TRIP REPORT

PIRACEMA CANAL TECHNICAL VISIT

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Preliminary Assessment of Fish Passage through the Itaipu Canal using Radio-telemetry Techniques

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For

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Background

The World Fisheries Trust, together with their Brazilian and Canadian partners, is implementing a project on enhancing "Sustainable Fisheries and Conservation" in Brazil, particularly in the São Francisco River. Key elements of this project are to make positive changes in fisheries management practices, to enhance social support programs for fishing families in riverine communities, and to transfer technologies for sustainable management and conservation.

Radiotelemetry is a technology that is particularly useful for assessing behaviour of fish during migrations, as in assessing the effectiveness of fish passes. It is also a technology that is quite new to Brazil, and could lend itself well to participatory research with local fishermen. The Itaipu Canal is an ideal laboratory for studying the behaviour of fish in fish passes, as well as for training in radio telemetry (Figure 1). A preliminary study of fish behaviour within the Itaipu Canal was initiated in January 2004 to test the tagging procedure, tags and tracking equipment; and provide some on-site training for Brazilian partners.

Initial study plans identified several objectives, some of which could only be partially achieved given the study timing and duration. These objectives were to:

Evaluate effectiveness of fish passage (ability to swim upstream, characteristics of upstream behaviour) at key points along the fish canal using representative species of the fauna important to fisheries or the hydro industry. If possible, also test environmental cues leading to upstream migration (e.g., rainfall, water flow, daylight, temperature). This information should lead to optimized protocols for operating the Itaipu fish pass, but also provide information for the design of fish pass and fish avoidance protocols at hydroelectric dams throughout the country.

Contribute to setting up longer-term monitoring plans, including:

- study design;
- equipment set-up and training of personnel; and
- recommended operating conditions of the fish canal

Networking of groups working on fish telemetry and associated with the Peixes, Pessoas e Agua project: Itaipu, NUPELIA, UFMG, fishermen; and

Training of Brazilian partners, including stimulating participatory research (especially between fishermen and researchers)

Given the high cost of renting receivers, the initial plan was to limit the use of rental equipment to 1 month and then replace the receivers with similar receivers purchased for the full-scale Itaipu Canal fish passage project. However, delays in the deliver of the Itaipu equipment resulted in a reduction in the scope of the study.

Figure 1. Portion of the Itaipu Canal above the mid-canal lake

Methods

Study Design

Alternative study designs were discussed and evaluated against project goals during the initial planning phase in Canada. The major limiting factor was the number of receivers available and the anticipated duration of the study. The short duration of the study required that the fish be rapidly caught, tagged and release in close proximity to the one receiver. The other two available receivers were deployed upstream and downstream from the release site. The stream sections between the receivers should present different gradients, and therefore, different migratory challenges. However, the initial challenges should not be too extreme since we would need some indication of upstream movement to confirm the basic migratory potential for the study species. The optimum location for our initial tests appeared to the in the upper portion of the canal above the lake. This section included both low and moderate gradient reaches and contained a small pond near the middle of the section that could afford the tagged fish an opportunity to acclimate to the canal after release prior to moving upstream or downstream.

The initial study plan was to capture and tag up to 30 fish of 4-5 different species as soon as possible and deploy the fixed-station receivers at three locations during the 2-3 day period when the tagged fish were recuperating from the tagging procedures. The proposed locations for the three receivers were: 1) lower end of the upper canal near the lake; 2) adjacent to the pond where all the fish would be released in the upper canal; and 3) the upstream exit for the canal. The receivers were to be downloaded every day during the first week to assess the fixed-station setups, identify any problems, maximize training opportunities and provide immediate information on the movements of the tagged fish.

The first task, once at the study site, was to assess the logistics of fish capture and holding, examine the canal, and review the alternative study designs with our Brazilian partners. The initial study plan describe above was approved at a meeting on 14 January 2004.

Fish Capture

Fishing operations were initiated on 16 January 2004 under the direction of Norberto, a professional fisherman from the São Francisco River. Two cast nets with different mesh size were used at several locations along the Itaipu Canal. Initial fishing efforts were concentrated at the proposed release site with the hope of tagging some fish that were in the process of migrating upstream (Figure 2). A non-migratory species common in the canal, the peacock bass or "tucunaré" (Cichla ocellarus), was captured in this pool and tagged, but no migratory species were captured at this location. Fishing efforts were thus moved to the more "natural" portion of the canal (the Bela Vista River) immediately below the first concrete fish ladder. A total of 5 different migratory species were captured at sites along the Bela Vista River. These species included: surubim catfish (Pseudoplatystoma fasciatum), the armoured catfish "armado" (Pterodorus granulosus), curimbata (Prochilodus lineatus), piau (Leporinus obtusidens), and piava (Schizodon borelli).

Figure 2. Norberto fishing with a cast net in the upper Itaipu Canal pond adjacent to the release site

The tagged species represent a number of fish types in terms of commercial/cultural importance and migratory capacity and behaviour:

The surubim catfish (3-15 kg, 80-152 cm) is a carnivore of great commercial interest in most of non-Amazonian Brazil that undergoes extensive reproductive migrations - though these are poorly characterized. The species is the focus of radiotelemetry research in the São Francisco River, where it is also the subject of stock re-building efforts and aquaculture. The individuals captured were all males, but largely spawned out. They were captured in the upper Bela Vista River.

The armado is also a migratory catfish, but is not as strong a swimmer as surubim and migrates shorter distances. It is native to the lower Paraná River basin, but is one of the species that was introduced to the upper basin by the construction of the Itaipu dam, where its invasion has been explosive. It is of relatively low commercial value, but currently is the core of the artesanal fishery in the Itaipu reservoir. The armado has a later reproductive period than the other migratory species considered in this study, and the individuals captured did not yet have fully formed gonads. It was also only found in the lower Bela Vista River. Traditional lore warns pregnant women not to eat this species, possibly because of the fat content. There were no pregnant women in our team, but neither did we eat any of these fish, so we cannot comment on this aspect.

The curimbata is a migratory detritivore characid fish (3-15 kg, 30-80 cm) that has been estimated to represent up to 80% of the fish biomass in some South American rivers (including the Paraná). It is thus an essential part of the riverine ecosystem, and the core of traditional fisheries. It is a strong swimmer, and has been shown to migrate up to 1500 km for reproductive purposes. All of the individuals tagged were captured at the base of the artificial parts of the fish passage. All were largely spawned out, and sex could not be determined.

The piau is a smaller omnivorous characid that is less numerous, but well appreciated - especially by sports fishermen. It is of secondary importance to commercial fisheries, because of its lower abundance, though it has been artificially stocked into the Itaipu reservoir and is an aquaculture candidate. It is migratory and also quite a strong swimmer, but little is known of its biology. The fish was relatively common in the mid-portion of the Bela Vista River, with individuals that were mostly spawned out (including those that were tagged).

The piava is a small (30 cm) herbivorous characid. It can be quite numerous as dense migratory schools, but for fisheries it is generally only important for subsistence purposes and local consumption, and little is known of its biology. It is also a strong swimmer.

Two migratory species that are particularly important to fisheries, dourado (Salminus brasiliensis) and pacu (Piaractus mesopotamicus) are targets of the long-term monitoring plans for the canal, but were not seen during this study. The absence of these species and the gonadal condition of the fish that were captured prompted the local biologists to conclude that we were relatively late in the migration season and there would be little value in tagging more than 2-3 fish of each of the species caught. Consequently, our capture and tagging targets were reduced from 30 to 10-15 fish.

Tagging

Two types of radio tags were used in this study and two methods of tag implanting. The Lotek MCFT-3BM was implanted in the smaller fish (30-50 cm) and larger MCFT-3A tags were implanted in fish greater than 50 cm. Tags were put in the fish using either esophageal implants (no surgery) or surgical abdominal implants. The esophageal implant approach is the quickest and least invasive method for inserting radio tags into a fish. No anesthetic is required as the tag is simply inserted through the fish's mouth and into its stomach. However, the shape of the fish's mouth, its stomach size, and the tag size may make this approach inappropriate or impossible, and the tag may be regurgitated. In contrast, surgical abdominal implants require considerably more time to apply and anesthetic to immobilize the fish, but eliminate concerns of tag rejection. For surgery, fish were either anesthetized with clove oil or immobilized with an electrical current.

Surgery with clove oil anesthesia consisted of initial anesthesia in a bath containing 1 ml of clove oil per 4 liters of water) until the fish became unresponsive to touch (2-3 minutes). The fish were then transferred to a moist sponge holder in a shallow basin for surgery, with the gills bathed by a continual gravity-fed mixture of the clove oil solution and fresh water from a small tube (Figure 3). This procedure is similar to that routinely used on the Columbia River to insert radio tags into juvenile salmonids (English et al. 2000).

Figure 3. Lisiane Hahn and Domingo Fernandez completing the application of an internal radio-tag and external tag to surubim catfish (*P. fasciatum*)

Electrical immobilization was carried out in a larger basin with the fish in a cloth sling. Electrical current (AC) was applied through sheet metal plate electrodes at either end of the bath, with slowly increasing amperage until the fish became immobilized and unresponsive to touch. This current was maintained throughout surgery. This method is used by the UFMG research team.

The surgical procedures were similar for both anesthetic/immobilization approaches. Where appropriate, scales were removed prior to making a 2 cm incision in the abdominal wall. A catheter was inserted into the incision and pushed out through the abdominal wall 3-5 cm posterior to the incision. The radio-tag antenna was then inserted through the catheter. The catheter was removed prior to inserting the radio-tag into the body cavity. The incision was closed using 3-4 stitches. The incision was sealed using Vetbond (a tissue adhesive manufactured by 3M).

Once the radio-tag had been successfully implanted, an external hydrostatic tag was applied and each fish was weighed and measured for fork and total lengths.

Fish holding and transport

All tagging was conducted in a fish laboratory located adjacent to the top of the lower fish ladder. This building contains 4 large tanks that were used to hold the fish both before and after tagging. Pumps provide each tank with an ample supply of freshwater from the canal. The water levels in each tank were maintained at 1-1.5 m during the holding periods and reduced to 0.3 m when fish were being removed for tagging or release. All fish were held in these tanks for at least one night prior to tagging and for 1-3 days between tagging and release. A fish transport tank on a trailer and with oxygen was used to transport the fish from the capture sites to the laboratory and from the laboratory to the release site (Figure 4 and 5).

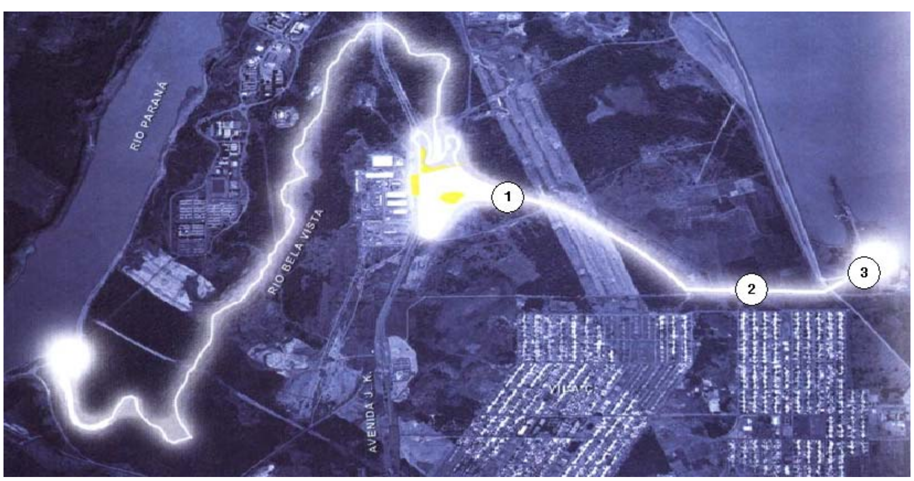
Figure 4. Transport tank and release process at the upper canal pond

Figure 5. Armoured catfish (Pterodorus granulosus) just prior to release

Tracking

Post-release tracking was conducted using both fixed-station and mobile tracking techniques. Fixed-stations were setup at the three proposed sites: Site 1- lower end of the upper canal near the lake; Site 2- adjacent to the pond where all the fish would be released in the upper canal; and Site 3 - the upstream exit of the canal (Figure 6). Each fixed-station included a Lotek SRX400 receiver, two 3-element yagi antennas (one pointed upstream and the other pointing downstream); one antenna switcher; a 12 volt battery to power the receiver, and coax cable to connect the antennas to the switcher and switcher to the receiver.

Figure 6. Locations of fixed-station receivers deployed for the January 2004 pilot study.



At two of the stations, the receivers, switchers and batteries were secured inside a metal box with a lock and both antennas were mounted on a single 3 m wooden pole adjacent to the box (Figure 7). At the site near the upstream exit of the canal, the receiver, switcher and battery was stored inside a small building adjacent to a flow control structure and the antennas were mounted on the railings at each end of the flow control structure. The heights of the antennas above the water were: 4 m at Site 1, 15 m at Site 2 and 4 m at Site 3.

Figure 7. Radio telemetry crew setting up and testing the fixed-station site adjacent to the upper Itaipu Canal pond where all the radio-tagged fish were released in January 2004

Mobile tracking was conducted using a SRX400 receiver and a single 3-element yagi antenna. Most of the mobile tracking along the canal between the receiver sites was conducted on foot while a vehicle was used for mobile tracking along the shoreline of the lake.

Data Management and Analysis

Fish detection data were downloaded from the Lotek receivers a minimum of two times each week, and more often if receiver memory began to fill up prior to the scheduled downloads. All fixed-stations were monitored daily for the first week to check the receiver memory status, accuracy of the internal clock and battery voltage.

Data logged by the Lotek receivers were downloaded to a laptop computer as hex-encoded files, which were converted to standard ASCII format using software developed by LGL Limited (SRXW303.EXE). This software assessed several diagnostics, including the number of invalid records. If the number of invalid records was large, the receiver was downloaded a second time.

The SRXW303 program also displayed the distribution of antenna noise by power level, so that problems with specific antennas could be isolated, and the appropriate troubleshooting measures could be taken. During the period when LGL personnel were in the field, all data files were transferred onto an LGL computer for data processing. At the end of the first week, all data files were transferred to computers maintained by two of the Brazilian partners (Lisiane Hahn and Angelo Agostinho, Maringa State University). In the subsequent weeks, the receiver data was sent via email after each download to Lisiane Hahn (lisi@wnet.com.br) and LGL staff (Karl English <kenglish@lgl.com>, Bill Koski <koski@lgl.com>, and Cezary Sliniwski <cezary@lgl.com>) along with notes of any irregularities.

Once received, all fixed-station data was organized into structured databases and analyzed using Telemetry Manager Version 2.8, specialized software developed by LGL Limited. The Telemetry Manager software facilitates the importing of the raw data files downloaded from the LOTEK SRX receivers and organization of these data into a database containing records for each logged data transmission from the tagged fish. The software then processes the data to remove records that did not meet the criteria specified for valid data records. Examples of invalid data included background noise, records with a signal strength that is below a set threshold, single records for a given frequency-code-location combination, and records that were recorded before the official release time and date. Telemetry Manager then compresses the data into an operational database that contains the time of arrival and departure from each zone, number of records, and maximum power for each series of detections for each radio-tagged fish. These data are immediately available for display on maps of the study area that show the location of each zone. These maps can be used to examine the numbers of fish of each species seen in each zone, the first and last seen locations for all fish, or the sequence of detections for individual fish.

Technology Transfer

All steps of the field work, including planning, were carried out together with the Brazilian partners. The technologies transferred during this project included: study design, tagging procedures, the setup and maintenance of radio-telemetry equipment, data management systems and data processing software. Field demonstrations and on-site training were the primary communication method. Copies of LGL's custom data processing software were provided to the Brazilian partners at no charge and installed on several computers during the field program. Initially, training focused on data downloading procedures and field assessments of receiver operation and troubleshooting. Data download protocols were developed with the Brazilian partners and documented in both English and Portugese (see Appendix A).

Results

Tagging and release

A total of 14 fish of 6 different species were radio-tagged and released into the upper portion of the Itaipu Canal adjacent to our Site 2 fixed-station receiver. Details on length and weight of each radio-tagged fish and the tagging methods used are provided in Table 1. Information on the tagging and release times are provided in Table 2. Only 2 of the fish were tagged using the esophageal implant approach due to concerns that this could affect their feeding behavior and the tags might be regurgitated. The tagging interval was shortest for these fish because no anesthetic was used. Most of the surgery was conducted with clove oil anesthesia, with the procedure usually taking 20-28 minutes to complete. These tagging periods were considerably longer than the 3-4 minutes required for surgical implants on juvenile salmonids (English et. al., 2000). Some of the additional time was due to training, but the majority was due to the fish having thicker and tougher skins, and longer intervals were required to anesthetize these large fish.

Table 1. Length, weight and tagging method for each radio-tagged fish

Fish No.	Channel	Code	Species	Weight (g)	Total Length (cm)	Standard Length (cm)	Tagger	Tagging Method	Anesthetic
1	5	5	curimbata	3400	55.0	47.0	Karl	esophageal	none
2	9	15	piau	550	35.0	28.0	Karl	esophageal	none
3	5	4	piau	550	36.0	29.2	Karl	surgery	cloveoil
4	17	104	curimbata	3350	58.0	49.2	Karl	surgery	cloveoil
5	9	10	piava	850	42.5	37.0	Luiz	surgery	cloveoil
6	5	3	piava	550	39.0	34.0	Luiz	surgery	electric
7	3	50	armado	2050	54.0	48.0	Lisiane	surgery	cloveoil
8	17	39	armado	1800	56.0	40.0	Luiz	surgery	electric
9	9	14	surubim	2950	77.0	66.5	Karl	surgery	cloveoil
10	9	7	surubim	2850	75.0	68.0	Karl	surgery	cloveoil
11	3	100	tucunaré		49.0	42.0	Norberto	surgery	cloveoil
12	5	2	tucunaré		41.0	35.5	Brian	surgery	cloveoil
13	3	25	surubim		86.0	77.0	Lisiane	surgery	cloveoil
14	24	25	armado		50.0	42.0	Lisiane	surgery	cloveoil

Table 2. Tagging date, tagging interval and release date for each radio-tagged fish

Fish No.	Channel	Code	Species	Tagging Date	Start Time (hh/mm)	End Time (hh/mm)	Tagging Interval (min)	Release Date	Release Time (hh/mm/ss)
1	5	5	curimbata	15-Jan-04	08:30	08:35	5	18-Jan-04	12:47:50
2	9	15	piau	15-Jan-04	08:45	08:50	5	18-Jan-04	12:00:40
3	5	4	piau	16-Jan-04	14:10	14:31	21	18-Jan-04	12:13:16
4	17	104	curimbata	16-Jan-04	14:41	15:04	23	18-Jan-04	11:58:11
5	9	10	piava	16-Jan-04	15:26	15:39	23	18-Jan-04	12:02:30
6	5	3	piava	17-Jan-04	12:25	12:53	28	18-Jan-04	12:04:10
7	3	50	armado	17-Jan-04	13:14	13:39	25	18-Jan-04	12:12:19
8	17	39	armado	17-Jan-04	13:49	14:28	39	18-Jan-04	12:09:40
9	9	14	surubim	17-Jan-04	15:06	15:26	20	18-Jan-04	14:43:50
10	9	7	surubim	17-Jan-04	15:32	15:52	20	18-Jan-04	12:47:10
11	3	100	tucunaré	19-Jan-04	17:25	17:49	24	20-Jan-04	18:00:00
12	5	2	tucunaré	21-Jan-04	10:20	10:40	20	21-Jan-04	12:27:00
13	3	25	surubim	21-Jan-04	11:20	11:40	20	21-Jan-04	12:25:00
14	24	25	armado	22-Jan-04	15:30	15:45	15	22-Jan-04	16:21:00

Tracking

Of the six species tagged, 2 species (surubim and curimbata) demonstrated that they could migrate upstream through the upper portions of the canal (Table 3). Two of the three surubim (Fish 9 released on 18 Jan. and Fish 13 released on 21 January) passed the upstream station (Site 3) and exited the canal on 28 January at 6:52 and 6:57 AM, respectively. Their last detections on the upstream antenna at Station 2 were 05:43 and 04:03 for fish 9 and 13, respectively. After residing in the mid-canal pool for 10 and 7 days, respectively, they migrated up stream and out of the canal at essentially the same time. The other surubim (Fish 10) migrated downstream 10 h after release and was last tracked on the downstream antenna of Site 1 just prior to the demobilization of this site on 18 February. This fish was detected in different parts of the lake as well as on the upstream antenna of Site 1 on several occasions during the one month study period.

The two curimbata detected as they exited the upper end of the canal were released on the same day (18 Jan.), however, their exit timing was 22 days apart. The first curimbata that exited the canal was tagged using the surgical method. The second curimbata to exit was tagged using the esophageal implant method. The travel time from Site 2 to Site 3 was similar for both fish, so the entire difference in exit date was due to the longer residence time at the release site (24 d) for the second fish. Initially, we had thought that this fish might have regurgitated its tag at the release site, however, its detection at the upstream site provided clear evidence that the fish retained its tag and the esophageal method may be viable tagging option for this species.

Table 3. Release dates and tracking results for each radio-tagged fish

Fish		Release	First Detection		Residence [d]		
No.	Species	Date	Site 1	Site 3	Site 1	Site 2	Site 3
1	curimbata	18-Jan		20-Jan		2.258	0.013
2	piau	18-Jan				25.850	
3	piau	18-Jan				25.840	
4	curimbata	18-Jan		11-Feb		24.236	0.014
5	piava	18-Jan				25.850	
6	piava	18-Jan	19-Jan		0.355	0.838	
7	armado	18-Jan	21-Jan		6.548	2.657	
8	armado	18-Jan	19-Jan		29.498	0.580	
9	surubim	18-Jan		28-Jan		9.653	0.019
10	surubim	18-Jan	19-Jan		30.036	0.686	
11	tucunaré	20-Jan	22-Jan		0.004	1.974	
12	tucunaré	21-Jan	24-Jan		5.846	3.316	
13	surubim	21-Jan		28-Jan		6.737	0.035
14	armado	22-Jan	23-Jan		0.002	0.406	

Of the other four species tagged, 3 species (armado Pterodorus, piava Schizodon and tucunaré Cichla) demonstrated clear downstream movements. The three tagged armado migrated downstream at different rates (ranging from 10 to 64 h to move from Site 2 to Site 1). One of the tagged armado was detected at Site 1 within 10 h of the release time but not detected again throughout the study. It is likely that this fish continued to move downstream. The other two fish were detected at Site 1 for time periods ranging from 8.6 d to 29 d. The one piava that moved downstream traveled faster than any other fish, taking only 1 h to move from Site 2 to Site 1. Both of the tagged tucunaré moved downstream but at different rates after different residence periods at the release site. None of these fish were detected during the last 3 weeks of the monitoring period, so it is likely that these fish continued their movement downstream.

Piau Leporinus was the only species tagged that did not leave the release site. These two fish were the smallest of the tagged fish (35-36 cm in total length and only 550 g). Both fish were continuously detected at the release site for the entire period that Site 2 was operational (15 Jan. – 13 Feb.). Problems with the internal battery on the Site 2 receiver resulted in no data being collected by this receiver from 13 Feb. to the end of the study period (18 Feb. 2004).

Technology Transfer

This small pilot study clearly demonstrated that radiotelemetry techniques could be used to track both upstream and downstream movement of several different fish species in the Itaipu Canal. Local fisheries technicians and scientists were trained in tagging procedures that were appropriate for all tagged species. Fixed-station receivers were successfully deployed, downloaded and operated by our Brazilian partners both during our joint work in the field and after our departure. All data transferred via the internet was received and processed such that the results could be provided back to our Brazilian partners within a few hours of receiving the latest download files. One of our Brazilian partners attempted to load and process the data using the software provided, but it appears that further training is required for this process. Most of the difficulties she encountered appear to be due to a lack of understanding of the program requirements (e.g. directory structure) and data formats required for successful import of the receiver data. We believe that current deficiencies in understanding can be readily resolved through the additional training planned for later this year.

Corporate and Public Awareness

Local news teams, including both newspaper and television, accompanied the work on three occasions, leading to at least two newspaper articles. In addition, the results of the study, the purpose of the work, the value of the technology and of participatory research were presented in a meeting with Itaipu's vice-president and management team for the environment and the "Fome Zero" program.

In-kind Contributions

The costs to World Fisheries Trust, CIDA and the Brazilian partners were a fraction of the total costs for conducting this study. Six of the 14 radio-tags used were provided to the study by Fisheries and Oceans, Canada at no cost (a contribution of $1800). All of the Lotek SRX400 receivers used for the fixed-stations were rented to the project by Nisga'a Lisims Government at 40% of the Lotek's standard monthly rental rate (a contribution of $4620). LGL Limited provided 8 yagi antennas at 30% of the purchase cost and 3 antenna switchers at no charge (a contribution of $2192). LGL personnel contributed more than 60 hours of uncharged project planning time prior to the field program (a contribution of $8600) and 4 person days of additional field training and consultation time to one of the Brazilian partners in January 2004 after the initial field work at the Itaipu project had been completed (a contribution of $4120). Use of the Telemetry Manager software is being provided free of charge – a value of about $4,000. The total of the above in-kind contributions to this project and related training activities was $25,328 (130 % of the costs billed by LGL Limited).

Benefits to Canadian Companies

The work conducted in January 2004 and related business development activities resulted in a contract being given to LGL Limited by Universidade Federal de Santa Catarina (UFSC) in Florianopolis, Brazil to assist them in the evaluation and testing of radio-telemetry equipment for an ongoing study on the Uruguai River. The work was successfully completed in early March 2004 when Bill Koski, one of LGL's radio-telemetry specialists, traveled to Brazil to work with UFSC personnel on the Uruguai River.

Our training and equipment evaluation efforts at the Itaipu Dam and on the Uruguai River have provided an opportunity to showcase the capabilities and advantages of radio-telemetry equipment available from Canadian manufacturing firms. A previous training workshop in Minas

Gerais in 1999, put on by WFT, UFMG, LGL and CEMIG in a previous CIDA project, led to significant purchases of Canadian-built equipment by Brazilian projects. In fact, the Lotek radio-telemetry equipment recently purchased by Itaipu for research in their canal was selected by Brazilian scientists who participated in our earlier training efforts - where Lotek receivers were compared with receivers manufactured in other countries. There are a number of other radio-telemetry products produced by other Canadian companies (e.g., antennas, power inserters, signal amplifiers, and smaller receivers) that will be required for the studies at the Itaipu Dam and other locations in Brazil. We anticipate that the success of this pilot study will result in further involvement of LGL personnel in the Itaipu Canal assessments and this involvement will lead to additional purchases of radio-telemetry equipment from Canadian suppliers.

Recommendations

We recommend that work proposed for next migration period (Sep. 04 – Mar. 05) should address the following three questions and key sections of the fish canal:

1) What flow conditions are best for upstream movement of fish through the baffled canal portions of the fish pass, including the steepest portion at the top of the canal?

This question is addressed best with the top section of the canal. This part is relatively short with differential inclines, has ponds at both ends for receiving fish, secure sites for fixed-station receivers below the area of interest so that fish that head downstream are not lost, and close enough to the control gates that flow could be readily and quickly adjusted without affecting the rest of the canal too much.

Do fish go beyond the large lake, or do they tend to just stop and reside?

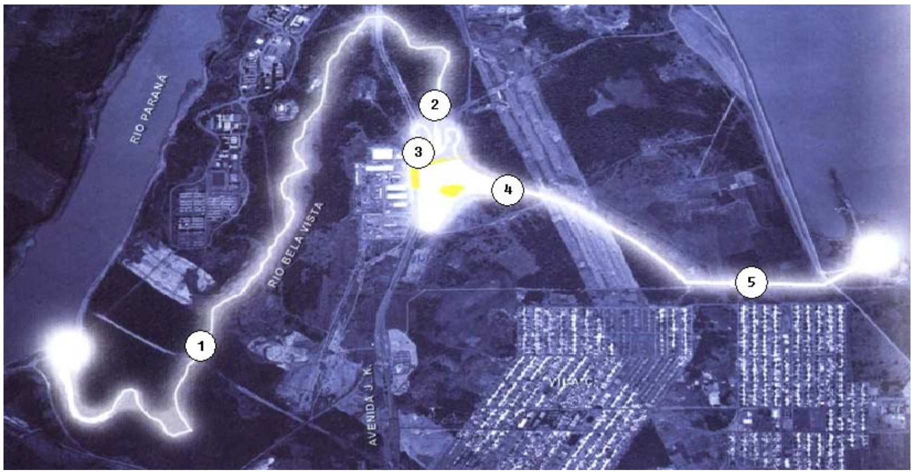
This question is likely to require longer term monitoring. This assessment would require the deployment of receivers where the canal flows into and out of the lake. Additional mobile tracking should be done at regular intervals to identify holding areas within the lake.

Can fish get up the two concrete ladders below the lake?

These ladders present the most significant challenges to the upstream migration of fish through the Itaipu Canal. A series of detectors distributed throughout each ladder will be needed to identify obstacles that block or delay the migration of the different species being studied. Experimentation with flows may reveal the optimal flow for passage through these sections that is the least selective. Monitoring in the two concrete fish ladders will require the use of underwater antenna and in line amplifiers to transmit the signals to a single receiver monitoring each ladder. This type of set-up requires an individual with experience in the deployment of the equipment and provides an excellent opportunity for additional training in techniques that are broadly applicable to assessments of these types of fish passage facilities. LGL personnel have extensive experience with these kinds of set-ups, and would be available to assist with this and other component of the study proposed for the next migratory period.

The above three question and more could be addressed with the deployment of the 5 receivers recently purchased for the Itiapu fish canal study at or near the locations showing in Figure 8. The receiver in the lower Bela Vista River would ensure that any fish released below the fish ladders could be tracked if they move downstream after release. Two receivers would be required to monitor multiple underwater antenna deployed in each of the two concrete fish ladders. Up to 7 antennas could be monitored by a single receiver. Given the flow patterns observed at the bottom of each ladder we recommend that one antenna be place just below the entrance to the concrete ladder, a second antenna be located within the first 30 m of the ladder, a third antenna be located half way up the ladder and a forth antenna be placed at the upper end of the ladder. The remaining two receivers would be deployed above the lake; one close to the Site 1 location used in the pilot study, and the second near the pilot study Site 2 location. The furthest upstream antenna should be deployed at the top end of the step section just above the pond where all the pilot study fish were released. Once the fish have passed upstream of that point there is nothing that should delay them from completing their migration through the remainder of the canal.

Figure 8. Proposed locations for five fixed-station receivers



With regard to the future training needs of the Brazilian partners, we strongly encourage some of the lead scientists to invest some time in understanding the data processing procedures that have been developed over the past 12 years of intensive research using radio-telemetry techniques in North America. One of the easiest and least costly ways to receive this training is to spend 2-3 weeks working with LGL Limited data processing staff in Sidney BC. Such a training opportunity is currently being planned for Lisiane Hahn to begin in May or June of 2004. Training related to the construction, deployment and maintenance of different types of underwater antenna would be highly valuable to individuals involved with the proposed radio-telemetry work on the Itaipu canal. Additional training on mobile tracking procedure using boats and aircraft would also be useful to address questions related to the fate and upstream destination of those fish that successfully pass through the Itaipu Canal.

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Appendix A. Receiver Check and Download Protocol

Summary of Receiver Check and Download Protocol

1. Look for problems - even if you don't have time to fix them, we need to know where the problems are.

2. Check all receivers at least once every 2 days.

3. Organize, backup, and download data each week (see Data Management Procedure)

4. Transmit the download data to Lisiane <lisi@wnet.com.br> and Cezary <cezary@lgl.com> and send notes on all irregularities to Lisiane and Cezary by email with copies to Karl <kenglish@lgl.com> and Bill <koski@lgl.com>.

Brief Check Procedure (no download)

SRX400 Check

- turn up volume and listen for receiver scanning channels, background noise, and tags that are being detected.

- press ESC to exit scan mode

- if you can't ESCape from the scan mode, after several attempts, you have just found a problem

    - turn off receiver and turn it on again

    - press <shift> F0 to get main menu and check memory (4) status (1)

    - record the number of data banks and records (eg., 2:12345)

- if you can ESCape from scan mode check the memory status and record the amount of data as above

- if you have found a problem (i.e., receiver is off, receiver is locked up, data banks are full or at 4 banks) contact Lisiane ASAP

    - most receivers have 8 data banks (0-7) (some receivers have 16 data banks).

- Restart scanning in code log by pressing Run (1), and Continue (2).

Download and Detailed Check Procedure

Power Check

- check and record voltage on battery
- check AC power supply (volts) if in use

SRX400 Check

- same as brief check described above

Download SRX400

- The download computer has been structured with the following directories:
    - Itaipu2004
        - January2004
            - Jan04 Week1
            - Jan04 Week2
        - February2004
            - Feb04 Week1
            - Feb04 Week2
            - Feb04 Week3
- Each general location directory has a copy of WINHOST.exe for downloading and SRXW303.exe software to evaluate the data.
- Data is processed and dumped in the general location directory
- make sure baud rate is the same on receiver and computer
    - SRX baud rate should be 19200 for most receivers
- attach serial cable to SRX and computer
- on computer – execute WINHOST.EXE software
    - under Link select “Connect” option
    - under Transfer selected “Capture SRX Data
        - in File Type box selected “All files”
        - in File Name box enter file name (example: F0101210.hex site, month, day, 0 represents the first download of the day)

- on SRX400 – select Dump (2) and HEX (5) from menu
- fill out the data sheets and check for problems with the wires and antenna while the data is downloading
- check and convert the file using LGL's software (SRXW303.EXE)
    - execute SRXW303.EXE, select file to convert
    - check log file status report

      Site number: 3
Low Battery Warnings: 0
Bad Dates (> Now): 0
Date Sequence Errors: 0
Data Gaps (hours): 0.00
Bad Records: 0
Total Records: 27758
Code 255 Records: 21198
Battery Checks: 410

      Earliest Data: 20000411 14:00:04
Most Recent Data: 20000428 16:40:55
Environment History: 20000418 16:01:04

    - Low Battery Warnings = number of Battery Low records
    - Bad Dates = number of records with dates later than the current time on the download computer.
    - Date Sequence Errors = number of times that dates go back in time rather than forward in time
    - if the number of records with Bad Dates or Date Sequence Errors represents more then 1% of the Total Records – DO THE DOWNLOAD AGAIN (this is a transmission error, not hardware)
    - Data Gaps = no battery checks and no data recorded for more than 1 hr and 10 sec. (should be at least one battery check within 1 hr and 5 sec of the last battery check)
    - if the Data Gaps is more than 3 hours, RECORD on RECEIVER CHECK SHEET.
    - bad records could be the result of Antenna # <0 or >7, Code > 255, Channel>25, Power >255. Consistent high numbers of bad records may indicate a problem with the receiver. Call or email Lisiane if you see this occurring.
    - Code 255 Records - indicate the amount of noise/collisions

- Battery Checks - number of battery check records

- the date and time for the Earliest Data should be close to the time for the last download and the Most Recent Data date/time should be close to the time you stopped the scan, if not RECORD on RECEIVER CHECK SHEET. The file may not be completely downloaded so try again giving it a slightly different name (i.e. F0101211.hex)

- For non-DSP systems, assess completeness/correctness of frequency table. Watch out for the "S" problem. If an S appears following the frequency table, that frequency is treated as a sensor frequency and is not scanned.

- Assess each diagnostic in the SRX303. Check graphs for noise by power level

  - if the receiver is filling up with low power noise (<20), you should call or email Lisiane to discuss changing the gain for a SRX system.

  - Lots of high power noise indicates signal collisions

- Check hits by channel, indicates tag channels in area.

- Run (1) and Initialize (1) the receiver. Do not reinitialize if there is any uncertainty as to the completeness of the download.

- listen for channel scan on SRX system

- make sure the volume is turned down

- Fill out the receiver box and office copies of the data form.

- Record all downtime events on the data form including tag testing, faulty wiring and note any changes to gains.

Other system checks

- look for aerial antennas that are pointed in the wrong direction or wrong angle

Data Management Procedure

a. ensure all download files are located on at least one computer, one CD disk, and the LGL ftp site. Hex files are the only required files to be sent to LGL.

b. on the computer maintain separate data directories for each month of data and within each month directory have separate directories for each week (Jan04 Week1, Jan04 Week2, etc.).

- When using two computers (primary – will have copies of all files and from which FTP transfer will occur, secondary – data download and backup only);

- Move all files (*.hex, lgl, log) from the location directory into the appropriate week directory;
- Zip all files in each week directory and name the same as the directory (you now have the individual files and the zip file in the directory);
- Copy only the zip file for each week onto the backup zip disk;
- Send each zip file for that week and send to Lisiane and Cezary via email.

c. Summarize all irregularities found at the stations and antennas in an email to Lisiane and Cezary.