PROJECT 18

Report to: Cleveland Nature Conservation Trust

Date: 1 July 1981

A Biological Survey of Westworth Reservoir, near Guisborough, Cleveland.

D.T. Crisp

CONTENTS

SUMMARY

1. Simple surveys of water chemistry, plankton, benthos and fish were made at Westworth Reservoir (Nat. Grid Ref. NZ/636134) in February and June 1981.

2. The reservoir is at an altitude of 229 m.O.D., has an area, when full, of 1.52 ha and a maximum depth of 7.3 m. The catchment consists partly of moorland and partly of man-made forest. The water level was drawn-down to 2.4 m during February and 1.8 m during June 1981. The main aim of the survey was to obtain factual information as background to discussions as to whether the reservoir area should be infilled and planted with trees or whether the water body should be retained with the water level maintained at 3.7 m or less.

3. The reservoir water has a low pH (5.9-6.1 according to Northumbrian Water Authority data for 1975-6, 4.5 when sampled in February 1981). Concentrations of calcium, magnesium and potassium are fairly low. The concentration of sodium is high, relative to Pennine waters, and may be augmented by windblown sea salt. The evidence suggests substantial inputs of ammonia- and nitrate-nitrogen from the afforested areas and concentrations of both are high within the reservoir.

4. No fish were found in the reservoir, its afferent streams or the upper reaches of the efferent stream.

5. The invertebrate fauna of the afferent and efferent streams was as might be expected from British upland streams, though rather lacking in diversity.

6. The macro-invertebrate fauna of the reservoir was sparse and not very rich in species. The main components were Chironomidae and Corixidae.

7. The zooplankton (as micro-crustacea) was sparse and only three species of Copepoda and one species of cladoceran were found. Large numbers of rotifers were found in June.

8. Although a number of species were recorded from the phytoplankton samples many of them were not typical lake or reservoir plankton genera.

9. The fauna and flora of the reservoir and its associated streams are fairly typical of base-poor upland waters and, with the possible exception of the two main corixid species (Corixa germari and Glaenocorisa propinqua), there are no biological features which urgently require conservation. The reservoir does have potential as an area for amenity and education.

10. In the event of retention of the reservoir at the reduced level (3.7 m) legally required of the Northumbrian Water Authority, it would be desirable for the water to be maintained close to this level continuously and for the loose masonry at present scattered around the reservoir edges to be moved into the water to provide oviposition sites for the Corixidae.

INTRODUCTION

During the winter of 1980-81 the F.B.A. was asked, by Mrs. A. Cooper, on behalf of the Cleveland Nature Conservation Trust, to advise on aquatic aspects of the future of Westworth Reservoir in Cleveland. As the value of advice may be very limited, unless based on some factual information about the system under discussion, it was desirable to make a simple survey of the reservoir and its fauna. Winter is not a good time of year for such surveys but as the advice was required quickly a simple survey was made on 10 February, 1981, followed by additional sampling on 10 June 1981.

The present report outlines the results of the surveys and then discusses them in the light of questions formulated by the Cleveland Trust.

The reservoir was formerly used to supply water to Guisborough, but is now no longer required for this purpose by the Northumbrian Water Authority. To fulfill its legal obligations the Authority must either breach the dam or otherwise ensure that the water level is drawn-down, and remains drawn-down, to a maximum depth of 12 ft. (3.7 m) so as to give a maximum content of 22600 m^3 (5 million gallons). The landowner (Lord Guisborough), the Northumbrian Water Authority, Langbaurgh Borough Council, and the North Yorkshire National Park Committee (who are being advised by the Cleveland Nature Conservation Trust and the Nature Conservancy Council) are currently discussing whether the reservoir should be drained, infilled and planted with trees or whether it should be retained as an area for nature conservation and/or a public amenity. Retention of the reservoir, would raise further questions about the best way to manage the water body and a small area of surrounding land which includes public footpaths.

DESCRIPTION OF THE RESERVOIR AND ASSOCIATED STREAMS

Westworth reservoir is situated in the County of Cleveland (Nat. Grid Ref. NZ/636134) at an altitude of 229 m.O.D.(750 ft.). When full it has a surface area of 1.52 ha (3.745 acres) a maximum depth of 7.3 m (24 ft.) and contains 69.5 x $10^3 m^3$ (15.3 m.g.) of water. It is fed by four inflows (See Fig. 1):

(a) A small inflow, probably of surface drainage water, which enters near the east side of the reservoir ("a" on Figure 1).

(b) A small, predominantly stony, stream which drains an area of open moorland (formerly afforested) and enters the reservoir from the southeast (designated "Stream 1" in the present report).

(c) A small stream which drains an afforested area and enters the reservoir from the southwest. The bed of this stream consists of gravel and sand (designated "Stream 2" in this report).

(d) A small inflow which enters the reservoir through a pipe close to the western end of the dam ("b" on Figure 1).

The reservoir discharges via the valve tower to a small stream (designated "Stream 3") which flows in a predominantly northerly direction towards Slapewath. Within the confines of the reservoir boundary fence this stream is heavily overgrown by vegetation and its bed is covered by mud and fallen tree leaves.

The main dam, the valve tower and the embankments on the East and West sides of the reservoir are made of dressed stones. The bottom of the reservoir is composed chiefly of mud and particulate peat but in some areas, especially near the mouths of inflowing streams, there are deposits of sand and, occasionally, fine shingle.

The masonry walls of the dam and embankments already show signs of invasion by Juncus. In February there were the remnants of a fairly extensive cover of aquatic vegetation on those portions of the former reservoir bed between the foot of the stonework and the existing water level (c. 8 ft. = 2.4 m on the valve tower staff). As this vegetation had been exposed for some time it was difficult to identify with certainty. Two elements could be tentatively distinguished; a higher plant, probably Callitriche sp., and a darker coloured plant - possibly a moss. There was no sign of vegetation other than algae below the February water level. On 10 June 1981 the reservoir was drawn-down to c. 6 ft. (1.8 m) and there was little sign of residual aquatic vegetation. Encroachment by terrestrial vegetation had continued. If the reservoir remains drawn-down it is likely that terrestrial vegetation will colonise the exposed parts of the former reservoir bottom and that such plants as Callitriche will develop below the new water level.

Figure 1 shows the outline of the reservoir when full to top water level. The dotted line indicates the approximate position of the water's edge if the reservoir is maintained at or around a depth of 12 ft. (3.7 m) on the valve tower staff. As compared with the full reservoir, this will give a reduction in water surface area from 1.52 ha (3.745 acres) to 0.60 ha (1.467 acres) and a reduction in maximum depth from around 7.3 m (24 ft.) to 3.7 m (12 ft.).

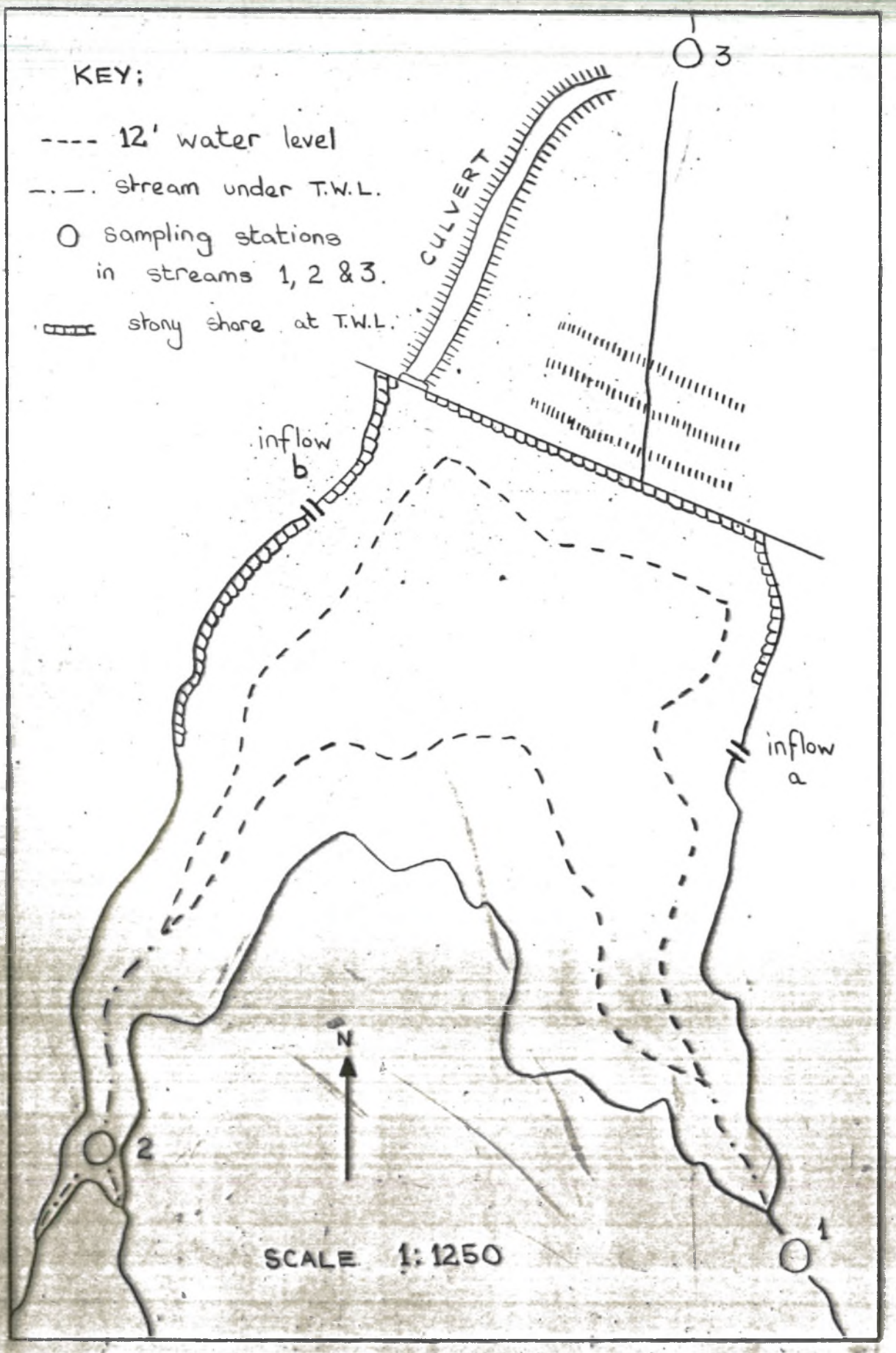

Fig 1. Map of Westworth Reservoir. [For further details see text.]

GENERAL APPROACH

The reservoir was visited on 10 February and 10 June, 1981 and simple surveys were made for the purpose of producing Figure 1 and estimating the areas given in the previous section. Various samples were taken from the reservoir, the two main afferent streams (1 & 2) and the outflowing stream (3) on both occasions.

The following aspects were examined:

(a) Water chemistry. Samples were taken from the reservoir and each of the three streams in February and from these places and also from the two minor inflows (a & b on Fig. 1) in June.

(b) Plankton. Samples of phyto- and zoo-plankton were taken from the reservoir.

(c) Benthic invertebrates. Samples were collected from the three streams and the reservoir.

(d) Fish. The three streams and the reservoir were investigated for the presence of fish in February.

WATER CHEMISTRY

Details of the analyses of water samples are given in Table 1.

(i) <u>February Samples</u>

The water was very acidic (pH 4.0 to 4.6). As the concentrations of calcium and magnesium were relatively low, the low pH's may reflect the combined effects of atmospheric pollution and low buffering capacity.

TABLE 1. Analyses of water samples taken from Westworth Reservoir, three streams and two small inflows on 10 February and 10 June, 1981.

Date & Sample	pH	Ca ($mg\ l^{-1}$)	Mg ($mg\ l^{-1}$)	Na ($mg\ l^{-1}$)	K ($mg\ l^{-1}$)	NH_3-N ($\mu g\ l^{-1}$)	NO_3-N ($\mu g\ l^{-1}$)	PO_4-P ($\mu g\ l^{-1}$)	SiO_2 ($mg\ l^{-1}$)
February 10									
Stream 1	4.00	1.46	1.9	11.4	0.75	5	197	3	6.20
Stream 2	4.30	5.20	2.8	12.4	0.95	5	696	3	7.33
Westworth Reservoir	4.47	4.24	3.0	28.3	0.94	191	374	3	6.24
Stream 3	4.61	4.80	2.9	26.0	0.85	172	382	3	6.73
June 10									
Stream 1	-	3.71	2.23	9.07	0.39	66	18	-	5.01
Stream 2	-	7.52	2.88	10.01	0.56	104	108	-	8.89
Inflow "a"	-	9.92	2.53	10.71	0.57	6	4	-	9.65
Inflow "b"	-	12.83	4.95	13.97	0.35	8	260	-	7.69
Westworth Reservoir	-	7.47	2.60	9.41	0.61	150	144	-	5.89
Stream 3	-	6.98	2.79	9.41	0.52	137	150	-	5.79

N.B. NO_3-N and NH_4-N analyses on June samples performed 6 days after collection.

The phosphate determinations indicate a low phosphate concentration but this may simply reflect the effects of storage, as no special precautions were taken to prevent loss of phosphate to the sample container.

The relatively high sodium concentrations in the reservoir and outflow, but not in the two main inflowing streams, indicate a substantial input of sodium to the reservoir, either as windblown sea salt or from some other source. Ammonia nitrogen shows a similar pattern and this is unlikely to represent an input from the sea but could be either from some other atmospheric source, or an input via one of the smaller aquatic inputs which were not sampled.

Nitrate nitrogen had a much higher concentration in Stream 2 (afforested) than in Stream 1 (moorland, previously afforested). The most likely explanation is the leaching out of nitrogenous fertiliser applied at some stage(s) in the forestry programme.

(ii) June Samples

Calcium and magnesium concentrations were higher than in February, but still relatively low. The fact that sodium concentration varied relatively little between the inflowing streams and the reservoir and its outflowing stream suggests that the variation in this respect observed in February might well have been an effect of windblown sea salt.

The most striking features of the June analyses, confirming a general pattern observed in February, are the large differences in concentrations of Ammonia nitrogen and nitrate nitrogen between samples from the afforested "stream 2" and the unafforested "stream 1".

This difference in nitrate nitrogen is parallelled by differences between "inflow a" (from unafforested land) and "inflow b" (from afforested land). It is, therefore, possible that the afforestation of part of the catchment is reflected in the relatively high concentrations of nitrate nitrogen and ammonia nitrogen which occur in the reservoir and the outflowing stream.

(iii) Additional chemical information

A summary of analyses of reservoir water for the period 1975-76 was provided by the Northumbrian Water Authority and is shown in Table 2. As compared with the February 1981 analyses, the data for 1975-76 show about the same concentration of nitrate-nitrogen (400 $\mu g\ l^{-1}$) but a much lower concentration of ammonium-nitrogen (40 $\mu g\ l^{-1}$, c.f. 191 $\mu g\ l^{-1}$). It is not clear to what extent these differences reflect the effects of draw-down and to what extent they arise from some other cause.

PLANKTON

In the February phytoplankton sample, only two planktonic species were seen: Asterionella and Melosira. In addition a few large benthic diatoms and some smaller epiphytic/benthic diatoms and a few filaments of green alga (Microspora?) were found. In the June sample, algae were more numerous but very few were of taxa typical of lakes and reservoirs. Asterionella and Melosira were less abundant than in February. Many Naviculoids were present, chiefly Navicula sp., Pinnularia and Surrirella. A few Euglenoids were present and only a single filament of Microspora (?) was found.

TABLE 2. Summary of analyses of water from Westworth Reservoir, 1975-6, by the Northumbrian Water Authority.

	mg/l	Average	Maximum	Minimum
pH		6.0	6.1	5.9
Acidity to pH 8.3	(CO_2)	15.0	15.0	14.0
Electrical Conductivity	(μS/cm)	135.0	140.0	130.0
Colour	(^oH)	<5.0	5.0	<5.0
Turbidity	(FTU)	3.6	5.7	1.4
Permanganate Value		1.3	1.4	1.1
Total Organic Carbon	(C)			
Suspended Solids				
Dissolved solids		95.0	105.0	85.0
Nitrogen: Ammoniacal	(N)	0.04	0.05	0.02
Nitrogen: Nitrite	(N)	<0.01	<0.01	<0.01
Nitrogen: Nitrate	(N)	0.40	0.50	0.30
Nitrogen: Organic	(N)			
Alkalinity to pH 4.5	($CaCO_3$)	5.0	5.0	5.0
Total hardness	($CaCO_3$)	35.0	35.0	30.0
Chloride	(Cl)	11.0	11.0	11.0
Sulphate	(SO_4)	34.0	35.0	33.0
Silica, M.R.	($Si\ O_2$)	8.0	8.0	8.0
Phosphate, Inorganic	(P)			
Fluoride	(F)			
Calcium	(Ca)	7.2	7.6	6.8
Magnesium	(Mg)			
Potassium	(K)	1.1	1.2	1.0
Sodium	(Na)	12.0	12.0	12.0

	μg/l	Average	Maximum	Minimum
Aluminium	(Al)	350		
Iron	(Fe)	160	210	100
Manganese	(Mn)	115	115	110
Copper	(Cu)	6	8	4
Zinc	(Zn)	66	68	64
Lead	(Pb)	<10		
Cadmium	(Cd)	<2		
Chromium	(Cr)	<1		
Antimony	(Sb)			
Arsenic	(As)	<10		
Barium	(Ba)			
Mercury	(Hg)	<1		
Nickel	(Ni)			
Selenium	(Se)	<10		
Silver	(Ag)			
Cyanide, Total	(CN)	<10		
Anionic Detergent	(Manoxol OT)	< 20		
Non-Ionic Detergent	(Lissapol NX)	<100		
Phenols	(C_6H_5OH)	<100		
Organochlorine pesticide residues	ng/l	<5		

Large numbers of rotifers (Brachionus sp.) were also found in the June phytoplankton sample, whereas small numbers of the genus Keratella were found in February.

The zooplankton sample taken in February contained only a few Copepod nauplii (indet.). The June sample yielded three taxa of Copepoda (Acanthocyclops languidus, Paracyclops fimbriatus and a Cyclopoid (indet.)) and one species of cladoceran (Ilyocryptus sordidus).

BENTHIC INVERTEBRATES

1. In the streams

The streams were sampled for invertebrates chiefly by means of kick samples (Hynes, 1961). The aim was to obtain an indication of the main components of the fauna, rather than any quantitative estimate of population density. The Coleoptera were identified by Mr. J. Blackburn and the other groups by Dr. P.D. Armitage.

The results (Table 3) are similar to those which might be expected from small upland streams, though perhaps rather lacking in diversity. Note that the specimens of Gyrinus natator taken in June were collected from a pool at the foot of the spillway channel close to Stream 3, not from Stream 3 itself.

TABLE 3. Invertebrates found in streams around Westworth Reservoir on 10 February and 10 June, 1981.

	10 February			10 June		
	Stream 1	Stream 2	Stream 3	Stream 1	Stream 2	Stream 3
Phylum Annelida						
Lumbriculus variegatus	–	1	–	–	1	1
Phylum Arthropoda						
O. Plecoptera						
Leuctra nigra	2	5	1	1	–	–
L. hippopus	16	31	8	–	–	–
L. sp. indet.	–	–	–	–	–	1
Capnia atra	8	4	–	–	–	–
Nemurella picteti	4	3	–	16	8	–
Nemoura cinerea	15	–	2	10	19	1
N. sp. indet.	–	1	2	16	–	1
O. Megaloptera						
Sialis lutaria	–	–	1	–	–	1
O. Trichopera						
Plectrocnemia conspersa	–	2	6	10	18	12
Stenophylax sp.	1	–	–	–	–	–
Potamophylax grp.	–	–	–	1	–	–
O. Coleoptera						
Deronectes(Stictotarsus)duodecimpustulatus	–	–	–	–	–	2
Agabus guttatus	–	–	–	1	1	–
Agabus sp. larvae	1	–	–	–	–	1
Gyrinus natator	–	–	–	–	–	13
Anacaena globulus	–	–	–	–	1	–

TABLE 3. Continued.

O. Hemiptera

Velia sp. indet.

O. Diptera

Thienemannimyia grp.

Macropelepia sp.

Corynoneura sp.

Eukiefferiella brevicalcar

Eukiefferiella sp. indet.

Eloeophila sp.

Heterotrissocladius sp.

Tanytarsus sp.

Pedicia rivosa

Dieranota sp.

Pilaria sp.

Simulium brevicaule grp.

S. latigonium

Muscidae indet.

TOTALS

10 February			10 June		
Stream 1	Stream 2	Stream 3	Stream 1	Stream 2	Stream 3
–	–	–	1	–	–
–	–	1	–	–	1
–	–	2	–	–	4
–	–	–	1	–	–
2	1	–	1	1	–
–	–	–	–	1	–
–	1	–	–	–	–
–	–	1	–	–	–
–	–	1	–	–	–
–	–	–	1	1	–
1	–	–	1	–	–
–	–	–	–	1	–
–	–	–	1	14	–
–	–	–	–	–	33
–	–	–	–	1	–
50	49	23	111	67	71

2. In the reservoir

The species found in the reservoir are listed in Table 4. Determinations were made by Mr. J. Blackburn (Coleoptera), Dr. D.T. Crisp (Corixidae) and Dr. P.D. Armitage (all others).

The material was collected by means of pond net sweeps over and through the bottom material. Apart from Corixidae, the fauna appeared to be rather sparse. This may partly reflect the effects of sudden and sustained draw-down. In general, the list is as would be expected from a small, acid, upland reservoir in northern England.

Partly because they were the most numerous group in the sample from the reservoir and partly because of a long-standing interest in the group, on the part of the author, the Corixidae collected from the reservoir were identified to species and a detailed analysis of the samples is given in Table 5.

The single specimen of Corixa punctata was taken in a seine net in February during the search for fish. This is a fairly ubiquitous species. The other Corixidae were collected during sweeps of a pond net at intervals round the reservoir margin in water from 20-100 cm deep. The two specimens of C. venusta were collected during a sweep over a sandbar close to the inflow of "Stream 1" in February. Macan (1954) found that C. venusta was typically found in mountain, moorland, heath and bog pools and Crisp (1962a) found it, usually in small numbers, in 7 out of a total of 36 Pennine reservoirs, tarns and pools which he examined.

TABLE 4. Invertebrates found in Westworth Reservoir, 10 February and 10 June, 1981.

	10 February	10 June
Phylum Annelida		
Lumbriculus variegatus	+	–
Tubifex tubifex	–	+
Phylum Arthropoda		
O. Megaloptera		
Sialis lutaria	+	+
O. Coleoptera		
Hygrotus (Coelambus) confluens	+	–
Hydroporus (Stictonotus) lepidus	+	+
Deronectes (Potamonectes) depressus agg.	–	+
D. (Stictotarsus) duodecimpostulatus	–	+
Oreodytes sanmarki	–	+
Hydroporini indet.	–	+
O. Diptera		
Macropelopia sp.	+	–
Procladius sp.	–	+
Chironomus sp.	–	+
Tanytarsus sp.	–	+
O. Hemiptera		
Glaenocorisa propinqua	+	+
Corixa punctata	+	–
C. venusta	+	–
C. germari	+	+

TABLE 5. Corixidae found in Westworth Reservoir, 10 February and 10 June, 1981. (Nomenclature according to Macan, 1956).

	10 February			10 June		
	male	female	TOTAL	male	female	TOTAL
Glaenocorisa propinqua	14	12	26	2	6	8
Corixa punctata	-	1	1	-	-	-
C. germari	5	4	9	1	5	6
C. venusta	1	1	2	-	-	-
Nymphs indet. Instar 1.	-	-	-	-	-	11
Nymphs indet. Instar 2.	-	-	-	-	-	6
TOTALS	20	18	38	3	11	31

The two most abundant species were C. germari and G. propinqua . C. germari and the closely related C. carinata are rarely found together, though they appear to share at least some habitat preferences and each of these two species is frequently found in association with G. propinqua. These three species have been regarded as rather scarce (e.g. Macan, 1956), though Crisp (1962a) suggests that this is simply a result of their rather specialised habitat requirements and the fact that little collecting has been done in such places as upland reservoirs which appear to meet those requirements. This point is pursued further in the literature appended to this report. In summary, C. germari, C. carinata and G. propinqua are typically found in fairly large bodies of water, often subject to severe wave action and with relatively steep sides. They occur in rather deeper water than most other British species. All three species appear to have a preference for rock or stone surfaces upon which to rest and C. germari (possibly the other two species as well) prefers to oviposit on stones (Crisp & Heal, 1958; Crisp, 1962a, 1962b, 1962c).

The only adult Corixidae found in June were G. propinqua and C. germari, in smaller numbers than in February and represented mainly by females. The nymphs found probably belong mainly to one or both of these species and their stage of development was similar to that observed at the same time of year for C. germari in a South Pennine reservoir (Crisp, 1962c). The presence of these nymphs shows that some successful oviposition had occurred, though the small numbers of nymphs, relative to adult numbers, may reflect the effects of draw-down.

FISH

1. In the streams

In February areas of approximately 25, 45 and 75 m^2 were carefully electrofished in streams 1, 2 and 3 respectively. No fish were found.

2. In the reservoir

Two hauls of a small seine net were made across the reservoir in February. Taken together, these hauls swept about 60-70% of the surface area (or volume) of the reservoir. No fish were found.

DISCUSSION & RECOMMENDATIONS

There was evidence in February that aquatic macroflora had existed in the reservoir but was being damaged by the draw-down. No signs of major relocation and recovery were apparent in June.

It is clear that the reservoir and its afferent streams lack fish and that the invertebrate fauna is not very diverse.

Probably the most interesting biological feature to emerge from the survey is the presence of the waterbugs Corixa germari and Glaenocorisa propinqua. These are generally regarded as rather scarce species, though this is debatable. Certainly they are interesting species which have rather specialised habitat preferences. Amongst these is a preference for stone surfaces as resting places and, for C. germari at least, as oviposition sites. Draw-down to 3.7 m (12 ft.) depth deprives these species of the stone banking around the margins of the reservoir and the only remaining submerged stonework is the valve tower. Therefore, if the reservoir were to be maintained at 3.7 m depth, it would be useful if the scattered masonry at the foot of the main dam were to be thrown into the reservoir, preferably

so as to lie in depths of 0.6-1.0 m (2-3 ft.) of water.

In the event of retention of the reservoir, it would be desirable for the depth to be maintained at or close to 3.7 m and for the size and rapidity of fluctuations about this level to be minimised as far as possible. The most harmful regime for aquatic fauna would be large and/or rapid fluctuations of water level. Given reasonably stable water levels, it is likely that aquatic plants would become re-established in the reservoir and that the region between the water-line and the former reservoir margins would also acquire vegetation.

Further afforestation of the reservoir margins or catchment might further reduce faunal diversity, though detailed studies of such effects in the U.K. are scarce. The application of fertilisers, herbicides and pesticides in connection with forestry could all have effects on aquatic fauna and should, therefore, be used with great care. It is important to note that the problem is not confined to the effects of the "active" ingredients but includes the effects of the solvents, carriers and additives with which they may be used. However, as forestry is clearly a practice of long-standing around Westworth Reservoir, it is perhaps unlikely that additional afforestation, especially if carried out with care and understanding, would have any major harmful effects.

In general, Westworth reservoir does not appear to have any biological features which urgently require conservation, but it does have potential value as an area for amenity and education and serious consideration should be given to this aspect. In the event of fire in the tree plantations the presence of the reservoir could be of crucial importance.

ACKNOWLEDGEMENTS

The author is indebted to Lord Guisborough and the Northumbrian Water Authority for permission to visit the reservoir. Mrs. A. Cooper kindly negotiated permissions for access and provided valuable background information. The Northumbrian Water Authority provided the data in Table 2.

Mrs. S. Robson and Mr. P.R. Cubby provided invaluable help both in the fieldwork and in the production of this report.

Most of the material collected has been examined by specialists in the relevant fields and the author is deeply grateful to Dr. J. Hilton (chemical analyses), Miss K. Atkinson (phytoplankton), Dr. G. Fryer (zooplankton), Dr. P.D. Armitage and Mr. J. Blackburn (benthic invertebrates) for their willing cooperation and helpful comments. They should not, however, be held responsible for any opinions expressed by the author!

The report was typed by Mrs. D. Jones.

REFERENCES (OTHER THAN THOSE INCLUDED IN THE APPENDIX - SEE OVERLEAF)

Hynes, H.B.N. (1961). The invertebrate fauna of a Welsh mountain stream. Arch. Hydrobiol. 57, 344-388.

Macan, T.T. (1954). A contribution to the study of the ecology of Corixidae (Hemipt.). J. Anim. Ecol. 23, 115-141.

Macan, T.T. (1956). A revised key to the British water bugs. (Hemiptera-Heteroptera). F.B.A. Sci. Publ. No. 16.

APPENDIX - REPRINTS OF A SELECTION OF RELEVANT PAPERS ON CORIXIDAE.

Crisp, D.T. & Heal, O.W. (1958). The Corixidae (O. Hemiptera), Gyrinidae (O. Coleoptera) and Cladocera (Subphylum Crustacea) of a bog in Western Ireland. Irish Naturalists' Journal. 12, 1-14.

Crisp, D.T. (1961a). A study of egg mortality in Corixa germari Fieb. (Hem. Corixidae). Ent. Mon. Mag. 96, 131-132.

Crisp, D.T. (1961b). The food of three species of Hydradephaga (Coleoptera) in an upland reservoir. Ent. Mon. Mag. 96, 133-134.

Crisp, D.T. (1962a). Some Corixidae (Hemiptera-Heteroptera) from bog and moorland waters. Trans. Soc. Brit. Ent. 15, 21-28.

Crisp, D.T. (1962b). Estimates of the annual production of Corixa germari (Fieb.) in an upland reservoir. Arch. Hydrobiol. 58, 210-223.

Crisp, D.T. (1962c). Observations on the biology of Corixa germari (Fieb.) (Hemiptera Heteroptera) in an upland reservoir. Arch. Hydrobiol. 58, 261-280.