**Farallon Islands Restoration Project**

**Evaluating the duration of potential risk exposure to susceptible non-target species following the application of rodent bait.**

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# Executive Summary

Introduced mice pose a threat to the Ashy Storm-petrel and other native and endemic species of the Farallons National Wildlife Refuge. To provide for species and ecosystem recovery, the removal of mice from the Farallons has been proposed. Methods being considered for removing mice include the aerial application of one of two EPA-registered grain-based rodent baits; Diphacinone-50 Conservation or Brodifacoum-25D Conservation. These anticoagulant based products have been used successfully in past rodent eradications.

Autumn has been proposed as the best timing for a mouse eradication attempt because most resident seabirds are absent from the islands at this time. However, risk of exposure to rodenticide exists for some non-target wildlife such as Western gulls. Individual western gulls would be at risk of consuming rodent bait until it has either been consumed or degraded to an unpalatable state. To better quantify this risk, develop mitigation measures for gulls and other non-target species, and inform the NEPA process, two trials were undertaken, the first beginning in 2011 and the second in 2012 to determine the length of time rodent bait would take to degrade and disappear on the South Farallon Islands.

In the first trial both Diphacinone-50 Conservation and Brodifacoum-25D Conservation bait degraded to a condition not considered palatable or available to Western gulls over a period of 101 days. However, trial results were confounded by a record-setting drought. A second trial was undertaken beginning in 2012 under wetter conditions. Degradation of Brodifacoum-25D Conservation in the second trial was rapid and bait degraded to an unpalatable state within seven days. For unknown reasons, Diphacinone-50 Conservation persisted in a palatable condition despite the higher rainfall until the conclusion of the second trial. Reasons for the difference in degradation rate observed between bait types are unknown.

Bait degradation did not differ greatly between sites but significant variation was found between substrates (baits broke down more rapidly on soil and in vegetation than on a rock substrate) and years. Other studies testify to the impact of rainfall on the rate of bait degradation and data from our trial supported the inference of a relationship between bait degradation and rainfall. On this basis, predictions of the time bait may be available and palatable to susceptible non-target species such as Western gulls were made using three different rainfall scenarios. Assuming rainfall similar to the average over the last 30 years, it is anticipated that Brodifacoum-25D Conservation bait would remain available and palatable to Western gulls for a period of up to five weeks. Diphacinone-50 Conservation may pose a risk to non-target wildlife for 15 weeks or longer.

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# Introduction

Introduced House mice (*Mus musculus*) are impacting the IUCN-Endangered Ashy Storm-petrel (*Oceanodroma homochroa*) and other native and endemic species of the Farallon National Wildlife Refuge. To eliminate these impacts and allow species and ecosystem recovery, the USFWS is assessing the potential for removing mice from the Refuge. To inform the NEPA process, the planning for a possible eradication attempt and the development of potential mitigation measures to protect non-target wildlife from harm, a number of trials have been completed.

This report documents the findings of two trials that aimed to determine the length of time rodent bait might remain available and palatable to susceptible non-target species specifically Western gulls (*Larus occidentalis*) if consumption by the target species, in this case mice, was precluded. Although a wider suite of methods is under consideration, the trial focused on the use of rodent bait as the application of rodent baits containing rodenticides is the only method that has been used successfully to remove mice from islands ([Keitt et al. 2011](#_ENREF_5), [Mackay et al. 2011](#_ENREF_6)). Non-toxic formulations of Diphacinone-50 Conservation and Brodifacoum-25D Conservation, two rodent bait types registered with the EPA for use in the U.S. to remove invasive rodents from island ecosystems, were used in the trial. Both bait types have been used successfully in past rodent eradications ([Howald et al. 2007](#_ENREF_2)).

The use of rodent bait containing a rodenticide on the Farallones presents a temporary risk to susceptible non-target wildlife. Western gulls were identified as being particularly vulnerable to the use of rodent bait containing rodenticides because they are omnivorous scavengers and individuals of this species will be present during the time of year that a mouse eradication might be undertaken. The duration of potential exposure will depend on how quickly rodent bait is consumed by mice and invertebrates[[1]](#footnote-1), but also the length of time that bait takes to degrade. Bait degradation for the purposes of our trials was only considered within the context of the risk posed to Western gulls and other bird species. The availability and palatability of rodent bait to mice was not considered within the scope of the trial.

Rates of bait disappearance were evaluated in 2010 with high rates of bait take recorded but degradation of remaining bait was not assessed (Appendix C). To determine the length of time that rodent bait, not consumed by mice, might persist on the South Farallon Islands, the breakdown of non-toxic Diphacinone-50 Conservation and Brodifacoum-25D Conservation rodent bait was monitored over the autumn and winter period beginning in 2011 and 2012. This report documents the methods used and the results of this monitoring. Differences between the two bait types and variability in bait degradation between sites, substrates and years are discussed. The influence of rainfall on bait degradation is evaluated and predictions made based on varying rainfall scenarios of the length of time that bait may remain palatable and available to non-target species.

# Trial Objective

Assess the rate of degradation of rodent bait products currently registered for rodent eradication on the South Farallon Islands.

# Methods

To determine the rate at which rodent bait would degrade after its application, non-toxic samples of two rodent baits (Table 1) were placed on Southeast Farallon Island (SEFI) and its fate monitored over subsequent months. Non-toxic bait consists of the same inactive ingredients (which comprise 99.9975% of the bait) as the toxic bait product so is considered representative of the actual bait product with respect to degradation rate. Monitoring was undertaken from November because this is the time that a mouse eradication operation involving an application of rodent bait is most likely to occur. The first trial began on November 10, 2011 and extended to March 16, 2012 and the second trial began and ended on November 27, 2012 and March 12, 2013 respectively. Both rodent baits are registered with the EPA for rodent eradications on U.S. islands. Conservation 25D was developed by Bell Laboratories for dry temperate climatic conditions similar to the Farallones. Ramik® Green, produced by HACCO undergoes a hot extrusion process during manufacturing that makes it weather resistant without the use of wax.

Table 1 Rodent Baits Tested on Southeast Farallon Island

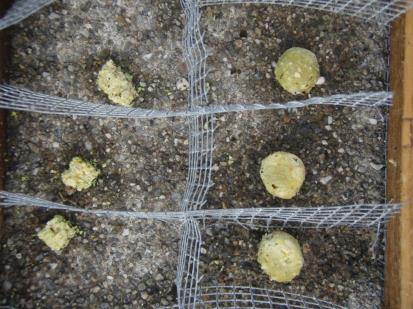
|  |  |  |  |
| --- | --- | --- | --- |
| Bait Name | Pellet Weight | Condition | Manufacturer |
| Brodifacoum-25D Conservation | 1g | Dry | Bell Laboratories |
| Diphacinone-50 Conservation | 1g | Dry | Hacco® |

Specially constructed exclusion cages (Figs. 1 & 2) were used to prevent bait take by birds or mice. Cages were uniquely labeled, their location and elevation recorded and the layout of baits and bait types within the cage documented for monitoring. Cages were anchored with a buried rock and wire or in the case of rock substrate, with masonry nails, to prevent disturbance by gulls and mice. Exact placement of the cages was coordinated with PRBO staff on island prior to their being secured and cages were placed on or near existing paths to minimize impacts to island resources, and to avoid impacts to other study plots.

Bait degradation rates can be affected by a range of factors ([Craddock 2003](#_ENREF_1)), so cages were established at six different sites on the island representing a range of microclimates. Three bait cages were deployed at each site, one in each of the three significant substrate types found on the island; rock, bare soil, and vegetation. Soil substrate was not sampled in the second trial. Bait cages at each site were placed within 20 meters of each other.

Between four and eight pellets of each bait type were placed into each cage. The number of bait pellets remaining and the condition of each was then assessed weekly and degradation scored as per the scale developed by Craddock ([2003](#_ENREF_1)) (Appendix 1). A photograph was taken during weekly inspections for later reference. If a pellet was obscured, the top of the cage was unscrewed to discern whether the pellet had

truly disintegrated or was simply hidden by vegetation growing inside the cage. Rainfall data were collected three times daily by Point Reyes Bird Observatory (PRBO) staff as part of a program for the National Weather Service.



|  |  |  |
| --- | --- | --- |
| Fig. 1 Photo of bait degradation cage with pellets. Wire mesh bottom on this cage not visible in picture. |  | Fig. 2. Close up of the two bait types during the trial (Brodifacoum-25D Conservation on left and Diphacinone-50 Conservation on right) |

To evaluate the relative availability and palatability of rodent bait over time and establish the duration of potential exposure to non-target species such as Western gulls, bait degradation scores determined after Craddock ([2003](#_ENREF_1)) were converted to a degradation index (Table 2). A degradation index of 1 indicates that bait is intact and identical to fresh bait whereas a degradation index of 0 indicates that the bait has completely disintegrated or disappeared. An assumption made in analyzing the data set was that bait was no longer palatable or attractive to non-target species of concern on SFI when it reached a condition degradation index of 0.4. Availability and palatability of rodent bait to mice was not considered. Bait with a condition score of 0.4 is described by Craddock ([2003](#_ENREF_1)) as a soft or moist pile of mush, 50% or more of which may be covered in mold. Bait in this condition, is considered to be less visible and not attractive to gulls and other bird species. It also cannot be readily manipulated or removed in one piece.

Table 2. Degradation indices used as a measure of bait availability and palatability to non-target species.

|  |  |
| --- | --- |
| Bait degradation score after Craddock ([2003](#_ENREF_1)) | Degradation index used for analysis |
| 1 | 1.0 |
| 2 | 0.8 |
| 3 | 0.6 |
| 4 | 0.4 |
| 5 | 0.2 |
| 6 | 0 |

To determine the effect of year, bait type and substrate on mean weekly bait degradation rate, and extent of bait degraded by week 15, we used a linear mixed model with Restricted Maximum Likelihood estimation, with sites specified as random effects. We included interactive effects of bait type x year, and bait type x substrate, but not year x substrate because one substrate type (soil) was only tested for one year. Bait degradation rate was expressed as an average for the site over one season. Models created within JMP v. 10.0, alpha was tested at 0.05 and diagnostics were checked using standard plots ([Quinn and Keough 2002](#_ENREF_10)).

The influence of rainfall on bait degradation was explored by linear regression on the extent of weekly bait breakdown and total weekly rainfall. Degradation rates and rainfall data collected from SEFI were compared with data collected from Palmyra Atoll, Wake Atoll and Anacapa. Data from SEFI and Anacapa were then used to predict the length of time over which bait might remain available and palatable to non-target species on the South Farallon Islands under three different rainfall scenarios. No index was available for invertebrate activity and only anecdotal data is reported.

# Results and Discussion

Bait degradation cages were checked for 18 weeks in the first trial and for 15 weeks in the second. One cage in the second trial was crushed by an elephant seal at 12 weeks precluding further monitoring of this cage. All cages successfully excluded mice and gulls and may have reduced access to bait by invertebrates. Weekly rainfall differed between the two trials, with almost twice as much rain falling by the 15th week in the second trial compared to the first (Fig. 3).

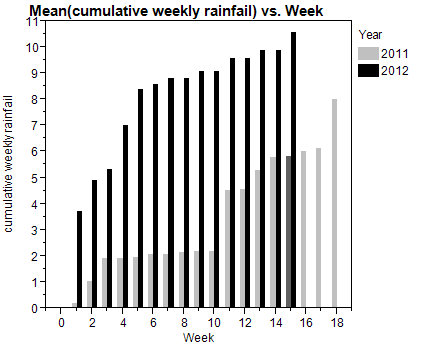
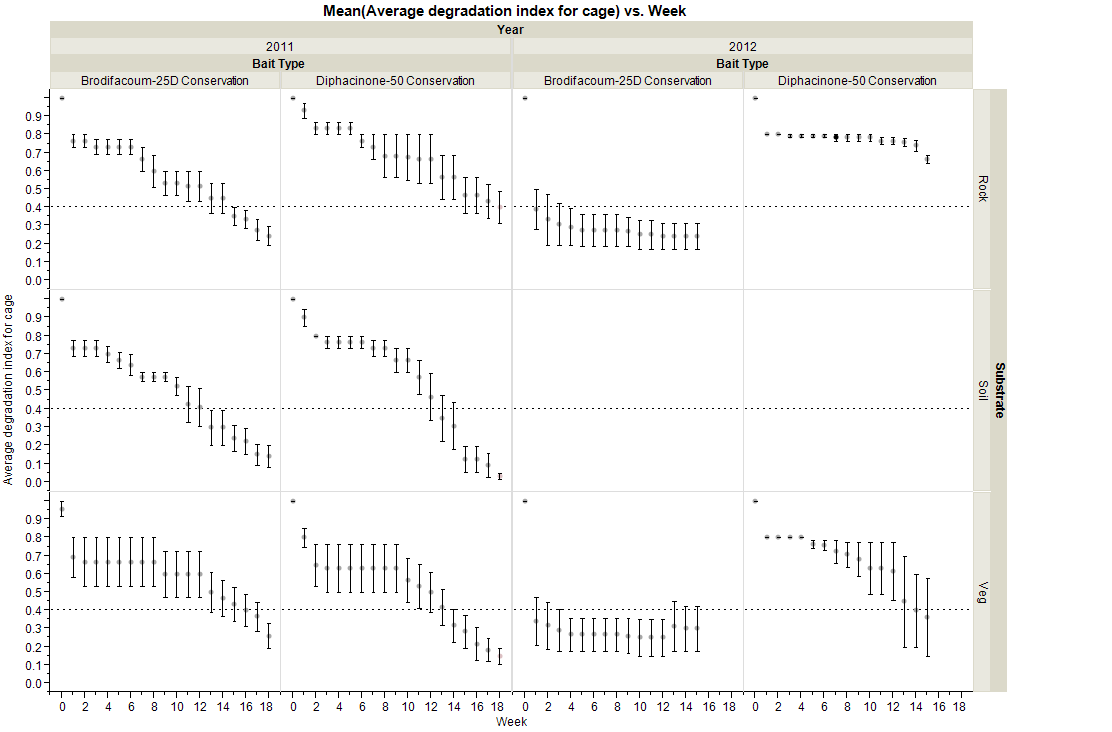


Fig. 3 Cumulative rainfall on SEFI during the two trials

During the unusually dry fall of 2011, 90% of Brodifacoum-25D Conservation baits degraded to a state considered unpalatable to gulls and other wildlife over a period of 17 weeks (Fig. 3). However, Brodifacoum-25D Conservation pellets degraded to a similar state within just three weeks in the second trial under what are considered to be normal rainfall conditions based on the last 30 years of rainfall data

(PRBO unpublished data). Ninety percent of Diphacinone-50 Conservation bait degraded to an unpalatable and unavailable state by 15 weeks in the first trial (Fig. 4). In contrast, more than 90% of Diphacinone-50 Conservation bait was still considered to be available after 15 weeks and at the conclusion of the second trial.

Rates of bait degradation during the first trial (Fig. 4) were considerably slower than anticipated and this is attributed to the unprecedented period of dry weather that ensued over the course of the trial. Monitoring in the first trial was undertaken during the driest December on record for the Farallones and for the Central California coast in general (Appendix 2). Degradation rates observed for Brodifacoum-25D Conservation during the second trial when more rainfall was experienced, were much closer to those expected and reinforce previous observations that degradation rates for cereal based rodent pellets are strongly influenced by rainfall (e.g. [Merton 1987](#_ENREF_7), [Howald et al. 2001](#_ENREF_4)).

Fig. 4. Relative availability and palatability of non-toxic Brodifacoum-25D Conservation and Diphacinone-50 Conservation rodent bait protected from consumption by vertebrate consumers observed over time on rock, vegetation and soil substrates during two trials undertaken beginning in the fall of 2011 and 2012 on SEFI. Vertical bars represent standard error. Bait that has degraded to a relative bait availability and palatability index of below 0.4 is considered to no longer pose a risk to non-target species such as Western gulls for the reasons outlined above.

A significant difference in mean bait degradation rate was found between substrate type, and interactive effects of bait x substrate, and bait x year (Table 1). Adjusted *R*2 for the model testing mean weekly bait degradation rate was 0.57, and 0.67 for extent of bait degraded by week 15, suggesting these variables explained 57% and 67% of the variation observed respectively. Of the three substrate types, baits broke down significantly faster on bare soil and in vegetation than they did on bare rock. It is thought that bait persisted longer on bare rock because it was able to dry out between periods of rainfall or dense fog. In contrast, bait degradation varied little between sites (Table 3).

Table 3: Fixed effects tests of year, bait and substrate on mean weekly bait degradation rate, and extent of bait degraded by week 15. Stars indicate statistical significance.

|  |  |  |
| --- | --- | --- |
| Parameter | Mean weekly bait degradation rate | Extent of degradation by week 15 |
| year | F1,36.4=0.38, *p*=0.537 | F1,38.0=0.26, *p*=0.613 |
| bait | F1,32.5=0.46, *p*=0.504 | F1,32.4=2.09, *p*=0.157 |
| substrate | F2,32.5=8.98, *p*<0.001\* | F2,32.5=11.38, *p*<0.001\* |
| bait x substrate | F2,32.5=3.84, *p*=0.032\* | F2,32.4=6.64, *p*=0.004\* |
| year x bait | F2,32.5=16.74, *p*<0.001\* | F2,32.4=8.11, *p*=0.008\* |

Linear regression found a loose but meaningful correlation between total weekly rainfall and the weekly extent of bait degradation for both Brodifacoum-25D Conservation (*R*2 = 0.4, *F* = 17.37, *df* = 26) and Diphacinone-50 Conservation (*R*2 = 0.23, *F* = 7.68, *df* = 26). Because repeated samples were taken, data on bait degradation rates were correlated over time violating the assumption of independent data points required for regression. However, based on our observations and similar conclusions about the influence of rainfall on bait degradation by other authors (e.g. [Merton 1987](#_ENREF_7), [Howald et al. 2001](#_ENREF_4)) we consider it reasonable to make an estimate of the length of time rodent bait might persist on the South Farallones Islands based on the degradation rates we observed.

It must also be noted that the sinusoidal pattern of bait degradation we observed for both bait types (Fig. 4) suggests that factors other than rainfall are also important in influencing the rate at which bait degrades. Bait formulation may possibly explain why the rate of degradation initially proceeds rapidly but then slows down and the presence and abundance of mold may also play a role. Pellets of both bait types remaining at the end of the first trial and pellets of Brodifacoum-25D Conservation at the conclusion of the second trial were all heavily molded, black in color and virtually impossible to see against a dark background.

Factors other than rainfall may have contributed to the higher bait degradation rate observed for Diphacinone-50 Conservation in the first trial including increased consumption by invertebrates. In the first trial, Diphacinone-50 Conservation pellets appeared to be exposed to a higher level of invertebrate consumption; slugs were detected in at least two cages and most bait pellets in these cages had disappeared within four weeks. However, as no indices of invertebrate activity were recorded, no

definitive conclusions can be made. In the first trial Diphacinone-50 Conservation baits were also observed to grow mold more quickly than Brodifacoum-25D Conservation.

Tables 4 and 5 below provide a comparison of the rate of breakdown observed during this trial for Brodifacoum-25D Conservation and Diphacinone-50 Conservation and the degradation rates for these bait types observed during trials conducted on Anacapa, Palmyra, Wake and Desecheo islands. As can be seen, rates of bait breakdown vary widely between islands. Because of the dissimilarities in climate between the tropical and temperate islands, and likelihood that bait degradation was also affected by invertebrate consumption on the tropical islands, it is considered that predictions of bait persistence on the South Farallon Islands should be extrapolated from SEFI trial data and information from Anacapa. Anacapa has a similar climate to the Farallones.

Table 4 Degradation of Brodifacoum-25D Conservation and rainfall amounts for five different sites.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Monitoring period (days) | Average time to reach bait degradation index 0.4 (days) | Total rainfall to reach bait degradation index 0.4 (inches) | Rate of bait breakdown with rainfall (extent of breakdown/inch) |
| SEFI 2011 | 126 | 101 | 5.88 | 0.10 |
| SEFI 2012 | 105 | 7 | 3.73 | 0.16 |
| Anacapa | 133 | 77[[2]](#footnote-2) | 4.51[[3]](#footnote-3) | 0.13 |
| Wake | 23 | 20[[4]](#footnote-4) | 2.36[[5]](#footnote-5) | 0.25 |
| Palmyra | 5 | 31 | 4.94 | 0.12 |
| Desecheo | 21 | 7 | 1.24 | 0.48 |

Table 5 Degradation of Diphacinone-50 Conservation and rainfall amounts for three different sites.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Monitoring period (days) | Average time to reach bait degradation index 0.4 (days) | Total rainfall to reach bait degradation index 0.4 (inches) | Rate of bait breakdown with rainfall (extent of breakdown/inch) |
| SEFI 2011 | 126 | 98 | 5.78 | 0.10 |
| SEFI 2012 | 105 | Trial ended before bait reached necessary degradation index | N/A | N/A |
| Wake | 23 | 204 | 2.365 | 0.25 |
| Palmyra | 5 | 5 | 7.30 | 0.08 |

Although information is limited, we believe that the approximate length of time that Brodifacoum-25D Conservation bait would remain available and palatable to non-target species on the South Farallon Islands can be estimated for different rainfall scenarios by extrapolating from the rate at which bait degraded with rainfall during this trial and on Anacapa (Tables 4 & 5). Assuming a normal fall rainfall pattern on the South Farallon Islands, it is anticipated that Brodifacoum-25D Conservation would pose a risk to non-target species such as Western gulls for up to five weeks (Fig. 5). This period could be reduced if rainfall is higher than normal (Fig. 5) or, as was observed in the second trial, a significant rainfall event (>2 inches) occurs.

Because of the disparity in results between years for Diphacinone-50 Conservation, predictions for this bait type is more difficult. Based on the results observed and the range of conditions experienced we conclude that this bait type could pose a hazard to susceptible non-target wildlife for a period of 15 weeks or longer.

Fig. 5. Fig 5. Hypothetical bait degradation rates for Brodifacoum 25D under three projected rain scenarios for the Farallones. Slopes were calculated by multiplying rainfall by the rate of bait breakdown calculated for Brodifacoum 25D and shown in Table 4. Rainfall for a wet year was estimated as twice the amount seen in a normal year and half the normal rainfall was used for a dry year. Both extremes have been documented on the Farallones.

There are several factors that we did not incorporate into our predictions of bait longevity but are likely to shorten the duration of bait availability and palatability. Growth of vegetation on the island after bait was applied during a recent gull hazing trial rendered most pellets invisible to the human eye even at close range. Consequently, bait in vegetated areas is likely to be obscured from non-target species such as Western gulls as a result of this growth. Bait availability could also be manually reduced by picking up

bait after the mouse eradication is deemed complete. Removing bait from rocky substrates where it is likely to persist the longest could reduce the time and effort required to mitigate non-target risks. Bait degradation cages are also considered to have inhibited bait uptake by invertebrates and it is likely that bait degradation rates would be higher if bait is unprotected.

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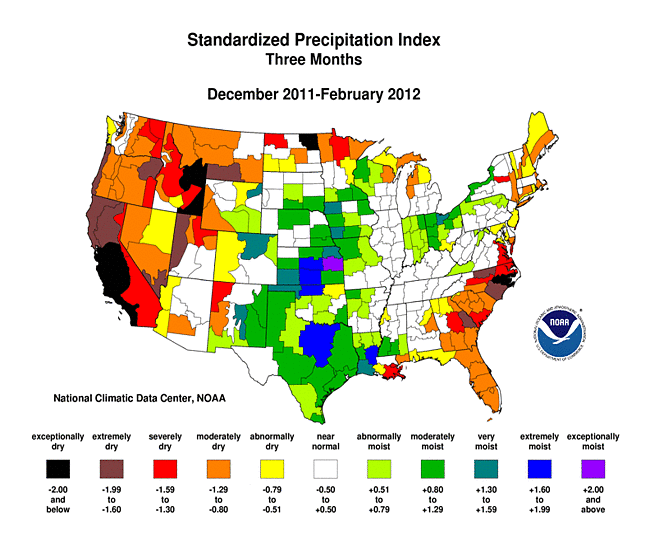
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# Appendix 1. Bait degradation scale used (Craddock 2004).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Pellet matrix** | **Change in shape** | **Presence of mold** | **Loss of volume** |
| **Condition 1**  ***Fresh pellets*** | Identical to fresh bait | Identical to fresh bait | None | None |
| **Condition 2**  ***Soft pellets*** | <50% pellet matrix is or has been soft/moist | Distinct cylinder still; smooth sides may have been lost | <50% bait pellets mold | Little or no volume lost |
| **Condition 3**  ***Mush pellets*** | >50% bait matrix is or has been soft/moist | <50% pellet has lost distinct cylinder shape | >50% bait pellets have mold | Bait has lost some volume (<50%) |
| **Condition 4**  ***Pile of mush*** | 100% of bait matrix is or has been soft | Pellets lost distinct cylinder shape & resembles a pile of mush with some grain particles in matrix showing distinct separation from main pile | >50% bait pellets have mold | Bait has lost some volume (<50%) |
| **Condition 5**  ***Disintegrating Pile of mush*** | 100% of bait matrix is or has been soft | Pellet has completely lost distinct cylindrical shape and resembles a pile of mush with >50% of the grain particles in the bait matrix showing distinct separation from each other and the main pile | >50% bait pellets have mold | Bait has lost a significant amount of volume (>50%) |
| **Condition 6**  ***Bait gone*** | Bait is gone or is recognizable as only a few separated particles of grain or powder. | Bait is gone or is recognizable as only a few separated particles of grain or powder. | Bait is gone or is recognizable as only a few separated particles of grain or powder. | Bait is gone or is recognizable as only a few separated particles of grain or powder. |

# Appendix 2 Map showing drought conditions extending over California during the 2011 trial.



1. Because of their different physiology, most invertebrates are not susceptible to anticoagulants such as diphacinone and brodifacoum ([Ogilvie et al. 1997](#_ENREF_9)). [↑](#footnote-ref-1)
2. 1 From Howald *et al*. ([2004](#_ENREF_3))

   Estimated based on qualitative information provided in Howald *et al.* (2001) [↑](#footnote-ref-2)
3. Estimated based on average monthly rainfall data for Anacapa provided by the Western Regional Climate Center. [↑](#footnote-ref-3)
4. Estimated based on qualitative information provided in Mosher *et al*. ([2008](#_ENREF_8)) [↑](#footnote-ref-4)
5. Estimated based on average monthly rainfall data for Wake provided by the Western Regional Climate Center. [↑](#footnote-ref-5)