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Photographing Bioluminescence, Ethics, and Lessons from a Misguided Ethnographer

Josephine N. Gruber
Regis University

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PHOTOGRAPHING BIOLUMINESCENCE, ETHICS, AND LESSONS FROM A MISGUIDED ETHNOGRAPHER

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By
Josephine N. Gruber

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Thesis written by
Josephine N. Gruber

Approved By

Thesis Advisor

Thesis Advisor

Thesis Reader

Accepted By

Director, University Honors Program

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Most importantly, I would like to dedicate this thesis to my family who have supported me through my college journey and have been my sounding board for every page written hereafter.

Preface

Like most people, I had never heard of Edward S. Curtis when I began an art history class about the history of photography. I had never heard of his prolific work: *The North American Indian* or the dynamic portraits it included. Four months and hundreds of pages of research later, I realized that was a lie. I *did* know who Edward Curtis and was; and, in fact, I was very familiar with his work. I had done a project in the third grade on the Kwakiutl people of northwestern America. My mom and I cut out the people from a Curtis photograph as part of a diorama, tirelessly making small Play-Doh foods one may find at a Kwakiutl winter potlatch meal. I had completely dedicated myself to that project, constructing mock homes and clothing and even providing my classmates with colorable masks to replicate those often worn at potlatches. Large portions of this effort were based on passages from *The North American Indian* that I had read while researching the Kwakiutl. It seems like fate now that Curtis would find a place in my thesis.

At the same time I was studying Curtis in art history, I was also compiling and creating figures for a biology research publication I had begun as a Freshman. I immediately fell in love with the visual nature of morphological biology and subsequently became fascinated with evolutionary biology by way of this research. My lab notebook quickly filled with anatomical measurements and observations of specimens as I prepared to remove tissue samples for closer analysis. It became an inside joke among my friends that I could always be found in the lab while working on a tissue sample preparation and staining protocol. When complete, I had the opportunity to use my experience with graphic design and photography to create attractive figures by photographing the slides I had prepared. I worked to create the perfect figure for the publication, tirelessly tweaking the colors and contrast until what I saw through the microscope matched what I saw on my computer screen.

In that moment, I could see the ghost of Curtis meticulously arranging the scene of a photograph, removing and replacing items to recreate a vision he wanted to capture on those beautiful glass-plate negatives. To him, it would have seemed like we were the same. Scientists. Photographers. Trying to show the world what we see. He would not have seen the longstanding ramifications that *his* edits would make. He did not see that removing an alarm clock in one photo and giving his subjects the same feather headdress time and again was actually constructing an image to suit his own preconceived ideas - one that would follow millions of Native Americans through to the present. He did not know that his views followed a Social Darwinist agenda that would prompt society then, as now, to use his work to falsely justify exploitation and injurious treatment of Native Americans. Despite the efforts of scientists today to debunk the pseudoscience of Social Darwinism, evidence of its subliminal influence is not difficult to find in modern politics and popular culture. To someone Like Curtis, who was steeped in the prevailing assumptions of Social Darwinism, it would have seemed the expected result of evolutionary processes that native cultures faced obsolescence and decline in the face of white, colonial conquest. As deplorable as this conclusion seems to most people now, almost everyone around Curtis saw Native Americans simply as living fossils of a bygone American era that must pass into history, as all organisms must when individuals with genes better suited to the environment are present. Removing a small alarm clock, by that logic, was a small-scale choice just as serious to Curtis as decreasing color saturation was a small-scale choice for me. He did not see that such a choice was perpetuating the notion that Native American culture was stuck in the past and its extinction, therefore, was imminent. Curtis himself wrote in the figure description for *The Vanishing Race*, the very first photograph in Folio I of *The North American Indian* that, "The Indians, as a race...are passing into the darkness of an unknown future," and goes on to say that this sentiment was the primary motivator for the entirety of his work (Curtis, 1907).

I hope the reader will, at times, have as much difficulty reading the words of Curtis as I did in writing them. Regrettably, this idea about 'the Vanishing Race', as he put it, was pervasive the world over at the time he was working. It is hard to see how people once believed this, not on a spiritual level, but on a scientific one. For them, Social Darwinism was scientific fact and Curtis was only one of its many practitioners. Curtis viewed himself as an ethnographer, diligently documenting cultures before they became extinct, as he honestly believed would be the case. To Curtis, his photographs served the same purpose as mine: to provide evidence of findings within a scientific publication. That led me to wonder 'how does science *today* prevent edited photographs from misrepresenting the present -- photographs that may have negative impacts in the future?' It is very unlikely that the small changes that I made to my photographs will have any significant scientific or social impact, but it is difficult to say if this is true of all photographic figures used in modern scientific literature. Data manipulation aside, the *way* in which real data are portrayed have very real implications for their interpretation. Yet, very few scientific journals have ethical guidelines regulations that are actively monitored by the publication with regard to photographic manipulation and representational efficacy. Despite the dramatic ramifications of manipulated photography in the work of Edward Curtis, I fear the warning his work represents is unknown to many and unconsidered by almost everyone in the scientific community. True, the stakes are higher for someone like Curtis who manipulates photographs that are supposed to document whole cultures. However, the lines between what manipulations are acceptable for photographs used for scientific purposes remain unclear. In this thesis, I hope to explore the role of the photograph in science, as well as the implicit and explicit biases associated with each use. Analysis of the various forms of manipulation present in Edward Curtis' photographs will serve to illustrate what ramifications implicit and explicit bias can have on both scientific photography and the way in which science is disseminated through photographs. This historical example highlights existing ambiguity within the scientific community regarding the use of the photograph and the pitfalls such ambiguity may generate.

Photograph of the author’s third grade diorama, featuring Curtis photographs of people at a Kwakiutl potlatch (ca. 2006)

Introduction

The photograph and science have been intimately related since the first microscope photograph was taken a mere 26 years after the photographic process itself was invented in 1839 (Castracane, 1865; Rosenblum, 2008). By 1865, Jesuit botanist Francesco Castracane degli Antelminelli had already seen the significance of the photograph, not only in his microscopy work, but across all scientific disciplines. He wrote the first published paper touting the importance of the photograph in capturing microscope views, calling the images “scientific illuminations,” capable of accurately showing his audience what he observed without the need to draw or paint (Castracane, 1865). Starting with Castracane and continuing to the present, the photograph is arguably one of the most important innovations in scientific documentation and dissemination. For example, my research on bioluminescent organs in deep sea fish requires photographs to be taken of prepared slides of tissue samples in order to fully and accurately describe the structure and position of light organs relative to other structures in the body. Not only are these photographs key to documenting my findings, they are invaluable tools for disseminating these findings to readers. A successful photograph, in this context, explains to a viewer all he or she needs to know about the associated research conclusions without the need of accompanying text. Modern journals, especially those in morphological biology, require photographs for their unparalleled ability succinctly and accurately to reflect research findings. The photograph is also a powerful tool within the scientific process, where it can aid data collection, calculation, and dissemination. Photographs used in methodology or kept for the researcher's own purposes are not edited in the same way as photographs used for documentation and dissemination, however.Their aesthetic qualities are not as important as the content of the photographs themselves. In my own research, methodological photography is the best way to determine volumes of various prey items consumed by bioluminescent fish. By photographing stomach contents and measuring each prey item using computer software to make digital measurements, I can more accurately determine prey volumes than would be feasible by using implements like a ruler. Photographs such as these are part of the raw data collection process and would not be suitable for presenting to a wider audience, however, and the sheer number of photographs make it difficult or impossible to include them even in supplemental information. Like data collected by any other method within science, the honesty, accuracy, and precision of the researcher are the only determinants of whether a photograph is used appropriately. Readers will never see these photographs unless they request them from the author and cannot decide for themselves if they agree with the author's conclusions. In these instances, the photograph is a tool first and foremost whose aesthetics are inconsequential to the research process of which it is a part.

Before the photographic process could reliably be used by scientists *en mass*, many depended on drawings and paintings to depict their findings instead. Although not strictly a prerequisite of scientific inquiry, an artistic eye and skilled hand always helped in creating illustrations of new species or documenting anatomy. One of the greatest known examples of such art-science is *The Birds of America* by the painter and ornithologist John James Audubon (Fessenden, 2013). Each hand-engraved plate shows incredible artistry and an accuracy that would only be possible after years of studying birds themselves (Cummings, 2015; Fessenden, 2013). Moved by Audubon's work, the prominent natural historian George Bird Grinnell created the Audubon society, believing Audubon's scientific artistry was inspiring enough to inspire the public to protect birds across the United States (Barrows, 1998). Today, science and art are largely considered separate domains. However, science has long relied on art not only as a medium to convey certain findings, but also for the depiction of the intrinsic beauty of nature that otherwise may be hard for the general public to experience.

By the 20th century, the photograph was being used more readily in science, gradually replacing hand-drawn and painted figures in certain disciplines. At the same time, artists were pushing the photograph beyond what they saw to be the 'limitations of science' and were making efforts to use the photograph as an artistic medium (Rosenblum, 2008). From this struggle to define the photograph's uses emerged the successful photographer and amateur ethnographer Edward Sheriff Curtis, who believed the photograph was perfectly suited to roles in both science *and* art. To him, the photograph was "one of the great art sciences" and could be used to document scientific findings in a way that was visually appealing and artistic (Egan, 2006). He taught himself photography and learned ethnography in the field under the tutelage of George Bird Grinnell, the same man who popularized the work of Audubon, and the rest of Grinnell's research team. It only took one expedition with Grinnell to instill in Curtis a love of exploring Native American culture and documenting it through photographs. Curtis applied the skills he developed - skills that earned him national renown as one of the best portrait photographers in the U.S. - to the photographs needed by the expedition to document what they learned about Native American culture and peoples. The expedition heralded Curtis's work as unbiased and pure scientific documentation. Not only that, his work was technically impeccable and visually stunning. His work quickly rose to national attention after he began working on *The North American Indian* - a voluminous compendium of photographs from nearly every Native American culture in the United States and Canada. In its day, it was a highly respected scientific publication with a backbone of photographic evidence supporting every chapter. Beyond the scientific community, the artistry of those same photographs captivated audiences and disseminated Curtis's work to broader audiences than any set of scientific photographs that came before it.

Whatever role the photograph has taken on from its invention to its present uses, it cannot be denied that it is ingrained within both the scientific community and popular culture. For this reason, it is critical that photographs be used ethically, no matter what their function may be. There remains substantial ambiguity about what photographic modifications are acceptable when an image claims to document scientific discovery, especially if it acts to disseminate such discoveries to a wider audience. Photographs used in scientific methodology require yet more ethical considerations because they are not subject to the review of the audience and are only shared beyond the researchers if requested. Edward S. Curtis provides a compelling case study worthy of consideration by those scientists using photographic evidence in their research and to engaged readers of scientific literature who are affected by misuses of photography. In this thesis, I will explore the ethical uses of photography in the scientific community by looking at the photographs used in my own research, the photographic and scientific ethical lines that were crossed by Curtis, and what we can do now to ensure we do not become the Edward Curtis's of our time.

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I. Morphology of the bioluminescent organ in glowbellies (Teleostei: Acropomatidae) in phylogenetic context

Introduction

In ray-finned fishes, bioluminescence has evolved independently at least 27 times (Davis, Holcroft, Wiley, Sparks, & Smith, 2014; Davis, Sparks, & Smith, 2016; Haddock, Moline, & Case, 2010). The most likely purpose of ventral bioluminescence in mesopelagic fish is counterillumination. Counterillumination decreases a fish's ability to be perceived by predators below against a background of downwelling light, a survival benefit that is positively selected for evolutionarily (Herring, 2002; Johnsen, Widder, & Mobley, 2004; Young, Kampa, Maynard, Mencher, & Roper, 1980). The frequency with which bioluminescence has evolved in mesopelagic species is indicative of its importance as a mechanism for predator avoidance (Davis et al., 2014, 2016; Haddock et al., 2010). While many species produce light ventrally, the exact structure utilized by species in a particular taxonomic group often varies. In order to determine the likely evolutionary origin of the luminescent organ, it is necessary to examine the structure in detail and compare the species studied with non-bioluminescent relatives.

Bioluminescence can be achieved via intrinsic enzymatic reactions or bacterial symbiosis. In the case of the former, light producing reactions take place within the organism's tissue by the reaction of the luciferin-luciferase complex. In teleosts, this has occurred in muscle, integumentary, and hepatopancreatic tissues (Ghedotti, Barton, Simons, & Davis, 2015; Johnston & Herring, 1985; Wassersug & Johnson, 1976). More commonly, a symbiotic relationship with luminescent bacteria is utilized (Davis et al., 2016). In such cases, the fish houses the bacteria in a specialized organ or tissue that is connected to the external environment. As such, these structures are typically ectodermal or endodermal in developmental origin (Chakrabarty et al., 2011; Johnson & Rosenblatt, 1988; Thacker & Roje, 2009). The light organ, because of its external connection, is often associated with the digestive tract (Thacker & Roje, 2009).

Glowbellies (Percomorpha: Acropomatidae) posses ventral light organs that bioluminesce by means of bacterial symbiosis. Previous work done by Haneda (1950) generally described external characteristics, while Matsubara (1953) expanded on external morphometrics. Gross dissection revealed the light organ as a compartmentalized, tubular structure with left and right arms connected by a medial lumen. The organ was described as being connected posteriorly to the anus and being embedded in ventral musculature (Haneda, 1950). Little histological confirmation of these claims exists. The two best known glowbelly species, *Acropoma hanedai* and *A. japonicum*, differ in light organ structure. Haneda (1950), as well as Matsubara (1953), distinguished *A. japonicum* as having fewer, dark chromatophores near the anus and a shorter light organ compared to *A. hanedai*. Thacker & Roje (2009) described the light organ of an unidentified *Acropoma* species as having a folded epithelium, rather than being a tubular structure. Beyond these more general characterizations of *Acropoma* light organs, often based only on visual observation and gross dissection, the light organ remains poorly described and understood (Fourmanoir, 1988; Okamoto, 2014; Okamoto & Golani, 2018; Yamanoue & Matsuura, 2002).

In order to more fully understand the evolution of the light organs in *Acropoma*, the phylogenetic relationships between *Acropoma* and other, related species must be more clearly understood. Previous use of genetic data for generation of phylogenies for teleosts have provided a better understanding of large-scale relationships, although much is left unknown about the specific relationships between genera and species within these analyses (Betancur-R et al., 2013; Davis et al., 2016; Near et al., 2015; Sanciangco, Carpenter, & Betancur-R, 2016; Smith & Craig, 2007; Smith & Wheeler, 2006; Thacker et al. 2015; Tsunashima et al., 2016). It is necessary to more closely examine the phylogenetic relationships within the order Acropomatiformes in order to draw conclusions about the possible evolutionary patterns of light organs within the order (Davis et al., 2016; Jordan & Richardson, 1910; Katayama, 1959; Near et al. 2013, 2015; Sanciangco et al., 2016; Schultz, 1940; Thacker et al., 2015).

The purpose of this research is to explore the histology of the light organ in *Acropoma hanedai* and *A. japonicum* in order to more fully understand the evolution of bioluminescence in glowbellies. We hypothesize that the light organ in *Acropom*a represents an independent evolution, based on the anatomical structure of the light organ and genetic sequencing-based phylogeny of Acropomatiformes and allies.

Methods

I performed histological sample preparation, following procedures outlined by Humason (1979), on museum specimens. Fish market specimens were fixed in formalin, preserved in ethanol, and cataloged at the James Ford Bell Museum of Natural History(JFBM). No living animals were used in this study, no animals were euthanized for the purpose of this study, and the procedure of the study complied with all laws and regulations of the United States. Samples from larger individuals were approximately 0.5-1.0cm^3 in size and taken ventrally from the body wall and about 2 cm anterior to the anus, around the anus, and 2 cm posterior to the anus. I used one specimen of *Acropoma japonicum* (JFBM 48680) with 127mm standard length (SL) and one specimen of *A. hanedai* (JFBM 48733) with 120mm SL. I sectioned and stained two whole specimens in three segments, one specimen of *A. japonicum* (JFBM 48680; 43mm SL) and one specimen of *A. hanedai* (JFBM 48733; 51mm SL).

I performed all sample processing at Regis University in Denver, CO. Samples were decalcified in 20% formic acid and 1.9% formaldehyde over a period of 5 days for samples taken from large individuals, while the thirds of whole specimens decalcified over a period of 14 days. Samples underwent an ethanol dehydration series, ranging from 85% to 100% ethanol and were cleared in xylene. After being embedded in paraffin, I sectioned samples with a rotary microtome to a thickness of 10 µm. After heat fixing samples to glass slides, I performed a Masson's Trichrome (MT) staining protocol, specifically to color collagen within samples blue (Sheehan & Hrapchak, 1980). I photographed prepared slides through a Leica DM2500 microscope using a QImaging MicroPublisher 5.0 RTV attached camera.

Histological analysis was corroborated through gross dissection of museum catalogued specimens fixed in formalin and stored in ethanol from the Field Museum of Natural History (FMNH) and the John Ford Bell Museum of Natural History(JFBM). Coelomic gross examination began with a ventral parasagittal cut from anterior the anus to the isthmus, then angled dorsolaterally to the pelvic girdle (Ghedotti, Gruber, Barton, Davis, & Smith, 2018). The right bioluminescent organ was embedded in the musculature of the body wall and was located by separating the skin and subsequent musculature with fine forceps. These specimens included *Acropoma hanedai* [FMNH 120390(3), JFBM 48681 (10), JFBM 48733 (9), JFBM 48743 (4)], *Acropoma japonicum* [FMNH 120943 (2), JFBM 48680 (6), JFBM 49707 (8)], and *Doederleinia berycoides* [FMNH 57378 (1), FMNH 120946 (2)], where the number of individuals examined in each group are indicated by parentheses.Gross dissection of other related acropomatiform specimens involved coelomic dissection by a simple incision of the ventral body wall to reveal the presence of any possible, previously unidentified, light organs. These specimens included *Epigonus occidentalis* [FMNH 67460 (4)], "*Epigonus*" *pandionis* [FMNH 67481 (2), FMNH 12174 (2)], *Howella simplex* [JFBM 48686 (2)], *Lateolabrax japonicus* [FMNH 55546 (2)], *Malakichthys griseus* [FMNH 120948 (3)], *Malakichthys wakiyae* [JFBM

48682], *Neoscobrops pseudomicrolepis* [FMNH 65090 (2)], *Parapriacanthus ransonettii* [FMNH 119258 (4)], *Pempheris schomburgki* [FMNH 93774 (3)], *Parascombrops phillipinensis* [JFBM 48684 (3)], *Synagrops bellus* [FMNH 65100 (2)], and *Synagrops japonicus* [JFBM 48705 (4)].

Results

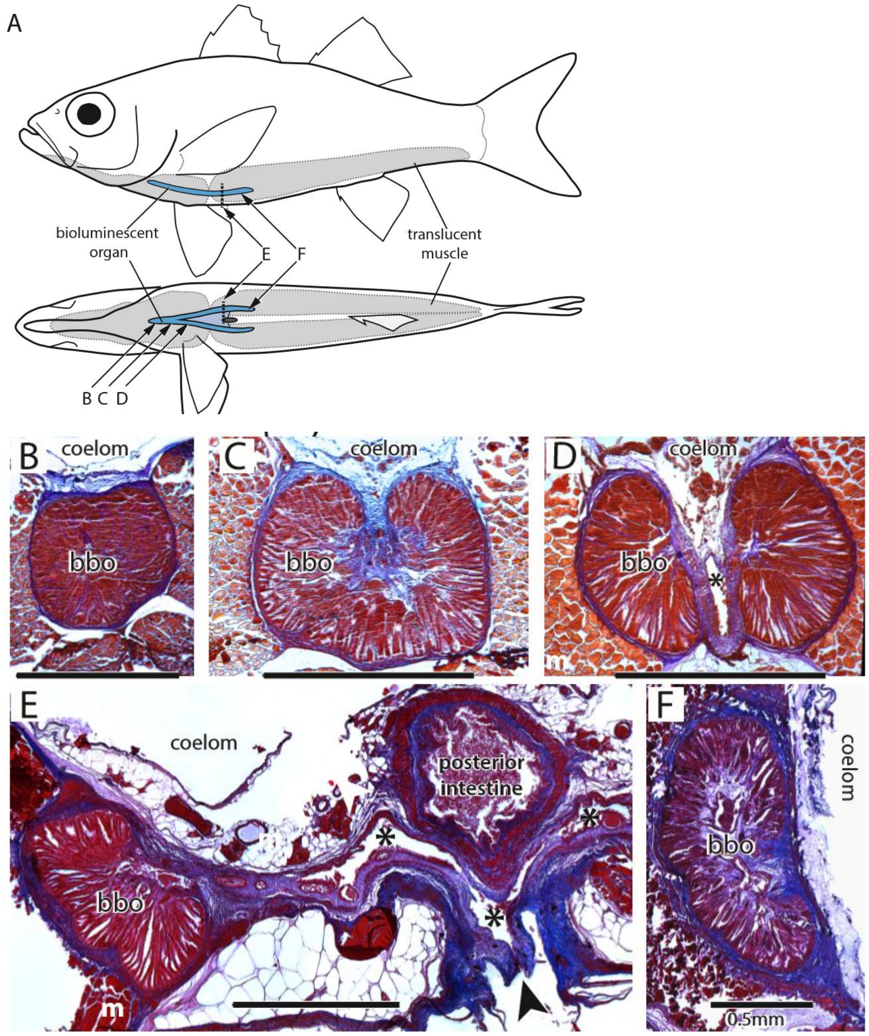

Figure 1. The ventral bioluminescent organ in *Acropoma japonicum* (JFBM 48680, 43mm SL with MT staining). All scale bars are 1 mm unless otherwise indicated. (a) Diagrammatic illustration of the bioluminescent organ in *A. japonicum*. Left lateral view top. Ventral view bottom. **Gray shading** indicates transparent muscle. Letters indicate location of sections depicted in b–f. (b–d) Cross sections of anterior bacterial bioluminescent organ. Asterisk (*****) indicates lumen connecting left and right component of bioluminescent organ; **bbo**=bacterial bioluminescent organ. (e) Cross-section of left lateral bioluminescent arm of the bioluminescent organ with connecting lumen immediately anterior to the anus. Note the connection of the lumen with the external opening. **Arrow head** = external opening of pouch surrounding anus; **m**=skeletal muscle. (f) Cross-section of left lateral ventral bioluminescent organ posterior to the anus. Note the absence of an associated lumen. Figure adapted from Ghedotti et al. (2018; fig. 2).

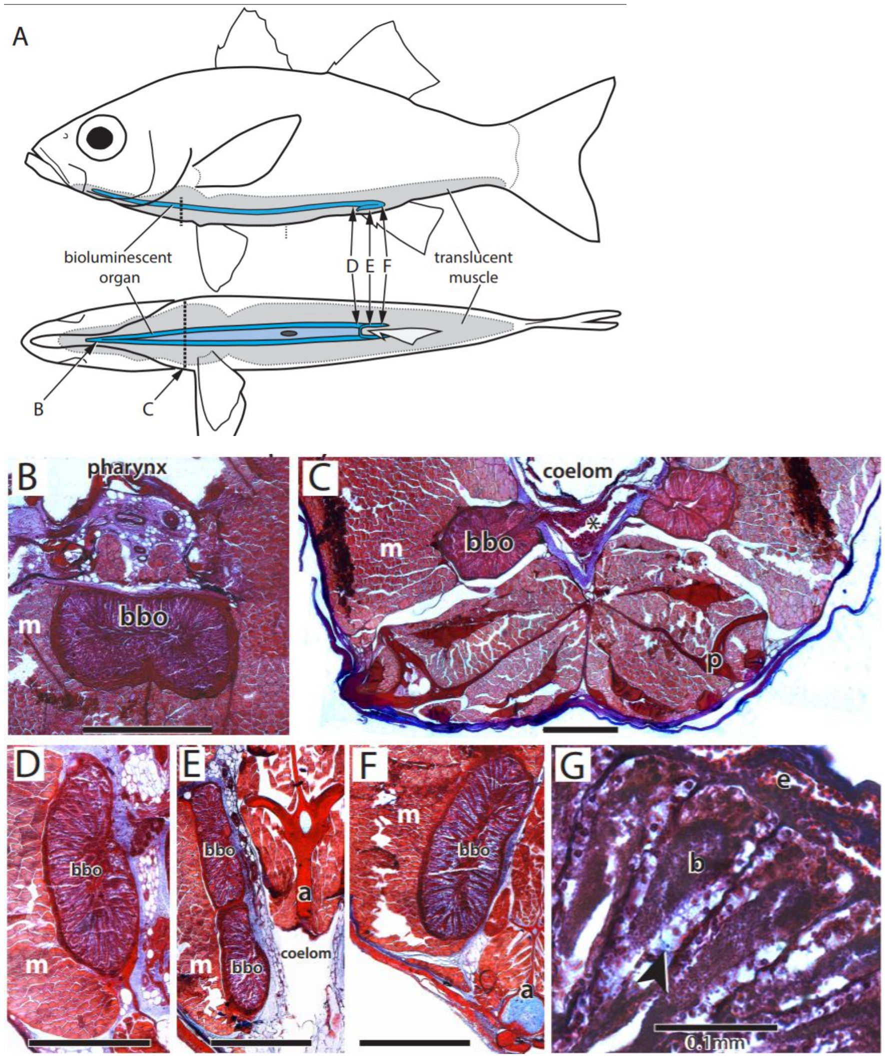

Figure 2. The ventral bioluminescent organ in *Acropoma hanedai* (JFBM 48733, 51 mm SL, MT staining). All scale bars are 1 mm unless otherwise indicated. (a) Diagrammatic illustration of the bioluminescent organ in A. hanedai. Left lateral view top. Ventral view bottom. **Gray shading** indicates transparent muscle. Letters indicate location of sections depicted in b–f. (b) Cross-section of anterior bacterial bioluminescent organ. **bbo** = bacterial bioluminescent organ; **m** = skeletal muscle. (c) Cross-section of ventral body wall immediately anterior to pelvic and pectoral fin origins showing connecting lumen of left and right arms of the light organ. Asterisk (*****) = lumen connecting left and right arms of bioluminescent organ; **p** = bone of pelvic girdle. (d–f) Cross-sections of left lateral ventral bioluminescent organ in region of anterior anal fin. **A** = proximal anal-fin radial. (g) Cross-section of bacterial bioluminescent organ in C showing close-up of lobules. **Arrow head** = cuboidal epithelial cell; b = bacteria (Photobacterium sp.); **e**=erythrocytes. Figure adapted from Ghedotti et al. (2018; fig. 3).

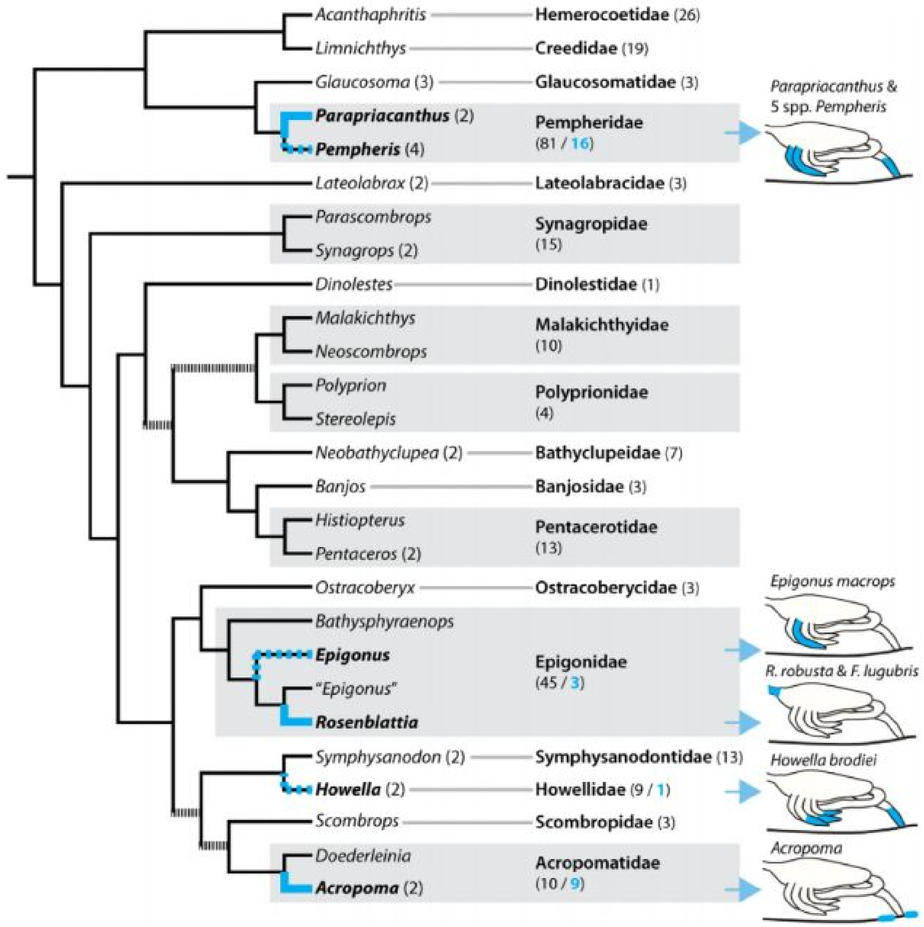

Figure 3. Evolutionary relationships among representative acropomatiform genera based on a maximum likelihood analysis of 16 gene fragments that produced a species-level phylogeny (Ghedotti et al., 2018 supp. info.). Numbers in parentheses after genera are numbers of species included in the analysis if greater than 1. Dashed lines indicate nodes present in the maximum likelihood analysis optimal tree that were not present in the 50% majority-rule Bayesian tree (Ghedotti et al., 2018 supp. info.). Blue lines indicate bioluminescent genera. Numbers under family names are the number of species in each family followed by a blue number for the number of bioluminescent species if greater than 0. The diagrams at right are left lateral views of generalized post-pharyngeal digestive tracts (anterior at left) for bioluminescent taxa with anatomical areas where bacterial bioluminescent organs originate indicated in blue (esophagus, pyloric cecum, posterior intestine, and/or proctodeum). Figure adapted from Ghedotti et al. (2018; fig. 4).

Histology of the *Acropoma japonicum* light organ partially supports, but expands on the findings of Haneda (1950). Two compartmentalized left and right lobes were present, unifying into a single structure anteriorly (Figure 1 a-c). The medial lumen was identifiable by histology and is lined by simple cuboidal epithelium anteriorly and stratified cuboidal epithelium medially near the anus, where it separates, and joins the stratified epidermis surrounding the anus (Figure 1 e). The compartmentalized light organ itself consists of folded lobules lined by simple cuboidal epithelium (Figure 2 g). Medially within the light organ, the epithelial layers are compressed apically to basally and a dense, connective tissue is located at the center of the light organ (Figure 1 c). Both the lumen and the light organ (both arms) are surrounded by blood sinuses, which are also lined by simple cuboidal epithelium (Figure 1 d). In regard to overall orientation, the anteriormost, single lobe of the light organ is medioventral. After differentiating into left and right arms posteriorly, both arms are situated dorsoventrally and connected by a medial lumen (Figure 1 d). Posterior to the anus, both arms are no longer connected by a medial lumen (Figure 1 e).

The light organ of *Acropoma hanedai* is not completely similar to the previous description or to *A. japonicum*, with significant differences between the two being revealed by this study. Again, left and right arms of the light organ emanate from a unified, anterior compartment (Figure 2 a). *Contra A. japonicum*, the medial lumen connects both arms through the entirety of the light organ, including the light organ portions posterior to the anus (Figure 2 b-e). The light organ extends from ventral to the eye region, where it is one anterior compartment and proceeds posteriorly where it loops below itself immediately anterior to the anal fin (Figure 2 e). Generally, the lobes are as wide as tall, though some dorsoventral elongation is evident near the anal fin skeleton (Figure 2 c & f). As in *A. japonicum*, the light organ and lumen are surrounded by collagen-rich tissue and are highly vascularized. Blood sinus are found all around the light organ (Figure 2 b).

Gross dissections of *Acropoma hanedai*, *A. japonicum*, and 11 other acropomatiforms were conducted to describe the light organ by naked eye or identify previously undescribed light organs, if present. Though not visible externally or internally, the light organ of *A. hanedai* and *A. japonicum* were discernible upon dissection into the body wall. What was observed, in this fashion, corroborated what was known about the light organ from histology.

A distinct ventral musculature, often indicative of the presence of a light organ, is translucent in live specimens. This musculature was separate from dorsal, opaque musculature in both *Acropoma* species when examining preserved specimens externally. The two muscle types were separated by a darkly pigmented line. Distinct chromatophores were dispersed around the anus in both, though these were more were concentrated in *A. hanedai*. Consistent with previous descriptions, the anal position of both *Acropoma* species was shifted more anterior than any non-*Acropoma* species that were analyzed.

A phylogeny was created by collaborators using maximum likelihood and Bayesian analysis of genetic samples from 35 ingroup Percomorpha and 6 outgroup non-Percomorpha, designed to include bioluminescent species (Figure 3)(Ghedotti et al., 2018). Four, non-*Acropoma* species included in the analysis are known to bioluminesce, while 61 of those that were included do not (Herring, 1992; Mayer, 1974; Mead & DeFalla, 1965). The resulting phylogeny indicated both *Acropoma* and *Doederleinia* are closely related to each other, with this clade also being closely related to Epigonidae, Howellidae, and Ostracoberycidae, *contra* previous analyses (Figure 3)(Ghedotti et al., 2018).

Discussion

This study elucidates the morphology of the light organ in both *Acropoma hanedai* and *A. japonicum*, which had previously only been investigated generally (Haneda, 1950; Thacker & Roje, 2009). The light organ and medial lumen are connected to a perianal pouch with simple to stratified cuboidal epithelium. Such a connection, in conjunction with an epithelial transition, suggests ectodermal tissue develops into the light organ. The close association with the anus additionally suggests a proctodeal developmental origin, *contra* previous work done by Nealson & Hastings (1979). The light organ of *Chlorophthalmus albatrossis* shares this developmental pattern as well as general structural similarity with the *Acropoma* light organ (Somiya, 1977).

This study also confirmed known distinctions between *Acropoma hanedai* and *A. japonicum* as well as contributing new information. The ontogeny, revealed through analysis of smaller individuals (around 40mm SL), suggests smaller individuals have more consolidated light organs in *A. hanedai* and *A. japonicum*, compared to larger counterparts, where the arms of the light organ separate laterally during development. As individuals of both species grow between 40mm SL and 120mm SL, the light organ begins to separate laterally. It is likely that the light organ separates due to increasing body width as the individual grows. However, smaller individuals did exhibit the same anterior anus position and relative extent of the light organ. This suggests that the forward shift in anus and the development of the light organ must occur at or before *Acropoma* reaches 40mm SL, suggesting a similar timing of anus migration as observed in *Aulotrachichthys* (Johnson, 1984; Trnski & Leis, 2000).

The phylogeny presented in Ghedotti et al. (2018) revealed a close evolutionary relationship between acropomatids, howellids, and epigonids (Figure 3). However, the light organs present in *Howella* and *Epigonus* are associated with the digestive tract (Herring, 1992; Mayer, 1974). Previous studies on these genera determined these light organs are likely endodermally derived (Herring, 1992; Mayer, 1974). The light organ in *Acropoma,* which is associated with the anus and is ectodermally derived, is unlikely to share a common evolutionary origin with the light organ in howellids or epigonids. The distant phylogenetic relationship between *Acropoma* and other species with similar bioluminescent organs and similar developmental origin suggests the *Acropoma* light organ evolved independently.

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II. Gut morphology and diet analysis of two glowbellies (Teleostei: Acropomatidae) and evolutionary implications

Introduction

Generally speaking, two species cannot occupy the same niche space (Colwell & Fuentes, 1975). Physiological, morphological, and behavioral specifications dictate the geographic and functional areas in which a species can survive and reproduce (Colwell & Fuentes, 1975; Geange et al., 2010). Two species exhibiting a high degree of overlap in one niche factor must diversify along another niche factor axis (Ebeling & Hixon, 1991). The interconnectedness of factors contributing to a species' niche are often varied, making them difficult to elucidate (Geange et al., 2010; Soberón & Nakamura, 2009). Although diets between species can be similar, co-occurrence often results in either dietary or spatial niche shift (Burghart et al., 2010; Choy et al., 2013).

Spatial niches in the mesopelagic are confined by a variety of factors, including depth, habitat type, and geographic prey distribution (Robinson et al., 2010). Analysis of three marine shallow water porgy species in the genus *Diplodus* reveal that co-occurrence between two or more species can result in either shift in niche depth or dietary composition (Sala & Ballesteros, 1997). The two smaller sparid species analyzed shifted niche depth when feeding in the same location, while the largest species often fed at the same depth, but shifted dietary niche composition to krill and copepods foraged at shallower depths when another *Diplodus* species was present (Sala & Ballesteros, 1997). The authors noted that it is likely that dietary niche shift occurred in that instance because the amount of spatial habitat was relatively abundant compared to the size of fish assemblage (Sala & Ballesteros, 1997).

Dietary niche shift is often observable between species that occupy the same niche space in similar densities (Burghart et al., 2010; Choy et al., 2013). Two co-occurring sparid species are found in the same geographic locations at similar densities, often consuming similar prey. Body shape and jaw morphometrics are mostly interspecifically differentiated, suggesting specialization for a specific diet type that limits ability to shift diet composition itself (Fanelli et al, 2011). Fanelli et al. (2011) determined that although diet composition was not dissimilar between the sparids, percentage of each prey type was variable between them when both species were found in the same location. Dietary niche overlap was highly dependent on resource availability, where percent composition shows the greatest difference during seasons of resource abundance (Fanelli et al., 2011). A classic study by Werner & Hall (1977) revealed that experimental habitat restriction separating species results in a 70% dietary niche overlap between two freshwater sunfish species (family: Centrarchidae), compared to only a 44% niche overlap when habitat is unrestricted and the species share habitat. This suggests preferential dietary niche shift occurs during interspecific co-occurrence, as a results of spatial niche shift. It is likely that habitat, behavior, and mouth size are all limiting factors that may hinder dietary niche shift.

Mesopelagic fish exhibiting quotidian migration experience different interspecific competition when feeding during the day in the mesopelagic and when feeding at night in the epipelagic (Bernal, 2014). When feeding in the mesopelagic, migratory myctophids compete with non-migratory stomiiformes for zooplankton, copepods, and small teleosts. Stomiiformes, often characterized as diet specialists, had high stomach vacuity when myctophids, described as generalists, co-occurred in the mesopelagic layer during the day. This suggests that a generalist diet may be better suited to variable competition environments where sympatric specialist predators are present (Bernal, 2014). A large-scale diet analysis of gonostomatidae, sternoptychidae, and melamphidae species compared diet along taxonomic lines. All species were considered to occupy the same spatial niche as they were caught in the same trawl drawn at a constant depth. This study found little dietary overlap along taxonomic lines (Burghart, Hopkins, & Torres, 2010).

A variety of factors impact piscine diets of the mesopelagic. Longitude, preferred food availability, sea-surface salinity, and layer depth all play a role in dietary composition (Noord et al., 2016). Myctophids consume primarily euphausiids near shore, copepods in intermediate zones, and zooplankton, calanoid copepods, and shrimp farther offshore (Noord et al., 2016; Bernal, 2014). Other mesopelagic species, like gempylids, consume primarily other teleosts, cephalopod larvae, and crustaceans and only 37.5% of individuals were found with stomach contents present (Vianna et al., 2012).

A recent study by Park & Huh (2018) characterized the diet patterns in the mesopelagic teleost *Acropoma japonicum* by collecting specimens across all seasons off the southeastern coast of Korea. Spatiotemporal and ontogenic changes to dietary composition were analyzed in *A. japonicum* through stomach content analysis, where 81.1% of specimens had measurable stomach contents. Diet was characterized as consisting largely of copepods and carid shrimp foraged in both pelagic and benthopelagic zones for specimens of various sizes and collected at different locations. Developmental dietary composition shifted to favor carid shrimp and other teleosts with greater frequency as body size increased, while the contribution of copepods, euphasiids, and amphipods to overall diet decreased through development (Park & Huh, 2018). Variation in dietary composition between sampling locations was attributed by Park & Huh (2018) to site-specific variation in prey abundance, due in part to presence of sympatric competitors. Specialization in pasiphaeid shrimp prey was observed in *A. japonicum* when sympatric competitors such as *Coilia nasus*, *Clupea pallasii pallasii*, and juvenile *Trichiurus lepturus* were present, although the abundance of the shared shrimp prey resource was unknown (Park & Huh, 2018). Diet consisted predominantly of carid shrimp in winter and copepods in summer, which was also attributed to seasonal differences in prey availability, although this was not measured directly (Park & Huh, 2018).

A discussion of dietary patterns and composition should consider gastrointestinal anatomy. Absorption of dietary nutrients in the digestive tract is dependant upon absorptive surface area, where a greater surface area maximizes nutrient uptake (Bekiaris et al., 2014). A greater intestinal length commonly fulfills this function where an animal needs to increase nutrient uptake from nutrient-poor diets (Kolodziejzac et al., 2013). It may be difficult for *Acropoma* species to achieve sufficient intestinal length for nutrient absorption, given the anterior shift in anal position reported by Becker et al. (2010) and Okamoto (2012), relative to other teleosts. The resultant decrease in distance between mouth and anus as a result of this anterior shift may be offset by increased intestinal curvature, which would accommodate of sufficient intestinal length for necessary nutrient absorption (Becker et al., 2010; Damsteegt et al., 2014; Walton et al., 2016). Also key to nutrient absorption, pyloric caeca increase total absorptive surface area and are often found at the anterior-most part of the intestine in teleosts (Buddington & Diamond, 1987). However, the number and length of pyloric caeca is highly variable and can be both species specific and intraspecifically variable (Buddington & Diamond, 1987; Denstadli et al., 2004).

The dietary composition of *Acropoma japonicum* has been well-characterized by previous studies, although little work has been done to investigate possible dietary niche shift when another species of *Acropoma* is present. Using specimens of both *A. japonicum* and *A. hanedai* collected in the same location, through comparison to known dietary composition of *A. japonicum* without a sympatric *Acropoma* competitor, this study seeks to investigate dietary niche shift resulting from co-occurrence of two similar acropomatiforms. I hypothesize that the presence of *A. hanedai* will result in a dietary niche shift in *A. japonicum* as a response to interspecific competition over prey. Additionally, I hypothesize that gut morphology of *A. hanedai* and *A. japonicum* will not be the same due, in part, to the differences in diet caused by niche partitioning.

Methods

Fish market specimens were collected from 47 Xinsheng 1st Road, Dongang Township, Taiwan, fixed in 10% formalin, preserved in 80% ethanol, and cataloged. Prior to analysis of gut morphometry or stomach contents, each specimen's standard length (SL) was measured with metric ruler, recorded, and specimens were sorted into bins of 10mm increments (0-10mm, 11-20mm, and so on). A total of 23 *Acropoma hanedai* [JFBM 48733 (11), JFBM 48743 (4), JFBM 48681 (8)] and 11 *A. japonicum* [JFBM 48680 (4), JFBM48707 (7)] specimens on loan from the James Ford Bell Museum and the University of Minnesota were analyzed for gut morphology and diet composition.

Gut morphometric analysis began with dissection with a cut from a point just dorsal to the pectoral-fin base into the coelom and then posterio-ventrally to the posterio-ventral most margin of the body cavity on the midline. A second cut was made from the point just dorsal to the pectoral-fin base ventrall and slightly anterior to the ventral midline anterior to the pelvic girdle. Dissection was followed by visual examination of gastric and post-gastric structures in the coelom before they were removed. Intestinal structures were severed as far anteriorly as possible and also immediately before the anal opening. Total number of intestinal bends evident were recorded, as was total post-gastric intestinal length, which was measured using a string and a metric ruler. The number of pyloric ceca was recorded; the longest and shortest cecawere identified and the position number of the shortest and longest caeca were identified by numbering ceca from the most dorsal cecum and numbering from dorsal to ventral (Figure 1). Cecum length was measured using string and a metric ruler from the junction with anterior intestine to tip.

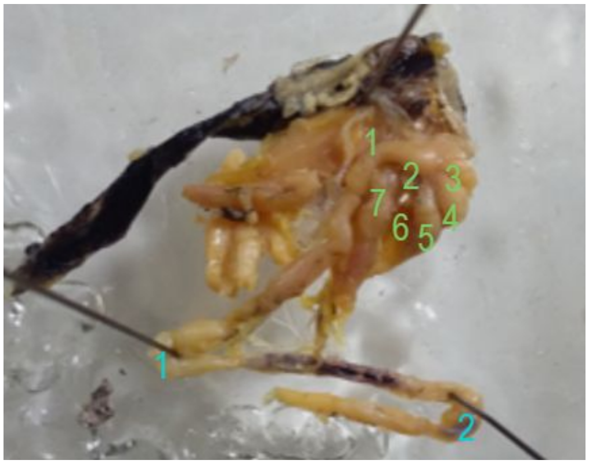

Figure 1. *A. hanedai* stomach, pyloric caeca, and postgastric intestine. Green numbers indicate an example of cecum numbering regime. Blue numbers indicate the position of intestinal curvatures.

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Before incision into the stomach occured, dissection area, tools, and intestine exterior were cleaned of loose tissues and debris. A clamshell half incision of the stomach was made dorsally and proceeded lengthwise from the anteriormost point of the stomach to the pyloric sphincter. All stomach contents were removed to glass slide fitted with 1mm^2 grid for imaging. Unidentifiable material and heavily digested prey were partitioned to one half of the side, while whole and identifiable prey were moved to the other. Stomach contents, especially identifiable prey items, were formed into roughly ellipsoid forms before being imaged. Stomach contents were photographed with QImaging MicroPublisher 5.0RTV on a Leica DM2500 before being placed in a cryogenic tube of 70% ethanol labeled with standard length and catalog number of parent specimen.

Photographed stomach contents were analysed using ImageJ to estimate diet volume using methods adapted from Alcaraz et al. (2003) and Egan et al. (2017). Major (R) and minor (r) axis of each prey item were recorded and used to calculated an ellipsoid area by the formula: $(\pi rR)/4$. Total visible prey area was estimated with a polygon tool. A scale factor for future calculations was determined by dividing polygon-measured area by ellipsoid calculated area. To estimate an oblate ellipsoid volume estimate of prey volume, it was first necessary to find scaled length and width of the prey. This was done by dividing the scaling factor by the major axis to find the scaled length (L) and minor axis to determine scaled width (W). Oblate ellipsoid volume was calculated with the formula: $4\pi/3(L*(\frac{1}{2} W)^2)$ in order to estimate volume of prey item. Proportion of overall diet classified into discrete prey types was used to determine a percent similarity (NO) of dietary niche overlap using the formula:

$$NO_{ijt} = \sum_{k=1}^{K} \min\left(p_{ik}\ p_{jk}\right)$$

(Pledger & Geange, 2009)

where p_{ik} and p_{jk} are minimum proportions, by volume, of the *k*th prey type found in *A. hanedai* (species *i*) or *A. japonicum* (species *j*) (Inoue, Suda, & Sano, 2005; Krebs, 1989; Nakamoura, Harinouchi, Nakai, & Sano, 2003; Pledger & Geange, 2009).

Results

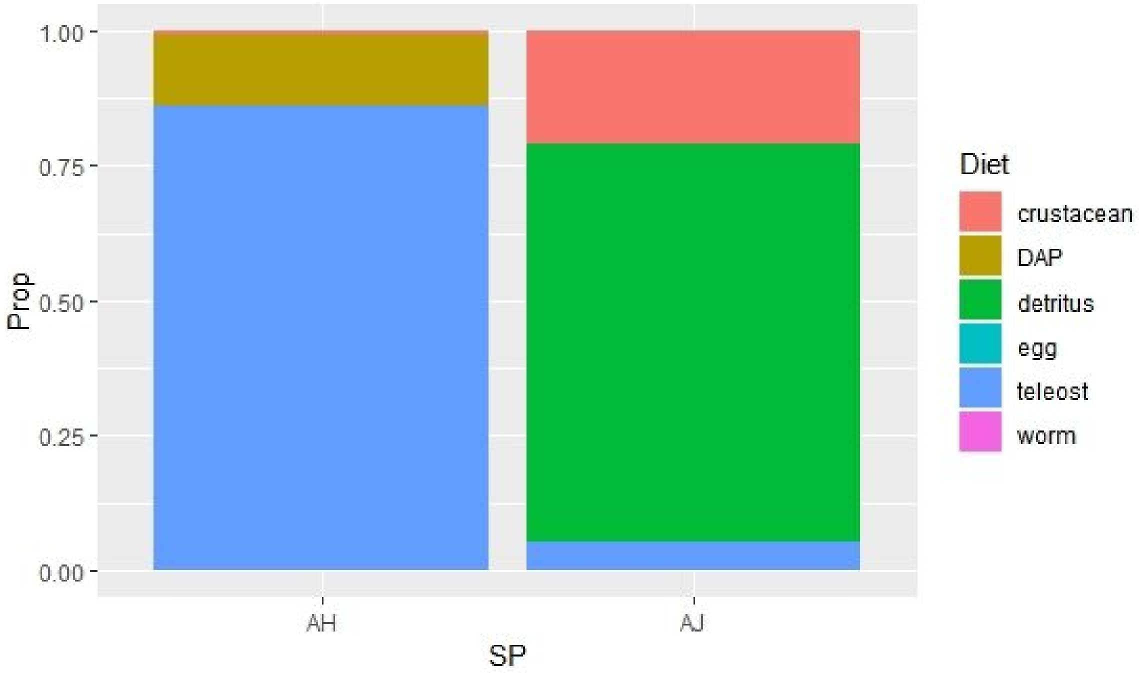

Figure 2. Proportional contribution of each of five prey categories for total stomach contents analyzed of AH (*A. hanedai*) and AP (*A. japonicum*). Each proportion represents the total volume of each prey type found across all individuals of one species divided by total volume of all recovered stomach contents for all individuals of the species. **DAP** digested animal prey. Percent similarity: 18.99%.

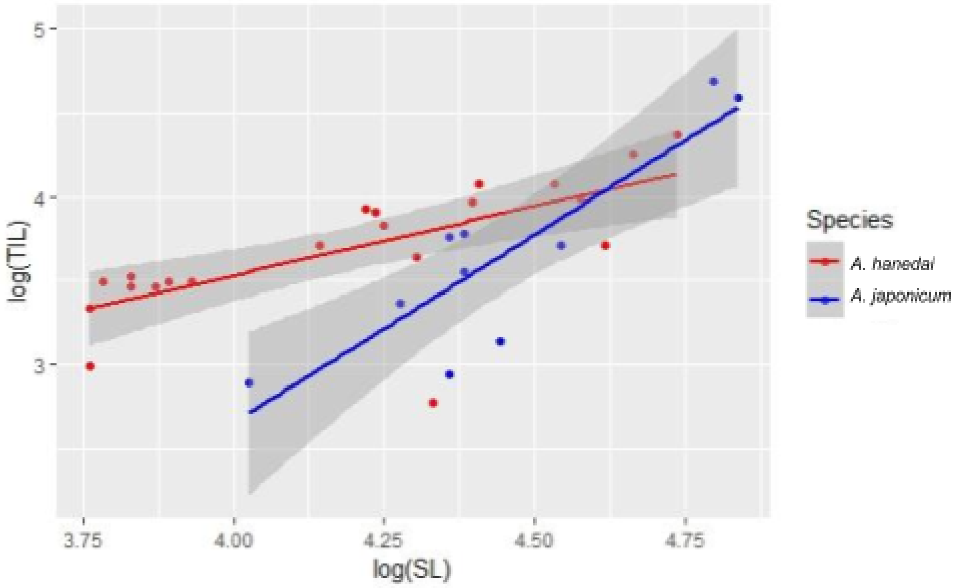

Figure 3. Comparison of standard length (SL, in mm) of individuals and their total, post-gastric intestinal length (TIL, in mm). Both the SL and TIL were log transformed, yielding a p-value of 4.03×10^{-4} suggesting the log-transformed SL was a satisfactory predictor of change in the log-transformed TIL. A comparison of the difference in slope between species yields a p-value of 5.132×10^{-3}.

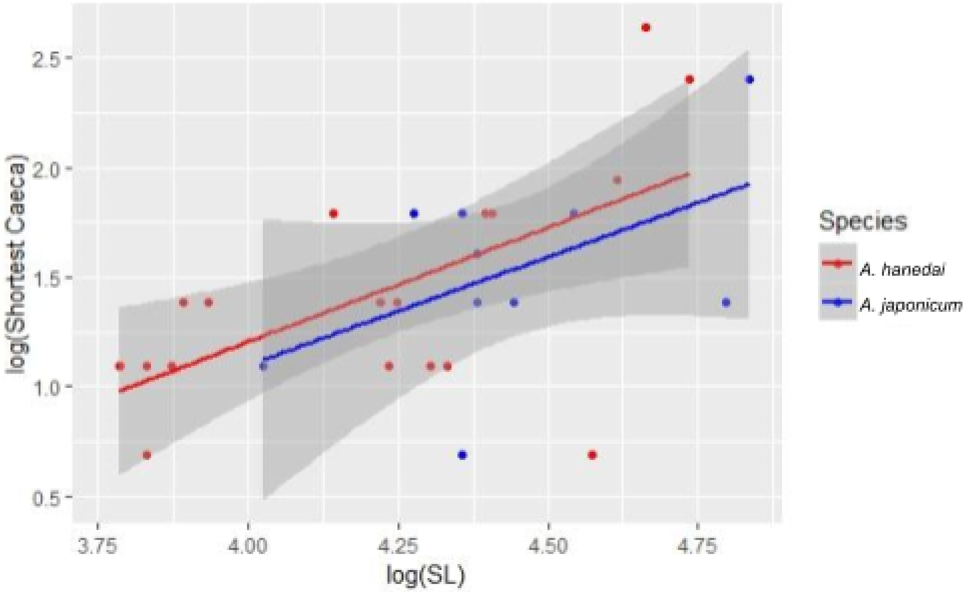

Figure 4. Comparison of standard length (SL, in mm) of individuals and the length of the shortest pyloric cecum (in mm). Both the SL and shortest cecum length were log transformed, yielding a p-value of 4.75×10^{-3} suggesting the log-transformed SL was a satisfactory predictor of change in the log-transformed caecal length. A comparison of the difference in slope between species yields a p-value of 0.93695.

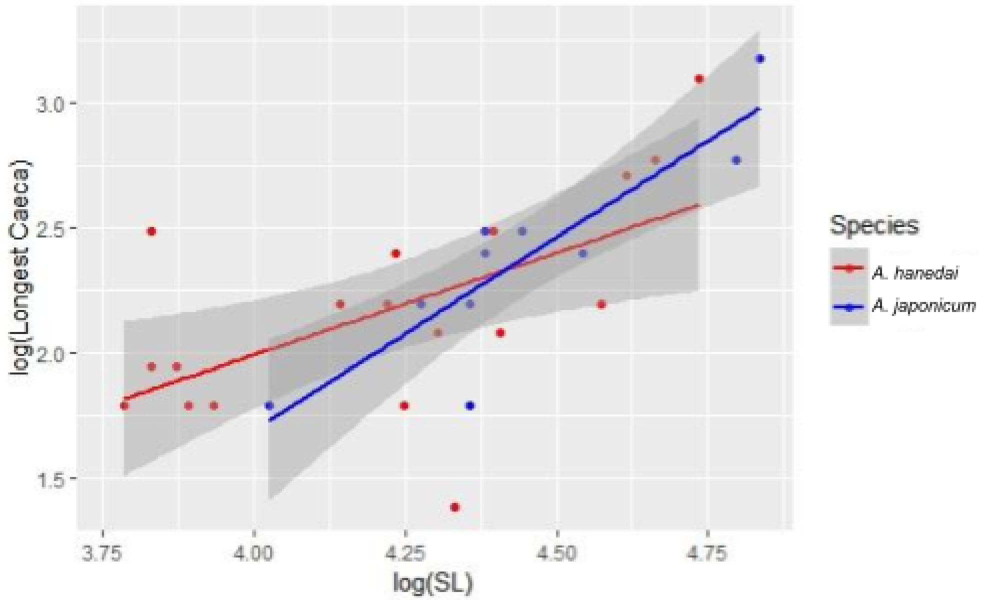

Figure 5. Comparison of standard length (SL, in mm) of individuals and the length of the longest pyloric cecum (in mm). Both the SL and longest cecum length were log transformed, yielding a p-value of 2.64×10^{-3} suggesting the log-transformed SL was a satisfactory predictor of change in the log-transformed cecal length. A comparison of the difference in slope between species yields a p-value of 0.15962.

Table 1. Pyloric ceca and post-gastric intestinal curvature trends compared between *A. hanedai* and *A. japonium*. The majority of longest caeca position, shortest caeca position, and number of intestinal curvatures, and number of pyloric caeca follows the range value for each species in parentheses. All p-values generated by Pearson's chi-square analysis.

	A.hanedai	***A.japonicum***	**p-value**
Number of Pyloric Caeca	3-8 (7)	6-8 (7)	0.7321
Position of longest pyloric caeca	1-7 (1)	1-6 (1&6)	0.1421
Position of shortest pyloric caeca	2-6 (3)	2-7 (7)	0.3253
Number of Post-gastric Intestinal Curvatures	0-4 (2)	1-2 (2)	0.6292

Diet Composition

Of the analyzed specimens, stomach contents were recovered from 91% of *A. japonicum* specimens and 83% of *A. hanedai* specimens. The remaining specimens could not be analyzed due to decomposition that occured before preservation Across all specimens, dietary composition consisted of other teleosts, crustaceans, a marine worm, eggs, and digested animal prey. Due to the advanced stages of digestion of some stomach contents, diet elements considered to be digested animal prey could not be classified more specifically.

The majority of overall dietary consumption of *A. hanedai* consisted of other teleosts (86.24%), while the majority of the *A. japonicum* diet was comprised of digested animal prey (73.66%) (Figure 2). Inversely, digested animal prey only contributed only to 13.13% of the diet in *A. hanedai* that were analyzed, and teleosts contributed 5.28% to the *A. japonicum* diet. Crustaceans were only found in appreciable amounts in *A. japonicum* (21.5%) and made up only 0.57% of the *A. hanedai* diet. A marine worm and eggs were each found in the stomach contents of only one individual and both were only observed in *A. hanedai* specimens. A percent similarity index reveals a 18.99% dietary niche overlap (Figure 2).

Gut Morphology

Graphical analysis of log-transformed lengths of the shortest and longest pyloric caeca, as well as the total post-gastric intestine, reveals a positive relationship between all metrics and the log-transformed standard length (SL). Trends observed in total intestinal length (TIL) suggest *A. hanedai* intestinal lengths are significantly longer than in similarly-sized individuals of *A. japonicum* at shorter specimen lengths (p=0.005132)(Figure 3). Conversely, the longest pyloric caeca compared to body length are observed in *A. japonicum*, although length of the longest caecum is similar between species (p=0.93695)(Figure 4). The shortest pyloric caecum measured per individual is generally longer in *A. japonicum*, as well, though only for individuals 80mm SL or larger. It is not likely this disparity is species-specific (p=0.15962)(Figure 5).

Generalized linear models revealed that SL was not a good predictor of trends in the number of pyloric caeca (p=0.435), position of the longest caecum (p=0.0987), or position of the shortest caecum (p=0.2278). This was also true when both variables were log-transformed (p=0.789, p=0.196, p=0.963 for same factors). Given this, a Pearson's chi-square test was considered more suitable to compare differences between *A. japonicum* and *A. hanedai*, although this did not reveal any significant difference in number or position of caeca between either species, likely due to significant variation between individuals of both species (Table 1).

Discussion

Diets between *Acropoma japonicum* and *A. hanedai* were analogous, despite the singular encounters of a marine worm and unidentifiable eggs in the stomach contents of two *A. hanedai* individuals. Dietary niche partitioning was observed between *A. japonicum* and *A. hanedai*, with a niche overlap score of only 18.99% indicating that the proportion of prey items, rather than the variety of prey items, were species-specific. Despite this support of our hypotheses regarding diet, little support is given to our hypothesis about gut morphology. Of the analyzed metrics, only total post-gastric intestinal length is indicative of any species-specific morphological specialization and was only observed in specimens at smaller lengths. The number, position, and length of pyloric caeca were not significantly different between *A. japonicum* and *A. hanedai*.

It is highly likely that specimens used in this study occupied the same spatial niche. Both *Acropoma hanedai* and *A. japonicum* were, in fact, frequently found directly in contact with each other in crates taken directly from fishing boats (pers. comm. M. Ghedotti, 2018). Assuming *A. japonicum* and *A. hanedai* share a spatial niche area, a dietary niche shift similar to what was observed would be expected (Bernal, 2014; Burghart et al., 2010; Choy et al., 2013; Fanelli et al., 2014). Other dietary analyses of *A. japonicum* not located in proximity to other *Acropoma* species indicate that carid shrimp and copepods comprise the majority of the dietary array, with unidentifiable, digested prey contributing in smaller proportions (Park & Huh, 2018). This study, however, observed the majority of the diet was comprised of digested prey in addition to carid shrimp with no copepods observed in the diet. Site-specific prey availability may affect these results. Park & Huh (2018) collected specimens from waters southeast of Korea, whereas samples used in this study were collected in waters south of Taiwan. Further analysis of prey abundance in both regions could discern whether observed niche partitioning is prey dependent.

Despite variation in gut morphology between *Acropoma japonicum* and *A. hanedai*, only total postgastric intestinal length was significantly different between species at smaller specimen lengths. Studies of intestinal length in Lake Tanganyika cichlids suggest that diet is a strong predictor of intestinal length, even after controlling for phylogenetic relationships and length of the individual (Wagner, McIntyre, Buels, Gilbert, & Michel, 2009). The tradeoff between sufficient absorptive surface area and digestive tissue maintenance may have resulted in innate species-specific differences, but this may also be the result of phenotypic plasticity in response to environmental conditions (Wagner et al., 2009). Amphibians exhibit plastic gut morphology in response to shifts in abundance of certain prey types (Ledon-Rettig, Pfennig, & Nascone-Yoder, 2008). Ledon-Rettig et al. (2008) noticed that plasticity in gut morphology was only observed in response to an increase in certain prey items in the diet, but not in other prey items, or shift in overall dietary composition. Determining whether prey-dependent gut morphological plasticity is the result of an increase in certain prey items merits further investigation.

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III. Historical context and ethical implications of the photography of Edward S. Curtis

Preface

The reader likely will have noticed the prevalence of photography in the preceding two chapters. Microscope photographs taken of histology sections were paramount in documenting and disseminating what we discovered about the structure and likely origin of light organs in *Acropoma hanedai* and *A. japonicum* in the first chapter. Perhaps less obvious, photography also played a key role in the methodology of the second chapter. Photographs of stomach contents were used to identify prey items in the diet, as well as to digitally measure and estimate the total stomach content volume. No edits or changes were made to these, as their visibility and aesthetic qualities were irrelevant to their use. In the first chapter, however, small changes were made to the photographs to make them suitable for publication. These changes included readjustment of white balance and saturation, as well as removal of blemishes caused by debris on the camera, scope, or slides themselves. The result was an image whose colors matched those seen through the scope and was free of distracting and unattractive bubbles, scratches, and other marks. I and my fellow researchers considered these manipulations to be small because they did little to change the way in which the image would be interpreted by a reader. However, loose guidelines dependent on the interpretation of the researcher have landed more than one scientist in hot water.

Photographic manipulations can seem insignificant to the larger picture of scientific literature and how science is communicated. After all, I am not alone in my choice to edit my work. In fact, few journals accept raw photographs for article submissions because they are visually unappealing. That said, ethical considerations are often absent when one thinks about manipulations that seem as small as altering color saturation and removing unsightly dust marks from photographs to prepare them for publication. Where is that line drawn? More importantly, what are the consequences of crossing that line, where manipulations come between the data and how it is interpreted? While it is impossible to look into the future as to how the small changes scientists make today will alter how their work will later be interpreted, we *can* look to the past at photo-manipulations that were once considered minor but have dramatically altered modern understandings of the data. I can think of no better example of small photographic manipulations gone wrong than the work of Edward S. Curtis.

Arguably the most eminent ethnographer working in North America, Curtis used photographs, written text, and more to describe and document Native American tribes across the U.S. and Canada. Under the careful review of modern ethnographers and historians, however, a litany of photographic manipulations have become apparent. Although he may have seen his photographic changes as small and insignificant, many have altogether altered the way in which his work is viewed by a modern audience. That said, his work may hold an even more important role today as a cautionary tale to scientists and researchers as to the importance of critically analyzing photographic manipulation choices.

Note: *In certain instances, names of tribes may appear misspelled or incorrect when referring to photograph titles or explanations of historical context because they are written as they were originally used, contrary to current usage.*

Introduction

Edward Sheriff Curtis was a little-known photographer in turn of the century America, who died largely in obscurity (Lyman, 1982). However, in recent decades, his work has seen a remarkable resurgence. Some tout his rediscovery as a Curtis Renaissance (Pritzker, 1993). Others are deeply worried by the popularity of a figure whose work, when discussed, has been highly controversial (Beck, 2001; Lyman, 1982). At the beginning of his career, Curtis opened and ran Curtis Studios, a portrait photography studio, with his family starting in 1898 (Gidley, 1998; Gidley, 2003; King, 2012; Lyman, 1982). One day, photographing Mount Ranier for his own pleasure, he happened to meet the prominent ethnographer George Bird Grinnell. Curtis was as fascinated with Grinnell's work with Native American tribes as Grinnell was with Curtis's photography (Gidley, 1998; Gidley, 2003; King, 2012). Eventually, Grinnell hired Curtis to photograph the Harriman Alaska Expedition in 1899 (Gidley, 1998;

Gidley, 2003; Lyman, 1982). On this trip, he learned from the rest of the team about taking notes on people and places, how to record sounds on wax roles, and what to photograph to illustrate findings (Dowling, 2013; Gidley, 2003; King, 2012; Lyman, 1982). Although he never received a formal education in ethnography, such training catapulted him into this burgeoning scientific field (Lyman, 1982).

After training more directly under Grinnell while he studied the Piegan (Blackfoot) of Montana, Curtis became enthralled with the native customs and peoples he experienced (Gidley, 1998; Gidley, 2003; King, 2012; Lyman, 1982). He approached J.P. Morgan and requested funds to study the many and varied tribes of North America (Gidley, 1998; Gidley, 2003; King, 2012). Armed with an advancement from Morgan of $75,000, funds from other donors and his own savings totalling near $25,000, and a forward from President Theodore Roosevelt slated to accompany his first publication, he set off (Gidley, 1998). A hobby project originally intended to take six years, *The North American Indian* became Curtis's 20-volume obsession and would consume the rest of his life (Gidley, 1998; Makepeace, 2000). He neglected his family and business for the project, ultimately losing both, and struggled financially the remainder of his days - every penny he earned went to his expeditions and publications (Makepeace, 2000). At the time of his death, Curtis had published 4,390 pages and 1,505 photographic plates describing over 75 Native North American tribes (Christie's Auction House, 2012; Northwestern University, 2003b). It took 27 years to complete and was $1.4 million dollars more than Curtis originally anticipated (roughly $20.1 million today) (Christie's Auction House, 2012). His writings included descriptions of customs, quotes and creation myths from translators and tribal elders, 10,000 wax recording of languages- many of which are now dead, and hours of motion picture recordings (Curtis, 1907; Dowling, 2013; Gidley, 1998; Gidley, 2003; Lyman, 1982; Makepeace, 2000). It is possible that nothing in the world is quite such a full account of Native American life in the early 20th century and history in North America (Gidley, 1998; Makepeace, 2000).

Upon its completion, reception of *The North American Indian* was not all that Curtis imagined. Although he estimated the cost of a full set of volumes and folios to cost $5,000, he could only sell a few subscriptions at $3,000 - $4,200 (Gidley, 1998; Northwestern University, 2003). Curtis went bankrupt publishing his life's work, as he was unable to sell sufficient copies at the necessary price to cover costs (Gidley, 1998). Of the 500 copies Curtis set out to produce, it is estimated only 272 were ever printed; 19 of those now reside in university collections like the set housed at Regis University (Christie's Auction House, 2012; Dowling, 2013; Northwestern University, 2003). Today, the rarity of Curtis's publications and the resurgence of interest in his work resulting from reprints of photogravures done in the 1970's have driven prices for a full collection as high as $1 million to $2.88 million at auction (Christie's Auction House, 2012; Dowling, 2013; Northwestern University, 2003). The hunger for Curtis images not only remains, but has increased with time, but their ownership still lies almost solely with the financially elite.

Controversy over Curtis's work has recently become as engaging as the work itself. Rightly so, as a preponderance of evidence suggests many of his photographs had been staged, edited, altered, or entirely misrepresented (Dartt & Dolan, 2016; Gidley, 1998; Gidley, 2003; Griffiths, 2018; Lyman, 1982; Stoll, 2003). What little we know about Native American culture in the early 20th century comes from Curtis photographs, which many argue should not be trusted (Egan, 2006; Ponce, 2000; Prins, 2000; Stoll, 2003). Moreover, Curtis operated under a pervasive Social Darwinist agenda that has led many to claim his work is too biased to be useful (Beck, 2016; Dartt & Dolan, 2016; Egan, 2006; Hicks, 2016; Ponce, 2000). To Curtis and his contemporaries, it seemed inevitable that these native cultures would wither and become extinct in the face of white influence, a sentiment illustrated in *A Vanishing Race* (1914) by Dixon, an academic, and Wanamaker, an amateur ethnographer (Figure 1)(Beck, 2016; Dartt & Dolan, 2016; Egan, 2006; Hicks, 2016; Ponce, 2000; Lyman, 1982). A motivation for *The North American Indian*, though we may never know how strong, was the fact that Curtis truly believed that if he did not document native cultures they would surely be lost to the annals of time as white culture overtook them (Beck, 2016; Egan, 2006; Gidley, 1998; Gidley, 2003; Lyman, 1982). He romanticized Native American lives and lifestyles in ways we are only beginning to realize (Beck, 2001; Beck, 2016; Denver Art Museum, 2017; Hicks, 2016; Ponce, 2000; Stoll, 2003; Stull-Meyers & Red Star, 2017; Vervoort, 2004). He would remove Euro-American industrial products like clocks and overcoats, favoring instead stereotypical items like peace pipes and buffalo skin shirts (Dartt & Dolan, 2016; Griffiths, 2018; Lyman, 1982; Stoll, 2003). Although careful analysis has been able to reveal such biases and manipulations, it is impossible to know *all* of what Curtis manipulated for his own reasons (Gidley, 1998; Gidley, 2003; Griffiths, 2018; Stoll, 2003). For this reason, some experts believe that all of Curtis's work, as voluminous as it is, has no realistic value as a historical or ethnographic record (Beck, 2016; Dartt & Dolan, 2016; Egan, 2006; Hicks, 2016; Stoll, 2003).

Figure 1. *A Vanishing Race* (1914). Photogravure by Dr. Joseph K. Dixon and Rodman Wanamaker. Image courtesy of The J. Paul Getty Museum.

While it may be easier to use Curtis as an example of scientific malpractice and discard his work completely, there is undeniable benefit in reviewing what he recorded (Egan, 2006; Makepeace, 2000; Ponce, 2000; Prins, 2000; Stoll, 2003). His portraits, biased or otherwise, were photographs of real people. They are someone's grandmother, grandfather, great grandmother, and great grandfather (Makepeace, 2000; Talahongva, 2014; Vervoort, 2004). In many instances, they are one of few surviving records of someone's ancestral past (Makepeace, 2000; Ponce, 2000; Talahongva, 2014; Vervoort, 2004). By paying to photograph and film native cultural practices that had largely been outlawed, Curtis reinvigorated local communities to maintain their religious expression (Curry, 2008; Makepeace, 2000; Ponce, 2000). His records now serve as a guidebook for Native Americans that want to rekindle the culture that was stolen from them (Makepeace, 2000). The images Curtis brought to the world, both then and now, were not of a defeated and meek Native American people. In contrast to Curtis, many other white, male artists in the early 20th century, like James Earle Fraser, were creating art inspired by an anemic sympathy for the plight of Native Americans, as seen in *End of the Trail* (1918), although their work often turned a blind eye to the hand of white sociopolitics in the condition (Figure 2)(Vittoria, 2014). Instead of portraying Native Americans in ways similar to Fraser and those like him, Curtis portrayed his subjects with a regal majesty that, it was hoped, would inspire a respect for those maligned and persecuted by this nation (Curtis, 1907; Gidley, 1998; Gidley, 2003). Whether or not that is how those photographs were used, both in popular culture of the 20th and 21st century, to fulfill that purpose, is another matter (Beck, 2016; Dartt & Dolan, 2016; Denver Art Museum, 2017; Griffith, 2018; Hicks, 2016; Unk., 1911).

Figure 2. *End of the Trail* (1918) by James Earle Fraser. Bronze Cast. Image courtesy of The Metropolitan Museum of Art.

By exploring the positive and negative consequences of some of the most famous and infamous Curtis images, including *Lodge Interior -- Piegan, The Vanishing Race, Yellow Bull -- Nez Perce*, and *Nez Perce Warrior* the dangers of photographic manipulations in scientific work will become evident. Each of these photographs epitomize three main categories of manipulations that can still emerge in images used in scientific literature. Looking on these historic records and the modern consequences of

Curtis's manipulations helps to extrapolate the impacts photographic manipulations in today's scientific literature may have in the future.

The North American Indian

The full scope of Curtis's work only truly becomes evident when confronted with the entirety of *The North American Indian* in physical space. I had the opportunity to interact with the specific volumes and folio prints that would be discussed in this thesis in person, not only because Regis University has a complete collection of *The North American Indian*, but because a thorough analysis of any artistic work is best done face to face - art to art historian. The daunting set of 20 volumes and 20 folios reside under lock and key in what is referred to as 'The Arc of the Curtis' - a case about three feet high and four feet square that takes up the majority of the real estate in the Special Collections archive in the Dayton Memorial Library. However, one of the most surprising and groundbreaking features of the collection, at least groundbreaking for the time in which it was created, can be found in the unassuming gold lettering on the spines of the books, themselves. Each volume is labeled with the tribal nation contained within the specific book, with about 75 tribes represented overall (Curtis, 1907; Northwestern University, 2003b). Few before Curtis, academic or otherwise, would have viewed a tribe as different from any other, where all 'Indians' were seen as belonging to the same, homogeneous identity (Beck, 2016; Murray, 2015; Stoll, 2003; Zamir, 2007). His separation of tribal identities alone was revolutionary in Curtis's day, as many considered 'The Indian' to be the highest level of classification necessary for those who were simply viewed as 'Others' (Gidley, 2003; Lyman, 1982; Stoll, 2003; Zamir, 2007). It is clear throughout his work that Native America was not a homogenous entity; rather, it was a collection of diverse cultures, beliefs, traditions, and histories varying not only by tribal affiliation but across geographic distributions (Curtis, 1907; Gidley, 2003; King, 2012; Murray, 2015; Northwestern University, 2003; Zamir, 2007). To greater and lesser degrees, individuality is carried throughout both the folios and volumes. Each folio includes a list and description of photographs, which includes the tribal affiliation of a person or setting being photographed; and each referenced many subjects by name, a dignity not often paid to Native Americans in the early 20th century (Curtis, 1907; Gidley, 2003; King, 2012; Murray, 2015; Northwestern University, 2003; Talahongva, 2014; Zamir, 2007). Additionally, Curtis gives the specific names of those who shared with him information about the cultural practices and language of their nation, often giving such voices greater weight than that of American or European ethnologists referenced throughout the work (Curtis, 1907; Talahongva, 2014; Zamir, 2007).

Curtis spent the whole of his professional life engaged in an endless struggle between his desire to create pictorialist, artistic photographs and his desire to work as an empirical scientist. The two are dogmatically opposed and the lasting struggle between them is evident throughout Curtis's work (Dowling, 2013; Egan, 2006; Gidley, 1998;

Murray, 2015; Lyman, 1982; Stoll, 2003; Vervoort, 2004). Pictorialism seeks to create an image that is unique to the identity of the photographer, such that any photograph can be stylistically attributed directly to its creator (Murray, 2015; Rosenblum, 2008; Sontag, 1977; Vervoort, 2004). Curtis himself suggested the same to the ethnographers who worked under him, often ridiculing their lack of artistic style in the ethnographic images they produced in the field (Gidley, 1998). Contrarily, such individualism is fundamentally rejected in scientific practice, which favors instead replicability of observation independent of the observer (Collins, 1992). Unlike pictorialism, ideal scientific observations made by two different observers should yield the same product, not one distinct or attributable to the observer (Collins, 1992). The core axioms of science and pictorialism are such that they cannot be unified in a single document or medium without being contradictory. To avoid this conflict, Curtis often chose to highlight either one or the other in his work, with the division being especially distinct and observable in his photography (Curtis, 1907; Egan, 2006; King, 2012; Murray, 2015; Lyman, 1982; Ponce, 2000; Stoll, 2003; Talahongva, 2014). Yet, this attempt to unify two categorically opposed systems is the cause of Curtis's enduring controversy, simply because the lines between the two are not always distinct (Gidley, 1998; Lyman, 1982; Makepeace, 2000; Ponce, 2000). Even for a trained eye seeking pictorial influence on scientific images, the personal influence of Curtis's technique and agenda can be difficult to fully discern.

Much of Curtis's remains polemic simply because we do not know the extent to which his work has been edited or manipulated to fit a Social Darwinist agenda that predominated 20th century society (Lyman, 1982; Murray, 2015; Stoll, 2003; Talahongva, 2014). In general, three types of photo-manipulations are readily identifiable (Egan, 2006; Gidley, 1998; Lyman, 1982). The most obvious of these, of course, is when objects are added or removed from the photograph during the printmaking process (Egan, 2006; Gidley, 1998; King, 2012; Lyman, 1982; Murray, 2015; Stoll, 2003). Such manipulations are the most familiar to the 21st century viewer, who is inundated with Photoshopped images every day (Heller, Rossetto, & Schuldt, 2018; Wilson, 2016). Requiring a more speculative eye, frequent pictorial stylistic choices become obvious as the second type of manipulation. Pictorialism, the style most favored by Curtis throughout his work, is characterized by diffused light, fuzzy focus, stark black and white contrast, and impressionistic interpretations of light (Egan, 2006; Murray, 2015; Rosenblum, 2008; Sontag, 1977; Vervoort, 2004). This style was favored by photographers who wanted to elevate photography to being considered an artistic medium in the early 20th century. Curtis and other early photographers hoped that by mimicking popular stylistic choices in painting that the photograph would be seen as artistic (Egan, 2006; Rosenblum, 2008; Sontag, 1977; Vervoort, 2004). While stylistic choice is not often considered a manipulation, the pictorial style Curtis employed imbues his images with emotional significance and detracts from their uses as scientific documents (Rosenblum, 2008; Sontag, 1977; Vervoort, 2004). It is unlikely that the final photographic manipulation found in *The North American Indian* would have even been discovered if it were not the tireless and exhaustive Curtis scholars. Close analysis of photographs in both the volumes and folios reveals that certain clothing items appear again and again across disparate tribes and geographic areas (Griffiths, 2018; Lyman, 1982). Throughout Curtis's visual work, the same feather headdress and buckskin shirt is observable in several portraits from unrelated and distant tribes and is even worn by individuals whose tribal affiliations suggest that they did not wear such regalia (Griffiths, 2018; Lyman, 1982). Although this form of manipulation may be the most hidden, it is also the one most difficult to rectify when it comes to the ethical consideration of Curtis's work. Simply put, we have no way of knowing how often he changed the clothing of those he photographed. We can only identify the clothing props he likely carried with him by their repeated use in his published work. If an item of clothing was altered only once and this choice was never recorded in field notes, journals, or correspondence of Curtis or the rest of his team (which is likely), we have no way of knowing if an alteration occurred (Griffiths, 2018; Lyman, 1982). To varying degrees, these photographic manipulations can completely alter the way Curtis's photographs are interpreted by a lay viewer, historian, or a modern anthropologist. From post-production removal or additions of objects to pictorialist style and prop clothing, the only way we may ever begin to fully understand the extent to which Curtis engineered the Native

American image to fit popular Social Darwinist theory is through careful analysis of distinct and iconic images present in *The North American Indian*.

Despite these manipulations, Curtis considered himself to be a scientist who used photographs to document his findings, just as many scientists today use photography for the same purpose. In his own words, Curtis claimed that photography was one of "the greatest art sciences", a claim that is reflected in nearly all his work (Egan, 2006). There is much evidence of artistic interpretation in Curtis's photographs, despite his claims that his work was scientific. Although Curtis also claimed that photography was able to "stand by itself" as a scientific, evidentiary document, we know now that simply is not true (Sontag, 1977). Both the implicit and explicit bias of the way Curtis photographed Native American subjects has and continues to have ramifications on the way Native Americans are seen in society today, as well as how they see themselves. For this reason, further analysis of his most prodigious and polemic works is necessary to understand the role that scientific photography plays in how science is understood and transmitted to society at large. To do this, I will analyze *Lodge Interior -- Piegan (Inside a Piegan Lodge*), *The Vanishing Race -- Navaho*, and two photographs demonstrating Curtis's use of prop clothing: *Yellow Bull -- Nez Perce* and *Nez Perce Warrior*. A careful inspection of these works will help to elucidate the photographic manipulations made by Curtis, the impact of those manipulations on an artistic interpretation of the work, and the impact of those manipulations on an anthropological interpretation of the work. In doing so, it is my hope that Curtis and his work can act as a case study, illustrating the importance of ethical photography and its use as a scientific, documentary element. Curtis is an example of how simple misuses of photography in science, that may seem insignificant to the researcher at the time, can have calamitous and far-reaching impacts on the way research is interpreted and incorporated in mainstream society.

Lodge Interior -- Piegan (Inside a Piegan Lodge)

Any analysis of Curtis work would be remiss in failing to analyze the well-publicized *Lodge Interior* photogravure. It has gained considerable notoriety in recent years following the discovery of an original print showing a clock that was removed during the printmaking process. None of the published or publicized versions of this photograph included the clock (Figure 3, Figure 4). The unaltered print was submitted to the Library of Congress during routine copyright processing for *The North American Indian*, although it is unknown if this is the only print of its kind that exists (Figure 5)(Lindberg, 2018). Similarly, it is unknown whether the original glass plate negative survives, although this is unlikely. Curtis and his daughter destroyed nearly all the glass negatives created on or before 1919, after the rights to the negatives were won by his wife in a divorce settlement of that same year. The version showing three figures, with the clock removed, was included as a photographic plate facing page 18 of Volume VI under the name *Lodge Interior -- Piegan*, which is inscribed below the image on the plate itself (Figure 3). In folio VI, the same image is printed with a closer crop that excludes the leftmost woman and assumes the name *Inside a Piegan Lodge.* The woman is not named in the figure description included with the folio or accompanying volume and the clock has again been removed (Figure 4). All three prints of the image are dated 1911, the published versions being printed by John Andrews & Sons (Figure 3, Figure 4). The unaltered print, which includes the clock and all three figures, is not thought to be part of any known publication or collection and its printmaker is unknown (Figure 5) (Lindberg, 2018).

While the clock removal in *Lodge Interior* is the most researched and discussed alteration to the photograph, three other edits are visible when comparing the published plate, folio print, and copyright proof. Some edits are more stylistic and others may have a more directed function in the Social Darwinist image of Native America Curtis often created. The most obvious edit, aside from the clock removal, is the close crop observed in Figure 4 that excludes the unnamed woman on the left. Additionally, a halo is seen around Yellow Kidney's head (male, left) in the volume and folio prints that is not observed in the copyright proof (Figure 4). This is likely evidence of a photographic manipulation technique known as 'dodge and burn', where certain areas of a print are exposed longer (burn) or shorter (dodge) than the rest of the image to darken or lighten that area, respectively (Blacklow, 2000). Finally, a review of the copyright proof also reveals a name on an unidentified cloth roll that hangs above Yellow Kidney. The roll is printed with, presumably, a name, is most legible only in the copyright proof (Figure 5). In the published plate, the area is blurred and the lettering is no longer distinguishable (Figure 4). Each of these edits were created to serve different functions, with each impacting a visual or ethnographic interpretation of the images to differing degrees which require further inquiry.

Looking first at the *Lodge Interior--Piegan* plate published in Volume VI of *The North American Indian*, the composition leads the viewer's eye undeniably to the empty space between Yellow Kidney and Little Plume where the clock has been edited out. Slanted, rectilinear beadwork of the lodge and poles lining the lodge door direct the viewer to the space, drawing attention to the void. While we know that something *is* missing, it is likely Curtis's intentions for creating this negative space was likely guided by his Social Darwinist agenda. Looking at the closer crop included in the folio, it becomes perhaps more clear *what* message Curtis wanted to portray with that space (Figure 4). The description within the folio brings attention to the small, understated pipe in the space between the two men, which Curtis notes is a position of honor within the lodge(Figure 4 d). That said, the pipe is not readily noticeable and does not attract as much attention as the negative space itself. The composition of the folio print so favors the negative space that the lower part of the legs of each seated man is excluded from the frame. Moreover, the negative space centered in the composition emphasizes the metaphoric space between the younger generation (Yellow Kidney) and the older generation (Little Plume). It becomes evident Curtis is trying to illustrate an unbridgeable gap that exists between the current generation of Native Americans and the historical past of Native America. As a Social Darwinist, Curtis likely was illustrating the loss of cultural heritage that once bridged this gap, an inevitability to many Social Darwinists, like Curtis, in the early 20th century.

However, this hypothesis is only valid under the assumption that Native Americans are unable to react to change and incorporate Western culture with their own, in the same way as any other culture. An object produced by Western society, such as a clock, occupying a position of honor within the lodge would totally contradict such a hypothesis, both in the interpretation of an anthropologist or simply that of a keen viewer. Looking at the copyright proof, the same rectilinear beadwork and poles framing the doorway direct you to a clock seated in the position of honor between Little Plume and his son. Instead of being struck by empty space, the viewer's attention is focused on a fine piece of Western industry that would be an honored object in any Western home. The strong white of the clock face demands attention in an otherwise gray composition and visually, sits comfortably in the ample space left for it between the two men. Located at a traditional place of honor, as Curtis described the portal of the lodge, the viewer can see that there is, quite literally, a place for Western industry within the existing structure and dogma of Native American society and culture. Had the clock remained in the print, it would show a change in cultural identity as a response to Western industrialization that would totally reject any Social Darwinist hypotheses posited by Curtis. The thesis of the entirety of *The North American Indian* was that Native American customs and culture must be documented and recorded before it inevitably was overcome by ‘superior Western society’. The clock holding a place of honor in a Piegan (Blackfoot) lodge would serve as excellent evidence *contra* this thesis and the hypothesis that Social Darwinism would spell the obvious downfall of Native American society. The composition of the copyright proof directs the viewer specifically to this evidence, whether this was the intent of the subjects or the photographer is impossible to know. Whatever the case, the original image shows three proud figures, who are beginning to find balance between cultural heritage and change, just as we all must.

Although the visual and anthropological changes implied by the removal of the clock have been well-established, it is not the only change of its kind present in *Lodge Interior*. Looking at the published plate, a roll above Yellow Kidney’s head seems to be painted with an obscured, light-colored design. Perhaps something one may expect to reside in a Native American lodge at that time. Yet, close inspection of the copyright proof reveals that the light smudge was actually a name that appears to be ‘Gast’ or ‘Cast’ (Figure 5). It is unknown at this time if the name refers to a manufacturer or a familial surname, but it is clear that the name was intentionally edited to be illegible in the final, published print. The area was cropped out entirely from the folio version. Closer inspection of the lettering seen in the copyright proof suggests the letters are stenciled or machine printed, indicating the roll was likely an industrially produced item. By obscuring the lettering in post-production, Curtis has removed another piece of Western influence that would contradict his Social Darwinist hypothesis. An object produced by western industry not only would be indicative of plasticity in Native American cultural practices, but also inclusion in a colonial, industrial, marketplace. The labeled roll would serve to show how Native Americans could adapt to change in Curtis's time, thereby further disproving his thesis that Native culture would eventually perish in the face of Westernization. The seemingly small change of intentionally blurring and obscuring the lettering of the roll in facts wholly changes the value of *Lodge Interior* and removes any value it may have had as a scientific or ethnographic documentary element.

The remaining observable modifications to *Lodge Interior* include the cropped framing of the folio print that excludes the leftmost woman and the dodge-and-burn technique used on Yellow Kidney. Both are likely more aesthetic choices, as opposed to the directed, evidentiary modifications like removing the clock and the lettering on the hanging fabric roll. Firstly, a woman has been cropped out of the folio print, but is observed in the published plate and copyright proof. Upon review of the adjoining pages in Volume VI of *The North American Indian* and the figure description of Folio VI, as well as a careful review of existing literature on the subject, the woman's name is never indicated. It is difficult to say exactly why Curtis chose to include her within the volume, but exclude her from the folio. Curtis's career could be described as a constant tug-o-war between his more artistic, pictorialist, vision and his scientific, ethnographic documentary work. Although he never stated so overtly, the volumes seem to be a more scientific inquiry, but the folios are more artistic. Simply put, the volumes include histories, music from rituals, and a description of tribal mythology that accompanies his photographs, while the photographs stand alone in the folios. One is likely meant as a document, the other for visual appreciation. For this reason, it is possible that the woman was included in the volumes because she was present in the lodge, something Curtis wanted to document. However, when he created the more artistic folio print, he excluded her to create a more favorable visual composition.

Similarly, the dodge and burn scar is only clearly evident in the folio print, indicating the technique may have only been used to alter the exposure in this version. Again, it is possible that the choice to lighten the exposure of Yellow Kidney was purely stylistic. Judging from the copyright proof, his face and right side are darkly exposed, so choosing to dodge-and-burn his figure would improve detail and overall image clarity, creating a more dynamic and engaging image. To achieve this, the developer cuts out the region to be lightened from a test print and carefully and quickly moves this cutout over the area to be lightened during the exposure of the new print. This method blocks the light from exposing the paper in this region for some time, creating a lighter exposure in that area. The process is not exact and a developer who was not an expert may shake the cutout too widely, inadvertently lightening a wider area than intended, resulting in the dodge and burn scar seen in the print. Considering the dodge and burn scar is not evident in all prints made of the image and the difficulty of expertly executing the procedure itself, the scar is more likely a printing error than a stylistic choice (Blacklow, 2000; Northwestern University, 2003).

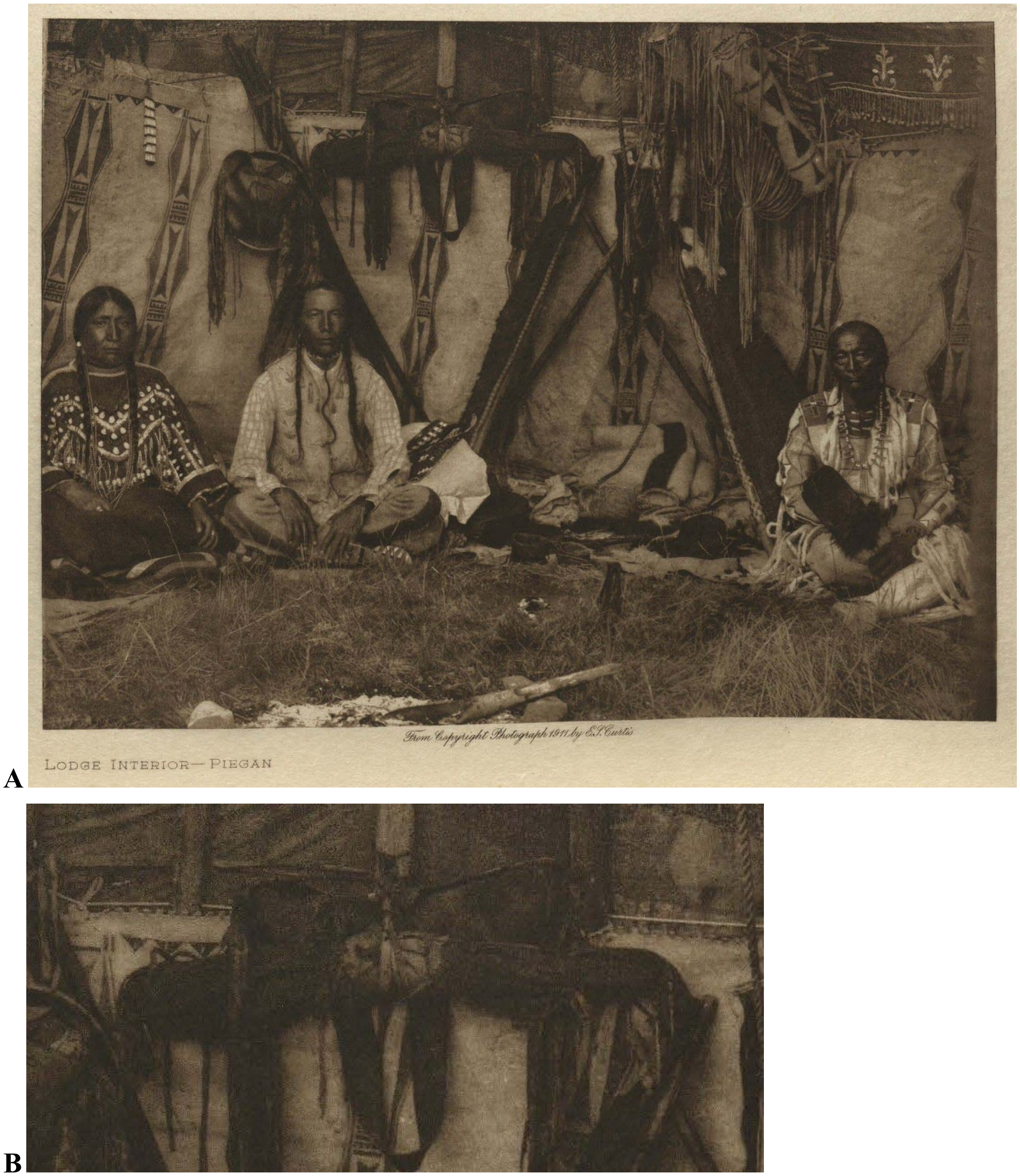
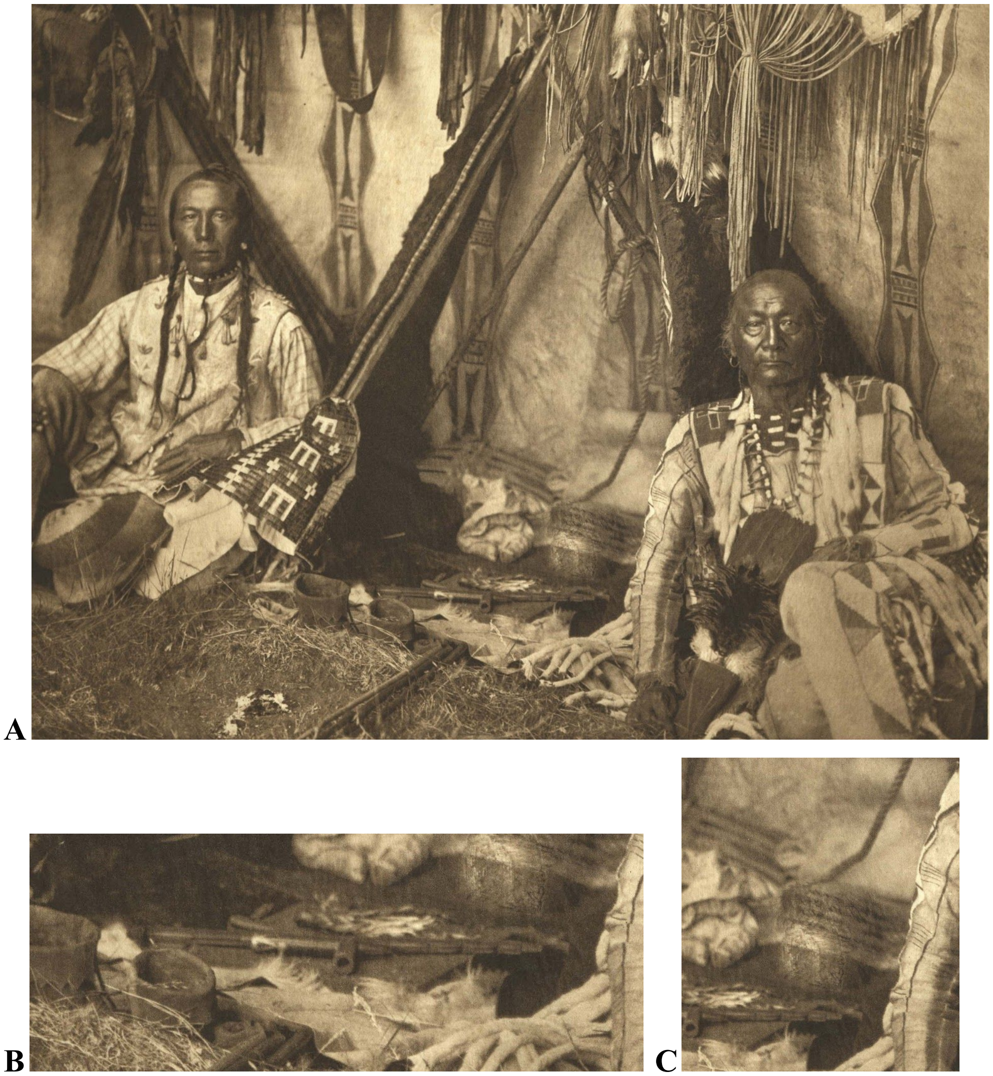
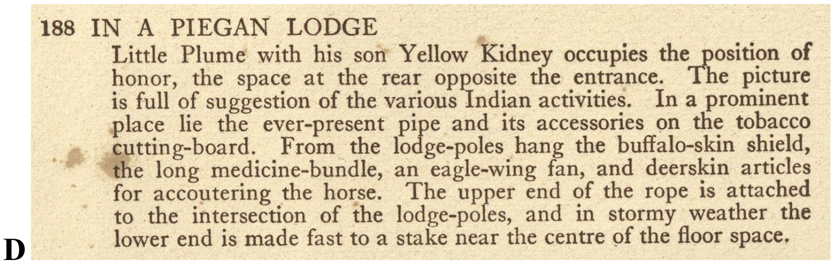


Figure 3. Full image (A) of *Lodge Interior - Piegan*, E.S Curtis, 1911 (Image courtesy of Dayton Memorial Library and Thomas J. Tracy Family Foundation Archives and Special Collections, Regis University 2019). Pictured (left to right): unnamed woman, Yellow Kidney, and Yellow Plume. Detail of fabric wrap with blurred lettering seen above Yellow Kidney (B).





188 IN A PIEGAN LODGE

Little Plume with his son Yellow Kidney occupies the position of honor, the space at the rear opposite the entrance. The picture is full of suggestion of the various Indian activities. In a prominent place lie the ever-present pipe and its accessories on the tobacco cutting-board. From the lodge-poles hang the buffalo-skin shield, the long medicine-bundle, an eagle-wing fan, and deerskin articles for accoutering the horse. The upper end of the rope is attached to the intersection of the lodge-poles, and in stormy weather the lower end is made fast to a stake near the centre of the floor space.

Figure 4. Full image (A) of *Inside a Piegan Lodge*, E.S. Curtis, 1911 (Image courtesy of Dayton Memorial Library and Thomas J. Tracy Family Foundation Archives and Special Collections, Regis University 2019). Detail of pipe located at position of honor within lodge (B). Detail of residual alarm clock removed during printmaking process (C) .

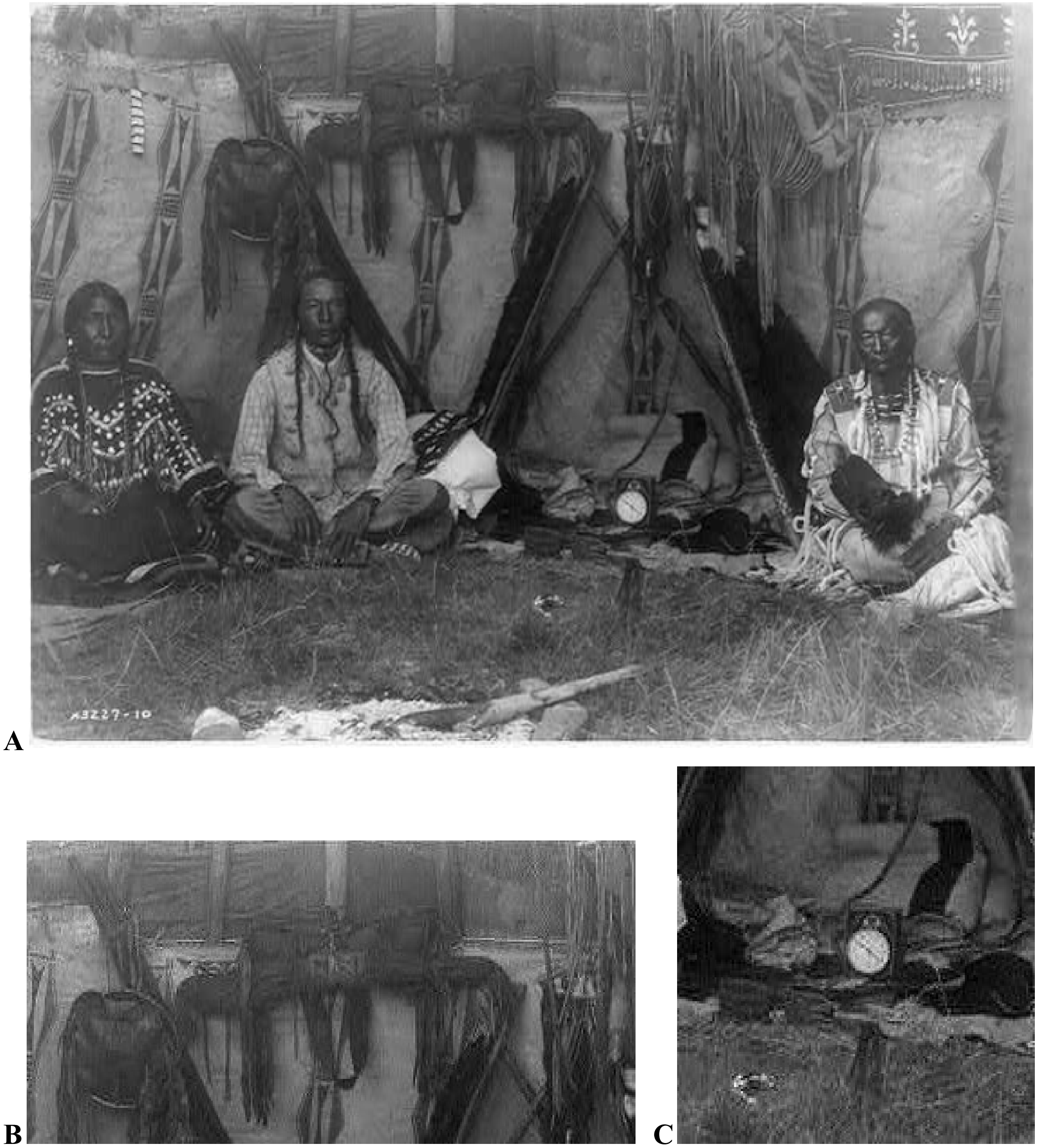


Figure 5. Full image (A) of *Lodge Interior - Piegan,* E.S. Curtis, 1911 (Photo courtesy of The Library of Congress). Detail of fabric roll above Yellow Kidney (B). Detail of alarm clock submitted to the Library of Congress that is not seen in versions printed for public or private collections (C).

The Vanishing Race - Navaho

Recently named one of the 100 most influential images of all time by *Time Magazine*, *The Vanishing Race - Navaho* is the first photographic plate in *The North American Indian* folios and is also, arguably, the most controversial (Figure 6)(The Editors of TIME, 2016). One of the reasons it remains so iconic is the strong, illustrative pictorialist style that Curtis employed when creating this photograph. In the early decades following its invention, society viewed the photograph as a medium of absolute truth, a truism that often held it back from being seen as an artistic medium (Sontag, 1977; Rosenblum, 2008). Early photographers like Edward Steichen and Alfred Stieglitz turned to painting and the artistic styles popular at the time as a model for how to elevate photographs to Art (Lyman, 1982; Rosenblum, 2008). Their use of fuzzy focus, diffused light, dramatic highlights and shadows, and evocative subject matter became known as pictorialism (Lyman, 1982; Rosenblum, 2008).

Curtis was perhaps unique in his time, however, because he believed that applying these pictorialist methods to his photographs would create images that were both truthful and scientific, as well as artistic. He could use the photograph to document what, to him, was the inevitability of 'Indian' cultures vanishing from the Earth and he could do it in an artistic way that attracted the attention and consideration of his audience. From this belief in the duality of photography *The Vanishing Race -- Navaho* was born and it has enjoyed immortality ever since (Gidley, 1998; Gidley, 2003; Lyman, 1982; Talahongva, 2014).

Pictorialist style permeates much of Curtis's work, but no photograph epitomizes the style and its effect on how Curtis photographs are interpreted quite as much as *The Vanishing Race - Navaho*. Stylistic choices are not as intuitive when one considers photographic manipulations, yet they can be the most impactful and lasting of all. From diffused light and fuzzy focus to stark contrast and obscured subject matter, what may have seemed small, artistic choices to Curtis have a lasting and understudied impact on the way his work was interpreted in his day and the way it is viewed now.

Likely the most striking compositional element in *The Vanishing Race - Navaho* is the prevalence of shadow. Some prints are darker than Curtis may have originally intended, as the acid paper used for the folio prints darkens with age. Yet, a dark exposure of the mountains and the sky, of the horses and their riders, was certainly directed by Curtis. The composition grows increasingly dark from foreground to background, where the end of the path being taken by the subjects is certainly an unknown void of shadow. Adding to the somber effect of dark contrast is the prominence of shadows cast by the horses on the path. They are elongated, as shadows are in the evening, and suggest that night approaches. Yet more darkness is in the subjects' future. Not only is the end of the day soon approaching, so is the end of the trail. It ends abruptly near the center of the photograph leaving nothing but the dark mountain before it. The ending trail, elongated shadows signaling the arrival of night, and the dark exposure all work to imply to the viewer that something other than the trail is ending, also.

Even though the title of the photograph tells the viewer that the subject is the Navajo people, his pictorialist technique obscures the identity of the subjects in the photograph itself - another paradox. The people on horseback face away from the camera with not a single face to reveal an individual's identity. All figures are draped in heavy woolen blankets or clothing, concealing the age and sex of who is pictured. We do not know who the subjects of the photograph are or even who is male or female, young or old. The anonymity of the subjects is compounded by Curtis's use of fuzzy focus. The scenery is ambiguous, divorcing the image from any sense of a real place. Surrounding the mountain or hill that dominates the background is a sort of inverse shadow - a halo of light. Not commonly used today, light shadows were common in Byzantine art beginning in 400 CE. In the triumphal arch mosaics like *Adoration of the Magi* of Santa Maria Maggiore (432-450CE), shadows of light are cast by the angels, a feature common of holy objects portrayed in early Byzantine art (Figure 7)(Harley-McGowan & McGowan, 2016). The light shadow serves to signify their separation from anything Earthly or familiar because, of course, light shadows do not exist in our reality. How Curtis achieved the light shadow effect around the mountain is unknown, but it may be that it served the same function as the light shadows common in Byzantine art. The mountain is no Earthly place, but rather some celestial or unknown realm. The unknown riders, should they continue to follow the path, are traveling directly to this unknown, dark, and mysterious place.

The viewer may not know the identity of the subjects, but Curtis does not leave one to think the subject could simply be *anyone*. Certain identifiable, albeit stereotypical, features are still observable. Long hair and bare heads would have been instantly recognized by any viewer in the 1900's as 'Indians', if the 'Navaho' name in the title was not sufficient. Further suggestions are made by the very nature of a group traveling totally on horseback with no caravan of belongings. Any white, Western settlers would have had some type of wagon or saddle bag for possessions if they were traveling in a group to a new settlement. That said, there are not enough clues to know anything more specifically about the subjects. Even though the title suggests the subjects were 'Navaho', such tribal affiliations would have held little significance for the early 20th century viewer. Curtis's audience would have only understood the word to mean the subjects were 'Indian'. The intent of this image would have been as clear to such a viewer as it is to viewers today. The future of Native Americans is both dark and uncertain and their passing into the annals of history is assured.

Unlike most art, interpretation of Curtis's intent need not be solely confined to visual analysis. Curtis included a description of *The Vanishing Race - Navaho* photogravure which makes his message unquestionable (Figure 6 b). He says plainly that, "The thought which this picture is meant to convey is that the Indians as a race...are passing into the darkness of an unknown future," leaving little to his audience's imagination as to his purpose in creating both *The Vanishing Race - Navaho* and *The*

North American Indian as a whole (Curtis, 1907; Egan, 2006). We see this message hammered home time and again in his photographic stylistic choices. The fuzzy focus and dark exposure that obscure the identity of both subject and landscape establish the notion that these could be any ‘Indian’ anywhere in the country. The dark shadows at the end of the literal path easily invoke notions of a dark future at the end of the metaphorical path on which the people travel. Finally, the mysterious light shadow so frequently used in Byzantine art is employed by Curtis to highlight that the mountain that lies beyond the path is mysterious and unknown, just like the unknown future he believes lies ahead of the Native American people. That said, Curtis was far from alone in this belief. A news article that appeared in *New York Times* in 1911 heralds Curtis’s work as a noble effort to capture that “fast vanishing race” by creating a “perfect record” through photographs. This iconic image was clearly successful in contributing to a growing sense that Native America is destined for extinction, as it was unable to withstand disease epidemics, famine, intentional cultural destruction, and massacres that were inflicted on Native American communities by the U.S. government and society at the time *The North American Indian* was published (Beck, 2001; Lyman, 1982).

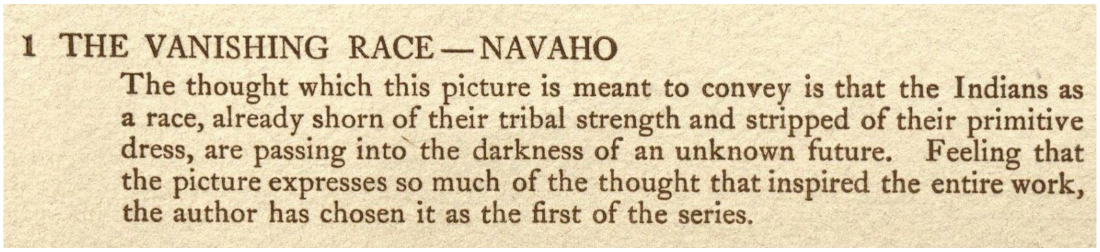
If *The Vanishing Race - Navaho* was an image that lived out the entirety of its fame in the early 1900’s it is unlikely it would be subject to academic and social debate today. Such an image would have been classified with countless other stereotypical ‘Indian’ iconographies that was common at the time, such as cigar store Indians and Wild

West sideshow props, and would have been dismissed just as easily in the present. A misguided product of its time. Yet, the photograph persists, thus demanding our continued analysis and interest. Such analyses have raised pertinent questions both about what this photograph seeks to convey and what it seeks to conceal. Curtis's pictorialist style was so effective in illustrating Social Darwinist views popular during his time that his work still fuels the flames of stereotype in Native America today. Photographs such as *The Vanishing Race - Navaho* effectively portray 'Indians' as a race of people whose decline was inevitable, rather than orchestrated by society, and credits what was seen as archaic and outdated social practice and community structures as the impetus for such decline. None of these photographs pointed their focus on what was more likely the cause of the observed decline in Native American society: government outlaw of rituals and language, massacres and genocidal campaigns, poor sanitation conditions, and government seizure of lands (Beck, 2001; Gidley, 1998; Gidley, 2003).

Photographic misrepresentation is but one of the numerous contentious topics surrounding Curtis's work. For someone who considered himself an ethnographer, a lack of photographic documentation of issues causing the decline in Native American societies would be a serious oversight by today's ethnographic practices.Instead, Curtis focused on generalities and only stylistically alluded to the downfall of Native American society through pictorialist photographs that avoided the hardships being faced throughout Native America. Such photographs hold little scientific value, as they do more to illuminate the perspectives of the white community on Native Americans than they do to illuminate the realities of Native American life and the cultural genocide being waged against them. His use of fuzzy focus, dramatic shadow and contrast, and light shadow in *The Vanishing Race - Navaho* may not be easily recognized as photographic manipulations because they pertain to *how* the photograph was taken, rather than anything added or removed from it. Yet, the way in which Curtis took his photographs was often the most misdirecting of his manipulations and remains one of the most difficult obstacles to interpreting Curtis photographs with any impartiality today.

A

B



1 THE VANISHING RACE—NAVAHO

The thought which this picture is meant to convey is that the Indians as a race, already shorn of their tribal strength and stripped of their primitive dress, are passing into the darkness of an unknown future. Feeling that the picture expresses so much of the thought that inspired the entire work, the author has chosen it as the first of the series.

Figure 6. (A) *The Vanishing Race - Navaho*, E.S. Curtis 1904. (B) Folio description of *The Vanishing Race - Navaho* (Images courtesy of Dayton Memorial Library and Thomas J. Tracy Family Foundation Archives and Special Collections, Regis University 2019).

<u>Figure 7.</u> *Adoration of the Magi* (ca. 435CE), Church of Santa Maria Maggiore. Image courtesy of Harley-McGowan & McGowan (2016).

Yellow Bull - Nez Perce & Nez Perce Warrior

Only through diligent scholarship and review of photographs included in *The North American Indian* has it become evident that Curtis added objects to his photographs, as well as removed and stylized them (Griffiths, 2018; Lyman, 1982; Zamir, 2008). Known as 'salvage ethnography,' many ethnographers like Curtis in the early 20th century would direct the clothing and ceremony of their subjects with the aim of showing cultural practices of Native Americans before the coming of the White Man (Gidley, 2003; Stoll, 2003; Zamir, 2007). While some of these 'salvage ethnographic' modifications were noted by Curtis, many were not (Stoll, 2003). It is only through rigorous comparisons of his photographs that the number of prop clothing items used by Curtis becomes evident (Griffiths, 2018; Lyman, 1982; Zamir, 2008). From buffalo skin shirts to feather headdresses, numerous Curtis portraits show the same clothing and ceremonial items being worn by a variety of people across geographically distant tribes (Gidley, 2003; Griffiths, 2018; Lyman, 1982). Only one of many examples, the same feather headdress is worn by two men pictured in *Yellow Bull - Nez Perce* and *Nez Perce Warrior* included in Folio VIII of *The North American Indian* (Figure 8) (Lyman, 1982).

Any modern scientist would likely balk at the principles underlying salvage ethnography, as the best scientific, anthropological practice today involves as little outside interference as possible. In Curtis's time, however, white society viewed cultural integration as base, favoring images of 'pure Indian' cultural practices, whether or not such practices were actually taking place (Gidley, 1998). To his audience, Curtis was elevating Native American culture to its former glory by adorning subjects in *Yellow Bull - Nez Perce* and *Nez Perce Warrior* with feather headdresses that had come to be synonymous with the Native American stereotype (Figure 8) (Beck, 2001; Gidley, 1998). The casual observer was not likely to notice that both men wear the same war bonnet and fewer still would know that each man's war bonnet was unique to his accomplishments in Nez Perce traditions and was not shared with anyone until that man died (James, 1996; Thompson, 2000). For them, the intrigue did not lie in Nez Perce or Native American culture, but rather in the oddity of the Exotic Other who wore tall feather headdresses that shrouded 'the Indian' in a mystery more important to them than the truth (Beck, 2001; Beck, 2016). Curtis understood on some level that the economic success of his ventures was contingent upon this reaction and played into creating the image that his audience had come to expect through the use of prop items like war bonnets and buffalo shirts. We may never know if Curtis saw these changes as necessary sacrifices of scientific accuracy or justifiable modifications of salvage ethnography.

Although it is undeniable that some of the clothing and ceremonial items worn by Curtis's subjects are props provided by Curtis himself, native agency in choosing to wear prop items, should not be overlooked. In a time when government policy outlawed Native American religious rites and sanctioned cultural genocide, many Native Americans were experimenting with new ways to define and cement identity. A translator with the Curtis expedition, Alexander B. Upshaw spent the majority of his life in the Carlisle Indian School (Zamir, 2007). Before graduating, he worked on the school newspaper writing articles maligning the savagery of Native American cultures, despite being an Apsaroke (Crow) himself. An early portrait taken in 1898 by a member of the Curtis expedition shows Upshaw with short, slick hair and typical Victorian clothing (Figure 9 a) (Lyman, 1982; Zamir, 2007). Another photograph of Upshaw taken in 1905 and printed in Folio IV, the portrait *Upshaw - Apsaroke* shows him bare-chested and wearing beaded necklaces with a feather headdress (Figure 9 b) (Zamir, 2007). It is unlikely that Upshaw was directed to wear these items, given his previous public statements about refusing to wear prop clothing for photographs (Zamir, 2007). Moreover, Curtis's son Harold journaled that Upshaw was a man whose "pride of race oozed from every pore," a sentiment mirrored by the strong man in Apsaroke regalia in the portrait (Figure 9 b) (Gidley, 2003; Zamir, 2007). The very title is suggestive of Upshaw's change in mindset, the hyphen aligning the man with the cultural identity he once rejected. We may never know if the items worn by Upshaw were props provided by Curtis, but we can be reasonably sure that it was Upshaw who decided to be photographed with war bonnet and necklaces. Upshaw may not have owned traditional Apsaroke items and could have chosen to wear prop items that he felt represented the cultural identity he was trying to embrace. There are no records to suggest whether the men in *Yellow Bull - Nez Perce* or *Nez Perce Warrior* were wearing a prop war bonnet at the direction of Curtis, but the case of A.B. Upshaw presents a compelling argument as to why Native American subjects might elect to wear prop items like those in Figure 8. More importantly, his case serves as an important reminder not to neglect native agency when considering the use of prop items in Curtis photographs.

In its own way, the use of prop items evident in photographs from *The North American Indian* is the most nefarious of the many manipulations Curtis employed. It undermines any scientific value his work may have maintained simply because we cannot know how prevalent his use of prop items really was. We only know about the use of certain props because they appear in more than one portrait, and there is no way to know whether other items were props that were simply worn only once. Knowing that Curtis was not opposed to providing props or directing his subjects about what to wear means we cannot say for certain how frequently this occurred and how many of his photographs these choices affected.

To a contemporary audience, the addition of prop items is an obvious violation of best practice with regard to using photographs as scientific documentary elements. His manipulations were significant, undocumented, and untraceable. Yet, for someone like Curtis working under the commonly-accepted principles of salvage ethnography, such additions would not only be commonplace, but ethically permissible. Moreover, native agency and the choice to wear prop items to reclaim cultural heritage should also not be overlooked. The crux of the issue lies in the moral ambiguity and fluid boundaries that lie between documentary and artistic photographic choices that, when crossed, can render a photograph incapable of being viewed as scientific. Claiming to scientifically analyze people and their cultures through photographs, as Curtis did, only heightens the risk that a photograph could not only be created in an unscientific way, but in a way detrimental to the very culture one is trying to understand. Curtis believed that the artistry with which he created his photographs would help disseminate his work to a wider audience. Unfortunately for him, he was right. Perhaps unwittingly, his photographs grew so popular they became the base from which many modern stereotypes about Native America would grow.

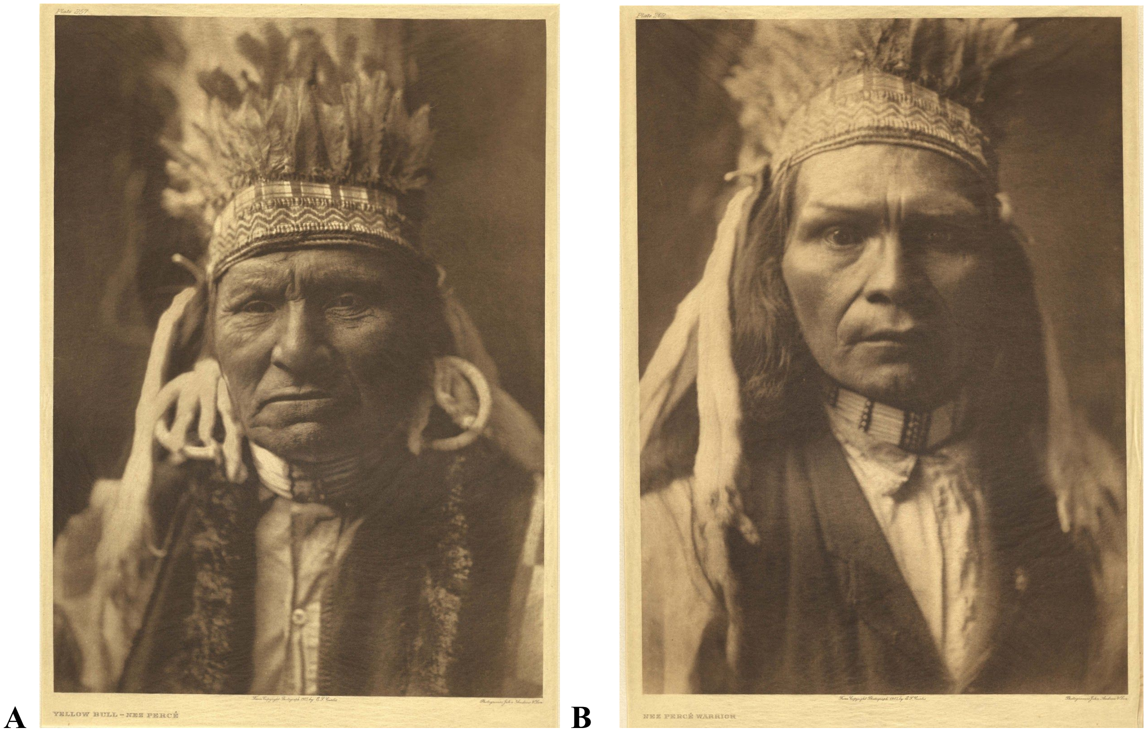


Figure 8. (A) *Yellow Bull - Nez Perce* (1905) (B) *Nez Perce Warrior* (1905). Note the same feathered headdress is worn by both men. (Image courtesy of Dayton Memorial Library and Thomas J. Tracy Family Foundation Archives and Special Collections, Regis University 2019).

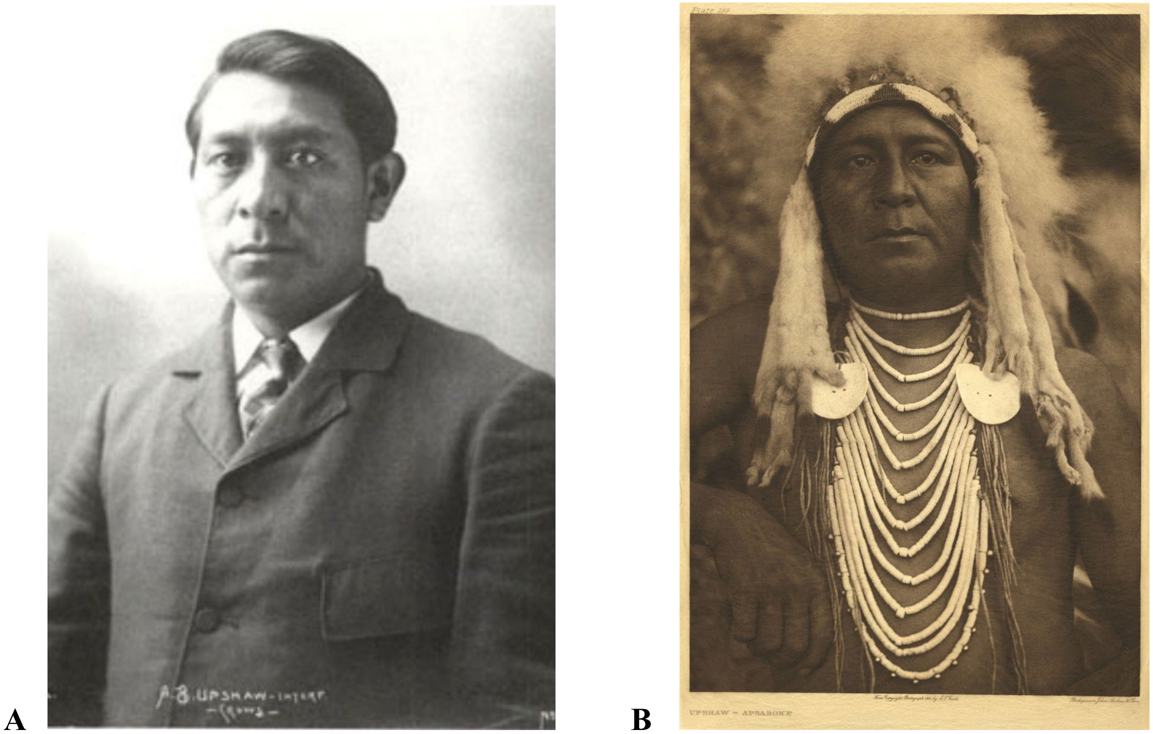


Figure 9. (A) *A.B. Upshaw* (1898) (B): *Upshaw - Apsaroke* (1905). Alexander B. Upshaw, translator and photographic assistant to the Curtis expedition team, is pictured in both images. (*A.B. Upshaw* courtesy of Zamir (2007), *Upshaw - Apsaroke* courtesy of Dayton Memorial Library and Thomas J. Tracy Family Foundation Archives and Special Collections, Regis University 2019).

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IV. Ethical usage of photography in scientific literature and lessons from a misguided ethnographer

Part I: Existing Ethical Guidelines for Photographs in Science

The photograph has long been used in science to collect data, document findings, and disseminate research. From making measurements to creating figures used in publications, the scientific community is dependent on the photograph. Readers who want a quick idea of a research project's findings will glance at the photographs and figures before anything else. What that glance may not reveal, however, are the details of how the photograph was constructed. Small changes to photographs to improve their clarity or visual appeal are not only common, but often required by journals that only want to publish the most attractive figures. It can be difficult to know, however, which of these changes impact the way a viewer interprets the photograph and its contents. The work of Edward Curtis suggests that we can be reasonably sure that some of these photo-manipulations will misrepresent the data they claim to represent. Curtis is a prime example of how a scientist can make small changes to a documentary photograph that result in dramatic misrepresentations of reality and the long-term consequences that misrepresented data can have on society. Considering the prevalence of photographs in science today, the importance of developing ethical guidelines and instituting regulations for the proper use of photography in science cannot be denied.

The foundational concept of peer review in science provides an existing structure for accountability, especially when it comes to the efficacy of documentation in publications. Any article submitted and published in a journal is subject to the scrutiny of a panel of experts and other researchers selected by the journal. Reviewers read submitted articles, deciding whether the data produced is consistent with the outlined method and whether the findings described by the author are corroborated by the data. The critical assumption associated with this process is that all modified or falsified data are detectable to those reviewers. In an age where digital manipulation has become widely accessible, this assumption may not always be true. For photographs used in scientific literature, it can be impossible for a reviewer to distinguish edits made by the authors without comparison to an original, unedited version. Despite the long history of photographs being used in science, few journals outline their proper use to the same degree they discuss the proper use of other documentary elements (CellPress, 2018; Journal of Fish Biology, 2011; Journal of Morphology, 2018). Antithetically, few journals will accept totally unedited photographs because they do not highlight the point being made or are not aesthetically pleasing. With few discrete regulations in place to differentiate aesthetic modifications and impermissible modifications that influence what the photograph aims to document, authors walk an uncertain path.

As would be expected of a journal with one of the highest impact factors in biology, *Cell* has some of the most clear and stringent regulations on photographic manipulation. The online submission requirements state that any omissions, removals, or modifications should be noted in either the methods or the figure legend (CellPress, 2018). Furthermore, all changes must be applied to the entirety of the photograph, rather than any single component. If this is not possible, component modifications must be clearly explained within the article. To ensure compliance, *Cell* screens all photographs for “image irregularities,” although they do not characterize what is considered an ‘irregularity’ (CellPress, 2018). Should any inconsistencies be detected, *Cell* asks that authors submit unaltered originals and a full description of steps taken to create the figures in question (CellPress, 2018). While these regulations may seem tedious to some, they provide clear expectations for authors in order to prevent both intentional and unintentional misuses of photography.

The research presented in the first chapter of this thesis was submitted to the *Journal of Morphology* which utilizes the guidelines and regulations of both the Wiley Online Library, who publishes the journal, and the Committee on Publication Ethics. As with all journals, they require that all data and subsequent representations be reported in a clear manner and presented with all due transparency (Journal of Morphology, 2018; Wiley Online Library, 2018). Similar to *Cell*, the peer review process maintains photograph compliance with publisher guidelines regarding photographs (Wiley Online Library, 2018). It is up to the reviewers to ensure transparency of photo-manipulation and credibility data collected *via* photographs. Any published photographs or other forms of documentation that are found to misrepresent data may be subject to removal from print (Wiley Online Library, 2018). This process prevents altered photographs from going to print, but it does little to help the researchers avoid creating misleading photographs.

Knowing the photo-manipulations that would lead reviewers to bar a paper from publication would prevent authors from submitting such images in the first place. More importantly, publisher transparency would begin a conversation about ethical use of photographs in science and generate an awareness of the ethical implications of misleading photographs.

Part II: Photographs as Documentation and Dissemination

Photographs of histological sections were used in the first chapter of this thesis to document the light organ structure of two bioluminescent species of glowbellies. Images of several sections were included to better illustrate to the reader what the light organ structure from anterior to posterior. Not all of the tissue samples could be included in the publication, obviously, as hundreds of sections were prepared and more were discarded before ever being placed on a slide and stained. Only the sections that best represented key features of the light organ were retained for the publication. After being photographed, Photoshop CC 2018 was used to remove dust particles and tissue fragments, as well as to adjust the color saturation and brightness of the images. Modifications ensured the figures included in the paper were visually appealing, but also easy to interpret. Increasing blue color saturation in the images mirrored the intensity of the blue stain as viewed through the microscope and compensated for color lost as a result of the camera being used. Similarly, increasing brightness helped to define detail in the image, so that tissues in the sample were as easy to differentiate in the photo as they were through the microscope.

Photo-manipulations used to prepare images in the first chapter for use in this thesis and the associated publication follow the guidelines and regulations of both the *Journal of Morphology* (where the article was submitted) and the Wiley Online Library that publishes the journal. In accordance with outlined guidelines from the *Journal of Morphology*, changes in color saturation and brightness were applied across the whole image (CoP, 2018; Journal of Morphology, 2018). Dust and tissue debris was only removed from the white spaces around the tissue samples, not the tissue itself. These changes were obviously not image-wide but they did not affect the portion of the image documenting tissue histology. Following peer review, it was determined that none of these changes impacted the way the images were interpreted and they were successfully published in October of 2018. Using *Cell* as an example of more stringent guidelines for scientific publication, the changes made to images in the first chapter are still acceptable, but should have been documented in the supplemental information (CellPress, 2018). For the sake of brevity, however, only information required by the publication was included and the photo-manipulations were not described. It should also be noted that the choice of which tissue sections to process and which to photograph is a visual manipulation itself from the original data. Unfortunately, the inherent bias in this choice is unavoidable. It would take hundreds of samples and thousands of photographs to document a whole tissue specimen. Even with the advent of online databases, sharing all this work would not be feasible or realistic. However, the samples photographed were representative of those analyzed and indicative of the light organ structure described in my thesis.

As a future scientist, developing a reputation of integrity is paramount to my vocation. Whether or not regulations on photo-manipulation were present in the journal where my work was submitted, I would have given careful consideration to every change I made to photographs that claim to be documentary. In my opinion, any photograph that claims to be documentary cannot be manipulated or distorted in ways that direct the viewer to a specific conclusion not in the original image. A documentary photograph should speak for itself, letting the viewer draw his or her own conclusions about the data it contains.Changes to color saturation and brightness reflected my direct observations and corrected camera deficiencies. These were, therefore, acceptable choices in accordance with my own ethics. Post-production manipulation was necessary to compensate for the limitations posed by the photographic equipment. Manipulations, in this instance, were necessary to create photographs that were representative of what was seen through the microscope. Removing distracting blemishes from the photographs likely did not manipulate the way a viewer would interpret my work; only dust and tissue debris found in the space around the tissue sample was removed. After careful consideration of these changes, I was comfortable presenting them as evidence that truthfully reflected my research findings.

Part III: Photograph as Method

In the second chapter of this thesis, photographs played an integral role in the data collection process. By photographing stomach contents removed from specimens, I was able to use computer software to measure dimensions and areas of prey items in order to calculate an estimate of the volume of each prey item. These photographs were not altered or manipulated in any way, as the aesthetic appeal of the images was not important to their use. It would have taken unnecessary time and effort to change aspects, such as color or contrast, that have no impact on the way prey items were measured. Calculated proportions of diet volume of each prey type were represented in Figure 2 of Chapter 2, but the photographs used to calculate these numbers were not. Because these images are not subject to the audience's scrutiny, there is minimal outside accountability safeguarding against their misuse. The integrity of my work and the ethics of my research collaborators are all that certify that these images were used truthfully for data collection.

Methodology photographs present a greater potential for photographic bias than photographs edited and presented as documentation. Photographs used in the data collection process are not presented to the reader for analysis, so there is no way to determine what the author has done to the photographs or how they have been used. Any changes made by the authors are not observable by the audience or even to peer reviewers, unless the original images are requested. Neither the *Journal of Morphology* or

Cell, whose guidelines were explored previously, mention any author submission or peer review guidelines about the use of photographs in methodology or how the uses of such photographs should be validated. The research conducted in Chapter Two will be submitted to the *Journal of Fish Biology*, which is also published by the Wiley Online Library. Neither the WOL nor the *Journal of Fish Biology* detail the proper use of methodological photographs, although proper reporting of statistics and results produced by any data collection means are explained (COPE, 2016; Journal of Fish Biology, 2011). Authors must outline the statistical methods used and justify their use in relation to the data analyzed by citing relevant sources (Journal of Fish Biology, 2011). Both of these conditions were met in the second chapter, which cited other diet studies that used photographs, computer software, and mathematical models to estimate prey volume. Citing other papers with similar protocols for using photographs in research methodology helps justify their use even if publication guidelines provided by the journal do not explicitly suggest to do so.

As with any data collection, the honesty, accuracy, and precision of the researcher are imperative to the proper use of photographs for data collection and calculation. I kept this in mind for every measurement and estimation I collected when gathering data for the second chapter of this thesis. I developed a stepwise system for taking every photograph and followed the same procedure for each measurement made using the computer software in order to provide precise data. Measurements were taken with the greatest possible care so that estimates of prey volumes were as accurate as possible. Most importantly, I did my best to reflect the data as impartially and as truthfully as possible. Dishonesty would not only discredit me as a researcher, but would not provide data to actually answer my research questions. It is more important to me, personally, to *understand* more about the diet of glowbellies than it is to support my hypothesis. Of course, there are always implicit biases when observations are made. However, I tried to remain aware of any bias within my methodology or reasoning and adjust my protocols to mitigate it. Despite never being subjected to the scrutiny of an audience, my photographs I used to collect and analyze data were ethically used to the best of my estimation.

Part IV: Photograph as Documentation, Dissemination, and Art

Edward Curtis not only believed that his photographs served as scientific documentation, but that creating artistic photographs could help disseminate his work. Unfortunately for him, he was right. Where most ethnographic publications stayed within academia, Curtis's work gained national fame and can easily be found in the present. One cannot visit a mountain town in the West without seeing a Curtis photograph emblazoned on gift shop curios. Curtis was only one of many ethnographers in the early 20th century who published work that suggested Native Americans were inherently predisposed to extinction, but the beauty of the photographs that he produced has guaranteed that he is the one we remember. Despite changing what we now know to be vital details in his work, stylizing his images, or using prop items to dress up his subjects, Curtis viewed his photographs as documents that truthfully represented his observations about Native America. Like any researcher, Curtis wished to disseminate these findings as widely as possible, which he accomplished through artistic photographic styles like pictorialism. While we now know that his work did not document observations as truthfully as would be expected of a modern ethnographer, his success in using artistic style to disseminate his work is undeniable.

The key danger in manipulating and using photographs lies in the ambiguous separation between aesthetic and art. An aesthetic manipulation may make a photograph more visually appealing, but does not modify the significance of what that photograph seeks to convey. Small edits to remove distracting errors in the photograph itself, enhancing color, or modifying brightness to make the photograph more engaging are often aesthetic modifications. Art, on the contrary, orchestrates the arrangement of real objects in order to create a visual statement. In art, the manipulations *become* the evidence, rather than being alterations to how the evidence is shown. It is the manipulations that tell the viewer what the artist wants them to know, not the underlying objects in the image itself. In these terms, aesthetic and artistic choices seems clearly divided; aesthetic being changes compatible with a scientific goal of conveying facts and art creating 'facts' to be interpreted in order to express the artist's opinion. The designation of what changes are considered aesthetic and which are artistic, however, are highly dependent on the opinion and ethics of who is making the changes. What one person may call an aesthetic change that only works to improve the visual appeal of an image, not modify its significance, another may call an artistic choice that reflects the creator's own opinion.

Curtis illustrates this time and again, making changes that he likely would have considered aesthetic, that we now know to be artistic choices that direct viewers to draw conclusions. He would have seen the alarm clock removed from *Lodge Interior* to be an aesthetic choice that simply improved the visual appeal of the photo. He knew his audience wanted to see Native Americans as exotic, mysterious Others that existed only in the past. Removing a contemporary object like an alarm clock, in this context, prevents the viewer from fixating on an object Curtis felt did not belong. Now, we know Curtis acted more as an artist in removing this object, supporting Social Darwinist conclusions about Native American society that the original image would not have supported. It is likely that even Curtis would admit the pictorialist style of *The Vanishing Race* was a more artistic than aesthetic choice; the diffused light and fuzzy focus suggesting to viewers more about Curtis's own ideas about Native Americans than anything about the Native Americans themselves. He may have used more artistic licence to convey this message, but he believed the message itself was evident to an audience that supported the scientific fact of Social Darwinism. In the moment, it can often seem clear whether a photographic manipulation is aesthetic or artistic, but hindsight may ultimately contradict that initial classification.

Curtis was not the only 20th century scientist to be led astray by pseudoscience. What makes him worth discussion nearly 100 years later is the prevalence of his photographs in modern culture and his focus on human subjects in his work. Both factors in combination frequently result in fierce defense or condemnation of his photographs (Beck, 2001; Lyman, 1982; Pritzker, 1993). For all his failures in truthfully documenting his subjects in a scientific manner, Curtis excelled in disseminating his work. He may not have sold many copies of *The North American Indian* in his lifetime, but his works were impactful and have not been forgotten. Curtis photographs are so ingrained in the Western American identity that I would be surprised if his work is ever truly forgotten. All that aside, we would not be talking about his work if Curtis turned his camera lens toward anything other than people or culture. Manipulations of any variety, aesthetic or artistic, are less forgivable when they shape the way we view an individual or a group of people. Alterations made to photographs that claim to document a culture or how someone identifies themselves must be exponentially more conscientious to do so in a way that could promote social justice. The photograph, by its very nature, is an implement of perspective. It suggests truth and conceals bias, making use with cultural subjects intrinsically complicated.

Part V: Suggestions for Ethical Photography

Science will not soon be free of its dependence on the photograph. Yet, the photograph - edited or not - is an inherently biased tool that can impact the way data are collected, documented, and disseminated to a wider audience. Considering the importance and the risks associated with using photographs in science, it is crucial that more robust guidelines are developed for photographs used in scientific literature. Disclosure of photographic manipulations and consistency in ethical guidelines between publishers can help the research of today remain usable in the future, as well as help authors utilize, rather than abuse the photograph.

One of the greatest difficulties in bringing Curtis's work into the present context lies in the uncertainty about what manipulations, and the biases they create, exist within his photographs. This concern is applicable anytime research is viewed through a modern lens. A way to address this would be to fully document any and all photo-manipulations within the methods or supplemental information section that accompanies scientific publications. Should information arise in the future that suggests these manipulations interfered with what the photographs documented, the editing procedure outlined in the methods or supplemental information would help readers in the future determine if the work can still be used. Had Curtis documented all the changes he made to his work, readers today could make more conclusive decisions about his bias and the proper uses of his photographs. Full disclosure of edits made to photographs used to document and disseminate research would allow the reader to decide if the edits influenced the data or were merely aesthetic modifications.

Photographs used in research methodology can be more easily integrated into the peer review process with the advent of cloud sharing. It may have previously been impossible to share what may be hundreds of photographs used during data collection, but online databases for authors to deposit photographs and reviewers to access them can now allow photographs to be integrated into the peer review and publication process. It would be impossible, nay unconscionable, to require peer reviewers to analyze all the submitted photographs. Instead, random selection of a small number of photographs for review of accuracy and precision of measurements would ensure authors use photographs ethically in their methodology, but also maintain a reasonable turnover time for the peer review process. Incorporating technology, such as cloud storage, at the review stage would widen the scope and capability of what peer review is able analyze before an article is accepted for publication, giving greater credence to data and conclusions drawn from photographs used for data collection.

Consistency in ethical guidelines between publications regarding the use of photographs used to collect data or document findings would aid author compliance across journals. Perhaps more importantly, it would begin a conversation about the role photographs play in the way science is conducted and how it is understood by a wider audience. Nearly every scientist is aware of the dangers of data manipulation and falsification of results, but few stop to consider how manipulating photographs may inadvertently play a role in creating and spreading misinformation. To the casual observer, the photograph is an implement of truth. The principle underlying the photographic process entails light reflected off of objects in nominal space being captured my some mechanism, be that glass plates like Curtis used or digital receptors in a camera attached to a microscope like I used. Even in an age of rampant photo-manipulation, our first reaction to a photograph is to believe it. Seeing is believing, isn't it? However, this is exactly what makes photographs unwieldy tools within science. We believe what a photograph shows us more quickly than we are apt to believe other forms of documentation. Free of a healthy skepticism, we may not scrutinize photographs with the same eye we review other information that is presented to us. Until *seeing is questioning*, we as a scientific community have a duty to formulate guidelines for the ethical use of photographs to prevent their misuse and misrepresentation of data.

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