CHAPTER 4

PHYSICAL FEATURES OF LAKES

Water transparency
Water temperature
Heat budgets
Having considered the formation and shape of lakes, the next essential aspect for study is the physical properties of their waters which mainly contribute to their economy. The following parameters were estimated:

**TRANSPARENCY**:

Monthly records of the light penetration were made for all the basins of the Dal, the Anchar and the Manasbal lakes, during the year 1970-71 (Figs. 7, 8 & 9).

1. **The Dal lake**:

   1) **The Nagin basin**: Round-the-year records of light penetration for this basin show the maximum disc visibility upto 4.0 to 5.0 m depth during the winter and the early spring. In the summer (June) the light penetration reduces to 3.50 m, the lowest value of 2.0 m being recorded on August 11. The secchi values increase October onwards (Fig. 7).
Fig. 7  Transparency records of Nagin and Hazratbal basin for the year 1970-71.
Fig. 8  Transparency records for Anchur and Gagribal for the year 1970-71.
Fig. 9 Transparency records for the Manasbal Lake (1970-71).
ii) The Hazratbal basin: Light penetration up to the maximum depth of 1.75 m to 2.0 m is recorded from January to April. In May the secchi disc visibility became limited to 1.25 m depth, while during the months of September - October it was visible only up to a depth of 0.65 m to 0.45 m (Fig.7).

iii) The Gagribal basin: The secchi readings in this basin never fell below 1.0 m. The light penetration to the maximum depth of 2.0 m was recorded for the month of April and to the minimum of 1 m depth for the month of August, though the readings varied from 1.50 - 1.60 m (Fig.8).

2. The Anchar Lake:

Compared to the Dal lake the light penetration in this lake is of a lesser extent. Secchi disc visibility ranges from 0.30 m - 0.60 m of depth. The lowest value of 0.30 m was recorded for July - August. The low values for secchi disc visibility in this lake are partially due to the presence of the suspended silt particles brought in by the feeding channel (Fig.8).

3. The Manasbal Lake:

The light penetration varies a great deal in this lake from month to month. During the spring months of March to May the light penetrates even to the depth of 4.25 m to 5.50 m. From June onwards the light penetration became limited to lesser depths and in October the secchi disc was visible only up to 2.50 m depth while during the remaining months the secchi disc visibility ranged between 2.75 m to 3.10 m depth (Fig.9).
Fig. 10 Isotherm diagram of Nagin basin.
TEMPERATURE:

Temperature has a profound influence on the various biological and chemical effects produced on the water body.

1. The Dal Lake:
   i) The Nagin basin:
      a) Winter and Spring conditions: During the winter (December, January and February) there is no evidence of any thermal stratification. The water is homothermal at 5°C (Fig.10). As the winter conditions in 1970-71 were not very severe the surface water temperature never fell below 4°C, so there was no inverse stratification. The first signs of stratification were observed on March 15, when the surface temperature was 14°C and the temperature at 2 m, 4 m and bottom (6 m) was 13.5, 13.2 and 12°C respectively resulting in an overall difference of 2°C from surface to bottom. With the rise in the air temperature the stratification also became more pronounced. Thus on April 27, the difference between surface and bottom temperature was 4°C, which further increased to 5.5°C on May 26. The temperature profiles do not show any sharp fall as will be evident from the temperature falling only by 1°C with each depth zone of 1 m extent. The bottom temperature, however, never remained constant, after the March stratification. On March 15, the bottom temperature was recorded at 12°C which rose to 17°C on April 27 and shot further upto 20°C on May 20.

      b) Summer temperature gradient: On June 22, a temperature gradient from surface to bottom was observed to occur. The layer stretching from surface to 2 m downwards
registered a temperature of 27.5°C. From this zone downwards the temperature registered a fall of 1°C for every 1 m depth zone till the bottom temperature of 23.5°C was recorded. The maximum surface water temperature on July 27 was recorded at 29°C, two degrees higher than that on June 22. The bottom temperature for July and August was seen to remain constant at 25°C, the highest recorded for this zone. On August 11 the difference between the surface and bottom temperature was only 3°C. In September, with a fall in the atmospheric temperature, the water surface also begins to lose heat. On September 29, the difference between surface and bottom temperature was only 2.5°C. From surface layer to 1 m depth there was a fall of 0.5°C, whereafter the temperature remained constant up to 2 m depth. The temperature again fell by 0.5°C from 3 m downwards and became constant up to 4 m depth zone. From 4 m depth zone a fall of 0.5°C was again registered and the bottom temperature at this time of the year was at 20.5°C. Since the bottom and surface layers register a simultaneous fall in temperature, it seems that the upper stratum affects the temperature of the bottom layer also, a fact that would indicate the non-existence of any kind of a barrier layer preventing small changes in temperature at the surface, influencing the bottom.

c) Autumn cooling: With the advance of the season there is a general fall in the photo- and nycto-temperatures. Due to increased wind action the basin shows a complete mixing and thus on October 21, both the surface and the
bottom temperatures were recorded at 18°C. Despite the appreciable fluctuation in the diurnal temperatures there is no change in the homo-thermy.

ii) The Gagrial basin:

a) Winter and Spring conditions: The basin is quite shallow and richly stocked with macrophytic vegetation throughout. In winter the lowest temperature of 6°C was recorded on January 24, with prevalence of homothermic conditions (Fig. 11). The increase in the atmospheric temperature in February, resulted in a corresponding increase in the water temperature to 9.5°C. With advancing spring in March and April, the quantum of solar radiation reaching the water surface increases and the surface layer of lake becomes warm. Due to shallowness of the basin any gain in temperature at the surface appeared to be passed on immediately to the bottom layer as well, which seemingly accounts for the isothermal condition prevalent throughout the water column. The highest spring temperature recorded throughout the entire water column in April was 19°C.

b) Summer temperature: The observations made during May to August did not indicate any stratification in the basin. On May 31, a difference of 0.5°C was recorded between the temperatures at 1 m and 2 m depth zones but this difference was not at all marked for any of the succeeding monthly observations. So under no circumstances the basins can be said to show thermal stratification or even a tendency towards it. Even on June 30, when the highest temperature of 28°C was recorded for this basin;
there was absolutely no tendency even towards surface heating. The water temperature dropped to 25°C on July 25 rising again to 27.5°C on August 21, indicating thereby the quick effect of sudden changes in the atmospheric temperatures on the entire water mass of the basin.

c) Autumn conditions: As it ought to be, with every fall in the atmospheric temperature there is a corresponding fall in the lake temperatures. A striking feature, however, is that on August 21, the temperature gradient recorded showed a characteristic indication of surface heating. On October 13, the temperature again became uniform from surface to bottom at 20°C. Then with advancing winter the temperature fell down and on December 15, it was recorded at 8°C. During the period of investigation the surface water always remained ice-free during the winter months and no freezing, whatsoever, was observed.

iii) The Hazrathal basin:

The temperature conditions are represented in Fig. 11.

a) Winter and Spring conditions: During the winter months of December to February the basin shows an isothermal condition. On January 21, 1971 the temperature recorded was 5°C, which increased to 9°C throughout the entire basin depth in February. During the year 1970-71 the winter was not severe at all with the result that the surface layer did not freeze and remained ice-free throughout. With an increase in the atmospheric temperature
in early March, quick changes in water temperature were also noted. The record taken on March 15, showed a characteristic thermal stratification, the surface temperature of 16°C falling by 0.5°C up to 1 m depth and by 3.5°C from 1 m to 2 m depth. Obviously the rising atmospheric temperature resulted in the warming up of the surface layer of the basin while the bottom layer continued to remain cold. With the advance of the season the difference between the surface and the bottom temperatures remained constant at 5°C and this condition lasted till April 30. There was, however, a marked difference vis-à-vis the March observations; while on the one hand the temperature fall between surface and 1 m zone increased from 0.5°C (in March) to 3°C (in April), the fall between 1 m to 2 m depth decreased from 3.5°C (in March) to 2°C (in April) on the other. This showed that the surface layer in the basin absorbed heat at a faster rate than even at 1 m depth zone. With the advance of the season the heat absorbed by the surface layers started to be transferred to the bottom layers possibly due to the convection currents, so that on May 26, a marked decrease in the temperature fall through every depth zone was observed. Thus a temperature fall of only 0.5°C from surface to 1 m zone and 1.5°C in 1 to 2 m depth zone was noticed.

b) Summer conditions: During the summer the highest surface temperature was recorded on July 27. The temperature fell by 1°C each from surface to 1 m and from 1 m to 2 m depth zones. In June and August, the temperature from surface
Fig. 11 Temperature records of Hazratbal, Gagribal and the Anchar.
to 1 m depth was the same while the temperature in 1-2 m depth zone was lower by 1°C. In September, with a slight fall in atmospheric temperatures, the surface water temperature on September 25, was recorded at 23.5°C and the bottom temperature at 23°C, with a difference of only 0.5°C between the two.

c) Autumn conditions: The type of thermal stratification developed in the summer without any distinction into epi-meta and hypolimnion cannot be designated as of the true type. The record for 25th of September shows a difference of only 0.5°C between the surface and the bottom temperatures, which, however, register a simultaneous fall with the advance of the season. In October, the day temperatures are much higher than the night which results in the surface layer of the basin getting warmed up while the lower layers remain unaffected. This is well illustrated by the record taken on October 21, when the surface water temperature was 19°C and the temperature at 2 m depth zone was lower by 2°C. With the further fall in the photo- and nycto-temperatures the water surface loses more and more of heat and the temperature is further lowered. This causes the loss of heat from the entire basin and the lake is isothermal in the month of November.

2. The Anchar lake:

This is a single basined lake unlike the Dal lake, which is multiple basined. The thermal conditions prevailing during different parts of the year in this lake are depicted
During the winter months the lake depicts isothermal conditions. On January 24, 1971 the temperature from surface to bottom was 5°C which rose to 8°C in late February. The winter temperature during 1970-71 never dropped below 5°C so that surface water remained ice-free. With the increase in the atmospheric temperature, the lake water temperature correspondingly varied because of its shallow basin. Accordingly the record taken on March 21 registered a difference of 3°C between the surface and bottom temperatures. The surface temperature was 16°C while the temperature at 1 m depth was only 13°C, a fact pointing to the quick warming up of the surface layer. On April 21, there was only a difference of 1°C between the surface and the bottom water as the prevailing winds at this time of the year helped in the mixing up of waters and the consequent reduction of the differential gradient. This small temperature gradient did not last long, because the cold water brought in by the River Sind into the lake, rendered the lower layers of the lake much colder. With the increase in the atmospheric temperature the surface layers started warming up; thus on May 20, the surface water was at a temperature of 21°C while the bottom water stood at a temperature of 17°C, showing a difference of 4°C. The noteworthy feature, however, is that there was no difference between the temperatures recorded from 1 m to bottom depth zone, despite an abrupt fall of 4°C from surface to 1 m depth. The lake basin
evidently does not show a true thermal stratification at all as there is no distinct epilimnion, and the hypolimnion,

b) **Summer conditions**: The temperature records for June - September do not show any regular pattern except that the water temperature is greatly influenced by the changes in the atmospheric temperature. The temperature difference between surface and bottom on June 20, was 7°C with 4°C difference between surface to 1 m layer and another 3°C from 1 m downwards to bottom. On July 24, there was only 2°C temperature fall from surface to 1 m depth and 2.5°C from 1 m downwards. With the advance of the season in August the surface water after getting warmed up considerably, transmits some heat to the bottom layer. Thus on August 22, the temperature fall from surface to 1 m depth was 2°C while from 1 m depth to bottom there was no fall at all. The abrupt fall in the temperature of the lower layers of the lake is closely correlated with the effluents coming from the River Sind which periodically bring in cold water into the lake imparting it an irregular pattern of thermal structure and thus preventing it from getting stabilized in its natural course.

c) **Autumn conditions**: During the autumn months of September, October and November, the temperatures in general fall low but temperature difference is maintained even upto late October. The temperature fall of 2°C was maintained constantly from surface to 1 m depth zone in
September while it got reduced to 1.5°C on October 17. The temperature from 1 m depth down to bottom remained constant throughout the months of August, September and October though evincing some monthly variations. The basin returns to an isothermal condition somewhere in late November when the atmospheric temperatures have fallen considerably. So the surface to bottom temperature recorded on November 30, was 8°C.

3. The Manasbal lake:

The temperature records are represented in diagram, fig. 12.

a) Winter and Spring conditions; The records taken in the winter of 1970-71 showed the lake to be isothermal. On December 30, 1970 the lake was isothermal at 6.5°C, though there was a difference of 0.5°C from surface to 1 m depth zone due to surface heating caused by the sunny day. With advancing winter the conditions did not, however, become any severe, as the temperature on January 31, was 5.5°C. The lake never froze, so there was no tendency of any inverse type of stratification, which could normally be expected under the usual climatic conditions of Kashmir at this period. In Spring when the atmosphere began to get warm the conditions in the lake also began to change accordingly. A slight indication of temperature gradient in the lake was evinced even in the late February; the record on February 27, showing a
difference of 2.5°C between the surface and the bottom water, and a fall of 1.5°C between surface and 3 m depth zone. This temperature gradient became more pronounced in the next month. The surface temperature on March 14, was 15°C which fell by 1.5°C at 1 m depth and by further 1 and 1.5°C between 1 m to 3 m and 3 m to 4 m depth zones respectively. There was further fall upto 5 m depth whereafter the fall of 1°C and 0.5°C occurred between 5 - 6 m and 6 - 7 m respectively. From 7 m depth zone till the bottom, the temperature remained constant at 8.5°C. So the difference between the surface and the bottom temperatures was registered at 7.5°C. This record would definitely point to the beginning of the establishment of the hypolimnion and the simultaneous formation of a thermocline. As there was a regular and steady fall in the temperature from surface to 7 m zone, no depth could at this stage be pin-pointed as the start of the thermocline. The difference of 7.5°C between the surface and bottom temperatures increased to 9.5°C in April. On April 16, the upper end of hypolimnic region became notably lowered from 7 m to 8 m depth with a temperature record of 9.5°C and 8.5°C at 8 m and 9-12m depth zone respectively. While there was a fall of 2°C from 1 m to 2 m zone and again from 6 m to 7 m zone; the fall between 3 m to 6 m and 7 to 8 m zones was of the magnitude of 1° and 1.5°C respectively. The surface to 1 m depth zone
Fig. 12 Isotherm diagram of Manasbal lake.
registered a temperature of 18°C showing an establishment of epilimnion. The thermocline was still in the process of getting established.

b) **Summer conditions**: In the summer extending from May to August, the atmospheric temperature increased and this had a direct bearing on the thermal structure of the lake. The record of May 16, showed the start of the thermocline getting stabilized at 5 m depth zone, with a fall of 3°C and 3.5°C between 5-6 m and 6-7 m depth zones respectively, indicating the upper limit of the thermocline at 5 m and lower limit at 8 m zone. The temperature at 8 m and 9 m remained at 11°C, then a fall of 1°C was registered between 9 to 10 m and again a difference of 0.5°C between 10 to 12 m. The bottom temperature had increased by 1°C from that of previous months, it however, remained constant at 8.5°C from March to April but rose to 9.5°C in May. The region between surface to 5 m can be designated as epilimnion because the temperature was almost constant except for a fall of 1°C between surface to 1 m zone, probably due to surface heating. With the increase in the atmospheric temperature in the subsequent months there was a definite change in the epilimnion, thermocline and hypolimnion temperatures. The record of June 26, showed the epilimnion extending down to 5 m wherefrom began the upper limit of thermocline. There was a fall of less than 2°C between 5-6 m but temperature drops of 3.5°C, 4.5°C
and 2.5°C were registered between 6 to 7 m, 7 to 8 m and 8 to 9 m respectively. The temperature at 9m depth zone was 0.5°C less than that recorded on May 16, but the temperature at 11m and 12 m depths remained the same. The hypolimnetic region had been lowered by 1m in June when it was 3 m thick against a thickness of 4 m in May. On July 21, the situation remained almost the same except for some minor variations. The epilimnion continued to extend down to 5 m with only 0.5°C temperature difference from the June reading. From 5 to 9 m there was a fall in temperature, the variation ranged between 2°C, 3°C, 5°C and 3.5°C in 5-6m, 6-7m, 7-8m and 8-9m depth zones respectively. The hypolimnion temperature increased to 11°C at 9 and 10 m depths and to 10°C at 11 and 12 m depths, so the overall temperatures in the hypolimnetic zone (9 to 12m) increased from those obtained in the month of June. The difference between the surface and the bottom water temperatures was 17.5°C in July against 18°C in the preceding month. On August, 31 the temperature in 11 - 12 m depth zone increased from 10°C to 11°C. The temperature at 9 and 10 m depth similarly increased by 2°C and 1°C respectively. The epilimnion extension upto 5 m depth was constant with surface temperature higher by 0.5°C on account of surface heating. The fall of temperature between 5 - 6 m, 6 - 7m, 7 - 8m & 8 - 9m depth zones was calculated at 2°C, 1.5°C, 4°C and 4.5°C respectively. The summer temperature gradient indicated
the thickness of the epilimnion, thermocline and the hypolimnion to be 5m, 4m and 3m respectively.

c) Autumn cooling: The observations pertain to three autumn months of September, October and November. The first reading was taken on September 30, when the epilimnion had extended by 2 m (surface to 7m depth) and the upper limit of thermocline started from 7m. The fall in temperature between 7 - 8m, 8 - 9m and 9 - 10m was recorded at 1.5°C, 5°C and 2°C respectively. The hypolimnion remained confined to 10-12 m depth only. So the two noteworthy features of this season were that i) the epilimnion had started extending downwards, while the hypolimnion started reducing in thickness. The record of October 29 confirms this phenomenon further, when the epilimnion was found right from surface to 9m depth zone, and from this depth the thermocline began with two falls in temperature, first of 3°C between 9-10m and the second of 2°C between 10-11 m depth zone. So the hypolimnion got reduced further in size. ii) the long stagnation period started to break. With the further fall in atmospheric temperature, it was expected that the lake would circulate in early November, but the record of November 17, showed the contrary results. On this day 1°C difference was recorded between surface to 1 m depth and from this depth (1m) right upto 9m the temperature remained constant. While there was no change in temperature between 11 - 12m zone, a fall of 1°C and 1.5°C was,
however, registered between 9-10m and 10-11m depth zones, respectively. Only when the epilimnion temperature fell as low as the hypolimnion, did the lake begin to circulate. Thus the lake circulated at 11°C on November 29, 1970.

The thermal structure of the lake clearly reflects the impact that the depth of the basin has on it. The lake shows a positive demarcation between the epilimnion and hypolimnion with a central metalimnion (thermocline) region during summer and remains thermally stratified for about 9 months in the year. The isothermy prevails for the remaining three months except in severe to very severe winters when the phenomenon of inverse stratification may be exhibited. During the course of the present investigations due to the mildness of the winters, not even single record of inverse stratification was, however, taken.

**HEAT BUDGETS:**

1. **The Dal lake**

   1) **The Nagin basin**

   The monthly changes in the annual heat storage are set in table III. The maximum heat storage is found in the month of July, estimated at 1554 g. calories on July 1, and 1556 g. calories on July 27. The minimum heat storage of 249 g. calories occurs in January. A close relationship exists between the external atmospheric temperature and the corresponding heat storage. The minimum heat storage in winter increased to 501 g. calories in February and by June 22, it touched the value of
Table 3
HEAT STORAGE IN THE NACIN BASIN

<table>
<thead>
<tr>
<th>Layer</th>
<th>Volume ( m^3 \times 10^6 )</th>
<th>Reduced depth (m)</th>
<th>Heat budgets g. cal/cm², 1970-71</th>
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<tbody>
<tr>
<td>0-3m</td>
<td>1.09</td>
<td>1.22</td>
<td>1532</td>
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<tr>
<td>3-6m</td>
<td>.133</td>
<td>0.15</td>
<td>17</td>
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<tr>
<td>Total</td>
<td>1.22</td>
<td>1.37</td>
<td>1554</td>
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<tr>
<td>Annual heat budgets in g. cal/cm²</td>
<td>98.91</td>
<td>98.8</td>
<td>98.8</td>
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<td>% heat storage above 3m</td>
<td>1.09</td>
<td>1.2</td>
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Changes in heat storage in the Nacin basin in g. cal/cm²/day. Loss of heat shown in brackets

<table>
<thead>
<tr>
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<td>(-2.7)</td>
<td>(-14.6)</td>
<td>(-11)</td>
<td>(-8.8)</td>
<td>5.9</td>
<td>13.7</td>
<td>7.8</td>
<td>8.4</td>
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<td>(-14)</td>
<td>(-.10)</td>
<td>.07</td>
<td>0.15</td>
<td>.09</td>
<td>.06</td>
<td>.11</td>
</tr>
<tr>
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<td>(-6.75)</td>
<td>(-2.7)</td>
<td>(-14.76)</td>
<td>(-11.14)</td>
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<td>13.85</td>
<td>7.89</td>
<td>8.46</td>
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22 June  | 27 July | 17 Aug. | 29 Sept. | 21 Oct. |
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<td>1.5</td>
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<td>(-3.6)</td>
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(-) Indicating loss of heat.
1501 g. calories. The heat budget remained almost constant for June, July and August, while from August to September there was an abrupt loss of heat, the value for September 29, being 1195 g. calories. From September to October the fall was gradual. The loss of heat from October to November was again abrupt; the value for November being only 890 g. calories and for both December and February still lower at 501 g. calories. It is rather interesting to note the major portion of heat income being stored in the 0-3 m depth zone as against the very little heat storage in the 3-6 m depth zone. The heat storage in the 0-3 m depth zone varied between 245 to 1537 g. calories while in 3-6 m depth zone the variation was in the range of 4-19 g. calories (Table III). This variation would point to the importance of the 0-3 m depth zone in the heat economy of this basin. On comparing the two depth zones on the percentage basis, it is seen that the percentage values vary between 98.4 - 98.9 in the upper zone and between 1.09 - 1.6 in the lower zone. The noteworthy point is that while month to month variation in heat storage in the upper stratum is high, it is low on percentage basis. Even under isothermal conditions the appreciable difference in the heat budget of the two depth zones is maintained. This is due to the small percentage of the total volume that the lower portion of the lake is comprised of.

The diurnal heat gain and heat loss shows an equally interesting pattern. The loss of heat from July 1
to August 29, was only 0.98 g. calories/day which increased to 6.75 g. calories/day from August 29 to September 17, and then fell to 2.7 g. calories/day between September 17 to October 1 and shot up once again to 14.76 g. calories/day between October 1 to November 1. The loss of heat continued up to January. From January onwards there was a rise in heat gain right up to July. Initially, i.e., from January 2 to February 25, the heat gain was only 5.97 g. calories/day which abruptly rose to 13.85 g. calories/day between February 25 to March 15. The heat gain was 7.29 and 8.46 g. calories/day between March - April and April - May respectively and then fell to 5.41 g. calories/day from May 26 to June 22. Between June 22 to July 27 the gain in the heat income was as low as 1.5 g. calories/day. From July onwards the heat was lost, at 3.6 g. calories/day from July 27 to August 11 and at 8.79 g. calories/day between September 29 to October 21. Comparing the daily heat loss and heat gain for different zones, there was a loss of 1 g. calorie/day in the 0-3m depth zone from July 1 to August 29 against a gain of 0.02 g. calories/day in the 3.6 m depth zone. Then again from June 22 to July 27 when there was a gain of 1.5 g calories/day in the 0-3m depth zone, the lower stratum showed no change whatsoever. The lower stratum remained unchanged even between July 27 to August 11, when the upper stratum showed a heat loss at 3.69 calories/day.
ii) The Hazratbal basin

The monthly heat budget (Table IV) shows an increase from January to July and a decrease thereafter. The minimum value of 384 g. calories was obtained on January 21 and the maximum of 2173 g. calories on July 27. The values for July and August remain close to one another but a sharp decline is recorded for the month of September and October. The difference in the heat budget of July - September in 1970 and 1971 is due to the different dates of sampling.

The daily calculation of heat budget shows a gain of 14.1 g. calories/day from January 21 to March 15, which abruptly drops to only 6.8 g. calories/day from March 15 to April 30 and increases again to 15.1 g. calories/day from April 30 to May 26. The daily heat gain dropped to 5.5 g. calories/day from May 26 to June 24 but increased again to 10.29 g. calories/day from June 24 to July 27. From July onwards the heat is lost, the initial loss of 1.3 g. calories being recorded between July 27 to August 25, which then increased to 12.2 and 15.5 g. calories in the months of August to September and September to October respectively. The noteworthy point, however, is that the heat gain is maximum from April 30 to May 26 against a maximum of heat loss from September 25 to October 21.
# Heat Storage in the Hazratbal Basin

## Annual Heat Budgets (g. calories/cm²) 1970 - 71

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<thead>
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<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
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<th>Jul</th>
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<td>2106</td>
<td>1875</td>
<td>1230</td>
<td>384</td>
<td>991</td>
<td>1239</td>
<td>1692</td>
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<td>2173</td>
<td>2135</td>
<td>1769</td>
<td>1365</td>
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## Changes in Heat Storage in the Hazratbal Basin in g. calories/cm²/day

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<tr>
<th>Jul 3</th>
<th>Sep 15</th>
<th>Nov 1</th>
<th>Jan 21</th>
<th>Mar 15</th>
<th>Apr 30</th>
<th>May 26</th>
<th>Jun 24</th>
<th>Jul 27</th>
<th>Aug 25</th>
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<th>Oct 21</th>
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</thead>
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<tr>
<td>(-3.2)</td>
<td>(-14.3)</td>
<td>(-16.2)</td>
<td>14.1</td>
<td>6.8</td>
<td>15.1</td>
<td>5.5</td>
<td>10.2</td>
<td>(-1.3)</td>
<td>(-12.2)</td>
<td>(-15.5)</td>
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</tr>
</tbody>
</table>

( - ) Indicating loss of heat.
iii) The Gagribal basin:

The monthly heat income of the basin is set in table V. The lowest heat budget of 428 g. calories was obtained on January 24 and the highest of 1956 g. calories on June 30. The heat budget interestingly declined on July 25 to a value of 1782 g. calories and then increased again to 1906 g. calories on August 21. From August onwards the heat budget registered a gradual fall. Comparing the values obtained in July, 1970 and 1971, the heat budget on July 16, 1970 worked out to 2083 g. calories (the highest record for this basin) against 1782 g. calories on July 25. The maximum value in 1971 was recorded in June while the maximum in 1970 was touched in July. The initial fall in the heat budget in July, 1971 was followed again by an increase in August.

The daily heat income during the entire year shows the maximum daily gain of 13.7 g. calories for the period extending from January 24 to March 18. The daily heat gain from March 18 - April 20 was at the rate of 6.6 g. calories against 11.9 g. calories from April 20 - May 31. The minimum daily heat gain of 4.7 g. calories was recorded for May 31 to June 30. From June onwards the basin started losing heat, starting initially at a daily heat loss of 8.5 g. calories between June 30 to July 25, and increasing to a maximum of 12.6 g. calories between September 24 to October 13. The heat gain of 6.8 g. calories recorded for July 25 to August 21 is rather anomalous, apparently.
**Table V**

Heat storage in the Gagribal basin

Annual heat budgets g. calories/Cm² 1970 - 71

<table>
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<tbody>
<tr>
<td></td>
<td>2083</td>
<td>1728</td>
<td>428</td>
<td>1141</td>
<td>1354</td>
<td>1853</td>
<td>1996</td>
<td>1782</td>
<td>1960</td>
<td>1692</td>
<td>1440</td>
</tr>
</tbody>
</table>

Changes in heat storage in the Gagribal basin in g. calories/Cm²/day

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<tbody>
<tr>
<td></td>
<td>(-5.3)</td>
<td>(-10.8)</td>
<td>13.7</td>
<td>6.6</td>
<td>11.9</td>
<td>4.7</td>
<td>(-8.5)</td>
<td>6.8</td>
<td>(-8.1)</td>
<td>(-12.6)</td>
</tr>
</tbody>
</table>

( - ) Indicating loss of heat
Comparison of the three basins:

Comparing the heat budgets of the three basins of the Dal lake, the Hazratbal basin shows the maximum monthly heat income of 2173 g. calories, the Gagribal next with 2083 g. calories and the Nagin the lowest of 1556 g. calories. The minimum monthly heat income follows almost the same sequence except that Hazratbal comes after Gagribal. Further, the heat loss during August - September varies considerably in the three basins. It ranges from 3.6 to 8.79 g. calories/day for the Nagin basin followed by 8.1 to 12.6 g. calories/day for the Gagribal basin and the maximum of 1.3 to 15.5 g. calories/day for the Hazratbal basin. Furthermore, the maximum heat income of 13.85 g. calories/day is recorded between February 25 to March 15 in the Nagin basin while the maximum of 15.1 g. calories and 13.7 g. calories in case of the Hazratbal basin and the Gagribal basin is recorded between April 30 - May 26 and January 24 - March 18 respectively. The daily changes in the heat income in different months with respect to heat loss or heat gain almost follows the same pattern in all the three basins, though the values for the Hazratbal and the Gagribal basins are always comparatively higher than those of the Nagin basin.

2. The Anchar lake:

The heat budget of the lake is given in table VI. The month to month quantum of heat storage, seemingly, shows a great variation. The lowest heat
### TABLE VI

Heat storage in the Anchar lake

**Annual heat budget; g. calories/\(\text{cm}^2\) 1970 - 71**

<table>
<thead>
<tr>
<th></th>
<th>Nov</th>
<th>Jan</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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</thead>
<tbody>
<tr>
<td>Total</td>
<td>480</td>
<td>300</td>
<td>873</td>
<td>1006</td>
<td>1112</td>
<td>1235</td>
<td>1408</td>
<td>1366</td>
<td>1126</td>
<td>903</td>
</tr>
</tbody>
</table>

**Changes in Heat Storage in the Anchar lake g. calories/\(\text{cm}^2\)/day**

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<tbody>
<tr>
<td>Change</td>
<td>(-3.2)</td>
<td>10.2</td>
<td>4.4</td>
<td>3.5</td>
<td>4.1</td>
<td>5.08</td>
<td>(-1.4)</td>
<td>(-8.0)</td>
<td>(-9.3)</td>
</tr>
</tbody>
</table>

(- ) Indicating loss of heat
A budget of 300 g. calories recorded for January 24 was followed by a progressive increase till the maximum of 1408 g. calories was touched on July 24. From July onwards the heat budget showed a gradual decline till on October 17, it touched the mark of 903 g. calories.

The diurnal changes in the heat storage of the basin show the heat loss of 3.29 g. calories during winter (November - January). Between January 24 to March 21, the heat is gained at 10.2 g. calories/day. The lowest heat gain (3.5 g calories) is recorded between April 21 - May 20. From July onwards the heat is lost, initially at 1.4 g. calories between July 24 - August 22. The highest loss of heat was recorded at 9.3 g. calories for the period from September 24 - October 17.

3. The Manasbal lake:

The monthly changes in the heat storage of this lake are shown in table VII. The quantum of heat storage appears to change with changing temperatures of different months. The maximum heat budget of 3679 g. calories was recorded for July 21 and the minimum of 929 g. calories for January 31. The heat budget goes on increasing from January onwards right up to July. From June to August the heat budget does not show much of variation and ranged between 3616 to 3679 g. calories. From July 21 to August 31 the heat loss amounted to 16 g. calories. But the major decrease in heat content takes place from August onwards. In the first instance 452 g. calories were lost from August 31 - September 30 while from September 30 -
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<tbody>
<tr>
<td>0-6m</td>
<td>5.18</td>
<td>1.05</td>
<td>2874</td>
<td>2772</td>
<td>2646</td>
<td>1386</td>
<td>756</td>
<td>693</td>
<td>1512</td>
<td>1953</td>
<td>2394</td>
<td>3112</td>
<td>3150</td>
<td>3087</td>
<td>2646</td>
<td>2225</td>
<td>1764</td>
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<tr>
<td>6-12m</td>
<td>2.96</td>
<td>1.15</td>
<td>504</td>
<td>540</td>
<td>540</td>
<td>426</td>
<td>216</td>
<td>236</td>
<td>306</td>
<td>306</td>
<td>414</td>
<td>514</td>
<td>529</td>
<td>576</td>
<td>565</td>
<td>486</td>
<td>432</td>
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<td></td>
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<tr>
<td>Total</td>
<td>8.14</td>
<td>3.20</td>
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Annual heat budgets in g. cal/Cm$^2$

% heat storage above 6m: 85, 83.7, 83, 76.5, 76.4, 74.6, 83.2, 86.5, 85.3, 86.0, 85.7, 84.3, 82.5, 82.2, 80.4

% heat storage below 6m: 15, 16.3, 17, 23.5, 23.1, 25.4, 16.8, 13.5, 14.7, 14.7, 15.7, 15.2, 17.5, 17.8, 19.6

Changes in heat storage in the Manusbal lake in g. cal/Cm$^2$/day

Loss of heat shown in brackets

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</thead>
<tbody>
<tr>
<td>0-6m</td>
<td>(-3)</td>
<td>(-3.9)</td>
<td>(-25.2)</td>
<td>(-20.3)</td>
<td>(-2.1)</td>
<td>19.04</td>
<td>13.8</td>
<td>14.7</td>
<td>17.9</td>
<td>1.5</td>
<td>(-1.5)</td>
<td>(-14.7)</td>
<td>(-14.7)</td>
<td>(-14.7)</td>
<td></td>
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<tr>
<td>6-12m</td>
<td>1.02</td>
<td>Zero</td>
<td>(-2.3)</td>
<td>(-6.8)</td>
<td>0.66</td>
<td>1.6</td>
<td>Zero</td>
<td>3.6</td>
<td>2.2</td>
<td>1.0</td>
<td>1.1</td>
<td>(-0.36)</td>
<td>(-2.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-1.98</td>
<td>-3.9</td>
<td>-27.5</td>
<td>-27.1</td>
<td>-1.5</td>
<td>20.1</td>
<td>13.8</td>
<td>18.3</td>
<td>20.1</td>
<td>2.5</td>
<td>-0.4</td>
<td>-15.06</td>
<td>-16.63</td>
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</table>

(-) Indicating loss of heat
October 29 nearly 500 g. calories were lost. The maximum heat loss of 1374 g. calories was, however, recorded between October 10 to November 29. During the period of isothermy the heat budget is rather low. The lake mixes in late November when the heat budget is 1812 g. calories. During the three months of isothermy the heat loss continues. Thus the loss between November 29 - December 30 was equal to 840 g. calories while that between December 30 to January 31, was 43 g. calories. With the start of the stratification period, due to rising atmospheric temperatures, the heat budget increased to 1818 g. calories on March 14.

The heat budget was worked out for the two depth zones in order to assess the role played by epilimnion and hypolimnion in regulating the heat storage of the lake. The records for August to October, 1970, showed the 0-6 m depth zone losing heat slowly for these three months and the 6-12 m depth zone, which includes the hypolimnion, gaining 36 g. calories of heat from August to September, and maintaining a constant heat budget for the next two months. From November to January both the zones lose heat. Even under isothermal conditions there is a marked difference in the heat storage of the two depth zones, calculated at 400 g. calories in the months of December and January. With the rise in atmospheric temperature in March the heat budget increased to 1512 g. calories and then to 1953 g. calories in April, in the upper depth zone (0-6m) while during the same period in the lower depth zone (6-12m) it remained constant at 306 g. calories.
Further, the heat exchange in the (6-12m) depth zone does not vary much, ranging from 216 g. calories in December to 576 g. calories in August; while in the upper (0-6m) zone the variation is tremendous, ranging from 693 g. calories in January to 3150 g. calories in July. Similarly, the heat exchange in the 0-6m layer is as rapid as it is slow in the 6-12 m layer indicating the independent manner in which the two layers behave in regard to the heat budget of the whole lake. A consideration of the heat storage of the two layers on the percentage basis presents still an interesting picture. From October 10 to November 29 there is a fall of 1260 and 114 g. calories in the upper and lower layers of the lake, respectively, which when calculated on the percentage basis of the total for the lake works out to a fall of 6.5 percent in the heat budget of the upper zone and an increase of 6.5 percent in the lower zone. The increase on percentage basis in the lower zone continues up to January when it touches the maximum of 25.4 percent of the total heat budget. Then, with the advent of spring, when the heat budget starts increasing, the percentage basis shows an opposite trend. From January 31 to March 14, the heat budget increases in the upper layer by about 8.5 percent while it decreases by almost the same value in the lower zone; despite its showing an overall increasing trend on g. calories basis. This points to a regular exchange of heat between the upper and the lower zones of the lake, inasmuch as, the heat lost in the upper zone is absorbed in the lower zone.
rather than getting lost to the external atmosphere.

The daily exchange of heat calculated round the year is depicted in table VII. The heat loss initiates in August at 1.98 g. calories/day, the values shooting up to 27 g. calories in the months of October to December and then falling to 1.5 g. calories between December to January. Heat is gained from January onwards at 20 g. calories till March, at 13.8 g. calories between March to April and at a still increased rate thereafter. The minimum heat gain of 2.5 g. calories was noted from June to July. From July to August heat loss is rather small (0.4 g. calories/day). The heat loss from August 4 to September 8, 1970 was estimated at 1.98 g. calories and from August 31 to September 30, 1971 at 15.06 g. calories, the difference in the two years being attributable to the different dates of sampling.

The daily increase or decrease in the heat storage of the two layers at 0-6 and 6-12 m depth shows a marked variation. From August 4 to September 8, 1970 there is 3.0 g. calories loss of heat in the upper zone against a gain of 1.02 g. calories in the lower zone. In the succeeding month also the upper zone loses 3.9 g. calories while the heat quantum of the lower zone remains constant. The maximum loss of heat in the upper zone is recorded between October - November while in the lower zone it is recorded between November - December. Similarly the maximum gain of 19.04 g. calories in the upper zone is recorded in January - March when in the lower zone the maximum gain of 3.6 g.
calories is recorded between April - May. Besides, from December 30 - January 31, the upper zone loses 2.1 g. calories while the lower zone gains 0.66 g. calories. Similarly between July 21 - August 31 the upper zone loses 1.5 g. calories when the lower layer gains 1.1 g. calories.