A Review of PLP Environmental Baseline Documents: Resident fish and juvenile salmon habitat, distribution and assemblage




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EXECUTIVE SUMMARY

Fisheries are critical to the economic, cultural, and ecological health of Bristol Bay. The Pebble Limited Partnership (PLP) embarked on a significant effort to characterize habitat, distribution, and relative abundance of resident fishes and juvenile salmon in streams that may be impacted by development of mining claims (the North Fork Koktuli, South Fork Koktuli, and Upper Talarik Creek). Study objectives, methodology, and the resulting data and interpretation are compiled largely into two chapters of the resulting Environmental Baseline Document (Chapter 15, and Appendix E). This report reviews and critiques the information provided based on criteria standard for the scientific peer review process including organization and clarity, repeatability of methods, the degree to which conclusions are supported, and general scientific soundness.

From 2004--2008, habitat and fisheries data were collected. Some habitat data are quantitative, while other data are anecdotal. The document concludes that streams in and around mining claims are primarily single-thread river systems and habitat is limited by cold winter and warm summer temperatures, soft waters, high metals concentrations, low nutrient concentrations, intermittent stream flows, and limited groundwater influences. However, mixed methods complicate interpretation of data. Data interpretation is often contradictory and fails to consider the importance of habitat complexity such as the frequent occurrence of wetland complexes, floodplains, beaver ponds, and off-channel areas that provide diverse and critical habitat function. Fish distribution was documented in 22 new streams, including upstream of reaches that are intermittent in some years. Methods and assumptions used to examine fish distribution likely underestimate actual distribution. For example, data were not collected in over half of the tributaries in the study area. Limitations of snorkeling methodology as well as other, mixed sampling methodologies render relative abundance results unrepeatable, uninterpretable, and useless for detecting future changes.

Methods and reporting reduce the utility of the document for its intended purpose: characterization of current conditions, and baseline documentation for future comparison. The format in which methods and results are reported is cumbersome, making data and interpretation difficult, and in some instances impossible to understand, access, analyze, independently interpret, or repeat. Site selection and general sample design is not well described for habitat, distribution, or relative abundance studies, calling into question the representativeness of results for characterizing the region. Overall, limitations of the information presented would prevent favorable peer review of data presented in the document.

INTRODUCTION

Bristol Bay supports the world's largest sockeye salmon runs (Dann et al. 2009, French et al. 1976, Ruggerone 2010) and some of Alaska's largest runs of Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*) and pink (*O. gorbuscha*) salmon (Minard et al. 1998). The salmon, in turn, support the region's economic, cultural and ecological health (Fall et al. 2006, Knapp 2004, Willson and Halupka 1995). Salmon returns are maintained by habitat complexity which, among other things, provides thermal and physical refuge for rearing, migrating, and spawning (Hilborn et al. 2003, Pearsons et al. 1992); and salmon returns deliver return marine derived nutrient's to Bristol Bay's nutrient poor upland environments, maintaining plant, fish, and wildlife species throughout aquatic and terrestrial systems (Cederholm et al. 1999, Denton et al. 2009, Gende et al. 2002, Kline et al. 1993, Naiman et al. 2002, Schindler et al. 2003, Willson et al. 1998).

Little data is available regarding historic habitat, distribution, and abundance of juvenile salmon and resident fishes in Bristol Bay watersheds, although fewer than half of Alaska's streams have been surveyed for fish distribution (ADFG 2011). Available data indicate that where streams have been surveyed in Bristol Bay, fish are ubiquitous. Juvenile Chinook and/or coho salmon were documented in 75% of headwater streams with a gradient less than 10%, and other fishes—including those important to subsistence—were documented in 96% of headwater streams with a gradient less than 10% (Buell 1991, Buell 1994, and Woody and O'Neal 2010).

Approximately 500,000 acres of mining claims are now staked on the watershed divide of two of Bristol Bay's largest salmon producing drainages—the Nushagak and Kvichak Rivers (DNR 2011, ADFG 2011). The Pebble claim, an estimated 10.8 billion ton copper, gold, and molybdenum resource, owned by the Pebble Limited Partnership (PLP; Ghaffari et al. 2011) is the most advanced claim relative to mine feasibility analysis and permitting. Consequently, an Environmental Baseline Document (EBD; PLP 2012a), was prepared that included 53 chapters on various subjects in over 30,000 pages. Over 6,500 pages the EBD relates to fish resource inventories conducted between 2004 and 2008. This report reviews and critiques the information provided based on criteria standard for the scientific peer review process including organization and clarity, repeatability of methods, the degree to which conclusions are supported, and general scientific soundness (ESA 2012). This review is limited to fish habitat, distribution, and abundance sampling methods, results, and interpretation. It does not address winter fish surveys, spawning escapement surveys, or radio telemetry also included in the EBD.

METHODS SUMMARY

Methods Presentation

Methods are summarized in Chapter 15 of the EBD (PLP 2012a, and described in more detail in the Consolidated Study Program, Appendix E of the EBD (CSP; PLP 2012b) which describes methodology for all data collection efforts incorporated in the EBD.

Habitat

Data were collected in main stem, tributary, and off-channel habitats (Appendix 1). Mesohabitat mapping was conducted in main stem portions of the North Fork Koktuli (NFK), South Fork Koktuli (SFK), and Upper Talarik (UT; Appendix 1). Stated objectives of habitat data collection are:

- To describe channel morphology and valley form characteristics in main stem and tributary channels
- To characterize riverine habitat types (e.g., pools, riffles, and runs/glides), their distribution throughout the river, as well as the amount of river and stream habitat available for fish
- To document the locations of special habitat features (e.g., tributaries, springs, seeps, and possible barriers to upstream fish migration) that may influence fish distribution and abundance throughout the mine study area
- To characterize the quality and quantity of off-channel habitat within representative off-channel habitat study areas

For the purposes of this report, habitat data collection methodology and general conclusions were reviewed. Habitat modeling was not included in this review, but was reviewed by a forthcoming report currently in draft form (P. Parasiewicz, personal communication, 10 May 2012).

Main Stem and Tributary Habitat Surveys

Most main stem and tributary data collection relied on the U.S. Forest Service (USFS) protocols for aquatic stream habitat data collection (USFS 2001). Modified Tier 1 (reach scale channel morphology and valley information i.e., discharge, substrate particle size distribution, bankfull width, bankfull depth, bed width, wetted width, and gradient) and modified Tier 3 (information regarding individual habitat types, i.e., beaver pond complexes, backwaters/sloughs, ponds/lakes, cascades, pools, riffles, runs/glides, and wetlands) methods were employed. Methods for describing several habitat parameters were inconsistent (e.g., discharge was estimated using flow meters or floats, gradient was estimated using a stadia rod and auto level or a clinometer, lengths were estimated using hip chains, Kevlar tapes, or laser range finders). Some data is quantitative, while other data is anecdotal.

Off-Channel Habitat Surveys

Off-channel habitat surveys were co-located with main stem habitat survey sites (PLP 2012b, Appendix 1). Surveys were conducted where "high concentrations of off-channel habitats were found," although high concentrations are not defined (PLP 2012a). Anecdotal data was collected in the SFK in 2005 and 2007, and in the UT in 2007. Quantitative USFS Tier 3 protocols (USFS 2001) were only employed in off-channel habitat in the NFK, and only in 2008 (Appendix 1). The EBD does not provide justification for the varying timing or methodology of off-channel habitat sampling protocols.

Mesohabitat Mapping

Mesohabitats are defined as "visually distinct habitat units on a reach-scale" (PLP 2012a). They were mapped using foot surveys in "selected sample areas" in main stems to visually identify runs, riffles, pools, backwaters, and beaver ponds. Main stem reaches that were not foot surveyed were evaluated with remote sensing including 2004 or 2008 digital imagery and/or videography. Data were combined to estimate the total area of each type of habitat type by stream reach, which was used in fish density calculations.

Other Habitat Parameters

Limiting factors for fish rearing, migrating, and spawning are described for each of the three study rivers (PLP 2012a). These interpret data for which methodology is described in other sections of the EBD including temperature, stream flow, and water velocity (Chapter 7, PLP 2012c), water quality (Chapter 9, PLP 2012d), and groundwater inputs (Chapter 8, PLP2012e). Although a review of methodology is outside the scope of this report, their impacts on fish are briefly discussed below.

Fish Distribution

The stated objective of fish distribution data collection is “to document and describe patterns of fish distribution…in main stem, tributary, and off-channel habitat types (PLP 2012a).”

Patterns of fish distribution among habitat types (e.g., pool, riffle, run, etc.) were evaluated at 2,850 sites from 2004--2008 in the main stem Koktuli River (KR), NFK, SFK, and UT (Appendix 1). The majority of NFK tributaries and upper tributaries of the SFK sampled coincide with initially proposed Tailings Storage Facilities (Table 1, DNR 2006a, DNR 2006b). Fish sampling was less concentrated in lower reaches of the SFK and UT main stems, while fewer than half of all tributaries were sampled, and tributary sampling was occasionally limited to tributary mouths (Appendix 1).

Snorkeling was the primary sampling method used to determine where fish were present. Other methods included single- and multi-pass electrofishing, minnow trapping, beach seining, gill/tangle netting, angling, and dipnetting. “Method and protocol selection was based on stream characteristics (e.g., water depth and velocity, water clarity) and the goal of each specific task” (PLP 2012b). Fish distribution surveys “typically progressed in an upstream direction…[though] in some instances, survey crews began at the headwaters and continuously electrofished in a downstream direction until fish were determined to be present (PLP 2012b).” Captured fish were identified, enumerated, measured, and released.

Additional data was collected from “areas of special interest…or because of the identification of a previously existing data gap,” (PLP 2012b), where primarily snorkeling methods were used to evaluate fish distribution and abundance (Table 1).

Table 1. Areas of special interest identified in the Environmental Baseline Document which were more extensively sampled than other portions of the study area (PLP 2012b). NFK=North Fork Koktuli, SFK=South Fork Koktuli, UT=Upper Talarik; J=June, J=July, A=August, S=September.

Area	2005				2006				2007				2008			
	J	J	A	S	J	J	A	S	J	J	A	S	J	J	A	S
NFK upper reaches and tributaries[a]															X	X
SFK main stem upstream of Frying Pan Lakeb					X			X	X	X	X					
UT lower reaches																X
SFK main stem “downwelling reach” downstream of Frying Pan Lake[b]	X		X			X			X	X	X					

[a]Coincide with initially proposed tailings storage facilities (DNR 2006a, 2006b)
[b]The intention was to sample during so-called “high,” “moderate,” and “low” flows; the CSP does not explain how those flow levels were determined

Fish Relative Abundance

The stated objective of fish abundance data collection is “to document and describe patterns of fish relative abundance in main stem, tributary, and off-channel habitat types.”

Data quality objectives for precision (repeatability) and accuracy of abundance estimates are lacking from the EBD and the Consolidated Study Program (CSP; PLP 2012b). Abundance data collection methods varied. Snorkeling was the primary method, though electrofishing, minnow trapping, and other methods were also used. “Snorkel surveys were calibrated by either replicating the snorkel survey or [one to four] pass electrofishing depletion estimates.” The CSP (PLP 2012b) does not explain site selection for or frequency of calibration effort, methods for correlating calibration data with uncalibrated snorkel data, or whether regression estimaors were actually applied to any data.

With respect to data analysis, the EBD (PLP 2012a) states that:

many of the sampling techniques were not conducive to estimating catch-per-unit-effort (CPUE), but where sufficient electrofishing or snorkeling data exist from all survey passes, relative abundance (fish/100 m) and density (fish/100m^2) were calculated separately for 2004-2007 data and 2008 data.

Reasons for treating 2008 data separately are not clear.

Main Stem and Tributary Habitat

Fish abundance was examined using two approaches.

1) From 2004-2007, fish abundance and habitat data (habitat type—e.g., riffle, pool, run; sample length; wetted width; substrate type; and cover type) were collected from 267 sites within the KR, NFK, SFK, and UT (PLP 2012b). Methods for site selection are not described, and it is unclear whether sampling included tributaries (PLP 2012b).

2) In 2008, 1721 fish abundance study sites were randomly selected from so-called "first preferred" (25% of total first preferred habitats, n~1229; e.g., pool, riffle, glide) and "non-preferred" (10% of total non-preferred habitats, n~492; e.g., cascade) habitat types. Methods for stratification and site selection are not explained in the CSP (PLP 2012b). Similarly, "first preferred" and "non-preferred" habitats are not quantitatively defined for each species of interest at each life stage.

Off-Channel Habitat

Fish abundance in off-channel habitat was evaluated from 2005-2008 by varying methodology. Data were evaluated to compare fish distribution and abundance among off-channel habitats as well as between off-channel and main stem habitats. One hundred forty two off-channel sites were compared to 88 main stem sites. While the CSP (PLP 2012b) refers to the off-channel sites sampled as 'representative,' it does not describe site selection methodology. Timing and location of off-channel sampling varied among watersheds and years (Appendix 1).

Index Surveys

Temporal changes in fish densities and habitat associations were assessed by annually sampling main stem and tributary "index" sites in the NFK, SFK and UT. Index surveys were conducted at nine main stem sites and three tributary sites in 2004, 2005, and 2007 using baited minnow traps. In 2008, index survey sites and methods were different from previous years. Surveys were conducted at 43 main stem sites which differed from the nine previously sampled mains stem sites (Figure 1). Tributaries were not sampled in 2008, though one tributary site was sampled in each of the NFK, SFK, and UT in 2004, 2005, and 2007. Methods in 2008 included snorkeling, seining and/or dipnetting. In 2008, habitat surveys were conducted in conjunction with fish surveys.

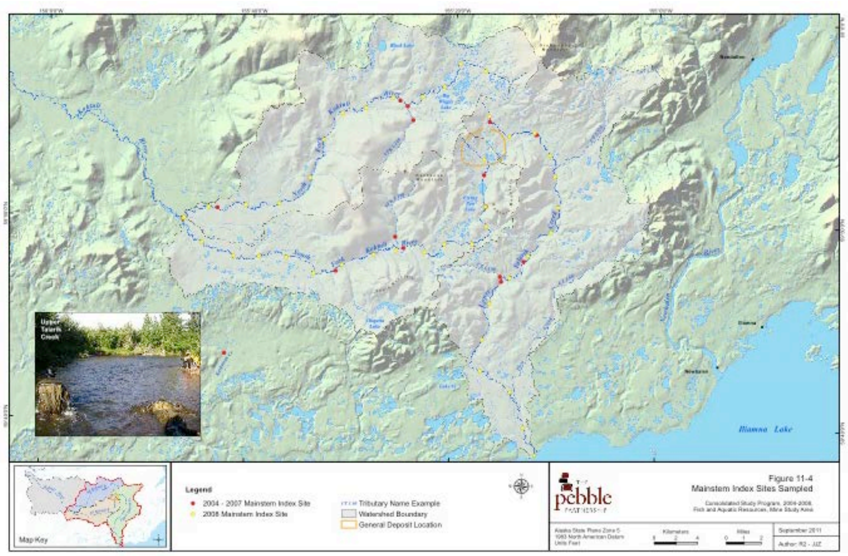

Figure 1. Index survey sampling sites. Site locations and methods in 2004, 2005, and 2007 (red) differed from those in 2008 (yellow). From PLP 2012b.

REPORTED RESULTS AND DISCUSSION SUMMARY

Data presentation

Fish habitat, distribution, and abundance data are summarized and interpreted in Chapter 15 of PLP's EBD, and detailed data are summarized in Appendix B of the same chapter (PLP 2012a). Data are presented by section (reach) of each river system and, when collected, tributary data is included within the reach into which the tributary flows. Data in the form of tables, figures, and maps are inconsistent between reaches (i.e., data presented for some sites is not presented for others, Appendix 1). Data included are in locked pdf format.

Habitat

All three study rivers (NFK, SFK, and UT) are described as single-thread, gravel-bedded channels ranging from straight and high gradient to meandering and low gradient. However, wetland complexes, floodplains, beaver ponds, and off-channel habitats were frequently described (Figure 2). The main stem of the NFK is dominated by riffle habitat, and the SFK and UT are dominated by riffle and run/glide habitat. Little instream cover but good quality spawning gravel was documented in all three study rivers. In all three watersheds, lakes, ponds and beaver ponds proved important to water storage and extended summer runoff. Despite frequently mentioned "barriers," the term is not defined, and barrier heights as low as 0.3 m are recorded.

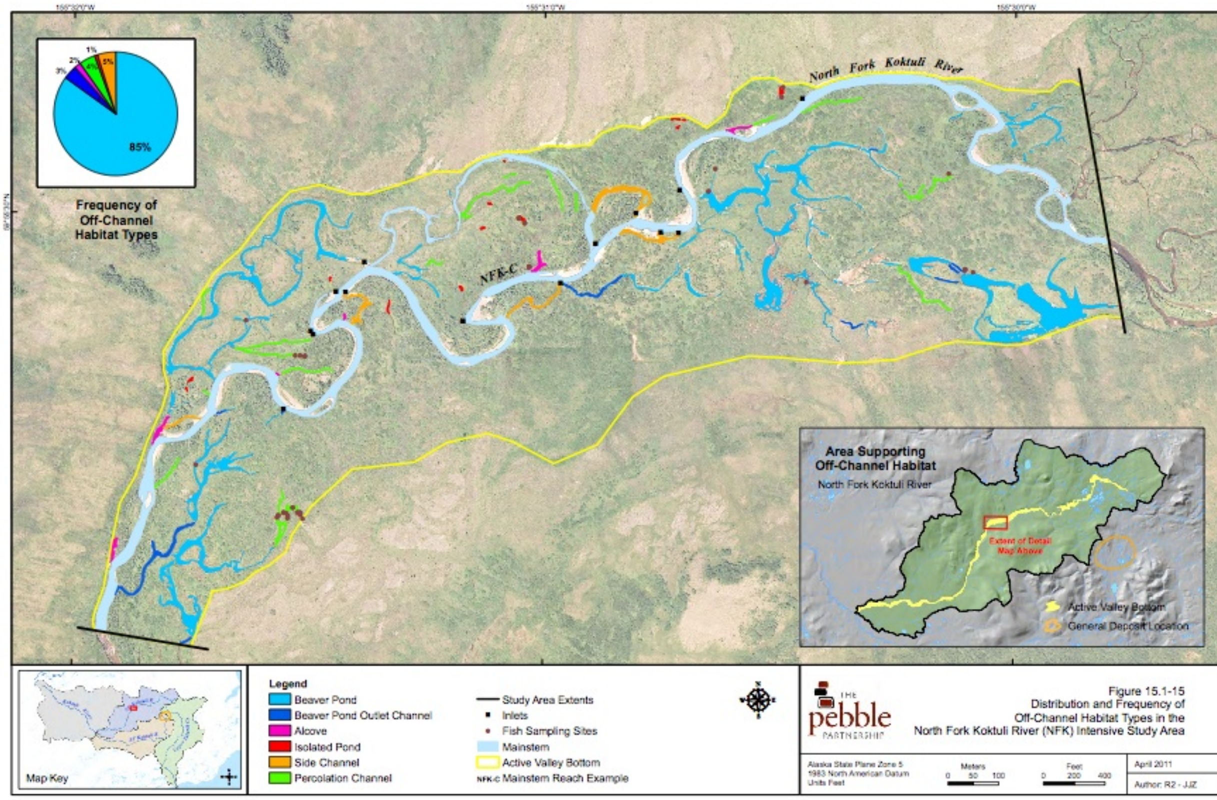

Figure 2. Off-channel habitat in one reach of the North Fork Koktuli River. From PLP 2012a.

Large groundwater downwelling, or "drying" reaches are described for a tributary of the NFK, and for a middle reach and several tributaries of the SFK. The EBD suggests dry periods functionally eliminate juvenile habitat from that reach of the SFK from February through April and results in fish stranding and/or dewatering of incubating eggs. Inter-basin transfer of downwelling water from the SFK to an upwelling area in UT was documented as part of a system of groundwater upwellings throughout UT that stabilize flow and temperature throughout the year.

The EBD suggests that high velocities, cold winter temperatures, warm summer temperatures, soft waters, high metals concentrations, low nutrient concentrations, intermittent stream flows, and limited groundwater influences all limit fish production throughout the study area.

Fish Distribution

Fish distribution data resulted in nomination of 22 new streams (23.1 miles) to the ADFG Anadromous Waters Catalog. "Sampling efforts at 1,260 sites upstream of documented anadromous fish distribution showed no anadromous fish present…though they are assumed to have the potential to support anadromous fishes."

Coho were the most widely distributed and relatively abundant anadromous fish (Table 2), with distribution extending above identified "downwelling reaches." Sculpin and Dolly Varden were the most widely distributed fish presumed to be resident (Table 2).

Fish Relative Abundance

Graphs presenting fish relative abundance data apparently combine data collected using multiple methods, as well as during multiple years. Data collected from 2004-2007 is combined (it is unclear if data presented are averaged across years), while 2008 data is presented separately. Results from efforts described to "calibrate" snorkel data are not reported (PLP 2012a). Additionally, main stem index data is reported only for 2008. Index data collected from 2004-2007 is excluded from the EBD (PLP 2012a) and inter-annual variability at index sites is not reported.

Chinook and/or coho salmon were the most frequently detected fish in the NFK, with relative abundance generally decreasing from downstream to upstream. Dolly Varden and/or sculpin were more frequently detected in upper reaches of the NFK. Coho and/or Chinook salmon were most frequently detected in lower reaches of the SFK, shifting to Arctic grayling in upper reaches. Coho salmon were most frequently detected throughout the UT, with the exception of the uppermost reach where sculpin were the most frequently detected (Table 2).

Table 2. Distribution, abundance, and habitat of resident and juvenile anadromous fish. Summarized from PLP 2012a. L=Lower, M=Middle, U=Upper, T=Throughout; <5=<5 fish/100m^2; >5=>5 fish/100m^2; N/R=Not Reported.

Species	Distribution			Habitat					
	NFK	SKF	UT	Run	Pool	Riffle	Off-channel	Back-water	Other
Chinook juveniles (*O. tshawytscha*)	T	L, M	T	>5	<5	>5	<5		
Chum juveniles[a] (*O. keta*)		L	M	5		<5	<5		<5[b]
Coho juveniles[c] (*O. kisutch*)	T	T	T	>5	>5	>5	>5	>5	>5[b]
Sockeye juveniles[a] (*O. nerka*)	L, U	T	T	<5	<5	<5	<5		<5[d]
Arctic grayling (*Thymallus arcticus*)	L	T	T	>5	<5	<5	<5		<5[b]
Dolly Varden[e] (*Salvelinus malma*)	T	T	T	<5	<5	<5	<5	<5	<5[f]
Rainbow trout (*O. mykiss*)	L, M	L, U	T	<5	<5	<5	<5	<5	<5[f]
Whitefish (various species)	L, M	T	L, M	<5	<5	<5			
Burbot (*Lota lota*)		L							N/R
Northern pike (*Esox lucius*)	M	T		>5	>5	>5			>5[d]
Sculpin (*Cottus* sp.)	T	T	T	>5	>5	>5	<5	>5	
Stickleback (various species)	L, M	T	T	<5	<5	<5	>5	>5	>5[b]
Lamprey (unspeciated)		L							N/R

[a]Chinook and chum salmon spend only a short time in freshwater after emergence before migrating sea, so are rarely documented in freshwater
[b]Beaver ponds and outlets
[c]Most widely distributed and relatively abundant anadromous species documented; distribution extended upstream of the "downwelling reach" of the South Fork Koktuli
[d]Lakes and lake outlets
[e]Assumed to be resident, though no data is presented to confirm that assumption
[f]Cascades

DISCUSSION/CRITIQUE

Data Presentation

The format in which results are presented make the environmental baseline studies difficult, and in some cases impossible, to understand, access, analyze, independently interpret, or repeat. The sheer size of the fish chapter makes it unnavigable, as do frequent references to other chapters regarding hydrology, water quality, temperature, and other subjects. All information is in locked pdf format, preventing copying, pasting, or commenting on data. Data are presented for individual stream reaches in variable and inconsistent formats between tables, figures, and maps (Appendix 1). Individual data points do not include specific dates or locations and cross-referencing among tables, figures, and maps is challenging at best. Relative abundance results from 2008 are presented separately from data for 2004--2007 without explanation, and rely on differently methodology used at different sites (Appendix 1). Lack of detail in methodology and in methods calibration, along with poor presentation of results makes research unrepeatable, violating a central tenant of the scientific method (Brown and Guy 2007), and thus the ability of the EBD to pass any standard peer-review process (ESA 2012).

Habitat

Habitat site selection is not well described, and thus the representativeness of habitat information is unclear. Methods of data collection varied, in some cases using different instruments to measure the same parameters, and in other cases combining and comparing anecdotal to quantitative data with no indication of which data are collected using variable methodologies and no calibration. So-called “barriers” are frequently documented throughout the study area as low as 0.3 m, though data to verify fish absence above barriers is not presented.

Habitat data interpretation suggests a multitude of habitat factors limit fish production, including high stream velocities, excessive summer temperatures, extreme winter temperatures, soft waters, high metals concentrations, low nutrient concentrations, ephemeral reaches, and limited groundwater influences. However, these conclusions are often contradicted. For example:

- “Natural exceedances” of estimated freshwater aquatic life criteria were reported for major elements (e.g., aluminum, iron), and trace elements (e.g., cadmium, copper, lead, zinc, cyanide, mercury). However, all exceedances occurred in less than 15% of samples, most at less than 3% of samples (PLP 2012a), often occur only during snowmelt, and calculations of whether measured concentrations exceed water quality standards may be erroneous (Zamzow 2012). Water quality data generally indicate waters of exceptional quality around the Pebble deposit (PLP 2012d, Zamzow 2011, Zamzow 2012)
- “Natural exceedances” of estimated freshwater aquatic life criteria were reported for temperature, however instream temperature variability is not reported.
- All three rivers are reported to have groundwater that provides winter flow (PLP 2012a, PLP 2012e).
- Anadromous waters are documented throughout the study area, including above ephemeral reaches.

Interpretation in the EBD fails to consider the importance of habitat complexity, crucial to salmonid productivity and persistence (Hilborn et al. 2003, Schindler et al. 2010). This ecosystem complex has remained relatively free of anthropogenic influence for millennia, and fish have adapted. Abiotic conditions prescribed by national or state standards do not dictate fish presence or abundance. Rather, habitat should be characterized where fish are present and abundant to understand how and where they thrive. The greatest testament to the suitability of habitat for salmon is the persistent presence of salmon.

Fish Distribution

Again, site selection criteria for fish distribution data collection are not explained, and over half of tributaries in the study area were not sampled for fish presence, suggesting distribution data underestimates true distribution. Independent data confirms more extensive anadromous and resident fish distribution than presented in the EBD (Woody and O'Neal 2010, ADFG 2012). While using mixed methods for presence/absence data collection is reasonable, conducting surveys in an upstream to downstream manner can bias results as fish may swim downstream to avoid capture and/or float downstream while stunned. Use of block nets to prevent migration out of or into sites is not described.

Despite biases resulting from site selection and sampling methodology, anadromous and resident fishes were documented upstream of reaches characterized as downwelling or ephemeral. This suggests conclusions that occasional lack of surface water flow limits and/or eliminates fish habitat are erroneous. Further, despite known anadromy of Dolly Varden in Bristol Bay watersheds (Lisac and Nelle 2000, Reynolds 2000, Taylor et al. 2008), the EBD reports Dolly Varden as exclusively resident due to a "lack of evidence of anadromy during the five years of study." No data, such as otolith microchemistry, is provided to support that statement.

Fish Relative Abundance

Review of relative abundance methods and results presented in the EBD raises a number of questions regarding sample design (e.g., How were sites, methods selected? How was frequency of sampling determined? Why are data from 2004--2007 combined while 2008 data is presented separately?) as well as data reporting (e.g., Where are results from snorkeling calibration efforts? Where are main stem index survey results from 2004--2007? Was any attempt made to estimate juvenile and/or resident productivity?).

Standardized methods are critical for comparison among and between sites and over time (Joly et al. 2010). However, relative abundance sampling methodology consisted of a variety of methods including snorkeling, electrofishing, minnow trapping, seining, angling, and visual observation. Each sampling method has different sources of bias (under or over-counting fish) and factors affecting precision or consistency of counts; therefore, relative abundance estimates for each method will vary (Heggenes et al. 1990, Bonar et al. 2009). The CSP does not explain why methods known to be affected by variation in sampling effort were employed without recording adequacies of effort to adjust for these potential biases. Unadjusted for, the results are uninterpretable (Joly et al. 2010). Indeed for the majority of methods, no effort was described to standardize capture efficiency, yet results from varying methods were apparently combined to generate relative abundance estimates or "densities were calculated from the method that generated the greatest count of fish" for each location (though that method is not specified). Resulting bias and inconsistency in results reduces statistical power to detect future changes (Bonar et al. 2009).

Snorkeling was the primary method used to determine relative fish abundance and density (PLP 2012a). Although snorkeling is commonly used to estimate salmonid abundance (Thurow 1994, O'Neal 2007), accuracy can change with observer experience, water clarity, temperature (Hillman et al. 1992), sun angle, vegetation, instream structure, river conditions, and fish behavior and size (Thurow 1994, O'Neal 2007). Snorkeling generally underestimates relative abundance compared to electrofishing (Rodgers et al. 1992). Efforts to calibrate snorkeling efficiency with additional snorkeling or electrofishing are mentioned in the EBD, but results are not presented (PLP 2012a, PLP 2012b). Biologists generally recommend snorkel calibration use a more accurate removal method to estimate accuracy of snorkeling (i.e., snorkeling should not be calibrated with additional snorkeling; Hankin and Reeves 1988, Doloff 1993, Thurow 1994, O'Neal 2007, Temple and Pearsons 2007).

An additional limitation to snorkeling is the potential misidentification of some species. Distinguishing between coho and Chinook salmon is difficult even under static conditions, and can require dissection of specimens (Pollard et al. 1997). Although Chinook and coho salmon are often segregated by habitat (Lister and Genoe 1970, Murphy 1989, Scarnecchia and Roper 2000), they can and do co-occur in Bristol Bay Rivers (Woody and O'Neal 2010, PLP 2012a).

Further, snorkeling is likely to overlook or underestimate benthic species such as sculpin (Hillman et al. 1992, Doloff 1993, Thurow 1994). Sculpin are a critical component of salmonid foodwebs (Adams and Schmetterling 2007), and often a key element of salmon and resident fish diets (Merz 2002, Madenjian et al. 2002). Sculpin often dominate fish assemblages in numbers and biomass (Adams and Schmetterling 2007), including several locations throughout PLP mining claims (PLP 2012a, S. O'Neal unpublished data). Also, sculpin can be more sensitive than salmonids to environmental stressors such as increased temperatures (Maret and MacCoy 2002, Edwards and Cunjack 2006), acidity (Kaeser and Sharpe 2001), fine sediments (Mebane 2001), and elevated levels of copper, cadmium and zinc—so much so that many state mandated chronic water quality criteria for aquatic life may not be adequately protective for sculpin (Besser et al. 2007). Because of their higher sensitivity as well as limited instream movement relative to salmonids (Petty and Grossman 2007), sculpin are useful as bioindicators (Adams and Schmetterling 2007), and thus their distribution and density should be well documented prior to development both within and outside of potentially affected streams (Karr and Chu 1999, Noble et al. 2007).

Index Surveys

While index surveys were conducted to estimate natural inter-annual variability prior to potential development, they suffered from poor and mixed methodology, and lack of data reporting, precluding the ability to estimate variability. In 2004, 2005, and 2007, baited minnow traps were used at nine main stem and three tributary sites evenly distributed throughout the NFK, SFK, and UT. Site selection (e.g., random, stratified) is not described and consequently, representativeness is unknown. Minnow traps select for species attracted to the materials with which they are baited (e.g., salmon roe) and their use has been abandoned in the region when they proved unreliable for capturing fish in areas of known fish presence (Bloom 1976, Buell 1991). In 2008, index survey site locations as well as methodology changed, rendering pre-2008 data incomparable and an estimate of inter-annual variability impossible. Results from 2008 are reported, while 2004, 2005, and 2007 results are excluded from the EBD. Quantifying natural variability is essential for detecting impacts from stressors such as climate change and development (Peterman 1990, Noble et al. 2007), and should be an emphasis of pre-development efforts.

CONCLUSION

Due to their economic, recreational, and cultural importance in the region, accurate characterization both within and outside of the proposed Pebble Mine project area is essential to measuring future impacts. Although data collected by PLP consultants is ample, study objectives and sample design are unclear; methodology is poorly described, variable, and often inadequate; data reporting is confusing and often incomplete; and interpretation is questionable and often contradictory. These limitations would prevent favorable peer review of data presented in the EBD, and raise grave concerns about the usefulness of fish assemblage information for either characterizing current fisheries condition or measuring potential impacts from mining in the future.

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Appendix 1. Data reported in Appendix E of EBD Chapter 15 regardig fish assemblage. Type T=Table, G=Graph, M=Map. Main stem or trib M=Main stem, T=Trib. NFK=North Fork Koktuli, SFK=South Fork Koktuli, and UT=Upper Talarik. Data are presented by reach (i.e., A through G). Shaded cells indicate data which are combined (it is unclear how data were combined).

Type	Description	Main stem or trib	NFK-A					NFK-B					NFK-C					NFK-D					NFK-E					NFK-F				
			2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
T	List of species	N/a			X					X					X					X					X					X		
T	Channel morphology data	M																														
		T											X				X															
T	Percent composition of primary habitat types	M															X															
		T											X				X															
T	Descriptive characteristics of primary habitat units	M															X															
		T											X				X															
T	Summary of pool habitat data	M															X															
		T											X				X															
T	Special habitat features	M															X															
		T															X															
T	Number of fish observations by lifestage, species, month, year, and	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X		X			X
		T						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X		X			X
G	Fish abundance by habitat type	M	X	X	X	X		X	X	X	X		X	X	X	X	X[a]															
		T											X	X	X	X	X[a]															
G	Fish density by habitat type	M	X	X	X	X		X	X	X	X						X															
		T											X	X	X	X	X[a]															
T	Densities of fish species by habitat type and lifestage	M															X															
		T															X															
G	Fish abundance by channel location	M															X															
G	Fish density by channel location	T															X															
G	Fish abundance in off-channel habitats	M															X															
G	Fish density in off-channel habitats	M															X															
T	Fish observations by method at index sites	M					X					X					X					X					X					
G	Fish density by habitat type at index sites	M					X					X					X					X										
M	Reach location	N/a			X					X					X					X					X					X		
M	Mainstem and tributaries of interest	N/a			X					X					X					X					X					X		
M	Fish sampling sites by method[b]	M			X					X					X					X					X					X		
M		T								X					X					X					X					X		
M	All aquatic habitat data collection sites[b]	M			X					X					X					X					X							
M		T													X																	
M	Anadromous fish distribution[b]	M			X					X					X					X					X					X		
M		T								X					X					X					X							
M	Resident fish distribution[b]	M			X					X					X					X					X					X		
M		T								X					X					X					X					X		
M	Main stem mesohabitat types	M			X					X					X					X					X							
M		T																														
M	USFS Tier 3 Habitat sites	M													X																	
M		T													X																	
	Notes												3 tributary sites										Tributary mouths sampled									

[a]Data are combined for 2004-2007, and presented seperately for 2008

[b]Tributaries are included on main stem maps; sampling dates are not indicated

Appendix 1 (cont'd). Data reported in Appendix E of EBD Chapter 15 regardig fish assemblage. Type T=Table, G=Graph, M=Map. Main stem or trib M=Main stem, T=Trib. NFK=North Fork Koktuli, SFK=South Fork Koktuli, and UT=Upper Talarik. Data are presented by reach (i.e., A through G). Shaded cells indicate data which are combined (it is unclear how data were combined).

Type	Description	Main stem or	SFK-A					SFK-B					SFK-C					SFK-D					SFK-E				
			2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
T	List of species	N/a			X					X					X					X					X		
T	Channel morphology data	M											X	X				X									X
		T						X				X	X				X						X				X
T	Percent composition of primary habitat types	M											X	X			X	X									X
		T						X				X	X				X						X				X
T	Descriptive characteristics of primary habitat units	M											X	X			X	X									X
		T						X				X	X				X						X				X
T	Summary of pool habitat data	M											X	X			X	X									X
		T						X				X	X				X						X				X
T	Special habitat features	M																									X
		T										X					X										X
T	Number of fish observations by lifestage, species, month, year, and	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		T						X	X	X	X	X	X	X	X	X	X						X	X	X	X	X
G	Fish abundance by habitat type	M	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	X[a]
		T						X	X	X	X	X[a]	X	X	X	X	X[a]						X	X	X	X	X[a]
G	Fish density by habitat type	M																					X	X	X	X	X[a]
		T						X	X	X	X	X[a]					X										X
T	Densities of fish species by habitat type and lifestage	M																									X
		T										X					X										X
G	Fish abundance by channel location	M						X	X	X	X																
G	Fish density by channel location	T																									
G	Fish abundance in off-channel habitats	M						X	X	X	X																
G	Fish density in off-channel habitats	M						X	X	X	X																
T	Fish observations by method at index sites	M					X					X					X					X					X
G	Fish density by habitat type at index sites	M					X					X					X					X					X
M	Reach location	N/a			X					X					X					X					X		
M	Mainstem and tributaries of interest	N/a			X					X					X					X					X		
M	Fish sampling sites by method[b]	M			X					X					X					X					X		
M		T								X					X										X		
M	All aquatic habitat data collection sites[b]	M			X					X					X					X					X		
M		T								X					X										X		
M	Anadromous fish distribution[b]	M			X					X					X					X					X		
M		T								X					X												
M	Resident fish distribution[b]	M			X					X					X					X					X		
M		T								X					X										X		
M	Main stem mesohabitat types	M			X					X					X					X					X		
M		T																									
M	USFS Tier 3 Habitat sites	M													X					X					X		
M		T								X					X										X		
	Notes																	Two mainstem sites sampled					Mesohabitat sampling covers a				

[a]Data are combined for 2004-2007, and presented seperately for 2008

[b]Tributaries are included on main stem maps; sampling dates are not indicated

Appendix 1 (cont'd). Data reported in Appendix E of EBD Chapter 15 regardig fish assemblage. Type T=Table, G=Graph, M=Map. Main stem or trib M=Main stem, T=Trib. NFK=North Fork Koktuli, SFK=South Fork Koktuli, and UT=Upper Talarik. Data are presented by reach (i.e., A through E or G). Shaded cells indicate data which are combined (it is unclear how data were combined).

Type	Description	Main stem or	UT-A					UT-B					UT-C					UT-D					UT-E					UT-F					UT-G				
			2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
T	List of species	N/a			X					X					X					X					X					X					X		
T	Channel morphology data	M					X					X																X	X								X
		T											X										X								X	X					X
T	Percent composition of primary habitat types	M					X					X																X	X								X
		T											X										X								X	X					X
T	Descriptive characteristics of primary habitat units	M					X					X																X	X								X
		T											X										X								X	X					X
T	Summary of pool habitat data	M					X					X																X	X								X
		T											X										X								X	X					X
T	Special habitat features	M					X					X																				X					X
		T																														X					X
T	Number of fish observations by lifestage, species, month, year, and	M	X			X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		T											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
G	Fish abundance by habitat type	M											X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	X[a]
		T											X	X	X	X												X	X	X	X	X[a]					X
G	Fish density by habitat type	M											X	X	X	X							X	X	X	X		X	X	X	X		X	X	X	X	X[a]
		T																														X					X
T	Densities of fish species by habitat type and lifestage	M																																			X
		T																														X					X
G	Fish abundance by channel location	M																X	X	X	X		X	X	X	X											
G	Fish density by channel location	T																					X	X	X	X											
G	Fish abundance in off-channel habitats	M																X	X	X	X		X	X	X	X											
G	Fish density in off-channel habitats	M																					X	X	X	X											
T	Fish observations by method at index sites	M					X					X					X					X					X					X					X
G	Fish density by habitat type at index sites	M					X					X					X					X					X					X					X
M	Reach location	N/a			X					X					X					X					X					X					X		
M	Mainstem and tributaries of interest	N/a			X					X					X					X					X					X					X		
M	Fish sampling sites by method[b]	M			X					X					X					X					X					X					X		
M		T													X					X					X					X					X		
M	All aquatic habitat data collection sites[b]	M			X					X					X					X					X					X					X		
M		T													X										X					X					X		
M	Anadromous fish distribution[b]	M			X					X					X					X					X					X					X		
M		T													X					X					X					X					X		
M	Resident fish distribution[b]	M			X					X					X					X					X					X					X		
M		T													X					X					X					X					X		
M	Main stem mesohabitat types	M			X					X					X					X					X					X					X		
M		T																																			
M	USFS Tier 3 Habitat sites	M			X					X																				X					X		
M		T													X										X					X					X		
	Notes																	Tributary mouths sampled																			

[a]Data are combined for 2004-2007, and presented seperately for 2008

[b]Tributaries are included on main stem maps; sampling dates are not indicated