

Influence of physical and chemical conditions on living organisms in inland waters

Shoreline

The greater the length of the shore line the greater the biological productivity. Increased irregularity of shore line results in

- 1) greater contact of water with land
- 2) increased areas of protected bays and covers
- 3) increased areas of shallow water for growths of rooted vegetation
- 4) greater diversification of bottom and margin conditions
- 5) reduction of the amount of exposed, wave-swept shoal and
- 6) increased opportunity for extensive, close superposition of the photosynthetic zone upon the decomposition zone. These and other possible results combine in various ways to increase the production of animals and plants.

Relation of photosynthetic and decomposition zones

The form of basin of a lake determines, among other things, the relative amounts of shallower waters. Within limits and under strictly comparable conditions, the greater the areas of shallow water the greater the biological productivity. Their exposed nature usually results in

- a. the absence of rooted plants
- b. the absence of organic bottom deposits and
- c. the absence of any permanent animal population save those whose burrowing habits make occupancy of position in such a habitat possible.

Nevertheless, a fairly substantial but largely concealed population may be present, although of all the shallow water faunas it is usually the smallest one.

In contrast to conditions described above, the steeper the slope of the basin, or the greater the exposure of shoals, or both, the greater the removal of the decomposition zone to the profundal depths of deeper lakes

A deeper lake with steep basin slope thus tends to automatically and continuously rob itself of its stores of organic matter. Lakes of the third order, because of shallow depth and continuous circulation except during the ice cover period, retain all organic accumulations in available position, the essential decomposition products either remaining immediately beneath the plant beds or else being constantly the tribute by the water.

Slope and the deeper decomposition zone

Form of basin also involves the slope of deeper portions of the basin. Upon the nature of this slope depends, to a large extent, the character of the bottom. The influence of gravity, aided by water movements in pulling to the lowermost bottom the various materials which settle through, is much more effective on a declivitous slope. Some basin slopes are so abrupt that very little of the loose, settling materials can remain on the steep sides. Thus the decomposition zones of such a lake are restricted to (1) those of the shallow, protected shoals (if any are presently), and (2) those at the bottoms of the deepest regions, separated by steep sides which maintain little or no decomposition deposits.

Productive volume, flotation phenomena and body form adjustments

Productive volume

Form of basin determines the extent of productive volume. By productive volume is meant that portion of water in which virtually all biological production occurs. In a lake of the third order, total volume is productive at least during the open season. In lakes of the second order, productive volume is almost exclusively confined to the epilimnion and the thermocline during most of the summer stagnation period. During the overturns, the entire lake temporarily becomes productive volume but the duration of these periods may be too short to be of any great consequence. Lakes of the first order resemble those of the second order in that they maintain the productive zone in the upper stratum, usually limited by the presence of a thermocline. In those lakes having no complete overturn, the productive zone, during open season, merely varies in volume with those conditions which determine the depth to which circulation may extend. During prolonged ice cover, lakes of the second and third orders undergo gradual reduction of productive volume due to encroachment of the underlying stagnation zone, while lakes of the first order, under these conditions, may undergo less change in productive volume due to their size and to the presence of the permanent, deeper stagnation region. Complete ice cover may not occur in lakes of unusual size and depth, even though located in colder regions.

Both depth and area of a lake basin combine in innumerable ways to produce a great heterogeneity of lake forms. Since inland lakes seldom exceed certain area limit, depth is fundamentally of prime importance in determining productive volume.

The average depth is the factor which determines whether a lake is eutrophic or oligotrophic, computing average depth as the quotient of volume of the lake over area of the lake (V/A). In oligotrophic lakes, the volume of the hypolimnion is greater than the volume of the epilimnion, and that in eutrophic lakes the reverse occurs.

Flotation phenomena

i). Non-motile organisms

In calm water, non-motile plankton organisms depend entirely upon the relation between their own specific gravity, the density of the water, and the viscosity of the water in maintaining their vertical position. Non-motile, attached animals, particularly the colonial forms such as the larger colonies of fresh-water sponges and certain fresh water Bryozoa (*Pectinatella*), may develop forms and masses of body, which could not be maintained in the absence of the buoyant effect of water, and even the soft bodied Hydra would be helpless without it.

All sessile animals depend, to some extent at least, upon the buoyancy of the water. Many higher aquatic plants are dependent upon the supporting effect of the water in order to maintain their proper form and orientation.

ii) Motile Organisms

Those plankters which possess powers of locomotion vary greatly in the efficiency of their progression, but some change of position in space is possible due to their own activity. While such locomotion may be almost negligible when compared with the shifting and transporting effects of the water, it may nevertheless be vital to the organism in many ways, such as in the capture of food, and in the change of water in contact with respiratory surfaces.

Locomotion in water, consumes less energy to maintain their position above the bottom, due to buoyant effect of water. In fact, those organisms whose specific gravity is essentially the same as the surrounding water expend practically no energy in merely keeping up in the water. Certain aquatic animals, because of the possession of air stores or other special means, are distinctly lighter than water and must use a certain amount of energy to keep below the surface when they need to do so. Many air breathing, aquatic insects have air stores so located that not only are they lighter than water but the posterior end is lighter than the anterior, enabling the insect to float at the surface in

the proper respiratory position.

iii) Reduction of specific gravity

Protoplasm alone has a specific gravity which closely approaches that of water, but the various cell products which occur in animals and plants may combine to produce bodies which are either heavier or lighter than water. Products which tend to make the body heavier (such as chitinous exoskeletons of arthropods, bones, shells or various kinds) and those which tend to make it lighter are often present in the same body so that the specific gravity of the whole depends upon which of the contrasting materials predominate. The most effective and the most common of those cell products which reduce specific gravity seem to be the following:

1. Gases originate from various sources (metabolic products, external and internal air stores, and others) and remain, at least for a time, enclosed within or attached to the body. These gas accumulations may be of sufficient magnitude to make an otherwise heavy-bodied animal (as, for example, certain aquatic insects) much lighter than water.
2. Fats and oils are commonly produced and stored within aquatic organisms, notably in the plankton crustaceans and in the plankton ie Algae.
3. Gelatinous and mucilaginous secretions of varying amounts are common as matrices and external envelopes which helps in flotation.

iv) Relations of surface to volume

(a) In different Species.

Since in relatively compact bodies of organisms, the relations between volume and surface tend to conform roughly to the well-known mathematical principle that the surface varies as the square of the dimension while the volume varies as the cube of the dimension. The smaller the body, the greater will be the relative expanse of surface.

If the body has a specific gravity greater than water, it will sink, although resistance to sinking will be offered by the viscosity of the water. The greater the surface compared to the volume the greater will be the friction between water and body. Because of this relation, particles of very small size, even though composed of a substance having a specific gravity greater than 1, may not sink at all.

Few aquatic organisms, irrespective of size, are spherical in form. Any departure from the spherical form results in relatively increased body surface. Relative increase of surface is accomplished in so many different ways by :

1. General body form. Main portion of body may present:
 - a. Various degrees of attenuation.
 - b. Various degrees of compression or depression or general flattening.
 - c. Miscellaneous forms of asymmetry.
2. Body surface sculpturing: ridges, furrows, striae, impressed or raised patterns.
3. Extensions and modifications of antennae, tentacles, gills, legs, cerci and others.
4. Development of special peripheral processes: hairs, setae, spines, bristles, filaments, radial axes, tubercles, cilia, pseudopodia, crests.
5. Formation of colonies: linear, dendritic, radial, lamellate, irregular.

Combinations of several of these structural features in the same organism may occur, sometimes with remarkable flotation results.

(b) In the same species

In certain plankton organisms, a striking seasonal change of body form of a very definite sort occurs. This change of body form is a response to changes in the viscosity of the water due to seasonal changes in temperatures.

(c) Accessory provisions of flotation

Cases and coverings of various kinds composed, of foreign materials are constructed by some aquatic organisms. While such cases often serve several other purposes. In certain cases that they either

increase the tendency of the whole organism to be in suspension or completely support it at the surface. Instances of this sort are not uncommon among the aquatic insects (certain caddis-fly larvae, certain aquatic caterpillars, and others).

(d) Hydrofuge structures

Hydrofuge structures, such as hydrofuge pubescences, hydrofuge caudal filaments, and hydrofuge smooth surfaces, often play an important and sometimes a vital part in the flotation of organisms. Once at the surface they may provide (1) for the proper orientation of the body into the breathing position and (2) for the ability to remain at the surface in this position without much effort during the breathing period. Examples are not uncommon among aquatic insects. Certain hydrofuge structures are related directly or indirectly to respiration in some air-breathing aquatic insects.

(e) Precision in flotation adjustment

Among the plankton, flotation at the proper level is sometimes a matter of precise adjustment. A very small discrepancy in adjustment may result in the following changes. (1) too great buoyancy, causing the organism to rise to an unfavorable level or even to rise to the surface. Owing to various hazards such as excess light, entanglement with the surface film, and evaporation; or (2) sinking to an unfavourable depth at which such features as reduction of effective light, critical reduction or absence of oxygen, and absence of proper nutritive materials may result seriously. Such adjustment is thus of vital importance to certain nonmotile plankters. This adjustment follows the seasonal changes of viscosity and density of water in such a way that organisms may continue to thrive is one of the marvels of aquatic life.

Water fleas swim intermittently but unceasingly, and certain microorganisms occupy proper levels by constant vibrations of flagella or cilia.

Body form adjustments

a) Streamline form

When a body is either in motion through quiet water or stationary in moving water, the water imposes some resistance over the body. Hence, the organism has to overcome this force to maintain its stationary position.

A body must occupy space by complete displacement of the water and that when either the body or the water moves; the body continues the process of displacement. Also, under these conditions, not only must the great weight (density) of the water be overcome in pushing it aside, but the internal friction (viscosity) of the water plus the friction of the water against the surfaces of the object must also be overcome. Thus, energy is expended by the object in overcoming these resistances, and, as will be shown later, the amount of this energy depends upon the form of the body when other conditions are the same.

Viscosity and density of water vary with certain conditions, particularly temperature; the resistance met by a moving organism or by an organism maintaining its position in moving water is considerable under all circumstances. Organisms vary greatly in their ability to overcome this resistance, owing to inherent differences, especially the form of the body. Obviously, certain forms of body are more effective for locomotion in water than others.

Among other things, it was found that the body consists of two principal parts: (1) the entrance or fore body, that part from the tip of the snout to the maximum transverse section; and (2) the run, or after body, that portion from the maximum transverse section to the tip of the caudal fin. It was also found that, in all specimens, the average position of greatest transverse section occurred at a distance of about 36 per cent.

The replacement of water following maximum displacement had something to do with the function of the after body.

Principle of streamline form

A body with streamline form moving through standing water and the same body maintaining a fixed

position in running water present the same essential conditions.

The position of maximum transverse section represents the maximum displacement of water. it likewise determines not only the maximum energy expended in displacement but also the termination of virtually all energy expended in displacement but also the termination of virtually all energy expenditure so far as body surface is concerned.

(b) Other forms of adjustment

Some animals living in the strongest currents possess spines on the exposed surface (Blepharoceridae). These projecting structures would be detrimental by increasing the resistance. These roughnesses actually help to decrease resistance. In bodies such as spheres and cylinders, the nature of the resistance may change markedly with relatively small changes in the conditions involved; at certain velocities, the resistance of a sphere may be reduced by roughening its surface. In some of the species, spines will be developed as a means of diminishing the resistance to the fierce currents in which they live. The spines on such a body would increase the resistance at some water velocities but would decrease the resistance at certain higher rates of flow.

Relations of organisms to movement of water, surface film relations

Relations of organisms to movements of water

Movements of water, in the various forms, affect aquatic organisms in many ways, directly or indirectly, and often play very important roles in aquatic environments.

a) Effects upon sessile animals

Different growth forms in the same animal are the result of presence or absence of water currents or movements especially in fresh water sponges.

The unbranched colonies are the result of unfavorable conditions, but this can scarcely be credited when both the branched and the unbranched forms occur side by side in the same water and on similar supports. Bryozoa have also been supposed to develop different growth forms in standing and in moving water.

b) Effects upon motile animals

Many motile animals show a definite orientation response to current; i.e., they exhibit either positive or negative rheotropism. Orientation reaction may be accompanied by locomotor activities, so that certain animals will not only head upstream but will swim, either maintaining their original position or making progress against the current. Sometimes the response to current depends upon some important event in the life history such as sexual maturity.

Atlantic smelt, established in the upper waters of the Great Lakes, which while essentially a lake inhabiting fish, becomes positively responsive to current at the onset of spawning season and exhibits spawning "runs" at night into certain adjacent inland waters flowing into the Great Lakes. Water in motion imposes pressure against certain surfaces of the animal, and it has been held that equality or inequality of current pressure on different parts of the body affords the stimulus to orientation of some aquatic animals, which, if true, furnishes an instance of the direct effect of current.

Certain fishes are supposed to orient in response to visual impressions as they float downstream (Clausen et al., 1931) but still other fishes have been thought to orient in response to the rubbing of parts of the body on the bottom as the current make them to floats downstream. The visual theory seems ineffective in those instances of runs at night (smelt) or in very turbid waters.

Certain phenomena such as morphological or physiological, may either be caused by, or correlated with, movements of water and their different velocities. A general correlation exists between the rate of flow and the shape of mussels in eastern Bavaria.

Current demand

Certain aquatic organisms exist permanently only in the presence of appropriate movements of water, and it is now known that current is demanded by some of them. For example, black-fly larvae (*Simulium*) of all species (one possible exception in Asia) inhabit only in rapidly running water. Wu (1931) has shown, among other things, that these larvae possess an inherent demand for current and that their universal absence from standing waters is due directly to the absence of the necessary current.

Secondarily, current is also related to *Simulium* larvae in such matters as proper food delivery and respiration.

Resistance to water movement

In general, animals which meet this problem successfully do so by means of one or more of the following features: (1) body form which offers least resistance, such as the streamline or the hemistreamline form; (2) unusually well developed burrowing or clinging habit; and (3) special forms of attachment to fixed, supporting objects.

A few may maintain their position because of unusually effective attachment devices (powerful adhesive suckers of the larvae of *Blepharoceridae*).

Provisions for clinging and attachment

Among the numerous, special provisions for increased efficiency in maintaining position in the face of strong water movement are the following:

1. Strong, recurved tarsal claws.
2. Exceedingly flat ventral surface.
3. Strongly depressed body.
4. Lateral margins of head and thorax produced in the form of flat margins for increased contact with the supporting object.
5. Legs, when of large size, flattened horizontally and applied by their sides as well as by the tarsi to the supporting object.
6. Special flattening of gills or the modification of the entire gill series to form a ventral attachment disk.
7. Special sucking disks. Examples: blepharocerid larvae; leeches; nymphs of May fly, *Ephemerella doddsi*.
8. Ventral adhesive pads, often bearing recurved spines. Examples: certain stream inhabiting aquatic Hemiptera and May fly nymphs.
9. Terminal attachment disks. Example: *Simulium* larvae posterior disk a combination of a row of hooks with a gelatinous secretion originating from the mouth.
10. Threads which anchor the animal directly to the support. Example: thread used by *Simulium* larvae when shifting position.
11. Threads which anchor case or shelter of animal. Example: certain caddis fly larvae.
12. Shelters, tubes, or cases which protect against the wash of currents and waves. Examples: sand constructed case of caddis fly, *Molanna*; cases of certain midge larvae; egg capsules of leeches; tubes of tubificid worms.
13. Adhesive secretions. Example: common hydra.

Provisions for burrowing

Burrowing is often accomplished by animals having no special structural provision for that purpose. In such instances, they are merely capable of forcing their way into bottom materials, aided by such features as (1) more or less pointed anterior end; (2) body movements of a penetrating sort; (3) setae; (4) longitudinal contraction and extension of a portion of the body; (5) extensile and protrusible body tubercles; and (6) strongly muscular body walls accompanied by freely moving, soft, internal organs and fluids. By such means as these, some of the softest bodied aquatic animals (*Oligochaeta* and others) penetrate the hard packed sand of barren, exposed shoals, thus maintaining their position in the presence of the strongest wave action.

Other animals have developed special structural features for effecting partial or almost entire penetration of bottom, such as (1) the flattened, shovel like, anteriorly directed front legs, the posteriorly directed hind legs depressed to the body and adapted for pushing, and the pointed sloping head of the nymphs of the May flies *Hexagenia* and *Pentagenia*, and the dragon flies *Gomphus*; (2) the long, upturned, mandibular tusks of burrowing May fly nymphs; (3) the muscular foot of clams and snails; (4) the long, spraddling, spider like legs of certain dragon fly nymphs (*Macromia*), so oriented on the body that they rest full length upon the sand and, wriggling movements, work the sand entirely over them thus gaining a certain anchorage; and (5) the strikingly flattened, shoal inhabiting dragon fly nymphs (*Hagenius*), which weight themselves down by working sand on top of the thin abdominal margins.

Burrowing by some species may be a direct response to excess light, but the end result of maintaining position remains the same.

Habits facilitating resistance to water movement

Animals, which, lacking special structural developments, manage to maintain position in current or wave-swept areas by reactions. These are exemplified by the habitual seeking of (1) the protected

sides of and the interstices between rocks; (2) fissures in bottoms and bottom materials; and (3) the more protected parts of rooted plants.

Influence on construction activities

Construction processes of certain animals can be properly performed only in the presence of water movement. A striking instance is that of the net building caddis fly larvae which can produce their nets only in moving water; in calm water, the attempt results only in a shapeless mass of threads.

Distribution of organisms

Since moving water is an effective transporting agent, movements of water play a very active part in the distribution of many aquatic organisms. Pieces of aquatic plants bearing various eggs, larvae, pupae, and even adults of insects, hydra, Bryozoa, Mollusca, and many others break from their attachments and drift with the water.

Molar agents

Sand, fine gravel, rocks of various sizes, and sometimes even boulders, carried or rolled by the water, become a veritable wearing, grinding, fragmenting machine which constitutes one of the serious menaces to the whole biota of those situations.

Indirect effects of water movement

Water movement is concerned with the life of aquatic organisms in a number of ways, the following being among the most important:

1. Constant shifting of bottom materials on shoals and other shallow waters may prevent the rooting and, therefore, the occupancy of these areas by higher aquatic plants.
2. Erosion or transportation of materials may completely alter the environment, converting it into some very different type for which the organisms are not suitable. The example of the cutting off of a sand-spit beach pool from the body of a lake.
3. Circulation, and in some instances the return to circulation, of essential nutritive substances in the water, both dissolved and suspended.
4. Production and maintenance of turbidity thus affecting the light penetration and certain other relations.
5. Delivery of food to sessile or sedentary animals, particularly when the food is in the nature of suspended, living organisms (plankton) and suspended, finely divided, nonliving materials.
6. Respiratory relations, such as (a) renewal of properly oxygenated water to respiratory surfaces and (b) renewal of dissolved oxygen supply from the air by the surface agitations incident to water movement.
7. Temporary exposure to air, as in seiches which imitate the ebb and flow of a tide and which, if of sufficient magnitude, may expose for a time a whole set of shallow water organisms to evaporation and other serious hazards.

Surface film relations

The surface film serves as a mechanical support for organisms and miscellaneous particulate materials. Both surfaces of the film may function in this way. The term neuston, originally applied to minute organisms, is now commonly extended to include all organisms associated with the surface film. Those related to the upper surface of the film comprise the supraneuston; those related to the lower surface, the infraneuston.

The larger animals commonly associated with the supraneuston are: (1) water striders (Gerridae); (2) broad-shouldered water striders (Veliidae); (3) water measurers (Hydrometridae); (4) hebrids (Hebrididae); (5) mesoveliids (Mesoveliidae); (6) whirling beetles (Gyrinidae); (7) springtails (Collembola); and (8) certain spiders.

Relations of organisms to Temperature relations, Light relations

Temperature relations

With the exception of the aquatic birds and mammals, all aquatic animals are cold blooded (poikilothermous), i.e., their internal temperatures follow, usually within close limits, the temperatures of the surrounding medium. It must be understood, however, (1) that exceptions in the form of unusual deviations from surrounding temperatures may occur, as, for example, the claim that certain fishes may have an internal temperature of as much as 10°C. higher than that of the surrounding water; and (2) that the degree of agreement between body temperature and external temperature may differ with the temperature level of the latter.

Some aquatic animals live in surroundings the temperature of which is below freezing (glacier worms and others), but it has usually been supposed that the freezing point of their body fluids is depressed by substances in solution. Even if this is true, there remains to be explained the fact that under those very low temperatures they are not only active but grow, develop, and reproduce.

Influence on metabolism

Within the ordinary temperature limits for a given cold blooded animal, decreasing temperatures diminish metabolism, and vice versa, a relation which is opposite that for warm blooded animals. This means that metabolic rate is, to a large extent, governed by the external temperatures. It also means that the falling temperatures of increasing depths in water or of increasingly northern latitudes inflict lower rates of metabolism. A general rule for this change in metabolism in cold blooded aquatic animals can be stated as follows: a rise of 1°C increases the rate of metabolism about 10 per cent. This means that the rate of oxygen consumption and carbon dioxide output doubles with a temperature increase of 10°C.

Influence on development and other biological processes

Rising temperature increases the rate of (1) development of animals, (2) respiratory movements, (3) heart beat and circulatory rhythms, (4) enzyme action, and (5) other physiological process, although the operative limits in each process may differ. A cold blooded aquatic animal may be expected to complete its life cycle more slowly and to produce fewer generations per unit of time in the northern than in the southern part of its range; like wise, the normal individual life span may be longer. Onset of hibernation, breeding season, changes in reproductive activity, germination of asexual reproductive bodies, and a host of other biological activities are profoundly influenced by surrounding temperatures.

Temperature toleration

Each organism has a maximum and a minimum environmental temperature between which life is possible but beyond which conditions are lethal. Even for individual species, these temperature limits are not absolutely fixed, since they may vary with different individuals, with the different sexes, with different life history stages, with different physiological states, and in different parts of the geographic range. In spite of this variation, it is possible roughly to divide animals into two groups: (1) those which are restricted to a narrow range of temperature change (stenothermic animals) and (2) those which tolerate a wide range of temperature change (euthermic animals). Also, there are intergrades between these two groups. It is a well known fact that acclimatization can shift temperature restrictions as well as those of other environmental factors. Somewhere between the maximum and minimum limits, an optimum region occurs, the position and extent of which vary with different animals. It is sometimes stated that the optimum is usually closer to the maximum than to the minimum, but in some instances the reverse condition prevails. Acclimatization may also affect the position of the optimum.

In temperate lakes of the first and second orders, only the non-migrating, profundal bottom organisms live under approximately a fairly even temperature throughout the year. On the contrary, those surface water forms which remain active throughout the year must endure the complete range

of temperature. Those not active in all seasons have developed various forms of hibernation, and aestivation, as a means of passing over the more rigorous conditions. Many aquatic animals remain active thorough wide ranges of temperatures, the active period ending only just before the extremes are reached.

Effects of extremes of temperature

The specific effect of extremely low temperature is usually considered as being mainly mechanical, while that of extremely high temperature is principally chemical, affecting the protoplasm. The chemical effect of excessively high temperature is more severe than the mechanical effect of correspondingly low temperatures. It is true that even in the temperate latitudes, certain aquatic animals (mosquito larvae and others) may be frozen into surface ice and recover on release. This phenomenon seems to be more common in the arctic and subarctic regions.

The occasional rise of surface water temperature to unusual heights (although only a few degrees above the usual summer maximum) in protected bays in times of clear, hot weather and dead calm water promptly leads to a dying off of surface plankton and certain other shallow water organisms.

Recognition of temperature differences

Some aquatic animals have a well developed recognition of changing temperature and may respond with considerable precision. Under experimental conditions, certain fresh water animals have been found to recognize temperature differences of 0.2°C and react to them.

In thermally stratified lakes, it is very difficult to determine the presence or absence of a limiting effect to downward distribution by the steep thermal gradient in the thermocline, since other varying conditions are simultaneously present, such as light, chemical stratification, and viscosity changes.

Light relations

The various relations of sunlight to aquatic organisms may be classified into two sets: (1) direct influences upon the organisms as a whole and (2) photosynthetic relations.

Direct influences

Lethal effects

Many aquatic organisms are sensitive to the higher intensities of sunlight and, in fact, must avoid them by occupying deeper levels in the water.

Plankton organisms occur in surface waters, exposed to the maximum light intensity. Many are phytoplankton and have photosynthetic relations, but it is a well established fact that in most natural waters the maximum populations of plankton occur at some lower depth, one of the important reasons being the more favorable light effects.

Both sunlight and ultraviolet light seemed to devitalize the diatoms (excepting *Synedra*) but stimulated the Chlorophyceae and the Myxophyceae, the ultra violet light providing a slightly greater stimulus. Since the ultraviolet light is quickly absorbed in the surface waters, its effects are very restricted.

Many aquatic organisms, especially bottom inhabiting forms, live in conditions of almost if not complete darkness and quickly succumb in direct sunlight. Light is often a powerful factor, sometimes the determining one, in the distribution of organisms in aquatic environments.

Behavior and orientation

Responses of aquatic organisms are often due to, or conditioned by, light. One of the most striking results of the alternation of day and night is the migration of certain plankton organisms from deep water to the surface at night and their return to the depths near dawn.

Light is the principal motivating influence of this migration. For some organisms, day is the period of general activity, night the period of quiescence; for other forms, the reverse is true.

In many aquatic animals, the light responses differ markedly with physiological state, age, life history stage, season and other conditions.

Other influences

Direct influences of light effects upon pigments and pigment production, upon growth, upon development, and in fact, upon many of the conditions involved in the general success of organisms.

Photosynthesis

One of the most profound influences of sunlight (and of moonlight to a limited extent) in water is its intimate role in the photosynthetic processes of all chlorophyll bearing, aquatic plants.

These plants furnish, directly or indirectly, the carbohydrate and the protein supply for the aquatic world. They occupy that strategic position between the inorganic and the higher organic components which makes the latter their complete dependents. The phytoplankton has been called the green pasture of the sea, and it plays a similar role in fresh waters too.

It becomes increasingly clear that the process commonly referred to as photosynthesis is a very complex phenomenon. Light, temperature, solutes, and carbon dioxide affect simultaneously the photosynthesis. However, it seems certain that light of the appropriate kind and intensity is the supreme factor.

Light requirements

The light supply has two important aspects: (1) light intensity and (2) effective wave lengths.

Intensity

The rate of photosynthesis increases with the intensity of light and in fact, if certain conditions of temperature and carbon dioxide are met, the rate of photosynthesis is proportional to the intensity of the incident light. However, the rates of photosynthesis differ in different plants.

1. Ultraviolet rays are of little or no consequence in photosynthesis. This has been demonstrated experimentally with terrestrial plants. Considering the fact that ultraviolet waves are completely absorbed in the uppermost, thin layer of the water and that various aquatic plants thrive far below the level of disappearance of these wave lengths, the aquatic situation seems to offer confirmation of the statement.

2. Experimental evidence appears to show that with equal intensity of incident light, photosynthesis is affected by different wave lengths, being greatest in the red and least in the blue violet. Certain investigators claim that the rate of photosynthesis diminishes with decreasing wave length.

Effective light penetration

The normal existence of healthy chlorophyll bearing plants at various depth levels in water may be taken as evidence that some of the effective light is present in sufficient intensity to enable these plants to perform photosynthesis.

Algae have been found in certain mountain lakes below a depth of 400m and at greater depths in the ocean, but it remains to be conclusively demonstrated that these plants are performing photosynthesis.

It seems certain that light is a very influential factor in determining the occurrence and distribution of chlorophyll in a lake. Therefore it may be expected that since light conditions differ in different waters the quantity and activity of chlorophyll will be influenced correspondingly. Nevertheless the processes of light penetration and photosynthesis in natural waters are so complex.

The maximum rate of photosynthesis in lakes in full sunlight usually occurs somewhere below the surface layer.

Plants inhabiting situations having moderately reduced light intensity usually have more chlorophyll than do those living in full sunlight.

That light intensity at which oxygen production in photosynthesis and oxygen consumption by respiration of the plants concerned are equal is known as the compensation point, and the depth at which the compensation point occurs is called the compensation depth. For a given body of water this depth varies with several conditions, such as season, time of day, degree of cloudiness of sky, condition of the water, and taxonomic composition of the flora involved. As commonly used the

compensation point refers to that intensity of light which is such that the plant's oxygen production during the day will be sufficient to balance the oxygen consumption during the whole 24hr period.

Photochemical nitrification

An indirect effect of sunlight is through a possible photochemical nitrification. A portion of the nitrification which goes on in the sea is photochemically activated. Some chemical nitrification in soil is activated by sunlight in the absence of the biological agencies.