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Letter to the Editor

Habitat Modification Experiment Failed to Find Evidence for Crested Auklet Population Enhancement: A Response to Divoky

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Divoky (2018) commented negatively on our paper (Major et al. 2017) concerning our before-after control-impact (BACI) study to test whether habitat modification could be an effective means of restoring nesting habitat of crested auklets (*Aethia cristatella*) breeding on Gareloi Island, Alaska, USA. Our study arose from a possible requirement to replace crested auklets killed in the Selendang Ayu oil spill (National Oceanic and Atmospheric Administration 2015). Our criteria for assessing restoration of crested auklets were rigorous and experimental: we quantitatively measured crested auklet numbers via counts of birds visible in crevices, and calculated capture-mark-recapture estimates of numbers of individuals attending study plots and delivering chick meals. The salient conclusion of our paper was that, based on experiments at Gareloi during 2009–2013, we did not find evidence of a positive effect of vegetation modification on crested auklet numbers. Divoky (2018) states that he disagrees with this conclusion. Fortunately, our fieldwork was designed to test the hypothesis of population enhancement scientifically (Major et al. 2017) and is easily reviewable. We welcome the opportunity for constructive debate and are happy to discuss and elaborate upon specific concerns related to our methods, analyses, and conclusions.

During 2009–2013, Major et al. (2017) undertook a BACI experiment designed to test whether habitat modification (i.e., devegetation) at a large crested auklet colony could be an effective means to enhance numbers of breeding crested auklets, allowing for population recovery. Using 3 quantitative techniques, Major et al. (2017) concluded that the experimental data obtained provided no evidence that habitat modification would be an effective means of restoring crested auklets. Divoky (2018) suggests that our analyses and the data used in those analyses were inadequate and flawed, and because of this our conclusions are unjustified. We disagree and will address each of Divoky's (2018) concerns as they appear in his letter.

Divoky (2018) alleges that in our paper's title we stated the aim of the study to be the restoration of a colony at Gareloi Island. Our paper title refers laconically to habitat modification as a possible means of restoring crested auklet colonies in general, not one specific colony. The aims of our study were, as stated in the abstract and introduction, to experimentally test whether habitat modification could be an effective means of restoring nesting habitat of crested auklets (Major et al. 2017). The mixed crested and least (*A. pusilla*) auklet populations at Gareloi total approximately 2 million birds and are close to the largest in the Aleutians, with birds breeding in crevices on 2 inland blocky lava flows with encroaching vegetation, and in beach boulder habitat (perpetually renewed by wave action, ~30% of the population) completely surrounding the island (Paragi 1996, Jones and Hart 2006). The island is obviously not in need of restoration to support auklets, but it was an ideal location to perform this experiment.

Divoky (2018) continues by alleging that we failed to disclose or discuss additional data that demonstrate that vegetation modification "…might indeed be an effective method of restoration for crested auklets." Our paper (Major et al. 2017) included all the demographic data collected that could be statistically analyzed. We excluded time-lapse digital photographs showing activity *a priori* because we judged them to be unreliable (see below for further explanation).

Divoky (2018) outlines various difficulties associated with auklet monitoring that are well-reviewed in the literature; auklets' underground nesting in rock crevices and their sporadic visibility on the surface of colony sites make their populations very difficult to count or monitor (Jones 1992, Renner et al. 2006, Sheffield et al. 2006). These issues led to us using 3 demographic methods in our experiment: direct counts of visible crevices, numbers of crested auklets attending the experimental plots (estimated from capture-mark-resighting), and numbers delivering food to chicks

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(also estimated from capture-mark resighting; Major et al. 2017). We chose these demographic measures *a priori* because they directly quantified the variables of interest: actual numbers of crested auklets present and provisioning chicks on study plots. By collecting 3 robust measurements, we captured a variety of reliable information about auklet abundance and demography. We excluded assessment methods that are known from peer-reviewed published scientific research to be poor, non-quantitative, non-specific to crested auklets, confounded by the experimental treatment, or indirect and anecdotal because we judged these to be unreliable and non-scientific. The result was that we found no evidence of differentially increased auklet numbers on plots with modified vegetation, compared to control plots, hence our conclusion "we found no evidence that vegetation removal increased crested auklet numbers at Gareloi Island" (Major et al. 2017:112).

Divoky (2018) presents concerns about our capture-mark-resight (following Sheffield et al. 2006) approach to estimate number of birds using control and modified plots, claiming that our proportion of the population marked was small (based on 614 color-marked crested auklets) and not adequate to accurately estimate abundance. In hindsight, our study may have benefitted from a larger proportion of marked birds, as is the case for most ecological studies. However, our marked population gave us precise and repeatable estimates of abundance that were useful to investigate change over time. Thus, our conclusions regarding the lack of evidence for change in bird numbers due to vegetation modification are based upon quantitative estimates with confidence limits that showed no tendency for vegetation removal to be associated with subsequently increased crested auklet numbers, either on devegetated or on nearby control (unmodified) plot halves (Major et al. 2017). Although Divoky has not visited our study plots, he suggests that our observation points were inadequate and our view of the plots was poor. It is common in this type of study that the view of some birds will be obstructed, highlighting the importance for consistency, multiple observers, and multi-day data collection, all of which were employed in our study. In fact, the number of marked birds observed each year at the 4 plots was consistent, suggesting that our resighting efforts were adequate to identify most, if not all, of the birds attending the surface of the colony in our observation areas (with some variability among years, as expected).

Divoky (2018) claims our BACI design was invalidated because of his belief that a change in numbers between 2009 and 2010 was due to a large area attraction caused by vegetation modification. We think a large area attraction hypothesis is interesting, but it is not supported by our data. A temporary increase in numbers that occurred at one plot (e.g., see Plot A in figure 2 in Major et al. 2017) was consistent with natural inter-annual variability in auklet breeding (e.g., Bond et al. 2011), and could not be confirmed as being due to attraction. We also note that Divoky's claim that this increase occurred between 2009 and 2010 is based on preliminary analyses from unpublished annual reports that used less robust and unreliable methods to estimate auklet numbers.

Divoky (2018) refers to time-lapse digital photographs of surface attendance as being indicative of an increase. Unfortunately, surface counts from photographs indicate auklet activity, not numbers, vary drastically from year to year, and are notoriously unreliable as estimators of breeding populations (Jones 1992, Renner et al. 2006, Sheffield et al. 2006). Sheffield et al. (2006:846) concluded "Our results also indicate that average maximum surface counts are poor indicators of breeding auklet abundance and do not vary consistently with auklet nesting density across the breeding colony." Surface counts are expected to change if individuals in a constant local population spend more or less time on the colony surface (where they are visible), which is why they are considered to reflect auklet activity, not numbers (Jones 1992). We excluded photographic surface counts from our analysis (Major et al. 2017) because they did not meet the criterion of a reliable quantitative demographic measurement of numbers of individual crested auklets. Further, because of weather and camera field of view, we were able to get reliable crested auklet counts from very few digital photographs. Thus, not only was this source of data unreliable as a measurement of auklet numbers, the quality of data produced was inadequate for statistical analysis.

Divoky (2018) refers to our 30 additional plots added in 2010 as showing evidence of increases related to vegetation modification. As stated by Major et al. (2017), we added 30 additional plots in 2010 that were delineated in areas of medium and low auklet density. These plots had no marked individuals and data (surface counts from digital photographs of birds) reflected activity not numbers or density of individuals. Further, vegetation and peat removed from these 30 additional plots was inadvertently deposited directly on adjacent parts of the colony site abutting on the new plots, blocking access to crevices (Fig. 1). We expected this to lead to birds that had lost access to their breeding sites standing around nearby on the surface, making it impossible to ascribe photographed activity changes to removal or deposition of vegetation and peat. Gall (2004) reported higher crested auklet surface counts on experimental plots covered with tarps (blocking access of birds to nest sites) compared to control plots in 2002. On average, only 45% of the area of the new plots was rocky and most of the areas devegetated in 2010 were dirt with no possibility for auklet nesting (Fig. 2). This contrasts with the 4 plots from 2009 (ABCD) that were nearly 100% suitable auklet breeding habitat. For these reasons, we do not believe the 30 additional plots referred to by Divoky produced useful information related to the effect of vegetation modification on crested auklet numbers or activity. Therefore, we used these data only in our analysis of active nests (i.e., counts of crevices with an adult, egg, or chick), identified through physical searches of the plots.

Next, Divoky (2018) questions our approach of counting visible crested auklet nests, stating "The utility of these counts as an indicator of abundance. . . is unclear." Counts of crested auklets in nest crevices during incubation were in fact our most direct measure of numbers, these birds were

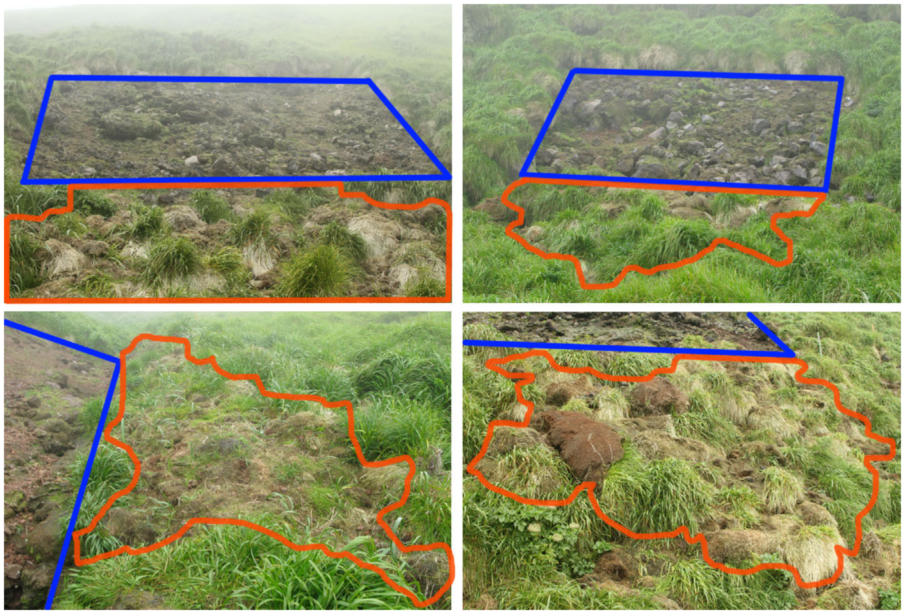

Figure 1. Crested auklet breeding habitat covered (bottom of image) by vegetation removed from adjacent new plots (devegetated during Aug 2010, date of photograph 26 July 2011, plot boundaries indicated by blue lines, adjacent dumped vegetation and peat outlined in orange) at Gareloi Island, Alaska, USA (ILJ).

confirmed breeders (i.e., in a nesting crevice with an egg or a chick), and we *a priori* selected the southeast inland colony at Gareloi because of the ease of direct observation of large numbers of crested auklet crevices (Jones and Hart 2006). In contrast, many other auklet colony sites have predatory Arctic foxes ([*Vulpes lagopus*] St. Lawrence Island; Sheffield et al. 2006), deep talus-lava caverns (Buldir: Byrd et al. 1983, Fraser et al. 1999; Kiska Island: Bond et al. 2013) and dense vegetation overgrowth (Semisopochnoi: Jones and Marais 2004, Segula: Renner et al. 2006), making adult auklets difficult to observe in large numbers. We performed extensive searches and counted many nests both before and after devegetation but were unable to detect any increase in crested auklet nests related to removal of vegetation.

Figure 2. Lack of crested auklet breeding habitat revealed on 2 new plots (devegetated during Aug 2010, date of photograph 26 July 2011) at Gareloi Island, Alaska, USA (ILJ).

Divoky (2018) goes on to suggest that instead of nest counts, counts of auklet feathers and feces are a preferred method of assessing auklet numbers at colony sites. Feces and feathers have been used in single-year auklet colony mapping studies (Jones 1988, Jones and Marais 2004, Jones and Hart 2006, Renner et al. 2006) as indicators to roughly compare auklet density across colony sites but were not applicable to our multi-year question for numerous reasons: 1) neither are identifiable to species, and we were interested in crested auklets only (in a mixed crested and least auklet colony); 2) both are subject to rapid weathering and modification by wind and rain immediately prior to examination (Fig. 3; Jones and Hart 2006), making them only useful for comparisons within a short period of time (e.g., 1 day; Jones 1988) and not for inter-year comparisons; 3) both are difficult to assign to local breeders (feces from birds flying over falls like rain in auklet colonies); 4) counts of feces are highly affected by substrate type (Fig. 4; Jones and Hart 2006), being much more detectable on bare rock compared to well vegetated sites (a confound with our experimental treatment); 5) feces are uncountable in many situations (Fig. 5; Jones and Hart 2006); and 6) although their deposition might correlate with activity, no quantitative relationships of these indirect observations to actual numbers of crested auklets are known. For these reasons, we *a priori* eliminated feces and feather counts from use in our study because we considered them unreliable.

Figure 3. Before-after photographs showing dissolution of least auklet droppings by an evening of light rain (17–18 Jun 2006), on 2 beach boulders (left = before, right = after) at Gareloi Island, Aleutian Islands, Alaska, USA (ILJ).

Divoky (2018) points to our capture-mark-resight data showing movement to devegetated plots as evidence of a positive population effect of the vegetation removal. We carefully measured movement by observation of crested auklets marked in 2009 to address the concern that changes in numbers of birds on devegetated plots, if it related only to short distance movement of local birds, would not be evidence of restoration. The aim of a restoration of crested auklets would be to attract new non-breeding birds to sites with new breeding opportunities, creating additional crested auklets to replace those killed in the Selendang Ayu oil spill. No evidence of an increase in breeders resulted from our BACI experiment. Nevertheless, observed movement of marked birds to devegetated plots was interesting; it showed that exchanges in numbers at plots could result from short-

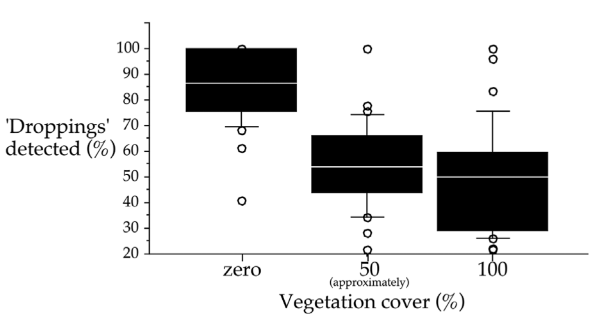

Figure 4. Box plot showing detectability of artificial auklet droppings placed experimentally onto substrates with 3 vegetation classes at Gareloi Island, Aleutian Islands, Alaska, USA (showing proportions of known numbers of droppings placed).

Figure 5. Typical pattern of mixed uncountable crested and least auklet droppings at the southeastern colony (date of photograph 13 Jun 2006) at Gareloi Island, Alaska, USA (ILJ).

distance movement rather than long-distance attraction. It was also consistent with birds preferring to sit on exposed rocks than in the dense, wet vegetation of the control plots, without necessarily having moved to new breeding sites. The movement data is thus ambiguous as evidence for a benefit of vegetation modification. However, as Major et al. (2017) mention in the discussion, our experiment was short-term, covering just 5 years. Over the long term, these movement patterns may result in attraction to devegetated sites, an interesting avenue for further research.

In summary, Divoky (2018) claims that our conclusion of no evidence of a population increase is unsubstantiated but fails to point to any clear evidence that indicates an increase in crested auklet numbers related to experimental vegetation modification. Divoky (2018) repeatedly refers to a large area attraction, for which there was no conclusive evidence. Some of Divoky's (2018) criticisms are consistent with the notion that auklet numbers are very difficult to measure, leading to their population changes being very difficult to quantify. We agree with him on this point and specifically designed our study to incorporate 3 robust quantitative methods to estimate auklet numbers and based our conclusions on the combined results.

Vegetation overgrowth on lava flows has only once been quantitatively reported to displace auklet populations; a study at Sirius Point, Kiska in which 11 study plots with dense auklet nesting delineated in 1986 (Deines and McClellan 1986, 1987) were revisited in 2001 and found to be empty of auklets and accessible crevices, and completely overgrown with grasses (*Calamagrostis*, *Poa*, and *Carex* spp.) and ferns (Jones et al. 2001). Further, a study by Drew et al. (2018) reported that newly created auklet habitat was colonized largely by least auklets, even though a nearby colony destroyed during a volcanic eruption, was largely crested auklets. That plant succession displaces auklets at some sites is recognized (Renner et al. 2017). However, whether this process is reversible by management activity is at present unknown (Major et al. 2017) and may be site-dependent and related to the underlying structure of lava and rock crevices. At Gareloi, we posit that birds were able to travel long distances under the vegetation (within the lava rock matrix) to access nesting crevices.

Divoky (2018) points to acoustic monitoring combined with time-lapse imagery as an "extremely useful tool" for crested auklet restoration efforts. Unfortunately, acoustic monitoring has not been tested on auklets (*Aethia* spp.) and like surface counts (i.e., from time-lapse photography) is an indirect measurement of activity with questionable relationships to individual birds and actual populations. Sheffield et al. (2006) determined that counts of auklets on the surface (outside of a capture-mark-resight study design) were poor indicators of breeding abundance that do not vary consistently with auklet nesting density. Such indirect measures of auklet activity rather than population size were long ago debunked as useful, defendable population monitoring tools (Jones 1992, Sheffield et al. 2006).

Finally, Divoky (2018) refers to an alternative proposal by Island Conservation to restore crested auklets killed in the Selendang Ayu oil spill by eradicating Norway rats (*Rattus norvegicus*) from Kiska Island (an island located farther west of Gareloi in the Aleutian chain). He states that because there are no reliable estimates of the population size of crested auklets on Kiska, the quantification of effects is precluded. Rats introduced to Kiska Island during World War II infest a major auklet colony, depredating crested auklet eggs, chicks, and nestlings (Bond et al. 2013) and have nearly extirpated burrow-nesting seabirds from the island (Buxton et al. 2013). This anthropogenic source of direct mortality on auklets on an island with no native terrestrial mammals would be eliminated by rat eradication (Eggleston and Jones 2006, Major et al. 2006) and is quantifiable by field measurements and demographic modeling (Major et al. 2013). Successful rat eradications and other management activities have restored numerous seabird populations without pre-existing precise population estimates (Jones and Kress 2012).

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LITERATURE CITED

Bond, A. L., I. L. Jones, W. J. Sydeman, H. L. Major, S. Minobe, J. C. Williams, and G. V. Byrd. 2011. Reproductive success of planktivorous seabirds in the North Pacific is related to ocean climate on decadal scales. Marine Ecology Progress Series 424:205–218.

Bond, A. L., I. L. Jones, J. C. Williams, and G. V. Byrd. 2013. Survival and reproductive success of crested auklets (*Aethia cristatella*) in the presence of introduced Norway rats (*Rattus norvegicus*). Marine Ornithology 41: 41–48.

Buxton, R., H. L. Major, I. L. Jones, and J. C. Williams. 2013. Examining patterns in nocturnal seabird activity and recovery across the western Aleutian Islands, Alaska, using automated acoustic recording. Auk 130:331–341.

Byrd, G. V., R. H. Day, and E. P. Knudtson. 1983. Patterns of colony attendance and censusing of auklets at Buldir, Island, Alaska. Condor 85:274–280.

Deines, F. G., and G. T. McClellan. 1986. Introduced Arctic Fox Compound 1080 baiting and wildlife surveys, Kiska Island, Aleutian Islands, Alaska, 24 March – 4 April 1986. Alaska Maritime National Wildlife Refuge, Homer, USA.

Deines, F. G., and G. T. McClellan. 1987. Second survey and monitoring of birds and mammals of Kiska Island, June 1986. Alaska Maritime National Wildlife Refuge, Homer, USA.

Divoky, G. J. 2018. Nesting habitat creation to restore crested auklet: a comment on Major et al. (2017). Journal of Wildlife Management 82:in press.

Drew, G., J. F. Piatt, and J. Williams. 2018. Biological responses of crested and least auklets to volcanic destruction of nesting habitat in the Aleutian Islands, Alaska. Auk 135:477–485.

Eggleston, C. J., and I. L. Jones. 2006. On the feasibility of eradicating Norway rats (*Rattus norvegicus*) from Kiska Island, Alaska. Pacific Seabird Group, Girdwood, Alaska, USA.

Fraser, G., I. L. Jones, J. C. Williams, F. M. Hunter, L. Scharf, and G. V. Byrd. 1999. Breeding biology of crested auklets at Buldir and Kasatochi Islands, Alaska. Auk 116:690–701.

Gall, A. 2004. Planktivorous auklets (*Aethia pusilla* and *A. cristatella*) nesting on St. Lawrence Island, Alaska as indicators of marine conditions in the Northern Bering Sea. Thesis, Oregon State University, Corvallis, USA.

Jones, H., and S. Kress. 2012. A review of the world's active seabird restoration projects. Journal of Wildlife Management 76:2–9.

Jones, I. L. 1988. A survey of the auklet colony at Village Cove Beach, St. Paul Island, Alaska in 1988. Alaska Maritime National Wildlife Refuge, Homer, USA. http://www.mun.ca/serg/VCBsurvey1988.pdf

Jones, I. L. 1992. Colony attendance of least auklets (*Aethia pusilla*) at St. Paul Island, Alaska: implications for population monitoring. Condor 94:93–100.

Jones, I. L., C. M. Gray, J. Dusureault, and A. L. Sowls. 2001. Auklet demography and Norway rat distribution and abundance at Sirius Point, Kiska Island, Aleutian Islands, Alaska in 2001. Alaska Maritime National Wildlife Refuge, USFWS, Homer, USA. http://www.mun.ca/serg/finalKiskaREP.pdf

Jones, I. L., and K. A. Hart. 2006. A survey of inland least and crested auklet breeding colonies at Gareloi Island in the Delarof Islands, Aleutian Islands, Alaska during 2006. Alaska Maritime National Wildlife Refuge, USFWS, Homer, USA. http://www.mun.ca/serg/Gareloi_REPORT.pdf

Jones, I. L., and J. Marais. 2004. Survey of the least and crested auklet colony near Sugarloaf Head, Semisopochnoi Island, Alaska, during 2004. Pacific Seabird Group, Girdwood, Alaska, USA. http://www.mun.ca/serg/SemiSURVEYreport.pdf

Major, H. L., A. L. Bond, I. L. Jones, and C. J. Eggleston. 2013. Stability of a seabird population in the presence of an introduced predator. Avian Conservation and Ecology 8:2.

Major, H., R. T. Buxton, C. Schacter, M. Conners, and I. L. Jones. 2017. Habitat modification as a means of restoring *Aethia* auklet colonies. Journal of Wildlife Management 81:112–121.

Major, H. L., I. L. Jones, G. V. Byrd, and J. C. Williams. 2006. Assessing the effects of Norway rats (*Rattus norvegicus*) on survival and productivity of least auklets (*Aethia pusilla*) at Kiska Island, Alaska. Auk 123:681–694.

National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, Alaska Department of Law, Alaska Department of Natural Resources, Alaska Department of Environmental Conservation, and Alaska Department of Fish and Game. 2015. Natural resource damage assessment plan for the M/V Selendang Ayu oil spill. Final Report, Industrial Economics. https://www.fws.gov/alaska/fisheries/contaminants/spill/pdf/selendang_Ayu/1_1_XXX_SelendangAyuNRDAR_draftAssessmentPlan102115_Report.pdf

Paragi, T. F. 1996. Index counts of least and crested auklets on Gareloi Island, Alaska. U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge Report 96- 09, Homer Alaska, USA.

Renner, H. M., M. Renner, J. H. Reynolds, A. M. A. Harding, I. L. Jones, D. B. Irons, and G. V. Byrd. 2006. Colony mapping: a new technique for monitoring crevice-nesting seabirds. Condor 108:423–434.

Renner, H. M., L. R. Walker, C. F. Waythomas, J. C. Williams, and Y. B. Artukhin. 2017. Crevice-nesting auklets are early-successional species requiring disturbance to persist. Arctic Antarctic and Alpine Research 49:585–599.

Sheffield, L. M., A. E. Gall, D. D. Roby, D. B. Irons, and K. M. Dugger. 2006. Monitoring planktivorous seabird populations: validating surface counts of crevice-nesting auklets using mark-resight techniques. Canadian Journal of Zoology-Revue Canadienne De Zoologie 84:846–854.