COPPER RIVER DELTA: AN INTEGRATED EXPANSION OF FRESHWATER ECOLOGICAL EVALUATIONS

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1. Introduction.

The Copper River Delta in the southeast Alaskan Chugash National Forest offers unique opportunities for investigations of pond and stream ecosystem structure and function and the implications of climate change on plant and animal communities of these aquatic habitats. The economic, recreational, and social impact of these investigations is large and carries very significant management implications. Emphasis on spawning and rearing of salmonid fishes in the Delta streams and on water fowl and terrestrial birds that nest in or around the ponds of the Delta are of particular concern.
Backed up by mountains and glaciers, the out wash wetlands are crossed by many clear tributaries of the turbid glacial Copper River and dotted with hundreds of ponds. Ground water influence results in cold temperatures and heavy iron flocks at seeps along the streams and in thick layers of the benthos of the ponds. Toward the sea, lie the wet lands uplifted in the 1964 earth quake, again crossed by streams and covered with hundreds of ponds (**ppt Slide 1, map of west Delta**). The uplifted ponds, altered from saline to freshwater by the quake, remain wet primarily from surface accumulation of precipitation. The outer band of coastal wetland ponds are saline.

The unique opportunities for research, and the excellent support of the Forest Service scientists, personnel, and facilities and equipment have attracted an outstanding group of researchers to the Delta. For example, researchers from Michigan State, Oregon State, Loyola of Chicago, and Notre Dame Universities have cooperated in projects n the Delta. This work has resulted in completed publications and theses (**ppt Slide 2, table of cooperators**)

A primary goal of the aquatic research on the Copper River Delta is to document the present ecological conditions of the streams and ponds with a focus on the food webs of fish and birds of special concern. Based on the detailed evaluation of the food webs and the physical chemical regulation (especially water level/water flow and cumulated temperature) of the transfers along the food chains, a monitoring program can be developed that follows the most critical, or keystone, elements of food chains that culminate in the critical species that are the main targets of management strategies. With regard to expected alterations resulting from climate change, ecological processes such as the timing of salmonid spawning, the patterns of maximum growth of juvenile salmonids, and the nesting and rearing of young of water fowl and pond-dependent terrestrial birds like the dusky black bird will receive special attention. Quantifying these couplings will require a combination of day length and cumulate temperature (temperature summation or degree-days) and hydrology data to determine the necessary predator and prey alignments (e.g. juvenile (streams) required to sustain vertebrate predators in pond and streams.

To this end, all site-specific, intensive sampling should be fixed within the context of long term hydrological records of pond depth and stream discharge and degree-day summations against calendar times. It is important that staff gauges and temperature recorders be placed in reference ponds and at reference locations in streams to which measurements made at other sites during sampling can be compared. Rating curves can be developed between reference sites and sample sites so that on-going field sampling can be placed in relation to the longer term records of water levels and flows and annual cumulative temperature. If stream staff gauges are placed a culverts, these can serve as monumented cross sections so that staff gauge measurements of water depth can be converted to stream discharge and these rating curves can be correlated with depth and flow measurements at stream sample sites.

2. Expansion of Spatial and Temporal Perspectives

A workable strategy for research on the Delta has been the time tested approach of developing a credible conceptual model of the aquatic ecosystems through intensive site-specific studies. During the development of conceptual models based on real data, careful selection of key elements of the models as candidates for future monitoring should follow. The elements chosen should be responsive to anticipated stressors to the aquatic ecosystems of the Delta; stressors that management actions will attempt to address in the future. Two prime examples are; uncoupling of food chain relationships as a consequence of the altered temperature patterns expected with climate change and sustainable harvest of important aquatic fish and wildlife species.

The three most important tools for meeting the objective of expanding spatial and temporal perspectives of aquatic ecosystem structure and function on the Delta will be: 1) color infrared aerial photography (and translation to GIS) to bridge the fine scale (single pond or stream reach) studies on the ground to a Delta scale; 2) an intensive and extensive monitoring network of continuous temperature monitoring of ponds and stream reaches on the Delta; and 3) hydrologic data to establish the annual patterns of stream flow and pond filling.

Spatial analysis will require annual remote sensing flights at the same season (the first set was in September) to enable comparisons between years of aquatic plant bed cover in the ponds and riparian plant composition along selected reaches of streams. The remote sensing should consist of at least three to five transects from the glaciers to the sea and these transects should include the signature ponds and stream reaches selected for intensive on the ground ecological work. In order to make maximum and efficient use of the remotely sensed data, it will be critical to acquire/develop the appropriate image analysis soft ware to digitize the images and sum the areas of coverage of the habitat types of interest.

Ponds. With regard to the invertebrate assemblages, the ponds can be viewed as "forest-like" layered systems. An upper "canopy" houses climbing forms that breathe dissolved oxygen (DO) where they move along the plant stems and upper floating and submerged leaves (Lily, Buckbean, and Marestail). This zone is also the main habitat of air breathing swimming and diving taxa. The "understory" houses swimming and climbing forms that breathe DO. The plant bed "floor" is inhabited by surface sediment sprawlers and shallow burrowers (**ppt Slide 3 drawing of side view of plant stands**). The stem climbers (**ppt Slide 4,Odonata**) (**ppt Slide 5, Trichoptera** constitute significant food items for birds like the dusky blackbird that nest at pond edges and water fowl moving through and between the plant beds. Because of their large size and vulnerability near the pond surface, especially when they are emerging to the adult stage, these taxa are likely among the most preferred prey items for nesting water fowl and terrestrial birds. Air breathing canopy and understory invertebrates (e. g. **ppt Slide 6, Corixidae and Dixidae**) are smaller and active swimmers and likely are more difficult to capture, but because of their greater abundance they may serve as important prey for water fowl. The sprawlers and burrowers of the bottom sediments of the ponds **ppt Slide 7, sprawlers and**

burrowers) are likely consumed as prey only when they emerge as adults. (Note that the legs of the libellulid dragonfly nymphs are not opposable which restricts them from climbing in the upper vegetation layers.)
There is evidence that the different aquatic plant species are inhabited by different invertebrates or differing densities of the same invertebrate. Such differences could have measureable effects on their availability as prey for birds. The dominant aquatic plant species in the ponds occur in fairly separate stands (especially lily and buck bean). By combining data on the area of cover of the dominant aquatic plant species of the ponds - lily **ppt Slide 8, stand of pond lily**, note some mixing with marestail but not buckbean), buckbean (**ppt Slide 8, stand of buckbean at pond edge**), and marestail (**ppt Slide 9, pure stand of marestail**), with data on densities of invertebrates, as mean numbers per square meter, it is possible to estimate the number of invertebrates in a given pond in the entire lily, buckbean, or marestail stand and the total for the pond. (Note, using length to weight regressions, these data can be expressed as biomass, which would be necessary for calculating invertebrate production would be more suitable for estimating food chain importance.). As an example, the color infrared image for the outwash pond Tiedeman South (**ppt Slide 10, Tiedeman pond image**) was digitized and the total area of the pond and the separate plant beds determined (**ppt 11, Table of plant bed areas in Tiedeman and other ponds**). In Tiedeman South in September, lily covered 10.5 % and buckbean 7.9 % of the pond surface. In some other example ponds the lily area cover ranged from 0.4 to 39 % and the buckbean cover ranged from o to 9.2. Using the plant bed areas and estimates of invertebrate densities it is possible to estimate the total abundance of key invertebrates (Odonata and Trichoptera) in the entire pond (**ppt Slide 12, Table of pond invertebrate densities**). The estimates indicate that the Tiedeman South pond was supporting 48,000 of the large climbing invertebrates and that twice as many were present in the lily beds as in the buckbean beds, even though there was only 25 % more cover by lily than buckbean in the pond. By combining such data, expressed as biomass, with feeding rates and efficiencies of a given biomass of birds occupying the habitat, or nesting near the pond, it would be possible to estimate the biomass of birds these invertebrate prey species could support. Eventually it should be possible to estimate the % of the bird production attributable to the production of these large invertebrates.

Therefore, associations between invertebrates and plant bed types, remote sensing of pond and plant bed areas and cover, together with stable isotope information linking particular invertebrates as food for water fowl and dusky blackbirds, should allow for predictions as to the pond types that provide the most potential for rearing bird populations.

Pond succession rates and the relative importance of the different dominant aquatic plant species contributing to succession should be discernable form the analysis of a large number of ponds, particularly in the uplifted wetlands, where the time of the setting of freshwater conditions in known (1964). For example if the ponds close from the center, lily would dominate the process, whereas if the ponds fill from the margins, then buckbean would be mor important in the succession process.

Streams. As in the case of the ponds, remote sensing should play a major role in establishing the areal coverage of habitat types, but for selected stream reaches in representative streams. The focus for the stream studies has been the spawning and rearing of salmonids, especially Coho salmon. Recently, there has been emphasis on the invertebrate food of juvenile Coho and Cutthroat and Dolly Varden trout. Benthic invertebrate samples taken with the Hess sampler have established the relative densities of the invertebrate taxa of a number of streams in riffle and pool habitats. It appears that stream habitat for both juvenile salmonids and their potential invertebrate prey could be simply classified into either erosional (riffles, runs, glides) or depositional (pools, backwaters, side channels) habitat. This would separate the invertebrates efficiently and would mesh quite well with the functional feeding group (FFG) method for characterizing stream invertebrates: scrapers and filtering collectors dominating the erosional habitats and gathering collectors and shredders (wherever coarse detritus accumulates) dominating depositional habitats. In the future, benthic invertebrate sampling should be conducted concomitant with sampling of juvenile salmonids in the same reaches. In general, the juvenile Coho would be found in the depositional habitats while more of their probable prey invertebrate taxa would occupy erosional habitats. Studies in northern California have demonstrated that during juvenile salmonid surveys in which the riffles and pools chosen for sampling followed the Hankin and Reeves method of determining fish densities, invertebrate samples could be taken and analyzed in the field on live material for FFG composition. In those studies, a crew of two could complete the enumeration and classification of the invertebrates in every other reach sampled by the Hankin and Reeves method for fish density. The critical point is that both the fish and invertebrate crews leave the field with their data at the same time. Both crews can preserve samples for return to the lab for later analyses(e. g. fish scales, otoliths, tissue for genetics; higher resolution invertebrate taxonomy). Invertebrate FFG relative densities determined from the field counts compared to counts on preserved material in the lab were shown to be statistically indistinguishable for specimens larger than 1 mm.

Drift net collections capture those stream invertebrates most likely to support the maintenance and growth of drift-feeding juvenile salmonids. This has been verified by comparison to gastric levage samples from filed collected fish take at the same time. Once the stream invertebrates with the highest probability of occurring in the drift have been identified, the benthic samples described above can be partitioned according to those probabilities. This allows benthic samples to be used to predict the level of likely prey delivery to the fish in a given reach of stream. In northern California streams, the most reliable drifters are gathering and filtering collector FFGs. Therefore, stream reaches in which those two functional groups dominate would be likely to support the best juvenile growth. During the summer, the most significant portion of invertebrate food items found by gastric levage in juvenile Coho in Delta streams is of terrestrial origin. For this reason, semi-quantitative samples in the form of timed sweep net collections in the riparian zone should be part of the protocol for sampling stream reaches, particularly in the summer. Those stream reaches bordered by riparian vegetation (especially alder) with the highest densities of terrestrial invertebrates should correlate, along with high in-stream densities of collectors, with the best fish growth. Remote sensing photography can be used to identify reaches with the best riparian vegetation likely to provide a good supply of terrestrial invertebrate prey taxa.

In both ponds and streams of the Delta, the timing of the maximum availability of aquatic and terrestrial invertebrates as prey for fish and birds can be predicted by temperature summation. That is, the degree-days required for the invertebrates to reach the most vulnerable stages for consumption by the vertebrate predators. This would be the time of emergence of the aquatic invertebrates and the times of mating and dispersal of the terrestrial invertebrates. This highlights the need for a network of continuous temperature recorders so that the degree-day accumulations required for egg to adult development of key invertebrates can be calculated. Furthermore, it seems clear that sampling intervals for stream and pond invertebrates should be chosen by degree-days rather than calendar days. As climate change alters the pattern of degree-day accumulations, and given the expected differing terrestrial and aquatic effects, significant changes in the timing of the availability of invertebrates as prey for juvenile salmonids, water fowl, and stream- and pond-side terrestrial birds would be predicted.

The Special Case of the Corixidae

All studies to date indicate that the Corixidae (water boatman; **ppt Slide 13. corixid**) are represented in Copper River Delta aquatic habitats by a single species, *Callicorixa vulnerata*. This appears to be unique when compared to other regions of Alaska and northwest North America where, in general, three to five species would be the rule. In summer, *C. vulnerata* appears to be the most abundant and continuously distributed invertebrate in Delta ponds. All sampling so far, shows that the nymphs of *C. vulnerata* rear in ponds and migrate *en mass* as adults to streams in late August to early September. In the autumn, *C. vulnerata* is by far the most visably abundant invertebrate in the streams. Large waves of adults literally blanket whole areas of stream bottom where the move slowly along. This migration of adults from ponds to streams coincides with the major Coho spawning and activity and egg production. Observations suggest that the fitness of this timing for *C. vulnerata* is the availability of massive quantities of energy rich eggs for the adults during their time of reproduction. Whenever minnow traps baited with roe are set for capturing juvenile salmonids in the fall, massive numbers of , *C. vulnerata* are captured. The energy rich egg diet should enhance and accelerate sexual maturation of the adults and the development of eggs in the females during the fall and winter and early spring. It is not known if the adults overwinter in the frozen and snow-bridged streams, as has been observed in corixids elsewhere, with the females migrating back to ponds for egg laying in the spring . Mating flights of adults diving into the water have been observed in streams at this time. However, it is possible that adult *C. vulnerata* could migrate back to the ponds in late fall and over winter there under the ice. It is likely that *C. vulnerata* represents important dietary intake by juvenile Coho (although it may be incidental to egg consumption by the fish) in the fall and fledgling birds in the spring and summer in and around ponds.

Conclusions

The major approaches for intensive, fine scale pond and stream reach studies leading to the development of credible conceptual models of food chain relationships should involve plant bed-related studies of pond invertebrates and erosional vs depositional stream invertebrate assemblages. Organizing the invertebrate data according to function would likely provide useful insights into food chain relationships. That is, the separation of invertebrates in relation to species and strata of the aquatic plants in ponds, by FFGs in stream reaches, and riparian inventories. Invertebrate data will be most relevant to food chain relationships if expressed as biomass and production and fitted into degree-day and depth/flow time tables for the key taxa. The continued development of such models will require extensive reference hydrological and thermal data.

The major extensive approach will undoubtedly involve a heavy investment in remote sensing and software to efficiently digitize large coverages of ponds and stream reaches. Such data will allow management of aquatic resources on the Delta to be framed at a scale large enough to have a measureable influence on fish and bird species of interest.

As the conceptual models of stream and pond food webs are refined, and those perspective are expanded to larger scales and time frames on the Delta, the time will be appropriate to plan and execute some field manipulations that would provide for important hypothesis testing.

Finally, all the studies of aquatic systems, and coupled terrestrial ones, should be framed within the context of the major shifts anticipated as a result of climate change. This means that all hypothesis-testing on the Delta in the future should be linked to climate change models.