Improving Dolphin Acoustic Classification:

Compound classification using whistles, echolocation, and burst pulses

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NOAA FISHERIES

Misclassification-Based Classification

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Objective:
Acoustic Classification of Dolphin Schools

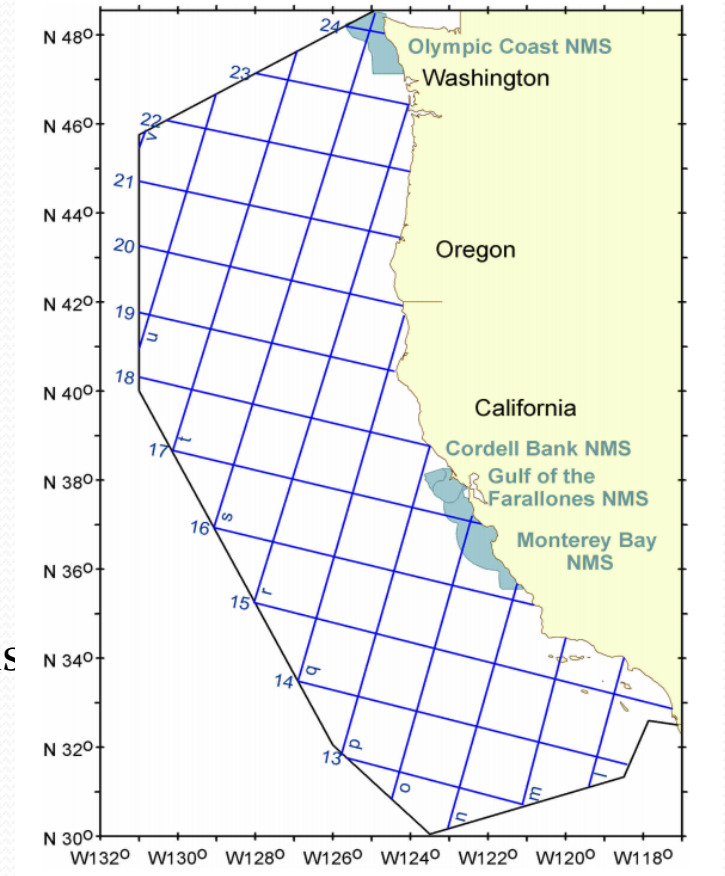
- Level of Classification: **Dolphin School** ('event')
- Consider **ALL** call types
- Minimize human intervention

  (less work, less bias, fewer errors?)

Methods:

2014 California Current Cetacean Ecosystem Assessment Survey

- Combined visual & acoustic shipboard cetacean survey
- Visual: confirm species identity
- Acoustic: Towed Hydrophone Array
- 2 Channel Recordings
  - 500 kHz sample rate
  - Frequency sensitivity ~ 1 - 120 kHz
- Matching Visual & Acoustic Detections
  - Field localization of single species schools
  - Post-cruise elimination questionable detections



Identify Qualifying Events:

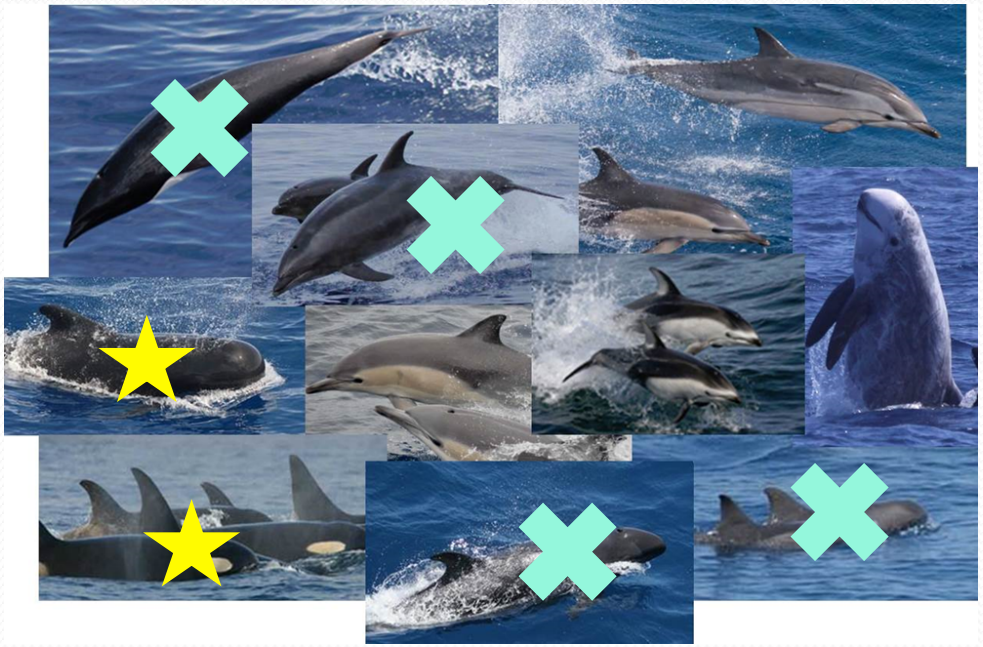
13 Striped Dolphins (*Stenella coeruleoalba*)

7 Long-Beaked Common Dolphins (*Delphinus **capensis***)

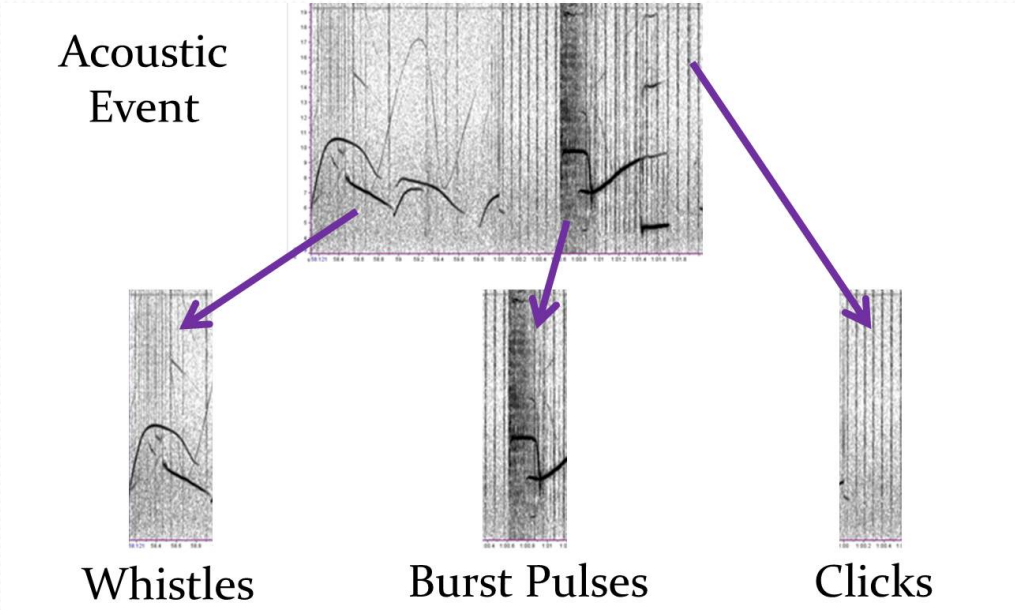
116 Short-Beaked Common Dolphins (*Delphinus **delphis***)

5 Risso's Dolphins (*Grampus griseus*)

10 Pacific White-Sided Dolphins (*Lagenorhynchus obliquidens*)



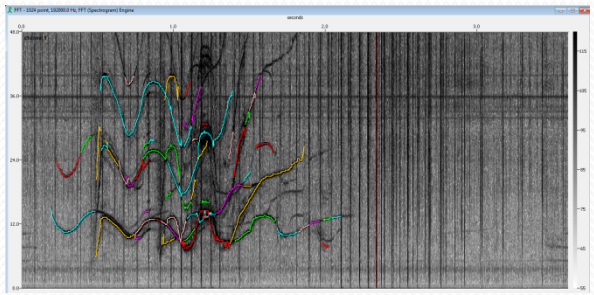
Can we predict the species of an event based on its Acoustic Features?

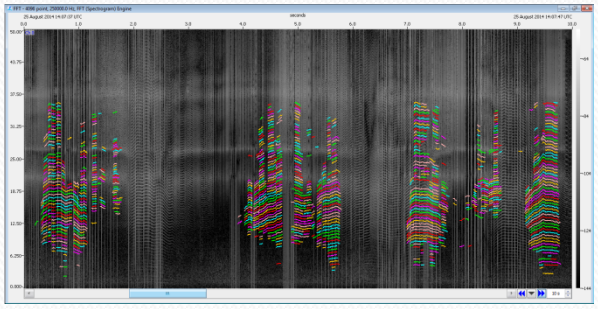


1. Detect Calls
2. Classify Calls
3. Classify Events

Detect Calls

Pamguard v 1.13.xx *with* ROCCA Module



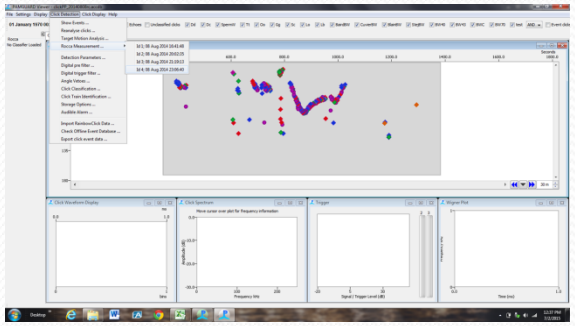


Whistle & Moan Detectors
- Decimated to 250 kHz
- FFT 4096
- Hop Size 2048 samples
- Keating *et al*. Poster

ROCCA Output (Measures/Call)

→ **50**

→ **50**



→ **Click Detectors** → **11**

	bp	dw	ec
Sc	142	8271	29146
Dc	13529	61902	119358
Dd	138182	501288	982187
Gg	4049	570	50286
Lo	5079	4794	91787
Gm	158	734	5401
Oo	0	2	1316
	161,139	**577,561**	**1,279,481**
	(50)	**(50)**	**(11)**

Classify Calls

- Select 50,000 Calls per call type

  to decrease computational time

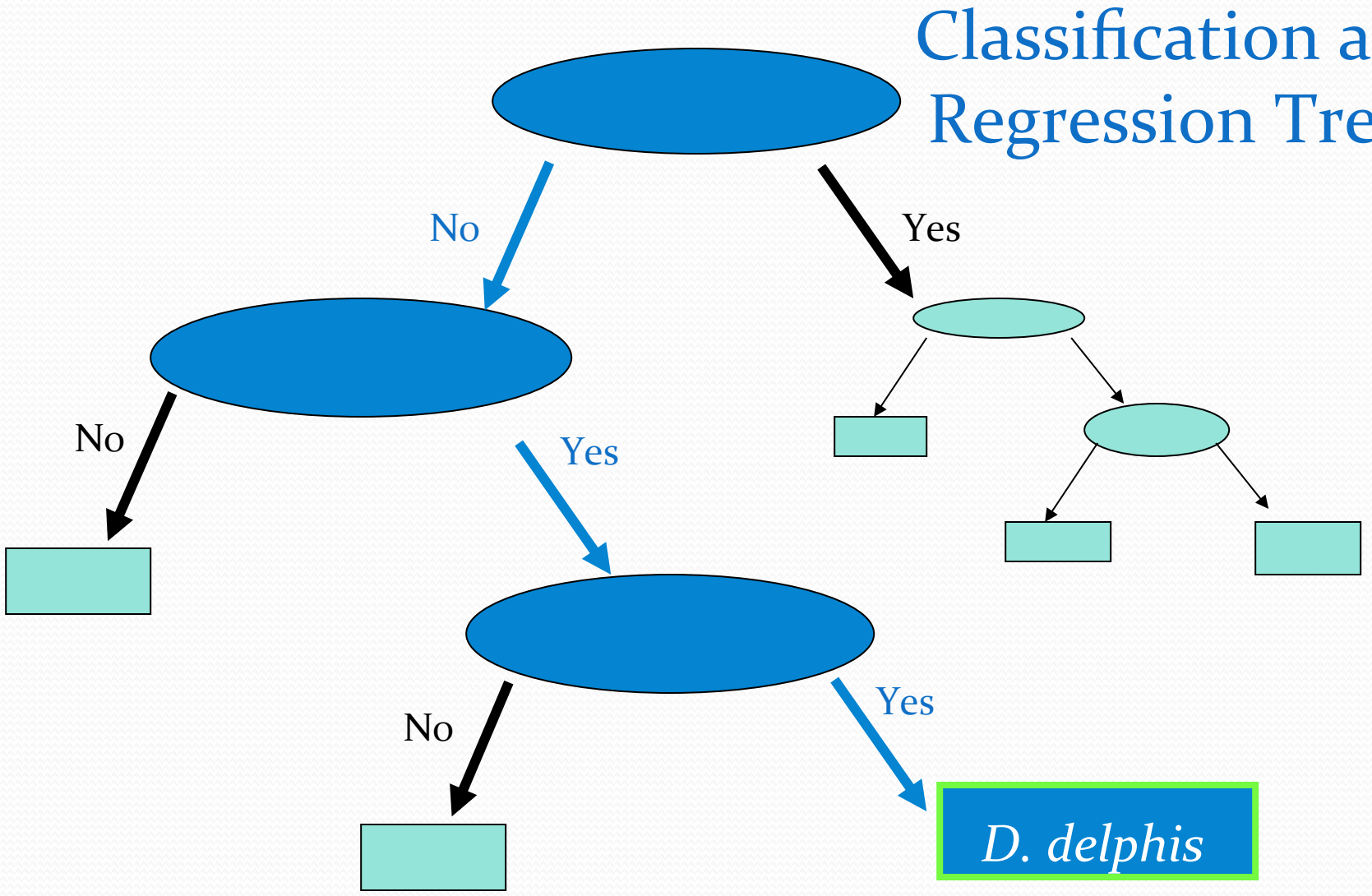
- Clustering: select maximum 1,000 most representative calls

  to address issues with repeated measures

- Random Forest

  tree-based classification model

Classify Calls



Classify Calls

- Select 50,000 Calls per call type

  to decrease computational time

- Clustering: select maximum 1,000 most representative calls

  to address issues with repeated measures

- Random Forest
  - Each tree built on 50 calls (or n/2)

  to balance number of calls used in model

  - Samples taken w/o replacement
  - 50,000 trees

Classify Calls

Whistles

OOB estimate of error rate: 56.8%

	Sc	Dc	Dd	Gg	Lo	Gm	Oo	class.error
Sc	621	136	107	4	75	57	0	0.379
Dc	312	229	214	66	125	54	0	0.771
Dd	280	188	293	91	114	34	0	0.707
Gg	21	11	9	475	25	29	0	0.167
Lo	158	109	51	221	317	144	0	0.683
Gm	142	54	60	42	80	356	0	0.515
Oo	2	0	0	0	0	0	0	1.000

Burst Pulses

OOB estimate of error rate: 66%

	Sc	Dc	Dd	Gg	Lo	Gm	lass.error
Sc	78	4	13	16	4	27	0.45
Dc	243	198	240	125	91	103	0.80
Dd	153	155	319	130	112	131	0.68
Gg	161	23	31	553	86	146	0.45
Lo	159	75	117	216	264	169	0.74
Gm	33	6	17	23	21	58	0.63

Clicks

OOB estimate of error rate: 60%

	Sc	Dc	Dd	Gg	Lo	Gm	Oo	class.error
Sc	334	76	62	75	89	141	223	0.666
Dc	92	322	250	171	51	64	50	0.678
Dd	106	237	276	144	76	88	73	0.724
Gg	60	109	88	537	84	85	37	0.463
Lo	71	60	77	63	522	104	103	0.478
Gm	161	61	56	106	119	345	152	0.655
Oo	215	41	34	35	78	135	462	0.538

Error Rates

- Whistles = 56%
- Burst Pulses = 66%
- Clicks = 60%

Species:
Sc = Striped dolphin
Dc = Long beaked common dolphin
Dd = short-beaked common dolphin
Gg = Risso's dolphin
Lo = Pacific White-sided dolphin
Gm = pilot whale
Oo = killer whale

Event Classification

All Data (by event)

	bp	dw	ec
Sc	142	8271	29146
Dc	13529	61902	119358
Dd	138182	501288	98[illegible]
Gg	4049	570	5[illegible]
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Gm	158	734	5401
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Call Classifier

Whistles

OOB estimate of error rate: 56.8%

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Sc	621	136	107	4	75	57	0	0.379
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Oo	2	0	0	0	0	0	0	1.000

[illegible]ulses

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Gg	161	23	31	553	86	146	0.45
Lo	159	75	117	216	264	169	0.74
Gm	33	6	17	23	21	58	0.63

Random Forest
25,000 Trees

For Each Call:
25,000 Decisions which will have some distribution of classifications to different species*

* If used to develop classifier, then only used testing not training data (~12,500 decisions)

Event Classification

call.event#.call#	Sc	Dc	Dd	Gg	Lo	Gm
bp.119.1061	0.082	0.137	0.187	0.1195	0.128	0.346
bp.119.1062	0.014	0.294	0.463	0.0094	0.081	0.139
bp.119.1063	0.012	0.364	0.450	0.0039	0.034	0.136
bp.119.1086	0.355	0.268	0.240	0.0012	0.020	0.116
bp.119.1089	0.238	0.176	0.329	0.0240	0.106	0.126
bp.119.1090	0.044	0.309	0.505	0.0096	0.053	0.078

Calculate the mean assignment probability for each call type, for each

calltype.event#.	Sc	Dc	Dd	Gg	Lo	Gm
bp.119	0.124	0.258	0.362	0.005	0.07	0.104

Event Classification

Mean assignment probabilities

Call type frequencies

Whistle rate

Event	Species	bp.k	dw.k	ec.k	%dw	%bp	%ec	dw.rate
1	17							
2	17							
3	13							
4	13							
5	17							
6	16							
7	22							

Random Forest:

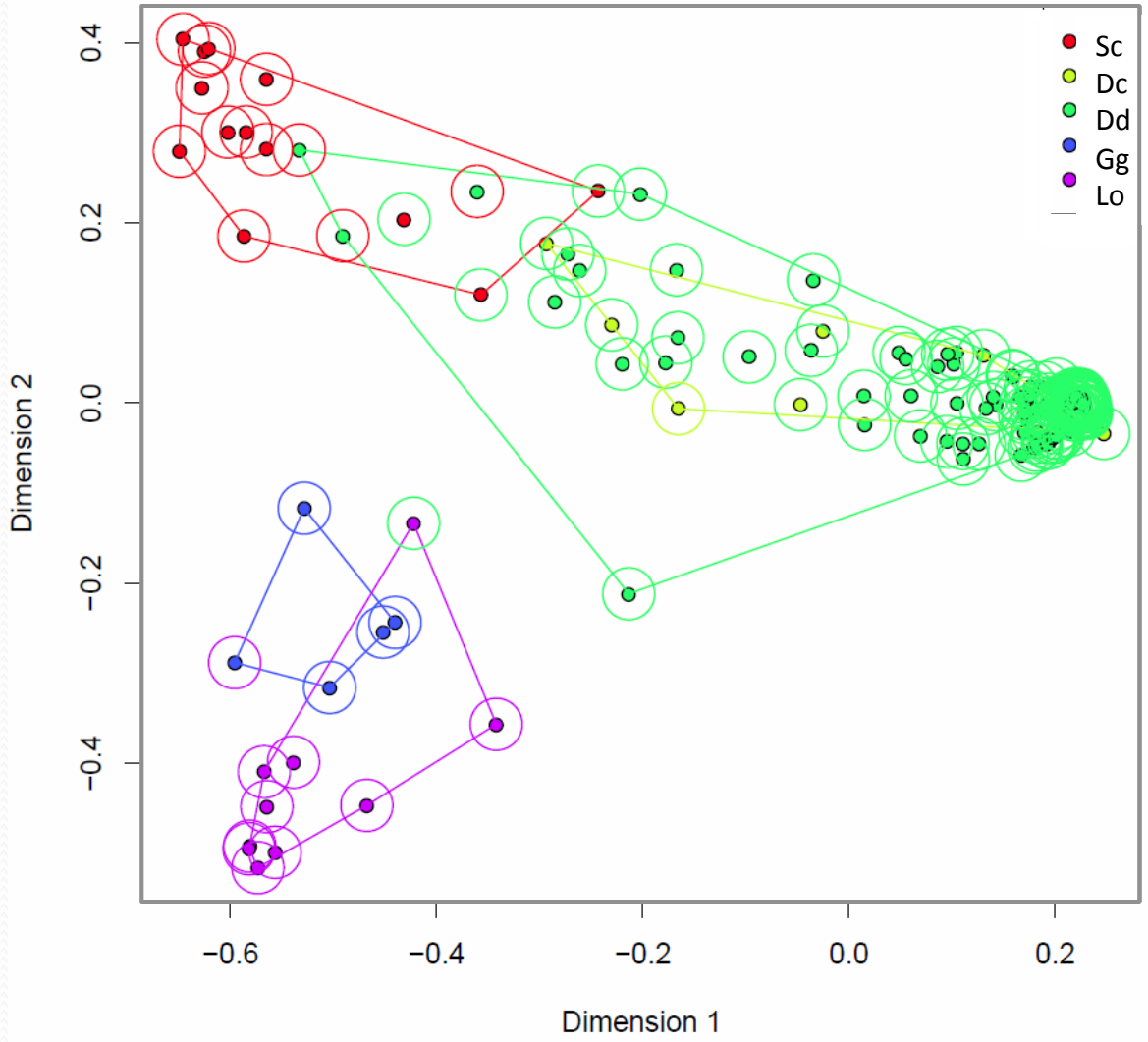
- No Replacement
- 5,000 Trees
- n/2 Events per Species*

* Eliminated killer whales & pilot whales

Event Classification

							Expected*
Out-of-Bag Estimation of Error Rate:						9.3%	39.7%
	Sc	Dc	Dd	Gg	Lo	Class Error	
Sc	10	0	3	0	0	0.231	0.913
Dc	0	1	6	0	0	0.857	0.953
Dd	3	0	112	0	0	0.026	0.233
Gg	0	0	0	4	1	0.200	0.967
Lo	0	0	1	0	9	0.100	0.933

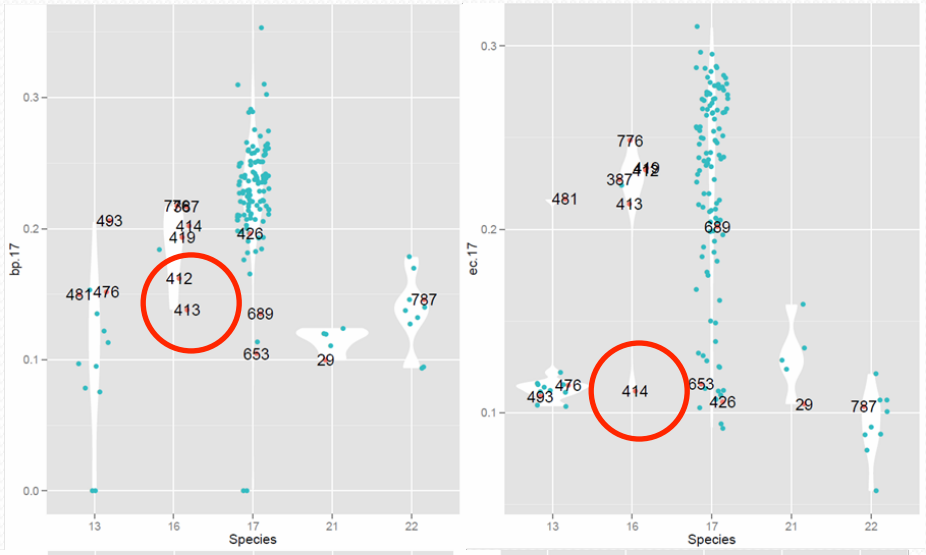
* *Prior probability based on disequilibrium of sample sizes*



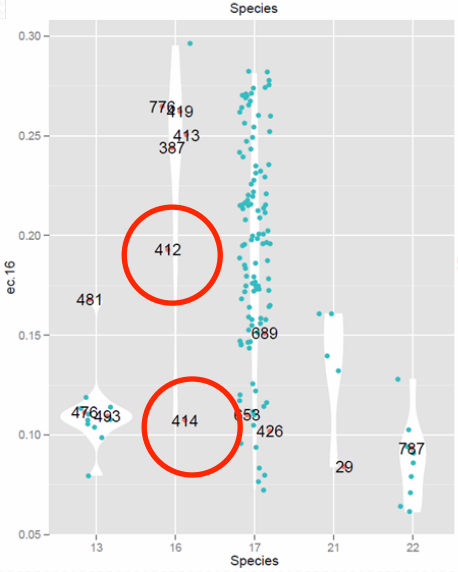
Sc Event

Sc -> Sc

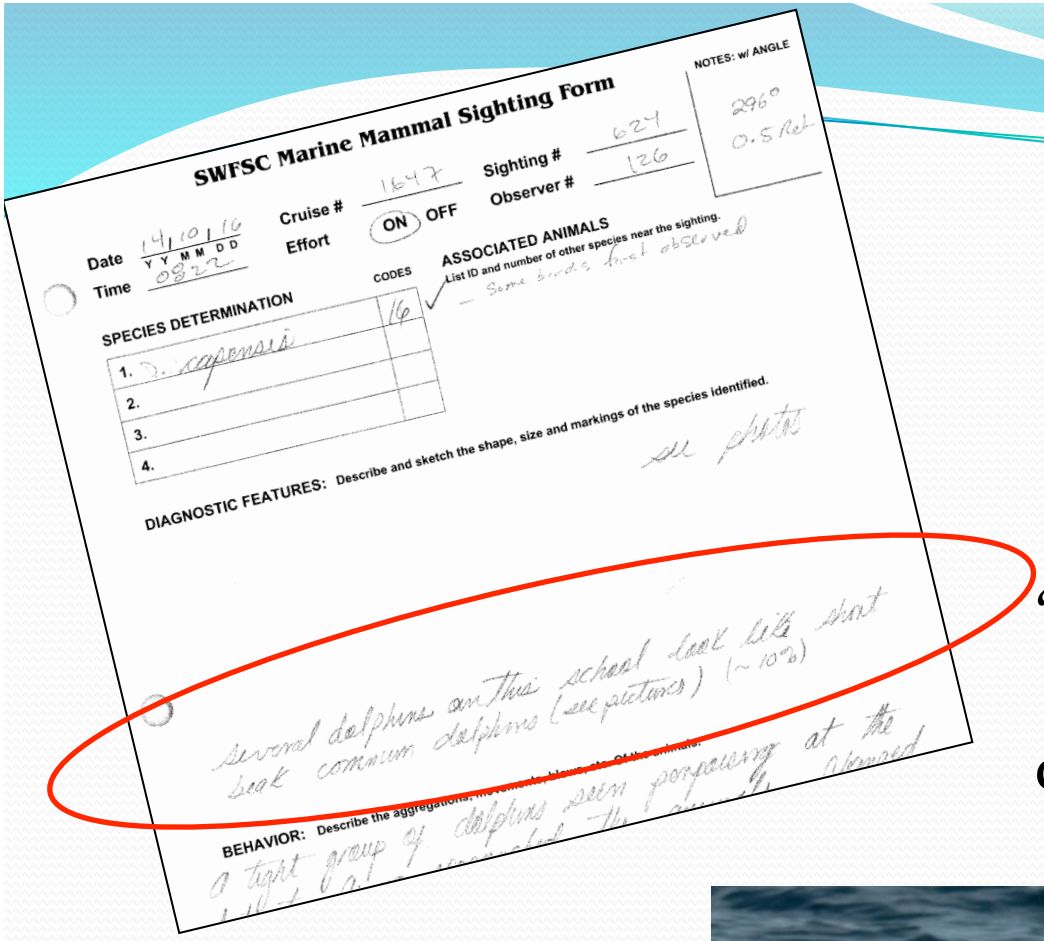
Sc -> Dd


bp.17
0.3
0.2
0.1
0.0
493
776
787
414
419
426
481
476
412
413
689
653
29
787
13
16
17
21
22
Species

ec.17
0.3
0.2
0.1
776
419
387
481
413
689
493
476
414
653
426
29
787
13
16
17
21
22
Species


ec.16
0.30
0.25
0.20
0.15
0.10
0.05
776
419
413
387
412
481
689
476
493
414
653
426
29
787
13
16
17
21
22
Species


ec.37
0.25
0.20
0.15
0.10
0.05
426
476
414
29
493
653
787
689
413
412
776
481
419
387
13
16
17
21
22
Species


SWFSC Marine Mammal Sighting Form

NOTES: w/ ANGLE
296°
0.5 Rel

Date 14/10/16 (YY MM DD)
Time 0822
Cruise # 1647
Effort ON OFF
Sighting # 624
Observer # 126

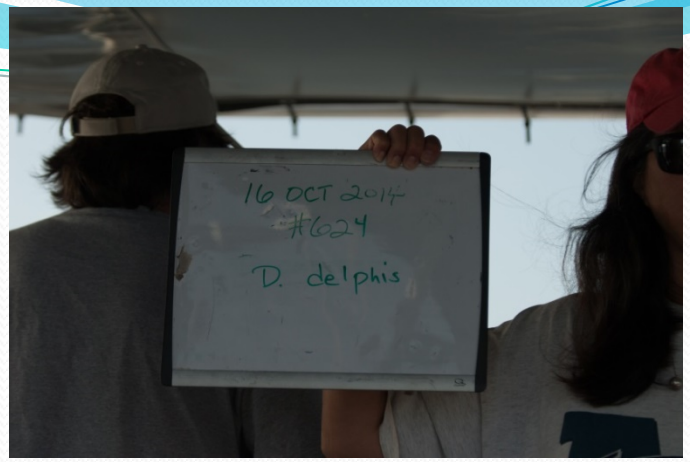
SPECIES DETERMINATION
CODES
ASSOCIATED ANIMALS
List ID and number of other species near the sighting.
— Some birds first observed

1. D. capensis 16
2.
3.
4.

DIAGNOSTIC FEATURES: Describe and sketch the shape, size and markings of the species identified.
see photos

Several dolphins on this school look like short beak common dolphins (see pictures) (~10%)

BEHAVIOR: Describe the aggregation; the
a tight group of dolphins seen porpoising at the



'several dolphins in this school look like short beak common dolphins (see pictures) (~10%)'

Conclusions

Correct Classification Scores:

Striped Dolphins **77%**

Long-Beaked Common Dolphins **15%**

Short-Beaked Common Dolphins **98%**

Risso's Dolphins **80%**

Pacific White-Sided Dolphins **90%**

Conclusions

- Automated w/ minimal human intervention
- Consideration of all call types improves classification
- There are lessons to learn in the misclassifications
  - Identify features to include in future classifiers
  - Identify biological questions where insight might be available from acoustic data
- Flexible framework for improvement of classification:
  - For call types (*e.g. inter-click interval*)
  - For events (*e.g. density of calls*)

Next Steps:

Improve Classifier– more species, more events

Test Classifier Performance

- Different Recording Hardware/Platforms
- Using hydrophone calibration data
- Distance to Group
- Duration of Encounter
- Mixed Species Schools

Software

- Integrate event data within Pamguard
- Develop an R package?
- Integrate into Pamguard to allow for real-time analysis?

In all chaos there is a cosmos, in all disorder a secret order

Carl Jung

Many Thanks To:
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