Estimating the Economic Returns to Ecological Conservation: The Onchocerciasis Control Programme in West Africa.

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1. Introduction

The objective of this study is to assess the economic benefits arising specifically from the ecological protection system operated by the Onchocerciasis Control Programme (OCP) in West Africa. It does not, therefore, attempt to assess the economic benefits of the complete Programme, something already attempted by Kim and Benton (1995); instead it argues that there are specific market benefits which have been generated by the Ecological Programme (EP) element.

It can be assumed that it would have been possible to achieve the same level of suppression of the disease, and the resultant economic benefits, without incurring the costs of ecological protection which have been achieved. Thus ecological protection has incurred costs, against which specific market and non-market benefits can be placed. Mention will be made of the non-market benefits, but because of the difficulties involved no attempt is made to assess them.

2. The Onchocerciasis Programme

Onchocerciasis, or river blindness, is transmitted to humans by the female blackfly, *Simulium damnosum s. l.,* the larvae of which develop in fast flowing rivers. The adults of the parasite, both sexes, live under the skin in nodules. When the females are fertilised they produce millions of microfilarial worms, which although concentrated under the skin, migrate throughout the body (Boatin et al. 1997). On reaching the eye, the microfilariae cause various levels of visual impairment including blindness (WHO 1995). The worms are responsible for other symptoms including debilitating skin lesions (WHO, 1995, Boatin et al. 1997).

The disease occurs in Africa, six\countries in the Americas and in Yemen (Boatin et al. 1997). In these countries the disease is more prominent in river valleys. In West Africa, onchocerciasis was at public health concern levels and an impediment to both human and socio-economic development in wide areas of river valleys. Africa is the most affected region in terms of the extent of the distribution and the severity of clinical manifestations of the disease. Of the 23.6 million people in Programme area 2.24 million were estimated to be infected and 49,350 to be blind. In addition to the very high cost in human health, at extreme levels of infection communities abandon their villages and their fields, leading to direct economic impacts.

The Onchocerciasis Control Programme (OCP) was operationally launched in 1974 in seven countries in West Africa (Benin, Burkina Faso, Cote d'Ivoire, Ghana, Mali, Niger and Togo) with the support of FAO, UNDP, WHO and the World Bank and the participating countries, with WHO as the executive agency. The initial area encompassed by the programme was 654,000 km^2, which was later expanded to over

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1,320,000 km^2 with the inclusion of parts of four more countries (Guinea, Guinea-Bissau, Senegal and Sierra Leone). The OCP operational area includes considerable proportions of almost all river basins in West Africa, including those of the Niger, Volta, Bandama, Sassandra, Comoe and Senegal. It has been a very large programme, the largest health programme in Africa. The budgeted cost for the period 1974 to 2002 is around US$570million in nominal terms (Kim and Benton 1995; OCP\WHO 1994). It has involved the continual use of a fleet of helicopters (for spraying insecticides) plus staff spread across all the participating countries.

The objectives of the OCP are to eliminate onchocerciasis as a disease of public importance and as an obstacle to socio-economic development. The Programme was initially based solely on the control of the blackfly vector (*Simulium damnosum s.l.*) by insecticide spraying of the breeding sites on river systems, where larval stages develop. At the peak of larviciding (spraying) activities, about 30,000 km of rivers were being treated (see Table 4). The spraying strategy is designed to interrupt the transmission of the parasite, *Onchocerca volvulus*, for a period of time longer than the longevity of the adult worms in humans, estimated to be about 14 years. The interruption of the cycle is achieved by destroying larval stages through aerial application of insecticides to breeding sites. The development of the aquatic stage from eggs to pupae is around one week, hence insecticide application is undertaken weekly.

The introduction of the drug Ivermectin (which can control the microfilariae, but not the adult worm which produces them) for mass chemotherapy in humans suggested that the combined use of Ivermectin and spraying would reduce the required duration of vector control to 12 years (Plaisier et al. 1997). Despite the introduction of Ivermectin, and in the absence of a drug to kill the adult worm, vector control by spraying has remained the method of choice to achieve the goals of the Programme (Hougard et al. 1997).

A major environmental concern of the project has been with the potential damage that repeated long-term spraying with larvicides might have on the aquatic fauna, namely invertebrates other than the blackfly, and upon the fish. There was also a need to ensure that toxins did not build up in the fish and human food chains. It was also of paramount importance to the human health objective that the larviciding programme should be effective, and that the vector should not develop insecticide resistance, so becoming uncontrolled. To forestall potential long-term ecological changes, including loss of economic value of fish as a food, which is basic to the diet of millions of of people in the region, an Ecological Programme was instituted as a key part of the OCP.

3. The Ecological Programme (EP); Its objectives and activities

The participating countries and donors initiated environmental and ecological studies before the launching of the Programme. An Ecological Panel (which was reformed as the Ecological Group in 1980) was set up in 1973 with the following objectives:

- Organise and evaluate a long-term monitoring programme of the aquatic environment with emphasis on its fauna.

- Identify criteria for the selection of pesticides for operational use and determine the conditions by which insecticides can be used in relation to season and in different areas of the Programme.
- Review the nature and magnitude of the development process being undertaken and proposed in the areas free of onchocerciasis, and to identify the environmental and human ecological implications of such development.

Methods, procedures and protocols for the monitoring and risk assessment programmes have evolved since 1974, the Programme being dynamic in face of continually changing situations (e.g.insect reinvasion, resistance, variability in hydrology, etc…). However, basic concepts and issues have remained.

To perform the role described above, the Ecological Group of experts operates by reviewing, annually, the monitoring activities results of National Hydrobiological Teams and ecotoxicological research carried on by the Hydrobiological Unit of the Programme, which also co-ordinates and assists the field work in the Programme area. The criteria for the evaluation of insecticide impact on the aquatic environment were the following:

- The vector control activities should not reduce the number of invertebrate species, or cause a marked shift in the relative abundance of species; temporary and seasonal variations in non-target invertebrate populations were acceptable;
- The pesticides applied should have neither a direct impact on fish, nor effect on the life cycle of fish species;
- Bioaccumulation of insecticides and biomagnification through food webs should be avoided;
- Human activities in the control area should not be impaired.

The achievement of the EP is underlined by its success in coping with the emergence of blackfly resistance to insecticides. When the Programme was initiated the organophosphorous compound temephos was the only insecticide used. It was selected because of its efficacy, its carry (distance over which it remains effective), its lack of impact on non-target fauna and also its acceptable cost. Five years after the beginning of the Programme, resistance of some sub-species of S. damnosum complex to temephos was detected (Guillet et al. 1980). Toxicological and effectiveness tests had been carried out on other larvicides under the guidance of the Ecological Panel and it was possible to advise the introduction of a second organophosphate insecticide, chlorphoxim, into the programme in 1980. After the development of the insect's resistance to this was also detected, the Programme adopted a strategy of rotational use of different classes of insecticides, with different modes of action, to prevent development of further resistance. (Table 4 outlines these developments by date).

Seven insecticides are currently used (Hougard et al. 1997). Six of them are formulated as emulsifiable concentrates (temephos, chlorphoxim, pyraclofos, permethrin, etofenprox and carbosulfan) while the seventh is a liquid concentrate of a biological insecticide, Bacillus thuringiensis H-14 (B.t. H-14). The rotational use of insecticides has been particularly effective, with only limited resistance to the organophosphates currently in use, while the susceptibility of the blackfly population to other classes of compounds remains unchanged.

These developments have increased the cost of larvicides used, although, because no assessment is available of this, this study will simply explore the implications of alternative assumptions about this extra cost. It could of course be argued that no extra larviciding cost should be charged to the Ecological Programme (EP), since without the changes in the larviciding procedures the OCP as a whole would have failed as the blackfly became uncontrollable. Pursuing the logic of that argument further would mean that, in some sense, all the human health and economic benefits (arising from the resettlement of millions of acres of land and their cultivation) could be attributed to the EP. In that case the internal rate of return to the EP would be extraordinarily high. A more restricted and modest assessment of the benefits is assumed below.

4. The benefits and costs of the Ecological Programme(EP)

a) Benefits

The monitoring system of the OCP has been reported and analysed in detail (Baldry et al. 1995), Calamari et al. (1999), Crosa et al. (1998), Paugy et al (1999)), and the Ecological Group receives annual assessments from all the monitoring stations in treated sections of river on (1) fish species numbers, condition and catches, and (2) on the existence of insect species. The evidence suggests that the management of the larviciding programme, which could have caused extensive damage to the aquatic fauna, has been managed with skill to avoid such outcomes. Paugy et al. (1999, p.377) concluded "*the fish structure has not changed and we can conclude that the pesticides sprayed by the OCP do not influence the structure of the main fish community, the species richness nor the fish biology*." Also "*no fish mortality was observe*d." (Calamari et al. 1999). Inevitably larviciding does affect a number of species of insects, but detailed toxicological testing led to management where choice of insecticide, and its amount was carefully calibrated to stream flow to minimise effects on non-target species; a system of river flow monitoring, with satellite data transmission to the helicopter spray bases was put in place as part of the EP. Thus it can be argued that the EP has created significant non-market benefits to aquatic fauna bio-diversity and conservation.

Another significant non-market benefit of the larviciding programme, has been the improvement in the quality of life for the greatly expanded populations in the areas formerly affected by the disease. The "nuisance" caused by repeated biting by the blackfly has been dramatically reduced through the effectiveness of spraying in killing the larvae. This is well illustrated Table 1 which shows the annual bite rate (ABR), and the infectivity of bites (ATP) at Leraba Bridge in Cote d'Ivoire. From 1975 when spraying began up to the time when it ceased in 1987, the ABR declined from 26,314 to 634 and the ATP from 1,263 to 3. After cessation of spraying the ABR rapidly rose to 1975 levels and above, but infectivity stayed below the critical level. Communities along rivers still being larvicided are fully aware of what will happen to the nuisance of biting when larviciding ends (as it does in OCP when the disease is suppressed) and greatly fear that outcome. Human happiness has been greatly increased by the reduction in biting rates while larviciding has been operated.

That improvement in human happiness and health has been associated with major market benefits. As assessed by Kim and Benton (1995), these were from two main sources. Firstly reductions in the disease increased the effective labour force. Secondly it has become possible to recolonise/colonise cultivable land which had been abandoned or never farmed due to the disease. Kim and Benton estimate that, throughout the OCP area, this additional farmed area will have increased from 10,000 hectares in 1983 to as much as 15.5 million in 2014. In combination with the increased effective labour force this gives rise to increased agricultural output. Depending upon the assumptions used, Kim and Benton estimated the Internal Rate of Return (IRR) of the OCP project to range between 14 and 21%. It is possible that these market benefits would have arisen even if the investment in the Ecological Programme (EP) had not been made. Certainly it is possible to imagine a vector control programme which was less benign to the aquatic fauna, but equally effective in controlling the blackfly. That line of argument does, however, assume that it would have been possible to have prevented resistance to insecticides developing to the same degree without having the EP. If that is not the case, then a significant proportion of any extra agricultural output generated could be attributed to the EP. However, we will proceed without attributing any agricultural output benefits to the EP, but will look instead for a class of market benefits specific to the EP.

b) Additional value of fish catch

It is strongly held by those who have worked on the OCP in the last two decades that without the EP a proportion of the fish caught in the river systems would have been unsaleable (or have commanded a lower price) because of accumulated toxins. In arriving at this judgement it is worth observing that when resistance to the first larvicide, temephos was first observed, consideration was given to applying DDT, which was still in widspread use globally, but particularly in Africa. That might have been effective in controlling the blackfly, but the damaging consequences for the food chain, had DDT been used, would have been severe or even catastrophic. Because the EP was in place, with its programme of testing alternative larvicides, that particular problem was avoided as were all possible similar mistakes in subsequent years.

There is no way of knowing precisely what loss of value of fish marketings would have occurred without the EP. Some of those consulted believe it might have been as much as 15% of the value which has been generated over the years. In the following analysis we will assume that the EP has created additional market benefits in term of the fish catch, and will test the sensitivity of the Internal Rate of Return (IRR) to alternative assumption about the size of these.

The basic fish catch data used are the total freshwater catch weights published by FAO for the countries in the OCP. These are presented in Table 2.

Since not all of the river systems of these countries have been affected by larviciding, fisheries, experts attached to the EP have provided the assumptions about the proportions of the national fich catch in the OCP treated areas; these are shown in the first row of Table 2. Thus the analysis focuses on these proportions of the catches shown. The first column of Table 5 shows the assumed fish catch in OCP affected areas by applying these proportions.

The question is, what fraction of these proportions of the catch would have been unsaleable[2] had the EP not produced the benign spraying regime which has been applied.

[2] This includes fish which would have been reduced in value at sale.

The second key element in generating an estimate of additional marketed fish value is the price of fish. A very good set of producer prices from 1974 to 1991 is available for a number of species at Mopti in Mali (Baumann, 1994). The prices for *Tilapia* are presented in Table 3, and these are used in the analysis which follows. Baumann provides prices for more expensive fish, such as *Lates niloticus* and *Hydrocynus*, but it seems advisable to use the more conservative *Tilapia* series. Comparable data for Tilapia at Mopti are available in graphic form up to 2000 (http://www.orleans.ird.fr/~pechedcn/fgraph.htm), and these have been used to up-date the price series to 2002[3]. Because the OCP costs are all recorded in US dollars, the fish price is converted to dollars as shown.

Several observations are in order about the selection of the price to adopt. Retail price series for the same fish species in the Bamako market are also presented by Baumann for some early years up to 1978. These were appreciably higher than the riverside price of fish presented in Table 3. They were, in fact, up to 200% higher. Since much of this additional value would have accrued to traders and merchants, rather than being to cover costs of fuel, capital depreciation, etc, the price used here greatly underestimates the economic value of each extra tonne saved for the market by the EP.

A key question is, "how representative are the prices at Mopti of fish prices throughout the OCP area"? Data from Kpando Torkor in Ghana from 1987 to 2000 suggest that, if anything, they may be an under-estimate, and it should be borne in mind that Mali and Ghana account for around 70% of the fish catch assumed to be affected by OCP activities. Thus the prices in these two countries are by far the most important.

c) Costs attributable to the Ecological Programme

Table 4 presents a summary from 1974 onwards[4] of the costs of the larviciding programme, in terms of the costs of the larvicides themselves and the costs of the helicopters. While the latter cost is strictly attributable to the year in question, larvicides invoiced in one year may not actually be applied until later. This is not seen as a significant problem for the analysis. The key question here is what proportion of these costs has been added as a consequence of adding more expensive larvicides to cope with the environmental protection issues which have arisen. It may be assumed that this has not affected the number of flight hours, which account for around two-thirds of the cost of larviciding. Only the cost of the chemicals is assumed to have been affected by the EP. Although the EP may have made some savings in chemical use, by conducting experiments which have adapted application rates to river flow conditions, it is consequently assumed that the net effect has been to increase costs. Table 5, which presents a "baseline" estimate of the IRR for the EP, assumes (in column 8) that from 1979 this extra cost rose to 70% of total pesticide costs by 1989. Until chlorphoxim was introduced in 1979 it is assumed there was no addition to larvicide cost. In the baseline estimate it is assumed that larvicide costs in that year rose by 20%.

[3] The data for the last few years of the project have virtually no effect on the calculated internal rate of return.

[4] Including projected costs for 1999-2002.

The other costs of the EP, are for the monitoring processes plus the small annual $30,000 cost of the meeting of the Ecological Group. These are included together (in column 6 of Table 5) at their budgeted cost. In the analysis which follows the full costs of the monitoring process is charged to the EP. In reality this overstates the cost since part of the monitoring programme is to check the infectivity of the blackfly. That is a necessary part of the OCP which is not directly attributable to making the spraying application more friendly to the environment. Nevertheless the full budgeted costs of monitoring are charged in the following analysis.

5. Results; Internal Rate of Return (IRR) of the OCP Ecological Programme

Table 5 sets out the structure of the analysis for the baseline estimates. The key additional assumptions to those set out above relate to the proportion of the fish catch which it is assumed would have been unsaleable if the EP had not made the changes it did to the larviciding programme. In the baseline estimate it is assumed (column 3 of Table 5) that no such benefits arose before 1979, and that in that year they were 2% of the catch in the affected areas, and that this rose to a constant 10% from 1982. Allowing for a 20% increase in the cost of larvicides in 1979, with a progressive rise to 70% when Bti was introduced in 1992, still results in an estimated IRR of 31%.

The estimate of the IRR is quite sensitive to the assumed proportional increase in the amount of marketable fish. Reducing the proportion assumed in Table 5 (column 3) by 20%, 30%, 40% and 45% produces IRRs respectively of 25%, 20%, 13%, and 5%. However, fisheries experts consulted are quite comfortable with the baseline assumptions; indeed they feel that these underestimate the additional fish harvest attributable to OCP’s environmentally orientated management of the larviciding programme. Furthermore, it should again be noted that, the use of riverbank fisherman's prices undervalues the additional marketable fish; a high proportion of the value added in marketing the fish is pure economic benefit.

It is worth briefly considering the time profile of the extra marketings assumed. For just as there are no assumed benefits in the first years of the project, it may be argued that the benefits will have tailed off as the kilometers of river sprayed was reduced from 1994 onwards (see Table 4). However, the IRR is insensitive to changes in either costs or benefits assumed more than 20 years after the OCP began. Even if it is assumed that there are no marketable benefits from 1994 to 1997, the IRR remains at 31% if nothing else is changed. That also underlines that the absence price data at Mopti after 1991 does not have much importance either. The assumption that there was no local price increase for Tilapia after 1991 almost certainly leads to underestimates of the benefits. The depreciation of the CFA since that time is a clear indication of price inflation, which almost certainly extended to fish prices.

A further sensitivity test is to consider what would happen if the EP had had a greater effect on the cost of larvicides than is allowed for in the baseline. A doubling of the assumed effect to add 140% to cost from 1992 onwards would only reduce the IRR to 17%, a very healthy figure.

6. Summary

To undertake cost-benefit analysis for a project such as OCP, spread over many countries, raises many difficulties. To do so for nine African countries makes it even more so. However the cost data for the Programme is clear and has been recorded in US dollars, which minimises the problems of coping with different inflation rates across countries. That problem has also been minimised by the fact that most of the countries lie in the CFA zone, and the US$/CFA exchange rate is clearly recorded. Since only one marketed output, fresh fish, has been considered, and the best price series available are in CFA, the analysis is fairly robust.

Quite conservative assumptions have been made in estimating the IRR for the Ecological Programme of the Onchocerciasis Control Programme. Costs have been attributed to it which cannot strictly be set against the particular benefits considered. A generous estimate has been made of the net additional larvicide cost imposed to meet the aquatic environmental standards set by the EP. On top of that the price used to value the additional marketed fish value underestimates its economic value. The combination of these assumptions with that about the extra marketable fish production saved by the programme results in a baseline IRR estimate of 31%. Sensitivity analysis even doubling the additional larvicide cost still leaves the IRR at a very healthy level of 17%.

The key assumptions in the analysis, therefore, relate to the additional marketed quantity of fish attributable to the EP. Expert opinion is that the level of up to an additional 10% of marketed output in the affected areas is reasonable, especially since conservative price valuations have been placed on it. That maximum of 10% accounts for only 3.3% of the total freshwater fish catch of the eight countries considered.[5]

It seems entirely reasonable to conclude that the environmental protection component of the OCP has had large positive economic benefits of a tangible market nature. In addition there are a number of non-market benefits which have been identified in the paper, for which there has been no attempt at valuation, but which must have been quite considerable. In the case of the OCP Ecological Committee's decisions, environmental protection has paid off very well.

[5] Although Niger is in the project, none of its fish catch is assumed to be affected.

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Table 1 Annual Bite Rates (ABR) and Annual Transmission Potentials (ATP) at Leraba Bridge, 1975-1992

Year	ABR	ATP	Year	ABR	ATP
1975	26,314	1,263	1984	3,238	71
1976	16,519	1,329	1985	616	0
1977	8,490	1,030	1986	915	21
1978	5,184	422	1987	634	3
1979	3,034	36	1988*	1,033	16
1980	3,485	213	1989*	3,418	4
1981	5,806	98	1990*	14,613	10
1982	2,680	184	1991	21,842	5
1983	1,258	106	1992	31,025	16

Source: Baldry et al. 1995, Table 4.1 p.21.

* Phasing out of vector control operations.

Table 2 Total Freshwater Diadromous Fish Catch in the Countries Where Catch Affected by OCP[a.] (tonnes)

	Benin	**Burkina F.**	**Côte D'Ivo**	**Ghana**	**Guinea**	**Mali**	**Sierra Leo**	**Togo**	Total
% of catch assumed in sprayed areas.	10%	100%	80%	15%	80%	30%	100%	10%	
1974	31400	5000	3600	41820	1000	75000	1000	3003	176873
1975	31360	5000	3600	42476	1000	75000	1100	3005	171683
1976	31940	6000	1700	56649	1000	75000	1330	3510	181844
1977	31940	6000	1700	47608	1000	75000	1628	3668	175916
1978	31650	7000	1703	45291	1000	75000	5197	3668	179292
1979	31650	7000	12600	43368	1000	83586	12138	3500	203776
1980	34050	6500	15600	44276	1100	88228	15809	3500	217955
1981	34050	7500	17600	44059	1300	75564	16410	3500	208191
1982	33850	7000	19600	45611	1400	73451	17080	3500	208332
1983	30800	7100	20000	48074	1600	61289	16574	3508	192196
1984	31200	7374	20021	46756	1803	54711	17088	3562	185515
1985	31907	7443	24060	51259	2003	54184	17100	3550	193506
1986	31139	7640	25213	60232	2502	61012	16610	3550	210243
1987	21351	7836	25229	65816	3002	55713	16610	3679	201519
1988	23266	7916	26370	62323	3001	55875	16610	3532	201392
1989	22626	8015	28468	61953	3001	71838	16606	4550	221798
1990	20830	7015	25400	65048	3001	70548	15590	4976	215762
1991	19046	7012	21654	64424	3501	68780	16121	4965	208648
1992	18171	7508	15710	61381	4005	68507	17085	5688	200104
1993	22698	7000	13828	55460	4605	64352	17042	6186	193307
1994	22604	8000	14721	58010	3805	62950	18042	5302	195742
1995	27430	8000	11221	53601	3347	133000	18038	5052	263155
1996	25101	8030	12628	81473	2848	111970	17540	5036	268772
1997	24375	8045	11950	74705	3624	99610	17539	5121	251270

Source: FAO Fisheries database.

a. Although Niger is in the OCP area it is judged that fish catches there were unaffected. Its data are therefore not presented.

Table 3 Price of Fresh Tilapia at Mopti in Mali

Year	Price Tilapia at Mopti (CFA/kg)[1]	Exchange Rate[2] CFA/$	Price of Tilapia at Mopti ($/kg)
1974	102	222.2	0.45905
1975	98	224.3	0.43691
1976	48	248.5	0.19316
1977	48	235.3	0.20399
1978	170	209	0.8134
1979	160	201	0.79602
1980	119	225.8	0.52702
1981	192	287.4	0.66806
1982	260	336.3	0.77312
1983	254	417.4	0.60853
1984	340	479.6	0.70892
1985	319	449.3	0.70999
1986	230	346.3	0.66416
1987	252	300.5	0.8386
1988	221	297.9	0.74186
1989	217	319	0.68025
1990	217	272.3	0.79692
1991	257	282.1	0.91102
1992	257[a]	264.7	0.97091
1993	257[a]	283.2	0.90749
1994	257[a]	555.2	0.4629
1995	257[a]	499.2	0.51482
1996	257[a]	511.6	0.50235
1997	257[a]	511.6[b]	0.50235

Source: 1. Baumann (1994). 2. IMF…….
a. Last price available is for 1991. b. 1996 exchange rate.

Table 4 Summary of the OCP Larviciding and its Costs

Year	Larvicides $1000	flight hrs $1000	Total $100	km	Phases of larviciding	Fin. Phases	Events
1974	167	97	263	1,058	Experimental Treatments	Phase I	
1975	616	1,043	1,658	6,655	Phase I core area	Phase I	Large scale intensive use of
1976	1,253	1,772	3,024	10,472	Phase II core area	Phase I	temephos (1 compound)
1977	994	2,313	3,306	20,357	Phase III East & West	Phase I	
1978	1,169	2,498	3,667	20,608		Phase I	
1979	1,538	2,771	4,308	23,862	South Côte d'Ivoire Exten.	Phase I	
1980	2,756	2,801	5,556	23,862		Phase II	Resistance to tem. - Intro. chlorphoxim (2 compounds)
1981	2,598	3,431	6,029	23,213		Phase II	Resistance to chlorphoxim
1982	2,218	3,128	5,346	20,923		Phase II	Introduction of Bti (3 compounds in rotation)
1983	1,798	3,364	5,162	19,310		Phase II	
1984	2,472	3,086	5,558	20,764		Phase II	
1985	2,666	3,051	5,717	23,156		Phase II	Intro. permethrin (4 compounds in rotation)
1986	4,278	3,748	8,026	23,156		Phase III	
1987	9,043	5,312	14,355	24,157		Phase III	
1988	4,668	4,601	9,269	32,215	South-West and West Mali	Phase III	Intro. carbosulfan (5 compounds in rotation)
1989	4,419	5,051	9,471	31,273	Guinée + first cessations	Phase III	Intro. pyraclofos (6 compounds in rotation)
1990	4,355	6,335	10,690	28,822	Sierra Leone	Phase III	
b	07,119	6,299	13,418	29,945		Phase III	
1992	4,453	6,583	11,037	28,505		Phase IV	Failure in Bti production
1993	3,135	5,250	8,385	27,940		Phase IV	
1994	3,888	4,857	8,745	21,828		Phase IV	Introduction of etofenprox (7 compounds in rotation)
1995	3,096	3,896	6,992	14,854	Troubles in Sierra Leone	Phase IV	
1996	3,659	4,021	7,680	14,757		Phase IV	
1997	3,775	3,842	7,617	14,681		Phase IV	
1998	2,406	4,150	6,556	14,041		Phase V	
1999	2,123	3,380	5,503	9,000	Cessation in Côte d'Ivoire	Phase V	Rotation of mainly 4 compounds (Bti, tem., pyra., perm.)
2000	2,123	3,380	5,503	9,000		Phase V	
2001	2,123	3,380	5,503	9,000		Phase V	
2002	1,486	2,211	3,697	6,500		Phase V	
Total	86,393	105,650	192,043	0		28 years	
Av.	2,979,079	3,643,099	6,622,178	19,100			

Table 5 Calculating IRR due to Ecological Programme - Baseline estimate

				A	B			C	E=A-B-C
	Catch in Areas of OCP	% Increase in saleable fish catch due to EP	Price of fish	Extra value of catch due EP	Cost of Ecological Programme	Larvicide Cost	% increase in Larvicide Cost due EP	Increase in Larvicide Cost due EP	**Net benefit**
	(tonnes)		*($/t)*	*($1000)*	*($1000)*	*($1000)*		*($1000)*	*($1000)*
1974	41893	0	456	0	520	167	0	0	-520
1975	42088	0	437	0	520	616	0	0	-520
1976	44032	0	193	0	520	1253	0	0	-520
1977	42990	0	204	0	520	994	0	0	-520
1978	47185	0	813	0	520	1169	0	0	-520
1979	65114	0	796	0	520	1537	0	0	-520
1980	72534	2	527	765	520	2756	20	551.2	-307
1981	72063	6	668	2888	520	2598	20	551.2	1817
1982	73492	10	773	56801	520	2218	40	1039.2	4122
1983	69983	10	609	4262	520	1798	40	887.2	2855
1984	68824	10	709	4880	520	2472	40	719.2	3640
1985	72883	10	710	5175	520	2666	45	1112.4	3542
1986	77229	10	664	5128	520	4277	45	1199.7	3408
1987	76120	10	839	6386	520	9043	45	1924.65	3942
1988	76814	10	742	5700	220	4667	60	5425.8	54
1989	83358	10	680	5668	220	4419	60	2800.2	2648
1990	78828	10	797	6283	220	4355	60	2651.4	3411
1991	75956	10	911	6920	220	7118	60	2613	4087
1992	72510	10	971	7041	220	4453	70	4982.6	1838
1993	69301	10	907	6286	220	3134	70	3117.1	2949
1994	71240	10	463	3298	220	3888	70	2193.8	885
1995	88881	10	515	4577	220	3096	70	2167.2	2190
1996	86777	10	502	4356	220	3659	70	2561.3	1575
1997	82082	10	502	4121	220	3774	70	2641.8	1259

IRR=31%