Report to Durrell Wildlife and Conservation International providing advice on conservation of endemic fishes in the Nosivolo River, Madagascar, November 2007.

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Introduction

The 120km long Nosivolo River is the most important watershed in Madagascar, in terms of biodiversity, harbouring at least 19 Malagasy endemic fish. Three species are endemic to this watershed and one of these, the 'Songatana' (*Oxylapia polli*), is Critically Endangered. *Rheocles sikorae* and *R. lateralis* have also in the past been listed as CR - now they are DD so these are probably of equal interest from a conservation perspective.

Approximately two thirds of the 120km long river has already had preliminary surveys for fish along with inventories of invertebrates, and surrounding land surveys to evaluate the degree of river-bank forest cover. Despite there being severe deforestation along the majority of the river, it appears that water quality is still good. The principle threats to the fish populations appear to be continuing deforestation, the presence of introduced fish (the cypinodonts *Xiphophorus maculatus* and *Gambusia holbrooki* and tilapiine cichlids) and over-fishing of the river (which is also linked to creating conditions favourable for exotic fish).

Durrell Wildlife's (DW) outreach work showed us that the local communities are receptive to conservation. They are aware of the decline of their fish populations and reacted positively to the idea of developing conservation strategies to ensure the wise-use of the river and watershed. DW has worked over the last two years to encourage the creation of community associations who can oversee the closed fishing season, and ensure that net sizes are respected. They have also proposed set-aside areas along the river and are discussing how river-edges could be restored to riverine bush and forest.

In 2005 DW, working with the Department of Biology, University of Antananarivo (DBA) and Conservation International (CI), developed a conservation plan for the Nosivolo watershed. Parts of this plan are already being implemented and with our partners we continue to refine the conservation strategies appropriate for the Nosivolo.

In 2005 Durrell made contact with the South African Institute for Aquatic Biodiversity (SAIAB) an organisation which has a wide range of experience in the field of fish conservation and fish ecology research. SAIAB undertook an initial reconnaissance trip under the direction of the Freshwater Fish Curator, Mr. Roger Bills (RB). He spent one week at Marolambo learning about the

different aspects of the conservation and research programme and was able to provide the project with pertinent advice both for conservation and for future research at Nosivolo. DW, CI and DBA identified that there was a need for further capacity development here in Madagascar in terms of developing Madagascar's expertise in fish population ecology and conservation and in developing links with an international fish research institution. We approached SAIAB to consider whether they would be interested in continuing the collaboration with the Nosivolo project. SAIAB (RB) has continued to show a strong interest in the Nosivolo project. In March 2007 Dr Noro Raminosoa (DBA) was invited to SAIAB to take part in the Institute's anniversary celebrations and to meet the directors of the Institute to discuss long-term collaborative potentials. Dr Raminosoa also received training in fish taxonomy and electric-fishing while there.

Figure 1. A map showing the Mangoro-Nosivolo River system (left) and the Nosivolo River a few kilometres downstream of Betampona (right).

Objectives

The overall objective is to further the conservation of the Nosivolo ichthyofauna through intensive research into the state of the native fish fauna of the upper Nosivolo, and to instigate capacity building towards the goal of developing in-country skills to an international level in fish research and conservation. The sub-objectives include the following.

- To conduct with the University of Antananarivo research in the upper Nosivolo.

- To train at least one Malagasy researcher in current fish ecology research techniques.

- To demonstrate the range of fish ecology research and conservation skills currently used on the African continent.

- To advise on research and monitoring methods.

- To assist Durrell, CI and DBA to improve the conservation plan for the endemic fish of the Nosivolo River.

- To develop further links between SAIAB, the University of Antananarivo and Project Nosivolo.

Outputs

1. Collaboration established between SAIAB and Malagasy partners (University of Antananarivo, Durrell, CI).

2. Research report outlining -
   2.1. Methods used,
   2.2. Results, conclusions and recommendations, and
   2.3. Advice and recommendations on conservation strategies.

3. Management Report outlining:
   3.1. Training undertaken with results (success) of the training, and techniques demonstrated during the field work;
   3.2. Strengths and weaknesses of the current research capacity with recommendations if/how it needs to be improved;
   3.3. Strengths and weaknesses of the current conservation capacity with recommendations if/how it needs to be improved;
   3.4. General observations, comments and recommendations; and
   3.5. The potential/future role(s) that the SAIAB could play.

4. Plans for SAIAB's continued involvement 2007- 2008.

1. Collaboration established - SAIAB and Malagasy partners.

1.1. The 2007 expedition into the Nosivolo River was arranged by Richard Lewis at Durrell Wildlife (DW) and funded by Conservation International (CI). The research team comprised Juliette Velasoa (DW), Tsilavina Ravelomanana and Clara Raharisoa (DBA) and myself (SAIAB). We were assisted well by two local fishermen Celetin Randany and Randriamantena Bernard. The whole trip was well organised and the team members got along very well. The trip itinerary is given in Appendix 1.

1.2. During the course of the field work Tsilavina Ravelomanana (DBA) and I discussed various ideas for potential research projects. There was also some training of DW and DBA staff in basic methods of fish survey work (sections 3 and 4 below).

2. Research report

2.1. Methods

2.1.1. The overall plan for the May 2007 expedition was to make biological collections more widely across the Nosivolo River catchment than in 2005. The aims of the biological collections were to make:

- age and growth analyses of fishes for use in determining effective fishing restrictions;
- morphological analyses for assessments of effective fishing net mesh sizes; and
- geographical analyses of morphology and genetics of fishes for use in conservation planning.

2.1.4. Our sampling plan was to travel from high in the Nosivolo catchment, zig-zag our way down the system, collecting down the Nosivolo River and it's tributaries. Tributaries isolated by large waterfalls were selected where possible. We sampled downstream to roughly where the main road from Marolambo-Mahanoro left the river which was approximately where the lower distributional limit for Songatana (*O. polli*) is supposed to be. Sample site details are given in Table 1.

2.1.4. Fish collection methods included seine, throw, fyke, gill and hand nets. These were used both during the day and night time although typically we found better results at night. Fishes were for the most part fixed in 10% formalin. Tissues were taken for genetic analyses and these were small

muscle fillets that were fixed in 95% ethanol. Tissue samples were linked to formalized fish specimens by the variable positioning of cuts.

2.1.5. Photographs of just dead fishes were taken at many sites in order to record live colouration and colour patterns as these are important diagnostic features in certain groups e.g. *Bedotia* and *Rheocles*. A protocol for live fish photography is given in Appendix 2.

2.1.6. All data relating to tissue samples and photographs were linked with voucher samples. These data are recorded in an accompanying Excel database.

2.2. Results and conclusions.

2.2.1. We sampled at 41 sites from near the airstrip at Sahakevo through to areas of the upper Mangoro River system around Ambotavy (Table 1, Appendix 3). We collected a good geographical collection of fish and some frog material comprising formalized whole specimens and tissues preserved in ethanol for genetic analyses.

2.2.2. Water conductivity is very low in the Nosivolo River and its tributaries. We only collected water samples at a few of our sites but the range amongst these was from site 08 on the Sahave River near Ambodivoara (18 uS) through to the Mangabe River, a tributary not very far to the south of Ambodivoara (41 uS) (Table 2).

2.2.3. Turbidity levels, although not measured were highly variable. This is presumably due to a combination of human activities and the recent precipitation within the different sub-catchments. Confluence areas are where variation in turbidity between sub-catchments was most obvious (Figure 2).

2.2.4. Age analysis and fish morphology. A small number of samples of fishes were been collected specifically for the estimation of ages of fishes. These will be used, together with an assessment of sexual maturity to determine age (and size) at sexual maturity. This is critical for exploited species as, if they are being captured prior to significant numbers breeding, then these species will decline and perhaps go extinct. Additional formalised samples will aid in the determination of fish morphology and sizes captured by different net mesh sizes.

Table 1. Fish sample sites during the DW/DBA/SAIAB May 2007 expedition.

Site M	Location	South ° ‘ “	East ° ‘ “	Altitude m ASL	Date sampled
1.1	Sahadinta River	20°16’06”	47°51’14”	720	21/05/07
1.2	Sahadinta River at Sahakevo	20°16’13”	47°51’05”	720	21/05/07
2	Manandriana River	20°22’14”	47°49’10”	738	22/05/07
3	Mangabe River at Ankiboka Village	20°07’07”	47°48’08”	792	25/05/07
4	Nosivolo River just below Marolambo	20°03’01”	48°08’17”	417	30/05/07
5.1	Nosivolo River at Ambodinonka	20°21’31”	47°48’19”	745	22/05/07
5.2	Nosivolo River at Ambodinonka	20°21’	47°48’	745	22/05/07
6	Manandriana River at Ambohitsara	20°22’27”	47°49’14”	733	22/05/07
7	Nosivolo River above Ambodivoara	20°18’43”	47°44’13”	723	23/05/07
8	Sahave River above Nosivolo confl.	20°18’57”	47°44’25”	718	23/05/07
9	Nosivolo River	20°18’54”	47°44’23”	724	23/05/07
10	Tsarakanja Stream at Tsarakanja	20°19’55”	47°53’57”	752	24/05/07
11	Tsarakanja Stream	20°17’22”	47°55’06”	653	25/05/07
12	Tsarakanja Stream	20°17’10”	47°55’14”	648	25/05/07
13	Nosivolo River at Anosy Rahindy	20°16’29”	47°59’22”	586	25/05/07
13	Nosivolo River at Anosy Rahindy	20°16’26”	47°59’10”	586	26/05/07
14	Tributary river above waterfall	20°14’36”	48°00’48	597	26/05/07
15	Nosivolo River at Betampona beach	20°12’26”	48°04’01”	475	26/05/07
16	Nosivolo River near Betampona	20°11’45”	48°03’46”	464	27/05/07
17	Tributary stream	20°09’14”	48°02’50”	650	27/05/07
18	Maintimbato Stream, Ambalamena	20°08’19”	48°02’10”	565	27/05/07
19	Balakaza stream	20°06’33”	48°03’14”	577	28/05/07
20	Sandrakafoza stream, Ambalaherana	20°04’46”	48°04’17”	553	28/05/07
21	Nosivolo River above the Sahanao	20°03’21”	48°09’06”	401	29/05/07
22	Sahanao River	20°04’16”	48°09’02”	389	29/05/07
23	Marolambo market	20°	48°	420?	30/05/07
24	Nosivolo River near Ambanza village	19°59’58”	48°12’07”	383	30/05/07
25	Sahamoloto stream	19°59’41”	48°11’51”	380	30/05/07
26	Manandoltra River	19°59’18”	48°16’02”	296	30/05/07
27	Sahantsio River below 'hotel'	20°05’31”	48°22’28”	150	30/05/07
28	Stream south of Mangoro system	20°04’45”	48°24’24”	180	31/05/07
29	Mangoro River at lower pontoon	19°56’52”	48°41’39”	8	31/05/07
30	Pangalane canal system on beach	19°54’06”	48°48’46”	7	31/05/07
31	Menara River, road to Moramanga	19°01’59”	48°56’11”	22	01/06/07
32	Andranomandevy River at hot springs	18°57’49”	48°51’07”	30	01/06/07
33	Sandrangato River, near Moramanga	19°03’48”	48°13’44”	934	02/06/07
34	Mahamavo River, Anosibe An'ala road	19°17’48”	48°13’00”	931	02/06/07
35	Manambolo River, Anosibe An'ala	19°26’03”	48°11’21”	602	02/06/07
36	Manambolo River, above Mahela	19°21’07”	48°10’37”	619	03/06/07
37	Manambolo River 2km above Mahela	19°21’19”	48°10’45”	629	03/06/07
38	Manambolo River, Anosibe An'ala	19°26’14”	48°12’07”	590	03/06/07
39	Sandrangato River	19°07’17”	48°13’58”	956	04/06/07
40	Ambodizana Stream, Ambotavy area	18°43’20”	48°18’17”	967	04/06/07
41	Unknown stream, Ambotavy area	18°43’15”	48°20’07”	965	04/06/07

Table 2. Water conductivities from selected sampling sites.

Site # M	Location	Conductivity uS
02	Manandriana River	19
03	Mangabe River at Ankiboka	41
04	Nosivolo River just below Marolambo	31
05	Nosivolo River at Ambodinonka	18
07	Nosivolo River above Ambodivoara	16
08	Sahave River, near Nosivolo confluence	18
31	Menara River on the road to Moramanga	23
32	Andranomandevy River at hot springs	54
34	Mahamavo River, Anosibe An'ala road	18
36	Manambolo River 3-4km above Mahela	24
39	Sandrangato River south of Moramanga	23
41	Tributary stream near Ambotavy	33

Figure 2. The confluence of the Sandranamby and Nosivolo Rivers at Marolambo showing the more turbid waters of the Sandranamby.

2.2.5. A protocol for extracting otoliths from fishes in the field without destroying the fishes is given in Appendix 4 and as a power point presentation file on an accompanying CD-ROM. This method was demonstrated to DBA and DW staff in Marolambo using *Ptychochrpoides katria* specimens of varying sizes. At this time a small number of otoliths were collected from *P. katria* specimens for otolith analysis. A larger number of fish specimens of *Rheocles* sp. were also preserved in buffered 95% ethanol for the same purpose - otoliths can be removed from these at a later stage.

2.2.6. A protocol for preparing otoliths for reading growth rings is given in Appendix 5 and as a power point presentation file on an accompanying CD-ROM. A kit for preparing otoliths is being made up and will be posted to Madagascar. Otolith preparation and reading can be done with some basic materials and it will be possible in the DBA laboratories. Skill in reading otoliths may take more time as this is difficult and discussions with researchers in this field will help with determinations.

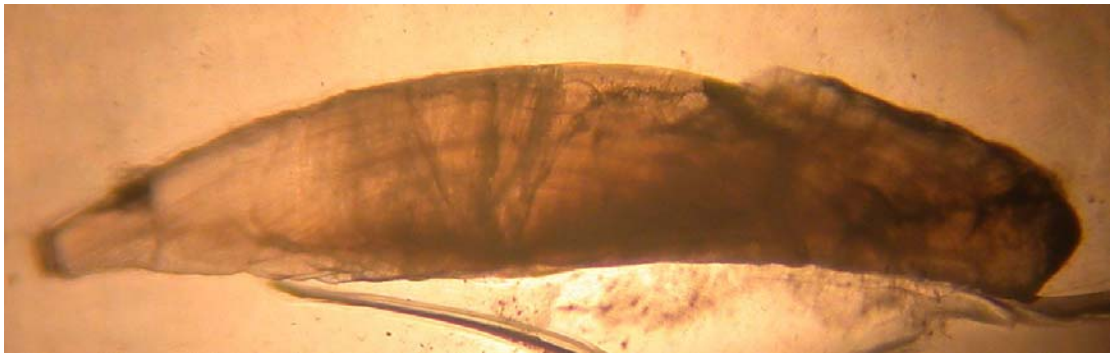

Figure 3. A sectioned otolith from a sexually mature *Ptychochromoides katria* showing growth rings.

2.2.7 Morphological and genetic variation in key taxa in the Nosivolo system.

Variation in key species will be examined using morphological and genetic methods to determine if there is population structuring within the tributaries and mainstream Nosivolo. If there is this will influence future conservation management plans as all distinct populations should ideally receive protection. The criteria for choosing taxa for this study were simply that they needed to be fairly common and widespread within the study region and I chose species from different groups. The taxa I initially planned to sample were as follows.

- Songatana - *Oxylapia polli* (family Cichlidae)
- Zono - *Rheocles* sp. (family Bedotidae)
- Zono - *Bedotia* sp. ‘nosivolo’ (family Bedotidae)
- Soboeta - *Ratsirakia legendrei* (family Eleotridae)
- Waterfall frog (*Mantidactylus lugubris* complex) (family Mantellidae)
- Freshwater crabs (family Potamonautidae)

2.2.8. Unfortunately, we did not collect many crabs, however, future studies should consider this group for future population structuring studies. Brief notes on the taxa studied are given below.

2.2.9. Genetic samples comprised of small muscle fillets removed from specific sites on specimens. The positions of cuts were recorded so that tissue samples could be linked to the fishes. Genetic samples were preserved in 95% ethanol and the fish voucher specimens were fixed in 10% formalin. Photographs of recently dead animals were taken to illustrate live colouration and colour patterns. All DNA numbers, photograph numbers were noted so that samples and fish specimens could be accurately linked. The numbers of genetic samples and their collection sites are given in Appendix 3.

Table 3. A summary of the numbers of tissue samples collected during the 2007 field trip in the Nosivolo River system.

Site	**Location**	***Rheocles***	***Bedotia***	***Ratsirakia***	***Oxylapia***	**Frog sp.**
01	Sahadinta River at Sahakevo	4				
02	Manandriana River				2	
03	Mangabe River, Ankiboka	3		1		
04	Nosivolo River, Marolambo	1		4	6	3
05	Nosivolo River at Ambodinonka	3		4		
06	Manandriana R., Ambohitsara				2	
07	Nosivolo River above Ambodivoara			4		2
08	Sahave River, Nosivolo confl.	4				
09	Nosivolo River				2	
10	Tsarakanja Stream at Tsarakanja		5	1		
11	Tsarakanja Stream			1		
12	Tsarakanja Stream		2			3
13	Nosivolo River at Anosy Rahindy	3	14	4	3	2
14	Tributary river above waterfall					2
15	Nosivolo River at Betampona		3			
16	Nosivolo River near Betampona		4			3
17	Tributary stream					1
18	Maintimbato R., Ambalamena	4	4	4	4	4
19	Balakaza stream					2
20	Sandrakafoza R., Ambalaherana	4				2
21	Nosivolo River above Sahanao					3
22	Upper Sahanao River	4	2			
23	Marolambo market					
24	Nosivolo River near Ambanza				3	
25	Sahamoloto stream	5				

26	Manandoltra River	5				
27	Sahantsio River below 'hotel'					2
28	Stream south of Mangoro system		2			
29	Mangoro River at lower pontoon					
30	Pangalane canal at Mahanoro					
31	Menara River, Moramanga road		11			
32	Andranomandevy River					
33	Sandrangato River, Moramanga					
34	Mahamavo River, Anosibe An'ala	5				
35	Manambolo River, Anosibe An'ala	5				
36	Manambolo River above Mahela	5		1		
37	Manambolo River above Mahela					
38	Manambolo River, Anosibe An'ala					
39	Sandrangato R., Moramanga	15				
40	Ambodizana R., near Ambotavy					
41	Tributary stream near Ambotavy					
Total		70	47	24	22	29

2.2.10. Songatana (*Oxylapa polli* Kiener & Maugé 1966).

Figure 4. *Oxylapia polli* from the Manandriana River (site M6, 20° 22’ 27.5” S, 47° 49’ 13.6” E, 22/05/2007).

- The Songatana is the flagship fish species for Durrell/CI/DBA Nosivolo conservation program so it is an obvious species to examine for population structuring. It also seems to be a habitat specialist and although widespread within the Nosivolo seems to be patchily distributed. The possibility that these populations are isolated from each other could influence conservation management plans. Its habitat specificity also makes it a good indicator species for high water quality and habitat integrity.

- We were able to collect specimens of *O. polli* in the mainstream Nosivolo River above Ambodivoara down stream to near Ambanza which seems to be close to its lower distributional limit. We were also able to collect it in two upper tributaries the Manandriana and the Maintimbato streams. Other tributary populations are known and these should be sampled in order to complete this study. No obvious colour or morphological variation was observed during our sampling.

- Interestingly, during night snorkelling in the Manandriana Steam *O. polli* was observed over varied substrates and in varied flows and not exclusively in rapids. This suggests that Songatana may have wider habitat preferences than their present mainstream Nosivolo distribution indicates. Current distributions may be a result of several impacts such as fishing pressure, alien fish predation and sedimentation of deeper run and pool habitats.

- Movement of *O. polli* into less complex habitats during the night-time exposes this species to throw netting activities. The restriction of throw netting at night is thus a management option that needs to be seriously considered.

2.2.11. Zono (*Rheocles* sp.).

Figure 5. *Rheocles* sp. from the Nosivolo River upstream of Ambodivoara (site M7, 20° 18' 43.4" S, 47° 44' 13.4" E, 23/05/2007).

- In 2005 the specimens of *Rheocles* collected in the Nosivolo River were tentatively identified from photographs by Melanie Staissny as being close to *Rheocles wrightae* Stiassny 1990. During the course of the 2007 SAIAB/DW/DBA expedition we were able to sample extensively within the Nosivolo catchment. We collected specimens from the type localities for *R. wrightae* (the Sandrangato River, 19° 07' 17.1" S, 48° 13' 58" E) and *Rheocles sikorae* (Sauvage 1891) (the Manambola River, 19° 26' 03.3" S, 48° 11' 21.4" E to 19° 21' 19.4" S, 48° 10' 44.5" E) in the northern part of the Mangoro catchment near Anosibe An'ala. Field observations suggest that *R. sikorae* and *R. wrightae* are synonymous (*R. sikorae* (Sauvage

1891) would be the valid species) and that they differ from *Rheocles* specimens from the Nosivolo catchment (Fig. 6). Morphological and genetic work is needed to confirm these suspicions and to determine points of discontinuity for species.

- *Rheocles* specimens collected within the Nosivolo in 2007 exhibited considerable variation (colouration, spot patterns and morphology) both within samples at a particular site and between sites. Spot pattern variation was also noted for *R. sikorae* and *R. wrightae* (Stiassny, 1990). Specimens in certain upper reaches of the Nosivolo and tributaries were unspotted and deep blue while those around Marolambo were more olive green - yellow and comprised greater numbers of spotted individuals (Fig 6). There is the possibility that upper and lower Nosivolo populations of *Rheocles* are therefore different. Interestingly, this situation appears to also occur in the *Bedotia* with blue (upper catchment) and yellow (lower catchment) species being present. Taxonomic studies on these two groups are a high priority as new species will raise the conservation importance of the Nosivolo sub-catchment.

- Given their taxonomic uncertainty and the obvious geographical variation *Rheocles* and *Bedotia* species are particularly interesting groups to study for morphological and genetic structuring within the greater Mangoro River system.

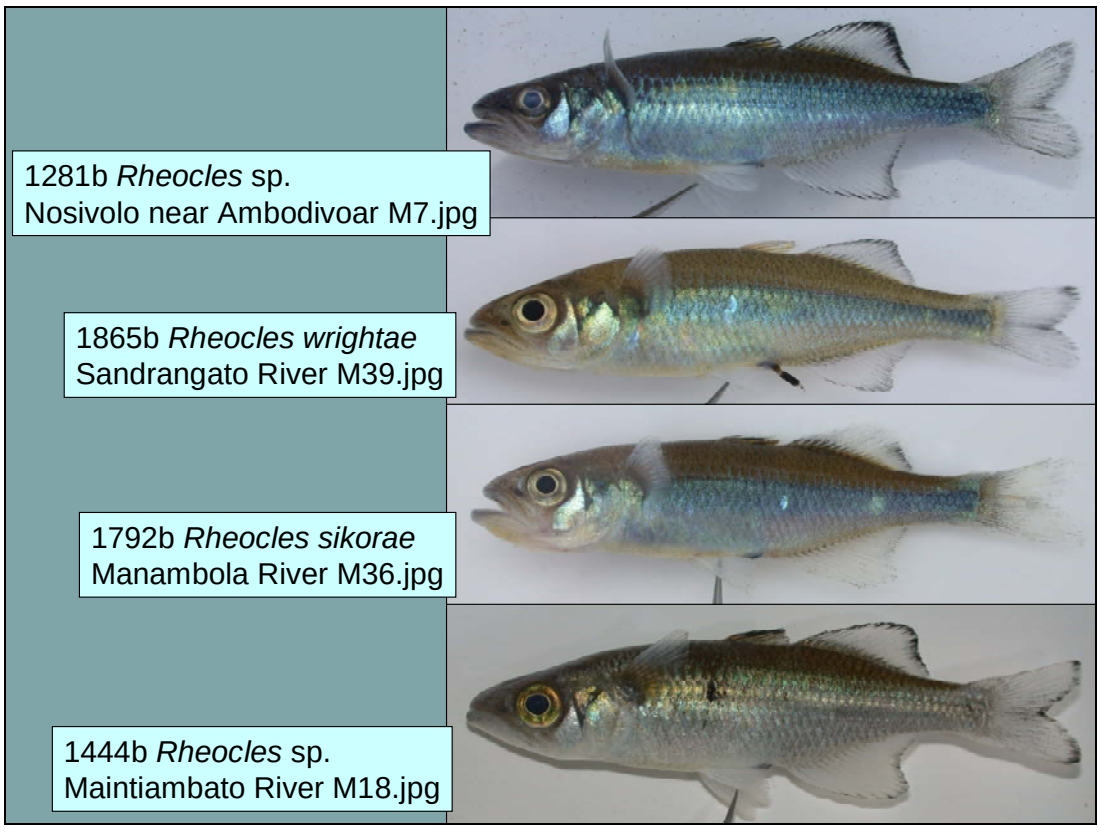

Figure 6. Variation in colouration, colour patterns and forms in *Rheocles* sp. from the Mangoro River system.

2.2.12. Zono (*Bedotia* sp. 'nosivolo blue').

- This *Bedotia* is undescribed and was originally discovered around Marolambo. It has been referred to in IUCN assessments and other reports as *Bedotia* sp. "nosivolo blue". There is apparently another *Bedotia* sp. "yellow" around the nosivolo-Mangoro confluence area which we did not visit on the 2007 expedition. Taxonomic descriptions and research to better understanding their distributions, habitat preferences and abundance are clearly needed.

- From our work so far their distribution appears to be patchy and a little lower within the system compared to *Rheocles*. We have collected *Bedotia* sp. "nosivolo blue" high up in some systems e.g. Tsarakanja and then in the mainstream around Maralambo so its habitat preferences appear to be broad. Where it was collected it does appear to be reasonably common.

Figure 7. Upper - *Bedotia* sp. 'nosivolo blue' male from the Sandranamby River (M11, 20° 02' 59" S, 48° 07' 40" E, 13/11/2005) and lower a female from the Nosivolo River below Marolambo (M4, 20° 02' 45" S, 48° 09' 44" E, 09/11/2005).

- Probably the greatest threat to these species is the loss of riparian vegetation and increased water turbidity from poor farming practices. This is because terrestrial insect fall and drifting invertebrates are a major dietary component for all bedotids (Loiselle & Stiassny, 2003). *Bedotia* and *Rheocles* species may both be fairly resilient to some of the other impacts

in the system. Fishing net mesh sizes for example are large and unlikely to catch the bedotids. Alien fishes present in the Nosivolo system are not open water fish predators and are thus only likely to impact upon eggs. Movement up the system of alien fish predators such as *Channa striata* is, however, a serious future threat.

2.2.13. Soboeta (*Ratsirakia legendrei* (Pellegrin 1919).

- *Ratsirakia legendrei* are recorded from several catchments on the east coast including the Mangoro River system. Samples from individual sites show considerable morphological and colour patter variation. The taxonomic status of *Ratsirakia* specimens within the Mangoro system needs to be determined. It is possible that there is more than one species in the Mangoro system and that these may be endemic.

- This species is one of the most widespread in the Mangoro River system being collected at 11 sites in 2007 and also being known from the Ambotavy area. Our collections would probably have been more comprehensive if we had used electric fishing methods as this seems to be a particularly effective method for eleotrids (pers. com. Dr Johan Rall). The geographic spread and numbers of samples collected during 2007 will allow us to answer the above taxonomic questions.

Figure 8. *Ratsirakia legendrei* from the Nosivolo River upstream of Ambodivoara (site M7, 20° 18' 43.4" S, 47° 44' 13.4" E, 23/05/2007).

2.2.14. Green waterfall frog (*Mantidactylus (Hylobatrachus) lugubris* complex).

- This species, tentatively identified as a species in the *Mantidactylus (Hylobatrachus) lugubris* complex (pers. com. Dr Frank Glaw), was common in cascade habitats both in small streams and in the mainstream Nosivolo River. They were also fairly easy to locate and collect during the day which enabled us to make widespread collections across our sampling area. Interestingly, this species did not appear to be present in similar habitats outside of the Nosivolo sub-system in either of the southern

tributaries or in the northern Mangoro tributaries around Anosibe An'ala. Thus this species may be a Nosivolo endemic. Little appears to be known about the finer details of *Mantidactylus* distributions (Anderon, 2003, pers. com. Dr Frank Glaw).

Figure 9. *Mantidactylus* sp. from the Sahampotaka stream in Marolambo (site M6, 20° 03' 14" S, 48° 08' 12" E, 10/11/2005).

2.2.15. The 2007 expedition was very productive in that the team worked well together and we collected a great deal of material. Progress on all of the above planned research is, however, stalled awaiting export to South Africa. These samples were collected specifically to study research questions relevant to the management of the fishes of the Nosivolo. Further progress in this research is entirely dependant on laboratory work such as morphological measurements and DNA sequencing.

2.3. Advice and recommendations.

2.3.1. The work that has been initiated during the two SAIAB/Durrell/DBA expeditions to the Nosivolo has the potential to deliver some valuable information concerning fish biology and biodiversity that is particularly relevant to fish conservation issues in the Nosivolo catchment. Two examples are:

- age at maturity for all exploited species and relating fish sizes and morphology to fish net mesh sizes; and
- if there is morphological and genetic structuring within species in different areas of the Nosivolo.

The samples collected will be able to answer these questions but laboratory analyses are needed.

However, no biological analyses have been possible yet as samples are still awaiting export (2005 and 2007 samples). It seems likely that only very low numbers of fishes may be permitted and consequently the planned research for this 2007 expedition will not be possible. If this situation remains the collections represent an unnecessary sacrifice of endangered animals and a considerable waste of research effort. The granting of specimen export permits is clearly a serious issue for both Malagasy authorities and research scientists. A reasonable solution to sensible requests needs to be found otherwise current and future research is going to be affected.

2.3.2. If laboratory analyses are possible then the logical extension of this work would be to broaden the sampling to incorporate additional tributaries and to explore likely areas of the Mangoro system where there may still be indigenous species remaining. Possible areas worth exploring would be:

- western tributaries of the Mangoro River south-east of Antananarivo;
- mainstream rivers and tributaries around the Mangoro-Nosivolo confluence; and
- northern tributaries of the Mangoro and Lake Aloatra region.

2.3.3. Protected areas (PA) research. Some future research efforts should examine protected areas within the Nosivolo. Some basic questions are as follows.

- What should be the ideal geographical spread of protected areas in order to preserve the current diversity.
- What is the ideal size of a PA in order to protect viable populations.
- What is the impact of protection on indigenous biota.

The above PA research could be developed into an MSc program.

2.3.4. Fish biology research - project. A better understanding of the biology of the main fish species would be highly desirable. This knowledge will aid DW in managing the system. The ideal situation would be for DBA students to visit Grahamstown (SAIAB and DIFS) to learn appropriate techniques, work up some of their samples and acquire appropriate materials before progressing too far into their studies. Students could then return to Madagascar and do most of their work there. Some techniques will still need to be done in RSA e.g. sectioning and staining of gonads and this can be done by professional laboratories and results sent back via e-mail.

2.3.5. Fish biology research - sampling. This will need monthly sampling of whatever species are studied. Probably the best options are *Rheocles*, *Bedotia* and *Pt. katria* as 20-30 specimens per month for one entire year will be needed. Additionally, monthly samples of invertebrates will be needed for comparisons with stomach contents. In the months when students are not present then DW staff or local people should be trained to take samples so that there are no gaps in the sampling.

2.3.6. Fisheries research project. An obvious project would be to look at the Nosivolo fishery in detail - estimating the total effort, the total catch of different groups and monitoring the impacts of conservation measures (particularly fishing bans and protected areas). This can be estimated by monitoring fishermen's individual catches and traded fishes at various points and a good technique is to involve local fishermen in this process (Ticheler et al., 1998).

3. Management report

3.1. Training and techniques

3.1.1. Madagascar is rather isolated from the rest of the world partly due to the expense of air tickets. Consequently, contact between DBA scientists/ students and international scientists seems to be largely confined to visits by international scientists. Exposure to certain field collection techniques is therefore not bad but the latter part of scientific studies e.g. laboratory techniques and the process of analysing and writing up data does not seem to be well experienced. Attendance at conferences appears to be a rare event for only senior scientists. The best situation would be for DBA scientists and students to visit foreign laboratories to conduct collaborative research and to attend conferences. A good fish conference to attend would be the next PAFFA conference in Addis Abbaba, Ethiopia in 2008 (http://www.sc.aau.edu.et/paffa2008.html).

3.1.2. In 2005 I suggested that biological studies of certain key fishes were needed to help with conservation planning for the Nosivolo project. During the planning of the 2007 trip I suggested that biological analyses be conducted to start this process. I was unaware that DBA had already started biological studies although I am still not clear on the progress of these studies. Consequently, instructions on many aspects of biological methods, as stated in my TOR, were not needed.

3.1.3. During the 2007 expedition I have demonstrated some basic field methods e.g. DNA tissue collection, fish preservation, otolith extraction and live fish photography. Notes on some of these are provided in Appendices 4-6 and as Powerpoint Presentation files on an accompanying CD-ROM. These methods need to be practiced and carried through to completion of work for researchers to become proficient.

3.1.4. Otolith preparation and reading of otolith rings for age analysis has not been done at DBA due to lack of expertise. This was not demonstrated in Madagascar but notes are provided in Appendix 5. Equipment to carry out this procedure is being assembled and will be posted to DBA. Reading of otoliths, however, is particularly difficult and is certainly helped by experience. The best situation would be for students from DBA to visit SAIAB/Rhodes University (Department of Ichthyology and Fisheries Science) in Grahamstown to learn this technique under the supervision of specialists.

3.1.5. Live fish photography is a simple but valuable field technique which enables comparisons of fish colouration from different sites (Fig. 10). This is particularly useful for groups exhibiting geographical colour variation as occurs in the bedotids (Figs. 6, 7 & 11).

Figure 10. Photography set up for live fishes.

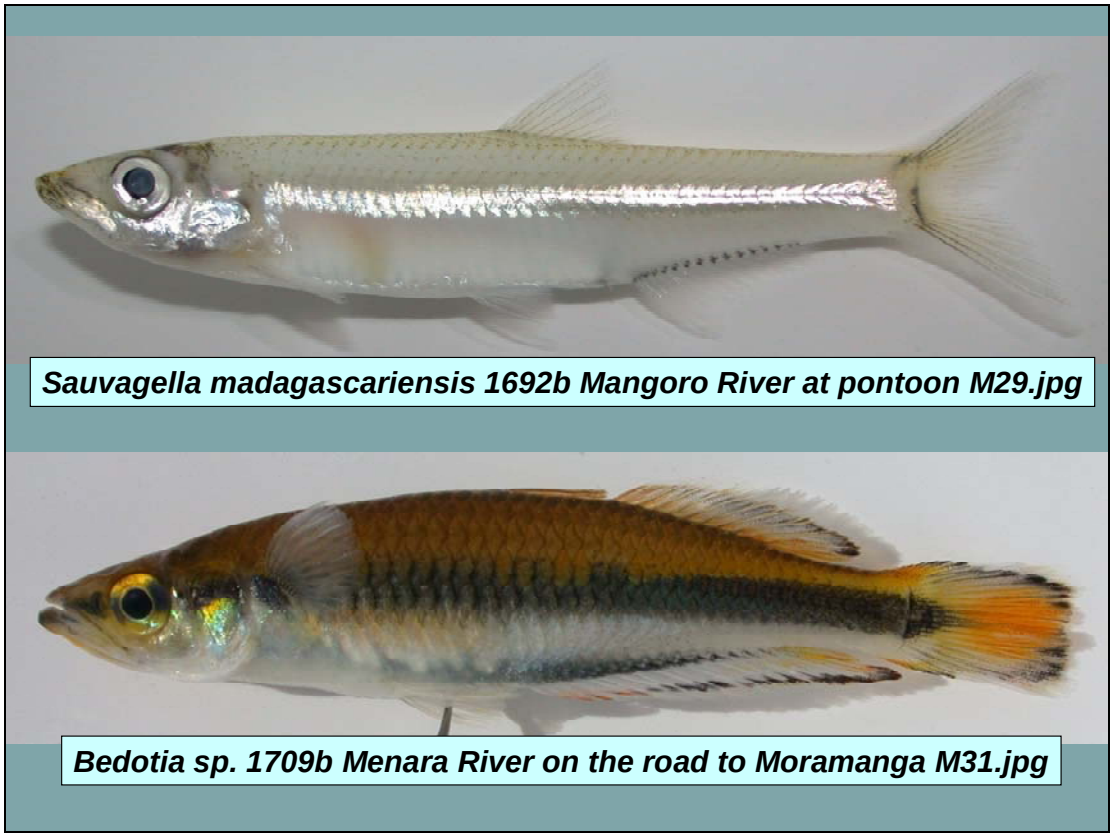

Figure 11. Photographs of fishes taken at preservation and several hours after preservation indicating the value of recording live colouration.

3.2. Strengths and weaknesses of research capacity

3.2.1. As I understand the research plan for the continuing Nosivolo project the DBA will be responsible for conducting most of the research. The principal investigators are Dr Noro Raminosoa and Mr Tsilavina Ravelomanana.

Strengths.

3.2.2. Researchers are familiar with local conditions and have a good knowledge of the Nosivolo region and its fishes. Researchers have experiences in other areas of Madagascar and thus can put the Nosivolo fauna and fishery into a broader research context.

3.2.3. There is good access to students to help with working on smaller projects and processing of material and data.

Weaknesses.

3.2.4. Lack of capacity and skills. Only two freshwater icthyologists are able to work on the Nosivolo project. One is, I understand, not far from retirement and the other is yet to qualify for his PhD. In addition, both have teaching commitments to the university and other on-going projects and so even their

time is limited. Presumably the bulk of the Nosivolo work is therefore going to be conducted by a team of students who have limited skills and experience. For certain methods there appear to be limited or no expertise in DBA e.g. - age and growth estimation using otoliths, sectioning of gonads, various genetic and morphological methods appropriate for studying population level variation. Training is needed to develop these skills.

3.2.5. Lack of equipment or use of old equipment. During the 2007 it was obvious that DBA lack much of the basic equipment needed to conduct efficient fish surveys. Ideally the following equipment should be used by the Nosivolo research team. This equipment should be well maintained and replaced as it gets damaged.

Fish measuring boards Seine nets of varied sizes with a central catch 'bag' and made from good quality knotless fish netting Varied hand nets Fyke (trap) nets GPS Digital camera Laptop computer	Electro-fishing gear (Samus) Chest high waders Diving masks and snorkels Dive torches Traps – e.g. locally made prawn traps Dissection kit Waterproof labelling paper Epindorf vials for DNA tissues

3.2.6. Lack of access to information about past research and collections of Madagascan fishes. During the course of this project I have had difficulty getting information about all the research collections made within the Mangoro River system. This has hampered my ability to understand fish distributions within the system and thus plan the research. Ideally information should be readily accessible in a database and GIS format. SAIAB has developed such a system for southern Africa and it is an incredibly useful research and conservation tool (Fig 12). SAIAB could help with the development of a similar system for either the Nosivolo or the whole of Madagascar.

3.2.7. One factor hindering taxonomic research is access to comparative museum material. At present there are a lot of fish collections at DBA in drums and bottles but these are unsorted and not accessible and infact their condition is unknown. A well curated fish collection is needed to be able to conduct taxonomic studies. A start on this could simply be organising existing samples - bottling, transferring formalin specimens into alcohol, labelling samples, photographs of material and listing all of these various items into a database. Once this has been done the next logical step would be to get information about collections at other institutions and perhaps get photographs and x-rays of significant specimens e.g. types. The collection could then act as a first point of contact for scientists researching the fish fauna of Madagascar. SAIAB can help with establishing a fish collection and we have brought the database system (Specify) we use to DBA. All of

SAIAB's Madagascan samples are already in this Specify system. Training in the use of the system is needed. I understand there has been money given for establishing a fish collection from the MacArthur Foundation (grant to Dr Noro Raminosoa).

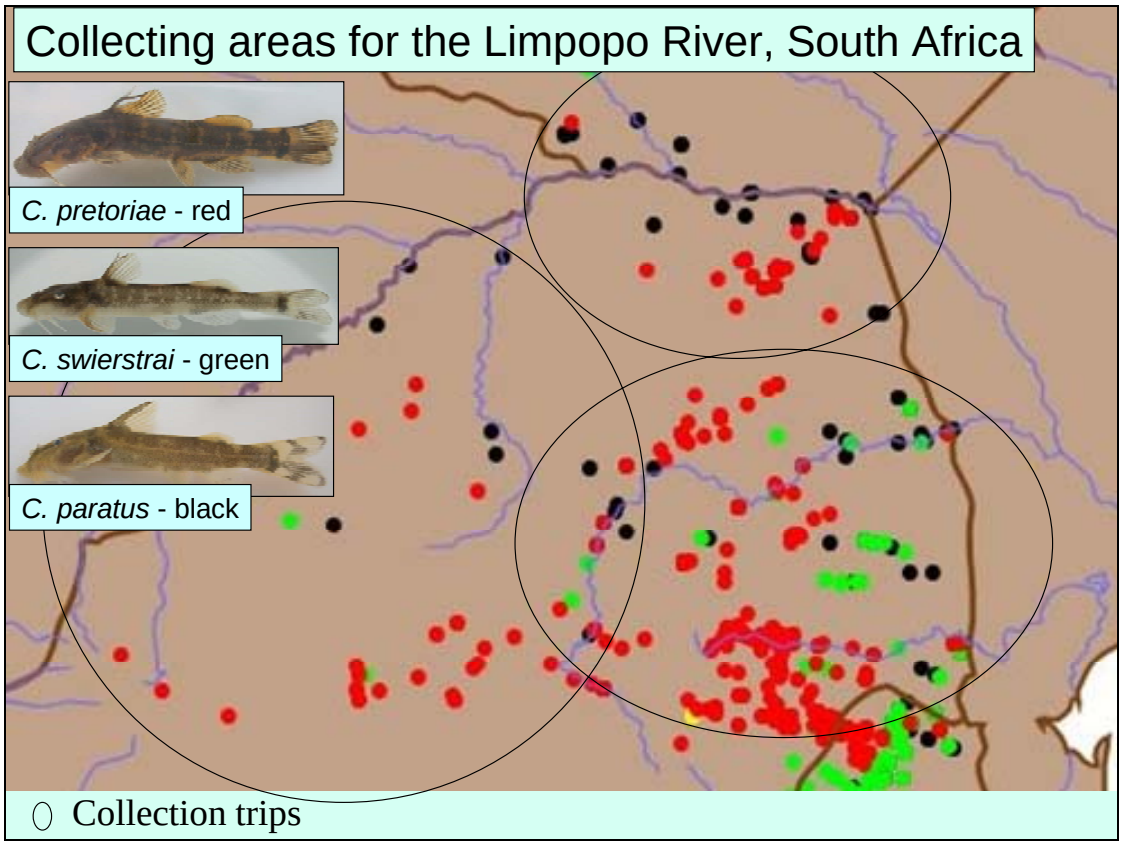

Figure 12. A map showing the distributions of three southern African *Chiloglanis* catfishes - generated from the SAIAB/IUCN programme.

Recommendations

3.2.8. Training of staff and students is needed to improve existing skills and introduce new techniques e.g. various basic fish biology techniques, genetic methods, museum curation techniques, GIS. Ways to do this could be through inviting scientists to Madagascar or sending students to appropriate research laboratories to learn skills. SAIAB and the Department of Ichthyology at Rhodes University are willing to help in this process if required either with formal co-supervision of students or in short ad-hoc training courses.

3.2.9. The Nosivolo research team needs to be better equipped. In addition to the above list an electro-fisher and fyke nets would be valuable and relatively cheap items.

- A good electro-fisher is produced by SAMUS (Poland) and is available via their web-site (http://www.electro-fisher.com/home.html). This device is small and light and is powered with a small motorbike battery and is

suitable for carrying over rough terrain. Certain modifications to improve the efficiency of this device are given in Appendix 6.

- Fyke nets are available via various companies world-wide. A good southern hemisphere source is TL Netmakers in Australia (http://www.tlnetmaking.net.au/index.html). Small fyke nets are probably ideal for a conservation monitoring program in the Nosivolo as they are easily set and typically do little harm to fishes so that after measuring and counting fishes can be released.

3.2.10. Organise all museum samples and put all associated information into a database system. Develop an information/ GIS system for the museum and other collection records for aiding all future research projects. SAIAB has been developing one for southern Africa for many years and can help with this if needed.

3.2.11. Museum collections. The ideal place for holding a fish collection is a museum and not a university. University collections world wide have a habit of being discarded when interested individuals retire or leave. In contrast, museums are tasked with looking after collections as part of their core operations. Thus the ideal long-term goal should be the funding and training of natural history museum staff.

3.3. Strengths and weaknesses of the current conservation capacity

3.3.1. The May 2007 expedition into the upper reaches of the Nosivolo catchment and other sections of the Mangoro system has given me a much broader understanding of the fishes of the Nosivolo River, their distributions and variation and the impacts affecting them than I gained in 2005. Juliette Velosoa and Tsilavina Ravelomanana have aided this process significantly by sharing their knowledge freely. The trip has also brought me up-to-date on the progress of the Nosivolo conservation programme in particular for DW and partly for DBA projects. In brief, some of my impressions are as follows.

Strengths

3.3.2. DW staff has an excellent rapport with the local people in the Nosivolo catchment. There has been significant progress since 2005 with the establishment of fishing associations and protected areas. In several villages where DW staff has not been active they were asked to come in and work - an indication that they are well known and respected.

Figure 13. Juliette Velosoa (DW) talks with elders and fishermen of Ambalamena village.

Weaknesses

3.3.3. Capacity and skills. A possible weakness is that DW conservators have not received formal training in environmental education. Also the number of conservation officers may not be enough. Various environmental education courses are available world-wide and it may be worth considering enrolling DW staff on some EE programs for further training. These could be higher degrees, diploma courses, short courses. Rhodes University's Education(http://campus.ru.ac.za/index.php?action=category&category=1453) department runs several courses that may be appropriate although there may be better examples elsewhere. If certain recommendations below are considered the numbers of DW staff employed in the Nosivolo will have to be increased.

3.4. General observations, comments and recommendations

3.4.1. Fishing impacts and associations. In 2005 I did not gain an appreciation for how efficient local fishermen were nor did I understand the fishing effort in the Nosivolo system. Consequently, I was sceptical that fishing could be the major reason for *O. polli* extinctions in upper catchments such as the Sahanao and Sandranamby Rivers. Having observed our fisherman helper, Celestin Randany (Fig. 14), over the two week expedition in May 2007 I have revised my opinion on this matter. Although I still have no system-wide data on fishing effort I consider that fishing activities are likely to be a major factor for *O. polli* rarity/extinctions in tributary streams. Several factors that are probably important are low productivity of river systems and thus small fish populations to start with, habitat specificity and territoriality of key fisheries species, high levels of fishing skill and effort, night fishing, fishing during breeding seasons and small mesh sizes of nets resulting of harvesting of sub-adults.

3.4.2. An assessment of the status and impacts of the fishery would be a worthwhile student study particularly if areas of fishing and non-fishing could be compared. An initial step would be the description/estimation of the levels of fishing at villages between Ambodivoara and Marolambo on a monthly basis. It is possible to set up a monitoring system that involves the fishermen themselves recording a large proportion of their catches (Ticheler et al., 1998). The added advantage of such an approach is that they should then become part of the assessment process and have a greater appreciation of the outcomes. A suggested catch data form was given in my 2005 report and in addition to this an assessment of the numbers of people fishing and the number of gear at each village would be needed. Monthly data collection for all fishing months would be necessary. A current project at SAIAB, which may be helpful in developing plans in the Nosivolo, shows methods of assessing water quality and environmental education involving local residents (Appendix 7).

Figure 14. Celestine Randany, using a thrown net for sampling fishes in the upper Tsarakanja Stream (site M12), 25/05/2007.

3.4.3. Further reduction of fishing effort, in smaller tributaries and in the mainstream Nosivolo River in cascade/rapid habitats, is probably needed if indigenous fishes are to be better protected. Current non-fishing areas are an excellent start but additional measures are suggested as ideas to discuss with communities.

- Expand existing protected areas
- Establish additional protected areas.
- Establish seasonal non-fishing areas at important breeding sites.
- Extend non-fishing periods to encompass a greater proportion of the breeding season rather than simply the peak breeding period.
- Stop or reduce the practice of fishing at night with throw nets.
- Increasing throw net mesh sizes to the point where only sexually mature fishes are being captured.

3.4.4. The two species on which mesh size restrictions should be based are the cichlids *O. polli* and *P. katria*. These are the largest and are probably the most impacted fisheries species. I will need fish samples for morphological measurements in order to calculate optimum mesh size estimates.

3.4.5. Numerous fishing associations have been established in villages along the Nosivolo River since 2005. These associations have established non-fishing periods and zones and in some villages catch data has also been collected. These are very positive developments. The process of establishing fishing associations is time consuming but needs to continue where possible. Analysis of catch data is now needed and results should be fed back to fishermen and villages so that they see the worth of their efforts and begin to see the trends.

3.4.6. Fishing associations are a potential way to introduce various environmental education messages into communities. An obvious example is improving agricultural methods and developing better sanitation so as to reduce soil erosion and river sedimentation and to improved water quality.

3.4.7. Protected areas. Through the efforts of DW several large (up to 3km) sections of the mainstream Nosivolo River, incorporating valuable fish habitats, have been established as non-fishing, protected zones by local Nosivolo residents. Some villages have imposed more general long-term bans on fishing in their areas. This is an impressive achievement by DW and local communities and they are to be congratulated on this. This indicates DW's methods are effective and that local communities are committed to solving the problems of declining fish stocks.

Figure 15. Part of the extensive (approximately 3km) protected non-fishing area on the Nosivolo River upstream of the village of Anosy Rahindy.

3.4.8. The next step should be to map the locations and extent (upper and lower limits) of PA's using GIS. An analysis of the distribution of PA's in the Nosivolo then needs to be made and gaps identified. This will enable the identification of additional PA's for the future. Fish and perhaps other important endemic aquatic organisms could be involved in this GIS analysis.

3.4.9. Feedback to local communities could be made at this point. This will show villages where their PA fits into the larger scheme of the Nosivolo conservation project and how their community is helping. Perhaps a poster/map showing these could be made for distribution to villages?

3.4.10. Communities could also be encouraged to consider additional conservation ideas e.g.:

- Conserving all biota in protected areas;
- Increase the numbers of PA's;
- Expand the concept of PA's to include a broader range of wetland types; and
- Protect riparian buffer strips along the entire river system.

3.4.11. When developing new PA's a more holistic concept of wetland conservation should be considered. Ideally PA's should include a range of wetland habitats e.g. small upland streams, upland swamps and seepage zones, larger tributaries as well as additional mainstream Nosivolo sections. Some of these wetlands will be above natural distribution limits of indigenous freshwater fishes and may well be important for some aquatic invertebrates and amphibians. Protected areas should also encompass protection of terrestrial vegetation and animals.

3.4.12. Additional potential sites for protection, based on the presence of certain fishes, are as follows.

- Upper tributaries where *O. polli* occurs e.g. Manandriana and Maintimbato rivers.
- Upper tributaries where *O. polli* is considered to have been fished to extinction. These rivers (e.g. Sahanao and Tsarakainja rivers) may still harbour low numbers of *O. polli* which could recover if fishing pressure is reduced.
- Tributaries where unique populations seem to have 'strongholds' e.g.:
    - the upper Nosivolo River above Ambodivoara which contains a 'blue' form of *Rheocles* cf. *sikorae*;
    - the Manandolotra River where *Rheocles lateralis* seesm to be common;
    - the Manombola River is the type loclity for *R. sikorae* and healthy populations still occur there; and

- the Sandrangato River is the type locaility for *R. wrightae* and healthy populations of this and another *Rheocles* (*R.* cf. *alaotrensis*) occur there.

3.4.13. Some potentially valuable areas that could be future PA's are not close to villages. An example was on the Nosivolo River downstream of Betampona village (Fig. 1). It was explained that this could not be protected as there was no one living there permanently. The logistics of establishing PA's away from villages should be considered. Perhaps "river guards" could be employed purely to look after PA's.

3.4.14. The presence of and distribution of other aquatic animals and plants within the Nosivolo system should be considered when planning future PA's. At present very little information on aquatic organisms except for fishes is available for the system. A possible way to rapidly develop inventories of key groups would be to run an AquaRap type expedition (Conservation International) as has been conducted in other poorly known but diverse regions (Alonso & Nordin, 2003).

3.4.15. Alien fishes. During the 2007 expedition we observed alien fishes in most water bodies from irrigation ditches and rice paddies above normal fish distribution zones through to the mainstream Nosivolo. The main species are *Xiphophorus maculatus* (Fig. 16), *Gambusia holbrooki* and several tilapiine cichlids (the identities of these are I think *Oreochromis mossambicus*, *Tilapia rendalli* and *T. sparrmanii*). These are much more widespread than I had realised in 2005. At that time I thought it likely that there were tributaries without alien fishes present and that alien eradicaton could be a feasible option for indigenous fish community rehabilitation. I now regard that as an unlikely possibility given the abundance and widespread distributions of alien fishes. Thus ideas of river rehabilitation expressed in my 2005 report are probably not feasible.

3.4.16. Alien fishes in the Nosivolo have, so far not caused extinctions of indigenous species. However, there are far worse alien predators are in the greater Mangoro system e.g. *Micropterus* sp., *Channa striata*. The latter is known from the upper Mangoro system around Ambotavy (pers. com. Dr J. Rall) and was collected by us in the Pangalane canal system on this trip near Mahanoro (Fig. 17). The spread of these predatory species upstream into the Nosivolo River should be slowed by numerous large cataracts/cascades but ultimately their penetration upstream is probable. *Channa striata* will almost certainly result in extinctions of indigenous species once fully established in the Nosivolo. Movement of these alien predatory fishes by people for aquaculture purposes should not be allowed and local people need to be informed that such moves would be detrimental to fisheries. This needs to be urgently addressed by perhaps producing a poster informing people not to move fishes around.

Figure 16. The alien cyprinodont, *Xiphophorus maculatus*.

Figure 17. The alien predator *Channa striata* collected at Mahanoro.

3.4.17. Soil erosion. Erosion of soil within the Nosivolo catchment appears to be high (Fig. 2). This has resulted in the sedimentation of considerable sections of the Nosivolo River and many of it's larger tributaries. Sedimentation results in the reduction of wetted area (surface area of river bed) as complex rocky habitats are converted into simple sandy runs. The rivers are transformed from rocky habitats harbouring sunstantial algal and invertebrate communities to sand substrate communities of lower diversity and biomass. Water turbulence and oxygenation is also reduced. Thus the productivity of the river and its ability to cope with pollution are significantly reduced.

3.4.18. Two major factors associated with high levels of erosion from farm lands are the farming of very steep slopes and the cultivation of land right down to the waters edge. An immediate remedy to this problem would be to encourage local farmers to reduce cultivation of steep slopes and to leave buffer strips of riparian vegetation. A longer-term programme of erosion management, employing a catchment management specialist, should be considered.

3.4.19. Buffer strips along rivers will reduce erosion and provide a valuable source of food for fishes. Many indigenous fishes rely to a considerable extent on terrestrial insects falling into the river for food (Loiselle & Stiassny, 2003). Buffer strips should not be confined to protected areas but should be the norm for the entire length of the river. The buffer strip width will need to be negotiated with local people but should be greater where high gradient slopes occur and they should start at the top of banks and not the waters edge.

Figure 18. Steep river banks tilled right to the waters edge result in massive levels of erosion.

3.4.20. Gold mining was observed first hand in 2005 around Marolambo (Bills, 2005). On this trip we did not see any mining activities although we were offered gem stones so certainly activities are continuing. Aluvial mining, particularly uncontrolled artisanal mining can be devastating to aquatic communities as huge amounts of sediments are washed into rivers. From a river conservation perspective these activities are not compatible with maintaining a productive fishery, high biodiversity or high water quality for good human health. If possible mining activities should be stopped entirely.

Figure 19. Gold mining activities in the Nosivolo River near Marolambo (November 2005).

3.4.21. Human health in the Nosivolo catchment appears to be poor. High numbers of children were observed throughout our trip coughing, sniffling or with distended abdomens. A general program aimed at improving at least child health through vaccinations, provision of vitamins, would be a good start.

3.4.22. Information from the Marolambo clinic in 2005 indicated high levels of Bilharzia. This parasite is transmitted through urine into water and there is a secondary snail host. As well as treating infected people the cycle of people urinating in the river needs to be stopped in order to eradicate the problem. Education about the disease through schools and a simple poster is suggested. If possible a catchment wide treatment program should be started although treatment would be expensive. If eco-tourism ventures e.g. canoeing or rafting are being considered to help the economy of the Nosivolo the eradication of bilharzia will need to be prioritised.

3.4.23. Access to clean drinking water is a basic human need. The lack of proper sanitation in most villages and the way the rivers are used (washing in rivers) are resulting in water quality deteriorating as one travels down the system. Behaviour of residents should change and suggestions are as follows.

- Houses and or villages establish specific dump sites and regularly burn and or compost rubbish.
- Properly constructed 'long-drop' toilets should be constructed.
- A well building program should be started, even for villages next to rivers.
- Associated with wells should be facilities for washing clothes (e.g. concrete basins, soak away drains).

Residents are unlikely to simply make such changes and so a specific project, run by DW/CI needs to be initiated if these changes are to have a long-lasting effect. Perhaps the best method would be to start in one village and show other village elders as its success becomes clear.

Figure 20. Animal pens wash waste directly into a tributary stream. Poor water quality is considered a factor in poor child health.

3.4.24. According to aquarium literature many of the indigenous species are particularly sensitive to poor water quality (elevated nitrates, low oxygen levels, increased bacterial loads). For example, Songatana (*O. polli*), the flagship species for this project, has proved extremely difficult to transport and keep successfully in aquaria.

3.4.25. Multiple impacts. Typically there are numerous impacts in aquatic systems and these usually work in synergy ie. impacts work together and increase their overall effect. An example of how this can work is where there is sedimentation or alien predatory fishes or both. If there is sedimentation

alone then a portion of the original habitat (crevices/refugia) is lost and food is reduced. This may result in reduced growth, recruitment, breeding success and thus a reduced population size but usually not extinction. With alien fishes alone there could be a degree of predation but it is possible for a portion of the indigenous fish population to survive by hiding in crevices at least prolonging the period of co-existence with the alien species. Where there are sedimentation and alien fish predators indigenous fishes have nowhere to hide and usually complete extinctions of populations occur rapidly. As impacts increase this situation becomes more complex.

3.4.26. Where there are multiple impacts, conservation actions aimed at affecting single impacts (e.g. fishing effort) are unlikely to have high success. An example was clearly seen in Ambodinonka where the villagers had imposed a long term fishing ban of several years. Unfortunately, the river is a simple sand substrate, having been inundated by sediments, and harbours little life. Continued bans on fishing in this area will result in little improvement in fishing unless sedimentation is reduced and the original rocky habitat is restored. People need to understand this concept as there may be a tendancy to blame continued poor fishing on poor advice from conservators.

3.4.27. The waters in the Nosivolo catchment are very low conductivity (Table 2) and thus fish productivity in pristine rivers was probably relatively low and not conducive to high fishing pressure. These impacts are likely even greater in smaller streams where the volume of water flow and the habitat surfaces are less. Thus tributary systems are probably more sensitive to impacts than the main stream Nosivolo. This should be factored into protected area management.

3.4.28. River health program. A broad ranging human-river health program is suggested to address all these above issues/impacts. I realise this is a significant expansion of the existing project but I don't think that the present efforts, good as they are, will have the desired long-term goal of improving fish conservation in the Nosivolo River. Such a program needs to initiate broader catchment conservation measures, address certain key human health issues and establish a long-term monitoring system for assessing catchment 'health'.

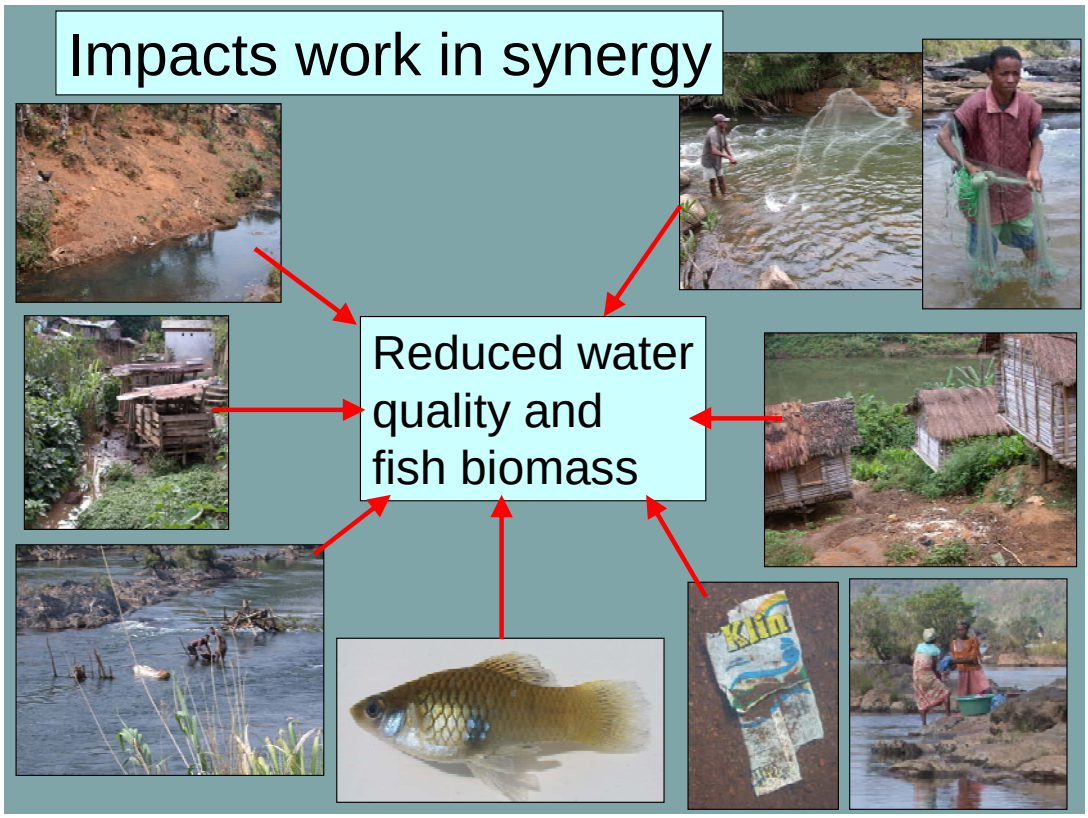

Figure 21. Multiple impacts within the river system work in synergy to create an overall greater impact on water quality and indigenous fish stocks.

Figure 22. A program of river health is suggested to address issues of soil erosion, riparian vegetation, human health and fish stocks.

3.4.29. I am concerned that I have suggested reducing fishing efforts and putting aside lands for conservation and that local people need some kind of compensation for not using their resources. Possibilities could be developing a variety of small businesses based on small-scale harvesting of other resources in a sustainable way. Examples are as follows.

- River safaris and or white water rafting above Ambodivoara.
- Butterfly farming – producing crysalises, eggs and pinned buterflies for the export trade and tourist market. Butterfly tourists may be a possibility too.
- Plant harvesting and cultivation e.g. ferns for the horticultural trade – export market.
- Farming aid. The diversity of anmial and plants cultivated in the Nosivolo appeared to me to be low. Stock health also appeared to be poor. An active programme aimed at improving the variety of – animal stock and plant strain improvement, seed imports, stock an dplant diversification, prawn aquaculture, husbandry horticultural training

Specialists would be needed to help develop these businesses.

3.5. Potential future role(s) that SAIAB could play.

Scientists at SAIAB have a range of skills in fish taxonomy and systematics, ecology and fisheries (http://www.saiab.ru.ac.za/). It is possible we can help with the Nosivolo program in a variety of ways and some are as follows.

- Helping equip the program.
- Training of students and staff in key research skills.
    - Ad-hoc, short courses.
    - Long-term co-supervision of students (Honours, MSc and PhD's).
- Research projects - either on our own or in collaboration with DBA/DW/CI.
    - Exploratory surveys.
    - Population level analyses using morphological and genetic methods.
    - Development of a mapping project for museum records - Nosivolo/Madagscar.
- Helping develop a museum and train staff in curation skills.

There is considerable scope for involving associated institutions, particularly different departments at Rhodes University, in various other sub-projects and training e.g.

- Library exchanges - training of librarians, improving literature holdings, and
- Environmental education courses for DW staff.

4. Plans for SAIAB's continued involvement 2007-2008.

Plans for SAIAB's continued work in Madagascar needs to be discussed after this report has been examined by Madagascan partners. My own involvement revolves around being able to ensure good quality research and collections are secured. The kind of work I'd like to do will involve the examination of samples in the laboratory and at present no collections have been sent to SAIAB. This will have a significant impact on future research work and collaboration and needs to be seriously discussed by Madagascan authorities.

5. Acknowledgements

All Durrell Wildlife (DW) and DBA staff I have had contact with during the 2005 and 2007 Nosivolo expeditions have been tremendously helpful. In particular, Juliette Velosoa, Tsilavina Ravelomanana and Richard Lewis have made my work productive and enjoyable. Tsilavina Ravelomanana has worked energetically in the field and has shared his much greater knowledge of Madagascan fishes openly with me. This has enabled me to gain greater insights into the fishes and their distributions in eastern Madagascar and has significantly improved this report. Our two fisheries guides Celetin Randany and Randriamantena Bernard worked hard, expertly collected fishes and also shared their knowledge of the fishes of the Nosivolo River with us. The residents of the Nosivolo River were always hospitable and helpful and I hope this report in some small way helps them to improve their environment. Dr Frank Glaw (Zoologische Staatssammlung, München, Germany) identified and provided information on the water fall frog. Vusi Mtombeni prepared otoliths of *P. katria* at SAIAB and demonstrated methods for reading otoliths.

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Appendices.

Appendix 1. R. Bills' itinerary during the May-June 2007 visit.

Day	Activity	Sites RB07M
May 17	Travelling Grahamstown – Johannesburg	
18	Travelling Johannesburg – Madagascar	-
	Talk & discussions with DW, DBA, CI at CI	
19	Meeting at Durrell Wildlife office, organising gear for fieldwork	-
20	Discussions with J. Rall (Golder)	-
21	Fly Antananarivo – Sahakevo, walk to Ambodinonka	1
	Sampled at Sahakeo	
22	Sampled Manandriana River (day & night time) at Ambohitsara	2,5,6
23	Sampled Nosivolo River upstream of Ambodivoara	7-9
	Sampled Nosivolo River at Ambodinonka	
24	Walked to Tsarakanja, sampled river (night time)	10
25	Walked to Anosy Rahindy sampling enroute and at AR (night time)	11-13
26	Sampled Nosivolo at AR (daytime), walked to Betampona, sampled tributary enroute and Nosivolo at Betampona	13-15
26	Randriamantena Bernard – sampled Mangabe River at Ankiboka	3
27	Walked to Maintiambato River at Ambalamena, samling enroute	16,-18
28	Walked Ambalamena to Marolambo, sampling enroute	19,20,4
29	Sampled the Nosivolo and Sahanao Rivers near Marolambo	21,22
30	Drive Marolambo to Ambinanindrano sampling enroute	4, 23-27
31	Drive Ambinanindrano to Mahanoro sampling enroute	28-30
June 1	Drive Mahanoro to Moramanga collecting enroute	31,32
2	Drive Moramanga to Anosibe An'ala collecting enroute	33-35
3	Collecting around Anosibe An'Anala (Manombola River)	36-38
4	Collecting on Sandrangato River and streams near Ambotavy	39-41
5	Travelling to Antananarivo	
6-8	Discussions with DW, CI & DBA, reporting back on trip, report writing, sorting samples, visiting DBA, setting up Specify database	
8 & 9	Return Grahamstown	

Appendix 2. Fish photography in the field.

Equipment you need

Good camera with a macro function (you need to know how to operate the macro function so read the camera manual)
White tray – I use a ceramic dish as it doesn't scratch and is easily cleaned
Fine forceps
Clean water – I carry water (1 litre) with me into the field for photography
Formalin (10%)

Procedure – day time photography

Set up all gear ready to take the photograph – fill he tray with water, get your camera and forceps out
Do all the above away from lots of people as they will probably create dust that will go into your tray
Place the live fish to be photographed into formalin – chose specimens that will illustrate characteristics e.g. adult male / female colouration, juvenile colour pattern, parasites, deformities etc.
Wait for the fish to die (usually 2-3 minutes)
As soon as it stops moving remove it and place it in the photo tray
Take care not to damage the fins at this point – the fish can sometimes wriggle on being held by the forceps or the weight of the fish can pull it out of the forceps damaging the fin in the process.
If the fish lies on the bottom of the dish in the desired position then forceps are not needed – usually, however, the fish floats or rolls over and needs to be held down
Use the forceps to hold the fish under the water – I try and use the back pelvic fin but depending on the fish bouyancy you can use the anal or caudal fins
Try to ensure the fish does not have any air bubbles or dirt on it – picking the fish out of water and dropping it back in usually dislodges air bubbles.
Ensure there isn't dirt on the water surface – if there is pour water in and overflow the dish – this skims surface particles away.
Make sure the fish fins aren't sticking out of the water – often the pelvic fin will just touch the surface and cause a light 'high spot'
Switch the camera on and set it on the macro setting
Position the tray in full sunlight and if possible angle the fish so that shadows are reduced – head towards the sun
Take several photos – I take shots from different angles and zoom extents.
Check your photo is good immediately – this may be difficult in bright light – go into shade and zoom in to the picture – look at the focus on the fin rays and scales – if they are not good repeat the photography.
Check you have the camera on macro (some cameras power save and switch off after a few seconds – when they switch back on they don't always come back as they were previously set e.g. the macro may not be on
Keep the camera still during photography.
Record photograph numbers on the field data sheet immediately and try to ensure the fish specimen can be identified with the photograph (bottle it separately or label it).

- Night photography

Sometimes specimens cannot be photographed at site. If so try and photograph them as soon as possible after preservation e.g. that night. Follow most of the steps above plus the following.
If using tap water from a municipal supply ensure it does not cover the fish with small bubbles – let water stand for an hour to de-gas.
Illuminate the specimen so that the camera's auto-focus can function.
Make sure the flash is angled so that there is no flash glare – check photos immediately for this. If there is retake the shot with the flash angled further until you get a good result.

Photography in the field – a tributary of the Sahantsio River (site M28) where I photographed a *Bedotia* species.

Appendix 3. Fish collections data.

Madagascar - Nosivolo River fish surveys - November 2007

Site # M	Location	Species present	Total Formalin	DNA
1.1	Sahadinta River	*Xiphophorus maculatus*		
1.2	Sahadinta River at Sahakevo	*Rheocles wrightae*	3	1
1.2	Sahadinta River at Sahakevo	*Rheocles wrightae*		1
1.2	Sahadinta River at Sahakevo	*Rheocles wrightae*		1
1.2	Sahadinta River at Sahakevo	*Rheocles wrightae*		1
1.2	Sahadinta River at Sahakevo	*Xiphophorus maculatus*	1	-
2	Manandriana River	*Oxylapia polli*	2	1
2	Manandriana River	*Oxylapia polli*		1
3	Mangabe River at Ankiboka Village	*Rheocles wrightae*	3	1
3	Mangabe River at Ankiboka Village	*Rheocles wrightae*		1
3	Mangabe River at Ankiboka Village	*Rheocles wrightae*		1
3	Mangabe River at Ankiboka Village	*Ratsirakia legendrei*	1	1
4	Nosivolo River just below Marolambo	*Ratsirakia legendrei*	9	1
4	Nosivolo River just below Marolambo	*Ratsirakia legendrei*		1
4	Nosivolo River just below Marolambo	*Ratsirakia legendrei*		1
4	Nosivolo River just below Marolambo	*Ratsirakia legendrei*		1
4	Nosivolo River just below Marolambo	Yellow frog	1	1
4	Nosivolo River just below Marolambo	Green frog	3	1
4	Nosivolo River just below Marolambo	Green frog		1
4	Nosivolo River just below Marolambo	Green frog		1
4	Nosivolo River just below Marolambo	*Rheocles wrightae*	1	1
4	Nosivolo River just below Marolambo	*Ptychochromoides katria*	3	1
4	Nosivolo River just below Marolambo	*Ptychochromoides katria*		1
4	Nosivolo River just below Marolambo	*Ptychochromoides katria*		1
4	Nosivolo River just below Marolambo	*Oxylapia polli*	6	1
4	Nosivolo River just below Marolambo	*Oxylapia polli*		1
4	Nosivolo River just below Marolambo	*Oxylapia polli*		1
4	Nosivolo River just below Marolambo	*Oxylapia polli*		1
4	Nosivolo River just below Marolambo	*Oxylapia polli*		1
4	Nosivolo River just below Marolambo	*Oxylapia polli*		1
4	Nosivolo River just below Marolambo	*Xiphophorus maculatus*	2	-
4	Nosivolo River just below Marolambo	*Oreochromis mossambicus*	1	-
4	Nosivolo River just below Marolambo	*Oxylapia polli*	1	1
4	Nosivolo River just below Marolambo	*Ptychochromoides katria*	1	1
5.1	Nosivolo River at Ambodinonka	*Rheocles wrightae*	13	1
5.1	Nosivolo River at Ambodinonka	*Rheocles wrightae*		1
5.1	Nosivolo River at Ambodinonka	*Rheocles wrightae*		1
5.2	Nosivolo River at Ambodinonka	*Ratsirakia legendrei*	15	1
5.2	Nosivolo River at Ambodinonka	*Ratsirakia legendrei*		1

5.2	Nosivolo River at Ambodinonka	*Ratsirakia legendrei*			1
5.2	Nosivolo River at Ambodinonka	*Ratsirakia legendrei*			1
5.2	Nosivolo River at Ambodinonka	*Xiphophorus maculatus*		2	
5.2	Nosivolo River at Ambodinonka	*Gambusia holbrooki*		1	
6	Manandriana River at Ambohitsara	*Xiphophorus maculatus*		5	
6	Manandriana River at Ambohitsara	*Tilapia rendalli*		1	
6	Manandriana River at Ambohitsara	*Oxylapia polli*		6	1
6	Manandriana River at Ambohitsara	*Oxylapia polli*			1
6	Manandriana River at Ambohitsara	*Awaous aeneofuscus*	-		
6	Manandriana River at Ambohitsara	*Gambusia holbrooki*		6	
7	Nosivolo River above Ambodivoar	*Agonostomus catalai*		1	1
7	Nosivolo River above Ambodivoar	*Ratsirakia legendrei*		16	1
7	Nosivolo River above Ambodivoar	*Ratsirakia legendrei*			1
7	Nosivolo River above Ambodivoar	Green frog		2	1
7	Nosivolo River above Ambodivoar	Tadpole (large dark)		3	1
7	Nosivolo River above Ambodivoar	Tadpole (small light)			1
7	Nosivolo River above Ambodivoar	Green frog			1
7	Nosivolo River above Ambodivoar	Brown frog		2	1
7	Nosivolo River above Ambodivoar	Brown frog			1
7	Nosivolo River above Ambodivoar	*Awaous aeneofuscus*		1	1
7	Nosivolo River above Ambodivoar	*Ratsirakia legendrei*			1
7	Nosivolo River above Ambodivoar	*Ratsirakia legendrei*			1
8	Sahavie River above Nosivolo confluence	*Rheocles wrightae*		7	1
8	Sahavie River above Nosivolo confluence	*Rheocles wrightae*			1
8	Sahavie River above Nosivolo confluence	*Rheocles wrightae*			1
8	Sahavie River above Nosivolo confluence	*Rheocles wrightae*			1
8	Sahavie River above Nosivolo confluence	*Ratsirakia legendrei*		1	
8	Sahavie River above Nosivolo confluence	Green frog		1	
9	Nosivolo River	*Oxylapia polli*		2	1
9	Nosivolo River	*Oxylapia polli*			1
10	Tsarakanja Stream at Tsarakanja village	*Bedotia sp. 'nosivolo'*		9	1
10	Tsarakanja Stream at Tsarakanja village	*Bedotia sp. 'nosivolo'*			1
10	Tsarakanja Stream at Tsarakanja village	*Bedotia sp. 'nosivolo'*			1
10	Tsarakanja Stream at Tsarakanja village	*Bedotia sp. 'nosivolo'*			1
10	Tsarakanja Stream at Tsarakanja village	*Bedotia sp. 'nosivolo'*			1
10	Tsarakanja Stream at Tsarakanja village	*Xiphophorus maculatus*		8	
10	Tsarakanja Stream at Tsarakanja village	*Gambusia holbrooki*		5	
10	Tsarakanja Stream at Tsarakanja village	*Tilapia rendalli*		1	
10	Tsarakanja Stream at Tsarakanja village	*Ratsirakia legendrei*		1	1
10	Tsarakanja Stream at Tsarakanja village	Crab sp.		1	1
11	Tsarakanja Stream	*Ratsirakia legendrei*		1	1
12	Tsarakanja Stream	Green frog		3	1
12	Tsarakanja Stream	Green frog			1
12	Tsarakanja Stream	Green frog			1
12	Tsarakanja Stream	*Bedotia sp. 'nosivolo'*		2	1
12	Tsarakanja Stream	*Bedotia sp. 'nosivolo'*			1

13	Nosivolo River at Anosy Rahindy	*Gogo ornatus*		4	1
13	Nosivolo River at Anosy Rahindy	*Gogo ornatus*			1
13	Nosivolo River at Anosy Rahindy	*Gogo ornatus*			1
13	Nosivolo River at Anosy Rahindy	*Gogo ornatus*			1
13	Nosivolo River at Anosy Rahindy	*Awaous aenofuscus*		1	2
13	Nosivolo River at Anosy Rahindy	*Tilapia rendalli*		1	1
13	Nosivolo River at Anosy Rahindy	*Gambusia holbrooki*	-		
13	Nosivolo River at Anosy Rahindy	*Xiphophorus maculatus*		7	
13	Nosivolo River at Anosy Rahindy	*Bedotia sp. 'nosivolo'*		6	
13	Nosivolo River at Anosy Rahindy	*Bedotia sp. 'nosivolo'*			3
13	Nosivolo River at Anosy Rahindy	*Bedotia sp. 'nosivolo'*			4
13	Nosivolo River at Anosy Rahindy	*Bedotia sp. 'nosivolo'*			3
13	Nosivolo River at Anosy Rahindy	*Bedotia sp. 'nosivolo'*			4
13	Nosivolo River at Anosy Rahindy	*Ratsirakia legendrei*		7	1
13	Nosivolo River at Anosy Rahindy	*Ratsirakia legendrei*			1
13	Nosivolo River at Anosy Rahindy	*Ratsirakia legendrei*			1
13	Nosivolo River at Anosy Rahindy	*Ratsirakia legendrei*			1
13	Nosivolo River at Anosy Rahindy	Green frog		4	1
13	Nosivolo River at Anosy Rahindy	Green frog			1
13	Nosivolo River at Anosy Rahindy	yellow tree frog		2	1
13	Nosivolo River at Anosy Rahindy	yellow tree frog			1
13	Nosivolo River at Anosy Rahindy	*Rheocles wrightae*		3	1
13	Nosivolo River at Anosy Rahindy	*Rheocles wrightae*			1
13	Nosivolo River at Anosy Rahindy	*Rheocles wrightae*			1
13	Nosivolo River at Anosy Rahindy	*Oxylapia polli*		3	1
13	Nosivolo River at Anosy Rahindy	*Oxylapia polli*			1
13	Nosivolo River at Anosy Rahindy	*Oxylapia polli*			1
14	Tributary river above waterfall	*Agonostomus catalai*		2	1
14	Tributary river above waterfall	*Agonostomus catalai*			1
14	Tributary river above waterfall	Green frog		2	1
14	Tributary river above waterfall	Green frog			1
14	Tributary river above waterfall	*Ratsirakia legendrei*			-
15	Nosivolo River at Betampona beach	*Tilapia rendalli*			
15	Nosivolo River at Betampona beach	*Gambusia holbrooki*		2	
15	Nosivolo River at Betampona beach	*Xiphophorus maculatus*			
15	Nosivolo River at Betampona beach	*Bedotia sp. 'nosivolo'*		3	1
15	Nosivolo River at Betampona beach	*Bedotia sp. 'nosivolo'*			1
15	Nosivolo River at Betampona beach	*Bedotia sp. 'nosivolo'*			1
16.1	Nosivolo River downstream of Betampona	*Rana*-like frog		1	1
16.1?	Nosivolo River downstream of Betampona	Green frog		4	1
16.1?	Nosivolo River downstream of Betampona	Green frog			1
16.1	Nosivolo River downstream of Betampona	*Bedotia* sp. 'nosivolo'		9	1
16.1	Nosivolo River downstream of Betampona	*Bedotia* sp. 'nosivolo'			1
16.1	Nosivolo River downstream of Betampona	*Bedotia* sp. 'nosivolo'			1
16.1	Nosivolo River downstream of Betampona	*Bedotia* sp. 'nosivolo'			1
16.1	Nosivolo River downstream of Betampona	Green frog			1
16.1	Nosivolo River downstream of Betampona	Green frog			1
16.1	Nosivolo River downstream of Betampona	*Gambusia holbrooki*		1	
16.1	Nosivolo River downstream of Betampona	Oreochromis mossambicus		1	

17	Tributary stream	Green frog	1	1
18	Maintiambato Stream near Ambalamena	*Bedotia* sp. 'nosivolo'	30	1
18	Maintiambato Stream near Ambalamena	*Bedotia* sp. 'nosivolo'		1
18	Maintiambato Stream near Ambalamena	*Bedotia* sp. 'nosivolo'		1
18	Maintiambato Stream near Ambalamena	*Bedotia* sp. 'nosivolo'		1
18	Maintiambato Stream near Ambalamena	*Ratsirakia legendrei*	1	1
18	Maintiambato Stream near Ambalamena	*Rheocles wrightae*	23	1
18	Maintiambato Stream near Ambalamena	*Rheocles wrightae*		1
18	Maintiambato Stream near Ambalamena	*Rheocles wrightae*		1
18	Maintiambato Stream near Ambalamena	*Rheocles wrightae*		1
18	Maintiambato Stream near Ambalamena	*Oxylapia polli*	5	1
18	Maintiambato Stream near Ambalamena	*Oxylapia polli*		1
18	Maintiambato Stream near Ambalamena	*Oxylapia polli*		1
18	Maintiambato Stream near Ambalamena	*Oxylapia polli*		1
18	Maintiambato Stream near Ambalamena	*Xiphophorus maculatus*	1	-
18	Maintiambato Stream near Ambalamena	*Ratsirakia legendrei*	6	1
18	Maintiambato Stream near Ambalamena	*Ratsirakia legendrei*		1
18	Maintiambato Stream near Ambalamena	*Ratsirakia legendrei*		1
18	Maintiambato Stream near Ambalamena	Green frog	6	1
18	Maintiambato Stream near Ambalamena	Green frog		1
18	Maintiambato Stream near Ambalamena	Green frog		1
18	Maintiambato Stream near Ambalamena	Green frog		1
18	Maintiambato Stream near Ambalamena	*Bedotia* sp. 'nosivolo'	1	
19	Balakaza stream	Green frog		1
19	Balakaza stream	Green frog		1
20 changed from 19	Sandrakafoza stream at Ambalaherana	*Rheocles wrightae*	26	1
20	Sandrakafoza stream at Ambalaherana	*Rheocles wrightae*		1
20	Sandrakafoza stream at Ambalaherana	*Rheocles wrightae*		1
20	Sandrakafoza stream at Ambalaherana	*Rheocles wrightae*		1
20	Sandrakafoza stream at Ambalaherana	*Rheocles wrightae*		1
20	Sandrakafoza stream at Ambalaherana	Green frog	7	1
20	Sandrakafoza stream at Ambalaherana	Green frog		1
20	Sandrakafoza stream at Ambalaherana	River frog		1
20	Sandrakafoza stream at Ambalaherana	Tadpole		1
20	Sandrakafoza stream at Ambalaherana	Xiphophorus maculatus	3	
21	Nosivolo above the Sahanao confluence	Green frog	3	1
21	Nosivolo above the Sahanao confluence	Green frog		1
21	Nosivolo above the Sahanao confluence	Green frog		1
21	Nosivolo above the Sahanao confluence	*Ptychochromoides katria*	1	1
21	Nosivolo above the Sahanao confluence	Another waterfall frog sp.	1	1
22	Sahanao River above the non-fishing zone	*Ratsirakia legendrei*	1	1
22	Sahanao River above the non-fishing zone	*Rheocles wrightae*	22	1
22	Sahanao River above the non-fishing zone	*Rheocles wrightae*		1
22	Sahanao River above the non-fishing zone	*Bedotia* sp. 'nosivolo'	11	1
22	Sahanao River above the non-fishing zone	*Bedotia* sp. 'nosivolo'		1
22	Sahanao River above the non-fishing zone	*Rheocles wrightae*		1
22	Sahanao River above the non-fishing zone	*Rheocles wrightae*		1

22	Sahanao River above the non-fishing zone	Crab sp.		1	1
22	Sahanao River above the non-fishing zone	*Rheocles wrightae*			15
22	Sahanao River above the non-fishing zone	*Xiphophorus maculatus*		3	-
23	Marolambo market	*Ptychochromoides katria*		5	1
23	Marolambo market	*Ptychochromoides katria*			1
23	Marolambo market	*Ptychochromoides katria*			1
23	Marolambo market	*Ptychochromoides katria*			1
23	Marolambo market	*Ptychochromoides katria*			1
24	Nosivolo River near Ambanza village	*Ptychochromoides katria*		3	1
24	Nosivolo River near Ambanza village	*Ptychochromoides katria*			1
24	Nosivolo River near Ambanza village	*Ptychochromoides katria*			1
24	Nosivolo River near Ambanza village	*Agonostomus catalai*		1	1
24	Nosivolo River near Ambanza village	*Oxylapia polli*		3	1
24	Nosivolo River near Ambanza village	*Oxylapia polli*			1
24	Nosivolo River near Ambanza village	*Oxylapia polli*			1
24	Nosivolo River near Ambanza village	*Sicyopterus franouxi*		1	1
24	Nosivolo River near Ambanza village	*Oreochromis mossambicus*	-		
24	Nosivolo River near Ambanza village	*Bedotia sp. 'nosivolo'*	-		
25	Sahamoloto stream, north bank of Nosivolo	*Rheocles wrightae*		8	-
25	Sahamoloto stream, north bank of Nosivolo	*Rheocles wrightae*			1
25	Sahamoloto stream, north bank of Nosivolo	*Rheocles wrightae*			1
25	Sahamoloto stream, north bank of Nosivolo	*Rheocles wrightae*			1
25	Sahamoloto stream, north bank of Nosivolo	*Rheocles wrightae*			1
25	Sahamoloto stream, north bank of Nosivolo	*Rheocles wrightae*			1
25	Sahamoloto stream, north bank of Nosivolo	*Xiphophorus maculatus*			1
26	Manandoltra River	*Rheocles lateralis*		6	1
26	Manandoltra River	*Rheocles lateralis*			1
26	Manandoltra River	*Rheocles lateralis*			1
26	Manandoltra River	*Rheocles lateralis*			1
26	Manandoltra River	*Rheocles lateralis*			1
26	Manandoltra River	*Oreochromis mossambicus*		1	
26	Manandoltra River	*Gambusia holbrooki*		1	
26	Manandoltra River	*Xiphophorus maculatus*		1	
27	Sahantsio River below 'hotel'	*Awaous aeneofuscus*		2	1
27	Sahantsio River below 'hotel'	*Awaous aeneofuscus*			1
27	Sahantsio River below 'hotel'	Green frog		5	1
27	Sahantsio River below 'hotel'	Green frog			1
28	Stream south of Mangoro system	*Bedotia* sp.		24	1
28	Stream south of Mangoro system	*Bedotia* sp.			1
28	Stream south of Mangoro system	*Bedotia* sp.			1
28	Stream south of Mangoro system	*Awaous aeneofuscus*		1	
28	Stream south of Mangoro system	*Oreochromis mossambicus*		1	
28	Stream south of Mangoro system	*Gambusia holbrooki*		2	
29	Mangoro River at lower pontoon crossing	*Hypseleotris tohizonae*			1
29	Mangoro River at lower pontoon crossing	Mugilidae sp		3	1
29	Mangoro River at lower pontoon crossing	Clupeidae sp.		32	1

29	Mangoro River at lower pontoon crossing	Clupeidae sp.			1
29	Mangoro River at lower pontoon crossing	Clupeidae sp.			1
29	Mangoro River at lower pontoon crossing	Syngnathidae sp.		8	1
29	Mangoro River at lower pontoon crossing	Syngnathidae sp.			1
29	Mangoro River at lower pontoon crossing	*Glossogobius* sp.		3	1
29	Mangoro River at lower pontoon crossing	*Ambassis* sp.		2	1
29	Mangoro River at lower pontoon crossing	Gobiidae sp.			1
29	Mangoro River at lower pontoon crossing	Kuhulia rupestris		1	-
30	Pangalane canal system on beach	*Eleotris sp.*		3	1
30	Pangalane canal system on beach	*Eleotris sp.*			1
30	Pangalane canal system on beach	*Eleotris* sp. sharp nose		2	1
30	Pangalane canal system on beach	*Eleotris* sp. sharp nose			1
30	Pangalane canal system on beach	*Channa striata*	-		
30	Pangalane canal system on beach	*Tilapia sparrmanii?*	-		
30	Pangalane canal system on beach	*Cynoglossidae*	-		
30	Pangalane canal system on beach	*Carangidae*	-		
30	Pangalane canal system on beach	*Gerreidae*	-		
30	Pangalane canal system on beach	*Soapie?*	-		
30	Pangalane canal system on beach	*Tetradontidae*		1	-
30	Pangalane canal system on beach	Black perciform		1	1
30	Pangalane canal system on beach	*Eleotridae juveniles*		3	
30	Pangalane canal system on beach	*Eleotridae juveniles*			
30	Pangalane canal system on beach	*Eleotridae juveniles*			
31	Menara River on the road to Moramanga	*Bedotia sp.*		41	3
31	Menara River on the road to Moramanga	*Bedotia sp.*			1
31	Menara River on the road to Moramanga	*Bedotia sp.*			1
31	Menara River on the road to Moramanga	*Bedotia sp.*			2
31	Menara River on the road to Moramanga	*Bedotia sp.*			1
31	Menara River on the road to Moramanga	*Bedotia sp.*			3
32	Andranomandevy River at hot springs	Atherinidae sp.			1
32	Andranomandevy River at hot springs	Atherinidae sp.			1
32	Andranomandevy River at hot springs	Atherinidae sp.			1
32	Andranomandevy River at hot springs	Atherinidae sp.			1
32	Andranomandevy River at hot springs	Atherinidae sp.			1
32	Andranomandevy River at hot springs	*Kuhlia rupestris*			1
32	Andranomandevy River at hot springs	*Kuhlia rupestris*			1
33	Sandrangato River south of Moramanga	*no fish caught*			-
34	Mahamavo River, Anosibe An'ala road	*Rheocles wrightae*			1
34	Mahamavo River, Anosibe An'ala road	*Rheocles wrightae*			1
34	Mahamavo River, Anosibe An'ala road	*Rheocles wrightae*			1
34	Mahamavo River, Anosibe An'ala road	*Rheocles wrightae*			1
35	Manambolo River 2km from Anosibe An'ala	*Rheocles wrightae*			1
35	Manambolo River 2km from Anosibe An'ala	*Rheocles wrightae*			1
35	Manambolo River 2km from Anosibe An'ala	*Rheocles wrightae*			1
35	Manambolo River 2km from Anosibe An'ala	*Rheocles wrightae*			1
35	Manambolo River 2km from Anosibe An'ala	*Rheocles wrightae*			1
35	Manambolo River 2km from Anosibe An'ala	Green frog			1

35	Manambolo River 2km from Anosibe An'ala	Tadpole sp.		1
35	Manambolo River 2km from Anosibe An'ala	Green/Brown frog		1
35	Manambolo River 2km from Anosibe An'ala	*Xiphophorus maculatus*		
36	Manambolo River 3-4km above Mahela	*Rheocles wrightae*	18	1
36	Manambolo River 3-4km above Mahela	*Rheocles wrightae*		1
36	Manambolo River 3-4km above Mahela	*Rheocles wrightae*		1
36	Manambolo River 3-4km above Mahela	*Rheocles wrightae*		1
36	Manambolo River 3-4km above Mahela	*Rheocles wrightae*		1
36	Manambolo River 3-4km above Mahela	*Ratsirakia legendrei*	1	1
36	Manambolo River 3-4km above Mahela	Shrimp	34	1
36	Manambolo River 3-4km above Mahela	Shrimp		1
36	Manambolo River 3-4km above Mahela	Crab sp.	0	1
36	Manambolo River 3-4km above Mahela	*Xiphophorus maculatus*	3	
36	Manambolo River 3-4km above Mahela	Tadpole		1
37	Manambolo River 2km above Mahela	*Rheocles wrightae*	24	
37	Manambolo River 2km above Mahela	*Oreochromis mossambicus*	2	
37	Manambolo River 2km above Mahela	*Xiphophorus maculatus*	2	
37	Manambolo River 2km above Mahela	Crab sp.	1	1
37	Manambolo River 2km above Mahela	Tadpole	1	-
37	Manambolo River 2km above Mahela	Shrimp	2	-
38	Manambolo River in Anosibe An'ala town	*Oreochromis mossambicus*		
38	Manambolo River in Anosibe An'ala town	*Xiphophorus maculatus*		
39	Sandrangato River south of Moramanga	*Rheocles wrightae*		1
39	Sandrangato River south of Moramanga	*Rheocles wrightae*		1
39	Sandrangato River south of Moramanga	*Rheocles wrightae*		1
39	Sandrangato River south of Moramanga	*Rheocles wrightae*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Rheocles cf. alaotrensis*		1
39	Sandrangato River south of Moramanga	*Awaous aeneofuscus*		1
40	Ambodizana stream near Ambotavy	no fish collected	-	-
41	Tributary stream near Ambotavy	*Microctenopoma ansorgii*		2
41	Tributary stream near Ambotavy	*Tilapia rendalli*		
41	Tributary stream near Ambotavy	*Gambusia holbrooki*		
			623	286

Appendix 4. Otolith removal method.

There are several ways to remove otoliths for age analysis and for a thorough review of the broader subject see Dr Steve Campana's website:

http://www.marinebiodiversity.ca/otolith/english/pubs.htm

Having extracted a few otoliths from Nosivolo fishes the following method is effective (see also figures below).

1. Using a scalpel blade and on both sides of the head:
 - cut from the lower operculae forwards to the lower; and
 - cut from the upper operculae forwards until you hit bone.

2. Cut through the gular tissue freeing the lower jaw.
Force the head backwards exposing the upper mouth, throat and pharyngeal basket.

3. Cut the skin and tissue in front of the pharyngeal basket and scrape it backwards exposing the underlying bones of the lower head.

4. The largest otolith pair (Sagitta in cichlids) are in the swollen section of bone on the lower head. Chip the bone away here carefully with the sharp point of the blade. The otoliths should be visible. Take care not to push them into the brain when trying to extract them. Retrieve the otoliths using fine forceps or the tip of the scalpel blade. They are large in the cichlids and may be visible though the bone before extraction if you know where to look.

5. Once extracted place dry them with tissue paper and place them in a gelatin capsule. Label the capsule with a unique code so the fish and otolith and any other samples taken, e.g. DNA tissues, can be matched up together.

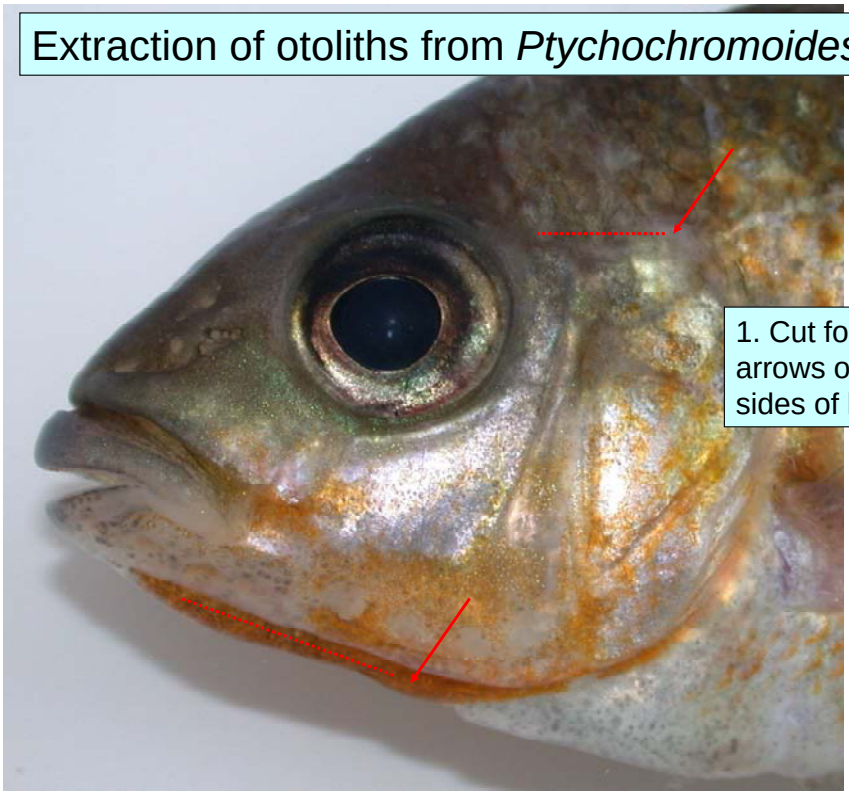
Preservation

The otoliths can be stored dry until needed.

Preserve the fish and keep for size and gonad analysis. At least photograph it as a final record but ideally accession specimens into a museum as permanent vouchers.

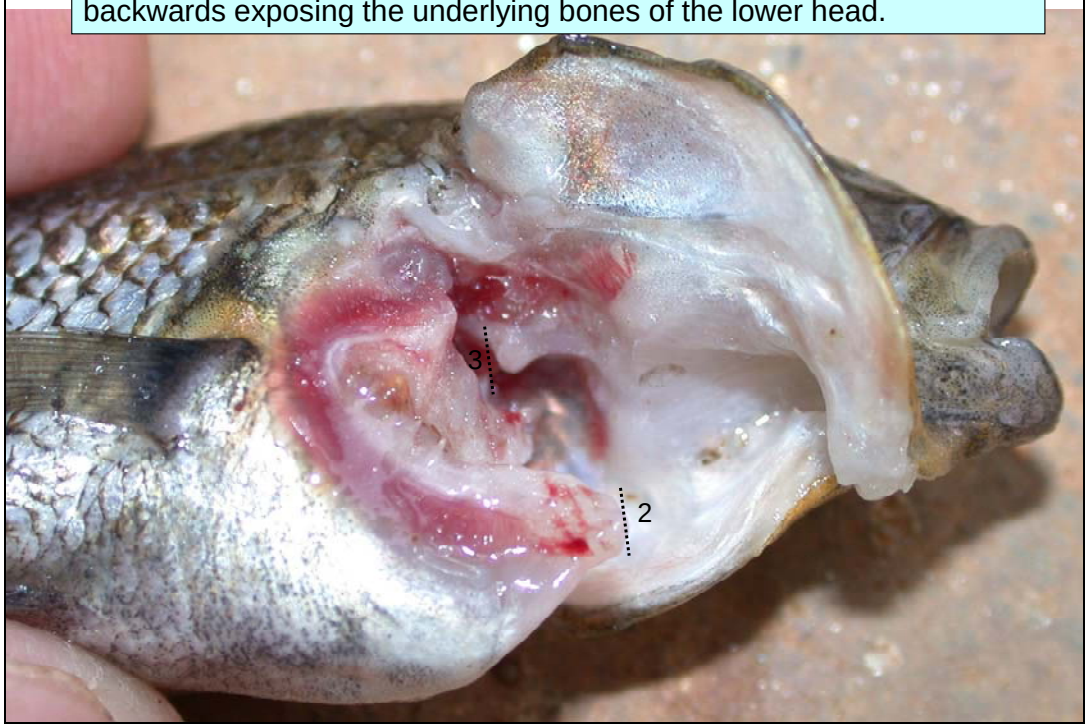
If you have no time to do the above procedure in the field fish can be preserved in the field in buffered 95% ethanol. I use sodium bicarbonate (baking soda) as a buffer and saturate the ethanol solution. Do not use formalin as this can make otolith removal from the tissues difficult and it acidifies and damages the structure of the otolith.

Extraction of otoliths from *Ptychochromoides katria*

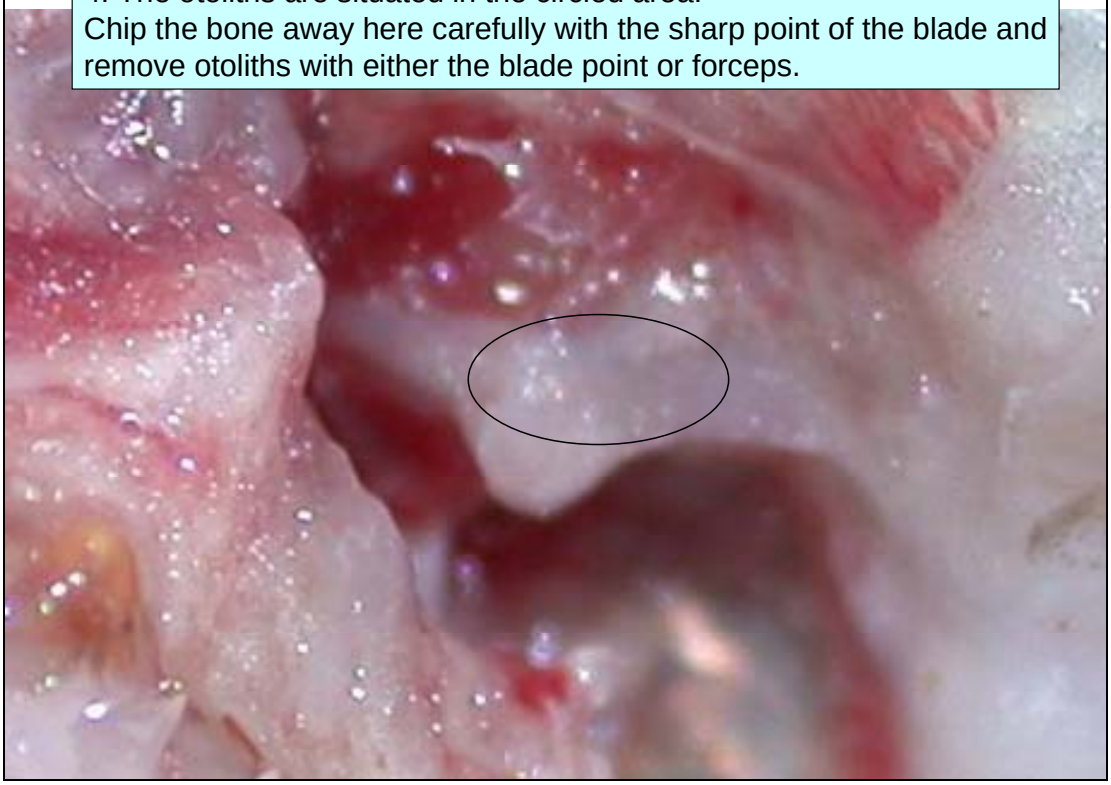


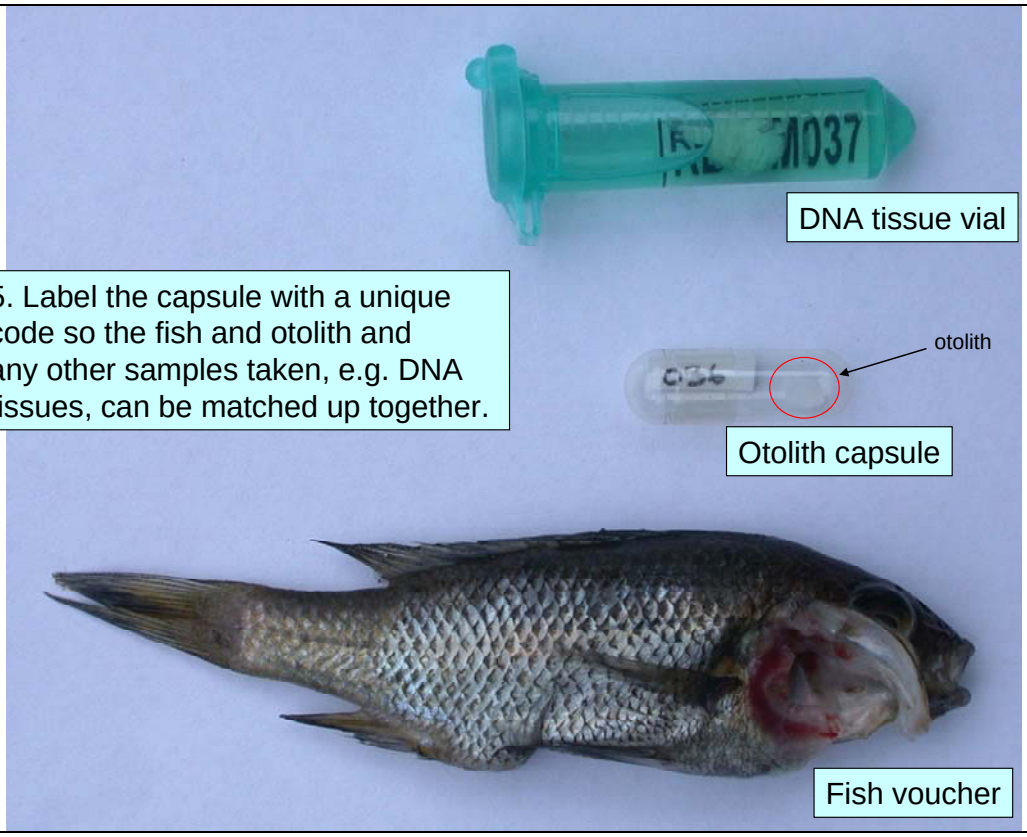
1. Cut forwards from arrows on both sides of head

2. Cut through the gular region freeing the lower jaw
3. Cut the skin and tissue in front of the pharyngeal basket and scrape it backwards exposing the underlying bones of the lower head.



4. The otoliths are situated in the circled area.
Chip the bone away here carefully with the sharp point of the blade and remove otoliths with either the blade point or forceps.





Appendix 5. Preparation of otliths for examination.

Equipment needed

Glass sheet roughly 20cm x 20cm	DPX mountant/glue
Plastic mould	Low power binocular dissecting
Plastic clothes pegs (3-4)	microscope and light source
Vaseline	Label paper and pencil
Cotton buds	Fine forceps
Polyester resin and hardener	Disposable plastic syringes (5-10ml)
Sand paper (100 & 800 grit)	Low power binocular dissecting
Glass microscope slides	microscope with light source

Procedure

1. Using cotton buds, smear Vaseline on the glass and inside the mould.
2. Clip the mould onto the glass sheet.
3. Mix the polyester resin and hardener in the ratio of 10 drops hardener: 125ml resin.
4. Pour into the mould, filling the cavities to the half way point.
5. Wait for the resin to set slightly (approximately 30-60 minutes).
6. Place a unique label into the mould identifying the otolith.
7. Place the otoliths into the moulds ensuring that they are horizontally placed. **NB** If otoliths are positioned obliquely reading of rings can be extremely difficult giving variable and unreliable results so this stage is critical.
8. Fill remainder of mould cavities with resin and leave to harden for 24 hours.
9. Remove from mould the next day. The resin can chipped and split so take care when doing this.
10. Sand down the blocks initially using #100 grit sand paper. Sand into the otolith until nearly ½ way through then start on the other side. Final sanding of otolith should be done carefully with a finer grade of paper (800-1000 grit).
11. Periodically check progress under a microscope by examining for ring visibility. Check both sides as often rings are better viewed from one side.
12. Once the resin-otilith 'block' is thin enough to see the rings in the otolith glue it to a glass microscope slide using DPX mountant. Completely cover the resin block/otolith slice in DPX. This should harden over the next 24-48 hours.
13. View rings under a microscope by altering light source power and angle and also the magnification levels. You can photograph at this point if necessary.
14. Repeat counts should be done and an average taken as the accepted age. Different people can also act as a check on accuracy.
15. The slides of otoliths and the fishes should all be kept in a museum as vouchers for the study so that future workers can check your work.
16. In the case of diadromous fishes otolith slices can be further used for isotope analysis to see when fishes move from sea to freshwaters.

Two excellent web-sites dealing with otolith research are as follows.

http://www.marinebiodiversity.ca/otolith/english/home.htm
http://www.cmima.csic.es/aforo/index.jsp

Appendix 6. Notes on improving the functioning of the Samus electric-fishing gear.

Improvements in operating Samus eletric-fishing gear (http://www.electro-fisher.com/home.html). Discussions held with Ian Cowx and Roger Bills in Grahamstown April 2007.

Anode
Separate anode and nets – have a hoop anode and a net
Anode should be a hoop not square or rectangular as current high points are generated at corners
Anode material should be copper or stainless steel rather than aluminium for better conductivity
Angle hoop so that the hoop can be fully immersed in water in shallow waters
Non-conducting poles should be used
If possible recess switch into pole
Ideally these should be hollow and cables run through centre to reduce the possibility of damage

Cathode
Needs to be thicker than the one supplied by Samus – about 5x thicker. Use 4-5 Samus cathodes or get a thicker cable e.g. battery cable in RSA
Prior to use wash the cathode in acetic acid/ vinegar overnight, also perhaps lightly sand down with glass paper
Float placed on cathode anterior to reduce snagging

Cables supplying power
Increase cable size and insulation - twin core covered cable was suggested – connect both cores together at both ends
'High' point for electricity production around the solder point – take it out but maybe silicone or araldite glue to stop fraying of lead

Waterproofing
Keep battery in a watertight tuperware container
Battery terminal connected to pin plugs
Heavier duty pins should be fitted
If possible replace electronic box with a heavier duty and water resistant box

Safety
Gear should not be mounted over the chest / heart

Useful extra gear to get
Multimeter for checking wires and switches
Conductivity meter to test water prior to fishing
Soldering iron and wire
Insulation tape
Spare parts – plug, fuses, electrical wire

Appendix 7. Schools river monitoring projects at SAIAB.

BLOUKRANS RIVER WATER QUALITY AUDIT

Adapted from the Somerset Educational (Pty) LTD: Microlife Water Quality Test Kit

MAKANA PRIMARY SCHOOL

6-8 March 2007

Facilitator: Gaji Magajana

SAIAB
South African Institute for Aquatic Biodiversity
A Facility of the National Research Foundation

1. DATA RECORDING SHEET 1: POLLUTION

GROUP:……
LEARNER NAME: ……
Resources: Clipboard, pen/pencil, paper

Use your senses to see and smell if the water is polluted. DO NOT DRINK THE WATER.

Answer the following questions:

1. What is the colour of the water and what does it smell like?

2. Are there any obvious signs that the water is polluted with solid waste? If yes, list the items.

3. Do you think that people wash or bathe here? Why?

4. Are there any dead animals in the water (fish, frogs, birds etc)?

5. Is there excessive water plant growth (macrophytes) or algae (microphytes) in the water?

6. Do you see any signs of soil erosion (muddy water)?

7. Using your answers to the questions asked, do you think the water is very polluted? / slightly polluted? / not at all polluted?

DATA RECORDING SHEET 2

GROUP:……
LEARNER NAME: ……
Resources: Clipboard, pen/pencil, A4 blank paper, net, white trays, magnifying glass, plastic container, Water life identification sheet, Water quality slide, mini SASS score sheet.

Macro invertebrate count

Method

1. Use a fine-meshed net (stocking) scoop up organisms after disturbing the river bottom with your feet.
2. Brush organisms off the river rocks into the white tray and rinse off any invertebrates that remain clinging to the net.
3. Take your net and sweep it through any vegetation growing in the water. Do this for two minutes.
4. Empty contents into the white tray as before.
5. Using your reference sheet and the magnifying glass, try to identify as many animals as possible.
6. Count each group of animals and record your findings in the results table

Invertebrate group	***Site 1***	***Site 2***	***Site 3***
Snail			
Flatworms			
Leech			
Roundworms			
Sludge worm			
Mayfly nymphs			
Damselfly and dragonfly nymphs			
Stonefly nymphs			
Aquatic bugs			
Caddisfly larvae			
Aquatic beetles and their larvae			
Aquatic fly larvae			
Freshwater crabs and shrimps			

DATA RECORDING SHEET 3

GROUP:…….
LEARNER NAME: ……
Resources: Clipboard, pen/pencil, A4 blank paper, thermometer, small tubes with stoppers, DO Test Tabs, plastic cork, DO colour chart, Aluminium foil.

Temperature, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

Method

A. Record the temperature of the water at the same spot where you are going to collect your sample of water as follows:

1. Hold the thermometer 10cm below the water surface for two minutes
2. Remove the thermometer from the water, read the temperature and record the temperature as degrees Celsius.
3. NB, take first temperature reading near shore, the second one a little deeper in the water.

B. Choose one of the small tubes and a stopper to take water sample for Dissolved Oxygen

1. Holding the tube in your hand place it in the water about 10cms below the surface at the same place where you measured the temperature.
2. Carefully remove the tube from the water, keeping the tube full to the top.
3. Drop two Dissolved Oxygen (DO) Test tabs into the tube.
4. Push the plastic cork into the tube until it fits tightly. More water will overflow as the cork is pushed in. There should be no air bubbles in the sample.
5. Invert the tube over and over for about 4 minutes until the tablets have dissolved.
6. Wait 5 minutes to allow colour to develop
7. Compare the colour of the sample to that on the Dissolved Oxygen colour chart. Record the result as ppm Dissolved Oxygen.
8. Find your temperature result of the water sample on the % saturation chart. Find your Dissolved Oxygen result of the water sample at the top of the chart.
9. The % saturation of the water tested will be indicated where the temperature row and Dissolved Oxygen column intersect. Record the result in the table.

C. Choose one of the small tubes and stopper to take water sample for Biochemical Oxygen Demand (BOD)

1. Submerge the small tube into the water sample. Carefully remove the tube, keeping the tube full to the top. Cap the tube.
2. Wrap the tube with aluminium foil, store it in a dark place at room temperature for 5 days.
3. Unwrap the tube. Add two Dissolved Oxygen test tablets to the test tube.
4. Cap the tube. Invert over and over until tablets have dissolved. Wait 5 minutes.
5. Compare the colour of the sample to the Dissolved Oxygen colour chart. The difference in the Dissolved Oxygen level between the uncovered tube in the previous test and the covered tube is the Biochemical Oxygen Demand.

	Time of the Day	**Temperature °C**	**Dissolved Oxygen (DO) ppm**	**Biochemical Oxygen Demand (BOD)** ***NB: Wait for 5 days for results***
Site 1				
Site 2				
Site 3				

DATA RECORDING SHEET 4

GROUP:……
LEARNER NAME: ……
Resources: Clipboard, pen/pencil, A4 bank paper, pH test strip, pH colour chart, nitrate/nitrite colour indicator strip

4.1 pH

Method	
1. Hold the pH test strip between your index finger and thumb. 2. Dip the test strip into the water to be tested. 3. Hold the test strip under water for about 10 seconds until it changes colour. 4. Shake off excess water and match the colours on the strip to the colour chart for pH. 5. Record the pH below.	
pH: site 1	
pH: site 2	
pH: site 3	

4.2 Nitrates and Nitrites

Method		
1. Dip the nitrate/nitrite indicator strip in the water so that both pads are immersed and hold for 2 -3 seconds. 2. Shake off excess water and wait for 1 minute before taking a reading. 3. Compare the colours of the indicator pads on the stick with those on the chart. 4. Record your results in the table.		
Site	***Nitrate***	***Nitrite***
Site 1		
Site 2		
Site 3		

DATA RECORDING SHEET 5

GROUP:…….
LEARNER NAME: …….
Resources: Clipboard, pen/pencil, A4 blank paper, sterile propette, tablets, test tube, Coliform colour chart, lid with turbidity disk.

5.1 Coliform

Method	
1. Using as sterile propette draw up a sample of water and add it to one of the large test tubes containing a tablet. Repeat this until the tube is filled to the 10ml line (second line). 2. Replace the cap on the test tube. **Do not shake the tube.** 3. Stand the tube upright, with the tablet flat on the bottom of the tube 4. Incubate at room temperature, out of direct sunlight for 44 – 48 hours. Store the tubes between 21°C to 27°C. Do not disturb, handle or shake tubes during the incubation period. 5. Compare the picture of the tube to the picture on the Coliform colour chart. Record the results as negative or positive.	
Coliform: site1	
Coliform: site 2	
Coliform: site 3	

5.2 Turbidity

Method				
1. Hold the lid in your hand at least 20cm below the surface of the water 2. Look at the turbidity disk through the water. Which numbers are visible? 3. Record your findings using the table below to as a reference.				
Which numbers are visible?	**5,4,3,2**	**4,3,2**	**3,2**	**2/none**
Estimated Turbidity	**≤ 10 NTU**	**10-20 NTU**	***20-30 NTU***	***≥30 NTU***
Turbidity (NTU) : site1				
Turbidity (NTU) : site 2				
Turbidity (NTU) : site3				

WATER QUALITY AUDIT QUESTIONS

1. Water life as indicator of river health status: Macro invertebrates

1.1 Which are the most common group of animals?
……
1.2 Which are the least common?
……
1.3 What is the result on the water quality slide at each site?
……
1.4 What is the result on the mini SASS score sheet at each site?
……
1.5 Which site is the most polluted?
……

2. Dissolved oxygen (DO) and Biochemical Oxygen demand (BOD)

2.1 Which site has the lowest DO?
……
2.2 What could be the cause of this this?
……
2.3 Which site has the highest BOD?
……
2.4 What could be the cause of this?
……

3. pH and Nitrates/Nitrites

At the three different sites, is the water neutral, slightly acidic or slightly alkaline?
……
Is there a presence of nitrates in the water?
……
Is there a presence of nitrite in the water?
……
Where do think the nitrates found in the water come from?
.....

4. Coliform and turbidity

Are the results on the coliform colour chart negative or positive?
……
What does a negative result indicate?
……
What does a positive result indicate?
……
Which site has the highest turbidity, and why is this the case?
……

BLOUKRANS RIVER WATER POLLUTION

PILOT LEARNING PROGRAMME

MAKANA PRIMARY SCHOOL

2006

SAIAB

South African Institute for Aquatic Biodiversity

A Facility of the National Research Foundation

CONTENTS

1. PHASE ONE

1.1 Context

The learning programme was implemented over six days. The programme was offered to grade 8 learners of Makana Primary school. Due to time limitations and a short notice for the school, the programme was run after school hours. The learning programme involved investigations about water quality of the Bloukrans River in Grahamstown. The investigations included basic scientific methods applied by learners with the guidance of the facilitator, and assistance from a community member who is an expert on identification of small water animals, Mr Nathi Mthwa. The small water animals were used as an indication of the state of the water quality.

1.2 Rationale

Following a fact finding mission conducted earlier in the year, it became apparent that amongst the causes of pollution in the river is excessive littering by communities in the catchments areas. Investigations conducted earlier in the year showed that certain areas have been demarcated by the municipality as no dumping zones, however these signs are not observed by the community. Even in open spaces where there are clearly visible skips (rubbish containers) communities still dump waste near and around the containers.

The learning programme highlights and addresses issues of water pollution linking them with the school's curriculum. In the past the Kowie Catchment Campaign started some work with the schools where schools would identify areas of the river for clean-up. Schools represent an important part of the community that can be a vehicle to drive the message of a cleaner Bloukrans River. It is in this light that Makana Primary has been selected to engage further with the water pollution message on this river.

The aims of the learning programme are:

- to introduce learners to basic scientific procedures on how to conduct scientific investigations
- to assist educators in dealing with environmental issues in the curriculum by responding, addressing and creating awareness about environmental concerns in the local context.
- To highlight causes and impact of water pollution in the Bloukrans River streams.

1.3 Brief description

LEARNING PROGRAMME:
WATER POLLUTION IN BLOUKRANS RIVER STREAMS

TIME	VENUE	ACTIVITY
MONDAY 16 OCTOBER 2006 : 30 LEARNERS		
14H00 - 15H30	Makana Primary	Introduction: water pollution in Bloukrans River streams
TUESDAY 17 OCTOBER 2006: 15 LEARNERS		
14H00 - 15H30	Field trip group 1	Lunch. Water quality tests, data recording
WEDNESDAY 18 OCTOBER 2006: 15 LEARNERS		
14H00 - 15H30	Field trip group 2	Lunch. Water quality tests, data recording
THURSDAY 19 OCTOBER 2006: 4 LEARNERS		
14H00 - 15H00	Institute for Water Research	Group leaders visit Institute for Water Research at Rhodes University (IWR) for laboratory water tests
FRIDAY 20 OCTOBER 2006: 30 LEARNERS		
14H00 - 15H00	Makana Primary	Data analysis. Discussion on poster and script for drama
THURSDAY 26 OCTOBER 2006: 30 LEARNERS		
11h00 - 12h00	Makana Primary	Drama and poster presentation

Day 1: Learners were introduced to the learning programme and its background making reference to the fact sheet. Participating learners were registered and group leaders selected. Learners were required to answer a short test to determine the level of their knowledge about pollution in general; further discussion followed based on their responses. The small water animal's identification key was introduced. Discussions on how to use the water quality slide and mini SASS score sheet was done. Learners were shown and taught how to use the apparatus, equipment and tools to be used for the investigation. The opportunity to interact, set their own objectives within the provided guidelines was afforded to all participating learners.

Day 2 and 3: learners were taken on a field trip to the Bloukrans River streams in two groups of 15 each on separate days. Learners were taken through the various tests to be done in the field trip, how to record data collected, in the sheets to be provided. The following investigations and tests were conducted; (i) sensory water quality tests, (ii) water temperature tests, (iii) pH tests, (iv) water life tests using the mini SASS score sheet, and (v) the water quality slide.

Day 4: The four group leaders visited the Institute for Water Research (IWR) at Rhodes University. At IWR further water tests were done eg. the amount of oxygen in the water, bacteria and other tests. Learners were shown how to use the laboratory apparatus in conducting water investigations.

Day 5: Results from IWR were reported by group leaders to the larger group. All learners were guided on how to do data analysis on data collected on the field trips. Discussions were done on the drama to be produced by the group, and also the possibility of a poster. Time-frames were discussed with the learners and set by the group.

Day 6: Learners presented the drama to the lower grades at the school the time-frame for the poster was re-scheduled to be finished at a later stage.

1.4 Teaching methods, tools and techniques

This learning programme covers the following learning areas at grade 8 level i.e Natural Sciences, Arts and Culture, Mathematics, and Life Orientation.

Natural sciences:	LO1 - Scientific investigations
	AS1, AS1.1, AS1.3
Arts and Culture:	LO2 - Reflecting
	AS 3 - composite
	AS 1 - Drama
Mathematics:	LO5 – Data handling
	AS 1, AS 2
Social Sciences:	LO1 – Geographical enquiry
	AS 1.1

The following teaching methods are embedded in the learning programme

- Environmental auditing: the whole learning programme is about the audit of the river environment.

- Experimentation: learners conduct tests on instructions provided. This allows learners to do basic research work on their own. Learners learn to solve data related problems, taking pH readings form the pH meter, using a thermometer to record temperature, oxygen meter readings etc. Group work approach is used as means of enriching the experience for all participants.

- Field work: as part of the field work the learners conduct sensory experience through which they would become aware of the quality of the river. The field work encourages active learning where they get to touch, talk and think about their experiences on the field trip.
- Story telling: learners represent their reflections on the learning programme by means of a drama. This engages learners to do more research work about the issue of pollution.

1.5 Description of teaching and learning support materials used

1.5.1 Data recording sheets

The plan was to do the data recording at three different sites for the two groups so as to compare the results. Due to poor weather conditions and the fact that learners needed more time at each site than was originally allocated this was not possible.

DATA RECORDING SHEET 1

GROUP LEADER NAME: Khayalethu Gongqa
GRADE: 8

OBSERVATION TEST: BLOUKRANS RIVER STREAMS	
ACTIVITIES:	**RESOURCES**
1. Use all senses to observe the water and the area around the river. Look, smell, touch, listen. 2. Test the speed of the water **NOTE: Please do not taste the water**	Clip board, Pen/pencil, paper
RECORD OBSERVATIONS: **SITE 1:** • Water unclear; water flow is slow; water has bad smell; saw plastics, shoes, bottles, tyre, cloths in and around water; saw a dead fish (Carp) in water, observed human foot prints. **SITE 2** • Lots of stones in the water; water flow is faster than site 1; green plants on stones; water has foam and has loud sound; water is looks deeper.	

DATA RECORDING SHEET 2

GROUP LEADER NAME: Khayalethu Gongqa
GRADE: 8

<table>
<tr><th colspan="3">TEMPERATURE TEST: BLOUKRANS RIVER STREAMS</th></tr>
<tr><th colspan="2">ACTIVITIES:</th><th>RESOURCES</th></tr>
<tr><td colspan="2">1. Fill the small bottles provided with river water.
2. Insert a thermometer, wait for two minutes before reading the temperature.
3. Take at least two readings in each bottle and calculate the average reading.</td><td>Clipboard, Pen/pencil, paper, thermometer</td></tr>
<tr><td rowspan="3">SITE 1</td><td>Reading 1</td><td>Reading 2</td></tr>
<tr><td>19°C</td><td>19.3°C</td></tr>
<tr><td colspan="2"><u>Average reading:</u>

19°C</td></tr>
<tr><td rowspan="3">SITE 2</td><td>Reading 1</td><td>Reading 2</td></tr>
<tr><td>14°C</td><td>14°C</td></tr>
<tr><td colspan="2"><u>Average reading:</u>

14°C</td></tr>
</table>

The temperature readings were taken on different days due the bad weather experienced, the two sites could not be visited on the same day.

DATA RECORDING SHEET 3

GROUP NAME: Anam Centwa
GRADE: 8

<table>
<tr><th colspan="3">pH TEST: BLOUKRANS RIVER STREAMS</th></tr>
<tr><th colspan="2">ACTIVITIES:</th><th>RESOURCES</th></tr>
<tr><td colspan="2">6. Fill the container provided with river water.
7. Place pH stick into the water and count about 15 seconds or until the colour changes.
8. Compare the colours on the pH stick with the colours on the colour code chart.
9. Record the number written above the colour blocks.</td><td>Pen/pencil, paper, pH stick, colour code chart</td></tr>
<tr><td rowspan="2">SITE 1</td><td>Colour</td><td>pH</td></tr>
<tr><td></td><td>6.93</td></tr>
<tr><td rowspan="2">SITE 2</td><td>Colour</td><td>pH</td></tr>
<tr><td></td><td>7.19</td></tr>
</table>

The pH readings were done at IWR from water samples taken during the field trips. This was due to the fact that pH sticks available seemed to have expired, so could not yield any results but at least learners understood how to use the pH stick. A pH meter was used.

DATA RECORDING SHEET 4

GROUP NAME: Anam Centwa / Khayalethu Gongqa
GRADE: 8

WATER LIFE TEST: BLOUKRANS RIVER STREAMS	
ACTIVITIES: at 3 different spots	**RESOURCES**
1. Use a fine-meshed net (stocking) scoop up organisms after disturbing the river bottom with your feet. 2. Empty organisms into the tray 3. Brush organisms off the river rocks into the tray. 4. Examine carefully and identify using a magnifying glass for the smaller organisms 5. Put back all animals in the water **NOTE: After a flood you may not find many organisms**	Pen/pencil, paper, Clip board, plastic mugs, large plastic container, water animals field guide, mini SASS score sheet, Water Quality Slide, magnifying glass.

1. IDENTIFY AND RECORD ORGANISMS SEEN

SITE 1

- Identified the following invertebrates: Bloodworms, true fly – some pollution

SITE 2

- Identified the following invertebrates: Snails, – clean water

2. USE THE MINI SASSI SCORE SHEET: CIRCLE THE SCORE OF EACH GROUP FOUND.

SITE 1

- Identified the following invertebrates: Bloodworms, true fly – Highly impacted stream – poor condition

SITE 2

Identified the following invertebrates: Snails, – impacted stream?????

1.5.2 Water quality slide and mini SASS score sheet

The miniSASS score is a technique that can be used to measure the health of a river and the general quality of water in that river. It uses the composition of invertebrates living in the river and is based on sensitivity of various animals to water quality. For each group of animals found in the samples, the score should be circled in the table provided. An average score is calculated by dividing with the number of groups found. This score is then interpreted by using the interpretation guide provided.

The water quality slide is a rough pollution indicator. It works on the same principle as the mini SASS. Results are taken by reading the level of pollution with the corresponding colour block that shows on the window next to the animal. The higher the level of pollution is in the water, the less available

would be the most pollution sensitive animals and in most seriously polluted water there will be no life at all.

1.6 Logistical matters

A local Primary school, Makana was approached to avail an appropriate grade level to participate in the project. The envisaged programme was discussed with the school for in order to avoid clashes with the schools planned calendar. A pre-visit to the Bloukrans River was conducted to select suitable sites prior the field excursions. The Institute for Water Research (IWR) was contacted for to book a visit to their laboratory and to lend nets and other equipment to be used during the filed trip. The Kowie River catchments campaign was approached in the selection appropriate sites to investigate.

The South African Institute for Aquatic Biodiversity (SAIAB) covered the costs for transportation of learners, light meals, stationery and other learner support materials. Transport for learners was organised from Rhodes University transport department. Other tools and equipment eg.Camera, computer, surgical gloves, water kits and photocopying were accessed and organised with the relevant people from SAIAB. In addition a community member, Mr Nathi was contracted to assist in the project and SAIAB covered his allowance.

2. PHASE TWO

The following evaluation form was designed to evaluate the programme. Three people evaluated the learning programme i.e education intern at SAIAB, colleague and Educator form Makana Primary school.

2.1 Evaluation by SAIAB Education Intern

LEARNING PROGRAMME

WATER POLLUTION: BLOUKRANS RIVER STREAMS

INSTRUCTION: *THIS EVALUATION FORM IS MEANT TO PROVIDE A CRITICAL ANALYSIS OF THE LEARNING PROGRAMME, YOUR GENUINE RESPONSES WOULD HELP IMPROVE THE PROGRAMME*

Please rate the following questionnaire on the scale of 1 to 4

1=poor, 2=average, 3=good, 4=excellent

1. LOGISTICAL MATTERS

How was the organisation of this learning programme in terms of the following:

1.	Booking with school	1	2	3	4
2.	Transport	1	2	3	4
3.	Budget	1	2	3	4
4.	Relevance of venues and sites visited	1	2	3	4
5.	Time management	1	2	3	4
6.	Professionalism	1	2	3	4

2. LEARNER PARTICIPATION ***LEARNER PARTICIPATION***

1.	Learner participation in the learning programme	1	2	3	4
2.	Opportunities for participation	1	2	3	4
3.	Were activities geared at the correct phase?	1	2	3	4
4.	Was language used understood?	1	2	3	4

3. LEARNING PROGRAMME FACILITATION

1.	Was content provided meaningful?	1	2	3	4
2.	Did the approach fit into the National Curriculum principles?	1	2	3	4
3.	Any new knowledge and skills acquired by learners?	1	2	3	4
4.	Teaching methods used	1	2	3	4
5.	Use of teaching and learning support materials	1	2	3	4
6.	Facilitation of the learning programme	1	2	3	4

4. WHAT ARE THE STRENGTHS OF THIS LEARNING PROGRAMME

The project was based on water pollution and learners now know what causes it and how it affects the environment. Finally, the learners know how to control pollution (land and rivers)

5. WHAT ARE THE WEAKNESSES OF THIS LEARNING PROGRAMME

The weakness was only the bad weather because it was raining.

6. RECOMMENDATIONS

Project ignited and promoted in learners positive attitude towards science. The project should be promoted to other schools in order to build up the supply of tomorrow's scientists and also to know how to control pollution.

2.2 Evaluation by Makana Primary Educator

LEARNING PROGRAMME

WATER POLLUTION: BLOUKRANS RIVER STREAMS

INSTRUCTION: *THIS EVALUATION FORM IS MEANT TO PROVIDE A CRITICAL ANALYSIS OF THE LEARNING PROGRAMME, YOUR GENUINE RESPONSES WOULD HELP IMPROVE THE PROGRAMME*

Please rate the following questionnaire on the scale of 1 to 4

1=poor, 2=average, 3=good, 4=excellent

1. LOGISTICAL MATTERS

How was the organisation of this learning programme in terms of the following:

1.	Booking with school	1	2	3	4
2.	Transport	1	2	3	4
3.	Budget	1	2	3	4
4.	Relevance of venues and sites visited	1	2	3	4
5.	Time management	1	2	3	4
6.	Professionalism	1	2	3	4

2. LEARNER PARTICIPATION

PARTICIPATION	***LEARNER PARTICIPATION***				
1.	Learner participation in the learning programme	1	2	3	4
2.	Opportunities for participation	1	2	3	4
3.	Were activities geared at the correct phase?	1	2	3	4
4.	Was language used understood?	1	2	3	4

3. LEARNING PROGRAMME FACILITATION

1.	Was content provided meaningful?	1	2	3	4
2.	Did the approach fit into the National Curriculum principles?	1	2	3	4
3.	Any new knowledge and skills acquired by learners?	1	2	3	4
4.	Teaching methods used	1	2	3	4
5.	Use of teaching and learning support materials	1	2	3	4
6.	Facilitation of the learning programme	1	2	3	4

4. WHAT ARE THE STRENGTHS OF THIS LEARNING PROGRAMME

Scientific investigations provided a new dimension to learning.

5. WHAT ARE THE WEAKNESSES OF THIS LEARNING PROGRAMME

Could have done better on participation by learners. The timing of the project in terms of school's calendar was not perfect. It would have been better if this was included in our planning earlier in the year so as to make the connection with what is taught. Also use of equipment like microscope could further enhance the learning experience.

Evaluation by colleague

LEARNING PROGRAMME

WATER POLLUTION: BLOUKRANS RIVER STREAMS

INSTRUCTION: *THIS EVALUATION FORM IS MEANT TO PROVIDE A CRITICAL ANALYSIS OF THE LEARNING PROGRAMME, YOUR GENUINE RESPONSES WOULD HELP IMPROVE THE PROGRAMME*

Please rate the following questionnaire on the scale of 1 to 4

1=poor, 2=average, 3=good, 4=excellent

1. LOGISTICAL MATTERS

How was the organisation of this learning programme in terms of the following:

1.	Booking with school	1	2	3	4
2.	Transport	1	2	3	4
3.	Budget	1	2	3	4
4.	Relevance of venues and sites visited	1	2	3	4
5.	Time management	1	2	3	4
6.	Professionalism	1	2	3	4

2. LEARNER PARTICIPATION ***LEARNER PARTICIPATION***

1.	Learner participation in the learning programme	1	2	3	4
2.	Opportunities for participation	1	2	3	4
3.	Were activities geared at the correct phase?	1	2	3	4
4.	Was language used understood?	1	2	3	4

3. LEARNING PROGRAMME FACILITATION

1.	Was content provided meaningful?	1	2	3	4
2.	Did the approach fit into the National Curriculum principles?	1	2	3	4
3.	Any new knowledge and skills acquired by learners?	1	2	3	4
4.	Teaching methods used	1	2	3	4
5.	Use of teaching and learning support materials	1	2	3	4
6.	Facilitation of the learning programme	1	2	3	4

4. WHAT ARE THE STRENGTHS OF THIS LEARNING PROGRAMME

Very worthwhile LP, learners get to know about effects of pollution (other than just visible plastic, etc) It also uses scientific methods. Drama production was great (little short), useful in getting message to other learners at school.

5. WHAT ARE THE WEAKNESSES OF THIS LEARNING PROGRAMME

Perhaps E-coli counts could also have been carried out.

Only group leaders got hands-on experience. It would have been great for all learners to 'get their feet wet'

6. RECOMMENDATIONS

Perhaps this LP could be used a couple of times a year (in different seasons; after heavy rains; after the Arts festival etc). In this way a long term data set could be collected and this could show trends. These trends/patterns could then feed back into the LP.

2.4 General comments by learners

Learners thought that the Learning Programme provided them with an opportunity to do some work outside the classroom environment. They felt that there is a lot they learnt about water pollution in general. They felt that the most enjoyable moment was doing the drama. Learners felt that the idea of a visit to the Bloukrans River should be incorporated into their school work programme and should not be optional.

3. PHASE THREE

Summary of events

The learning programme photos

Pic 1: Makana primary learners and their teacher on the field trip

Pic 2: Site 1

Pic3: Learners recording their observations

Pic 4: Dead fish found in water – Carp

Pic 5: Mr Mthwa assisting learners in using the nets

Pic 6 & 7: Bloodworm identified from the water sample

Pic 8: Gaji and learners taking pH Readings from pH stick

Pic 9 Learner taking water temperature reading from thermometer

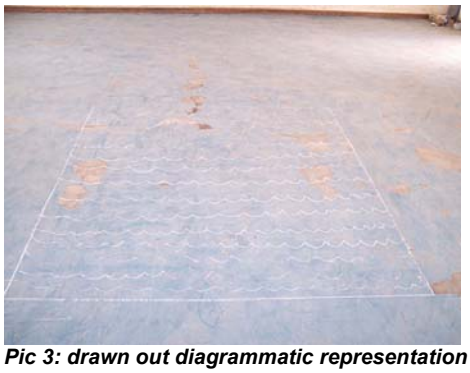
Pic 10: Gaji & Nathi turning stones for more Animals

Pic11: Group on the field trip with Vanessa, one of the evaluators of the learning programme

Some pictures from the drama

Pic 1: the drama group

Pic2: drama group with Bulelwa from Nombulelo High who wrote the drama script



Pic 3: drawn out diagrammatic representation of a the Bloukrans river

Pic 4: one of the learners as the story narrator.

Pic 5: the tree with falling leaves,

Pic 6: other characters, the snail, bloodworm, Municipal officer

Pic 7: woman spilling water outside after washing dishes

Pic 8: animals in the river tell of their struggles to survive

Pic 9: community member drinking polluted water

Pic 10: Community member got sick – visiting clinic

Pic 11: drunk person urinating in water

Pic 12: Dead fish, outside the river

Pic 13: at the end, all actors introduce themselves & tell about their roles in the drama

3.1.2 The Drama script

Written by Bulelwa Gqiza, learner from Nombulelo High School

This is a Grade 8 presentation on the basics of water pollution. What causes it? And how it affects the environment and everything that is part of it (The pupils here all have been part of a project on water pollution)

Scene 1: (Shows how pollution affect the environment)

Narrator-"This is …river. It is a polluted river and we get to see how the animals live in this condition."

(The creatures in the river tell us exactly how it feels to be in that type of environment)
Snail – "We Snail don't like this at all, although I can survive it is completely bad for me."
Bloodworm- (In the water) "We bloodworm don't have that much difficulty surviving but this water is still polluted.
Dead Fish- (Killed by the water) "We fish can never survive in this water, we live in fresh water, we fish we'll soon all die.

(We then see another natural polluter a tree that is also responsible for pollution too)
We then see how we human have a major role played in polluting water.
Drunk man – (Coming towards the river) "Yo! undincedile lomlambho, abekho apha, Kudala ndifuna akuzinceda iyandisinda nokundisinda le-bottle (atsho eyilahla in the river)

Scene 2 : Where it all started?!

(Here we see how polluted areas are polluted. What motivates pollution? It all starts with one person then everyone else follows. We see how the No 1 polluters pollute the river mostly and how uncaring, we can be most of the time).

Washing Lady- (We see this lady throwing a bucket full of used, dirty water in the river as she doesn't have anywhere to throw them). "I am so tired, this has been quite a tiring one. I had to many clothes to wash. I'll just throw it here."

(A girl who has been cleaning her home goes to the river too)
Girl= "I have been looking for a rubbish bin for too long now. I'll just throw it somewhere in here. (She throws the papers, tins and all human materials in there)

(An unaware man who seems to be traveling sees the river and goes to refresh and quench his thirst)
Thirsty man- 'I am so tired, thank goodness that I found this river - I need to drink now. (He bents down to drink) he soon develops a running stomach. (This shows how bad polluted water can be for any living thing.

There are people responsible for protecting the environment and controlling issues like pollution. A man from a local municipality who has been keeping an eye on the river comes to take a pH test and bacteria tests in the river. This will show the condition of the river.

Officer-"I came here last week to do some water tests. The water was in a good condition. Today I'm here to take another one. (He gets some water from the river). Things are looking bad. This river is now in a bad condition."

The narrator-(warming us) "stop water pollution

Every (tells us about their visits to rivers and the results)

“Sight 1 next to vukani is in a bad condition”
“Sight 2&3 Under a bridge is in a good condition”
“Stop water pollution”

Everyone introduces him/herself and tell of the character they player.

3.2 Analysis of the learning programme and lessons learnt

All evaluators generally felt that the learning programme perfomed above average in the following areas namely, logistical matters, learner participation and programme facilitation. The use of scientific methods allowed learners to look beyond the obvious indicators of pollution like plastic, papers. The visit to IWR provided an opportunity for learners to do some basic laboratory work and with the brief motivational talk by Ms Gola of IWR opened a window for possible careers relating to water. The use of drama was the strength of the learning programme in carrying the message across to a wider audience in a fun way.

One of the weak points noted from the evaluations was the participation by only group leaders during the field trips. Even though learners participation was not very poor, participation was largely by group leaders. Group leaders were selected as a means to maintain focus on the work at hand, but this strategy showed also to be a limiting factor for creative learners who were not group leaders. Learners took time to grasp the content that went along with the learning programme. This can be attributed to the fact that there was too much expectation placed on learners. Learners were exposed to the content on pollution and at the same time were taken through the methods and procedures to be followed in collecting (sensory investigations, use of pH sticks, thermometer, mini SASS score sheet and water quality slide) and recording data, all done in one session. This clearly did not work very well as it showed in their lack of focus at times during the field excursion.

Due to poor weather conditions and the fact that learners needed more time at each site than was originally anticipated it was not possible to stick to the planned programme of working in three sites. This outcome affected the plan such that there could not be comparison of recorded data. Even though instructions were available and explained thoroughly the learners did not seem to follow exactly what they needed to do. For an example some learners even group leaders in some cases did not record data in their sheets even though these were discussed by all during the field excursion. This is perhaps due to learners not being used to this kind of learning experience where they work independently doing scientific investigations on their own.

3.3 Recommendations

The learning programme has been a learning curve in many ways for me as the facilitator and the learners as well. As this was a pilot project to be implemented with different schools in a year, some changes will be effected to

improve the programme. Areas of improvement would include time management, provision of more content by providing full information sessions to learners, encourage own fact finding about the Bloukrans River. Participation of all learners during the field excursion should be noted in future programmes

Some of the data recorded in the data recording sheets has been taken from interpretations of the water quality slide and the mini SASS score sheet. Results seem to show contrasting interpretations of the two water pollution instruments. The two instruments give a rough indication of the level of pollution in the water and have to be used as such. Further thorough investigations need to be done in future to clarify this contrasting information. One of the reasons could be the fact that some important link could have been missed during the identification of animals that could change the appearance of the results drastically, that needs to be investigated as well.

There is enough scope to develop the content, investigations and activities depending on the knowledge and comprehension level of the group. In future as per recommendations from one of the evaluators, inclusion of microscopes usage, bacterial tests etc should be considered within the limited time frames of the learning programme.