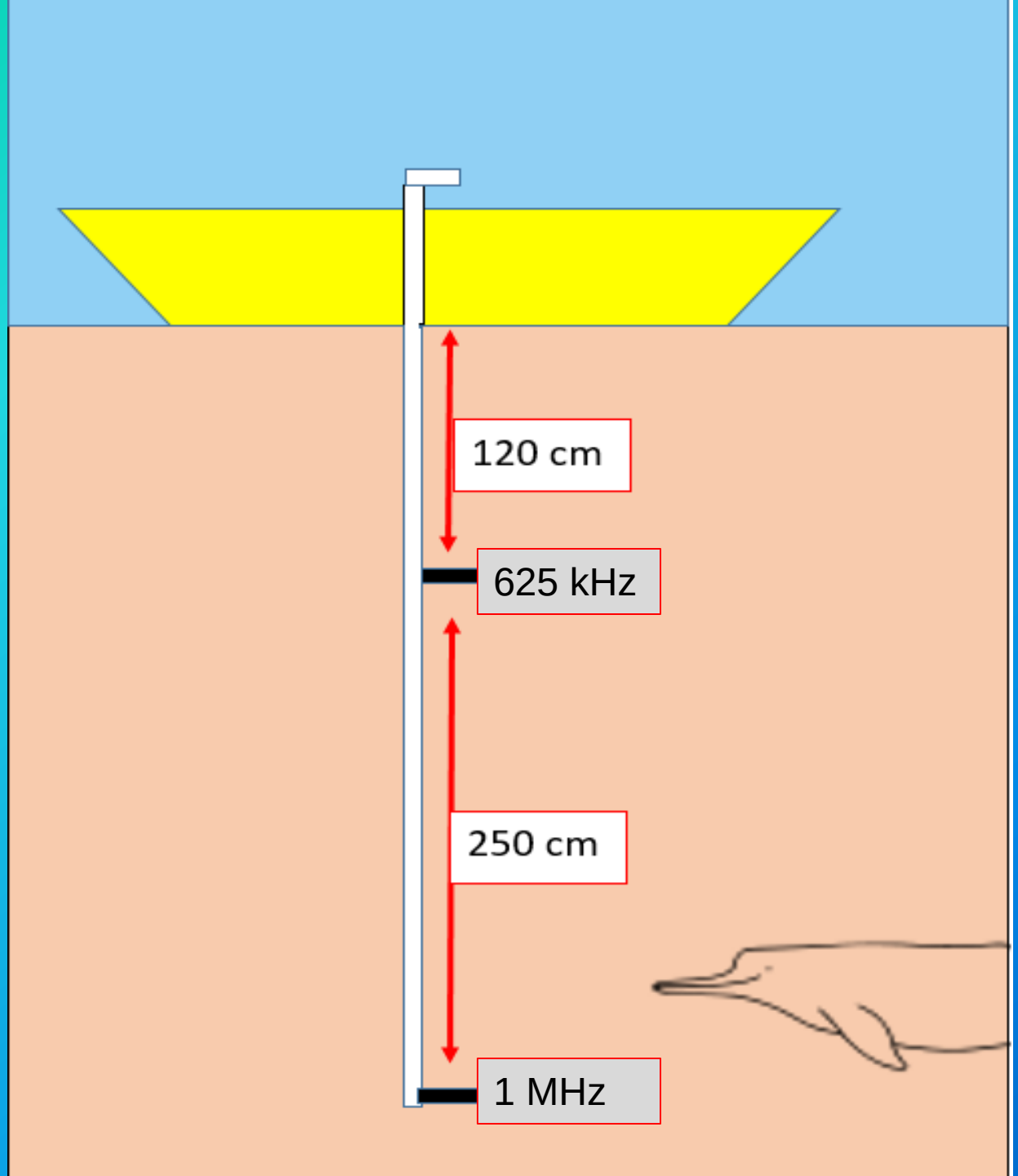


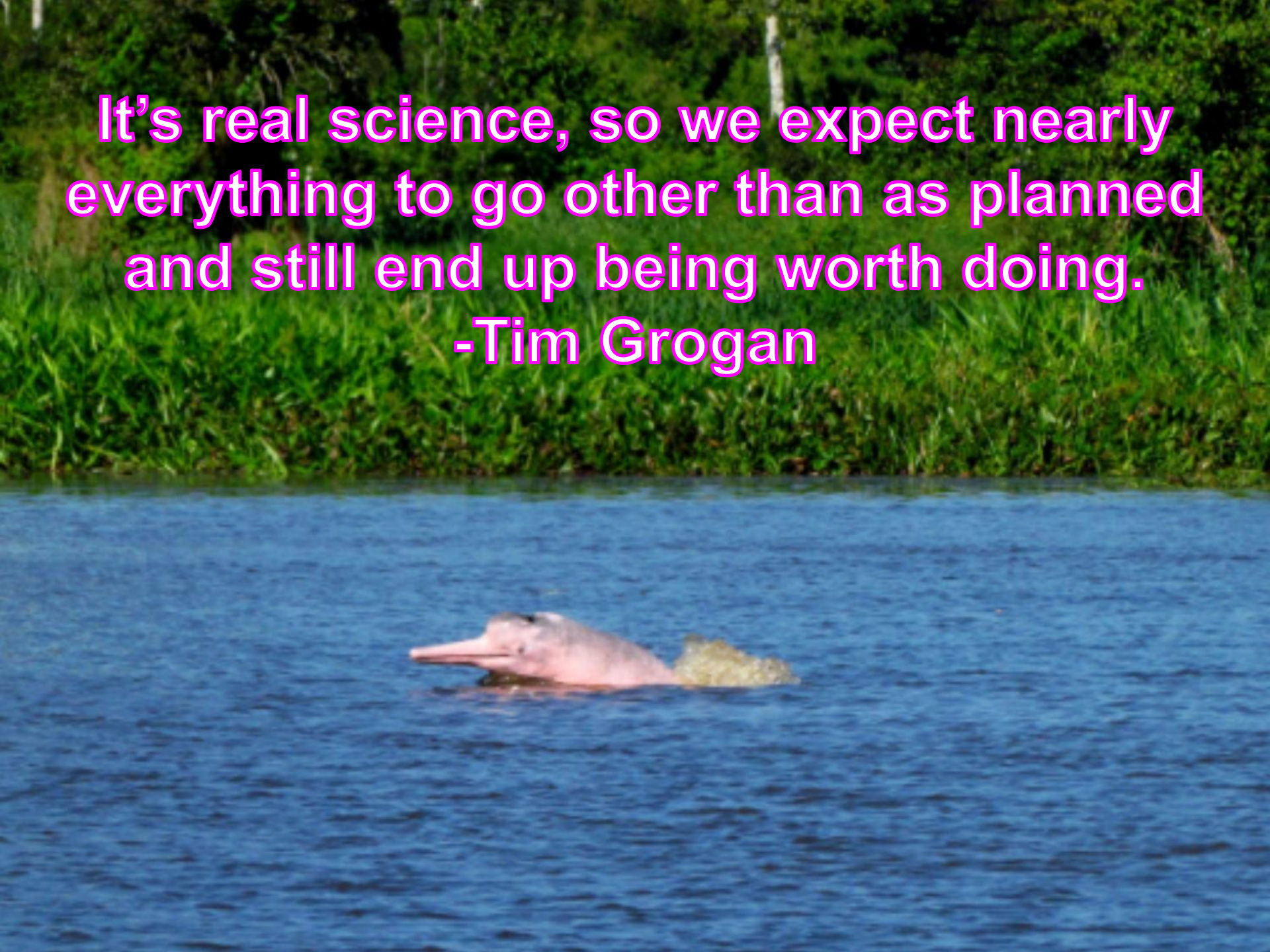
Water Temp 11.8 C Frequency 50 kHz Spacing 3.16 M Depth 3.81 M Plane XY Console 1	RECEIVING DIRECTIVITY RESPONSE CR3 SER. # 9196-07	Acoustic Test Facility NUWC Keyport Time 14:09:59 Date 22 Apr 2010 Technician MF

High Amp:-9.1 High angle: 232.5 Low Amp:-9.8 Low Angle: 359.9 Total Plot Variation is .7 dB


120 cm
250 cm


120 cm
C 75
250 cm
C305


120 cm
625 kHz
250 cm
1 MHz


It’s real science, so we expect nearly everything to go other than as planned and still end up being worth doing.
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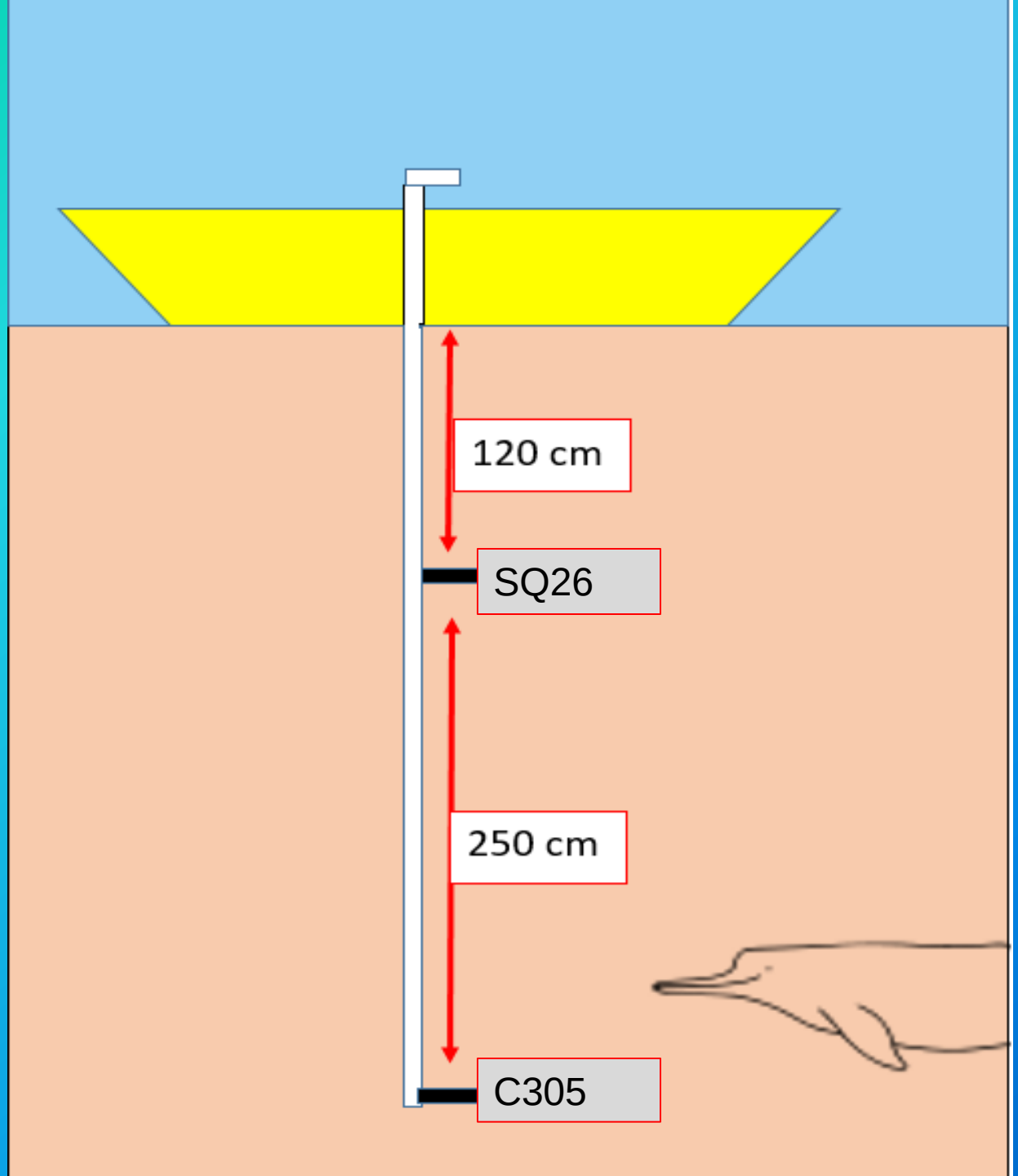
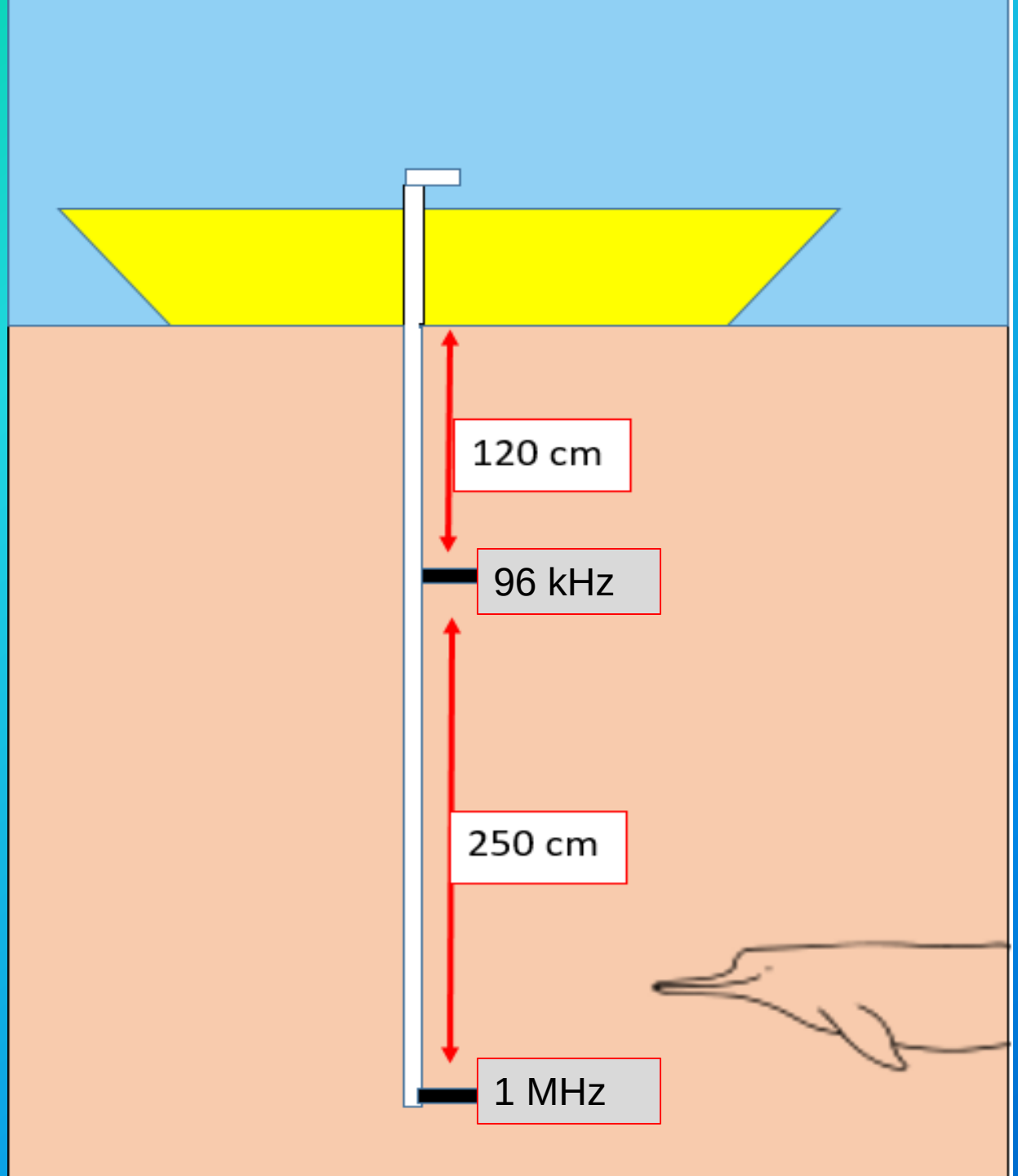
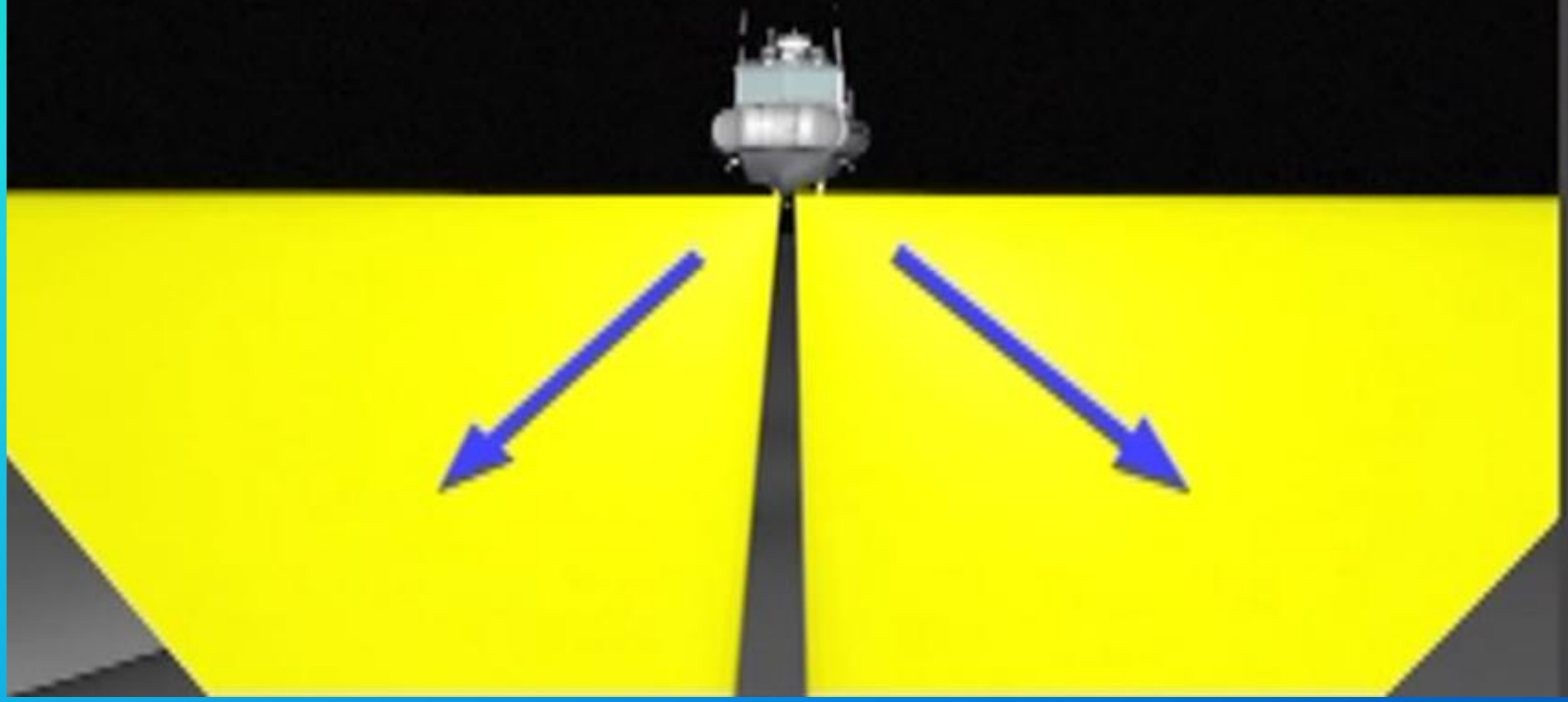

120 cm
SQ26
250 cm
C305

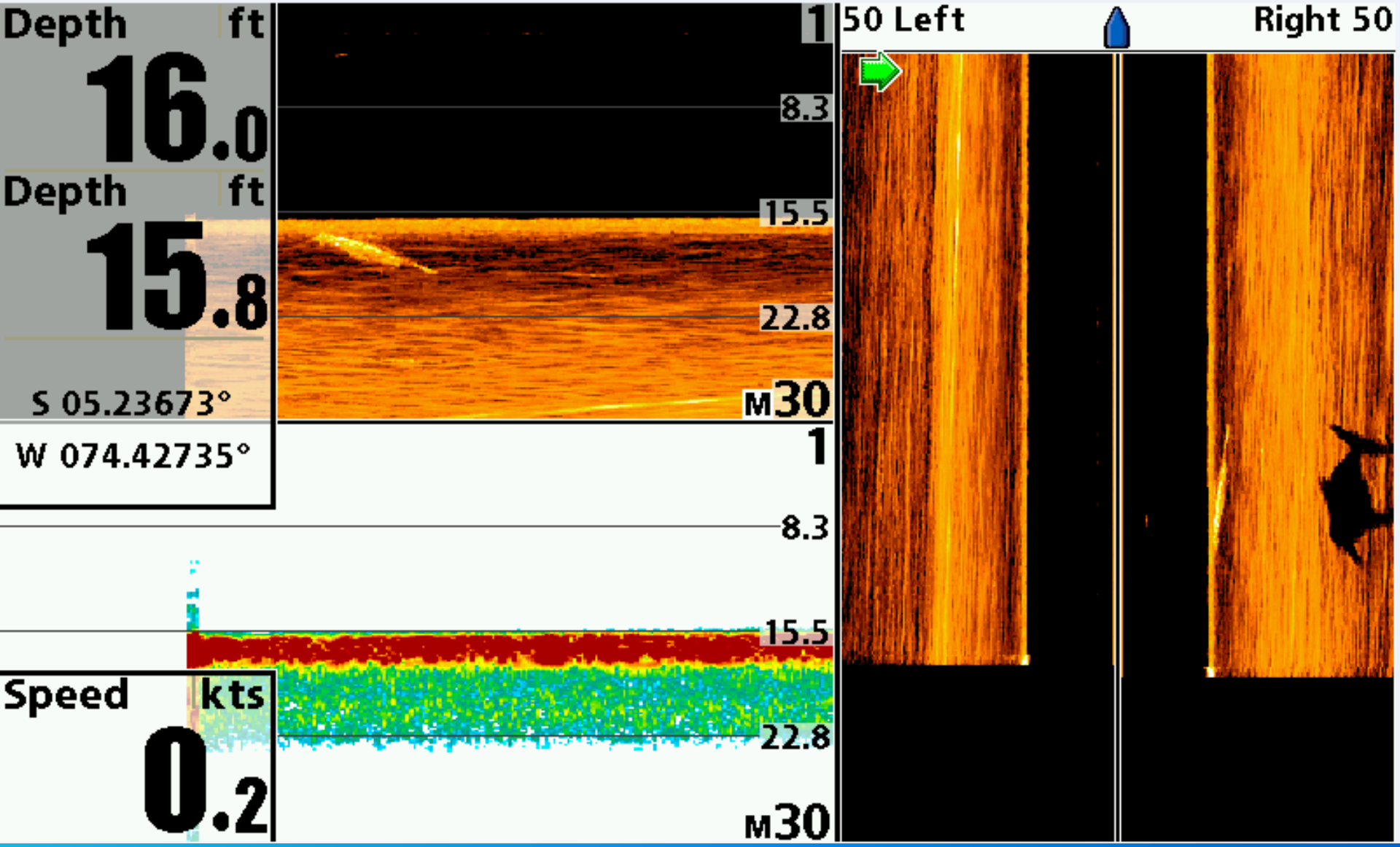

120 cm
96 kHz
250 cm
1 MHz

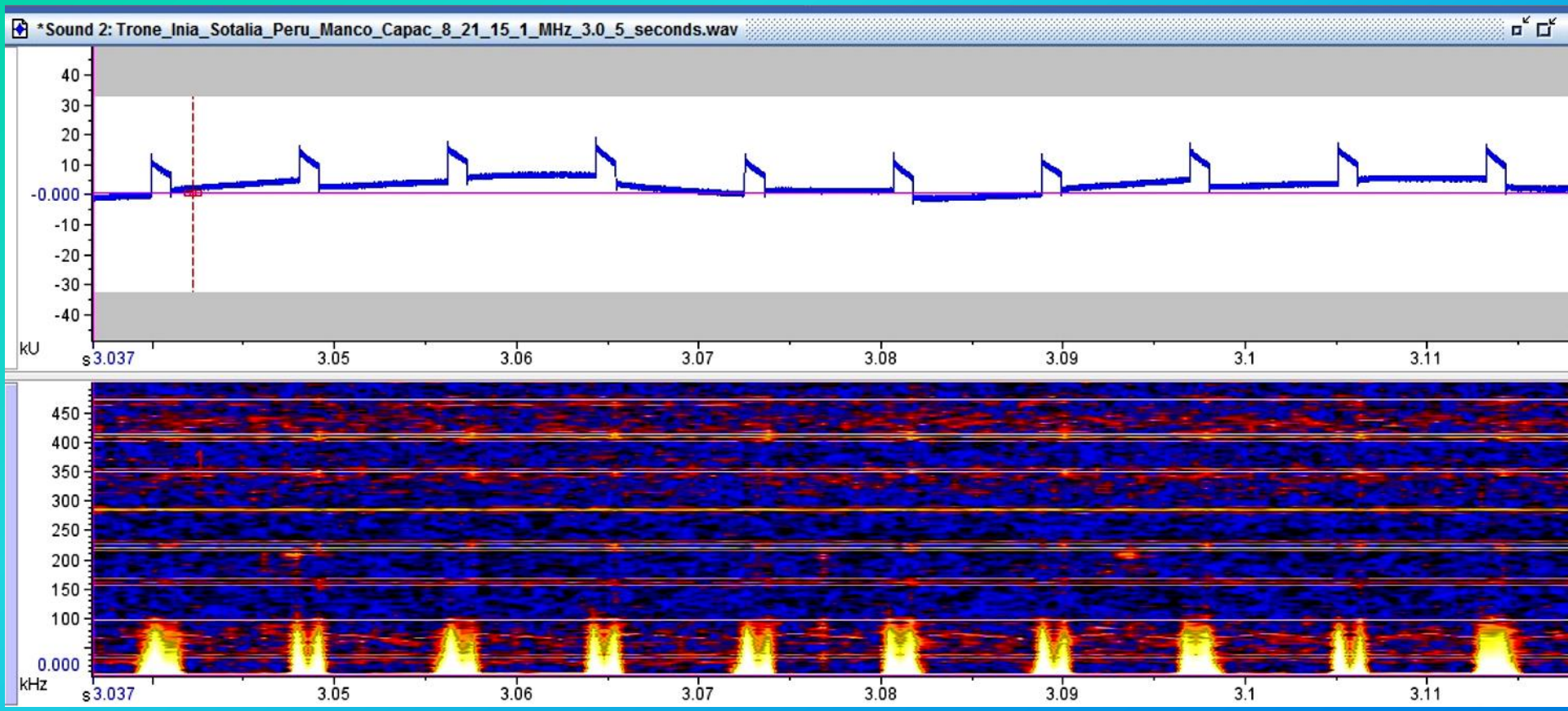

TEBAIV

Humminbird 977c
Side Scan Sonar

Down beam: 200 kHz
2 side beams: 800 kHz each



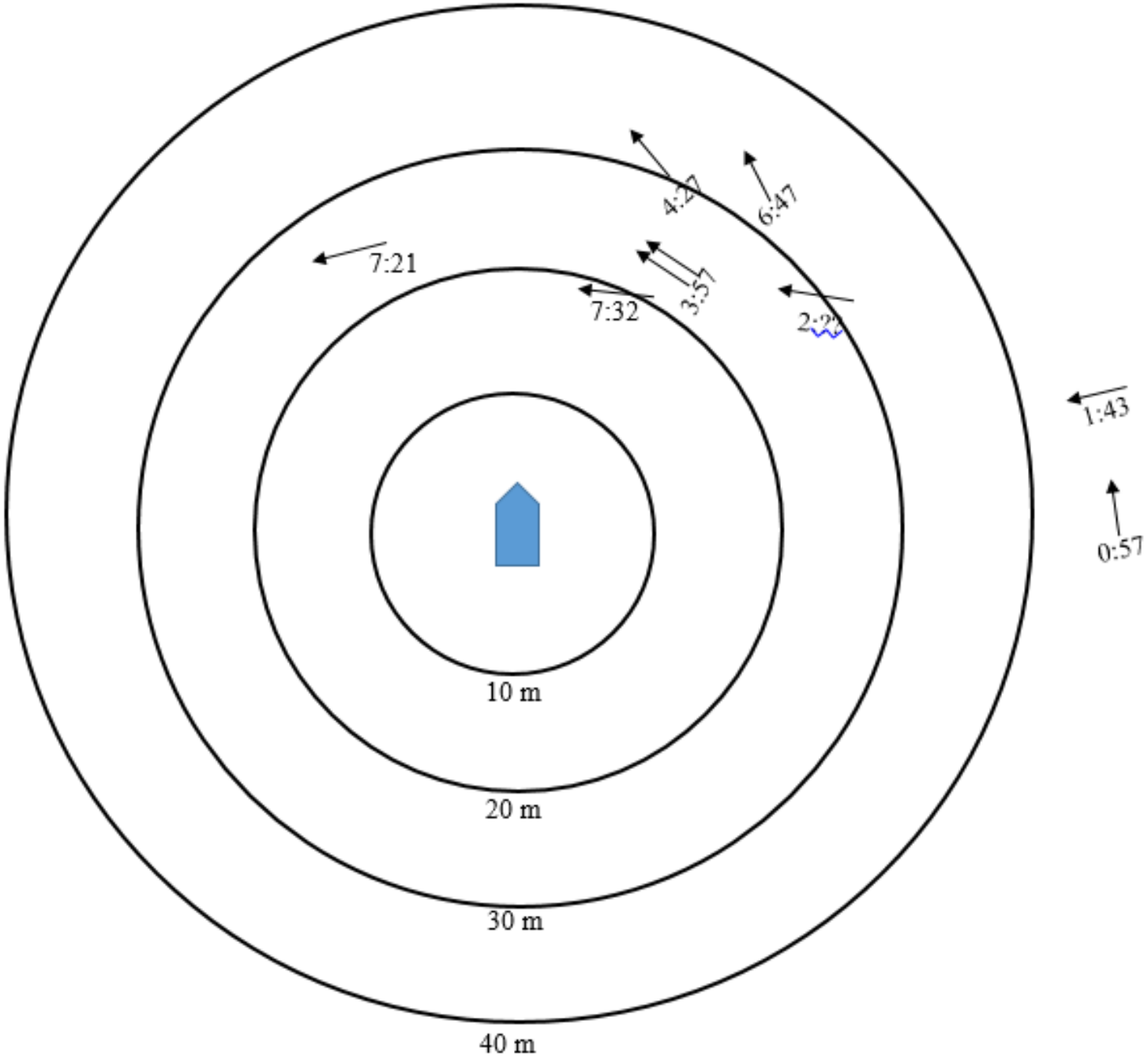

Depth ft
16.0
Depth ft
15.8
S 05.23673°
W 074.42735°
1
8.3
15.5
22.8
M30
1
8.3
15.5
22.8
M30
Speed kts
0.2
50 Left
Right 50

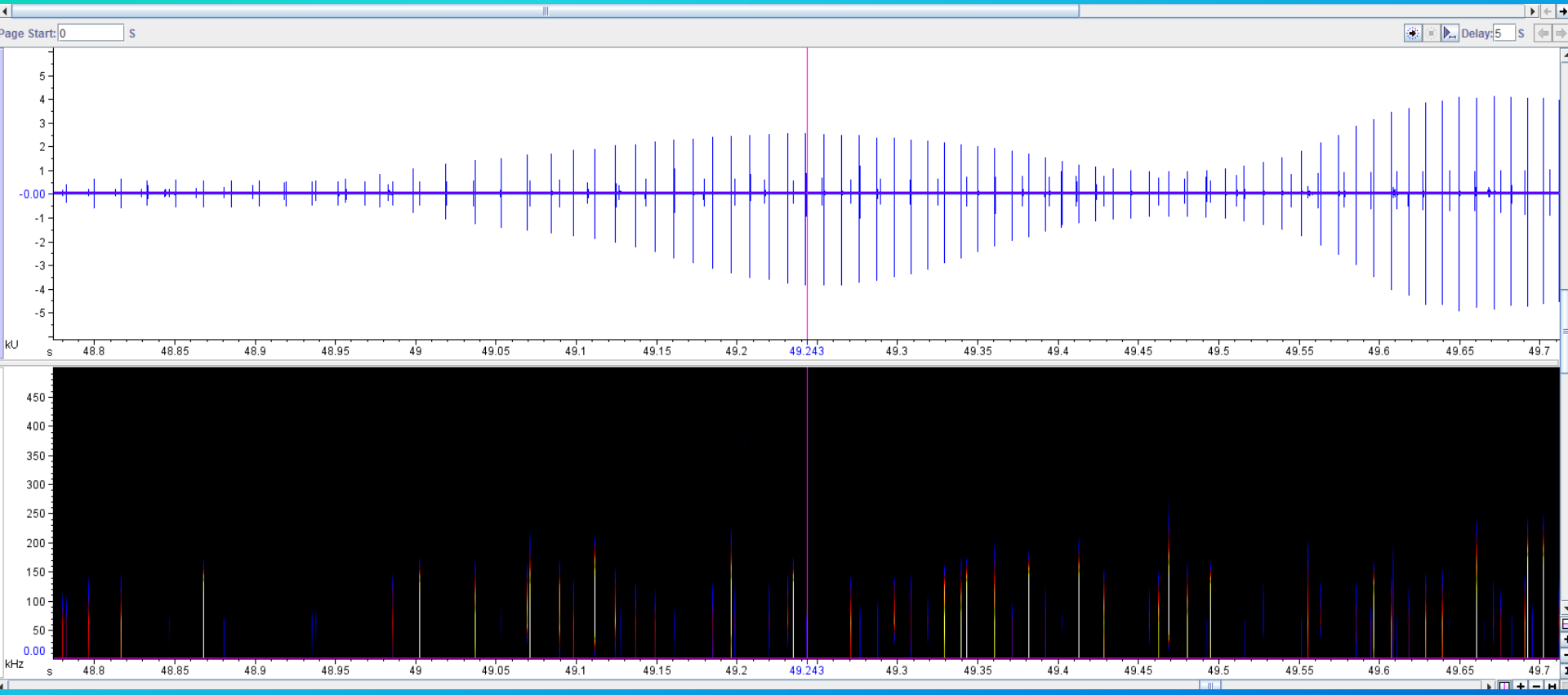


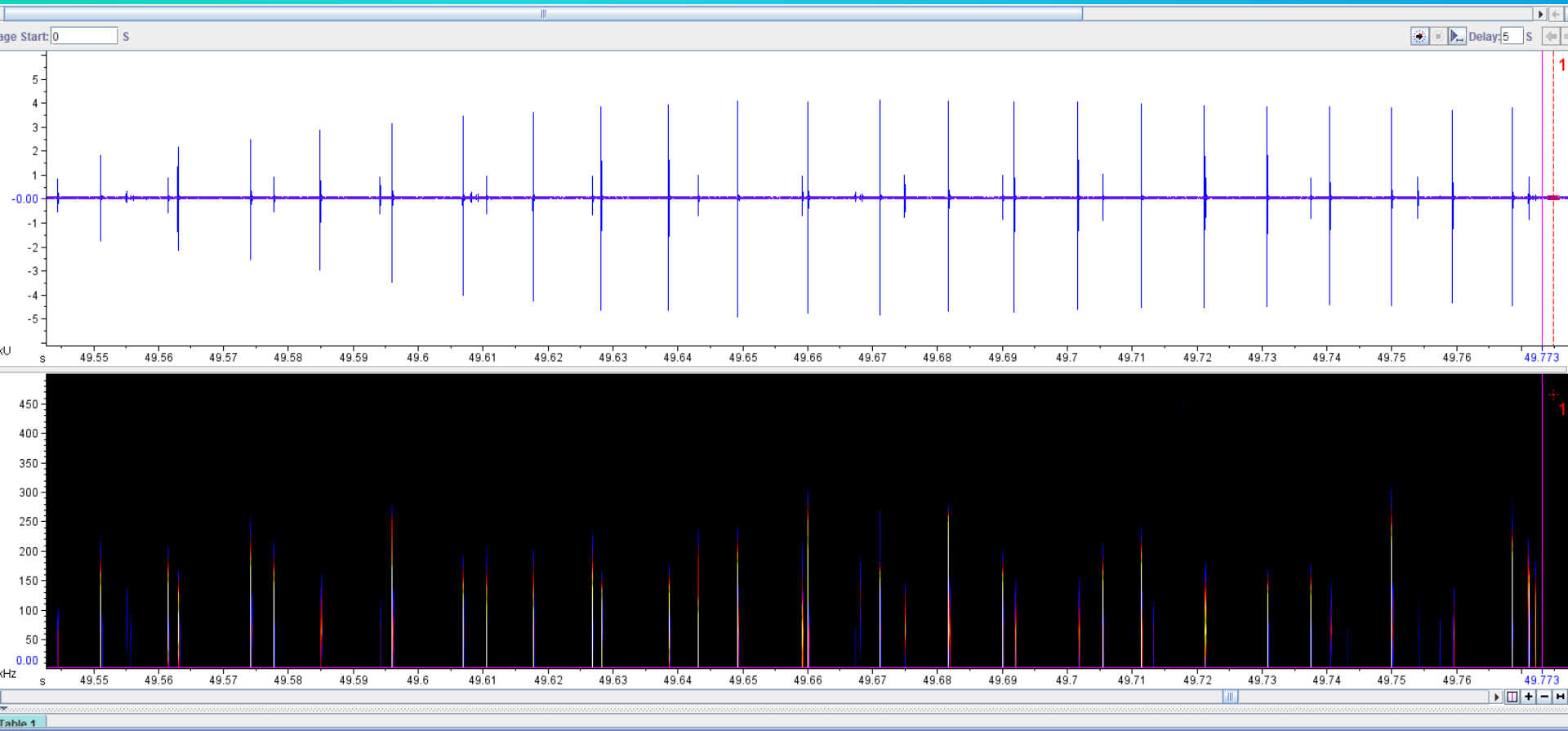
Down beam: 200 kHz

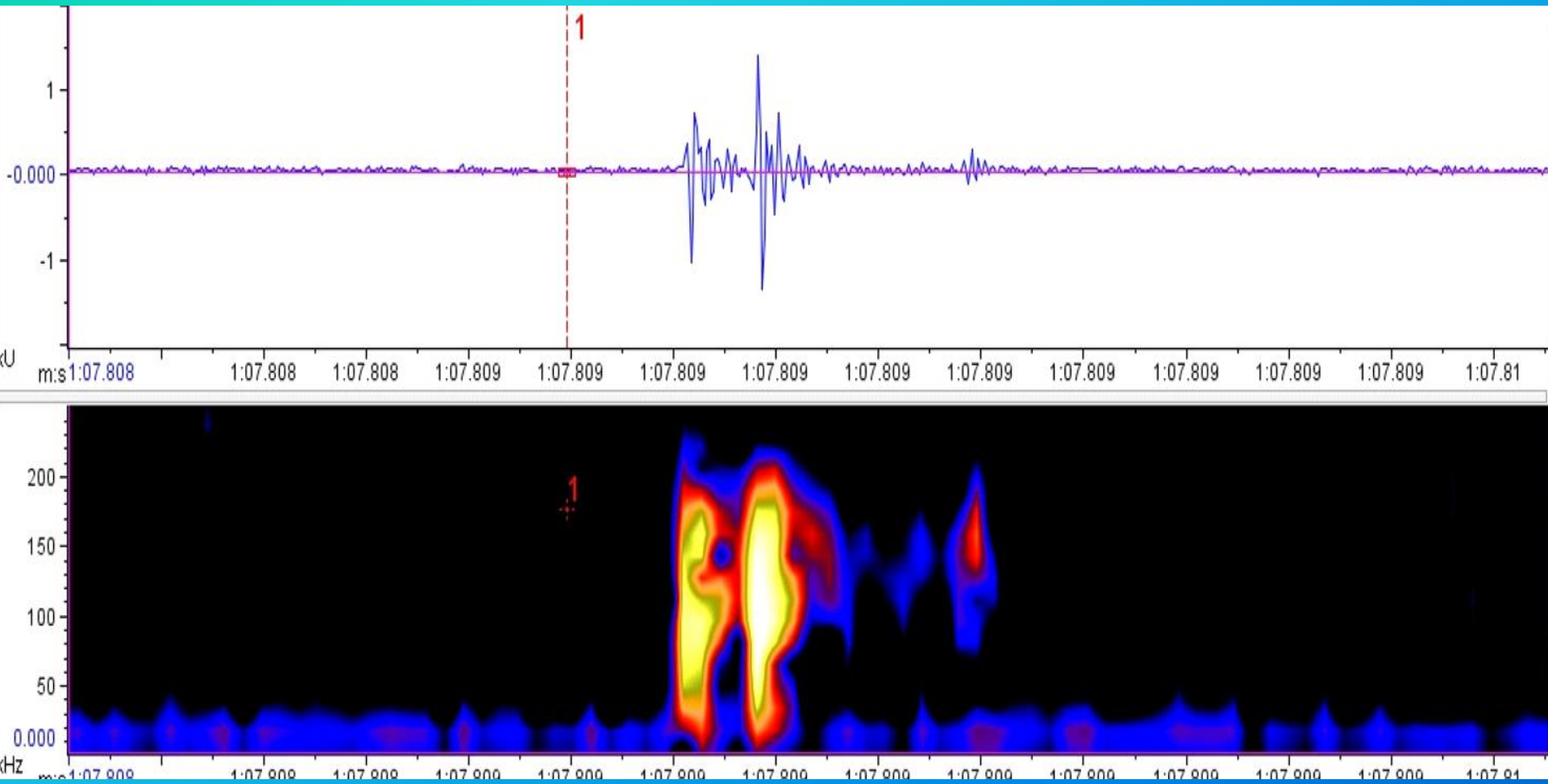
2 side beams: 800 kHz each

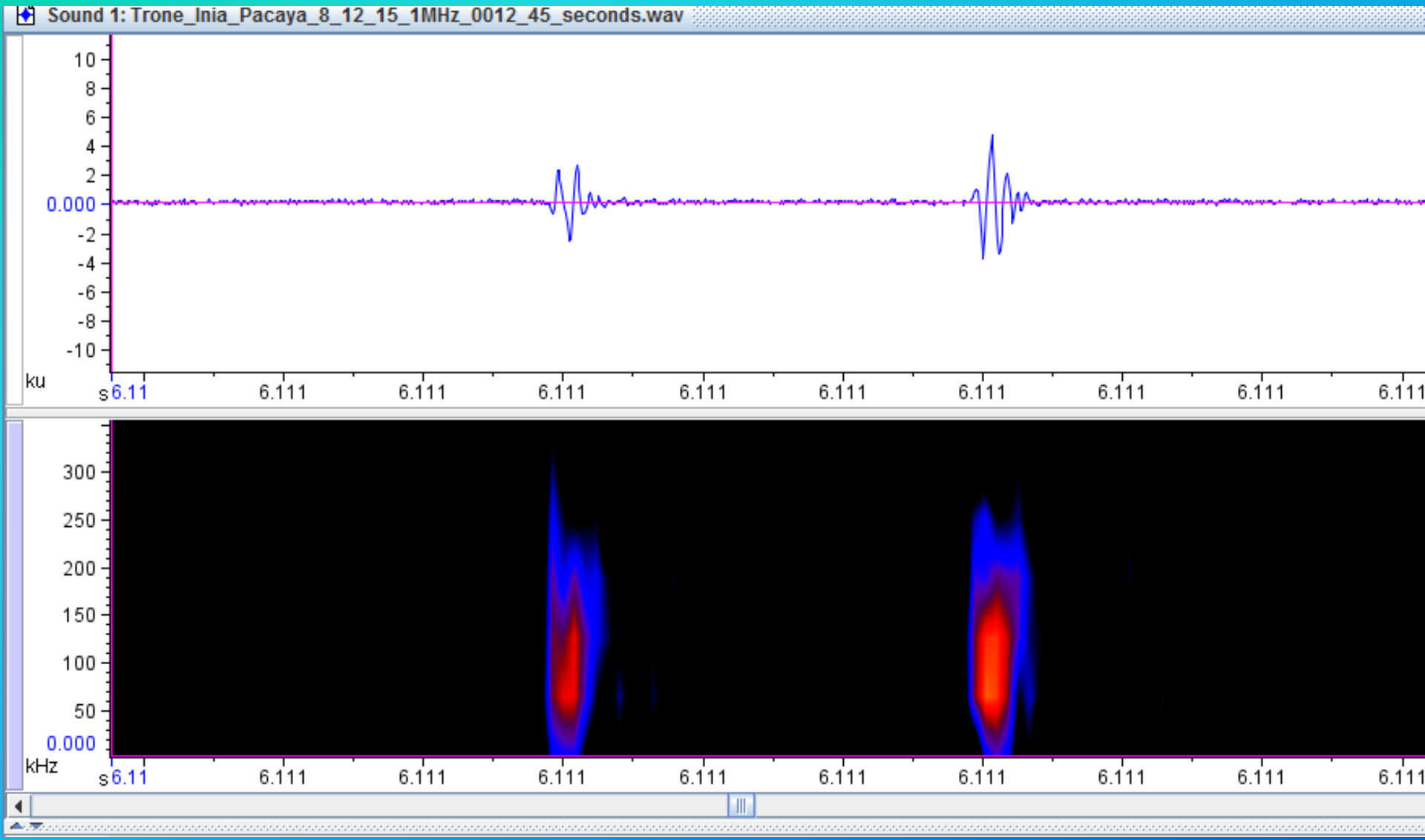
Could not correlate clicks with dolphin

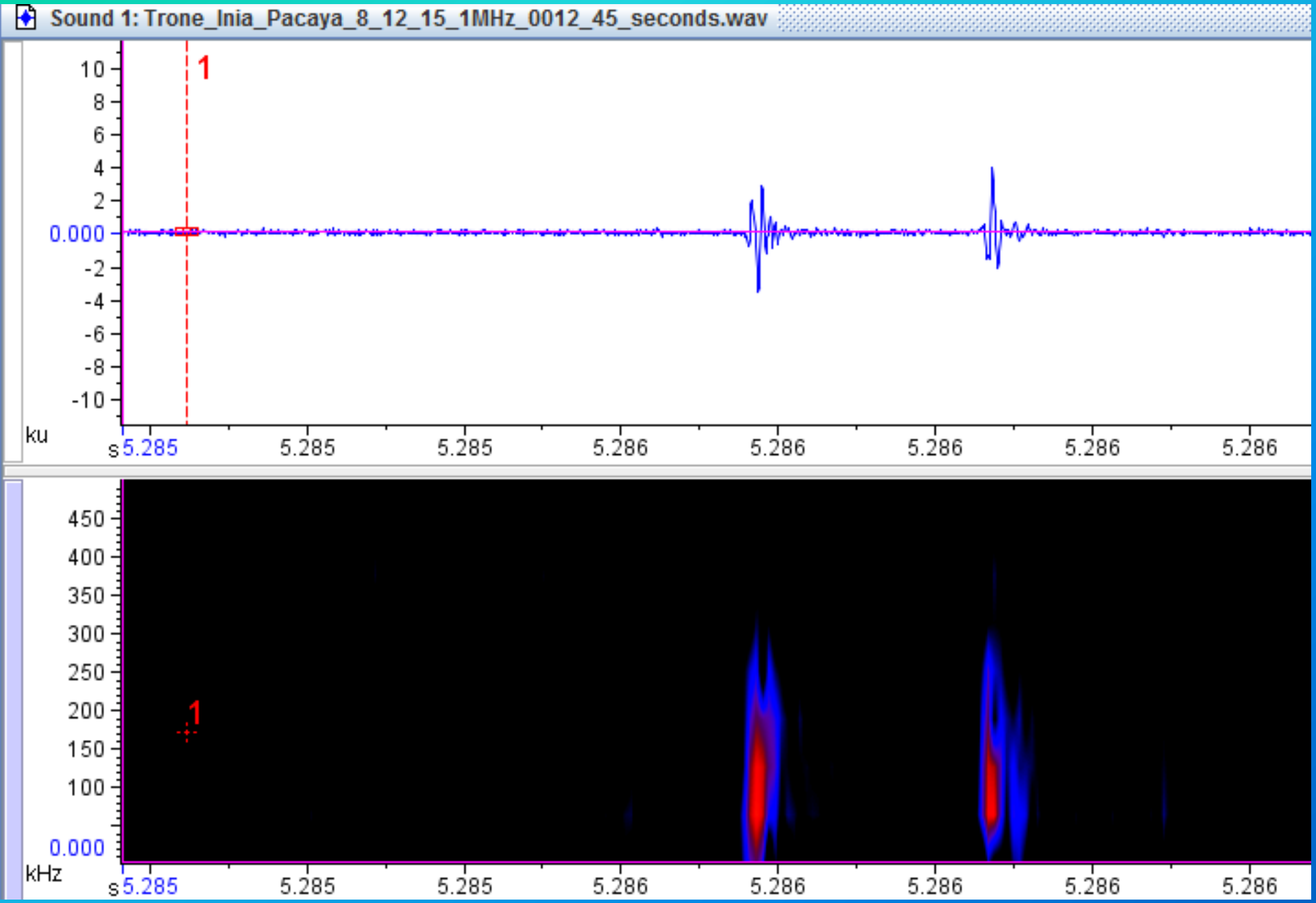

4:27
6:47
7:21
3:57
7:32
2:22
1:43
0:57
10 m
20 m
30 m
40 m

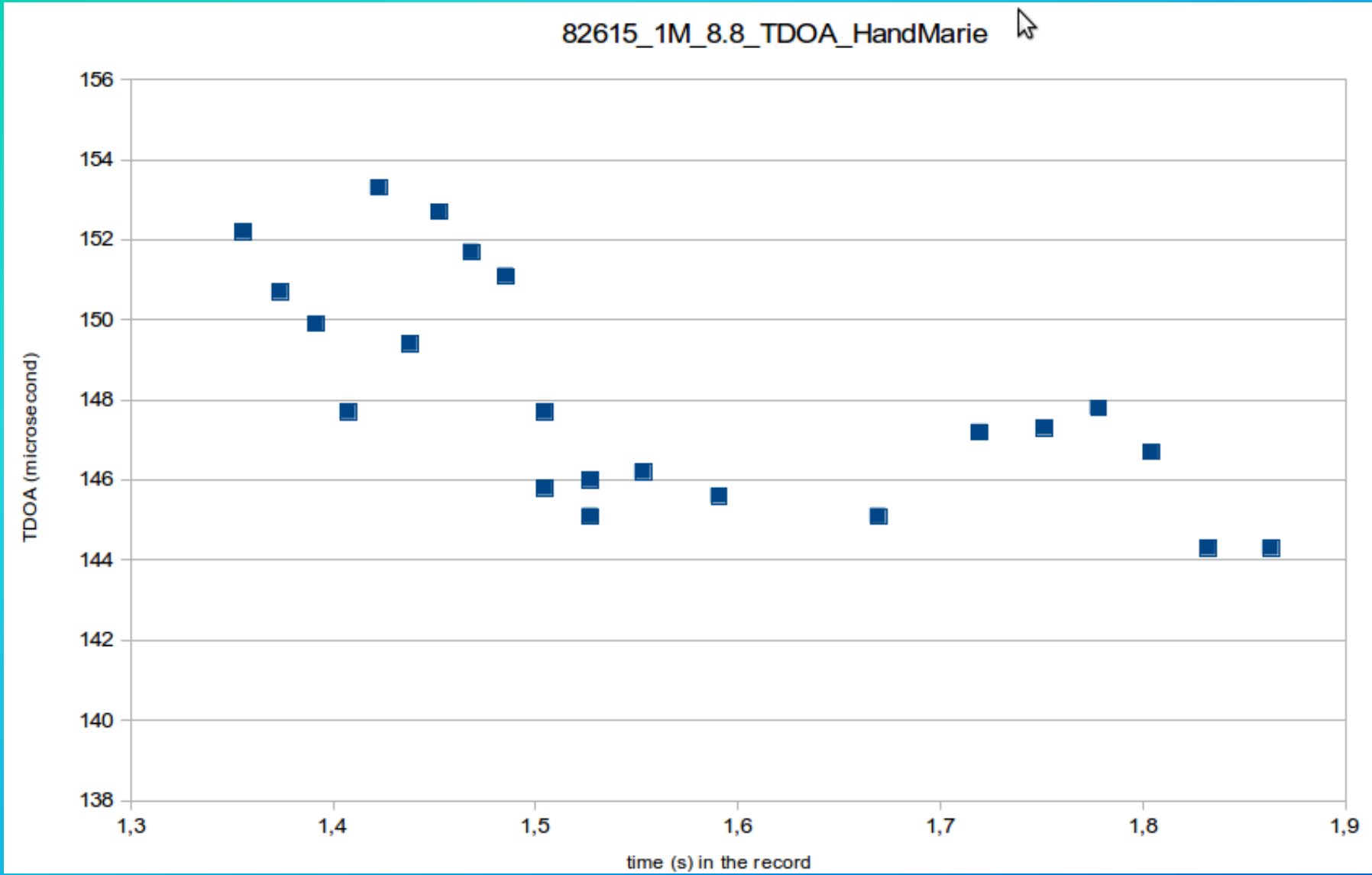

Page Start: 0 S
Delay: 5 S
kU
5
4
3
2
1
-0.00
-1
-2
-3
-4
-5
s
48.8
48.85
48.9
48.95
49
49.05
49.1
49.15
49.2
49.243
49.3
49.35
49.4
49.45
49.5
49.55
49.6
49.65
49.7
kHz
450
400
350
300
250
200
150
100
50
0.00


age Start: 0 S
Delay: 5 S
5
4
3
2
1
-0.00
-1
-2
-3
-4
-5
kU
s
49.55
49.56
49.57
49.58
49.59
49.6
49.61
49.62
49.63
49.64
49.65
49.66
49.67
49.68
49.69
49.7
49.71
49.72
49.73
49.74
49.75
49.76
49.773
1
450
400
350
300
250
200
150
100
50
0.00
kHz
Table 1

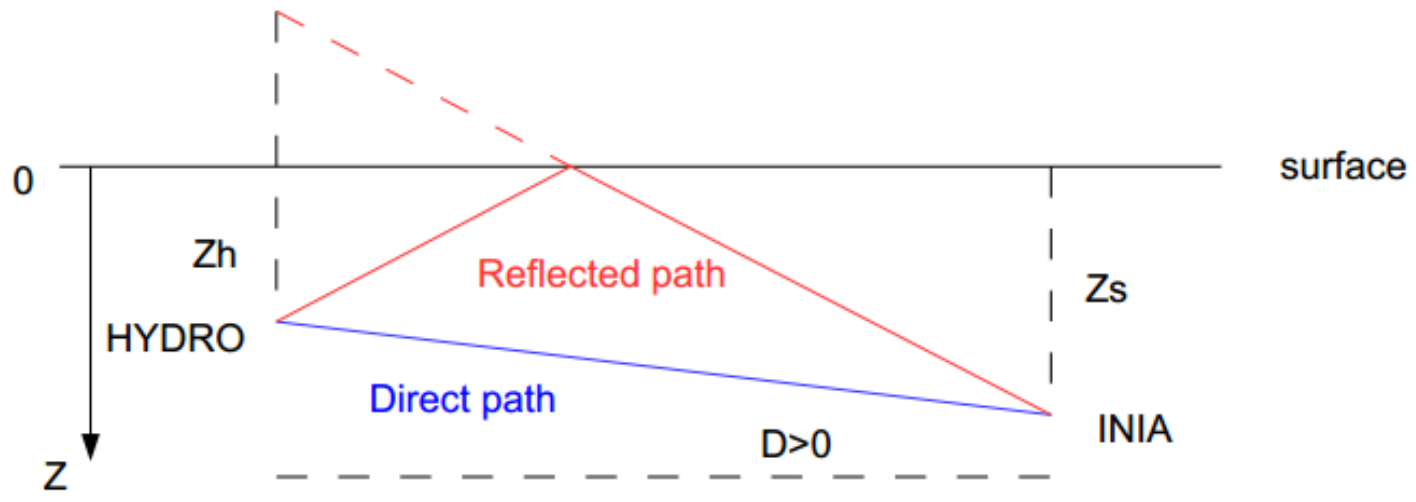

1
1
-0.000
-1
kU
m:s 1:07.808
1:07.808
1:07.808
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.809
1:07.81
1
200
150
100
50
0.000
kHz


Sound 1: Trone_Inia_Pacaya_8_12_15_1MHz_0012_45_seconds.wav
10
8
6
4
2
0.000
-2
-4
-6
-8
-10
ku
s 6.11
6.111
300
250
200
150
100
50
0.000
kHz

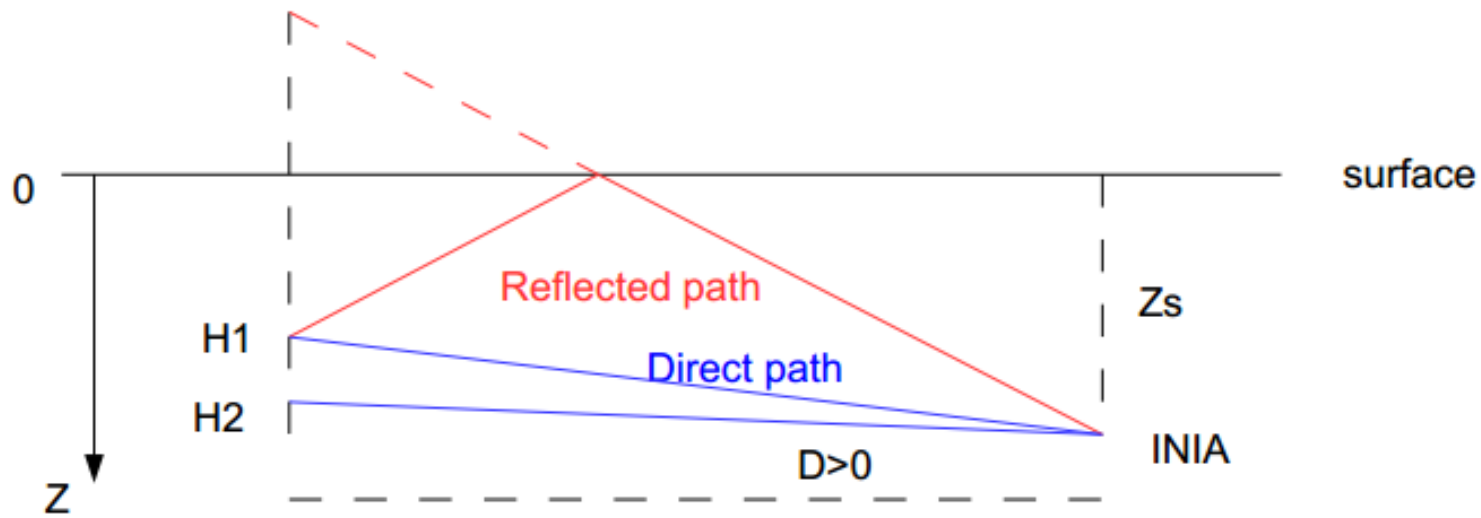

Sound 1: Trone_Inia_Pacaya_8_12_15_1MHz_0012_45_seconds.wav
1
10
8
6
4
2
0.000
-2
-4
-6
-8
-10
ku
s 5.285
5.285
5.285
5.286
5.286
5.286
5.286
5.286
450
400
350
300
250
200
150
100
0.000
kHz
1
s 5.285
5.285
5.285
5.286
5.286
5.286
5.286
5.286


82615_1M_8.8_TDOA_HandMarie
156
154
152
150
148
146
144
142
140
138
TDOA (microsecond)
1,3
1,4
1,5
1,6
1,7
1,8
1,9
time (s) in the record

- TDOA=sqrt((Zs+Zh)^2+D^2) – sqtr((Zs-Zh)^2+D^2)



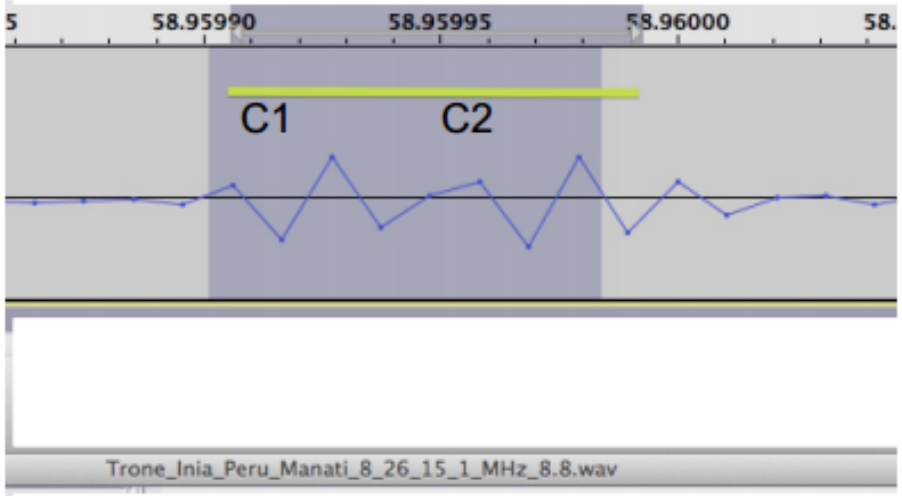
TDOA(H2) > TDOA(H1)



- Then if the second clic is the surface reflection of the first, TDOA of the vertical array (H1, H2), with H2 below H1, verifies :

TDOA(H2) > TDOA(H1)

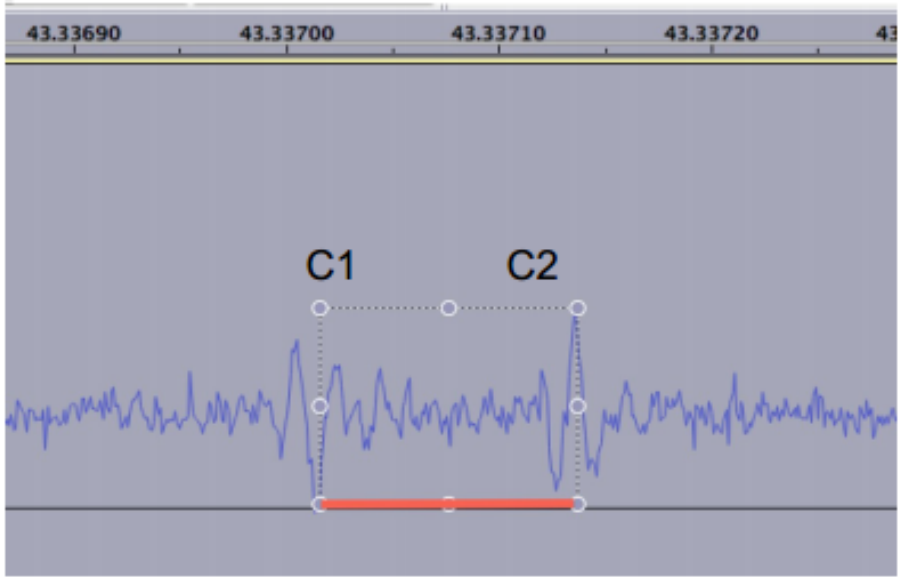
8_26_15_96_8.8_highPass



TDOA(H1) ~= 10 microseconds

T1Mhz-15.625101 + 1.000016 * T96k

8_26_15_1MHz_8.8_highPass



TDOA(H2) ~= 15 microseconds

Then TDOA(H2) > TDOA(H1)

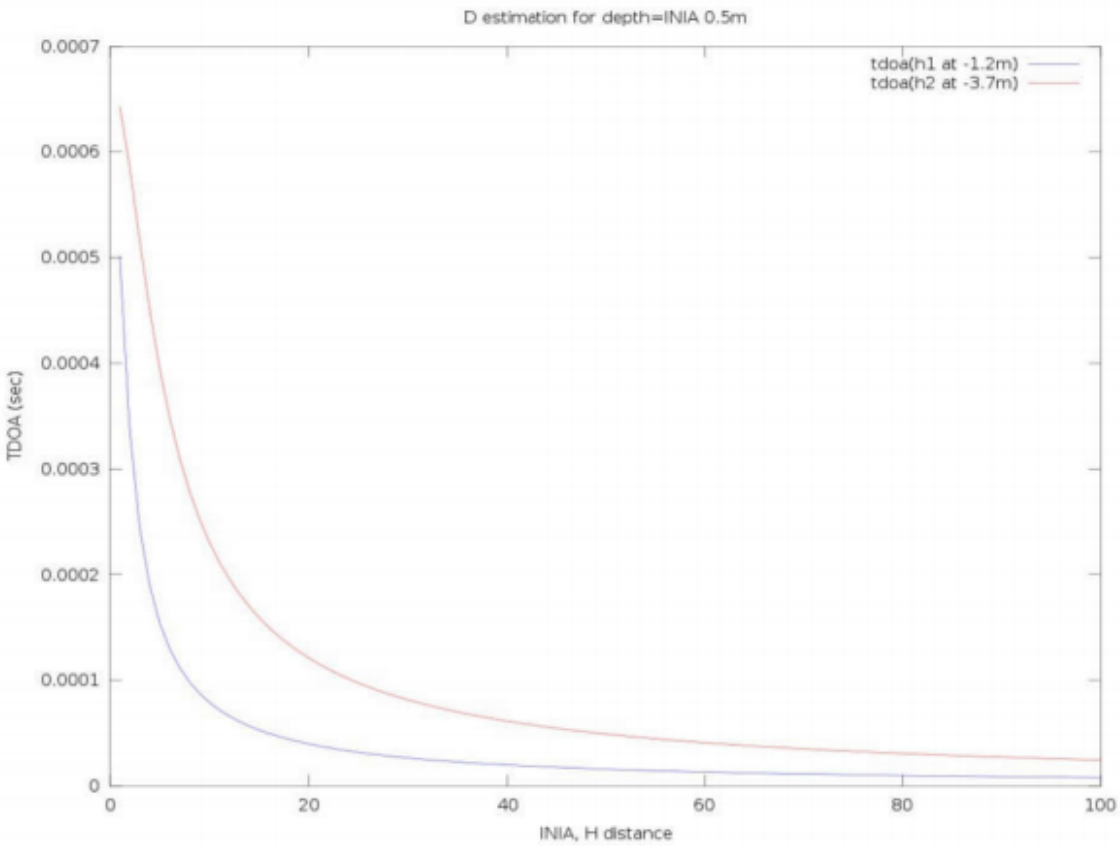
Then C2 is a reflection of C1 and H2 is below H1 (1MHz is below 96 kHz).
We also see the phase inversion in H2, and the decrease of the central frequency of the reflected clic.

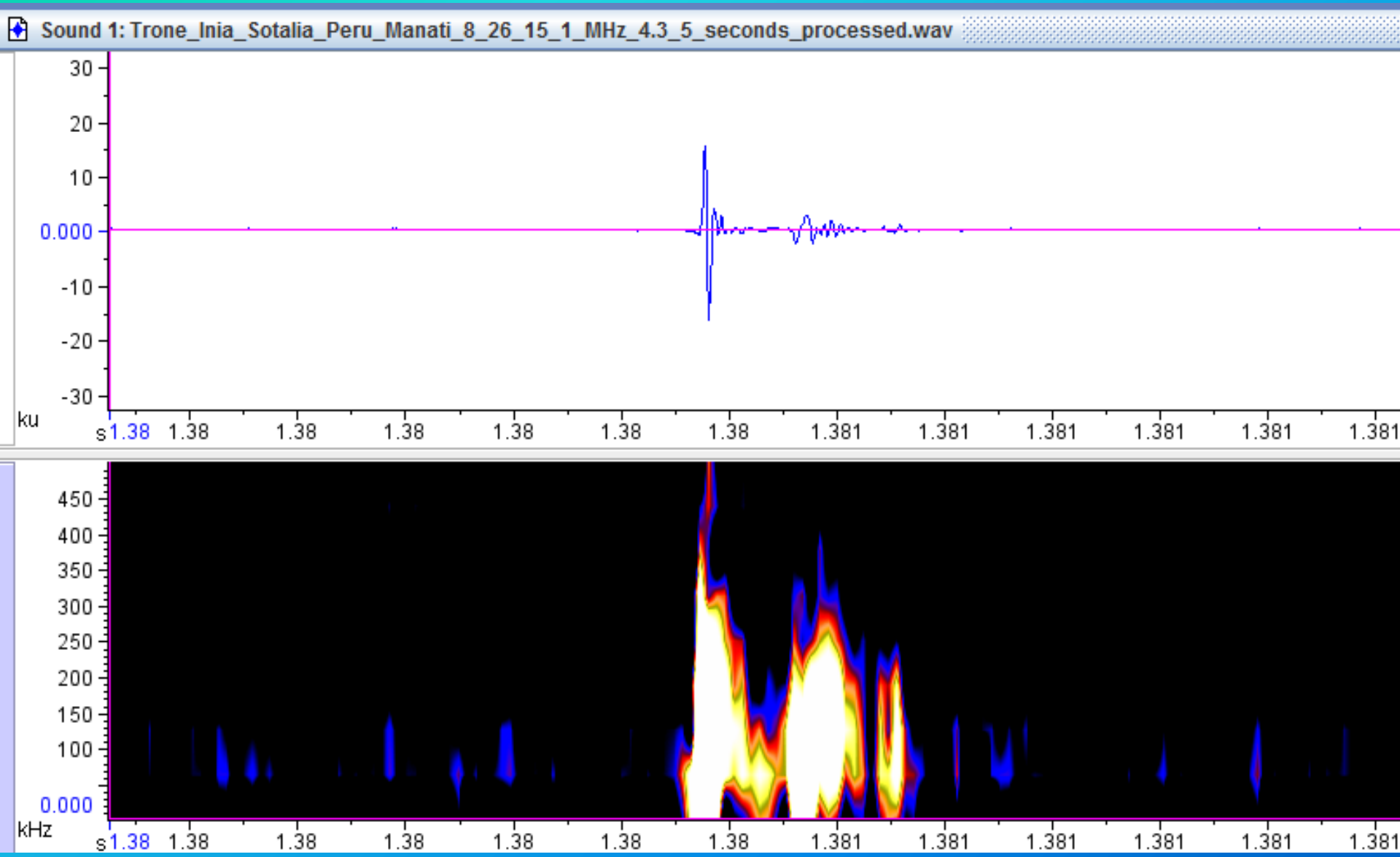
NB:If 96 kHz was below 1MHz then it can't be a reflected clic

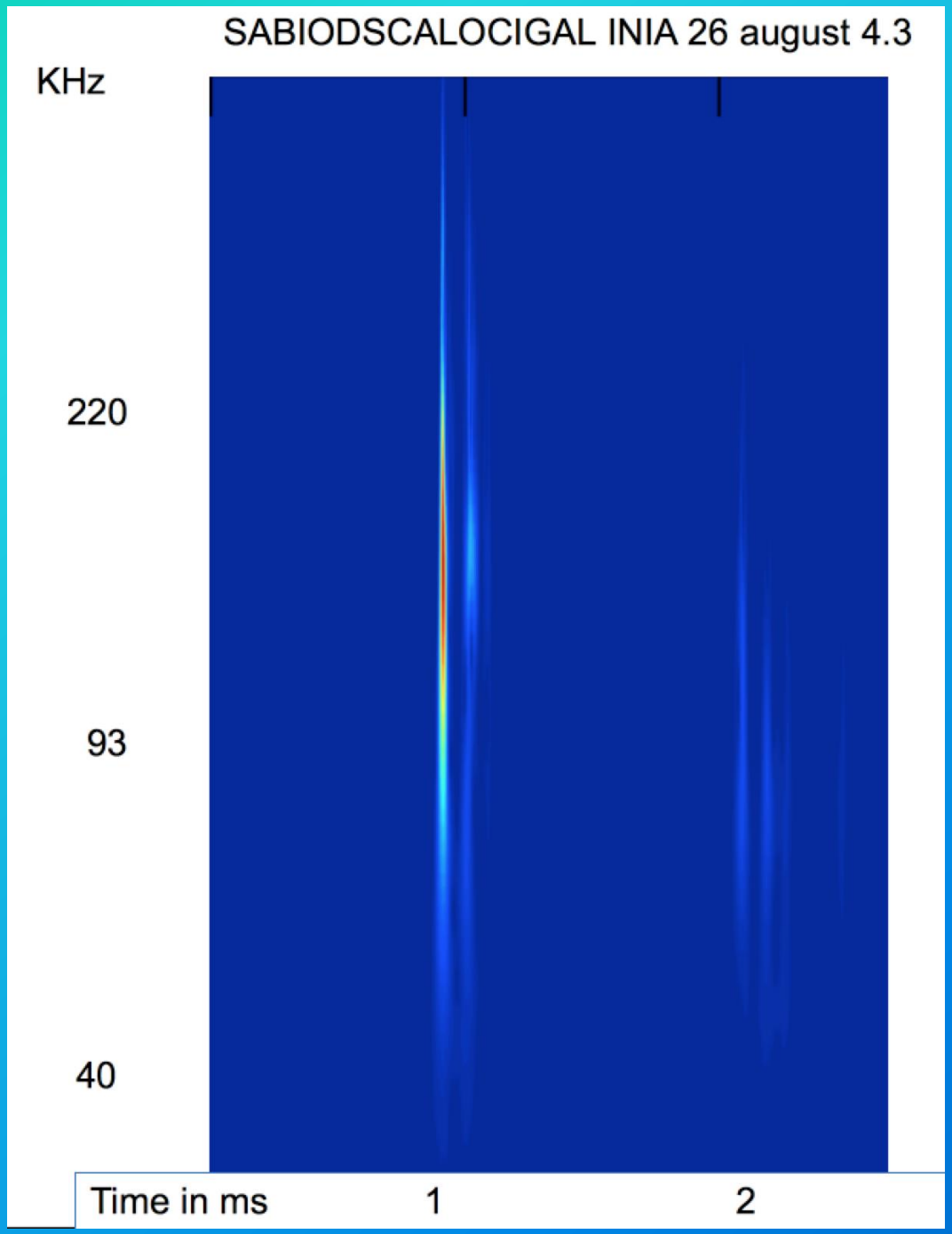
Possible positions of the INIA :

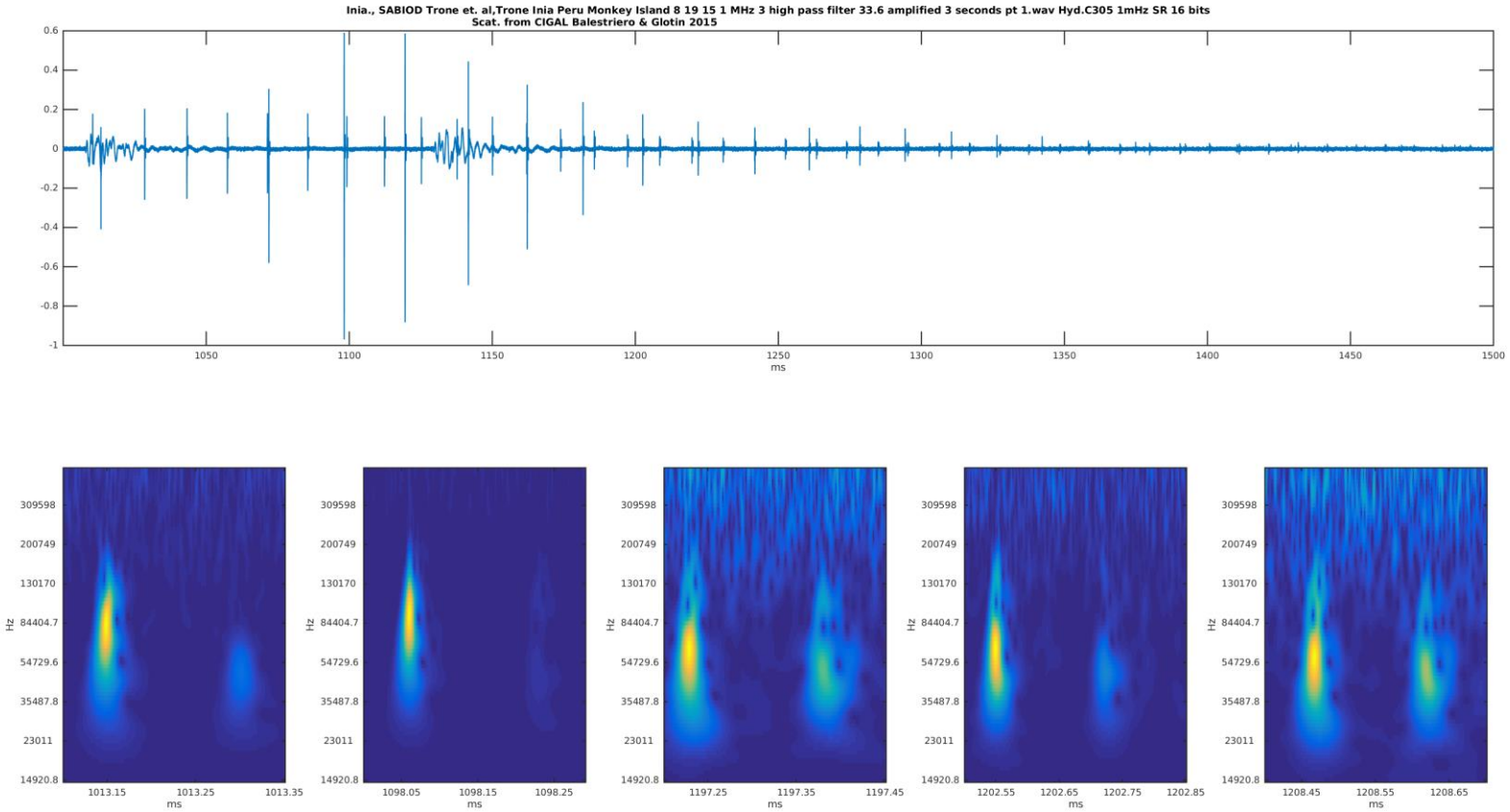
Depth	hydrophone distance
-2 m	80m
-1 m	50m
-0.5m	20m

Here is the computation for the -0.5m depth :




Sound 1: Trone_Inia_Sotalia_Peru_Manati_8_26_15_1_MHz_4.3_5_seconds_processed.wav
30
20
10
0.000
-10
-20
-30
ku
s1.38 1.38 1.38 1.38 1.38 1.38 1.38 1.381 1.381 1.381 1.381 1.381 1.381
450
400
350
300
250
200
150
100
0.000
kHz
s1.38 1.38 1.38 1.38 1.38 1.38 1.38 1.381 1.381 1.381 1.381 1.381 1.381


SABIODSCALOCIGAL INIA 26 august 4.3
KHz
220
93
40
Time in ms
1
2

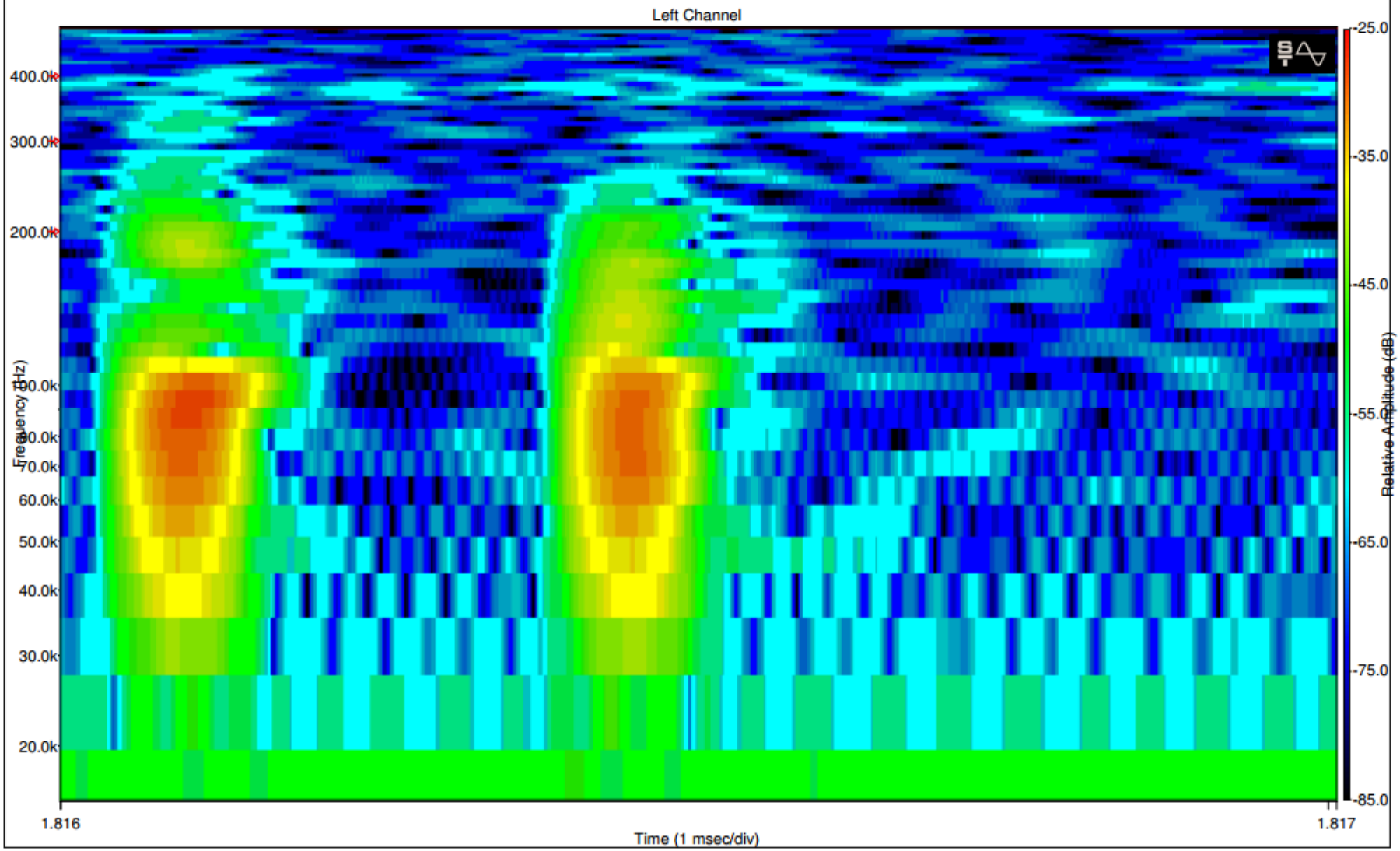

Inia., SABIOD Trone et. al,Trone Inia Peru Monkey Island 8 19 15 1 MHz 3 high pass filter 33.6 amplified 3 seconds pt 1.wav Hyd.C305 1mHz SR 16 bits
Scat. from CIGAL Balestriero & Glotin 2015
ms
Hz
309598
200749
130170
84404.7
54729.6
35487.8
23011
14920.8

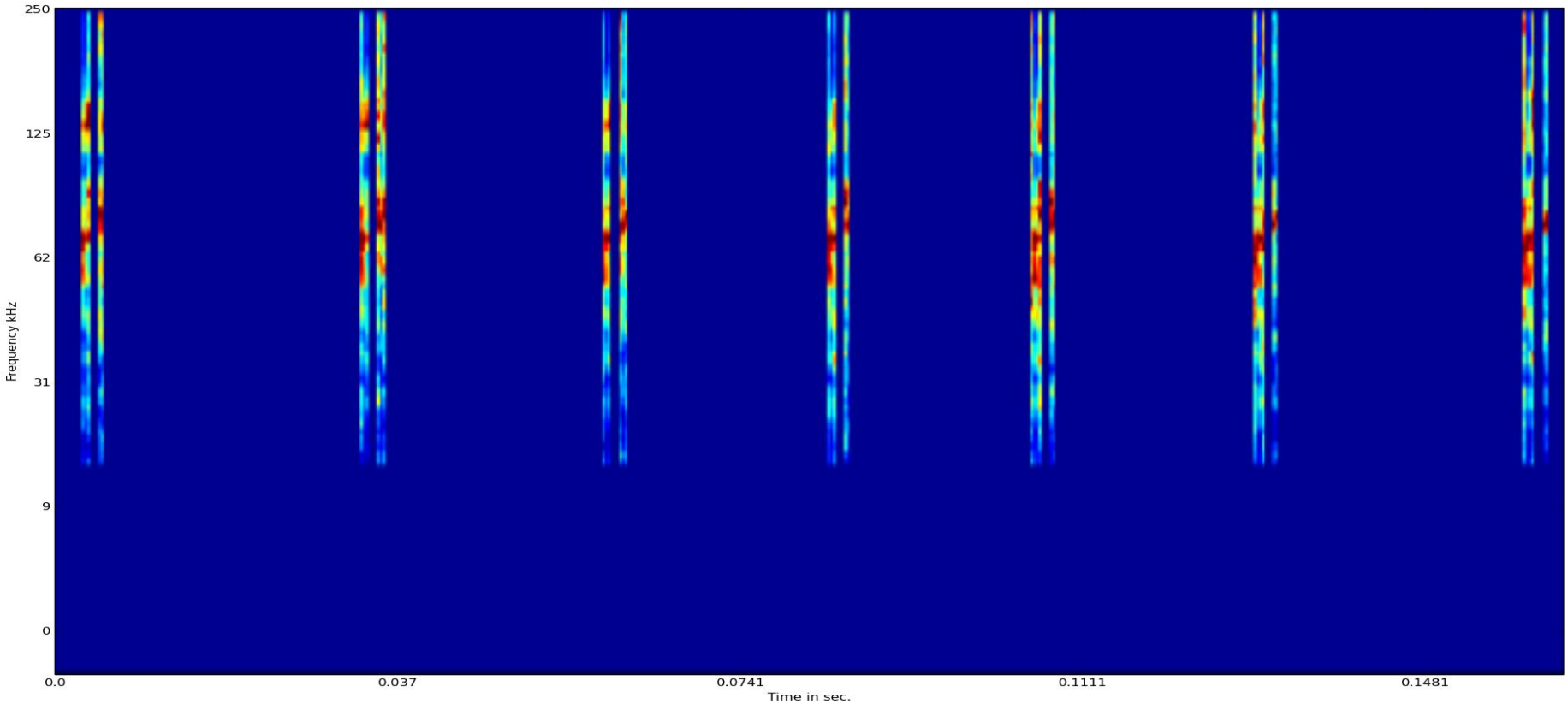
Overlap: 99 %

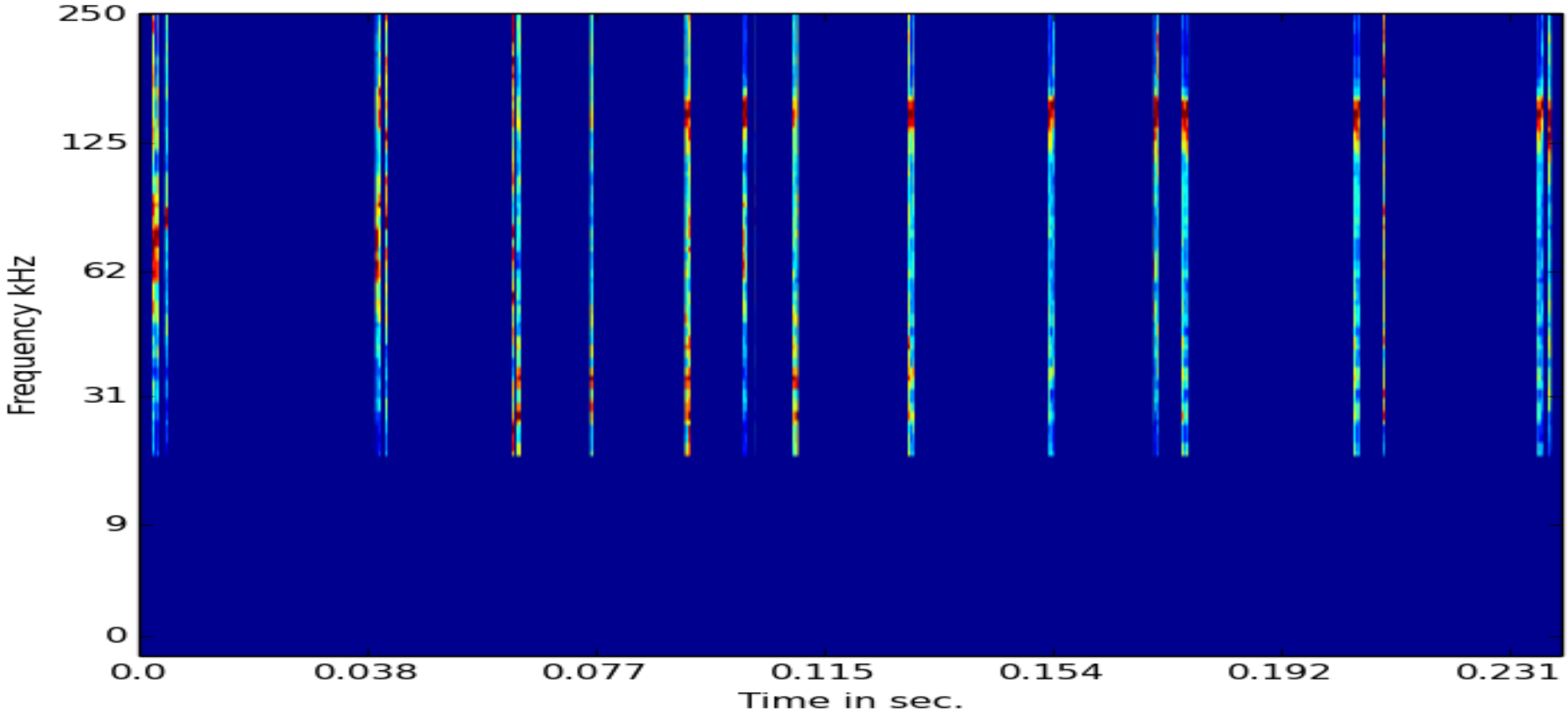
Sampling: 1000000 Hz
FFT size: 128
Averaging: 1
Window: Hanning

Amazon River Dolphins Recorded by Marie Trone
with C305 Hydrophone and IOTech PersDAQ3000

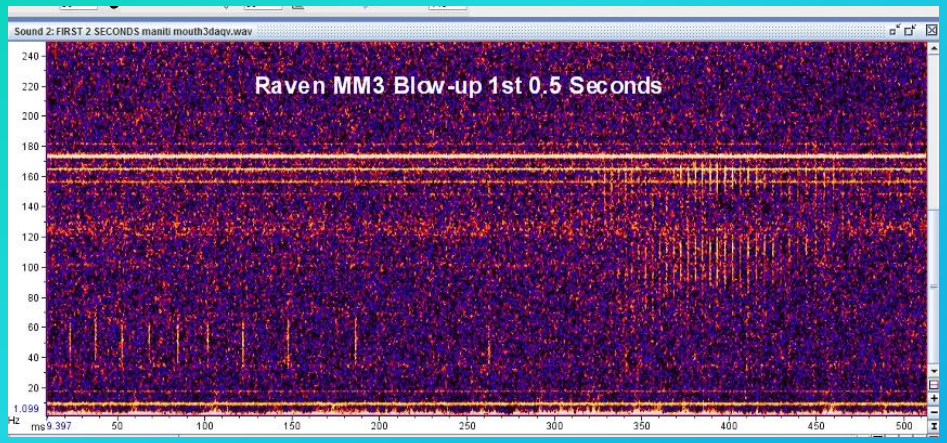
Printed by: SpectraLAB - FFT Spectral Analysis System
Licensed to: Joseph R. Olson
Wed Aug 19 18:09:58 2015

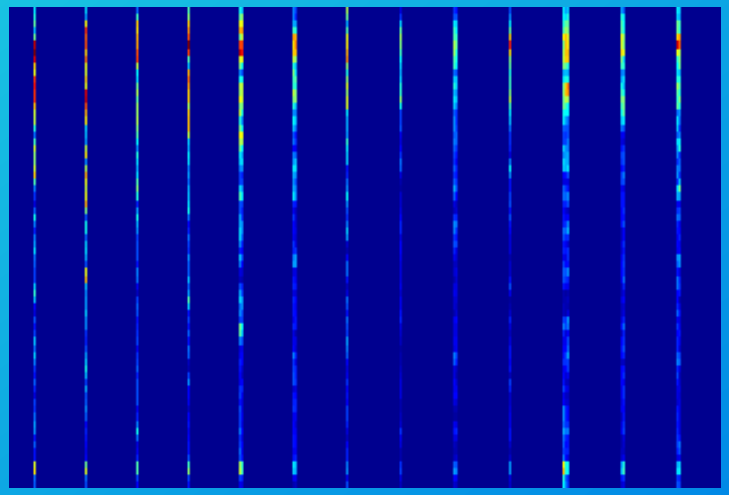



250
125
62
31
9
0
Frequency kHz
0.0
0.037
0.0741
0.1111
0.1481
Time in sec.

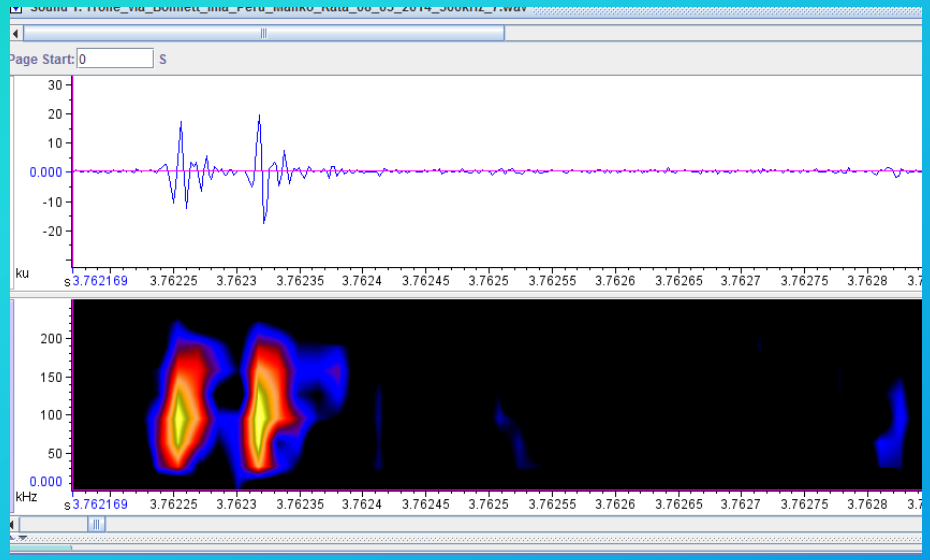

250
125
62
31
9
0
Frequency kHz
0.0
0.038
0.077
0.115
0.154
0.192
0.231
Time in sec.

Gabor used to identify peak frequencies

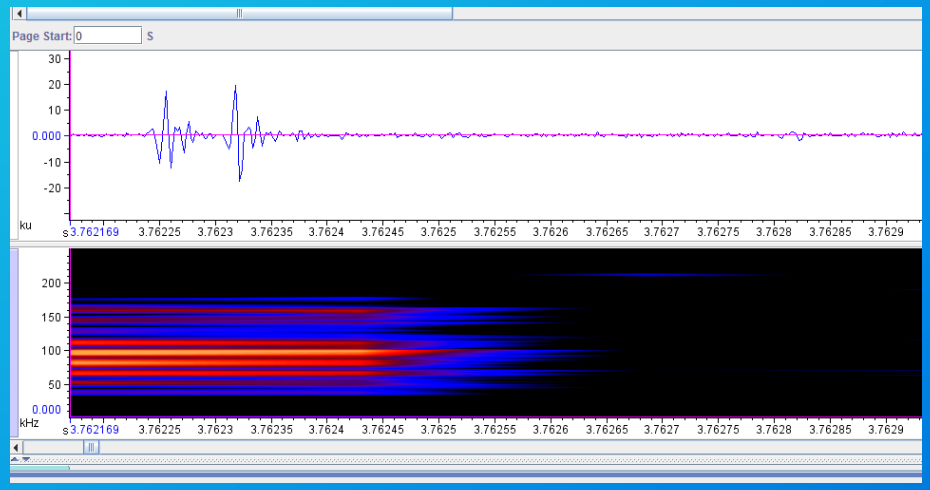




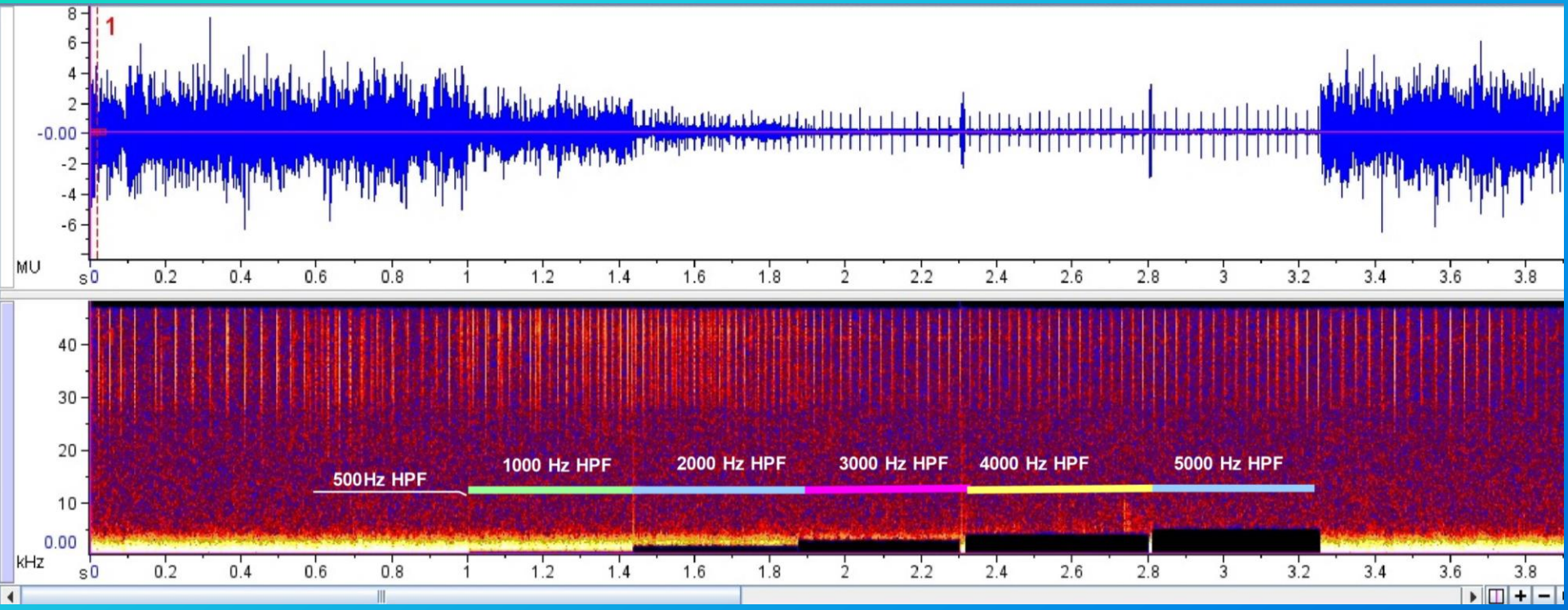
FFT time-frequency trade-off



Bin size 15



Bin size 256

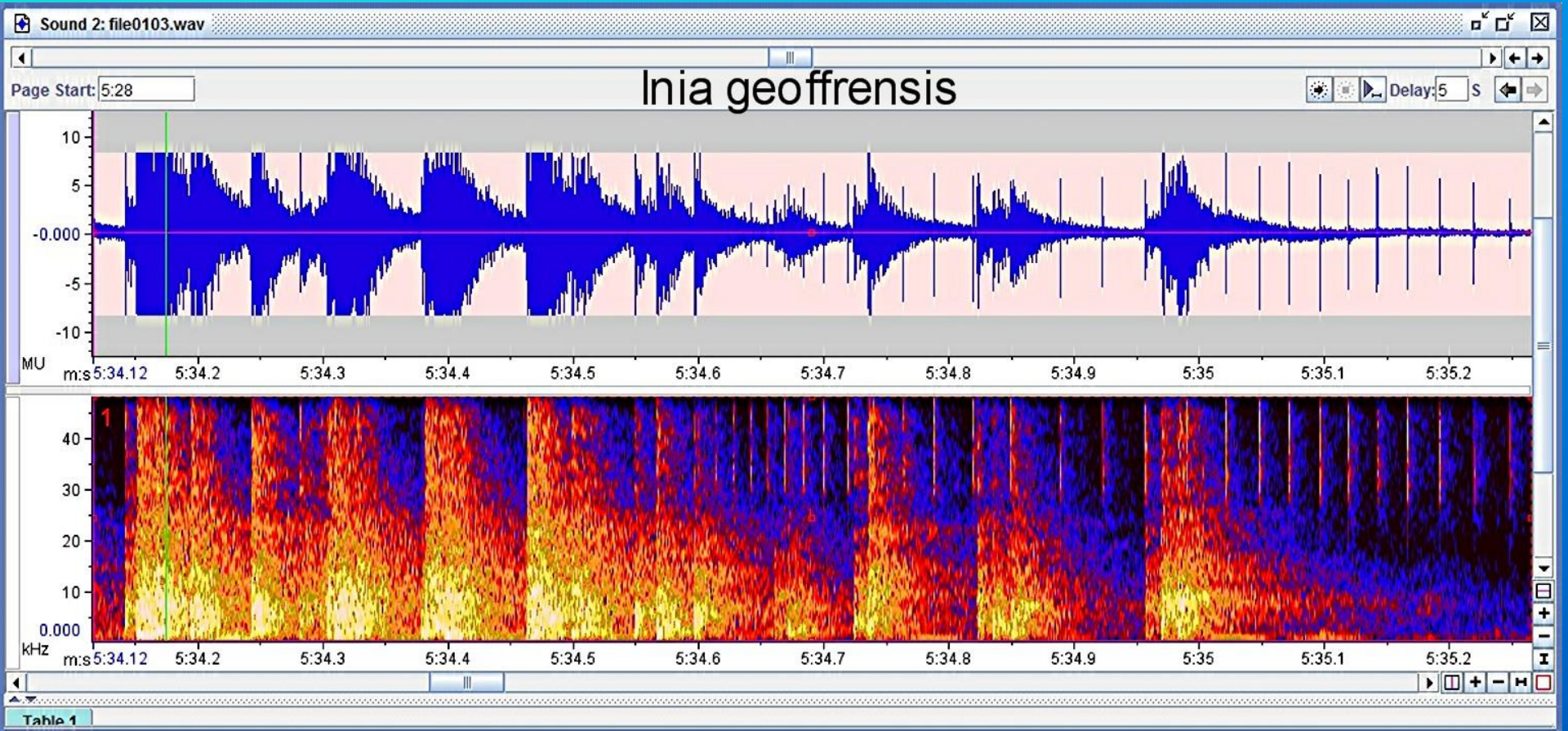


March 5, 2014
96 kHz sample rate

Popcorn

Real-time

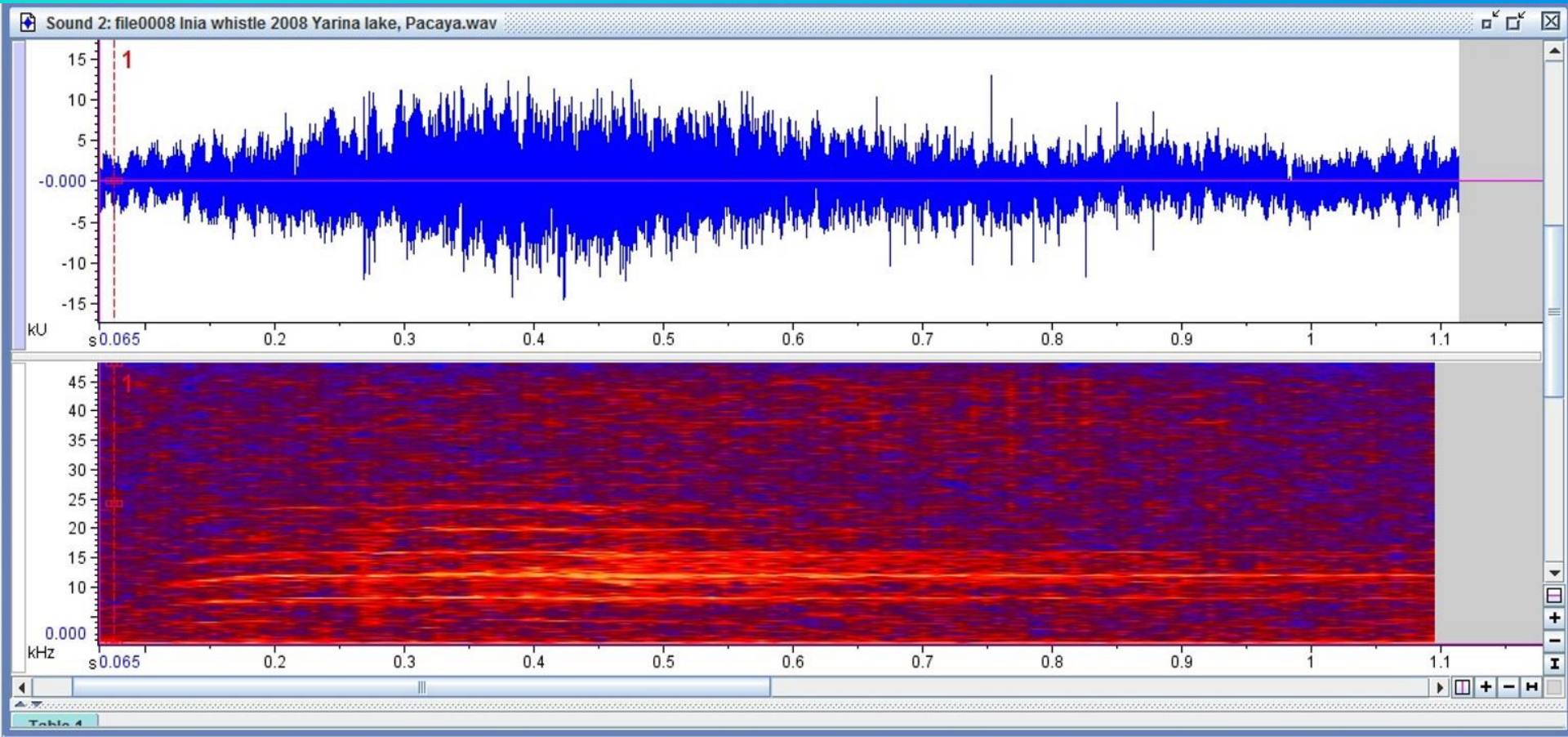
Slowed 90%



Whistle

Real-time

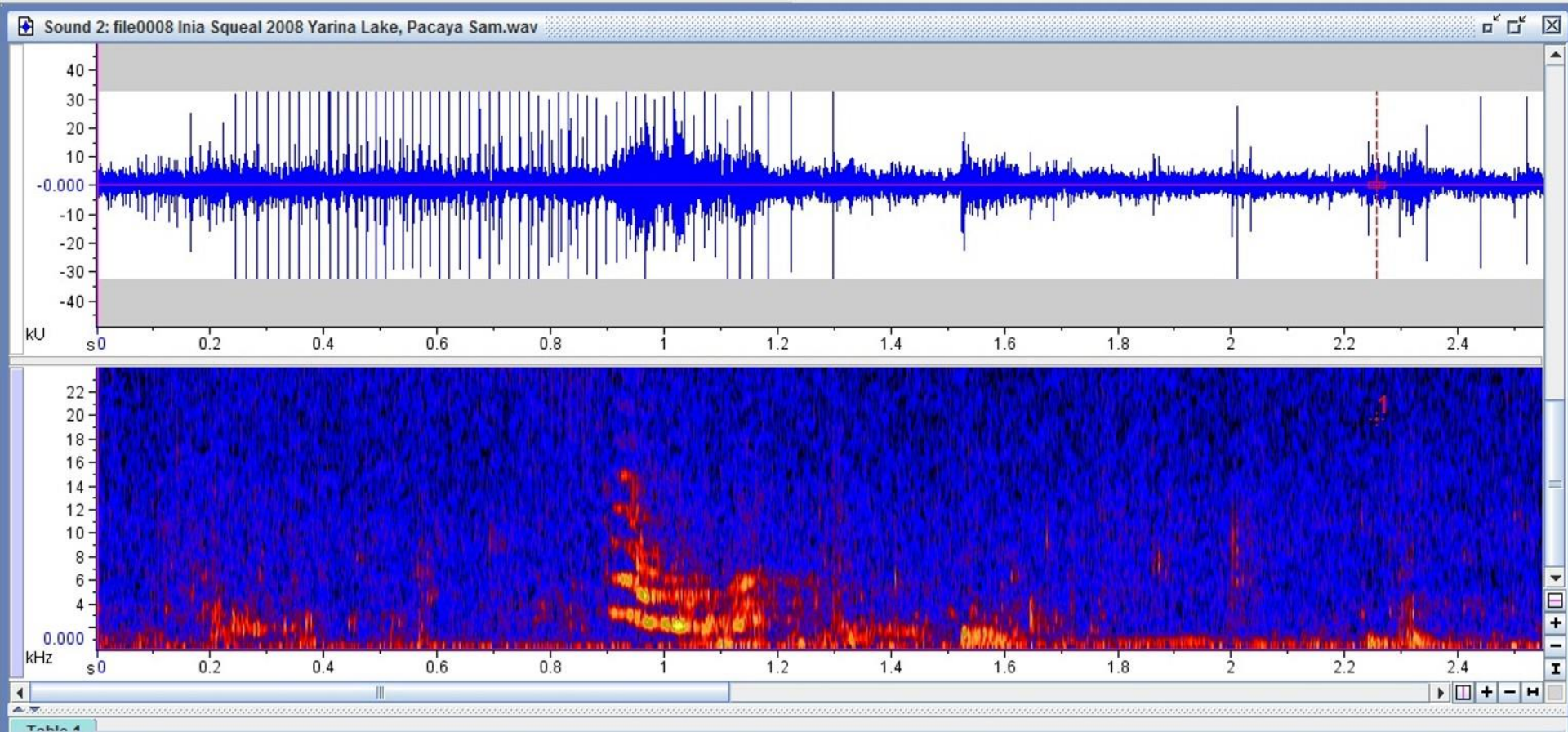
Slowed 90%



Squeal, often observed w/ mother & juvenile pairs

Real-time

Slowed 90%



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- -International Expeditions
- -Dolphin Communication Project

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