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Diurnal Changes of Selected Physico-Chemical Properties of Water and Aquatic Insects in a Seasonal Pond

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ABSTRACT

Diurnal changes of selected physico-chemical parameters of water (temperature, dissolved oxygen [DO], conductivity, total dissolved solids [TDS], turbidity and pH) and aquatic insects in a seasonal pond in Aborlan, Palawan were investigated in January 2002. Physico-chemical parameters were measured every hour using digital equipment starting 9 AM until 8 AM the next day. Dip net was used to sample aquatic insects at different times (9 AM, 1 PM, 5 PM, 12 midnight, and 5 AM).

All water parameters measured tended to be higher at daytime than at night. Water temperature ranged from 22.8-31.4°C while DO ranged from 2.4-6.2 mg/L. Water conductivity and TDS, which ranged from 79.1-87.8 µS/cm and 39.5-43.5 mg/L, respectively exhibited the same trend with dimodal peaks at 11 AM and 6 PM. Turbidity irregularly fluctuated ranging from 16.3-31.2 NTU while pH did not vary much ranging from 5.5-6.3. There was a significant linear correlation between water temperature and other measured physico-chemical properties of water.

Most aquatic insect groups showed nocturnal behavior but Libellulidae (dragonfly nymphs) and Corixidae (water boatmen) were constantly collected at different sampling times and most abundant at 9 AM. The physico-chemical properties of the water in the pond were influenced by temperature and most aquatic insects are nocturnal in behavior and seemed affected by the diel water temperature.

Keywords: diurnal change, water physico-chemical parameters, aquatic insects, seasonal pond, Palawan

INTRODUCTION

Ramsar Convention defined wetland ecosystems as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including marine waters the depth of which at low tide does not exceed 6 m". Philippine wetlands are extremely diverse and a large proportion of human population depends on them (Simpson and Bugna, 2001).

Big wetlands in the Philippines such as Taal Lake and Lanao Lake have been extensively studied (Santiago *et al*., 2001). It has been recognized that other wetland areas in the country have been largely ignored leaving a research gap (Simpson and Bugna, 2001). In temperate regions, Williams (1987) provided an account on the ecology of temporary waters including ponds while Diaz-Espejo *et al*. (1999) investigated the sediment phosphate of a seasonal pond. Limited information is available for natural Philippine ponds except for those intended for aquaculture.

Ponds are shallow and small natural bodies of water in natural or contrived hollow formed when precipitation runoff or groundwater fills a depression of the earth's surface. Although smaller than lakes, these lentic water bodies are noted for rich and abundant varieties of plant and animal life, all maintained in a delicate ecological balance. This life ranges from invisible bacteria to insects, fish, small animals and birds (Encyclopedia Americana, 1996).

Most ponds in the country are not limnologically explored and less is known about their environmental conditions. There is limited knowledge on their biodiversity and their dynamics are poorly understood.

The diurnal cycle of selected physico-chemical properties of water in a seasonal pond was investigated to obtain information on their natural characteristic change. The study includes the diurnal pattern of aquatic insects.

MATERIALS AND METHODS

The Study Site

The pond is situated inside the main campus of the Western Philippines University in Aborlan, Palawan, which is c. 69 km south of Puerto Princesa City. Located in climate type III (season not very pronounced, relatively dry from November to April and wet during the rest of the year) at 9°26'43" N and 118°33'28" E, the pond is considered seasonal because it is dependent on rainfall for its water input. Thus, water depth varies from 2 m during rainy season at the deepest portion to 10 cm or below during dry periods. Williams and Feltmate (1992) use the term "temporary ponds" for shallow natural bodies of water that experience a recurrent dry phase of varying duration.

The pond is irregular to oval-shaped depending on water depth with an area of 1,743 m^2. Its basin is composed of organic matter from the plants, which grew therein prior to the accumulation of water, and mud of soil from the underlain ultramafic rock. A small spring, which has been used for washing and bathing, is found at its north side. Few water hyacinth (*Eichhornia crassipes* (Mart.) Solms) are growing just after the spring. Few nearby residential houses can be seen at southeast side and an outlet is located at south portion. Grasses are growing at the edge of the pond and trees are found nearby.

Three (3) stations near the edge of the pond were chosen where the selected physico-chemical parameters of the water were measured and aquatic insects were sampled.

Measurement of Physico-chemical Parameters of Water

The selected physico-chemical properties of water such as water temperature, pH, total dissolved solids (TDS), dissolved oxygen (DO), conductivity, and turbidity were measured at each station every hour for 24 hours using a digital water quality instrument.

The mean of three readings of each physico-chemical parameter from the three sampling stations was considered and was subjected to correlation analysis to determine their relationships.

Sampling of Aquatic Insects

Ten (10) random dippings of dip net at each station was done at 9 AM, 1 PM, 5 PM, 12 midnight, and 5 AM to sample aquatic insects. The samples were emptied in big plastic tray to remove the debris and rotten leaves while the insects were sorted by families and placed separately in plastic vials containing 70% ethyl alcohol.

Pooled total number of individuals from the three sampling stations was considered.

RESULTS AND DISCUSSION

Diurnal Pattern of Physico-chemical Properties of Water

All measured physico-chemical properties of water in the pond tended to be higher at daytime than at night . Water temperature, which ranged from 22.8 - 31.4°C, changed markedly even on a diel basis since the pond is a shallow temporary habitat (Williams and Feltmate, 1992). It was expected to be higher during daytime than at night due to solar radiation (Ruttner, 1975). However, its range is lower than the usually recommended upper limit of 32°C (Hammer, 1977) and within the optimum range (25-35°C) for bacterial activity (Tchobanoglaus and Burton, 1991) since most values obtained were higher than 25°C

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The trend of DO followed that of temperature. Other lentic water bodies showed the same DO pattern (Peetragorn, 1993; Goltenboth, 1996) attributed to the photosynthetic activity of algae (Tebutt, 1983). The principal sources of DO of standing waters are from atmosphere and algal photosynthesis (Hammer and Hammer, 1996). With low solubility, low oxygen in water from atmosphere is added by algal photosynthesis (Kalff, 2002). Sunlight at daytime allows algae and other photosynthetic bacteria to photosynthesize to produce more oxygen causing higher DO level. High photosynthetic rates during the day and high respiration rates at night yield diel DO changes (Tchobanoglous and Burton, 1991). At night, the absence of light allows algae to operate on chemosynthetic basis and consume oxygen (Tebutt, 1983) aside from oxidation of organic and inorganic matter by anaerobic organisms (Sawyer *et al.*, 1994).

A noticeable abrupt DO increase at 10 AM to 11 AM and at 12 noon to 1 PM followed after a slight DO increase at 9 AM to 10 AM and at 11 AM to 12 noon, respectively. This abrupt DO increase is implicated to high photosynthetic activity brought about by increasing intensity of solar radiation towards mid-day since photosynthetic rate increases linearly with irradiance (Kalff, 2002). The slight DO increase is possibly due to large quantities of decaying organic matter on the bed and extensive patches of respiring algae, which can very quickly deplete DO (Williams and Feltmate, 1992). Aerobic organics use free oxygen for oxidation of organic and inorganic matter (Sawyer *et al.*, 1991) while oxygen is replaced by aeration at the surface and photosynthetic activity of green plants (Hammer, 1977). As a result, DO level of the water, which ranged from 2.4 to 6.2 mg/L was lower than the Philippine Fresh Surface Water Standard (PFSWS) of 5 mg/L as most DO readings obtained within 24 hours were lower than this standard.

The same pattern of TDS and conductivity was observed since they are closely associated (Tebutt, 1983; Sawyer *et al.*, 1994; Tchobanoglous and Burton, 1991). Un-ionized species of weak acids and bases will not carry a current, although they are a portion of TDS in water. Likewise, uncharged soluble organic nutrient such as ethanol and glucose cannot carry current and so are not measured by conductance (Sawyer *et al.*, 1994). Kalff (2002) stated that the greater the concentration of salts, acids and bases in natural waters, the greater the conductivity. The lower TDS and conductivity during dark hours than at daytime implies that lesser ions and soluble materials are available in the pond at night than at daytime. The plausible explanation is the low production of organic acids and other inorganic substances as a result of low decomposition of organic matter by microbes at night. Anaerobic bacteria dominate the oxidation of organic matter at night since less oxygen is available. At daytime, both aerobic and anaerobic oxidation can occur (although aerobic oxidation dominates) resulting to high decomposition products.

There was a dimodal peak of the diurnal pattern of conductivity and TDS, which were at 11 AM and 6 PM. The possible cause of these peaks is the phosphate from soap and detergent used during bathing and washing at the spring and probably from nearby residential houses. Synthetic detergents and soaps have high phosphate content (Grolier Encyclopedia of Knowledge, 1998). Washing and bathing at the spring mostly occur in the morning (6 to 9 AM) and in the afternoon

(3 to 6 PM). It is possible that phosphate reached the sampling stations at the time of measurement.

Conductivity of the water ranged from 79.1 to 87.8 μS/cm which is lower than other freshwater bodies, *i.e.*, Lake Lanao having an average conductivity of 120 μS/cm (Goltenboth, 1996); Huay San Stream: 200 μS/cm (Chatsriroong, 1996). This indicates that the pond water has low ions and dissolved substances, which probably came mainly from oxidation of organic matter. On the other hand, TDS ranged from 39.5-43.5 mg/L. Tchobanoglous and Burton (1991) stated that inland surface waters with 250 mg/L TDS or below have weak (low) domestic wastewater concentration and those with less than 450 mg/L can be used for irrigation. The water in the pond can therefore be used for irrigating ricefields. This is confirmed by the PFSWS for TDS which is less than 500 mg/L

Water pH did not vary much ranging from 5.5-6.3 indicating that the water is slightly acidic, although the trend seemed to indicate that it is higher during daytime than at night. This pattern is attributed to the utilization and production of carbon dioxide (CO_2) by algae in the water. At daytime, algae use the dissolved CO_2 through photosynthesis and this removal is responsible for high pH (Williams and Feltmate, 1992; Tchobanoglous and Burton, 1991; Sawyer *et al.*, 1994). During dark hours, algae produce rather than consume CO_2 as their respiratory processes exceed their photosynthetic processes. Such CO_2 production tends to reduce pH (Sawyer *et al.*, 1994). pH range of the water (5.5-6.3) was below the PFSWS which is 6.5 to 8.5. The relatively acidic condition of the water is suspected to be due to the soil. Asio (1997, pers. comm..) stated that Aborlan soil is deeply weathered and highly acidic.

During the 24-hour period, water turbidity, which ranged from 16.3 to 31.2 nephelometric turbidity units (NTU) showed a highly irregular pattern but also tended to be higher at daytime than at night. Water turbidity is due to clay and silt particles, or the presence of microorganisms (Tebutt, 1983). The irregular pattern of turbidity can be attributed to intermittent wind that disturbed the water. It was relatively higher at daytime than during dark hours possibly because of temperature. Water thermal expansion is caused by high temperature and the water can be readily mixed by wind. Such mixing can disturb the water including the clay, silt and microorganism making it turbid at daytime. Lower water temperature at nighttime makes the water viscous and resists wind mixing.

Relationship of the Different Physico-chemical Properties of Water

As observed, most physico-chemical parameters of water in the pond tended to be higher at daytime that at night and seemed to be linearly correlated. To verify this, correlation analysis was done.

Water temperature is linearly correlated with other parameters measured suggesting that it is the most important environmental factor in this lentic system affecting other properties of water (Tebutt, 1983).

Water temperature increases with increasing sun radiation which causes linear rise of photosynthetic rates (Kalf, 2002) resulting to corresponding DO increase in water, thus, a significant linear relationship between water temperature and dissolved oxygen ($r = 0.5875$, $P<0.01$). On the other hand, higher temperatures (up to some limit) increase metabolic rates, thereby increasing the rate of organic matter that is recycled. The high decomposition of organic matter during respiration and the end products in the form of large-molecular-weight organic acid plus a wide variety of low-molecular-weight molecules (Kalff, 2002) leads to the increase of soluble materials in water thereby increasing water conductivity and TDS, which are highly correlated with each other. The greater the concentration of salts and bases in natural waters, the greater is the water conductivity, thus, a linear relationship between water temperature and conductivity ($r=0.5366$, $P<0.01$) and with TDS ($r=0.6484$, $P<0.01$). The more substances from organic matter are dissolved in water, the higher the conductivity of the water ($r=0.9062$, $P<0.01$).

Water conductivity was linearly correlated with DO ($r=0.5935$, $P<0.01$), which in turn was linearly correlated with TDS ($r=0.4548$, $P<0.05$). According to Wetzel (1978), the amount of DO in water depends on the concentration of various ions, which are measured in terms of conductivity. DO in water is consumed by the oxidation of dissolved ammonia (NH_3^+) and ammonium (NH_4^+), substances that like organic matter, are present in water as a result of biological activity to nitrate ion (NO_3^-) (Baird, 1999). As temperature rises, chemical enzymatic reaction rate in microbial cell increases (Nyer, 1992) and the rate of biochemical reactions that use oxygen increases (Tchobanoglous and Burton, 1991). Since there is also an increasing DO due to solar irradiance (Kalff, 2002), this allows an increasing decomposition of organic matter during respiration thus, results to increasing amount of ions and soluble materials in the water.

Turbidity is positively correlated with temperature ($r=0.5425$, $P<0.01$) and the latter is correlated with TDS ($r=0.4204$, $P<0.05$). As mentioned earlier, the thermal expansion of water results from increasing temperature. Hot water readily mixed by wind disturbs the clay, silt and microorganisms, thereby increasing turbidity. Turbidity is caused by clay, silt particles, presence of microorganisms (Tebutt, 1983) and fine particulate organic matter (FPOM). The pond contains lots of organic matter from plants. This serves as the source of FPOM which are oxidized by microbial organisms with organic acids and molecules as end products resulting to high TDS.

Significant correlation was obtained between water temperature and pH ($r=0.4789$, $P<0.05$), which was also correlated with DO ($r=0.4219$, $P<0.05$). As mentioned earlier, the increase in temperature causes corresponding increase of DO in water through the process of photosynthesis. The increase in DO and the decrease of CO_2, which is utilized by algae for photosynthesis result in increase pH (Williams and Feltmate, 1992; Tchobanoglous and Burton, 1991; Sawyer *et al.*, 1994).

Diurnal Periodicity of Aquatic Insects

The different insect families sampled at different times during the 24-hour period are presented in Figure 6. More aquatic insect families were collected during dark hours at 12 midnight and 5 AM than during morning daylight at 9 AM which tended to decrease in the afternoon. This suggests that most aquatic insects are nocturnal in behavior which are possibly controlled by light and temperature. Activity in aquatic invertebrates is largely controlled by light and temperature (Bishop and Hynes, 1969). Light specifically light intensity rather than wavelength is one critical factor responsible for the circadian activity patterns recorded by authors (Hughes, 1966; Elliott, 1967). Negative phototaxis has been recorded for many aquatic insects and serves to maintain these organisms in areas of low light intensity. Linked to this are the strong positive thigmotaxis observed in many benthic forms (Bishop and Hughes, 1969), the definite orthokinesis during periods of low illumination and the positive skotokinesis observed by Hughes (1966). On the other hand, aquatic insects may respond behaviorally to conditions of elevated temperature by emigrating from, or changing distribution within stressed regions (Williams and Feltmate, 1992).

Among the 11 aquatic insect families, Libellulidae (dragonfly nymphs) and Corixidae (water boatmen) were constantly collected with the highest number being obtained at 9 AM. Libellulids are common and chiefly occur in ponds and swamps (Borror and White, 1970) and predominate on temporary ponds (Williams and Feltmate, 1992), thus are present in subsequent samples (Usher and Jefferson, 1991). They are extremely mobile (Usher and Jefferson, 1991) and are predators, feeding on various small aquatic organims (Borror *et al.*, 1989). They are swallowers and carnivorous, eating the whole animal or parts (Cummins, 1973). If food is scarce locally, nymphs may wander in search of it even at night (William and Feltmate, 1992).

Like libellulids, the corixids are common in ponds, spending much time clinging to submerged vegetation (Borror and White, 1970) and congregate in large clusters near shores (Williams and Feltmate, 1992). This could be the reason why they were always caught during samplings since the sampling stations were located near the edge of the pond. On the other hand, they feed on algae and other minute organisms (Borror and White, 1970; Borror *et al*., 1989). As herbivores, they are considered scrapers, foraging on algae and associated attached micro flora (Cummins, 1973) and ingest fine particulate organic matter (FPOM) (Williams and Feltmate, 1992). Moreover, corixid species is related to the presence of vegetation and the amount of accumulated organic matter (Macan, 1938), which are abundant in the ponds.

Although this study is limited only to selected physico-chemical properties of water in a seasona pond, the overall results suggest that the diurnal pattern of the physico-chemical properties of the water in the pond is influenced by temperature which in turn is influenced by solar radiation.

Most aquatic insects are nocturnal in behavior and seemed affected by the diel water temperature.

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