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Evidence of Residual Effects From the Capture and Handling of Yukon River Fall Chum Salmon in 2002

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by

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Disclaimers

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Introduction

The Yukon River originates in the coastal mountains of northern British Columbia and flows over 3,200 km through British Columbia, Yukon Territory, and Alaska to empty into the eastern Bering Sea, draining an area of over 850,000 km^2 (Figure 1; Brabets et al. 2000). The Yukon River drains portions of the Brooks Range, the Alaska Range, the Wrangell-St. Elias Range, and numerous smaller mountain ranges. Five species of Pacific salmon (*Oncorhynchus* spp) spawn within the Yukon River drainage, although chinook (*O. tshawytscha*) and chum (*O. keta*) salmon are most abundant.

Two genetically distinct races of chum salmon occur within the Yukon River (Seeb and Crane 1999). Summer chum salmon tend to enter the river in June and July and spawn in tributaries of the lower and middle portion of the main-stem. Fall chum salmon tend to enter the Yukon River from July through mid-September and spawn in areas of upwelling ground water in the middle and upper portions of the drainage. Important fall chum salmon spawning areas include portions of the Tanana, Chandalar, Porcupine, and Kluane rivers, and the Canadian Yukon River main-stem (Barton 1992).

Fall chum salmon support important commercial and subsistence fisheries in the U. S. and commercial and First Nation fisheries in Canada. Buklis (1999) describes the recent history of U. S. commercial fisheries in northern and western Alaska, including the Yukon River. The 1996-2000 average harvests in the U. S. and Canada are 116,953 and 15,316, respectively (Vania et al. 2002), although this time period includes years of reduced returns and fishery restrictions. The primary goal of Yukon River salmon management is to maintain the abundance of spawning populations in selected spawning locations throughout the drainage (Vania et al. 2002). However, most fisheries occur large distances from the spawning grounds and there can be a substantial delay before the consequences of management decisions are observed on the spawning grounds. The ability of management to achieve the spawning goals is greatly increased by the availability of in-season estimates of abundance downstream of or near the areas where fisheries occur.

Several important fall chum salmon spawning populations have been monitored near their spawning grounds for many years, but in-season estimation of abundance in the mainstem Yukon River has only been achieved recently. Prior to 1995, the abundance of migrating fall chum salmon was estimated using sonar near Pilot Station, Alaska, a village in the lower Yukon River, by the Alaska Department of Fish and Game (ADFG; Pfisterer 2002) and with mark-recapture methods near the U. S.-Canada border by the Department of Fisheries and Oceans Canada (DFO; Johnson et al. 2002). The ADFG initiated a mark-recapture project to estimate the abundance of fall chum salmon in the upper Tanana River in 1995 (Cappiello and Bromaghin 1997). That project was expanded to include the Kantishna River drainage, a tributary of the Tanana River, in 1999 (Cleary and Bromaghin 2001). In 1996, the U. S. Fish and Wildlife Service (USFWS) initiated a mark-recapture project to estimate fall chum salmon abundance on the Yukon River mainstem above the Tanana River confluence near Rampart, Alaska (Gordon et al. 1998). The Tanana and Rampart projects provide important information from the middle portion of the Yukon River drainage, and have greatly improved the ability of managers to assess fall chum salmon abundance in-season and adjust harvest rates accordingly. The abundance estimates have become valuable for managing fall chum salmon, particularly in the middle and upper portions of the drainage where large subsistence fisheries occur, and have contributed to a better understanding of the relative magnitude of the upper Yukon River and Tanana River fall chum salmon populations.

In 1996, USFWS biologists associated with the Rampart mark-recapture project became aware that mark rates, i.e., the proportion of captured fish that have been marked, at Canadian research sites were substantially lower than mark rates observed at the project's recapture site near Rampart, Alaska. Subsequent investigations indicated a progressive reduction in mark rates as distance from the tagging site increased. Nine hypotheses regarding phenomena that could contribute to a reduction in mark rates were developed and the plausibility of each hypothesis was evaluated using available data (Underwood et al. 2000a, 2000b). Although the data were not conclusive, the potential cause judged to be most consistent with all available information was that the capture or tagging process increased the mortality rate between the recapture site near Rampart, Alaska and upriver locations. A similar effect would be produced by fish progressively exiting the migrating population and moving to, and perhaps even attempting to spawn in, unmonitored areas other than their original destination. Such a behavioral response and actual mortality will be referred to collectively as a prematurely-terminated migration (PTM).

The results of subsequent analyses of data collected in conjunction with the Rampart mark-recapture study continue to be inconclusive, but primarily consistent with a PTM hypothesis. Underwood et al. (2004b) documented a progressive reduction in mark rates with distance from the marking site, with samples being obtained from multiple locations and with several types of gear. They also found that the number of times a chum salmon was captured in a fish wheel was inversely related to the probability of recapture at upriver locations, suggesting that simply being captured may be a causative factor and that the effects may be cumulative. Underwood et al. (2004b) concluded that the most plausible explanation of the observations was delayed mortality, i.e., the hypothesis of PTM.

The National Marine Fisheries Service (NMFS), in cooperation with the USFWS, conducted a radio telemetry study of Yukon River fall chum salmon in 1998 and 1999. Because a report detailing study results is not yet available, a summary of pertinent results follows (J. Eiler, National Marine Fisheries Service, personal communication). Fall chum salmon were tagged with transmitters at the marking site. The upriver migration of tagged fish was primarily monitored with fixed receiver stations (Eiler 1995), though a small number of aerial surveys were also flown. The results of this study provide mixed support to the PTM hypothesis. Although a small-scale experiment documented negative effects from holding fish prior to release, which is consistent with the PTM hypothesis, data on the final fate of radio-tagged fish were inconsistent between years. In 1998, most tagged fish were tracked to the upper mainstem Yukon River or tributaries known to contain fall chum salmon populations. However, in 1999, a relatively large proportion of radio-tagged fish appeared to remain in the Yukon River mainstem or small tributaries not thought to support populations of fall chum salmon. While this result is consistent with the PTM hypothesis, the magnitude of the effect is somewhat less than would be expected based on the mark-recapture data (Underwood et al. 2000a). The mark-recapture project documented substantial declines in mark rates in both 1998 (Underwood et al. 2004b) and 1999 (Tevis Underwood, USFWS, unpublished data). The cause of the difference in the telemetry results in 1998 and 1999, and the apparent discrepancies between the telemetry and mark-recapture projects, is unknown.

The potential for the Rampart mark-recapture project to increase fall chum salmon mortality is cause for concern. The fish wheel sites used in the project are locally known as productive sites. Annual catches at the marking and recapture sites have exceeded 18,000 and 40,000 chum salmon, respectively, and weekly estimates of capture probabilities have exceeded 0.10 and 0.15 at the two sites, respectively (Underwood et al. 2000a). An increase in mortality due to project operations therefore has the potential to affect a substantial number of fish and a substantial proportion of the population. Important fisheries, particularly subsistence and First Nation fisheries, occur in upper portions of the drainage, and it could be difficult to justify operation of an assessment project that may substantially elevate mortality, particularly in years of low abundance when fisheries are restricted or closed. This possibility, in combination with a weak fall chum salmon return, led to the early termination of project operations in 2000 (Underwood and Bromaghin 2003).

In 2001, the USFWS initiated a study to further investigate the declining mark rates of fall chum salmon upriver from the mark-recapture study area (Bromaghin and Underwood 2003). One objective of the study was to more rigorously document the reduced mark rates previously observed upriver from the Rampart recapture site. With the exception of data collected at Canadian research sites, upriver samples for mark rates had not been collected throughout the fall chum salmon migration (e.g., Underwood et al. 2004b). Because the mark-recapture study design called for a constant number of tagged fish to be released each day (e.g., Underwood et al. 2000a), one would expect mark rates to vary with abundance through time. In 2001, fish wheels were operated systematically throughout the duration of the run at two upriver locations, near Beaver and Circle, Alaska. The consistent collection of mark-rate data through the duration of the migration was expected to more conclusively document mark rates at these locations.

A second study objective of the study initiated in 2001 was to investigate the relationship between characteristics of the capture and handling of individual fish at the marking site and the probability of recapture in upriver locations (Bromaghin and Underwood 2003). Prior to 2001, sampling protocols of the mark-recapture study were designed only for purposes of abundance estimation (e.g., Underwood et al. 2004a). Once fish were captured by the fish wheel, most slid down a chute into a live-box, from which they were later removed, tagged, and released. The time tagged fish were released was recorded, but the time of capture could only be coarsely approximated. A relatively small number of fish were taken directly from the chute and processed without entering the live-box. In 2001, operations at the marking site were modified so that holding times were recorded with more precision. In addition, fish were intentionally held under a continuum of conditions, from being tagged and immediately released to being tagged and held for several hours, potentially under crowded conditions. The increased precision with which holding times were recorded allowed the probability of recapture in upriver locations to be modeled as a function of holding time. The objective of this component of the study was to identify handling practices associated with decreased recapture rates so that such practices might be avoided in future studies.

In 2001, Bromaghin and Underwood (2003) found that mark rates observed at upriver recapture sites were significantly less than at the Rampart recapture site, as had been previously observed (Underwood et al. 2004a). The length of time fall chum salmon were held in a live-box was associated with an increased probability of recapture at both the marking site and the Rampart recapture site, as well as with a reduced migration rate between those two sites. Conversely, the length of time fish were held was associated with a decreased probability of recapture at locations upriver from the Rampart recapture site. Bromaghin and Underwood (2003) speculated that one possible explanation of the results is that holding fish impairs their ability to migrate, leading to slower swimming speed and elevated recapture rates within the traditional mark-recapture study area, and that marked fish progressively exit the migrating population upriver of the Rampart recapture site, i.e., the PTM hypothesis. However, Bromaghin and Underwood (2003) noted that the magnitude of the effect of holding fish in a live-box was inadequate to fully explain the observed decline in mark rates.

The study initiated in 2001 was continued in 2002. The objectives of the study were largely unchanged, to more fully document mark rates upriver from the mark-recapture study area and investigate potential causes of the reduced mark rates. Whether or not the 2001 results would be replicated was, of course, also of interest. Because of the reduction in mark rates between the Rampart and Beaver recapture sites noted in 2001 (Bromaghin and Underwood 2003), an additional fish wheel was added near Stevens Village, roughly midway between Rampart and Beaver, in 2002. Digital photographs were taken from a subsample of fish captured in each location to enhance documentation of the lack of tag loss previously reported (Underwood et al. 2004b), as well as to generally document the condition of the primary and secondary mark locations. Finally, methods were modified slightly to increase the holding time for some fish with the intent to magnify the effect observed in 2001.

Potential Implications to Management and Research

The results of this study raise questions regarding the use of fish wheels and live-boxes in fishery management. Use of fish wheels is common in some portions of the Yukon River drainage, and live-boxes have been viewed as a tool allowing the capture of target species and the live release of non-target species. In some years of low salmon abundance when subsistence fisheries were restricted, fish wheels could only be operated if a live-box was attached or if the fish wheel operator was present, so that non-target species could be released alive (e.g., Bergstrom et al. 1998). The release of fish from a live-box is certainly less harmful to the fish than the traditional 'dead-box', which is not submerged, but results from both years of study imply that live-boxes may not be as innocuous as was previously believed.

Fish wheels, many with live-boxes, have become a fairly common research platform within the Yukon River drainage, and elsewhere in Alaska (e.g., Kerkvliet and Hamazaki 2003; Savereide 2003; Underwood and Bromaghin 2003; Cleary and Hamazaki 2002; and Johnson et al. 2002). If the use of live-boxes was found to negatively affect salmon, the cost to research programs in terms of reduced sample sizes, increased personnel costs to actively monitor fish wheels, or the need to develop alternative capture techniques could be substantial. However, with the exception of Cleary (2003), other researchers that have investigated the effects of capturing and handling salmon using fish wheels have not obtained similar findings regarding recapture probability or travel time. Kerkvliet and Hamazaki (2003) did not observe differences among Kuskokwim River coho salmon held for different lengths of time. Cleary and Hamazaki (2002) found that Tanana River fall chum salmon with longer mean holding times sometimes had elevated migration rates, rather than reduced migration rates as observed in this study. The cause of the differences among these findings is unknown. The large sample sizes obtained in this study, or the increased precision with which holding time was measured, may have made the effect discernable. For example, the precision with which Kerkvliet and Hamazaki (2003) measured holding time is unclear, and they binned holding time into categories prior to analysis. However, other explanations are possible and the causes for the apparent differences between studies merits additional investigation.

The elevated capture probability of held fish at the Rampart recapture site has implications for the annual Rampart fall chum salmon mark-recapture study. Although protocols have been modified to reduce holding times in recent years, some fish have been held at the marking site in every year of the study (e.g., Underwood and Bromaghin 2003). An increased recapture probability for tagged fish is effectively a 'trap-happy' response, and it negatively biases abundance estimates (Seber 1982). Underwood et al. (2004a) reported that abundance estimates are less than run reconstructions based on all available upriver data sources in five of six years, though differences are relatively small and measures of precision of the data sources used in the run reconstruction are not generally available. Negative biases caused by holding fish might be responsible for the tendency of the estimates to be less than the run reconstructions. To avoid potential bias, abundance estimation should be based on data from fish that are not held. In 2002, the estimate of abundance increased by approximately 40% when data on held fish were excluded. However, the number of marked fish was reduced by approximately 50% and the standard error of the estimate increased by nearly 350%. For these reasons, although the point estimate was expected to increase, the magnitude of the increase must be viewed with caution.

Conclusions

The results from the two years of study conclusively document that holding Yukon River fall chum salmon in a live-box at the Rapids marking site increases their probability of recapture at that location, increases their travel time to the Rampart recapture site, and increases their probability of recapture at the Rampart site, all of which are consistent with the PTM hypothesis. These results also imply that historic estimates of fall chum salmon abundance obtained by the Rampart mark-recapture study are negatively biased, though the magnitude of the bias is difficult to determine with the available data.

Evidence that the effects of holding fall chum salmon in a live-box persist as they continue their migration above the Rampart recapture site were obtained in 2001 (Bromaghin and Underwood 2003), but that was not confirmed by findings in 2002. That negative effects persist through the migration in some years seems likely. However, in either case, holding fall chum salmon in a live-box clearly does not explain the reduction in mark rates observed at upriver locations. These results, in combination with the findings of Underwood et al. (2004b), suggest that negative and cumulative effects may be caused by the capture event itself, rather than holding conditions. The results of this study suggest that negative effects can be reduced, but not eliminated, by ceasing to hold fall chum salmon in a live-box.

The potential for use of fish wheels to impair the migratory fitness of Pacific salmon is a serious concern given their widespread use in fishery management and research. Work completed to date has provided valuable insights into the potential effects of fish wheels and has answered some questions, yet additional questions remain unanswered. Researchers using fish wheels to capture salmon are encouraged to continue investigations so that a full understanding of the effects of fish wheel capture on fish can be obtained as quickly as possible.

Recommendations

A continuation of this research is unlikely to provide new insights into the effects of fish wheels, so additional work of this type is not recommended. Results from 2001 and 2002 conclusively document that holding fall chum salmon in a live-box at the Rapids marking site increases the recapture probability of tagged fish at the Rampart recapture site, introducing a negative bias into abundance estimation. For that reason, use of live-boxes should be discontinued at the marking site.

As previously discussed, all the known spawning grounds upriver from the mark-recapture study area have been sampled, as have numerous mainstem locations, and nearly all mark rate estimates have been substantially less than estimates obtained at the Rampart recapture site. That fact adds some credence to the conclusion that spawning populations are not spatially segregated at the marking site. However, mark rate estimates from the Chandalar and Sheenjek rivers, two of the largest fall chum salmon populations, are only available from one year (Underwood et al. 2004b). While the mark rates observed in both tributaries in that year were quite low, it would be prudent to obtain additional data in at least one more year.

One possibility that has not yet been investigated is the potential segregation of fish on and off shore within the mark-recapture study area. Such a segregation could produce a progressive decrease in mark rate upriver from the mark-recapture study area if tagged and untagged fish gradually mix as they migrate upriver. One approach to investigating this possibility would be to compare the mark rates of fish captured in the Rampart recapture fish wheel and those captured in gill nets off shore at the same location. Given the relatively small mark rate observed in fish captured in the fish wheel, say 3% to 5%, it is likely that at least several hundred fish would need to be harvested in the gill nets. Given the reduced abundance of fall chum salmon in recent years and the importance of the fish to fishers, the implications to management and the disposition of the harvested fish need to be carefully evaluated prior to conducting such a study.

Further, consideration should be given to alternative methods of investigating causes for the differences in mark rates. Use of radio telemetry may be an option, but the high cost of tags and the immensity of the study area may reduce the attractiveness of this approach. Comparing genetic estimates of stock composition at the marking site with estimates of abundance from upriver data sources might provide useful insights into the potential for stock-based selectivity at the marking site, though available data is consistent with a lack of selectivity. In addition, the possibility of evaluating the effectiveness of alternative capture and marking methods at the marking site may have merit.

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