Effect of Turoa oil spill on aquatic insects in the Mangawhero river system

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Abstract

Oil (17,000 l) was spilled from Turoa Skifield on Mt Ruapehu and entered the headwaters of the Mangawhero and Makotuku Rivers where it persisted for up to 5 months. Brown trout, rainbow trout, long-finned eels, and blue duck were not killed. However, in the upper reaches, aquatic insects were disturbed and killed by the oil spill within 2 weeks. The total numbers of aquatic insects were not significantly affected at the lower stations within Tongariro National Park over the following year. The mayflies *Deleatidium* nr *myzobranchia* B and *D.* nr *lillii* A (Ephemeroptera: Leptophlebiidae) were significantly reduced in numbers in the Makotuku River following the oil spill and may be indicator species for oil pollution.

Comparisons with overseas studies confirmed a recovery time of at least 6 months for the "sensitive" orders of aquatic insects following an oil spill of this magnitude.

Keywords: oil; aquatic insects; pollution; Ephemeroptera; New Zealand.

INTRODUCTION

Since 1965 there has been an increasing number of studies of oil pollution in inland waters, generally related to large oil spills (Jones et al. 1980). There have been no published studies in New Zealand.

On 8 December 1979, about 17 000 l (3700 gallons UK) of home heating oil were spilled from the Turoa Skifield installation (1650 m a.s.l.) on Mt Ruapehu in Tongariro National Park (Refer NZMS 273A and Fig. 1). The discharge entered the headwaters of the Mangawhero and Makotuku Rivers although an unknown quantity went into the ground. (The reader is referred to Michaelis 1981 unpublished for full details).

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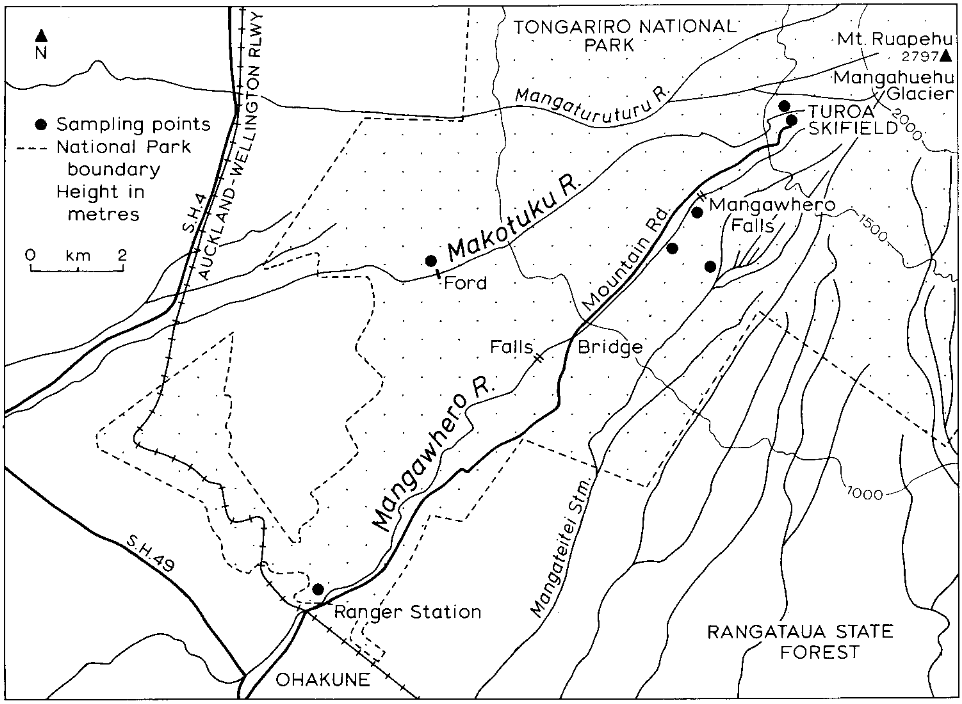

Fig. 1. Map of southwestern Ruapehu to show location of Turoa Skifield and the Mangawhero and Makotuku Rivers. Sampling sites are indicated by crosses enclosed in circles. The path taken by the oil spill is indicated by arrows.

Terrestrial vegetation was destroyed by oil spills from ski-tow facilities at Temple Basin in Arthurs Pass National Park (Norton & Burrows 1979) but was not investigated in the present study. The author had previously sampled the Mangawhero and Makotuku Rivers as part of a survey of Tongariro National Park (Michaelis 1980 unpublished) so it was decided to compare the rivers "after pollution" with "before pollution".

The mayflies *Deleatidium* spp. (Ephemeroptera: Leptophlebiidae), common in New Zealand streams and rivers, are typically affected by organic pollution (Hirsch 1958, Dacre & Scott 1973) and this suggested trying *Deleatidium* as an indicator species in the present study.

BACKGROUND TO THE OIL SPILL

The accidental discharge of 17 000 litres from the TOR 1 building by skifield staff started about 1300 hr on 3 December 1979 and continued until about 1800 hr. Oil flowed across No. 1 carpark into the drainage system leading into the Mangawhero River. The balance flowed through culverts under the Mountain Road, down the west side of the ridge and into the tributary of the Makotuku River referred to above. An unknown quantity of oil penetrated the porous substrates of the catchment and the volume entering the rivers is not known. It is thought that a greater quantity entered the Makotuku River than the Mangawhero River (W. E. Cooper, pers. comm.). Concentrations of oil would be reduced with time because of the evaporation of volatile components, absorption into the ground and the riverbed, microbial degradation, and washing away down the river. To these natural reductions must be added the "mop-up" operations within the National Park, although their significance could not be assessed. Concentrations of oil would also be reduced with distance down the river

Fig. 2. Mangawhero River near Ohakune Ranger Station at altitude 650 m. This stretch of the river was just upstream of the regular sampling site and is the main trout spawning area within the Park.

Fig. 3. The headwaters of the Makotuku River (1450 m a.s.l.) in Oct 1980. Oil entered the river from the Ski field in the middle distance.

because of dilution of oil by inflowing tributaries. The "slug" of oil would also be longitudinally dispersed.

Turoa Skifield is a high rainfall area with an average annual rainfall estimated at 4000 mm, higher than at Ohakune Mountain Road (2597 mm) or Ohakune Junction (1426 mm). At all 3 stations, rainfall exceeded the normal in December 1979 and January 1980 but was normal in February 1980. At Ohakune Junction, there was no rain on 8 and 9 December but 29 mm on 10 December and further rain until 15 December; a wet period from 26 December 1979 until the end of the month and heavy falls on 16 and 22 January 1980.

The oil

Data supplied by Mobil Oil N.Z. Limited indicated that Mobil Heating Oil No. 2 is diesel:kerosene = 6:4 blended to satisfy low temperature requirements. An oil-soluble blue dye based largely on xylene is added (1:5000). No data are available for the acute toxicity of the dye to fish.

The receiving waters

The Mangawhero River and its tributary the Makotuku River rise on Mt Ruapehu and are part of the Whangaehu River System which enters the sea south of Wanganui (Fig. 1). Neither river was affected by the 1969 eruption (Glover 1978) nor by the 1975 eruption of Mt Ruapehu (Nairn et al. 1979) but both rivers are prone to heavy flooding (Mead 1979).

The Mangawhero River rises at 1840 m a.s.l. in a small stream that skirts the east of the Turoa Skifield. The Turoa Alpine Marsh Area (Michaelis 1980 unpublished) lies above the oil spill. At Mangawhero Falls, discharge was 0.052 m^3s^{-1}, giving a dilution factor of 1:21 between the Falls and the Ohakune Ranger Station and 1:220 between the Falls and Ore Ore (Michaelis, unpublished results, 7 December 1980). At the Ohakune Ranger Station (Fig. 2), the river discharge averaged 1.2 m^3s^{-1} with a range of 0.26 to about 40 m^3s^{-1} (Rangitikei-Wanganui Catchment Board, unpublished data).

The Makotuku River rises at 1720 m a.s.l. to the west of the skifield. A tributary rises at 1540 m a.s.l. below the skifield and to the west of the Mountain Road (Fig. 3). The Makotuku River is a similar size to the Mangawhero River and discharges an average of 0.85 m^3s^{-1} at S.H. 49A (just below the Park Boundary) with a minimum flow of 0.085 m^3s^{-1} (Rangitikei-Wanganui Catchment Board, unpublished data).

The rivers flow through the National Park for 9 km and 13 km respectively (Fig. 1).

Chemical analyses showed that water from the Mangawhero River at the roadbridge and the Makotuku River at Horopito Ford was very similar. It was of neutral pH (6.9 and 6.8 resp.), soft (according to the scale of Taylor 1958) and poor in calcium (using the scale of Ohle 1934). It was nearly saturated with dissolved oxygen.

Benthic flora and fauna

Ohakune (presumably the Mangawhero River) was the type locality for 23 new species of aquatic insects collected by T. R. Harris (1920-1927) and others. For this reason, the Mangawhero River should be preserved for scientific study in its natural state. At the Ohakune Ranger Station, the river is fast flowing with a substrate of boulders and stones. It supported a growth of submerged moss (? *Hypnum cupressiforme*) and contained much detritus from the overhanging beech forest. The abundant fauna was dominated by insects (21 taxa) such as the dobson-fly *Archichaulioides diversus;* stoneflies *Stenoperla prasina, Austroperla cyrene, Megaleptoperla grandis*, and *Zelandoperla decorata;* mayflies *Nesameletus* sp., *Coloburiscus humeralis*, and *Deleatidium* nr *myzobranchia* B; and the cased caddis *Beraeoptera roria.*

The Makotuku had a similar substrate and water velocity to the Mangawhero. At the Horopito Road end ford its fauna was again dominated by aquatic insects (19 taxa) but was not as abundant as that of the Mangawhero River at Ohakune perhaps because of its higher altitude. Included were the stoneflies *Austroperla cyrene* and *Stenoperla prasina;* the mayflies *Deleatidium* nr *lillii* A, *D.* nr *myzobranchia* B and *Zephlebia dentata;* the caddisflies *Helicopsyche poutini* and an unidentified rhyacophilid; and unidentified Orthocladine chironomids.

Of a total of 20 species of aquatic insects, 11 abundant species were common to both rivers, while 9 species were found in only one of the rivers.

In both rivers, the fauna was numerically dominated by the mayfly genus *Deleatidium* and this is a common situation in New Zealand stony streams and rivers, particularly at that altitude (McLellan 1975).

Fishery and birdlife

Distributions of small native fish are not known but both rivers contain brown trout *Salmo trutta,* rainbow trout *S. gairdneri* (Pisces: Salmonidae) and the long-finned eel *Anguilla dieffenbachii* (Pisces: Anguillidae). The Mangawhero River below the National Park boundary has been heavily fished since before 1930 (Graynoth & Skrzymski 1973). The main spawning areas are the Mangawhero River within the Park and the Makara Stream (a tributary of the Makotuku River) which was not affected by the oil spill. The blue duck (whio), *Hymenolaimus malacorhynchos,* is known from the Mangawhero River within the Park as well as the more common grey duck *Anas superciliosa* (Aves: Anatidae).

METHODS

Chemical analysis of water and gravel samples for oil

Four samples of bulk water, 2 samples of gravel, and 1 sample of diesel were collected into glass bottles (2.5 l) by Tongariro National Park Ranger staff on 13 December 1979 from various locations within the catchments of the Mangawhero and Makotuku Rivers. A further water sample from each river was collected by the author on 1 March 1980. All samples were analysed by Chemistry Division DSIR, Lower Hutt, using gas-liquid chromatography on a hexane extract from the samples.

Additional observations were continued by the author at various locations on both rivers until the smell or visible sign of oil was no longer evident.

Samples of flora and fauna

Sampling sites were located as in Fig. 1. Sites used by the author prior to the spill (15/16 September 1979) were re-established except that the "ford" area of the Makotuku River had been bulldozed as part of the diesel spill "clean-up". A new site was established 50 metres upstream.

At all sites quantitative samples were taken from substrates of stones (20-200 mm diam.) and gravel (2-20 mm diam.) with a Surber sampler (area sampled 0.09 m^2; mesh diameter 0.24 mm). Three to 5 samples were taken at each site. Samples were preserved in the field in 10% formalin. In the laboratory, samples were washed through a series of sieves (min. mesh diameter 0.24 mm) for easier sorting. Animals were separated into different taxa and stored in vials of 70% ethanol. Densities of animals were expressed as number per square metre (no./m^2).

Mosses were collected and preserved in glycerol (Michaelis 1981).

Additional observations were made at other sites in the rivers and in adjacent catchments. Aquatic macrophytes have been deposited with Botany Division, DSIR, Christchurch, and insects with the New Zealand Arthropod Collection at Entomology Division, DSIR, Auckland.

RESULTS AND DISCUSSION

Persistence of oil in the catchments

Field observations by Ranger staff and the author for the presence of oil showed some inconsistencies with chemical analyses (Michaelis 1981 unpublished).

The 2 samples of gravel from the carpark (13 Dec 1979) indicated oil was present. It is interesting that none of the 6 water samples (13 Dec 1979-1 Mar 1980) analysed indicated the presence of oil, yet all smelled of oil at the collection site. A similar analytical problem was encountered in a study of Happy Valley Creek in Alaska (Nauman & Kernodle 1975). The DSIR Chemistry Division regard the odour of oil as good evidence of its presence in water samples (pers. comm.). On the basis of smell as indicating presence of oil, the oil persisted at least 3 months at sites where it was impounded (the weir at the ford on the Makotuku River, and the weir above the Mangawhero Falls). Observations lower down the Mangawhero River, e.g., at Ohakune, showed that oil persisted between 1-2½ months.

After 5 months, no evidence of the oil remained in the National Park. Crude oil residues persisted for almost a year in the Trail River, Northwest Territories of Canada (62°N lat) (Rosenberg & Wiens 1976), but their analytical methods were not given.

Effect of the oil spill on aquatic flora and fauna

The immediate impact of the oil spill is not known because it was 5 days before the first biologist was notified and took any samples (D. J. P. Turner, pers. comm.). Two weeks after the spill, the Makotuku River at Horopito Ford contained dead encrusting lichens and mosses on submerged and emergent stones. There were no live insects but 2 dead pupae of *Aoteapsyche raruraru* (Trichoptera: Hydropsychidae) and larvae of Rhyacophilidae and *Megaleptoperla grandis* (Plecoptera: Gripopterygidae) in poor condition. At Mangawhero Falls, there were no insects at all, but down at Ohakune all insects were alive and appeared unaffected. Similar lethal effects of oil spills on bottom fauna have been described in Hayford Creek, California (Bury 1972) and in Happy Valley Creek, Alaska (Nauman & Kernodle 1975).

In the headwaters of the Makotuku River the number of invertebrates was very low, even 10 months after the spill and no Ephemeroptera were collected. At Mangawhero Falls, no live insects were collected 3 months after the spill. The fauna of these 2 sites can be compared with the sparse but more diverse fauna of Turoa Springs and the adjacent catchments of Mangateitei Stream and Mangawhero River tributary where the altitude was similar (1150-1450 m) and there was no pollution (Michaelis 1980 unpublished, 1981 unpublished).

Lower down the rivers, the number of invertebrates was higher. This permitted more intensive collecting and numerical analysis before and soon after the oil spill. Drift of aquatic insects was recorded on the Mangawhero River at Ohakune but the data available are inconclusive (I. D. McCallum, pers. comm.).

The results of quantitative sampling at the Mangawhero River at Ohakune and the Makotuku River at Horopito Ford are presented in Fig. 4 and Michaelis (1981 unpublished). The abundance of invertebrates was not noticeably reduced in the Mangawhero River but there was a decrease in the Makotuku River immediately following the oil spill (Fig. 4).

Because of difficulties in identifying immature specimens both species of *Deleatidium* in the Makotuku River were grouped. *Deleatidium* nr *myzobranchia* B was numerically dominant. There was a marked decrease in numbers of *Deleatidium* in the Makotuku River following the oil spill and a slight decrease in the Mangawhero River (Fig. 4).

A statistical comparison was made between the series of 3 samples taken before the spill (15/16 September 1979) and the 14 samples taken after the pollution (22/23 December 1979-4/5 October 1980) from both the Mangawhero River (Ohakune) and the Makotuku River (Horopito Ford). The 14 samples taken during the year following the pollution were combined to reduce possible seasonal effects in numbers of insects. A second statistical comparison was made between the 3 samples before the spill and

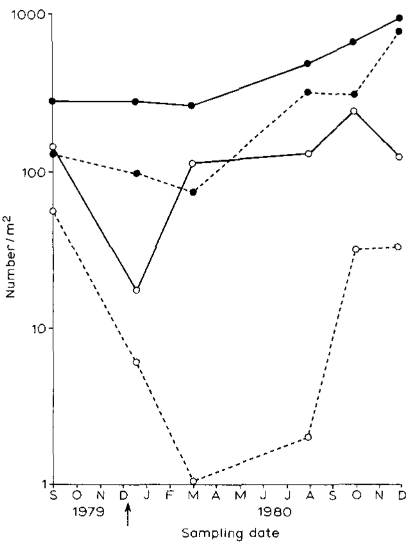

Fig. 4. Effect of the oil spill on abundance of invertebrates in Mangawhero and Makotuku Rivers. Logarithmic plot of total number of invertebrates (solid line) and of *Deleatidium* spp. (dotted line) per square metre from September 1979 to December 1980 at the Mangawhero R. (Ohakune Ranger Station) (closed circles) and Makotuku R. (Horopito ford) (open circles). Arrow indicates date of oil spill.

the 5 samples taken immediately after the spill but the results were the same as before. This suggests that seasonal effects were of limited importance.

Mann Whitney tests showed that there was a significant decrease in numbers of *Deleatidium* spp. in the Makotuku River following pollution. The numbers of *Deleatidium* spp. taken were too small to say whether the 2 species were affected differently. There was no significant change in total numbers in either river (Table 1). In the Makotuku River the decrease in numbers of *Deleatidium* spp. was compensated for by increased numbers of *Zelandoperla fenestrata* (Plecoptera: Gripopterygidae), *Aoteapsyche raruraru,* and Tipulidae. It may be that some more tolerant species increased in numbers as a result of increased algal growth caused by the presence of low levels of diesel fuel as observed with Chironomidae in the Trail River (Rosenberg & Wiens 1976).

Recovery of the fauna was quicker at the lower sites than at high altitude sites closer to the oil spill. Three months after the spill, the total number of invertebrates had returned to the level before the spill in the Makotuku River at the ford and the Mangawhero River in Ohakune. The numbers of *Deleatidium* spp. took 8 months to

Table 1. Comparison by Mann Whitney tests of bottom fauna before (3 samples, September 1979) and after (14 samples, December 1979-October 1980) the diesel spill from Turoa Skifield on 8 December 1979. (S = significant, NS = not significant).

Category	Mangawhero River Ohakune Ranger Station			Makotuku River Horopito Ford		
	Mean (numbers/m²)		P	mean (numbers/m²)		P
	Before	After		Before	After	
EPHEMEROPTERA						
Deleatidium nr *myzobranchia* B	128	333	>0.10NS			
Deleatidium nr *myzobranchia* B } *D.* nr *lillii* A				53	9.8	<0.05S
TOTAL NUMBERS	276	421	>0.10NS	144	123	>0.10NS

return to those before the spill in the Mangawhero River at Ohakune and 10 months in the Makotuku River at the ford. At Mangawhero Falls, no live larval insects were recovered until 6 months after the spill (Orthocladine chironomid) and it was 1 year before a single stonefly was recovered (*Zelandoperla fenestrata*). Assuming that mayflies were present before the spill, it would be interesting to know how long until mayflies recolonise the area and the fauna recovers its diversity and abundance.

Many studies have been of continuing oil pollution for which it was difficult to estimate a recovery time. However some estimates are available from the literature. Following an aviation fuel spill of 5000 gallons (U.S.) (18 900 l), recolonisation by Ephemeroptera, Plecoptera, and some Trichoptera was prohibited for at least 6 months (Bugbee & Walter 1973). Recovery time would be about 5-20 years in a small Spanish river following proposed treatment to remove large-scale pollution from petrochemical wastes and an oil refinery (Meynell 1973).

The recovery time of the benthic fauna in some rivers and streams was investigated following lahars (mud flows) associated with eruptions by Mt Ruapehu. The fauna regained normal levels within 6 months after the 1969 eruption and 6-9 months after the 1975 eruption but the headwaters were affected by later runoff and took up to 2 years to recover (E. J. Cudby, pers. comm.).

Effect of the oil spill on the Mangawhero fishery and birdlife

No dead fish were reported by the public from any stretch of the Mangawhero or Makotuku River following the oil spill. Four days after the oil spill, no evidence of live or dead fish was seen in the Makotuku River upstream of the Horopito Road ford (R. McLay, pers. comm.). Spawning proceeded as usual from April-June 1980 in the Mangawhero River (B. J. Williams, pers. comm.).

No harmful effects of the oil spill on aquatic birds were observed (B. J. Williams, pers. comm.).

CONCLUSION

The minimal impact of the oil spill is considered to be due to firstly, its fortuitous location in an area of steep and porous substrate at a high altitude where stream fauna is sparse and secondly, its fortuitous timing prior to persistent heavy rain at a time of year when trout were not spawning and many aquatic insects had emerged from the water.

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