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Diatom Succession in the Recent Sediments of Skaha Lake, British Columbia

PREPARED FOR THE
OKANAGAN STUDY COMMITTEE

CANADA - BRITISH COLUMBIA OKANAGAN BASIN AGREEMENT

TASK 121
Geolimnology
(Paleolimnology Supplement)

Diatom Succession in the Recent Sediments of Skaha Lake British Columbia

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NOTICE

This report was prepared for the Okanagan Study Committee under the terms of the Canada-British Columbia Okanagan Basin Agreement. The information contained in this report is preliminary and subject to revision. The Study Committee does not necessarily concur with opinions expressed in the report.

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ABSTRACT

Two sediment cores were obtained from Skaha Lake in 1970 and the microfossils in these cores examined to obtain information on recent historical changes within the lake and its drainage basin. Sediment accumulation over a period of years incorporates the remains of organisms living in the lake, and forms a stratigraphic record of the development of the lake from which its history may be reconstructed.

Of the two cores examined, only the deep water core from the center of the lake, containing chiefly euplanktonic diatom species, showed significant changes related to the recent eutrophication of Skaha Lake. The greatest change in diatom assemblages has occurred within the last 25 years, with diatoms more common in eutrophic waters showing marked increases in relative abundance. Prior to 1940 there was little change in diatom dominants and the more common diatoms were indicative of oligotrophic conditions. The main factor considered responsible for the eutrophication of Skaha Lake is the effluent discharge from the Penticton sewage treatment plant that commenced operations in 1947. With the installation of tertiary treatment facilities in 1971, conditions should improve and blue-green algal blooms should become less of a nuisance.

Additional information on sediment cores and the historical development of the main Okanagan lakes will be included in Preliminary Report No. 34 - 'The Limnogeology of the Okanagan Mainstem Lakes'.

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INTRODUCTION

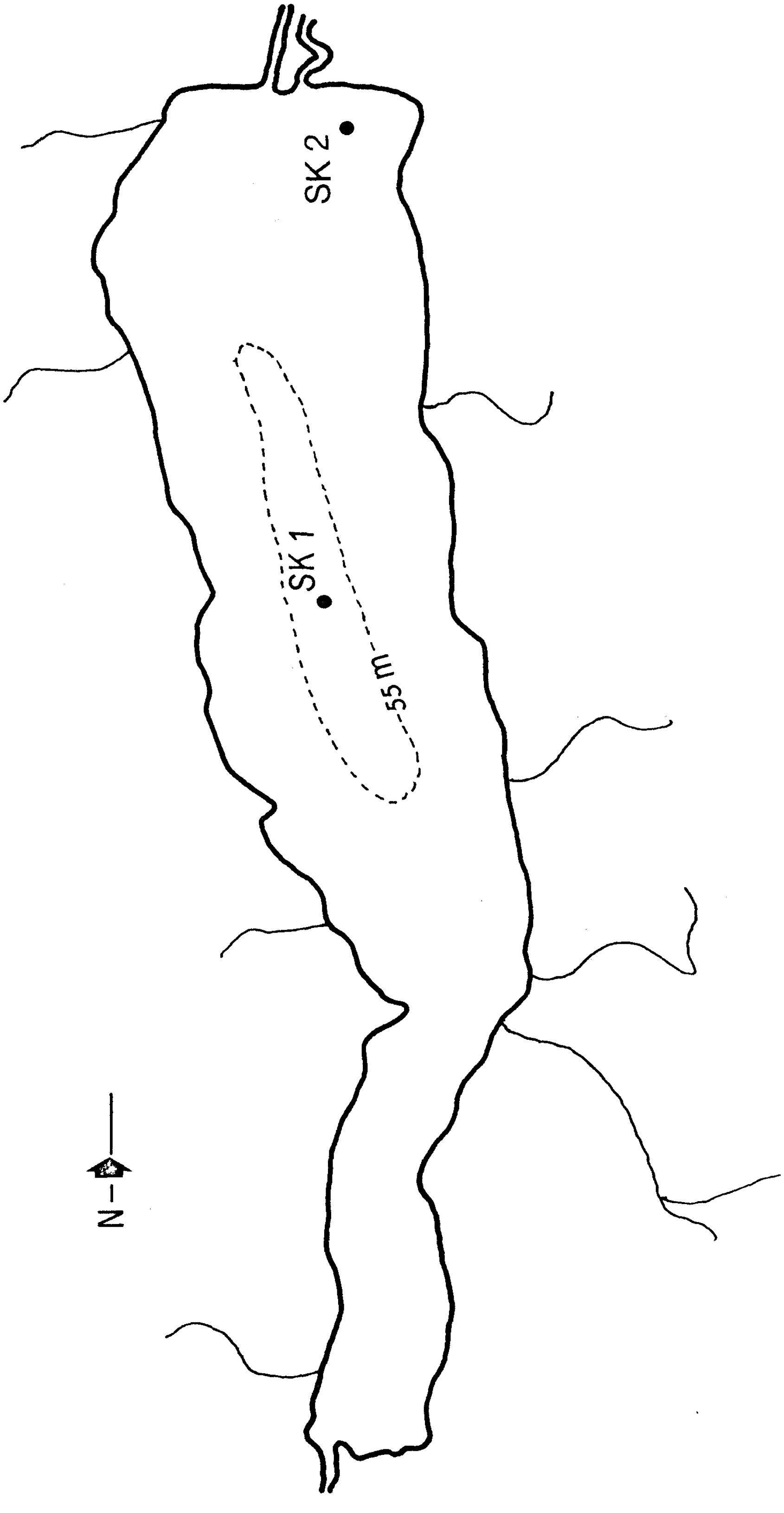
Much can be learned about the developmental history of a lake by the examination of micro-fossils in lake sediment. If the sediment has not been grossly disturbed, they provide the investigator a reasonable chronological history of changes within the lake and upon its drainage basin. The effects of man-induced environmental disturbance on a lake are recorded in the most recent, near-surface, sediment, generally in the strata between 50 cm and the sediment surface. An appreciation for the magnitude and duration of these disturbances can be gained by a detailed examination of the diatom assemblages in near-surface sediment. As sediments accumulate they incorporate the remains of organisms living in the lake. As this process occurs, year after year, they form a stratigraphic record of the development of the lake from which the lake's history can be inferred. The utility of this approach in assessing lake eutrophication has already been proven in several studies on well-known lakes (Nipkow, 1927, Pennington, 1943, Stockner and Benson, 1967). The purpose of this study was to examine the diatom microfossils in the recent sediment of Skaha Lake to ascertain the degree and rate of change in planktonic diatom communities following recent cultural disturbances. Such Information will hopefully provide a better time-scale and baseline for the interpretation of the present trophic state of Skaha Lake.

MATERIALS & METHODS

Two short cores were obtained from Skaha Lake for analysis (Fig. 1). Core SK2 was obtained with a Mackereth corer (Mackereth 1969) in 1970 at a water depth of 6 meters by the author, and Core SKI was obtained with a gravity corer in 1971 by Dr. Brian St. John, C.C.I.W., Burlington, at the area of maximum water depth - 60 meters. Both cores were sectioned within a week of their procurement. Core SK2 was 45 cm long and was sectioned at 0.5 cm intervals to 10 cm, and at 1.0 cm intervals for the remainder. Core SKI was 105 cm long and was sectioned at 1.0 cm intervals to a depth of 20 cm, and at 5.0 cm intervals for the remainder. Samples were obtained from the non-smeared inner portion of each section. Loss of weight on ignition (L.O.I.) values were determined only for Core SKI. L.O.I. values were obtained by burning oven-dried samples in a muffle furnace at 500° C for 2 hours.

Approximately 1 g. of fresh sediment from each core was macerated in concentrated nitric acid diluted 1:1 with distilled water. Samples were boiled until they reached half the original volume, then $K_2Cr_20_7$ was added for final oxidation. The samples were repeatedly decanted, rinsed, and allowed to resettle until no trace of acid remained. Permanent slides were made using Hydrax mounting medium. Counts of approximately 300 - 400 diatom frustules per slide were made under 1250 X magnification. The monographs of Hustedt (1930), Cleve-Euler (1951), and Patrick and Reimer (1966) were used for species identification. The more common diatoms were identified to species, others to genera.

Fig.I. Map of Skaha Lake showing approximate location of cores



Data were processed on an IBM 360 computer at the University of Manitoba Computer Center. Output gave percentage composition of the total diatom population for all species, the order Centrales, and the four pennate tribes represented. Computer output data for the relative abundance of each species, genus, and group enumerated from the sediment cores were plotted by a Calcomp digital plotter as a function of sediment depth.

RESULTS AND DISCUSSION

Physical-chemical features and dating of the Cores.

Microscopic examination of both cores revealed a rather homogeneous sediment throughout the length of both cores. Two silt lens were observed at approximately the same location in both cores, one at 8 - 9 cm and the other between 25 - 30 cm. The silty inorganic nature of these lens was revealed both by the determination of percent organic (L.O.I.) (Fig. 2), and by microscopic analysis.

The organic content of core SKI was relatively low, averaging 8 - 9% L.O.I. throughout its length. Highest values were measured in the strata from 2 cm to the surface, 10 and 11% L.O.I., respectively.

The upper $ cm of both cores were unconsolidated; remaining portions held their shape upon extrusion. The sediment was a dark-brown color and had a paste-like consistency. No obnoxious odors were detected when the cores were sectioned. Much more detailed chemical and physical analyses of cores from each of the Okanagan Lakes will be presented in the main geological report (Task 121).

The length of the postglacial sediment column in Skaha Lake has not been measured and there were no distinct visable markers in either core that could be readily dated. Therefore, the silt lens were used to determine a rough annual sedimentation rate. It is probable that several events occurring between 1939 - 1942 led to the deposition of the first silt lens, now at 8 cm depth. The first extensive straightening of the Okanagan River between the control dam and Skaha Lake was done in 1939 - 40. An estimated 54,000 cu. yds of material were

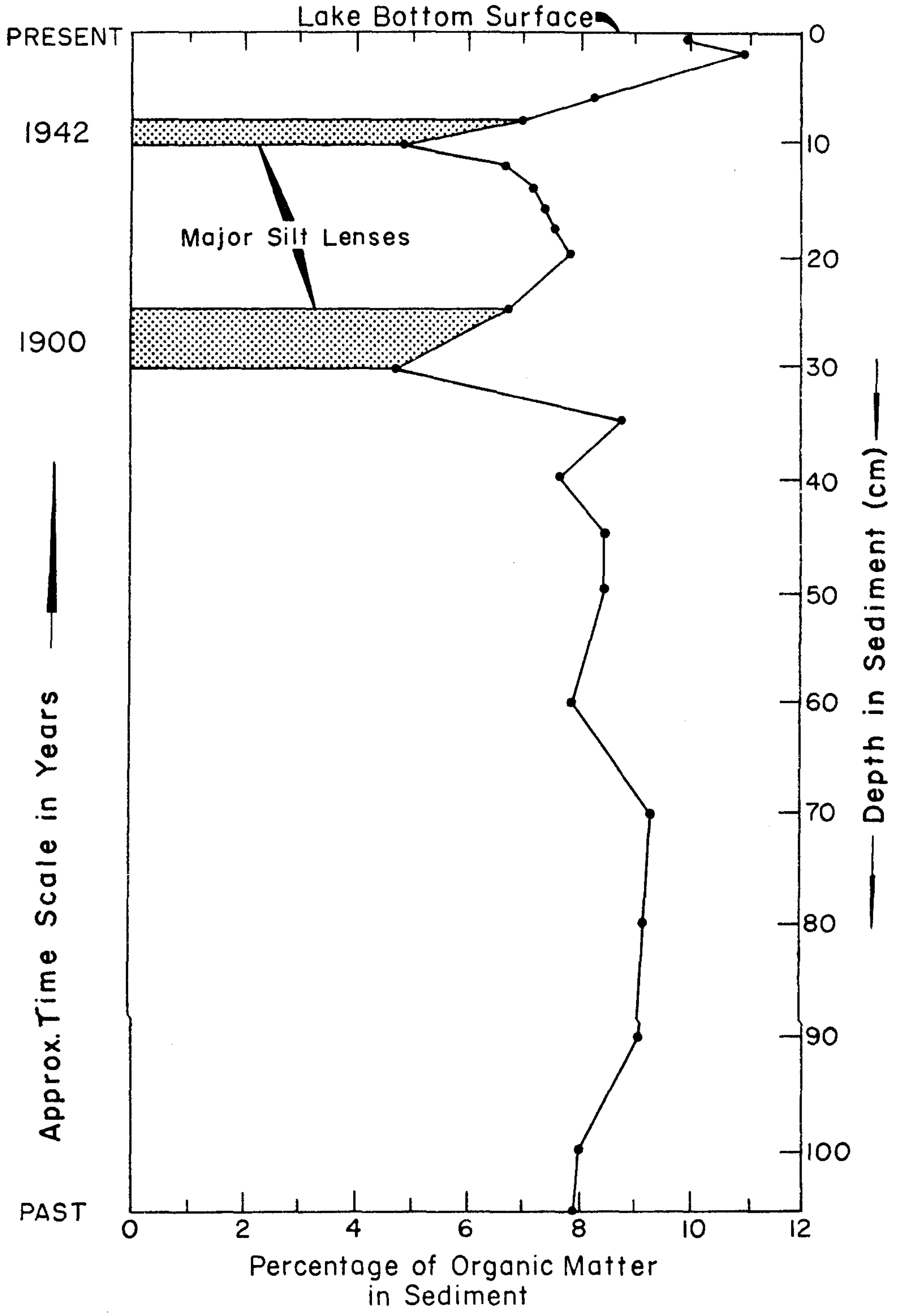


Fig.2. Plot of lake bottom core sample from the deepest part of Skaha Lake showing silt lenses at 8-10 and 25-30 centimeters.

handled during this period (Okanagan Flood Control Report, p. 99, 1946). Of even greater significance was the failure of the Ellis Creek Dam which broke on the 13th of May, 1941, releasing a flood of approximately 700 acre feet. Gravel and silt filled the Okanagan River from the Fairview Road bridge to at least 1000 feet downstream from the creek mouth, and lighter material was no doubt carried out into the lake (Okanagan Flood Control Report, p. 100, 1946). Clean-up operations with periodic dredging continued on the river throughout the summer and fall of 1941. Then in April and May of 1942 the 'Great Flood' occurred, moving tons of silt, grave], and boulders into the Okanagan River and on into Skaha Lake.

If these events are collectively responsible for the first silt lens located at 8 cm in both cores, and there is every reason to believe that this **is** true, then an average annual rate of sedimentation from this period to the present in Skaha Lake would be between 2.7 and 3.0 mm/yr. This is not an unrealistically high rate, and, in fact, is very similar to the estimated sedimentation rate for lake Washington over the past 50 - 70 years (Stockner and Benson 1967, Edmondson and Allison, 1970).

The second silt lens now at 25 - 30 cm is more than likely attributable to the commencement of dredging operations on the Okanagan River in 1910. They were done to improve navigation, between Skaha and Okanagan Lakes which began on a regular basis in 1914 (Okanagan Flood Control Report, p. 83, 1946). Between 1910 - 1917 the river was continually being improved and a control dam was built in 1915 at the outlet of Okanagan Lake. There is little doubt that this channel improvement work, the first recorded, would displace a considerable amount of silt, some of which would in turn be deposited in Skaha Lake. An estimated annual sedimentation rate for Skaha Lake using this second silt layer is between 3.8 and 4.5 mm/yr, slightly higher than the rate computed using the first silt layer. Both sedimentation rates estimated by interpolation assume an even sedimentation rate over a given time period which is unrealistic in light of the periodic flooding that is known to have occurred over the past 50 - 70 years.

For the present discussion, these silt lens markers will be used to date changes in plankton diatom succession. Events occurring in deeper sections of core SKI will be referred to simply as pre- 1900 (Fig. 2). *Presence of species,*

Cores SKI and SK2 differed in respect to the number of species found. Core SK2 was a shallow water core and included many littoral diatom species, SKI contained almost exclusively planktonic diatoms. For discussion purposes the cores will be treated separately, making comparisons where appropriate.

SKI. In the strata from the first silt layer at 8 cm depth to the sediment surface, the dominant diatoms were *Melosira italica*, *Cyclotella comta*, *Fragilaria crotonensis.* and *Asterionella formosa* (Table 1). In the strata from 8 cm to the second silt lens at 25 cm, *Fragilaria crotonensis* was replaced by *Fragilaria pinnata* and *Cyclotella ocellata* became the second most common diatom (Table 1). From 25 cm to 105 cm the five dominants were similar to what was found from 8-25 cm, except that *Fragillaria construens* increased in abundance (Table 1). There was a

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See Table 1 on page 14

relative constancy in the presence of particular species encountered from stratum to stratum, with noteworthy shifts occurring only in the top 10 cm.

SK2. The dominant diatoms in the top 8 cm were different from those found in core SKI (Table 1), reflecting the presence of more littoral species. From 8 cm to a depth of 45 cm there was little change in the relative proportion of species and there was no discernible shift in diatom dominants (Table 1). The three dominants found throughout the length of the core were Fragilaria construens, F. pinnata, and Achnanthes lavanderi (Table 1). With the exception of F. construens, the latter diatoms are chiefly epiphytic littoral species.

Species Diversity

Explicit in the definition of diversity is the relative proportion of each species enumerated per sample stratum. Diversity can be calculated using the Shannon-Wiener function;

$$H = -\sum_{i=1}^{S} p_i \ln p_i,$$

where p represents the proportion of the i^{th} species. A plot of diversity values gives one an indication of changes in the diatom assemblages from strata to strata, with low values depicting a strong domination by a few species, and high values indicative of a more even species distribution.

The number of species observed in each core varied, but for SKI were no more than 20 or fewer than 10. In core SK2 there were considerably more species - a high of 40 but no fewer than 20. The greater number seen in SK2 is a reflection of the presence of littoral species, which occupy a very diverse and heterogeneous habitat in lakes. The low number in SKI is a reflection of the more homogeneous habitat of the plankton.

SKI. Below a sediment depth of 25 cm and before any notable environmental disturbances the average H value was 1.43, exhibiting wide and unexplanable variations (Fig. 3). The average value in the upper 25 cm was considerably higher, 2.08, reflecting not only the presence of more species but a more evenly distributed relative abundance. As seen in other lakes (Stockner and Benson, 1967) diversity shows initial increases with increasing eutrophication, but after a time values decrease as a few species with a greater potential rate of increase become dominent. No decrease in H values are apparent in Skaha Lake.

SK2. Diversity values were considerably higher throughout the length of this core, and values shoved considerable variation with depth (Fig. 4). The only trend was observed in the top 6 cm when the average value was 2.51, below the average for the whole core - 2.80. This reduction in diversity as well as in number of species may be related to the reduction in light penetration following eutrophication and the concomitant decrease in the area of the littoral zone in Skaha Lake.

The chronology of Skaha Lake.[1]

The Okanagan Salish Indians were the original inhabitants of the Okanagan Valley, living a somewhat nomadic existence along the shores of the lakes. These tribes lived close to nature and caused little environmental damage. The first white settlers arrived in the vicinity of

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[1] Most information presented here comes from a book by R.N. Atkinson (1967), and personal communication with The City of Penticton, Engineering Department.

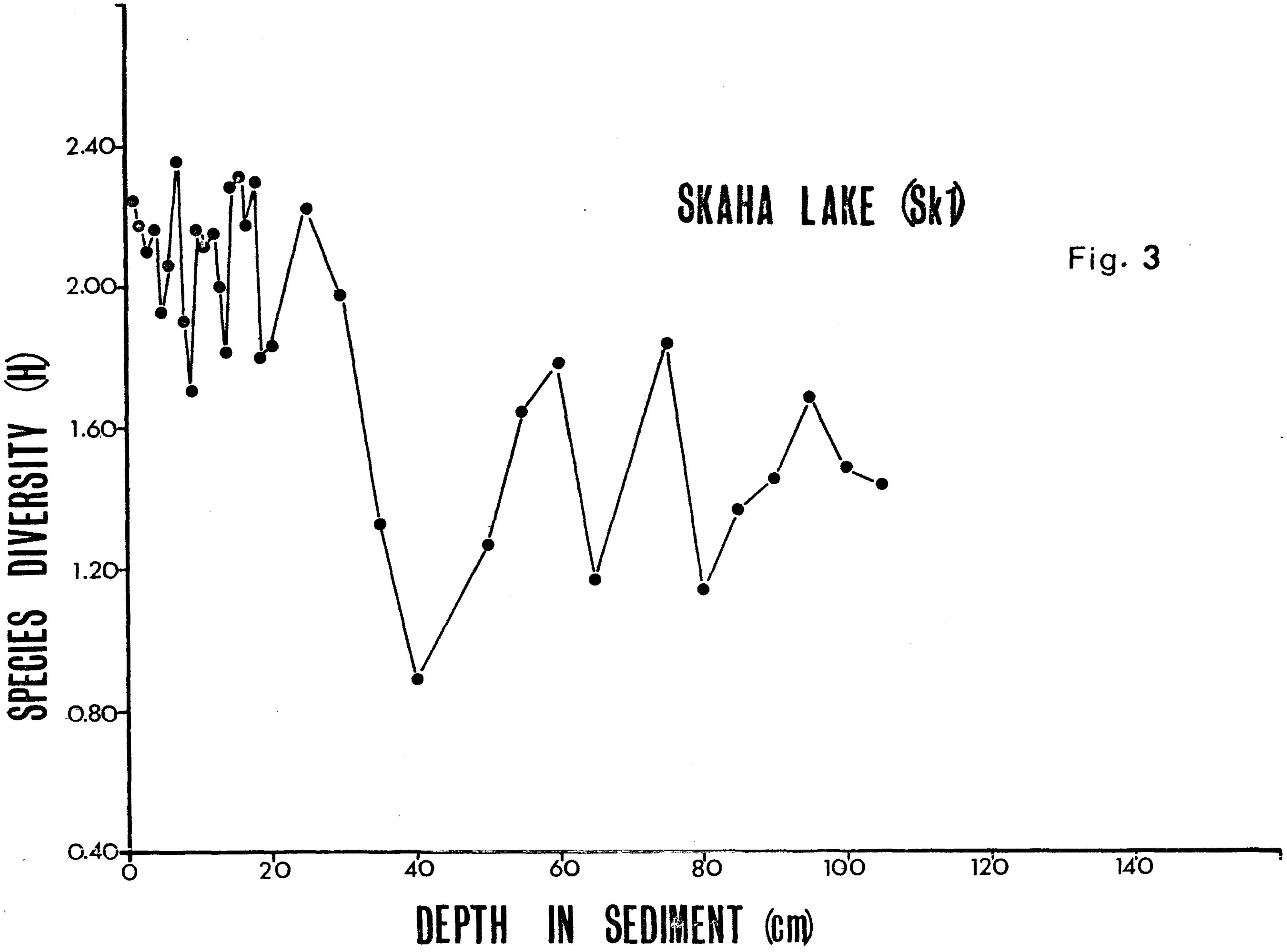
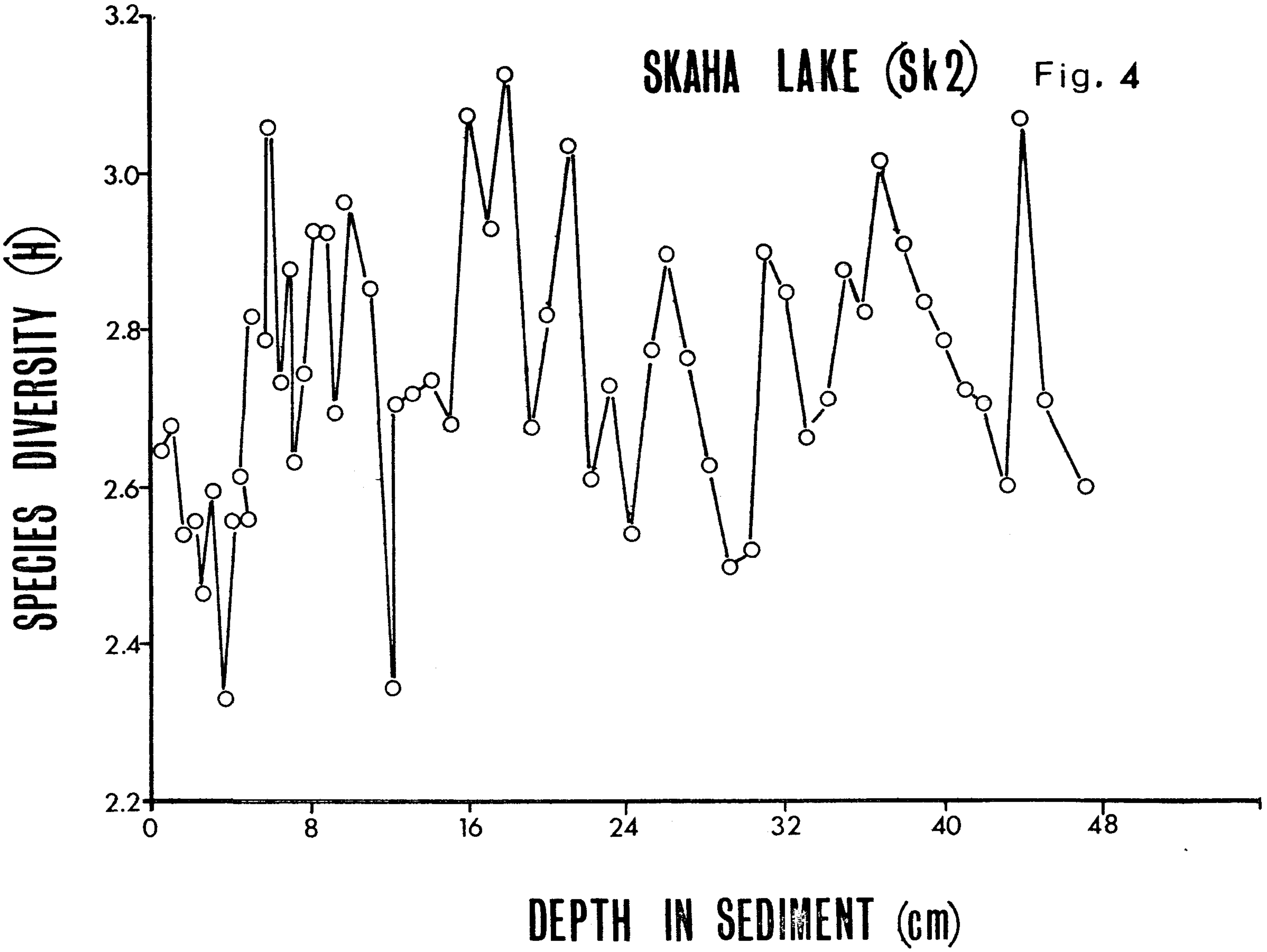
SKAHA LAKE (Sk1)
SPECIES DIVERSITY (H)
2.40
2.00
1.60
1.20
0.80
0.40
0
20
40
60
80
100
120
140
DEPTH IN SEDIMENT (cm)

Fig. 3


SKAHA LAKE (Sk2)
Fig. 4
SPECIES DIVERSITY (H)
3.2
3.0
2.8
2.6
2.4
2.2
0
8
16
24
32
40
48
DEPTH IN SEDIMENT (cm)

Penticton about 1865 and by 1909 Penticton had become a municipality in what was then termed "unorganized territory". Most of the early settlers obtained their livelihood by raising livestock, and each ranch had some acreage devoted to raising forage crops and some fruit trees.

The new municipality grew slowly in the first few decades of the twentieth century, reaching a population of about 6,000 by 1941. During this period more acreage was devoted to orchardry and many of the streams in the valley were regulated for irrigation purposes.

In 1948 the municipality became incorporated as the City of Penticton, and its population grew from about 8,000 in 1948 to a present population of approximately 17 - 18,000 inhabitants.

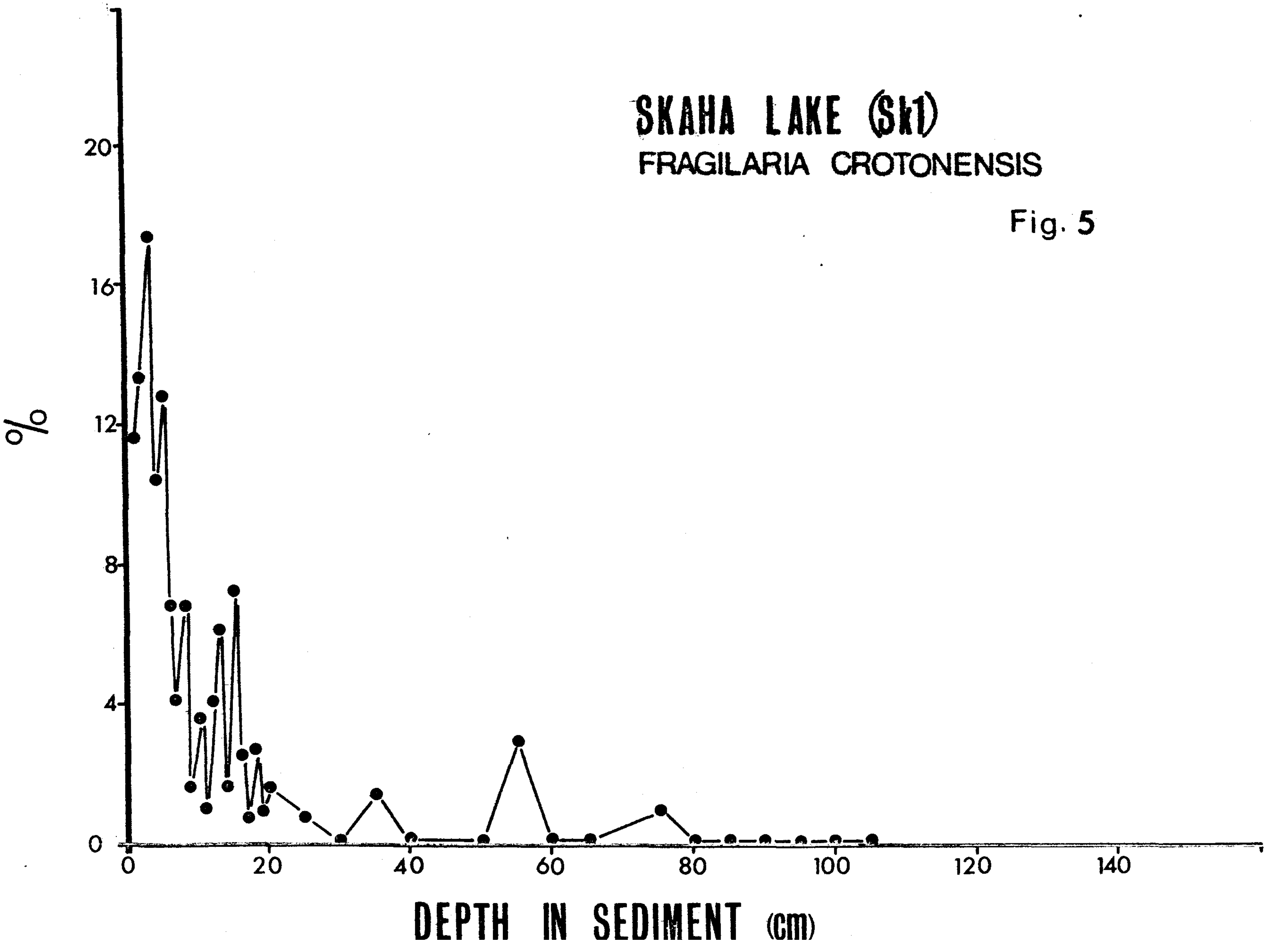
Between 1946 - 47 the first sewage collection system in Penticton was built, and secondary treated sewage effluent was discharged directly to the Okanagan River a few kilometers upstream from Skaha Lake in 3947. In 1960 a new sewage treatment plant was constructed to upgrade the old facility and in 1970-71 this plant was expanded to include tertiary treatment with lime precipitation to remove phosphorus. Prior to the Installation of these treatment facilities, septic tanks and earth closets were the only means of waste disposal.

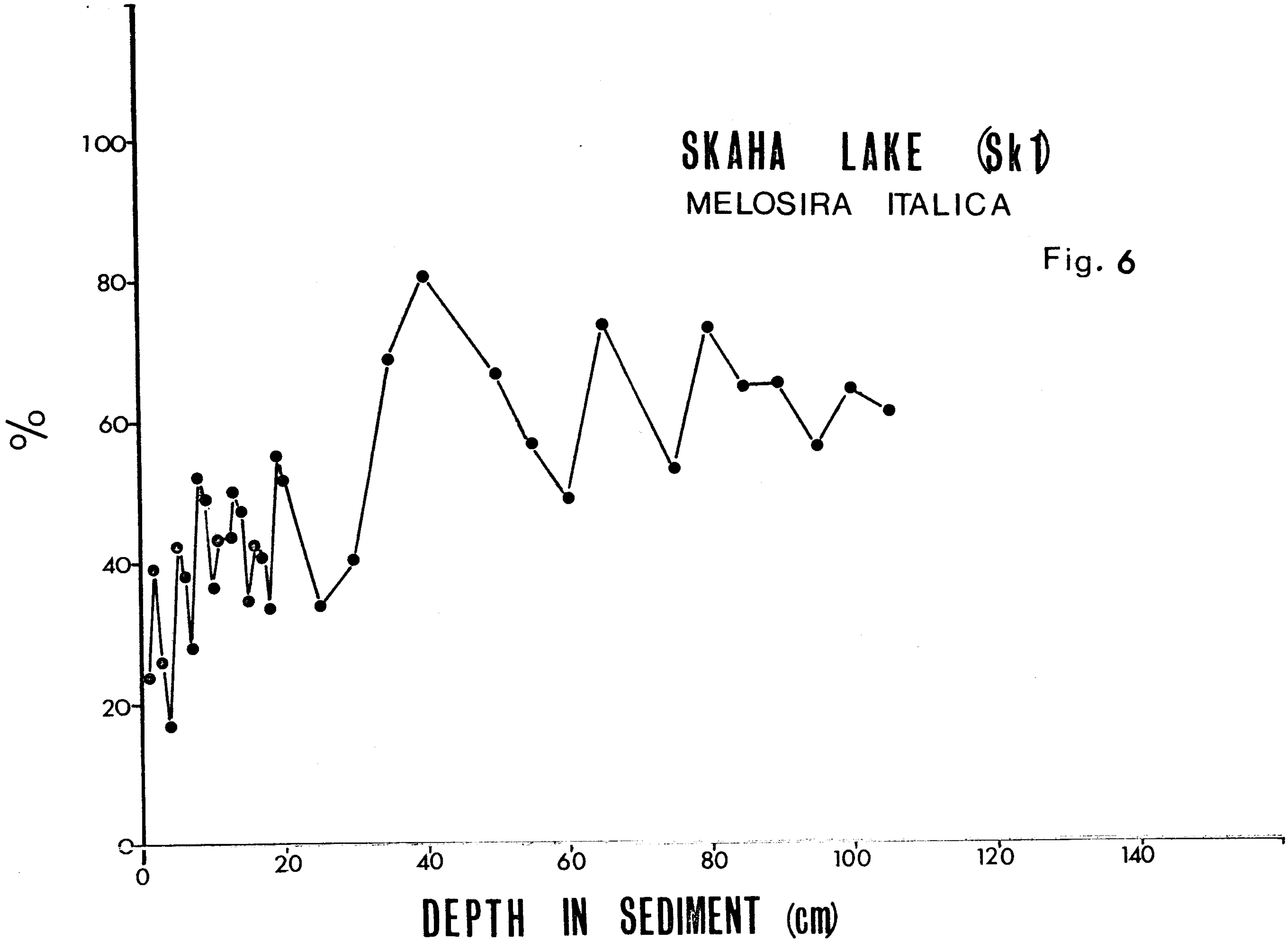
The first objectionable blue-green algal blooms occurred in Skaha Lake in 1966, causing considerable public attention and a resultant loss in the tourist trade. Blue-green algal blooms have occurred sporatically since then and in 1970 and 1971 two small blue-green blooms were noted, <u>Gleotrichia echinoidia</u> in August and <u>Anabaena</u> <u>flos-aquae</u> in September.

Of all the recent historical developments on the Skaha Lake watershed, the Installation of the Penticton sewage treatment plant on the Okanagan River has undoubtedly had the most pronounced effect upon the lake. Other events that have led to short-term changes in the lake are those related to work on the Okanagan River. These operations displaced a considerable quantity of material, chiefly silt, and altered the natural flow pattern of the river. The periodic flooding in the valley has also had some effect on the stability of the lake biota. *Shifts in the diatom assemblages following cultural eutrophication.*

SKI. The most obvious change was the marked increase in *Fragilaria crotonensia.* and the decrease of *Melosira italica* (Figs. 5 & 6). Other, Bore subtle changes in relative abundance were noted in the diatoms *Cyclotella ocellata* and *Asterionella formosa.* (Fig. 7). *C. ecallata* decreased gradually from 20 cm to 8 cm and was rarely encountered in the sediment from 7 cm to the surface (Fig. 7). *A. formosa* showed initial increases with increasing eutrophication but became less abundant in the top 4 cm (Fig. 7). An increase in the relative abundance of *Cyclotella comta* is responsible for the slight increase in total *Cyclotella* species noted in the upper 8 cm of sediment (Fig. 8). *Stephanodiscua astraea* was common only in the top 6 cm of sediment, ranking 6th in relative abundance, and was rarely encountered in deeper sections. *Fragilities construens* showed little change in relative abundance throughout the core.

The diatom groups Araphidineae and Centrals have been used to assess the trophic character of lakes (Stockner, 1971). As a lake


SKAHA LAKE (Sk1)
FRAGILARIA CROTONENSIS
Fig. 5
%
20
16
12
8
4
0
0
20
40
60
80
100
120
140
DEPTH IN SEDIMENT (cm)



SKAHA LAKE (Sk1)
MELOSIRA ITALICA
%
100
80
60
40
20
0
0
20
40
60
80
100
120
140
DEPTH IN SEDIMENT (cm)

Fig. 6

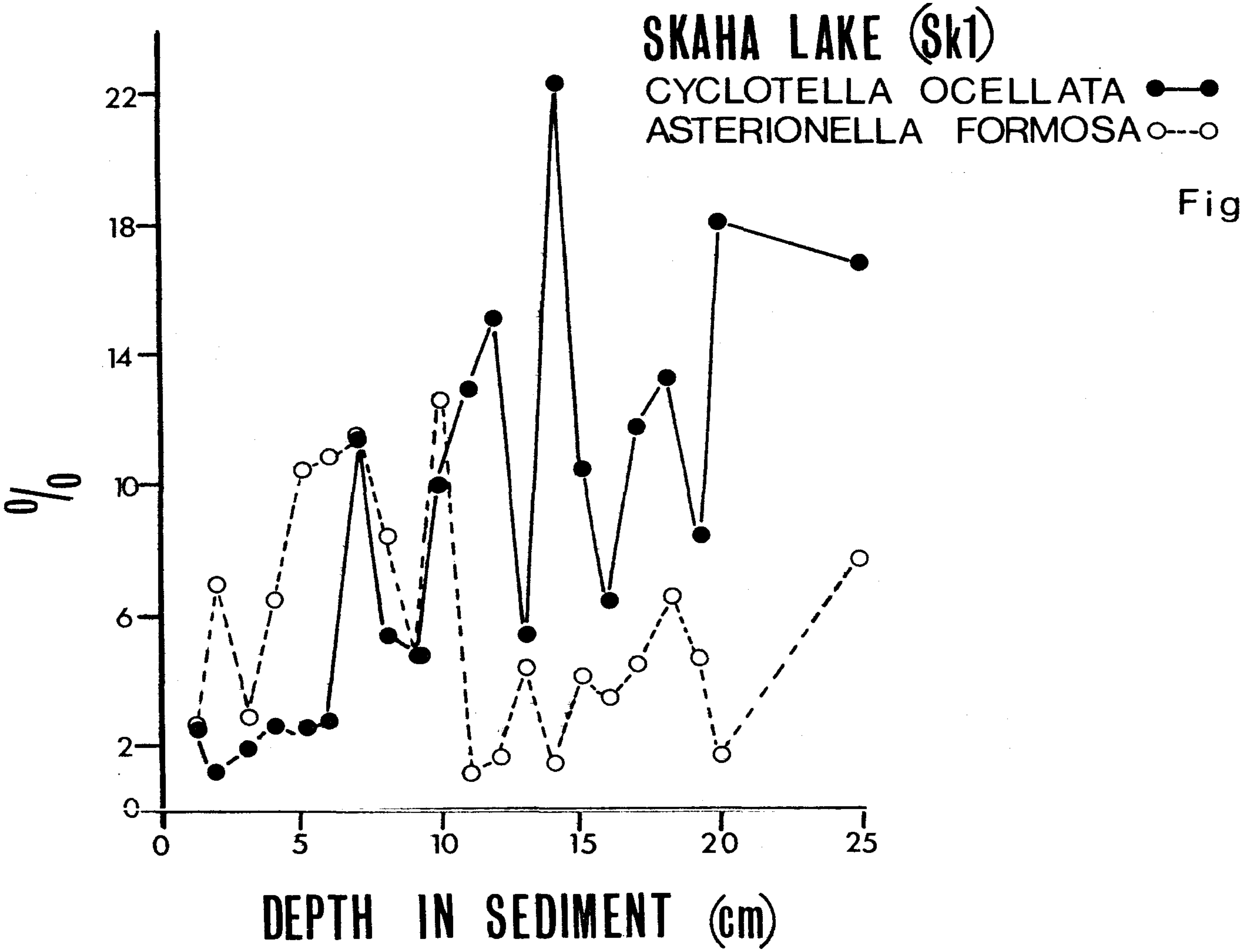

SKAHA LAKE (Sk1)
CYCLOTELLA OCELLATA ●—●
ASTERIONELLA FORMOSA ○---○
%
22
18
14
10
6
2
0
0
5
10
15
20
25
DEPTH IN SEDIMENT (cm)

Fig. 7

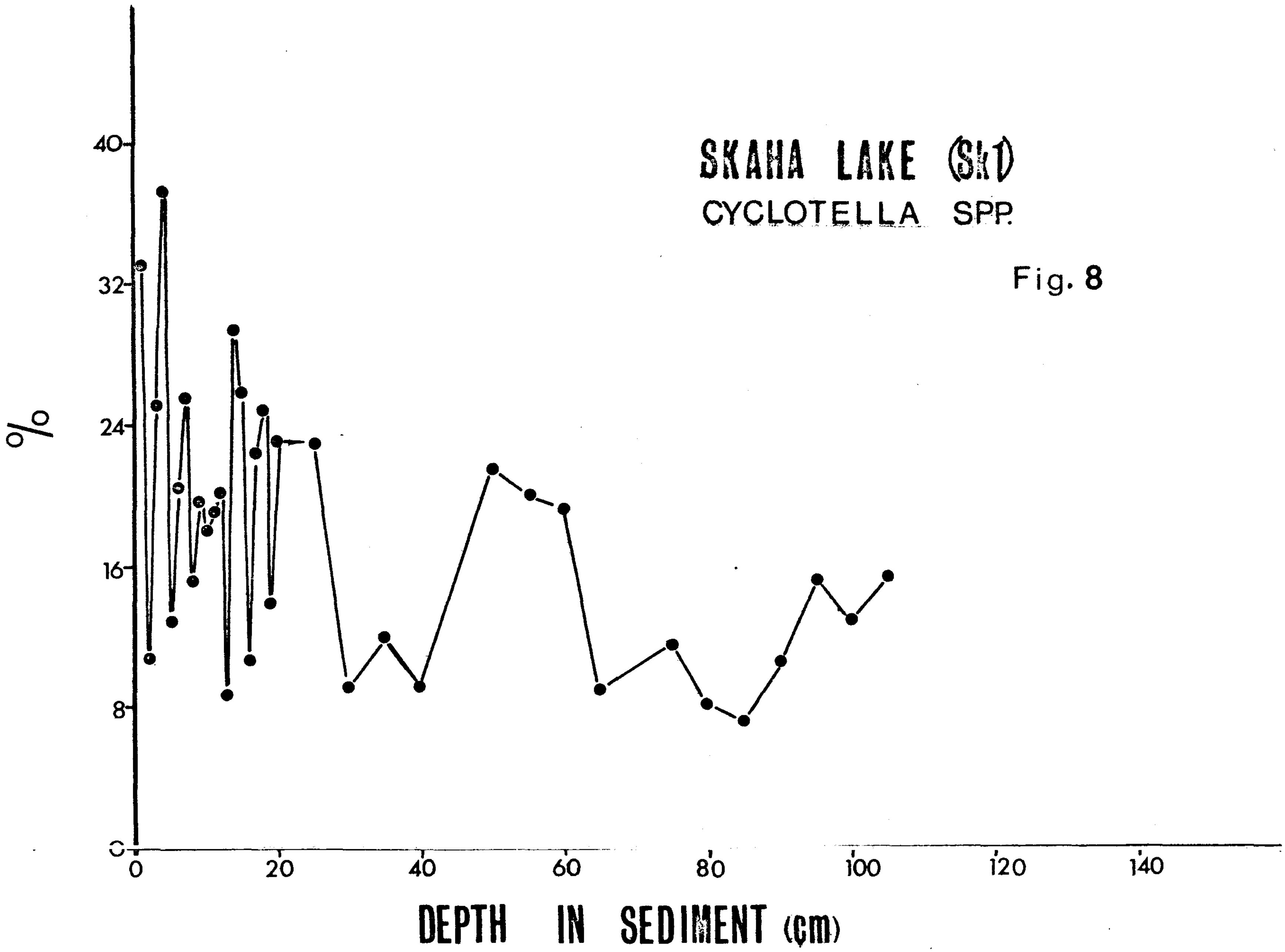

SKAHA LAKE (Sk1)
CYCLOTELLA SPP.
%
40
32
24
16
8
0
0
20
40
60
80
100
120
140
DEPTH IN SEDIMENT (cm)

Fig. 8

becomes more eutrophic, the araphidinate diatoms increase substantially while the centric diatoms decrease. This pattern is well illustrated in counts of araphidinate diatoms from Skaha lake sediments, where commencing at a depth of 40 cm a marked increase occurs (Fig. 9).

SK2. The marked shifts in relative abundance noted in core SKI were not as significant in this shallow littoral core. Achnanthes lavanderi was the only diatom that increased in relative abundance in the upper 8 cm of sediment (Fig. 10). Melosira italica and Cyclotella spp. both showed some increase between 8 and 20 cm, but decreased in the near surface sediment (Fig. 11 and 12). Fragilaria construens and F. Pinnata changed little in relative abundance throughout the core, showing little response to cultural eutrophication (Table 1). The diatom group Araphidineae decreased to a value of < 15% at 8 cm, but rose quickly again in the most recent sediment, reaching a value of > 50%. (Fig. 13).

Unfortunately, very little is known about the ecology of littoral diatom species and therefore little can be inferred from the observed changes in diatom assemblages in core SK2. The following discussion will deal exclusively with core SKI, and the changes noted in the euplanktonic diatoms.

Interpretations

The most striking changes have occurred within the top 8 cm of sediment of SKI, and these changes correlate well with the period of sewage discharge to the lake that has occurred over the past 25 years.

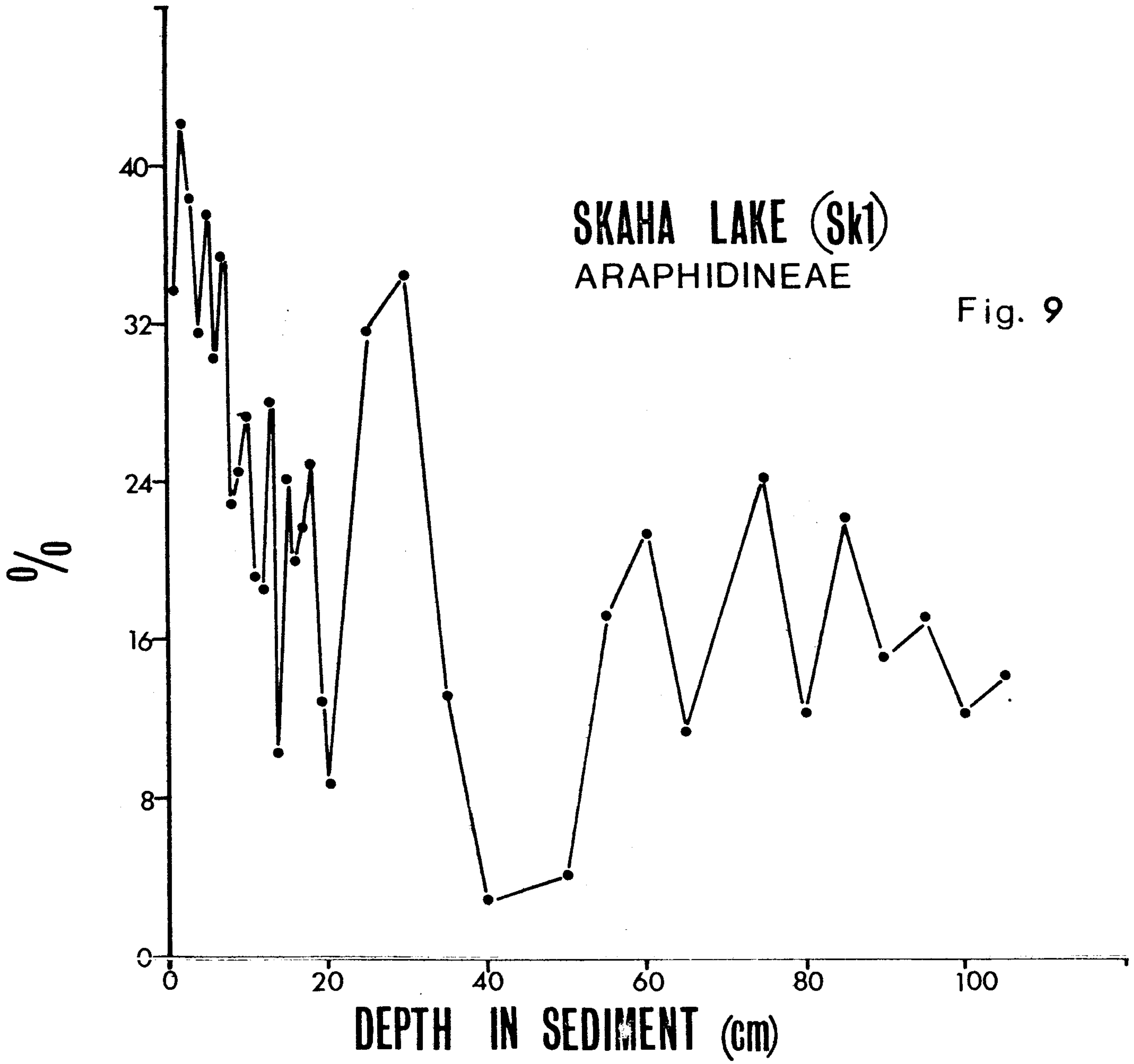

SKAHA LAKE (Sk1)
ARAPHIDINEAE
%
40
32
24
16
8
0
0
20
40
60
80
100
DEPTH IN SEDIMENT (cm)

Fig. 9

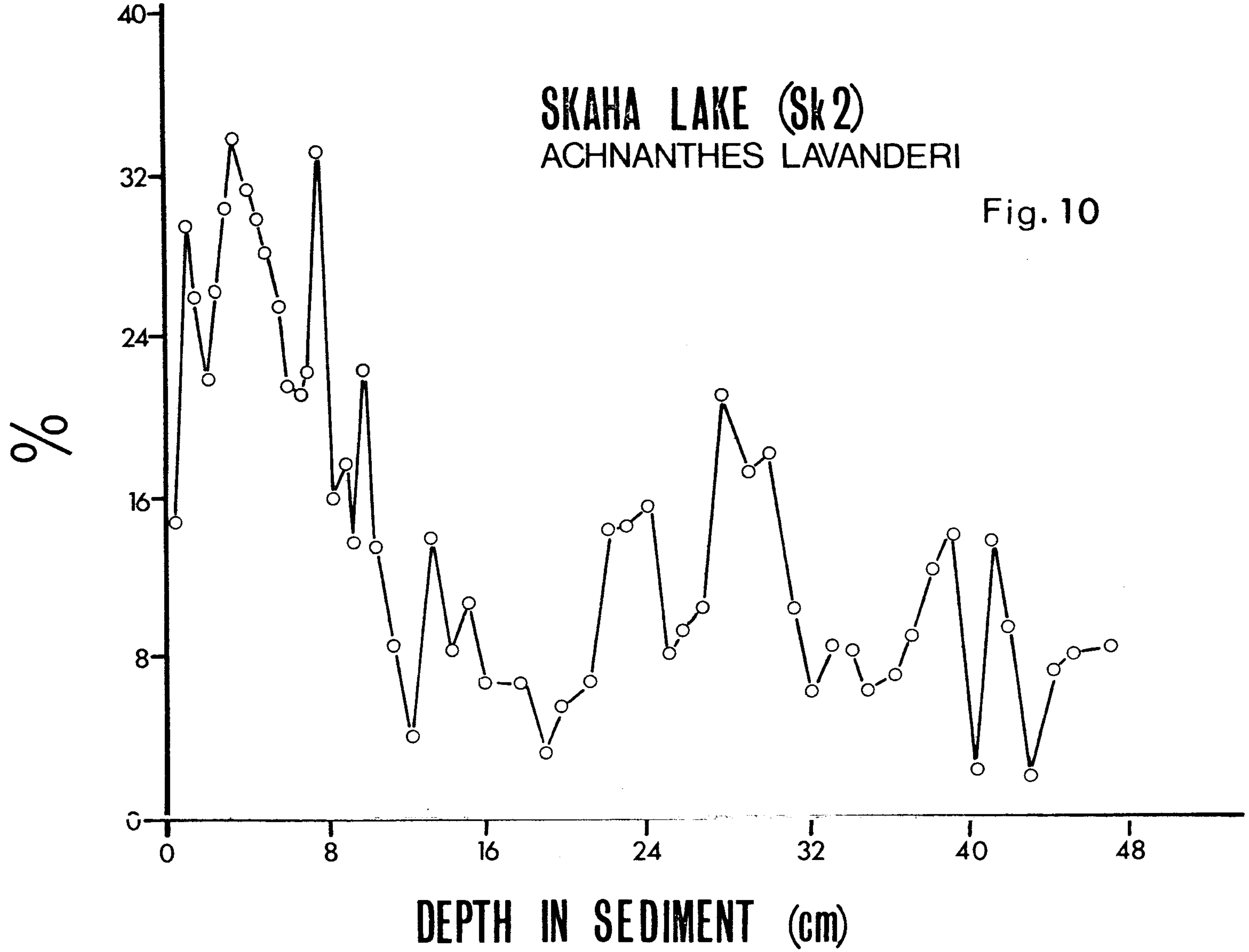

SKAHA LAKE (Sk 2)
ACHNANTHES LAVANDERI
%
40
32
24
16
8
0
0
8
16
24
32
40
48
DEPTH IN SEDIMENT (cm)

Fig. 10

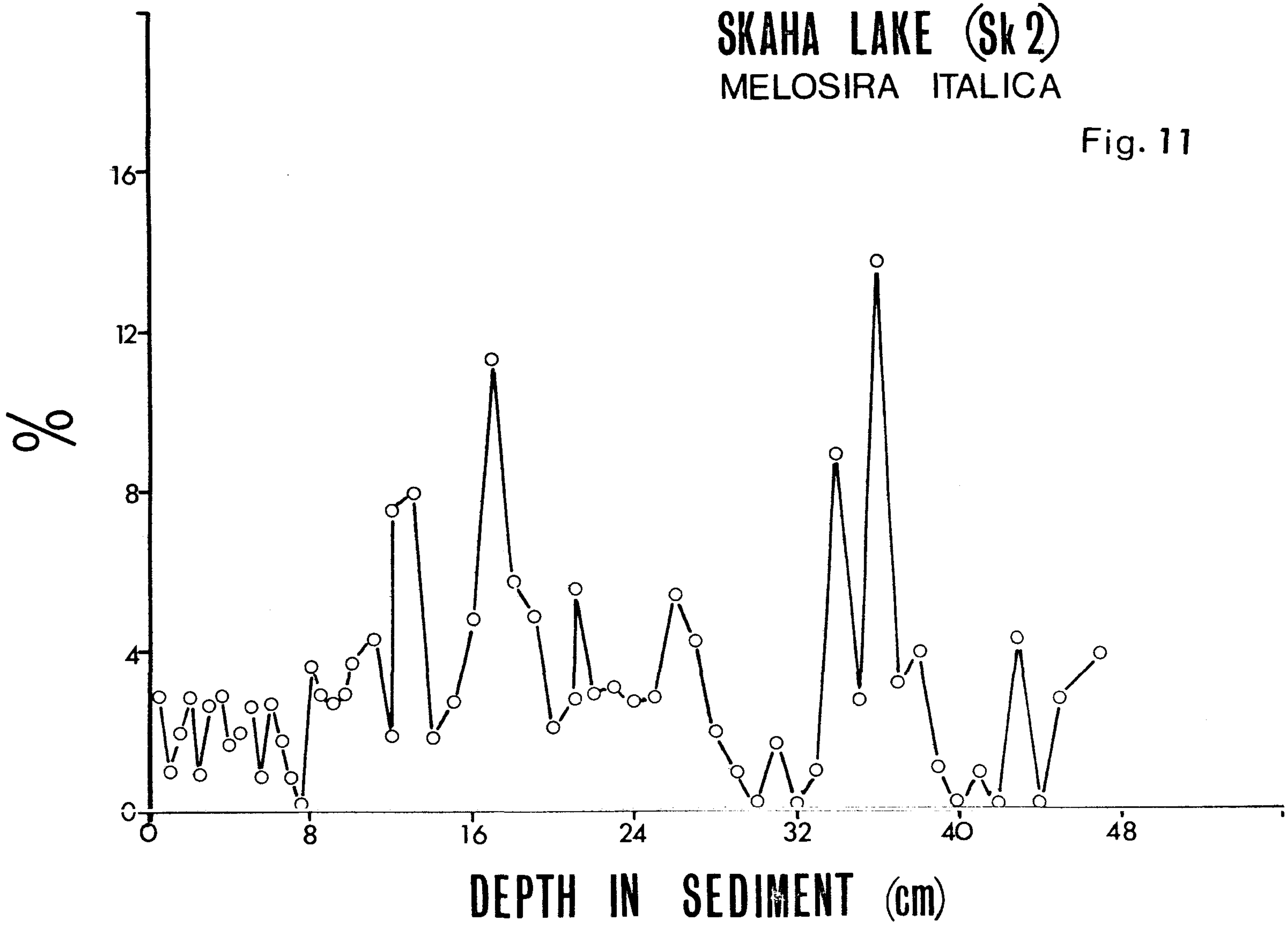
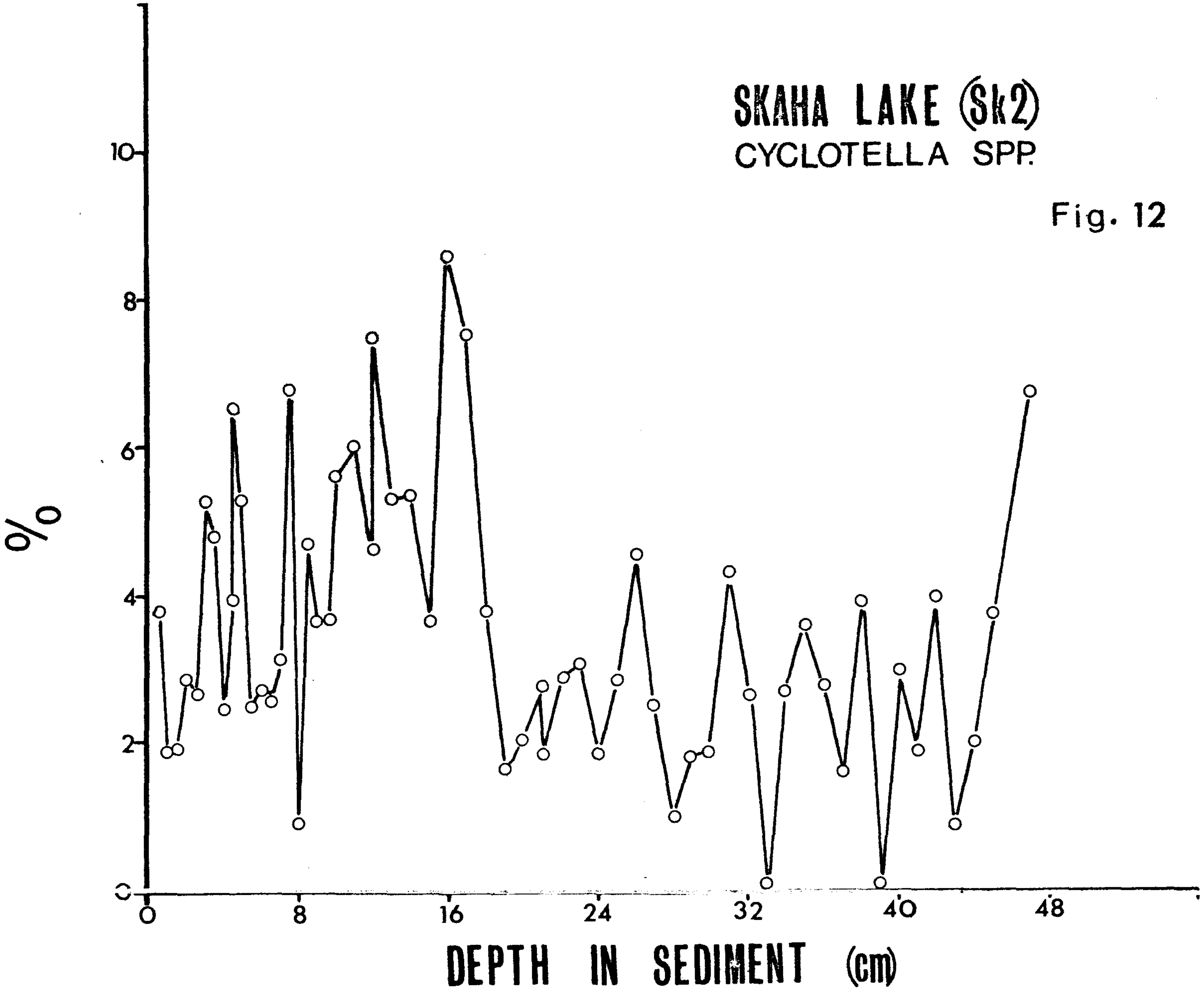

SKAHA LAKE (Sk 2)
MELOSIRA ITALICA
%
0
4
8
12
16
0
8
16
24
32
40
48
DEPTH IN SEDIMENT (cm)

Fig. 11



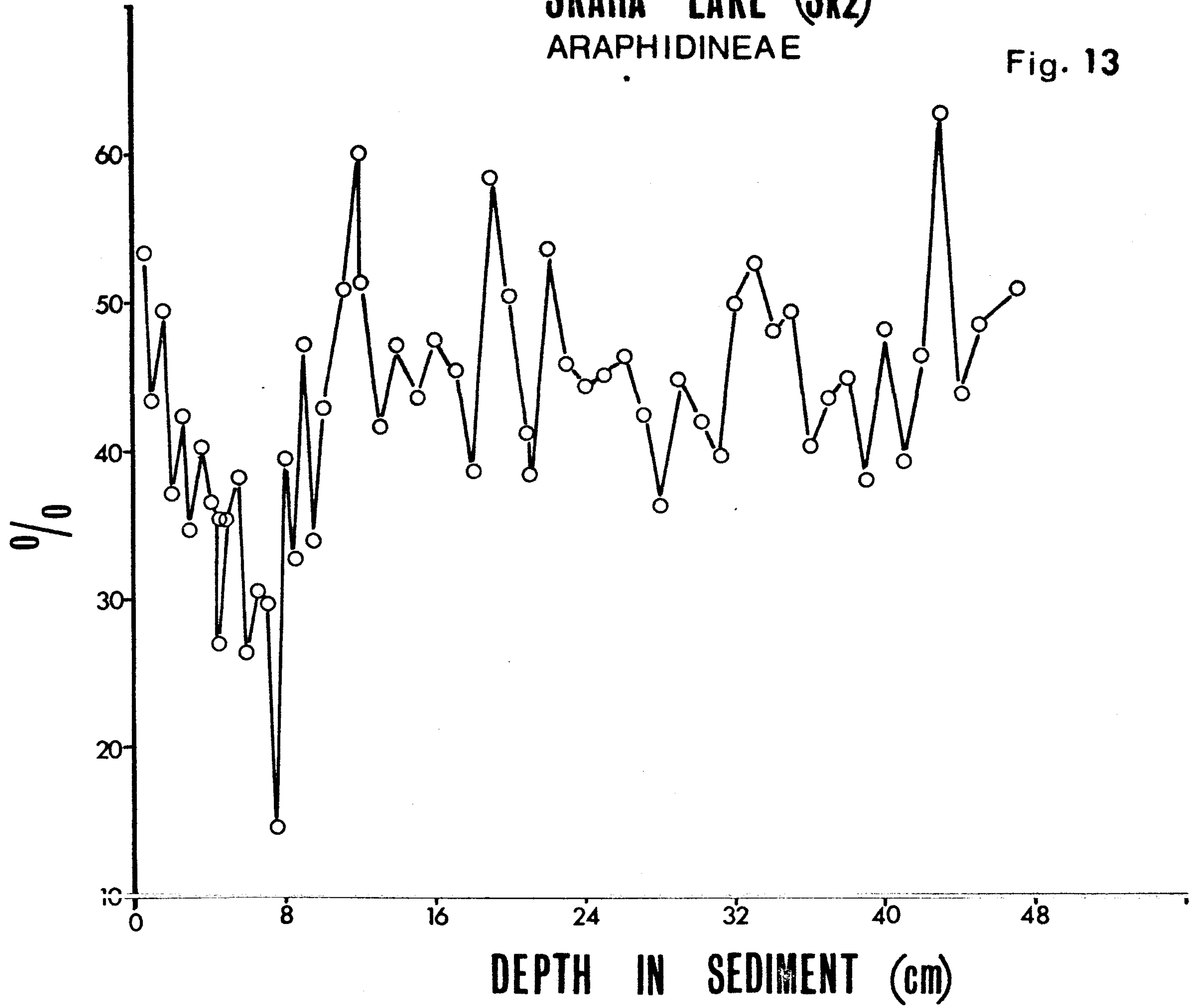
SKAHA LAKE (Sk2)
CYCLOTELLA SPP.

Fig. 12

SKAHA LAKE (Sk2)

ARAPHIDINEAE

Fig. 13



It is reasonable to conclude that the marked increase in *Fragilaria cretonnes* and the decline of *Melosira* *italica* and *Cyclotella* *ocellata* arc directly attributable to sewage enrichment. Other more subtle shifts in dominants are also part of the overall diatom community response to increasing nutrient loads. The recent blue-green blooms are also directly related to sewage discharge.

A similar diatom response as noted in Skaha Lake has occurred in Lakes Washington and Windermere following nutrient enrichment from domestic wastes (Stockner and Benson 1967, Stockner, 1971). The inverse relationship between Fragilaria *crotonensis* and *Melosira* *italica* has been noted in a vast majority of temperate lakes that have recently undergone cultural eutrophication (see Stockner, 1971 and 1971a for a review). Clearly, *Fragilaria* *crotonensis* is a reliable character-form of eutrophic waters. It is currently one of the most common diatoms in Skaha, Osoyoos and Wood Lakes, all very productive lakes.

As previously mentioned, in many temperate eutrophic lakes the diatom group Araphidineae replaces the more Oligotrophic group - Centrales. This can be seen in Skaha (Fig. 9), and is largely due to the increase in *F.* *crotonensis* and *A.* *formosa*, and the decrease of *M.* *italica* and *C.* *ocellata.*

In Lake Washington the peak abundance of *F.* *crotonensis* correlated with the first occurrence of blue-green algal blooms. A similar pattern can be seen in Skaha Lake (Fig. 5) when blooms first occurred in 1966. Following diversion of all sewage from Lake Washington, the blue-green blooms dissipated rapidly and Melosira italica increased rapidly to become dominant, replacing F. crotonensis (Edmondson, personal communication, Stockner 1971). This rapid reversal was noted within 2 years of sewage diversion.

It is likely that with the installation of tertiary treatment facilities, a similar reversal will be noted in Skaha Lake. Within the next few years diatoms should predominate the plankton throughout the growing season, thereby reducing the likelihood of reoccurring blue-green algal blooms. It should be noted however, that as the population of Penticton increases, even with 80% phosphorus removal, a greater nutrient load will reach the lake and nuisance conditions could reoccur. If this happens, land irrigation is the only feasible alternative to prevent the eutrophication of the lake.

TABLE 1. A ranking of the dominant diatom species in cores SKI and SK2.

Core SK1

rank	0 - 8 cm	9 - 25 cm	26 - 105 cm
1.	Melosira italica	Melosira italica	Melosira italica
2.	Cyclotella comta	Cyclotella ocellata	Cyclotella ocellata
3.	Fragilaria crotonensis	Cyclotella comta	Fragilaria pinnata
4.	Asterionella formosa	Fragilaria pinnata	Fragilaria construens
5.	--	--	Cyclotella comta

Core SK2

	0 - 8 cm	9 - 25 cm	26 - 45 cm
1.	Achnanthes lavanderi	Fragilaria construens	Fragilaria construens
2.	Fragilaria construens	Fragilaria pinnata	Fragilaria pinnata
3.	Fragilaria pinnata	Achnanthes lavanderi	Achnanthes lavanderi
4.	Stephanodiscus astraea	Achnanthes spp.	Achnanthes spp.
5.	Amphora ovalis	Amphora ovalis	Amphora ovalis

SUMMARY

Of the two cores examined, only the deep water core (SKI), containing chiefly euplanktonic diatom species, showed significant changes related to the recent eutrophication of Skaha Lake. The greatest change in diatom assemblages has occurred within the last 25 years (7-8 cm) with diatoms more common in eutrophic waters showing marked increases in relative abundance. Prior to 1940 there was little change in diatom dominants and the more common diatoms were indicative of Oligotrophic conditions. The main factor responsible for the eutrophication of Skaha lake is the effluent discharge from the Penticton sewage treatment plant that commenced operations in 1947. With the installation of tertiary treatment facilities in 1971 conditions should improve and blue-green blooms should become less of a nuisance.

ACKNOWLEDGEMENTS

The author wishes to thank Mr. David Evans and Dr. Brian St. John for assistance in obtaining the cores. Mr. Evans and Mr. David Findlay provided the sediment diatom counts and Mr. G. Krucik prepared the computer program for final data analysis. Many others assisted in various aspects of the study, including Mr. M. Pomeroy and Mr. R. Harper. Mr. M. Thomson, Study Director, provided excellent laboratory facilities. To these people I extend my most sincere appreciation.

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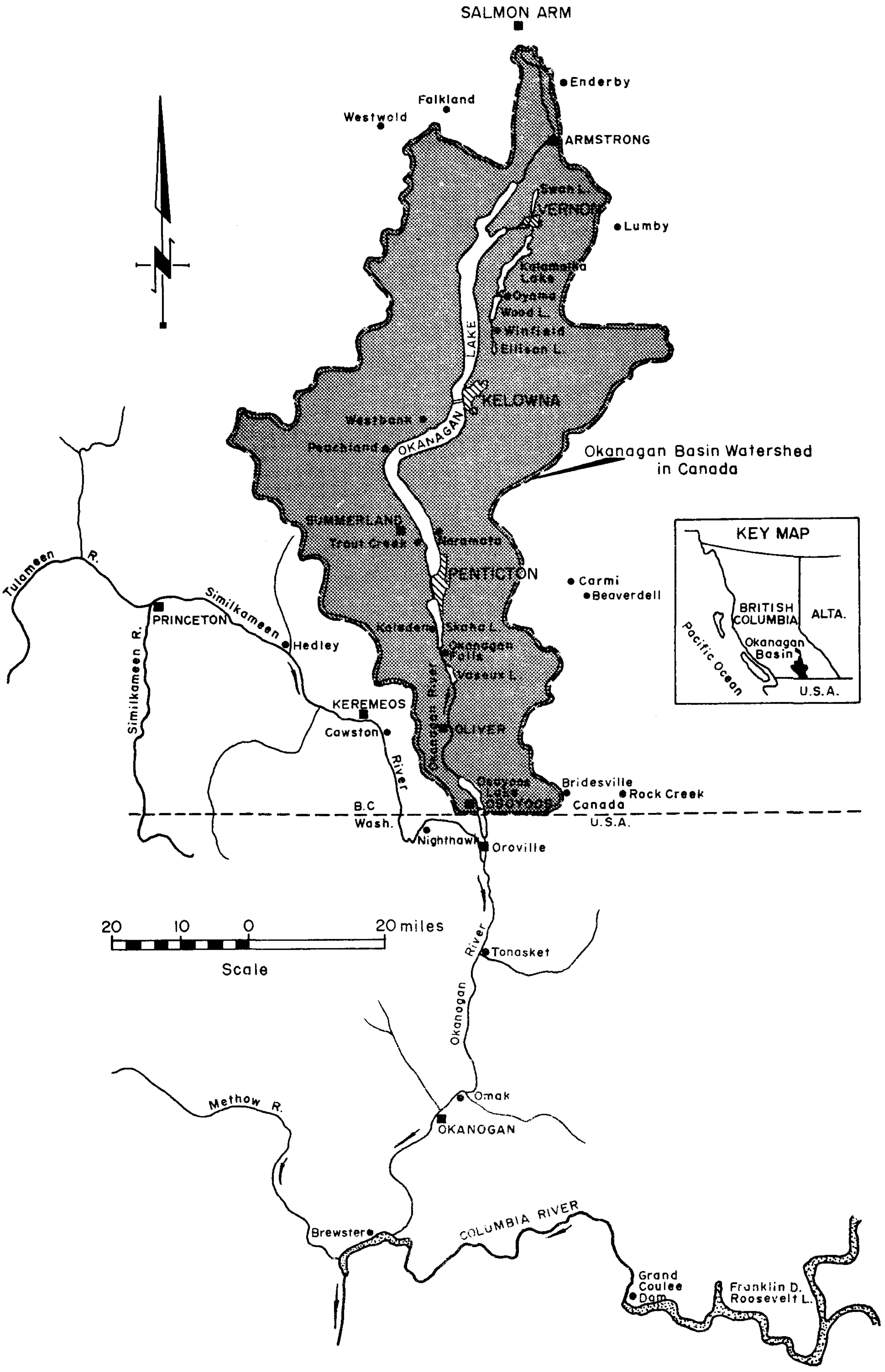

OKANAGAN DRAINAGE BASIN IN CANADA