THESIS PROPOSAL

FISH MIGRATION PATTERNS IN THE UPPER URUGUAY RIVER AND CAPACITY OF OVERCOMING OBSTACLES

Maringá, Brazil, September 2003

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MARINGÁ, September, 2003

Introduction

For countless generations man has marveled at the annual returns of migrating fish. The awareness that many of these animals have often traveled great distances, encountered many obstacles or predators and managed to seek out and find specific sites has inspired great admiration. Over the ages man has developed many explanations, theories and even superstitions regarding these miraculous fish migrations. Although man has expected the annual return of specific fish populations and indeed in many cases depended upon such movements for his own survival, the answers to many questions still elude the lay observer as well as the scientific researcher (Mckeown, 1984).

Fish marking has become an essential technique in the study of the behavior of fish populations. Researchers have marked animals for hundreds of years, in several ways. Izaak Walton wrote in 1653 that stream watchers tied ribbons to the tails of Atlantic salmon (McFarlane et al, 1990). Since then, marks have evolved into a smorgasbord of buttons, clamps, clips, punches, threads, beads, streamers, dyes, stains, transmitters, chemicals, molecular profiles and statistical tricks, which are basically divided into external, internal and natural marks. The diversity of methods for marking is directly related to the animal to be marked. Several species of fish have been marked in several kinds of environments (Nielsen, 1992).

Radio transmitters were used for the first time in salmon in 1956 (Stasko & Pincock, 1977), practically at the same time researchers were trying to use similar marks in birds and mammals. Biotelemetry became popular and rapidly common from 1970 on (Nielsen, 1992).

Johnson (1990) examined salmonid marking on the northern Pacific coast of North America. Each year more than 40 million salmon are tagged with coded wire tags. The tagging occurs in at least 300 hatcheries in the USA and in many Canadian hatcheries. More than 1,200 new tagging codes are used annually. Taking into account only the Pacific shore of North America, more than 40 million salmon are marked with coded wire tags every year, including more than 1,200 new codes.

The tagged fish migrate to sea, where they mix with fish tagged in Japan and Russia. Eventually they are harvested by thousands of commercial fishers, who report the capture location of tagged fish in hundreds of statistical areas. Various agencies then collect the data and try to make sense of them - no mean task (Nielsen, 1992).

The first studies on fish migration in Brazil were performed in the fifties on the upper Parana River (Godoy 1959, 1967, 1975; Morais & Schubart, 1955). The mid Paraná was later studied by researchers from Argentina in the sixties (Bonetto & Pignalberi, 1964; Bonetto *et al*., 1971). The Paraná Basin was the only one in South America where long-distance marking experiments were performed successfully (Barthem & Goulding, 1997).

Although other species have been marked, most of the information on fish migration in South America is of the curimbatá (*Prochilodus* spp). Experiments have shown that the curimbatá *Prochilodus scrofa* congregates in large schools and migrate up-river to spawn in the upper regions of tributary streams. After spawning, fish return about 600km down-river to the principal feeding areas. The annual migratory cycle in the Paraná basin thus covers about 1,200km, with spawning occuring during the flood season. Studies have shown that the curimbatá migrates up river at a velocity of 5-8 km/day, but returns down river at a slower rate: about 3-5 km/day (Barthem & Goulding, 1997).

Nowadays, the use of telemetry techniques for monitoring the movement of fish and for determining the areas used by the species have answered questions on migratory patterns much more quickly, not only confirming the results of traditional tagging but also justifying the resources applied to these studies.

Biotelemetry can reveal several aspects of the behavior of the marked animal that other marking techniques cannot. The repeated localization of an animal in a determinate spot shows patterns of movement and defines territories and home areas. These data can be related to environmental conditions (Nielsen, 1992). Radiotags are also useful when and where the animal can't be captured or seen, as in turbid or rapid waters.

Biotelemetry can also monitor movements on a large scale. The transmitted signal may be recorded even at great distances, from satellites or aeroplanes. This enhances the effectiveness of the migration studies, as only marked animals need to be monitored. In comparison, hundreds of animals need to be captured and examined to find an individual mark with traditional marking techniques (Stasko & Pincock, 1977).

In this project, migratory fish species will be monitored with radiotelemetry techniques in the Upper Uruguay River and in the "Piracema Channel" of the Itaipu Dam to characterize fish migration patterns in natural flood waters and in fish ways,

Sub-project 1: Study of dourado (*Salminus brasiliensis*) migration in the Uruguay River using radiotelemetry techniques

Justification

The Uruguay is the third largest river in the Prata basin, approximately 1838km in length and with a drainage area of 365.000km^2 (OEA, 1969). Its headwaters are in the Serra do Mar and Serra Geral, the coastal ranges of southern Brazil. Its main source, the Pelotas River, originates only 64km from the Atlantic coast and flows to meet the Canoas River at 1800m above sea level, thus giving rise to the mainstream of the Uruguay River. The Uruguay then flows west through southern Brazil between the states of Rio Grande do Sul and Santa Catarina and southwest along the border between Brazil and Argentina. At Monte Caseros (Argentina) it turns south and begins the formation of the border between Argentina and Uruguay. In Buenos Aires it combines with Paraná River, forming the great estuary of the Prata River (Di Persia & Neiff, 1986).

The current state of knowledge of the diversity of fish fauna in the Uruguay River is similar to that of the other basins in the Neotropical region. Few species have been collected and ecological studies are scarce, relative to the great diversity and richness of the fish fauna. Even the large-bodied, economically important, species are missing precise taxonomic definitions and many are already endangered (Hahn, 2000).

Since 1989, fish fauna surveys have been conducted in the basin, trigged by environmental impact studies for the construction of power dams. Surveys were conducted in the Upper Basin (Itá, Machadinho and Campos Novos dams) by Bertoletti *et al*. (1989) and in the Middle Uruguay River (Garabi dam) by Bertoletti *et al*. (1990). These studies laid the groundwork for a number of other research studies in the basin over the last 10 years.

In 1995, studies to assess the environmental impact of the Ita and Machadinho dams (currently in-active) were restarted. These studies discovered new species in the area and investigated the biology and ecology of various species (Zaniboni *et al*., 1997 e Meurer & Zaniboni, 1997).

Between 1997 and 1999, a fish fauna survey was performed in another region of the Upper Uruguay River, between the cities of Mondaí and Itapiranga in western Santa Catarina (Hahn, 2000). During the survey, studies of the biology of two species important to the regional fisheries were performed: the dourado (*Salminus brasiliensis*) and curimbatá (*Prochilodus lineatus*).

Currently, several research projects are working on the Upper Uruguay River to better understand the environmental impact of the Ita and Machadinho power dams on the local fish fauna. These projects are studying the reproductive behavior of several migratory species as well as the production of those species in captivity (Zaniboni *et al.*, 2002).

The Uruguay River basin has suffered a variety of negative impacts since the beginning of the last century. Nearly all of the riparian vegetation had been removed by the fifties, when the last “balsas” (boats) used to transport wood taken from he margins of the river sailed down the Uruguay River to Argentina (Pasavento, 1982).

When the wood trade ended due the lack of raw material, the people who lived on the river margins in the basin began to fish more extensively. The abundance of “noble” species such as the bracanjuva (*Brycon orbygnianus*), the surubim (*Pseudoplatystoma corruscans*) and the dourado, stimulated the fisheries in the region. But the intensive fishing pressure, which is still common today, has caused an accelerated decrease in the fish populations, and the bracanjuva, for example, is critically endangered of extinction (Marques, 2002).

Water pollution in the upper part of the basin has been occurring for almost a full century. Pig and poultry farming is extensive in the region, and the wastes are generally dumped directly into tributaries of the Uruguay River with no treatment.

One of the major impacts on the fish fauna of the Uruguay River has been the construction of hydro dams. There are currently five large dams operating on the river, two of which are on the lower portion of the river (Salto Grande and Negro River) on the lower portion and three on the upper portion (Passo Fundo, Itá and Machadinho). There are approximately 20 proposals for new dams on the basin, and four of them have already been approved. None of them has any kind of fish ways or other fish passage facilities. Small hydroelectric stations (PCH’s) that already exist or are being built in several tributaries of the basin also contribute to this problematic situation.

The fish most affected by dams are those which perform reproductive migration each year. The interruption of migratory routes and the reduction of the spawning areas have become important threatening factors to populations of these species. Due to the rapid construction of new dams, and the threatened status of several local fish species, it is crucial to the survival of these species that research takes place and is conducted in a timely manner.

The dourado (*Salminus brasiliensis*) is targeted by both sport and subsistence fisheries because of its highly appreciated taste and aggressiveness. It also suffers the influence of the environmental conditions along the entire river, as it occupies different areas of the basin during the year. The destruction of habitat, the interruption of the migratory routes by dams, pollution and especially, over-fishing, have caused this species to be considered vulnerable according to the red list of endangered species of the state of the Rio Grande do Sul (Marques, 2002).

The lack of information on the behavior of species such as the dourado makes it difficult to build effective mitigative strategies to counter the anthropogenic environmental impacts and to properly manage fisheries. Until recently, research techniques used for the study of fish behavior only produced results after many years, even decades, and the information was not always accurate. Radiotelemetry affords a new option to provide some of this information on migration behaviour in a faster and more definitive manner.

This sub- project proposes the study of the movements and habitat use of the dourado in the Upper Uruguay River, using radiotelemetry, and to evaluate the impacts caused by the construction of the Itá hydroelectric dam. This will help guide future decisions on development in other areas of the basin.

Working Hyotheses

The Dourado of the Uruguay River perform annual long distances migratory displacements every year - as observed in other river basins. In the case of our study area, we propose that the fish use stretches of the river in the Turvo Forest Park as a homerange and migrate to the upstream sections to reproduce.

Interruption of the migratory route by the dam may induce the species to spawn in river stretches immediately downstream of the dam.

General goal

- To characterize the dourado's migration patterns in the Upper Uruguay Basin.

Specific goals

- To describe the migratory movements of the dourado in the Upper Uruguay River;
- To identify the dourado's homerange;
- To identify different dourado populations in the study area;
- To suggest adaptations to biotelemetry research techniques for migratory fishes in the Uruguay Basin and other Brazilian regions.

Material and Methods

Study area

The study area of this project is a portion of the Upper Uruguay River approximately 350km long, in the states of Rio Grande do Sul and Santa Catarina, between RS and Argentina (Figure 1).

- Six fixed stations will monitor the passage of the marked fish and are located:
- Station 1: along the powerhouse channel of the Ita dam,
- Station 2: 3 km upstream from the Mouth of Passo Fundo River, Goio-En, SC;

- Station 3:;Mouth of Chapecó River, Águas de Chapecó, SC
- Station 4: Mouth of Antas River, Mondai, SC;
- Station 5: Mouth of Peperí-Guassú River
- Station 6: 15km downstream of Turvo Forest Park

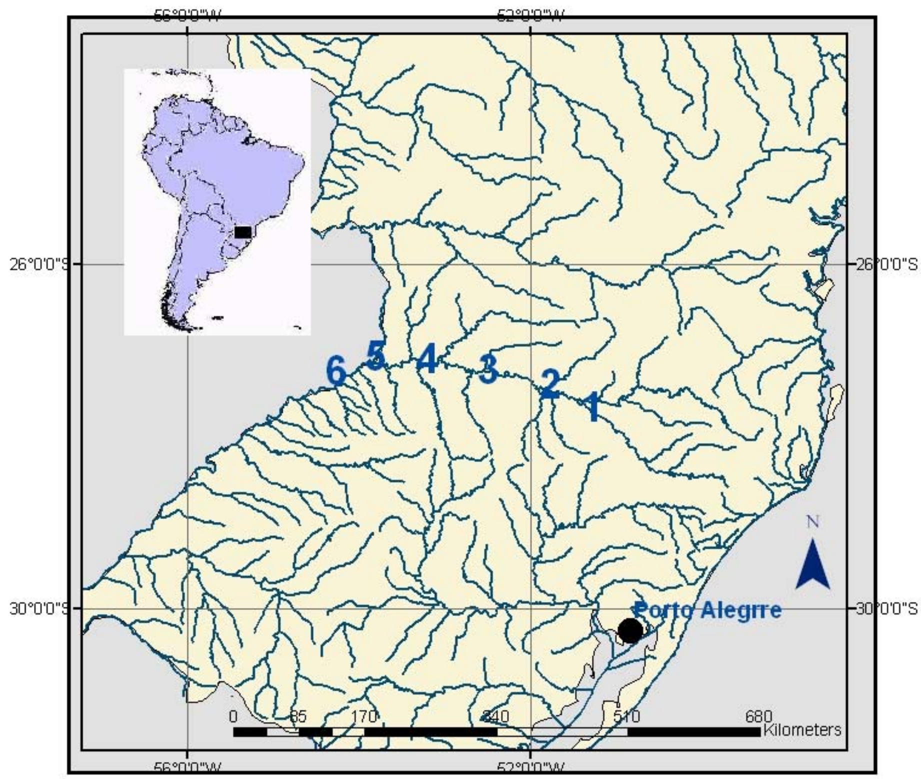

Figure 1. Study area, between Itá (SC) and Turvo Forest Park (RS). The numbers indicates radiotelemetry fixed stations: 1. Itá, 2. Goio-En, 3. Foz do Chapecó, 4. Mondaí, 5. Itapiranga and 6. Turvo Forest Park.

Telemetry Equipment

The fish marked with transmitters, which pass by the fixed stations, will be monitored by aerial antennas. The signs will be transmitted through a cable from the antennas to a signal-processing unity (SRX-400 receiver), which interprets the signal and stores it in memory.

Antennas*:* 2-3 "Yagi" model aerial antennas (four elements, 150MHz, Lotek Engineering Inc.) will be installed at the fixed stations. A "H" antenna attached to a single-engine plane will be used for aerial surveys.

Radiotransmitters: Model MCFT-3L transmitters (Lotek Engineering Inc.) will be implanted in 100 (one hundred) dourado. Transmitters contain a 3V battery with approximately 30 month life span, are 16mm by 73mm in size, and weigh 25,59g (weigh in water 11,1g). The transmitters have a 30cm long stainless steel antenna.

The frequencies, channels and codes of the transmitters to be used during project are described in Table 1.

Table 1. Channels, frequencies and codes to monitor marked fish

Channel	Frequence	Codes
4	149.380	1-37
20	149.620	1-5
15	149.600	1-37
18	149.660	1-36
10	149.840	1-5

Receivers: The signal processor that will be used on the project will be the Lotek model SRX-400 W7 receiver, which can be programmed for frequencies between 148.000- 152.000 MHz. For aerial surveys, a receiver equivalent to the model W7, but with no memory will be used. The receivers will be programmed for a scanning period of 2,5s per frequency.

Sample Collection

Fish to be marked will be collected from two locations in the study area: along the powerhouse channel of Ita dam and along the Yucumã waterfalls in the Turvo Forest Park, RS. These are at upper and lower end of the study area, respectively.

Adult fish will be captured throughout the year using rods with artificial bait and cast nets. The fishing effort will be increased from November to February. Live fish in good physical conditions will be marked with radiotransmitters immediately after capture.

Implant of Radiotransmitters

All captured fishes will be anesthetized for about 4-5 minutes in a bath of clove oil (eugenol) diluted in river water, measured (total length, standard length, height of the body) and weight. A file will be kept of fish characteristics and sample a will be taken from the dorsal fin for DNA analyses. Fish will be examined and only those with no apparent signs of diseases, external parasites, or injury will receive a transmitter.

Fish to receive transmitters will be placed in a holding tray with the ventral side up and the gills will be continuously irrigated with the anesthetic solution through a tube placed under the operculum. The surgical equipment will be disinfected with germicide solution prepared freshly for each tagging session. An incision of approximately 1 to 2 cm will be made 5 mm anterior to the pelvic fin to implant the tag. The incision will be deep enough to reach the peritoneum and to allow the antenna and the radiotransmitter to be inserted below the wall. A catheter will be inserted through the incision, between the pelvic fin and the viscera and directed 5 to 10mm from the center of the middle of the ventral line and posterior to the origin of the pelvic fins. Pressure will be applied until the point of the catheter passes through the skin of the fish. A needle will be used to pull back the incision, leaving the catheter free to guide the transmitter antenna through the body wall. The tag will then be inserted through the main incision, gently pulling the free end of the antenna and the catheter and leaving the tag nestled in the body cavity. The position of the tag inside the body of the fish will be adjusted by pulling the antenna until the tag reaches the horizontal position directly below the incision. The incision will be closed with absorbable sutures (Adams *et al*., 1998).

Immediately after surgery, fish will be placed in a tank with re-circulating water until they recover their balance, breathing and swimming movements, after which they will be released into the river. Only those that show a good reaction to the surgery will be released. All surgeries will be performed on the margins of the river to avoid mortality caused by the stress of transport.

Localization of Marked Fish

The localization of marked fish will be monitored by six fixed stations installed along the river in the study area (figure 1) which record the passage of the marked fish and store the collected data.

At each station directional antennas will be installed pointing upstream, downstream and into tributaries. These antennas will pick up signals from the marked fish and send them to the receiver, which stores the data. Every 20 days the data stored in each station will be a downloaded using a notebook computer, with CF4 host software provided by Lotek.

In addition to the data collected from fixed stations, an aerial survey of the region will be performed monthly. Flights will average four hours in duration. When a signal is picked up, the researcher will mark the position with a GPS and will record the frequency, code and power of the signal.

Tags return

To ensure that the tags of marked fish that are caught by fishermen are returned to the project, fishing communities will be informed about the project through the distribution of folders, posters and t-shirts, as well as through newspapers, TV News and lectures. Data will be collected from fishermen on the location and conditions under which tagged fish were caught.

Data Analysis

Data analysis will be performed using version 2.8 of “Telemetry Manager” developed by the Canadian company LGL Environmental Research Associates Ltd. Data files that are downloaded from the receivers are imported into the Telemetry Manager software, which builds a new operational database of all the signals picked up from the tagged fishes, eliminating signals from background noise and nonsensical records. The software summarizes the time of arrival and departure from every zone and enumerates how often a tag is detected within the give zone.

Sub-project 2: Evaluation of the capacity of migratory fish to negotiate the “Piracema Canal” of the Itaipu Dam

Justification

The Itaipu reservoir, formed in November 1982, has a total area of 1.460km^2, 835km^2 of which is in the Brazil and 625km^2 of which is in Paraguay (Agostinho *et al*., 1992).

The Itaipu dam has interrupted the natural migratory route of the reofilic fish in the Paraná River. A decrease in the migratory fish population has been observed downstream the dam, due to such factors as the loss of spawning area and impact of the spillway, which compromise egg and larva survival. One method being used to mitigate the impact of Itaipu dam is a side channel constructed to allow migratory fish access to upstream spawning areas (Borghetti *et al*., 1994). The side channel, called the "Canal da Piracema" was build beside the Itaipu dam, with the purpose of diminishing the impacts caused by interruption of the river course and to facilitate up and downstream movements of fish.

Studies performed by Prof. Manoel Pereira de Godoy indicate that, similarly to what happens to the salmon in the Northern Hemisphere, some species of migratory fish of the Paraná River Basin tend to return to natal spawning ground to reproduce. There is therefore an expectation that fish, which reproduce upstream of the dam, as well as their offspring, need to return to portions of the Paraná River downstream of the dam.

Studies performed to date by the Itaipu power company and state researchers have identified 189 fish species, most of which are migratory, dwelling within the Itaipu reservoir and its surroundings, including portions of the Paraná River immediately upstream and downstream of the reservoir. The channel therefore represents an opportunity to the study of migratory behavior of fish in the Paraná Basin and to evaluate structures of this kind for the management and conservation of migratory species impacted by dams in environmental conditions similar those found an Itaipu.

Despite indications that the "Canal da Piracema" is functioning to transport for migratory fish up and downstream, its effectiveness has not yet been confirmed.

Working Hypothesis

Migratory fish are able to overcome obstacles during reproductive and trophic migration.

General goal

- To evaluate the capacity of migratory fish to overcome obstacles.

Specific goals

- To evaluate the channel utilization by migratory fish species.
- To characterize fish movement in different regions of the channel.
- To assess the effects of changes in flow regime on migration behaviour.

Material and methods

Study area

The "Canal da Piracema" is located near the Itaipu dam. Five fixed stations with receivers and antennas installed along the channel will monitor the passage of tagged fish (figure 2).

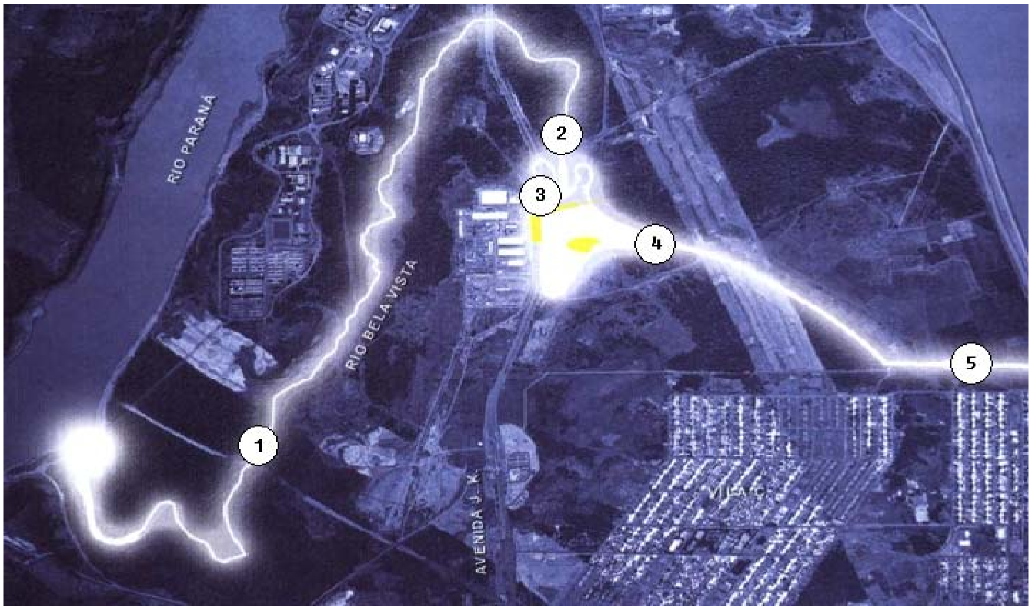

Figure 2. Fixed stations on Itaipu's "Piracema Canal".

Fish tagging

Five species from Paraná River Basin will be tagged with radiotransmitters: pacu (*Piaractus mesopotamicus*), dourado (*Salminus brasiliensis*), curimbatá (*Prochilodus lineatus)*, surubim (*Pseudoplatystoma spp.*) and piracanjuba (*Brycon orbygnianus*). The project will focus primarily on dourado, curimbatá and pacu. The number of transmitters implanted in each target species will be determined by the number captured. Other migratory species that are captured may be implanted with transmitters if they are of interest to the research.

Fish will be caught with fish trap and castnets at two locations on the canal: 1) along the impounding canal and 2) on the Bela Vista River (near the mouth on the Paraná River).

The procedure used to the implant of transmitters will be the same as that used on the Uruguay River (as described above) and will follow Adams *et al* (1998), except that fish will be transported to Itaipu's fish lab to perform surgeries.

Data Collection

Data will be obtained by downloading data directly from the five monitoring stations onto a laptop or via a modem to a remote computer. Mobile monitoring on the canal will be also performed by boat or from land. The spots where signals are noted will be plotted with a GPS. During the study period the movement of the marked fish in the canal will be monitored at two different flow rates of water: 6 and 12 m^3/s.

Telemetry Equipment

Tagged fish will be monitored at fixed stations by aerial and sub-aquatic antennas. The signals will be transmitted through a cable to the signal processing unit. The signals will be read by the processor and stored on a static memory of the Lotek SRX- 400 W31 model receiver. The data will be transmitted to a remote computer through a modem, included in the SRX-400 W31 receiver, or through a direct download at the station. A W31 Lotek model receiver will also be used for the mobile survey.

Antennas*:* Yagi model aerial antennas (four elements and 150MHz) will be used at the fixed stations.

Transmitters**:** Lotek MCFT-3L and MCFT-3A transmitters will be implanted in 80 fish of different species. Transmitters contain a battery with a life -time that may vary from 14 to 40 months.

Data Analysis

Data analysis for this sub-project will use Telemetry Manager, a software developed by LGL Environmental Research Associates Ltd.

Timetable

Activities / months	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2001												
Reconnaissance of fixed stations (Uruguay River)	X	X	X	X								
Equipments purchase and importation					X	X	X	X	X	X		
Preliminary tests							X	X	X	X	X	
Fixed stations installation											X	X
Tagging												X
Downloads												X
Aerial surveys												X
2002												
Tagging	X	X	X	X	X							
Downloads	X	X	X	X	X	X	X	X	X	X	X	X
Aerial survey	X	X	X	X	X		X	X	X			X
Project publicizing	X		X		X		X			X		X
2003												
Tagging	X	X	X	X	X							
Downloads	X	X	X	X	X	X	X	X	X	X	X	X
Aerial survey	X	X	X	X	X	X	X	X	X	X	X	X
Reconnaissance of "Piracema Channel" at Itaipu Dam									X	X	X	X
"Piracema Channel" Project elaboration							X	X				
2004												
Itaipu's equipaments purchase and importation												
Preliminary tests (Itaipu dam)	X											
Analysis "Telemetry Manager" (LGL- Canadá)					X	X	X	X	X			
Fixed stations instalation at Itaipu dam										X		
Tagging										X	X	X
2005												
Downloads	X	X	X	X	X	X						
Analysis	X	X	X	X	X	X	X	X	X			
Writing									X	X	X	
Thesis											X	

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