WATER QUALITY PROBLEMS IN KINLOCH MARINA, LAKE TAUPO

by

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INTRODUCTION

Kinloch marina has experienced water quality problems almost since its inception in the late 1950s. These problems which take the form of dense macrophyte and filamentous algal growths had become serious enough by 1962 for the Kinloch Marina Association to invite Professor V. Chapman of Auckland University to make an appraisal of the weed problems there (Chapman 1964). From results of a single sample water analysis Chapman suggested that inorganic nutrients were not responsible for the substantial algal growths he described as being present. A further visit to the marina was made by Dr C.F. Hill of the New Zealand Electricity Department in 1969. He drew up a plant species list and provided some water analysis data from a single sample which showed, in contrast to Chapman, high levels of 'soluble phosphates' (108 mg m^{-3}) and nitrate (308 mg m^{-3}) (Hill 1969).

In 1974, a report on the marina was prepared by Worley, Downey, Muir and Associates with a view to possible extensions. They state that the inflows of nutrients from septic tanks and village stormwater drains were responsible for blue-green algal scums and growths of various types of weed and algae. Water analysis, however, was not done. Also in 1974, Mr C.J. Richmond of the Wildlife Service took several water samples from the marina and identified a number of groundwater seepages into the marina. The analyses (done by Dr G.R. Fish of the Fisheries Research Laboratory, Rotorua) showed fairly high levels of PO_4-P (88 mg m^{-3} and nitrate (100 mg.m^{-3}). Of particular importance was a sample collected from one of the groundwater springs entering the marina. This contained 95 mg PO_4-P m^{-3} and 900 mg NO_3-N m^{-3}. Fish concluded that the groundwater seeping into the marina was the course of the nutrients. Fish's algal species list showed the presence of blue-green and filamentous green algae (see later).

In 1976 a report to the Marina Association was prepared by Mr Ian Gibbs who stated that the marina had no "significant enrichment problem which adds to its weed and algal growing propensity than does a normal swimming pool." He concluded that lining of the walls and bottom of the marina would produce no improvement. He suggested pumping out the algae and killing the "leafy weed" with a herbicide at regular intervals.

Dr B. Coffey of the Ministry of Agriculture and Fisheries wrote a short report on the effect of suction dredging on the aquatic weeds and silt in the marina. He suggested that diver operated suction dredge techniques were superior to other methods in weed clearance in a small area like this marina.

There is clearly some confusion arising from these reports as to the nature and cause of the marina problem and the best method of dealing with it.

In August 1979 the DSIR Freshwater Section was approached by the Marina Association to appraise the extent of the water quality problems in the marina, assess the basic cause of these problems and to suggest recommendations for improvement. The study continued intermittently until August 1982. This report details the results of the vegetation analysis, the problems encountered in the marina, the water analysis programme and the efforts made to solve the aquatic weed problem. This report is intended primarily to document the DSIR Freshwater Section's work on the marina and also to assist the Marina Association in planning future management options for the marina. For this latter purpose some recommendations are given on ways in which water quality might be improved.

DESCRIPTION OF THE MARINA

The plan of Kinloch marina is depicted in Fig.1. Features relevant to the text of this report are illustrated in the figure. The marina consists of two basins, an inner and an outer basin. At a lake water level of 357 m above mean sea level the central areas of the basins are up to 4.5 m deep. Water depths at the berths are generally from 3 m sloping to 1 m at the breastwork. The boat ramp is at the northwest corner of the outer basin. In the southeast corner of the inner basin there is a large electrically driven water pump. This is designed to pump 1530 m^3hr^{-1} (12 cusecs) from the marina to the lake via an outflow pipe. However, at present, in normal operation the capacity is only 714 m^3hr^{-1} (Worley, Downey and Muir 1974). At this rate the marina water column is replaced every 18 hours at low water level and 42 hours at high water level. The pump is specifically maintained to create a flow of water through the marina to improve water circulation, and also to remove the floating algal scums in the through flow current.

The marina is not lined, and the sediments are pumice overlain with a fine organic ooze up to 30-40 cm deep in places. Ground water from the catchment enters the marina along the northern edge. On 1 September 1982 when the lake level was very low, thirteen identifiable ground water flows were counted along this edge (Fig.1), and presumably water is seeping all along here. In February 1974 when the lake level was also low Richmond (1974) found that the seepage of cold ground water was sufficient to cause cooler water temperatures along the north side as opposed to elsewhere in the marina. Temperatures we measured on 1 September 1982 in the marina confirm Richmond's findings. The temperatures we recorded are shown in Fig.1.

It will be difficult to estimate the exact flow of this gound water now that the marina is full although during the period of excavation water apparently flowed from land into the marina at a rate of 250 $l\ s^{-1}$ (Chapman 1964) and before excavation the swamp where the marina now stands had a continuous outflow strong enough to cause a 'rip' which could be fished (Mr M. Abrahams, personal communication).

THE MARINA VEGETATION

Since the time we initiated our studies on the marina, the bottom has been almost completely covered by algae. There are three types: a dense tall (up to 75 cm) community of *Nitella hookeri* in the deeper water, a community of filamentous algae (*Spirogyra* and *Oscillatoria*) forming mats on the bottom in shallow water or over the *N. hookeri* in deeper water and, finally, loose strings of diatoms mostly *Melosira* spp., which festoon the clumps of vascular plants, or are merely suspended in the water in "mushroom like" growths. The diatom strings and *Oscillatoria* mats form floating scums on sunny days when photosynthetically produced oxygen becomes trapped amongst the filaments causing the algae to rise to the surface.

The vascular aquatic macrophytes form a relatively small component of the marina vegetation and occur largely in depths of less than 3 m. *Potamogeton crispus* and *P. ochreatus* are probably the most widespread, but *Elodea canadensis* and *Lagarosiphon major* occur in small clumps throughout the marina too. This is similar to the situation Coffey (1977) reported earlier. A summary of plant species presence derived from the various reports is given in Table 1. With the exception of *Lagarosiphon major* and *Azolla filiculoides* the lack of a plus sign does not necessarily mean the species was absent; (e.g. Coffey, 1977 did not identify the smaller algae and Richmond 1974 did not report on the vascular plants). The dense filamentous and scum forming algae have been identified since 1964 as being the dominant vegetation type in the marina (Table 1).

THE MARINA PROBLEMS

The marina problems are caused almost entirely by the filamentous algae and diatom strings. The excessive algal growth results in a loss of aesthetic value, is a direct nuisance to boats and can be a nuisance on the adjacent beach front.

(a) Loss of aesthetic value

The dense mats of *Spirogyra* and the masses of diatom strings around wharf piles are generally unsightly. However, of major concern are the floating scums of algae, generally *Melosira* and blue-green algae (*Oscillatoria*) which rise to the water surface on sunny days particularly in summer. Apart from giving the marina a very unpleasant aspect some of the marina algae, particularly *Oscillatoria* and *Nitella* have a characteristic musty smell.

Hill (1969) found this smell was noticeable in the marina when the water was disturbed.

The algal scum problem is very noticeable at the boat launching ramp (Fig.1). Boat owners object to algae sticking to their trailers when these are pulled from the water, and they object to wading in these scums particularly having paid a launch ramp fee.

(b) Direct nuisance to boats

The dense *Nitella hookeri* beds in the berths become compacted under the boats at low water and are hard to clear. There have been reports of fouling of boat engine cooling pipes and propellors by *Nitella*.

(c) Nuisance to the beach

When the marina pump is operating in summer, the floating algal scums are pumped from the marina out into the lake just off one of the bathing beaches. Much of it ends up on the beach where it rots.

MARINA WATER CHEMISTRY

As described in the Introduction there was some conflict regarding the cause of the algal growth in the marina. However, algal growths of the type described above are generally characteristic of waters rich in nutrients. Analyses of growth promoting nutrients in the marina had either not been done or were reported from single samples. We therefore set up a monitoring programme to last from one summer to the next to examine the nutrient status of the marina water.

Sampling programme and analysis

From 10 January 1980 to 4 February 1981 surface water samples were collected at weekly or fortnightly intervals from two sites. No samples were collected in October 1980. The sites (A and B) are shown in Fig.1. Site A was from the middle of the inner basin of the marina and site B was from the lake in a depth of 1 m just opposite the marina. In addition, samples from the Whangamata spring, representing groundwater in the region were done at 2-3 monthly intervals. On one occasion when the lake was exceptionally low

(1 September 1982) the groundwater inflows to the marina were sampled.

Analyses, using routine auto-analytical procedures at the DSIR Freshwater Section, were on filtered (Whatman GF/C) waters for the following dissolved nutrients: nitrate-nitrogen, ammonium-nitrogen, organic nitrogen, reactive phosphorus and organic phosphorus. Nutrients in particulate form were not analysed because of the large variations in the amounts of algae in the water which changed depending on time of day, season, cloud cover, pump operation etc. Spring and groundwaters in the area were also analysed for sodium, potassium, calcium, magnesium, chloride and sulphate. The results for ammonium-nitrogen, organic nitrogen and organic phosphorus are presented in Table 2, whilst those for nitrate nitrogen and reactive phosphorus are given in Figs. 2 and 3. Spring water analyses are given in Tables 3 and 4.

Nitrogen

Levels of ammonium-nitrogen (Table 2) were generally below 10 mg m^{-3} and were much the same in the marina and the adjacent lake water. Maximum values in the marina were higher than in the lake although they only rose above 12 mg m^{-3} on three occasions (Appendix 1).

Dissolved organic nitrogen levels in the marina were significantly higher in winter than in summer, and were consistently higher than in the lake in winter. Levels of DON were fairly high and reached 150 mg m^{-3} on a number of occasions in the marina (Appendix 1).

Nitrate-nitrogen (Fig.2) reached high concentrations in the marina relative to those in the adjacent lake water. It is interesting to note that the NO_3-N concentrations in the inshore lake water are themselves several times higher than NO_3-N reported for the surface waters of the open lake where values range from not detectable to 2.0 mg m^{-3}. This is indicative of inshore enrichment of NO_3-N. The very irregular pattern of NO_3-N in the marina during the two summer periods (Fig.2) reflects the use of the marina pump. When the pump is operating, marina water is replaced with lake water. The pump operates frequently in summer to remove the surface algal scums during the holiday period. We collected samples on two days in winter when the pump was operating (20 July, 1980 and 23 August, 1980) and on these occasions, nitrate levels had dropped considerably.

Phosphorus

Dissolved organic phosphorus values were very low - generally less than 5 mg m^{-3}, and no clear differences between lake and marina water are evident (Table 2)

Dissolved reactive phosphorus (Fig.3) follows the same pattern as nitrate. Of particular importance is the large concentration in the marina relative to that in the lake.

Nutrient sources

It is clear that the marina waters are highly enriched (relative to lake water) with available plant nutrients and this, combined with sheltered conditions, is undoubtedly the reason for the problem algal growths which occur there. The question now arises as to the source of these nutrients. The groundwater flows into the marina were described earlier and the nitrogen and phosphorus values for the Whangamata spring (typical of ground waters in the area) during the study period are given in Table 3. Table 3 also shows values for the groundwater seeps into the marina collected recently by us and by Richmond (1974). A comparison of these values with those in the marina clearly shows that this groundwater is the cause of the enrichment.

To what extent the groundwaters flowing into the marina are further enriched with effluent from septic tanks is not known precisely but the nitrogen and phosphorus values in the marina flows do not show enrichment much above that in Whangamata spring water (Table 3). However, it would be surprising if there was no influence from septic tanks as an examination of a borough plan of Kinloch indicates tanks from about half the houses might be expected to drain towards the marina. This represents a maximum population of some 400 during peak holiday periods (Taupo County Council 1981).

Analyses of sewage effluent from Taupo and of groundwater passing through a septic tank discharge (M. Gibbs, 1977 and unpublished data) shows that this type of effluent is characterised by Na and Cl as the dominant ions (Table 4).

Natural groundwaters in the Taupo area, including the Whangamata spring are, in contrast, sodium bicarbonate dominated waters. The springs entering the marina are the latter type (Table 4). The elements which differ the most between natural and sewage contaminated ground water are N and P. Whereas the major ions in sewage are between 1 and 4 times higher than natural ground water, phosphorus is up to 140 times higher. Gibbs (1977) and Timperley and Pickmere (1981) found local septic tank DRP values to be between 6 and 10 g m^{-3} (compared with 70 mg m^{-3} in ground water, Table 3). Thus, even a small amount of septic tank contamination would show up as a rise in phosphorus.

From this we can conclude that the two sampled ground water springs entering the marina may have a small amount only of septic tank contamination. It is possible that the particular springs we sampled do not drain septic tank discharge fields, as Gibbs (1977) showed that plumes of contaminated water from septic tanks can be very narrow.

However, the fact that phosphorus and nitrogen in the marina are often equal to but never higher than in the natural ground water indicates that septic tank enrichment at present must be a very small component of the marina inflows. Thus sewage reticulation in Kinloch is unlikely to result in an improvement in the present quality of the marina water; but, if reticulation does not proceed and the population of Kinloch rises, then the marina problems are likely to get worse.

EFFORTS TO CONTROL THE PLANT PROBLEMS

1. Prior to this study

(a) The water pump: Although the water pump does improve circulation (Figs. 2, 3) and removes surface algal scums reasonably well, there are limitations. By virtue of its position (Fig.1) the boat ramp, perhaps the most 'sensitive' area in the marina, is largely unaffected by the pump generated current. Floating algae often collect in this corner. In addition, algae pumped out from the marina end up on the lake beach.

(b) Nessie: The marina has a barge called Nessie with hydraulically operated circular cutting blades at one end. A propellor in a movable tube gives movement and steerage. Nessie was designed to cut or disturb aquatic plants so that they would float to the surface and be drawn off by the pump current. Although Nessie has some effect in assisting algal mats to float on sunny days, most of the algae including *Nitella hookeri* merely sink again. There is no doubt that Nessie would work well in areas where vascular macrophytes (e.g. *Lagarosiphon*) are a problem such as Motuoapa Marina.

(c) Divers: The Taupo Underwater Club was once employed to handweed the Marina. At a total cost of $300, 15 divers working for 2 days were able to clear the berths in the inner basin fairly successfully. The weed removed was dumped on the side and later removed by trailer.

(d) Suction dredge: A suction dredge belonging to New Zealand Diving Equipment Ltd was hired at a cost of approximately $6000 in September 1977 to clear the marina. It seems there were mixed feelings locally over the success of this in relation to its cost. However, Dr B. Coffey (Coffey 1977) investigated conditions in the marina before during and after dredging. His report concluded that the operation had worked well and that this type of dredging is the most direct and environmentally acceptable method of weed clearance for the marina.

(e) Hand rakes: These are provided by the marina operators for boat owners to keep their berths clear. Apparently few owners have taken the trouble to use them.

2. During this study

(a) Bottom rake: A steel rake some 2 m wide with teeth 0.5 m long was made up by Mr M. Abrahams of Kinloch. The shafts projecting from the front of the rake were kept off the bottom with an oil drum float, and the rake was towed behind a small dinghy with a 4 h.p. outboard motor. The rake was towed backwards and forwards across the central area of the marina basins. Each tow ended at the boat ramp where the *Nitella* was pulled off the rake for disposal. In this way most of the dense *Nitella* beds in the central marina area were removed in one day. However, although only relatively small clumps remained they were widely distributed through the marina. The rake could not be used effectively in the berths because of the difficulty of manoeuvering it.

(b) Plastic bottom seals: Large opaque plastic sheets laid on the bottom sediments can be used to prevent plant growth. Even permeable mesh screens have been used effectively for this purpose (Perkins et al. 1979). As a complementary control method to the rake, which cannot be used in the berths we attempted to control plant growth in two contrasting marina berths (sites C, D in Fig.1) with plastic sheets.

The sheets were heavy gauge black polythene 4 m x 8 m (the size of a berth). Prior to the sheets being laid down the algae were scoured off the bottom of the berths with high pressure water hoses from the Kinloch Fire Brigade. The sheets were weighted down with long thin concrete posts on 18 November 1980 and removed on 27 August 1982. After 10 months and 22 months, biomass samples from 5 quadrats on each sheet and 5 from an adjacent berth were collected. Plant species were separated, washed free of sediment and dried to constant weight.

After 10 months the sheets were covered with considerable algal growth including blue-green algal mats, the filaments of which were quite firmly attached to the sheets. There were also *Spirogyra* mats and even some *Nitella hookeri*. The latter was growing on a loose sediment which had settled on the sheets. Of interest was the fact that at site D where there were vascular macrophytes in the adjacent berths, these stopped abruptly along the edge of the sheet. Results of the biomass analyses are given in Table 5. There was no significant difference in total plant biomass on and off sheet D although vascular plant growth was suppressed. Sheet C had significantly lower plant biomass than the adjacent berth ($p = <0.05$).

After 22 months the depth of fine organic sediment which had settled on the sheets was up to 15 cm thick and this supported considerable plant growth. *Nitella hookeri* on the sheet at site C was 70 cm high. Some small individual vascular plants were encroaching on to sheet C, although the biomass was low relative to the adjacent berth (Table 5).

The fine organic sediment which had settled on the sheets was a major contributor to the fact that there was no significant difference ($p = <0.05$) in total plant biomass between the sheets and the adjacent berths at both sites. This organic sediment, undoubtedly generated within the marina could minimised if the bottom of every berth was covered and if the central basins were regularly raked. However, blue-green algal mats and diatoms strings grew on the sheets even in the absence of this organic sediment.

The type of plant growth in Kinloch marina is such that plastic seals are not as effective here as they are in other areas in the North Island e.g. Lake Rotoiti (J. Clayton - personal communication) where berths have been kept clear of vascular macrophytes for 10 years with plastic bottom seals.

CONCLUSIONS AND RECOMMENDATIONS

The marina problems are due to excessive algal growth rather than vascular macrophyte growth as occurs in Motuoapa Marina and around the lake boat ramps. This algal growth is caused by the high levels of nutrients in the marina water. These nutrients come from groundwater flows which may be partly enriched with septic tank drainage.

There are three management options which might be considered. Two are expensive and one is labour intensive.

Option 1: The best, but by far the most expensive way of solving the problem would be to line the marina to prevent groundwater from entering and to remove plant root contact with the sediment.

Option 2: A trench or drain lined on the bottom and the south side could be constructed all along the north side of the marina to intercept the groundwater flow. This could be pumped out at intervals perhaps using the marina pump via an alternative intake.

The marina pump would still have to be used to maintain adequate circulation and to prevent stagnant water in both Options 1 and 2. However, in Option 2, with reduced nutrients and algal growth bottom rooted vascular macrophytes such as *Lagarosiphon* and *Elodea* would flourish. These would have to be cut regularly by Nessie.

Option 3: This labour intensive option involves a series of different operations which could reduce but will not solve the problems.

Twice a year (spring and autumn) the central areas of the marina should be raked out using the rake described above. The pump should be run during this operation.

Once every 5 years the marina bed should be cleaned out with a diver operated suction dredge to remove the accumulated fine sediment. This would best be done following a raking and if permitted, a single application of algicide.

Berth owners must be reminded that they have a responsibility to keep their individual berths clean. This can be done with the hand rakes.

The marina pump should be operated every day during the summer months.

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TABLE 1. Summary of plant species presence in the Kinloch marina 1964 - 1982. + = present, - = absent, ? = no data.

SPECIES	Chapman 1964	Hill 1969	Richmond 1974	Coffey 1977	This stud 1982
	Year and Reference				
MAT AND SCUM ALGAE					
Spirogyra	+	?	+	?	+
Oscillatoria	?	+	+	?	+
Melosira	?	+	+	?	+
LARGE BOTTOM ALGAE					
Nitella hookeri	+	+	?	+	+
VASCULAR PLANTS					
Potamogeton crispus	+	+	?	+	+
P. ochreatus	?	+	?	+	+
P. cheesemanii	?	+	?	+	+
Myriophyllum triphyllum[1]	+	+	?	+	+
Lagarosiphon major	-	-	?	+	+
Elodea canadensis	+	+	?	+	+
Callitriche stagnalis	+	+	?	+	+
Azolla filiculoides	-	+	?	-	-
Nasturtium officinale	?	?	?	-	+
	Spirogyra was the major scum forming alga. Diatoms were of minor importance	Dense cover of algae (mostly Melosira and Oscillatoria) over the larger plants and the bottom	Plankton net sample only	Vegetation dominated by filamentous and epipelic algae. Lagarosiphon identified for the first time.	Major problem seen as being the dense filmentous algal growth (Melosira, Oscillatoria and Spigyra most important) N. hookeri is th most abundant macrophyte.

[1]Chapman recorded "M. robustum" but this identification is almost certainly wrong.

TABLE 2. Summary of analyses for ammonium nitrogen, dissolved organic nitrogen and dissolved organic phosphorus in Kinloch marina and adjacent inshore Lake Taupo water. Appendix 1 gives the full data set. Values as mg $m^{-3} \pm$ standard error.

		MARINA			LAKE		
		NH_4-N	DON	DOP	NH_4-N	DON	DOP
Winter	$\bar{x}$	5.9	137	2.0	7.8	74.8	1.5
(May - October)	SE	0.97	11.22	0.28	1.76	5.64	0.21
Summer	$\bar{x}$	6.8	70	3.8	5.5	69	2.8
(Nov - April)	SE	0.84	7.59	0.77	0.58	6.55	0.35

TABLE 3. Values (mg m^{-3}) of nitrate-nitrogen and dissolved reactive phosphorus (DRP) in Whangamata spring water and in groundwaters entering the marina.

SITE	DATE		NO_3-N	DRP
Whangamata spring	7. 8.79		620	79
	20. 2.80		702	70
	11. 6.80		842	70
	18. 9.80		895	71
	19.11.80		894	70
	21. 1.81		992	67
	4. 3.81		1166	75
	19. 5.81		625	67
	22. 4.82		881	65
Marina groundwater flows	5. 3.74*		900	95
	2. 9.82#	(E)	1400	100
		(W)	1400	80

* Richmond 1974

\# (E) - east side, (W) = west side of marina.
Samples were collected from flows 3 and 12 on Fig.1.

TABLE 4. Proportions (% of total) of cations and anions in local spring waters and sewage effluent.

	Whangamata Spring *	Marina groundwater (E)	Marina groundwater (W)	Taupo sewage effluent #	Acacia Bay septic tank †
Cations					
Na^{+}	46.98	62.13	52.03	68.07	66.36
K^{+}	7.53	3.65	4.04	8.93	10.88
Ca^{++}	25.89	19.72	26.75	17.98	12.30
Mg^{++}	19.60	14.49	17.18	5.02	10.45
Anions					
Cl^{-}	24.13	4.10	12.74	87.68	87.82
SO_4^{--}	12.56	18.54	16.81)		
			)	8.02	2.04
HCO_3^{-}	63.00	77.32	70.27)		
PO_4^{---}	0.31	0.12	0.18	4.3	9.53

Data from:

* M.Timperley (in press)

\# M.Gibbs (unpublished)

† M.Gibbs 1977

TABLE 5. Composition of biomass of aquatic macrophytes and large benthic algae on and adjacent to the plastic sheets on the bottom of Kinloch Marina. Sheets were placed on 18 November 1980. Figs. in g m^{-2} (dry wt) with standard errors.

DATE	SPECIES	SHEET C				SHEET D			
		ON		ADJACENT		ON		ADJACENT	
		$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.
9.9.81	*Nitella hookeri*	113.4	43.0	186.8	63.0	12.2	8.0	4.8	4.0
	Potamogeton spp.	0		0		0		39.0	16.0
	Lagarosiphon major	0		0		0		0	
	Spirogyra spp.	0.60	0.60	0		26.8	20.0	1.20	0.40
	TOTAL VEGETATION	113.8	43.2	186.8	63.0	39.0	21.8	44.0	13.4
27.8.82	*Nitella hookeri*	136.0	55.8	269.0	87.0	14.6	9.40	2.6	1.2
	Potamogeton spp.	0		0		0.60	0.60	7.4	6.00
	Lagarosiphon major	0		0		2.40	2.40	2.60	2.60
	Spirogyra spp.	0		0		0	0	19.00	11.6
	TOTAL VEGETATION	136.0	55.8	269.0	87.0	19.80	9.2	31.80	17.6

APPENDIX 1. Analyses of ammonium-nitrogen, dissolved organic nitrogen and dissolved organic phosphorus in Kinloch Marina and adjacent inshore Lake Taupo water. - = no data, ND = not detectable, values as mg m^{-3}

DATE	MARINA NH_4-N	MARINA DON	MARINA DOP	LAKE NH_4-N	LAKE DON	LAKE DOP
1980						
10 Jan	15.5	140	8.5	7.4	64	ND
16 Jan	5.5	94	6.8	1.8	55	3.7
23 Jan	5.3	103	8.7	4.2	92	3.8
31 Jan	4.5	80	5.7	4.0	76	3.6
4 Feb	8.5	117	6.3	2.9	57	2.2
5 Feb	3.8	67	4.2	1.4	52	2.2
14 Feb	3.8	56	3.6	4.9	38	3.2
20 Feb	6.4	46	3.2	5.0	55	1.2
27 Feb	1.6	80	4.4	3.8	77	2.3
6 Mar	5.5	49	2.5	5.3	48	1.9
12 Mar	0.6	110	5.7	8.6	62	2.2
19 Mar	3.8	97	3.2	5.5	62	3.0
26 Mar	2.8	80	2.2	6.6	91	1.5
2 Apr	7.5	61	3.3	5.4	46	1.8
9 Apr	12.3	165	1.9	4.8	49	1.2
16 Apr	4.7	305	1.5	1.5	59	2.3
23 Apr	2.8	95	3.1	6.4	73	1.7
30 Apr	3.3	152	4.4	5.9	72	ND
7 May	4.7	120	-	24.8	82	2.4
14 May	2.8	166	2.6	3.9	71	2.4
21 May	7.1	91	3.3	4.3	78	2.8
29 May	9.8	131	2.4	10.0	46	0.3
3 Jun	14.3	167	3.0	6.8	75	1.0
11 Jun	8.3	95	3.9	6.4	62	0.8
18 Jun	7.9	142	2.9	3.1	64	1.5
24 Jun	10.5	161	3.7	6.1	103	2.5

1 Jul	11.0	103	ND	3.0	47	ND
8 Jul	7.6	122	ND	44.7	152	1.4
16 Jul	23.5	161	ND	5.9	70	1.7
23 Jul	15.0	204	2.4	6.6	63	1.3
30 Jul	11.8	82	1.1	4.8	66	0.7
6 Aug	12.3	124	ND	3.8	55	2.0
13 Aug	10.1	191	1.0	7.7	50	ND
21 Aug	8.1	67	0.7	9.5	80	2.8
27 Aug	14.2	65	ND	6.2	99	0.6
3 Sep	2.6	134	2.9	5.0	-	4.3
10 Sep	6.7	96	1.6	6.2	68	1.5
18 Sep	4.5	226	2.8	2.8	92	0.4
2 Nov	8.8	30	ND	3.0	146	4.1
19 Nov	9.4	93	ND	5.4	62	3.4
26 Nov	4.7	52	0.5	3.4	53	8.9
3 Dec	3.4	132	7.8	8.6	73	1.6
10 Dec	5.2	18	ND	2.5	41	4.8
17 Dec	8.5	27	ND	7.8	159	8.2
24 Dec	9.7	32	ND	8.7	45	2.4
1981 7 Jan	11.2	61	13.8	3.8	49	3.0
21 Jan	11.9	42	ND	11.3	-	0.8
14 Feb	15.5	12	ND	11.1	54	0.9

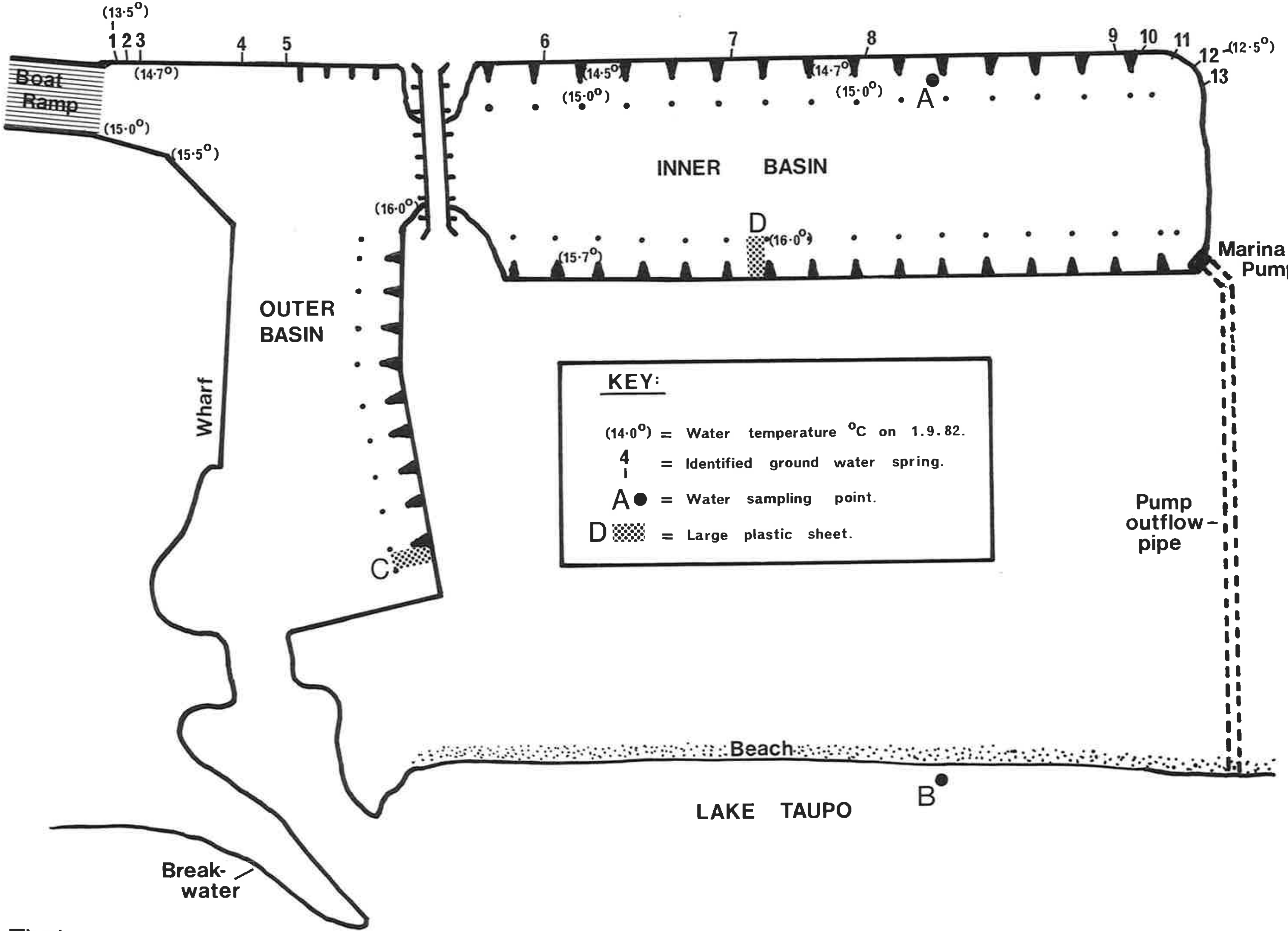

Fig.1 Plan of Kinloch Marina with features mentioned in the text.

Fig. 2

Nitrate-Nitrogen: Variation with time in Marina (■) and lake edge (▲)

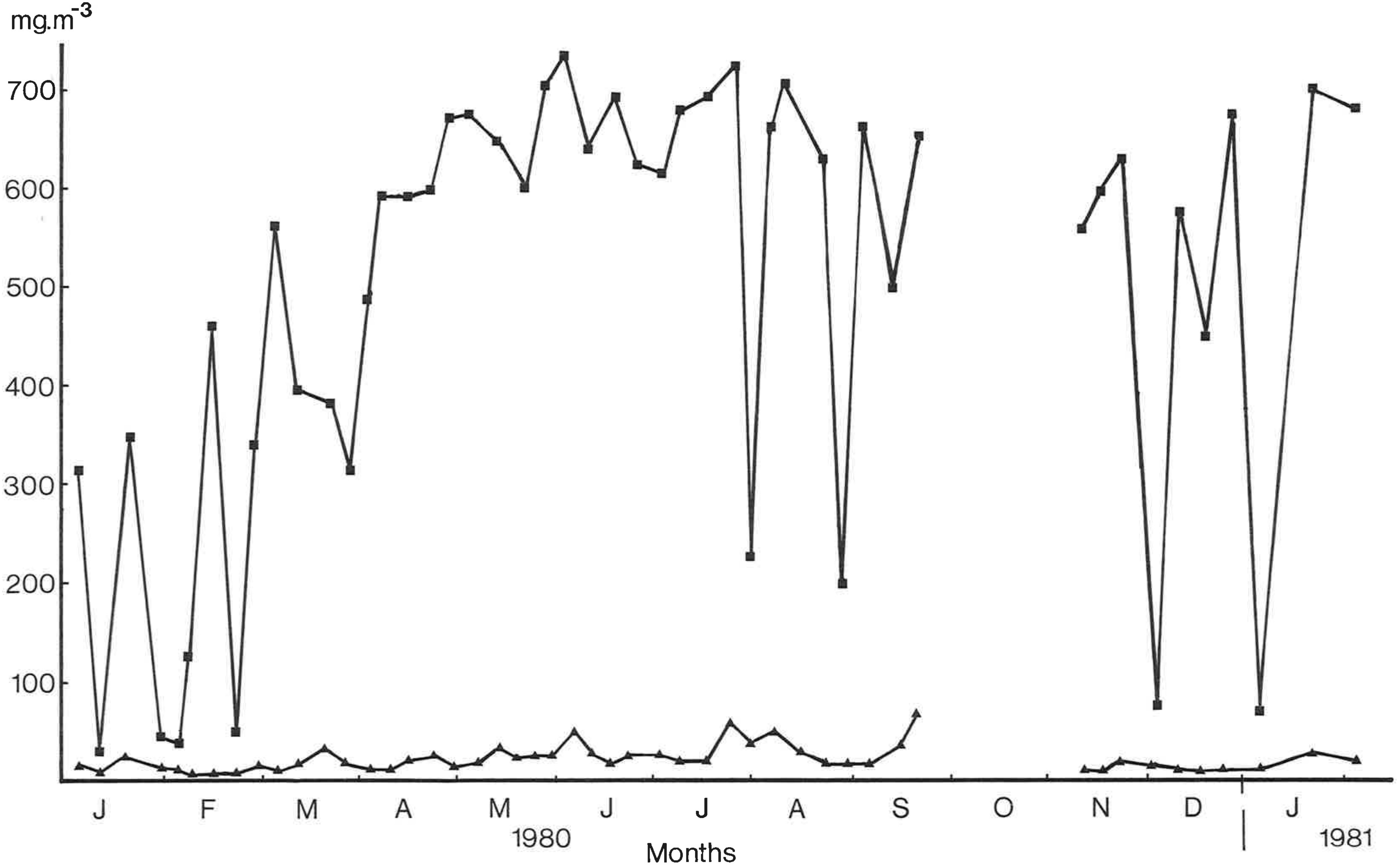

Fig. 3 Reactive Phosphorus: Variation with time in Marina (■) and lake edge (▲)