Value Scope Research Ltd(1) and Compass Resource Management Ltd(2)

Summary and Key Findings of Upper Columbia River White Sturgeon Recruitment Failure Hypothesis Review

Upper Columbia River White Sturgeon Recovery Initiative, Jan 2007 – July 2008

Final Report

Dr Robin Gregory(1) and Dr Graham Long(2)
November 25 2008

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INTRODUCTION

This report summarizes the work undertaken over five workshops by the Upper Columbia River White Sturgeon Recruitment Failure Hypothesis Review (RFHR) technical working group (TWG), during the period January 2007 to July 2008. The primary purpose of this work was to develop a well-defined and broadly agreed-upon set of hypotheses that explain the apparent recruitment failure of white sturgeon populations in the upper Columbia River. Linked to this were two other objectives. First, to identify required research actions and feasible mitigation options based on these hypotheses and, to the extent possible at this time, to define a logical and flexible sequence of management actions that would recognize complementarities between learning achieved through research and improvements in recruitment achieved through mitigation. Second, to agree on a realistic implementation strategy in light of budget allocations, permitting requirements, and other constraints so as to facilitate prompt management actions.

BACKGROUND

The Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) was formed in 2000 in order to coordinate and help plan actions dedicated to the recovery of white sturgeon populations in the Upper Columbia River basin upstream of the Grand Coulee Dam. Members of the Technical Working Group (TWG) of the UPRWSRI include more than 25 Canadian and U.S. groups – representing federal, state and provincial governments, industry, First Nations, and public stakeholders – with an interest in the recovery of white sturgeon. Although there remains some debate about population estimates, it is commonly agreed that about 3,000 adult white sturgeon reside between the Hugh Keenleyside Dam in southern British Columbia and the Grand Coulee Dam in the U.S. state of Washington. Smaller populations are found in Arrow Lakes reservoir and are suspected in other reservoirs as well. Recruitment appears to have declined sharply starting in the early 1970s, and there is no evidence of significant successful recruitment over the past two decades.

The UCWSRI published a recovery plan in November, 2002, and since that time this plan has directed the efforts of the recovery program. However, these efforts did not correct the apparent recruitment failure (RF) of white sturgeon populations, and in 2006 the Canadian government listed Upper Columbia white sturgeon (*Acipenser transmontanus*) populations as endangered under the federal Species at Risk Act (SARA). This designation added both visibility and urgency to the recovery initiatives; one product of this is the requirement for near-term development of a National Recovery Strategy.

Two events helped create the impetus for the work reported here. First, research conducted during the first five years after publication of the recovery plan added substantial new information about habitat use, mortality rates, and genetic diversity of Upper Columbia River white sturgeon populations. However, there existed widely varying points of view among members of the TWG concerning the interpretation of this information and its implications for prioritization of the recruitment failure hypotheses. Second, the Upper Columbia River Water Use Plan, developed by a multi-stakeholder group concerned with balancing the needs of hydroelectric power generation against other environmental, social, cultural, and economic uses of Upper Columbia River flows, was ordered (in February, 2007) by the Comptroller of Water Rights in British Columbia. This requires a feasibility study that will recommend the best response measures for white sturgeon stocks below the Keenleyside dam.

In light of these events, the TWG decided that a careful review of hypotheses to explain recruitment failure was required in order to refocus white sturgeon recovery efforts in the Upper Columbia River. The process selected to guide this review is based in methods drawn from decision analysis and multi-attribute utility theory and their application to environmental problems through structured decision making (SDM), which is an organized process for engaging multiple parties in a decision-focused dialogue that considers both facts (technical analysis) and values (objectives, meeting legal obligations, etc.). Core elements of SDM include four steps: defining the scope of the problem and project objectives; using these to create and evaluate a suite of management alternatives; making choices about preferred actions over time based on a clear understanding of priorities and uncertainties; and addressing trade-offs in light of implementation requirements for preferred alternatives. Iteration is recognized as a key element of the SDM process, in that initial insights provided at an early stage (e.g. identifying objectives) often need to be adjusted or refined in light of subsequent discussions (e.g., defining alternatives or tradeoffs). Of particular interest to the UCWSRI was the strong case record of SDM, in previous applications by regulatory agencies and utilities that include BC Hydro, the Canadian Department of Fisheries and Oceans, and the US Fish and Wildlife Service, in encouraging the exposure of trade-offs across alternatives and focused dialogue among parties to address them directly. In addition, SDM methods have been widely applied in cases where decision frameworks need to be flexible so that they can adjust both short- and long-term management choices in light of what is learned through monitoring or adaptive management trials.

Based on recommendations from SDM, the TWG therefore adopted an iterative approach to identifying, screening, aggregating and evaluating hypotheses addressing the apparent recruitment failure of Upper Columbia River white sturgeon. Although both research questions and mitigation actions were considered, the focus of the discussions was to develop a broadly agreed-to plan for guiding and aiding decisions about management actions: the examination of hypotheses for RF was specifically linked to the recognized need for near-term management actions in light of the relatively short time frame (approximately 20 years) that exists before the probability of biological extinction of Upper Columbia River white sturgeon becomes unacceptably high. The fundamental management task was thus one of making the best use of available information, combined with the informed opinions of a broad range of technical experts, to ameliorate RF in a limited timeframe, with limited financial resources, and within a highly charged political environment.

GENERAL APPROACH

The approach developed through discussions between the consultants and members of the TWG, outlined to participants at the first workshop, involved application of the four key SDM steps to understanding the observed recruitment failure of Upper Columbia River white sturgeon:

1. Identify project objectives and competing hypotheses and present them in a consistent manner that avoids ambiguity and facilitates understanding, comparison, and evaluation
2. Screen out unhelpful hypotheses in order to focus discussions on a smaller set of mitigation and research alternatives and their relative contribution to observed RF
3. Establish priorities across hypotheses, with reference to uncertainty and the confidence that experts hold in them, and connect hypotheses to in-river mitigation options that plausibly could be undertaken
4. Identify and prioritize high importance research projects required to initiate mitigation actions, in light of tradeoffs with respect to budget, jurisdictional, resource and sequencing constraints.

Discussions at the first meeting of the TWG resulted in the adoption of the suggested process by members and their agreement to a series of facilitated meetings, to be held over a 12-18 month time period. The five meetings occurred over the period January, 2007 – July, 2008 at intervals of several months, with the intervening time spent collecting data, conducting analyses, and developing spreadsheets and other materials as visual aids to assist in the presentation of ideas and data. Several off-line meetings were held with members of the TWG in order to make rapid progress on specific topics; results were then reported back to the TWG at the next session. Discussions of the TWG were lively and often extended, with substantial participation from all TWG members. The facilitators emphasized the need for the diverse views of participants to be given full consideration., with the result that deliberations were respectful, often heated, and with a goal not of consensus but of clarification of opinions and rationale and a better understanding of key reasons for agreement, disagreement, and uncertainty.

RESULTS

The eight steps noted below provide a summary of the resulting analyses and discussions, presenting results from the five workshops and associated analyses in a roughly chronological order. A concluding section provides several recommendations based on the discussions and findings.

1. LIST POSSIBLE HYPOTHESES AND SCREEN-OUT CLEARLY UNHELPFUL HYPOTHESES

A first task was to develop a draft list of hypotheses to explain white sturgeon recruitment failure, organized by life stage and location. Prior to the first meeting of the TWG, a review of materials previously developed by the UCWSRI yielded a "straw dog' list of over 100 hypotheses that could explain white sturgeon recruitment failure. This large number of hypotheses was included as input to the first meeting so as to ensure comprehensiveness: it was important that all potentially significant explanations for the apparent recruitment failure of white sturgeon were included in the initial discussions of the TWG. Further, it was recognized that any hypothesis could be considered as a single cause of recruitment failure, as a contributing factor to RF, or as a contributor to observed RF through a lag effect.

The hypotheses were grouped under the following eight white sturgeon life stages:

1. Spawning / staging
2. Incubation / hatching (eggs incubate for 7-10 days before hatching)
3. Pre-feeding (0-10 days): includes both free embryo, pre-hiding stage and hiding pre-feeding stage
4. Larval dispersal and feeding (11-40 days)
5. Young of the year (41-365 days)
6. Younger juveniles (age 1-10)
7. Older juveniles (age 11-25)
8. Adults (age 25 and older)

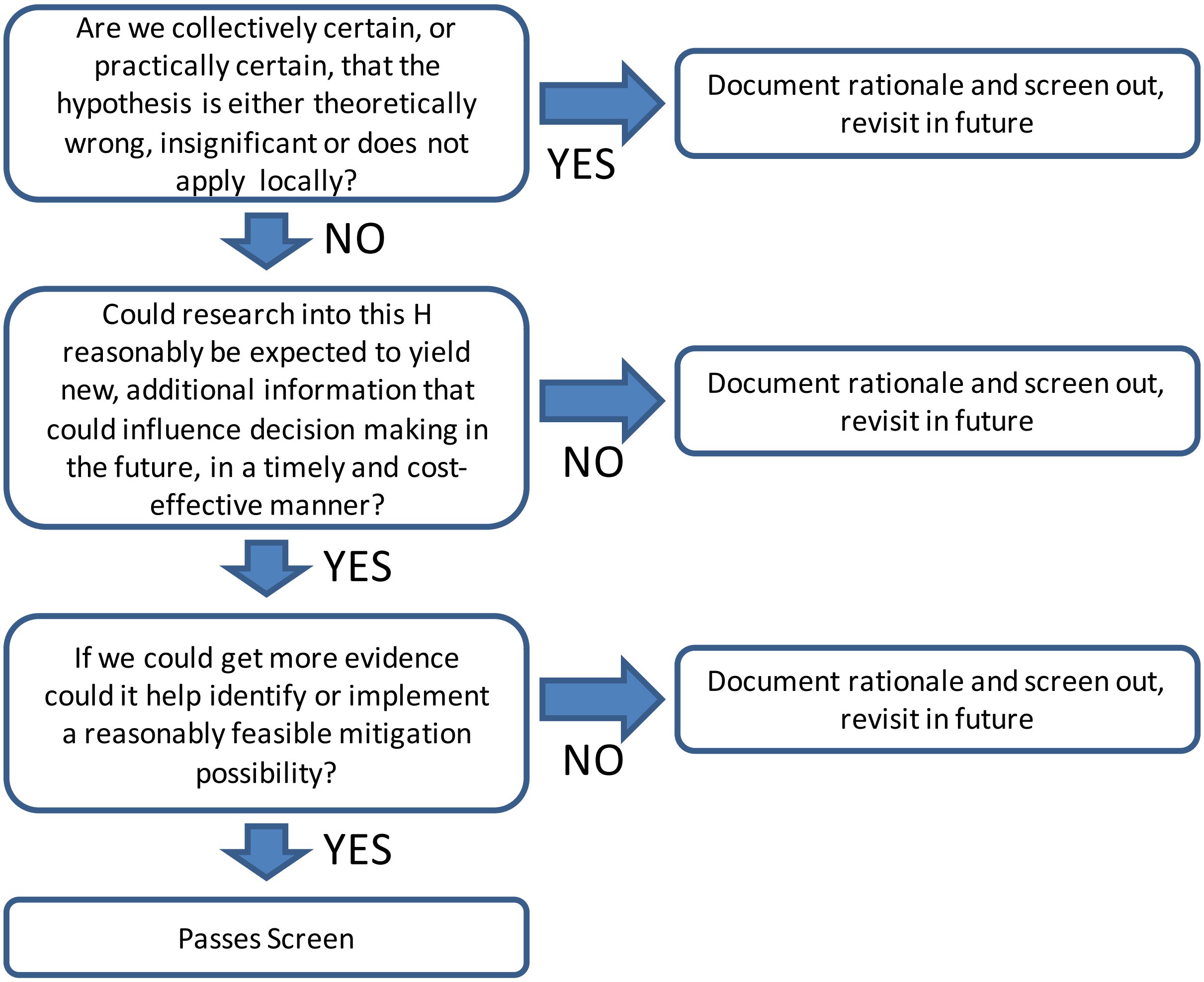
It was agreed that the question to be addressed by the group is "What is contributing to current recruitment failures," thus allowing for time lags so that actions from years or decades earlier might still be influencing recruitment failures. The important distinction here is between recruitment variance, across years, and lack of recruitment: the focus of these discussions was on contributors to recruitment failure and not contributors to variance.

It also was agreed that the two main WS spawning areas, Pend d'Oreille / Northport (aka "lower-Columbia", abbreviated to LCR) and Revelstoke (aka "mid-Columbia", abbreviated to MCR), would be considered as distinct. Participants felt that data generally are better for the former, but that both geographic locations are important in terms of understanding reasons for a lack of recruitment. It was decided to make judgments for each location separately but to ask the same impact hypothesis questions, keeping in mind that some entries will only be relevant for one of the two locations. For example temperature during the spawning / staging life stage is thought to be a possible reason for a lack of recruitment at the mid-Columbia but not the lower-Columbia.

The review of the hypotheses was conducted using a two-stage screening process.

In Stage 1, participants briefly discussed each of the 100 or so hypotheses by answering a sequence of logical questions (see below). This was intended to reduce the number of possible hypotheses by eliminating those that were considered to be (a) theoretically wrong, (b) insignificant, or (c) locally inapplicable. In Stage 2, the remaining hypotheses were reviewed in terms of (a) their importance in terms of relative significance as a contributor to recruitment failure, and (b) of this group, the anticipated success of management initiatives in being able to address or "fix" the identified problem. Stage 1 received significant attention as part of the first workshop; Stage 2 (which involved weightings of research and mitigation projects) received less attention at this early stage in the discussions because it was agreed that additional information concerning the hypotheses and management alternatives, to be made available only at subsequent workshops, was required.

Figure 1: Stage 1 Screening



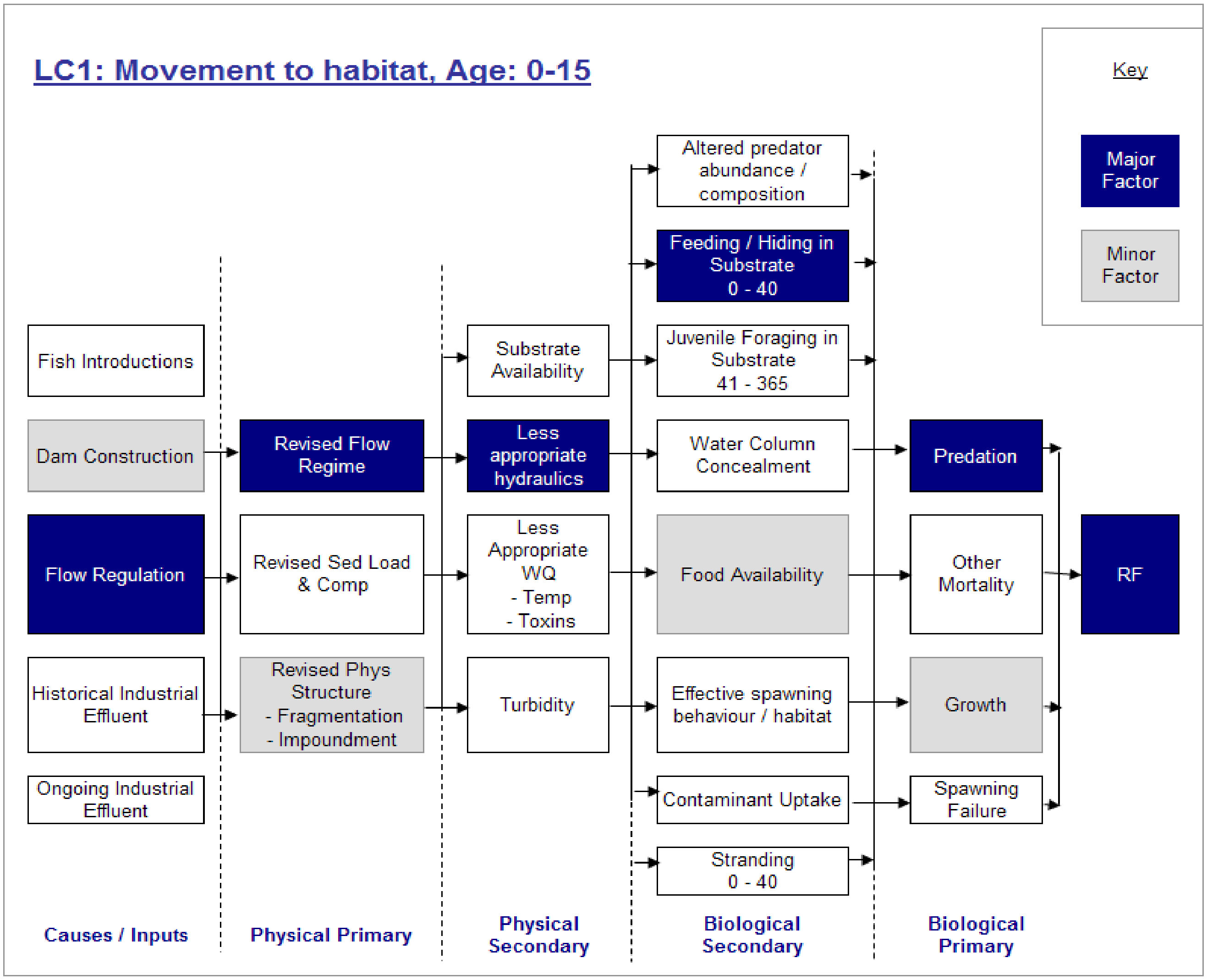
At the end of this exercise, 28 hypotheses remained as explanations for recruitment failure in either the LCR or MCR areas. In addition, substantial progress was made in clarifying the intent and focus of these hypotheses, so that each could be stated in terms that were less ambiguous and helped to ensure clear communication.

2. AGGREGATE AND REDEFINE HYPOTHESES AND EXAMINE THE EVIDENCE

Twenty eight hypotheses, although fewer than 100, is still too many to examine in detail. Therefore we sought to reduce the overall number of hypotheses in each location by 'bundling' together hypotheses to create sensible groups. For example, if two hypotheses were identical in every way except that they applied to two sequential life stages, and if the practical implications of those two life stages (in terms of research, for example) were the same or very similar, then the group would decide to bundle these hypotheses together.

A downside of the first attempt at bundling the hypotheses is that, in some cases, as the hypothesis became broader in coverage its definition also became more ambiguous. For this reason, the group developed a generic influence diagram that would force any hypothesis to be clearly described. The hypotheses were aggregated and characterized in terms of a 'pathway' through the influence diagram; the example shown in Figure 2 links primary causes (on the left-hand side) to recruitment failure (on the right-hand side), the ultimate subject of concern. In the Figure 2 example, the hypothesis "LC1" concerns the impact of changed flow regime on feeding and hiding substrate and related impacts on food availability and predation during the first 15 days of a juvenile's life. Other hypotheses were described by taking different routes though the same diagram.

Figure 2: Influence Diagram developed to describe hypothesis pathways



This pathway deals with the effects of backwatering of Roosevelt combined with reduce discharge from upstream dams on the effectiveness of the drift phase whereby larvae are carried to suitable hiding habitat. Since there is an argument that these larvae do not rely directly on flows to reach suitable habitat but instead seek hiding habitat soon after hatch and then proceed to move downstream at intervals in and out of the substrate, a secondary effect is the influence of the flow regime on the productivity of suitable prey abundance as the larvae shift to feeding.

The influence diagrams provided a consistent and comprehensive basis for discussing the pros and cons of each of the 28 hypotheses. This was done through development of a 'Science Court' approach, by which one or more members of the TWG would volunteer to provide a summary of the arguments for and against each hypothesis. This required a careful review of the available data; in many cases, short reports were prepared and handed out in advance of the second workshop to participants in order to facilitate subsequent discussion. At the end of each hypothesis discussion, the group as a whole would provide their summary “verdict” as to whether the hypothesis would be retained, as a possibly important reason for recruitment failure, or dropped. An example of the type of evidence that TWG members prepared for and against each hypothesis is shown below.

Evidence For LC1

- Larvae do drift
- Lengthy drift phases (i.e., with reduced flows) required to reach suitable habitat likely result in increased predation
- Comparison with other populations suggest that drift is a key variable potentially affecting R (Jager 2001), paddlefish/shovelnose comparisons
- Drift has been identified within the recovery area
- Recruitment failure of HLK, KOOT and ROOS subpopulations between 1969 and 1976, coincident with the completion of major upstream storage dams (Keenleyside and Mica) and substantial reduction in spring – summer flows
- Steve McAdam’s research indicating a strong preference for clean, small gravel
- Speculative: while there is a lot of ‘riverine habitat’ available (see below), the amount or location of preferred larval rearing substrate may be such that most larvae are not carried to these areas under prevailing (post-regulation) flow conditions
- High Roosevelt reservoir elevations (backwatering) occur at same time as spawning and larval drift

Evidence Against LC1

- There is a lot of habitat available. The effective amount of riverine habitat hasn’t changed since 1940
- Effective drift distance for ROOS group (all?) changed in 1940 in conjunction with Roosevelt reservoir, yet RF didn’t occur until 1970s
- Drift may be a response to poor substrate, and isn’t a preference
- Drifting may not be the strategy leading to survival
- Drift duration may be very low (time), suggesting it may not be the primary impact
- Drift affected by many variables, therefore general uncertainty may decrease its priority

The “science court” exercise proved to be very effective at providing additional clarify with respect to the meaning and importance of the various hypotheses. A first round of discussions reduced the number of hypotheses to 22, 10 for the LCR and 12 for the MCR. Hypotheses were then organized by one of five principal types of impact: temperature, flow, predation, contaminants, and food availability. Further review of the hypotheses provided initial estimates of the expected cost, any anticipated political or jurisdictional problems, and the time required to either (a) complete any additional studies or research and (b) complete project implementation, at either a small scale (i.e., trial test, if appropriate) or as a large-scale application. This information was discussed briefly, in terms of its implications for mitigation and research projects and whether any required actions were clearly "show-stoppers" in the sense of being politically or economically infeasible, but (consistent with the iterative cycling through of key decision making steps) more detailed discussion was left to a later workshop.

A second round of the "science-court" debates, following recombination of the hypotheses and their aggregation where appropriate, resulted in the reduction of the number of hypotheses for explaining recruitment failure to eleven: 5 for the LCR and 6 for the MCR. These are summarized below, first for the LCR and then for the MCR; both results include a verbal description of the hypothesis, the life stage to which it applies, and a description in terms of the influence diagram pathways. This substantial reduction in the number of recruitment failure hypotheses, along with the additional clarity provided by the influence diagrams and subsequent re-examination of each hypothesis, was felt by the TWG to provide a solid groundwork for moving forward with more detailed discussions and weighting of the hypotheses.

Label	Original Hypothesis	Life stage	Pathway description
LC1/LC3	Changes in flow patterns (magnitude and timing) and reduction in turbidity reduce the survival of young sturgeon	Age 0	Dam installation and operations cause reduced turbidity and altered hydraulics (flow volume and velocities). The altered hydraulics no longer serve to disperse newly hatched free embryos to suitable hiding habitat. Embryos suffer predation while searching for suitable habitat, and post-hiding phase juveniles also suffer predation while moving downstream. Increased predation occurs in part due to lack of cover associated with reduce flow volume and turbidity.
LC2/LC4	Diminished suitability and availability of habitat (primarily related to substrate conditions) downstream of spawning areas has led to reduced survival of early life stages	0-365 days; the smaller the juvenile the more likely the effect	Dam installation and operations combined with natural and industrial sources of sediments have in-filled substrate interstices or overlain substrates rendering them unsuitable for use by early life stages. Juveniles then succumb to a combination of reduced food availability (impacting growth) and predation (during search for food and habitat).
LC5/LC6	Changes to the fish community have resulted in increased predation on eggs, free embryos, larvae and juvenile sturgeon and significantly reduced survival	0-365 days	Dam installation and operations combined with fish introductions have altered the fish community and increased the number of predators. Since juveniles are not growing normally and do not have suitable refuge habitat, they are more available for a longer time period to a larger predator population and their survival is significantly reduced.
LC7/LC8	Contaminated effluent from smelter and pulp mill sources leads to direct or indirect toxicity, impacted health, reduced spawning success, and reduced habitat and prey availability.	0-365 days	Industrial effluents introduced to the river contaminate prey items and fish. Sturgeon are directly contaminated or indirectly due to contaminants accumulated in their prey. Sturgeon can succumb immediately, suffer reduced health and growth, have their gender or spawning capabilities impacted, or become more susceptible to predators.
LC9/LC10	Food of the appropriate type and size is not available at the right time and place to promote survival of young sturgeon.	Age 0	Substrate condition and availability has been altered by sediment additions and the inability of flows to clean the substrate. Invertebrates prey species are unable to find suitable substrate and die or succumb to sediment toxicity. Sub-yearling sturgeon cannot find suitable or sufficient prey, and they starve or their growth is reduced and they succumb to predation.

Label	Description	Life stage	Pathway description
MC1/MC2/MC5	Changes in flow and temperature patterns (magnitude and timing) reduce the success of or delay spawning, egg development, and post-hatch embryo growth and development. As a result, the over-wintering fitness of post-hiding phase juveniles is impacted and survival significantly reduced.	Pre-spawn and spawning adults, incubating eggs, and 0-365 day old juveniles	Dam installation and operations has altered the hydrograph (flow volume and velocities) and hypo-limnetic water withdrawals reduced overall river temperatures and delayed warming and cooling rates. Mature adults defer or postpone spawning while waiting for suitable cues. If adults do spawn, incubation and the post-hatch hiding phase of their progeny takes longer. Further, juveniles start to feed too late to build up metabolic reserves to provide for adequate over-wintering fitness. Sub-yearling juveniles starve over the winter or suffer from increased predation.
MC3/MC4/MC6	Changes in flow patterns (magnitude and timing) and reduction in turbidity reduce the survival of eggs and young sturgeon	Egg incubation and 0-40 days post-hatch	Dam installation and operations cause reduced turbidity and altered hydraulics (flow volume and velocities). The altered hydraulics no longer serve to disperse newly hatched embryos to suitable hiding habitat. Load shaping also exposes incubating eggs and post-hatch embryos to stranding mortality. Free embryos suffer predation while searching for suitable habitat, and post-hiding phase juveniles also suffer predation while moving downstream. Increased predation occurs in part due to lack of cover associated with reduce flow volume and turbidity.
MC7/MC8	The suitability and availability of habitat (primarily related to substrate conditions) downstream of spawning areas has led to reduced survival of eggs and early life stages	Incubating eggs, 0-40 day larvae, and 25-365 day larval/juvenile stages	Dam installation and operations (hydrograph changes and downstream reservoir backwatering) has resulted in substrate armouring of the upper reach, and altered substrate conditions in the river-reservoir interface area rendering these areas unsuitable for egg incubation and the post-hatch hiding phase, or post-hiding feeding juveniles. Juveniles succumb to a combination of reduced food availability (impacting growth) and predation (during search for food and habitat).
MC9	The installation of HLK dam eliminated the ability of mature adults from below the dam to access spawning habitat in the mid-Columbia reach upstream of Arrow Lakes resulting in lost recruitment.	Mature adults (25+ years)	The construction of HLK dam without suitable passage facilities eliminated the ability of sturgeon residing below the dam either seasonally or during the interval between spawning events to move past the dam into Arrow Lakes and upstream to the Columbia River. This eliminated the ability of this segment of the population to spawn in the upstream Columbia River and therefore reduce spawning success to that provided by residents upstream of HLK or at replacement spawning areas downstream of HLK.
MC10/MC11	Changes to the fish community have resulted in increased predation on eggs, free embryos, larvae and juvenile sturgeon and significantly reduced survival	0-365 days	Dam installation and operations altered the fish community and increased the number of predators. Since juveniles are not growing normally (delayed development; see MC1/2/5) and do not have suitable refuge habitat, they are more available for a longer time period to a larger predator population and their survival is significantly reduced.
MC12	Food of the appropriate type and	11-365 days	Substrate condition and availability has been altered below the spawning area (armoured) and in the area of the river-reservoir

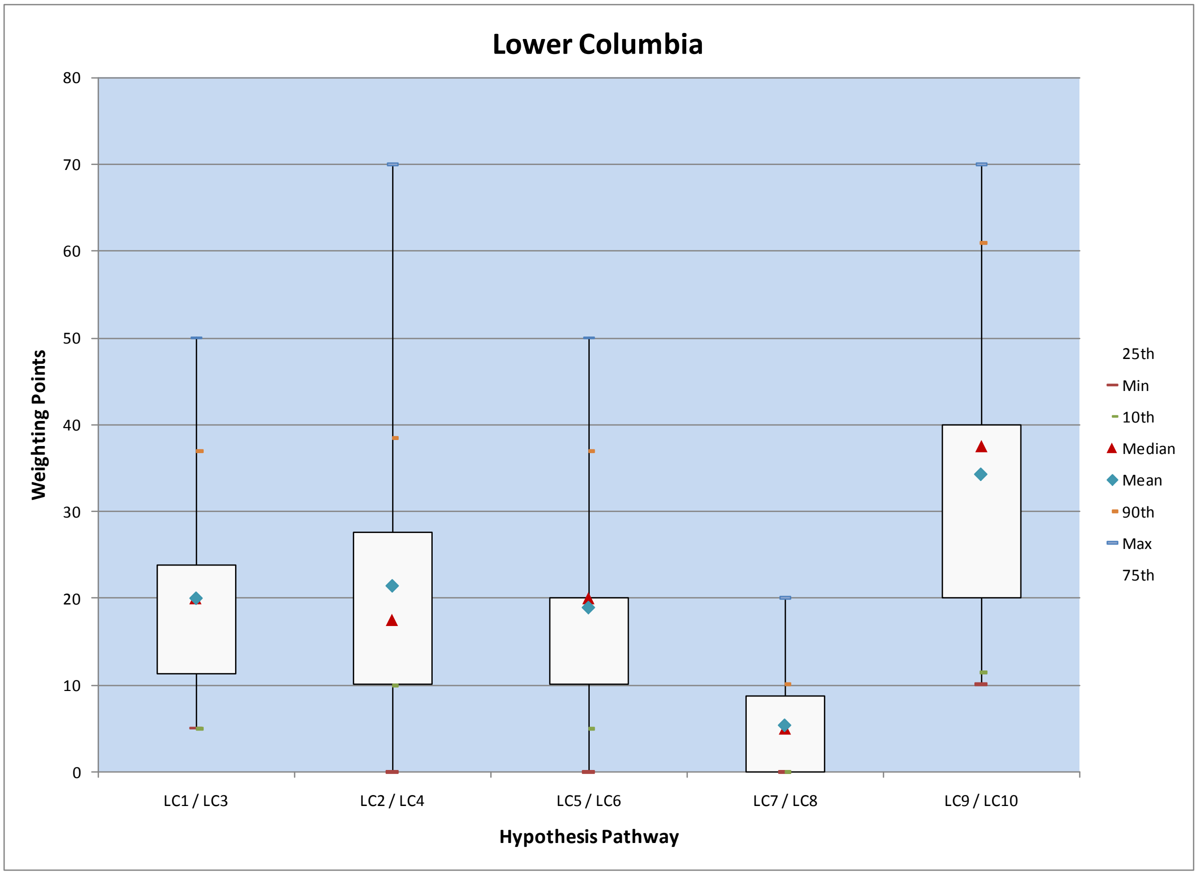
	size is not available at the right time and place to promote survival of young sturgeon.		interface. Invertebrate prey species are unable to find suitable substrate. Sub-yearling sturgeon cannot find suitable or sufficient prey, and they starve or their growth is reduced and they succumb to predation.

Separate consideration was given to one of the critical hypotheses (labeled MC13) that concerned whether fish historically spawned upstream of Arrow or whether these sturgeon instead were inadvertently trapped after construction of the dam while exploring Arrow Lakes and upstream reaches. This question was asked of each TWG member in terms of the probability that the statement “Fish historically did not spawn upstream of Arrow” is true. The median and mean result for this elicitation was a probability of .8, which means that members of the TWG felt quite confident that the trapped populations were exploring Arrow Lakes and upstream reaches in a transient manner. The range of responses was from .5 to 1.0; one person considered it to be equally likely that historically fish did or did not spawn upstream of Arrow, whereas another member of the TWG was certain that fish historically did not spawn upstream of Arrow.

3. EXPLORE THE DEGREE OF BELIEF IN THE CONTRIBUTION OF EACH HYPOTHESIS TO RF

At this point, the group members had a good understanding of their peers’ views on a) which hypothesis areas are mostly likely contributing to recruitment failure, and b) the degree of agreement and disagreement among TWG members. For example, Figure 3 illustrates the range of opinion across the TWG about the relative contribution of each of the five hypotheses for recruitment failure in the Lower Columbia River. Consistent with the use of SDM methods, weighting exercises of this type were used extensively during workshops 2, 3, and 4 in order to focus discussion on key points of agreement and disagreement among TWG members, not as a way to distinguish “right’ from “wrong” answers or “popular” from “unpopular” points of view but rather as a way to enrich the discussions and guard against the natural tendency in many group deliberations to engage in what is often termed “group think,” whereby more moderate (but not necessarily correct) views win out over time whereas outlying and dissenting perspectives (which may be shown over time to have been correct) are silenced.

Figure 3: Range of TWG Weightings for Hypothesis Pathways in the LCR



This result was used to focus subsequent discussions. For example, it is clear that there is not a strong belief in the contribution to recruitment failure of hypotheses dealing with contaminants (LC7 / LC8). On the other hand, many participants placed a high relative weight on the contribution of alterations in substrate condition and availability as the result of sediment additions and the inability of flows to clean the substrate (LC9 / LC10).

Figure 4: Range of TWG Weightings for Hypothesis Pathways in the MCR

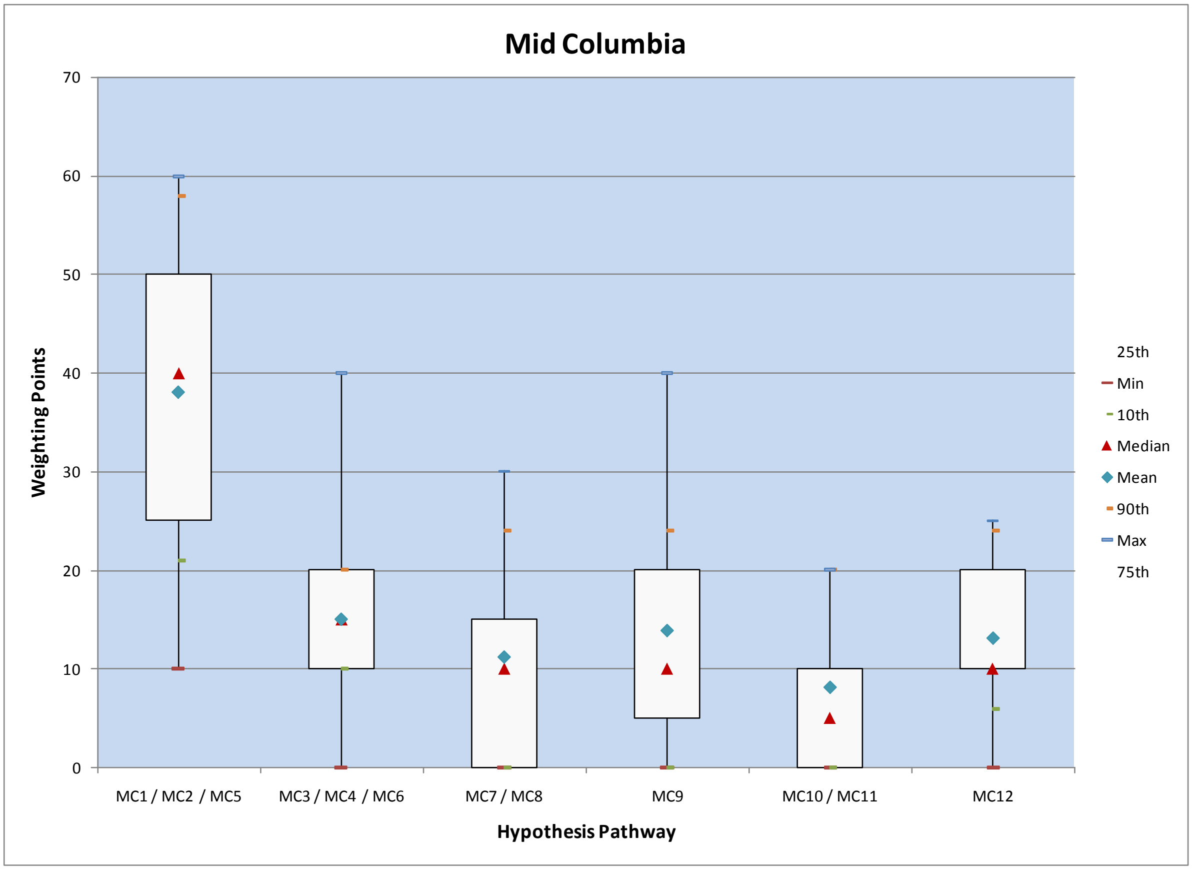


Figure 4 illustrates the range of opinion across the TWG about the relative contribution of each of the six hypotheses for recruitment failure in the Mid-Columbia area. In this case, changes in flow and temperature (MC1/ MC2/ MC5) are considered by many participants to be the leading cause of recruitment failure. On the other hand, neither predation (MC10/ MC11) nor armouring of the substrate (MC7/ MC8) are considered by most TWG members to be primary reasons for RF in this reach..

4. IDENTIFY REALISTIC IN-RIVER MITIGATION OPTIONS TO ADDRESS KEY HYPOTHESES

At this stage in the discussions, with a relatively high comfort level in terms of leading hypotheses for recruitment failure and the different perspectives on the hypotheses held by TWG members, it was important to begin to shift attention from the clarification of hypotheses to the characterization of mitigation actions that would address the concerns identified by the hypotheses. This took place in two steps: first, the mitigation projects were ranked in terms of their anticipated importance to WS recovery efforts, and then key elements of possible mitigation options were identified. This discussion included information on the anticipated deliverables, timelines, likely funding sources, and costs (or the development of terms of reference to begin to more clearly identify costs), along with the identification of a likely task manager and any interdependencies that existed with respect to other leading hypotheses (that might, in turn, affect the conduct – timing, scale, placement -- of a mitigation action). These are shown below for both the LCR and the MCR.

	Primary H	Mitigation Option	Description
A	LC1LC3	LC - Turbidity augmentation	Artificial addition of material (most likely bentonite clays) upstream of one or more spawning locations at concentrations designed to raise turbidity to 11 NTUs or greater. Turbidity increases to be targeted at lower (<90 kcfs at the border) discharge volumes when predator search patterns would be most affected.
B	LC1LC3	LC - Deliberate flow manipulation	Increase freshet flows to greater than 200 kcfs at the border for the prime spawning through larval dispersal
C	LC1LC3	LC - Flow - backwater timing manipulation	Reduce the water level in Lake Roosevelt to increase suitable riverine habitat during spawning through larval dispersal, followed by increasing levels (backwatering) to wet and increase the availability of potential juvenile habitat
D	LC2LC4	LC - Substrate modification - clean	Use artificial means to clean gravels and larger substrate materials, including excavation and removal of accumulated fines, loosing and turnover of substrates to mobilize fines causing embeddedness, and in limited areas hydraulic cleaning.
E	LC2LC4	LC - Substrate modification - add	The addition of large rock to increase the suitability of spawning areas, and of clean large gravels upstream of hiding habitat areas to increase accessibility of preferred substrate for hiding free embryos
F	LC5LC6	LC - Predator control program - general	The removal of known or potential juvenile sturgeon predators through directed increased harvest or a bounty paid for identified species.
G	LC5LC6	LC - Walleye reduction program	The targeted removal of walleye, a juvenile sturgeon predator, from the spawning through early juvenile life history area, through directed increased harvest or a bounty paid to anglers.
H	LC9LC10	LC - Fertilize transboundary reach	Large river fertilization to increase primary and invertebrate production to increase prey base for juvenile sturgeon. This technique is being tested in the Middle Kootenai River.
I	LC9LC10	LC - Seeding of varial zones	Re-vegetation of drawdown zones using planting of flood resistant wetland plant species, or annual seeding and fertilization of fast germinating crop species such as fall rye.
J	LC9LC10	LC - Embayment fertilization	Involves the addition of fertilizer to inflow tributary flows where the immediate confluence area is partially enclosed by embayment headlands which act to concentrate the lower trophic level response.

	Primary H	Mitigation Option	Description
A	MC1MC2MC5	MC - Selective withdrawal	Use of existing turbine or spillway intakes gates or refitted withdrawal structures designed to selectively feed warmer surface waters from the upstream reservoir to the downstream river during spawning through pre-winter juvenile growth period.
B	MC1MC2MC5	MC - Spawning / Rearing Channel	Installation of an artificial channel of suitable dimensions and complexity, and provided with suitable flows to provide necessary depth and velocities designed to support spawning through pre-winter

			juvenile growth period.
C	MC1MC2MC5	MC - Flow manipulations	Increased freshet flows to adequate volumes to support spawning through larval dispersal; would include the seasonal deferral of much of the load shaping capacity of REV
D	MC1MC2MC5	MC - Reservoir manipulations (REV/MCA)	Involves the drawdown of Revelstoke and Kinbasket reservoirs in order to bring warmer surface runoff into the vicinity of turbine intakes where is can be drawn off to warm downstream river during spawning through pre-winter juvenile growth period.
E	MC3MC4MC6	MC - Reservoir manipulations (ARR)	Reduction of the water level in Arrow Lakes Reservoir to increase suitable riverine habitat during spawning through larval dispersal, along with suitable backwatering to wet and increase the availability of potential juvenile habitat
F	MC3MC4MC6	MC - Incubation and Dispersal Flow	Extension of proposed WUP spawning flow release tests to include free embryo and larvae development phases. If successful, these tests would be used as evidence for future hydraulic manipulations
G	MC3MC4MC6	MC - Turbidity augmentation	Artificial addition of material upstream of the Revelstoke spawning location at concentrations designed to raise turbidity to protect eggs, free embryo, and larvae from predations
H	MC3MC4MC6	MC - Predator control program - localized	The removal of known or potential juvenile sturgeon predators through directed increased harvest or a bounty paid for identified species. Focused on predators found immediately downstream of the spawning area.
I	MC7MC8	MC - Substrate Modification	The addition of large rock to increase the suitability of spawning areas, and of clean large gravels upstream of hiding habitat areas to increase accessibility of preferred substrate for hiding free embryos. Alternatively, the use of artificial means to clean gravels and larger substrate materials, including excavation and removal of accumulated fines, loosing and turnover of substrates to mobilize fines causing embeddedness, and in limited areas hydraulic cleaning.
J	MC7MC8	MC - Flushing Flows	The release of high volume, prolonged discharges from REV suitable for dislodging and moving embedded substrates in order to flush fines downstream to the reservoir interface.
K	MC7MC8	MC - Construction of large scale eddies	The excavation of deep pools either where river topography or constructed groins will maintain their structure
L	MC9	MC - Transport HLK wild adults upstream, to aid spawning	The capture and movement of adult sturgeon found downstream of HLK to upstream of the dam. To be used if it is demonstrated that the mid-Columbia stock is unable to establish self sustainability due to poor abundance
M	MC9	MC - Build a volitional fish passage structure in HLK	Provision of a large stepped channel of a suitable gradient, depth and velocity to promote sturgeon upstream migration, or provision of a fish trap and truck, or fish lift apparatus suitable for sturgeon
N	MC9	MC - Move ARR adults DS of HLK?	The capture and movement of all adult sturgeon found upstream of HLK to downstream of the dam. To be used if the mid-Columbia stock is shown to not be self-sustainable
O	MC9	MC - Larval / juvenile release from HLK	The movement of naturally recruited juveniles or the

		adults (that are in the LC)	release of the progeny of spawners specifically captured from the HLK population. Juveniles would be genetically tested to ensure their relationship to mid-Columbia sturgeon.
P	MC9	MC - Transport hatchery juveniles upstream of HLK, to build population	The release of the hatchery progeny of sturgeon broodstock collected from downstream of HLK but not tested for genetic compatibility with mid-Columbia sturgeon.
Q	MC12	MC - Fertilize MCR	Large river fertilization to increase primary and invertebrate production to increase prey base for juvenile sturgeon. This technique is being tested in the Middle Kootenai River.
R	MC12	MC - Embayment Fertilization	Involves the addition of fertilizer to inflow tributary flows where the immediate confluence area is partially enclosed by embayment headlands which act to concentrate the lower trophic level productive response.

In order to keep track of this information, templates were developed that showed the overall mitigation project emphasis along with a detailed accounting of the type of mitigation or research activity that would be required, any sub-hypotheses to be addressed as part of this work, and the anticipated clarity of results. This latter question was considered to be important because of the wide range of anticipated results, with some mitigation or research actions expected to provide definitive answers as to the role played by the identified explanation for recruitment failure and other actions expected to provide substantially less clarity. This might affect, for example, the timing or expenses associated with progression from a small-scale or trial application of a mitigation or research project to its implementation in the Columbia River itself, which in turn could affect the importance of the project in terns of its ability to make a significant contribution to addressing Upper Columbia River WS recruitment failure within a biologically reasonable period of time. Figure 5 shows an example template; members of the TWG were encouraged to continue to develop and refine the templates as more information becomes available.

Figure 5: Typical template, this example for one mitigation project relating to hypothesis aggregate LC1/LC3

Mitigative Project Feasibility Research Requirements

				Ballpark	Ballpark	Clarity of Results Expected
			Location (1)	Cost(2)	Time(3)	From Research as
Title of Research	Sub Hy	Research Method (C		$k Total	Yrs Total	Described(4)
WUP feasibility response - if changes a feasible response	WUP		Desk	$ 65	1	Possibly clear
Environmental impact assessment	Effects of material on primary and secondary productivity, drinking water WQ, fish, irrigation etc		Other	$ 500	2	Definitive
Material type and delivery	What material, where and how to deliver ...		Desk	$ 100	1	Likely clear
Material type and effectiveness for recovery success	What le	Mesocc	Lab	$ 300	3	Likely clear
Complete implementation design				$ -	1	Likely clear
Permits/approvals				$ 100	1	Definitive
Communications				$ 200	3	Definitive
Implement				$ 3,000	3	Likely clear
Monitoring - turbidity and R success	Is it working?		Field	$ 500	3	Likely clear
Monitoring - expected adverse effects	Acceptable adv		Field	$ 300	3	Likely clear
				$ 5,065	4	

(1) Choose from list using in-cell drop down

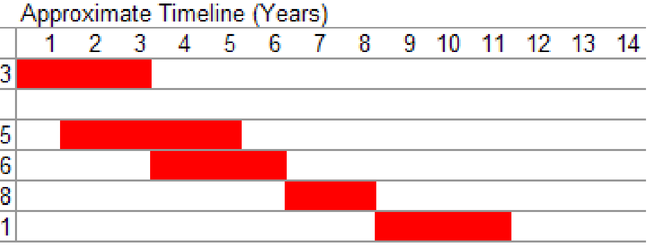
(2) Quick assessment is fine; Total all estimated direct costs over full length of research program

(3) Quick assessment is fine; Estimate Years from now to completion of study.

(4) Use in-cell drop down; what level of clarity on the issue should we expect from this research?

	Cost$k	Years	Start Yr	End Yr
Hypothesis Importance Confirmation Time	$ 2,140	3	0	3
Collect Baseline Data				
Mitigation Project Feasibility Research	$ 565	4	2	5
Mitigation Project Planning and Permitting	$ 500	3	4	6
Mitigation Project Build / Implementation	$ 3,200	2	7	8
Monitoring to Point of Biological Response Confirmation	$ 800	3	9	11
	$ 7,205			

Approximate Timeline (Years)



5. EXPLORE THE PLAUSIBILITY OF MITIGATION OPTIONS

At this stage the TWG members had provided information about their degree of belief in each hypothesis and about their predictions to the likely success of the associated mitigation options. The next task was to refine the understanding of each of the mitigation and research options, so as to continue to move the discussions from the review of hypotheses explaining recruitment failure to the development of a coordinated and realistic set of management actions that could address RF. The first task was to more clearly distinguish between research and mitigation projects, with research initially defined as tasks required to yield information that would be useful in conducting a mitigation activity

With this distinction in mind, a weighting task was given to participants. The task was described as providing importance weights to each of the mitigation options, in order to foster additional discussion about the various alternatives. This was done by developing weighting protocols that asked the individual members of the TWG to give '10' weighting points to the mitigation option (or options) they considered to be most important and then, thinking in terms of ratios or proportions, to provide a weight between 0 and 10 that represents the relative importance of each of the other options. This was done separately for the Lower and Mid Columbia regions. Findings are shown below, in terms of sorted (from highest to lowest ranked) and normalized (in terms of points out of 100) results.

FIGURE 6: WEIGHTS FOR LOWER COLUMBIA MITIGATION OPTIONS

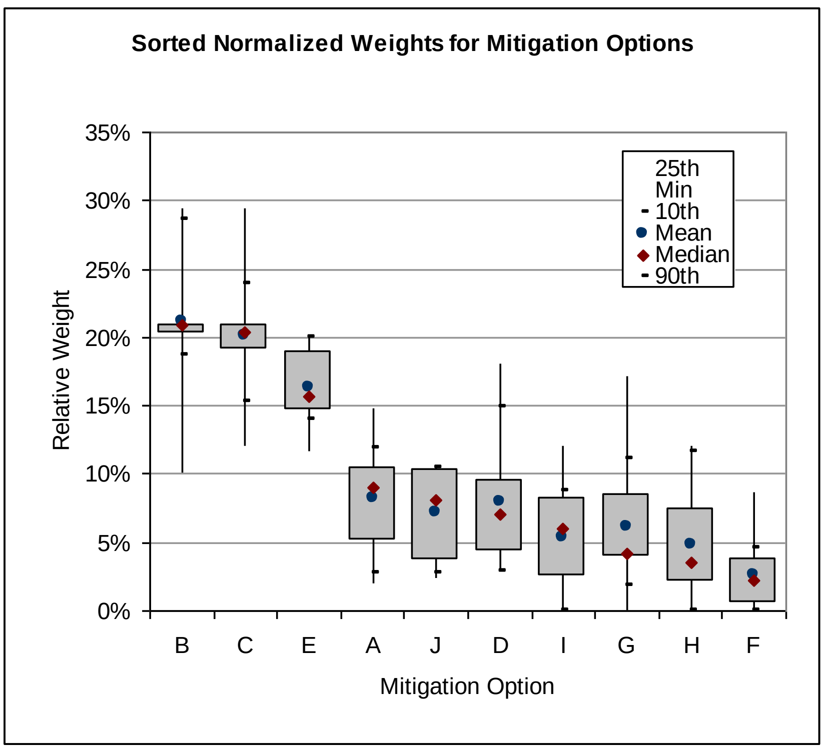
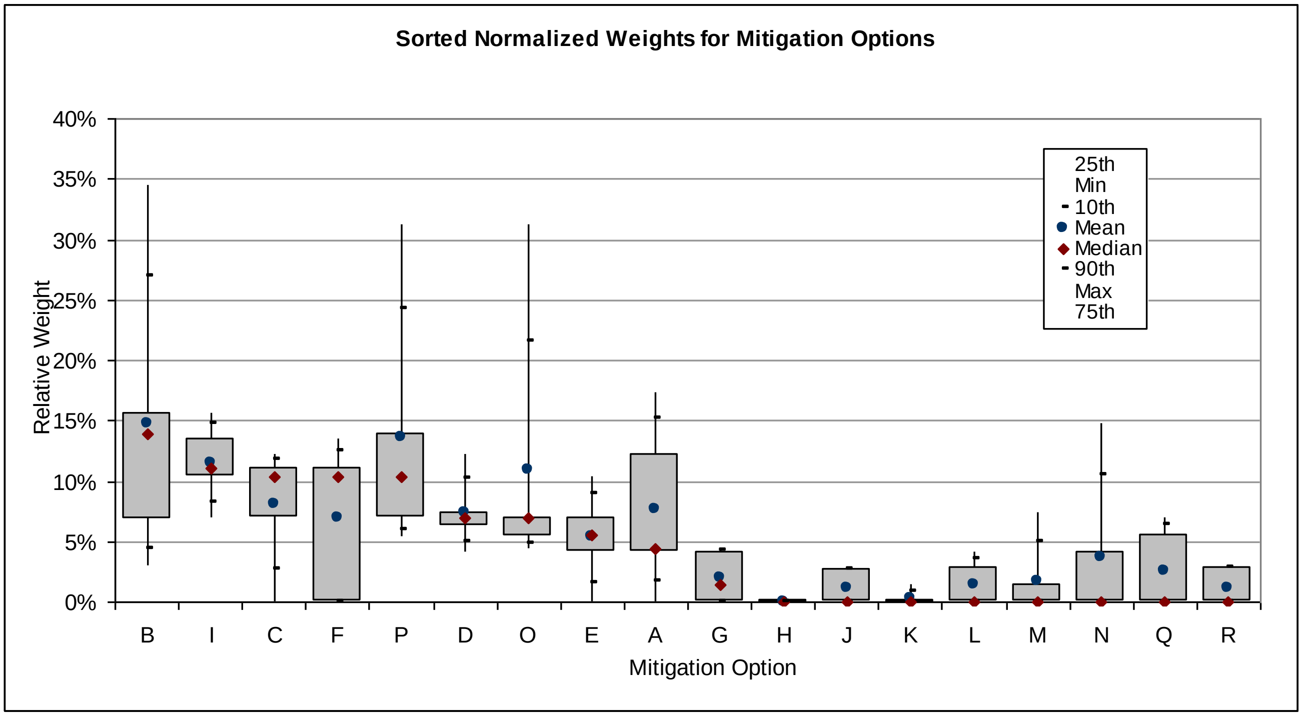


FIGURE 7: WEIGHTS FOR MID-COLUMBIA MITIGATION OPTIONS



6. CHARACTERIZE RESEARCH PROJECTS REQUIRED TO INITIATE MITIGATION PROJECTS

With mitigation priorities more clearly defined, TWG members then returned to the discussion of research options. Several different types of research were discussed, and it was emphasized that careful delineation of research alternatives was required because the results of research would help to make or break the case for many of the recruitment failure hypotheses and, in turn, the related mitigation projects. After extensive discussion, research options were defined more clearly in terms of the following distinction:

- required research, describing cases where mitigation could not occur without this research being done
- supporting research, describing cases where results would be helpful to the conduct of mitigation activities but are not strictly required.

In addition, TWG members clarified the timing of the research, in terms of the years needed to initiate studies (permitting, etc.) as compared to the years needed to complete them and to implement findings. An important distinction was made between Implementation that would first need to be done at a small-scale (e.g., as laboratory trials or conducted in smaller tributaries) as compared to research that could be implemented at a large-scale (e.g., in the main river). This distinction was recognized as important to the timing and realization of benefits, in light of the listing of Upper Columbia River as endangered and the relatively short time horizon (+/- 25 years) over which concerns regarding biological extinction might still be addressed .

The listing of research projects provided below shows, for both the LCR and MCR, the highest ranked research activities. An important distinction was the extent to which each of the proposed research projects would facilitate the initiation of one or more of the highest ranked mitigation options, as further discussed in the next section.

Lower Columbia

P1	Historic Reconstruction: Finalize stock structure analysis
P2	Historic Reconstruction: Impact timelines for each H
P3	Historic Reconstruction: Work plan workshop
P4	Modeling: Improve bathymetry of Little Dalles
P5	Predators: Synthesize existing literature
P8	Larval Hiding: Substrate mapping - what's where
P9	Larval Hiding: Complete lab studies linking survival and substrates
P10	Larval Hiding: Mesocosm studies
P11	Larval Hiding: Physical feasibility study for substrate enhancement
P12	Larval Hiding: Make a determination if substrate is limiting
P13	Larval dispersal: Drift pattern analysis
P14	Early feeding: Study successful habitat components
P15	Early feeding: Larval field sampling
P16	Early feeding: Prey availability
P17	Early feeding: Starvation lab studies
P18	Early feeding: Simple enclosure feeding study
P19	Flow: Plan the opportunistic flow response

Mid Columbia

M1	Historic Reconstruction: Finalize stock structure analysis
M2	Historic Reconstruction: Impact timelines for each H
M3	Historic Reconstruction: Work plan workshop
M4	Modeling: Habitat availability at reservoir interface
M8	Larval Hiding: Substrate mapping
M9	Larval Hiding: Lab studies linking survival and substrates
M10	Larval Hiding: Mesocosm - how the pattern of drift relates to substrate
M11	Larval Hiding: Physical feasibility study for substrate enhancement
M12	Larval Hiding: Is substrate limiting? Compare lab and field
M12a	Larval Hiding: Stranding impact assessment
M13	Larval dispersal: Drift pattern analysis
M14	Early feeding: Study successful habitat components
M15	Early feeding: Larval field sampling
M16	Early feeding: Prey availability

M17	Early feeding: Starvation lab studies
M18	Early feeding: Simple enclosure feeding study
M20	Temperature: Biological and engineering investigations

7. EVALUATE THE IMPORTANCE OF EACH RESEARCH PROJECT

At the fourth meeting of the TWG (February, 2008), weighting exercises were introduced to prioritize each of the identified research projects. Because the goal of the deliberations was to develop recommendations for management actions based on the improved understanding of hypotheses about reasons for the apparent recruitment failure of WS, it was important to link each of the proposed research projects to the highest ranked mitigation options. The entire TWG completed the weighting exercise for the LCR; a separate sub-group was convened in April, 2008 to complete the weighting exercise for the MCR (with results later distributed to, and discussed by, the entire TWG).

The completed weightings, separated for the LCR and the MCR, are shown in the accompanying tables. Results are shown both for the unsorted rankings and sorted by medians in terms of their relative importance. For both the LCR and the MCR, the rows of the sorted table show the leading mitigation options, in descending order (top to bottom). The columns of the table show the leading research projects, also in descending order (left to right). In all cases, mitigation actions were ranked first. The upper left-hand corner of the table thus shows the most important research items that address the most important mitigation options: if resources or personnel or time are limited, these are clearly the most critical. As a result, discussions of the TWG focused on this upper-left portions of the table because it was recognized as holding the greatest promise for providing a focused and efficient set of activities to address WS sturgeon recruitment failure. The discussions also covered several topics related to the practical question, for each leading hypothesis, of what could actually be done in light of constraints. During this portion of the workshop participants made frequent reference to the detailed background sheets on research study and mitigation option requirements that had been prepared as part of earlier workshops.

Further attention also was given at this time to the link between research and mitigation, in that participants recognized that the "hard" constraint placed in earlier group discussions on defining research items – which is that research was viewed as a necessary precondition for undertaking mitigation actions – in fact should be "softened" in many cases because the research was viewed as helpful or supportive rather than necessary (one example: enclosure feeding studies). Participants also noted that several of the research items could be combined because of similarities in focus: R10 (larval hiding: mesocosm studies) and R12 (larval hiding: determine if substrate is limiting), for example, could be combined with other larval hiding activities (R8, substrate mapping; R9, lab studies to link survival and substrates; R 11, physical feasibility study for substrate enhancement).

6 SORTED THE MITIGATION / RESEARCH OPTION MATRIX BY DESCENDING WEIGHTS

LOWER COLUMBIA

UNSORTED

	Primary H	Mitigation Option	Median Group	RESEARCH ITEMS																
				1	2	3	4	5	8	9	10	11	12	13	14	15	16	17	18	19
A	LC1LC3	LC - Turbidity augmentation	9%	R	R	S		S		S	S			S	S					S
B	LC1LC3	LC - Flow - deliberate flow manipulation	21%	R	R	S	R		S	S	S		S	R	R	R				R
C	LC1LC3	LC - Flow - backwater timing manipulation	20%	S	R	S	R		S	S	S		S	R	S	R	S	S	S	S
D	LC2LC4	LC - Substrate modification - clean	7%	R	R	S	S		R	R	R	R	R	S	R	S				
E	LC2LC4	LC - Substrate modification - add	16%	R	R	S	S		R	R	R	R	R	S	R	S				S
F	LC5LC6	LC - Predator control program - general	2%	R	S	S	S	R			S		S	S						
G	LC5LC6	LC - Walleye reduction program	4%	R	S	S	S	R					S	S						
H	LC9LC10	LC - Fertilize transboundary reach	4%	S	S	S	S		S					S	S	R	R	R	R	
I	LC9LC10	LC - Seeding of varial zones	6%	S	S	S	S		S					S		R	R	R	R	
J	LC9LC10	LC - Embayment fertilization	8%	S	S	S	S		S					S	S	R	R	S	S	
				9.3%	9.1%	4.7%	7.3%	1.9%	6.7%	6.4%	4.6%	4.7%	6.5%	4.7%	7.7%	7.8%	6.8%	3.8%	3.0%	8.5%

R = Required (Mitigation project initation could not occur without this R)
S = Supports

SORTED

	Primary H	Mitigation Option	Group Weight	RESEARCH ITEMS																
				1	2	19	15	14	4	16	8	12	9	11	3	13	10	17	18	5
B	LC1LC3	LC - Flow - deliberate flow manipulation	21%	R	R	R	R	R	R		S	S	S		S	R	S			
C	LC1LC3	LC - Flow - backwater timing manipulation	20%	S	R	S	R	S	R	S	S	S	S		S	R	S	S	S	
E	LC2LC4	LC - Substrate modification - add	16%	R	R	S	S	R	S		R	R	R	R	S	S	R			
A	LC1LC3	LC - Turbidity augmentation	9%	R	R	S		S					S		S	S	S			S
J	LC9LC10	LC - Embayment fertilization	8%	S	S		R	S	S	R	S				S	S		S	S	
D	LC2LC4	LC - Substrate modification - clean	7%	R	R		S	R	S		R	R	R	R	S	S	R			
I	LC9LC10	LC - Seeding of varial zones	6%	S	S		R		S	R	S				S	S		R	R	
G	LC5LC6	LC - Walleye reduction program	4%	R	S				S			S			S	S				R
H	LC9LC10	LC - Fertilize transboundary reach	4%	S	S		R	S	S	R	S				S	S		R	R	
F	LC5LC6	LC - Predator control program - general	2%	R	S				S			S			S	S	S			R
				9.3%	9.1%	8.5%	7.8%	7.7%	7.3%	6.8%	6.7%	6.5%	6.4%	4.7%	4.7%	4.7%	4.6%	3.8%	3.0%	1.9%

R = Required (Mitigation project initation could not occur without this R)
S = Supports

UNSORTED

	Primary H	Mitigation Option	Median Group Weight	M1	M2	M3	M4	M8	M9	M10	M11	M12	M12a	M13	M14	M15	M16	M17	M18	M20
				RESEARCH PROJECTS (SEE 'CONSOLIDATED R' SHEET)																
A	MC1MC2MC5	MC - Selective withdrawal	4%	S	S										S			S	S	R
B	MC1MC2MC5	MC - Spawning / REARING CHANNEL	14%	S		S			R	R	S	R	S		S			S	S	R
C	MC1MC2MC5	MC - Flow manipulations	10%	S	S								R		S			S	S	S
D	MC1MC2MC5	MC - Reservoir manipulations (REV/MCA)	7%	S	S										S			S	S	R
E	MC3MC4MC6	MC - Reservoir manipulations (ARR)	6%	S	S	S	R	S	R	R		S	S	R	R			S	S	
F	MC3MC4MC6	MC - Incubation and Dispersal Flow	10%	S	S	S	S	S	R	R		S	S	R	R			S	S	S
G	MC3MC4MC6	MC - Turbidity augmentation	1%	S	S	S		S	S	R				R					S	
H	MC3MC4MC6	MC - Predator control program - localized	0%						S	S				S	S			S	S	
I	MC7MC8	MC - Substrate ~~Addition~~ Modification	11%	S	S			R	R	R	R	R		S	S			S	S	S
J	MC7MC8	MC - Flushing Flows	0%	S	S		S	R	R	R	S	R		R	S			S	S	S
K	MC7MC8	MC - Construction of large scale eddies	0%	S	R		S	S							R		S		S	
L	MC9	MC - Transport HLK wild adults upstream, to aid spawning	0%	R	R	S	S	S	S	S		S	S	S	S	S	S	S	S	S
M	MC9	MC - Build a volitional fish passage structure in HLK	0%	R	R	S	S	S	S	S		S	S	S	S	S	S	S	S	S
N	MC9	MC - Move ARR adults DS of HLK?	0%	R	R	S														S
O	MC9	MC - Larval / juvenile release from HLK adults (that are in the LC)	7%	S	S	S	S	R	S	S				S	S			S	S	S
P	MC9	MC - Transport hatchery juveniles upstream of HLK, to build population	10%	S	S	S	S	R	S	S				S	S			S	S	S
Q	MC12	MC - Fertilize MCR	0%	S	S										S	R	R	S	S	
R	MC12	MC - Embayment Fertilization	0%	S	S										R		R	S		
				8%	9%	6%	4%	5%	5%	3%	6%	7%	7%	3%	3%	4%	3%	3%	3%	12%

R = Required (Mitigation project initation could not occur without this R)
S = Support (Mitigation project would be supported by, but does not depend on, this R)

SORTED

	Primary H	Mitigation Option	Median Group Weight	M20	M2	M1	M12a	M12	M11	M3	M8	M9	M4	M15	M10	M13	M14	M18	M16	M17
				RESEARCH PROJECTS (SEE 'CONSOLIDATED R' SHEET)																
B	MC1MC2MC5	MC - Spawning / REARING CHANNEL	14%	R		S	S	R	S	S		R			R		S	S		S
I	MC7MC8	MC - Substrate ~~Addition~~ Modification	11%	S	S	S		R	R		R	R			R	S	S	S		S
C	MC1MC2MC5	MC - Flow manipulations	10%	S	S	S	R										S	S		S
F	MC3MC4MC6	MC - Incubation and Dispersal Flow	10%	S	S	S	S	S		S	S	R	S		R	R	R	S		S
P	MC9	MC - Transport hatchery juveniles upstream of HLK, to build population	10%	S	S	S				S	R	S	S		S	S	S	S		S
D	MC1MC2MC5	MC - Reservoir manipulations (REV/MCA)	7%	R	S	S											S	S		S
O	MC9	MC - Larval / juvenile release from HLK adults (that are in the LC)	7%	S	S	S				S	R	S	S		S	S	S	S		S
E	MC3MC4MC6	MC - Reservoir manipulations (ARR)	6%		S	S	S	S		S	S	R	R		R	R	R	S		S
A	MC1MC2MC5	MC - Selective withdrawal	4%	R	S	S											S	S		S
G	MC3MC4MC6	MC - Turbidity augmentation	1%		S	S				S	S	S			R	R		S		
H	MC3MC4MC6	MC - Predator control program - localized	0%									S			S	S	S	S		S
J	MC7MC8	MC - Flushing Flows	0%	S	S	S		R	S		R	R	S		R	R	S	S		S
K	MC7MC8	MC - Construction of large scale eddies	0%		R	S					S		S				R	S	S	
L	MC9	MC - Transport HLK wild adults upstream, to aid spawning	0%	S	R	R	S	S		S	S	S	S	S	S	S	S	S	S	S
M	MC9	MC - Build a volitional fish passage structure in HLK	0%	S	R	R	S	S		S	S	S	S	S	S	S	S	S	S	S
N	MC9	MC - Move ARR adults DS of HLK?	0%	S	R	R				S										
Q	MC12	MC - Fertilize MCR	0%		S	S								R			S	S	R	S
R	MC12	MC - Embayment Fertilization	0%		S	S											R		R	S
				12%	9%	8%	7%	7%	6%	6%	5%	5%	4%	4%	3%	3%	3%	3%	3%	3%

R = Required (Mitigation project initation could not occur without this R)
S = Support (Mitigation project would be supported by, but does not depend on, this R)

8. ALLOCATE BUDGETS TO RESEARCH AND MITIGATION PROJECT PRE-FEASIBILITY PROJECTS.

The last remaining issues concerned the identification of a proposed time-line for conducting the higher priority research and mitigation projects and the allocation of budgets.

Discussions of research needs focused on the benefits (for both the LCR and MCR) of studies that would address information gaps through the reconstruction of historic data (stock structure analysis and impact timelines for each hypothesis): previous analyses (Tables 1 and 2) had shown that the two highest ranked research options for the LCR, and the three highest ranked research options for the MCR, required historic reconstruction. In general, these studies also were considered to be relatively inexpensive. After additional discussion, four additional key areas of research and mitigation interest were identified for the LCR:

1. Substrate modification (additions and cleaning)
2. Flow manipulations to address temperature concerns (both more detailed planning for the opportunistic flow response, a WUP requirement, and implications for Treaty renegotiations beginning in 2014)
3. Fertilization and feeding
4. Turbidity augmentation

Interest in larval hiding and feeding studies led to a discussion of how these might best be conducted in light of study objectives and a realistic set of program alternatives. In all cases, the potential mitigation actions involve substrate modification (either cleaning or adding substrate). In some cases there was said to be theoretical support for the link from research to mitigation, in other cases the link was empirical; the intervention for some cases was thought to work on a small scale and in other cases possibly on a large scale (sustainably).

Many of the mitigation and research components for the Mid Columbia were the same as for the LCR. The discussion helped to clarify the desired sequencing of mitigation activities (e.g., finalize the stock structure analysis before reconstructing impact timelines for each hypothesis, and only then hold a workshop to review implications: M1 then M2 then M3). Refinements were made to several of the proposed mitigation options and differences between studies proposed for the MCR and the LCR were highlighted: one example was the different physical conditions in the MCR that would affect conduct of M11 (substrate enhancement) and M12 (substrate as a limiting factor), and similarly differences in temperature in the mid- and lower Columbia River that would affect the conduct of mitigation options addressing early feeding (M17 and M18). Study needs and timing were said to influence, and to closely link with, the Feasibility Study that would be conducted for the Water Comptroller beginning early in 2009.

The insights from this discussion were documented through use of a consequence table, showing (in rows) the key considerations (aka constraints or objectives) and (in columns) an illustrative set of alternatives, covering minimum to maximum (“VW to Cadillac”) feasible options. These are summarized below.

		Alternatives		
Objectives	**Units**	**A: Minimum**	**B: Moderate**	**C: Maximum**
Time	Years	6	10	11-13
Cost	Million of dollars	1.6	3.5	8.6
Regulatory issues (next 2-3 years)	Probability of “green light”	0.5	0.8	0.9 – 1.0
Regulatory issues (next 3-4 years)		0.9	0.9	0.9
Socio-Economic benefits	Employment	Lower	moderate	Higher
Technical Risk	P of observed success, given H is true	0.2	0.6	0.9
Other information benefits	Index	1	1.5	2

This exercise helped to clarify several important features of the proposed research and mitigation on larval feeding. First, there is a relatively small set of key considerations, including not only the obvious issues of time and cost and technical success (a conditional probability, assuming the H is shown to be correct) but also the anticipated response of regulators and the benefits of the information that is provided for other issues relevant to recruitment failure. Second, alternative approaches are possible: there are several different ways to proceed depending on decisions that are made regarding urgency (time) and opportunities that are available to secure additional funds. Third, there is an important asymmetry between benefits and costs: costs are relatively straightforward to observe, whereas beneficial impacts on recruitment failure as the result of overcoming substrate limitations will depend not only on the actions taken but on the ability to successfully detect changes in variables. Fourth, it is helpful to make use of this information to develop an additional fourth (or fifth and sixth) option that seeks to retain the benefits of C (e.g., higher probability of technical success) while avoiding some of the associated costs (e.g., the five-fold difference in costs between A and C).

This discussion also refocused attention on the key implementation issues related to cost and sequencing, leading to the development of Table 1 which shows the annual budget allowances (in $000s) for the highest-ranked studies (both LCR and MCR) and the current status of funding (showing either existing funding sources, e.g., WUP or BPA or WDFW, or the need to locate supplemental funding sources, e.g., TBA) (Note: items dependent on the outcomes of previous activities are marked with an arrow). For the LCR, the discussions noted that, in the short run, the primary source of funding will be the continuing allocations from the Water Use Plan (WUP) committee. The total budget required for the current FY (08/09) is $50,000 and for next year (09/10) it is $200,000; these funding levels are considered to be reasonable in light of existing funding commitments. Funding requirements for future years are also shown, although it is recognized that the focus of the current exercise is only this year and next. The detailed level of analysis provided in Table 3 was considered to be important because (a) it recognizes existing limits on funding capabilities, thus keeping work on recruitment failure in touch with reality, and (b) it provides an initial sequencing mechanism, with clear links to annual budgets and to planning requirements that will be faced by both the RFHR working group and the Upper Columbia River White Sturgeon Recovery Team as part of its forthcoming review.

At the end of the meeting there was an active discussion of how these products might be used to assist members of the RFHR working group in their discussions with external partners and attempts to locate additional funds to conduct research studies and/or mitigation activities, including the benefits of possible US / Canada collaborations or sharing of information. These discussions focused on the Case Management Team in the United States (with Mike Paisley designated as the contact person), the Department of Fisheries and Oceans (with Dan Sneep designated as contact – later replaced by Tola Cooper) and the BC Hydro projects staff (with Gary Birch as contact).

Table 1: - Annual budget allowances for the highest-ranked studies (both LCR and MCR) and current funding status

			Year					Fiscal (CAN)			Total	Other		
Code		Title	08	09	10	11	12	08/09	09/10	Beyond	$ Req	Barriers	FUNDING STATUS	Notes
P1, M1		Historic Reconstruction: Finalize stock structure analysis												
	a	Microchemistry	X	X					20		20		PARTIAL (BCH MOE AFSAR)	some funding may be required
	b	Genetics	X	X							-		F	
	c	Aging re-evaluation	X	X				10	10		20		TBA	
	d	Tagged fish movements	X	X				20			20		TBA	Could get funding from AFSAR?
	e	Synthesis	X	X					20		20		TBA	
P2, M2		Historic Reconstruction: Impact timelines for each H												
	a	Historic Reconstruction: Impact timelines for each H	x	X				5	15		20		TBA	Should include an evaluation of turbidity H
P3, M3		Historic Reconstruction: Workplan workshop												
	a	Synthesis of P1, M1, P2, M2		X					50		50		TBA _AS?	
	b	Workshop		X					20		20		TBA	2-days facilitated, same group as involved in prep of a)
P19		Flow: Plan the opportunistic flow response												
	a	WUP requirement		X							-		WUP REQUIREMENT	
	b	Plan baseline monitoring program (inc analysis of recent historic rec. data)	X	X				15	35		50		TBA	Requires fleshing out
	c	Implement baseline monitoring program (environ. variables)		X	X	X	X		?	?	?		TBA	Adapt exisiting opp. Flow program to annual program
P15		Early feeding: Larval field sampling												
	a	Larval field sampling (BPA work D-ring + limited trawling)	X	X							-		UNDERWAY (BPA), BCH (WUP)	
	b	Experiment with 15-40do larvae capture techniques (re: fertilization)		X					150	100	250		TBA	
	c	Information synthesis (re: embayment fert + varial zone seeding)		X					-		?		INC in Feasibility work (Gary)	
P14, M14		Early feeding: Study successful habitat components												
		Early feeding: Study successful habitat components	X	X					-		-		IN KIND (WUPs)	
P16		Early feeding: Prey availability												
	a	Ongoing US work (add additional site by border)	X	X	X	X			-		-		UNDERWAY (BPA); FUNDING BEYOND TH	funded '08/09, additional site covered by TC
	b	New Canadian work (beyond current)			X?	X?			-		?	Depnds on Ben's work findings		contingent on US results
P17		Early feeding: Starvation lab studies	X			↓		-			-		WUP money transfer ($10k)	
P18		Early feeding: In-situ enclosure feeding study				P	?				?		TBA	future consideration?
P4		Modelling: Improve bathymetry of Little Dalles		X							-		USGS	
P5		Predators: Synthesize existing literature			?					?	?		TBA - BPA, WDFW OR STOI (IN KIND)	future consideration?
M20		Temperature: Biological and engineering investigations		X	X	X							PARTIAL - SOME WUP ONGOING - IN SITU WORK FROM BCH MICA5&6?	
	a	Larval development, growth and survival							-		-		WUP	funded
	b	Spawning component - contingent on future studies elsewhere								?	?			contingent
	c	In-situ variation in developmental rate							?		?			addressed in Mesocosm studies
	d	engineering: can you change T via ops / physical works							50		50		Mica5 or BCH internal	seek Mica5/6 funding? Or ESRF funding?
M4		Modelling: Habitat availability at reservoir interface												
	a	Modelling: Habitat availability at reservoir interface				X	X			?	?		TBA	contingent
P, M 8-12		Larval Hiding investigations												
		Show (prove?) that substrate condition / availability limits recruitment in SOME cases												
	a	Lit research (moved over to LCR Works feasibility review - may help make case for	X						See note				TBA	Funding included in line 'New a' below.
		Show (prove?) that substrate condition / availability may limit recruitment in THIS case												
	b	Use 08 Substrate mapping (video drops in US)	X		X			-	-		-		F	
	c	Sediment transport modelling - CAN			X					50	50		TBA WUP?	
	d	Sediment transport modelling - US			X					100	100		TBA	Need to extend model to US
	e	Geophysical facies mapping in CAN (enhanced mapping technique)	X		X					100	100	US is funded	TBA WUP?	Work in US is Ffnded
	f	Lab / field: representative flows and substrates; scouring, feeding, pred excl			X	X	X			500	500		TBA WUP?	Use existing lab facilities in US? $ could be lower.
		Design / implentation plan												
	g	engineering feasibility and design			X	X				150	150		TBA	
NEW		Other Feasibility Studies												
	a	LCR Works Feasibility Review		X					30		30		WUP FUNDING	Funding Includes P, M 8-12 Part a
	b	MCR Spawning / rearing channel feasibility study					X		50	50	100	Funding from BCH pr	TBA MICA5?	Candidate for DFO funding?

	08/09	09/10	Beyond	$ Req
Funding currently identified	50	250	-	300
Funding TBA	-	200	1,050	1,250
				1,550

CONCLUSIONS

The work of the Upper Columbia River White Sturgeon Recruitment Failure Hypothesis Review (RFHR) technical working group (TWG), conducted over the past 18 months, has resulted in substantial progress with respect to understanding the reasons for the apparent recruitment failure of Upper Columbia River WS. Equally important, substantial progress has been made in linking this understanding to development of a realistic work plan for resource managers that combines near-term research projects with high priority mitigation actions.

The use of a decision-focused framework provided an efficient approach to developing new analyses and to encouraging open discussion. Initial discussions focused on development of a clear problem statement and the identification of geographic areas of emphasis. A key contributor to the understanding of the hypotheses was the development of influence diagrams, depicting the hypotheses in a consistent and detailed manner. Linking the leading hypotheses to management actions required that research requirements, as a precursor to mitigation activities, be defined clearly. Both research and mitigation projects were then defined in light of cost and other leading constraints, with attention given to their preferred sequencing in light of the many interrelationships across proposed actions. Because of data gaps and the extensive uncertainty associated both with reasons for WS recruitment failure and the range of expected consequences associated with mitigation actions, extensive reliance was placed on judgements by technical experts on the TWG and on group discussions (e.g., the "science court" debates) designed to clarify reasons for agreements or disagreements among participants.

The prioritized listing of research and mitigation actions reflects, and is built on the foundation provided by, the improved understanding of hypotheses to explain WS recruitment failure. The main thrust of the work covered in this report has been on the development of this clear definition of hypotheses. However, new information is expected to continuously be coming on stream as the result of studies currently underway, both on the Columbia River and other similar rivers, as well as new studies that will be initiated in the near future. Thus the recruitment failure hypotheses should be reviewed on a regular basis to ensure that the latest information has been incorporated and to ensure that the opinions of TWG members, both supportive and dissenting, are given a careful and full hearing. As has been true over the past 18 months, areas of disagreement need to be quickly identified and explored in a collaborative and respectful manner, thereby aiding understanding and helping to avoid conflict.