

1 Successful suction-cup tagging of a small delphinid species, *Stenella attenuata*: Insights into  
2 whistle characteristics

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22           The Delphinidae is the most diverse family of cetaceans, with 38 species recognized.  
23   Small pelagic delphinids are also the most abundant cetaceans world-wide, yet their  
24   communication and behavior remain poorly understood. Many populations live in relatively  
25   remote habitats, which creates challenges in accessing study animals. Small odontocete species  
26   often face numerous anthropogenic stressors. For example, many pelagic delphinids incur  
27   significant interactions with fisheries (Gerrodette and Forcada 2005, Geijer and Read 2013).  
28   With a wide distribution, many delphinid populations utilize habitats that also are important for  
29   human seagoing activities that produce intense sound, such as seismic surveys or naval sonar  
30   exercises that may disturb or harm them. Many U.S. naval sonar exercises take place on naval  
31   training ranges such as those in in Hawai'i (Baird *et al.* 2013), California (Carretta *et al.* 1995,  
32   Henderson *et al.* 2014), and the Bahamas (DeRuiter *et al.* 2013). At least one delphinid stranding  
33   event involving melon-headed whales (*Peponocephala electra*) was correlated with military  
34   activities (Southall *et al.* 2006); a mass stranding of melon-headed whales has also been  
35   associated with multi-beam echosounder operations as part of a seismic survey (Southall *et al.*  
36   2013). Because many of these delphinid groups can number in the 100s to 1,000s, fisheries or  
37   sonar exposures can account for the highest estimates of marine mammal “takes” in related  
38   Environmental Impact Assessments (Department of the Navy 2013). Given the potential for  
39   anthropogenic interactions with large numbers of individual delphinids, improved methods of  
40   studying small delphinids are invaluable to understand, reduce, or mitigate potential human  
41   influences on these animals.

42           One important tool for studying the acoustic behavior of cetaceans is the digital acoustic  
43   recording tag (DTAG) (Johnson and Tyack 2003). Deployed using noninvasive suction cups, the  
44   DTAG is equipped with two hydrophones for recording environmental noise and sounds

45 produced by the tagged animal, nearby conspecifics, as well as various sensors that capture  
46 diving behavior and 3D orientation and movement of the tagged animal. Acoustic data from  
47 DTAGs have been used to gain insight into delphinid vocal behavior, such as the production of  
48 repeated call types in short-finned pilot whales (*Globicephala macrorhynchus*) and melon-  
49 headed whales (Kaplan *et al.* 2014, Sayigh *et al.* 2013).

50 Because they are attached directly to the animal, DTAGs can facilitate distinguishing  
51 focal (tagged animal) vocalizations from those of conspecifics (Johnson *et al.* 2009). Thus, these  
52 tools potentially offer a way for studying individual vocal behavior, an aspect of communication  
53 that was previously limited to studies involving captive animals, well-known resident  
54 populations, or sound localization methods using arrays (Caldwell and Caldwell 1965, Watkins  
55 and Schevill 1974, Sayigh *et al.* 1990).

56 Acoustic recording tags have been used to examine the ecology of various baleen whales,  
57 beaked whales, and larger odontocetes (Miller *et al.* 2004, Johnson *et al.* 2009, DeRuiter *et al.*  
58 2013). Yet, acquiring focal tag data from small odontocetes has long remained a challenge. The  
59 size, speed, high activity, and social contact of many delphinids and some porpoises can limit  
60 tagging opportunities or dislodge tags, and attempts to tag wild, free-swimming small  
61 odontocetes have been relatively unsuccessful with a few exceptions. Hanson and Baird (1998)  
62 tagged free-swimming Dall's porpoise (*Phocoenoides dalli*) with suction cup time-depth  
63 recorders (TDRs), but for short periods of time (41 min maximum). Six pantropical spotted  
64 dolphins (*Stenella attenuata*) were tagged with TDRs for periods ranging from five min to just  
65 over 12 h (Baird *et al.* 2001), although attempts to tag common bottlenose dolphins (*Tursiops*  
66 *truncatus*) with TDRs were unsuccessful (Schneider *et al.* 1998). Acoustic data loggers (A-tags)  
67 have been successfully deployed on harbor (*Phocoena phocoena*) and finless (*Neophocaena*

68 *phocaenoides*) porpoises, but tagging was accomplished during capture-release events  
69 (Akamatsu *et al.* 2007). Similarly, the latest, smaller version of the DTAG, the DTAG3, has been  
70 deployed on harbor porpoise (DeRuiter *et al.* 2009) and common bottlenose dolphins (Wells *et*  
71 *al.* 2013), but tags were hand-placed on animals in captivity (DeRuiter *et al.* 2013) or during  
72 brief capture and release events (Wells *et al.* 2013). Kaplan *et al.* (2014) recently deployed  
73 DTAG3s on melon-headed whales, although maximum durations were limited to 57 min (largely  
74 due to the behaviors of the tagged animals). Thus, there has been a paucity of focal-individual  
75 bioacoustic data from noninvasively tagged animals, limiting analyses of individual call behaviors  
76 and descriptions of successful attachment.

77         Recently, Silva *et al.* (2016) presented whistle characteristics and daytime dive behavior  
78 recorded during the first successful deployment of DTAG3s on free-swimming pantropical  
79 spotted dolphins (*Stenella attenuata*). Here, we use these DTAG3 data to further explore the  
80 whistle repertoire of pantropical spotted dolphins, by presenting visual categorizations of whistle  
81 contours, addressing evidence of repeated whistle types, and providing new data on individual  
82 call behaviors. A second goal of this study is to evaluate attachments of DTAG3s to small  
83 delphinids. We compare the pantropical spotted dolphin data described here to that of Kaplan *et*  
84 *al.* (2014), who successfully deployed multiple DTAG3s on melon-headed whales off Hawai‘i,  
85 providing a short description of the successful attachment methods. Thus, this work provides  
86 insights into the acoustic behavior of small delphinids and a description and evaluation of  
87 successful tagging methodology and species-specific deployment details.

88         Tagging was conducted from an 8.2 m Boston Whaler off the west (leeward) side of the  
89 island of Hawai‘i in May 2013. When groups were encountered we recorded location (with a  
90 GPS), predominant group behavior (*e.g.*, travel, feeding, milling), direction and speed

91 (categorized as slow travel, travel, or fast travel) of travel, and estimated group size (see  
92 McSweeney *et al.* (2009) for details of behavioral categorization). In order to deploy a DTAG3,  
93 the boat gradually passed through the group, either allowing animals to approach the boat and  
94 bowride or approaching animals that were generally surfacing frequently and traveling in a  
95 predictable direction. When an animal surfaced near the bow, the DTAG3 was deployed with a  
96 carbon-fiber pole and attached with suction-cups. For each tagging attempt, we recorded: the  
97 age/sex class of the target animal (based on body size, spotting patterns, and the  
98 presence/absence of calves/juveniles in attendance; Perrin *et al.* 1976), its behavior immediately  
99 before tagging, the reaction to tagging (*e.g.*, fast dive, tail slap), behavior after tagging (if seen  
100 again), tag position on the animal's body, reason for tag release, and any tag damage. Location,  
101 predominant group behavior and direction of travel were also recorded at the end of the  
102 encounter. When possible, photos of the tagged animal were obtained for individual  
103 identification. After tagging, the tag boat generally moved away from the tagged animal (*ca.*  
104 several hundred meters) to limit any potential influence on behavior and to reduce vessel noise  
105 on the acoustic tag record. Tag attachment was monitored by listening to the intermittent VHF  
106 pulse of surfacing tagged animals. During this time the research vessel moved with the group  
107 (which could be dispersed over several kilometers) at approximately the speed of the group. This  
108 slow moving through the traveling groups did not appear to influence the behavior of individuals  
109 or the group, as animals did not change observed behaviors (besides a few animals coming to  
110 bowride) or direction of travel. Individual animals that surfaced within 50 m of the tag vessel  
111 were photographed for future photo-identification and population studies. The research vessel  
112 stayed with the group until tag recovery except for DTAG sa147d. For this deployment,

113 researchers left the group 4 h 41 min after tagging, and then returned to the area later that night  
114 to recover the detached tag.

115         The process of selecting whistles for analyses was described in detail in Silva *et al.*  
116 (2016). Briefly, acoustic data were initially analyzed in MATLAB (MathWorks, Natick MA)  
117 using a toolbox designed for DTAG analysis (available at [http://soundtags.st-](http://soundtags.st-andrews.ac.uk/dtags/dtag-3/)  
118 [andrews.ac.uk/dtags/dtag-3/](http://soundtags.st-andrews.ac.uk/dtags/dtag-3/)). The acoustic recording for each tag was viewed as consecutive ten-  
119 second spectrograms (FFT size 1024 samples, Hamming window, 50% overlap), and the entirety  
120 of acoustic files were audited. Times of all whistles with a clear start and end were marked  
121 within this program. For visual categorization, whistles were defined as tonal signals greater than  
122 0.3 s in duration (Driscoll 1995), in an attempt to follow established criteria for whistles from  
123 *Stenella* spp. Using criteria defined by Bazua-Duran and Au (2002), 463 of these whistles were  
124 deemed “loud and clear” and thus selected for categorization

125         A spectrogram of each whistle was printed using uniform settings: y-axis from 0-48 kHz  
126 and x-axis where 1.2 cm = 0.1 s. All spectrogram prints were randomly shuffled to remove any  
127 sequence information. Four judges participated in whistle classification by visual inspection of  
128 the spectrograms. They included one author (TLS) and three independent judges with some  
129 experience visualizing dolphin whistles, but no prior experience with pantropical spotted dolphin  
130 sounds. The three independent judges were instructed to group the whistles into as many  
131 categories as they wanted based on similarities of the fundamental frequency contour, but were  
132 given no further instructions, following Sayigh *et al.* (2007).

133         When three out of four judges grouped two whistles together, a category was created.  
134 Whistle categories were assigned arbitrary letter designations. Whistles that were not grouped  
135 together by three judges were not considered further. Tag deployments on the same day often

136 overlapped in time (Table 1) resulting in some whistles being recorded on multiple tags. If  
137 duplicate whistles were selected for analysis, only the whistle of highest amplitude (based on  
138 visual inspection of spectrograms) was included in the categorization. To evaluate potential  
139 differences in the fundamental frequency shape and characteristics of categorized whistles, ten  
140 whistles were randomly selected from each major (more than 10 whistles) whistle category and  
141 were used to create whistle contour plots. Using Raven Pro 1.5 beta version build 21 (Charif *et*  
142 *al.*, 2010; Cornell Lab of Ornithology, Ithaca, New York), a frequency measurement was taken  
143 every 0.05 s along the fundamental frequency for the entire length of the whistle. These  
144 measurements were plotted using Microsoft Excel to produce contour traces.

145         The majority of whistles grouped by judges into one category (termed ‘type B’) were  
146 recorded from a single tag (sa147d) deployed on an animal classed as an adult male. Particularly  
147 high amplitudes of these whistles (based on visual inspection) suggested that this whistle  
148 category was potentially produced by the tagged animal. Based on these observations, we chose  
149 to focus on this tag for a more in-depth look at an individual’s whistle repertoire.

150         To explore the possibility that type B whistles were produced only by the tagged animal,  
151 the received level (RL) and angle of arrival (AOA) were calculated for whistles recorded on  
152 sa147d. The AOA is calculated from the time delay between the two hydrophones, and indicates  
153 the angle from which the sound is arriving. Whistles produced by the tagged animal should have  
154 a relatively high received level and a consistent AOA, while whistles produced by nearby  
155 animals will have varying angles of arrival as these animals move in relation to the tag (Johnson  
156 *et al.* 2009).

157         From the 463 whistles analyzed, 136 were recorded on sa147d and were used to address  
158 individual sound production. Whistles from sa147d were extracted using a custom MATLAB

159 script and saved as individual sound files with an additional 0.1 s added onto the beginning and  
160 end of each whistle. All selected whistles were individually imported into MATLAB and  
161 amplitude corrected for nominal tag hydrophone sensitivity (-175 dB re 1 V/ $\mu$ Pa). Low  
162 frequency flow and boat noise were reduced by applying a user-selectable 6-pole variable  
163 bandpass Butterworth filter (3,000-40,000 Hz) (Jensen *et al.* 2011). The root mean square (rms)  
164 intensity of the last 0.1 s of each clip was calculated and used as a noise measure. For signal to  
165 noise ratio (SNR) calculation, signal duration was defined as the length of the window  
166 containing 95% of the total energy after subtracting the noise energy (Madsen and Wahlberg  
167 2007) and excluding the additional 0.1 s at the beginning and end of the clip. SNR was  
168 calculated as the difference between rms signal amplitude and rms noise amplitude on a decibel  
169 scale and only calls with SNR greater than 10 dB were analyzed further (Jensen *et al.* 2011).

170 Received sound pressure level (rms) was calculated for each remaining whistle. DTAG  
171 toolbox scripts were used to estimate the AOA of each whistle by cross-correlating time  
172 differences of arrival between the two tag hydrophones (Johnson *et al.* 2009; 45 mm separation).  
173 Received level was plotted with AOA for all whistles analyzed from sa147d.

174 We further examined where type B whistles were recorded in time and depth. For this  
175 analysis, all type B whistles recorded on sa147d were included, even if they were not initially  
176 selected for analysis. A dive profile for sa147d was created using DTAG toolbox MATLAB  
177 scripts. The time and depth where each type B whistle was recorded was annotated within the  
178 dive profile. Time intervals between each type B whistle as well as the number of type B  
179 whistles recorded in ten-minute bins and five meter depth bins were quantified. The percent time  
180 spent in five meter depth bins for sa147d was also quantified. A chi-square test was used to  
181 determine if type B whistles were recorded more often than expected in any particular depth bin



182 based on the amount of time spent in each depth bin. Counts for the deepest five depth bins were  
183 pooled to meet the sample size requirements of chi-square.

184 Whistle categorization resulted in judges grouping 345 of the 463 whistles (75%) into ten  
185 categories. Whistles that were not grouped together by three judges (118/463) were not  
186 considered further. Five categories had more than 25 whistles each, accounting for 83% (286 out  
187 of 345) of categorized whistles (Table 1). Eight categories had 10 or more whistles (Table 1).  
188 The remaining two categories contained four and nine whistles each. Overlapping deployments  
189 of tags on the same days resulted in many cases where the same whistle was recorded on  
190 multiple tags. For each whistle category, the number of whistles that were recorded on a  
191 simultaneously deployed tag was also reported (Table 1).

192 Certain whistle categories dominated several tag records. Over half of type A whistles  
193 were recorded on tag sa147b. Of type B whistles, 74/75 were recorded on sa147d; one was  
194 recorded on sa146a. Although the type C category only contained nine whistles, all were  
195 recorded on the first day of tagging; eight were recorded on tag sa146a and one on sa146b. For  
196 type H whistles, 32/39 were recorded on sa146b. Whistles within the same category exhibited  
197 similar contour shapes (Fig. 1), with whistle E2 contours being the most similar in shape and  
198 duration (Fig. 1B) and whistle Q showing the most variation in contour shape (Fig. 1H).

199 Whistle categorization suggests that pantropical spotted dolphins repeat stereotyped  
200 whistles. The recording of whistles in some categories on two days of tagging (Table 1) may be  
201 suggestive of shared whistles across groups or subgroups as found in short-finned pilot whales  
202 (Sayigh *et al.* 2013) and killer whales, *Orcinus orca* (Ford 1989). However, pantropical spotted  
203 dolphin group membership is likely fluid, making stable group repertoires unlikely. Given large  
204 group sizes (400 and 140, respectively) and the relative proximity of tagging locations (36 km),

205 it is possible that some animals were common to both groups and therefore could have produced  
206 the same whistles recorded on different days. Alternatively, whistles could be shared across  
207 larger sets of groups within an area. Future photo-identification analysis could confirm the  
208 presence of animals common to both groups, although this has yet to be determined.

209         Of 136 whistles initially selected from sa147d, 86 had suitable SNR (>10dB) for  
210 computing received level. Of these 86 whistles, 74 were type B whistles, three were type D  
211 whistles, five were type D3 whistles, one was a type A whistle and three were not grouped by  
212 three judges. Type B whistles exhibited significantly higher received levels than other whistles  
213 (Mann-Whitney-Wilcoxon test,  $W = 0$ ,  $P < 0.0001$ ). The median RL of type B whistles was 141  
214 dB re 1  $\mu$ Pa (IQR: 140 - 142.5). Other whistles (those not categorized as type B) had a median  
215 RL of 114 dB re 1  $\mu$ Pa (IQR: 112.7 - 115.1) (Fig. 2). Angles of arrival also differed significantly  
216 between type B and other whistles (Mann-Whitney-Wilcoxon test,  $W = 754$ ,  $P = 0.0001$ ). For  
217 type B whistles, AOA ranged from -44.7 to -27.1 degrees, whereas AOA for other whistles  
218 varied more substantially, from -43 to +41.9 degrees (Fig. 2). Based on these data, we conclude  
219 that type B whistles were likely produced by the tagged individual, and that examining  
220 individual whistle production using DTAGs can be done in some cases.

221         Caldwell *et al.* (1970) report individually distinctive signature whistles recorded from  
222 five captive Atlantic spotted dolphins (*Stenella frontalis*) captured in Florida waters and Herzog  
223 (1996) reports stable signature whistles produced by individuals of this species in the wild for  
224 over 10 yr. The recording of a repeated whistle type from a single animal suggests it may be  
225 producing signature whistles, a novel observation for *S. attenuata*. The identification of type B  
226 whistles as a potential signature whistle was only possible after judges classified them as the  
227 same whistle type, demonstrating the utility of whistle categorization in exploring both group

228 and individual whistle repertoires. While the repeated nature and stereotyped contours of the  
229 remaining whistle categories also suggests signature whistle production by this species, we chose  
230 not to conduct a detailed analysis of these categories, as they exhibited high variability in  
231 amplitude and AOA and were likely not produced by tagged animals, but by other animals  
232 nearby. Some slight variation in AOA was also noted for type B whistles and was to be expected  
233 as the tagged animal moves its head with respect to the tag location. In addition, tag placement  
234 on the flank as opposed to more anterior, dorsal locations may cause slight variations in AOA as  
235 the dolphin undulates while swimming.

236 Janik *et al.* (2013) found that signature whistles in free-swimming common bottlenose  
237 dolphins could be identified based on a temporal production pattern. Using recordings of animals  
238 whose signature whistles are known, Janik *et al.* (2013) reported that signature whistles were  
239 characterized by a bout structure in which at least 75% of whistles were produced within 1-10 s  
240 of another whistle of the same type. However, this was a conservative criterion created to avoid  
241 identifying false positives; out of seven potential signature whistles that could have been  
242 identified from recordings of wild animals, only four were identified as such. Thus, not all  
243 bottlenose dolphins in the aforementioned study used the 1-10 s bout production pattern; the  
244 longest inter-whistle interval for a signature whistle was 89.5 min (Janik *et al.* 2013).

245 Type B whistles did not follow the 1-10 s bout production pattern (Fig. 3). Intervals  
246 between type B whistles were between 1-10 s only 4.1% of the time, and between 10-20 s 42%  
247 of the time. Given the variability shown by bottlenose dolphins and the fact that we present data  
248 for only one animal from a different species, it is impossible to use bout structure to determine  
249 whether or not the type B whistle is a signature whistle. Additional acoustic recordings and

250 tagging of multiple associated animals may provide insights into potential pantropical spotted  
251 dolphin signature whistle production.

252 Two other whistles recorded on tag sa147d had similar angles of arrival to type B  
253 whistles, but had RLs approximately 30 dB lower (Fig 2). Documented source levels for Atlantic  
254 spotted dolphin whistles range from 115 – 163 dB re 1  $\mu$ Pa (Frankel *et al.* 2014). Based on the  
255 dynamic range of Atlantic spotted dolphin whistles and the attachment of the tag directly to the  
256 animal, it is possible that the tagged animal (sa147d) produced these lower amplitude whistles,  
257 suggesting that pantropical spotted dolphins may produce different whistle types at different  
258 amplitudes. Additional tag recordings may help identify instances of production of multiple  
259 whistle types by the tagged animal.

260 All occurrences of type B whistles on tag sa147d, regardless of whistle quality ( $n = 97$ ),  
261 were overlaid on a dive plot for this animal to investigate timing and depth information for type  
262 B whistle production. No type B whistles were recorded in the first 10 min of tag deployment  
263 (Fig. 3) although they were generally noted throughout the rest of the tag record. Production of  
264 type B whistles peaked between 10-20 min after tag deployment. Increased whistle rate has been  
265 shown to indicate stress in common bottlenose dolphins (Esch *et al.* 2009). It is unclear if the  
266 observed pattern indicates a possible response to the tagging, as dolphins also increase whistle  
267 rate during feeding, socializing, and in the presence of vessels (Acevedo-Gutiérrez and  
268 Stienessen 2004, Buckstaff 2004, Quick and Janik 2008). Given that no other whistle types were  
269 attributed to specific tagged animals, we were unable to quantify individual-specific whistle rates  
270 on the other tags. Quantification of whistle production and behavior before, during and after  
271 tagging, as well as a larger sample size could provide insights into whether whistle rates may be  
272 influenced by tagging and if tagging may induce stress.

273 Type B whistles were produced at depths ranging from 0-40 m (Fig. 3, Fig. 4). Based on  
274 the time spent in each depth bin, the number of type B whistles produced in each bin did not  
275 differ significantly ( $\chi^2$  test,  $P = 0.226$ ), suggesting that type B whistles were produced  
276 independent of depth.

277 Pantropical spotted dolphin reactions to tagging appeared relatively minor and  
278 attachments were of generally longer duration compared to other small odontocete bioacoustic  
279 tag data. To place these data in a better context, DTAG attachment performance for pantropical  
280 spotted dolphins was compared with that of melon-headed whales (Table 2). For this evaluation,  
281 attachment of the tag to the animal was considered a successful deployment. Seven attempts  
282 were made (Table 2) to tag pantropical spotted dolphins, resulting in six successful deployments.  
283 While the tag made contact with the focal animal in all seven attempts, one deployment only  
284 lasted 29 s and was not analyzed, and in one attempt, the tag did not stick. Spotted dolphin  
285 reactions to tagging ranged from a flinch to fast dives and accelerated swimming speeds. Eleven  
286 deployment attempts on melon-headed whale resulted in nine successful deployments, one  
287 missed attempt, and one tag that did not stick. Melon-headed whales exhibited slightly stronger  
288 reactions to tagging including barrel rolls, tail flicks, and tail slaps (Fig. 5, Table 2).  
289 Additionally, tag deployment durations for the two species differed substantially. Spotted  
290 dolphin tag deployments averaged ~2.9 h and ranged from ~29 s to ~6 h. All but one of the  
291 spotted dolphin tags stayed on for more than one hour. For three of six pantropical spotted  
292 dolphin deployments, the reason for tag release is unknown. Of the other three tags, one was  
293 dislodged following a breach, and two ended at the programmed time for tag release (Fig. 5,  
294 Table 2).

295 For melon-headed whales, tag attachment durations averaged  $\sim 0.25$  h and ranged from  $\sim$   
296 2 s to  $\sim 58$  min (Table 2). Five out of nine deployments lasted 2 min or less. Less adverse  
297 reactions to tagging in spotted dolphins likely resulted in longer tag durations compared with  
298 melon-headed whales. Melon-headed whales seemed to engage in active behaviors to  
299 intentionally dislodge the tag. No melon-headed whale tag deployment resulted in a tag releasing  
300 at the programmed time. Reasons for tag release included animals breaching (two deployments),  
301 barrel-rolling away from the tag pole during the deployment (potentially impacting attachment;  
302 one deployment), accelerating and burst swimming (two deployments), and pre-existing tag  
303 damage (one deployment) (Fig. 5, Table 2); the reason for release was unknown for three  
304 deployments.

305 Observations after the initial tagging event occurred for three of seven pantropical spotted  
306 dolphins and five of eleven melon-headed whales. The remaining animals were not seen after  
307 tagging and no behavioral observations could be recorded. While initial reactions to tagging  
308 were variable and generally indicative of some response, most animals of both species resumed  
309 pretagging behavior within *ca.* 5 s after a tagging attempt was made, regardless of whether the  
310 attempt was successful or not.

311 Deployments on melon-headed whales resulted in damage (loss of suction cups and  
312 broken brackets) to the tag in five out of eleven tagging attempts. No tag damage was noted  
313 after any attempts or deployments with pantropical spotted dolphins. While these differences in  
314 tag damage may be a result of variations in species behavior this notion is confounded by  
315 improvements to the tag (as a result of these experiences with melon-headed whales). The  
316 structure of the DTAG3 and the suction-cup mechanism were updated between the studies of  
317 these two species. Improvements included a thicker and more robust bracket that held the suction

318 cups (to reduce bracket tearing) and a denser suction cup stem, to prevent it from slipping out of  
319 the bracket under high speeds. While the stronger reactions of melon-headed whales may have  
320 been more likely to cause tag damage and early release, it is possible that the longer deployment  
321 times and lack of tag damage seen with pantropical spotted dolphins was due at least in part to  
322 improvements in the tag. Thus, future deployments on melon-headed whales may benefit from  
323 these tag improvements, suggesting the need for follow-up studies.

324         While reactions to tagging and the resulting deployment durations may be species-  
325 dependent, the behavior of animals prior to tagging could play a role in successful deployments.  
326 Melon-headed whales typically engage in resting and slow travel during daytime hours  
327 (Aschettino et al. 2011, Brownell *et al.* 2009), while pantropical spotted dolphins tend to exhibit  
328 more steady movement during the day (Baird *et al.* 2001). This typical daytime behavior of each  
329 species was observed in these data sets; nine of eleven melon-headed whales exhibited milling  
330 behavior or slow travel prior to tagging, while five of seven pantropical spotted dolphins  
331 exhibited bow-riding or travel. It is possible that differences in behavior states between the two  
332 species influenced tagging reactions and resulting deployment durations. Animals in a more  
333 active behavior mode, regardless of species, may be more receptive to tagging than animals in a  
334 resting mode. Future tagging studies of small delphinids may consider daily activity patterns of a  
335 particular species when planning deployments.

336         This work represents one of the first successful tagging studies of a small delphinid  
337 species. Here, we highlight the benefits of DTAGs in studying delphinid vocal behavior by  
338 documenting repeated, stereotyped whistles and providing preliminary support for signature  
339 whistle production in pantropical spotted dolphins. Until the development of the DTAG3, data  
340 collection opportunities on small delphinids were limited by their active behavior and the

341 comparatively large size of acoustic logging tags. We consider spotted dolphin deployment  
342 durations of multiple hours and 33% success in tags remaining attached for planned lengths of  
343 time to be important achievements and advancements in tagging of small pelagic delphinids. Tag  
344 data are extremely useful for establishing natural acoustic and behavioral patterns as well as for  
345 evaluating impacts of noise or other anthropogenic activities on delphinids. This study  
346 demonstrates success in using tags to evaluate communication and behavior of these small,  
347 abundant animals and shows promise for future studies focusing on small cetaceans.

348

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363



364 **LITERATURE CITED**

365 Acevedo-Gutiérrez, A., and S. C. Stienessen. 2004. Bottlenose dolphins (*Tursiops truncatus*)  
366 increase number of whistles when feeding. *Aquatic Mammals* 30:357-362.

367 Akamatsu, T., J. Teilmann, L. A. Miller, *et al.* 2007. Comparison of echolocation behaviour  
368 between coastal and riverine porpoises. *Deep Sea Research Part II: Topical studies in*  
369 *Oceanography* 54:290-297.

370 Aschettino, J.M., R.W. Baird, D.J. McSweeney, *et al.* 2011. Population structure of melon-  
371 headed whales (*Peponocephala electra*) in the Hawaiian Archipelago: Evidence of multiple  
372 populations based on photo-identification. *Marine Mammal Science* 28:666-689

373 Baird, R. W., A. D. Ligon, S. K. Hooker, and A. M. Gorgone. 2001. Subsurface and nighttime  
374 behaviour of pantropical spotted dolphins in Hawai‘i. *Canadian Journal of Zoology* 79:988-996.

375 Baird, R. W., D. L. Webster, J. M. Aschettino, G. S. Schorr, and D. J. McSweeney. 2013.  
376 Odontocete cetaceans around the main Hawaiian Islands: habitat use and relative abundance  
377 from small-boat sighting surveys. *Aquatic Mammals* 39:253-269.

378 Bazúa-Durán, C., and W.W. Au. 2002. The whistles of Hawaiian spinner dolphins. *The Journal*  
379 *of the Acoustical Society of America* 112:3064-3072.

380 Brownell, R. J., Jr., K. Ralls, S. Baumann-Pickering and M. M Poole. 2009. Behavior of melon-  
381 headed whales near oceanic islands. *Marine Mammal Science* 25:639–658.

382 Buckstaff, K. C. 2004. Effects of watercraft noise on the acoustic behavior of bottlenose  
383 dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. Marine Mammal Science 20:709-725.

384 Caldwell, M. C., and D. K. Caldwell. 1965. Individualized whistle contours in bottlenose  
385 dolphins (*Tursiops truncatus*). Nature 207:434-435.

386 Caldwell, M.C., Caldwell, D.K. and J.F. Miller. 1970. Statistical evidence for individual  
387 signature whistles in the spotted dolphin, *Stenella plagiodon*. (No. TR-7). LOS ANGELES  
388 COUNTY MUSEUM CALIF.

389 Carretta, J. V., K. A. Forney, and J. Barlow. 1995. Report of 1993-1994 marine mammal aerial  
390 surveys conducted within the US navy outer sea test range off southern California. NOAA  
391 Technical Memorandum NMFS-SWFSC-217, La Jolla, California. 90 pp.

392 Charif, R., A. Waack, and L. Strickman. 2010. Raven Pro 1.4 User's Manual. Cornell Laboratory  
393 of Ornithology, Ithaca, NY.

394 Department of the Navy. 2013. Hawaii-southern California, Final Environmental Impact  
395 Statement/Overseas Environmental Impact Statement (EIS/OEIS). Prepared by Naval Facilities  
396 Engineering Command, Pacific/EV21.CS, Pearl Harbor, HI.

397 DeRuiter, S. L., I. L. Boyd, D. E. Claridge, C. W. Clark, C. Gagnon, B. L. Southall, and P.L.  
398 Tyack. 2013. Delphinid whistle production and call matching during playback of simulated  
399 military sonar. Marine Mammal Science 29: E46-E59.

400 Deruiter, S. L., A. Bahr, M. A. Blanchet, *et al.* 2009. Acoustic behaviour of echolocating  
401 porpoises during prey capture. The Journal of Experimental Biology 212: 3100-3107.

402 Driscoll, A. D. 1995. The whistles of Hawai'ian spinner dolphins, *Stenella longirostris*. Master's  
403 Thesis. University of California, Santa Cruz.

404 Esch, H. C., L. S. Sayigh, J. E. Blum, and R. S. Wells. 2009. Whistles as potential indicators of  
405 stress in bottlenose dolphins (*Tursiops truncatus*). *Journal of Mammalogy* 90:638-650.

406 Ford, J. K. 1989. Acoustic behaviour of resident killer whales (*Orcinus orca*) off Vancouver  
407 Island, British Columbia. *Canadian Journal of Zoology* 67:727-745.

408 Frankel, A. S., D. Zeddies, P. Simard, and D. Mann. 2014. Whistle source levels of free-ranging  
409 bottlenose dolphins and Atlantic spotted dolphins in the Gulf of Mexico. *The Journal of the*  
410 *Acoustical Society of America* 135:1624-1631.

411 Geijer, C. K., and A. J. Read. 2013. Mitigation of marine mammal bycatch in US fisheries since  
412 1994. *Biological Conservation* 159:54-60.

413 Gerrodette, T. and J. Forcada. 2005. Non-recovery of two spotted and spinner dolphin  
414 populations in the eastern tropical Pacific Ocean. *Marine Ecology Progress Series* 291:1-21.

415 Hanson, M. B., and R. W. Baird. 1998. Dall's porpoise reactions to tagging attempts using a  
416 remotely--deployed suction--cup tag. *Marine Technology Society Journal*, 32:18-23.

417 Henderson, E. E., M. H. Smith, M. Gassmann, S. M. Wiggins, A. B. Douglas, and J. A.  
418 Hildebrand. 2014. Delphinid behavioral responses to incidental mid-frequency active sonar. *The*  
419 *Journal of the Acoustical Society of America*, 136:2003-2014.

420 Herzing, D.L. 1996. Vocalizations and associated underwater behavior of free-ranging Atlantic  
421 spotted dolphins, *Stenella frontalis* and bottlenose dolphins, *Tursiops truncatus*. *Aquatic*  
422 *Mammals*, 22:61-80.

423 Janik, V. M., S. L. King, L. S. Sayigh, and R. S. Wells. 2013. Identifying signature whistles from  
424 recordings of groups of unrestrained bottlenose dolphins (*Tursiops truncatus*). *Marine Mammal*  
425 *Science* 29:109-122.

426 Jensen, F. H., J. M. Perez, M. Johnson, N.A. Soto, and P.T. Madsen. 2011. Calling under  
427 pressure: Short-finned pilot whales make social calls during deep foraging dives. *Proceedings of*  
428 *the Royal Society Biological Sciences* 278:3017-3025.

429 Johnson, M. P. and P. L. Tyack. 2003. A digital acoustic recording tag for measuring the  
430 response of wild marine mammals to sound. *Oceanic Engineering, IEEE Journal of Ocean*  
431 *Engineering* 28:3-12.

432 Johnson, M. P., N. Aguilar de Soto, and P. T. Madsen. 2009. Studying the behaviour and sensory  
433 ecology of marine mammals using acoustic recording tags: A review. *Marine Ecology Progress*  
434 *Series* 395:55-73.

435 Kaplan, M. B., T. A. Mooney, L. S. Sayigh, and R. W. Baird. 2014. Repeated call types in  
436 Hawaiian melon-headed whales (*Peponocephala electra*). *The Journal of the Acoustical Society*  
437 *of America* 136:1394-1401.

438 Madsen, P. T. and M. Wahlberg. 2007. Recording and quantification of ultrasonic echolocation  
439 clicks from free-ranging toothed whales. *Deep Sea Research Part I: Oceanographic Research*  
440 *Papers* 54:1421-1444.

441 McSweeney, D.J., R.W. Baird, S.D. Mahaffy, D.L. Webster and G.S. Schorr. 2009. Site fidelity  
442 and association patterns of a rare species: pygmy killer whales (*Feresa attenuata*) in the main  
443 Hawaiian Islands. *Marine Mammal Science* 25:557-572.

444 Miller, P. J., M. P. Johnson, and P. L. Tyack. 2004. Sperm whale behaviour indicates the use of  
445 echolocation click buzzes "creaks" in prey capture. *Proceedings of the Royal Society Biological*  
446 *Sciences* 271:2239-2247.

447 Perrin, W.F., J.M. Coe, and J.R. Zweifel. 1976. Growth and reproduction of the spotted porpoise,  
448 *Stenella attenuata*, in the offshore eastern tropical Pacific. *Fishery Bulletin* 74:229-269.

449 Quick, N. J., and V. M. Janik. 2008. Whistle rates of wild bottlenose dolphins (*Tursiops*  
450 *truncatus*): influences of group size and behavior. *Journal of Comparative Psychology* 122: 305.

451 Sayigh, L., N. Quick, G. Hastie, and P. Tyack. 2013. Repeated call types in short-finned pilot  
452 whales, *Globicephala macrorhynchus*. *Marine Mammal Science* 29:312-324.

453 Sayigh, L. S., H. C. Esch, R. S. Wells, and V. M. Janik. 2007. Facts about signature whistles of  
454 bottlenose dolphins, *Tursiops truncatus*. *Animal Behaviour* 74:1631-1642.

455 Sayigh, L. S., P. L. Tyack, R. S. Wells, and M. D. Scott. 1990. Signature whistles of free-ranging  
456 bottlenose dolphins *Tursiops truncatus*: stability and mother-offspring comparisons. *Behavioral*  
457 *Ecology and Sociobiology* 26:247-260.

458 Schneider, K., R. W. Baird, S. Dawson, I. Visser, and S. Childerhouse. 1998. Reactions of  
459 bottlenose dolphins to tagging attempts using a remotely-deployed suction-cup tag. *Marine*  
460 *Mammal Science* 14:316-324.

461 Silva T. L., T. A. Mooney, L. S. Sayigh, P. L. Tyack, R. W. Baird, and J. N. Oswald. 2016  
462 Whistle characteristics and daytime dive behavior in pantropical spotted dolphins (*Stenella*  
463 *attenuata*) in Hawai‘i. *The Journal of the Acoustical Society of America* 140:421-429.

464 Southall, B. L., R. Braun, F. Gulland, A. D. Heard, R. W. Baird, S. M. Wilkin, and T. K. Rowles.  
465 2006. Hawaiian melon-headed whale (*Peponacephala electra*) mass stranding event of July 3-4,  
466 2004. NOAA Technical Memorandum NMFS-OPR-31. 73 pp.

467 Southall, B.L., Rowles, T., Gulland, F., Baird, R. W., and Jepson, P.D. 2013. Final Report of the  
468 Independent Scientific Review Panel Investigating potential contributing factors to a 2008 mass  
469 stranding of melon-headed whales (*Peponocephala electra*) in Antsohihy, Madagascar.

470 Watkins W. A. and W. E. Schevill. 1974. Listening to Hawaiian spinner porpoises, *Stenella* cf.  
471 *longirostris*, with a three-dimensional hydrophone array. *Journal of Mammalogy* 35:319-328

472 Wells, R. S., K. A. McHugh, D. C. Douglas, S. Shippee, E. B. McCabe, N. B. Barros, and G. T.  
473 Phillips. 2013. Evaluation of potential protective factors against metabolic syndrome in  
474 bottlenose dolphins: feeding and activity patterns of dolphins in Sarasota Bay, Florida. *Frontiers*  
475 *in Endocrinology* 4:139.

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Table 1. Number of whistles in each whistle category that were grouped by three judges. The top three rows represent day 1 of tagging. The bottom five rows represent day 2 of tagging. The number of whistles from a tag that were grouped by three judges into a given whistle category is listed. The number of whistles in each category that were recorded on multiple tags is also listed. Tag IDs correspond to the following information: sa – species, *Stenella attenuata*, 146, 147 - day of tagging (Julian day), a-d – the order animals were tagged.

Tag	Whistle category									
	A	B	D	E2	H	D3	G	Q	C	BB
sa146a	11	1	4	13	4	0	6	0	8	2
sa146b	8	0	1	23	32	0	2	1	1	1
sa146a and sa146b	5	1	2	31	29	0	1	1	2	1
sa147b	47	0	0	0	0	0	0	0	0	0
sa147c	6	0	28	0	3	8	6	9	0	0
sa147d	8	74	23	0	0	10	3	1	0	1
sa147b and sa147c	10	0	0	0	0	0	0	0	0	0
sa147c and sa147d	5	45	32	0	0	13	8	3	0	1
Total	80	75	56	36	39	18	17	11	9	4

Table 2. DTAG3 deployment summary for pantropical spotted dolphins and melon-headed whales.

Species	Date	Tag ID	Hit/miss	Behavior before	Reaction behavior	Behavior after	Deployment duration (hours:minutes:seconds)	Reason for tag release	Tag damage
<i>Pantropical spotted dolphin</i>	May 2013	sa146a	hit	milling	flinch/acceleration	milling	02:08:50	unknown	none
	May 2013	sa146b	hit	travel	acceleration	travel	01:38:47	unknown	none
	May 2013	sa147a	hit	bow ride	acceleration	unknown	00:00:29	breach	none
	May 2013	sa147b	hit	bow ride	fast dive	unknown	00:25:50	unknown	none
	May 2013	sa147c	hit	bow ride	acceleration	unknown	04:24:00	planned burn	none
	May 2013		hit, tag did not stick	travel	fast dive	unknown	n/a	n/a	none
	May 2013	sa147d	hit	slow travel	fast dive	slow travel	05:58:00 (audio 02:26:00)	planned burn	none
<i>Melon-headed whale</i>	Oct 2011	pe292a	hit	slow travel	fast dive	slow travel	00:13:00	acceleration	none
	Oct 2011	pe292b	hit	slow travel	tail flick/fast dive	slow travel	00:34:37	breach	suction cup moved, socket broke
	Oct 2011	pe297a	hit	bow ride	acceleration	unknown	00:00:02	tag damage	suction cup and socket broke
	Oct 2011		miss	milling	acceleration	unknown	n/a	n/a	none
	Oct 2011	pe297b	hit	milling	barrel roll	unknown	00:02:00	animal rolled on tag	4 suction cups missing
	Oct 2011	pe297c	hit	milling	acceleration	unknown	00:02:00	breach	1 suction cup missing
	Oct 2011	pe297d	hit	milling	tail slap	acceleration	00:04:00	acceleration	2 suction cups missing
May 2012	pe134a	hit	travel	barrel roll	travel	00:42:56	unknown	none	
Aug 2012	pe237a	hit	slow travel	fast dive	slow travel	00:57:39	unknown	none	
Aug 2012		hit, tag did not stick	slow travel	fast dive	unknown	n/a	n/a	none	
Aug 2012	pe237b	hit	slow travel	fast dive	slow travel	00:02:00	unknown	none	



Figure 1. Contour traces for 10 randomly selected whistles from eight whistle categories. A representative whistle from each category is also shown as a spectrogram. All whistles are from pantropical spotted dolphins. Letters assigned to whistle categories are arbitrary designations. A. type A. B. type E2. C. type B. D. type G. E. type D. F. type H. G. type D3. H. type Q.

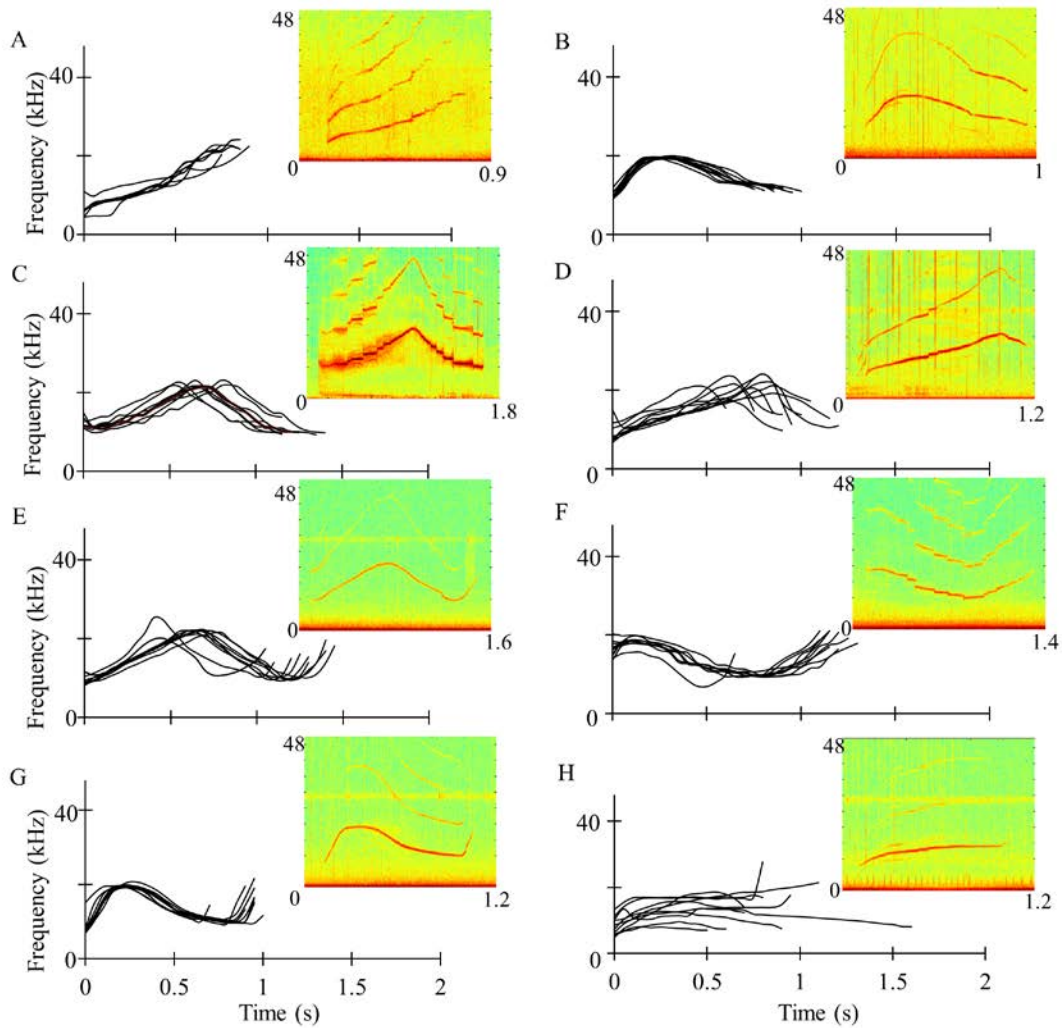


Figure 2. Received level vs. angle of arrival for type B whistles ( $n = 74$ ) and other whistles ( $n = 12$ ) recorded on sa147d.

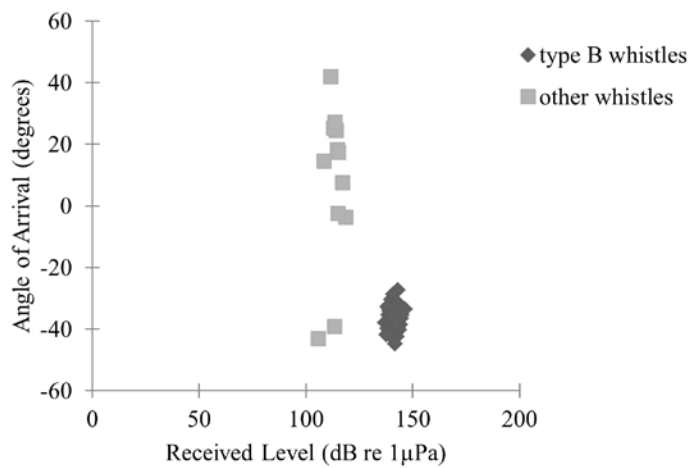


Figure 3. A. Dive plot for sa147d with concurrent type B whistle production. Circles indicate depth and time of type B whistles recorded on sa147d. B. Number of type B whistles produced every 10 min over the tag duration.

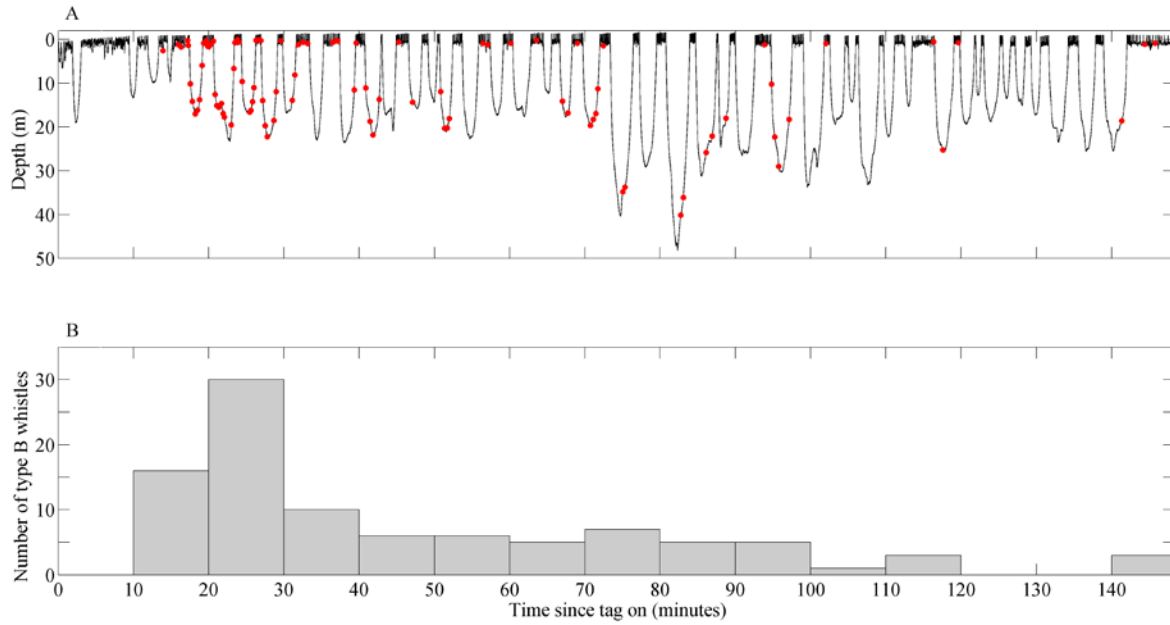


Figure 4. Percent time spent in five meter depth bins for tagged animal sa147d and the number of type B whistles produced in the same five meter depth bins.

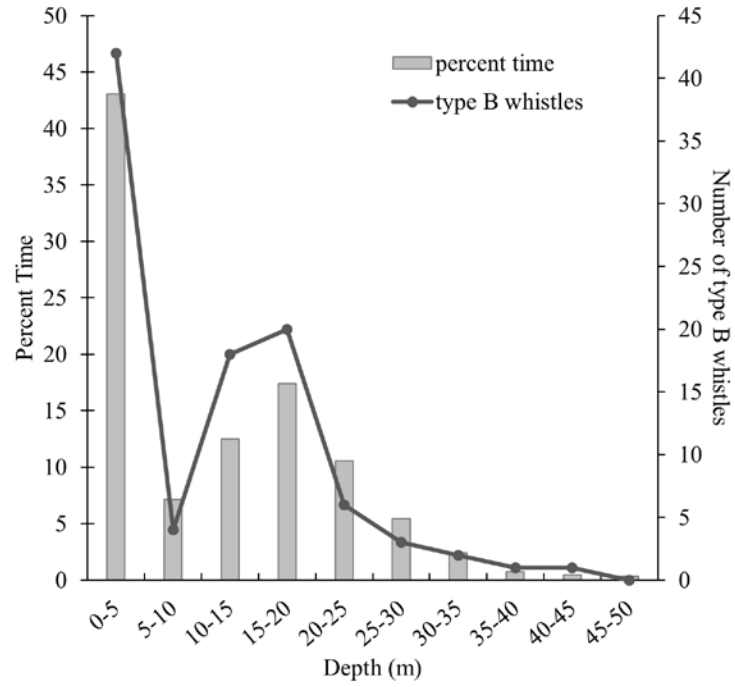


Figure 5. Reactions to tagging and reasons for tag release for pantropical spotted dolphins (*Stenella attenuata*) and melon-headed whales (*Peponocephala electra*).

