Title: The Indigenous Sentinel Network: The use of community-based monitoring to enhance food security in northern coastal communities

Authors: Lauren M. Divine[1], Bruce Robson[1,2]

[1]Ecosystem Conservation Office, Aleut Community of St. Paul Island, St. Paul Island, AK 99660

[2]Community and Ecology Resources, LLC, 2442 NW Market St. #761, Seattle, WA 98107

Contact: lmdivine@aleut.com

Abstract: Collecting long-term standardized, scientifically rigorous data that are useful for tribal, regional, state, and federal governmental agencies is critical for resilience and collaborative adaptation planning in communities that depend on subsistence resources for food security. However, management decisions intended to mitigate negative ecological impacts on shared subsistence resources in the Arctic are often hampered by a lack of scientific information. One means of supplementing ecological observations to support long-term planning efforts, and the focus of this white paper, is to maximize the use of data collection efforts by trained local individuals that live in Arctic communities. The BeringWatch Indigenous Sentinel Network (ISN), an internet-based system that facilitates monitoring efforts in Bering Sea Native villages, was designed and refined over 16 years by Tribal employees, contractors and local volunteers; this effort was principally led by the Aleut Community of St. Paul Island (ACSPI) Ecosystem Conservation Office (ECO). ISN is an online database tool for non-scientists in remote communities to record and communicate environmental and ecological information. ISN fills a distinct niche; the focus is on effective real-time ecological monitoring by community members with local and traditional knowledge (rather than retrospective interviews) and the program is taxonomically broad in scope. ISN has been increasingly recognized for its flexibility and adaptability and is currently expanding its geographical focus from the Bering Sea region to tribal communities in mainland Alaska and beyond. This paper explores how ISN has been utilized for long-term data collection of key marine mammal subsistence resources in one Alaska Native community, St. Paul, Bering Sea, Alaska. This case study highlights the importance of rigorous, standardized data collected at a local level and informed by local and traditional knowledge to provide valuable information that informs conservation and management decisions that impact food security for Indigenous communities.

Background

The Pribilof Islands are among the most unique places in the world. The five island archipelago in the eastern Bering Sea, Alaska, provides vital breeding and feeding habitat for more than half of the world's population of *laaqudan* (northern fur seal, *Callorhinus ursinus*) and foraging and resting areas for the endangered western distinct population segment of *qawan* (Steller sea lion, *Eumetopias jubatus)*. The prehistoric users of the Pribilof Islands created one of the world's most specialized and successful maritime hunter-gatherer traditions, lasting from roughly 4000 BP to the time of Russian contact in 1741 (Veniaminov 1984). The Indigenous peoples, known among themselves by regional autonyms, became known to their historical colonizers as 'Aleuts'. Prehistoric culture across the Aleutian and Pribilof Islands was based almost entirely on marine resources, including hunting all sea mammal species found

throughout the region—including trips to the uninhabited Pribilof Islands, fishing the offshore and coastal waters, foraging for fish and shellfish on the rocky reefs, and hunting birds on land and at sea.

Today, two permanent Alaska Native communities occur in the Pribilof Islands - St. Paul (population 504, >90% Alaska Native) and St. George (population 107, >90% Alaska Native). These communities rely heavily on access to marine resources for sustenance; physical, emotional, and spiritual health; and to maintain continuity of customary and traditional ways of life.

Marine mammals continue to serve as cornerstones of Unangax̂ culture and traditional ways of living on St. Paul and St. George. Even after Russian occupation and enslavement of Unangan for the purpose of harvesting *laaqudan* pelts on the Pribilof Islands (Black 1983, Torrey 1983), the predominance of marine mammals in Unangax̂ subsistence diets despite the availability of Russian foodstuffs demonstrates the maintenance of cultural traditions during a time of intense colonialism. The subsistence use and cultural importance of *laaqudan* and *qawan* to Unangan on St. Paul Island has been documented since the early 1800s (e.g. Veltre and Veltre 1981; Veniaminov 1984) when these species were historically abundant in the Bering Sea and bred in large numbers on the Pribilof Islands.

In recent years St. Paul Island has observed rapid and dramatic changes in the distribution and abundance of both *laaqudan* and *qawan*. *Laaqudan* were listed as depleted under the Marine Mammal Protection Act (MMPA) in 1988. Historically, a majority (i.e., 75%) of the worldwide population of *laaqudan* bred on the Pribilof Islands (Gentry 1998). In 2018, that estimate dropped to approximately 40.5% of the population, with a majority of *laaqudan* breeding on St. Paul Island. Since 1998, pup production on St. Paul Island has declined by 57.7%. In conjunction with the overall decline of the St. Paul population segment, subsistence harvests of *laaqudan* on St. Paul Island have declined by 82.6% since 1998 (ECO, unpub. data). The reasons for continued decline of *laaqudan* birth and survival rates remain poorly understood; factors under current investigation and debate include climate change (Francis et al. 1998; Hare and Mantua 2000); competition with commercial fisheries (Robson et al. 2004; Gudmunson et al. 2006); predation; and emigration (NMFS, unpub. data). Understanding the factors that may influence *laaqudan* population dynamics are a high priority for resource managers at both the local and regional levels to promote population recovery, which is vital in the context of ensuring local food security.

Similarly, within recorded history *qawan* were also abundant in the Bering Sea and bred in large numbers on the Pribilof Islands (Kenyon and Rice 1961; Trites and Larkin 1996). However, abundances of *qawan* on the Pribilof Islands have also declined to exceedingly low levels and the sole remaining breeding rookery, Walrus Island, is currently in danger of extinction. In the 1870s, approximately 10,000 to 12,000 animals were distributed at breeding rookeries on the Pribilof Islands (Elliott 1880). By 1916, these breeding rookeries had been largely extirpated due to a combination of hunting and culling (Loughlin et al. 1984). Over the last 50 years, *qawan* pup production on Walrus Island has declined by over 98%, from 2,866 pups born in 1960 to only 48 pups born in 2015 (Fritz et al. 2015). Subsistence takes of *qawan* on St. Paul have declined in parallel with the historical decline of the species. Similar to the decline of the *laaqudan* population, the cause of the decline on the Pribilof Islands in recent decades remains unexplained. The highest ranked threats to recovery of *qawan* are environmental variability, competition with fisheries, killer whale predation and toxic substances (NMFS 2008).

The decline of keystone subsistence resources such as *laaqudan* and *qawan* in conjunction with increasing environmental variability and unpredictability of subsistence resources has created an urgent need for ongoing resource monitoring programs. Recognizing the need for standardized long-term data collection concerning marine mammal resources of the Pribilof Islands, the communities of St. Paul and St. George, together with technical and scientific advisors, agency partners, and local volunteers, developed a regional community-based coastal and ocean monitoring program that enabled community members to collect reliable local ecological data in order to support and inform decisions that affect the region. The first generation of the monitoring program, called the Sentinel Database, was implemented in 2004 using personal digital assistant devices to collect data in the field and upload to a Microsoft Access database. The Sentinel database was taken online in 2008 and the BeringWatch name was added to reflect the growing use of the database in Bering Sea communities. Data collection via the BeringWatch program is rooted in traditional ecological knowledge and western science methods, recognizing the diversity of qualitative and quantitative data that are valuable in decision-making processes (conservation, policy, management), especially in a rapidly changing environment. The BeringWatch program has incrementally broadened its reach and effectively operated for over 16 years in several Bering Sea and Aleutian Islands communities, including Akutan, False Pass, King Cove, St. George, St. Paul and Unalaska.

The ISN Framework

In 2018, the BeringWatch program launched the Indigenous Sentinels Network (ISN) in response to a growing need for practical and easy to implement community-based monitoring programs across Alaska and Canada. As Indigenous organizations seek to become more active partners or lead their own monitoring efforts at a local level, demand for ISN has expanded out of the Bering Sea. ISN fills a distinct niche for communities seeking to implement a monitoring program without starting from scratch or making a significant monetary investment in software infrastructure. The focus of ISN is on effective real-time ecological monitoring by local community members (knowledge holders) and is taxonomically broad in scope. ISN provides a flexible and customizable framework that enables local Sentinels (i.e. local resident observers and data collectors) to record and monitor ecological phenomena and anomalies and analyze and communicate these data effectively to scientists, managers, other community members, stakeholders, and the general public. These monitoring and reporting activities produce results that strengthen community ties with the principal players involved in collecting ecological information (e.g., NOAA National Marine Fisheries Service, Department of Fisheries and Oceans Canada, academic researchers). Communities determine the structure of their monitoring program and focal species or phenomena of concern or interest. ISN also works to assist organizations to build capability to monitor focal and novel (e.g. invasive) species and address community needs in order to maintain or improve long-term food security. The ISN framework was specifically designed with flexibility in mind-- producing a customized community-based monitoring program complete with an online database, data collection tools (web and mobile applications), a handbook of standardized protocols and hands-on training, embedded quality control, technical assistance, and a web-based, password protected database for secure archiving, interpretation and dissemination of information. Data collection via ISN is rooted in local and traditional knowledge and western science methods, recognizing the diversity of qualitative and quantitative data that are valuable in decision-making

processes (policy, management, conservation), especially in a rapidly changing environment. The internet-based system for ecological monitoring and collection of subsistence harvest data developed by the BeringWatch program and utilized by ISN is well suited for broader application throughout coastal, marine and interior regions of the Arctic. The program has established successful partnerships with Alaska Native Organizations and First Nations across Alaska and Canada which seek to join ISN and utilize these tools for data collection in their communities.

Here, we explore how ISN as an observing program for data collection and dissemination has been successful from a food security perspective. We use marine mammal harvest monitoring on St. Paul Island as a case study to demonstrate how ISN addresses a collective need for long-term subsistence resource monitoring from communities, agency and academic partners, and resource managers, while providing some consistency in data collection efforts so that data are repeatable and standardized.

Marine Mammal Harvest Monitoring

The currently employed real-time marine mammal harvest monitoring methods (Zavadil et al. 2006) were first established in 1999 under the BeringWatch program, the precursor to ISN (Fig. 1). On St. Paul Island, the Ecosystem Conservation Office (ECO) collects harvest information during the federally regulated sub-adult male *laaqudan* (northern fur seal) harvest season, which occurs June 23 to August 8 annually. During each subsistence harvest, ECO staff monitor and record the number of *laaqudan* harvested, released, tagged, entangled in marine debris, and the number of *laaqudan* successfully disentangled during each subsistence fur seal harvest. Harvest monitoring data are recorded in a standardized format using a mobile app on a handheld device (e.g. iPad or Android tablet) in real time in the field and uploaded to the BeringWatch ISN database after each harvest. ECO staff are also able to record any environmental or biological data of interest (e.g. species interactions, anomalous observations, LTK information that provides context to animal behavior) while monitoring harvests.

ECO also utilizes proven, standardized methods to collect *qawan* (Steller sea lion) harvest data from hunters within a 12 to 48-hour period following a subsistence hunting trip. *Qawan* hunting is monitored on a daily basis throughout the year and is supplemented with marine mammal stranding surveys completed on a weekly basis as part of the Marine Mammal Stranding Network. These weekly surveys also include observations of entangled *laaqudan* and *qawan* branded as a part of long-term longitudinal studies of survival and dispersal. *Qawan* harvest monitoring data is recorded in the same standardized format as *laaqudan* data and entered in the BeringWatch ISN database immediately after collection. Data that are collected include the sex and age class of successfully hunted animals, the location of the hunt, status of the animal (retreived or struck and lost), and any other pertinent information provided to ECO by subsistence hunters. Consistent year-round shoreline monitoring allows the ECO to document observed changes in the frequency and causes of marine mammal strandings by establishing a long-term baseline rate to compare future data collections to. The ECO archives all brand resight data in the BeringWatch ISN database and data are shared with National Marine Fisheries Service throughout the year as brands are observed. Brand resight information is valuable for estimating survival and immigration/ emigration rates of *qawan* in Alaska. All harvest monitoring data for *laaqudan* and *qawan* are shared with the federal co-managers of marine mammals on St. Paul Island, National Oceanic and

Atmospheric Administration, and the tribal community of St. Paul annually through published subsistence harvest reports and via oral reports at tribal meetings, respectively.

ECO staff collect subsistence data directly from hunters via voluntary hunter reporting and active monitoring by ECO staff in a standardized format and enter quality-controlled data in the BeringWatch ISN database. This combination of communication methods has led to a high level of accurate reporting on St. Paul, even when animals have been struck and lost (Zavadil et al. 2006). Indeed, ECO staff estimate that voluntary reporting of *qawan* has remained high (up to 100%) for at least the past decade (Lestenkof et al. 2018). Active participation by ECO during *laaqudan* subsistence harvests enables 100% reporting for this subsistence species. Consistently high reporting rates have enabled ECO to establish a record of effective local marine mammal management and monitoring; BeringWatch has been a valuable component of verifying local capacity to responsibly manage marine mammals and monitor subsistence use accurately.

Biosampling

The ECO has collected bio-samples (e.g. blood, muscle, liver, blubber) of *laaqudan* and *qawan* since 1998 to assess body condition, diets and contaminant loads (i.e. mercury, lead, organohalogen contaminants) of marine mammals utilized for subsistence foods. For all sampling protocols ECO has worked with the Marine Mammal Laboratory (MML) and academic researchers to develop and employ standardized data and tissue collection protocols that have been implemented in the ISN mobile apps and online database. Detailed harvest data and chain of custody information for samples are critical for collaborating partners such as the Alaska Marine Mammal Tissue Archival Project (AMMTAP), an interagency project involving the collection, archival and analysis of tissues from marine mammals from Alaska for retrospective research on contaminant levels and animal health (Kucklick et al. 2013; Reiner et al. 2016).

Additional Marine Mammal Surveys

The St Paul Island Sentinels conduct regular surveys of *laaqudan* at standardized and repeatable 'vantage points,' or observation locations, to determine timing of arrival of adult males, timing of departure of adult females and pups and numbers of overwintering *laaqudan* annually. These surveys are designed to evaluate the timing of occupation for each age and sex class of *laaqudan* in order to understand the potential impacts of climate change on migration patterns and habitat use, and ultimately address food security questions on St. Paul Island. Rapid environmental shifts in the Arctic have impacted the ecology and phenology of Arctic marine mammals, such as occupation timing and habitat use of ice-related seals and cetaceans (Moore and Huntington 2008). Additionally, traditional knowledge from northern and western Alaskan communities has documented how marine mammal migratory routes and timing have been affected by physical changes in Arctic marine environments, such as warmer water temperatures and changes in sea ice dynamics (Huntington et al. 2017). Consistent long-term data collection efforts, such as our *laaqudan* monitoring program via ISN, provide valuable information as they can catch rare events, changes in highly variable systems, time-lagged responses, and biotic responses to cumulative stressors (Dodds et al. 2012). In this way, long-term data collection using ISN has been vital to detect changes in migration timing and length of occupation on St.

Paul in recent years. Through the use of ISN, ECO has established a strong case for local management and monitoring capacity.

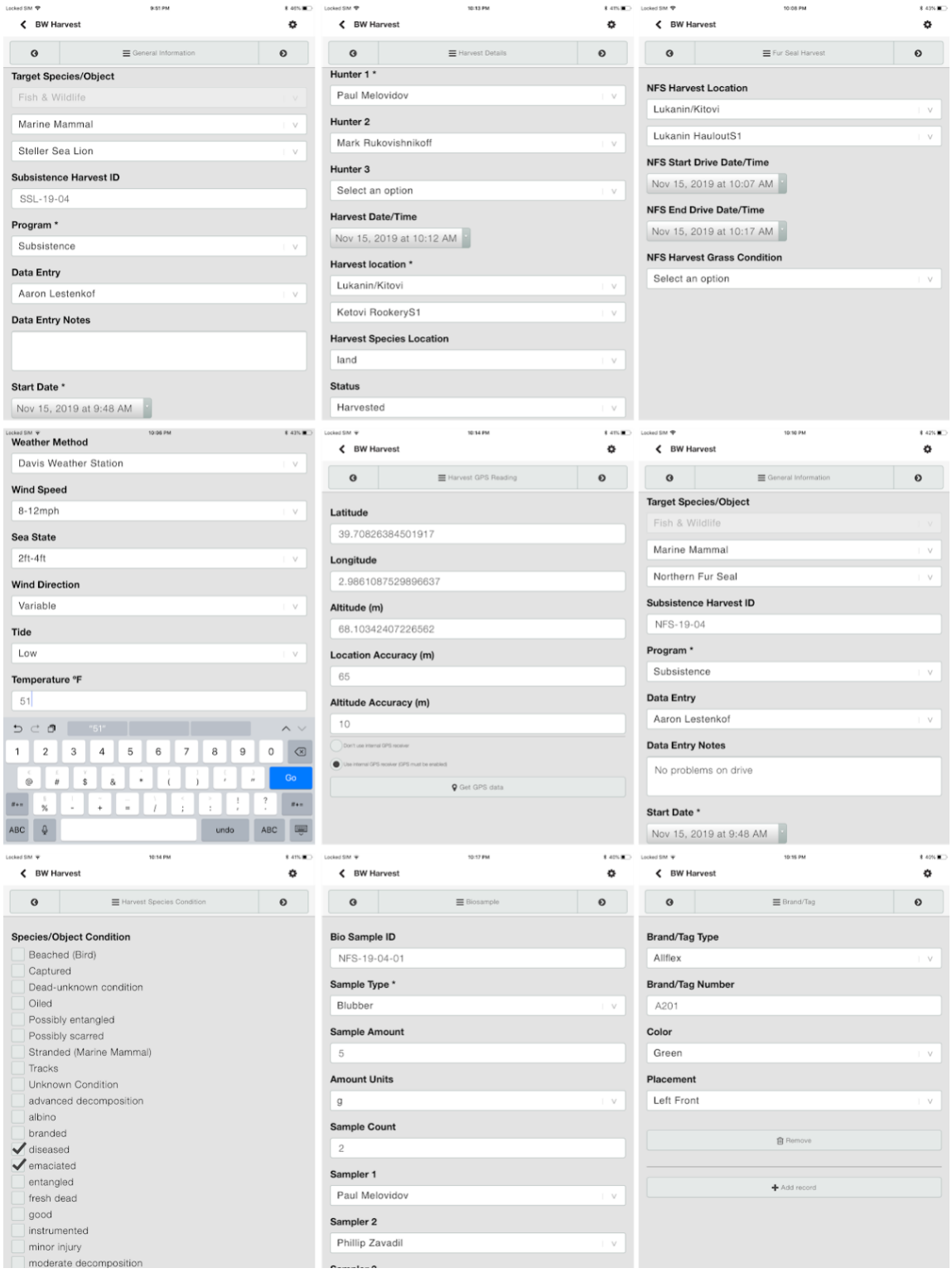

Figure 1. Screenshots of the mobile ISN app that shows the environmental and biological information as part of an observation logged . This example shows a user logging a biosampling event of a tagged *laaqudax* (northern fur

seal) that was subsistence harvested. All the information can be recorded and stored offline in the application and will automatically upload to the online database for archival when the device is back in wifi signal.

Expansion of ISN

Alaska, home to some of the world's most diverse ecosystems, intact wilderness and abundant natural resources, is experiencing among the most severe impacts of coastal change observed in the United States. Having warmed an average of 1.5°C over the last 60 years, more than twice as fast as the continental U.S. (USGCRP 2014), Alaska is often referred to as the "canary in the coal mine" for climate change impacts. Alaska's coasts are also home to over 80% of Alaskan residents including the large majority of 229 federally recognized Alaska Native tribes. These coasts also support many of the world's most economically important fisheries (Worm et al. 2009) and over 50% of U.S. seafood production comes from the Bering Sea alone (National Research Council 1996).

Despite an increase in research intensity in the Arctic in recent decades, the rapid pace of climate change has increased scientific uncertainty regarding future productivity and resilience of this and other arctic ecosystems. As a result, there is an urgent need to increase the seasonal breadth and spatial resolution of monitoring efforts to track changes across the Arctic. This is where community-based monitoring can play a valuable role. The value of the ISN approach and the proven competence of Indigenous communities to collect these data have been demonstrated through various BeringWatch/ ISN projects conducted over the past decade by Alaskan tribal organizations such as the ACSPI ECO, the St. George Traditional Council Kayumixtax Eco-Office, the Agdaagux Tribe of King Cove, and the villages of False Pass, Akutan, and Unalaska.

One of the strengths of ISN is its ability to scale from local to landscape level observations, providing an existing framework to build custom community-based monitoring programs based on each community's needs. For example, the technical infrastructure necessary to support a series of new observation protocols for use in the Interior of Alaska to monitor subsistence species within freshwater streams and rivers were implemented in the BeringWatch/ ISN database and mobile apps in partnership with the Tanana Chiefs Conference (TCC) during a 2018 community-based monitoring project. The project was implemented to fill data gaps and improve monitoring regarding the major species of Pacific salmon and whitefish species that are important to Yukon River communities as subsistence foods. Current monitoring capacity in the region is limited and TCC sought to supplement current efforts with a prototype TCC data monitoring program and technical infrastructure using the existing ISN framework. Initial protocols and data structures were designed to collect counts, spawning observations and length data on salmon and whitefish; river and stream temperature monitoring; LTK observations related to natural indicators of salmon run timing; driftwood assessments as an indicator of river flow; and monitoring for invasive species. Together, ECO and TCC are expanding the data collection scope of ISN in the TCC region, as well as sharing ISN with users across the Yukon watershed in Alaska and Canada as a potential platform for coordinated community-based monitoring of subsistence resources.

In addition to the inherent flexibility of the program to easily facilitate sampling programs in new regions, we have built the capacity for additional languages into the current ISN online database code and mobile apps. There is the potential for incorporating Indigenous language versions, such as

Unangam Tunuu, Yup'ik and Gwich'in, for use in regions where English is not spoken nor the preferred language.

Summary

In summary, the Indigenous Sentinel Network is a flexible framework that provides the tools Indigneous organizations need to implement coordinated data collection efforts across the Arctic landscape, as well as for specific surveys that address each Indigenous community's unique needs and concerns related to food security. We seek to further improve the subsistence harvest data collection tools already within our BeringWatch ISN Program and expand our focus to include systematic collection of a wider range of LTK information. We have been successful with previous efforts at building new partnerships with regional tribes and native organizations, and are currently planning to expand data collection procedures and protocols to include coastal vulnerability assessments, coastal erosion detection systems, and assessing real time changes in inventories of indicator species. The expansion of the BeringWatch ISN Program will provide a flexible and culturally appropriate data repository and is specifically designed to enable local community members to engage in rigorous, consistent scientific and LTK data collection. By pursuing these broader goals, the Aleut Community of St. Paul Island and its partner tribes and native organizations will be able to identify and effectively adapt to current and future issues regarding changes to subsistence resources thereby enhancing the food security and resilience of tribal communities in response to environmental changes. We look forward to building on existing partnerships and creating new partnerships as we expand the BeringWatch ISN to new tribal communities as it is a proven, effective, and tribally-driven environmental program that can enhance tribal resilience efforts throughout the Arctic.

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