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DEPTH DISTRIBUTION OF THE SLIMY SCULPIN (*Cottus cognatus*) IN A SMALL LAKE IN NORTHWESTERN ONTARIO

by

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TABLE OF CONTENTS

ABSTRACT

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The seasonal and diurnal depth distribution of the slimy sculpins in Lake 302 (L302) of the Experimental Lakes Area, northwestern Ontario was studied during the open water season of 1983. During the spring and fall, when Lake 302 was thermally mixed, slimy sculpins were seen at all depths in the lake. Water temperatures at this time ranged from 5 to 13°C while oxygen concentrations ranged from 1.5 to 9.5 $mg \bullet L^{-1}$. There was no apparent diurnal movement at this time. When L302 became thermally stratified, the sculpins appeared to congregate in the metalimnion of the lake. During the day, slimy sculpins were seen in the upper regions of the metalimnion where water temperatures ranged from 10 to 20°C and oxygen concentrations ranged from 8 to 11 $mg \bullet L^{-1}$. At night, most sculpins were seen in the lower metalimnion and upper hypolimnion, where water temperatures ranged from 7 to 10°C and oxygen levels ranged from 0.5 to 8 $mg \bullet L^{-1}$. Water temperature was most closely associated with sculpin depth distribution in L302. Oxygen concentrations also appeared to be a determining factor although when temperatures in the lake rose in mid-summer, temperature became more important. Food availability and light penetration were secondary and only important when temperature and oxygen conditions were optimal.

Key words: seasonal distribution; diurnal; temperature; oxygen; food availability.

RESUME

Mohr, L.C. 1985. Depth distribution of the slimy sculpin (*Cottus cognatus*) in a small lake in northwestern Ontario. *Can. Tech. Rep. Fish. Aquat. Sci.* 1374: iv + 13 p.

On a étudié pendant la saison de l'eau libre de 1983 la distribution saisonnière diurne, selon la profondeur, du chabot visqueux dans le lac n° 302 de la Région des Lacs Expérimentaux, dans le nord-ouest de l'Ontario. Au printemps et à l'automne, au moment où les couches de température du lac n° 302 étaient mélangées, on a constaté la présence de chabot visqueux à toutes les profondeurs dans le lac. Les températures de l'eau à ce moment variaient entre 5°C et 13°C, tandis que la concentration en oxygène variait de 1,5 à 9,5 $mg \bullet L^{-1}$. Pendant la nuit, la plupart des chabots observés l'ont été dans les couches inférieures du mésolimnion et dans les couches supérieures de l'hypolimnion, où les températures de l'eau variaient entre 7°C et 10°C, et où la concentration en oxygène allait de 0,5 à 8 $mg \bullet L^{-1}$. La température de l'eau était très étroitement liée à la distribution des chabots selon la profondeur dans le lac n° 302. La concentration en oxygène semblait également constituer un facteur déterminant même si la température devenait un élément plus important lorsque les températures du lac devenaient plus élevées vers le milieu de l'été. La présence de nourriture et la pénétration de la lumière étaient secondaires et n'étaient importantes que lorsque la température et la concentration en oxygène atteignaient leur niveau optimal.

Mots-clés: distribution saisonnière, rythme circadien, température, oxygène, présence de nourriture.

INTRODUCTION

At present, very little is known about the depth distribution of the slimy sculpin, especially in small Canadian Shield lakes. Wells (1968) has observed seasonal changes in slimy sculpin depth distribution in Lake Michigan and Sinclair (1968) reported diurnal changes in the distribution of young Cottus asper. Although several life history studies of the slimy sculpin have included observations on sculpin depth distribution, these data generally have been limited to maximum depth sightings in various lakes (Van Vliet 1964; Scott and Crossman 1973; Ebert and Summerfelt 1969).

Many factors such as water temperature, oxygen concentrations, water clarity, food availability and lake bottom type can influence sculpin distribution (Bond 1963; Ferguson 1958; Otto and Rice 1977; Symons et al. 1976; Van Vliet 1964). In addition, Bond (1963) also suggested that certain interspecific factors such as competition or predation can affect sculpin distribution and abundance. For example, predation on sculpins by deep water species such as lake trout (Salvelinus namaycush) and burbot (Lota lota) indicate that the slimy sculpin inhabits deep hypolimnetic waters where these predator species occur (Carlander 1969; Scott and Crossman 1973); in contrast, the slimy sculpin prey primarily on dipteran larvae (Van Vliet 1964; Mohr 1984; Craig and Wells 1976) which are more frequently found in the shallower epilimnetic regions of a lake (Davies 1980). Intraspecific competition is also a factor in determining slimy sculpin depth distribution because most sculpins are territorial and remain solitary except during the spawning season (Van Vliet 1964).

The primary purpose of this study was to determine at which depths the slimy sculpin (Cottus cognatus) occurred in a small Canadian Shield lake and if any seasonal or diurnal changes in sculpin depth distribution took place. The second purpose of the present study was to determine whether oxygen, temperature, dipteran emergence and light penetration in Lake 302 had any affect on slimy sculpin distribution. Lake 302 is presently being artificially acidified. The data presented in this study should be viewed as baseline data to be compared to similar data collected in later years of acidification. This data should also be useful in better understanding the habits of the slimy sculpin in this lake as well as other Canadian Shield lakes.

MATERIALS AND METHODS

Lake 302 is located in the Experimental Lakes Area in northwestern Ontario. The lake has a total surface area of 23.7 ha and a volume of $2.27 \cdot 10^5$ m^3. Lake 302 is subdivided into a north basin and a south basin. Two vinyl-impregnated nylon curtains ensure complete separation of the two basins. Both basins are roughly the same size although the north basin is slightly deeper (North Zmax = 13.8 m, South Zmax = 10.9 m). Lake 302 is typical of other small lakes in the Experimental Lakes Area which usually experience a complete fall turnover. Other fish species present in Lake 302 include white sucker (Catostomus commersoni), lake whitefish (Coregonus clupeaformis), pearl dace (Semotilus margarita), finescale dace (Chrosomus neogaeus), northern red-belly dace (Chrosomus eos) and fathead minnow (Pimephales promelas).

In 1982, six linear rope transects, three in each basin, were permanently established along the bottom of Lake 302. Each transect started at shore and ended at a depth of approximately 9.5 m in the south basin and 11 m in the north basin. During the ice free season in 1983, two divers using SCUBA equipment simultaneously made counts of slimy sculpins along four of the transects. Slimy sculpins were counted in 2 m depth intervals (0-2, 2-4, 4-6, 6-8, 8^+) for a linear distance of 5 m along each transect. Each diver recorded all sculpins seen within 0.5 m to each side of the rope transect. All counts were recorded on an underwater writing slate after each 5 m length was completed. Occasionally each diver would count sculpins seen on both sides of the transect. It was thought that these checks would eliminate diver biases in the final count.

Sampling for this study took place once a month during the open water season in 1983 (May-October). Day and night sculpin counts were collected usually within 12 hours of each other. Night counts took place only after total darkness occurred (2000-2300 h) and day counts took place close to mid-day (1100-1200 h) on sunny cloudless days. No artificial light source was necessary on the day dives while two underwater dive lamps were used on the night dives.

During both day and night counts, rocks and gravel along the bottom of the lake were disturbed to expose any hidden sculpins. In most cases counts were made without differentiating sizes or sexes of sculpins seen. However in late June and mid-July numerous young of the year sculpins were observed and these were counted separately from other sculpins. Casual observations on bottom type, congregation of sculpins, visibility and sculpin association with other fish species were also made. Each monthly count was conducted on or close to (within one or two days) days when water chemical sampling occurred in the lake.

Throughout this study the term metalimnion is used. This term is defined as the region in a lake where temperature drops at least 1°C with every 1 m decrease in depth (Hutchinson 1957). Slimy sculpin counts were made in depth intervals and it was felt that the metalimnion would be more appropriate for comparative purposes than the more restrictive planar thermocline. The dipteran emergence data presented in this report represent seasonally integrated total emergence for the 1983 open water season in Lake 302. These data give a good assessment of available standing crop in the lake (I. Davies, Freshwater Institute, personal communication).

RESULTS

DISTRIBUTION

A total of 391 slimy sculpins were observed in the north basin of Lake 302; 241 of these were counted at night while 150 were counted during the day. Included in these totals were 78 young of the year sculpins seen in late June and July. Most of the young-of-the-year sculpins were seen during the day (67) while only a few were seen at night (11). Approximately equal numbers of sculpins were seen in late June, July, August and September while only half as many were seen in early June and October (see Appendix 1).

On June 2, slimy sculpins in the north basin were seen along all depth contours (Fig. 1). During the day they were seen as deep as 8 m while at night they were as deep as 10 m. By June 22, sculpin distribution was more concentrated with 91.5% located in the 4-6 m depth range during the day and 75% located in the 4-8 m depth range during the night. On July 12, 1983 sculpin distribution during the day was similar to the results from June 22. At night more sculpins were seen in the 6-8 m depth range than were found at this depth in June. By August 18 no sculpins were seen in water shallower than 4 m. During the day 89.3% of the sculpins were located in the 4-6 m depth zone while at night 86.0% were found in the 6-8 m depth zone. The results during the day on September 6 were similar to the results during the day on August 18 although a few more sculpins were seen in the 8+ depth zone in September than were seen there in August. Some scuplins were present in the 2-4 m zone during the September night count although the majority (72%) were still seen in the 6-8 m depth zone. By October 5 the slimy sculpins were once again distributed evenly throughout all depths of the north basin, both during the day and during the night.

In the south basin a total of 159 slimy sculpins were seen, 93 during the night and 66 during the day. Only six young of the year sculpins were seen in this basin. These were seen during the day in late June and July. Most of the sculpins in the south basin were seen in July and August. Slightly fewer were observed in June while very few were seen in September and October (see Appendix 1).

On June 2, 1983 the slimy sculpins in the south basin were distributed throughout all depths at night and were grouped together in the 0-2 m depth zone and the 4-6 m depth zone during the day (Fig. 2). By June 22, the sculpins were concentrated entirely in the 4-8 m depth zone during the day while at night they were seen in water either less than 2 m or greater than 6 m in depth. On July 12 most of the slimy sculpins were observed in the 6-8 m depth zone and had identical day and night distribution. The distribution of sculpins during the day in the south basin changed very little from July through to September. At night however, more sculpins were found in the 8+ m depth zone in August and by September almost 90% of the sculpins in this basin were observed in water deeper than 8 m during the night. By October 5 the slimy sculpins were observed in shallower waters during the day and were found distributed evenly at all depths during the night.

TEMPERATURE

Surface water temperatures in the north basin ranged from 22°C on August 24 to 11°C on October 4, 1983. Temperatures at the bottom of the deepest depth zone (11 m) ranged from 5.4°C in early June to 6.9°C in October. The north basin was thermally mixed only in October with water temperatures never exceeding 14°C. During the rest of the study period, this basin was thermally stratified. The metalimnion was well defined by late June and extended from 2.5 to 6 m. In July, August and September it extended from 4 to 8 m.

The south basin of Lake 302 had slightly warmer water temperatures than the north basin. This was especially evident in the hypoliminion where temperatures in the south basin were usually 3 to 5°C warmer than those in the north basin. In the south basin surface temperatures ranged from 12°C in October to 22.6°C in August. Temperatures at the 10 m depth ranged from 8.6°C in early June to 11.6°C in October. The south basin was thermally mixed in October when temperatures in this basin were approximately 12°C. In early June this basin was just starting to stratify and temperatures ranged from 9 to 13°C. During the remainder of the study period the south basin was stratified with the metalimnion located in the 2-8 m depth zone in late June and in the 6-9 m depth zone in August and September.

OXYGEN

Oxygen profiles in the north basin changed very little from one sampling date to another. Surface oxygen concentrations ranged from 8.2 to 9.2 $mg \cdot L^{-1}$ and increased gradually until maximum concentrations of 9.4 to 11.6 $mg \cdot L^{-1}$ were reached at depths of 5 to 6 m. The oxygen concentration then decreased rapidly to values of 0 to 1.9 $mg \cdot L^{-1}$ at the 10 m depth. The maximum oxygen concentrations were always found within the metalimnion of this basin.

The south basin of Lake 302 had consistent oxygen profiles on all sampling dates except October. Surface oxygen concentrations ranged from 7.8 to 9.5 $mg \cdot L^{-1}$ and maximum concentrations, usually found at a depth of 6 m, ranged from 8.4 to 10.8 $mg \cdot L^{-1}$. Oxygen concentrations decreased below 6 m to values ranging from 0 to 2.7 $mg \cdot L^{-1}$. The maximum oxygen concentrations were always found at depths within the metalimnion. In October this basin had experienced a complete turnover and oxygen concentrations averaged 9.6 $mg \cdot L^{-1}$ at all depths in the basin.

LIGHT PENETRATION

In the north basin light penetration into the water column changed very little throughout the study period. The amount of light in the water column decreased rapidly as it passed through the epilimnion. At a depth of 4 m light penetration was generally less than 10% of surface light and at a depth of 7 m the amount of light present was less than 1% of surface light. Light readings were taken to a maximum depth of 9 m and these were usually 0.5% or less of surface light readings.

In the south basin light penetration was also consistent throughout the study. The largest amount of light entering the lake had dissipated by the time it reached the metalimnion. At 4 m in depth light penetration was already less than 20% of the surface light available and by 7 m it was less than 5%. Below 7 m in depth light penetration varied from 2.5 to 0.1% of surface light with the highest levels occurring in early June and October.

DIPTERAN EMERGENCE

Total dipteran emergence for the open water season in the north basin of Lake 302 was 4.42×10^4 emergents per square metre (Davies 1980). Approximately 84% of these emergents were found at depths less than 4 m. The most productive area of the north basin was the 0-2 m zone which accounted for 47% of the total basin emergence.

In the south basin total emergence in 1983 was 3.90×10^4 emergents per square metre. In this basin 75% of the total emergence took place at depths less than 4 m. The most productive region of the south basin was the 2-4 m depth zone which accounted for 45% of the total basin emergence.

DISCUSSION

SEASONAL

In a study of Lake Michigan sculpins, Wells (1968) reported that the sculpins occupied all depths in the lake during the winter months. During this time they are active feeders. Van Vliet (1964) reports that most of the growth in adult sculpins in northern lakes occurs during the winter. Shortly after spring ice-off occurs mature male and female sculpins move to the shallow regions (0-1.5 m) in a lake to spawn. In Lake 302 slimy sculpins do not become sexually mature until age 2+ (Mohr 1984). Van Vliet (1964) reported that no non-spawning fish were present on spawning sites in his study which would indicate that juvenile sculpins (age 1+ or less) remain in the deeper regions of a lake during the spawning period. This seems to occur in June in Lake 302 when sculpins are spawning (Mohr 1984). When spawning is complete the females leave the shallow waters and move deeper leaving the male sculpins to attend the eggs and fry. After the fry hatch and absorb their yolk sacs, they move to deeper waters along with the males (Van Vliet 1964; Wells 1968). Sculpin fry hatch in late June in Lake 302 and their downward movement was evident from field observations when juveniles were seen among the adults in deeper waters as the season progressed.

During the time that Lake 302 was thermally stratified (June - September) slimy sculpins were seen most frequently in the metalimnetic zone of both basins. Sculpins are capable of recognizing and responding to lethal temperatures of approximately 25°C and prefer temperatures between 10 and 15°C (Otto and Rice 1977; Symons et al. 1976; Wells 1968). The metalimnetic zone of both basins of Lake 302 contained temperatures similar to these preferred temperatures. The metalimnion in Lake 302 also contained the zone of maximum oxygen concentration which would be favourable to slimy sculpins. Bond (1963) reported that oxygen concentrations of 2.0 $mg \cdot L^{-1}$ caused an avoidance reaction in sculpins and that levels of 1.5 $mg \cdot L^{-1}$ or lower could be lethal if they persisted for several hours. In the north basin of Lake 302 oxygen concentrations of 2.0 $mg \cdot L^{-1}$ were found at the lower levels of the metalimnion and most sculpins remained in or above this zone. In the south basin however, when temperatures in the metalimnion reached or exceeded 15°C (August and September), the sculpins were found in the hypolimnion presumably in search of cooler waters even though oxygen concentrations were well below 2 $mg \cdot L^{-1}$.

By October of 1983, when both basins of Lake 302 were no longer stratified slimy sculpins were found at all depths in the lake. At this time, water temperatures were below 15°C throughout the lake and oxygen levels were above 7.0 $mg \cdot L^{-1}$ at all depths.

Seasonal sculpin distribution appeared to be dependent on feeding and food availability only during the periods when Lake 302 was not thermally stratified. During the period when this lake was thermally stratified, no sculpins were seen in the 0-4 m depth zone where the majority of dipteran emergence occurs. However, when the lake was not stratified (spring and fall) sculpins were present at depths of 0 to 4 m. It seems that slimy sculpins occupied the areas of highest food availability only when water temperatures in these areas became tolerable. This is also reflected in their seasonal condition factors. In 1982, sculpin condition was greatest in June, decreased throughout the summer (July, August and September) and increased slightly again in October (Mohr 1984).

DIURNAL

Diurnal changes in slimy sculpin distribution in Lake 302 were most evident once the lake had become thermally stratified. During this time, most sculpins were observed in the upper regions of the metalimnion during the day while at night most were seen 2 to 4 m deeper in the lower regions of the metalimnion. At night sculpins were usually seen in water with temperatures ranging from 7 to 10°C which is the preferred temperature of the slimy sculpin (Otto and Rice 1977; Symons et al. 1976). It appeared that the low oxygen concentrations found in the lower metalimnion and hypolimnion were not a great enough deterrent to make the sculpins leave the cool temperatures at night. However the night habitat of the sculpins in Lake 302 did not contain much available food. This could be one of the reasons why the sculpins appeared to move upward into shallower waters during the day. Slimy sculpins are sight feeders (Van Vliet 1964) and the shallower upper metalimnetic zone with greater light penetration and more available food was a better area for the sculpins to feed in than the deeper waters they occupied at night. Also, high oxygen concentrations (6 to 10 mg•L^{-1}) were usually found in the upper region of the metalimnion.

Although more food was available in the epilimnion of Lake 302, water temperatures in this zone were generally too high for the slimy sculpins. Otto and Rice (1977) reported that slimy sculpins showed an avoidance for temperatures 6 to 10°C above their preferred or acclimated temperature. The upper limit of the metalimnion generally had temperatures which would be considered avoidance temperatures for slimy sculpins.

When Lake 302 was not stratified sculpins occupied the same regions of the lake during the day as they did at night. Oxygen concentrations and water temperatures were optimal at this time at all depths above 10 m and no noticeable diurnal changes took place. One exception was the grouping of sculpins at 4 to 8 m in the south basin during the day in early June and October. Very small sample sizes (5-6 sculpins) may be the reason for these inconsistent results. The segregation in early June in the south basin could also be the division between spawning and non spawning sculpins; however, the congregation during the day on October 2 remains unexplained.

In conclusion, slimy sculpin distribution in Lake 302 appeared to change both seasonally and diurnally. Water temperature seemed to be the most critical parameter in determining sculpin distribution especially the upper depth at which sculpins could be found. Oxygen concentration was important in determining maximum depth at which sculpins were seen. However, when lake temperatures increased in mid-summer slimy sculpins were observed in areas of low oxygen and low temperatures at night and in areas of high oxygen and high temperatures during the day. Light penetration was very limited below 4 to 5 m in Lake 302. Since it was assumed that sculpins were equally visible during both day and night dives, light penetration appeared to have little or no effect on sculpin distribution. Dipteran emergence which was highest in the epilimnion of Lake 302, was a limiting factor in sculpin distribution only when water temperatures in the lake were not restricting sculpin movement. No natural predators exist in Lake 302 which might alter the slimy sculpins depth distribution. However, this could be a factor in other Canadian Shield lakes.

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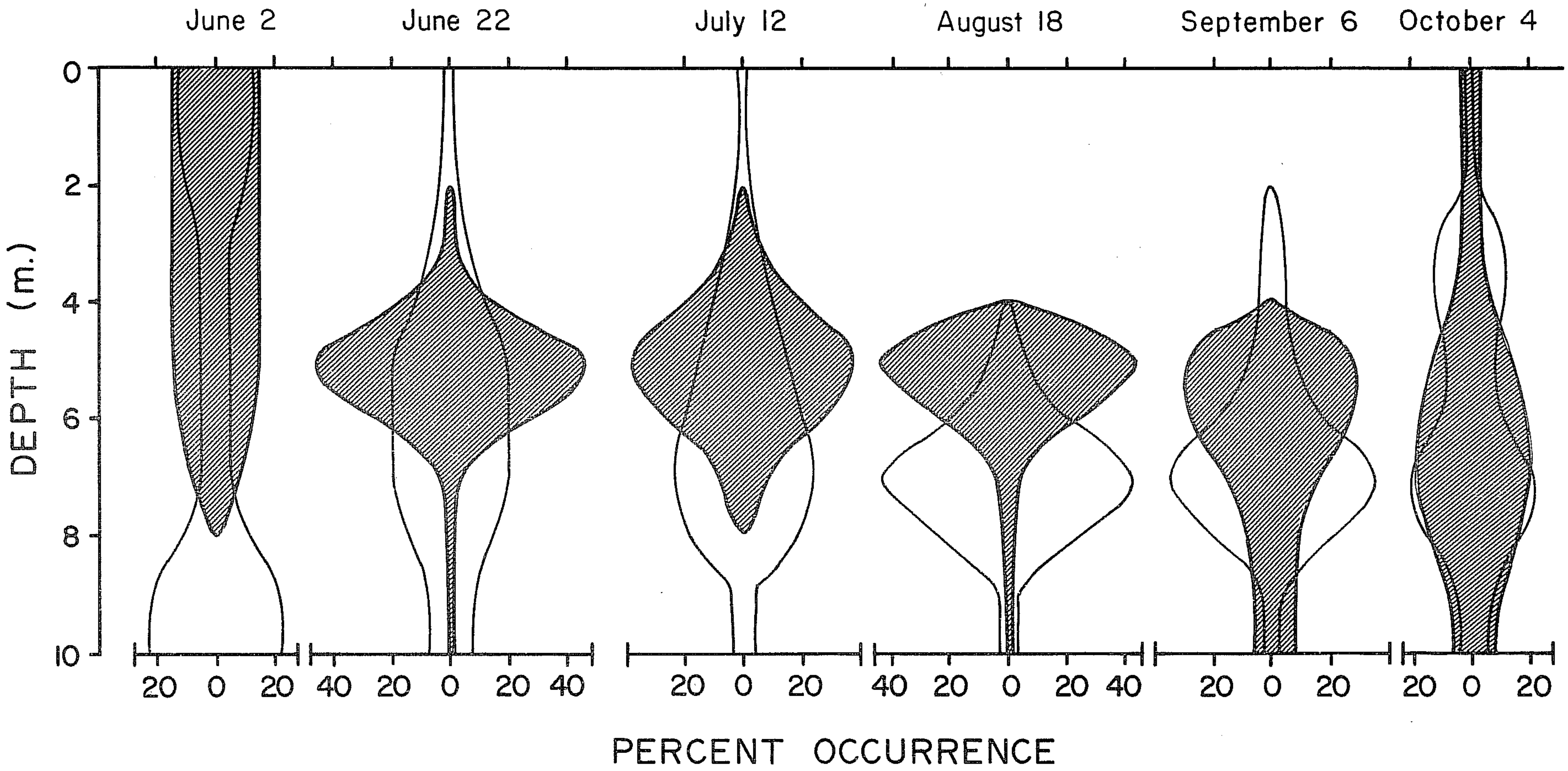

Fig. 1. Percent occurrence of slimy sculpins in the north basin of L302, Experimental Lakes Area, 1983. Shaded areas represent day results and open areas represent night results.

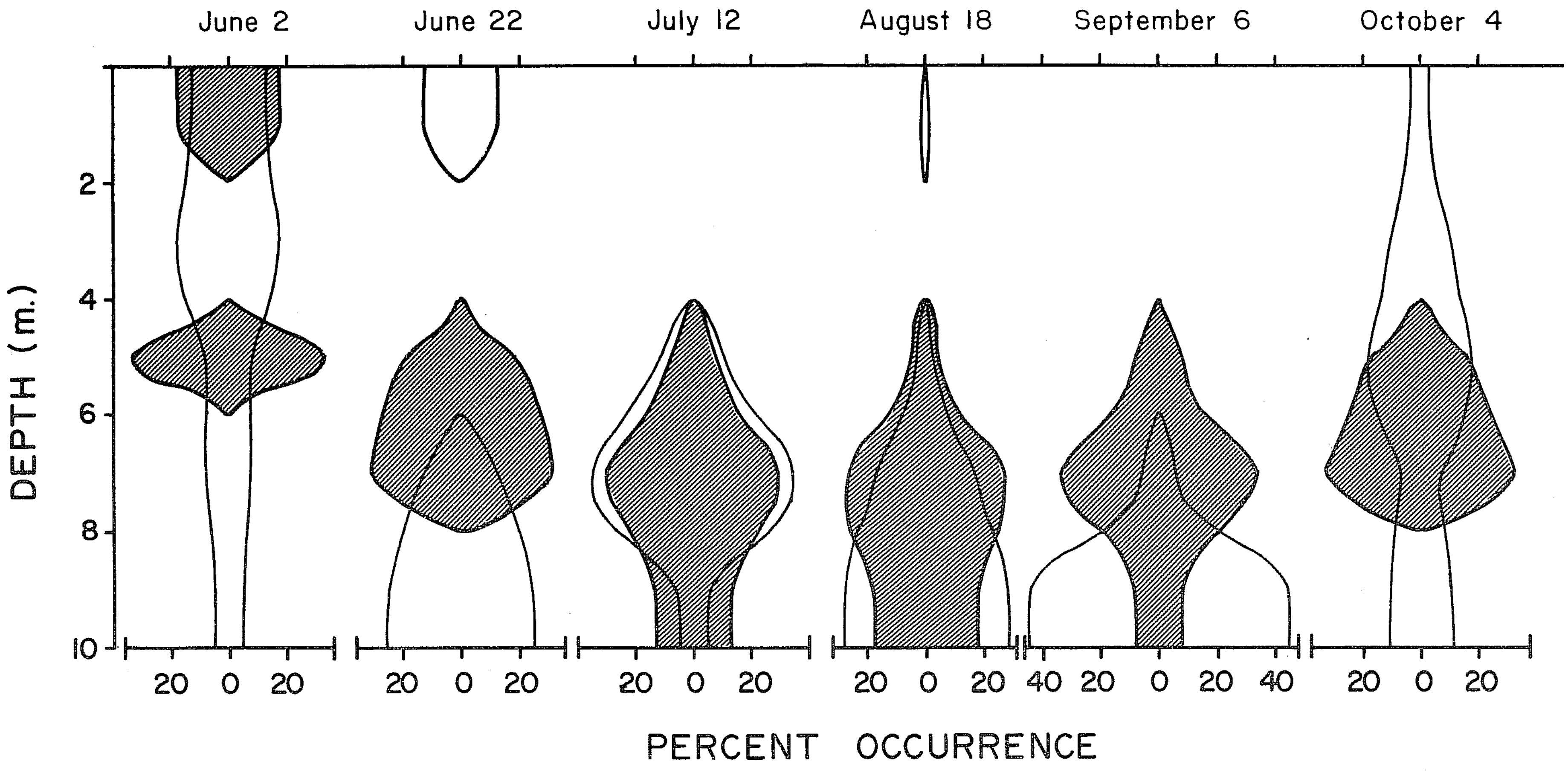

Fig. 2. Percent occurrence of slimy sculpins in the south basin of L302, Experimental Lakes Area, 1983. Shaded areas represent day results and open areas represent night results.

APPENDIX 1

Monthly sculpin counts, oxygen concentrations, water temperatures and light penetration data from Lake 302 (L302), Experimental Lakes Area, northwestern Ontario, 1983

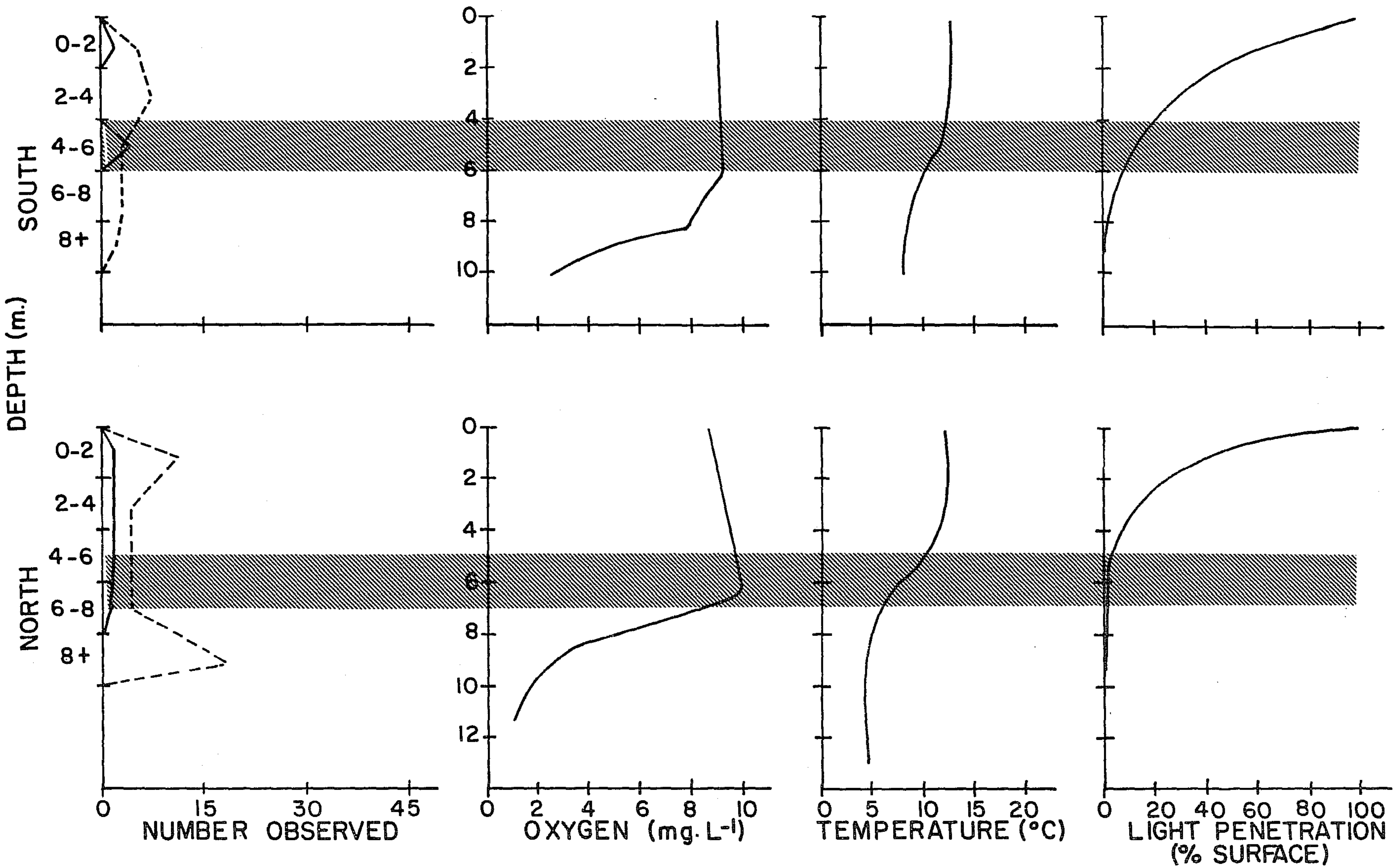

Fig. A1. Association of slimy sculpin abundance, oxygen concentration, water temperature and light penetration in both basins of L302, Experimental Lakes Area, June 2, 1983. Solid lines(——) represent day results and dashed lines(- -) represent night results. The shaded area is the metalimnion.

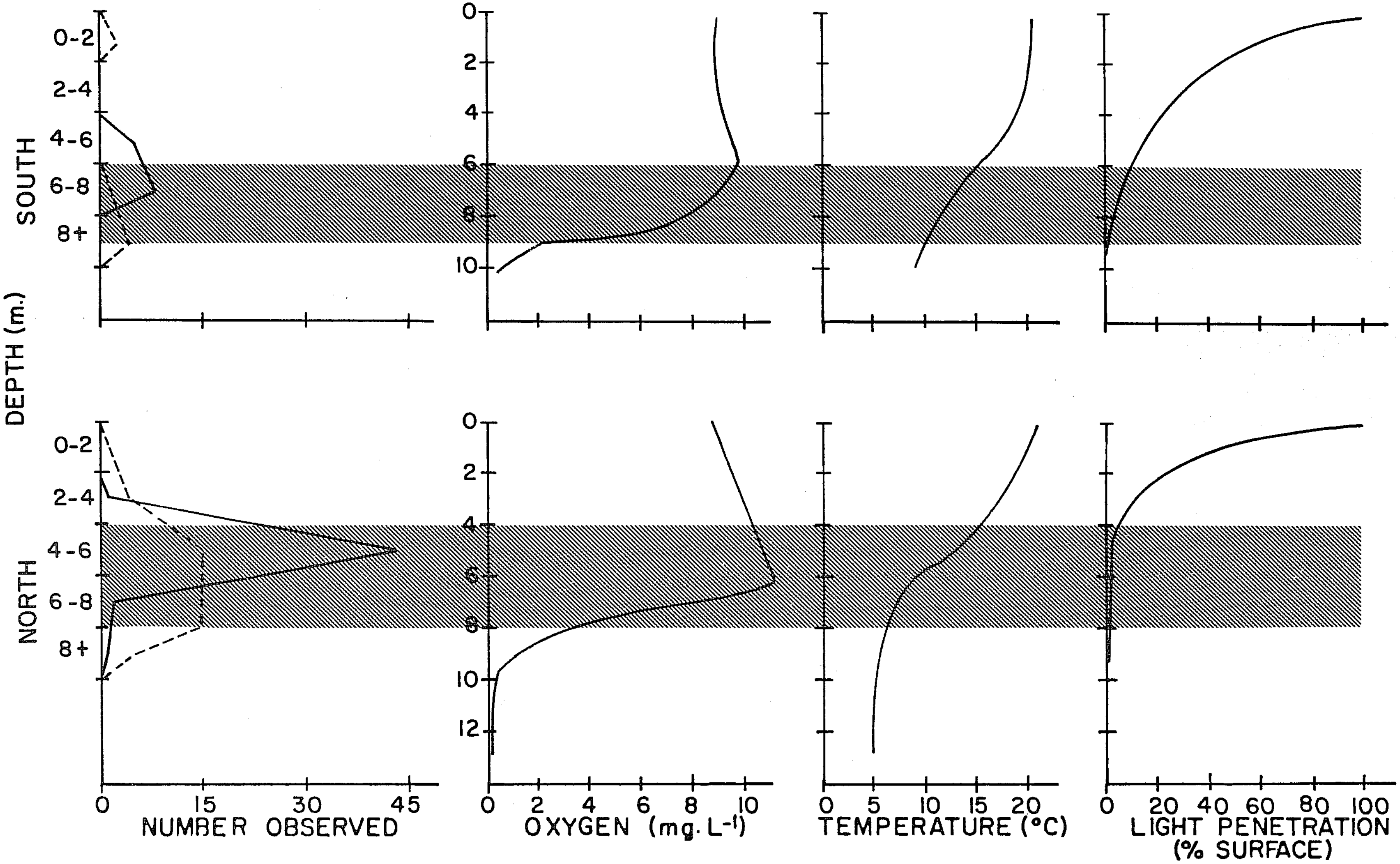

Fig. A2. Association of slimy sculpin abundance, oxygen concentration, water temperature and light penetration in both basins of L302, Experimental Lakes Area, June 22,1983. Solid lines(——) represent day results and dashed lines(- -) represent night results. The shaded area is the metalimnion.

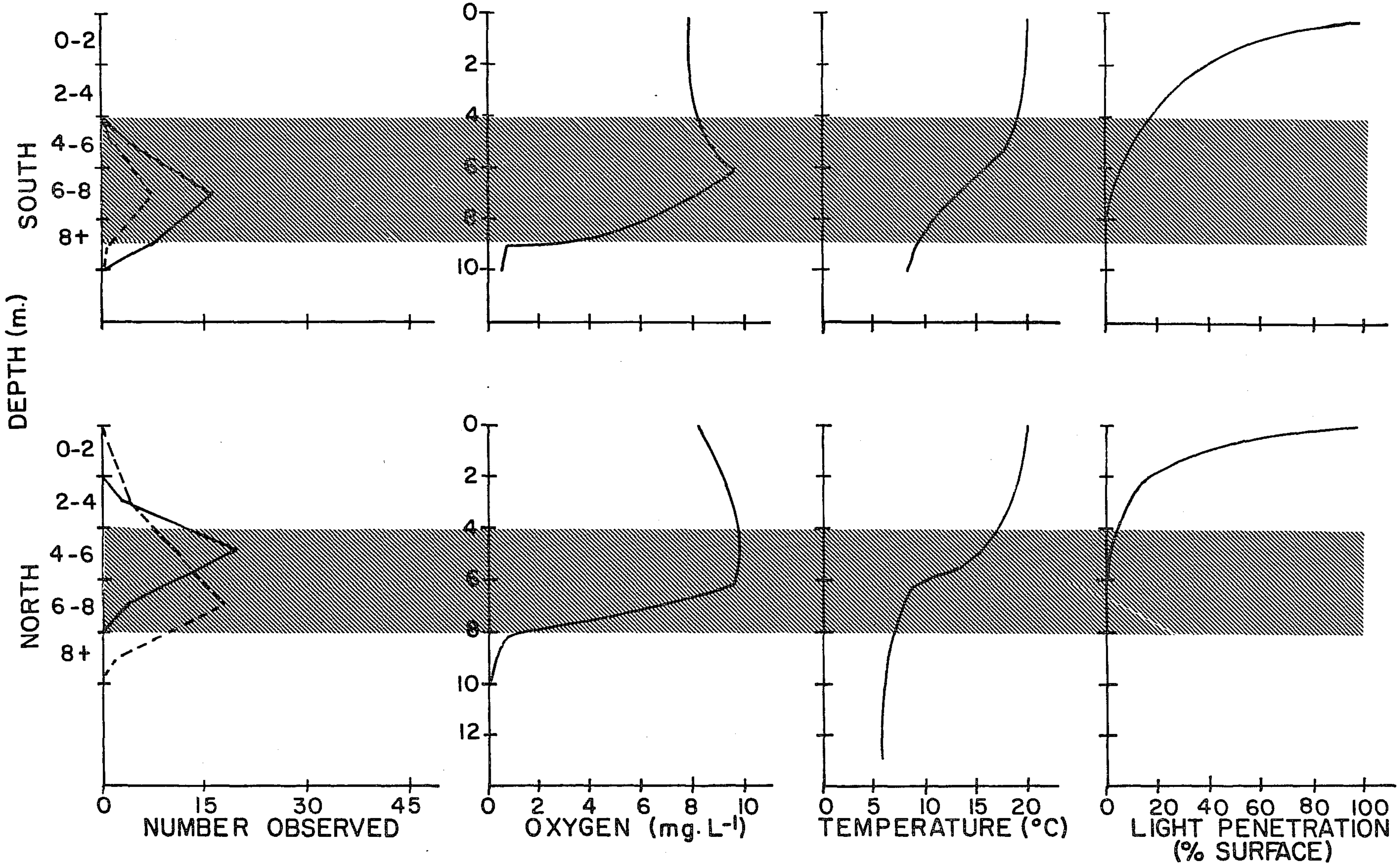

Fig. A3. Association of slimy sculpin abundance, oxygen concentration, water temperature and light penetration in both basins of L302, Experimental Lakes Area, July 12, 1983. Solid lines(——) represent day results and dashed lines(- -) represent night results. The shaded area is the metalimnion.

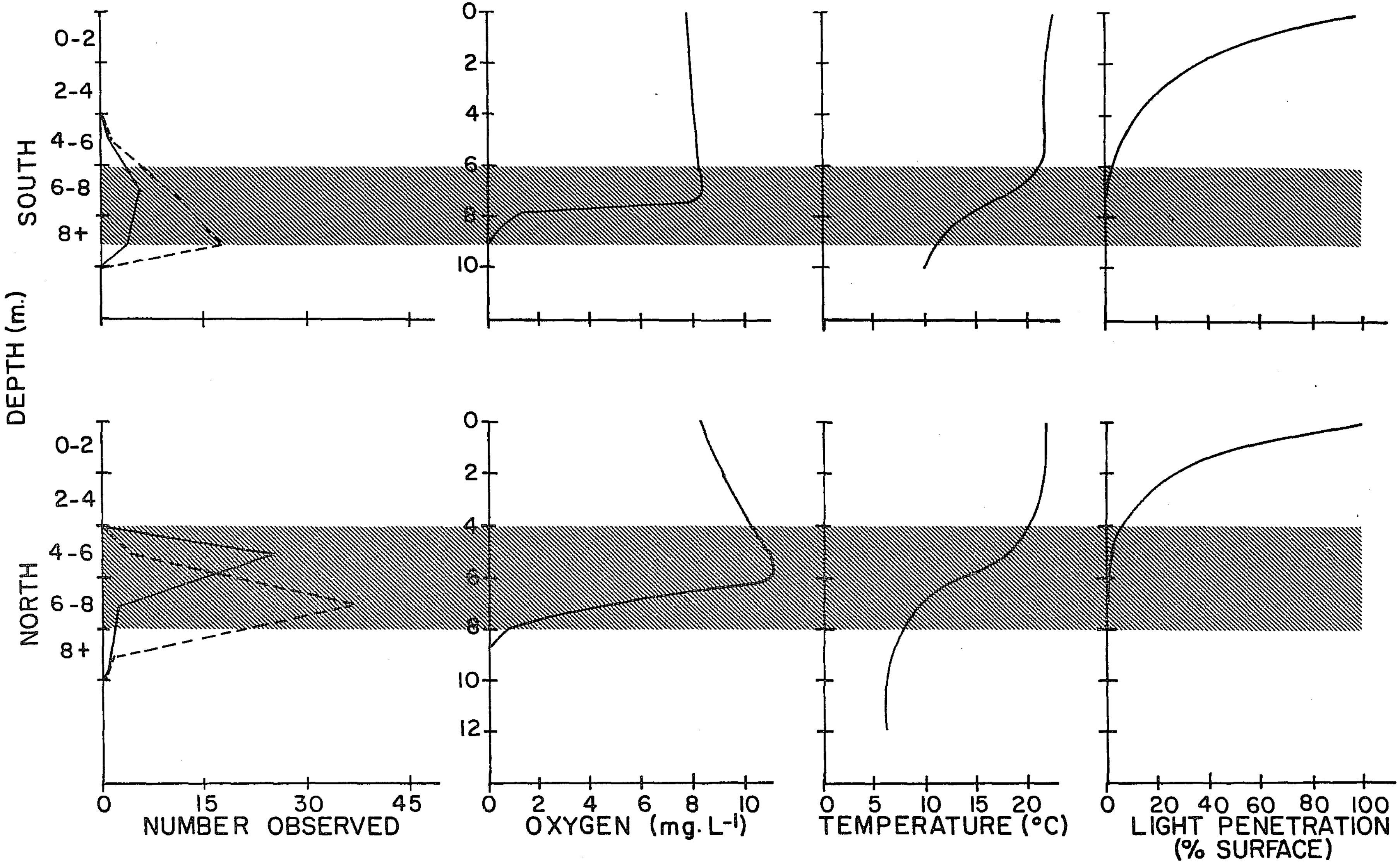

Fig. A4. Association of slimy sculpin abundance, oxygen concentration, water temperature and light penetration in both basins of L302, Experimental Lakes Area, August 18, 1983. Solid lines(——) represent day results and dashed lines(- -) represent night results. The shaded area is the metalimnion.

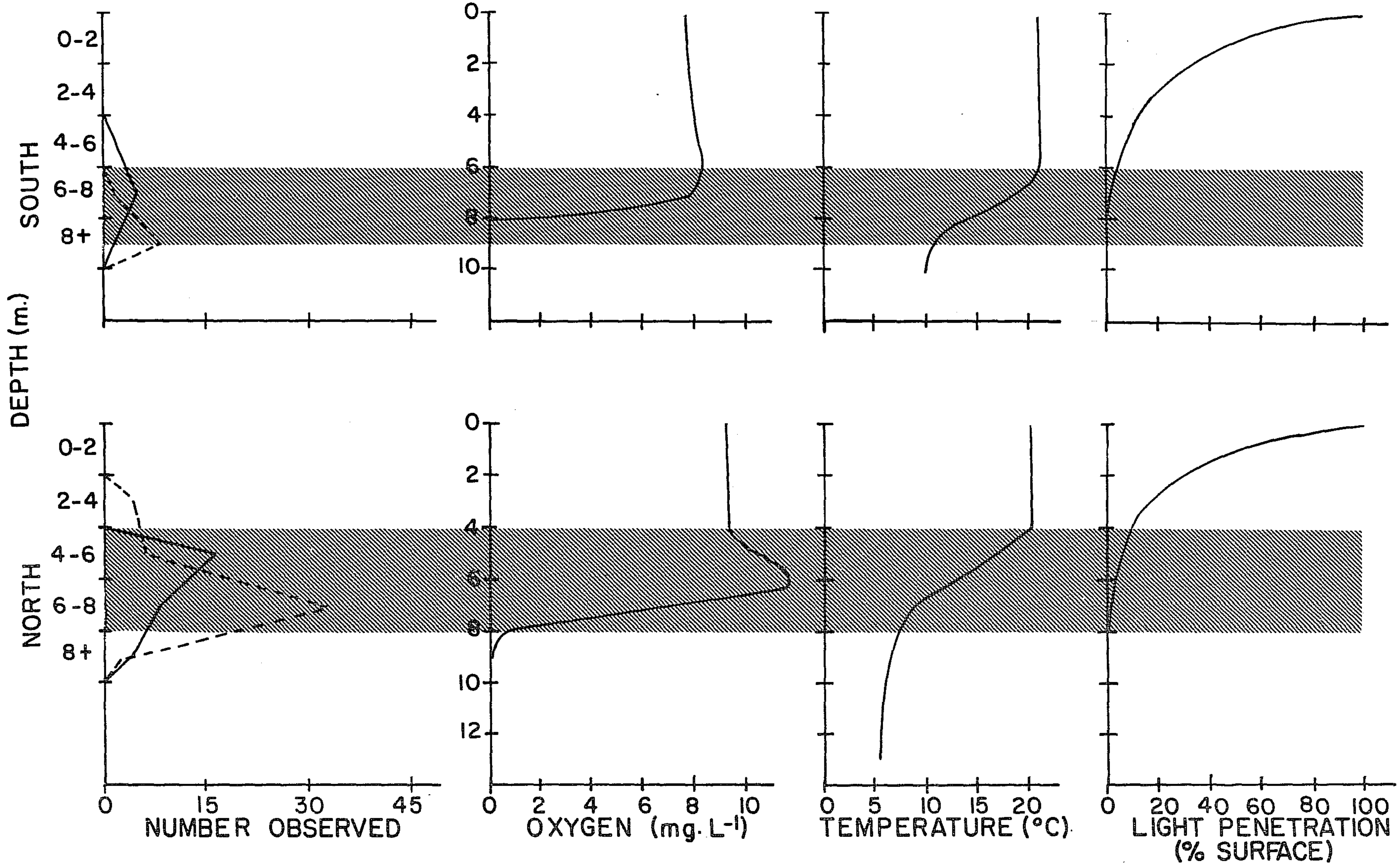

Fig. A5. Association of slimy sculpin abundance, oxygen concentration, water temperature and light penetration in both basins of L302, Experimental Lakes Area, September 6, 1983. Solid lines(——) represent day results and dashed lines(- -) represent night results. The shaded area is the metalimnion.

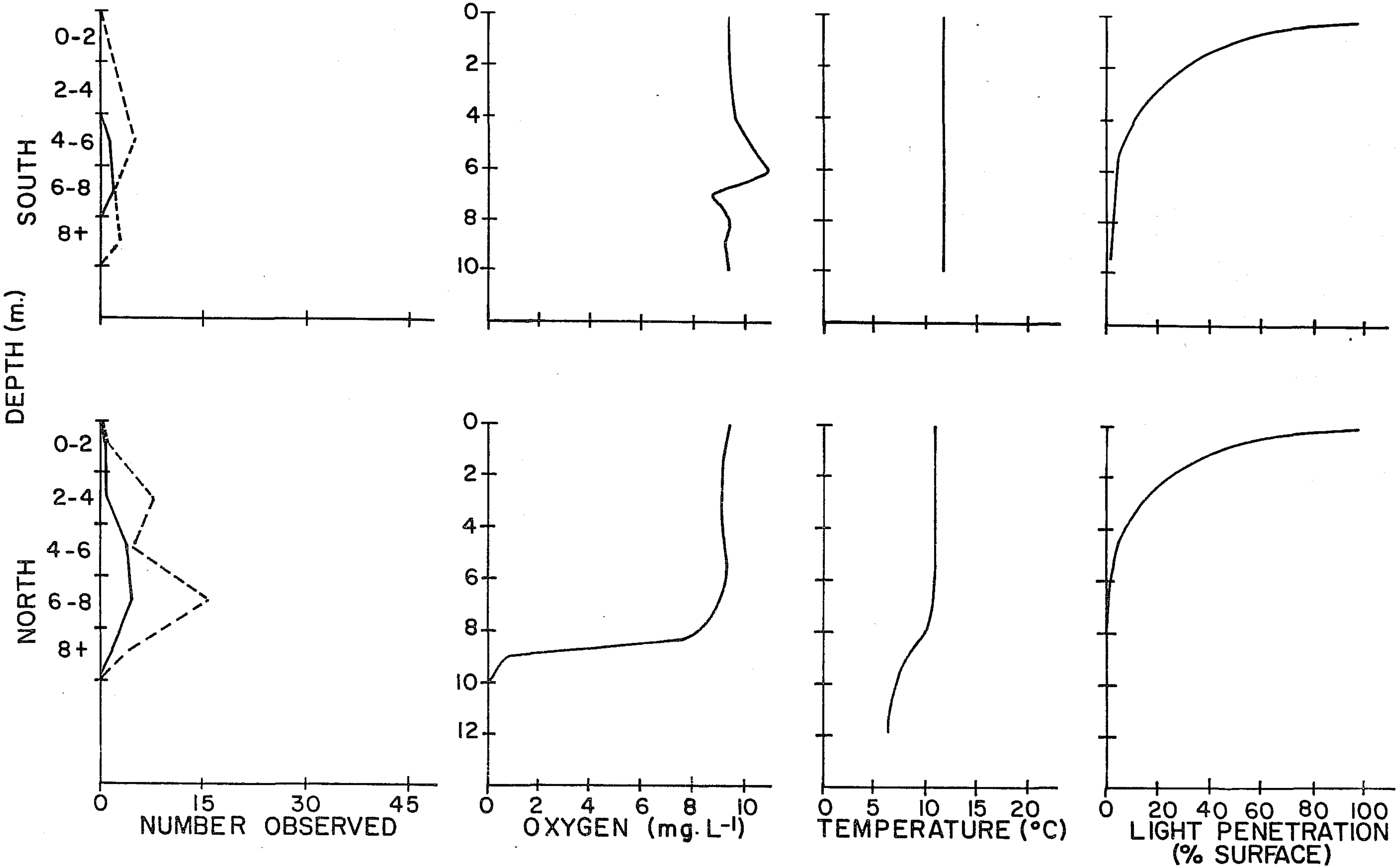

Fig. A6. Association of slimy sculpin abundance, oxygen concentration, water temperature and light penetration in both basins of L302, Experimental Lakes Area, October 4, 1983. Solid lines(——) represent day results and dashed lines(- -) represent night results.