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

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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 5th, 2012 collected during SOCAL-BRS. On August 5th, 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 5th, Cuvier's beaked whale clicks were detected and verified on six separate occasions. Each occasion on August 5th 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

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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).

Click Type	***Symbol***	***# of Clicks***
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.

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

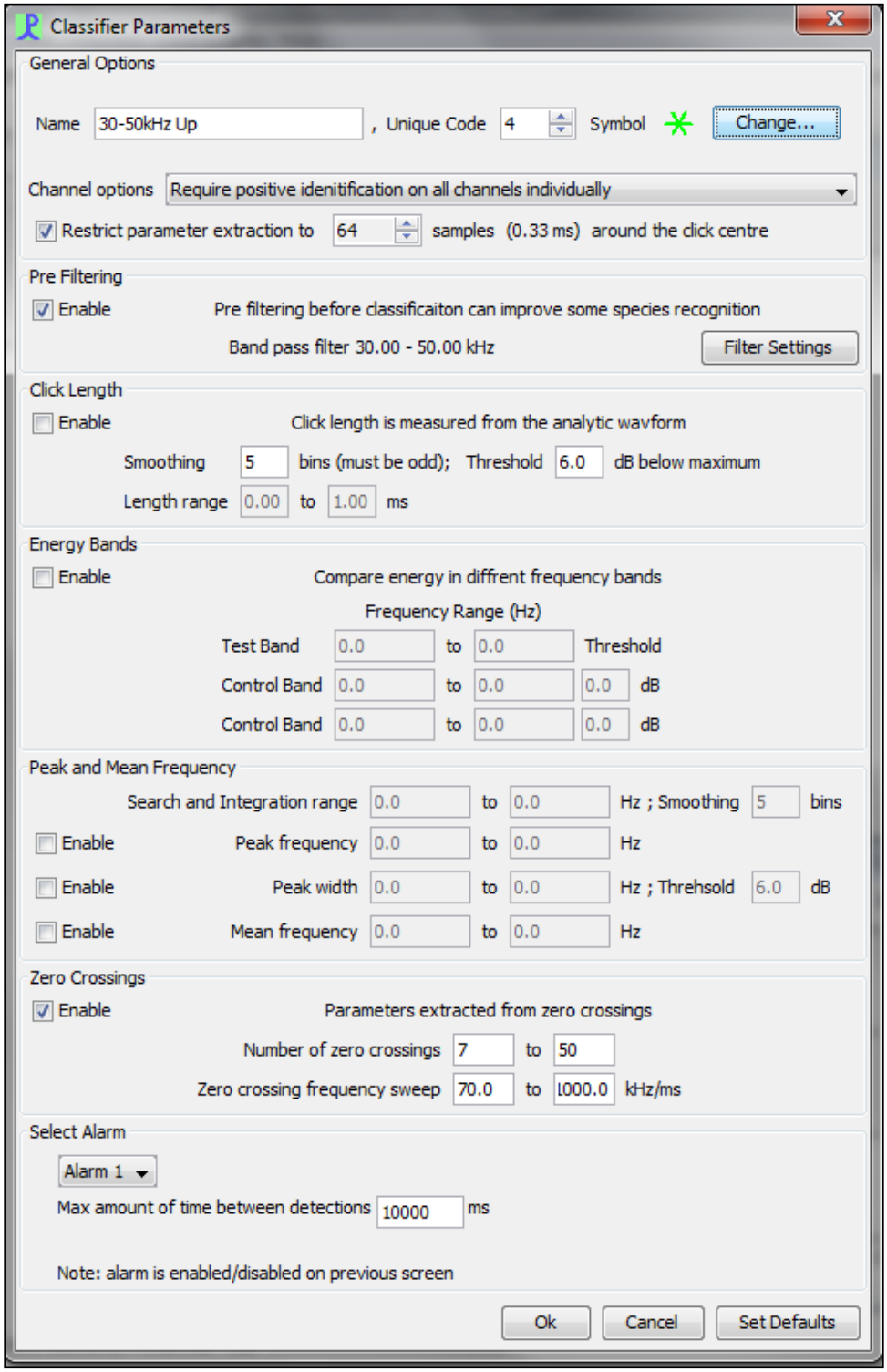

Figure 1. *BRS2012* PAMGUARD *30-50 kHz Upsweep* classifier parameters (green star).

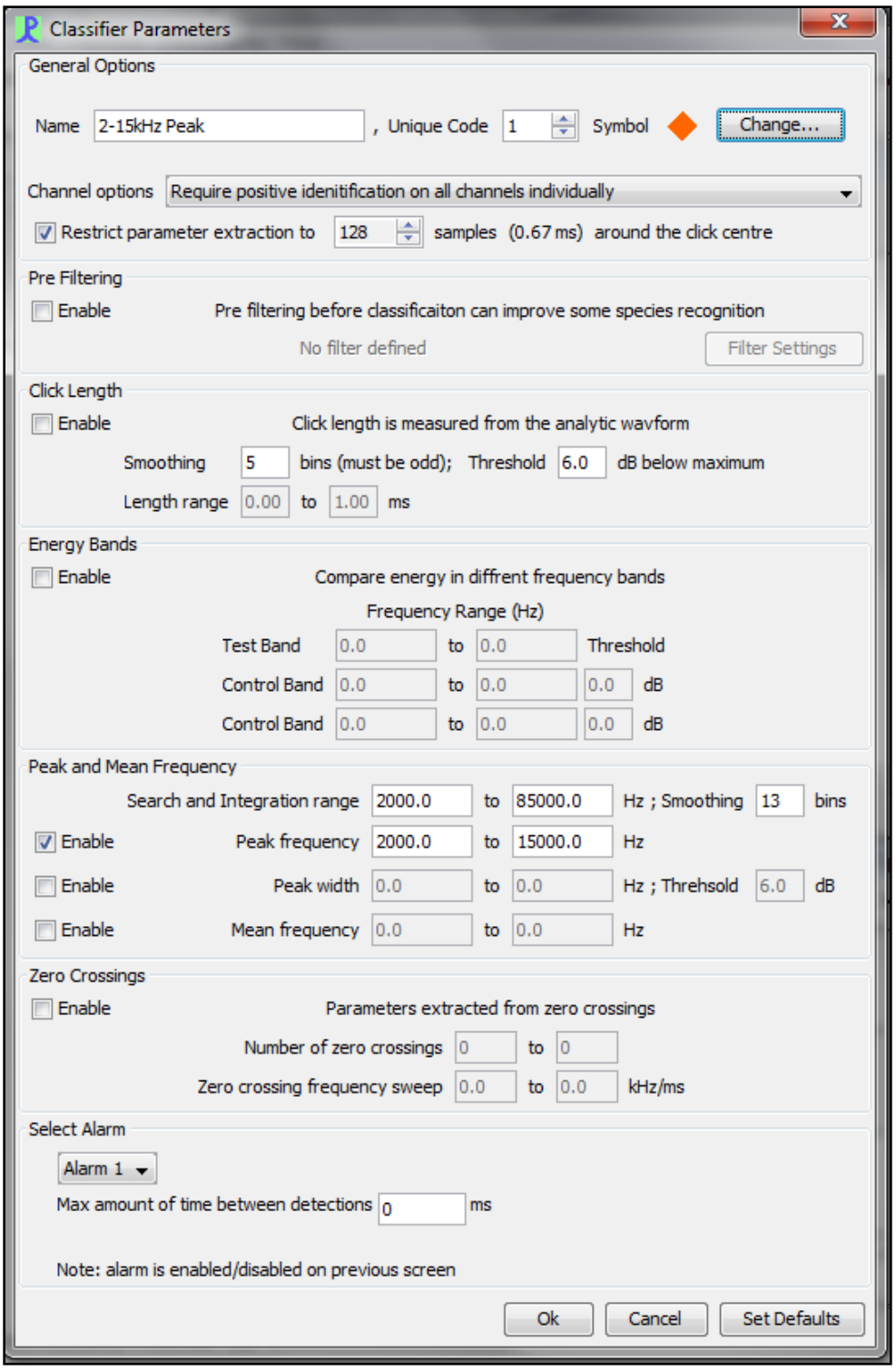

Figure 2. *BRS2012* PAMGUARD *2-15 kHz Peak* classifier parameters (orange diamond).

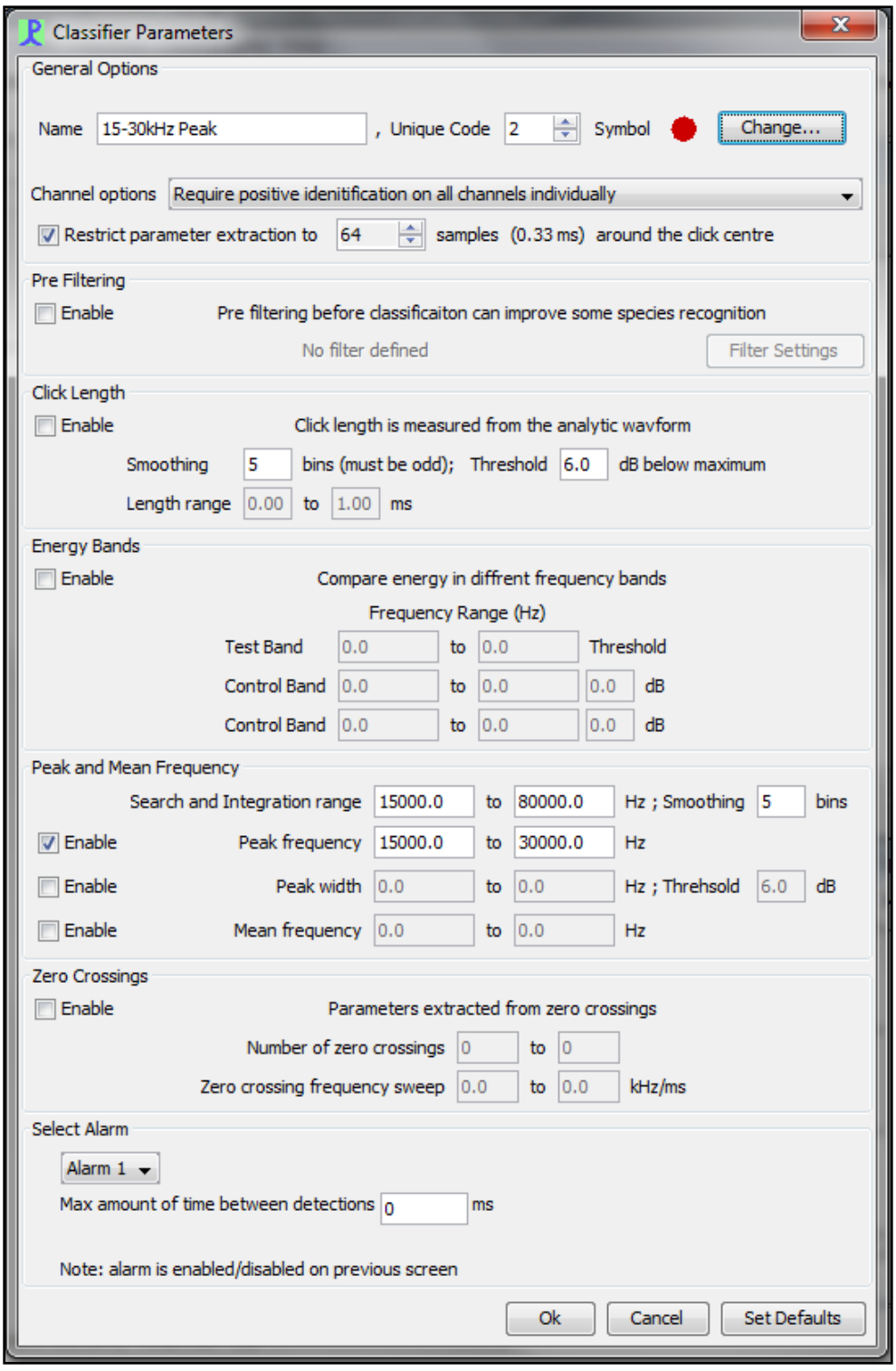

Figure 3. *BRS2012* PAMGUARD *15-30 kHz Peak* classifier parameters (red circle).

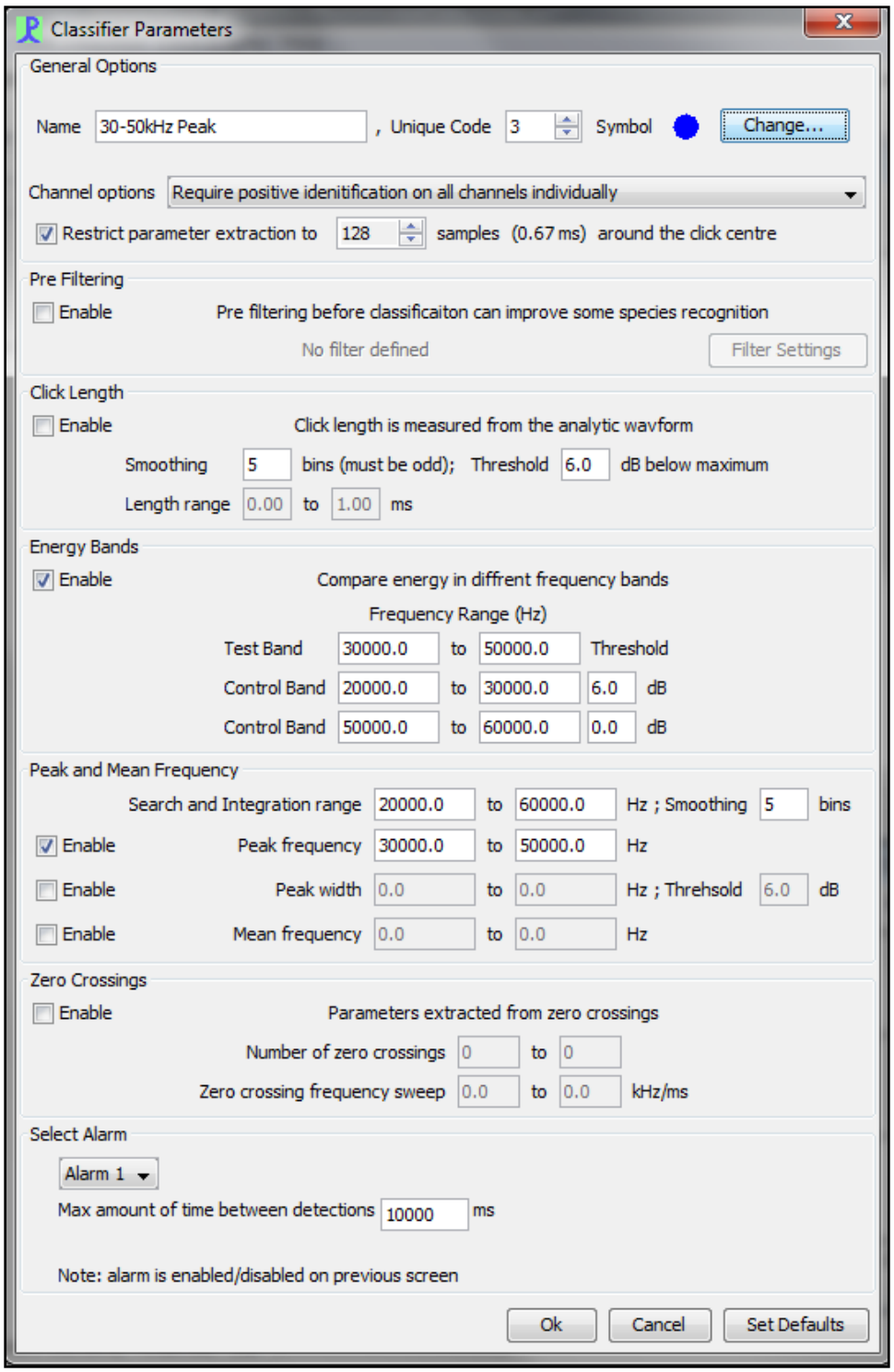

Figure 4. *BRS2012* PAMGUARD *30-40 kHz Peak* classifier parameters (blue circle).

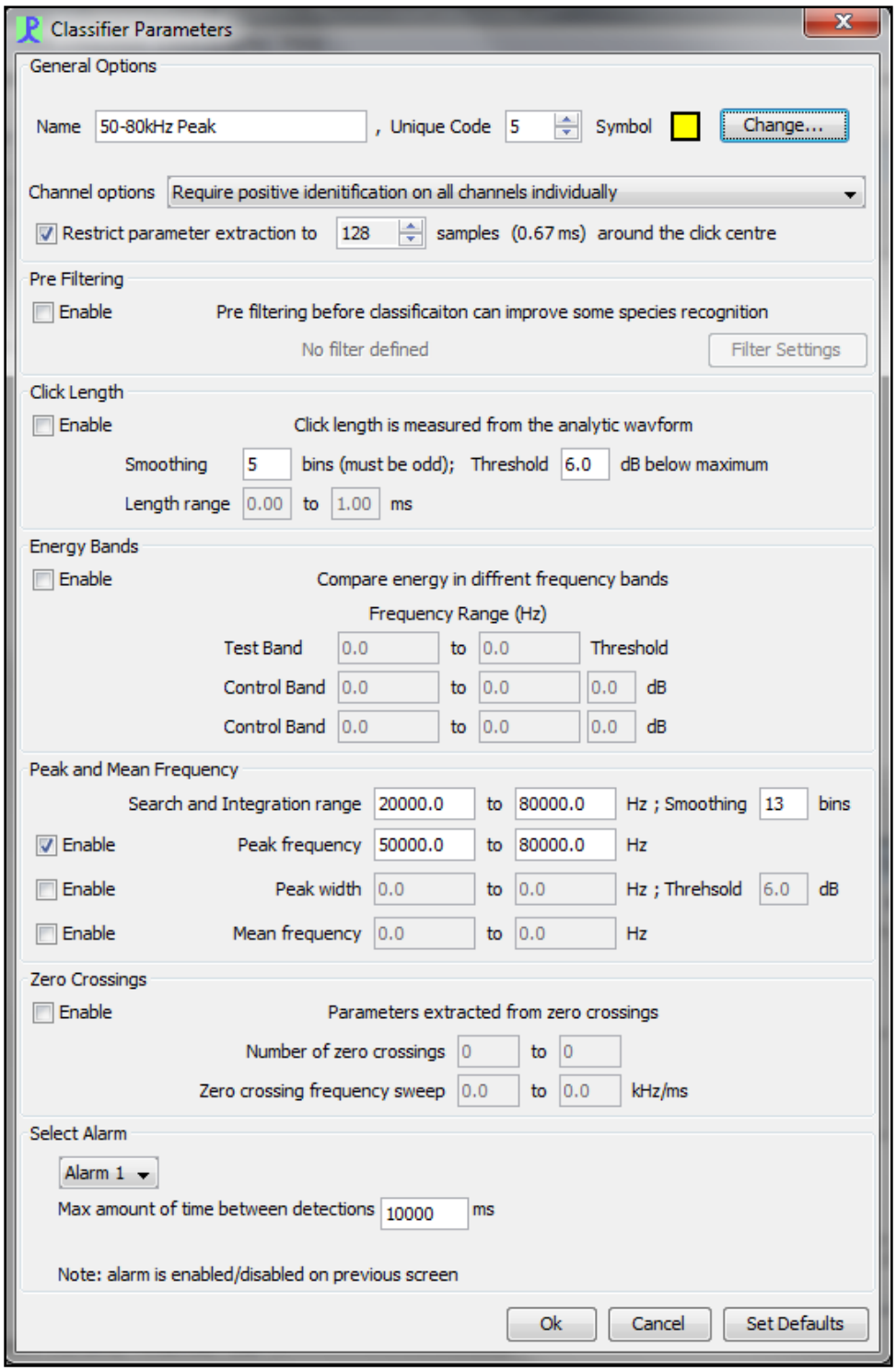

Figure 5. *BRS2012* PAMGUARD *50-80 kHz Peak* classifier parameters (yellow square).

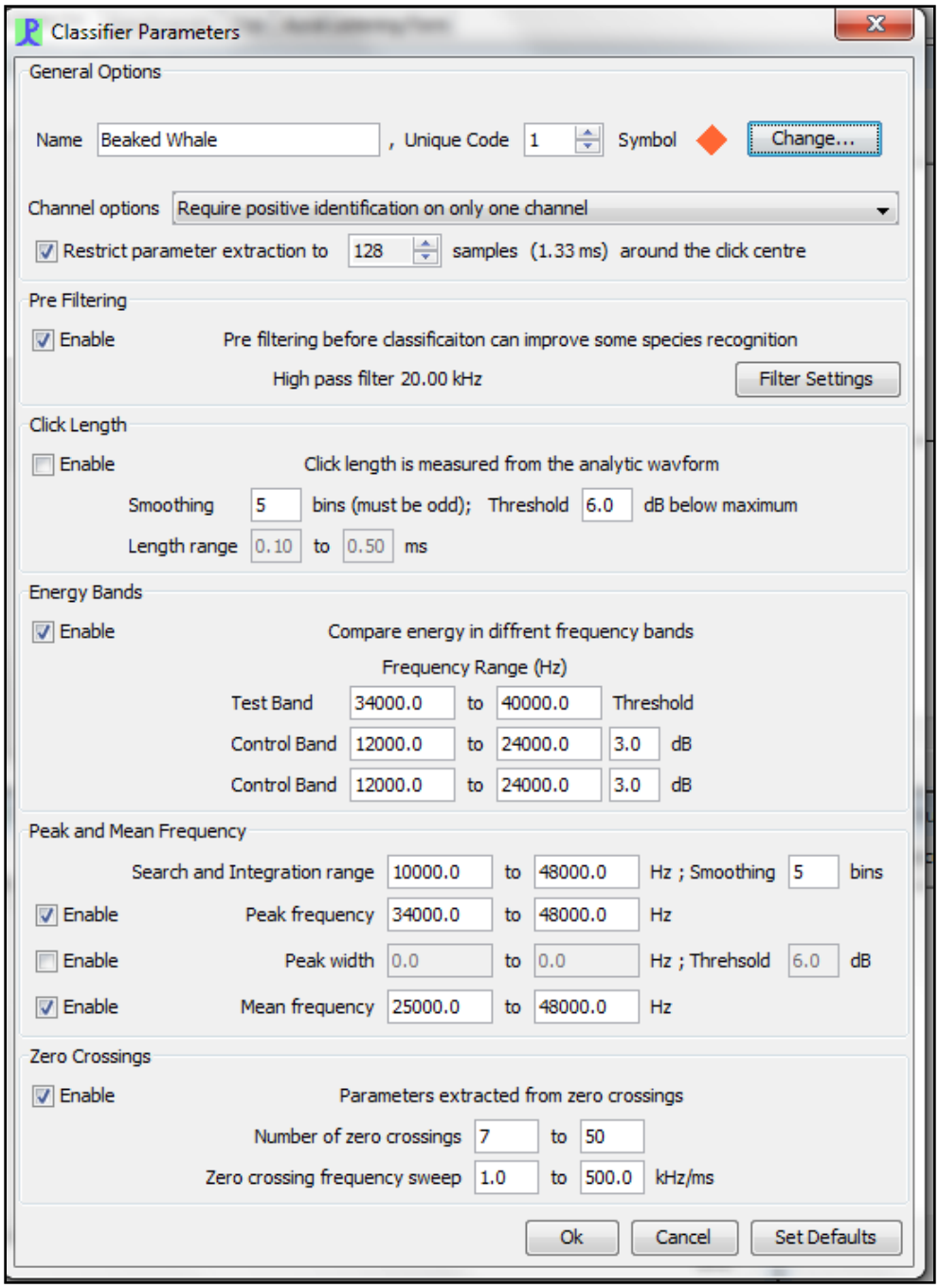

Figure 6. *YACK2011* PAMGUARD classifier parameters (orange diamond) used in Yack *et al.*, 2010, Yack 2013, and Jacobson *et al.*, 2013.

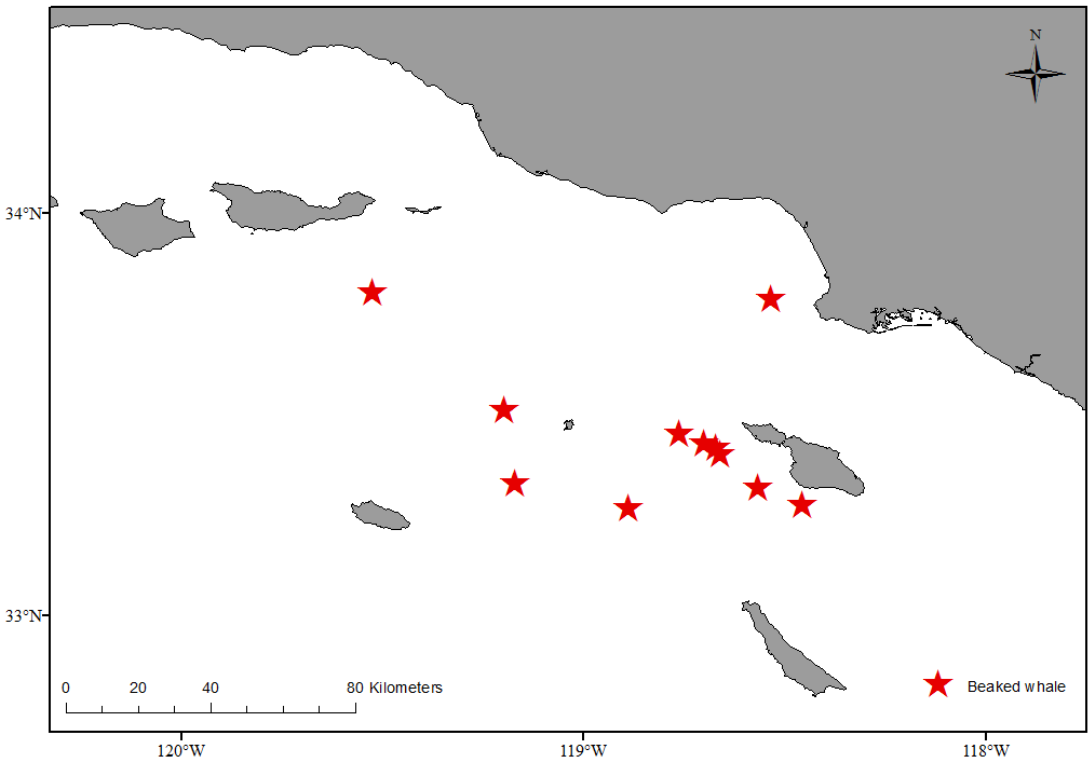

Figure 7. Locations of acoustic detections of 11 groups of beaked whales during SOCAL-BRS 2012 based on the new suite of click classifiers.

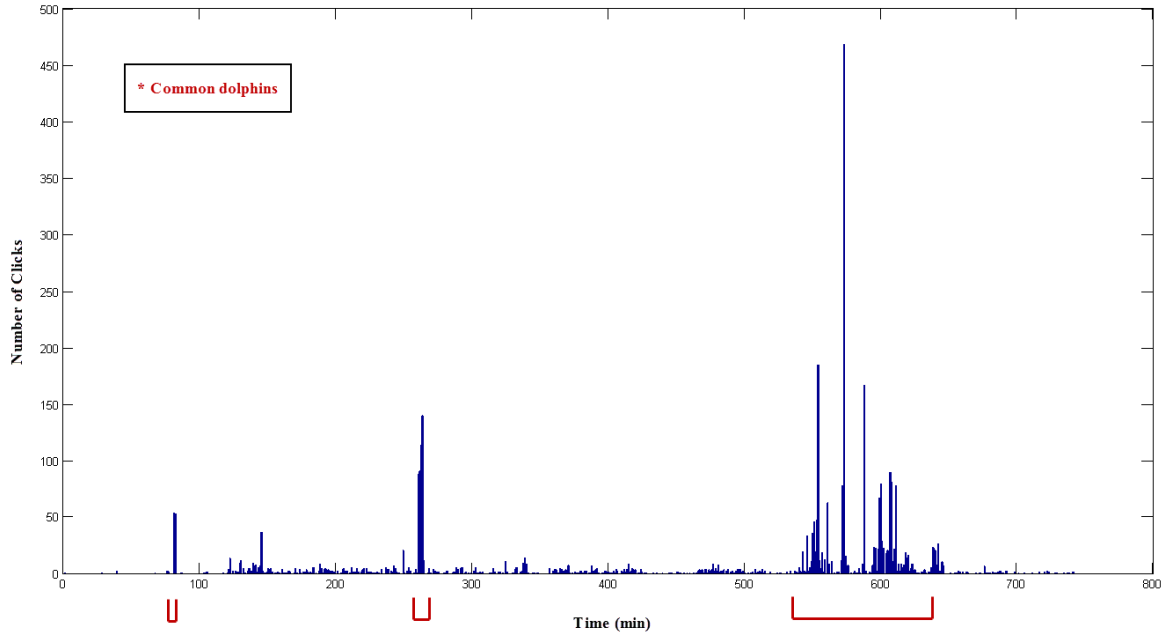

Figure 8. Number of *BRS2012 50-80 kHz Peak* clicks per minute time bin on 8/5/2012. Red brackets indicate detected and verified species present.

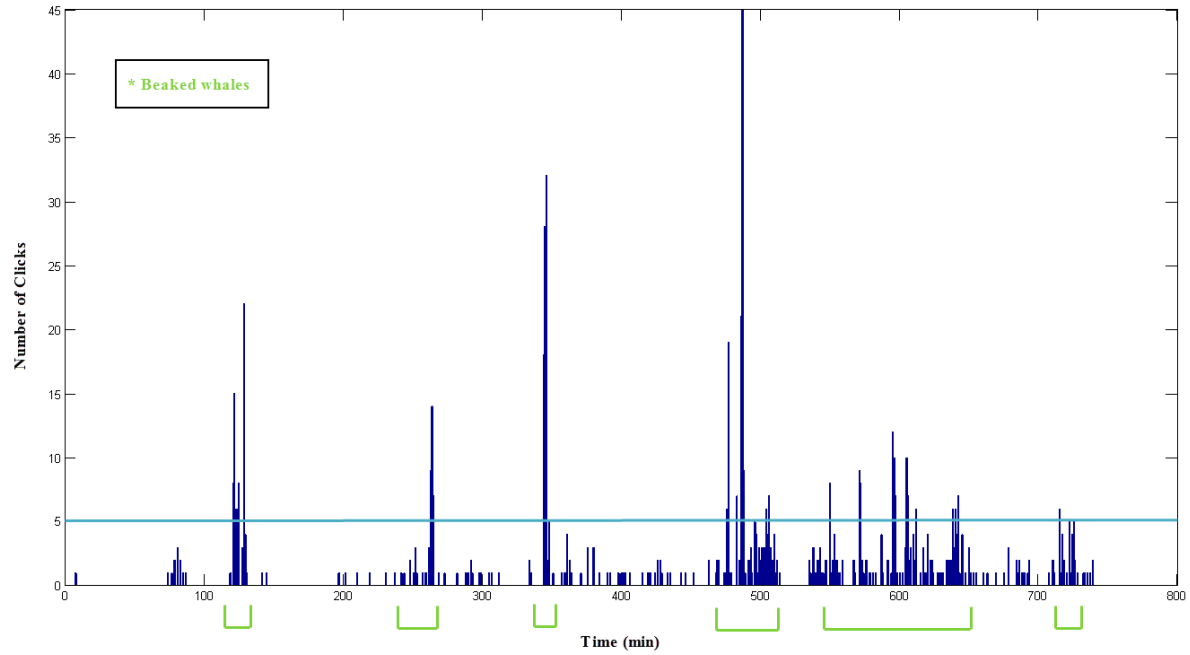

Figure 9. Number of *BRS2012 30-50 kHz Upsweep* clicks per minute time bin on 8/5/2012. Green brackets indicate detected and verified species present.

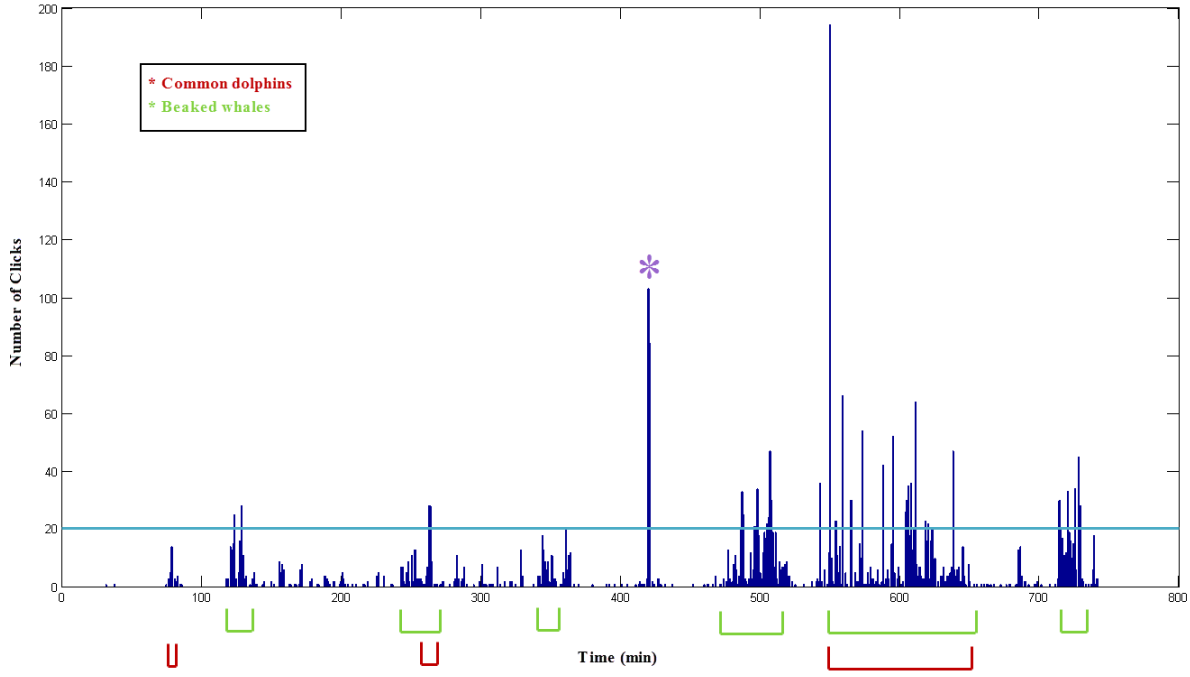

Figure 10. Number of classified clicks per minute time bin on 8/5/2012 using the *YACK2011* beaked whale classifier. Red and green brackets indicate detected and verified species present; and (*) indicates a false detection of beaked whales.

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