

Capabilities and Potential Applications of Adult Salmon Tagging Methods in the Yukon River Basin

Discussion Paper for the U.S./Canada Yukon River Panel
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Introduction

The purpose of this discussion paper is to provide the U.S./Canada Yukon River Panel with background information on current tagging methods for studying salmon returns in large river systems. Technical aspects, potential applications, and the kinds of data to be expected are described.

Upper Yukon River salmon spawn in numerous tributaries, and support important fisheries in both the U.S. and Canada. Under the Interim Yukon River Salmon Agreement (1995), the U.S. and Canada have agreed to conduct cooperative research to determine the migratory patterns, exploitation, productivity and the status of stocks of common concern. The assessment and inventory of wild stocks is specified in the agreement as an integral part of any effort to maintain, restore and enhance salmon returns in the upper basin.

Mark-recapture, radio telemetry, and studies combining both methods have been suggested as a means for providing fisheries managers with additional information on 1) total and stock specific run strength, 2) stock composition and timing, and 3) the location of spawning areas in the Yukon River basin. The immense size and isolation of this watershed make collecting this normally routine fisheries data with traditional methods extremely difficult. Mark-recapture studies have been conducted successfully in large river systems. Likewise, technological advances in telemetry have made large-scale tagging programs in remote areas more feasible, productive, and cost effective. Telemetry equipment and expertise is potentially available to facilitate research in the Yukon River basin. While the Yukon River Joint Technical Committee (JTC) has a technical role in defining and prioritizing research needs and objectives, the JTC looks to the Panel for direction, consistent with what is technically and practically feasible as determined by the JTC.

It should be noted that this paper, when addressing mass tagging and/or radio tagging, focuses on the Upper Yukon River basin or sub-basins. While these drainages are very large in themselves, the overall Yukon River drainage would be vast in study scope. Although much could be learned from studies in the Upper Yukon River basin or sub-basins, substantial fisheries are also located in the lower Yukon River.

Description of Existing Programs and Information Needs

The Interim Yukon River Salmon Agreement calls on the U.S. and Canada to conserve stocks originating in the Canadian portion of the basin, develop and conduct cooperative research and management programs, and identify potential restoration and enhancement opportunities. This section briefly describes current management and

research programs, and information needs for salmon in the Yukon River basin relative to adult salmon tagging methods.

Current Management and Research Programs

Components of the current management and research programs can be categorized as follows:

1. improving in-season management through continued development of in-season run timing and abundance estimation projects (Pilot Station sonar, Tanana River mark-recapture, upper Yukon River mark-recapture, various test fisheries);
2. catch monitoring and sampling programs to determine harvest levels and characteristics (age, size and sex), and survey programs to estimate non-commercial harvests;
3. escapement estimation and associated sampling programs using hydroacoustic technology, mark-recapture techniques, observational towers, weir and fishway enumeration, and indices of abundance from aerial and ground surveys;
4. stock identification programs involving scale pattern analysis (SPA) for chinook salmon and genetic stock identification (GSI) research (protein electrophoresis and various DNA techniques) on chinook and fall chum salmon;
5. continuing development of a comprehensive database to monitor trends in returns (age, size, sex, and stock composition) and stock-recruitment characteristics to enable forecasting of future run sizes, to assess spawning escapement objectives, and to assess the status of stock rebuilding and stabilization programs;
6. improving knowledge on distribution and survival of chinook and fall chum salmon through the use of coded-wire tags (Whitehorse Hatchery chinook, Toklat River fall chum).

Chinook salmon. The information provided by these programs is only sufficient to manage Yukon River chinook salmon on a broad geographic scale. Harvests, particularly from commercial fisheries, are known with fair accuracy, and can be post-seasonally apportioned to region of origin (lower, middle, and upper basin) using SPA techniques (Schneiderhan 1994). Post-season run reconstructions are conducted annually for the upper Yukon River aggregate stock using U.S. harvest information apportioned by SPA, and Canadian population estimates of chinook salmon migrating into the upper Yukon River as determined by the Canadian Department of Fisheries and Oceans (DFO) mark-recapture program. Run reconstruction has recently been

made possible for the Yukon River aggregate stock using Pilot Station sonar abundance estimates in conjunction with harvest information. Over time, run reconstructions will increasingly contribute to our understanding of stock productivity.

Chum salmon. As with chinook salmon, current management and research programs are only sufficient to manage Yukon River fall chum salmon on a broad geographic scale. Harvests, particularly from commercial fisheries, are reported with fair accuracy although very little information is available on the stock composition of the catch. Techniques to estimate stock composition are being investigated. Currently, fall chum abundance is estimated on the mainstem Yukon River near Pilot Station using hydroacoustic techniques, and just upriver of the U.S.-Canada border using mark-recapture techniques. In 1995, a mark-recapture feasibility study was initiated to estimate fall chum abundance on the upper Tanana River. Fall chum abundance is also estimated for several major spawning areas. While precise spawning locations are not adequately documented, it is believed that a relatively large portion of the basin-wide fall chum escapement is accounted for annually.

Coho salmon. Current management and research programs associated with Yukon River coho salmon are limited. Although coho salmon are harvested in subsistence and Aboriginal fisheries, there is no directed commercial fishery for this species. Currently, the first portion of the coho salmon run is estimated near Pilot Station. Although these estimates are not complete due to termination of the project each year prior to the conclusion of the coho migration, it is generally held that the overall abundance of coho salmon in the Yukon River basin is less than chinook, summer chum, or fall chum salmon returns. Coordinated management of coho salmon between the U.S. and Canada is not considered in the existing interim agreement, and any commercial harvest of coho salmon will likely remain a function of management strategies for harvesting fall chum salmon.

Information Needs Relative to Adult Salmon Tagging Methods

Chinook salmon. Written documentation of chinook salmon distribution in the upper Yukon River basin began more than a century ago and is ongoing. Results of cursory radio telemetry studies conducted in 1982 and 1983 in the Canadian section of the upper Yukon River were reported by Milligan et al. (1985). Although the collection of other fisheries data has continued in both the Porcupine and upper Yukon River drainages, many information gaps still exist. It is believed that chinook salmon spawning in many areas remains undocumented. Relatively little information is currently available for the Porcupine River; however, chinook abundance in this drainage is thought to be substantially less than in the upper Yukon River drainage.

The ability to project and assess run size by stock or stock group in more than the few areas now possible would greatly improve management of Yukon River chinook salmon. In addition, information regarding stock-specific productivity and run-timing would allow further refinements to fishery management strategies. In addition, there is a lack of information on the availability and utilization of spawning and rearing habitats in many areas of the Yukon River basin which limits our understanding of restoration and enhancement opportunities.

Chum salmon. Written documentation of chum salmon distribution began more than a century ago and is ongoing. The telemetry studies in the Canadian section of the Yukon River drainage in 1982 and 1983 also involved chum salmon. However, as with chinook salmon, many information gaps remain. Less is known of the spawning distribution of chum salmon in the Canadian section of Yukon River drainage compared to that of chinook salmon. In the Porcupine River drainage, chum salmon escapements are monitored in two major spawning tributaries (the Sheenjek River in Alaska and the Fishing Branch River in Canada). However, the relative contribution of these two populations to the entire Porcupine River escapement is unknown.

The ability to project and assess run size by stock or stock group in more than the few areas now possible would greatly improve management of Yukon River fall chum salmon. Even post-season stock identification is not yet sufficiently accurate for Yukon River fall chum salmon. New techniques for distinguishing chum salmon stocks, based upon DNA characteristics, hold some promise. Apart from the aggregate Yukon River fall chum population, the inability to reconstruct returns limits our knowledge of stock-specific run-timing, harvests, productivity, and spawning escapement requirements. This is particularly problematic for understanding why some chum salmon populations, such as the Fishing Branch River stock (Porcupine River drainage), are not responding to rebuilding efforts to the extent anticipated.

Coho salmon. Yukon River coho salmon have a later but overlapping run timing relative to fall chum salmon, however, very little is known of the abundance and distribution of this species. Efforts to obtain information on run characteristics have been restricted due to funding limitations and inclement survey conditions during the period when coho salmon spawn. Only one stream in the basin, a tributary of the Tanana River, has an established escapement goal for this species. It is extremely difficult to manage coho salmon returns without reliable in-season estimates of total run abundance, and information on run timing, distribution and location of spawning stocks. These data gaps also restrict our ability to reconstruct coho salmon returns; information needed to examine stock productivity and spawning escapement requirements. Currently, no stock identification studies have been attempted on Yukon River coho salmon.

Technical Review of Adult Salmon Tagging Methods

Mass Tagging (Mark-Recapture)

Mark-recapture techniques for estimating the abundance of fish populations are established tools of fishery management, and are routinely used with acceptable accuracy and precision. Fish are captured, marked, and released. In studies involving returning adult salmon, fish are subsequently captured further upriver in fisheries, at weirs and during spawning ground surveys, and the proportions of marked and unmarked fish used to estimate abundance. A successful mass tagging study must include two interrelated components: 1) sampling, both the tagging and subsequent recovery, must meet certain statistical assumptions as closely as possible, and 2) the statistical methods used for data analyses must be consistent with the sampling design.

Sampling requirements. Several factors related to sampling are essential. Adequate numbers of fish must be captured and tagged proportionately throughout the run, and subsequently recaptured to provide useful estimates. Capture and tagging methods must not alter the behavior or physical abilities of the fish. Tagged fish must be marked in a way that is clearly visible and recognizable if recovered. Insufficient numbers of fish tagged or recaptured, disproportional mortality between marked and unmarked fish, physical loss of tags, dysfunctional behavior of tagged fish, and other factors can introduce unacceptable bias. The significance of these factors is difficult to evaluate, but can sometimes be measured in properly designed studies.

Statistical estimation methods. The statistical method used to estimate abundance from mark-recapture information depends on the sampling method, and the assumed behavioral and movement characteristics of the fish. Numerous mark-recapture models exist for a variety of populations and sampling designs, however, their application to salmon returns in large rivers requires special considerations. Simple methods, such as the Chapman estimator (Seber 1982), are often used in these situations, with results which are assumed acceptable for management purposes. However, assumptions made in traditional models may be violated when used for riverine applications. More advanced and perhaps more appropriate estimation techniques for migrating salmonid populations are currently appearing in the scientific literature (Dempson and Stansbury 1991; Schwarz et al. 1993; Labelle 1994), although many of these newly-developed approaches are fairly specialized and can be somewhat limited in their application. As with any statistical procedure, one must use the best available technique with a full realization of its possible flaws, design studies to evaluate the assumptions, or be unwilling to accept the uncertainty of the technique and not attempt the procedure.

Past applications. Mark-recapture techniques for estimating abundance of fish populations have been used extensively since the initial application to fisheries work in 1896 by Petersen (Seber 1982). This procedure has probably been used more than any other for estimating abundance of small freshwater fish populations. In western Canada and Alaska, numerous mass tagging studies have been conducted successfully on salmon returns in large rivers (Greenough 1971; McBride and Bernard 1984; McGregor and Clark 1988; Alexandersdottir and Marsh 1990).

Similar tagging programs have been conducted on salmon in the Yukon River drainage. Since 1982, mark-recapture studies have been conducted to estimate abundance of chinook and fall chum salmon in the Canadian section of the Yukon River (Yukon River Joint Technical Committee 1994). In addition to estimating spawning escapements, this program has provided a measure of annual variation in chinook and chum salmon returns. Mark-recapture studies have been conducted intermittently to estimate abundance of chinook salmon in the Chena and Salcha Rivers (Evenson 1995). These estimates provide a means for developing escapement objectives based on actual abundance numbers, rather than relying solely on indices from aerial surveys. A preliminary mark-recapture study is currently being conducted on fall chum salmon in the Tanana River to assess the feasibility of estimating abundance with this technique.

Potential Yukon River applications. Mark-recapture studies for salmon in other portions of the upper Yukon River could provide in-season abundance estimates for salmon returns passing the tagging site. These independent estimates of run strength could be useful for comparative purposes with other estimates of abundance in the basin. Information on migration rates, bank orientation, and timing could also be obtained where tagged fish are recovered in fisheries and at escapement sites. Concentrated efforts to recover tagged fish on spawning grounds could be expensive and inefficient if conducted independent of other research activities, but could provide information on run timing.

Radio Telemetry

Since the 1960s, radio telemetry has been used to study free-ranging animals including various fish species. Radio transmitters emit electro-magnetic signals that can be detected and identified, making it possible to locate radio-tagged fish even when visibility or access is limited. Until recently, most telemetry studies have been limited to small numbers of tagged individuals, usually fewer than 40, and to relatively small areas. Technical advances in equipment and survey methods have made it possible to track wide-ranging species and larger numbers of individuals. Increasingly, telemetry is being used to obtain quantitative information on large aggregates of fish, such as Pacific salmon. Although costly, telemetry studies can provide information that could not be obtained with more conventional methods.

Radio tagging. There are three methods for tagging fish with radio transmitters: inserting the tag through the mouth and into the stomach, attaching it externally, or implanting it surgically into the body cavity. Placing the tag in the stomach is a common approach for tagging adult salmon since the fish are not feeding extensively after entering freshwater, and it is a simple procedure with minimal adverse effects (Burger et al. 1985; Liscom et al. 1985; Eiler et al. 1991). Problems with tag regurgitation, injury due to inexperienced handlers, and extended post-tagging delays (holding prior to resuming upriver movements) have been reported in some studies. External transmitters have been used successfully (Gray and Haynes 1977; Barton 1992; Bendock and Alexandersdottir 1993), although tissue deterioration around the attachment site and increased mortality have also been reported (Mellas and Haynes 1985; Eiler 1988), particularly in riverine areas where higher water velocities and drag caused by the tag may be problematic. Surgical implants are time consuming, and susceptible to bacterial and fungal infections (Mellas and Haynes 1985), especially in adult salmon whose immune system stops functioning as they approach spawning areas.

Advances in micro-circuitry have resulted in numerous innovations in transmitter design and capabilities. In addition to smaller and lighter tags, it is also possible to encode transmitter signals and program predetermined transmitting periods. If equipped with electronic sensors, the transmitters can also relay information about the fish (such as activity patterns and metabolic functions) and its surroundings (such as water temperature and depth).

The type of transmitter used depends largely on physical limitations (such as size of the fish and attachment method), operating criteria (such as signal output and battery life), and objectives of the study. A typical transmitter used to study adult salmon spawning in large rivers in Alaska and western Canada is cylindrical, about 6.5 cm long and 2 cm in diameter, has a 30 cm external transmitting antenna, and weighs 20 g (Eiler 1990). Battery life of this transmitter is about 120 days. Transmitters are tuned to different frequencies to make it possible to identify individual fish. In studies involving hundreds of fish, coded transmitters are often used to reduce the number of frequencies required. Transmitters are frequently equipped with a motion sensor and activity monitor (sensor that indicates that the transmitter has not moved for a specified period of time) to aid in determining the status of the fish (Eiler 1995). Transmitter costs are substantially higher than conventional tags, ranging from under \$100 (U.S.) to over \$200 (U.S.) per tag depending on the capabilities of the transmitter. The salmon transmitter described above equipped with motion sensor and activity monitor costs about \$160 (U.S.) per tag.

Reception range (the distance that the transmitter can be detected) is difficult to determine under field conditions because it can be affected by a number of factors, including the tracking methods used, frequency range of the transmitters, water

conductivity and depth, topography, and electronic noise. During field studies on salmon in the Taku and Stikine Rivers in Alaska and British Columbia, the transmitter previously described had an average reception range of 3-5 km when tracked from aircraft flying at an altitude of 300 m.

Radio tracking. Transmitter signals from radio-tagged fish are picked up with receiving antennas connected to a radio receiver. A variety of antenna types are available depending on the application, such as broad coverage, increased range, or directionality to determine the specific location of the fish.

Radio receivers suitable for field conditions (compact, lightweight, durable, and water resistant) are used to detect and convert transmitter signals into audible or electronic signals. Miniaturized field computers, specifically designed to interface with the receivers, can be programmed to analyze the transmitter signals and record the data into electronic files. Tracking systems currently exist that integrate GPS (Global Positioning System) information, making it possible to automatically record standardized locations with the other information collected. The electronic files created can be downloaded directly into computerized databases for analysis.

Telemetry data can be collected using a variety of techniques, such as locating radio-tagged fish on foot, and from boats, vehicles and aircraft. However, telemetry studies on salmon returns in large rivers can be difficult due to the vast and often isolated areas involved, and the need to tag and track hundreds of highly mobile fish to obtain meaningful results. In some situations, aerial tracking is an effective method, because it provides the greatest reception range (Winter 1983), and can cover extensive areas in relatively short periods of time. Helicopters equipped with directional tracking antennas can locate radio-tagged fish within 10 m of their actual location. However, tagged fish can be overlooked when tracking large numbers of individuals due to the speed of the aircraft and the numerous frequencies being scanned. Under these conditions, conventional tracking methods are often inadequate. In addition to being costly, inclement weather and mountainous terrain can also make aerial tracking hazardous.

A remote tracking system with a satellite up-link has been used successfully to study salmon in large river systems (Eiler 1995). Automated tracking stations, located at sites throughout the drainage, record the movements of radio-tagged fish migrating upriver. A satellite up-link retrieves the information for in-season analysis. This system can provide detailed information on salmon distribution and movements even when tracking hundreds of fish over large, isolated areas. In addition to the equipment, there are substantial costs associated with site selection and station installation, particularly in remote areas where access is often limited. For this reason, multi-year studies are the most cost effective when using tracking stations in large, remote drainages. Although initial costs are relatively high, operating costs are substantially reduced in

subsequent years.

Past applications. Radio telemetry has been used to address a variety of questions related to the life history and management of fish populations. Studies have been conducted to determine fish distribution in lakes and river systems, and in some cases, have identified important spawning populations in previously unknown locations (Lough 1983; Eiler et al. 1992). Telemetry has been used to collect basic biological information such as movement patterns and run timing (Burger et al. 1985; Rosberg and Greer 1985), habitat utilization (Nettles et al 1987; Lorenz and Eiler 1989) and fish behavior (Hanson and Margenau 1992; Heggenes et al. 1993). Specific management issues, such as hooking mortality (Bendock and Alexandersdottir 1993) or the impacts of development (such as hydroelectric dams, logging, and agricultural practices), have also been addressed using this technique (Gray and Haynes 1977; Liscom et al. 1985).

Radio telemetry has been used in several studies on salmon in the Yukon River drainage. Cleugh and Russell (1980) used radio telemetry to examine migrational behavior of chinook salmon migrating upstream of the Whitehorse Rapids Dam. In other studies, radio-tagged chinook and fall chum salmon provided information on distribution, movement patterns and the location of spawning areas in the Canadian section of the Yukon River (Milligan et al. 1985, Milligan et al. 1986). Radio telemetry has also been used to study the distribution and estimate the abundance of chum salmon in the upper Tanana River (Barton 1992), and locate chum salmon spawning areas in the Hodzana and Koyukuk Rivers (Glesne et al. 1985; Melegari and Troyer 1995).

Potential Yukon River applications. The immense size and isolation of the Yukon River basin limits the information that can be obtained with traditional assessment methods. Questions exist concerning the run characteristics, status, and river of origin of Yukon River salmon. For example, although GSI studies (using protein electrophoresis) have classified fall chum salmon into general sub-groups, problems exist in separating U.S. and Canadian stocks due to genetic similarities of some populations (Wilmot et al. 1992). Radio telemetry has been an effective technique for studying fish in large river systems where access and visibility are limited. Telemetry studies on salmon can provide detailed information on distribution, movement patterns (such as migration rates and bank orientation), timing, and location of spawning areas. In addition, barriers or impediments to upstream migration can also be identified for potential mitigation through restoration or enhancement activities. DNA samples from radio-tagged fish tracked to spawning areas would provide GSI baseline data. Spawning ground surveys for radio-tagged fish can provide site-specific information on spawning areas, and facilitate expanded stock identification baseline sampling (protein electrophoresis) to refine river of origin estimates. Large scale telemetry programs can also provide a framework for other studies related to local management issues, such as stock-specific movement patterns through commercial and subsistence fisheries.

Combined Program (Mass Tagging and Telemetry)

Combined mark-recapture and radio telemetry studies could provide information beyond that which could be obtained if either method were used separately. In a consolidated study, most of the fish captured are marked with inexpensive spaghetti tags while a lesser number are tagged with the more expensive radio transmitters. The ability to estimate run abundance with mark-recapture techniques is maintained, while detailed information on stock-specific migration patterns and spawning distribution can be addressed by the telemetry component of the study. This integrated approach also makes it possible to apportion the run to identified spawning areas (estimating stock-specific abundance) and evaluate some mark-recapture assumptions. Although additional information could be obtained, added costs would also be associated with an expanded study.

Estimating stock composition. Mass tagging provides limited information on distribution unless the likelihood of detecting and recovering tagged fish on the various spawning grounds can be determined. Incomplete knowledge of the location of spawning areas, and difficulties associated with accessing spawning areas and tag retrieval further limit this approach. With telemetry, tracking methods are well established, and the probability of detecting radio-tagged fish is comparable for all spawning areas if tracking stations are available in sufficient numbers, are well sited, perform effectively, and/or there is a well designed and executed tracking survey program. Linking abundance estimates and telemetry data also makes it possible to expand the information obtained from the radio-tagged fish to the entire run passing the tagging site. The proportions of radio-tagged fish which migrate to various spawning areas provide direct estimates of the underlying proportions of the upriver migrants. These stock-specific estimates may be the sole source of information for many spawning populations, or they may serve as comparative checks on those stocks with existing information.

Evaluating assumptions of mark-recapture models. Mark-recapture data for estimating population numbers accurately (without bias) requires appropriate models of salmon migratory behavior after tagging. Telemetry data can document fish behavior (such as drop back, holding patterns, bank orientation, and migration rates) after tagging, making it possible to evaluate some assumptions used in mark-recapture estimation models. As indicated earlier, the degree to which the assumptions of the model are met is crucial in assessing the validity of the final abundance estimates. Such an evaluation, however, requires an assumption that spaghetti and radio-tagged fish behave similarly after release.

Past applications. Studies involving both mass tagging and radio telemetry have been successfully conducted in large river systems to estimate escapements, stock-specific abundance, distribution, stock composition and timing in Alaska and/or northern British Columbia (Eiler et al. 1988; Johnson et al. 1992; Koski et al. 1993).

Potential Yukon River applications. The primary advantage of combining mass tagging and radio telemetry is the potential to estimate stock-specific abundance, timing and movement patterns. Tagging studies in large river systems are relatively expensive, but a consolidated study maximizes the information obtained and may be more cost efficient compared to implementing mass tagging or radio telemetry separately.

Adult Salmon Tagging Program Approaches

Central to any discussion on research programs in the Yukon River basin is the need for the Yukon River Panel to define the primary concerns, goals and objectives regarding salmon stocks of mutual concern. Further, it is necessary for the Joint Technical Committee to advise the Panel on what types of programs are technically and practically feasible to obtain the information desired. Potential adult salmon tagging applications are numerous and varied in the Yukon River basin. This section briefly identifies and describes aspects of several study approaches which have been discussed.

Study Scope

A primary consideration is whether to conduct studies that focus on salmon returns in a particular tributary and its accompanying drainage (sub-basin approach), or on stocks returning to a wider geographical area of the watershed (Yukon River basin approach). Some of the basic considerations associated with these two approaches are addressed in the following sections, although many are not necessarily confined to either approach, and need to be evaluated in regards to both. Study considerations, including research objectives, study area size and remoteness will have a direct impact on project logistics and costs.

Sub-basin approach: The sub-basin approach focuses on stocks returning to individual river systems as varied in size and morphology as the Porcupine, Sheenjek, Black, and Stewart Rivers. Limited information is available on salmon returns in many drainages, and this approach would provide an opportunity to obtain detailed information on run characteristics and habitat utilization.

A major consideration for any project is field logistics and the associated costs. The sub-basin approach may simplify these factors compared to studies on a larger scale. Less equipment may be required due to smaller run sizes and geographic areas involved. Conversely, the same amount of equipment required for a basin-wide study could be used in a smaller sub-basin to obtain more detailed information. A higher proportion of individual fish from the return could be tagged and tracked to spawning destinations, thereby increasing data resolution and confidence. Many tributaries are relatively narrow and shallow compared to sections of the Yukon River main stem, making them more conducive for telemetry studies (easier to track and record radio-tagged fish). However, operations in an isolated tributary (such as the Porcupine River) could increase the costs and effort required to a comparable level with programs conducted over a wider but more accessible area.

Fish capture methods that provide adequate numbers of fish for tagging throughout the run are essential. Some tributaries are relatively clear compared to the Yukon River main stem, which makes fish capture more difficult. This problem would be magnified for mark-recapture studies, since a greater number of fish must be tagged and recovered upriver from the tagging site to obtain usable results. Establishing effective capture and/or recapture programs in tributaries in the absence of established fisheries could be difficult. Effective capture sites and techniques would have to be developed. Conversely, releasing fish in the absence of intensive fishing effort would increase the numbers of tagged fish that continue moving upriver; this approach would reduce the interceptions and recoveries by upstream fishers. This factor could be a disadvantage for mark-recapture studies, unless adequate spawning ground recoveries could be made. A total abundance estimate could be obtained for sub-basins containing a tributary enumeration program (sonar or weir) without conducting a concurrent mass tagging program, by dividing the tributary abundance estimate by the proportion of radio-tagged fish in the tributary.

Yukon River basin approach: The basin approach would focus on obtaining information for stocks returning to a considerably larger portion of the Yukon River system. An advantage to this approach is the potential to provide broader information on upper Yukon River salmon returns. Comparative information for stocks destined for different sections of the basin could be obtained. If sufficient tags were applied, the basin approach would also increase the potential for locating unknown spawning populations since a wider area of the basin would be surveyed. Information from tagged fish could be used to update and refine stock identification baselines. The opportunity also exists to implement studies designed to compare and evaluate existing river of origin estimates. Questions related to mainstem spawning could be addressed, particularly when combined with spawning ground surveys to verify spawning activity. A large-scale study, particularly if conducted over a period of years, could also provide a framework for small studies focusing on local management issues such as stock-specific movement patterns (migration rates, holding patterns, and bank orientation)

and timing through fisheries.

Fisheries occurring in the Yukon River main stem could facilitate fish capture operations by making it possible to contract with experienced fishers in established fishing locations. This would increase the likelihood that adequate numbers of fish could be captured throughout the run for both mark-recapture and telemetry studies. Fish tagged and released downstream from existing fisheries would be more likely to be intercepted and removed from the sample. This factor would facilitate mass tagging studies, since recovery efforts upriver from the tagging site are necessary.

A major consideration associated with the basin approach is the logistical support required for any large scale study conducted over a vast, isolated area. Field operations will face significant logistical difficulties and associated costs. Additional equipment will be necessary to tag and track adequate numbers of fish. Sections of the Yukon River main stem are often relatively wide and deep. Although initial ground surveys in 1995 suggest that telemetry studies are feasible in the Upper Yukon, additional work would be required to locate and prepare sites suitable for remote tracking stations in main stem areas. Although there is the potential to dilute existing agency resources, a broad study may also help identify and prioritize areas needing more focused studies.

Species

Numerous studies could be conducted to address research needs in the Yukon River basin. This section describes several tagging programs that could provide information on the run characteristics for salmon species in the drainage. The studies described should not be considered a complete listing of the potential projects. It should also be noted that tagging programs would provide more complete information if conducted for at least a full population cycle; for example, four years for fall chum salmon or six years for chinook salmon.

Fall chum salmon. Possible tagging studies on fall chum salmon include: 1) a combined mass tagging-telemetry study on the Yukon River below the confluence with the Porcupine River (Yukon River basin approach), 2) a telemetry study on the Porcupine River (sub-basin approach), and 3) a combined mass tagging-telemetry study on the Yukon River upriver from the U.S.-Canada border.

The primary study objectives for the combined tagging study below the Yukon-Porcupine River confluence (Yukon River basin approach) would be to estimate total run abundance; estimate stock-specific abundance, timing, migration rates, movement patterns and bank orientation; and identify previously undocumented spawning areas. Questions related to mainstem spawning could be addressed, particularly when

combined with spawning ground surveys to verify spawning activity. Reliable fish capture methods and gear are established in fisheries located upriver from the Yukon-Tanana River confluence. These fisheries could capture sufficient numbers of fish for tagging, and may be more cost efficient than establishing new capture sites and methods. This study approach would provide more complete information on chum returns in the basin, and would also help identify and prioritize other information needs in the drainage. Field logistics would be difficult and costly, and sample size considerations and the analytical methods would need to be evaluated in regards to the large numbers of fish potentially passing the capture site.

Limited information is available on the distribution of fall chum returns in the Porcupine River. Telemetry studies in this system could provide detailed information on run characteristics including stock composition and timing, migration rates and movement patterns, and information on the location of previously undocumented spawning areas. Questions related to spawning in the Porcupine River main stem could be addressed, particularly when combined with spawning ground surveys to verify spawning activity. Although this approach is limited to a smaller portion of the fall chum salmon return, a higher proportion of fish from the Porcupine River run could be tagged and tracked to spawning destinations, thereby increasing data resolution and confidence. Although smaller than the Yukon River main stem, the Porcupine River is vast and remote, and field logistics would be difficult and costly. Fish capture in this river system could be difficult due to the relatively clear water and lack of established capture sites and methods. Mass tagging studies could be particularly difficult due to problems associated with capturing adequate numbers of fish. However, data from two established escapement enumeration projects in the drainage (Sheenjek River sonar and Fishing Branch River weir) combined with telemetry information could provide stock specific abundance estimates without conducting a conventional mass tagging study.

A combined mass tagging-telemetry study in the Yukon River main stem, upriver of the U.S.-Canada border, could provide similar information as the Yukon River Basin approach, but on a smaller scale. The DFO currently conducts mass tagging studies near the border, which could be enhanced by associated telemetry studies. While study objectives would remain similar to those identified in the two previous examples, the results would apply specifically to Canadian spawning stocks. This information would complement and expand the information obtained from studies conducted in the Canadian section of the Yukon River main stem in the early 1980s (Milligan et al. 1986).

Chinook Salmon. Stock identification methods have been effective in categorizing Yukon River chinook salmon stocks on a broad geographic scale (Wilmot 1992; Schneiderhan 1994), and have improved management capabilities. However, information is still needed on distribution, movement patterns, and utilization of

undocumented spawning areas. Though spawning distribution is thought to have remained relatively stable in the Yukon River, previous telemetry studies were cursory. More intensive studies involving both telemetry and mass tagging could potentially document additional spawning stocks as well as provide information on their relative magnitude. Impediments to spawning migration in specific tributaries could also be documented, potentially identifying opportunities for restoration or enhancement activities.

Limited information is available on chinook salmon in the Porcupine River. Tagging studies could provide useful baseline information to assess abundance, run timing, movement patterns, spawning locations, or stock identification.

Coho Salmon: Little information is available on coho salmon in the Yukon River basin. Tagging studies below the Yukon-Porcupine River confluence or in major tributaries would provide substantial new information on this species. The primary objectives for this type of study would include determining spawning distribution and the location of spawning grounds, and estimating the relative magnitude of various spawning stocks. However, it is uncertain if adequate numbers of fish could be captured throughout the run due to the cold weather and icing conditions late in the fall. Survey work would also be extremely difficult under winter conditions.

Public Involvement

To increase project success, local support and direct involvement by local residents is needed. Telemetry and mass tagging programs could provide opportunities for participation by local residents, thereby providing socio-economic benefits. Local residents could be involved in various program activities, including salmon capture and tagging, installation of project equipment, and tag recovery efforts (for example, weir operations). The satellite-linked technology associated with the remote tracking stations used in telemetry studies could provide a means for interested parties to monitor project progress via a computer-modem up-link. Incorporating aspects of the program in school district curricula or through village and/or renewable resource council meetings could foster a greater sense of involvement and appreciation of project goals. Additionally, local involvement in a multi-year program would promote greater awareness of fishery management techniques and the rationale for management decisions.

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