Summary of Kintama's Proposed Contract Work for the COAST Project, 2011

For the 2011 Statement of Work, we intend to model our program of work on our NPCC Fish & Wildlife Program RM&E Categorical Review proposal for the 2012-2014 funding cycle. This is an evolution from the work in prior years, and therefore 2011 will act as a bridging year, allowing us to address the efficacy of 1) array re-configuration, and 2) capture and tagging of smolts at dam bypasses and subsequent release at or below Bonneville Dam to estimate early marine survival and migration patterns in the ocean.

Long-Term Project Objectives

1. Document the Early Ocean Migration Patterns of Columbia River Chinook
2. Determine the Role of the Ocean in Survival of Columbia River Chinook
3. Key Factors Determining Early Ocean Survival of Columbia River Chinook

Long-Term Project Deliverables

1. Early Ocean Migration Paths of Chinook Stocks
2. Relative Survival Rates of Chinook Stocks in the Early Ocean, the Estuary and the Hydrosystem
3. Correlations Between Early Ocean Chinook Survival and Key Environmental Factors
4. Testing the Efficacy of Transportation Actions for Snake River Stocks
5. Testing the Delayed Mortality Theory

Proposed Physical Layout of the Coastal Ocean Acoustic Salmon Tracking (COAST) Telemetry Array

We examined how the current 69 KHz array can be re-configured to increase the statistical precision and associated power to the extent feasible under the current budget. We also factored in the cost of extending the shelf sub-arrays farther offshore, to depths of 300m, 400m, & 500m (most sub-arrays currently extend to 200m depth) in order to extend the array beyond the (assumed) edge of the smolt spatial distribution. The resultant optimized plan is to tag approximately 800 smolts, and to extend two existing marine sub-arrays to a depth of 500m. We view it as more important that a concerted effort is made to extend the array clearly beyond the depth range where the majority of the migrating smolts occur rather than simply increasing the tagged smolt numbers under the budget. This strategy should allow us to quickly learn whether the smolt distribution extends even farther offshore than the depth contour of 500m.

From prospective large-scale 2nd Generation array elements, for which Kintama has secured permits (Fig. 1), a sub-set of sub-array locations and configurations was selected to achieve the following:

(1) Continued use of 69KHz arrays and V7 tags (limiting tagged smolts to >130mm, but see categorical review proposal for an analysis of the percentage of the smolt range that this covers).

(2) Continue use of sub-arrays sited at Astoria (RKm 22) and Sand Island (RKm 8) to partition the lower Columbia river into "Upper Estuary" (Bonneville Dam to Astoria), and "Lower Estuary" (Astoria to Sand Island), as well as "Plume" environments (Astoria and/or Sand Island to Willapa Bay; Fig. 1).

(3) Re-deploy a sub-array south of the Columbia River at Cascade Head. In previous work, Kintama had seen little southerly migration for tagged groups of hatchery smolts. However, there is a need to repeat this work now that Kintama is tagging run of the river fish of mixed sources to determine the extent of southerly migration for different genetic groups.

(4) Continue use of coastal marine sub-arrays at Willapa Bay and Lippy Point to ensure continuity of survival time series established in 2006-2010. Instead of adding a third marine sub-array to better partition data between Willapa and Lippy, as per the Categorical Review proposal, for 2011 these resources have been prioritized towards the Cascade Head sub-array.

(5) Extend the offshore limit of each coastal sub-array from 200m to 500m water depths, beyond the outer edge of the assumed salmon smolt migration pathway. Kintama's current Willapa Bay sub-array has repeatedly detected tagged Chinook smolts in roughly uniform distribution out to the current limit of the sub-array at the shelf edge (~230m water depths), indicating some tagged smolts may migrate beyond the current extent of the sub-array (NOAA's trawl surveys, which were the basis of the original prototype array design, report the Chinook distribution as apparently being bounded by the ca. 150m isobath, so our work has provided valuable new information not evident from the trawl surveys at that time). In addition, we have evidence to suggest that returning adults tagged by Kintama in 2008 may have migrated beyond the current extent of our current sub-arrays.

Figure 1. Potential 2011 Acoustic Array. Red and orange sub-arrays indicate existing COAST and POST sub-arrays, respectively. To add to these we propose to deploy the sub-array at Cascade Head, and we propose to extend the existing and new COAST arrays to around 500 m depth (also shown in yellow). Smolts will be collected and tagged at Bonneville Dam (BON) and Lower Granite Dam (LGR). All smolts will be released at or below Bonneville Dam. (The Cape Alava and Cape Elizabeth sub-arrays were alternative options to Cascade Head considered by Kintama before deciding that a sub-array south of the Columbia R was a higher priority).

Study Design

A nested series of telemetry array experiments is being proposed in 2011. Overarching these specific *experimental questions* are a number of more fundamental life history issues concerning *exploratory questions* - where do different stocks go in the ocean, what is their speed of migration/duration of residency in the estuary, and what is the fine-scale distribution of the stocks as they migrate along the

coastal shelf (as above we have already determined that fish swim further off the continental shelf than had previously been demonstrated from trawl surveys). To address these questions, we propose to tag 1) in-river migrating yearling Chinook smolts of unknown origin at Bonneville Dam and 2) Snake River yearling Chinook at Lower Granite Dam which will be transported to below Bonneville Dam. *Post-hoc* genetic analyses, sub-contracted to CRITFC, will determine the origin of smolts tagged at Bonneville and Lower Granite Dam.

As basic information about the marine life history of the various Chinook populations that will be tagged at Bonneville Dam is almost absent for the juvenile life history stage, it is anticipated that these data will usefully contribute to the scientific body of knowledge on their marine life histories. A telemetry array is expected to give unprecedented information because pairing the post-release movements and survival of these animals with the stock of origin should give an unprecedented ability to illuminate these questions. As well, we can address critical uncertainties regarding post-Bonneville and early marine survival of in-river migrating smolts from the Snake and upper/mid Columbia River, and Snake River smolts released from transportation barges.

We propose to tag a minimum of 800 smolts in each year of the study. Amongst smolts >130 mm FL that will be tagged at Bonneville Dam will be some number that *post-hoc* genetic analysis will identify as being from the various upstream source populations. Based on John Ferguson's memo to James H. Lecky, dated 15 October 2009 *"Estimation of Percentages for Listed Pacific Salmon and Steelhead Smolts Arriving at Various Locations in the Columbia River Basin in 2009"*, we expect that 22% of the total tags (n=175) will be allocated to Snake River yearling Chinook collected at Bonneville Dam, and 56% of the total tags (n=450) will be allocated to mid-upper Columbia River yearling Chinook collected at Bonneville Dam. The remaining 22% of the total tags (n=175) will be allocated to Snake River yearling smolts collected, tagged, and transported at Lower Granite Dam.

There is an added benefit to tagging smolts in both the Snake River and at Bonneville Dam: if tags were implanted into yearling smolts solely at Bonneville, only 28% would be expected to be applied to Snake River smolts, weakening the statistical power of the survival comparison with upper Columbia River stocks. By adding 22% known-origin Snake River smolts, this increases the fraction of Snake River smolts migrating below Bonneville to 44% (22%+ (1-0.22)*28% ≈ 44%). Therefore, if no statistically significant difference in post-Bonneville survival is found for Snake River smolts migrating in-river or transported, then it is reasonable to pool the animals and estimate a single common post-Bonneville survival estimate for Snake River smolts. This can then be compared with either the survival of either all non-Snake River smolts (56% of expected sample, or roughly a 50:50 split relative to the 44% combined Snake River group, nearly maximizing power), or two subsamples of the populations (with, of course, a resulting reduction in statistical precision and power). Please see the Categorical Review proposal for a fuller discussion of statistical precision and power.

Although specific release strategies are in the preliminary planning stage, we may release four groups of tagged smolts below Bonneville Dam at approximately one week intervals, providing good direct data for comparison with NOAA's PIT tag-based estimates of adult survival variation with timing of ocean entry. Transported release groups may be released as two groups, with similar timing of ocean entry as the in-river groups tagged/released at Bonneville Dam.

Hypotheses to be tested

The expected tagging allocations will allow us to estimate post-Bonneville and early marine survival for yearling Chinook and formally test hypotheses related to delayed or differential-delayed mortality

attributed to Snake River hydrosystem and transportation, respectively. The two experimental tests whose statistical power we specifically examined are:

1) Differential-delayed mortality of transported smolts (T) due to elevated post-release mortality of transported smolts below Bonneville Dam.
2) Delayed mortality of Snake River spring Chinook smolts relative to other Columbia River populations due the cumulative effects of the stress of Snake River dam passage.

As with the transport and other survival comparisons to be made in this current proposal, the key point here is to compare the relative post-Bonneville survival of Snake River-origin smolts with that of other populations that have historically had higher SARs (this potentially includes comparisons with Upper Columbia River spring & fall yearlings and Yakima River spring Chinook), and between listed stocks with unlisted stocks (on the assumption that differences in below Bonneville survival will be of interest).

Relative Survival Estimates

As a result of these planned changes to the study design, Kintama will not have direct measurements of freshwater hydrosystem survival for acoustically tagged smolts in the future. To continue this comparison we will need to relate our survival rate estimates for the estuary and coastal ocean with hydrosystem and estuary survival estimates derived from various regional PIT & JSATs tagging projects and rely on the past consistency of Kintama's acoustic tag based survival estimates for the hydrosystem with the estimates based on PIT tags.

Key Factors Determining Early Marine Survival

Shifting the majority of tagging operations to Bonneville Dam means that Kintama's array studies will provide data on coastal survival rates and movements of a wide range of yearling Chinook stocks. As these tagged animals move out of the river and over the coastal array they will provide information for a wide range of stocks on the timing of ocean entry, duration of estuarine and coastal shelf residence off Washington and British Columbia (from speed of movement), and on the survival rates of these animals. These data can then be related to the direct measurements of smolt abundance and indicators of feeding success derived from the NOAA & DFO Coastal salmon surveys (Project 1998-014-00, "Ocean Survival of Salmonids", directed by Dr Ed Casillas, NOAA, and Project 2003-009-00, "Canada-USA Shelf Salmon Survival Study", directed by Dr Marc Trudel, DFO).

Kintama's measurements of smolt survival and movements are direct measurements that cannot be easily obtained from the two coastal shelf surveys because smolt movement, ship movement, survival, and survey timing are confounded in complex ways that can make the use of catch levels as proxies for abundance difficult. However, although the coastal array measurements of survival have strengths in providing a geographically fixed and continuous monitoring effort which eliminates some of the aliasing problems inherent to ship-based measurements, the array does not provide any detail on the environmental conditions that the smolts are exposed to. In contrast, ship-based measurements provide direct information on plankton, forage fish, and predator abundances, species composition, and biochemical indices (e.g., lipids) as well as a wide range of physical and chemical measurements that can be related to the telemetry-based survival observations. As per the Categorical Review proposal, the long-term aim is to develop triggers associated with poor ocean conditions, with these being directly based on survival observations, which can be used to inform hydrosystem management decisions.