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Grizzly bear monitoring by the Heiltsuk people as a crucible for First Nation conservation practice

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ABSTRACT. Guided by deeply held cultural values, First Nations in Canada are rapidly regaining legal authority to manage natural resources. We present a research collaboration among academics, tribal government, provincial and federal government, resource managers, conservation practitioners, and community leaders supporting First Nation resource authority and stewardship. First, we present results from a molecular genetics study of grizzly bears inhabiting an important conservation area within the territory of the Heiltsuk First Nation in coastal British Columbia. Noninvasive hair sampling occurred between 2006 and 2009 in the Koeye watershed, a stronghold for grizzly bears, salmon, and Heiltsuk people. Molecular demographic analyses revealed a regionally significant population of bears, which congregate at the Koeye each salmon-spawning season. There was a minimum of 57 individual bears detected during the study period. Results also pointed to a larger than expected source geography for salmon-feeding bears in the study area (> 1000 km²), as well as early evidence of a declining trend in the bear population potentially explained by declining salmon numbers. Second, we demonstrate and discuss the power of integrating scientific research with a culturally appropriate research agenda developed by indigenous people. Guided explicitly by principles from *Gwi'ilas* or customary law, this research methodology is coupled with Heiltsuk culture, enabling results of applied conservation science to involve and resonate with tribal leadership in ways that have eluded previous scientific endeavors. In this context, we discuss the effectiveness of research partnerships that, from the outset, create both scientific programs and integrated communities of action that can implement change. We argue that indigenous resource management requires collaborative approaches like ours, in which science-based management is embedded within a socially and culturally appropriate context. We emerge not only with a set of guiding principles for resource management by the Heiltsuk, but a broadly applicable strategy that fosters intimacy with traditional lands and resources and provides a powerful engine for conservation.

Key Words: *bear population monitoring; British Columbia; conservation; First Nations science; grizzly bear; noninvasive mark-recapture; salmon; social and ecological resilience; traditional stewardship; values*

INTRODUCTION

Across northern North America, traditional territories of indigenous people comprise some of the highest priority areas for conservation (Oviedo et al. 2000). Thus, in many priority areas, indigenous self-determination in resource management represents an otherwise unavailable engine for improved resource stewardship and biodiversity conservation (Delcourt 1987, Saleh 1998, Schwartzman and Zimmerman 2005, Xu et al. 2005, Nepstadt et al. 2006). Recognizing this, strategies that embrace enduring connections between indigenous people and natural systems are now seen as having great potential to achieve tangible conservation outcomes (Chapin 2004). However, self-determination in resource management requires approaches that are themselves self-determined.

Globally, there is emerging success in improving renewed self-determination in indigenous resource management by connecting and integrating knowledge from local communities, policymakers, and scientific researchers to support local action (see reviews by Cash et al. 2003, McNie 2007, Adams et al. 2014). From these efforts it is clear that research can have the greatest impact across sectors of different actors when it is created from the outset to integrate support for local action in a collaborative framework for decision making, i.e., 'research action arenas' (van Kerkhoff and Lebel 2006).

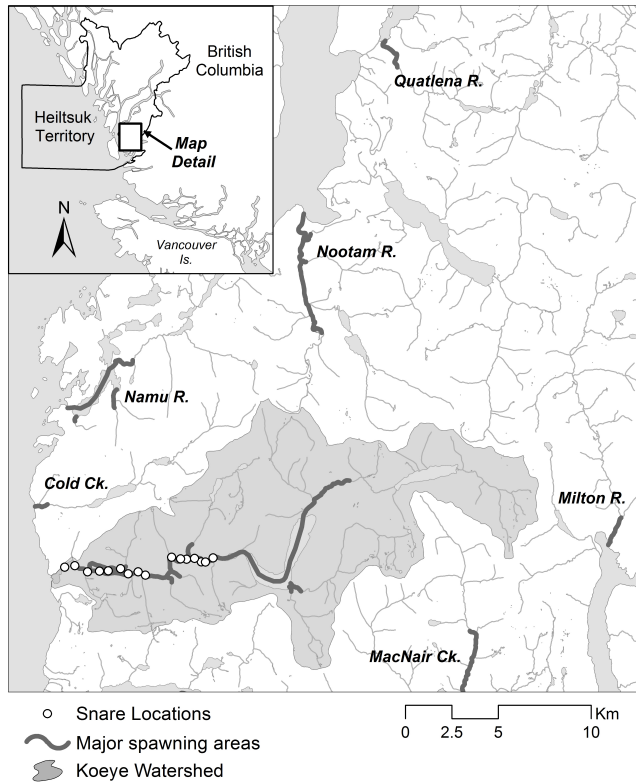
Opportunities to integrate support for local action directly into research agendas are particularly relevant in Canada, where First Nations are rapidly regaining sovereignty in resource management. Whereas millennia-old indigenous laws and cultural practices assign local people influence over local resources, more recent legal tools provide opportunities in a complex society in which multiple parties lay claim to the same resources (see Trosper 2009; HLUP, undated living document). Embedded in Canada's Constitution Act of 1982, and increasingly empowered by landmark court decisions, the legal notion of 'Aboriginal Rights and Title' provides indigenous people considerable authority in resource management within their territories (reviews in Dalton 2006, Sullivan 2006, Wyatt 2008). One way this transition has been operationalized is via a process termed 'comanagement,' broadly referring to power and responsibility sharing between federal or provincial governments and indigenous governments. The nature of these arrangements varies from limited local consultation as a part of government or academic research to local indigenous governments regaining substantial self-management capacity and authority (Notzke 1995).

Within these social and legal contexts, the Heiltsuk First Nation, in what is now referred to as coastal British Columbia (BC), Canada (Fig. 1), has catalyzed a diverse set of participatory collaborative relationships. The network includes academia,

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tribal government, provincial and federal governments, resource managers, conservation practitioners, as well as local community leaders. The focus of these relationships is cocreating research agendas, which support actions to improve resource authority and stewardship across their traditional territory.

Fig. 1. Study area and major spawning areas in the Koeye River, Heiltsuk Territory (British Columbia, Canada) and surrounding watersheds.



Bear-salmon-human systems provide a model system to illustrate the utility and power of this push to develop indigenous-led research action arenas. The Heiltsuk rely heavily on salmon (*Oncorhynchus spp.*) and have interacted with salmon and other salmon consumers such as grizzly bears (*Ursus arctos horribilis*) for their entire existence as a people (HLUP, undated living document). Grizzlies and salmon also both figure prominently in their culture. In fact, where the three still co-occur, interactions among bears, people, and salmon represent some of the most ancient and enduring confluences between ecology and human culture in North America (Clarke and Slocombe 2009). Along the Pacific coast, salmon are posited to have spawned societies of great social and ecological resilience (Trosper 2003). In a similar way, coastal grizzly bear diet and demography are largely driven by salmon abundance (Hilderbrand et al. 1999, Gende and Quinn 2004, Levi et al. 2012).

Efforts to re-establish self-determined stewardship, however, come at a challenging time for bear-salmon-human systems. Across BC, myriad human stressors, including climate change, habitat loss, pollution, negative hatchery effects, and overexploitation have caused widespread local extirpations and salmon run declines of up to 50% or more of historic abundances

(Slaney et al. 1996, Northcote and Atagi 1997, Price et al. 2009, Darimont et al. 2010). Unpublished data from Heiltsuk fisheries reveal the same pattern of decline across Heiltsuk Territory (Heiltsuk Integrated Resource Management Department, unpublished data). Although grizzly bears are expected to show similarly broad and significant declines in the face of salmon reductions, few studies have addressed this interaction at scale for coastal bears in BC (see Boulanger et al. 2004a, Bryan et al. 2013). Trophy hunting of grizzly bears, banned by Heiltsuk Tribal law but sanctioned by the BC government, poses an additional threat to bears. Clearly, to detect and address similar problems in Heiltsuk Territory, science-based leadership from diverse sectors of society, especially the Heiltsuk themselves, is required.

In this context of ecological decline, the process of creating durable science-based actions provides a ‘crucible,’ a stringent test or trial, for First Nations conservation practice. Successful models for science-based action in Heiltsuk Territory can form the basis for improved action across broader geographies to conserve bear-salmon and other wildlife systems at relevant social, ecological, and evolutionary scales. At the nexus of the research-action arena described is Coastwatch, the research arm of the Heiltsuk nonprofit Qqs Projects Society (<http://www.qqsprojects.org>). Coastwatch envisioned, designed, and leads bear monitoring activities, which focus primarily on noninvasive hair-capture techniques during autumn salmon spawning.

Recent advances in molecular methods to estimate grizzly populations from hair samples (Woods et al. 1999, Mowat and Strobeck 2000, Mowat et al. 2005, Boulanger and McLellan 2001, Boulanger et al. 2002, Poole et al. 2001, Proctor et al. 2010) enable a culturally acceptable and analytically powerful means to estimate demographic trends in bear populations. The methods are easily implemented in the field and do not require the capture or other harassment of individual bears. Importantly, molecular methods also enable users to identify potential causal factors behind changes in bear numbers should they be detected (review in Proctor et al. 2010).

Beyond science, a key dimension of this work is that, culturally, it was conducted by upholding traditional values, embodied in a set of exemplary principles from the Heiltsuk Nation’s *Gvi’ilas*, i.e., customary law. In our study, aligning contemporary research and management with *Gvi’ilas* was a core feature of how research was designed and implemented. Ecological results are coupled to this socio-cultural framework and provide basic but powerful information on the demography of bears and its relationship to patterns in salmon availability. Because this knowledge was created through a collaborative network of actors, we also discuss the conservation potential of participatory partnerships among First Nations leadership, local community members, policy makers and managers, as well as academic researchers, in driving the full life-cycle of applied conservation science within traditional territories. In doing so, we highlight the importance of research partnerships that, from the outset, create both scientific programs and integrated communities of action that can implement change. We emerged not only with a set of guiding principles for resource management by the Heiltsuk, but also a general framework for integrating scientific research with a culturally appropriate research agenda developed with, and for, indigenous people.

Table 1. Summary of exemplary principles from Heiltsuk First Nation’s *Lhaxvai* (authority or power of place) and *Gvi’ilas* (customary law) that frame the management issues and scientific questions addressed by Heiltsuk grizzly bear (*Ursus arctos horribilis*) research. As with *Gvi’ilas* generally, principles are not specific to individual actions or resources. This table illustrates how cultural values guide empirical research methods that matter to Heiltsuk people. Linkages across columns present, verbally, the social framing of the “research action arena” (see text) that legitimized scientific knowledge and is fostering science-based action through Heiltsuk grizzly bear research.

<i>Gvi’ilas</i> and <i>Lhaxvai</i> Customary Principles	Principles in Action - Implications for Contemporary Heiltsuk Grizzly Bear Management	Contributions of Appropriate Scientific Knowledge or Tools
1. Heiltsuk have been present in traditional territory since time began and will be present until time ends.	<p>Time horizons must respond to an enduring presence in place; there is a single, irreplaceable Heiltsuk geography.</p> <p>Science-based management must derive from customary perspectives on generational obligations.</p> <p>Bear management must operate at scales reflecting the geographic ecology of populations within Heiltsuk Territory, including consideration of cultural, political, or other jurisdictional boundaries.</p>	<p>Long-term ecological monitoring (LTEM) programs are warranted for culturally important species, like grizzly bears and salmon, with which the Heiltsuk have always interacted.</p> <p>Design and sampling of LTEM spans large areas, recognizing not only Heiltsuk jurisdiction but also growing understanding of the spatial requirements of mobile grizzly bears.</p> <p>Demographic data provide a lens into population trends or histories suited to the long historic and prospective time horizons of Heiltsuk management philosophies.</p>
2. Regard homelands as an extension of immediate physical home and village; acceptance of responsibility over traditional territory as much as over immediate home.	<p>Management actions must respond to the potential impacts of all actors, Heiltsuk and non-Heiltsuk, on bears within Heiltsuk Territory.</p>	<p>Design of LTEM acknowledges local (e.g., influence of youth cultural learning camps), regional (e.g., at-sea salmon harvests, trophy hunting) and international (e.g., climate change) stressors on bear-salmon-human systems at Koeye. Local and regional data relating to these stressors included in demographic models that feed decision making.</p> <p>Noninvasive molecular techniques allow for efficient sampling that can combine the geography of human influence on bears with patterns in bear behavior and abundance (e.g., presence of trophy hunters, bear movements between denning, spring feeding, and salmon fishing areas).</p>
3. Individuals are human beings first, Heiltsuk second, and thus bear responsibility to contribute to the well-being of all humans.	<p>Heiltsuk grizzly bear management should provide models for programs across the entire range of the species.</p> <p>Heiltsuk management actions must respond to the status of grizzly bears globally and among all people.</p>	<p>Design research initiatives that place understanding of Heiltsuk Territory grizzly bears in global context, which then guides adaptive management under Heiltsuk authority.</p> <p>Beyond Heiltsuk management needs, design research that can be published in internationally well-regarded, peer-reviewed journals.</p> <p>Seek authentic and productive conservation partnerships with allies outside Heiltsuk Community.</p> <p>Grizzly bear management actions have science-based framing in the broader context of the species and our understanding of its ecology and human impacts at scales that encompass full cultural breadth of human interaction with bears.</p>

(con'd)

4. Out of respect and understanding, certain areas should be off-limits to some, or all, human activities.	Grizzly bears are sensitive species. Human disruption can have especially negative impacts; there is a need to respect their privacy. Heiltsuk formalized this need by proposing grizzly bear sanctuary areas within traditional territory. These areas will provide sanctuary to grizzly bears with emphasis on sustaining areas of high abundance, and areas of contemporary or historic cultural significance Trophy hunting inconsistent with management philosophy. Commercial engagement with grizzly bears, hunting or otherwise, should be strictly limited.	The Heiltsuk's first Conservancy Management Plan was written for the Koeeye Conservancy. Grizzly bears serve as a focal species. Heiltsuk bear research provides demographic and spatial data essential to adaptive management, which is central to the plan. Noninvasive molecular techniques provide one of the first scientific approaches to rigorous bear research that respects the privacy of bears as directed under <i>Gvi'ilas</i> . Spatial data showing movement of individuals between Koeeye and watersheds in which bears are commonly killed, in part, have motivated Heiltsuk to declare a ban on grizzly bear trophy hunting in adjacent watersheds. Knowledge of bear numbers, population trends, and other demographic information required to inform decisions about eco-tourism or other human use of Koeeye.
5. The right to use a river system comes with the responsibility to maintain a river system, in its natural or ecological entirety.	Given the cultural significance of the Koeeye Conservancy Area, sustaining autumn grizzly bear aggregations and year-round presence is a management priority. Management actions must reflect prioritization of system-level values in the natural communities persisting in the Koeeye Area, i.e., salmon fishery, or any other resource exploitation, cannot supersede persistence of grizzly bear numbers and behaviors.	Data on the demography and behavior of bears in the Koeeye is directly translated into management actions such as hunting closures and seasonal prohibitions of mechanized boat travel into known feeding or transit areas. Investment in research programs that integrate different ecological elements in design; study of both salmon and bears in synchrony is favored wherever logistically and financially possible.
6. Primary focus should be on what is left behind, not what is taken.	Aim to reduce potential of human-bear conflicts to the benefit of both. Understand future impacts of human resource use (especially salmon harvest) and behavior on grizzly bears. Manage not to "maintain a harvestable surplus" of bears, but rather to maintain areas that encompass the full spectrum of bear behavior and population structure. Monitor relationship between grizzly bears and salmon. Monitor human activities in areas known to be important to key aspects of grizzly bear annual cycles.	Site fidelity information, inferred from demographic data from bears, inform risk management plan for reducing human-bear conflict Statistical examination of salmon in maintaining bear numbers revealed demographic link. This information will be useful for growing Heiltsuk influence over salmon harvest management.

METHODS

Study area

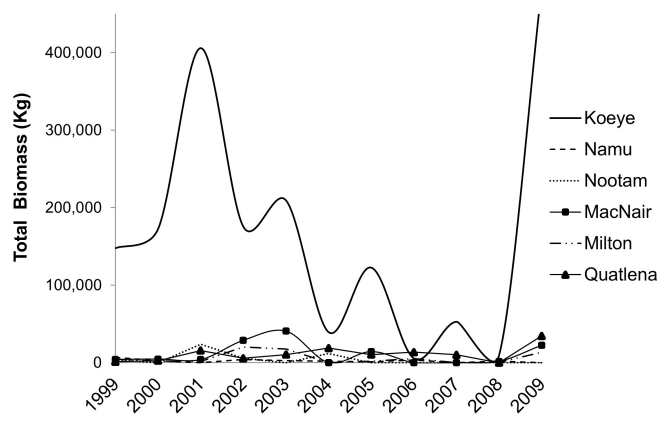
Along what is now known as the central coast of British Columbia, the Heiltsuk People comprise the largest First Nation community (~2200 people). Heiltsuk traditional territory spans outer coastal archipelagos up into the high alpine divides of the coast mountain range, encompassing nearly four million hectares of coastal wilderness in western Canada (Fig. 1). Within this

territory, bear monitoring work focused on the Koeeye watershed (51°77'28.08" N, 127°89'42.08" W; Fig. 1), which includes 18,000 ha of temperate rainforest approximately 110 km north of Vancouver Island on the mainland coast. The valley is almost entirely roadless, with the exception of a service road (< 1 km) associated with a small lodge on a hill above the river mouth. Aside from a small patch of regrowth around the river mouth and the remains of an old limestone quarry in the lower estuary, the entire watershed is cloaked in untrammled meadow and

forest systems. The only contemporary human presence includes a year-round caretaker and a six-week period of youth camps during July and August of each year. Notably, this and nearby watersheds hosted a significant Heiltsuk population prior to European contact (Cannon 1998, 2000, Cannon et al. 1999; Heiltsuk Cultural Center, *unpublished data*), and remains of village sites are easily observed today. The Koeye watershed is now recognized as a protected area under government-to-government agreements between the Heiltsuk Nation and the BC provincial government (see Price et al. 2009).

Most of the low elevation forest in the study area is within the Coastal Western Hemlock biogeoclimatic zone (Pojar and Mackinnon 1994). The Koeye drainage has a large estuary, tidal meadows, diverse and free-flowing river and stream systems, and several large lakes along its short (23.1 km) course to the sea. Along the lower main stem, from estuary to Koeye Lake (12.6 km; Fig. 1), major aggregations of spawning salmon occur and include pink (*Onchorynchus gorbuscha*) and chum (*O. keta*). Relatively large runs of coho (*O. kisutch*) access many feeder streams along this section, whereas sockeye (*O. nerka*) utilize the lake and tributaries upstream. Throughout the study period and amid considerable variation in salmon returns, salmon biomass, estimated as annual return numbers multiplied by mean mass of each sex assuming a 50:50 sex ratio (Darimont et al. 2008a), in the Koeye was significantly greater than in any neighboring watersheds (Fig. 2).

Fig. 2. Total biomass (return estimates multiplied by mean body mass) of salmon returning to spawn for Koeye and adjacent watersheds over the decade between 1999 and 2009.



Sourcing traditional law or *Gvi'ilas* to guide scientific questions

Given our interest in creating an enabling social context for resource management research, we looked to traditional Heiltsuk law, or *Gvi'ilas*, via consultation with community members, especially elders and hereditary chiefs, and examination of written material in a Heiltsuk land use document (HLUP, undated living document). From these sources, we identified six main principles (Table 1) on which we organized and executed this work from the outset. Notably, this framework also guided and enabled presentation of community-vetted scientific results to Heiltsuk decision makers, namely through the recently formed Heiltsuk Integrated Resource Management Department (HIRMD).

Field methods

To collect grizzly bear DNA, we used barbed wire snares to capture hair samples. Hair snares consisted of a single ~30 m strand encircling three to six trees at a height of ~50 cm, baited with scent lure (Woods et al. 1999, Kendall et al. 2009). Our sampling focused along the main stem of the Koeye, from the estuary to the lake (Fig. 1), and coincided with peak salmon abundance (September-October). From 2007-2009, we collected hair samples from baited snares distributed systematically every ~500 m along the river. Snares were set on alternating sides of the river where possible. We also included data from a pilot season in 2006 involving passive snares, i.e., barbed wire strands across trails and wire on rub trees, located along paths frequently used by grizzlies (Boulanger et al. 2004a).

Sampling sessions were each approximately 10 days in length and involved 16 snares. Because sampling was limited by weather events, sessions were pooled within seasons to account for heterogeneity of detection probabilities created because of unequal sampling coverage per session (Table 2). We sampled the same area each year, though the number of sessions varied; two, four, three, and five sessions for 2006-2009, respectively. We reported 'snare-days,' i.e., the cumulative number of days that all snares were available for bears during a given year, and 'mean number of snares,' i.e., the average number of snares available each session (Table 2).

To relate grizzly bear populations and movements to salmon availability, we simultaneously counted salmon and assessed their availability to bears. Although salmon spawning, i.e., escapement, is often used to estimate resources available to bears, escapement does not necessarily reflect salmon availability, because water levels and other factors can influence grizzly fishing success. Therefore, we combined salmon count estimates during standard stream-walk surveys with a field assessment of water flow and visibility to provide an index of salmon availability (Boulanger et al. 2004a). Availability was ranked on a scale from one to three for each sampling session.

Sampling effort and genetic analysis

We collected 781 hair samples from 2006-2009. Samples were excluded from genetic testing based on inadequate genetic material for extraction (113 samples; 14.5%) and nongrizzly appearance (47 samples; 6%). Additionally, 82 samples from 2007 were not analyzed because of budgetary constraints. For the remaining 529 samples, 344 (65%) were successfully genotyped. Twenty-four samples (4.5%) contained DNA from > one bear and were excluded from analyses.

Species, individual identity, and gender of bears were determined through analysis of DNA extracted from the hair samples (Woods et al. 1999). Seven nuclear microsatellite loci were used to define unique individuals (Paetkau et al. 1995). Rigorous data-checking procedures were followed to eliminate genotyping errors (Paetkau 2003, Kendall et al. 2009). Multidimensional cluster analysis based on similarity of 7-locus genotypes provided unambiguous species assignment for all individuals. Gender was assigned using the sex-linked amelogenin marker (Ennis and Gallagher 1994).

Estimation of demographic parameters and population trends

To estimate demographic parameters and population trends, we

Table 2. Summary of sampling effort for Koeys grizzly bear (*Ursus arctos horribilis*) DNA mark-recapture analysis 2006–2009. Salmon availability numbers are observational indices calculated in the field during each session (see text). Effort is presented as snare days/average snares set. The number of unique bears detected each year is given along with whether they were new bears or recaptures. The number of recaptures in the subsequent years is shown for bears detected in each year. The number of female bears (from the total bears listed) is given in parenthesis. For example, in 2006, 4 bears were detected of which 1 was a female. Recaptures for each of the three years subsequent to the first sampling period (2006) are divided by year in the three columns adjacent to the total recaptures.

Year	Sessions	Effort	Salmon Availability		Capture Summary					
			Mean	SE	Detections	New	Recaps	2007	2008	2009
2006	2	209/20	2.0		4 (1)	4 (1)		3 (1)	2 (1)	1 (0)
2007	4	468/10.5	1.78	0.28	30 (14)	27 (13)	3 (1)		19 (10)	10 (4)
2008	3	773/20	2.0	0.32	41 (23)	22 (13)	19 (10)			14 (6)
2009	5	658/14	1.8	0.40	19 (9)	3 (2)	16 (7)			

used the Pradel model “robust design” (Pollock et al. 1990, Pradel 1996) with the Huggins closed N model (Huggins 1991) in program MARK (White and Burnham 1999) to model both demography and estimate superpopulation size, i.e., cumulative number of bears that traversed the Koeys watershed during sampling, for each year that was surveyed. Superpopulation size and detection probability (p^*) were estimated for each year using the Huggins closed population size model (Huggins 1991). This approach allowed changes in yearly detection probabilities caused by sampling differences between year one, in which no scent lure was used, and subsequent years (see Pradel 1996, Boulanger et al. 2004b; note, size of the study area was held constant). The main advantage of the Pradel model robust design is that it estimates detection rate for each year using the within year sessions, and therefore it is possible to get estimates of λ with as little as two years of data (Pollock et al. 1990).

The change in population size (λ), as well as apparent survival (θ), and rates of additions between years (f), were estimated using the Pradel model. Apparent survival (θ) is the probability that a bear that was in the sampling area in one year (i.e., 2006) would still be in the sampling area in the subsequent year (i.e., 2007), encompassing both deaths and emigration from the sampling area. Rates of addition, (f), is the number of new bears in the sampling area in a given year per bear in the area during sampling the previous year. It encompasses both births and immigration. Apparent survival and rates of addition are summed to estimate change in population size (λ) between each year. Finally, population rate of change is equivalent to the population size for a given sampling period divided by the population size in the previous sampling period ($\lambda = N_{t+1}/N_t$). Accordingly, estimates of λ will be 1 with a stable population, less than 1 if the population is declining and greater than 1 if the population is increasing.

Models, which tested for sex-specific, session-specific, and year-specific variation in demographic and detection probability parameters, were introduced into the analysis. In particular, we were interested in the relative contribution of apparent survival (θ) and/or rates of additions (f) to population trend (λ) in the study area. We estimated the relative contribution of θ and f to λ by introducing models that held either θ or f constant while varying the other parameter for males, females, or both sexes pooled. For example, support for a model, with f varying each year while apparent survival was held constant, would suggest that yearly variation in f was influencing trend more than apparent survival (Schwarz 2001, Nichols and Hines 2002). Once we

determined a base model, we added the mean salmon availability for each year as a temporal covariate to determine if salmon availability would influence demography. For example, a year with high salmon availability might result in higher apparent survival, i.e., more bears from the previous year being present, or the addition of new bears, caused by either increased reproduction or immigration from other areas.

The relative support of models was evaluated using the Akaike Information Criterion (AIC) index. The model with the lowest AIC_c score (adjusted for low sample size) was considered the most parsimonious, thus minimizing estimate bias and optimizing precision (Burnham and Anderson 1998). The difference in AIC_c values between the most supported model and other models (ΔAIC_c) was also used to evaluate the relative support of models when their AIC_c scores were close to the most supported model. In general, any model with a ΔAIC_c score of less than 2 had substantial support and was also worthy of consideration. Akaike weights (w_i), which reflect the proportional support for each model, were also estimated. Estimates of demographic parameters and superpopulation size were model averaged using the Akaike weights from all candidate models in the analysis, therefore accounting for all models and model selection uncertainty in the final estimates.

Source geography

In 2010 and 2011, a larger grid-based study of grizzly bear populations overlapped the Koeys study area and extended north along the mainland coast and proximal islands (Bryan et al. 2013; C. Darimont, *unpublished data*). By sampling a broader geography during the spring emergence from denning sites, samples from this companion study provided an opportunity to begin gathering information about the potential source geography for autumn bear aggregations in the Koeys and to determine travel distances between capture locations. We identified genetically unique individuals detected on both scales and measured the distances between their sampling locations using spatial analysis tools in a geographic information system (GIS).

RESULTS

Numbers of bears detected

We detected a total of 57 individual bears with annual detections ranging from 4 in 2006 to 41 in 2008. Detections, i.e., counts of unique bears, progressively increased until 2008, then decreased in 2009 despite a similar sampling effort (Table 2). After 2008, the

Table 3. Pradel model selection results for the Koeys grizzly bear (*Ursus arctos horribilis*) DNA mark-recapture analysis 2006-2009. A model with yearly detection probabilities was used for all models. Akaike Information Criteria (AIC_c), the difference in AIC_c values between the i th model and the model with the lowest AIC_c value (ΔAIC_c), Akaike weights (w_i), number of parameters (K), and model deviance are presented.

No.	Survival (θ)	Additions (f)	AIC_c	ΔAIC_c	w_i	K	Deviance
1	Trend [†]	Salmon(F) [‡]	661.4	0.00	0.17	8	644.3
2	Trend	Constant [§]	661.7	0.28	0.15	7	646.8
3	Sex*Trend	Salmon	662.5	1.07	0.10	10	640.7
4	Trend	Sex+salmon	662.7	1.35	0.09	8	645.6
5	Sex*Trend	Salmon(F)	662.9	1.53	0.08	10	641.2
6	Trend	Salmon(M)	663.2	1.80	0.07	8	646.1
7	Year	Constant	663.6	2.26	0.06	8	646.5
8	Trend	Salmon	663.7	2.33	0.05	8	646.6
9	Trend	Year	663.8	2.44	0.05	9	644.4
10	Sex*Trend	Sex+salmon	663.9	2.57	0.05	10	642.2
11	Trend+salmon	Salmon(F)	664.9	3.53	0.03	9	645.5
12	Sex*Trend	Sex+salmon	665.3	3.89	0.02	11	641.2
13	Year	Year	665.8	4.37	0.02	10	644.0
14	Sex+year		665.9	4.54	0.02	9	646.5
15	Sex*salmon	Salmon	666.1	4.72	0.02	9	646.7
16	Sex+salmon	Salmon	666.5	5.14	0.01	9	647.1
17	Salmon	Salmon(F)	668.1	6.71	0.01	7	653.2
18	Constant	Constant	670.5	9.16	0.00	6	657.9
19	Constant	Year	670.9	9.53	0.00	8	653.8
20	Sex	Sex	673.8	12.42	0.00	8	656.7
19	Year*sex	Year*sex	720.2	58.83	0.00	40	607.1

[†]A linear trend in the given parameter was assumed.

[‡]Salmon availability was assumed to influence the parameter for females (F), males (M), or both sexes pooled if no sex was specified.

[§]The parameter was held constant meaning that it did not change in value for the duration of the study.

majority of bears detected in the watershed were recaptures from previous years, suggesting high fidelity and a relatively low number of bears entering the watershed among years. In 2009, only 3 individuals were newly detected, with the remainder (16) being recaptures from previous years. Approximately equal numbers of male and female bears were detected and recaptured in most years.

Demography and population trends

The Pradel analysis suggested that a model with linear decreasing trends in apparent survival (θ) for both sexes, and rates of additions (f) influenced by salmon availability for female bears (f constant for male bears) had the lowest AIC_c score indicating support by the data (Table 3, model 1). Other supported models, as indicated by ΔAIC_c values of less than 2, included a constant f each year (model 2), and models with salmon abundance influencing θ of both male and female bears (models 3-6). Overall, models with linear decreasing survival trends for male and female bears had more support than models with survival influenced by salmon availability (models 1-6). Models that assumed constant values for apparent survival and additions (model 18) or equal year-specific trends (model 13) were less supported. The Huggins closed model for each within-year sampling session assumed different capture probabilities for each year, but constant capture probabilities within each session. Models with capture probabilities varying as a function of sampling effort were less supported.

Model-averaged demographic parameter estimates from all the candidate models in Table 3 suggested higher apparent survival (θ) with low rates of addition for most years (f ; Table 4). Notable

increases in rates of addition were in the 2007-2008 interval; notable decreases in apparent survival were in the 2008-2009 interval. The rate of change (λ), which is the sum of apparent survival and rates of addition, was below one, implying a declining superpopulation of bears for all years except for females between 2007 and 2008. Estimates of λ were imprecise, presumably because of the short time sequence of years sampled (Table 4).

Given that θ estimates were greater than f estimates in all years of the study for both sexes, apparent survival was a more dominant driver of population trend. This suggests that survival and fidelity drove population trend in the area, as opposed to reproduction and new bears entering the watershed (Fig. 3). Rates of addition (f) increased in 2008 especially for female bears, which was associated with increases in salmon availability. The increase in additions in 2008 caused a positive trend ($\lambda > 1$) in female superpopulation size. Increased rates of addition could have been caused by either new adult bears in the study area or a surge of productivity (cubs or yearling bears). A large decrease in θ and as a result λ occurred between 2008 and 2009 for both females and males.

Estimates of per session detection probability were combined to estimate p^* , the probability that a bear that was detected would be captured at least once during all of the sessions of sampling (Table 5). In this context, p^* is equivalent to the proportion of the superpopulation of bears that was sampled each year. Estimates of p^* were low for 2006, which resulted in highly imprecise estimates. Estimates of p^* increased each year with resulting gains in the precision (CV) of superpopulation estimates (Table 5).

Table 4. Model averaged demographic parameter estimates for males and females for the Koeye grizzly bear (*Ursus arctos horribilis*) DNA mark-recapture analysis 2006-2009. Estimates of apparent survival (θ), rates of addition (f), and population rate of change (λ) are displayed with lower (LCI) and upper (UCI) 95% confidence limits listed for each. Models used for estimates are listed in Table 2.

	Year	Estimate	SE	LCI	UCI	CV
Female						
θ	2006-7	0.95	0.14	0.04	1.00	15.0%
	2007-8	0.88	0.12	0.44	0.99	13.3%
	2008-9	0.36	0.10	0.20	0.57	27.4%
f	2006-7	0.03	0.06	0.00	0.56	183.6%
	2007-8	0.20	0.26	0.01	0.87	134.6%
	2008-9	0.04	0.06	0.00	0.52	165.2%
λ	2006-7	0.98	0.15	0.00	1.28	15.6%
	2007-8	1.08	0.29	0.51	1.65	27.0%
	2008-9	0.40	0.11	0.21	0.63	28.6%
Male						
θ	2006-7	0.91	0.17	0.14	1.00	18.1%
	2007-8	0.81	0.13	0.45	0.96	16.1%
	2008-9	0.41	0.11	0.22	0.64	27.5%
f	2006-7	0.01	0.03	0.00	0.07	342.1%
	2007-8	0.08	0.18	0.00	0.92	233.0%
	2008-9	0.01	0.03	0.00	0.07	339.9%
λ	2006-7	0.92	0.17	0.10	1.25	18.3%
	2007-8	0.89	0.20	0.15	1.27	22.1%
	2008-9	0.42	0.11	0.22	0.64	27.2%

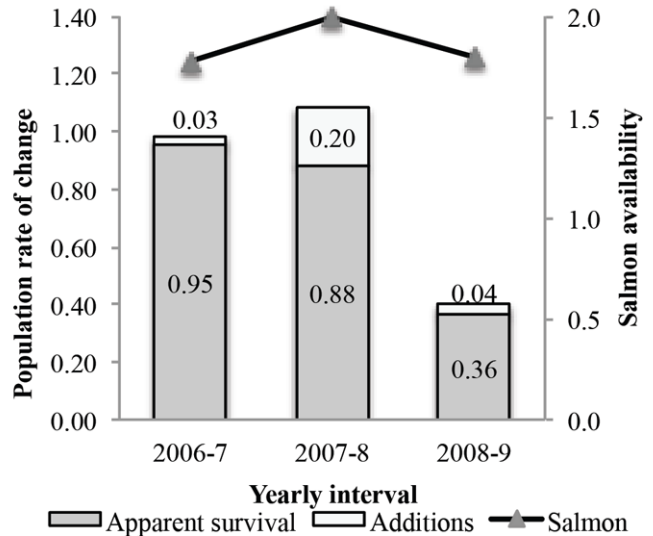
Table 5. The number of unique bears detected (M_{t+1}), estimates of detection probability (p^*), and corresponding superpopulation estimates for males and females for the Koeye River grizzly bear (*Ursus arctos horribilis*) DNA mark-recapture project 2006-2009. Confidence intervals (CI; upper/lower) and coefficient of variation (CV) are also shown.

Year	Detection Probability			Superpopulation Estimate			
	(M_{t+1})	p^*	CI	Estimate	SE	CI	CV
Males							
2006	3	0.06	0.02/0.17	46	37.15	13/189	80.2%
2007	16	0.56	0.37/0.72	29	6.45	21/49	22.2%
2008	18	0.73	0.56/0.85	25	3.68	20/36	14.9%
2009	10	0.87	0.72/0.95	11	1.48	10/18	13.0%
Females							
2006	1	0.06	0.02/0.18	15	17.55	3/94	113.7%
2007	14	0.56	0.38/0.72	25	5.87	18/44	23.1%
2008	23	0.73	0.58/0.86	32	4.35	26/45	13.8%
2009	9	0.87	0.73/0.96	10	1.39	9/16	13.5%

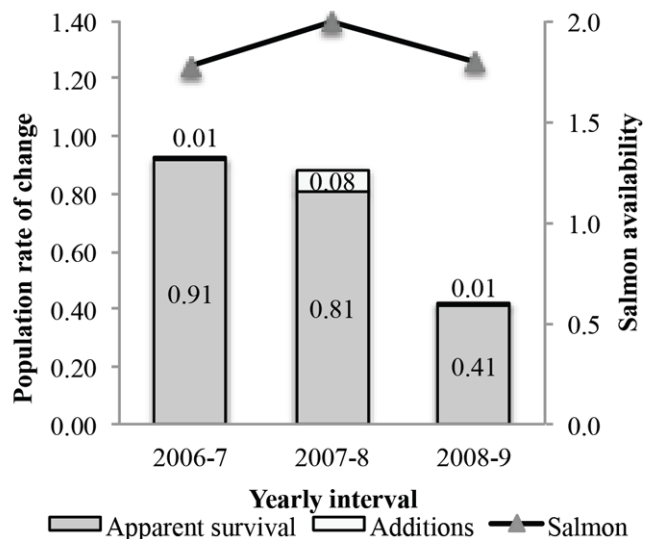
Trends in model averaged superpopulation estimates suggested a declining superpopulation of males and an increasing (2006-2008) and then decreasing superpopulation (2008-2009) of females (Fig. 4). The estimates of superpopulation from 2006 were very imprecise and, therefore, the most definitive estimates occurred from 2007-2009. The same general estimates of trend (i.e., declining) were also evident from estimates of λ (Table 5).

Fig. 3. Model averaged estimates of rates of addition of new grizzly bears (*Ursus arctos horribilis*) shown with estimates of salmon availability for female (A.) and male (B.) bears in the Koeye River study area 2006-2009.

A. Females

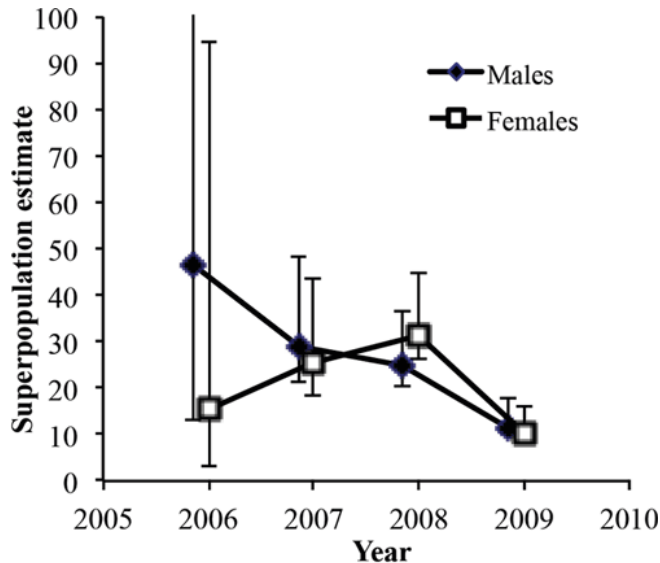


B. Males



Source geography for autumn aggregations of bears in Koeye
 Eight individuals detected during our study were detected the following spring in neighboring watersheds (Fig. 5). The majority were males (75%), which were located farther from the Koeye (range = 2.8-75.6 km, mean = 33.4, SD = 29.7) than females (7.1 and 32.4 km from their capture locations within Koeye).

Fig. 4. Trends in superpopulation estimates for male and female grizzly bears (*Ursus arctos horribilis*) for the Koeye River, Heiltsuk Territory (British Columbia, Canada) 2006-2009. The upper confidence limit for the male superpopulation estimate in 2006 was 189 (not shown). Points are staggered to ease interpretation of confidence limits.

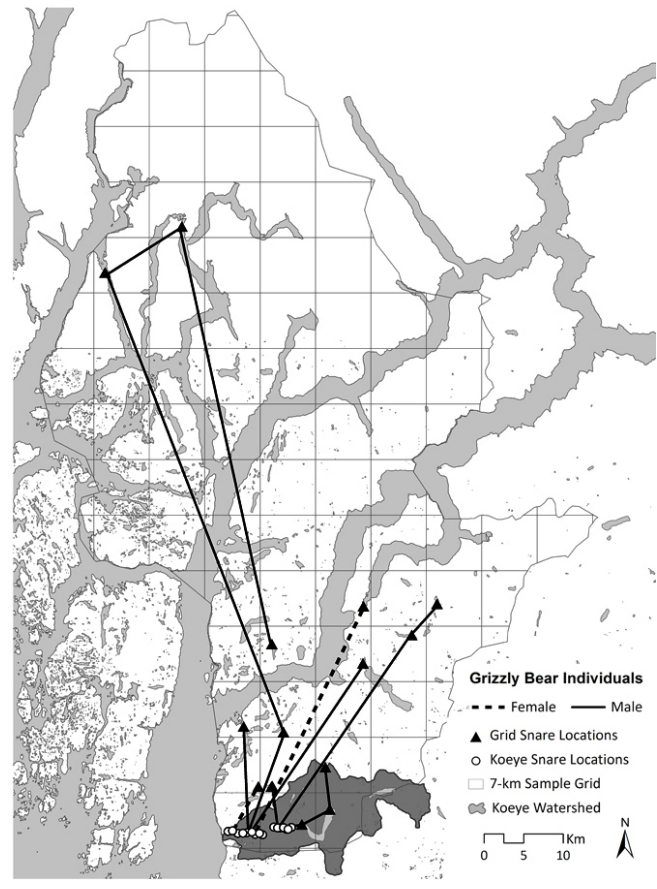


DISCUSSION

We coupled Heiltsuk values with a noninvasive scientific approach, which provided detailed ecological knowledge to inform local resource management. The collaborative research action arena, driven by Heiltsuk values, ensured lessons learned directly flowed to the Heiltsuk Integrated Resource Management Department. Had this research occurred without the involvement and leadership of the Heiltsuk community, perhaps presented fully-formed and funded, as is commonly the case in Heiltsuk Territory and beyond, communication to local management authority would have been far less frequent, detailed, and ultimately would have had far less of an impact (see also Adams et al. 2014).

Scientifically, noninvasive monitoring and demographic modeling of the population of bears utilizing the lower Koeye watershed during the autumn revealed a total of nearly 60 individual bears over the course of the study (Table 2). Given the geography sampled, this result suggests the Koeye supports the most southerly major aggregation of salmon-feeding grizzly bears in North America. In addition, though the short time period of this study limits the precision of population and demographic trend estimates, results suggest a declining population in the Koeye (e.g., $\lambda < 1$ in most years for males and females; Fig. 3; Tables 4, 5), likely mediated by salmon returns (Fig. 4). And last, integration of our results with those of a grid-based study across broader geography (Bryan et al. 2013; C. Darimont et al., unpublished data) has defined a minimum source geography for bears feeding on salmon in the Koeye, which encompasses a

Fig. 5. Location of hair snare stations where individual grizzly bears (*Ursus arctos horribilis*) were originally identified in Koeye watershed during this study (circles) and then recaptured during independent spring grid-based sampling (triangles) on a large spatial scale in Heiltsuk Territory (British Columbia, Canada). Lines represent minimum distances traveled between snares by female (dashed) and male (solid) bears. Grids were 7 km, snares placed in suitable habitat within each grid cell, established in spring 2010 (see text).



significant portion of Heiltsuk Territory (> 1000 km²), and which overlaps the traditional territories of several other First Nations (Fig. 5). Together these demographic and ecological results, for the first time, describe the aggregation of salmon-feeding grizzly bears occupying the Koeye conservancy and point toward its regional significance and potential vulnerability to shifts in salmon abundance and phenology.

What follows are our interpretations of not only these scientific results, but also how our collaborative research and framing of results can influence management in an indigenous-led context. Also, we framed our discussion to be relevant to other social and ecological contexts in which indigenous people are formally empowered to once again manage resources.

Growing evidence suggests that integration across science-based management paradigms and those of other cultures can improve conservation outcomes (Cash et al. 2003 and references therein).

Specifically, scientific knowledge can be effectively incorporated into cross-cultural management settings when it is respectful of multiple knowledge sources and values, acknowledging so called 'legitimate knowledge' (Clark and Holliday 2006). A primary conceptual aspect of such an approach is 'value-focused thinking' (Keeney 1992), a process of clarifying or exposing what matters most to local people most affected by resource decision making in terms that resonate culturally (Turner et al. 2008). Such processes provide a starting point for relationships that are critical to identifying environmental, social, and cultural priorities (Gregory et al. 2007). However, they require commitment to cultivating relationships first, then maintaining mutual commitment over time, all of which enables trust and a shared vision. This vision then frames the development and implementation of research that serves, and is empowered by, local resource management (Adams et al. 2014). Not all resource management science need proceed this way. However, in cases in which it occurs across cultural boundaries, investment in collaborations, which commit to the kind of approach we advocate here, may be essential. We note, however, that the precise manner in which science and indigenous communities interact might vary according to the culture and context in which collaborations are born (Adams et al. 2014).

In our case, Heiltsuk traditional law, or *Gvi'ilas*, guided the framing of our scientific questions and the application and utility of the results. We illustrate this approach using the six exemplary *Gvi'ilas* principles that framed our collaborative research process (Table 1). By doing so, we also illuminate the juxtaposition between how scientific knowledge can be produced and how its social empowerment within a First Nations context can become a social-ecological crucible for First Nations conservation action.

***Gvi'ilas* principle 1: Heiltsuk have been present in traditional territory since time began and will be present until time ends**

More than any other, this *Gvi'ilas* principle guided the scale of the research. As a reflection of Heiltsuk history with bears and salmon, time horizons for management issues exist on generational timescales. Similarly, although our sampling focused on one watershed, we identified implications across Heiltsuk Territory, reflecting the geographic ecology of both the Heiltsuk and grizzly bear populations. Our data revealed an influx of individual bears into the Koeeye in the fall season and an indication as to which neighboring watersheds connect these mobile consumers.

Our work was guided and informed by a long history of relationships among the Koeeye, its people, salmon, and bears (Heiltsuk Tribal Council 2013; Heiltsuk Cultural Education Center, *unpublished data*). Such history is best reflected by Heiltsuk traditional knowledge about bears acting as coastal 'gardeners' by distributing salmon nutrients to stream-side forests (see HLUP, undated living document). This process can increase plant growth, shift plant communities and eventually fuel aquatic productivity, all of which support subsequent generations of salmon (Reimchen 2000, Hocking and Reynolds 2011). Similarly, according to Heiltsuk stories, the Heiltsuk have themselves historically cultivated productive patches of berries, such as salmonberry (*Rubus spectabilis*) through fertilization with salmon carcasses (see also Turner and Peacock 2005). Given, and affirming, this rich history of interaction, self-directed research

to increase the understanding of contemporary bear ecology reconnects the Heiltsuk with the land and resources into the future. It also provides a uniquely powerful and enduring engine for conservation impact in keeping with other guiding *Gvi'ilas* principles.

***Gvi'ilas* principle 2: the right to use a river system comes with the responsibility to maintain a river system, in its natural or ecological entirety**

The scientific questions posed for grizzly bears in the Koeeye were basic but necessary for a watershed with high Heiltsuk use: (1) How many bears use the Koeeye? (2) When are they in the area? (3) Where do they come from? (4) Are males and females behaving differently? (5) And, how do processes such as the phenology and demography of salmon runs influence bear movement and abundance over time? Before we began, the answers to these questions were unknown. As a result, contemporary resource management decisions relating to minimizing bear-human conflict at the Koeeye, managing salmon, and enforcing a tribal ban on grizzly trophy hunting were all constrained by a lack of knowledge.

One of the primary lessons that emerged was the contrast between grizzly genders in their use of the Koeeye. Males appeared to spend less time within the watershed during salmon spawning, whereas females were more likely to be detected across multiple sampling sessions (Table 5). Moreover, females moved greater distances within the watershed across more continual time intervals than males (Table 5; W. Housty and C. Filardi, *unpublished data*). We infer from these patterns that females may be moving more at local scales with relatively high within- and among-season fidelity. Accordingly, the locations of females with cubs, which can demand extra caution from people using the Koeeye, might be hard to predict from week to week. In contrast, males on average appear to cover much larger geographic areas in their seasonal movements; many individuals might only be using the Koeeye when other regional resources are scarce. Accordingly, considerations of human safety might be particularly important during low salmon years, when local resources are relatively scarce and local bear density relatively high. Moreover, in higher salmon years, males might be more vulnerable to trophy hunting when they are more evenly dispersed (and mobile) among watersheds, which include those that face high hunting pressure.

Data suggest that the future of the Koeeye watershed's bear population may depend in large part on salmon availability. Rates of addition were very low in most years but correlated with salmon availability (Fig. 3). This suggests low immigration and likely, low reproduction of bears. It may be that cubs are less likely to be detected by hair snares in their first year. However, there is little reason to believe yearlings should not have reasonable capture rates. If this is so, rates of addition would reflect immigration and the previous year's reproduction, if family groups stayed in the Koeeye, which observational evidence and molecular results suggest (W. G. Housty and C. E. Filardi, *personal observations*). Thus we speculate that low reproductive rates may play a role in observed declines. Available salmon biomass declined up to 2008, which supports this hypothesis. When salmon availability is low, both physiological, i.e., nutritional, (Boulanger et al. 2004a, Belant et al. 2006, Bryan et al. 2013) and social, i.e., dominance hierarchies, (Gende and Quinn 2004) factors have been implicated

in lower reproductive output. This coupling between salmon and grizzly abundance is consistent with observations (Hilderbrand et al. 1999, Jacoby et al. 1999) and modeling (Levi et al. 2012) across larger, cross-population spatial scales.

Similar to rates of addition, apparent survival was low, especially in the 2008-2009 interval. This could potentially be caused by emigration, higher mortality, or a combination thereof. A coupled increase in salmon in adjacent watersheds in 2009 might have caused bears, which were present in Koeve in 2008, when regional returns were very low, to emigrate. Alternatively, or interacting, following low returns in 2008, bears might have sought human food resources, which is known to lead to human-caused mortality. When hungry bears seek alternative foods near human habitation there is often increased conflict (Whittaker and Knight 1998, Gunther et al. 2004). Following the precipitous decline in sockeye in the nearby Wuikinuxv/Rivers Inlet system in 1999, at least 10 starving grizzlies were killed by BC conservation officers in a remote village in a single month (Associated Press 1999). Males would be particularly at risk. Larger bodied males, particularly large in coastal areas, find it more difficult to meet metabolic demands when salmon are in short supply (Rode et al. 2001, Robbins et al. 2004) and likely take additional risks to find food. Finally, trophy hunting of males might be influencing these rates of addition estimates in concert with behavioral effects of salmon returns. Although the Heiltsuk prohibit grizzly hunting at the Koeve, it occurs every year in adjacent watersheds where our movement data suggest individuals travel (Fig. 5). Within any watershed, males might be especially vulnerable during periods of low salmon, when foraging bouts that expose them to hunters might be more frequent and longer.

One important assumption of our analyses is that the number of grizzly bears identified on salmon streams reflects the overall size and status of grizzly bear numbers in the Koeve area. This assumption could be violated if other resources such as abundant berry crops drew bears away from stream-side snares. Given the value of salmon to fitness, however, we suspect that bears would not abandon opportunities to seek salmon, making it unlikely that other food resources were significantly influencing these patterns.

***Gvi'ilas* principle 3: regard homelands as an extension of immediate physical home**

By regarding traditional territory as a real and physical extension of a home or village, the Heiltsuk accept a responsibility to tend to the function and harmony across the ecological systems that hold all of their history and futures. This compels intimate, long-term ecological monitoring of highly valued elements of traditional territory and drove the primary scope of our research.

Data across all years allow the Heiltsuk to assess the value of the Koeve to regional grizzly-salmon systems in Heiltsuk Territory and beyond. The high numbers of bears we detected, the geographic data from migrants, and data showing a superabundance of salmon at Koeve relative to nearby streams, collectively suggest the Koeve supports a regionally significant bear-salmon aggregation. In contrast, the provincial government's habitat quality model, which incorporates a suite of landscape and vegetative features (Fuhr and Demarchi 1990, MacHutchon 2007), categorizes the relatively flat outer coastal habitat of the Koeve as 'low' or 'very low' quality. The model used remote

sensing and other geographic computer tools but did not incorporate salmon density or ground-truthed data. Our project underscores the value of field-based inquiry, initiated and conducted by local people. Notably, however, the Heiltsuk have long recognized the Koeve as a high-density grizzly system (W. G. Housty, *personal communication*). Accordingly, this work affirms that areas outside the village are homelands about which the Heiltsuk have good ecological understanding, a valuable source of local ecological knowledge.

Overall, preliminary findings highlight the need for continued Heiltsuk monitoring of Koeve bears to better determine the drivers of annual and inter-annual population trends. Longer time series of salmon availability and bear population trend data are critical to better understand these dynamics on the temporal scale at which they most strongly interact. Clearly, these patterns, and the hypotheses they generate, argue for investigation on larger geographic scales, which reflect the source geography of bears identified in our results. This geographic scope is critical to Heiltsuk management, but was unapparent prior to our study. Notably, data reported here have instigated the Heiltsuk to lead a multi-First Nation bear management strategy, a social-ecological endeavor, which recognizes that bear movements transcend territorial jurisdictions. We suspect that such multination integration will be a common pattern with other mobile species as management authority is regained by other nations. In this way, cultural leadership can direct applied science across Heiltsuk and neighboring homelands, which are extensions of current homes.

Another dimension of this principle manifested in our study was the framing of research actions and results in terms of Heiltsuk geographies as opposed to provincial management units or externally defined ecological clines. By framing research in the context of geographic scales reflecting oral history, lineage affinities with place, genealogy, and other aspects of Heiltsuk social geography, all results were presented in language that resonated with the lexicon that Heiltsuk people (including HIRMD) use to define their history, concerns, interests, and aspirations. Because of this, scientific results were partitioned across the landscape in ways that matched the geographic framing Heiltsuk people use to discuss any issue relating to their homelands. It is difficult to overstate how powerful this simple aspect of framing has been to the impact of this work on the social process of improving science-based resource management.

***Gvi'ilas* principle 4: out of respect and understanding, certain areas should be off-limits to some, or all, human activities**

This principle influenced our collaborative work across two dimensions. First, Heiltsuk sense of respect for bears compelled us to place bears themselves off-limits to us as researchers. Instead of using common wildlife science techniques, such as capture and radio collaring, we employed noninvasive molecular methods in ways consistent with cultural values. As an additional benefit, this technique compelled us to spend more time on the river among spawning salmon and grizzlies, thus enabling significant reconnection by Heiltsuk people with bear-salmon systems. Moreover, this cultural direction aligned with emerging information to suggest that our technique was not only more culturally appropriate, but also perhaps more scientifically defensible. Approaches that employ tools that place individual animals under the dominion of researchers, such as radio-

telemetry collars or physical markings can affect the welfare of individuals, potentially biasing results (Darimont et al. 2008b, Cattet et al. 2003, 2008, Saraux et al. 2011). We suspect a suite of similarly noninvasive methods will characterize resource management programs that First Nations or indigenous people lead and can add to improved integration of scientific and indigenous approaches.

A second impact of this principle relates to defining areas of restricted human use to provide sanctuary for grizzly bears. By defining the source geography for bears feeding on salmon in the Koeye, Heiltsuk people now have a clearer sense of the size and shape of areas necessary to mitigate impacts to bears from human activities, including trophy hunting. To respect and buffer the Koeye grizzly aggregation from the impact of human activities on their behavior and survival, geography beyond the Koeye must be considered (Fig. 5).

***Gvi'ilas* principle 5: primary focus should be on what is left behind, not what is taken**

The Heiltsuk recognize and accept a continental-scale responsibility to manage this vestigial grizzly-salmon system. The Koeye hosts a significant, and likely southernmost, remaining aggregation of its kind in western North America. Grizzlies have been extirpated from nearby Howe Sound to the south all the way down to their former range in Northern Mexico (Laliberte and Ripple 2009). Salmon have been either likewise exterminated or dramatically diminished in watersheds to the south along the coast (Slaney et al. 1996, Northcote and Atagi 1997, Gresh et al. 2000, Quinn 2005, Price et al. 2009). Accordingly, Koeye bears might contribute a source population to beleaguered grizzly populations to the south. In this way, resource management leadership by local people can affect and leave a legacy for conservation outcomes beyond territorial borders. This drove an interest by the Heiltsuk to invest in grizzly bear conservation of a key salmon-feeding aggregation in their territory.

Heiltsuk attention to this grizzly-salmon system has differed from investments by other levels of government, which has been limited. In neighboring Wuikinuxv Territory, for example, recent work sponsored by the provincial government detected grizzly declines associated with the collapse of a sockeye salmon (*O. nerka*) run over a period of three years (Boulanger et al. 2004a). This work was not conducted with or on behalf of the Wuikinuxv Nation. The sockeye system remains collapsed. Neither the provincial government, which manages terrestrial wildlife, nor the federal government, which manages fish, have responded with a conservation strategy or plan. Trophy hunting of grizzly bears, banned by Heiltsuk Tribal law but sanctioned by the BC government, poses an additional threat to bears. A recent audit of hunting management revealed that government managers failed to keep mortality below their own upper limits across half of the areas open for hunting (Artelle et al. 2013). Clearly, to detect and address similar problems in Heiltsuk Territory, science-based leadership from diverse sectors of society, especially the Heiltsuk themselves, is required.

***Gvi'ilas* principle 6: individuals are human beings first, Heiltsuk second, and thus bear responsibility to contribute to the well-being of all humans**

Grizzly bears are important to humans where they still coexist. In these areas, which are beyond urban and other highly developed regions, indigenous nations play an increasingly important role

in resource management. We have provided a framework for how culturally driven and science-informed management of grizzly bears can provide models for actions in other areas. By actively engaging *Gvi'ilas* to guide research collaboration, this work places the interpretation and impact of the science in a unique philosophical and societal context.

In an overarching way, our study, which couples society, culture, and ecology, exemplifies an engine for conservation action that is largely unavailable to practitioners outside of indigenous communities. This locally led and collaboratively executed project illustrates how the Heiltsuk First Nation values natural systems with respect and reciprocity in a manner that has an impact on decision making. Embodied in what Heiltsuk call *Gvi'ilas*, this ancient system acknowledges that the Heiltsuk are deeply connected with natural resources defined within their traditional territory. These assets are additionally respected because they sustain people physically and spiritually, not only because they can be traded for money. Embedded within this view is an emphasis on limiting resource use and, ideally, enhancing the resource should there be appropriate opportunity. This perspective is at the heart of why the Heiltsuk sought to learn more about the bears and salmon on the Koeye; not to exploit them more, but rather with the aim of sustaining them and the Nation's relationship with the full breadth of biological diversity, which has defined their culture for millennia.

More broadly, research can empower and legitimize the unique, geographically rooted epistemologies that characterize many indigenous communities and, in so doing, enable an interweaving of the analytical power of science with concepts such as *Gvi'ilas*. Legitimate union between high-quality science and First Nations perspectives on resource use represents a key advance in conservation practice, which serves the interests of all people. Heiltsuk leadership on this program moves us, collectively, away from a history of conflict between First Nations values and wisdom on the one hand, and scientific knowledge and conservation interests on the other. In this way, the work reported here involves one foot firmly rooted in the past and another stepping powerfully into the future. Connecting the Heiltsuk to the past is a sacred watershed in which many thousands of hours of fieldwork occurred; these experiences are maintaining an enduring intimacy with place into the future.

The Koeye might never again host a large village site, but this project has been an important process in translating ancient Heiltsuk intimacy with traditional lands, reasserting a presence, and guiding contemporary resource stewardship. It offers a touchstone system within Heiltsuk Territory and a social-ecological crucible for First Nations conservation practice. Successful resource management by indigenous people may require approaches like this one, in which collaborative science-based management is embedded within a socially and culturally appropriate framework for action. Such a strategy can foster unique, ancient intimacy with traditional lands and resources representing a rich element of our collective humanity. And, in the context of indigenous resource management or comanagement, which is now so often crippled by conflict, the approach presented here can also provide a powerful engine for conservation.

Responses to this article can be read online at:
<http://www.ecologyandsociety.org/issues/responses.php/6668>

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