

# NOAA Technical Memorandum NMFS



SEPTEMBER 2013

## **SUMMARY OF PAMGUARD BEAKED WHALE CLICK DETECTORS AND CLASSIFIERS USED DURING THE 2012 SOUTHERN CALIFORNIA BEHAVIORAL RESPONSE STUDY**

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NOAA-TM-NMFS-SWFSC-517

U. S. DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
National Marine Fisheries Service  
Southwest Fisheries Science Center

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## Introduction

The objective of the Southern California Behavioral Response Study (SOCAL-BRS) is to determine the effects of mid-frequency (~3 kHz) Navy sonar signals on cetaceans (Southall *et al.*, 2012). Beaked whales are focal species for this study because previous beaked whale strandings have been associated with Navy sonar (Cox *et al.*, 2006). Deep-diving species, such as beaked whales, typically have long dive times and short surfacing intervals, making visual detection difficult. However, beaked whales produce sounds during much of their dive-cycle (53-59%), which provides an alternative means for detecting them (Barlow *et al.*, in press). To increase the probability of detecting beaked whales and improve our ability to track these species once detected, towed hydrophone arrays and improved echolocation click detection software were used for real-time passive acoustic monitoring of cetacean sounds during SOCAL-BRS. This report describes beaked whale detectors and classifiers used during these surveys in the summer and fall of 2012.

## Methods

Cetacean echolocation click detectors and classifiers were built using PAMGUARD software (Gillespie *et al.*, 2008). Software configurations within the ‘Click Detector’ module allow the user to specify parameters for click detection (the presence of a cetacean echolocation click or similar sound) and classification (the categorization of clicks based on their signal characteristics). These parameters included the following categories: detection channel, click duration, pre-filtering, click length, energy bands, peak and mean frequency, and zero crossing.

In 2012, a new suite of click classifiers (*BRS2012*) were developed and tested for SOCAL-BRS. Clicks in each classification category were displayed using a different colored symbol. The suite consisted of five click classifiers prioritized in the following order: 30-50 kHz *Upsweep* (green star), 2-15 kHz *Peak* (orange diamond), 15-30 kHz *Peak* (red circle), 30-50 kHz *Peak* (blue circle), and 50-80 kHz *Peak* (yellow diamond). The 30-50 kHz *Upsweep* classifier (Fig. 1) was designed to detect the upsweep characteristic in clicks from small beaked whales (the genera *Ziphius* and *Mesoplodon*) using the zero crossing parameter. In the additional four classifiers, the peak frequency parameters were used to classify the remaining clicks into rough species categories. The 2-15 kHz *Peak* classifier (Fig. 2) was developed to identify sperm whales (*Physeter macrocephalus*) and Baird’s beaked whales (*Berardius bairdii*). Propeller cavitation noise was also classified in this category. The 15-30 kHz *Peak* classifier (Fig. 3) was designed for Risso’s dolphins (*Grampus griseus*) and killer whales (*Orcinus orca*). The 30-50 kHz *Peak* classifier (Fig. 4) was developed for *Ziphius* spp. & *Mesoplodon* spp. beaked whales for which the upsweep click characteristic was not present or detectable. The 50-80 kHz *Peak* classifier (Fig. 5) was designed for smaller dolphins whose click frequencies are above the range of beaked whales. Unclassified clicks were discarded to improve software performance and to conserve hard drive space.

The *BRS2012* classifiers were used for the duration of 2012 SOCAL-BRS. In post-processing we compared the *BRS2012* click classification scheme to an approach that was used in previous beaked whale studies (Yack *et al.*, 2010; Yack 2013; Jacobson *et al.*, 2013). The previous approach (developed by T. Yack) consisted of a single click classifier for beaked whales (*YACK2011*) that combined multiple parameters (Fig. 6). PAMGUARD parameters were adjusted for the detection of beaked whale clicks in the pre-filter, energy band, peak and mean frequency, and zero crossing categories. The two sets of click classifiers are compared using recordings from August 5<sup>th</sup>, 2012 collected during SOCAL-BRS. On August 5<sup>th</sup>, a group of Cuvier's beaked whales (*Ziphius cavirostris*) was detected along with two groups of common dolphins (*Delphinus* spp.) from the *Derek M. Baylis* (65' Wyliecat Sailing Vessel). The boat was maneuvered throughout the day to stay near the Cuvier's beaked whales. Acoustic signals from the beaked whales were received intermittently when they were diving and presumably foraging. The common dolphins were incidental detections; they were not intentionally pursued but appeared in the vicinity of our vessel several times.

## Results and Discussion

The *BRS2012* click classifiers implemented during SOCAL-BRS 2012 resulted in acoustic detections of 11 groups of beaked whales over 26 days of effort (Fig. 7). In our comparison data for August 5<sup>th</sup>, Cuvier's beaked whale clicks were detected and verified on six separate occasions. Each occasion on August 5<sup>th</sup> was an assumed detection of the same group of beaked whales over a period of dive cycles and passes under the array. Additionally, three groups of common dolphins were detected and visually verified using the *BRS2012 50-80 kHz Peak* classifier (Fig. 8). The *BRS2012 30-50 kHz Upsweep* classifier showed high counts (> 5) of detected clicks on all six occasions (Table 1, Fig. 9). The *YACK2011* classifier indicated high click counts (> 20) for the six occasions when Cuvier's beaked whales were heard but showed additional high counts when common dolphins were present and beaked whales were not (Table 2, Fig. 10). Although a more thorough comparison is needed to verify the results from this one day, it appears that the *BRS2012* click classifier yields a lower rate of false beaked whale detections than the *YACK2011* classifier.

## Acknowledgements

Funding was provided by the Environmental Readiness Division (OPNAV N45) and the Office of Naval Research (ONR). We thank Shannon Rankin and Yvonne Barkley for support during the SOCAL-BRS 2012 project and Tina Yack for the previous beaked whale detector. In addition we thank Shannon Rankin and Eiren Jacobson for manuscript reviews.

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Table 1. Count of clicks using the PAMGUARD *BRS2012* classifiers on 8/5/2012 over 12 hrs. of effort (Note: Unclassified clicks were discarded).

<i>Click Type</i>	<i>Symbol</i>	<i># of Clicks</i>
30-50 kHz Upsweep	Green Star	740
2-15 kHz Peak	Orange Diamond	29,149
15-30 kHz Peak	Red Circle	69,536
30-50 kHz Peak	Blue Circle	58,725
50-80 kHz Peak	Yellow Square	3,740
Total		161,890

Table 2. Count of clicks using the PAMGUARD *YACK2011* classifier on 8/5/2012 over 12 hrs. of effort.

<i>Click Type</i>	<i>Symbol</i>	<i># of Clicks</i>
Beaked whale	Orange Diamond	3,061
Unclassified	Black circle	279,169
Total		282,230

**Classifier Parameters**

**General Options**

Name: 30-50kHz Up, Unique Code: 4, Symbol: \* (green star) [Change...]

Channel options: Require positive identification on all channels individually

☒ Restrict parameter extraction to: 64 samples (0.33 ms) around the click centre

**Pre Filtering**

☒ Enable Pre filtering before classification can improve some species recognition  
Band pass filter 30.00 - 50.00 kHz [Filter Settings]

**Click Length**

☐ Enable Click length is measured from the analytic waveform  
Smoothing: 5 bins (must be odd); Threshold: 6.0 dB below maximum  
Length range: 0.00 to 1.00 ms

**Energy Bands**

☐ Enable Compare energy in different frequency bands

Frequency Range (Hz)			Threshold
Test Band	0.0 to 0.0		
Control Band	0.0 to 0.0	0.0	dB
Control Band	0.0 to 0.0	0.0	dB

**Peak and Mean Frequency**

Search and Integration range: 0.0 to 0.0 Hz ; Smoothing: 5 bins

☐ Enable Peak frequency: 0.0 to 0.0 Hz

☐ Enable Peak width: 0.0 to 0.0 Hz ; Threshold: 6.0 dB

☐ Enable Mean frequency: 0.0 to 0.0 Hz

**Zero Crossings**

☒ Enable Parameters extracted from zero crossings

Number of zero crossings: 7 to 50

Zero crossing frequency sweep: 70.0 to 1000.0 kHz/ms

**Select Alarm**

Alarm 1

Max amount of time between detections: 10000 ms

Note: alarm is enabled/disabled on previous screen


[Ok] [Cancel] [Set Defaults]

Figure 1. *BRS2012* PAMGUARD 30-50 kHz Upsweep classifier parameters (green star).



**Classifier Parameters**

**General Options**

Name: 2-15kHz Peak, Unique Code: 1, Symbol:  Change...

Channel options: Require positive identification on all channels individually

☒ Restrict parameter extraction to 128 samples (0.67 ms) around the click centre

**Pre Filtering**

☐ Enable Pre filtering before classification can improve some species recognition

No filter defined Filter Settings

**Click Length**

☐ Enable Click length is measured from the analytic waveform

Smoothing: 5 bins (must be odd); Threshold: 6.0 dB below maximum

Length range: 0.00 to 1.00 ms

**Energy Bands**

☐ Enable Compare energy in different frequency bands

Frequency Range (Hz)

Test Band	Control Band	Threshold
0.0 to 0.0	0.0 to 0.0	0.0 dB
0.0 to 0.0	0.0 to 0.0	0.0 dB

**Peak and Mean Frequency**

Search and Integration range: 2000.0 to 85000.0 Hz ; Smoothing: 13 bins

☒ Enable Peak frequency: 2000.0 to 15000.0 Hz

☐ Enable Peak width: 0.0 to 0.0 Hz ; Threshold: 6.0 dB

☐ Enable Mean frequency: 0.0 to 0.0 Hz

**Zero Crossings**

☐ Enable Parameters extracted from zero crossings

Number of zero crossings: 0 to 0

Zero crossing frequency sweep: 0.0 to 0.0 kHz/ms

**Select Alarm**

Alarm 1

Max amount of time between detections: 0 ms


Note: alarm is enabled/disabled on previous screen

Ok Cancel Set Defaults

Figure 2. *BRS2012* PAMGUARD 2-15 kHz Peak classifier parameters (orange diamond).

**Classifier Parameters**

**General Options**

Name: 15-30kHz Peak, Unique Code: 2, Symbol:  [Change...](#)

Channel options: Require positive identification on all channels individually

☒ Restrict parameter extraction to 64 samples (0.33 ms) around the click centre

**Pre Filtering**

☐ Enable Pre filtering before classification can improve some species recognition

No filter defined [Filter Settings](#)

**Click Length**

☐ Enable Click length is measured from the analytic waveform

Smoothing: 5 bins (must be odd); Threshold: 6.0 dB below maximum

Length range: 0.00 to 1.00 ms

**Energy Bands**

☐ Enable Compare energy in different frequency bands

Frequency Range (Hz)

Test Band	Control Band	Control Band	Threshold
0.0 to 0.0	0.0 to 0.0	0.0	0.0 dB
0.0 to 0.0	0.0 to 0.0	0.0	0.0 dB

**Peak and Mean Frequency**

Search and Integration range: 15000.0 to 80000.0 Hz ; Smoothing: 5 bins

☒ Enable Peak frequency: 15000.0 to 30000.0 Hz

☐ Enable Peak width: 0.0 to 0.0 Hz ; Threshold: 6.0 dB

☐ Enable Mean frequency: 0.0 to 0.0 Hz

**Zero Crossings**

☐ Enable Parameters extracted from zero crossings

Number of zero crossings: 0 to 0

Zero crossing frequency sweep: 0.0 to 0.0 kHz/ms

**Select Alarm**

Alarm 1

Max amount of time between detections: 0 ms


Note: alarm is enabled/disabled on previous screen

[Ok](#) [Cancel](#) [Set Defaults](#)

Figure 3. *BRS2012 PAMGUARD 15-30 kHz Peak* classifier parameters (red circle).

**Classifier Parameters**

**General Options**

Name: 30-50kHz Peak, Unique Code: 3, Symbol:  [Change...](#)

Channel options: Require positive identification on all channels individually

☒ Restrict parameter extraction to 128 samples (0.67 ms) around the click centre

**Pre Filtering**

☐ Enable Pre filtering before classification can improve some species recognition

No filter defined [Filter Settings](#)

**Click Length**

☐ Enable Click length is measured from the analytic waveform

Smoothing: 5 bins (must be odd); Threshold: 6.0 dB below maximum

Length range: 0.00 to 1.00 ms

**Energy Bands**

☒ Enable Compare energy in different frequency bands

Frequency Range (Hz)			Threshold
Test Band	30000.0 to 50000.0		
Control Band	20000.0 to 30000.0	6.0	dB
Control Band	50000.0 to 60000.0	0.0	dB

**Peak and Mean Frequency**

Search and Integration range: 20000.0 to 60000.0 Hz ; Smoothing: 5 bins

☒ Enable Peak frequency: 30000.0 to 50000.0 Hz

☐ Enable Peak width: 0.0 to 0.0 Hz ; Threshold: 6.0 dB

☐ Enable Mean frequency: 0.0 to 0.0 Hz

**Zero Crossings**

☐ Enable Parameters extracted from zero crossings

Number of zero crossings: 0 to 0

Zero crossing frequency sweep: 0.0 to 0.0 kHz/ms

**Select Alarm**

Alarm 1

Max amount of time between detections: 10000 ms

Note: alarm is enabled/disabled on previous screen

[Ok](#) [Cancel](#) [Set Defaults](#)

Figure 4. *BRS2012* PAMGUARD 30-40 kHz Peak classifier parameters (blue circle).

**Classifier Parameters**

**General Options**

Name: 50-80kHz Peak, Unique Code: 5, Symbol:  Change...

Channel options: Require positive identification on all channels individually

☒ Restrict parameter extraction to 128 samples (0.67 ms) around the click centre

**Pre Filtering**

☐ Enable Pre filtering before classification can improve some species recognition

No filter defined Filter Settings

**Click Length**

☐ Enable Click length is measured from the analytic waveform

Smoothing: 5 bins (must be odd); Threshold: 6.0 dB below maximum

Length range: 0.00 to 1.00 ms

**Energy Bands**

☐ Enable Compare energy in different frequency bands

Frequency Range (Hz)

Test Band	0.0	to	0.0	Threshold
Control Band	0.0	to	0.0	0.0 dB
Control Band	0.0	to	0.0	0.0 dB

**Peak and Mean Frequency**

Search and Integration range: 20000.0 to 80000.0 Hz ; Smoothing: 13 bins

☒ Enable Peak frequency: 50000.0 to 80000.0 Hz

☐ Enable Peak width: 0.0 to 0.0 Hz ; Threshold: 6.0 dB

☐ Enable Mean frequency: 0.0 to 0.0 Hz

**Zero Crossings**

☐ Enable Parameters extracted from zero crossings

Number of zero crossings: 0 to 0

Zero crossing frequency sweep: 0.0 to 0.0 kHz/ms

**Select Alarm**

Alarm 1

Max amount of time between detections: 10000 ms


Note: alarm is enabled/disabled on previous screen

Ok Cancel Set Defaults

Figure 5. *BRS2012* PAMGUARD 50-80 kHz Peak classifier parameters (yellow square).

**Classifier Parameters**

**General Options**

Name:  , Unique Code:  Symbol: 

Channel options:

☒ Restrict parameter extraction to  samples (1.33 ms) around the click centre

**Pre Filtering**

☒ Enable Pre filtering before classification can improve some species recognition  
High pass filter 20.00 kHz

**Click Length**

☐ Enable Click length is measured from the analytic waveform  
Smoothing  bins (must be odd); Threshold  dB below maximum  
Length range  to  ms

**Energy Bands**

☒ Enable Compare energy in different frequency bands  
Frequency Range (Hz)

Test Band	Control Band	Threshold
34000.0 to 40000.0	12000.0 to 24000.0	3.0 dB
	12000.0 to 24000.0	3.0 dB

**Peak and Mean Frequency**

Search and Integration range  to  Hz ; Smoothing  bins

☒ Enable Peak frequency  to  Hz

☐ Enable Peak width  to  Hz ; Threshold  dB

☒ Enable Mean frequency  to  Hz

**Zero Crossings**

☒ Enable Parameters extracted from zero crossings

Number of zero crossings  to

Zero crossing frequency sweep  to  kHz/ms

Figure 6. YACK2011 PAMGUARD classifier parameters (orange diamond) used in Yack *et al.*, 2010, Yack 2013, and Jacobson *et al.*, 2013.

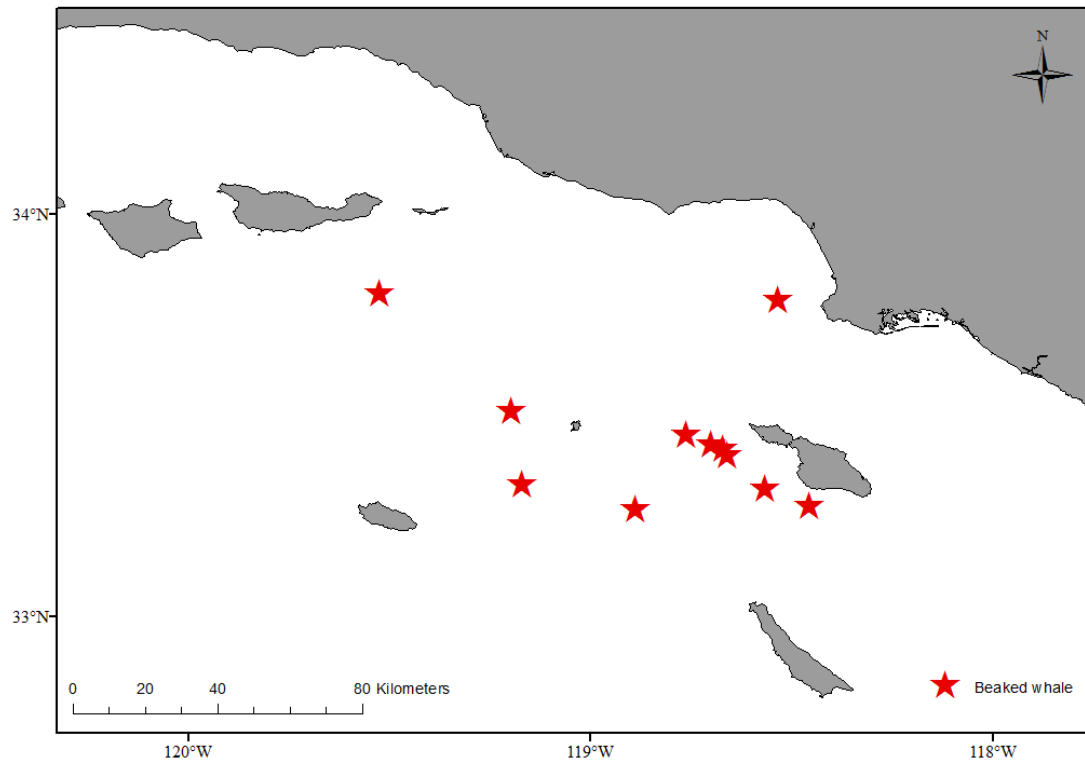


Figure 7. Locations of acoustic detections of 11 groups of beaked whales during SOCAL-BRS 2012 based on the new suite of click classifiers.

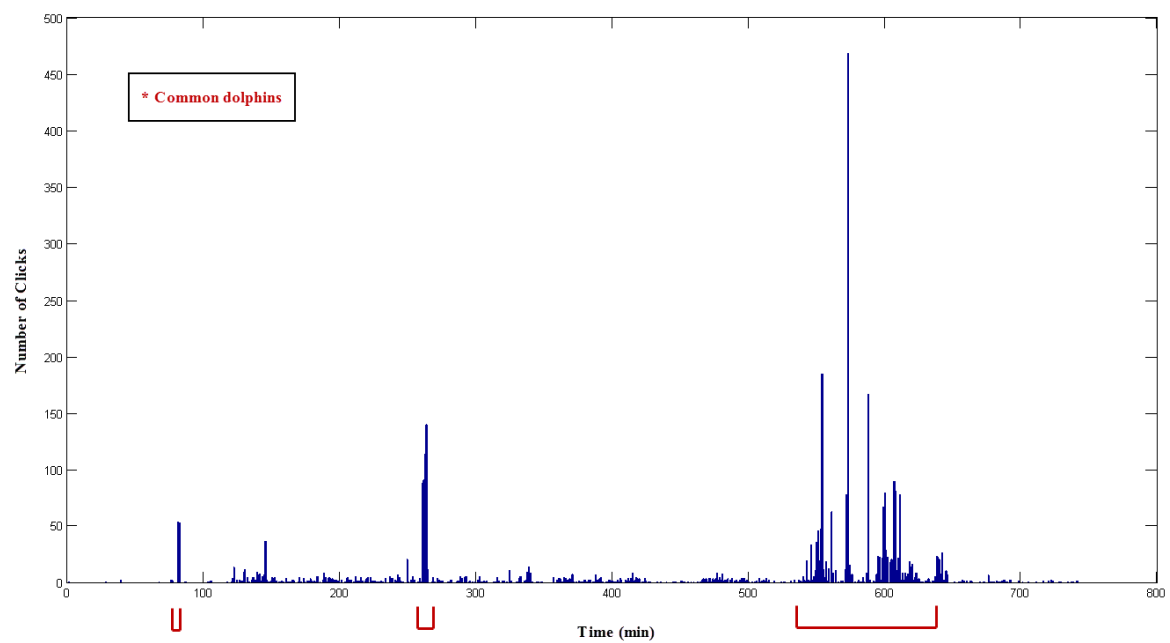


Figure 8. Number of *BRS2012 50-80 kHz Peak* clicks per minute time bin on 8/5/2012. Red brackets indicate detected and verified species present.

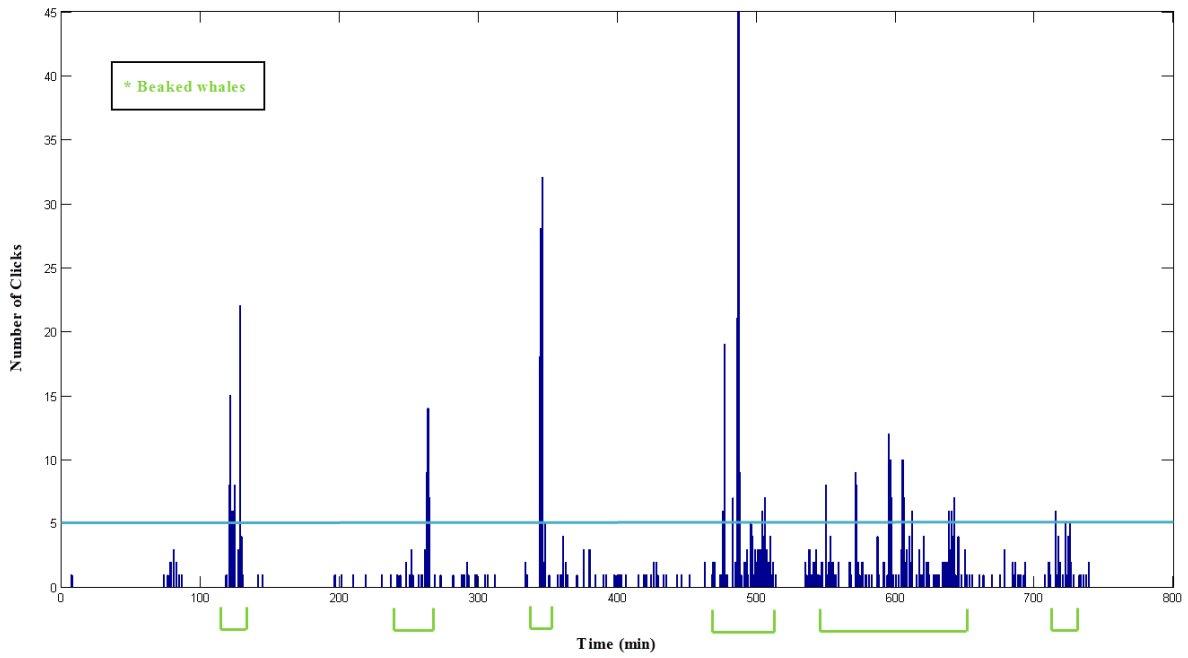


Figure 9. Number of *BRS2012* 30-50 kHz *Upsweep* clicks per minute time bin on 8/5/2012. Green brackets indicate detected and verified species present.

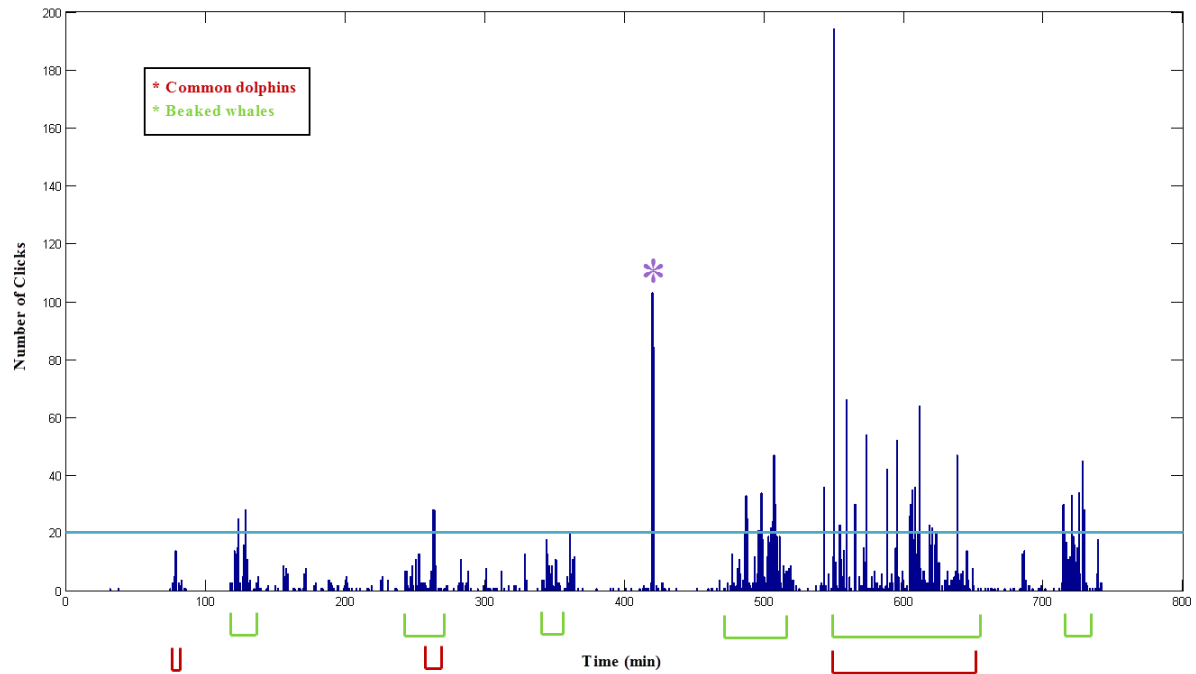


Figure 10. Number of classified clicks per minute time bin on 8/5/2012 using the *YACK2011* beaked whale classifier. Red and green brackets indicate detected and verified species present; and (\*) indicates a false detection of beaked whales.



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