

December 17, 2010

Reference: 4404/WP 2358

Rio Tinto Alcan
158 West Stewart Street
Vanderhoof, BC V0J 3A0

Attention: Justus Benckhuysen, Nechako Operations Coordinator

Re: Investigation of Nechako white sturgeon remote telemetry options

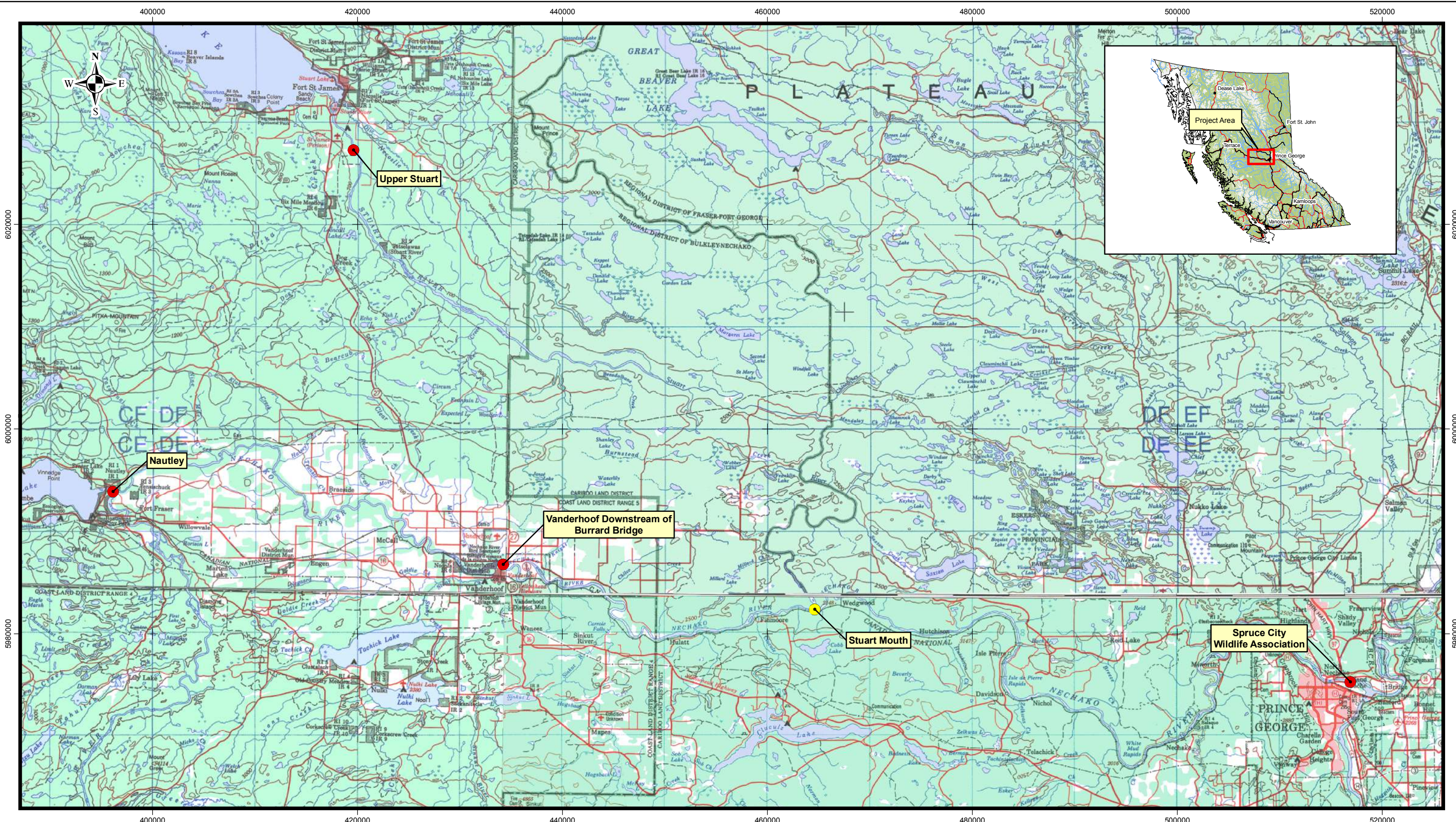
Mr. Benckhuysen,

Triton was retained to investigate the remote telemetry options available to the Nechako White Sturgeon Recovery Initiative (NWSRI). The following letter report outlines the various options available for this as well as the addition of acoustic tracking and remote access to the program. Various peer reviewed journal articles and provider websites were queried to assess the pros and cons of the various options. In addition, NWSRI staff were contacted to get an idea of future research goals of the program.

Introduction

The NWSRI program continuing goal is to develop a conservation fish culture program that will rebuild and maintain the white sturgeon population in the Nechako River until the cause of the decline can be determined and corrected (NWSRI 2010). Radio tagging has been used since 2002 to allow for the tracking of adult white sturgeon movements in the river. Telemetry data collected to date has helped to better understand the migration patterns and timing of movements of the population, as well as to identify critical habitats within the system.

The existing radio telemetry program includes five base stations that operate year round. The base stations are located at the mouth of Stuart River, upstream of the Stuart River mouth, the Nautley River, Vanderhoof (Nechako River) and on the Nechako River near the confluence with the Fraser River (Figure 1). Four of the stations use SRX400 radio receivers (Lotek Wireless) and one, located at the Stuart confluence, uses an SRX600 (Lotek Wireless). The SRX600 has all the same features as the SRX400 with the addition of a second processor to allow for multiple code recognition simultaneously, increased memory, and USB hook-up for faster downloads. Three of the stations are powered by 110 V service with a battery backup for power failures, while two of the stations, located at the confluences of the Stuart River and the Nautley River with the Nechako, are operated by batteries which are charged by solar panels.



Legend

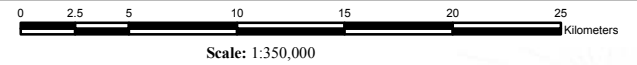
- SRX400 Telemetry Receiver (Cellular Option)
- SRX600 Telemetry Receiver (Satellite Option)

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NECHAKO RIVER TELEMTRY REVIEW PROJECT

**Figure 1.
Telemetry Station Locations**



Ideally the stations would be downloaded and checked every couple of weeks to ensure proper functioning; however in 2010 station downloads were as infrequent as every two months. The majority of the time the stations were still functioning as required and had available space in their memory banks but in one instance a tagged sturgeon remained in the vicinity of the Nautley basestation which resulted in the memory bank filling in less than three weeks resulting in loss of additional data.

There are currently 101 active radio tags in the system, with approximately 42 tags set to expire in the spring/summer of 2011. The tags most commonly used (MCFT-3L; Lotek Wireless) have a lifespan of approximately 4 years. Currently the majority of the active tags are the 1994 code-set which are limited in function compared to the newer 2000 code-set. The 2000 code-set tags allow for more 212 codes per frequency as opposed to 170 codes per frequency for the 1994 code-set and also have the ability to provide temperature, pressure and mortality data, which the 1994 code-set tags do not. Lotek is discontinuing the 1994 code-set tags in favour of the 2000 code-set and as a result future radio tag programs will have to make use of 2000 code-set tags. However, since the receivers cannot track both code-sets at the same time this may result in a period where there are both 1994 and 2000 code-set tags active in the river but not all can be tracked using the current set up. One option to track both code-sets during the transition period would be to double-up on the receivers at the stations having one scan the 1994 and the other the 2000 code-set (requiring twice as many receivers) or double-tag fish for a set time with both code-sets until the 1994 have all expired (requiring double the radio tags) (Personal Communication, Cory Williamson).

Future Goals

The future goal of the NWSRI is to increase the data gathered on migrating sturgeon throughout the program study area in order to better understand migration routes and timing and to further refine the knowledge on critical habitats in the system. The NWSRI plans to continue tagging both adult and juvenile white sturgeon for the duration of their research (Personal Communication, Cory Williamson) and will therefore require a flexible system that can be adapted to achieve different research goals. One option being investigated is the integration of acoustic capability to the existing radio tagging system to increase tag detection.

Acoustic vs. Radio Telemetry

In addition to radio telemetry, the other primary form of telemetry that can be used in the Nechako to achieve the research goals is acoustic telemetry. The following sections provide a comparison of the two options in terms of functionality and cost.

Radio

Radio telemetry consists of a transmitter (tag) which sends radio waves of a unique signal through the water column to the air, where they are picked up by a radio antenna (Science News 2010). Radio tags can be tracked using antennae mounted on aircraft, boats, points along shorelines and on foot (hand held). Radio telemetry allow for real time, short distance tracking which is optimal for determining duration, time and space of life stage events. As outlined by

Neely *et al.* (2009), radio telemetry is used to observe aspects of fish ecology not reliably revealed by standard sampling practices such as identifying critical spawning and rearing habitat, observing movement patterns and evaluating fish response to environmental variables.

The transmitter used in radio telemetry ranges in size and battery life depending on the size of the study subject. The general rule of thumb is that the tag should not exceed 2% of the body mass (Winter 1983). The transmitter's currently used in the NWSRI program are MCFT-3L which are 11 grams in water and have a battery life of approximately 1686 days. These tags have been discontinued and replaced by the MCFT2-3L, which have the same weight in water, have a battery of life of up to 3000 days (8 years) and have sensors which can monitor temperature and motion (mortality). Nanotags, which would be suitable for tagging juveniles, have also been developed with weights ranging from 0.25 g to 4.3 g and estimated tag life of 33 to 678 days. However, it is unknown whether the signal strength of the smaller tags would be strong enough to allow detection by the current base stations. Lastly, radio telemetry also allows for different types of data to be collected. For example, electromyogram (EMG) tags record muscle contractions which can be used to study energy expenditures while swimming or identify spawning events.

Radio transmitters operate on lower frequencies than acoustic tags and therefore do not experience as much distortion through water. In addition they can transmit more information per unit time. However, radio waves do not transmit well through saline, highly conductive or deep water (Koehn 1999). In addition, radio, mechanical and electrical sources can all interfere with the collection of radio telemetry data. This is particularly true in urban or populated areas with frequent vehicle or boat traffic such as Vanderhoof. Logging of error codes or the inability to resolve a code due to interference has occurred throughout the sturgeon radio telemetry programs. Further, incidences of fish passing radio basestations without being detected have also occurred each year suggesting that detection of submerged tags by land based radio basestations is less than 100%.

Acoustic

Acoustic telemetry involves the transmission in water of ultrasonic energy or sound signals at frequencies generally above our hearing range. It has been stated that acoustic tags provide better location accuracy and can even produce 3-D positioning by using triangulating signals from multiple microphones (Science News 2010). This can be useful when designing migratory studies in fish. If set up correctly, an acoustic telemetry system would allow you to know if a fish leaves or enter an area as no tagged fish should be able to pass an acoustic array without being detected. For example, an acoustic array documented the route of a sturgeon tagged in California and was received in the Fraser River, more than 1000 km away and over a 19 month period (Welch et al 2006). The individual was implanted with both a radio and acoustic tags, however it was the acoustic array that were fundamental to the long distance tracking and data storage capability. The adult sturgeon in the study was tagged with an acoustic transmitter with a weight of 16 grams and an expected battery life of approximately 16 days.

As in radio telemetry, acoustic transmitters range in size and battery life depending on the size of your study subject as well as the power output and delay between code transmissions. Acoustic

tags have a shorter battery life than radio tags of equivalent size because of the higher output required to push the sound waves through water (Personal Communication, Denise King). The L-AMT-2.1 acoustic tags marketed by Lotek are 0.43 grams and have an estimated battery life of 76 days. This can be extended or shortened depending on the burst rate programmed into the transmitter.

Acoustic telemetry is primarily a passive monitoring method requiring a series of fixed basestations. Active tracking is possible by boat utilizing an acoustic receiver and a separate hydrophone, however, aerial based telemetry surveys cannot be used with acoustic telemetry. A typical acoustic system involves setting up the receivers as “gates” or “curtains” across the river. Each receiver has a built in hydrophone and receiver spacing is generally determined based on range testing and historical data acquisition. Lotek has done various range testing in riverine systems and found that a range between 50 – 100 m provided the best results. According to Vemco, if 100 % detection is required typical spacing is between 100 – 1000 m. Vemco provides range test tags to conduct this research and recommend tests in a few different environmental conditions and at different times of year.

Table 1. Summary of Acoustic and Radio telemetry comparison.

Attribute	Acoustic	Radio	Relevance to Nechako
Transmitter battery life	Short (compared to radio tags of similar size/burst rate)	Long (~4-5 years)	Variable. Cost benefit for longer life however behaviour of interest may not occur every year (ex. spawning) so just because tag is active doesn't mean additional data will be collected.
Water depth	> 20 m	< 20 m	Low to Moderate. Majority of river habitat less than 20 m. Increased ability to track in lakes may be a benefit of acoustic tags.
High Conductivity	Good	Poor	Low. Not a high conductivity system generally.
Low Conductivity	Good	Good	Low. Not a low conductivity system generally.
Migration patterns	Good	Fair	Critical. Need confidence that all tags are being detected.
Salt Water	Good	Poor	Low. No marine component.
Turbid Water	Poor	Good	Low. System generally low turbidity.
Data Transmission (information/unit time)	Poor	Excellent	Moderate.
Mobile tracking options	Poor (limited to boat)	Good (boat, air, land)	Moderate to High. Aerial telemetry has been relied upon in the past to identify spawning events.

Service Providers Analysis

Utilizing online resources and relevant scientific journals, such as Transactions of the American Fisheries Society, a total of seven companies were found that provide biotelemetry tracking systems (Table 2). The majority of these providers appeared to specialize in terrestrial studies, were found overseas, or were no longer in service while a small number of companies were consistently used in fisheries studies in North America, including white sturgeon. Overall, it was found that two companies that provide telemetry products, Lotek Wireless and Vemco, were most commonly used in fish research. Lotek provides both radio and acoustic telemetry products while Vemco is focussed primarily on acoustic telemetry.

Table 2. Biotelemetry service providers

Company	Specialization	Country	Website
Lotek	Aquatic (radio/acoustic)	Canada	www.lotek.com
Vemco	Aquatic (radio/acoustic)	Canada	www.vemco.com
Telonics	Terrestrial	USA	www.telonics.com
Advanced Telemetry Systems	Terrestrial/Aquatic	USA	www.atstrack.com
Custom Telemetry	Fish Tags	USA	No website
Biotrack	Terrestrial (partnership with Lotek)	United Kingdom	www.biotrack.co.uk
Sonotronics	Aquatic (radio/acoustic)	USA	www.sonotronics.com

In addition to the white sturgeon monitoring on the Nechako River, four studies were found that used Lotek radio or acoustic telemetry for research on sturgeon. Two of these used only one method of tracking while the other researchers utilized an integrated system of both acoustic and radio to achieve their desired results. In one case the integrated approach utilized a hybrid transmitter that housed radio and acoustic components in one casing which were monitored using both radio and acoustic receiver (Parsley et al. 2007). The other study used two separate transmitters, with the sonic tag attached externally and the radio tag inserted internally (Geist et al. 2005). In both integrated programs the acoustic tags were used to provide coverage of areas where water depths would attenuate radio signals (Parsley et al. 2007).

Vemco acoustic telemetry products were utilized in two sturgeon studies and one study using an integrated approach of Vemco acoustic and ATS radio telemetry (Parsley et al. 2008 and Klimley et al. 2001). All studies involved marine or estuarine environments or tracking in depths greater than 20m. The integrated program was studying movements between marine and freshwater systems (Welch et al. 2006)

Another study on white sturgeon was reviewed and it was found to use the integrated radio-acoustic approach, using Sonotronics acoustic and ATS radio. The objective of this study was to determine water column habitat use and as the depth of the river exceeded 20 m it required them to use ultrasonic tags to locate fish (Paragamian and Duehr 2005).

Lotek Wireless Products

A summary of the products required for an acoustic program through Lotek can be found in Table 3. The acoustic receivers must be retrieved to be downloaded and their batteries changed. There is no option for remote access with Lotek acoustic products. In addition to radio and acoustic tags of varying sizes, Lotek also produces a series of dual mode tags that emit both radio and acoustic signals for applications or environments that may not be compatible with a single technology.

Table 3. Lotek radio and acoustic products.

Product	Model Number	Specifications	Cost	Acoustic/Radio
Transmitter	MCLFT2-3L	Battery life (~3000 days at a 5s burst rate)	\$252 each	Radio
Receiver	SRX400 upgrade	Includes upgrade and battery replacement plus 2 year additional warranty	\$3,540 per receiver	Radio
Receiver	SRX600		\$12,530	Radio
Transmitter	L-AMT-2.1	Battery life (~76 days at a 10s burst rate)	\$300 each	Acoustic
Transmitter	Dual Mode	Both radio and acoustic signals	Not available	Radio/Acoustic
Receiver (with hydrophone)	WHS4000	Battery life (100 days)	\$3,500	Acoustic

Vemco Products

A summary of the products required for an acoustic program through Vemco can be found in Table 4.

Table 4. Vemco acoustic products.

Product	Model Number	Specifications	Cost
Transmitter	V6, V7, V8	No sensor, battery life based on size (range from 155 – 200 days)	\$330-\$350
Sensor Transmitter	V9, V13, V16	Temp/depth, battery life based on size (starting at 400 days)	\$480-\$780
Receiver	VR2W	Standard receiver, battery life (15 months)	\$1,460
Receiver (with hydrophone)	VR2C	Cabled receiver allows integrating into existing infrastructure, battery life (15 months)	\$3,500
Receiver (with hydrophone and remote access modem)	VR4-Global	Provides remote and near real time communication, battery life (8 months)	\$8,500 (includes 1 year iridium data service)
Communication Package		Software and tools to download data from VR2W receivers	\$195

Remote access options

The ability to remotely access the telemetry base stations would allow for more frequent downloads, decrease the risk of data loss due to the memory bank being full or battery/power failure, and eliminate the need to access the sites monthly. However, in addition to the initial cost of set up, there will also be an ongoing (i.e. monthly) fee associated with the cell or satellite service provider that should be considered.

As identified in Table 4, Vemco designs receivers with remote access capabilities built right in. This should allow for more user-friendly operation and the benefit of one company being able to assist with and troubleshoot both the telemetry and remote access components of the unit.

Modifying the current radio program for remote access would involve either upgrading the current SRX400 receivers (4) or purchasing new SRX600 receivers since the SRX400 units as they are would not be reliable for remote access monitoring (Personal Communication, Henry Tam, Lotek Wireless Inc.). Some of the limitations mentioned included lose synchronization between the modem and receiver in the event of a power failure, requiring a site visit. Further loss of signal during a download would terminate the download requiring it start from the beginning. This could be costly depending on the amount of information being processed and type of system (satellite or cellular).

The addition of modems to each of the stations would be required to download the data. Four of the five existing base stations are estimated to be within cell range (Personal Communication, Cory Williamson), while one of the stations, located at the mouth of the Stuart River, will most likely need to be accessed via satellite. Lotek does not provide modems for remote access, and none of their receivers are designed with that application in mind. As a result, a 3rd party

company would be required to outfit the receivers for remote access. Because of the added complexity these units may be less user-friendly to operate and also more difficult to troubleshoot if problems arise (i.e. would need to talk with different depending on where the problem is). Incompatibilities between hardware and software that limit functionality are also more likely compared to a unit with put together by one manufacturer with remote access capabilities built into the design.

Three companies were researched that could provide remote monitoring via cellular or satellite systems with Lotek radio receivers. It was recognized by all companies that creating an interface for the SRX400's is possible but some upgrading may be required. The cost to upgrade and or purchase new radio receivers from Lotek is listed in Table 3.

Rom Communications Inc.

Rom Communications (ROM) provides Wireless Monitoring, Tracking, Remote Control, Data Retrieval and Asset Management Solutions that are managed by the customer through the Internet. They are a company that has been used previously for satellite and cellular monitoring systems by Triton and Rio Tinto Alcan. Without having the ability to closely examine the receivers, ROM is not able to confirm their ability to create the interface or provide a definite quote, but from examining the specs they are fairly confident they would be able to assist in the project.

Listed in Table 5 is the equipment necessary to provide remote access via cellular or satellite monitoring. Not included in the table is the monthly monitoring fee which is approximately \$55/month for satellite and \$35.00/month (based on usage) for cellular. As well as an installation service of \$85.00/hour plus travel.

Table 5. Rom Communication products.

Product Description	Model	Price
Iridium Cellular monitoring system	EV1C	\$1,299 each
Cell antenna	Ant21	\$75 each
Iridium Satellite monitoring system	EV1I	\$1,599 each
Iridium antenna	Ant27	\$165

J&S Instrumental

J&S Instrumental is an engineering company that specializes in the design and manufacturing of turnkey data acquisition systems. They have done numerous projects with Lotek and are familiar with their receivers. They are limited in providing only cellular monitoring through Verizon, however are open to providing satellite coverage as a “research” project. Table 6 outlines the cost necessary to upgrade the current equipment.

Table 6. J&S Instrumental products

Product Description	Price (USD)
Test receiver and create interface	\$1,700/unit (shipping not included)
Upgrade of firmware (if necessary)	\$100/unit
Monitoring	~ \$35/ month (based on usage)

FST Environmental

FST is a manufacturer of remote environmental monitoring systems, instrumentation and communication technology. They also have experience working with Lotek receivers and can provide both cellular and satellite coverage. They are known for rugged equipment that operates well in sub-zero temperatures. Unfortunately a quote from FST could not be acquired for inclusion in this report.

Remote Access Summary

Based on the information attained it is possible to access all base station sites by either cellular or satellite monitoring to remotely monitor the radio telemetry program. Three companies were found that could provide the equipment and technical support to achieve this goal. ROM has no previous experience working with Lotek receivers specifically but has provided remote monitoring to other projects in the area (ex. Summer Temperature Monitoring Program) and they can provide both cellular and satellite monitoring. The approximate cost for set-up by ROM for cellular monitoring is \$1,374/system plus a \$35/month monitoring fee. The approximate cost for satellite is \$1,764/system plus a \$55/month monitoring fee.

Both FST and J&S have experience with Lotek receivers, however, J&S cannot provide satellite monitoring which would exclude the most remote and difficult to access basestation. For cellular monitoring by J&S the cost would be \$1,800 USD/system plus a \$35/month monitoring fee.

Remote Access Cost Comparison:

All costs are estimates for comparison purposes and do not include applicable taxes, service charges, or other accessories such as cable, solar panels, batteries etc that may be required.

Radio Telemetry (Lotek)

- Upgrade of 4 SRX400 receivers to SRX600 = \$14,160
- Add 4 cellular modems (\$1,800 (J&S)/unit - \$1,374 (ROM)/unit) = \$5,496 - \$7,200
- Add 1 satellite modem (\$1,764/unit) = \$1,764
- Monitoring = \$35/month per unit (cell) - \$55/month (satellite) = \$2,340/year
- Total = \$23,760 - \$25,464

Acoustic Telemetry

The number of receivers required is unknown at this time and therefore only per unit costs are reported. Both the Vemco and Lotek receivers have built-in hydrophones but only the Vemco receiver includes remote access capabilities in the cost. The Lotek receiver would need a satellite or cellular modem to be attached at a cost similar to that listed for the radio telemetry options above.

- VR4-Global receiver (Vemco) = \$8,500/unit
- WHS4000 receiver (Lotek) = \$3,500/unit
- Monitoring (1 year included with VR4-Global) = \$1,200/year

Summary

The NWSRI plans to use telemetry in order to accurately measure rates and distances of sturgeon movements, gather information on migration and survival, and to obtain real time data for specific timing windows for sturgeon life history stages (i.e., spawning). There are many companies that offer acoustic telemetry with Vemco (Acoustic) and Lotek (Radio & Acoustic) being the most widely used for aquatic research in North America. Both systems have their pros and cons:

Radio Telemetry

Pros:

- Radio tags make more efficient use of power, providing a longer life for comparable size transmitter;
- Multiple tracking options such as air, boat and land;
- Transmit more information per unit time than acoustic;
- Tags provide many data options such as temperature, mortality and depth sensors;
- Electromyogram radio tags allow researchers to obtain quantitative estimates of the metabolic costs of activity;
- Transmitters are typically less expensive than acoustic transmitters;
- A substantial amount of radio telemetry equipment is currently in use by the NWSRI which can be upgraded if needed at a much lower cost than purchasing new equipment.

Cons:

- Radio tags do not transmit effectively in salt water or in fresh water where depths exceed 20 m;
- Radio, mechanical and electrical sources can all interfere with the collection of radio telemetry data;
- Signal transmission through water (particularly at depth) is limited;
- Cannot guarantee 100% detection;
- Upgrading of current SRX400 receivers is required for remote monitoring;
- Third party interface between modem and receiver is required for remote monitoring.

Acoustic Telemetry

Pros:

- Acoustic tags transmit effectively in salt water, fresh water and depths over 20 m;
- Signal can transmit great distances through water;
- Can provide 100% detection with the proper instalment of “gates”;
- VR4-Global (Vemco) receiver has built in remote access capabilities;
- Sensor transmitters can provide data such as temperature, depth or acceleration.

Cons:

- Have a shorter battery life than radio transmitters of comparable size;
- WHS4000 (Lotek) receiver does not have remote access capabilities;
- Multiple receivers required for 100% detection;
- Limited mobile tracking (boat only) and requires the use of a separate receiver and hydrophone;
- Noise from boat motors, turbulence and hydroelectric dams can disrupt or mask the signal;
- Tags and receivers more expensive then comparable radio telemetry option.

Remote Access

Being able to remotely access the telemetry stations should allow for more frequent downloading and lower the risk of missing out on new data should the memory of a receiver fill up. However, the setup and ongoing costs associated with remote access need to be considered and it is recommended that the need of each station be assessed individually. For example, the station at the Stuart confluence is the most remote and therefore the highest priority for remote access. However, the other stations are located in urban areas (Vanderhoof and Prince George) or are more easily accessed (Nautley and upper Stuart station) and it may be more economical to identify a local contractor to download and maintain those sites.

Recommendations

Based on the information collected on the current telemetry program of the NWSRI, the future research goals, and the telemetry options available, several recommendations can be made:

- Radio telemetry should still be relied upon for largescale and longterm tracking of sturgeon movements, identification of spawning, and location of critical habitat. There are many different companies which offer radio telemetry equipment; however, as the NWSRI has been implementing Lotek tags and equipment, switching to another company would not be practical as tags and receivers are specific to each company. Radio telemetry is the most economical option and, knowing its limitations, can still provide a substantial amount of data to the NWSRI.
- Adding remote monitoring capabilities to the current telemetry program would provide many advantages. It would allow for more frequent downloads, decrease the risk of data

loss due to the memory bank being full or battery/power failure, and eliminate the need to access the sites monthly. As the initial and ongoing costs can be significant to upgrade all stations, selecting a few of the more remote stations or those stations which continually have a large amount of data stored on them could be a practical alternative. Another option for those basestations in residential areas is to have the property owners assist in downloading the data or ensuring they are functioning correctly on the regular basis.

- Integrating an acoustic program into the current radio program would be beneficial for better understanding of movements and habitat use of the Nechako white sturgeon. Because of limited transmitter battery life and the need of purchasing multiple receivers to achieve 100% detection, acoustic telemetry would be most practical for specific studies such as migratory movements of juvenile sturgeon out of the current known area as opposed to longterm monitoring.

Should you have any questions on the information contained in this report or require any additional details on the products listed, please contact us.

Yours truly,

Triton Environmental Consultants Ltd.



Jen Bond
Biologist

References

- Geist, D.R., R.S. Brown, V. Cullinan, S.R. Brink, K. Lepla, P. Bates and J.A. Chandler. 2005. Movement, swimming speed, and oxygen consumption of juvenile white sturgeon in response to changing flow, water temperature, and light level in the Snake River, Idaho. *Transactions of the American Fisheries Society*. 134:803-816.
- Klimley, A.P., B.J. Boeuf, K.M. Cantara, J.E. Richert, S.F. Davis and S.V. Sommerahn. 2001. Radio-acoustic positioning as a tool for studying site-specific behaviour of the white shark and other large marine species. *Marine Biology*. 138:429-446.
- Koehn, J.D. 1999. Why use radio tags to study freshwater fish? Australian Society for Fish Biology. Available at <http://www.asfb.org.au>. (accessed November 30, 2010).
- Nechako White Sturgeon Recovery Initiative. 2010. Available <http://www.nechakowhitesturgeon.org/sturgeon> (accessed December 2, 2010)
- Neely, B.C., K.D. Steffensen and M.A. Pegg. 2009. A comparison of gastrically and surgically implanted telemetry transmitters in shovelnose sturgeon. *Fisheries Management and Ecology*. 16:323-328.
- Paragamian, V.L. and J.P. Duehr. 2005. Variations in vertical location of Kootenai River white sturgeon during the prespawn and spawning periods. *Transactions of the American Fisheries Society*. 134:261-266.
- Parsley, M.J., C.D. Wright, B.K. van der Leeuw, E.E. Kofoot, C.A. Peery and M.L. Moser. 2007. White Sturgeon (*Acipenser transmontanus*) passage at the Dalles Dam, Columbia River, USA. *J. Appl. Ichthyol.* 23:627-635.
- Science News. 2010. Tracking fish is more than just a game of tag. Available http://science.calwater.ca.gov/publications/sci_news_0610_tags.html. (accessed December 6, 2010)
- Welch, D.W, S. Turo and S.D. Batten. 2006. Large-scale Marine and Freshwater Movements of White Sturgeon. *Transactions of the American Fisheries Society*. 135:386-389.
- Winter J.D. 1983. Underwater biotelemetry. In L.A. Nielsen & D.L. Johnson (eds) *Fisheries Techniques*. Bethesda, MD: American Fisheries Society, pp. 371 – 395.

Personal Communication

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