TRIP REPORT

Technical Assistance in Assessment and Management of Mussel Fouling in Brazilian Hydroelectric Facilities

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INTRODUCTION

Limnoperna fortunei invaded South America in the early 1990s. The mussel is presumed to have come in ballast water from Hong Kong to Argentina. It became established in the Rio de la Plata estuary, from which it has been spreading into other waterways of South America. As far as the author is aware, no effort has been made to contain the spread of this mussel up to October 2003.

TRIP REPORT

September 13-14th, Travel to Brazil; meeting with CETEC Research Institute (Belo Horizonte) - Monica Campos (CETEC) and Maria Edith Rola (CEMIG).

September 15-16th Site visit to CEMIG's Volta Grande dam (interior of Minas Gerais), including fish hatchery, led by João de Magalhaes Lopes

September 17th ABRAGE meeting on *Limnoperna* (Niagara Flats Hotel, Belo Horizonte), including presentation titled "Freshwater Bivalve Infestations; Risks to Industry and Current State of Control"

September 18th Abrage meeting (Cont'd). Travel to Itaipu, Parana.

September 19th Tour of Itaipu Hydroelectric dam and fish culture facility, discussion of mussel control measures and research

Sept 20th Tour of Iguassu Falls; discussion of research plans for CEMIG, public outreach, and policy; return to Belo Horizonte.

Sept 21th Tour of Ouro Preto with Maria Edith and Flavio Jose Froes de Oliveira (CEMIG personnel). Discussion of program for upcoming seminar.

Sept 22nd left Belo Horizonte at 8:30 a.m. and arrived in Toronto on Sept 23rd at 7 a.m.

TECHNICAL REPORT

Overview

The distribution of *Limnoperna* is currently restricted to a relatively small geographic area in Brazil on the Parana River. So far, only one hydroelectric dam has experienced an infestation. The Itaipu hydroelectric power plant has been dealing with a Limnoperna infestation for at least two years. How fast this mussel will spread throughout Brazil will depend on number of factors, most important of which are:

preventing the interconnection of separate watersheds to limit the spread of *Limnoperna* through natural water movements;

regulating stocking of fish for aquaculture purposes to make sure that *Limnoperna* is not transferred with the fish stock;

regulating ship and boat traffic from areas infested with *Limnoperna* (such as instituting the use of antifouling coatings on hulls to prevent adult attachment, treatment of ballast water to prevent transfer of larvae);

and educating stakeholders, other government departments as well as general public on the various vectors which may transfer *Limnoperna* and why it is important to prevent spread.

The Brazilian electric power industry sector will suffer the greatest economic losses if *Limnoperna* is allowed to spread. This will be followed by other industrial facilities which use fresh water for cooling or other processes. Aquaculture and fishing sectors are likely to be impacted to various degrees. Municipal drinking water intakes, irrigation channels and private water intakes will also be affected.

Environmental impact will also occur, but is harder to predict. Generally negative impact may be expected on any native clams and mussels due to Limnoperna using them as settling substrate and suffocating them. The *Limnoperna* is a filter feeder and if the infestation reaches high density in a particular body of water, the structure of the plankton community will be affected with the rest of the food chain to follow. By filtering large volumes of water, *Limnoperna* is likely to transfer energy from the pelagic layer to the benthos. This will favour bottom dwelling fish as opposed to pelagic fish. At the same time, the clarity of water may be expected to increase as particles are removed from the water column and deposited on the bottom. This may lead to increased growth of aquatic weeds causing a change to the current fish habitat in many locations.

The key priority at this time is to slow, if not prevent, the spread of *Limnoperna* in Brazil. This can only be accomplished with the help of the government at the federal and state level. Such action will minimize economic and environmental impacts and allow time for research into the life cycle of *Limnoperna* in Brazil. The energy sector, which is facing the greatest economic penalty, is in the best position to insist that the government take regulatory action to help prevent spread and assist in stakeholder and public education.

The model which might have the most success would be to appoint a specific government department as the “lead agency” for invasive species, *Limnoperna* in particular. This agency would then gather representatives of the appropriate stakeholders (drinking water, energy, fish, aquaculture, shipping, ecotourism) to help plan regulatory action, disseminate information and develop communication package for each sector. Given the size and diversity of Brazil it might be necessary to develop an educational package which could be delivered to local governments and industry in the various regions.

OUTCOMES OF SITE VISITS, INTERVIEWS, AND WORKSHOP

CEMIG

The Companhia Eletrica de Minas Gerais is the principal hydroelectric company in the state of Minas Gerais - originally a government monopoly, but now partly privatized. It is experiencing early stages of mussel invasion in some of its more southern dams, and for several years has been working on monitoring and control strategies – effort led primarily by Maria Edith Rola and Vasco Torquato under the supervision of Procópio Rezende. CEMIG has the advantage of having a small, central group clearly in charge of the issue, coordinating research and distributing information to the various CEMIG facilities. They need to develop site specific response plan for each of the dams if and when *Limnoperna* be found at those locations. Such plans would include tracing the cooling water in each facility from the point of entry, through all the cooling circuits to the point of exit and identifying components which might be impacted by

Limnoperna. The next step would be to decide on how best to prevent mussels from impacting the vulnerable components. CEMIG also needs to verify the life cycle of *Limnoperna* in Brazil, the environmental limits (temperature, calcium and pH in particular) and the susceptibility of the mussel to various mitigation strategies (chemicals, UV and filters) under local conditions.

CEMIG's principal field research station is located at the fish hatchery adjacent to their dam in Volta Grande, in the interior of Minas Gerais.

The fish hatchery has a separate intake from the reservoir. If *Limnoperna* should get into the reservoir, this intake will introduce *Limnoperna* into the piping, fish tanks and fish ponds. This would not be desirable from an operational view point. It would be desirable to have a coarse filter on the intake to prevent shells and adults from entering, followed by a UV unit to destroy veligers. An UV unit would also help control algae and bacteria coming from the reservoir, as well as larvae of non-target fish.

After lunch we toured the power plant. I explained that there is a need to trace cooling water in each facility from the point of entry, through all the cooling circuits to the point of exit. We tried to do that at Volta Grande. Cooling water comes in through an inaccessible opening in the face of the dam, protected by a fixed screen. This could be the first point of impact. *Limnoperna* could grow over the screen and reduce or cut off the flow. The cooling water then passes through mechanical strainers. Nobody was able to tell us the gap size of the strainers; they are not self cleaning. If shells start coming from the reservoir, these strainers could become plugged very easily. They should be replaced by self cleaning strainers with a fairly small gap size. On the Great Lakes the gap size tends to be around 5/1000 of an inch.

Following the strainers, the water then branches out into numerous small cooling lines to service various pieces of equipment. To protect this equipment, in the short term, addition of chlorine as sodium hypochlorite or chlorine gas on continuous or semi-continuous basis would guarantee that no settlement of veligers took place in the piping.

There is an independent intake for the fire water pump. There is no strainer on the intake. This introduces a possibility of adults being transported into the Fire Protection system during testing and or use.

At this time it is not clear if the *Limnoperna* will breed continuously at these locations or if there will be discreet breeding season. Monitoring for veligers once adult mussels are found in the reservoir will be necessary to determine the breeding season.

The monitoring program, as well as the site specific evaluation and preparation of individual mitigation strategies is best coordinated centrally with assistance from representatives from individual sites. This suggestion was discussed with Maria Edith who appreciated the value of having site-specific engineering input.

We compiled a list of what might be most useful projects for CEMIG. They include:

determining the length of the breeding season at each location;
determining the growth rate of *Limnoperna* in various bodies of water;
determining the calcium/pH requirements of adult and larval *Limnoperna*;
determining if the chemical controls established for zebra mussels directly applicable to *Limnoperna*;

determining if UV control Limnoperna veligers the same way it controls zebra mussels;
determining if antifouling coatings, effective for zebra mussels, also work for *Limnoperna*;
determining if *Limnoperna* affects fish habitat the same way the zebra mussels have altered it on the Great Lakes and what is the potential impact on economically important fish species;
determining if is *Limnoperna* likely to be a food source for any of the native fishes;
determining if any of the reservoirs are high in heavy metals and could this become an issue with Limnoperna accumulating them and passing them up the food chain;
determining if CEMIG control the aquaculture stocking in their reservoirs to prevent introduction of *Limnoperna*.

Further, we discussed research methodology, what could be done in the lab and what could be done in the field, perhaps using a mobile laboratory. We also discussed how researchers need to be focused on obtaining information which is of benefit to CEMIG, recognizing that some projects will be more pure science rather then applied.

Information sharing was another topic of interest. I described some of the industry workshops we organized, and the company newsletter which was used to keep various sites informed. We also covered the interaction our company had with the Ministry of Environment and Ministry of Natural Resources to establish achievable mitigation strategies and monitoring to verify lack of impact on the receiving environment.

We also discussed the program for upcoming seminar, making sure as many site people as possible could attend, to invite experts on chlorination systems to give a presentation, encouraging Maria Edith to use a CD of my presentation and to give the presentation again, at the seminar, in Portuguese. She also agreed to use the above list of research projects as a guide for her request for next years funding. We also spent some time discussing how to involve the Ministry of Environment in the issue of *Limnoperna*. There would be no point in developing a mitigation strategy which would not receive the approval from the regulator. If the regulator is involved from the beginning, sees the impact *Limnoperna* is having, is party to developing the best available mitigation strategy, there is better chance for smooth cooperation.

CETEC

The Fundaçao Centro Tecnológico de Minas Gerais (CETEC) has been contracted by CEMIG to research the *Limnoperna* issue for them and develop and implement strategies for its control. Monica Campos is the researcher in charge of this program.

We discussed the above list of research priorities with Monica and discussed on how to structure some of the experiments in the lab. I also described our use of the mobile field laboratory and why the data obtained in the field tend to be different from data obtained in the lab (animals less stressed, local water chemistry may interact with control chemicals differently from dechlorinated water in the lab etc.). We discussed research projects underway as well as plans for the future. We reviewed her proposed presentation for the upcoming Wednesday meeting and made some changes to the presentation.

I also met with Jose Roberto Tavares Branco and his staff. He is the head of the Materials Lab. He was interested in developing an antifouling coating. I explained that this is already a crowded

market and possibly testing those used against zebra mussels would be a better investment. We also discussed a number of other ideas and possibilities for research.

Itaipu

Itaipu Bi-Nacional operates one of the world's largest dams, situated on the Paraná River mainstem on the border between Paraguai, Brazil, and Argentina. The dam is operated jointly by Brazil and Paraguai. This is the first dam in Brazil to experience the invasion of *Limnoperna*, and has been one of the pioneers in dealing with the issue. The program is primarily driven by Carla Canzi, though other individuals from other departments are also involved.

We spoke primarily to Leonida Correia dos Santos, supervisor of the lab. It seems that the work is quite segregated among the different groups, to the point that the biology section does not know what the calcium levels in the water might be as this is handled by the chemistry department.

There was a concern as to what mussels may do to the face of the dam once they settle on it (under deposit corrosion). I suspect the reservoir will be long silted over before there is any impact.

There seems to be a lot of activity going on in the lab but I was not clear as to the purpose of some of the tests and samples that were being done.

Accompanied by Carla we went on the tour of the dam. Tour was given by Mario Lucio Ozelame. He is a very knowledgeable and technically competent engineer, very interested in developing the best possible protection system for his facility. We looked at their experimental chlorine installation, walked the cooling water system and discussed other possible treatment options. He is considering testing an Amiad self cleaning filter which in N.America has been shown capable of excluding zebra mussel veligers from cooling water, provided the flow is fairly moderate. It was a very good tour and productive exchange of information. It gave Maria Edith an idea of how technical plant people could assist in planning a treatment strategy.

In the afternoon we went back to the lab. We hoped to see the fish by-pass system but that did not happen. We did get a tour of their caged fish culture facility. The cages were heavily colonized by *Limnoperna* and there was a number of dead fish floating in the pens.

At the present time the chlorination system has been installed on only one unit of the dam. Further, the installation is not permanent as this was considered a research effort. Permanent chlorine injection needs to be installed on each of the units of Itaipu, possibly in combination with self cleaning filters to protect critical components from ingress of shells. The level of chlorine required to prevent veliger settlement should be verified to make sure only the least amount required is used. Although I was assured that mussel shells could not become lodged in the fire protection system, this is one are which would bear double checking.

Embrapa - Pantanal

The Empresa Brasileira de Pesquisas Agropecuário (Embrapa) is one of the leading government organization for agricultural research, but also addresses water and fisheries management issues through its research station in the Pantanal wetlands (Mato Grosso do Sul). Márcia Divina heads an Embrapa research program on *Limnoperna* in the Pantanal, and, with WFT

assistance, participated in the recent International Conference of Invasive Species in Windsor, Ontario, June 2003.

The Pantanal wetland is likely to see habitat changes should the *Limnoperna* invade. There is some hope that certain tributaries of the wetland have very low pH and this low pH could act as a barrier against *Limnoperna* spread. To verify this possibility, adult and larval *Limnoperna* should be tested for pH tolerance in the lab, using Pantanal water. Further, any shipping or boat traffic entering Pantanal should either have antifouling coatings applied to the hulls or have the hulls cleaned, ideally with a steam lance. As there seems to be a number of ecotourism lodges in the Pantanal, these locations could serve as educational outpost disseminating information on *Limnoperna* and how to prevent transfer of mussels.

ABRAGE - workshop

The Associaçao Brasileira de Grandes Barragens (ABRAGE) is an association of the majority of larger hydroelectric companies in Brazil. The environmental working group, chaired by Procópio Rezende of CEMIG, organized the present workshop on control of *Limnoperna* mussel.

There seems to be increasing awareness of what *Limnoperna* could do to hydroelectric plants and that steps must be taken now to prevent economic impact. There does seem to be some conflicting information on treatment, rates of spread and life cycle. With the exception of Itaipu, there are no concrete mitigation plans in place at any of the facilities.

The workshop took place in the Niagara Flats Hotel, Bello Horizonte, September 17,18 2003. Simultaneous translation was provided on the first day. Personnel from CEMIG and other utilities were there as well as a person from the Ministry of Environment (Robson Jose Calixto) and a person from the Navy (Flávio da Costa Fernandes). The meeting started at 9 a.m. Numerous presentations were made by the various participants. The overall impression was that the industry is getting ready to deal with the problem. Chlorination trials are underway at Itaipu and more information on *Limnoperna* is being gathered. The Ministry representative was not sure how to control discharge from the power plants that might have chemicals in it and what the responsibility of the Ministry was. The Navy has apparently done nothing to help limit the spread. For example they could have required ballast exchange for ships coming from Argentina freshwater ports.

At this point, the *Limnoperna* is not widely spread in Brazil and it could be slowed down through public education, use of antifouling paints on ships and private boats, restriction of shipping of aquaculture fish if the water they are in may contain Limnoperna veligers.
In Pantanal wetland, the *Limnoperna* may find a pH barrier that would prevent colonization of certain parts.

My presentation started at 5p.m. continued till 7p.m. I described our experience with biofouling mussels, some of the mitigation techniques we used and I touched on the impact to the environment. There were lots of questions, mostly aimed at use of various mitigation techniques. After the presentation I had more one on one discussions with the various site people asking for more details on both impact and mitigation.

The meeting resumed at 9 a.m. The purpose was to find a path forward. There was no consensus except to reconvene on October 14 for three days of meetings.

Privately I suggested to Maria Edith that the three days of meetings should be attended by as many plant people as possible. Some presentation from the September meeting should be repeated to help everybody achieve the same level of knowledge (my presentation given by her and the Itaipu presentation). The tracing of cooling water in hydroelectric facilities to discover problem areas should be explained with the help of flow diagrams and each facility should be encouraged to do an evaluation. An expert on chlorination should be invited to give a basic do and do not of chlorination systems. The Ministry of Environment should be there so that monitoring requirements for discharge could be addressed at the same time. I also offered continued help over the Internet to answer questions as they come up.

FOLLOW-UP FROM TRIP

Since my return I have managed to put Maria Edith in touch with Prominent Fluid Controls, a company that specializes in chlorination systems as well as UV sterilization and has an office in Brazil. Representative of the company was invited to attend the October meeting and give a presentation.

Staff member of José Roberto Tavares Branco from the State Technological Research Station (CETC) Materials Lab contacted me for a list of antifouling paints which were successful against Zebra Mussels. I compiled the list as well as manufacturer information and e-mailed it.

João de Magalhaes Lopes from Volta Grande wrote that he is very interested in pursuing a UV installation for the fish hatchery intake. We discussed how best to test the efficacy of a UV system. I suggested a small test installation at Itaipu as a joint experiment.

In the experiment, water would be pumped out of the reservoir, through the UV unit and then through a biobox to see if after the UV there would not be any settlement. Before and during the experiment they would monitor that there are veligers in the incoming water and they would examine what is coming out of the biobox (checking if the veliger look damaged or not). To prove that it is the UV doing the job they would also have to run a control. Same exact set up but no UV before the biobox. So ideally, UV protected line, no settlement in biobox, while in the control you would get settlement.

I suggested they run the experiment for 3 month at least; find out how often they have to change the UV bulbs and other mechanical things. Only after such an experiment would they be sure the UV unit would do the job,

João also reported that he went to the dam at São Simão with Mônica and Maria Edith to survey for *Limnoperna* and track the path of incoming cooling water in the plant, as I had demonstrated at Volta Grande. They identified a number of filters that can be closed by the *Limnoperna*, but fortunately could not find any larvae in the plant or in the reservoir.

Maria Edith was also in touch to verify how best to look for veligers in large volumes of water they collect. I explained the sugar separation method described in my book. It may not be appropriate for all locations; heavy silt load would probably make sugar separation unusable.

FINANCIAL REPORT

I had no additional expenses as I was very well looked after by CEMIG personnel.